DALLAS AREA RAPID TRANSIT
LIGHT RAIL PROJECT

DESIGN CRITERIA MANUAL

VOLUME 1
FACILITIES DESIGN
(BASELINED VERSION)

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January 31, 2003

Design Criteria Manual Volume

Revision History

As of: February 6, 2003

Revision Number	Revision Date	Description of Changes	Document Number
0	Mar-87	Vol.'s 1 & 2 Revised PBDC	BR7Y-001-00-0387
1	Jan 88	Complete Revision PBDC REV 1	BR7Y-001-01-0188
2	March 88	Revised PBDC	BR7Y-001-02-0388
3	May 88	Ch 18 Mined Tunnels Revised PBDC	BR7Y-001-03-0588
4	July 88	DC 1 Major Revision PBDC	BR7Y-001-04-0788
5	Dec 90	DC Vol 1 Major Revision H-Z	BR7Y-001-05-1290
6	April 92	Incorporated 1991 LRT VE Decisions H-Z	BR7Y-001-06-0492
7	Sep 96	Revisions for Buildout Design H-Z	BR7Y-001-07-0996
8	Dec 96	Ch 8,9,14, and 15 Revised H-Z	BR7Y-001-08-1296
9	April 02	Ch 1,12,13,22 and 26 Revised GEC-LAN/STV	BR7Y-001-09-0402
10	Feb 03	Complete Revision ACT 21	BR7Y-001-10-0203

CONTENTS

CHAPTER		Page

CHAPTER		Page

CHAPTER		Page

<u>CHAPTER</u> Page

<u>CHAPTER</u> Page

CHAPTER Page

LIST OF FIGURES

NUMBER TITLE

LIST OF TABLES

CHAPTER 1 - TRACK ALIGNMENT

1.1 INTRODUCTION

This chapter illustrates and discusses the various elements of track alignment, including different types of alignments, curvature, special trackwork, speed requirements, and clearances. Using currently accepted railroad and transit engineering practices, these criteria provide guidelines for safety, passenger comfort, and economy. Unless otherwise stated in this document, the track safety requirements for the system are not less than those prescribed by the Federal Railroad Administration's "Track Safety Standards" for Class 5 tracks. The track safety requirements for yard tracks are not less than prescribed for Class 3 tracks. Criteria relating to other elements of design, such as transit system drainage, and to work items made necessary by transit system construction, such as miscellaneous utility work, are based on the current specifications and practices of the agencies concerned in the jurisdictions involved. For further information, refer to Chapter 6 - Utilities and Chapter 7 - Drainage.

1.2 SURVEY CONTROL

1.2.1 Horizontal

The horizontal control for all alignments shall be based on survey control points established under the direction of the Authority. Coordinates for control points established for the system shall be located on NAD 1983 Texas Coordinate System, North Central Zone (Lambert Grid), as established by the National Geodetic Survey (NGS). The accuracy of the horizontal ground control and of supporting ground surveys shall as a minimum be second order, Class I, as defined by the Federal Geodetic Control Committee and published under the title Classification, Standards of Accuracy and General Specifications of Geodetic Control Stations. Scale factor on DART Project is 1.000136506, to convert from grid to surface values. All coordinates and distances shall be published as surface values. For further information, refer to the DART Project Survey Manual.

1.2.2 Vertical

The vertical control shall be based on the National Geodetic Vertical Datum of 1988 (NGVD), as defined by the NGS descriptions with the most recent adjustments. The accuracy of the vertical ground control and of supporting ground surveys shall as a minimum be second order, Class I, as defined above.

1.3 TRACK ALIGNMENT

The parameters for the design of track alignments shall be in accordance with the Design Criteria and recommendations of the current edition of Manual for Railway Engineering published by the American Railway Engineering and Maintenance-of-Way Association (AREMA). The horizontal alignment of main line tracks shall consist of tangents joined to circular curves by spiral transition curves. Spirals shall also be used in all revenue tracks and secondary tracks to the yard. Curvature and superelevation shall be related to design speed and the acceleration and deceleration characteristics of the design vehicle. Wherever practical, the track geometrics shall accommodate the maximum operating speed of 65 miles per hour (MPH), where the location of curves, spacing of stations, construction limitations, and the performance characteristics of the design vehicle require an operating speed less than the maximum, the track geometrics shall accommodate the reduced speed.

These criteria are based on standard track gauge of 4 feet 8-1/2 inches measured perpendicular to the rail 5/8 inch below the top of rail.

1.4 SPEED REQUIREMENTS

Main Line. Curvature and superelevation shall be related to the characteristics of the vehicle design, the effects of acceleration, deceleration, and speed command levels of the signal system. Wherever the vehicle operational characteristics permit attainment of the highest speed command level, every effort shall be made in the development of the geometric design to accommodate that speed. Wherever restrictions limit the speed to another command level, every attempt shall be made to maintain an alignment to accommodate that speed command level.

Main Line, Highway Median. Wherever the vehicle operational characteristics permit attainment of an operating speed of 10 MPH over the posted highway speed, every effort shall be made in the development of the geometric design to accommodate that speed. Wherever restrictions limit the speed to less, every attempt shall be made to maintain an alignment to accommodate a main line design speed equal to the posted highway speed.

Main Line, Transitway Mall. Speeds in the transitway mall will be limited by pedestrian, traffic signal, street vehicle considerations and curvature.

Yard Track. The geometric design for yard track shall accommodate the operational requirements for each particular location.

1.5 TRACK CONTROL AND DESIGNATION

The alignment control shall be the centerline of the main line track carrying traffic in the direction of line stationing because it forms the basic control for all other system facilities, each control centerline shall be stationed throughout its length. The identification of this control centerline is shown below for each of the rail lines. The main line track that handles rail traffic in the opposite direction is also identified below.

Line	Control Centerline	Opposite Main Line Track
North Central	NC-NB	NC-SB
West Oak Cliff	WOC-SB	WOC-NB
South Oak Cliff	SOC-SB	SOC-NB
CBD Mall	CBD-NB	CBD-SB
Oak Cliff	OC-SB	OC-NB
Northeast	NE-NB	NE-SB
Southeast	SE-SB	SE-NB
Northwest	NW-NB	NW-SB
Irving/DFW	I -NB	I –SB

The alignments of opposite main line and secondary tracks shall have separately defined geometry with station equalities to the control centerline at spiral tangent points.

1.6 TRACK SPACING

Track spacing shall vary, depending upon curvature and upon the type of construction used for the particular section of line. Normal track centers shall be 15 feet 6 inches with center catenary pole structure. Without center poles, track centers shall be a minimum of 14 feet 0 inches on tangent tracks. Track centers of 14 feet 0 inches with center poles of dimension 1 foot or less in width will be allowed upon approval of DART. Every attempt should be made to place center catenary poles of larger dimension in areas where track centers are 15 feet 6 inches or greater. Center-to-center dimensions for parallel tracks near stations with center platforms shall depend upon the width of the station platform. Refer to Sections 1.9.2 and 1.9.3 for further guidelines pertaining to track spacing.

1.7 HORIZONTAL ALIGNMENT

The horizontal alignment of mainline tracks shall consist of a series of tangents joined to circular curves by means of spiral transition curves. Superelevation shall be used to maximize running speeds where it does not interfere with pavement grades in areas of mixed traffic operation. The nomenclature used to describe horizontal alignments shall be consistent with that illustrated in Figure 1.1.

1.7.1 Tangent Alignment

The **minimum length of tangent** track between curved sections of track shall be as follows:

Condition	Tangent Length
Desirable Minimum	200 ft
Minimum	100 ft or 3 times the design speed (in mph), whichever is greater
* Absolute Minimum	40 ft or 1.5 times the design speed (in mph), whichever is greater

(* Not to be used without prior DART approval)

If adjacent curves in the same direction which are in close proximity to one another cannot be replaced by a single simple curve due to geometric constraints, a series of compound curves shall be the preferred arrangement. Broken back curves, (e.g., short tangents between curves in the same direction) shall be avoided.

At station platforms, the horizontal alignment shall be tangent throughout the entire length of the platform, unless otherwise approved by DART. The tangent shall be extended beyond both ends of the platform as follows:

Condition	Tangent Length
Desirable Minimum	75 ft
Minimum	60 ft
* Absolute Minimum	50 ft

(* Not to be used without prior DART approval)

All special trackwork shall be located on horizontal tangents. Refer to Section 2.7 of Chapter 2 for minimum tangent length criteria in areas of special trackwork.

1.7.2 Curved Alignment

Intersections of horizontal tangents shall be connected by circular curves which may be either simple curves or spiraled curves as required by this criteria.

(a) Circular Curves

Circular curves shall be specified by their radius. Degree of curvature, where required for calculation purposes (including along freight railroad tracks), shall be defined by the arc definition of curvature as determined by the following formula:

$$D = \frac{5729.578}{R}$$

Where D = degree of curvature

R = radius of curvature, in feet

Minimum Radii:

The **minimum radii for mainline tracks** shall be as follows:

Location	Minimum Radius
Aerial structures:	500 feet
At-grade ballasted:	500 feet Desirable Minimum 300 feet Absolute Minimum*
In-street: (Embedded or Paved Track)	250 feet Desirable Minimum 150 feet Minimum 100 feet Absolute Minimum*

The **minimum radii for yard and service tracks** shall be as follows:

Location	Minimum Radius
Yard and service tracks:	150 feet Desirable Minimum
	100 feet Absolute Minimum*

(* Not to be used without prior approval of DART)

Minimum length of circular curve:

The desired minimum length of circular curve along main line tracks shall be 200 feet.

The **absolute minimum** circular curve length shall be determined by the following formula:

$L = 3V$ or 60 feet, whichever is greater.

Where L = minimum length of curve, in feet

V = design speed through the curve, in mph

Turnouts and reverse curves behind turnouts are exempted from these criteria as their curve lengths are dictated by turnout geometry. For multitrack layouts, where two or more tracks follow the same general alignment, the tracks should be placed on concentric curves. Minimum curve radius criteria shall apply to the inside curve.

The design speed for a given horizontal curve shall be based on its radius, length of spiral transition, and actual and unbalance superelevation through the curve as described in the following sections.

(b) Track Superelevation

Mainline tracks shall be designed with superelevation so as to permit desired design speeds to be achieved without resorting to excessively large radii of curvature. Note that due to local constraints, the design speed may be less than either the system maximum speed or the maximum possible speed for a curve of a given radius. The design speed criteria stated herein are based on a maximum lateral acceleration of the passenger of 0.1 g.

Equilibrium superelevation (Total superelevation) is the amount of superelevation that would be required so that the resultant force from the center of gravity of the light rail vehicle will be perpendicular to the plane of the two rails and halfway in between them at a given speed. If a curved track is superelevated so as to achieve equilibrium at a given speed, a light rail vehicle passenger would experience no centrifugal force through the curve at that speed. Equilibrium superelevation shall be determined by either of the following equations:

$$E_q = E_a + E_u = 4\left(\frac{V^2}{R}\right)$$

or

$$E_q = 0.0007\, V^2 D$$

Where E_q = Equilibrium (Total) superelevation, in inches

E_a =Actual track superelevation to be constructed, in inches

E_u = Unbalance superelevation, in inches

V = Design speed through the curve, in mph

R = radius of curve, in feet

D = degree of curve, in degrees (arc definition)

In practice, the full equilibrium superelevation (E_q) is rarely installed in track as doing so would require excessively long spiral transition curves. It could also produce passenger discomfort on board a train which is moving much slower than the design speed or stopped in the middle of a steeply superelevated curve. Therefore, only a portion of the calculated E_q, the actual superelevation E_a, shall be designed for. The difference between the equilibrium superelevation and the actual superelevation is called the unbalance, and is designated as E_u.

Actual superelevation (E_a) shall be attained and removed linearly throughout the full length of the spiral transition curve by raising the outside rail while maintaining the inside rail at the profile grade.

The **maximum values for actual and unbalance superelevation** shall be as follows:

Superelevation		**Value**
E_a	=	4 inches Maximum desirable *
		6 inches absolute Maximum
E_u	=	1-1/4 to 1-1/2 inches desirable *
		3 inches absolute Maximum

(* Not to be exceeded without prior approval of DART)

Note: Use E_u up to 3 inches before using E_a >4 inches (Subject to DART approval).

In some unique situations, Negative Unbalance Superelevation may be necessary. In these instances, DART approval will be required. In no case may the Negative Unbalance Superelevation exceed 1-1/2 inches.

In areas of mixed traffic operation with rubber-tired vehicles (CBD areas), the desired location for a pavement crown shall be at the centerline of the tracks. Where this is not feasible, a normal pavement crown of a maximum of ¼-inch per foot across the rails may be maintained in the street pavement to promote drainage. Note that this practice will introduce a constant track superelevation (E_a) of approximately 1-inch. If, at curves, the street pavement is neither superelevated nor the crown removed, this crown related superelevation may dictate the maximum allowable operating speed. On curved track, this 1-inch could be either positive or negative depending on which side of the crown line the track is located. In such cases only, so as to minimize the need to extensively regrade street pavements which could affect curb reveal heights and other civil features, the unbalanced superelevation will be allowed to go to its maximum prior to the introduction of any additional actual superelevation. Thus, normal pavement crown shall remain ($E_a = \pm 1$ inch) until $E_u = 3$ inches is reached. At this point, either a limit shall be placed on the LRT design speed or the pavement crown shall be revised so that E_a may be increased until E_q is equal to a maximum of 7 inches. When E_q would exceed 7 inches, a limit shall be placed on the LRT design speed.

If the Street Grade is steep and the maximum allowable Negative Unbalance Superelevation of 1-1/2 inches is not adequate to make a reasonably acceptable grade crossing, then the split profile may be used with DART prior approval.

E_a shall be set so that trains will have a positive E_u on curves where speed is likely to vary.

(c) Spiral Transitions

Spiral transition curves shall be used in order to develop the superelevation of the track and limit lateral acceleration, during the horizontal transition of the light rail vehicle, as it enters the curve. Spiral transition curves shall be clothoid spirals as depicted in Figure 1.2 and as defined by Hickerson[1]. Spirals shall be required on all mainline track horizontal curves with a radius less than 10,000 feet.

The minimum length of spiral shall be the greater of the lengths determined from the following formulae (rounded off to the next largest 5 feet). In any case the desirable minimum spiral length is 60 feet:

The **minimum spiral length** shall be the greatest length obtained from the following formulas:

$L_s = VE_a$
$L_s = VE_u$
$L_s = 33\ E_a$ for speeds ≤ 30 mph
$L_s = 50\ E_a$ for speeds > 30 mph and ≤ 50 mph
$L_s = 60\ E_a$ for speeds > 50 mph

Where:

L_s = Length of spiral in feet.
V = Design speed in miles per hour.
E_a = Actual superelevation in inches.
E_u = Unbalanced superelevation in inches.

Where geometric conditions are extremely restricted, such as in un-superelevated, embedded track in a CBD area, the spiral length may be reduced to the absolute minimum of 30 feet provided, that prior DART approval has been obtained.

On parallel tracks with concentric circular curves, the shortest spiral length shall comply with the minimum spiral length requirements.

Extremely long spirals shall be avoided by applying compound curves.

A spiral and Superelevation are not required for yard and secondary tracks where design speeds are less than 10 mph.

1. Thomas F. Hickerson, Route *Location Design*, 5th edition. (New York: McGraw-Hill, 1964), pp. 168-171, 374-375.

Table 1.1 provides minimum spiral lengths for various combinations of design speed, radius of curvature, and desirable Actual Superelevation (E_a). This Table shall be used as a Design Aid.

(d) **Compound Circular Curves**

Where compound curves are used, they shall be connected by a spiral transition curve. The absolute minimum spiral length shall be the greater of the lengths as determined by the following (rounded off to the next largest 5 feet):

The **minimum spiral length** shall be the greatest length obtained from the following formulas:

$L_s = V(E_{a2} - E_{a1})$

$L_s = V(E_{u2} - E_{u1})$

$L_s = 33\,(E_{a2} - E_{a1})$ for speeds ≤ 30 mph

$L_s = 50\,(E_{a2} - E_{a1})$ for speeds > 30 mph and ≤ 50 mph

$L_s = 60\,(E_{a2} - E_{a1})$ for speeds > 50 mph

Where L_s = minimum length of spiral, in feet.

E_{a1} = actual superelevation of the first circular curve, in inches

E_{a2} = actual superelevation of the second circular curve, in inches

E_{u1} = unbalanced superelevation of the first circular curve, in inches

E_{u2} = unbalanced superelevation of the second circular curve, in inches

V = design speed through the circular curves, in mph

(e) **Reverse Curves**

Where extremely restrictive horizontal geometrics make it impossible to provide sufficient tangent length between reversed superelevated curves, the curves may meet at a point of reverse spiral upon approval from DART. The point of reverse spiral shall be set so that:

$$L_{s1} \times E_{a2} = L_{s2} \times E_{a1}$$

Where E_{a1} = actual superelevation applied to the first curve

E_{a2} = actual superelevation of the second circular curve, in inches

L_{s1} = the length of the spiral leaving the first curve

L_{s2} = the length of the spiral entering the second curve

A maximum separation of one foot between the spirals is acceptable in lieu of meeting at a point.

The superelevation transition between reversed spirals shall be accomplished by sloping both rails of the track throughout the entire transition spiral as shown on Figure 1.10. Note that through the transition, both rails will be at an elevation above the theoretical profile grade line. This method of superelevation transition creates additional design considerations including an increased ballast section width at the point of reverse spiral and possible increased clearances. Such issues shall be investigated in detail and any impacts identified in the waiver application to DART.

(f) Double Reverse Curves.

Double reverse curves shall not be used in the system unless the distance between the point of change from the first curve to the second curve and the point of change from the second curve to the third curve is at least 450 feet.

(g) Variations In Train Operating Speeds

Variation in train operating speed through a curve will result where ever that curve lies in an acceleration or deceleration zone. Such zones will exist adjacent to stations and elsewhere throughout the system. These zones will be established by the train simulation program.

The track superelevation, E_a, for such a curve in direct fixation track shall be varied along the curve so that a more or less uniform unbalanced superelevation, E_u, will be maintained for cars at the middle of a 360-foot- long train. If uniform unbalanced superelevation cannot be obtained, consideration shall be given to using a compound curve or an extra long transition spiral. The absolute maximum unbalanced superelevation experienced by cars at the head and tail ends of the train shall be between the limits of +3 inches and –1.5 inches. The desirable value of unbalanced superelevation shall be between 1-1/4 inches and 1-1/2 inches.

DART RAIL PROJECT -- TABLE 1.1
CURVE RADIUS/MINIMUM SPIRAL LENGTH TABLE WITH 1.5 INCHES UNBALANCED SUPERELEVATION
E_a = Actual Superelevation

E_a (inches)	VELOCITY (mph) 15	20	25	30	35	40	45	50	55	60	65	
0.00	600	1,067	1,667	2,400	3,267	4,267	5,400	6,667	8,067	9,600	11,267	Radius (ft.)
	23	30	38	45	53	60	68	75	83	90	98	Spiral (ft.)
0.50	450	800	1,250	1,800	2,450	3,200	4,050	5,000	6,050	7,200	8,450	Radius (ft.)
	23	30	38	45	53	60	68	75	83	90	98	Spiral (ft.)
0.75	400	711	1,111	1,600	2,178	2,844	3,600	4,444	5,378	6,400	7,511	Radius (ft.)
	25	30	38	45	53	60	68	75	83	90	98	Spiral (ft.)
1.00	360	640	1,000	1,440	1,960	2,560	3,240	4,000	4,840	5,760	6,760	Radius (ft.)
	33	33	38	45	53	60	68	75	83	90	98	Spiral (ft.)
1.25	327	582	909	1,309	1,782	2,327	2,945	3,636	4,400	5,236	6,145	Radius (ft.)
	41	41	41	45	63	63	68	75	83	90	98	Spiral (ft.)
1.50	300	533	833	1,200	1,633	2,133	2,700	3,333	4,033	4,800	5,633	Radius (ft.)
	50	50	50	50	75	75	75	75	90	90	98	Spiral (ft.)
1.75	277	492	769	1,108	1,508	1,969	2,492	3,077	3,723	4,431	5,200	Radius (ft.)
	58	58	58	58	88	88	88	88	105	105	114	Spiral (ft.)
2.00	257	457	714	1,029	1,400	1,829	2,314	2,857	3,457	4,114	4,829	Radius (ft.)
	66	66	66	66	100	100	100	100	120	120	130	Spiral (ft.)
2.25	240	427	667	960	1,307	1,707	2,160	2,667	3,227	3,840	4,507	Radius (ft.)
	74	74	74	74	113	113	113	113	135	135	146	Spiral (ft.)
2.50	225	400	625	900	1,225	1,600	2,025	2,500	3,025	3,600	4,225	Radius (ft.)
	83	83	83	83	125	125	125	125	150	150	163	Spiral (ft.)
2.75	212	376	588	847	1,153	1,506	1,906	2,353	2,847	3,388	3,976	Radius (ft.)
	91	91	91	91	138	138	138	138	165	165	179	Spiral (ft.)
3.00	200	356	556	800	1,089	1,422	1,800	2,222	2,689	3,200	3,756	Radius (ft.)
	99	99	99	99	150	150	150	150	180	180	195	Spiral (ft.)
3.25	189	337	526	758	1,032	1,347	1,705	2,105	2,547	3,032	3,558	Radius (ft.)
	107	107	107	107	163	163	163	163	195	195	211	Spiral (ft.)
3.50	180	320	500	720	980	1,280	1,620	2,000	2,420	2,880	3,380	Radius (ft.)
	116	116	116	116	175	175	175	175	210	210	228	Spiral (ft.)
3.75	171	305	476	686	933	1,219	1,543	1,905	2,305	2,743	3,219	Radius (ft.)
	124	124	124	124	188	188	188	188	225	225	244	Spiral (ft.)

DART RAIL PROJECT -- TABLE 1.1 (continued)
CURVE RADIUS/MINIMUM SPIRAL LENGTH TABLE WITH 1.5 INCHES UNBALANCED SUPERELEVATION
E_a = Actual Superelevation

E_a (inches)	15	20	25	30	35	40	45	50	55	60	65	
	VELOCITY (mph)											
4.00	164	291	455	655	891	1,164	1,473	1,818	2,200	2,618	3,073	Radius (ft.)
	132	132	132	132	200	200	200	200	240	240	260	Spiral (ft.)
4.25	157	278	435	626	852	1,113	1,409	1,739	2,104	2,504	2,939	Radius (ft.)
	140	140	140	140	213	213	213	213	255	255	276	Spiral (ft.)
4.50	150	267	417	600	817	1,067	1,350	1,667	2,017	2,400	2,817	Radius (ft.)
	149	149	149	149	225	225	225	225	270	270	293	Spiral (ft.)
4.75	n/a	256	400	576	784	1,024	1,296	1,600	1,936	2,304	2,704	Radius (ft.)
		157	157	157	238	238	238	238	285	285	309	Spiral (ft.)
5.00	n/a	246	385	554	754	985	1,246	1,538	1,862	2,215	2,600	Radius (ft.)
		165	165	165	250	250	250	250	300	300	325	Spiral (ft.)
5.25	n/a	237	370	533	726	948	1,200	1,481	1,793	2,133	2,504	Radius (ft.)
		173	173	173	263	263	263	263	315	315	341	Spiral (ft.)
5.50	n/a	229	357	514	700	914	1,157	1,429	1,729	2,057	2,414	Radius (ft.)
		182	182	182	275	275	275	275	330	330	358	Spiral (ft.)
5.75	n/a	221	345	497	676	883	1,117	1,379	1,669	1,986	2,331	Radius (ft.)
		190	190	190	288	288	288	288	345	345	374	Spiral (ft.)
6.00	n/a	213	333	480	653	853	1,080	1,333	1,613	1,920	2,253	Radius (ft.)
(1)		198	198	198	300	300	300	300	360	360	390	Spiral (ft.)
6.00	n/a	178	278	400	544	711	900	1,111	1,344	1,600	1,878	Radius (ft.)
(2)		198	198	198	300	300	300	300	360	360	390	Spiral (ft.)

(1) Desirable radii, using 1.5 inches unbalanced superelevation.
(2) Absolute minimum radii, using 3 inches unbalanced superelevation.
(3) Desirable Spiral Length : 60 feet

NOTES ON TABLE 1.1: CURVE/RADIUS/MINIMUM SPIRAL LENGTH

1. The table shall be used as a design aid to apply the project design criteria.

2. The applicable design criteria are:

   a. Track superelevation shall be based upon the following formula:

   $$E_a + E_u = (4V^2)/R$$

   Where:

   E_a = Actual superelevation, in inches.
   E_u = Unbalanced superelevation, in inches.
   V = Design speed, in miles per hour.
   R = Curve radius, in feet.

   b. The desired maximum actual superelevation, Ea shall be 4 inches. The absolute maximum shall be 6 inches.

   c. The desired unbalanced superelevation, E_u shall be between 1-1/4 inches and 1-1/2 inches. The absolute maximum shall be 3 inches.

   d. Actual superelevation, E_a shall be applied in 1/4 inch increments. Actual superelevation of less than 1/2 inch shall not be used.

   e. Minimum spiral length, Ls shall be the greatest value determined from the following formulas:

   $L_s = V\,E_a$
   $L_s = VE_u$
   $L_s = 33\,E_a$ for $V \leqslant 30$ mph
   $L_s = 50\,E_a$ for $V > 30$ mph and $V \leqslant 50$ mph
   $L_s = 60\,E_a$ for $V > 50$ mph

3. Because the relationship between E_a, V and R is absolute, given values for two of these variables the value of the third, as derived from the table, is correct. It is <u>not</u> a maximum or minimum allowable value. In general, values should not be interpolated, and the tables should be used according to note.

4. The values of L_s, as derived from the table, are minimum allowable values. For any combination of E_a and V, the spiral length shall equal or exceed the tabulated value of L_s.

5. The table shall be used as follows:

   a. <u>If speed, V, and radius, R, are known</u> - Find the appropriate V column. Scan down the column to find the first value of radius $\leqslant$ R. Use actual superelevation = E_a. Use spiral length $\geq L_s$. If there is no value of radius $\leqslant$ R, this combination of V and R is not permissible.

b. If actual superelevation, E_a, and radius, R, are known - Find the appropriate E_a row. Scan right along the row to find the first value of radius > R. Move left one column. Use speed = V. Use spiral length $\geq L_s$. If there is no value of radius > R, this combination of E_a and R is not permissible.
c. If actual superelevation, E_a, and speed, V, are known - Find the appropriate E_a row and V column. Let the radius at the intercept of E_a and V = R. Move up one row. Let this radius = R_z. Use a value of radius, R, such that $R_z > R \geq R$. Use spiral length $\geq L_s$, where L corresponds to R.
d. If speed, V, and spiral length, L_s, are known - Find the appropriate V column. Scan down the column to find the first value of spiral length > L_s. Move up one row. This is the minimum allowable radius. Use this R and E_a combination or any other R and E_a combination above it in the column. If there is no value of spiral length > L_s, this combination of V and L_sd is not permissible.
e. If actual superelevation, Ea, and spiral length, Ls, are known - Find the appropriate Ea row. Scan right along the row to find the first value of spiral length > Ls. Move left one column. This is the minimum allowable radius. Use this R and V combination or any other R and V combination left of it in the row. If there is no value of spiral length > Ls, this combination of Ea and Ls is not permissible.
f. If radius, R, and spiral length, L_s, are known - Scan down all columns to find the first values of radius $\leqslant$ R. Scan the first values of radius $\leqslant$ R to determine those for which spiral length $\leqslant L_s$. Use any E_a and V combination for first value of radius $\leqslant$ R and spiral length $\leqslant L_s$. If there are no values of radius $\leqslant$ R or spiral length $\leqslant L_s$, this combination of R and L_s is not permissible.

1.8 VERTICAL ALIGNMENT

1.8.1 General

The vertical alignment shall be composed of constant grade tangent segments connected at their intersection by parabolic curves having a constant rate of change in grade. The nomenclature used to describe vertical alignments shall be consistent with that illustrated in Figure 1.11.

The profile grade line in tangent track shall be along the centerline of track between the two running rails and in the plane defined by the top of the two rails. In curved track, the inside rail of the curve shall remain at the profile grade line and superelevation achieved by raising the outer rail above the inner rail.

In areas of horizontal curvature where the profile is given for the right track only, the top of rail elevation of the left track shall be adjusted uniformly throughout the curve to compensate for the difference in horizontal curve lengths.

1.8.2 Vertical Tangents

The minimum length of constant profile grade between vertical curves shall be as follows:

Condition	Length
Desirable Minimum	100 feet or 3 times the design speed (in mph), whichever is greater
Minimum	40 feet

In CBD areas, where the need to conform to existing street profiles makes compliance with the above criteria economically unfeasible, the above requirement may be waived upon application to DART. Where a tangent between vertical curves is shorter than 40 feet, consideration shall be given to reverse or compound vertical curves, so as to avoid abrupt changes in vertical acceleration which could result in both passenger ride discomfort and excessive vehicle suspension system wear and tear.

The profile at stations shall be on a vertical tangent that extends 40 feet beyond each end of the platform. Special trackwork shall be located on vertical tangents. Refer to Section 2.8 of Chapter 2 of this criteria for minimum vertical tangent length criteria in areas of special trackwork.

1.8.3 Vertical Grades

The following profile grade limitations shall apply:

Mainline tracks on tangent

Maximum Desirable	4.0%
Absolute Maximum*	6.0%
Minimum (for drainage on direct fixation track)	0.15%

(* Not to be used without prior DART approval)

Where feasible, the lowest gradient possible shall be used.

Mainline tracks on Curves

The absolute maximum gradient for main line track on curved sections of track shall be determined from the formula:

$G_m = 6 - 230/R$

Where: G_m is the absolute maximum grade in percent and R is the horizontal curve radius in feet.

Station Area

Desirable	0.0%
Maximum	1.5%

No minimum grade is specified at passenger stations provided adequate track drainage can be maintained.

Special Trackwork

Desirable	0.0%
Desirable Maximum	1.0%
Absolute Maximum*	4.5%

(* Not to be used without prior DART approval)

Yard and Secondary Tracks

Desirable	0.0%
Maximum	1.0%

Yard Storage Tracks & Pocket/Tail Tracks Used For Storage

Desirable	0.0%
Maximum	0.2%

All tracks entering the yard shall either be level, sloped downward away from the mainline, or dished to prevent rail vehicles rolling from the yard onto the mainline.

Through storage tracks shall have a sag in the middle of their profile to prevent rail vehicles from rolling to either end. It is desirable that the profile grade of a stub end storage track descend toward the stub end, and, if adjacent to a mainline or secondary track, be curved away from that track at its stub end. If it is necessary for the profile grade of a storage track to slope up toward the stub end, the grade shall not exceed 0.2 percent.

Tracks located within maintenance shop buildings shall be level. (0.0% Grade)

1.8.4 Vertical Curves

All changes in grade shall be connected by vertical curves. Vertical curves shall be defined by parabolic curves having a constant rate of change in grade.

Elements of a vertical curve are shown in Figure 1.11. For elevations along the vertical curve, use the following formula:
$E_x = E_a + g_1 x + 1/2 r x^2$

Where:

E_x = elevation of a point on the vertical curve, in feet.
E_a = elevation of the PVC, in feet.
g_1 = grade into the vertical curve, in %.
g_2 = grade out of the vertical curve, in %.
x = distance from PVC to point on vertical curve, in stations.
r = rate of change of grade, in % per station.
r = $(g_2 - g_1)$ /LVC, where LVC is specified in stations.
Station = 100 feet
PVC = Point of vertical curve
LVC = Length of Vertical Curve

1.8.4.1 Desirable Length of Vertical Curve

The desirable length of vertical curve (LVC) in main line track for both sag and crest conditions shall be determined by the following formula, but desirable minimum should be not less than 200 feet:

LVC = 200A

Where:

LVC = Length of vertical curve in feet.
A = The algebraic difference in the grades (in percent) approaching and leaving the curve.

1.8.4.2 Minimum Length of Vertical Curve

Except in embedded track, the absolute minimum length of vertical curve in main line track shall be the greatest of the lengths determined by the following formulas:

LVC = 100A (crest) for speeds $\geq$ 50 mph

LVC = 70A (crest) for speeds $<$ 50 mph

LVC = $(AV^2)/60$ (sag) for speeds $\geq$ 65 mph

LVC = 70A (sag) for speeds < 65 mph

For Both Crest and Sag for all speeds, the **Absolute Minimum LVC** shall be greater of:
LVC = 100 feet
LVC = 3V*
* For A < 1% this formula does not apply.

In embedded track, minimum length of vertical curve shall be the greatest of the lengths determined for both sag and crest by the following formulas:
LVC = 3V

LVC = 35A

LVC = 100

Where LVC = length of vertical curve, in feet

A = $(G_2 - G_1)$ = algebraic difference in gradients connected by the vertical curve, in percent.

G_1= percent grade of approaching tangent

G_2= percent grade of departing tangent

V = design speed, in mph.

Both sag and crest vertical curves shall have the maximum possible length, especially if approach and departure tangents are long. Vertical broken back curves and short horizontal curves at sags and crest of vertical curves shall be avoided.

Minimum vertical curve length and/or design speed may be governed by the overhead contact system (OCS) due to the maximum permissible rate of separation or convergence between the track grade and the contact wire grade. Coordination with the OCS designer shall be required to assure compliance with this limitation.

1.8.5 Compound Vertical Curves

Compound and unsymmetrical vertical curves shall be permitted provided each curve conforms to the requirements stated in Section 1.8 and prior DART approval has been obtained.

1.8.6 Reverse Vertical Curves

Reverse vertical curves shall be permitted provided each curve conforms to the requirements stated in Section 1.8 and prior DART approval has been obtained.

1.8.7 Combined Vertical and Horizontal Curvature

Where possible, combined vertical and horizontal curvature shall be avoided. Where any part of the vertical curve occurs within the circular portion of a horizontal curve with radius less than 6000 feet, the length of the vertical curve shall be increased to 1.5 times the calculated minimum required length.

Where a vertical curve occurs within a spiral or in a horizontal curve where the radius of curvature is in excess of 6000 feet no increase in the calculated minimum revised vertical curve length is required.

1.9 CLEARANCES

1.9.1 Static, Dynamic and Car Dynamic Envelope

Figure 1.3 identifies the exterior extent or envelope of a vehicle on tangent track in the static and dynamic states. The solid line in Figure 1.3 identified as the Static Envelope represents the shape of a vehicle at rest with all mechanical features in perfect condition. The dashed line, or the Dynamic Envelope, indicates the lateral limits that a vehicle may reach in motion taking into consideration such factors as vehicle roll, track tolerance, and skew. This dashed line can be thought of as the physical dimensions of the vehicle for design purposes, but with no clearances or construction tolerances added. Track tolerances utilized in development of the dynamic envelope are a maximum of 2" for direct fixation and 4" for ballasted construction applied at the mirror of the car. Since ballasted track is more easily displaced than direct fixation track, the outline for ballasted track conditions is shown.

Offset dimensions from centerline of track to the Clearance Envelope are shown at three points along the side of the car. These points are designated on Figure 1.3 and appear at the bottom of the car, at the mirror and the top of the car body. The horizontal dimension to the mirror from centerline of track may be disregarded if approval has been given by DART for 14 foot track centers with center catenary poles in accordance with Section 1.4.

A report on the criteria and methods used to determine acceptability of design and as-built clearances at specific locations is in Appendix D.

1.9.2 Variations of the Clearance Envelope due to Curvature and Superelevation

In horizontal curves, side clearances shall be increased to account for increased vehicle end overhang and middle ordinate. Furthermore, track superelevation must also be taken into consideration.

The additional clearances required on curves due to end overhang outside of curve is equal to $(R^2+747.65)^{1/2}-R$ and due to middle ordinate inside of curve is $R-(R^2-15.88^2)^{1/2}$. Additional clearances at turnouts due to car overhang are shown on Figures 1.4 through 1.9.

Clearances on the inside of curves shall be increased 2 inches for every 1 inch of actual superelevation. Transition in clearance requirements for curves shall be provided over that part of the transition spiral and adjacent tangent as required. Widening to the outside and the inside of the curve shall begin at a point 50 feet into the tangent and be completed at a point 50 feet in advance of the tangent.

The minimum distance between center line of tracks on curves, as shown on Figure 2-6 shall be the greater of 12.917 feet + e + m or 14 feet.

Where e = end overhang which is $(R^2 + 747.65)^{1/2} - R$ and
m = mid-ordinate which is $R - (R^2 - 15.88^2)^{1/2}$

Minimum distance to poles shall be distance C_2 and C_3 as shown on Figure 2.8 and on Figure 2-9 $C_2 = 7.750 - e + 0.165\ E_a$ or $C_2 = 7.10 + m + 0.176\ E_a$, whichever is greater; $C_3 = 7.750 + e - 0.165\ E_a$. Selection depends on the direction of curvature. If approval has been given by DART for 14 foot 0 inch track centers with 1 foot maximum width center catenary poles, the constant 7.000 shall be substituted for 7.750 in the above equations for C_2 and C_3.

Minimum distances C_1 and C_4 to outside walls as shown on Figure 2.9 shall be as follows: $C_1 = 7.58 + e - 0.011\ E_a$, or $C_1 = 7.93 + e - 0.112\ E_a$, or $C_1 = 8.00$ feet, whichever is greater; $C_4 = 7.93 + m + 0.112\ E_a$, or $C_4 = 8.00$ feet, whichever is greater.

1.9.3 Horizontal and Vertical Clearances and Tolerances

Any structure and emergency walkway alongside DART rail lines shall be clear of the Clearance Envelope by a distance equal to the sum of the applicable clearances and tolerances outlined below:

Construction Tolerances:

Aerial Structures	1"
Catenary Poles	2"
Catenary Pole Deflection	1"
All other Structures	3"
Running Clearance Along All Structures	5/8"
Acoustical Treatment Where Required	3"

The above dimensions are design values, the applicability of which depends on the type of track construction, as well as on the type of structure, which the vehicle Clearance Envelope must clear. When the applicable clearances and tolerances are added to the Clearance Envelope dimensions, the resulting envelope shall be referred to as the Design Envelope. With the exception of passenger station platforms, all structures installed above the top of the nearest rail must be set either at or beyond this Design Envelope.

The distance from the edge of the special use (high block) platform to the car body shall be 3 inches from the Static Car Outline.

A clear space for a service walkway shall be provided on one side of each track for emergency egress and maintenance access. The space shall be adjacent to the vehicle (with no obstructions between the space and the vehicle). The space shall have a minimum width of 22 inches (24 inches desirable) and a minimum height of 84 inches. The upper corners of the space may be clipped 3 inches horizontally and 12 inches vertically. The space shall be measured from the top of the low rail, except in tunnels and on structures with walkways. The space may be raised 8 inches. The clear space must be outside of the vehicle dynamic envelope (including track and maintenance and construction tolerances).

The following clearances shall be provided in the design and construction of the DART system. All vertical and horizontal clearances shall be verified with the appropriate authorities by the section designer at the time of final design.

The following horizontal clearances shall be applicable for tangent alignment on ballasted track except as noted. These clearances shall be compensated for curvature and superelevation when required. Clearance compensation factors shall be as shown on clearance diagrams and directive drawings. For clearances of special trackwork, see Figures 1.4 through 1.9.

Horizontal Clearances - Tangent Alignment.

- o Between adjacent main line parallel tracks, center-to-center, 15 feet 6 inches minimum with an 18 inch maximum diameter center catenary pole, and 14 feet 0 inches without center catenary pole. Track centers of 14 feet 0 inches with center catenary pole width of 1 foot 0 inches or less allowable upon approval by DART.

- o Track centers between main line tracks at center platform stations will be platform width plus 9 feet 4 inches on tangent alignments.

  Embedded track centers will be 14 feet without center catenary poles and 15 feet 6 inches with center catenary poles.

- Between parallel **yard tracks**, track center to center distance shall be as follows:

	Minimum	Desirable
- Lead track to a ladder track	16'-0"	18'-0"
- Running track to a ladder track	18'-0"	20'-0"

	Minimum	Desirable
- Ladder track to a ladder track		
With roadway	30'-0"	42'-0"
With catenary pole	18'-0"	20'-0"
- Drill track to a storage track	17'-0"	20'-0"
- Storage track to a storage track (with no poles)	15'-0"	15'-0"
With pole	16'-0"	16'-0"
With service aisle	18'-0"	20'-0"
- Shop building tracks	14'-0"	**
- Wayside storage tracks	16'-0"*	20'-0"*
- Transfer zone tracks		
With pole	16'-0"	16'-0"
Without pole	14'-0"	14'-0"

* No catenary pole between tracks.

** Desirable track centers shall be determined on the basis of maintenance space needs between LRVs in the shop.

Fixed structure, measured from centerline of track and nearest point of fixed structure except as otherwise noted below:

	Minimum	Desirable
Tunnel Track	7'-0"	8'-6"
Tunnel Track (Wall adjacent to walkway)	6'-1" + Walkway Width	7'-0" + Walkway Width
Tunnel Track (Wall opposite walkway)	7'-0"	8'-6"
- Fixed structure equal to or less than six (6) feet in length:		
Direct Fixation	7'-0"	8'-6"
Ballasted	7'-0"	8'-8"
- Fixed structure greater than six (6) feet in length:		
Direct Fixation	8'-6"	12'-0"
Ballasted	8'-6"	12'-0"
- Between handrail and centerline of nearest track provided walkway is available elsewhere on the right-of-way.	7'-0"	8'-0"

	Minimum	Desirable
- Between acoustical barrier and centerline of nearest track;		
Direct Fixation	8'-6"	12'-0"
Ballasted	8'-6"	12'-0"
- Fences parallel to track measured from centerline of track on retained fill or embankment:	8'-6"	12'-0"
- Between centerline of a catenary pole and centerline of nearest track:		
Direct Fixation	7'-2 1/2"	8'-0"
Ballasted	7'-4 1/2"	8'-0"
- C. to C. distance between LRT and Freight Track	20'-0"	25'-0"

Stations.
The minimum horizontal dimensions shall be as follows:

- Length of platform - **410 feet unless otherwise noted.**

- Edge of platform to centerline of track - 4' 8" on tangent alignments.

Vertical. - Vertical clearance, guideway structure over public highways and local public roads and streets shall be as required by the Authority having jurisdiction over the roads. Minimum vertical clearance shall be 16'- 6".

The vertical clearance over a guideway structure to a fixed structure, measured from top of rail to the nearest point of obstruction, shall be as follows:

Exclusive LRT Right-of-Way	22'-0"
Mixed Use with At-Grade Roadway Crossings	24'-0"
Mixed Use with At-Grade Railway Crossings	28'-0"

Lower clearances under existing structures may be considered with approval of DART and coordination with the overhead catenary system design.

Under the rail vehicle, between rails, structures will be allowed to intrude on the clearance envelope a maximum of 3/4 inch above top of rail on a tangent track.

Streets. The minimum lateral clearance for streets and highways shall normally be two feet, measured from the face of the curb to the DART right-of-way line. This distance must be increased where signs, hydrants, utilities, sidewalks, or traffic signals must be accommodated in this space. Clearances of guideway structure adjacent to streets or expressways shall be in accordance with the current issue of the Texas Department of Transportation Operations and Procedures Manual and standards of local agencies having jurisdiction over the roadway affected.

Railroads. All railroad clearances and trackwork shall comply with current plans and specifications of the respective railroad or the Texas Railroad Commission, whichever is greater. All railroad clearances, joint-use drainage structures, common support structures, and right-of-way lines are subject to verification by the individual railroad company. In the absence of such plans and specifications, trackwork shall comply with the current AREMA Manual for Railway Engineering and Portfolio of Trackwork Plans and shall be approved by a responsible officer of the affected company.

Catenary Protection Envelope at Overhead Structures. A catenary wire safety barrier/system will be developed by the final line section designer, and constructed at all locations along the LRT corridor where pedestrians or maintenance staff maybe allowed or placed too close to train catenary wires. These existing or proposed structures will normally cross over or run parallel to the tracks, as pedestrian overpasses or access pathways respectively. Locations will generally consist of structures such as bridges, U-walls, retaining walls, buildings, tunnel portals, aerial walkways, escalators and utility facilities; but not necessarily limited to these elements. The LRT corridor should be reviewed for existing and proposed locations, where the catenary wire will potentially become too close to a space occupied by people. These situations should be identified for further evaluation with the safety clearance envelope.

The Catenary Safety Envelope, Figure 1.13 should be used to analyze potential locations for the intrusion inside the horizontal or vertical safety envelope dimensions from the pedestrian access level of the structural elements. If this situation exists, then catenary safety measures (devices) should be designed into these elements of the project. A distance of 12 feet (desirable) from the Overhead Catenary System (OCS) messenger wire to a pedestrian access level above or an access point to the sides of the structure under consideration will satisfy the safety clearance criteria. A minimum dimension of 8'-6" is acceptable when approved by DART; in both cases a catenary safety barrier is not required, but may be desirable. A situation may exist where the safety clearance distance is met at an individual site, however the designer has the flexibility to incorporate safety devices due to a special element of risk, or hazard that may be present at the site. Hence, the designer should be alert to the site conditions and then evaluate these locations for safety devices on a case by case basis.

The calculation methodology used for determination of whether or not a person would be within the safety envelope is presented in greater detail in Figure 1.13. This figure is a design aid to help the designer apply the design criteria.

The type of catenary safety devices that the Authority finds acceptable for vertical and horizontal applications consist of three types. These are; vertical devices including a steel fence and tube railing system (Fence Panel Railing System) and chain link fencing, and a horizontal device defined as a catenary wire shield. The vertical barriers shall rise to a height that will provide the safety clearance dimensions stated above. When chain link fencing is used, the designer may elect to use curved tops if the situation warrants and field conditions are not prohibitive. The tops shall curve inward towards the pedestrian area. The horizontal device is a cover or shield placed over the messenger wire for a specified distance out from a structure. The shields are normally attached to the side of a structure and should be as light weight as possible, however strong enough to support a person.

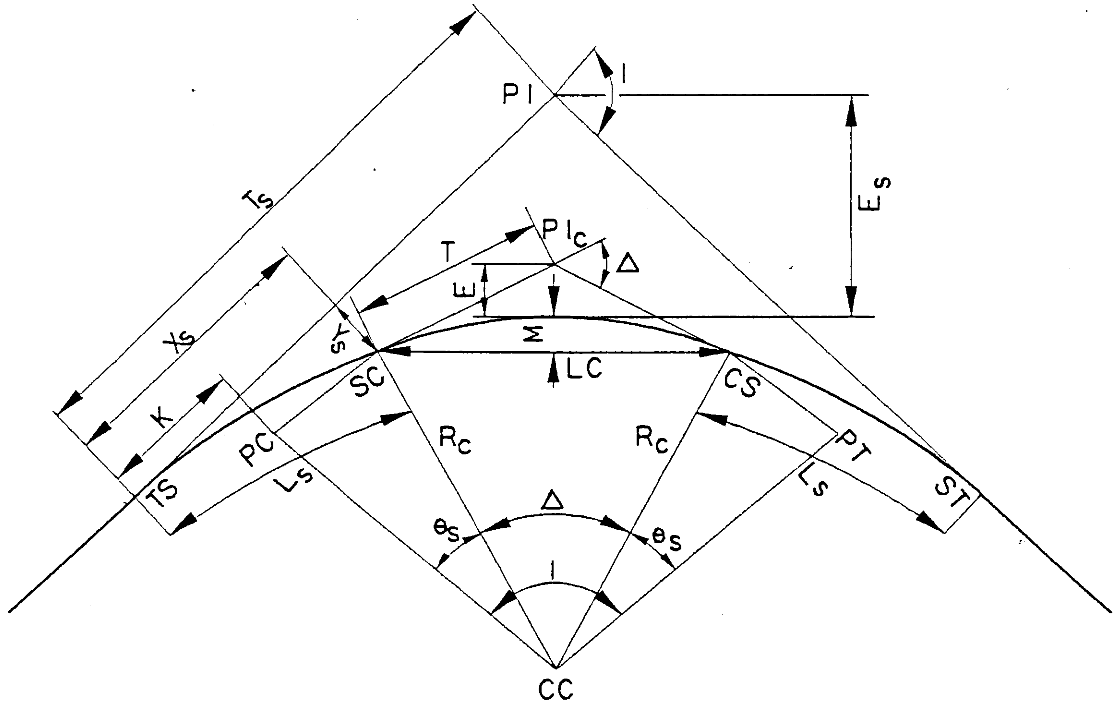
See Figure 1.14 for a typical shield layout detail.

The Fence Panel Railing System consists of welded wire panels that are attached to a steel fence post and tubing frame. The unit is supported from a concrete deck similar to chain link fence and is protected from corrosion. Chain link fence will include the use of standard chain link fabric, with or without curved tops. Plexiglass / glass is an optional material that can be substituted for the steel fencing, of either type. If there is an unusually high risk of vandalism, either expected or observed, the glass option is suggested. The height of a vertical barrier will be determined by the dimension needed to maintain the distance from the access level or point of access of the structure to the OCS messenger wire, a distance of 12 feet (desirable) or 8'-6" (minimum).

OCS wire shields (Figure 1.14) shall consist of a corrosion resistant, triangular shaped, steel framework with a fabric covering and be designed to support the weight of a falling person. The shield design and color will have to be selected individually for each site to enhance the appearance of the existing structure.

The final line section designer will presumably evaluate the conditions at each site, since in the majority of cases no two sites will include the same conditions or are of the same construction type or materials, and design a specific catenary safety barrier for each structure.

Clearance Envelope for Structures. Clearances for wayside structures located below top-of-rail in ballasted track construction shall comply with Figure 1.12.



CIRCULAR CURVE DEFINITIONS

CC	CENTER OF CIRCULAR CURVE
CS	POINT OF CHANGE FROM CIRCULAR CURVE TO SPIRAL
D_c	DEGREE OF CIRCULAR CURVE (ARC DEFINITION)
E	EXTERNAL DISTANCE FROM PIc
E_s	EXTERNAL DISTANCE FROM PI
I	TOTAL CENTRAL ANGLE
K	DISTANCE FROM TS/ST TO PC/PT OF CIRCULAR CURVE MEASURED ALONG MAIN TANGENT
L	LENGTH OF SPIRAL ARC FROM TS TO ANY POINT ON SPIRAL
L_s	LENGTH OF SPIRAL ARC FROM TS/ST TO SC/CS
LC	LONG CHORD OF CIRCULAR CURVE
Lc	LENGTH OF CIRCULAR CURVE
LT_s	LONG TANGENT LENGTH OF SPIRAL
M	MID ORDINATE DISTANCE OF CIRCULAR CURVE
P	OFFSET OF PC/PT OF CIRCULAR CURVE MEASURED FROM MAIN TANGENT
PC	POINT OF CIRCULAR CURVE
PI	POINT OF INTERSECTION OF MAIN TANGENTS
PI_c	POINT OF INTERSECTION OF CIRCULAR CURVE TANGENTS
PT	POINT OF TANGENT OF CIRCULAR CURVE
R_c	RADIUS OF CIRCULAR CURVE
SC	POINT OF CHANGE FROM SPIRAL TO CIRCULAR CURVE
SI	POINT OF INTERSECTION OF SPIRAL
ST	POINT OF CHANGE FROM SPIRAL TO TANGENT
ST_s	SHORT TANGENT LENGTH OF SPIRAL
T	TANGENT LENGTH OF CIRCULAR CURVE
TS	POINT OF CHANGE FROM TANGENT TO SPIRAL
T_s	TANGENT LENGTH FROM TS/ST TO PI
X	DISTANCE FROM TS/ST OF ANY POINT ON SPIRAL PROJECTED TO MAIN TANGENT
X_s	DISTANCE FROM TS/ST TO SC/CS PROJECTED TO MAIN TANGENT
Y	OFFSET OF ANY POINT ON SPIRAL MEASURED FROM MAIN TANGENT
Y_s	OFFSET OF SC/CS MEASURED FROM MAIN TANGENT
θ	CENTRAL ANGLE OF SPIRAL ARC L
θ_s	CENTRAL ANGLE OF SPIRAL ARC Ls
Φ	DEFLECTION ANGLE OF A CHORD BETWEEN TS/SC AND ANY POINT ON SPIRAL
Δ	CENTRAL ANGLE OF CIRCULAR CURVE

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DART PROJECT

DART

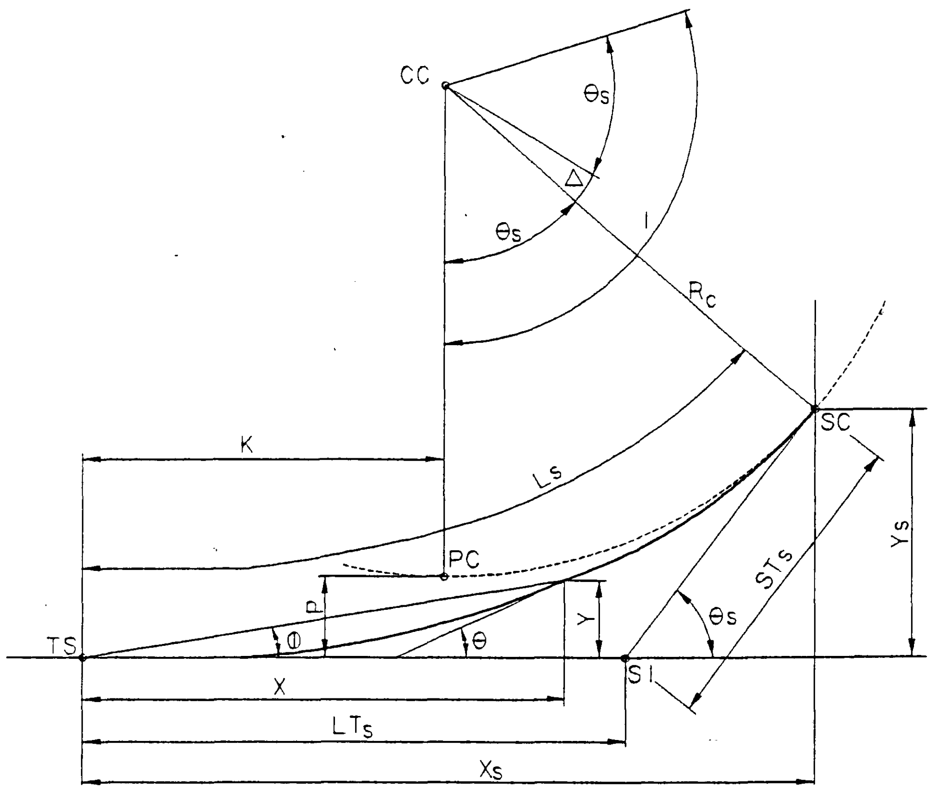
DART DESIGN CRITERIA

DART DESIGN CRITERIA CIRCULAR CURVE WITH SPIRALS

SCALE: NONE

FIGURE: 1.1

JAN. 2003, REV 10



SPIRAL TRANSITION CURVE

EQUATIONS

$$X = \frac{L}{100}(100-0.3046174198\theta^2(10)^{-2}-0.4295915398\theta^4(10)^{-7}-0.3019870768\theta^6(10)^{-12}) - Xs \text{ AT THE SC/CS}$$

$$Y = \frac{L}{100}(0.5817764173-0.12658516\theta^3(10)^{-4}-0.1226910578\theta^5(10)^{-9})-Ys \text{ AT THE SC/CS}$$

$$\Delta = I-2\theta s$$

$$\theta s = \frac{LsDc}{200}$$

$$\theta = \left(\frac{L}{Ls}\right)^2\theta s$$

$$\Phi = \text{ARC TAN } \frac{Y}{X}$$

$$Dc = \frac{100(360)}{2\pi Rc}$$

$$E = Rc\left(\frac{1}{\cos\frac{\Delta}{2}}-1\right)$$

$$Es = \frac{(Rc-P)}{\cos(I/2)} - Rc$$

$$K = Xs - Rc \sin \theta s$$

$$LC = 2Rc\sin\frac{\Delta}{2}$$

$$Lc = \frac{100\Delta}{Dc}$$

$$LTs = Xs - \frac{Ys}{\tan\theta s}$$

$$M = Rc(1-\cos\frac{\Delta}{2})$$

$$P = Ys - Rc(1-\cos\theta s)$$

$$STs = \frac{Ys}{\sin\theta s}$$

$$T = Rc \tan\frac{\Delta}{2}$$

$$Ts = (Rc+P)\tan\frac{I}{2} + K$$

APPROXIMATE FORMULAS

$$X = Ls$$

$$K = \frac{Ls}{2}$$

$$Y = \frac{Ls^2}{6R}$$

$$P = \frac{Ls^2}{24R}$$

$$L.T. \quad \frac{2}{3}Ls$$

$$S.T. \quad \frac{1}{3}Ls$$

NOTES:

1. I, Δ, θ, Φ AND Dc IN DEGREES. ALL OTHER DIMENSIONS IN FEET.
2. REFERENCE T. HICKERSON, ROUTE LOCATION AND DESIGN MCGRAW-HILL, INC. 1967.

ACT 21

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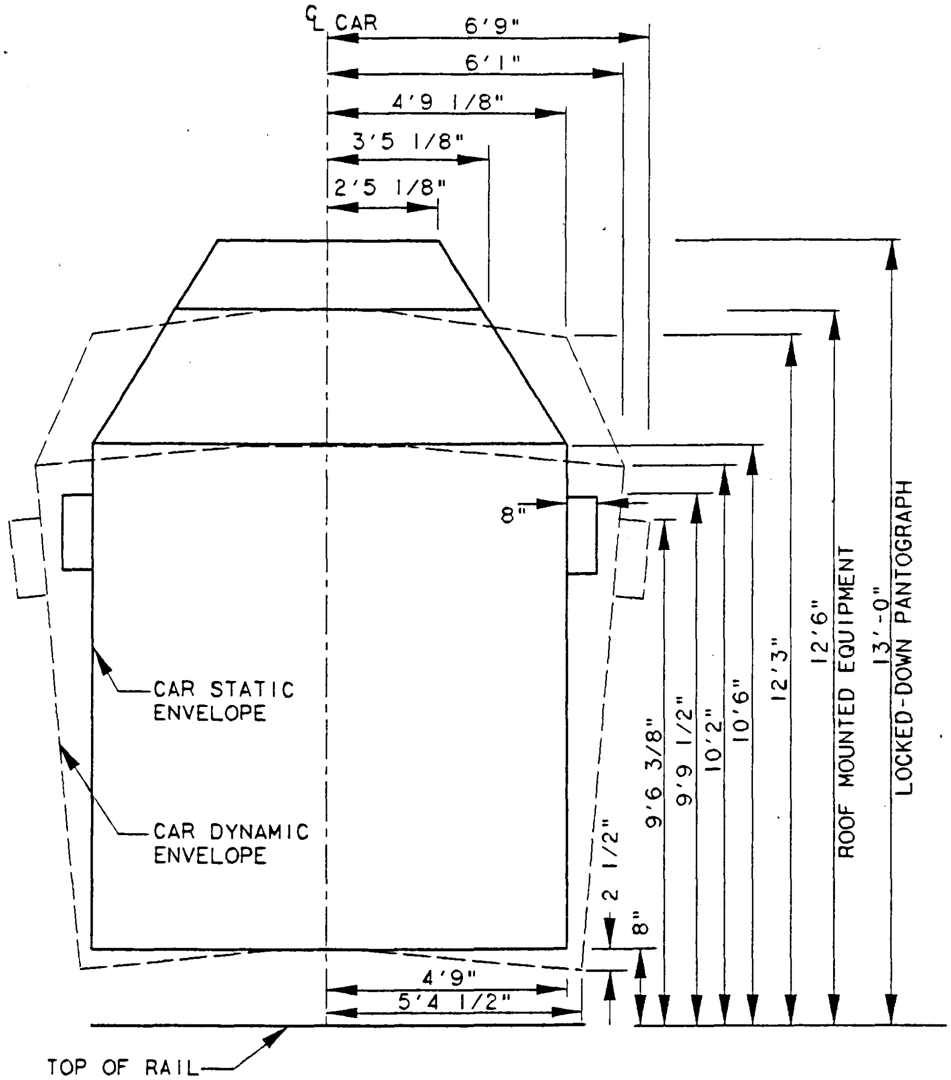
DART DESIGN CRITERIA

SPIRAL TRANSITION CURVE

SCALE: NONE

FIGURE: 1.2



INCLUDES:

VEHICLE DYNAMIC ENVELOPE (SEE SYSTEM DESIGN CRITERIA CHAPTER 2 FOR EXACT VALUES)
TRACK TOLERANCE-4 INCHES HORIZONTALLY AT THE MIRROR FOR BALLASTED TRACK. (SEE 1.9.1) -SUBTRACT 2 INCHES HORIZONTALLY AT THE MIRROR FOR DIRECT FIXATION TRACK.

EXCLUDES:

CONSTRUCTION TOLERANCE (SEE (1.9.3))
CURVATURE-SUPERELEVATION, MIDORDINATE AND OVERHANG(SEE 1.9.2)

——— STATIC OUTLINE
– – – DYNAMIC OUTLINE

TANGENT SECTION

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DART PROJECT

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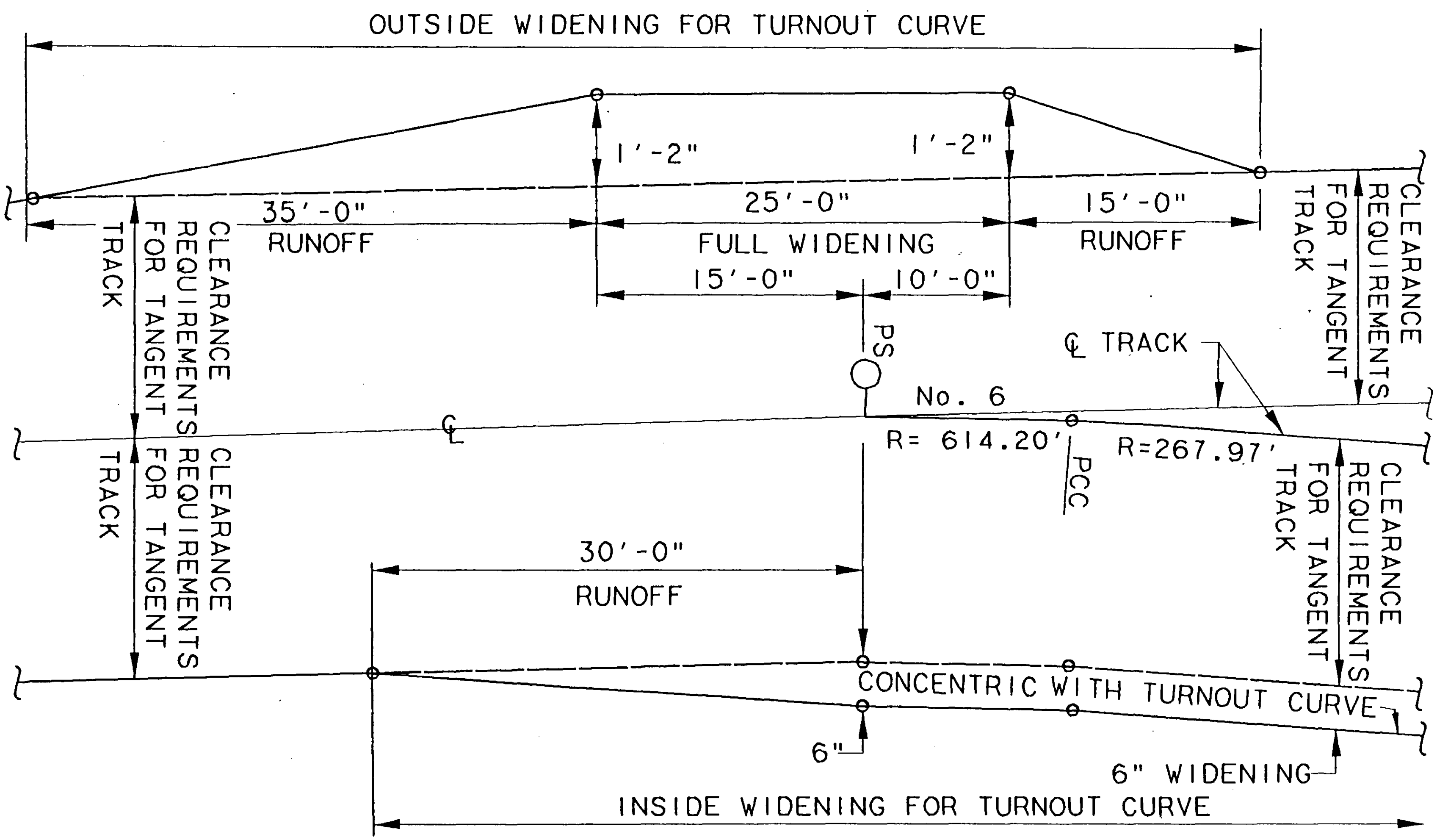
DART DESIGN CRITERIA

DART DESIGN CRITERIA CAR DYNAMIC ENVELOPE

SCALE: NONE FIGURE: 1.3



NOTES:

1. SEE REQUIRED CLEARANCES FOR TANGENT TRACK.

2. CLEARANCE WIDENING COMPUTED BASED ON THE UPPER AND OUTER POINT ON THE MIRROR OF A SKEWED CAR WHICH IS 5.415 FEET FROM THE CENTERLINE OF TANGENT TRACK.

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CLEARANCE WIDENING
NO. 6 TURNOUT

SCALE: NONE

FIGURE: 1.4

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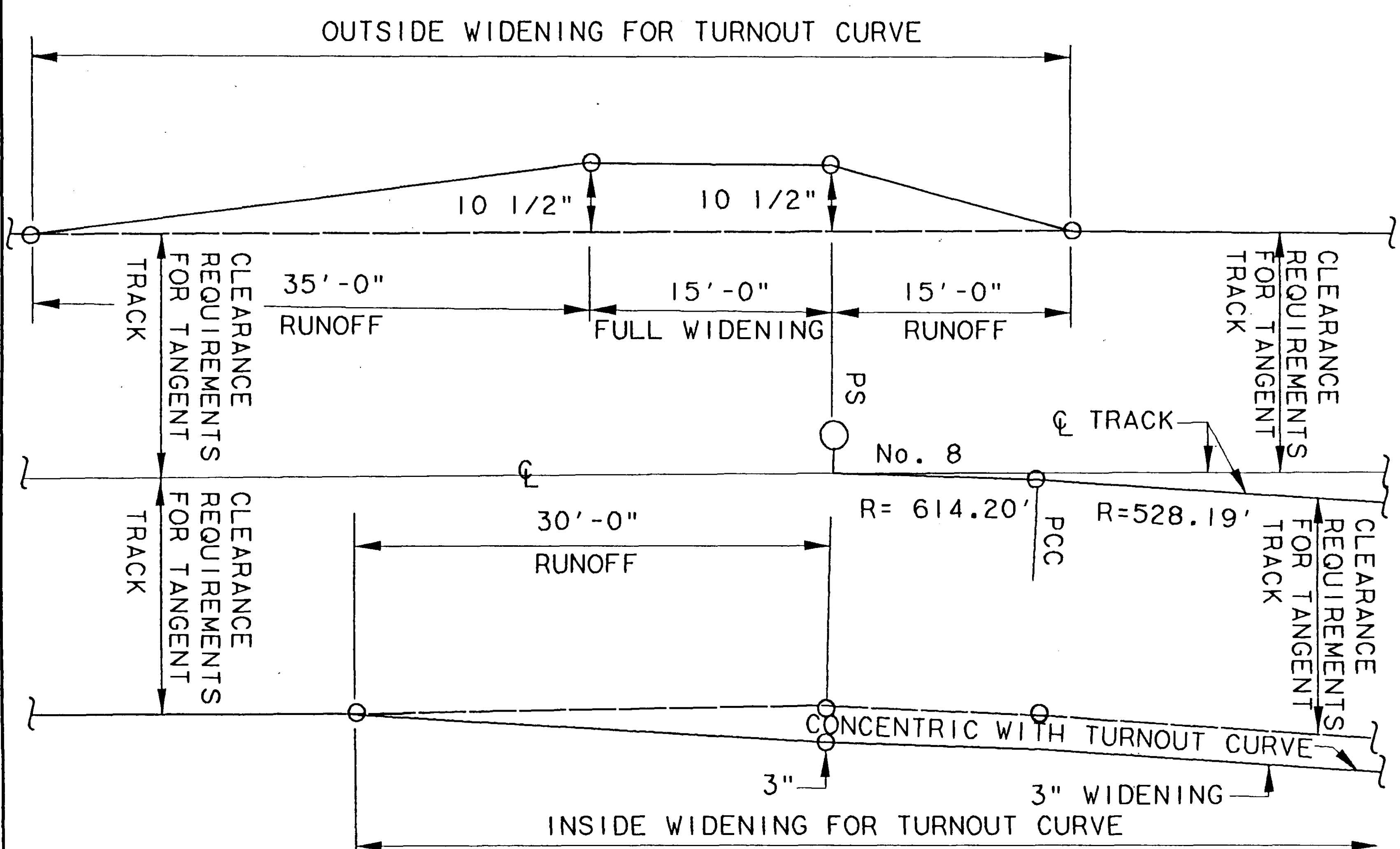

NOTES:

1. SEE REQUIRED CLEARANCES FOR TANGENT TRACK.

2. CLEARANCE WIDENING COMPUTED BASED ON THE UPPER AND OUTER POINT ON THE MIRROR OF A SKEWED CAR WHICH IS 5.415 FEET FROM THE CENTERLINE OF TANGENT TRACK.

ACT 21
CARTER BURGESS
JACOBS ENGINEERING
STV INCORPORATED
KAI ALLIANCE

DART PROJECT

DART DESIGN CRITERIA

CLEARANCE WIDENING
NO. 8 TURNOUT

SCALE: NONE

JAN. 2003, REV 10

FIGURE: 1.5

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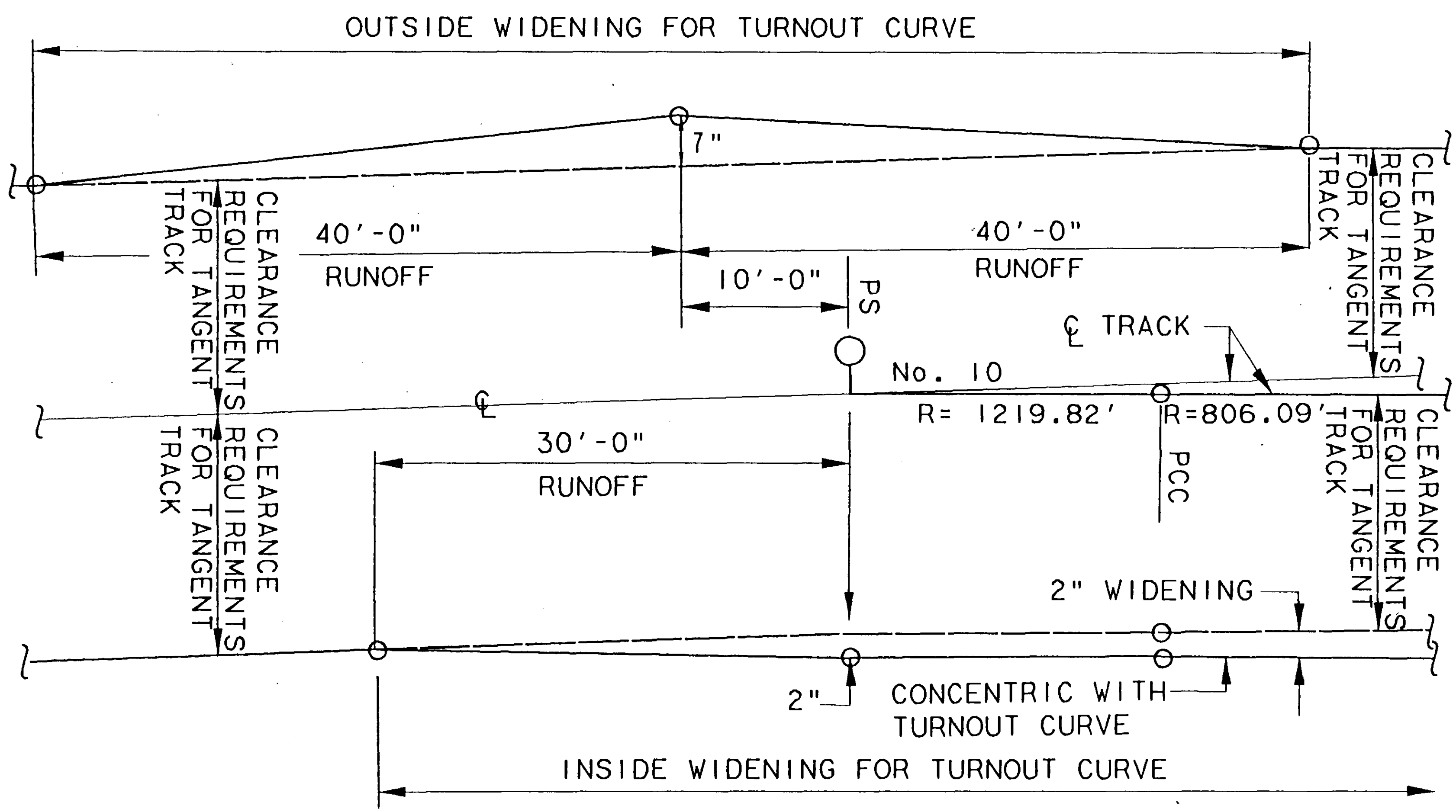

NOTES:

1. SEE REQUIRED CLEARANCES FOR TANGENT TRACK.

2. CLEARANCE WIDENING COMPUTED BASED ON THE UPPER AND OUTER POINT ON THE MIRROR OF A SKEWED CAR WHICH IS 5.415 FEET FROM THE CENTERLINE OF TANGENT TRACK.

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DART DESIGN CRITERIA
CLEARANCE WIDENING
NO. 10 TURNOUT

SCALE: NONE
FIGURE: 1.6
JAN. 2003, REV 10

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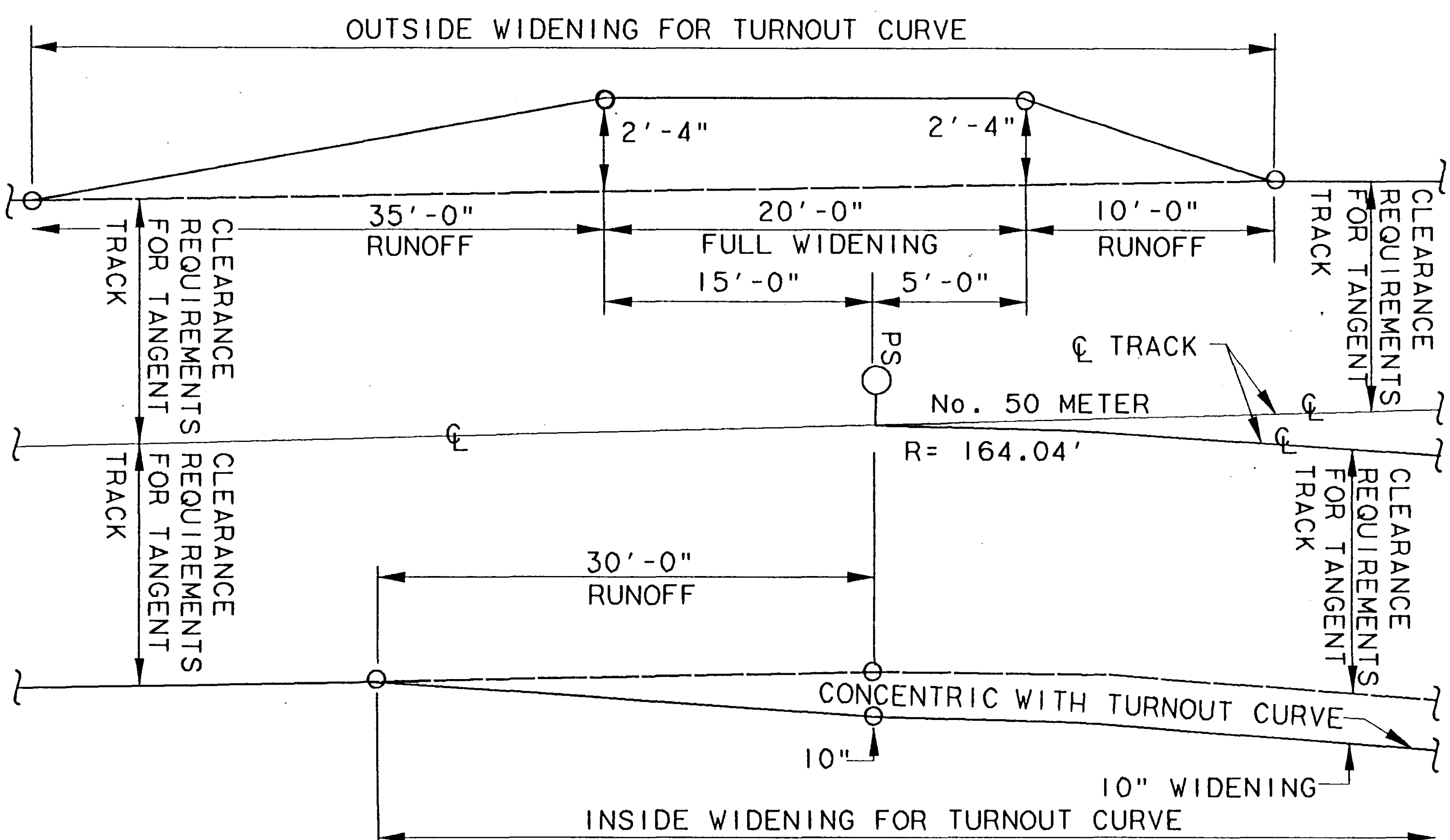

NOTES:

1. SEE REQUIRED CLEARANCES FOR TANGENT TRACK.

2. CLEARANCE WIDENING COMPUTED BASED ON THE UPPER AND OUTER POINT ON THE MIRROR OF A SKEWED CAR WHICH IS 5.415 FEET FROM THE CENTERLINE OF TANGENT TRACK.

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DART

DART DESIGN CRITERIA

CLEARANCE WIDENING NO. 50 METER TURNOUT

SCALE: NONE

FIGURE: 1.7

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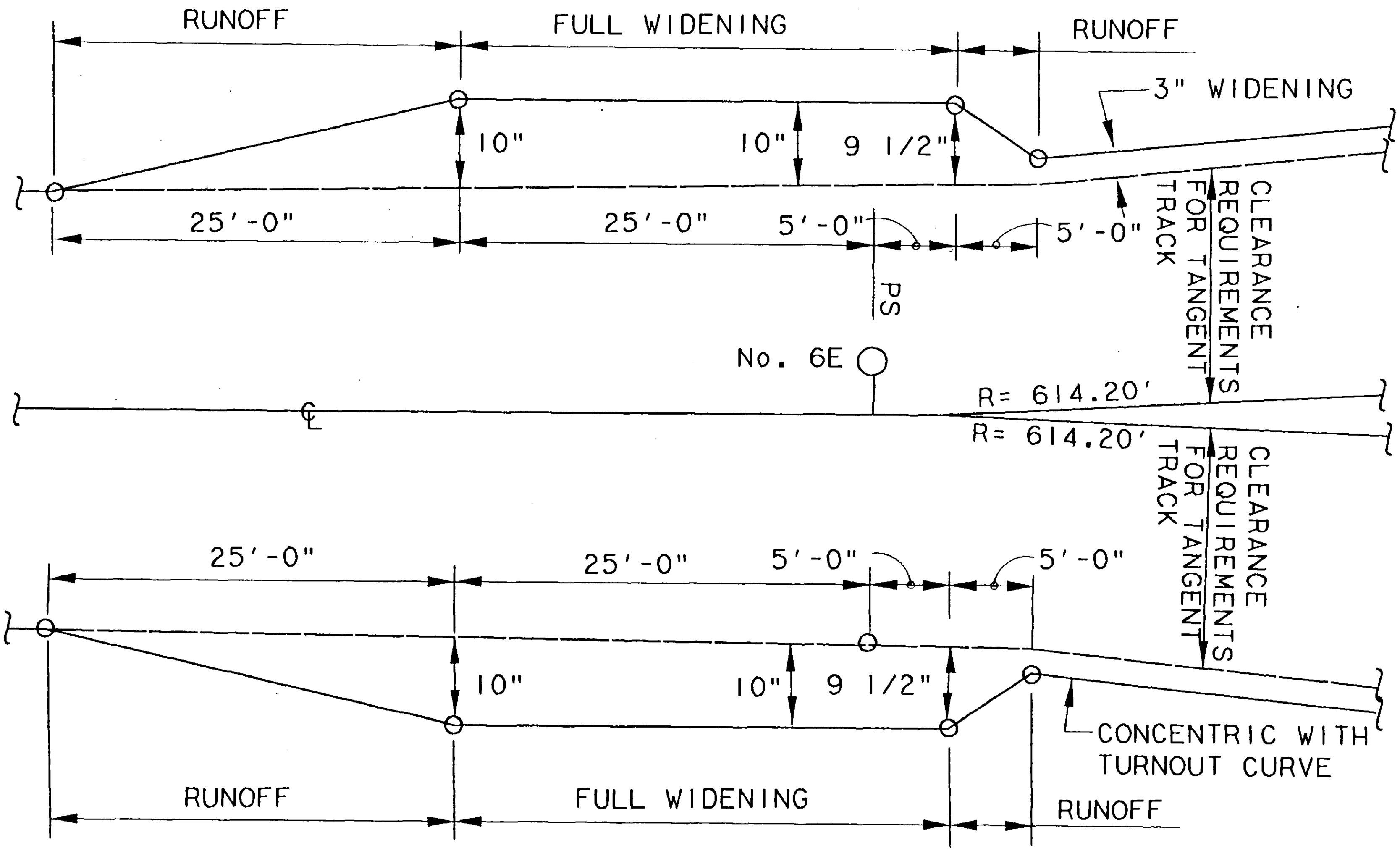

NOTES:

1. SEE REQUIRED CLEARANCES FOR TANGENT TRACK.

2. CLEARANCE WIDENING COMPUTED BASED ON THE UPPER AND OUTER POINT ON THE MIRROR OF A SKEWED CAR WHICH IS 5.415 FEET FROM THE CENTERLINE OF TANGENT TRACK.

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DART DESIGN CRITERIA

CLEARANCE WIDENING NO. 6
EQUILATERAL TURNOUT

SCALE: NONE

FIGURE: 1.8

JAN. 2003, REV 10

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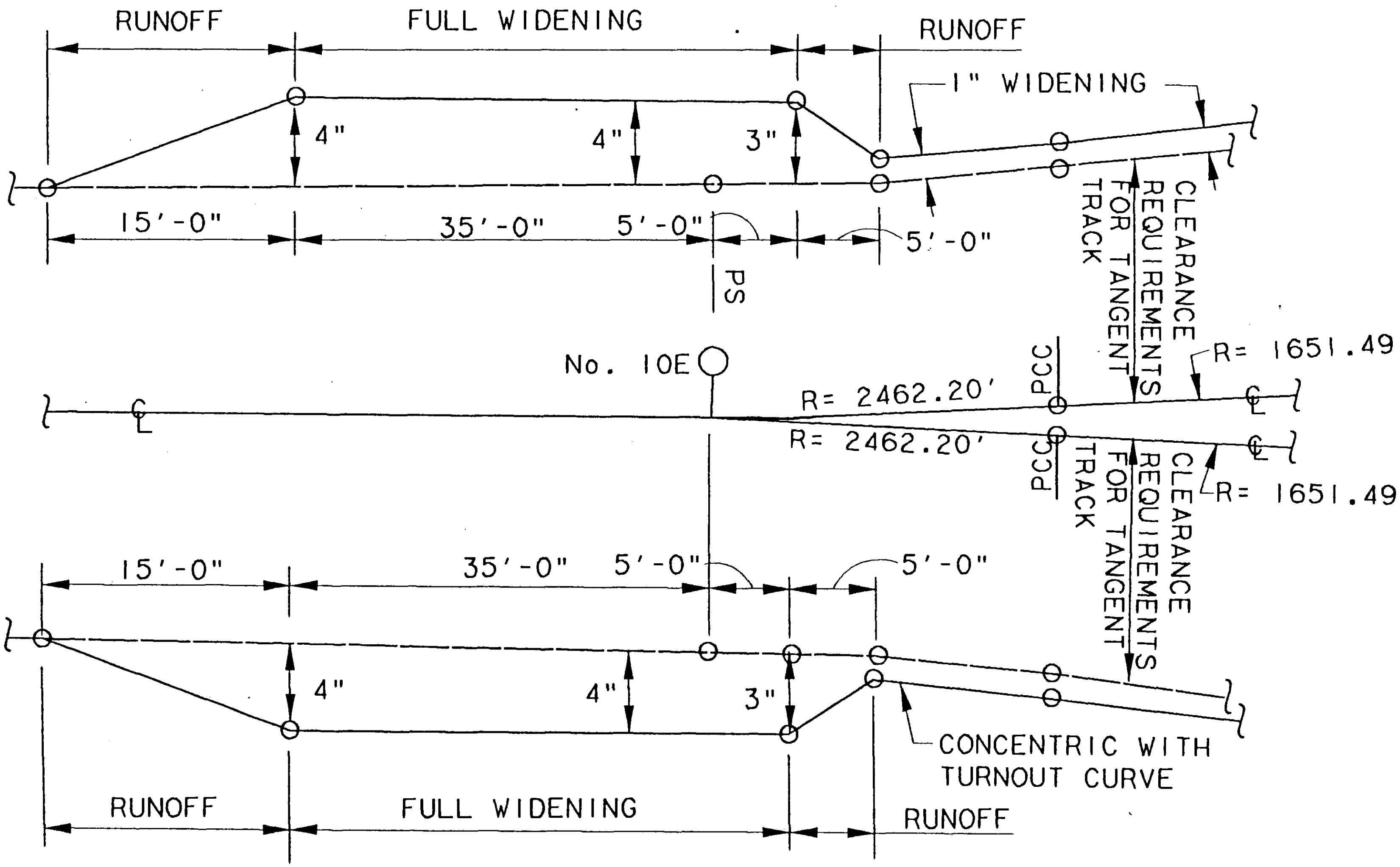

NOTES:

1. SEE REQUIRED CLEARANCES FOR TANGENT TRACK.

2. CLEARANCE WIDENING COMPUTED BASED ON THE UPPER AND OUTER POINT ON THE MIRROR OF A SKEWED CAR WHICH IS 5.415 FEET FROM THE CENTERLINE OF TANGENT TRACK.

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DART PROJECT

DART DESIGN CRITERIA

CLEARANCE WIDENING NO. 10
EQUILATERAL TURNOUT

SCALE: NONE

FIGURE: 1.9

JAN. 2003, REV 10

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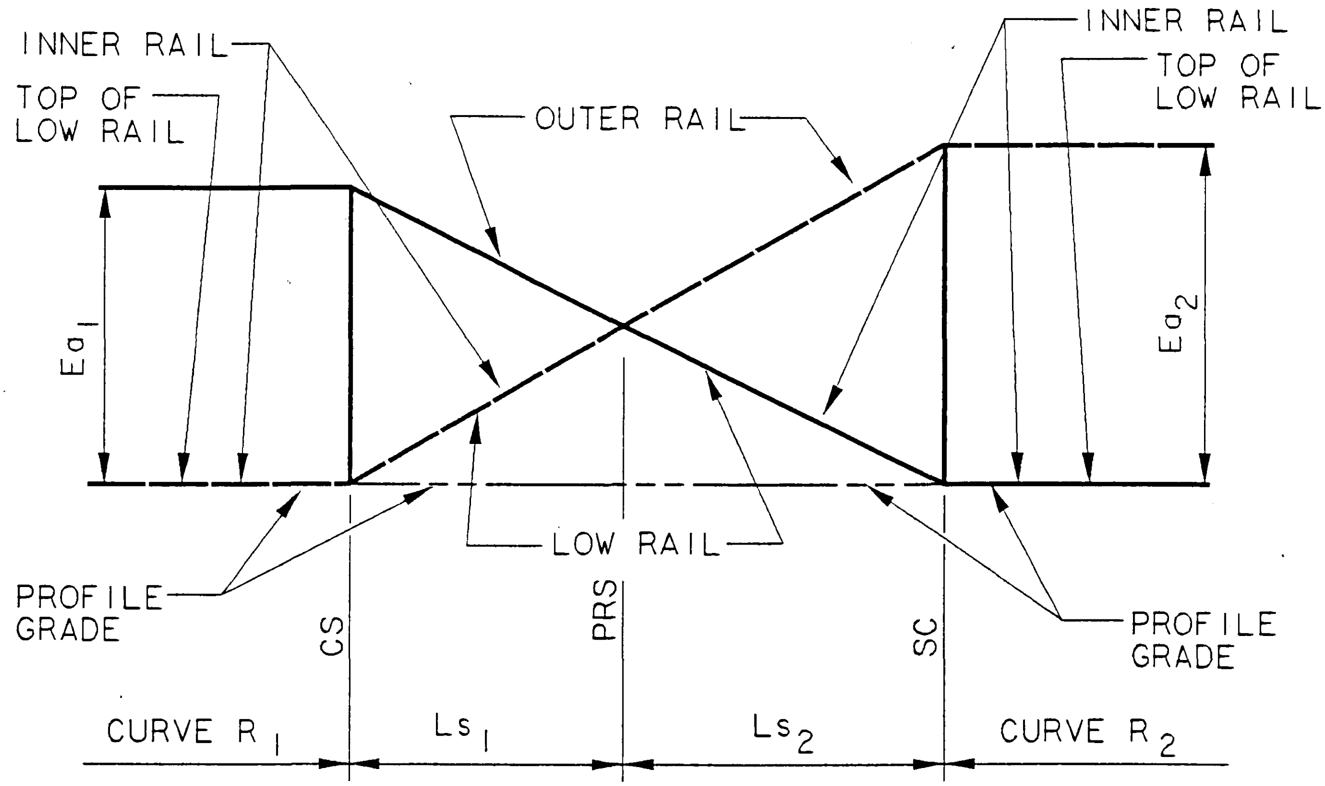
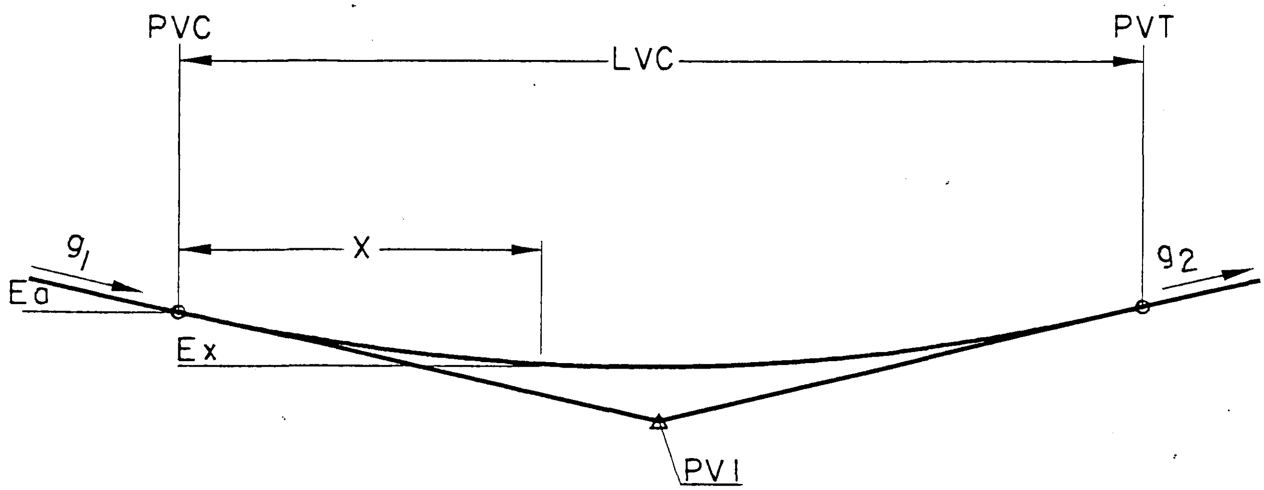


NOTE:

ON SUPERELEVATED CURVE, TOP OF RAIL ELEVATIONS SHOWN ON PROFILE ARE FOR THE LOWER RAIL.
PROFILE GRADE FOR REVERSE CURVES WILL BE AN IMAGINARY LINE CONNECTING LOW RAIL PROFILES AS SHOWN ABOVE.

ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA SUPERELEVATION TRANSITION SCALE: NTS FIGURE: 1.10



$$Ex = Ea + g_1\ X + 1/2r\ (X^2)$$

Where :

Ex = ELEVATION OF A POINT ON THE VERTICAL

Ea = ELEVATION OF THE PVC, IN FEET.
CURVE, IN FEET.

g_1 = GRADE INTO THE VERTICAL CURVE, IN%.

g_2 = GRADE OUT OF THE VERTICAL CURVE, IN %.

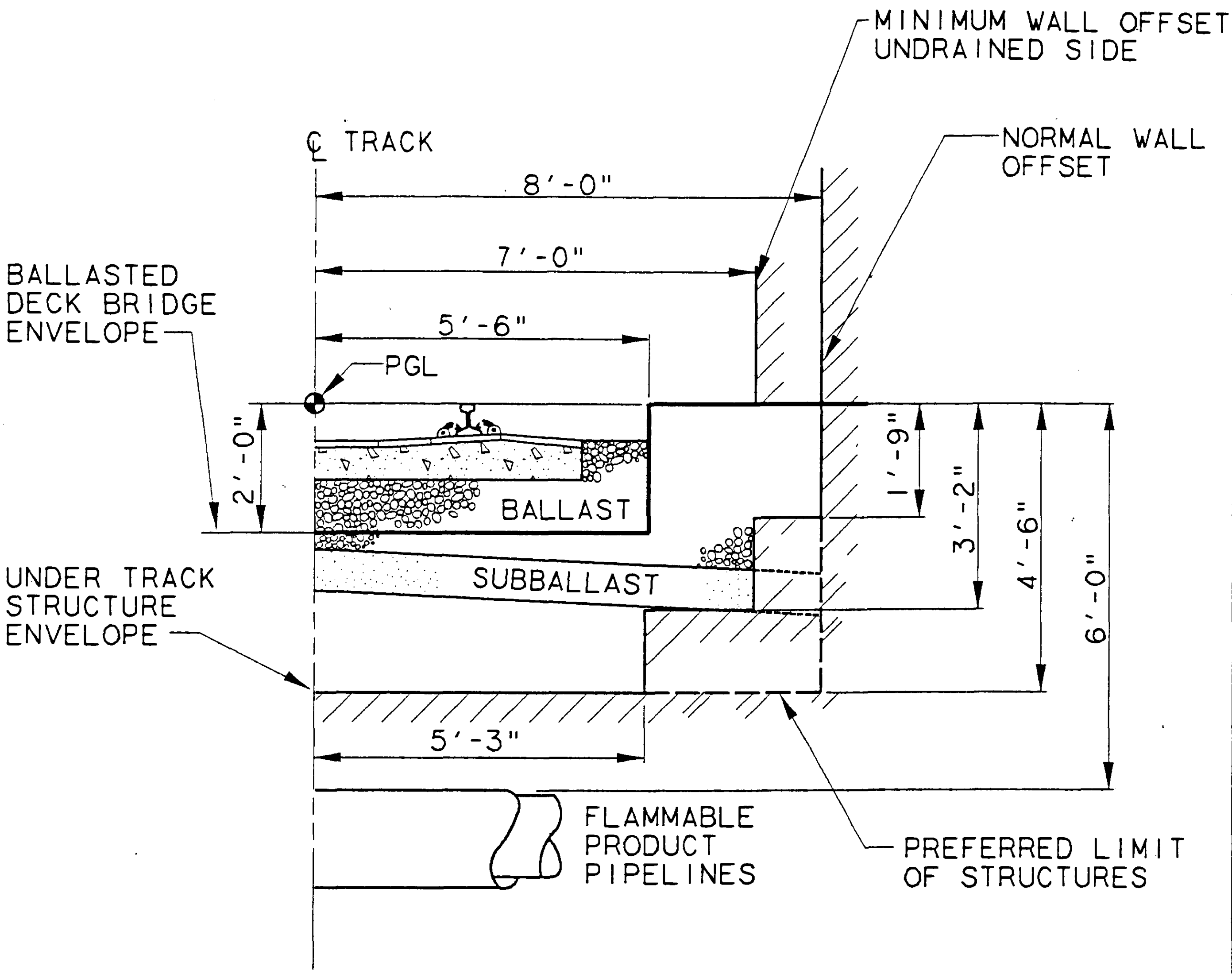
X = DISTANCE FROM PVC TO POINT ON VERTICAL CURVE, IN STATIONS.

r = RATE OF CHANGE OF GRADE, IN % PER STATIONS.

$r = \dfrac{g_2 - g_1}{LVC}$ WHERE LVC IS SPECIFIED IN STATIONS.

STATION = 100 FEET

ACT 21 — CARTER BURGESS, JACOBS ENGINEERING, STV INCORPORATED, KAI ALLIANCE	DART PROJECT — DART	DART DESIGN CRITERIA
		VERTICAL CURVE EQUATION
		SCALE: N.T.S. FIGURE: 1.11



UNDERTRACK STRUCTURES SHALL BE OUTSIDE THIS STRUCTURAL ENVELOPE EXCEPT:

1. NECESSARY TRACK RELATED CONDUIT AND CABLE STUB-UPS.
2. DRAINAGE INLETS.
3. DIRECT BURIED CABLES, MUST BE BELOW SUBBALLAST.

ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA BELOW TRACK CLEARANCES BALLASTED TRACK SCALE: N.T.S. FIGURE: 1.12

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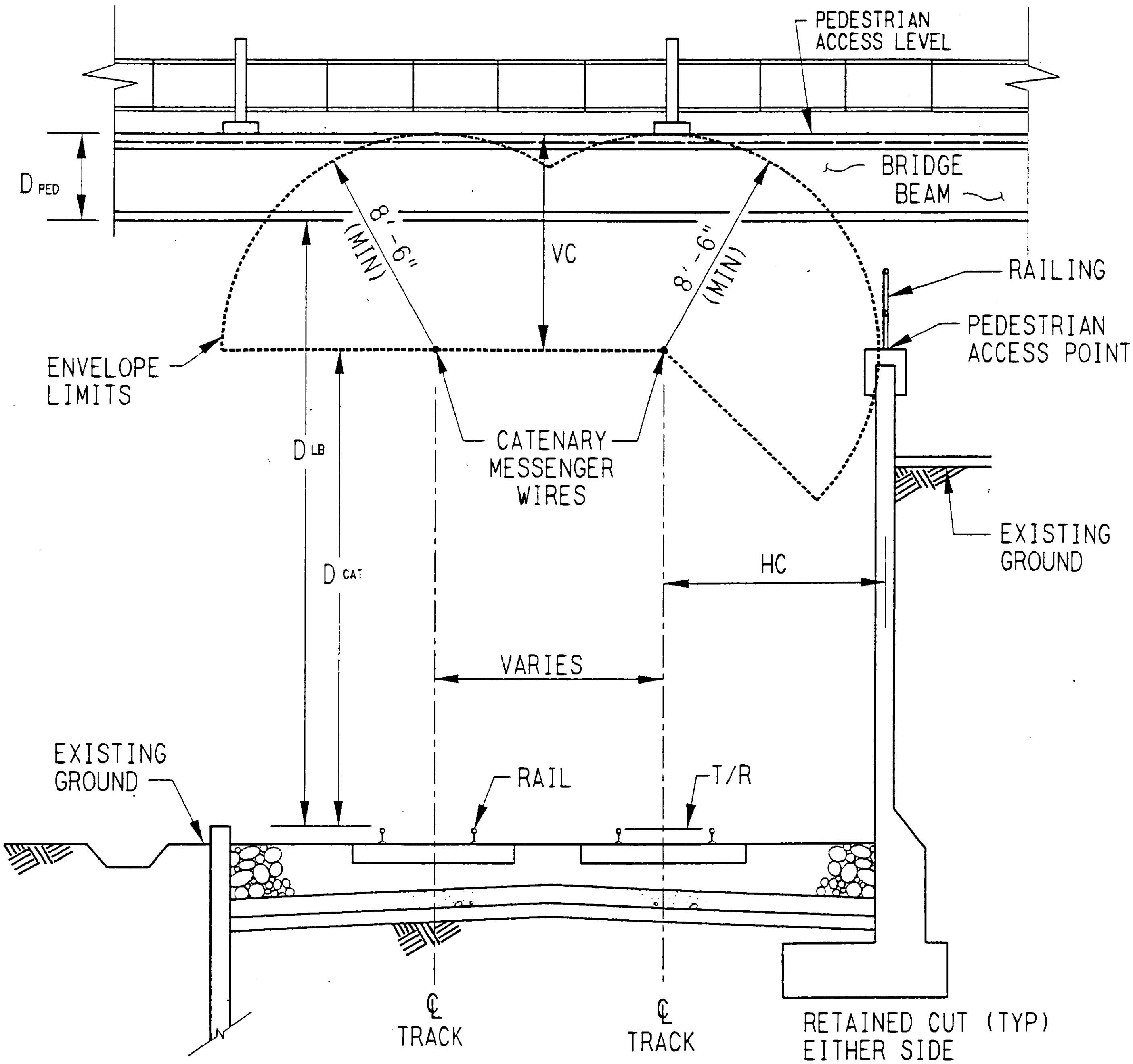

VERTICAL

$VC = (D_{LB} + D_{PED}) - D_{CAT}$

WHERE; VC=VERTICAL CLEARANCE
D_{LB}=DIST. TOP OF RAIL TO LOW BEAM
D_{PED}=LOW BEAM TO PEDESTRIAN ACCESS LEVEL
D_{CAT}=TOP OF RAIL TO CATENARY WIRE

HORIZONTAL

HC=HORIZONTAL CLEARANCE;
CATENARY WIRE TO WALL/RAILING CENTERLINE DIST.

NOTES:

1. TOP OF WALL ELEVATION WILL VARY DEPENDING ON ADJACENT FACILITY.
2. ENVELOPE FIGURED FROM THEORETICAL CENTERLINE OF CATENARY MESSENGER WIRE.
3. MEETS CLEARANCE CRITERIA
   VC OR HC > 12'-0"; DESIRABLE
   > 8'-6"; MINIMUM

   SAFETY DEVICES REQUIRED
   VC OR HC < 12'-0"; UNLESS MIN ALLOWED
   VC OR HC < 8'-6"

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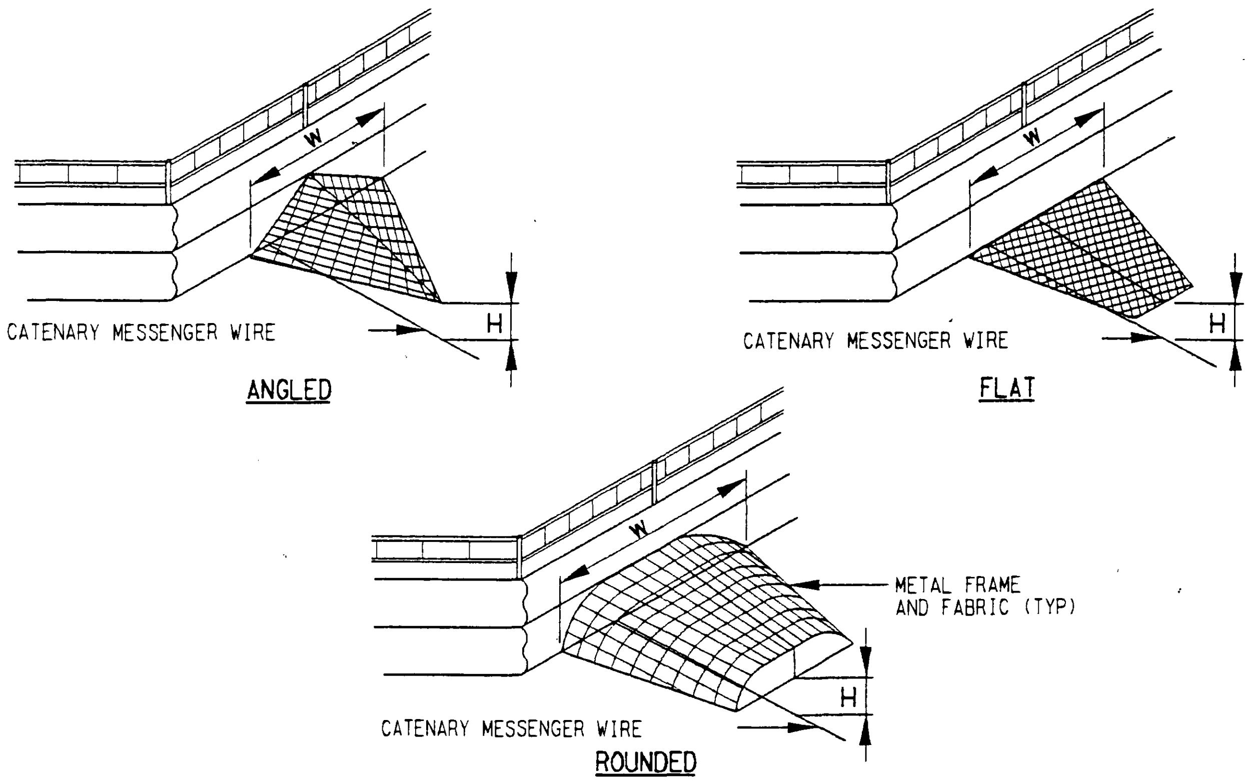
DART DESIGN CRITERIA

CATENARY SAFETY ENVELOPE

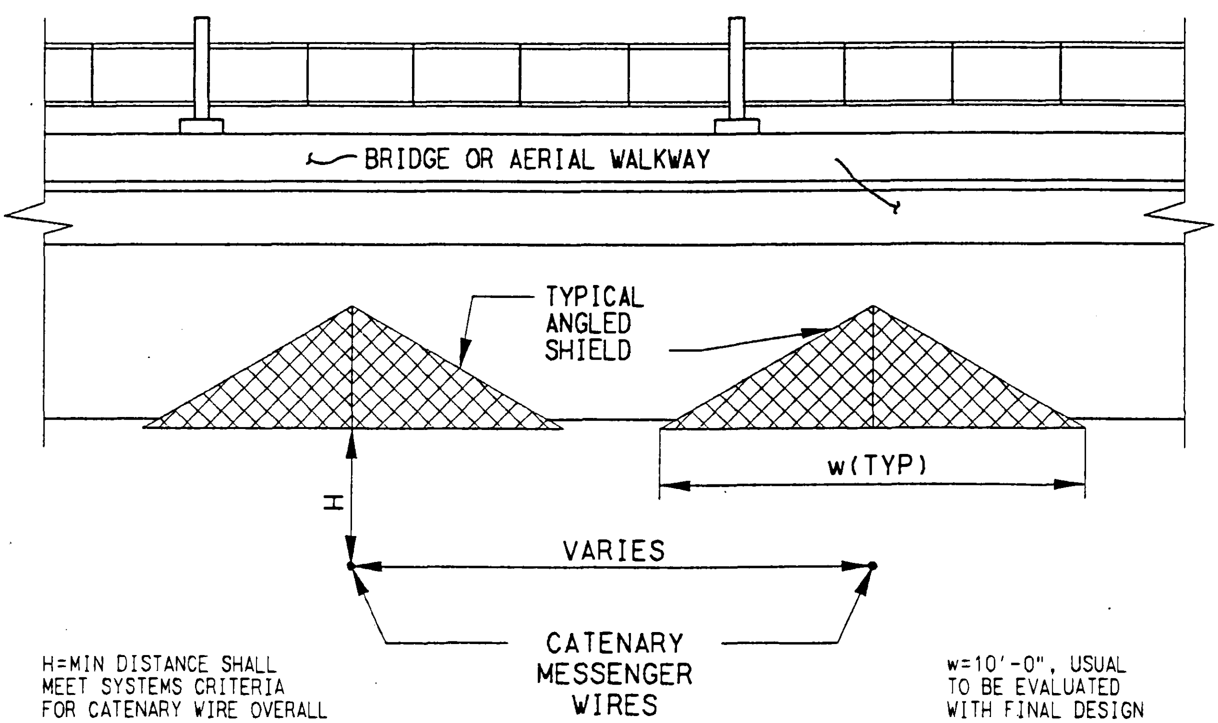
SCALE:

FIGURE: 1-13

JAN. 2003, REV 10



HORIZONTAL SHIELDS



H=MIN DISTANCE SHALL MEET SYSTEMS CRITERIA FOR CATENARY WIRE OVERALL VERTICAL CLEARANCE

w=10'-0", USUAL TO BE EVALUATED WITH FINAL DESIGN

ELEVATION

ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA CATENARY WIRE SAFETY SHIELD SCALE: FIGURE: 1.14

JAN. 2003, REV 10

CHAPTER 2 - TRACKWORK

2.1 INTRODUCTION

This chapter presents the various types of trackwork that may be used on the DART system. Related subjects covered include trackwork locations, use of derails, requirements for ballast, information about ties, rail fasteners and joints, and considerations for grade crossings.

Track materials and special trackwork shall comply with design criteria, directive drawings, and standard drawings for the DART rail system. These criteria and drawings are based on the current edition of the American Railway Engineering and Maintenance-of-Way Association (AREMA) Manual for Railway Engineering and Portfolio of Trackwork Plans. They have been modified as necessary to reflect the physical requirements and operating characteristics of the DART rail system.

2.2 CLASSIFICATION OF TRACK

Track shall be divided into three classes:

- Main line track. Main line track shall consist of all track constructed for the purpose of carrying revenue passengers.
- Yard track. Yard track shall consist of all other track constructed for the purpose of switching, storing, or maintaining transit vehicles. Pocket, interline connector, transfer zone, or yard lead tracks shall be constructed to main line track standards.
- Test track. Test track shall be constructed to the same alignment standards as main line tracks.

2.3 TRACK CONSTRUCTION TYPE

Trackwork shall be divided into five types of construction. Sections 2.3.1 through 2.3.5 provide an overview of the track construction types.

2.3.1 Tie-and-Ballast Construction

Construction shall conform to the following:

- Main line track. At-grade track shall consist of concrete ties, resilient track fastenings, ballast, and subballast upon a prepared subgrade. Bridges less than or equal to 500 feet in length shall have ballasted decks. Bridges over 500 feet in length shall have Direct Fixation tracks subject to approval of DART.

- Yard track. Yard track shall consist of timber ties, tie plates, cut spikes, ballast, and subballast upon a prepared subgrade. Concrete ties may be used in areas where there is need for restraining rail due to curve geometry.

Refer to Figures 2.1 through 2.9 for sections of various tie-and-ballast track construction. These sections will be used where sufficient right-of-way is available and must be modified to accommodate available widths.

2.3.2 Direct-Fixation Construction

Direct-fixation construction shall be used for main line track on non-ballasted aerial structures and in subway structures. When bounded by aerial, subway, or U-wall sections of track, direct-fixation construction also shall be used on track slab at grade for sections less than 350 feet in length. Revenue track and special trackwork shall be fastened directly to the track concrete using direct fixation (standard or special) trackwork fasteners.

Resilient direct fixation rail fasteners shall be used to secure track to concrete. (Refer to the trackwork standard drawings for direct fixation details.) Consideration shall be given during the design of adjacent facilities for the clearance required to install the fasteners (see Figure 2.10).

The direct fixation rail fastener shall consist of two resilient rail clips, elastomeric plate with two female anchorage assemblies, and associated hardware. The fastener shall restrain movement of rail in the vertical, lateral, and longitudinal directions to a degree sufficient to support the rail in the anticipated operating and maintenance conditions. The fastener shall also be designed to minimize stray currents from running rail to ground, and to abate vibration and noise.

The rail hold-down assembly required in direct fixation special trackwork units shall be the same basic rail hold-down assembly used in main line track direct fixation construction. The reinforcing steel of the concrete track structure shall be designed to provide for the resilient direct fixation fastener securing devices.

2.3.3 Dual Block Concrete Pad Construction

In lieu of direct fixation construction, dual block concrete pad construction can be used. The dual block system consists of precast, reinforced concrete block and resilient rail fasteners. The base of each block is placed upon a resilient pad encased in a rubber boot which provides resilient separation between the rail support and the surrounding concrete. Due to the damping provided by the rubber boot, the dual block construction may be required in noise and/or vibration sensitive areas. The surrounding concrete is a second pour made after the dual blocks are placed, aligned and supported on an invert or deck slab.

2.3.4 Embedded Track Construction

Embedded track construction shall be used for main line tracks in the transitway mall. Embedded track may use girder rail. In Embedded track, the base slab concrete is poured with slots for rail installation. The rail is installed for line and gauge and embedded in a filler material. The rail is supported along its length in the filler material without discrete supports under the base. The filler material used shall provide resiliency in the Embedded track structure and minimize the noise and vibration. Embedded track shall be designed to minimize stray current in accordance with systems design criteria.

2.3.5 Shop Track Construction

Shop track shall consist of all track constructed within the limits of the maintenance shop building and adjacent shop aprons. Two types of track shall be used in the shops: pit track and Embedded track. Except in pit areas, the standard form of construction shall be, in general, conventional Embedded track with welded girder rail or with welded 115RE rail with a formed flangeway. A reinforced-concrete track slab shall provide the foundation beneath this form of track construction. Rail hold-downs shall be used to secure the rails to proper gauge, line, and surface during construction. Refer to systems criteria for stray current and grounding issues. A subsequent pour of concrete shall embed the track to the elevation of the top of the running rails.

2.3.6 Shop Pit

In shop track through-pit areas, 115RE welded rail shall be used. The rail shall be supported by individual parts, with rail welded to the posts in a manner that permits maintenance baskets to roll on top of the rail base. Alternative methods of support and fixation can be used subject to DART approval.

2.4 TRACK GAUGE

Standard track gauge throughout the system shall be 4 feet 8-1/2 inches, as measured perpendicular between inside faces of running rail at a point 5/8-inch below the top of rail. Track gauge shall be widened as necessary on short radius curves of 500 foot radius or less.

Gauge in girder rail track areas shall be 4'-8". Gauge in girder rail track areas shall be coordinated with vehicles procured for actual wheel flange, wheel base, and back-to-back axle dimensions.

2.5 TRACK CONSTRUCTION TOLERANCES

Track construction tolerances shall comply with the criteria shown in Table 2-1.

TABLE 2-1

TRACK CONSTRUCTION TOLERANCES

Class and Type of Track	Gauge Variation	Cross Level and Superelevation Variation	Vertical Track Alignment		Horizontal Track Alignment	
			Total Deviation	Middle Ordinate In 62' Chord	Total Deviation	Middle Ordinate In 62' Chord
Direct Fixation and Embedded Track	+1/8" - 1/16"	± 1/8"	± 1/4"	± 1/8"	± 1/8"	± 1/8"
Mainline Ballasted Track	± 1/8"	± 1/8"	± 1/2"	± 1/8"	± 1/2"	± 1/8"
Yard Ballasted Track	+3/16" - 1/8"	± 3/16"	± 3/8"	± 1/4"	± 3/8"	± 1/4"
Shop Track	± 1/8"	± 1/8"	± 1/4"	± 1/8"	± 1/4"	± 1/8"

Notes:

(1) Total deviation is measured between the theoretical and actual alignment centerline at any point in the track.
(2) Total horizontal and vertical deviation in road crossings ± 1/4".
(3) In the Station Platform areas: Total Horizontal deviation shall be 0" towards Platform and 1/8" away from platform; Total Vertical deviation shall be 0" above Platform and 1/8" below platform.

2.6 RAIL

Except as specified below, standard running rails shall be 115RE section, manufactured in accordance with current AREMA "Specifications for Steel Rail." Specially treated, control-cooled rail shall be used as follows:

- End-Hardened Rail. End-hardened rail shall be used for all bolted joints except where premium rails are used.

- Premium Rail. Either head hardened or Fully heat-treated rail shall be used for all special trackwork.

"A" rails shall not be used as running rails in main line track and special trackwork, but may be used for yard track and secondary track, except for shop track running through pit areas. Rails to be used for welded rail shall be furnished with blank ends. Rail ends to be used in bolted joints shall be drilled in accordance with the most current AREMA requirements and beveled in accordance with the most current version of AREMA Plan No. 1005.

Premium rail is used in curves of 500 feet radius or less, and shall extend a minimum of 5 feet into the tangent track on the approach and departure ends of the curve. Minimum rail length shall be 15 feet 8 inches, except as necessary in special work and turnouts. Rails to be used in curves with a centerline radius of less than 450 feet shall be pre-curved. The pre-curving of the rail shall be accomplished through standard shop methods.

Girder rail used in Embedded track shall be of an appropriate section, control-cooled and manufactured in accordance with current AREMA "Specifications for Steel Rail". Premium girder rail shall be used for the same applications as 115 RE rail.

2.7 SPECIAL TRACKWORK

The term "special trackwork" designates the trackwork units necessary where tracks converge, diverge or cross one another. Special trackwork includes turnouts, crossings and crossovers. All special work design shall be based on AREMA standards except as modified to meet the special conditions of the LRT system. Special trackwork which conforms with European standards may be considered depending on the type of special trackwork required and specialization of the item.

Special trackwork on the LRT system will consist of ballasted, direct fixation and embedded trackwork. Ballasted special trackwork shall be constructed on conventional timber switch ties using insulated rail fasteners. Embedded special trackwork shall consist of tongue switch and mate turnouts and track crossings. Direct fixation turnouts will be similar to ballasted track turnouts except that the rails, switches and frogs will be fastened to a second pour concrete slab using insulated resilient rail fasteners. As it will be less costly than other types, the design should utilize ballasted special trackwork whenever possible.

- **Ballasted Special Trackwork**

All special trackwork shall be designed and constructed in strict accordance with the DART project Standard and Directive Drawings. Turnouts and crossovers shall be located in ballasted track wherever possible. To minimize future maintenance consider using Geotextile Fabric under all ballasted special track work.

- **Embedded Special Trackwork**

Embedded special trackwork shall be designed to suit the restricted street configurations. Standard components shall be used whenever feasible. The designer shall look for opportunities to make multiple use of custom embedded special trackwork components, such as curved frogs of a particular radius.

Embedded turnouts may vary in design sizes from conventional railroad designs. Generally, embedded turnouts include curved switches and frogs and are designated by the turnout radius (100 feet, 25 meters, etc.).

Embedded switches shall be of the tongue switch and mate variety generally in accordance with the designs illustrated in the AREMA "Portfolio of Trackwork Plans". Specific dimensional requirements will be developed during preliminary engineering based on information that will be obtained from special trackwork fabricators concerning available casting patterns and manufacturer's standards. At a minimum, mates will be modified from AREMA design in order to reduce point batter by either reducing the flangeway width or by providing flange-bearing design, or both as needed.

Embedded frogs shall be of the monoblock steel section with welded toe and heel arms. To both ease frog point batter and provide a consistent running surface at frogs and track crossings consideration will be given to flange bearing design. Crossing frogs shall be designed in a similar manner.

- **Direct Fixation Special Trackwork**

Alignment design should minimize special trackwork requirements in Direct Fixation track environment. Exceptions can be made in situations where the route geometry forces a particularly complex special trackwork layout with multiple turnouts and track crossings.

Special trackwork shall be located so as to reduce the exposure of pedestrians to the operating or movable mechanisms and to minimize requirements for special catenary and signal structures. Special trackwork shall not be located in areas designated for pedestrian crosswalks. Where this objective proves to be difficult to achieve, crosswalks may be located between the switch and the frog provided that pedestrians are nowhere exposed to a metallic walking surface or flangeway wider than would occur if the pedestrian crossing were located away from the special trackwork unit.

The limits of any trackwork design or construction contract shall not be located within a special trackwork unit or superelevated curve.

Special trackwork shall be located in tangent track, unless otherwise approved by DART. There shall be no actual superelevation (E_a) in any special trackwork units. All special trackwork shall be located on tangent vertical profile grades.

The minimum length of horizontal tangent track between any point of switch and the end of a station platform shall be 60 feet unless approved otherwise by DART.

Tangent distances between turnout point of intersection and the beginning of horizontal or vertical curve shall be in accordance with directive drawings and were developed based on the following criteria:

- Minimum distances are obtained by locating the beginning of horizontal or vertical curves at a point that is 35 feet from point of switch or point of frog.

- Desirable distances are obtained by locating the beginning of horizontal or vertical curves ahead of a turnout at a point that is either 45 feet (approximately the length of one articulated LRV car body section), or 60 feet (for railroad traffic) from the point of switch. Curves following a turnout are set beyond the last long switch tie.

- Absolute minimum distances are obtained by locating the beginning of horizontal or vertical curves 20 feet ahead of the point of switch. Non-superelevated horizontal curves may begin beyond the farthest end of the joint bars connecting the running rail to the heel of the frog. Vertical curves and superelevated horizontal curves following a turnout shall not begin until after the last long switch tie.

Turnouts are set to provide connections to branch lines, storage tracks and industrial sidetracks and to merge two main tracks into a single track at the end of a double track segment. Crossovers consist of two turnouts located to allow traffic to cross over from one track to another, both tracks usually being in parallel. Where a pair of crossovers are required, one right hand and the other left hand, it is desirable that they be located as two single crossovers. If this is not possible, or if extraordinary site conditions make it more economical, a double crossover may be used. The size of turnout or crossover selected depends upon its purpose, desired design speeds and local geometric constraints. Maximum operating speeds through the diverging moves on turnouts shall be as indicated in Table 2-2.

Table 2-2

MAXIMUM OPERATING SPEEDS THROUGH DIVERGING MOVES OF TURNOUTS

TURNOUT NO.			MAXIMUM SPEEDLIMIT (MPH)
6	-	Lateral	10
8	-	Lateral	15
10	-	Lateral	20
6	-	Equilateral	15
8	-	Equilateral	25
10	-	Equilateral	30
48m	-	Lateral	10
25m	-	Lateral	5
50m	-	Lateral	5
186ft	-	Lateral	5

2.7.1 Configurations

The units and their criteria to be used on the system include:

- No. 10 turnouts, at minimum, at junctions between routes (19-foot-6-inch curved split switch).
- No. 10 turnouts (19-foot-6-inch curved split switch) for main line track crossovers, turnouts to the yard, pocket tracks, and end-of-line storage.
- No. 8 turnouts (19-foot-6-inch curved split switch) may be considered for main line track crossovers, turnouts to the yard, pocket tracks, and end-of-line storage, only if a No10 turnout cannot be accommodated due to site specific physical constraints.
- No. 10 equilateral turnouts (26 foot curved split switch) for pocket tracks, for aerial tracks and subway track installations. No. 10 lateral turnouts (19- foot-6-inch curved split switch) for at-grade locations.
- No. 6 turnouts (13-foot curved split switch) for yard tracks, or if space permits, No. 8 turnouts (13-foot curved split switch).

Combinations of these units to be used on the system shall include the following arrangements:

- Turnback Tracks. This is a three-track arrangement in which a center pocket track is situated between main line tracks. On aerial and subway track construction, equilateral turnouts will be used to provide the connection from the center pocket to the main line tracks. At-grade sections will use lateral turnouts.

- Emergency Storage Tracks. This arrangement includes a single crossover between two main line tracks at wide track spacing followed by a modified crossover that has been lengthened to serve as a center pocket track and a crossover.

- Universal. This configuration employs two single back-to-back crossovers connecting main line tracks.

- Double Crossover. This trackwork consists of four lateral turnouts connected together by a rail crossing composed of two end frogs and two center frogs. It shall be used in all direct-fixation locations.

Details of these units and configurations are shown on the trackwork standard and directive drawings.

2.7.2 Location Criteria

Crossovers and turnouts shall be located on tangent track and on constant profile grades with a desired maximum grade of ±1 percent and an absolute maximum grade of ±4.5 percent. The installation of special trackwork on a horizontal or vertical curve may be considered, but will require prior approval by DART.

Special trackwork is a source of noise and vibration. Those factors will be considered, as will the recommendations of the acoustical consultant when selecting locations and alternative designs for special trackwork.

Special trackwork shall not be located within 250 feet of a transition between ballasted track and direct fixation track. The desirable minimum length of tangent track between any point of switch and a future end of a station platform shall be 60 feet. The desirable horizontal and vertical tangent distance preceding a point of switch shall be 50 feet, and the absolute minimum shall be 20 feet. The minimum distance measured from a point of switch through a turnout to a horizontal or vertical curve point shall be as shown in Table 2-3.

2.7.3 Switch Machine Locations

Switch machine locations shall be positioned as follows:

- Subway and aerial structures. On turnout side, in tension.
- Emergency crossovers. On turnout side, in tension.
- At-Grade junctions. On turnout side, in tension.
- Terminals:
  - On turnout side, in tension, for switch machines at stations with center platforms.
  - On main line side, in compression, for switch machines at stations with side platforms.
- Embedded track. Switch machines and switch points in Embedded track will not be located in pedestrian areas or in areas where there is inadequate drainage.

2.7.4 Component Features

The basis of design for all special trackwork components is the AREMA "Portfolio of Trackwork Plans"; however, certain features of the special trackwork components may vary from AREMA design. Any deviation from the trackwork standard drawings shall require approval by DART.

Possible variations include:

- Special trackwork will be welded.
- Frogs with extended arms to provide adequate clearance for rail welds and suspended joints.
- Main line switches utilizing extended switch points with a floating heel block and tie spacing increased in the closure area and after the frog.
- Embedded track turnouts utilizing double tongue welded flex switches and frogs of the rolled section block type.
- Gauge plates beneath the switch and frog.

- Rail crossings in conformance with the standards indicated on AREMA Plan No. 820-68.

- All turnouts with Samson switch points with undercut stock rails according to AREMA Plan No. 221-62, point detail 5100.

- Direct fixation turnouts supported by special direct fixation fastenings.

- Curved switch points and stock rails pre-curved, using standard shop methods.

- Closure rails with radii less than 450 feet pre-curved, using standard shop methods.

TABLE 2-3
LIMITING DIMENSIONS FOR SPECIAL TRACKWORK

Turnout No.	Type of Track Construction	Minimum Distance From Point of Switch Through Turnout To Point of Curve (Vertical or Horizontal)	
		Desirable	Minimum*
6	Ballasted	75'	60'
8	Ballasted	90'	75'
10	Ballasted	120'	100'
50 Meter	Ballasted	75'	60'
6 Equil.	Ballasted	75'	60'
10 Equil.	Ballasted	120'	100'

* May require change in long tie layout.

Note:

(1) For curves of opposite direction than the turnout curve the section 1.3.4, Minimum Tangent Length applies.

(2) There are no restrictions at non-ballasted track structure for long switch ties adjustment or shimming when minimum distances are applied.

2.8 DERAILS

Derails shall be installed on access tracks to railroad sidings and on any yard or secondary track normally used for the storage of unattended vehicles if:

- o Any of those tracks are directly connected to the main line track.
- o Their prevailing grade descends to the main line track.

Descending grades to the main track should be avoided whenever possible. The location and direction of derails, which will be electrically operated and interlocked with wayside signals, shall be approved by DART. (See Systems Design Criteria Chapter 4 - Signals System for more information.)

2.9 APPROACH SLABS

A transitional approach slab shall be provided at all transitions between ballasted track, direct fixation track, and Embedded track. (See the trackwork standard drawings for details.)

2.10 END OF TRACK RESTRAINING DEVICE

A rail-mounted retarding device shall be used on stub-end tracks located in yards, on main lines, or on sidings. This device shall limit movement by absorbing vehicle energy and it shall include an anti-climbing feature. Should conditions warrant, an additional hydraulic car-retarder shall be considered. (Refer to the trackwork standards and directives for details.)

2.11 CORROSION PROTECTION

Refer to Systems Design Criteria (Vol. 2) Chapter 8 - Corrosion Control and Chapter 9 - System Grounding for additional information concerning corrosion protection.

2.12 SUBBALLAST AND BALLAST

A flexible-base material shall be used for subballast. Asphalt base may be considered where soil conditions warrant and where use is economical and technically adequate. Ballast shall be crushed stone conforming to the current AREMA specifications of ballast.

2.12.1 Subballast

Subballast or an accepted alternate material shall be used for all ballasted track. Subballast shall not be used on ballasted deck bridges or U-wall construction. The subballast for all tracks shall consist of a uniform layer placed and compacted over the entire width of the roadbed following the profile and cross section. The depth of subballast measured from the bottom of the ballast to the top of the subgrade shall be a minimum of 8 inches. Subsurface conditions shall be determined in accordance with Chapter 10 - Geotechnical Information. All subballast material shall conform to current Texas Department of Transportation "Specifications for Flexible Base, Item 247."

2.12.2 Ballast

The minimum depth of ballast from the bottom of the tie to the top of the subballast (beneath the lowest running rail) shall be 12 inches. Cribs and shoulders shall be filled with ballast to the top of the tie. If not direct-fixation construction, the minimum depth of ballast beneath the bottom of ties on ballasted-deck bridges and U-wall construction shall be 8 inches.

Shoulder ballast shall extend 12 inches beyond the end of ties parallel to the plane formed by the top of the tie. The high outside shoulder shall be increased to 18 inches for curves where the radius (R) equals 1,000 feet or less. In at-grade sections, shoulder ballast shall then slope at 2:1 to the subballast. For additional details refer to the trackwork standard drawings. All ballast shall conform to the current AREMA specification for ballast. No. 4A size ballast shall be for main line tracks and No. 5 size ballast shall be for yard. Crushed cementitious rock such as limestone or dolomite and Slag shall not be used for either mainline or yard track ballast.

2.13 TIES

Cross ties for main line ballasted track segments shall be concrete. Timber ties shall be used for ballasted special trackwork and yards.

2.13.1 Concrete Ties

Concrete cross ties used in main line ballasted track shall be 8'-3" long and spaced a maximum of 30 inches center-to-center. Tie spacing shall be 24 inches center-to-center in ballasted deck bridges and in locations where restraining rails are used. They shall include a cant (1:40) on the rail bearing area. Tie spacing at approach slabs shall be as shown in the trackwork standard drawings. Concrete crossties used in main line ballasted track at-grade crossing shall be 10'-0" long and spaced at 24 inches center-to-center.

2.13.2 Dual Block Concrete Pads

Dual block concrete pads may be used in main line track construction in lieu of direct fixation track. The ties shall be spaced a maximum of 30 inches center to center. The individual blocks shall be encased in a rubber boot. The tie assembly shall be held in place with a second pour of concrete. Ductile iron shoulders shall be deeply embedded in the concrete block to form an integral part of the rail support system.

2.13.3 Timber Ties

All timber ties shall be treated mixed hardwoods with anti-splitting devices installed in accordance with current AREMA specifications. All timber ties shall be air seasoned and treated with an appropriate preservative in accordance with the current AREMA "Specifications for Ties."

<u>**Timber Cross Ties**</u>. Timber cross ties shall be used in yard ballasted track. All timber cross ties shall be new, pre-bored, 7" grade treated tie, 8 feet 6 inches in length. They shall conform to

current AREMA "Specifications For Timber Cross Ties." Timber cross ties shall be spaced a maximum of 24 inches center-to-center.

Timber Switch Ties. All timber switch ties shall be new, treated 7 inch by 9 inch ties, in lengths specified in the trackwork standard drawings. They shall conform to the current AREMA "Specifications for Timber Switch Ties." Timber switch ties shall be field bored, and holes shall be treated with an appropriate preservative.

2.14 RAIL FASTENERS

2.14.1 Ballasted Track Rail Fasteners

Concrete ties shall use resilient clip track fasteners suitable for the loading and operating conditions of the system. The fastener assembly shall also have an insulating tie pad and clip insulators. Main line timber cross ties shall also use a resilient clip track fastener, where applicable, complete with double-shoulder canted (1:40) tie plates, spring clips, rubber pad, insulated anchorage bushing, and timber screw spikes (plate hold-down). The same resilient clip track fastener shall be used on main line timber switch ties wherever possible. Screw spikes or another rail hold-down shall be used as required. Special plates shall be used to support switch and frog components, and the use of these plates may require the use of specially modified rail fastening devices in lieu of the resilient clip track fastener. Yard track and yard special trackwork shall utilize screw spikes, hooked twin plates, and tie plates.

2.14.2 Direct Fixation Rail Fasteners

Direct fixation rail fasteners for aerial and direct fixation slab track shall provide the required lateral and longitudinal restraint for continuous welded rail and the electrical insulation required for the negative return current and the proper operation of track signal circuits. Direct fixation rail fasteners shall have the following longitudinal spacing:

Trackwork	Spacing
Tangent or curved track with radius greater than 500 feet	30-inch centers
Curved track with radius 500 feet or less and greater than 300 feet	27-inch centers
Curved track with radius 300 feet or less	24-inch centers
Track carrying railroad traffic	24-inch centers

Direct fixation rail fasteners shall provide a longitudinal restraint force of 2,400 pounds per fastener and restrain a broken rail gap to less than 2 inches wide. On aerial structures, low restraint fasteners may be required to allow the structure to expand and contract without overstressing the rail.

2.15 GUARDED TRACK

All main line ballasted and direct-fixation tracks having a centerline radius less than or equal to 500 feet shall have the inside running rail guarded with a restraining rail. All ballasted yard track having a centerline radius of less than or equal to 250 feet shall have the inside running rail guarded. In the event the planned operating speed for any curve in yard track is greater than 10 miles per hour, the need for additional guarding requirements shall be determined during detail design. This type of guarding protection shall be achieved by using a fabricated assembly with an adjustable and replaceable wear bar. The guard shall protrude 1 inch above the top of the low rail and shall be electrically isolated from the running rail. The guardrail shall extend 32 feet into tangent track. Alternative designs employing other methods of guarding will be considered. The operating speed on track with restraining rail shall not exceed 25 miles per hour in any application. (Refer to the standard drawings for additional details.) Special trackwork shall be guarded in the frog and crossing areas. Guarding for main line and yard track frogs and crossings shall consist of an AREMA type design using a spacer block bolted to the running rail.

2.16 JOINING RAIL

2.16.1 Welding

Unless otherwise specified, girder and tee rails shall be joined by pressure-weld methods into continuously welded rail (CWR) strings. Contiguous strings of CWR shall be joined together with electric flash butt welds wherever possible. Thermite welding may be used only with prior approval of DART. String lengths shall be determined during final trackwork design. Girder rail shall be welded to tee rail by use of a specially designed rail plug. This plug will facilitate a change in cross section from girder rail to tee rail. Rails to be welded shall not be drilled for joint bars. Any rail to be welded which contains bolt holes shall first be cropped a minimum distance of 3 inches from the center of the last hole. All pressure welds shall be checked by a brush recorder that monitors the flashing process. These pressure welds also shall be magnetic-particle tested. All welds shall be ultrasonically tested as outlined by the AREMA Manual for Railway Engineering by an individual qualified in the ultrasonic testing of rail weldments. Additionally, a selected number of welds will be radiographed. An acceptance criteria for allowable size and number of weld defects will be determined during final trackwork design.

2.16.2 Bolted Joints

Except where specified below, the use of bolted joints shall be minimized. The standard bar for use with 115RE rail shall be 36 inches in length, with 6 holes conforming to the current AREMA specifications for Rail Drillings, Bar Punchings and compression type high strength collar pins. As may be necessary according to these criteria, joint bars shall be located in special trackwork and in other locations. Special provisions shall be made to allow for the electrical bonding of rail joints for traction power and signaling requirements.

2.16.3 Epoxy Bonded Joints

Epoxy bonded joints shall be electrically bonded to provide a continuous path for traction power negative return current and signal circuits. Epoxy bonded joints shall comply with the following parameters:

- o They shall employ an identical drilling pattern as standard joint bars.
- o They shall be compatible with the standard direct fixation rail fasteners used on the DART system.
- o They shall comply with the general requirements of a rail joint as defined by Chapter 4 of the current AREMA Manual for Railway Engineering.

2.16.4 Insulated Joints

Insulated joints of the epoxy-bonded type shall be used wherever it is necessary to electrically isolate contiguous rails from each other to comply with track signaling criteria. Track bolts shall be the Compression type high-strength collar pins. Insulated joint bars shown in Figure 2.11 shall also comply with the physical parameters listed in Section 2.17.3 of these criteria. (The Systems Designer will define insulated joint locations.)

2.17 GRADE CROSSINGS

2.17.1 Highway

Main line track grade crossings shall be prefabricated from rubber, a rubber and steel composite or Concrete Panels (The type of Grade Crossing has to be in accordance with the requirements of local authority which has jurisdiction over the street on which the Grade Crossing is located.). They shall be designed for ease of replacement, electrical isolation, and use of running rail in track circuits. Yard grade crossings shall utilize prefabricated timber panels and asphalt. Rail joints and welds shall not be located within grade crossing limits. Geotextile fabric shall be used before placing ballast at all grade crossings as shown on the standard drawings. Track underdrains shall be used at all grade crossing sites in conjunction with suitable geotextile filter fabrics. Grade crossings shall be located on tangent tracks wherever possible. Grade crossings located in curved track and special trackwork shall be avoided wherever possible. Cross ties shall be spaced in accordance with the grade crossing panel manufacturer's recommendations and as addressed in section 2.13.1 of this chapter. Mainline track grade crossing will incorporate pedestrian crossings as required. Pedestrian crossings in Stations shall be concrete and shall be located as needed.

2.17.2 Railroad

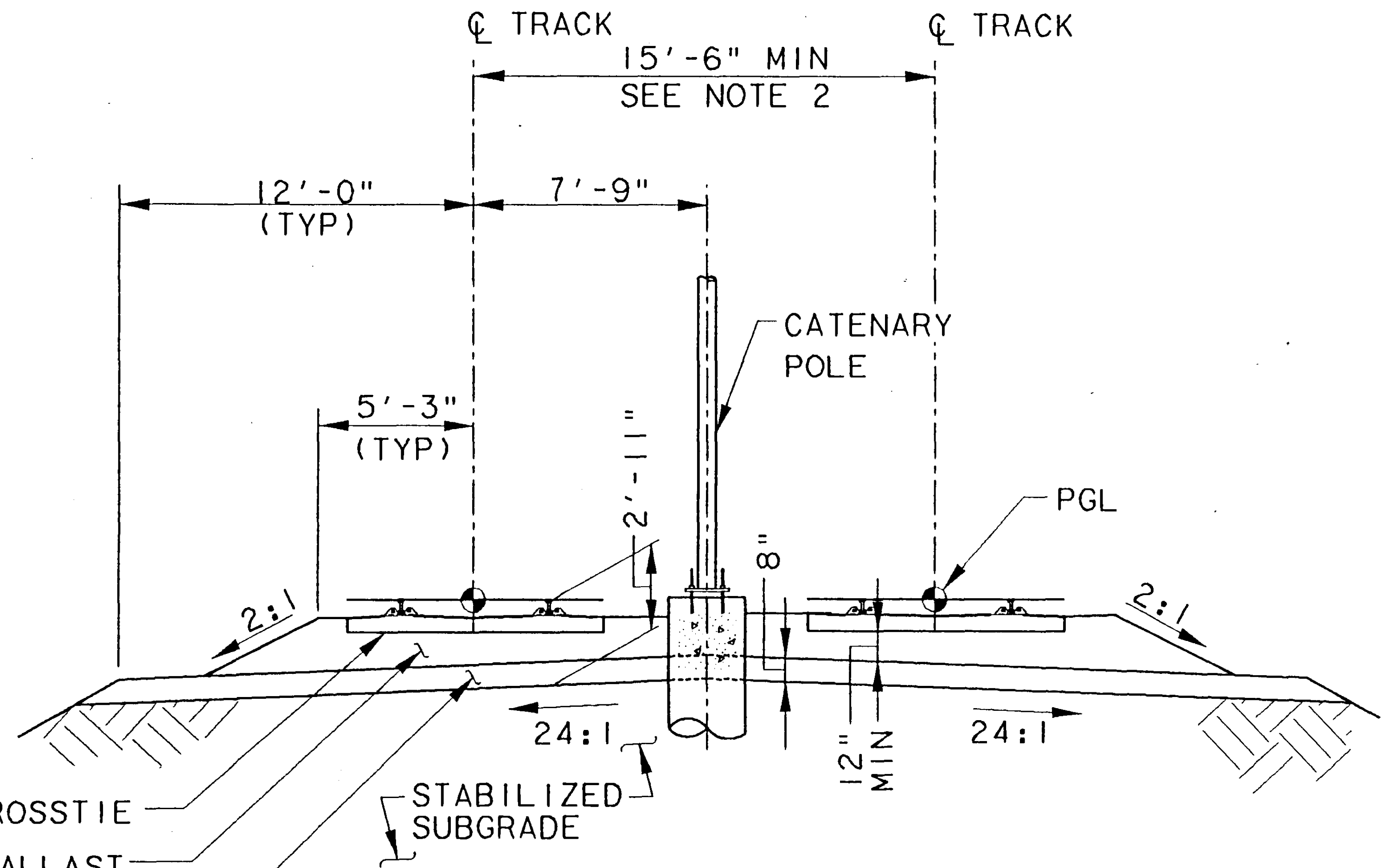
Railroad at-grade crossings of DART main line tracks shall be restricted to those railroad tracks that serve industrial sidings. Such crossings will be a rigid design in accordance with AREMA Plan 820.

2.18 RAIL ANCHORS

Rail anchors shall be applied to all tracks constructed with timber tie. Application of rail anchors shall conform to the AREMA manual Specification for Rail Anchors, Chapter 5.

2.19 GAUGE RODS

In Embedded track construction gauge rods shall be installed on all curves with a radius less than 400 feet.



NOTES:

1. SEE OTHER TYPICAL DRAWINGS FOR SLOPES, R/W, AND RELATIONSHIPS TO OTHER FEATURES.
2. TRACK CENTERS MAY BE REDUCED TO 14'-0" IN AREAS WHERE A CENTER POLE IS NOT REQUIRED OR WITH A CENTER POLE OF WIDTH EQUAL TO OR LESS THAN 1 FOOT UPON DART APPROVAL.

TANGENT AT GRADE

CARTER BURGESS
JACOBS ENGINEERING
STV INCORPORATED
KAI ALLIANCE

DART PROJECT

DART DESIGN CRITERIA

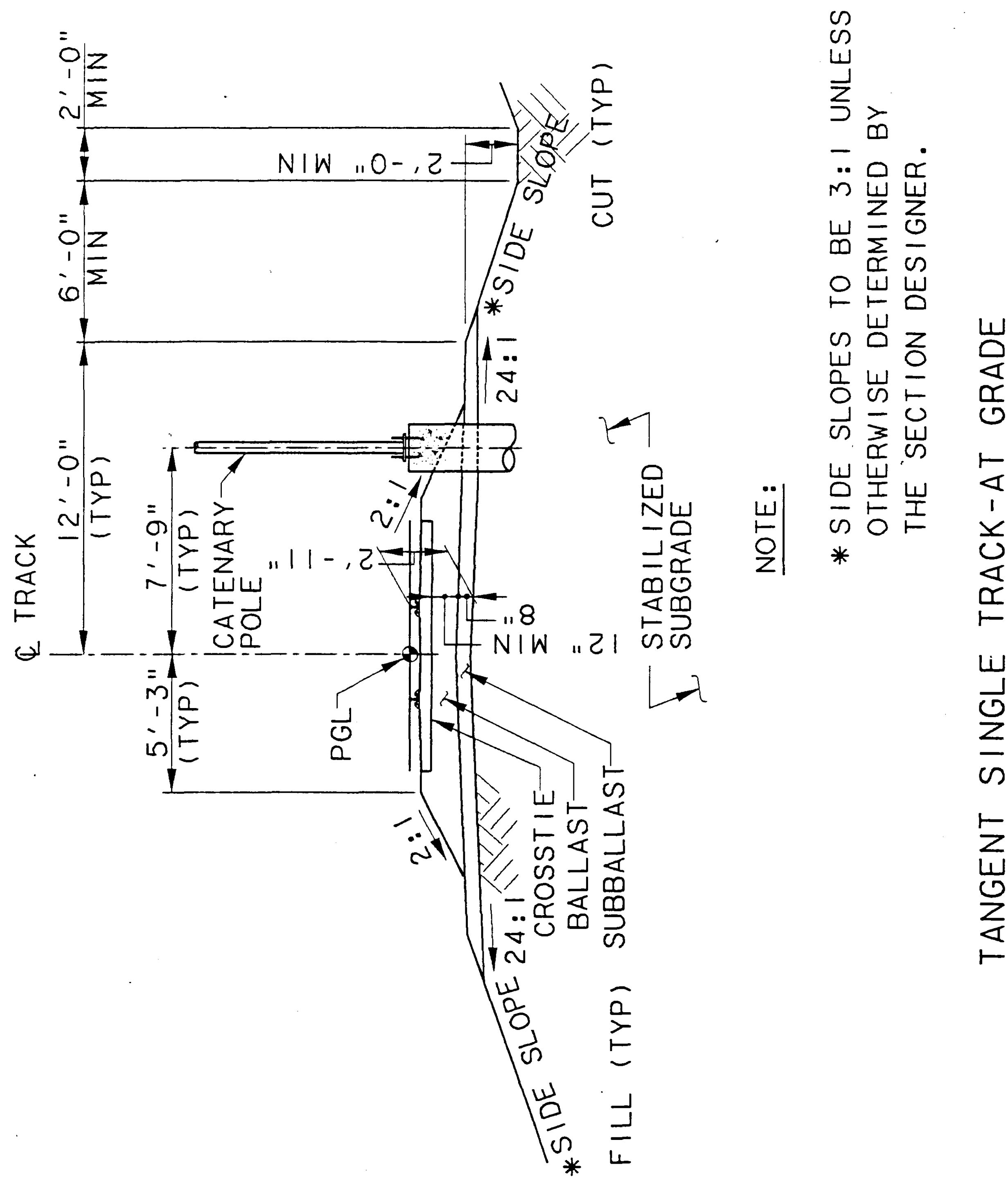
TANGENT AT GRADE

SCALE: 1" = 6'-0"

FIGURE: 2.1

JAN. 2003, REV 10

DWG. NO. KX6-0001



DWG. NO. KX6-0002

ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA TANGENT SINGLE TRACK -AT GRADE SCALE: 1" = 6'-0" FIGURE: 2.2

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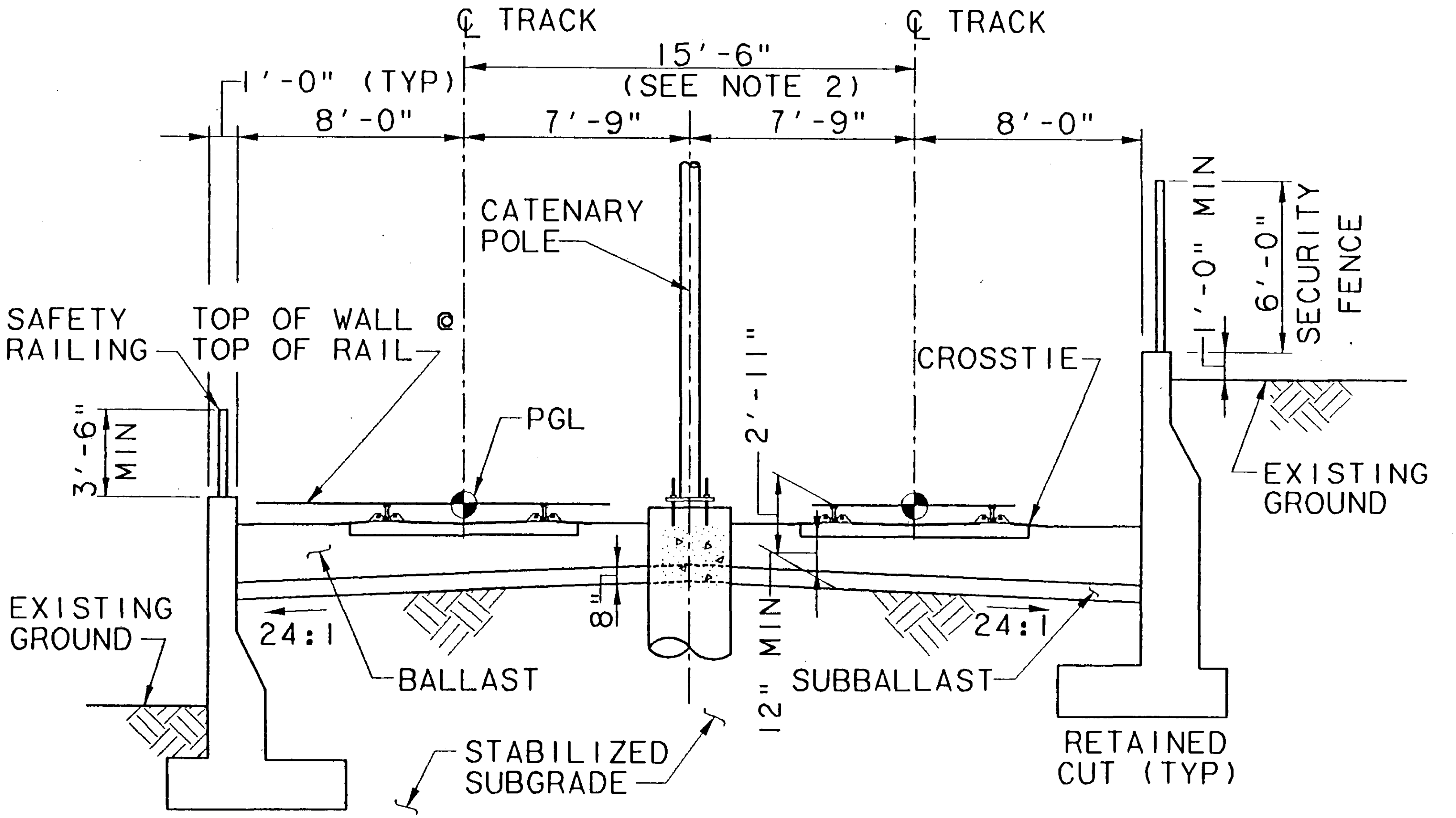

NOTES:

1. TOP OF WALL ELEVATION AND TREATMENT WILL VARY DEPENDING ON ADJACENT FACILITY.
2. TRACK CENTERS MAY BE REDUCED TO 14'-0" IN AREAS WHERE A CENTER POLE IS NOT REQUIRED. OR WITH CENTER POLE OF WIDTH EQUAL TO OR LESS THAN 1 FOOT UPON DART APPROVAL.
3. COORDINATE UNDERDRAIN LOCATIONS WITH RETAINING WALL DESIGNS.

TANGENT RETAINED CUT AND FILL

DWG. NO. KX6-0003

ACT 21
CARTER BURGESS
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STV INCORPORATED
KAI ALLIANCE

DART PROJECT

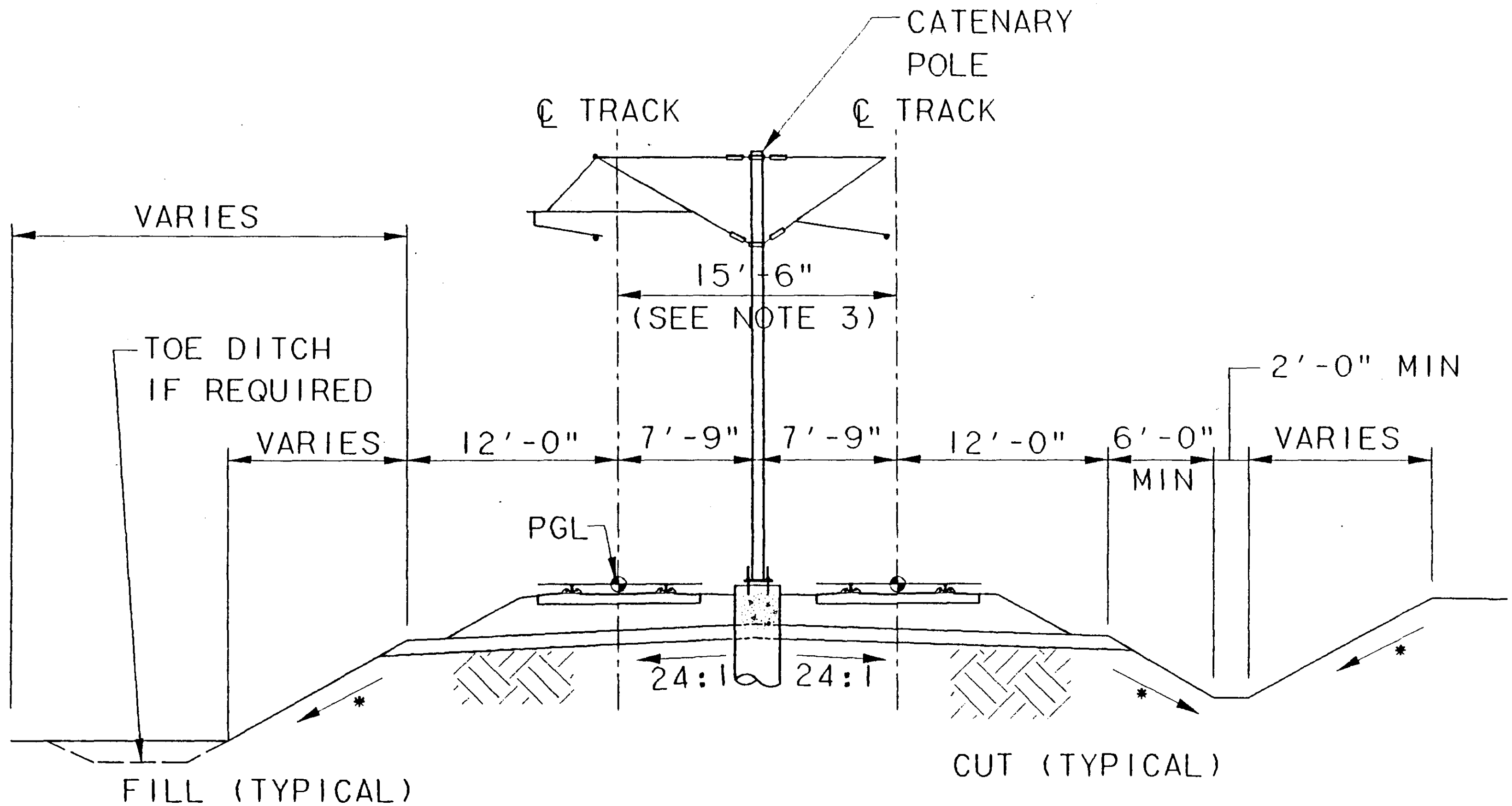
DART

DART DESIGN CRITERIA

TANGENT RETAINED CUT AND FILL

SCALE: 1" = 6'-0"   FIGURE: 2.3

JAN. 2003, REV 10



NOTES:

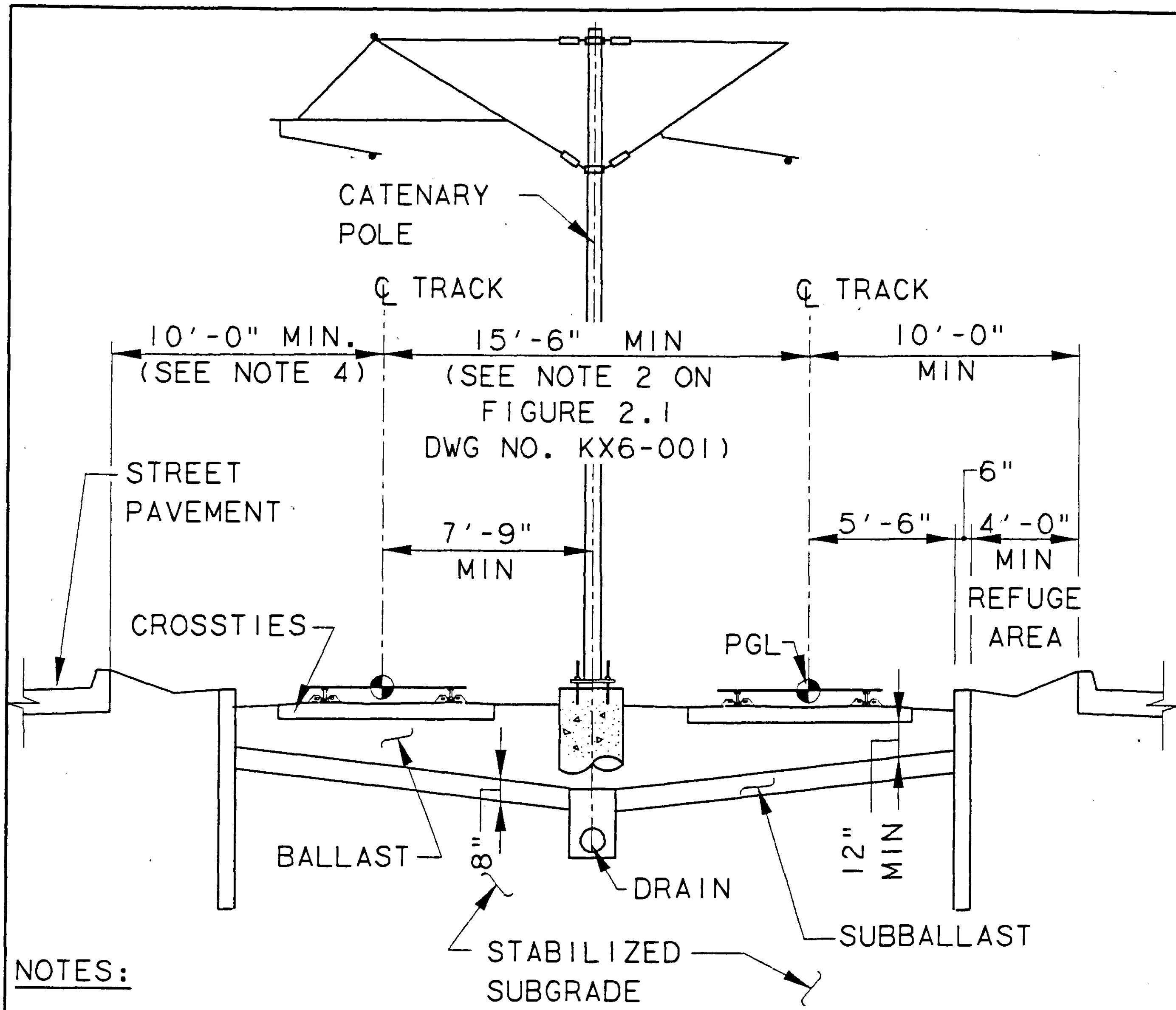
1. SEE FIG NO. 2.1 (KX6-0001) FOR TANGENT AND FIG NO. 2.8 (KX6-0046) FOR CURVES, FOR SLOPES AND DIMENSIONS NOT SHOWN HERE.
2. * SIDE SLOPES TO BE 3:1 UNLESS OTHERWISE DETERMINED BY SECTION DESIGNER.
3. TRACK CENTER MAY BE REDUCED TO 14'-0" IN AREAS WHERE A CENTER POLE IS NOT REQUIRED. OR WITH A CENTER POLE OF WIDTH EQUAL TO OR LESS THAN 1 FOOT UPON DART APPROVAL.

AT GRADE-CUT AND FILL

ACT 21
CARTER BURGESS
JACOBS ENGINEERING
STV INCORPORATED
KAI ALLIANCE

DART
DART PROJECT

DART DESIGN CRITERIA
AT-GRADE - CUT AND FILL
SCALE: 1" = 10'-0"
JAN. 2003, REV 10
FIGURE: 2.4
DWG. NO. KX6-0004



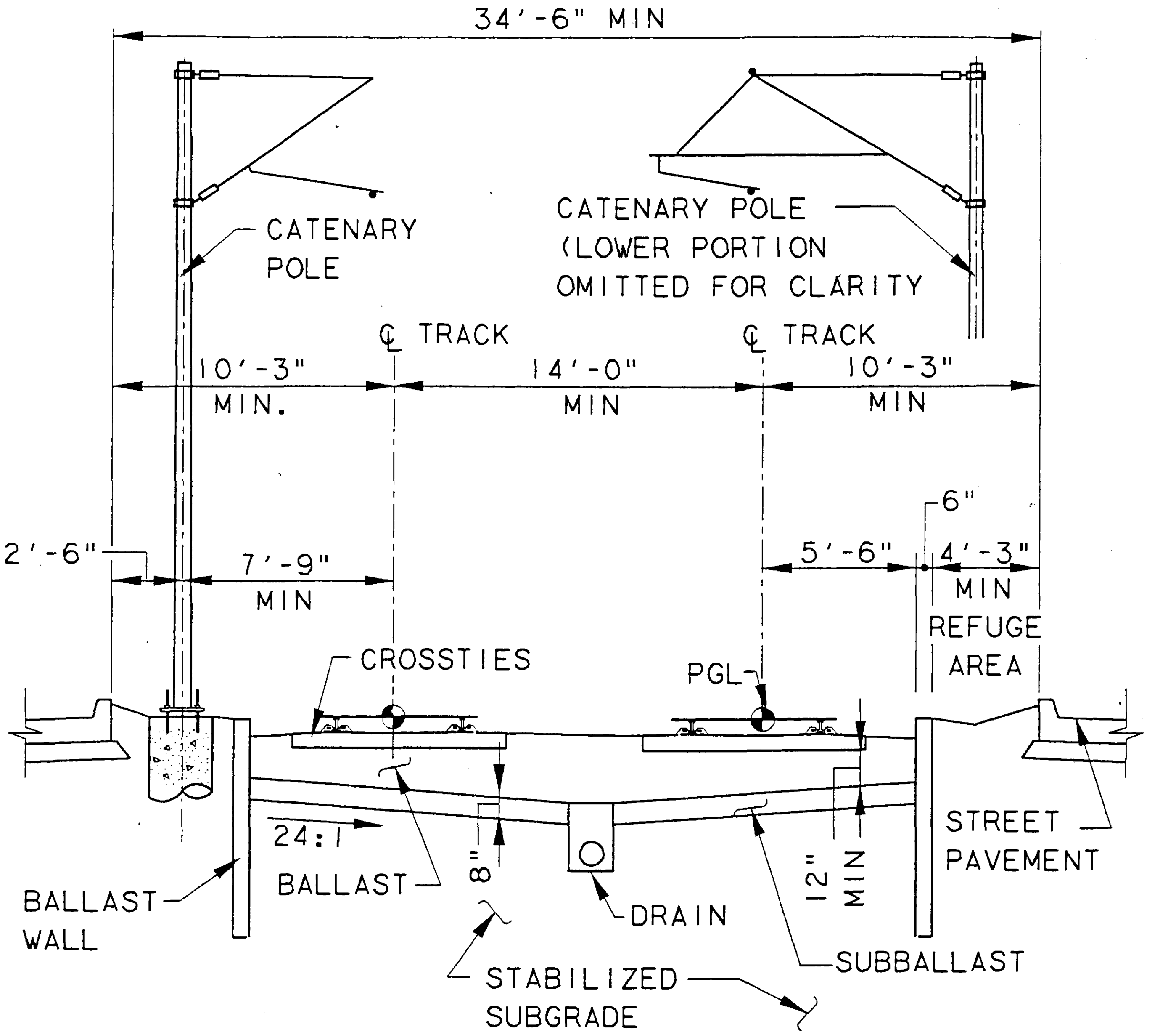
NOTES:

1. TOP OF RAIL ELEVATION SHALL BE THE SAME AS MEDIAN EDGE OF PAVEMENT AT ALL ROAD CROSSINGS.
2. FOR CURVES: MINIMUM DISTANCES TO POLE SHALL BE C_2 AND C_3 AS GIVEN ON FIGURE NO. 2.8 (KX6-0046).
3. FOR CURVES: MINIMUM DISTANCE TO CURB SHALL BE 1.50' GREATER THAN THAT DETERMINED FOR C_1 AND C_4 AS GIVEN ON FIGURE NO. 2.9 (KX6-0047).
4. MINIMUM DIMENSIONS OF 7'-6" TO FACE OF CURB ALLOWABLE UPON APPROVAL OF DART.
5. DRAIN SHALL BE ROUTED AROUND CATENARY POLE FOUNDATION

STREET MEDIAN

DWG. NO. KX6-0006

ACT 21 — CARTER BURGESS, JACOBS ENGINEERING, STV INCORPORATED, KAI ALLIANCE	DART PROJECT — DART	DART DESIGN CRITERIA
		STREET MEDIAN-CENTER POLE
		SCALE: 1"=6'-0" FIGURE: 2.5



NOTES:

1. TOP OF RAIL ELEVATION SHALL BE THE SAME AS MEDIAN EDGE OF PAVEMENT AT ALL ROAD CROSSINGS.
2. FOR CURVES: MINIMUM DISTANCE BETWEEN CENTER LINE OF TRACKS, SEE SECTION 1.9.2 OF DESIGN CRITERIA, CHAPTER 1.

STREET MEDIAN

DWG. NO. KX6-0007

ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA STREET MEDIAN-SIDE POLE SCALE: 1"=6'-0" FIGURE: 2.6

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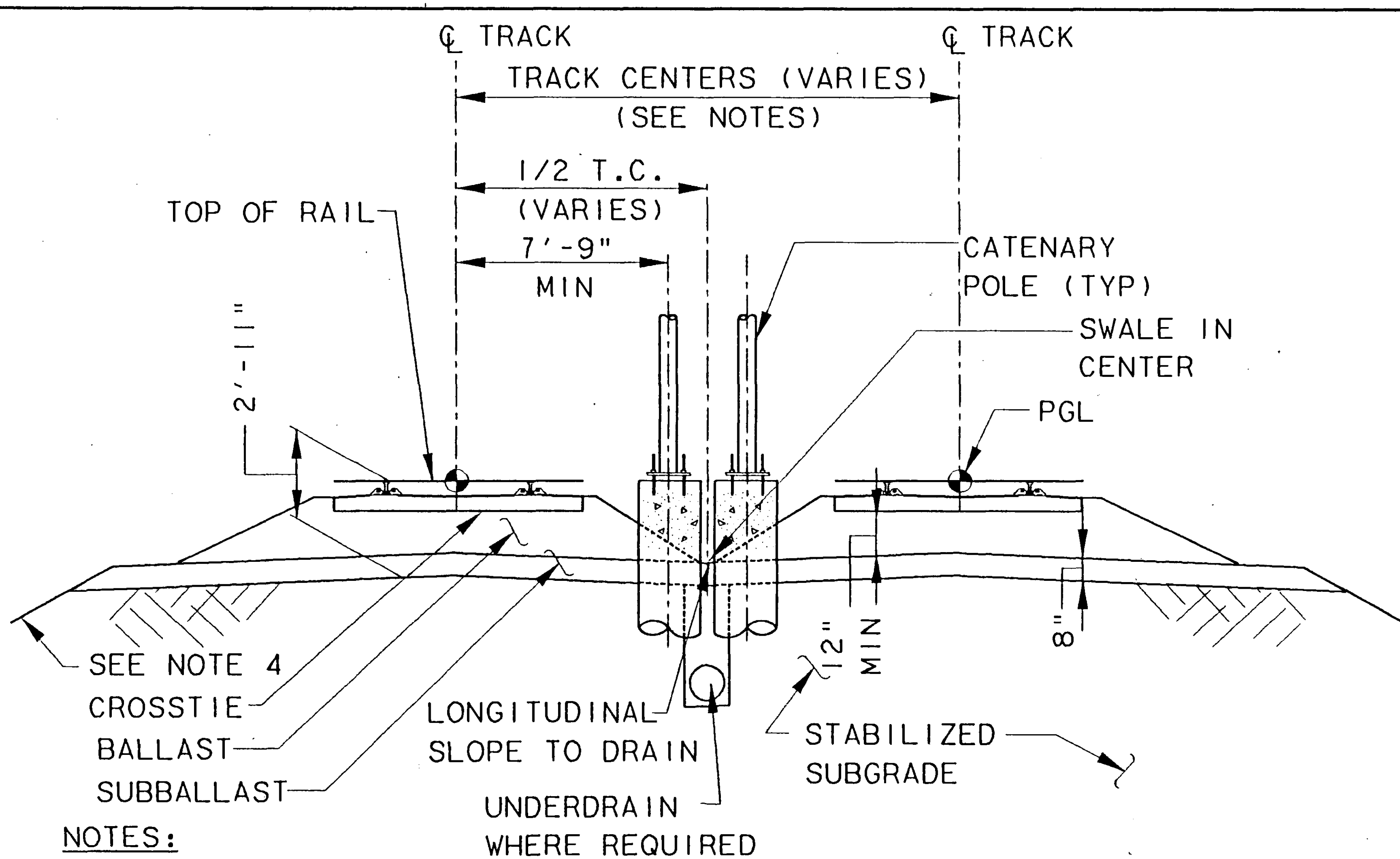

NOTES:

1. BELOW 19'-0" CENTERS DESIGN AS DOUBLE TRACK SECTION. ABOVE 32'-0" CENTERS DESIGN AS TWO SINGLE TRACK SECTIONS WITH DITCH BETWEEN.
2. PROVIDE POSITIVE SURFACE AND SUBSURFACE DRAINAGE AT CENTER SWALE.
3. MAY USE ONE CATENARY POLE WITH EXTENDED ARMS WHERE CENTERS PERMIT.
4. SEE FIG No. 2.1 (KK6-0001), 2.3 (KK6-0003) AND 2.4 (KK6-0004) FOR ALTERNATE EDGE TREATMENTS.

WIDE TRACK CENTERS AT GRADE

ACT 21
CARTER BURGESS
JACOBS ENGINEERING
STV INCORPORATED
KAI ALLIANCE

DART
DART PROJECT

WIDE TRACK CENTERS AT GRADE
SCALE: 1"=6'-0"
FIGURE: 2.7
DART DESIGN CRITERIA
DWG. NO. KX6-0008
JAN. 2003, REV 10

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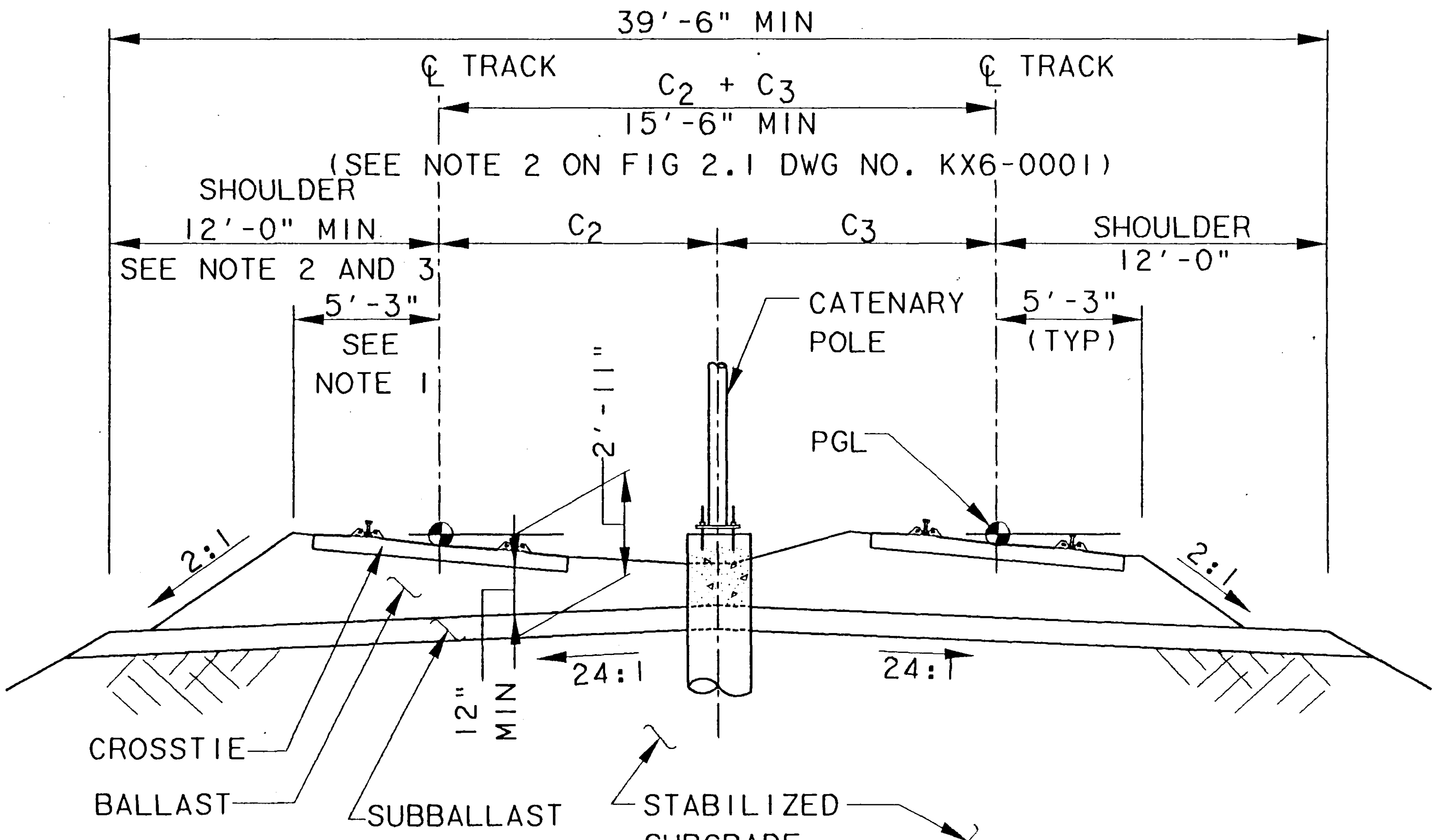


NOTES:

1. FOR RADIUS LESS THAN 1000'; INCREASE TO 5'-9".
2. FOR SUPERELEVATED CURVES WHERE Ea IS GREATER THAN 2", INCREASE SHOULDER TO 13'-6".
3. ADD ONE FOOT TO REQUIRED SHOULDER WHERE R $\leq$ 1000'.
4. C_2 , C_3 : SEE SECTION 1.9.2 OF DESIGN CRITERIA, CHAPTER 1.

CURVED AT GRADE WITH CENTER POLE

ACT 21
CARTER BURGESS
JACOBS ENGINEERING
STV INCORPORATED
KAI ALLIANCE

DART
DART PROJECT

DART DESIGN CRITERIA

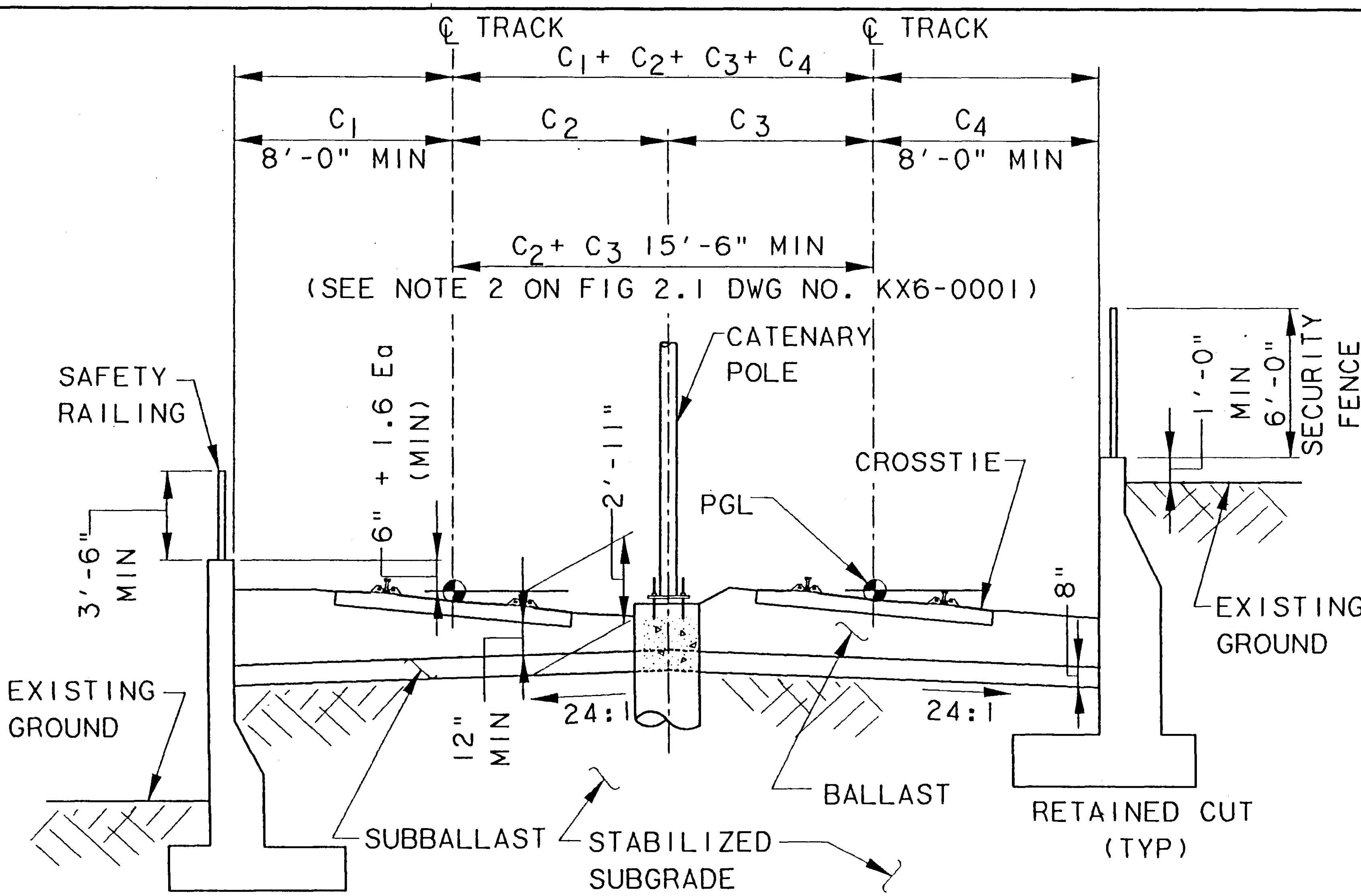
CURVED AT GRADE

SCALE: 1" = 6'-0"

JAN. 2003, REV 10

FIGURE: 2.8

DWG. NO. KX6-0046



NOTES:

1. C_1, C_2, C_3, C_4: SEE SECTION 1.9.2 OF DESIGN CRITERIA, CHAPTER 1.
2. COORDINATE UNDERDRAIN LOCATIONS WITH RETAINING WALL DESIGNS.

CURVED RETAINED CUT AND FILL WITH CENTER POLE

ACT 21
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JACOBS ENGINEERING
STV INCORPORATED
KAI ALLIANCE

DART PROJECT

DART DESIGN CRITERIA

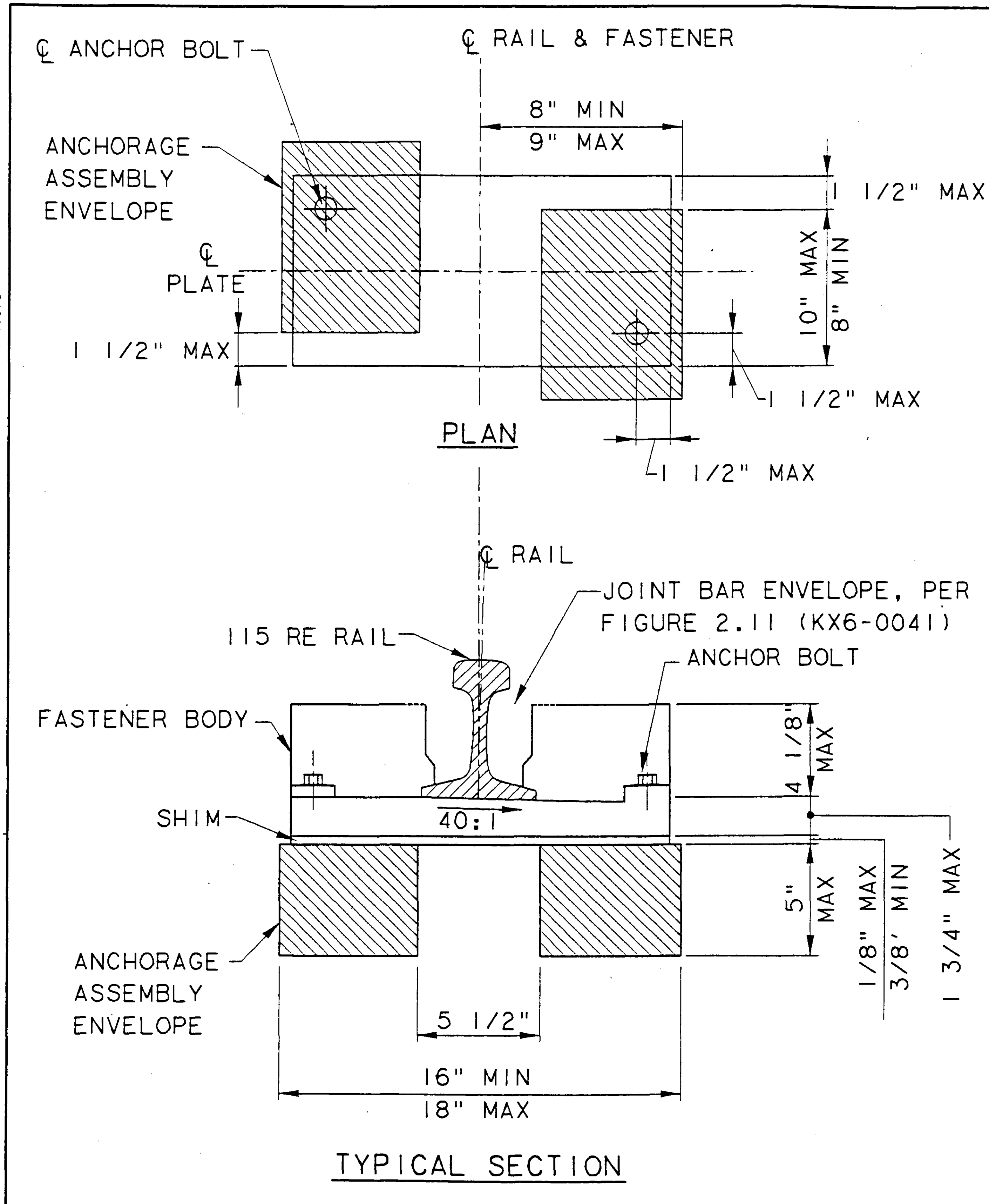
CURVED RETAINED CUT AND FILL

SCALE: 1" = 6'-0"

JAN. 2003, REV 10

FIGURE: 2.9

DWG. NO. KX6-0047



ACT 21
CARTER BURGESS
JACOBS ENGINEERING
STV INCORPORATED
KAI ALLIANCE

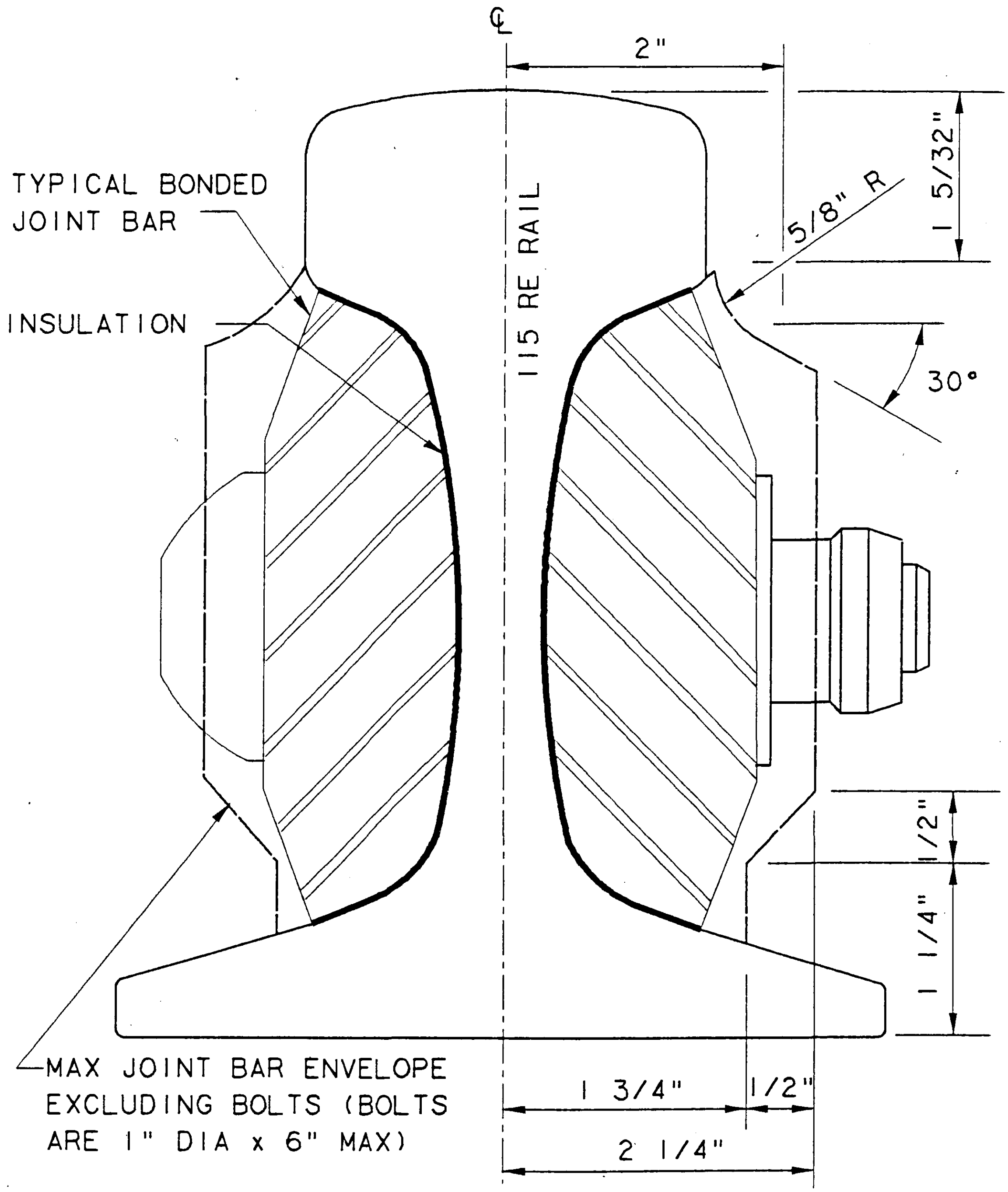
DART PROJECT

DART

DART DESIGN CRITERIA

DIRECT FIXATION RAIL FASTENER CLEARANCE ENVELOPE

SCALE: 1" = 6'-0" FIGURE: 2.10



NOTE:

NOT INTENDED TO EXCLUDE USE OF STANDARD AREA JOINT BARS IN YARDS.

DWG. NO. KX6-0041

ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA JOINT BAR ENVELOPE SCALE: 1"=1'-0" FIGURE: 2.11

CHAPTER 3 - TRACKWAY

3.1 INTRODUCTION

This chapter establishes criteria for the design of at-grade sections of the trackway and provides, together with other system requirements, a determination of right-of-way requirements for line sections of the DART rail system. Trackway is defined as that portion of the DART rail system rail line that has been prepared to support the track and its associated structures. At-grade trackway is that trackway that is neither on aerial structures, in subways, in U-wall sections, nor paved track. At-grade trackway generally includes the entire right-of-way exclusive of stations, and includes the subgrade, slopes of cuts and fills, the drainage systems for diverting or carrying water away from the track area, and the catenary pole foundations. The trackway may contain longitudinal and transverse direct-burial cable, ductbanks, electrical conduits, utilities structures, or acoustical barriers. These criteria are to be used in conjunction with all appropriate chapters of the Civil Design Criteria, as well as the Structural Design Criteria chapters. Some dimensions indicated in these criteria are also shown on the trackwork standard and directive drawings, and the at-grade standard and directive drawings.

3.2 SUBGRADE

The subgrade is the finished surface of the trackbed below the subballast. The subgrade supports the loads transmitted through the ballast and subballast. The support of the track depends ultimately on the stability of the subgrade. Uniformity is the goal of subgrade design because it is differential rather than total vertical movement that leads to unsatisfactory track geometry.

The designer shall specify stabilization requirements that will limit differential vertical movement resulting from shrinking or swelling of soil within a 62-foot length to 1 inch. Total settlement due to fill construction shall be limited to 2 inches during a 2 year period following completion of the trackwork installation. Where soil characteristics do not permit the economical achievement of these requirements by soil stabilization methods, alternative trackway designs shall be submitted for consideration.

3.2.1 Stabilization of Subgrade

Lime, cement or other means of stabilization of the subgrade shall be provided where indicated by geotechnical investigations. The material and method selected shall be evaluated and recommended by the designer.

3.2.2 Configuration

The subgrade shall be crowned and sloped away from the apex of the crown on a slope of 24 horizontal to 1 vertical. The location of the apex of the crown shall be, for single track, at the centerline of the track; for double track, at a line midway between the two tracks; and for three tracks, at the centerline of the middle track. If the track center-to-center spacing is more than 19 feet, each track shall be considered to be a single track. For single track, where a future double track is planned, the crown shall be located for double track. (Refer to the trackwork standard and directive drawings for further information.)

3.2.3 Elevation

The elevation of the top of subgrade shall be determined from the profile grade line (PGL) of the tracks. The minimum dimension from the PGL to top of subgrade is shown on the trackwork criteria figures and on the trackwork standard directive drawings. The depth of the track structure shall be used to determine the highest allowable subgrade elevation under each track. On curved, superelevated track, the PGL is the top of the inside (lower) rail.

Elevations at the apex and shoulders of the subgrade shall then be developed from the PGL elevation and the slope of the subgrade. When tracks are not all on the same PGL, the top-of-rail to top-of-subgrade distance must be checked on the lower track or tracks to determine that the minimum required depths of ballast and subballast are maintained on all tracks.

3.2.4 Dimensions

The width of the subgrade is determined by the track centers and the track geometry. It is a function of the length of tie, depth and configuration of ballast and subballast, and superelevation of the track. All dimensions included in this chapter are based upon a tie length of 8 feet 6 inches and a track gauge of 4 feet 8-1/2 inches. The subgrade must be of sufficient width to support the subballast. Widths of top surface of subballast are shown on Figures 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8 and 2.9 in Chapter 2 - Trackwork, and on the trackwork directive drawings.

3.2.5 Single Track

On tangent track, the minimum width of the top surface of subballast shall be 24 feet. For tracks with curvature requiring an actual superelevation (E_a) greater than 2 inches, the width of the subgrade and subballast shall be increased by 18 inches on the outer side of the curve. Where the radius is less than or equal to 1,000 feet, the width shall be increased an additional foot. See Figure 2.8 in Chapter 2 - Trackwork.

3.2.6 Double Track

On tangent track with 15-foot 6 inch track centers the desirable minimum at-grade width of the top surface of subballast shall be 39-1/2 feet. Where track centers are more than 19 feet, they shall be treated as two single tracks. For tracks with curvature requiring an actual superelevation (E_a) greater than 2 inches, the width of the subgrade and subballast shall be increased by 18 inches on the outer side of the curve. Where the radius is less than or equal to 1,000 feet, the width shall be increased an additional foot. See Figures 2.1, 2.4 and 2.8 in Chapter 2 - Trackwork.

3.2.7 Three Tracks

On tangent track the minimum width of the top surface of subballast shall be 55 feet. This assumes track centers of 15 foot 6 inch; if greater track centers are required, they shall be treated as a special case. For tracks with curvature requiring an actual superelevation (E_a) greater than 2 inches, the width of the subgrade and subballast shall be increased by 18 inches on the outer side of the curve. Where the radius is less than or equal to 1,000 feet, the width shall be increased an additional foot.

3.2.8 Subgrade Width Transition

The transition from one subgrade width to another shall take place uniformly throughout the length of the spiral of a curve and at a rate of 1 foot per 100 feet for other locations such as hi-rail access points.

3.2.9 Ballast Walls

Ballast walls shall be used as necessary to prevent ballast contamination from adjacent material or drainage. The condition will occur predominately in narrow right-of-way areas that do not have space for side ditches, and do not require retaining walls. Drainage swales or appropriate grading should be provided behind the wall to prevent the drainage water from entering the track ballast.

3.3 SLOPES

Side slopes of earth generally shall be three-horizontal to one-vertical, or flatter. Steeper slopes may be used in rock cuts in accordance with the designer's recommendations. To minimize maintenance costs, consideration shall be given to the use of slopes flatter than three-horizontal to one-vertical, where sufficient right-of-way is available. All slopes shall conform to the designer's recommendations, unless otherwise directed by DART. A typical treatment of cut-and-fill slopes is shown on Figure 2.4 in Chapter 2 - Trackwork.

Where geotechnical conditions warrant, benches shall be provided along the face of a cut. For deep cuts, intermediate benches shall be provided at locations where the vertical height of slope is 15 feet or more. Where the cut is in rock with an overburden of soil, a bench shall be provided at the rock and soil interface. Where such benches are provided, they shall have a minimum width of 10 feet to permit maintenance by conventional earth-moving equipment. Access to these benches shall be provided to this maintenance equipment.

3.4 DRAINAGE

Track stability requires that water seeping or flowing toward the track shall be intercepted and diverted before it reaches the track, and that water falling upon the track area shall be quickly drained. Drainage shall be provided to prevent the presence of non-flowing water, to an elevation 4 feet below the subballast. In addition, trackway drainage design must be coördinated with existing drainage structures in accordance with the standards set forth in this chapter and as indicated in Chapter 7 - Drainage.

3.4.1 Side Ditches

Side ditches shall be provided parallel to DART tracks through sections in cut. Intercepting ditches at the tops of slopes and along benches shall be provided where required. The design of ditches shall conform to criteria given in Chapter 7 - Drainage and as shown in the at-grade standard and directive drawings.

Side ditches shall not be used on the tops of fills. They shall be used at the bottoms of fills as necessary to provide continuity of drainage as shown in Figure 2.4 in Chapter 2 - Trackwork.

3.4.2 Track Drains in Paved Track

Transverse slotted drains shall be installed at regular intervals between the rails in paved track. These drains shall be designed to drain the girder rail flangeway and the area between the rails.

In special trackwork, drains shall be provided for the drainage of the switch throwing mechanism.

3.4.3 Underdrains in Retained Sections

Longitudinal perforated drains shall be provided immediately adjacent to retaining walls and immediately below the surface of the subgrade. The underdrain pipe shall be encased in an envelope of suitable filter fabric and crushed stone. The fabric shall extend up to and under the ballast. A similar drainage arrangement shall be provided between the edge of the DART trackway and an adjacent railroad track where lateral clearance does not permit a drainage ditch. (For further details see the trackwork directive drawings.)

At a sag in the track profile and 100 feet either side of the low point, an underdrain shall be provided. The criteria in Chapter 7 - Drainage shall apply. (Refer also to the trackwork directive drawings and to Chapter 14 - Earth Retaining Structures.)

3.4.4 Underdrains in Cut to Fill Sections

When on a descending grade from a cut section to a fill section, and high groundwater is indicated, a lateral cross-drain shall be provided at the change of sections.

3.5 UNDERTRACK STRUCTURES

Duct banks, direct burial cable, conduits, utilities, or other structures may cross or run alongside and closely adjacent to the DART rail system track. None of these facilities shall infringe, however, upon the envelope shown on Figure 1.12 in Chapter 1 - Track Alignment. Duct banks and direct burial cable shall run longitudinally along the outside of tracks or below the space between tracks. Duct banks, direct burial cables and conduits crossing under the tracks shall be kept sufficiently clear of the subballast. In all cases they shall be below the surface of the subgrade. Where manholes, pull boxes, or conduit "stub-ups" come to the surface, encroachment within the subballast and ballast may be necessary. The extent of this encroachment shall be kept to a minimum. In no case shall the duct banks or direct burial cable be permitted to adversely affect the drainage system. (For further guidance, refer to Chapter 6 - Utilities.)

3.6 WAYSIDE ACCESS

To the fullest extent possible, access to trackway at track level shall be provided for maintenance and emergency work. This requires providing access for:

- o Trucks carrying personnel, tools, and material to drive to the trackway.
- o Vehicles equipped with flanged wheels to drive onto the track at strategic locations.

3.6.1 Highway Vehicle Access Points

Access by highway vehicles shall be provided, as directed by DART, to the at-grade trackway near subway portals, crossovers, rail line junctions, and any other at-grade points where high maintenance requirements are anticipated.

3.6.2 Hi-Rail Vehicle Access Points

At strategic points, hi-rail vehicle set-offs shall be provided. The locations of these points will be determined by systemwide overview and furnished to the designer. In general, a hi-rail set-off shall be provided for both tracks between each interlocking pair, unless there is an at-grade highway crossing. Access, however, shall be provided at intervals not exceeding 2 miles (preferably at 1-mile intervals). Consideration shall also be given at these access points to providing adequate space for vehicle turning and for limited parking for DART trucks and other maintenance vehicles.

3.7 SPECIAL TRACKWAY CONDITIONS

Special trackway conditions may be encountered which are not covered by the above criteria. Some are listed in this section. Any others should be referred to DART for resolution.

3.7.1 Slab Track At-Grade

Slab track at-grade shall be used to connect two portions of a trackway with direct-fixation track which are no more than 350 feet apart. Ballasted bridge decks shall be no longer than 500 feet. (Refer to directive drawings and standard drawings for the configuration and dimensions of slab track.)

3.7.2 Special Trackwork

To provide for switch operating mechanisms, where tracks diverge to a branch or yard through a turnout, the sub-grade shall be widened by 3 feet between a point 8 feet ahead of and 8 feet behind the point of a switch. The widening shall take place on the side that switch-operating mechanisms will be located. (Refer to section 2.7 of Chapter 2 - Trackwork and to the trackwork directive drawings for more information.)

3.7.3 Yards

The configuration of the subgrade underlying yards requires special consideration. The subgrade shall have lateral slopes of 24:1 for drainage. Approximately 8 inches of subballast shall be used on top of the subgrade. The yard ballast shall be even with the top of the tie between tracks, and additional ballast shall be placed along the outside edge of perimeter tracks to provide for an adequate walkway space.

For Yard related Track Criteria refer to Chapter 1 – Track Alignment and Chapter 2 – Trackwork.

CHAPTER 4 - STREETS/HIGHWAYS AND PARKING

4.1 INTRODUCTION

This chapter covers the design of all streets, parking lots, parking structures, bus-related facilities, pedestrian facilities, and driveways that will be owned and maintained by DART. It also covers facilities not owned by DART, but which need to be replaced or rearranged as a result of the construction of the DART system.

The design of replacement facilities shall be performed generally on a replacement-in-kind basis; however, the minimum replacement standards and design procedures agreed to by the Authority and each owner shall govern. If betterments are included, they shall be approved by the Authority in accordance both with the cooperative agreement and with more detailed agreements with the owner. All design involving rearrangement work shall be in accordance with adopted design criteria, standard drawings, and specifications, and will be submitted to DART for approval.

The section designer shall coordinate its work and submit rearrangement designs for review and approval by the Authority in accordance with its contract and the terms and conditions of all cooperative agreements. The section designer also shall coordinate its work with the section designers of adjacent sections so that all rearrangements are compatible. Any necessary coordination with agencies, owners, and private developers shall be conducted through DART.

The objectives of this chapter are:

- Provide for the safety of patrons at DART stations.
- Efficiently accommodate traffic circulation patterns for vehicular and pedestrian movement.
- Provide convenient parking facilities.
- Establish criteria for the reconstruction of local roads, streets, and highways disturbed by DART construction.

Unless otherwise indicated in this chapter, all applicable codes and standards shall conform to the latest editions of all applicable appropriate codes, regulations, standards, and recommendations in the jurisdiction in which the improvement is to be located. Refer to the appendix of this criteria for additional information.

4.2 ACCESS TO STATION SITE FACILITIES

4.2.1 RAIL STATION ACCESS

All stations will have:

- o Pedestrian walkways.
- o Bicycle facilities, such as lockers or racks, depending on need (as specified by a Board resolution approved on June 11, 1985).
- o Transfer facilities such as turn-in lanes and bus bays to allow easy passenger transfer from bus to rail and vice versa.
- o Kiss-and-ride dropoff facilities; the size of individual facilities to be determined by site and demand analysis.
- o Free parking spaces for the mobility-impaired.

Depending on site-specific criteria such as land availability, ridership projections, and other factors, several design features are planned only where appropriate at selected stations. They are:

- o Elevators and stairs that would be used only where site constraints inhibit walkway and ramp access to station platforms. Elevators are preferable to escalators, therefore escalators should only be used where absolutely necessary.
- o Taxi stands where such transportation is common and used.
- o Park-and-ride lots.

The quantity of berths, spaces, or other transfer or storage capacities will be established by DART.

4.2.2 Separation Between Modes

Separation between modes of transportation in the station area should be provided in the following order of priority:

- o Rail and other modes.
- o Pedestrian and other modes.
- o Bus and automobile transportation.
- o Kiss-and-ride and park-and-ride traffic.

o Bicycles and motor vehicle traffic.

4.3 DART SYSTEM STREETS - DESIGN DETAILS

4.3.1 Definitions

Design Year Traffic Volumes. All roadways serving DART station and parking facilities, and all off-site improvement to support DART operations shall be designed to accommodate AM and PM peak hour traffic volumes provided by DART for its designated design year.

Design Year Level of Service. Unless otherwise stated below, all roadway facilities to be constructed or improved by this project shall be designed to accommodate design year traffic volumes at level of service D or better, as defined in the applicable chapters of the current edition of the Highway Capacity Manual published by the Transportation Research Board.

For the purpose of design, DART roadways shall be classified as follows:

DART Station Access Roadways. Any roadway within DART station right-of-way and outside a delineated DART parking lot, excepting DART maintenance roadways. A DART station access roadway may carry bus traffic, kiss-and-ride traffic, park-and-ride traffic, and emergency vehicles.

DART Maintenance Roadway. A roadway within DART right-of-way used to permit access for yard personnel and fire protection equipment to the maintenance-of-way area, around shop buildings, to traction power substations, signal bungalows, communications bungalows, and other maintenance roadways not intended for public use.

For design criteria relating to DART yard service aisles, paved roadways between storage tracks for movement of service vehicles and their personnel and equipment, see Chapter 2 - Trackwork and Chapter 3 - Trackway.

4.3.2 Design Vehicles And Design Speed

DART system roadways shall be designed to accommodate typical passenger cars, transit buses, and single unit trucks as described in AASHTO publications A Policy on Geometric Design of Highways and Streets and A Policy on Design of Urban Highways and Arterial Streets. For additional bus criteria, see Table 4-1. The minimum desirable design speed for DART system roadways entering or exiting from existing streets and highways is 30 miles per hour. All other DART roadways shall be designed for a minimum of 25 miles per hour, except at channelized intersections where the speed may be reduced to 15 miles per hour.

4.3.3 Local Municipal Design Criteria

All DART facilities shall be designed according to AASHTO criteria, except as specifically noted in this chapter. Non-DART roadway facilities shall be designed according to the requirements of the agency having jurisdiction over the roadway.

4.3.4 Horizontal Alignment

Sight Distance. Where there are sight obstructions, such as walls, cut slopes, and buildings on the inside of curves, a design to provide adequate stopping sight distance will be required if the obstruction cannot be removed. Sight triangles at intersections shall be designed in accordance with Section 4.3.7. In order to provide adequate sight distance, vertical curves shall be designed in accordance with Section 4.3.5 Vertical Alignment of this chapter.

TABLE 4-1

BUS SPECIFICATIONS

	Standard Bus[1]		Leyland	
	Minimum	Maximum	Articulated[2]	Olympian
Length	40'-0"	40'-0"	60'	40'-0"
Width	96"	102"	102"	98.5"
Width w/mirrors	108"	116"	118"	NA
Height	117.56"	138"	131"	164"-170"
Weight (lbs)	24,480	30,920	40,300	29,000 (52,455 load)
Front Step to Ground	12-1/2"	16"	12-3/4"	NA
Rear Step to Ground	12-3/4"	16-3/4"	15.5"	NA
Midpoint between two axles to Ground	11-1/2"	20-1/2"	13-3/4" Front 14" Rear	NA
Front Overhang (center of front axle to bumper)	85-1/2"	95"	29.8"	7'8-1/2"
Rear Overhang (center of rear axle to bumper)	88"	109"	117.4"	7'8-1/2"
Front Door Width	29-1/2"	44"	32"	NA
Rear Door Width	25-1/2"	45"	41"	NA
Width between Doors	18'-11-1/2"	20'-7-1/2"	34'-3"	NA
Wheelbase	285-1/2"	299"	212.38"	222" (Tractor)
Turning Radius				
LF Wheel (right turn)	36'-9"	39-1/2"	44'-10"	36'-8"
LF Body Corner (right turn)	42'-6"	44'-3"	43'-1"	NA
Bus Window Glass				
Left	6	13	10	NA
Right	5	11	9	NA
No. of Seats	45	48	67	83

1 Based on GMC TH8201, GFC "870", RTS 1101, GMC T80204, NEOPLAN AN440, EAGLE #10

2 Based on RTS1104, NEOPLAN AN460

Curvature. A change in direction of a DART roadway shall be made by simple curves having a radius which is compatible with the design speed for vehicular traffic. On access roadways, the minimum radius of horizontal curves measured to the center of the traveled way shall comply with the normal requirements. All curves shall be provided with widened section as specified in Table 4-2 and Figure 4-1 on bus access roadways. Where speed is restricted, the minimum inside radius shall be 30 feet with a minimum roadway width of 30 feet.

Superelevation. Horizontal curves on DART roadways should be designed without superelevation. If superelevation is used, the maximum rate shall be 2 percent, with a minimal transition length of 100 feet required for a two-lane roadway rotated about the centerline. For rotation about a pavement edge, or for multilane streets, the required length is determined by multiplying the minimum length times the number of lanes between the rotation axis and edge of pavement.

4.3.5 Vertical Alignment

Sight Distance. The minimum stopping sight distance shall comply with the section 4.3.4, Horizontal Alignment. A design requiring passing sight distance considerations should not be used on DART system streets.

Grades. The grades of DART system streets for public use shall not exceed 8 percent without approval of DART. The minimum grade of streets shall be 0.50 percent. Acceleration grades for roadways that accommodate buses shall not be greater than 4 percent. In general, bus roadway grades shall not be greater than 7 percent. Roadways restricted from public use may be designed with 0.0 percent grade provided there are no curbs and such roadways have sufficient cross slope to carry the runoff to adjacent drainage ditches. Maximum grades on the approaches to a street intersection shall not exceed 5 percent within 50 feet of the curb return. Maximum street grades at intersections along pedestrian routes shall not exceed 2% through the designated crosswalks in order to meet walkway maximum cross slopes of 2%.

Grade crossings shall be designed such that drainage will flow away from both sides of the crossing. No street drainage is to enter the trackway.

Grades shall be coordinated with track superelevation to produce a smooth crossing profile to motorists.

Vertical Curves. Parabolic vertical curves shall be used to effect a gradual change between breaks in the street grades when the algebraic difference in the grades is 1 percent or greater. Unless clearance requirements, sight distance, or appearance factors dictate, only symmetrical vertical curves are to be used on DART roadways. The use of asymmetrical curves shall be minimized and shall require prior approval from DART.

The minimum length of vertical curve on DART access and maintenance roadways shall be determined from the following formula:

L = kA, but not less than 100 feet

Where:

L = Length of curve, in feet

A = Algebraic difference in grades, percent

k* = Rate of vertical curvature as determined by the latest edition of AASHTO "Greenbook".

* On non-DART facilities, use applicable governmental design criteria "k" factors.

TABLE 4-2

MINIMUM TURNING ROADWAY WIDTH (BUS ROADWAYS)

	Minimum Roadway Width (ft)	
Inside Curb Radius (ft)	1 lane, one-way, able to pass stalled vehicle	2 lanes 2 way
30	38	44
40	33	39
50	30	36
75	28	34
100	27	33
150	26	32
200	24	32
>200	24	30
tangent	22	24

4.3.6 Cross-Sectional Elements

Traffic Lane Width. All roadways shall have at least one traffic lane for each direction of travel. Exceptions are those used mainly for service or maintenance purposes or as station loading areas. Lane widths specified below are exclusive of any curbs present and are applicable to all pavement types. When curbs are present, the lane width begins at the curb face. The number of traffic lanes provided on these roadways shall be sufficient to provide a level of service D or better according to the current edition of the Highway Capacity Manual, as projected for the design year specified by DART.

Where roadways are one-way and have only a single passenger car traffic lane, the preferred lane width on a tangent shall be 20 feet. An 18-foot minimum traffic lane may be used with the approval of DART. For single lane one-way roadways with combined bus and passenger car traffic, the minimum lane width shall be 22 feet. With the approval of DART, the lane width may be less than 18 feet for one-way maintenance roadways restricted from public use. Roadways may be striped for effective lane widths narrower than those specified above.

Lane width for roadways with more than one lane in each direction shall be 12 feet for bus lanes or lanes with combined bus and passenger car traffic. Lane width shall be 11 feet for roadways used exclusively by passenger cars. Minimum undivided roadway width for roadways with more than one lane in each direction shall be 48 feet for combined bus and passenger car traffic and 44 feet for roadways used exclusively by passenger cars.

Emergency access roads shall be designed according to OSHA standards to accommodate emergency vehicles. Minimum fire lane width shall be 20 feet and a preferred lane width of 22 feet.

Cross Slope. Normal roadway cross slopes shall be 1/4 inch per foot, 1/2 inch per foot maximum and 1/8 inch per foot minimum for drainage. Undivided pavements on tangents shall have a high point in the middle and slope downward toward the outer edges. On divided roadways each one-way pavement shall have a constant slope across the pavement downward toward the outer edge. Depending on drainage requirements or local conditions, the cross slope may vary at intersections or in unusual situations. If feasible, the pavement shall be sloped downward away from the curb adjacent to sidewalks and at curb pickup/dropoff areas for bus and kiss-and-ride patrons.

Curbs and Gutters. In general, all reinforced concrete roadways for public use shall have curbs of portland cement concrete constructed integrally with the pavements. Barrier type curbs 6 inches high shall be used. Separate curbs and gutters shall be provided on all asphaltic concrete roadways for public use. See the DART system civil standard drawings for details. Curbs may be omitted in yards and other maintenance facilities where they are not warranted by aesthetic considerations, drainage requirements, control of access, or for improving traffic flow and safety. See the DART system civil at-grade standard drawings for details. On all DART access and maintenance roadways, gutters shall match the grade and cross slope of the pavement of which they are an integral part. Valley gutters shall not extend across roadways.

Shoulders. Depending on the type and frequency of vehicular usage, shoulders may be provided on DART roadways without curbs. Shoulders may vary from 3 to 6 feet wide as required to provide a minimum 24 foot shoulder-to-shoulder roadway width. With the approval of DART, shoulders may be paved with asphaltic concrete or crushed stone. Shoulders shall have a 1/2 inch per foot cross slope away from the roadway edge. Shoulders shall not be used where curbs are necessary to protect slopes susceptible to erosion.

Pavement Structure. The pavement structure of the various roadways shall comply with Section 4.10 of this chapter, Pavement Structures.

Side Slopes. Side slopes shall be as flat as available right-of-way and soil conditions permit and shall comply with civil at-grade standards. Where rock is encountered on DART roadway right-of-way, the horizontal clearances specified in this section shall be maintained and the slope stability recommendations of a geotechnical engineer shall be used. The top of all cut slopes, other than those in rock, shall be rounded. The need for drainage interceptor ditches at the top of cut slopes shall be investigated. See Chapter 7 - Drainage for more information.

The desirable maximum cut or fill side slope shall be 3:1. Where the right-of-way is restricted, a maximum side slope of 2:1 may be used when recommended by the geotechnical engineer and approved by DART. Slopes in excess of 2:1 shall be protected with riprap or concrete.

Where heights are less than 4 feet, slopes shall be 4:1, or flatter (if possible).

Clearances. In the absence of a specific exemption, the minimum vertical clearance shall be 16 feet 6 inches over city streets and state and federal highways. Pedestrian structures shall have a minimum vertical clearance of 17 feet 6 inches over city streets and state and federal highways. The minimum vertical clearance shall be 23 feet above the top of rail over railroads. The minimum vertical clearance shall be verified with the applicable railroad. The minimum vertical clearance over DART rail lines shall be per Chapter 1 - Track Alignment. The minimum vertical clearance generally shall be 14 feet 6 inches over DART roadways. If required, lower clearances may be used only with the approval of DART.

Except as noted below, the minimum horizontal clearance shall be 2 feet 6 inches between the inside face of curb, or edge of shoulder, and any structure, fence, sign, light standard base, fire hydrant, tree, or pedestrian barrier. Along bus roadways and in loading areas where buses are making turning movements, the minimum horizontal clearance shall be 5 feet from the face of a curb to any such obstruction.

Guard Rail and Traffic Barriers. Concrete traffic barriers and metal guard rail shall conform to TxDOT specifications and the AASHTO Guide for Selecting, Locating, and Designing Traffic Barriers. These protective barriers may be used to shield vehicles from hazards along DART roadways, but should only be implemented where it would be less hazardous to strike the barrier than to leave the roadway. The influence of curbs shall be considered in barrier placement.

4.3.7 Vehicular Entrances To Station Sites

Vehicular entrances to station sites shall be in accordance with the following:

- o Vehicular entrances and exits serving DART facilities should be provided along secondary thoroughfares or major collectors when at all possible. Access to primary thoroughfares and minor collectors should be considered when necessary. Access to residential streets should be avoided. Access to the stations and parking facilities should not be provided from residential streets.

- o Where feasible, entrances shall be located so that drivers approaching the station from any direction will easily find a second entrance if they miss the first entrance.

- o Entrances should be located to intercept traffic along approach routes to DART facilities. Maximum use of right turn movements should be made for both inbound and outbound traffic. Right turns in and out of the stations are generally preferred to left turns.

- o The number of vehicular entrances along any one street shall be minimized. Entrances shall be at least 150 feet apart (400 feet on roadway with medians). A sufficient number of entrances shall be provided so that traffic entering the station site operates at a LOS D or better.

- o Provisions for queuing space shall be provided at entrance intersections. Wherever the volume of traffic entering or exiting a public street increases the street traffic volume beyond the street capacity, an auxiliary lane shall be provided in accordance with the design criteria of the applicable affected jurisdiction.

- o An exclusive right turn lane should be provided when the right turn volume or the adjacent main lane volume would operate below LOS D according to the current edition of the "Highway Capacity Manual." The lane should include a tapered section and be sufficiently long to store the required number of vehicles.

- o Wherever an entrance must be located near a "T" intersection, it shall be placed directly at the intersection. Offset intersections should be avoided. If an offset intersection is unavoidable and provision for left turn movements is not required, the distance between street centerlines shall be a minimum of 150 feet.

  When left turn movements are required, the distance between the centerlines of an existing roadway and an offset DART access roadway shall be a minimum of 300 feet (400 feet along roadways with medians). The actual distance between the centerlines at offset intersections is a function of traffic volume, adjacent land uses, and geometrics. This distance shall be determined by a traffic study. See Figure 4-2 for preferred and alternate arrangements.

- Vehicular entrances to station sites must provide adequate lane widths to allow simultaneous entering and exiting buses to easily negotiate the area. Minimum curb-to-curb distances at entrances shall be 44 feet. This applies only to vehicular entrances to station sites that contain one entering and one exiting lane. Vehicular entrances at T-intersections containing one entrance and two exit lanes shall be 54 feet wide at a minimum. In either case, the minimum width of the entrance lane shall be 26 feet to allow uninterrupted turn movements into the facility. These dimensions only apply to intersection angles of 90 degrees. Requirements for entrances/exits at angles other than 90 degrees will vary. Prior approval by DART is necessary.

- The distance between the intersection of two existing major thoroughfares and a DART access roadway shall be a minimum of 200 feet. However, access shall be provided in a manner which provides adequate left turn storage and does not interfere with traffic operations or the major thoroughfare.

- Unobstructed visibility shall be provided at exits and entrances to non-DART roadways in accordance with the design criteria for sight distance of the applicable governing agency.

Intersections. Intersection angles shall be as near to 90 degrees as possible. When intersection angles are skewed more than 15 degrees from a right angle, realignment of the streets, signalization, or channelization shall be considered. Grades at intersections shall comply with the vertical alignment requirements described in this chapter and shall be as flat as practicable, but still provide adequate drainage. Contour lines and spot elevations shall be used as necessary to effectively define design of the intersection area. Intersecting streets should not have horizontal curvature within 200 feet of the centerline of the intersection. Barrier-free ramps shall be provided at intersections as per the civil standard drawings and in accordance to ADA (TABA, State, Local and Federal) requirements. Cross slopes (street grades) of pedestrian routes across streets shall not exceed 2% through the crosswalk area.

Access Roadway Connections. Public street intersections with DART access roadways and bus access roadways at DART bus transfer facilities shall be designed as minor street intersections. Connections shall be designed to prevent encroachment of bus turning movements into opposing traffic lanes. Traffic volumes, existing signalization, available right-of-way, street widths, and other design elements shall be evaluated when considering channelization to eliminate encroachment of bus turning movements into traffic lanes moving in the same direction.

Curb Returns. Intersection curb return radii shall be to the face of curb. Roadways used by passenger vehicles exclusively shall have minimum radii of 20 feet. Where bus or maintenance vehicle turns are permitted, curb return radii shall be a minimum of 30 feet. At locations where buses make sharp turns (90 to 120 degrees), curb returns may require a three-centered compound curve with radii of 100, 30, and 100 feet with an offset of 5 feet to simulate the wheel path geometry of the bus. (See Figure 4-3 for the intersection detail.)

Driveways. Intersections that provide access from public streets to minor service and maintenance facilities shall conform to the driveway details of the civil at-grade standard drawings. Driveway lane width, exclusive of transitions, shall not be less than 12 feet for each direction of travel.

Sight Distance Triangles. Sight distance triangles shall be required at intersections so that signs, structures, landscaping elements, and other visual obstructions do not restrict visibility. For sight distances at intersections with state highways, refer to the SDHPT Highway Design Division Operations and Procedures Manual. For other non-DART facilities, use applicable governmental agency design criteria. See Figure 4-4 for the sight distance triangles to be used on all intersections within DART sites exiting to DART access roadways.

Channelization. Curbed traffic islands and medians are the preferred design for channelization.

Pavement markers or painted islands for street channelization must be approved by DART and designed in accordance with Chapter 5 - Traffic Control.

Triangular, bulb shaped and irregularly shaped islands (other than medians within the roadway) shall be not less than 75 square feet in area or have any side that is less than 12 feet long out-to-out after rounding of corners. Elongated or divisional islands shall have a width of not less than 4 feet curb-face-to-curb-face and a length of not less than 20 feet.

The minimum width of a median within a two-way access roadway shall be 6 feet from curb-face-to-curb-face; except that the width of medians designed as an integral part of a left-turn storage lane may, when space is limited, be reduced to a minimum of 4 feet. If either or both sides of a median strip are to be used for curb-side parking and the subsequent loading and unloading of passengers, the median shall have a curb-face-to-curb-face minimum width of 12 feet.

In medians where the face-of-curb-to-face-of-curb dimension is less than 6 feet, non-reinforced median pavement 4 inches thick shall be used. At medians with a left turn lane, median pavement shall be used in areas where the face-of-curb-to-face-of-curb dimension is 8 feet 6 inches or less. In standard medians where the face-of-curb-to-face-of-curb dimension is 15 feet, noses shall have median pavement for a distance of 12 feet from the nose face. See the civil standard drawings for details.

Auxiliary Lanes For Turning Traffic. Auxiliary lanes to accommodate right- or left-turning traffic shall be provided for two-way access roadways in accordance with criteria used by the agency having jurisdiction over the affected roadway. The need for storage capacity shall be determined at signalized intersections. The storage length of a left- or right-turn lane with a tapered area shall be sufficient to support design year level of service D intersection operation according to the Highway Capacity Manual and A Policy on Geometrics Design of Highways and Streets. At connections to public streets where existing traffic can make either right or left turns, at least two exit lanes shall be provided. The need for additional lanes shall be determined by evaluating design year traffic conditions against LOS D criteria in the HCM.

4.3.8 At-Grade Crossings

Divisional Island. Where DART rail lines cross streets at-grade, a traffic divisional island shall be provided to prevent drivers from maneuvering around the lowered crossing gates. When provided, crossing gate and median placement should be designed to discourage access by motorcycles, bicycles, and pedestrians, whenever possible. The island shall consist of a raised median that is a minimum of 150 feet long and a minimum of 6 feet face-to-face in width. Divisional islands shall be a minimum of 10 feet wide adjacent to crossings of streets with 4 or more lanes in one direction. On these streets, installation of crossing gates are required on both the median and side of street due to gate length considerations.

Curbing for the median island shall be 6-inch-high, barrier type. (See Figure 4-5 for details.) For transition length requirements, see the traffic control standard and directive drawings.

If the appropriate jurisdiction or agency will not permit a raised median on a two-lane, two-way street, a double row of closely spaced 6" pavement buttons may be considered.

Sidewalks. On DART right-of-way, sidewalks shall conform to the requirements of section 4.9 of this chapter. Sidewalks shall be designed to prohibit bypass of warning gates at signalized street crossings.

Local Requirements. Local at-grade crossings within a dedicated street right-of-way shall conform to the requirements of the applicable jurisdiction.

4.3.9 Guideway Access

Adjacent or special access roadways to all aerial, at-grade, or subway guideways within DART right-of-way shall be provided at maximum intervals of 2,500 feet. Where security fencing/barriers are provided, vehicular gates shall have a minimum opening of 15 feet. Personnel gates shall be at least 4 feet wide.

4.3.10 Dead End Streets/Alleys

DART construction may require the closure of existing streets or alleys adjacent to DART right-of-way. A street or an alley ending in a dead end shall meet appropriate municipal requirements.

4.3.11 Ventilation Grating Openings

Ventilation grating openings shall be located to minimize adverse effects on existing features of landscaping, improvements, and the environment. Such gratings may be located either in raised median strips, or other public land outside the traveled way. When location in preferred areas is not possible, grating openings can be placed at approved locations immediately behind the street curbs; but, the width of grating must not exceed 50 percent of the sidewalk width or 5 feet, whichever is less. Where possible, gratings shall be located outside of the far tangent points at street intersections and shall not be located in any crosswalk area. Covered openings for mechanical access with embossed metal cover plates are permitted in sidewalks. Steel grating shall be used for vent and fan shafts.

4.4 BUS TRANSFER FACILITY

4.4.1 Organization and Geometry

The functional organization of bus transfer facilities at DART rail stations is determined by site configuration, the volume and type of bus operations, passenger and bus traffic circulation, and access provisions. Design vehicle characteristics based on present and anticipated vehicles in the DART bus fleet are shown in Figures 4-6 through 4-8.

4.4.2 Bus Access Roadways

The following guidelines shall be used for bus access roadways:

- A two-way bus access roadway shall have a minimum width of 30 feet. For one-way bus access roadways, a minimum width of 30 feet is required. In cases where the bus access roadway is the same as the bus circulation lane, the minimum width of a two-way access roadway will be 44 feet. Roadways shall be widened in curved sections as shown in Table 4-2 and Figure 4-1.

- The curb radii at intersections along bus roadways shall comply with the Vehicular Entrances to Station Sites section of this chapter.

- The access roadway grade shall comply with Section 4.3.5 - Vertical Alignment of this chapter. If the algebraic difference between the bus access drive and the access roadway exceeds 5 percent, a vertical curve should be designed to provide for clearance of the underside of the design vehicles.

- The length of the bus access roadway, from the boundary of the kiss-and-ride to the nose of the passenger island, shall be a minimum of 100 feet in length to allow for proper bus weaving movement. If weaving movements are not required, however, a length of 50 feet is sufficient.

- o Bus access roadway pavement shall be constructed in compliance with Section 4.10 - Pavement Structures. It shall also have 6 inch high barrier-type integral curbs.

4.4.3 Passenger Transfer Area

The passenger transfer area includes the bus stalls, circulation lanes, passenger islands, pedestrian crosswalks, kiss-and-ride facilities, and park-and-ride facilities. Passenger transfer areas shall be designed to accommodate the loading and unloading of DART bus passengers. These areas also shall allow convenient access to adjacent kiss-and-ride and park-and-ride lots. Designs shall minimize pedestrian-vehicle and auto-bus conflicts.

4.4.4 Bus Stalls

Bus stall layout shall make efficient use of the site and use either shallow sawtooth or in-line platforms. DART will specify the use of sawtooth or in-line platforms.

Sawtooth Platforms. The recommended dimensions for a standard bus berth plus sawtooth pitch and width of circulation road are shown in Figure 4-9. An alternate shallow sawtooth platform layout having one-way access and bus berths on one side of the circulation lane is shown in Figure 4-10.

In-Line Platforms. Refer to Figures 4-11 to 4-13 for recommended configuration of in-line platforms.

4.4.5 Bus Circulation Lane

Bus circulation lanes shall be designed in accordance with the following:

- o Bus circulation lanes shall not be less than 30 feet wide for one-way bus movement two-way bus movement requires separation of lanes. Refer to Figures 4-8 to 4-11.

- o The circulation lane pavement shall be of reinforced concrete constructed in compliance with Section 4.10 - Pavement Structures. It shall have 6 inch high barrier type integral curbs.

- o To prevent standing water at the curb in the bus boarding and exiting areas, the slope of the pavement in the bus stall and circulation lane shall be away from the passenger island. In the case of a two-way bus circulation lane with passenger islands/loading platforms on both sides, the gutter/flowline shall be located at the center of the lane. If the passenger island is on one side only, the flowline shall be at the edge of the pavement opposite the island.

- The transverse slope and longitudinal grades of the gutters shall comply with Section 4.3.5 - Vertical Alignment and Cross-Sectional Elements sections of this chapter.

4.4.6 Passenger Island

The passenger island shall be a platform raised 7 1/2 inches above the bus stall gutter elevation. The edge of the platform will be a special type curb for passenger safety and provides for a 7-inch step up to the bus first step, a normal step riser. See the Civil Standard Drawings for special curb detail.

Minimum walking, queuing, and lateral clearance dimensions shall be based on maintaining level of service C or better based on current Highway Capacity Manual criteria. Queuing areas for each berth shall accommodate waiting patrons equivalent to the peak 5-minute queue demand at 3 or more square feet per waiting patron.

Minimum effective platform widths shall be 13 feet for single-loaded platforms (islands) and 20 feet for double-loaded islands. Total island widths shall include effective widths plus any additional widths needed to accommodate vertical obstructions and associated lateral clearances (See Figure 4-14.) The effective width is measured along a projection line of obstructions closest to the passengers. The passenger island sidewalk shall have a transverse slope of 1/4 inch per foot toward the curb.

4.4.7 Pedestrian Crosswalks

Pedestrian crosswalks shall be located so there is sufficient visibility to permit safe movement by prudent pedestrians and bus drivers. When required by DART, the crosswalks shall be emphasized by introducing a change in roadway elevation, and a change of pavement material, surface texture, or color. No crosswalk within the passenger transfer area shall be less than 12 feet in width. When required, the crosswalk elevation shall be raised a maximum of 4 inches above the elevation of the circulation road. The roadway pavement at either side of the sidewalk shall have a maximum slope of ramp 2.30 percent. In no case shall the sloping ramp be less than 15 feet in length. See Figure 4-15a and 4-15b for details.

Pedestrian islands at the crosswalk location shall be lowered to meet the crosswalk elevation with a slope not to exceed 8.30 percent. A minimum of 6 feet of the sidewalk width should be included in the sidewalk elevation transition. See Figure 4-15 for details. Bollards spaced at 4 feet center-to-center and 3 feet 6 inches above finished grade are permitted, if necessary, to define bus and pedestrian domains. They also may be installed parallel to sidewalk ramps at entry points to crosswalks. Crosswalks and sidewalk design and pavement material and texture should be selected to provide safe and barrier-free access to the physically handicapped and the elderly. Textured pavement is required for pedestrian crossing of bus access and circulation roadways.

4.4.8 Pavement Design Requirements

Pavement for bus access roadways, stalls, and circulation lanes shall be designed to comply with Section 4.10 - Pavement Structures. Passenger islands and sidewalks shall be designed according to Section 4.9.1 - Sidewalks of this chapter and the Civil At-Grade Standard Drawings.

4.5 PARKING FACILITIES AT STATION SITE

4.5.1 Conformance To Local Codes

Traffic control devices and pavement marking within DART-owned parking facilities shall conform to all applicable codes and ordinances, including minimum requirements for bay widths, driving aisle widths, handicap spaces, loading spaces, and fire lanes. When a local agency has no ordinance regulating parking design, the parking requirements contained in this chapter shall be the minimum allowable design.

4.5.2 Space Size and Orientation

Unless specific approval is obtained from DART, all DART facility parking space shall be at 45, 60, or 90 degree angles. 8.5 x 18 feet is desirable for standard spaces, and 7.5 x 16 feet for compact car spaces, unless local codes require other dimensions.

4.5.3 Capacity

Parking lot capacities will be determined by DART and provided to the section designer by the GEC. These parking requirements are to be fulfilled as economically as practicable. The reduction or increase in these capacities by more than 5 percent must be justified, and prior approval by DART is required.

4.5.4 Parking Stall Striping And Layout

<u>Standard Car Head-In Parking Stall</u>. Unless otherwise defined by ordinance, the standard car head-in parking stall shall accommodate standard and full-size automobiles, vans, and pickup trucks, and have a nominal size of 8.5 feet wide by 18 feet long. Stalls shall be defined by single 4-inch-wide white stripes. Where the standard car head-in stall is at 90 degrees to the curb, a maximum of 2 feet may be deducted from the length of the stall to allow for the overhang of the front of the vehicle over the curb. If this overhang area is obstructed to any extent, then the depth of the stall must be adjusted accordingly.

<u>Compact Car Head-In Parking Stall</u>. Unless otherwise defined or disallowed by ordinance, the compact car head-in parking stall shall accommodate only compact and subcompact automobiles and pickup trucks. Compact car head-in parking stalls shall be a minimum of 7 feet

6 inches wide and 16 feet deep. Compact car parking areas shall be segregated from standard car parking as much as possible to reduce the number of standard size cars and trucks misusing the smaller parking stalls. To encourage compact and subcompact usage of the smaller stalls, preferential treatments and locations may be appropriate. No more than 25 percent, or as allowed by code, of the total provided parking spaces shall be designated exclusively for compact cars.

Standard Car Pull-Through Kiss-and-Ride Stall. Unless otherwise defined by ordinance, the standard car pull-through kiss-and-ride stall shall accommodate standard and full-size automobiles, vans, and pickup trucks, and have a nominal size of 10 feet wide by 20 feet deep. These stalls should only be installed in the angled stall configuration and use an angle of no more than 60 degrees. The stalls shall be defined by 4-inch-wide white stripes. Entrance and exit driving aisles adjacent to these stalls shall be of sufficient width so parking maneuvers may be performed easily and safely. For additional design details, see Section 4.6 - Kiss-and-Ride Spaces.

Parallel Parking Stalls. Parallel parking areas shall not be used within parking lots and structures. More efficient parking can be obtained through modifications in the parking layout to accommodate head-in parking along perimeter curbs. Parallel parking generally should not be used within DART facilities, but may be used in circulation and access roadways if they do not interfere with efficient traffic operations, and no other reasonable parking alternatives exist.

Unless otherwise defined by ordinance, parallel parking stalls shall accommodate standard and full-size automobiles, vans, and pickup trucks, and have a nominal size of 25 feet wide by 10 feet deep. The stalls shall be defined by 4-inch-wide white stripes.

Handicapped Parking Stalls. The requirements for handicapped parking stalls are contained in the Elimination of Architectural Barriers Act, Article 7, Article 601b, Vernon's Texas Civil Statutes. Local ordinances should be reviewed for stricter interpretations of this act. See Section 4.5.8 - Design Considerations for the Handicapped for specific recommendations.

Motorcycle Parking Stalls. Motorcycle parking stalls may be delineated in those triangles and corners set off by the park-and-ride layout that are readily accessible to the station and that would otherwise be unused. Areas designated for motorcycle parking shall be at least 4 feet wide by 8 feet long. Concrete paving shall be used for all motorcycle spaces.

DART Maintenance Parking. Provide minimum of one maintenance parking space at each station site. Access to parking space shall not impede bus or pedestrian access. Locate as close as possible to maintenance buildings or rooms.

4.5.5 General Internal Circulation

General internal circulation patterns shall be based on the following considerations:

- A maximum separation shall be maintained between vehicular and pedestrian traffic.

- Circulation patterns shall be simple and direct, allowing for easy driver orientation. They shall permit drivers to search for parking spaces without impeding traffic flow or reentering public streets.

- Circulation roads within a parking lot may be required where normal aisle standards would provide inadequate circulation. Primary circulation and access roads shall be located on the perimeter of the parking area and away from concentrations of pedestrians.

- Vehicle speed and search patterns shall be considered when determining the length of an individual parking aisle. In general, no aisle shall be longer than 400 feet without having a cross aisle.

- Complicated intersections shall be avoided whenever possible to insure efficient traffic movement and pedestrian safety. Traffic signals shall not be permitted within station areas. Conditions needing traffic signalization are to be avoided in design.

- Vehicular circulation (both bus and auto) around station sites shall be counterclockwise for easy passenger drop-off and pick-up, as shown in Figure 4-16.

- Circulation patterns shall be designed to be easily comprehensible to the average driver. Direction signing should not be required to permit on-site circulation. Signing and directional arrows on pavement may be provided to expedite circulation.

4.5.6 Bus Access

Bus circulation patterns shall be in accordance with the following:

- The routing of buses in and out of the station area shall be developed in cooperation with the DART Department of Transit Operations.

- Exclusive bus loading/unloading areas will be provided next to DART stations in accordance with Section 4.4 - Bus Transfer Facility of this chapter.

- The path from bus loading/unloading areas to the station entrance shall be as direct as possible.

- Bus stops at DART rail stations that are located on adjacent public streets shall be recessed outside of traffic lanes where feasible.

4.5.7 Pedestrian Access

Pedestrian circulation patterns shall be in accordance with the following:

- Direct and safe approaches for pedestrians shall be provided from all adjacent streets into the station area.

- Pedestrian circulation in parking lots shall be provided along parking aisles. As described below, additional provisions for pedestrian circulation may be desirable or required in certain situations.

- Pedestrian walkways shall be provided in certain locations to minimize interference with vehicular traffic. These walkways may be provided to minimize pedestrian use of a circulation road or aisle and to control the number of points where pedestrians cross a circulation road. Where pedestrians originate from an outlying part of a large parking lot, consideration shall be given to providing a walkway that extends toward the station on as direct a path as possible.

- Pedestrians shall have the right-of-way over vehicles at selected crossings, on internal roadways. Any such crossing shall be designated with appropriate signing and may, at the direction of DART, be required to conform to the provisions of Section 4.4.7.

- Pedestrian crossings shall have a median refuge area, at any on-site roadway wider than four lanes.

- A pedestrian path shall be as direct as possible from any parking stall or bus transfer facility to the station concourses. The coefficient of directness is determined by the following equation:

  $$\text{Coefficient of Directness} = \frac{\text{Length of Path}}{\text{Straight Line Distance}}$$

  The preferred coefficient of directness is 1.2; it shall not exceed 1.4. Aisles may be used in the determination of the "Length of Path" in the above equation.

- Long ramps shall be interrupted with level areas at intervals for rest stops and to provide easy maneuverability by handicapped patrons. For specific requirements, see the Elimination of Architectural Barriers Act, Article 7, Article 601b, <u>Vernon's Texas Civil Statutes</u> and any locally applicable requirements.

- Crosswalks with adequate queuing areas shall be used where concentrated pedestrian flows cross circulation and parking aisles. Crosswalks and queuing areas shall be designed to provide a minimum level of service in accordance with the <u>Highway Capacity Manual</u>.

- Walkways and crosswalks shall be marked as prescribed in Chapter 5 - Traffic Control.

4.5.8 ADA Design Considerations

Parking facilities for the disabled shall be provided in the kiss-and-ride and park-and-ride areas at a location near the main station entrance. They shall conform to the Americans with Disabilities Act Accessibility Guidelines and the Texas Accessibility Standards of the Architectural Barriers Act and Local, State and Federal ADA accessible facilities shall be submitted to Texas Department of Licensing Regulation for review and approval prior to the Pre-Final submittal.

4.5.9 Bicyclist Considerations

If directed by DART, provisions should be made for bicycle access to parking facilities separate from that provided for motor vehicles. If economically feasible, separate access may be in the form of either an exclusive bikeway or a sidewalk bikeway. The bikeway may be built on the outside edge of the station access road. If this is not possible, bicyclists will be required to dismount and walk their bikes in areas of heavy pedestrian traffic. Where an exclusive bikeway is designated, it shall provide for two-way bike traffic and be designed according to Chapter 19 - Station Site Requirements. A sidewalk bikeway shall be a minimum of 8 feet wide and shall only be used where both bicycle and pedestrian volumes are low. The pavement structure shall be designed according to Section 4.10 - Pavement Structures.

Where facilities have stairways to platforms, designer shall provide 4" wide bike wheel run between stairs and railing.

Exclusive and sidewalk bikeways shall be marked and signed as per Part IX of the TMUTCD. Pedestrian use of exclusive bikeways should be discouraged through the use of "PEDESTRIANS PROHIBITED" signs (R9-3A) at potential pedestrian access points.

The capacity for bicycle storage will be provided by DART to the section designer. Bicycle parking shall be provided at a convenient distance from the station or sheltered area. All facilities shall be provided at street/sidewalk level. Access to the bicycle parking area shall not conflict with or intersect barrier-free handicapped access routes. Adequate space shall be provided for maneuvering bicycles in and out of the bicycle racks without difficulty. Approximately 15 to 20 square feet shall be provided per bicycle parking place. Racks shall be located adjacent to station entrances where bicycles can be locked to a secure stanchion by the bicyclist's chain and lock. If used, bicycle lockers shall be similarly placed, or, if there are parking structures, bicycle lockers shall be placed in these. Their placement shall not compromise pedestrian walkways nor detract from the architectural quality of the station.

During evening and nighttime hours, and during periods of adverse weather, adequate lighting shall be provided to help illuminate bicyclists in bicycle parking areas, on bikeways, and at intersections with circulation roadways. Adequate lighting shall also illuminate pedestrians walking on sidewalk bikeways and on sidewalks crossing exclusive bikeways.

4.5.10 General Design Considerations

<u>**Speed Control In Parking Areas**</u>. At least one speed limit sign visible to drivers immediately upon entering the parking area shall be installed on each circulation roadway or aisle. The posted speed limit should be commensurate with the design of the parking area.

Parking area layout and design shall discourage excessive vehicle speeds. Speed control in parking areas shall not be accomplished through the use of unwarranted Stop and Yield signs, or through the use of "speed humps," or pavement undulations.

<u>**Fee Collection and Access Control**</u>. Although parking fees may not be charged initially, space for centrally located fee collection boxes should be provided in DART surface parking facilities. For parking structures, the type and space reservation for access control and fee collection shall be recommended by the section designer and approved by DART.

<u>**Grading**</u>. Along roadways near the station concourse entrances and in bus and kiss-and-ride loading/unloading areas, grading shall be designed to achieve a 2 percent transverse slope away from the loading/unloading curb line. The drainage facilities shall be designed according to Chapter 7 - Drainage. In general, the cross slope of parking stall pavement shall be between 1 to 4 percent. It shall not be more than 5 percent. Drainage shall be directed away from areas where pedestrians will walk. Catch basins shall not be located in the aisles. If possible, no parking space shall have a slope from the head to the back greater than 2.5 percent.

<u>**Curbs, Medians and Bumpers**</u>. Curbs shall be 6 inches high, barrier type, and constructed of portland cement concrete. See Civil Standard Drawings for details. Curbs shall be provided around the entire outer edge of parking lot pavement to protect landscaping or fencing from vehicular damage. Curbs shall also be provided as necessary along circulation roads, at raised concrete medians, and at intermediate points in the large lots. Exposed corners of curb shall have a minimum radius (to face of curb) of 2 feet. With DART approval, wheel stops may be used at the head of parking stalls. Wheel stops, though, will be used for all herringbone line stalls. Where columns supporting structures are to be located in a parking facility, correctly placed bumpers may be used for column protection. Wheel stops shall be 6 feet long, approximately 6 inches high, and shall be precast reinforced portland cement concrete.

Bollards, boulders or similar devices shall be used at landscape areas subject to damage by buses at inside turning radius along bus lanes.

<u>**Clearances**</u>. Minimum vertical clearance between any overhead obstruction and parking lot surface shall be 14 feet 6 inches. Clearance shall be 7 feet where access is limited to passenger cars. Clearance can be 12 feet where access is limited to standard (single deck) buses. The passage of vehicles exceeding the lower clearance specified, however, must be prevented by curbs, fencing, or an equivalent type of barrier. At the head of parking stalls, horizontal clearance shall be 2 feet 6 inches from the front face of curb to any obstruction. At the sides of

stalls, no horizontal clearance need be provided between stalls and vertical obstructions except at walls, where a minimum clearance of 2 feet shall be provided outside of the parking stall.

Pavement Structure. The pavement structure of the parking lots at DART stations shall be designed according to Section 4.10 - Pavement Structures. For paving purposes, circulation roadways within the delineated areas of the parking lot shall be considered part of the parking lot. Circulation roadways outside the delineated area of the parking lot shall be considered part of the station access roadway.

Border of Parking Areas. Parking lots shall be designed to avoid the use of earth retaining structures and to keep all work within DART right-of-way lines.

Where fills higher than 10 feet are required, the section designer shall coordinate with DART for the possible use of guard rail protection or pedestrian railing. These borders preferably shall be wide enough for landscaping and planting.

Fencing. Generally, suburban station parking lots shall not be provided with perimeter fencing. Screening walls shall be considered in residential areas. Where local ordinances, aesthetical considerations, noise, or safety require fencing, the matter shall be reviewed by DART case by case.

Planted Areas. Planted areas shall be designed according to Chapter 19 - Station Site Requirements. Landscaping must not interfere with sight distance requirements. Special attention shall be given to the grading and drainage of landscaped areas so that these areas do not become a source of water that can contribute subsurface drainage to pavement foundation layers. Where island size does not require installation of catch basins for the interior collection of storm water, the island shall be graded to a minimum slope of 2 percent and crowned to give positive drainage over the curb.

Placement of Lighting Standards. Placement of lighting standards shall conform to lighting requirements contained in Chapter 26 - Lighting, and shall be coordinated with the station landscaping and utility plans.

Passenger Orientation. Traffic related signs shall comply with Chapter 5 - Traffic Control. Informational signs shall comply with the architectural standard drawings.

Street Furniture. Benches will be needed along the bus platforms and kiss-and-ride facilities and shall be integrated with shelters along streets adjacent to stations without bus transfer facilities. DART will determine if seating already built into shelters needs to be supplemented with benches.

Trash Containers. Several small conveniently placed trash containers shall be integrated with other street furniture. Container size and location may vary at each bus transfer facility, but they should be located outside the shelters wherever possible.

Shelters. At bus transfer facilities one shelter per bus shall be provided; two shelters shall be provided for each route served by articulated buses. At shared bus/rail platforms, canopies or shelters shall cover at least one-third of the platform length and the entire platform width. Shelters shall be designed of durable low maintenance materials and should contain wind screens that will block wind and blowing rain, but not impair visibility. To accommodate queuing along the bus berth, shelters shall be located toward the back of single-sided platforms and near the centerline of double-sided platforms.

Paving. In most applications, local regulations, engineering requirements, and economic considerations will dictate the use of ordinary concrete. At bus transfer facilities adjacent to DART stations, however, the use of textured surfaces, expansion joint patterns and color can enhance safety and clarity of use by providing a contrast to the surroundings. When approved by DART, pavers may be used in locations such as crosswalks in the busways and along the busways.

4.6 KISS-AND-RIDE SPACES

4.6.1 Capacity

The required design capacity for a station will be determined by DART and provided to the section designer by the PSD. It will be based on the individual requirements of each station. The kiss-and-ride spaces shall be for attended vehicles only.

4.6.2 Location

Location of kiss-and-ride spaces shall be in accordance with the following:

- o Kiss-and-ride spaces located off-street, either in a parking lot or a parking structure, shall be as near to the station concourse entrances as practicable, and shall be physically separated so not to appear an integral part of long-term parking areas within the parking lot or parking structure.
- o When possible, kiss-and-ride spaces shall have an access separate from that of the park-and-ride spaces.
- o When possible, kiss-and-ride circulation shall be physically separated from bus circulation.
- o Kiss-and-ride spaces located within a parking structure shall only be upon levels of the structure that have direct access to an adjacent street.
- o The preferred location of a kiss-and-ride zone is adjacent to the main entrance of the station. The configuration should permit vehicle loading on the right-hand side.

- The kiss-and-ride area shall be laid out for one-way traffic.

4.6.3 Access Roads

Access roads shall be single lane with a minimum width of 20 feet to allow space to maneuver around a stopped vehicle. When possible, kiss-and-ride traffic shall be able to re-circulate on-site if a parking space is not available. Kiss-and-ride traffic shall not be routed through the park-and-ride areas, but instead should use circulation roads or access roads. Kiss-and ride traffic circulation through the station shall be one way.

4.6.4 Signs and Markings

All kiss-and-ride parking spaces shall be defined by appropriate signs and markings. Signs and markings shall be in accordance with TMUTCD or as directed by DART and shall be as shown on the architectural standard drawings and the traffic control standard and directive drawings.

4.6.5 Design Details

Pickup/Dropoff Area. Kiss-and-ride (pickup/dropoff) facilities shall be provided adjacent to each parking area. Kiss-and-ride parking spaces may be either parallel to the curb or at a 45 or 60 degree angle maximum. Their placement shall depend on the configuration of the available area and the most effective use of that area to accommodate the required number of spaces. Kiss-and-ride spaces preferably shall be next to the station entrance. Angle parking may be used when providing the required number of spaces as parallel spaces would cause the most distant space to be farther than 200 feet from the station entrance or would necessitate the addition of islands with parallel spaces.

Pickup/dropoff arrangements for kiss-and-ride areas are in the following order of preference:

- 45 degrees to the aisle (Figure 4-19).
- 60 degrees maximum to the aisle (Figure 4-19).
- Parallel to curb (Figure 4-20).

Pickup/dropoff lanes parallel to the curb shall be 10 feet wide and 25 feet long except that the beginning and ending stall of a series of spaces may be 22 feet. Parallel pickup/dropoff spaces shall begin at least 20 feet from a crosswalk.

At least one barrier-free ramp for the handicapped should be provided for each 150 feet of curb in passenger pickup/dropoff area. The design of the barrier-free ramp shall comply with the Civil Standard Drawings.

Short-Term Parking. Short-term parking spaces shall be incorporated into the kiss-and-ride area to:

- o Provide short term parking during off-peak periods.
- o Promote better evening kiss-and-ride service.
- o Provide a reservoir of additional spaces when kiss-and-ride pick up/dropoff areas are congested.

Although other considerations may prevail, a short-term parking area should be included where possible. The short-term parking spaces shall be located off the access roadway to the kiss-and-ride parking area and shall be designed in accordance with the Parking Facilities at Station Site section of this chapter with the appropriate signs.

4.7 PARK-AND-RIDE

Parking spaces initially may be at-grade with provisions for structured parking in the future, or may be structured parking with expansion capability. Refer to specific station site plans for park-and-ride requirements. See the Architectural Chapters 23 and 24 and Chapter 26 - Lighting, for additional requirements.

4.7.1 Design Details

The park-and-ride area shall be designed for self-parking. Designs with parking spaces laid out at 90 degrees to the aisle will generally be used. But, some parcels of land may be of such a size or shape as to warrant the use of another angle. Small car and standard size parking spaces shall be configured according to appropriate municipal codes. Space arrangement and aisle dimensions for small and standard size cars shall preferably conform to the right-angle parking.

The aisle widths shown shall be used where spaces are provided along one or both sides of an aisle. Where a significant number of stalls of different layout standards (90 degree versus angle parking) are used along one or both sides of an aisle, the greater aisle width shall be used. Mixing parking aisles at at-grade level is not recommended, but may be permitted where made necessary by site constraints. Vehicles and other objects shall be excluded from corners of parking lots to provide adequate intersection sight distances. Aisles shall be aligned to facilitate convenient pedestrian movement toward the station. To minimize speeding and aid pedestrian orientation, aisles shall not be longer than 400 feet. Aisle length may be limited by offsetting aisles, or by changing the aisle alignment.

A system of traffic circulation produced by the arrangement of parking aisles and spaces shall be designed to minimize vehicular travel distances, conflicting movements, and number of turns. Vehicular movements within the parking area shall be dispersed by strategic location of entrances, exits, and aisles. Entrances and exits should not be located on crest vertical curves. A minimum of one entrance and exit shall be incorporated in the lot layout for each 500 spaces. If possible, access joints shall be provided at separate locations and shall access different streets. Separate access for public transit vehicles is also recommended.

Two-way circulation roads within parking areas shall have a minimum roadway width of 22 feet. One-way circulation roadway minimum width may be 18 feet with the approval of DART. Circulation roads shall be curbed. The minimum vehicular inside turning radius for vehicles other than buses shall be 16 feet. The minimum outside turning radius shall be 26 feet.

4.7.2 Reservoir Areas

Within the parking lot and immediately adjacent to every entrance and exit to a public street, a reservoir area shall be provided for the momentary storage of vehicles. The momentary storage of vehicles entering or leaving the parking lot shall not interfere with the normal activity of parking vehicles. The size of a reservoir area shall be sufficient to meet inbound and outbound storage requirements during the peak 15 minute periods for inbound and outbound movements. Reservoirs shall not extend closer to an off-site street than the back of the sidewalk on that street. The reservoir area may be provided as a circulation road or an area extending in any direction within the site.

4.8 PARKING STRUCTURES

4.8.1 Functional Elements

Ground levels shall contain entrances and exits, reservoir areas, and internal ramps. Ground levels may also contain ADA accessible parking, kiss-and-ride and park-and-ride areas. Upper levels and underground levels generally shall contain only ramps and as many parking spaces as practicable. The possible expansion of the parking structures shall be a design consideration.

4.8.2 Internal Circulation

Traffic circulation within parking structures shall be designed to minimize vehicular travel distances and number of turns. Circulation on one-way ramps preferably shall be counter-clockwise. Designs shall not require travel on internal ramps to reach patron pickup/dropoff areas. A reservoir area shall be provided for parking structures immediately adjacent to entrances and exits. Reservoir areas in parking structures shall be provided according to the requirements prescribed in Section 4.7.2 - Reservoir Areas. Areas between the building line and the back of a sidewalk may be included as part of the reservoir area. Internal ramps flanked by parking spaces shall not be used as reservoir areas.

4.8.3 Entrances And Exits

Visibility shall be provided at exits in accordance with the requirements prescribed for sight distance in Section 4.3.4 Horizontal Alignment and Figure 4-3 by excluding columns, walls, and objects that are more than 2 feet 6 inches above the high point of the traveled way from the indicated areas. Entrance and exit lanes shall be 12 feet wide. Driveways for parking structure entrances and exits shall be designed to meet appropriate municipal design criteria and standards. Driveways from other streets and highways shall be designed as prescribed in Section 4.3.7 - Vehicular Entrances to Station Sites.

4.8.4 Ramps

Where site conditions permit, adjoining street grades shall be used to minimize the need for ramps between parking levels. Internal ramps shall be located to avoid operational conflicts with entrances and exits. The ramps shall be placed in such a manner that they are not a direct and natural path for pedestrian travel. Parking spaces shall not be located on curved internal ramps.

External ramps may be necessary in some locations. Parking spaces shall not be located on external ramps, whether curved or straight.

Ramp grades shall be kept as low as practicable. Excluding areas of transition, grades shall not exceed 5 percent on ramps with perpendicular or diagonal parking or 12 percent on ramps without parking; however, 8 percent is the preferred maximum grade without parking. The grade on curve ramps shall be calculated along the inside edge of the roadway.

Where the difference in grades between a ramp and a floor exceeds 6 percent, a transition shall be provided. Transitions shall have a grade equal to one-half of the sum of the two grades. Ramps shall be round at all breaks in grade for a distance of 3 feet on each side of the grade break. See Figure 4-21 for details. For additional requirements, see the Parking Structures section of Chapter 19 - Station Site Requirements.

Straight ramps without parking on them and curved ramps shall have a cross section as shown in Figure 4-22. The ramps shall have a transverse slope as shown. On curved ramps, the transverse slope shall slope down toward the center of the curve. Where grades on the exit ramps exceed 8 percent, the pavement structure shall be the same, for a minimum of 100 feet behind the intersection, as the pavement structure for the bus loading and unloading zone.

4.8.5 Parking Spaces And Aisles

The layout of the parking structure shall be done in a manner to permit future conversion of standard size parking spaces to small car usage. A modular bay design shall be used that permits layout of both small car and standard car spaces and aisles. The percentage of compact sized car stalls to be provided in the initial striping plan will be furnished by the GEC. The nominal parking lot space and aisle dimensions are given in Section 4.7 - Park-and-Ride. Space and aisle layout may accommodate both standard size and small car dimensional requirements on all parking levels. Grades greater than 5 percent will not be acceptable for parking.

If one-way traffic flow is acceptable, angled parking using spaces at angles of 60 degrees may be the most efficient. This layout is especially adaptable to two-bay double-helix structures with parking on the sloped floors. Spaces shall be placed so that the maneuvering of a vehicle in or out of a parking space will not block or inhibit the free flow of traffic on ramps where parking is prohibited. Traveled ways, other than parking aisles and ramps, shall be 24 feet wide for two-way travel with diagonal and perpendicular parking and 16 feet wide for one-way travel and diagonal parking. The minimum vehicular inside turning radius shall be 16 feet, and the minimum outside turning radius shall be 30 feet. Design vehicle turning paths shall be used in designing for vehicle turns. For parking spaces for the handicapped refer to Section 4.5.4 - Parking Stall Striping and Layout.

4.8.6 Pedestrian Circulation

Horizontal pedestrian circulation in parking structures shall be provided by parking aisles. Additional provision for horizontal pedestrian circulation by walkways is preferred for special conditions only. Facilities for vertical pedestrian travel shall be placed at appropriate locations in the structure to preclude the use of vehicular ramps by pedestrians. DART will determine the need for stairways and elevators. See Chapter 19 - Station Site Requirements, for additional guidelines.

4.8.7 ADA Accessibility Considerations

ADA accessible parking spaces shall be located adjacent to or in proximity of an ADA accessible route to the station platform. Elevators in multilevel structures shall comply with the requirements stipulated in the Elimination of Architectural Barriers Act, Article 7, Article 601b, Vernon's Texas Civil Statutes. All ADA accessible parking shall be on the ground floor of the structure and near the pedestrian exit leading to the station platform. Refer to Chapter 19 – Station Site Requirements, and ADA guidelines, local codes for additional requirements.

4.8.8 Clearances

Columns between the head and end of a parking space shall be located, where practicable, not closer than at every third space. Clear span structures should be used where possible to facilitate parking maneuvers, enhance security, and maximize space efficiency. Where clear span structures cannot be used, a clear distance of not more than 13 feet from the head of the space shall be provided. Columns shall not encroach upon the standard parking space width specified in this chapter or interfere with the proper operation of car doors or driving aisles. Unit parking depth is the width of an aisle plus the depth of the adjacent parking space on each side of the aisle.

Vertical clearance between the floors of any structure and any overhead obstruction, including signs, lighting fixtures, piping, or any other appurtenances, shall be 7 feet 6 inches on all levels unless otherwise specified. Appropriate signage and a flexible structure shall be provided to prevent entry of overheight or overweight vehicles to travel areas or within the parking structure.

Horizontal clearance on straight ramps and other traveled ways shall be 1 foot from the inside of curb to a wall or other obstruction. Horizontal clearances on curved ramps shall be designed to accommodate vehicle overhangs at the specified curve radius. At the head of parking spaces, horizontal clearance shall be 2 feet 6 inches from the front face of islands or curbs to a wall or other obstruction. At the sides of spaces, no horizontal clearance need be provided between spaces and columns. A clearance of 2 feet shall be provided between the sides of parking spaces and walls. When using 90 degree parking, spaces shall be designated "Head-in Parking Only" with appropriate signage.

4.8.9 Curbs, Medians and Islands

Curbs shall be used at the head of parking spaces and placed according to the clearance requirements prescribed in this chapter. As shown in Figure 4-22, curbs shall be provided within parking structures as a border on all ramps and other traveled ways adjacent to walks. Curbs shall be 6-inch high, barrier type, constructed of Portland cement concrete. See the Civil Standard Drawings for details of barrier type curb.

Raised islands shall be used at the head of all parking spaces abutting partitions, railings, and non-structural walls. Raised islands shall be 6 inches high with a barrier type curb constructed of Portland cement concrete.

All exposed corners of curbs and raised islands shall have a minimum radius-to-face-of-curb of 2 feet.

4.8.10 Drainage

Drainage shall be provided for all levels within a structure. Levels within parking structures shall be sloped to drain at 1 to 1.5 percent. Drainage shall be away from the center of aisles and generally toward the head of parking spaces. Vertical drain pipes shall be located so as not to compromise parking space and aisle dimensional requirements. Drain pipes shall also be located to not obstruct the vertical clearance of 7 feet 6 inches on any level.

4.8.11 Architectural Requirements

Parking structures must comply with local fire and building codes. See the Architectural Chapters 23 and 24 for additional requirements.

4.9 PEDESTRIAN FACILITIES

4.9.1 Sidewalks

A sidewalk shall be provided next to all curbside parking lanes and to all loading zones. Sidewalks intended for use by the general public shall have a minimum width of 6 feet. Minimum sidewalk width at kiss-and-ride areas, near stations, and at bus transfer facilities shall be 8 feet. (See the Architectural Chapters 23 and 24 areas, near stations, and at bus transfer facilities shall be 12 feet, or the adjacent sidewalk plus 6 feet, whichever is greater. Sidewalks providing access to service and maintenance facilities shall have a minimum width of 3 feet. Sidewalks shall be constructed of reinforced Portland cement concrete 4 inches thick. Sidewalks shall be elevated above street level and drainage shall be provided by a cross slope toward the curb of 2% maximum. For construction details, see the Civil Standard Drawings.

4.9.2 Barriers

Pedestrian facilities should be configured to avoid conflicts with major vehicular movements or other potentially hazardous conditions. However, if such conditions cannot be avoided, pedestrian barriers shall be provided to discourage or prevent pedestrians from crossing at these locations. Pedestrian barriers may consist of railing, fencing, walls, or landscaping.

4.9.3 Bridges and Undercrossings

Pedestrian bridges and undercrossings shall be avoided if any other acceptable alternate design is feasible. Where undercrossings are provided, they shall be adequately sized and well lighted. Undercrossings shall be placed so that continuous visibility is provided into the undercrossing when viewed from the approaches. Maximum consideration shall be given to the safety and protection of patrons. All local codes, DART criteria and ADA requirements shall be included in the design of these facilities.

4.10 PAVEMENT STRUCTURES

The following design criteria shall be used on DART right-of-way. The appropriate design criteria of the governing agency shall be used when the facility is not on DART right-of-way.

4.10.1 Pavement Cross Sections

Rigid Pavement. A rigid pavement section shall consist of a jointed reinforced Portland cement concrete slab, a subbase and/or improved subgrade. The pavement section shall be designed according to "AASHTO Pavement" using the following guidelines for design variables:

- o Performance period – 20 years
- o Analysis period – 30 years
- o Traffic – supplied by traffic consultant on a site-specific basis
- o Reliability – 80 percent minimum, S_o = 0.30 unless supplied by the traffic consultant through DART (site specific)
- o Roadbed swelling – PSI supplied by the getotechnical consultant (site specific)

- Serviceability – $P_o = 4.5$ $P_t = 2.5$

- Effective modulus of subgrade reaction – k supplied by the geotechnical consultant (site specific). Subgrade shall be lime or cement stabilized as recommended by the geotechnical consultant (site specific)

- Pavement layer materials characterization – $E_c = 3.12 \times 10^6$ psi minimum ($f_c = 3000$ psi)

- P.C.C. modulus of rupture – $S_c = 550$ psi minimum ($f_c = 3000$ psi)

- Drainage – C_d supplied by the geotechnical consultant (site specific)

- Load transfer – Roadways w/curb and gutter J = 4.2, roadways w/flexible shoulder J = 4.4, parking J = 3.6

- Loss of support – LS value supplied by the geotechnical consultant (site specific)

- Minimum Reinforcement - #3 grade 60 bars at 2 feet 0 inches center to center (L = 20')

- Minimum section for parking lots – 5 inches thick, 3000 psi reinforced concrete pavement with 6 inches of cement or lime modified base

Flexible Pavements. A flexible pavement section shall consist of a surface course, a base course, and a subbase. Flexible pavements will be considered only for parking lots. The pavement section (thickness of each layer) shall be designed according to "AASHTO Pavement" using the following guidelines for design variables:

- Performance period – 10 years

- Analysis period – 30 years

- Traffic – supplied by the traffic consultant (site specific)

- Reliability – 80 percent minimum, $S_o = 0.40$ unless supplied by the traffic consultant through DART (site specific)

- Roadbed swelling – PSI supplied by the geotechnical consultant (site specific)

- Serviceability – $P_o = 4.2$ $P_t = 2.5$

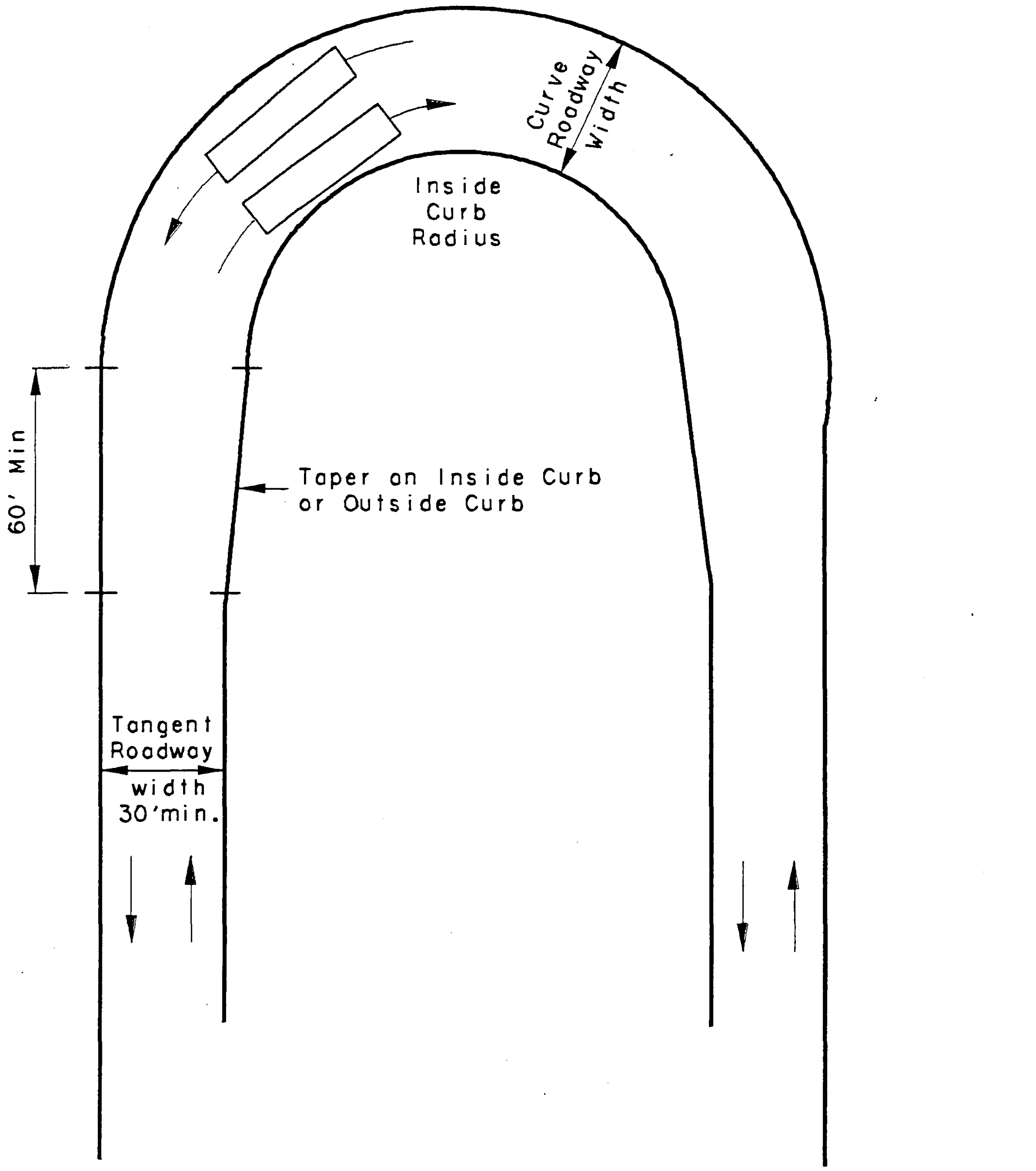
- Effective roadbed soil resilient modulus – MR supplied by the geotechnical consultant (site specific)

- o Pavement layer materials characterization – E_{ab}, E_{bs} & E_{ac} supplied by the geotechnical consultant based on his recommendation of layer materials (including surface course, base course and subbase) and subgrade preparation. (Site Specific)

- o Layer coefficients – a values calculated based on E values supplied by the geotechnical consultant

- o Drainage – m_i value supplied by the geotechnical consultant (site specific)

- o Minimum section for parking lots – 3 inches of full depth asphaltic concrete (1-1/2 inch surface course, 1-1/2 inch base course) with 8 inches of granular subbase



Note: See table 4-2 for dimensions.

ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA CURVE WIDENING FOR BUS ACCESS ROADWAYS SCALE: NTS FIGURE: 4-1

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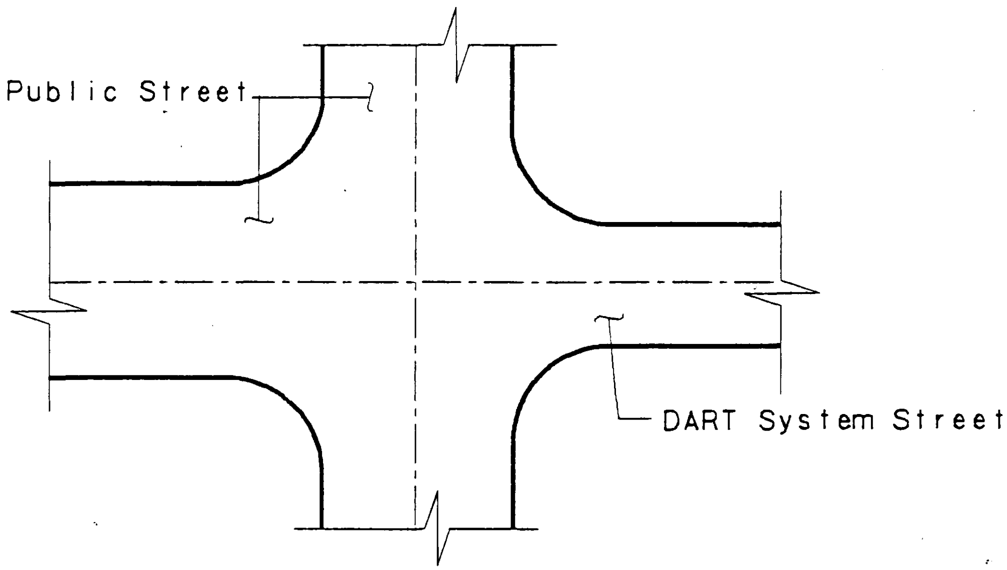

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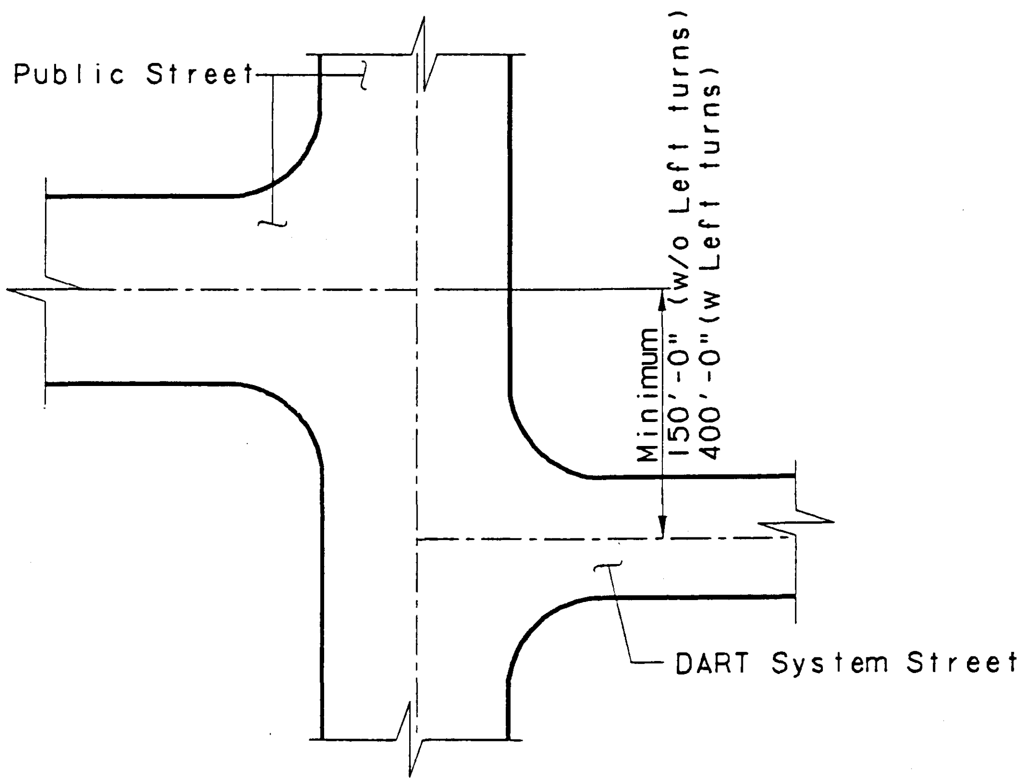
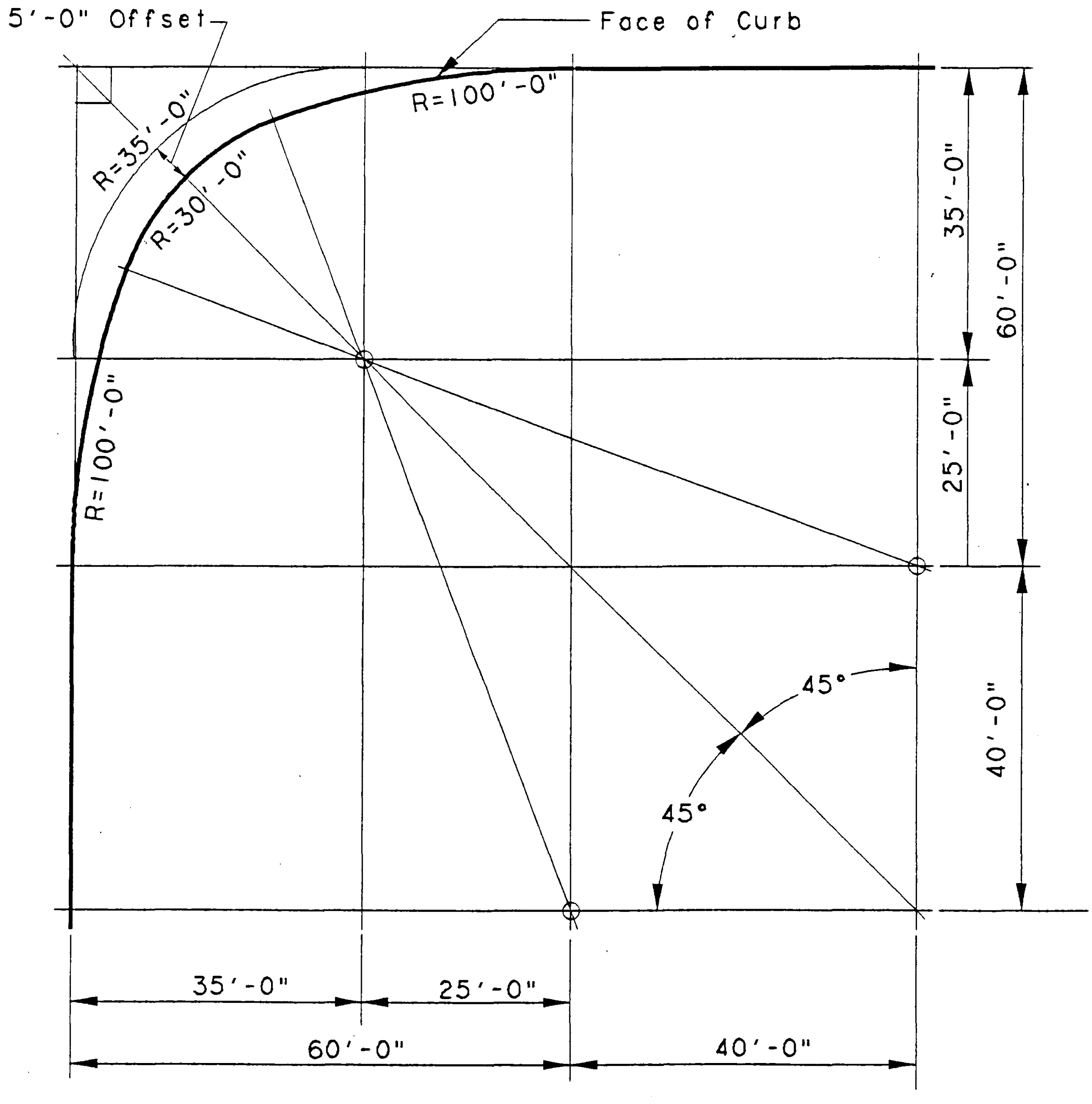


ALTERNATE

ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA ALIGNMENTS WITH EXISTING TEE INTERSECTIONS SCALE: NTS FIGURE: 4-2



100'-30'-100' RADIUS
WITH 5' OFFSET

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STV INCORPORATED
KAI ALLIANCE

DART PROJECT

DART

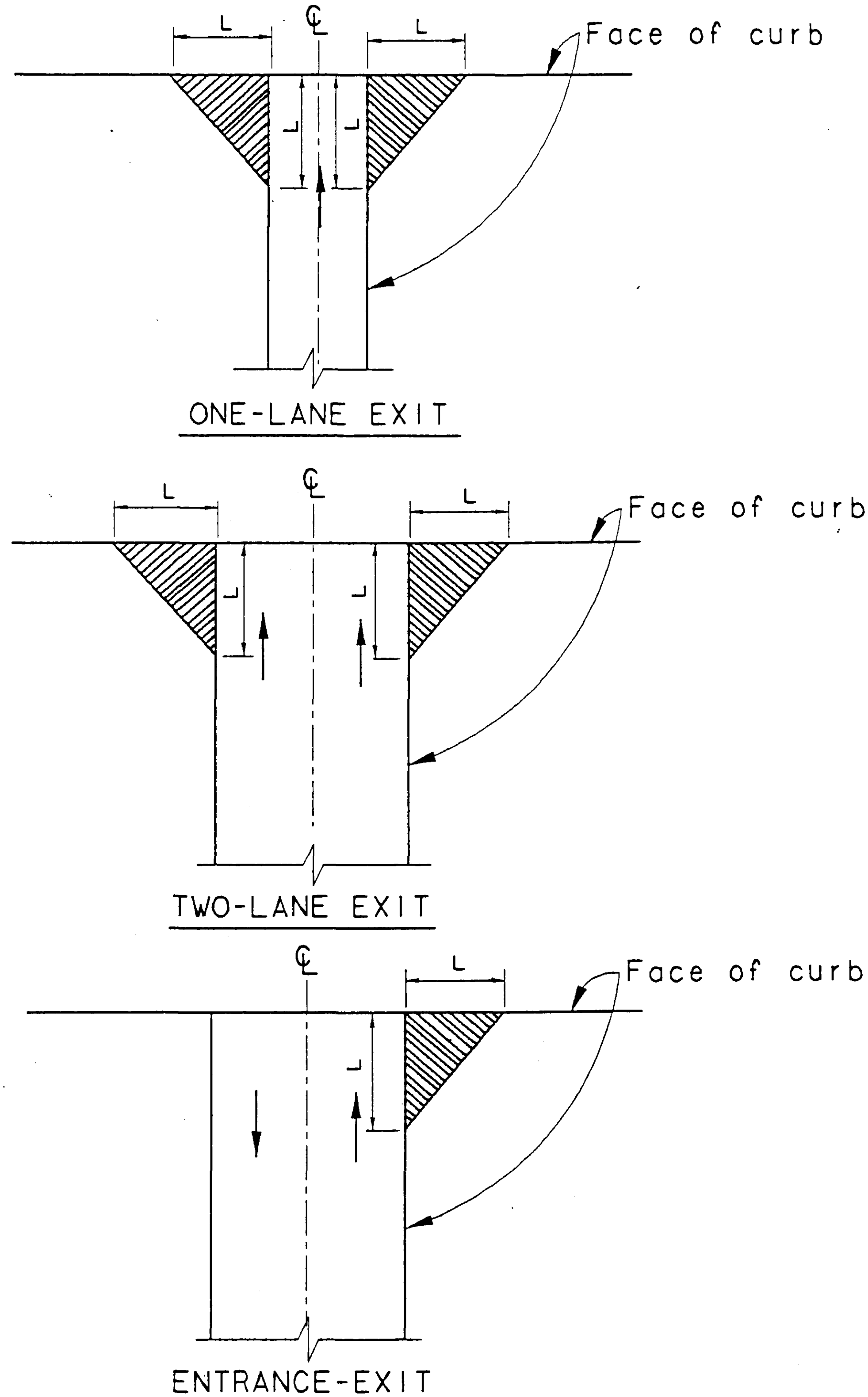
DART DESIGN CRITERIA

90° INTERSECTION THREE CENTERED CURVE

SCALE: NTS

FIGURE: 4-3

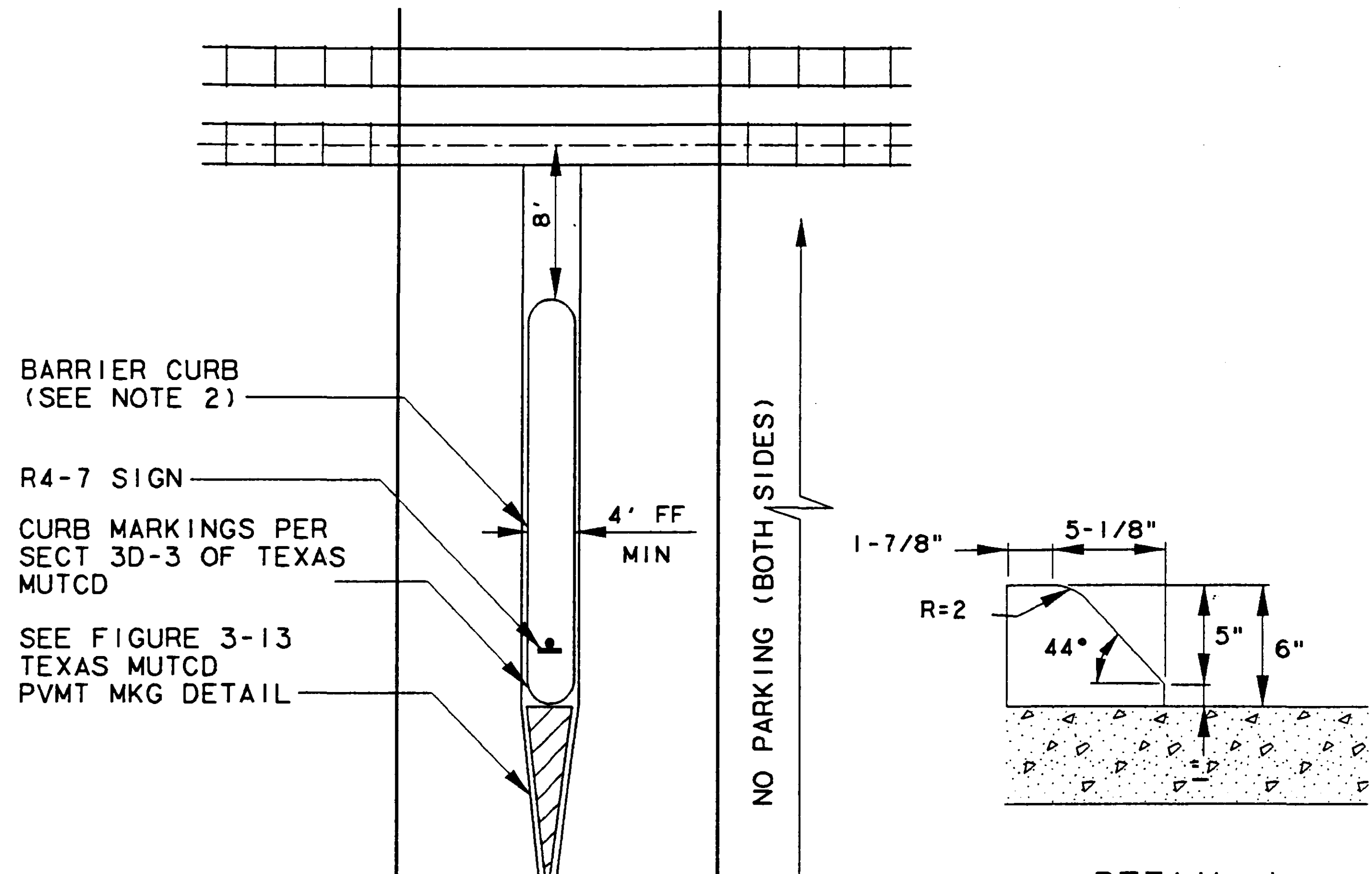
JAN. 2003, REV 10



Notes: Exclude objects more than 2'-6" high from shaded area.
Dimension L is 25' for passenger car only exits.
Dimension L is 45' for exits which include buses.

ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA SIGHT DISTANCES FOR PARKING ENTRANCE AND EXITS SCALE: NTS FIGURE: 4-4

JAN. 2003, REV 10



DETAIL I
(MOUNTABLE CURB)

NOTES:

1. MEDIAN LENGTH DESIRABLE-150° MINIMUM-75' (UNLESS OPERATIONAL CONSIDERATIONS REQUIRE FURTHER REDUCTION.
2. FOR TWO(2) LANE STREETS MEDIAN CURB SHOULD BE IN ACCORDANCE WITH DETAIL.

F-F WIDTHS (FT)

STREET	MEDIAN	LANE (NO)
26-36	4-10	11-13 (2)
44	4	10 (4)

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DART

DART DESIGN CRITERIA

PROPOSED TYPICAL GRADE CROSSING LAYOUT

SCALE: NTS

FIGURE: 4-5

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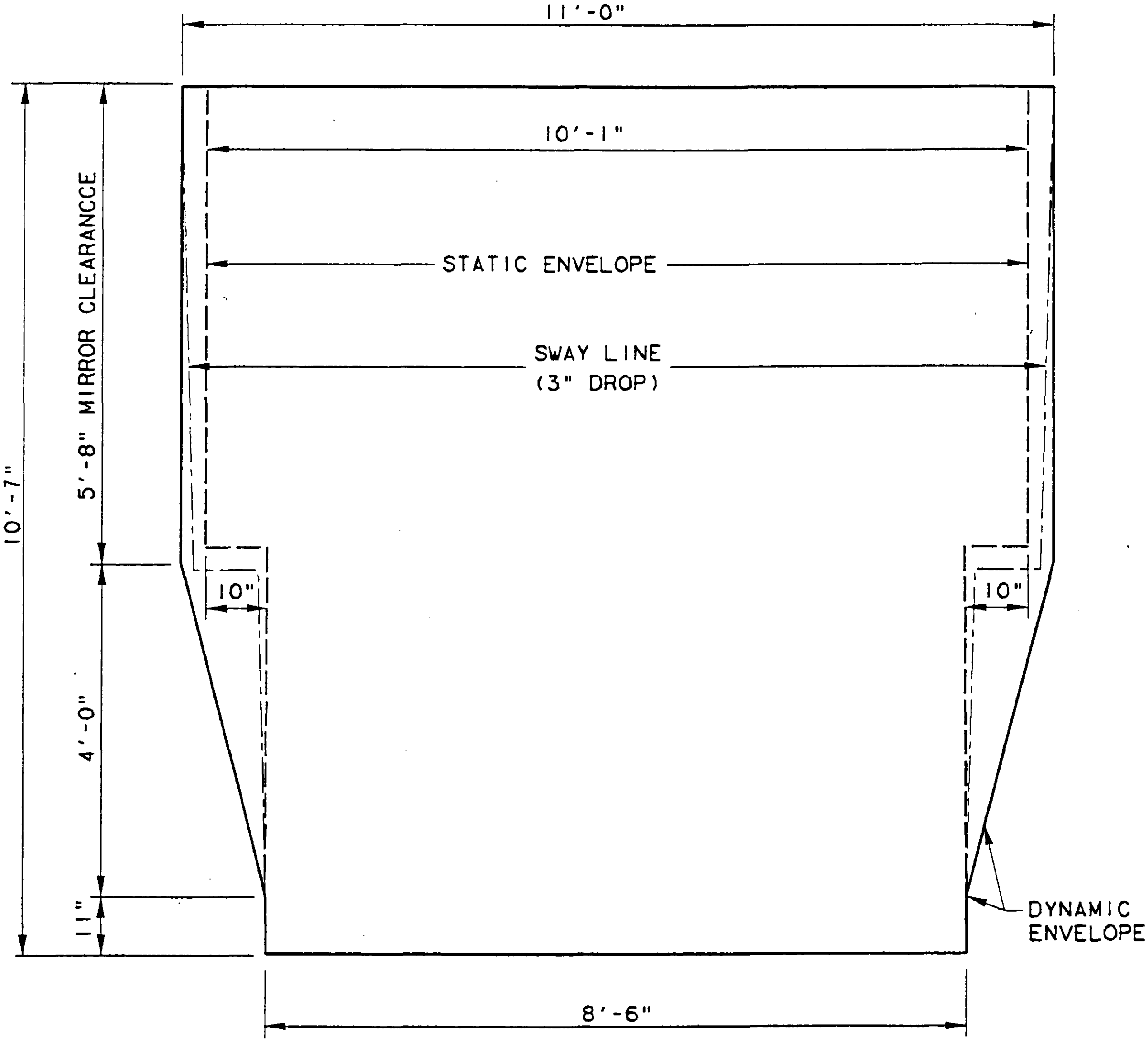

NOTE: ENVELOPE INCLUDES MIRROR CLEARANCE

ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA
		COMPOSITE TRANSVERSE SINGLE-DECK BUS SERVICE
		SCALE: NTS FIGURE: 4-6

JAN. 2003, REV 10

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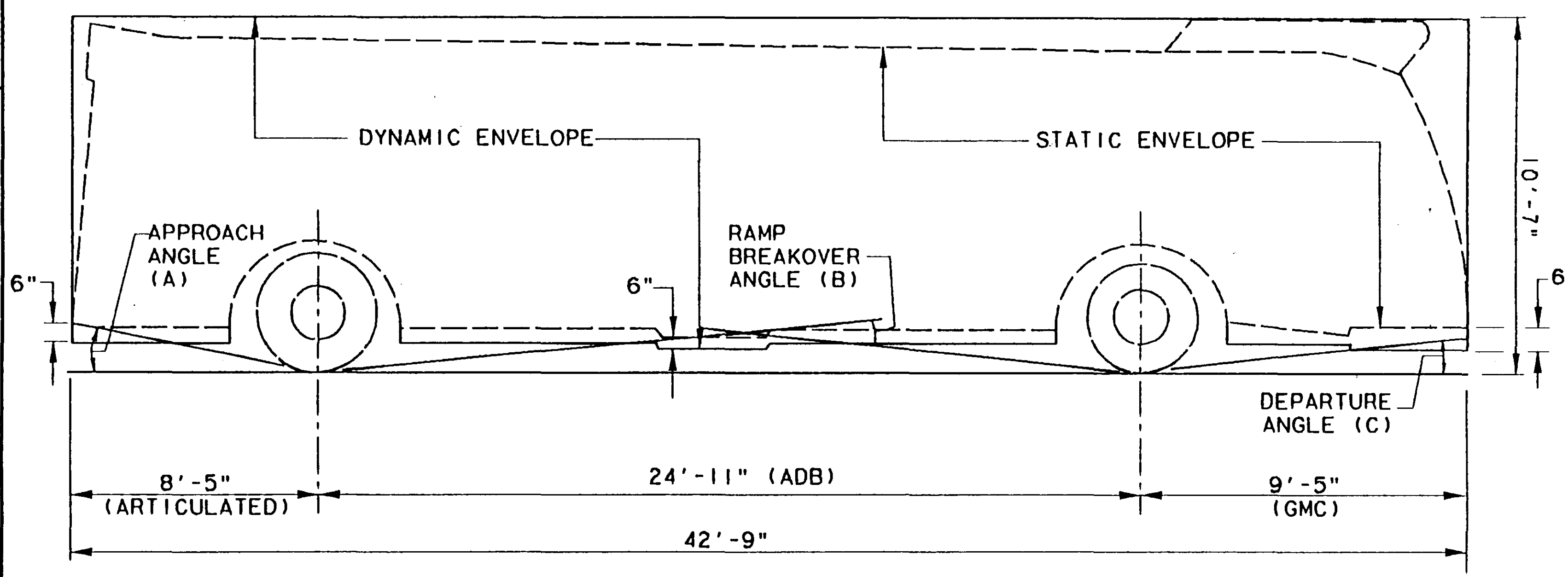

ANGLE	FLEXIBLE	GMC	FLEXIBLE ADB	AM GENERAL ARTICULATED	NOVA
A	* ≥ 8.0°	* ≥ 8.0°	▼ 10.0°	▼ 8.0°	* 11.15°
B	* 9.6°	* 10.3°	▼ 10.0°	▼ 9.0° (DRIVE LIMIT)	* 10°
C	* ≥ 9.0°	* 6.8°	▼ 9.0°	▼ 8.0°	* 8.35°
A'	—	—	—	4.6° (8.1%)	—
B'	—	—	—	2.9° (5.0%)	—
C'	—	3.8° (6.6%)	—	—	—

NOTES:

1. ANGLE BASED ON ACTUAL MEASUREMENTS. —*

2. ANGLE REQUIRED BY BUS SPECIFICATIONS. —▼

3. A, B AND C ARE ANGLES (EQUIVALENT SLOPES SHOWN IN PARENTHESIS) TO BE USED AS DESIGN CONTROLS IN DETERMINING PAVEMENT GRADING AT DRIVEWAYS, PROVIDING 6" DYNAMIC UNDER-CLEARANCE BELOW THE STATIC CONDITION.

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KAI ALLIANCE

DART PROJECT

DART

DART DESIGN CRITERIA

COMPOSITE SIDE BUS ENVELOPE
STATIC & DYNAMIC UNDERCLEARANCE

SCALE: NTS

FIGURE: 4-7

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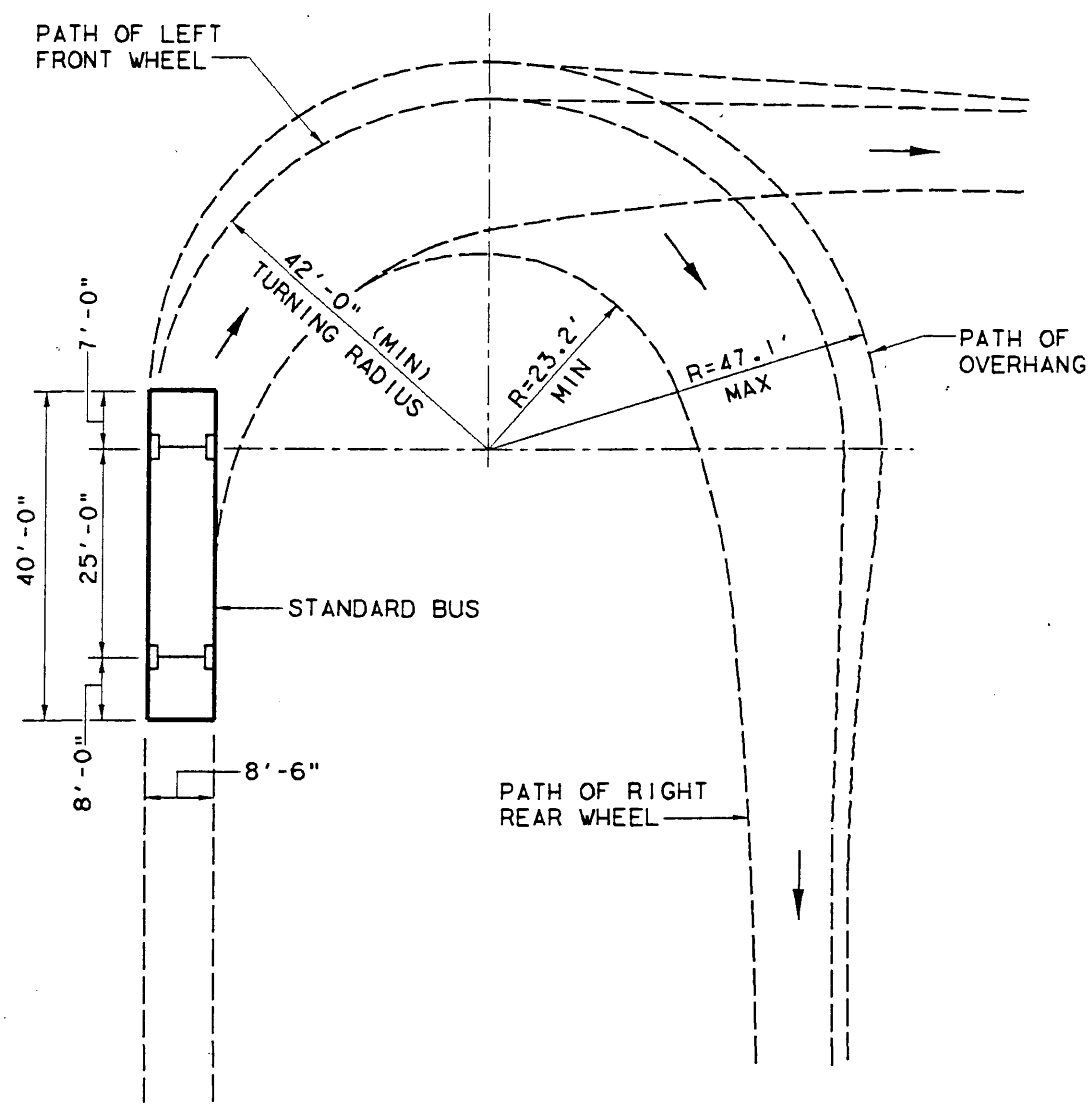

NOTE:
THIS IS JUST A TEMPLATE TO CHECK THE TURNING PATH OF THE STANDARD DART BUS.
SEE FIG. 4-10 FOR MINIMUM CURB RADII IN BUS BAYS.

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DART

DART DESIGN CRITERIA

MINIMUM TURNING PATH FOR 40' STANDARD BUS

SCALE: NTS

FIGURE: 4-8

JAN. 2003, REV 10

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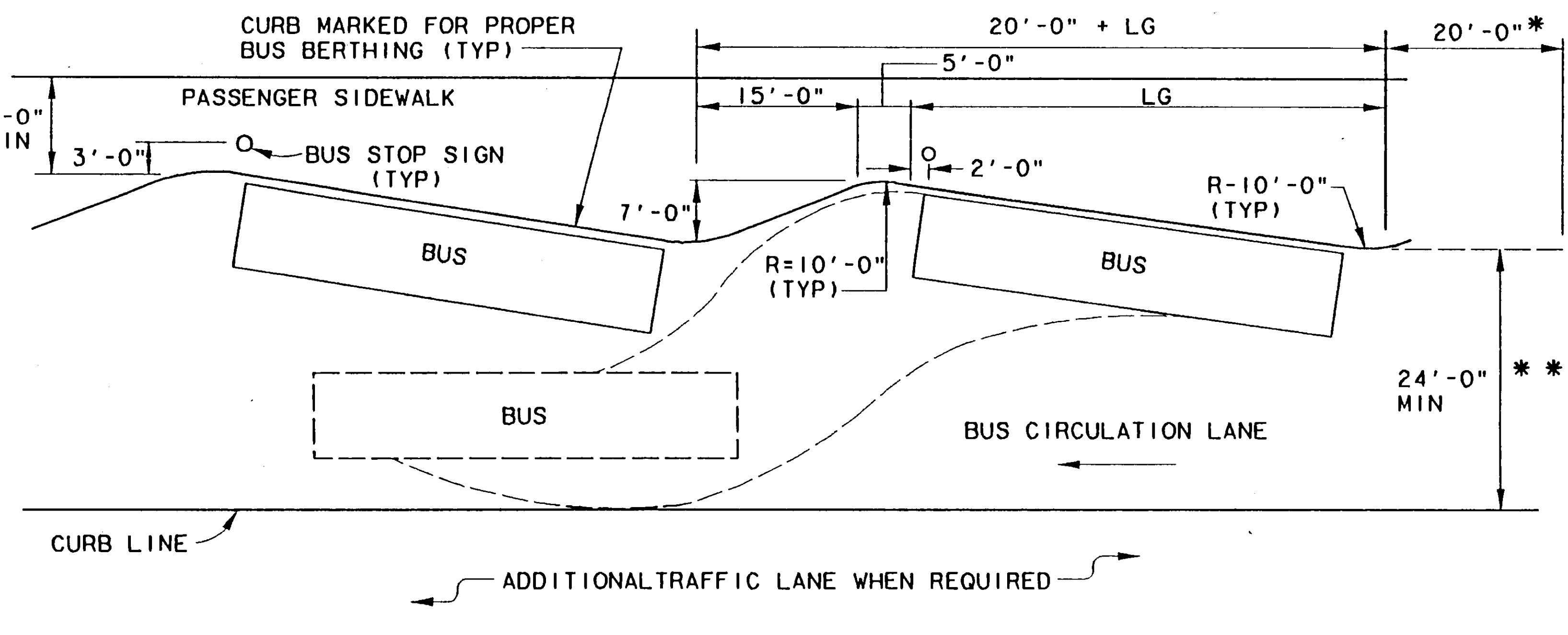

LG= 45' FOR 40' BUSES AND 65' FOR 60' ARTICULATED BUSES

* ADDITIONAL 20' TANGENT LENGTH REQUIRED WHEN AN ARTICULATED BUS STALL PRECEDES ANOTHER STALL

* * MIN. BUS CIRCULATION LANE WIDTH IS 30' WHEN USED AS A FIRE LANE.

ACT 21

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DART PROJECT

DART

DART DESIGN CRITERIA

SHALLOW SAWTOOTH PLATFORM DETAIL

SCALE: NTS

FIGURE: 4-9

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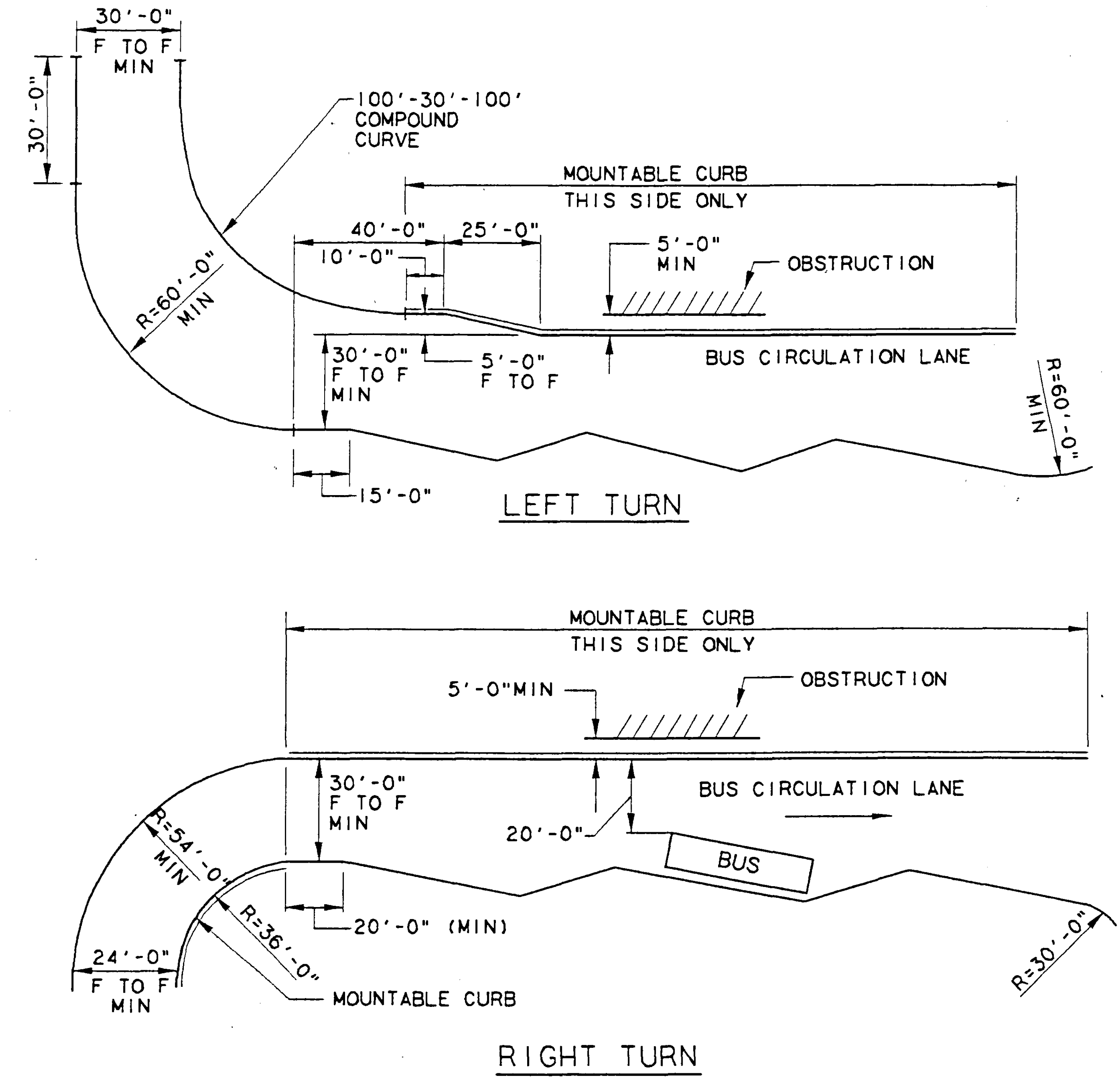

SEE FIGURE 4-11 FOR
TYPICAL SHALLOW SAWTOOTH
PLATFORM DIMENSIONS

ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA BUS BAY SHALLOW SAWTOOTH LAYOUT SCALE: NTS FIGURE: 4-10

JAN. 2003, REV 10

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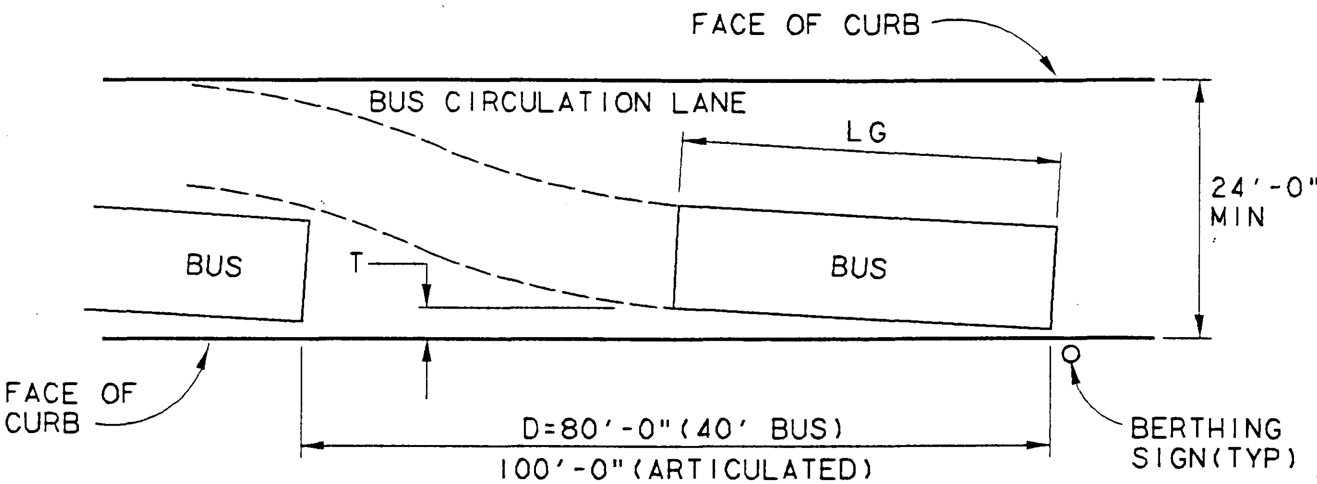

NORMAL BERTH IN-LINE PLATFORM

LG = LENGTH OF BUS

T = TAIL OUT(2'-0" RECOMMENDED)

D = BERTH LENGTH, VARIABLE BASED ON 'T'

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KAI ALLIANCE

DART PROJECT

DART

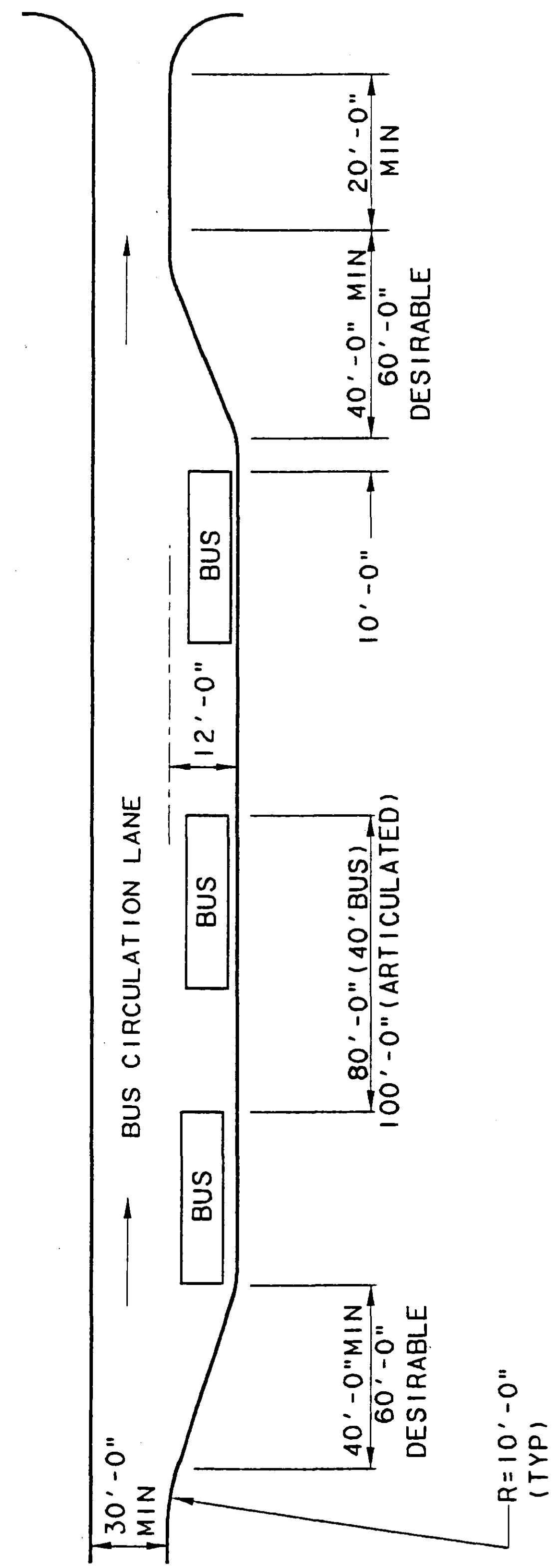
DART DESIGN CRITERIA

IN-LINE PLATFORM
BERTH LENGTH

SCALE: NTS

FIGURE: 4-11

JAN. 2003, REV 10



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KAI ALLIANCE

DART PROJECT

DART

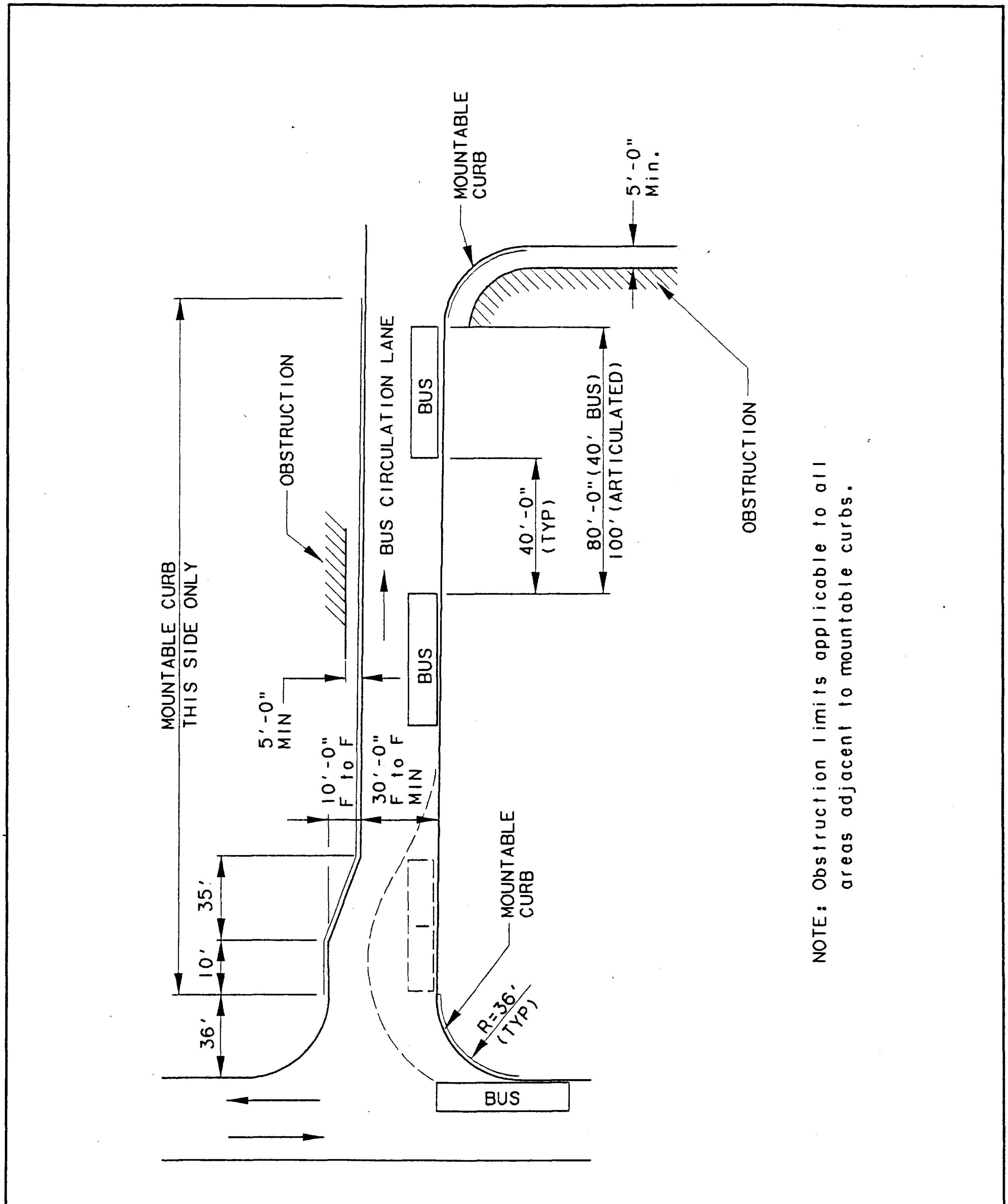
DART DESIGN CRITERIA

IN-LINE PLATFORM LAYOUT

SCALE: NTS

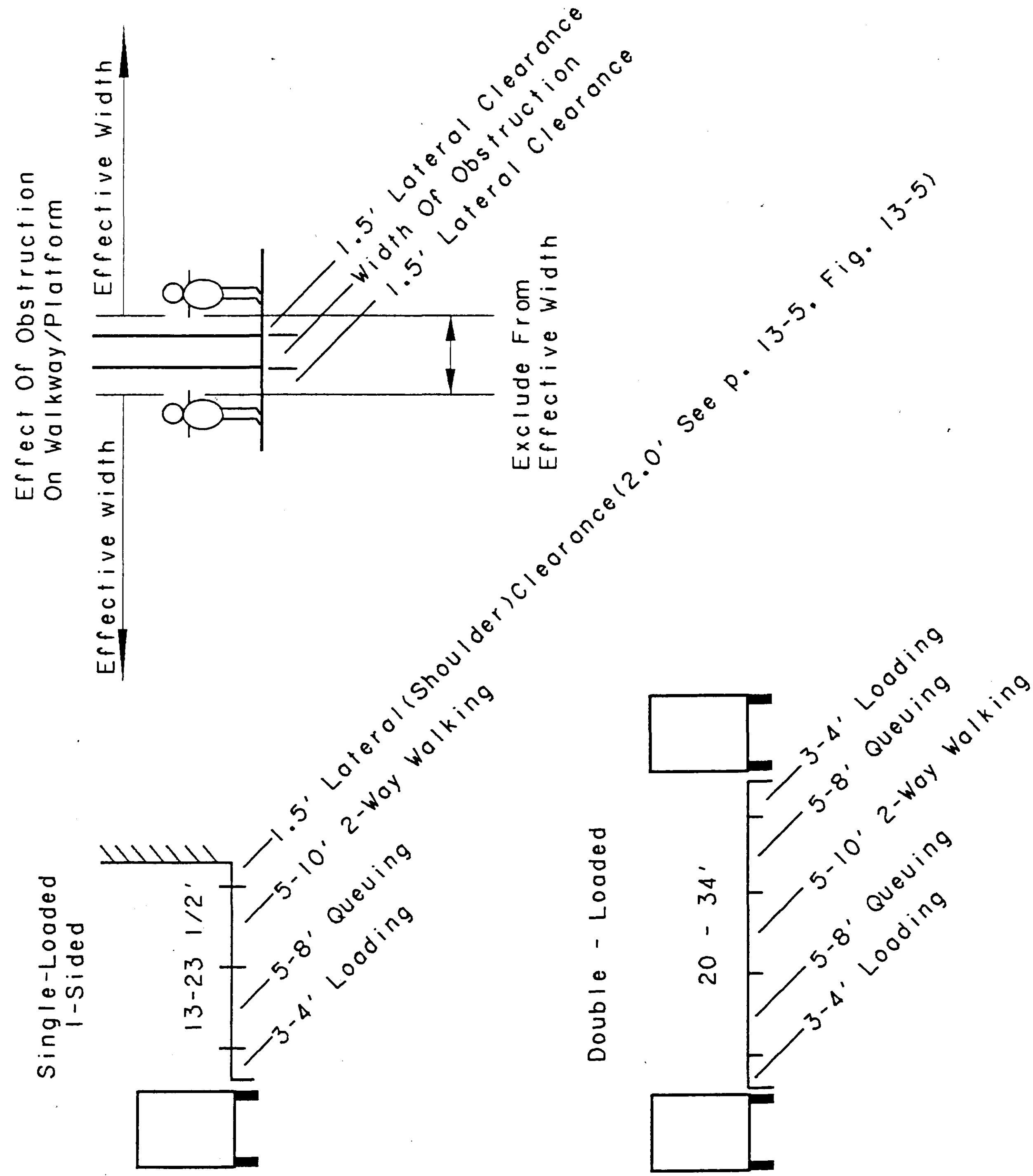
FIGURE: 4-12

JAN. 2003, REV 10



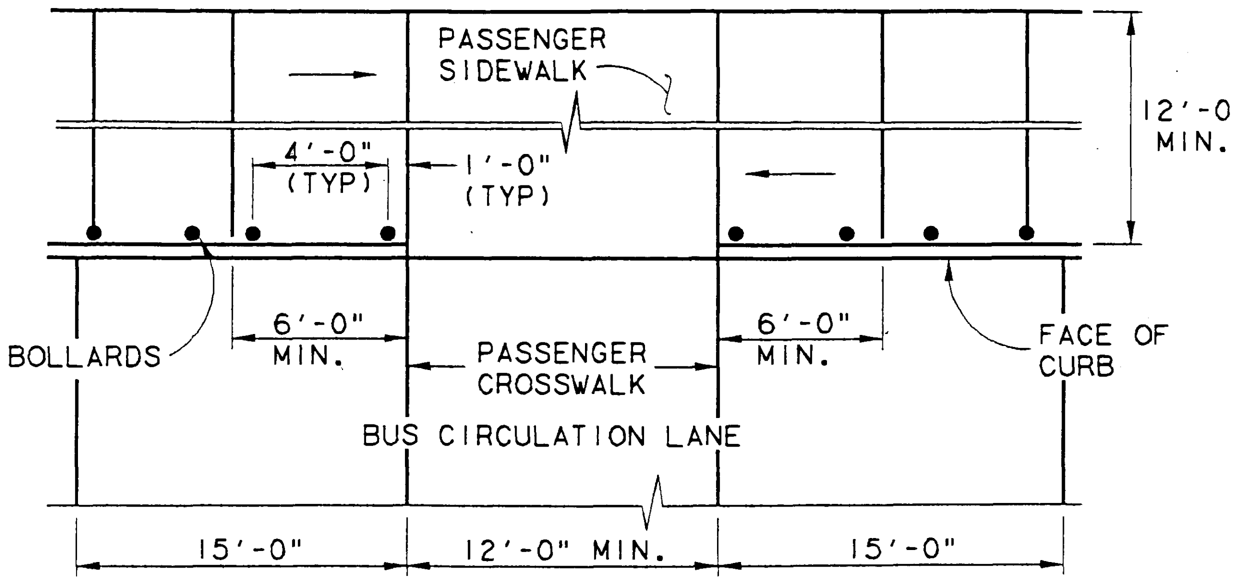
ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA BUS BAY PARALLEL TO CURB SCALE: NTS FIGURE: 4-13

JAN. 2003, REV 10

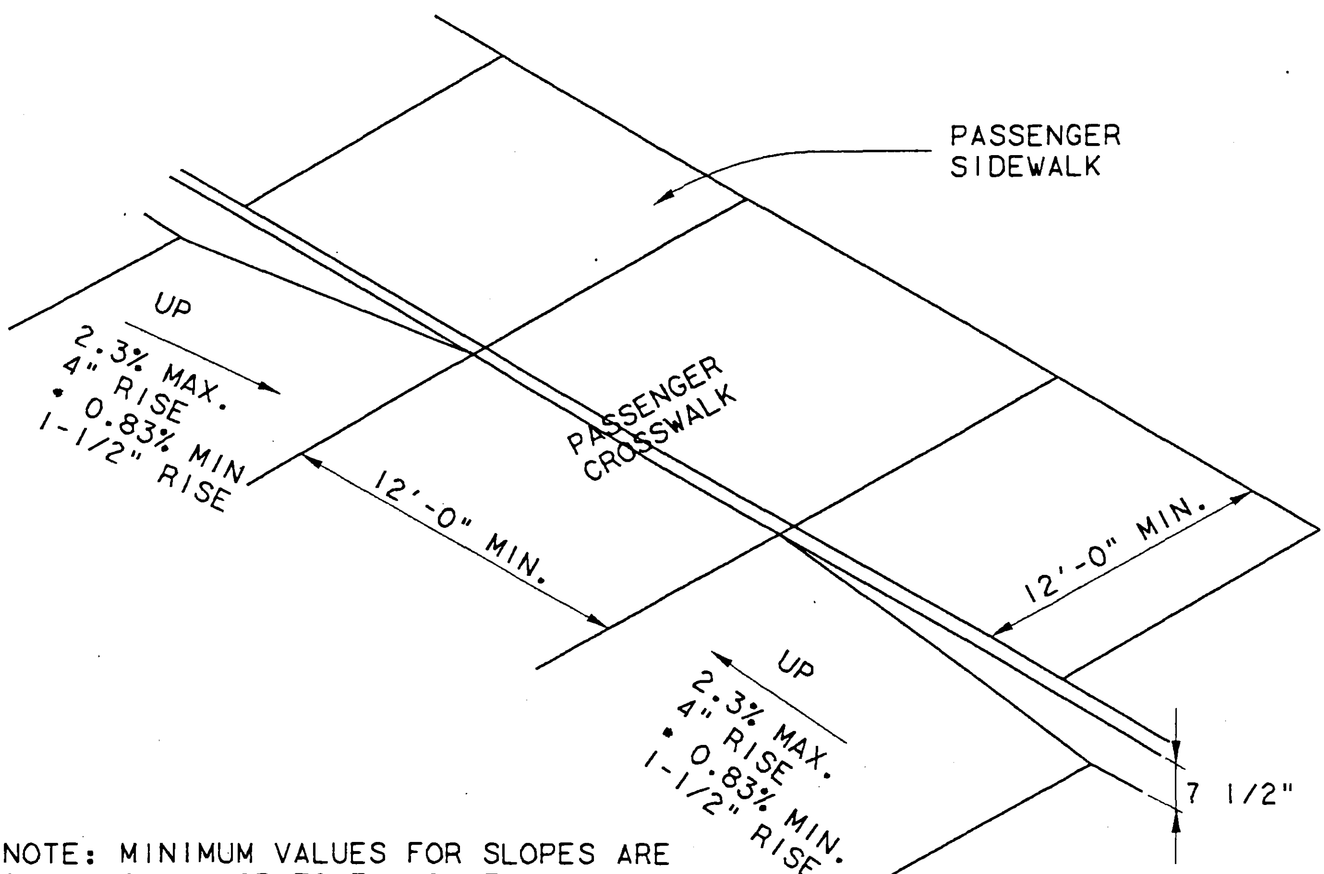


ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA MINIMUM EFFECTIVE WIDTH BUS PASSENGER PLATFORMS SCALE: NTS FIGURE: 4-14

JAN. 2003, REV 10



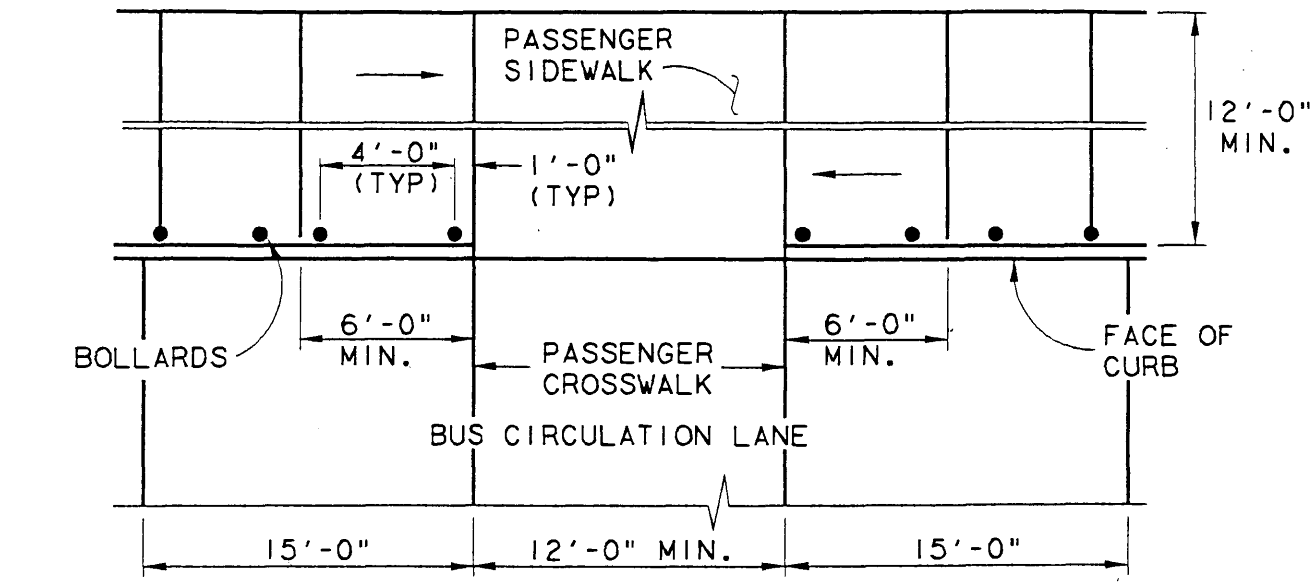
PLAN



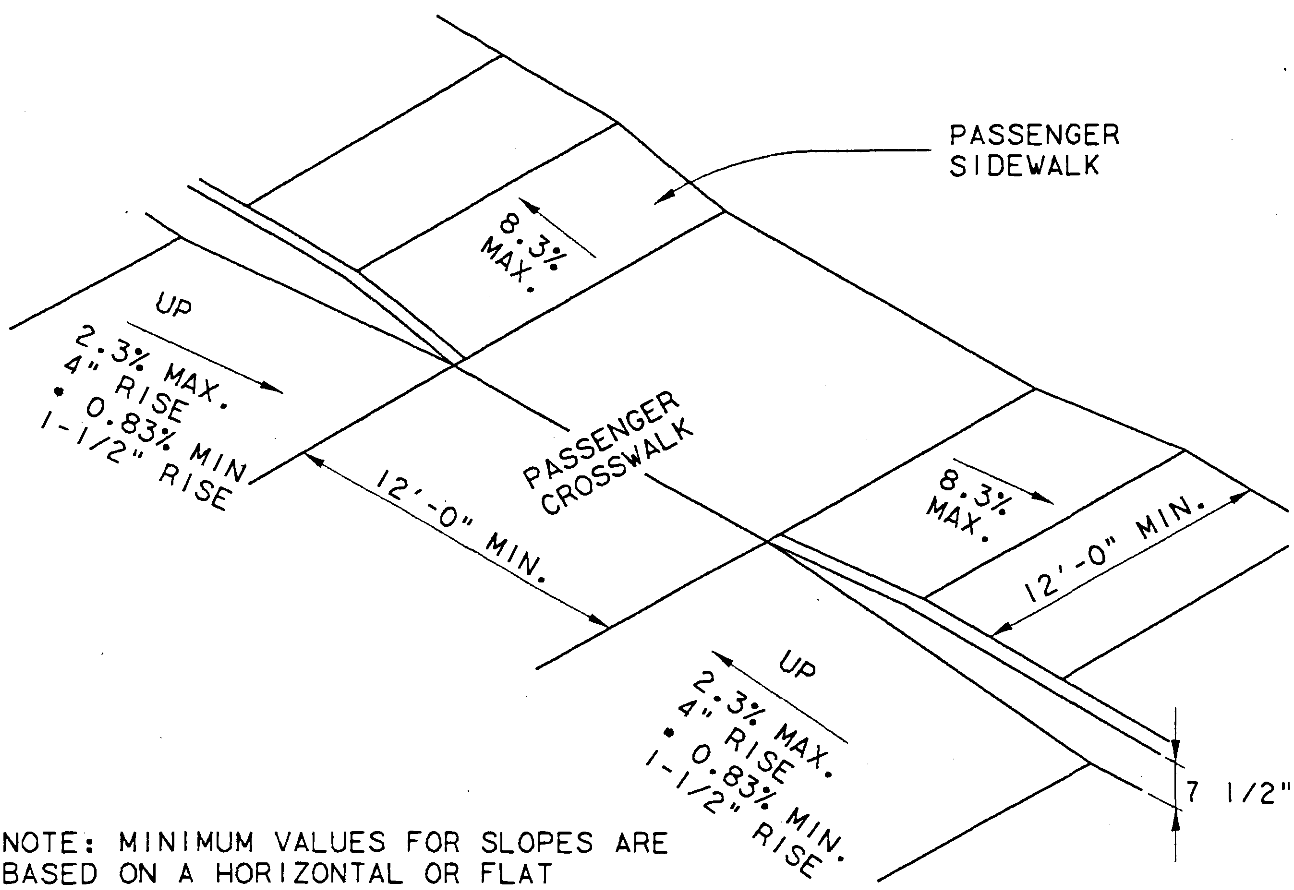
• NOTE: MINIMUM VALUES FOR SLOPES ARE BASED ON A HORIZONTAL OR FLAT DRIVEWAY

ACT 21 — CARTER BURGESS, JACOBS ENGINEERING, STV INCORPORATED, KAI ALLIANCE	DART PROJECT — DART	DART DESIGN CRITERIA SIDEWALK-CROSSWALK DESIGN (PRIMARY) SCALE: NTS FIGURE: 4-15a

JAN. 2003, REV 10



PLAN



• NOTE: MINIMUM VALUES FOR SLOPES ARE BASED ON A HORIZONTAL OR FLAT DRIVEWAY

ACT 21

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STV INCORPORATED
KAI ALLIANCE

DART PROJECT

DART

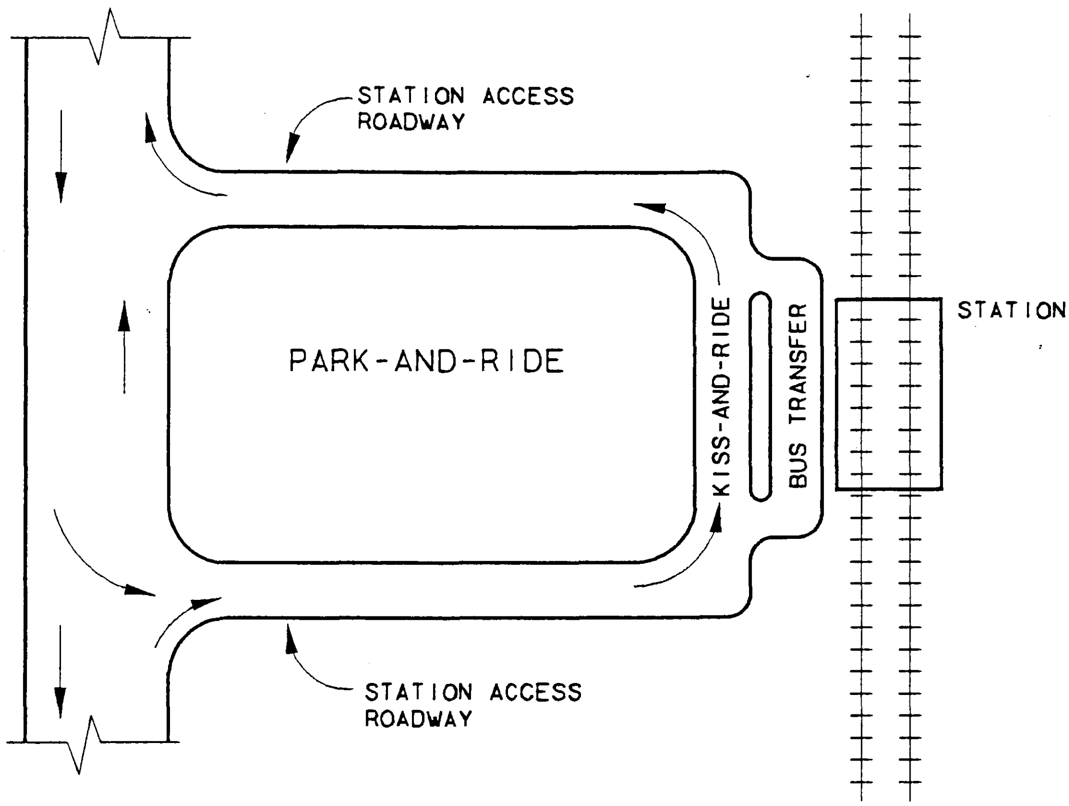
DART DESIGN CRITERIA

SIDEWALK-CROSSWALK DESIGN (SECONDARY)

SCALE: NTS

FIGURE: 4-15b

JAN. 2003, REV 10



ACT 21

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STV INCORPORATED
KAI ALLIANCE

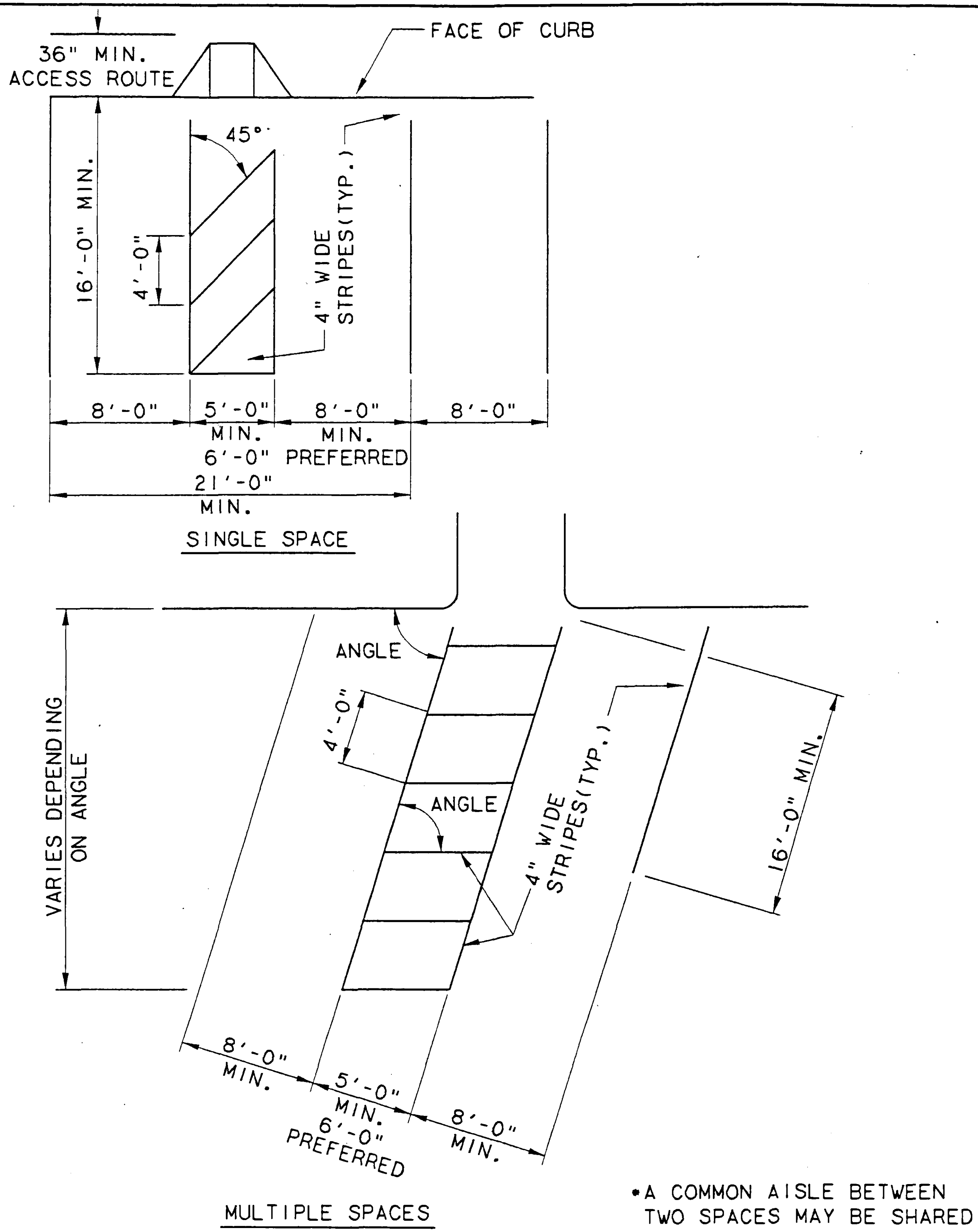
DART PROJECT

DART DESIGN CRITERIA

TRAFFIC CIRCULATION AT STATION ENTRANCES

SCALE: NTS

FIGURE: 4-16



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PARKING SPACE,
HANDICAPPED

SCALE: NTS

FIGURE: 4-17

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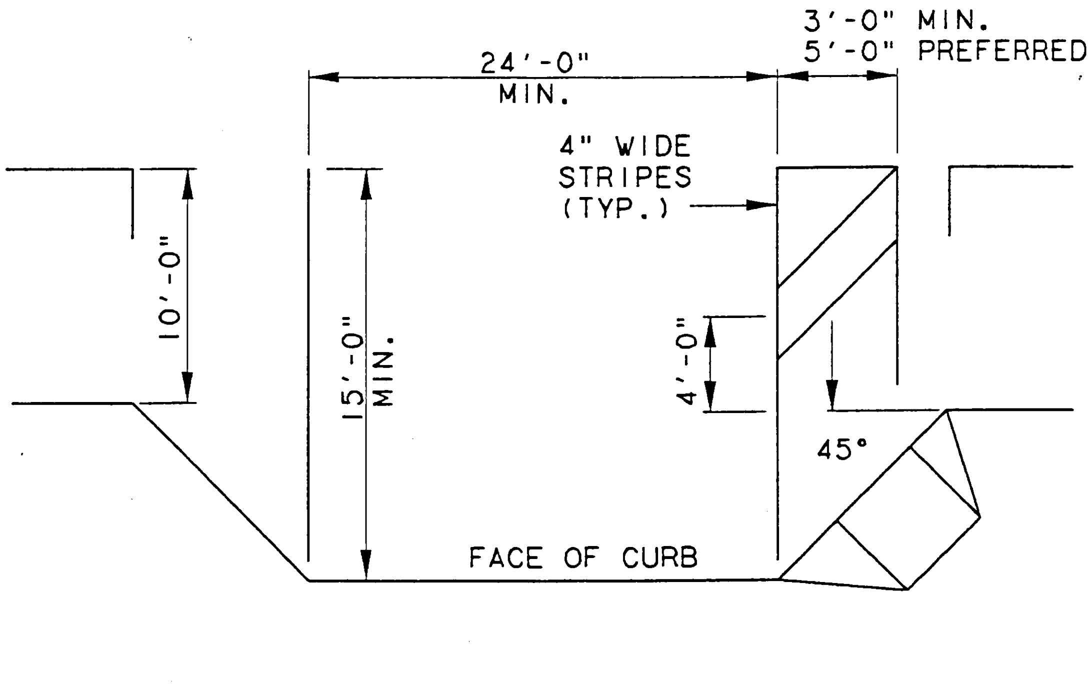

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PARKING SPACE, PARALLEL HANDICAPPED

SCALE: NTS

FIGURE: 4-18

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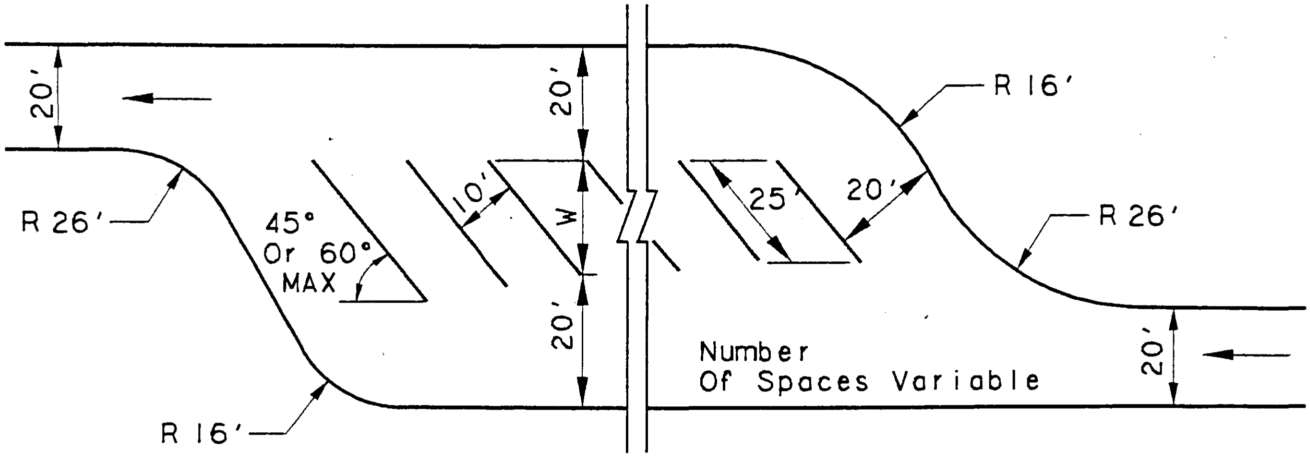
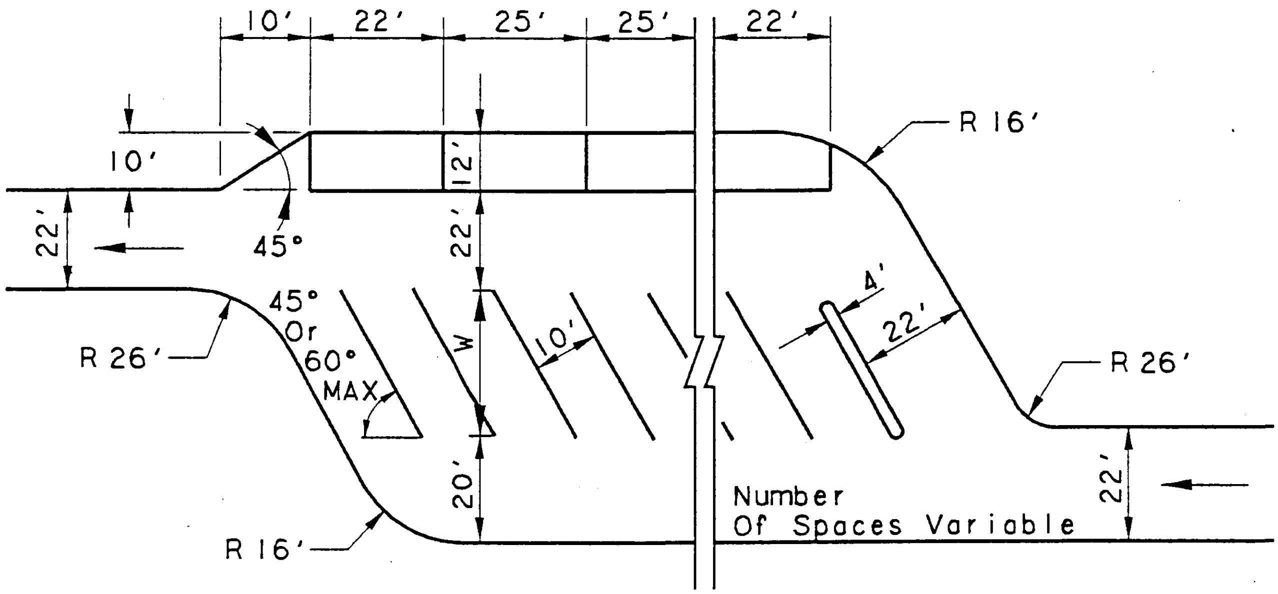


STANDARD KISS-AND-RIDE FACILITY



KISS-AND-RIDE FACILITY WITH PARALLEL PICKUP / DROPOFF LANE

NOTES:

1. Pickup/Dropoff lane may be designed to accomodate buses upon direction of dart
2. 45° Parking layout preferred.
3. 45° Parking layout W = 17.68'
   60° Parking layout W = 21.65'

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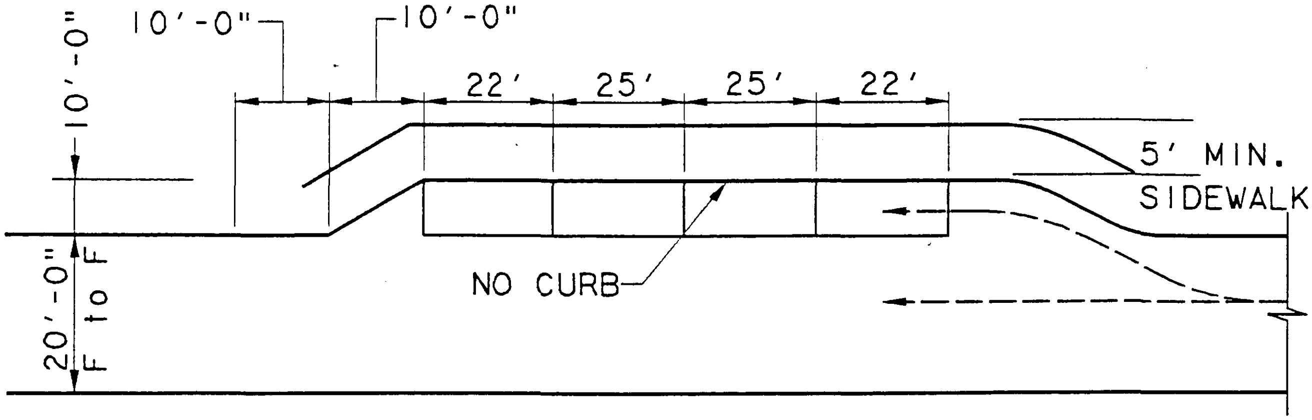
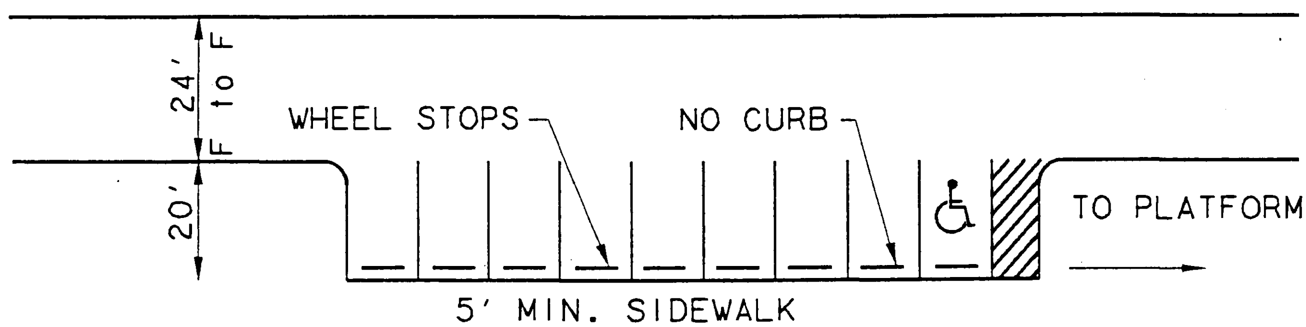
KISS-AND-RIDE PARKING SPACE LAYOUT 45° OR 60° TO CURB

SCALE: NTS

FIGURE: 4-19



KISS-AND-RIDE FACILITY
WITH ONE PICKUP/DROPOFF LANE



KISS-AND-RIDE FACILITY
TWO WAY IN CONJUNCTION WITH
PARK AND RIDE

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KISS-AND-RIDE PARKING SPACE
LAYOUT PARALLEL TO CURB

SCALE: NTS

FIGURE: 4-20

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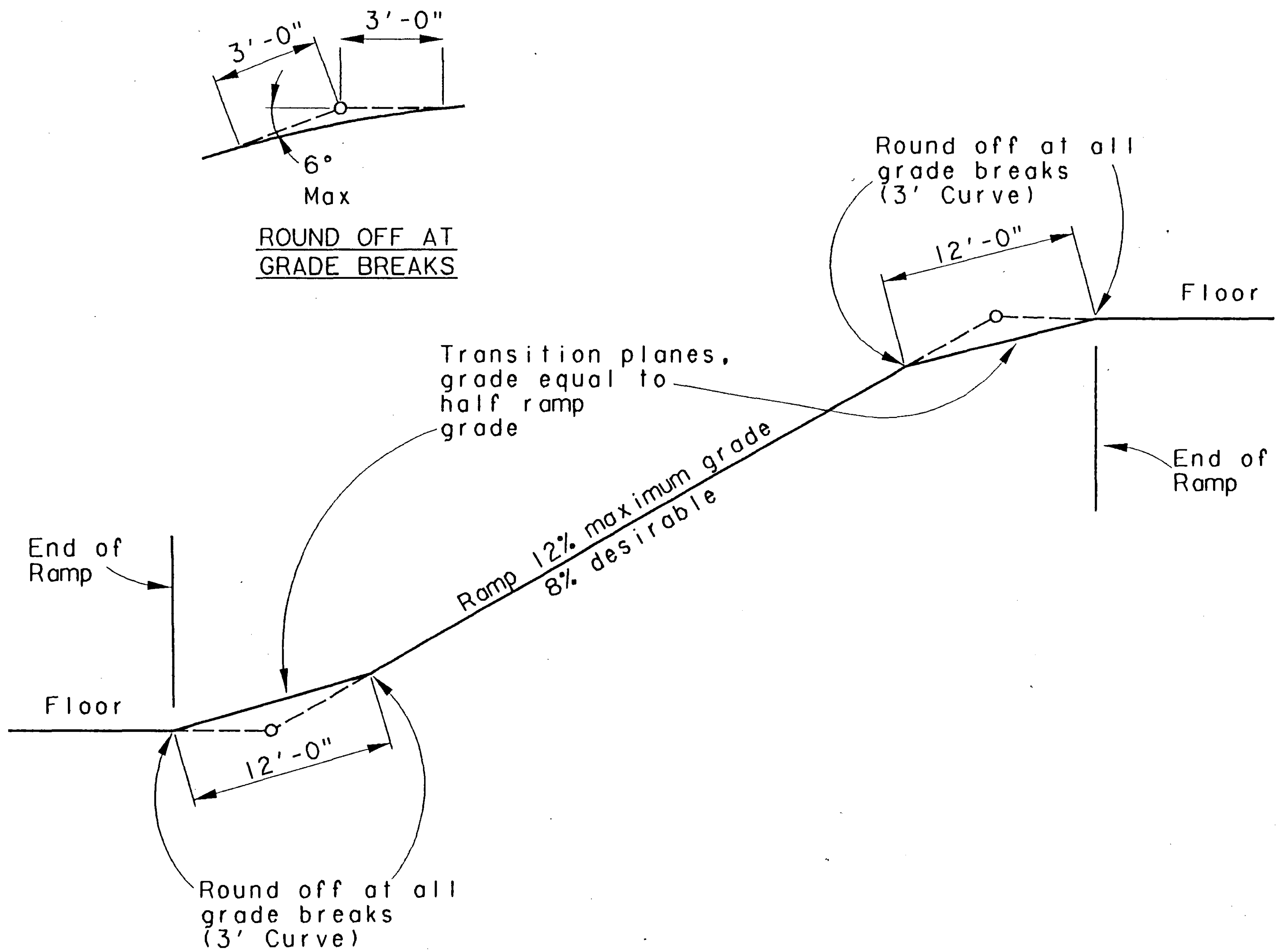

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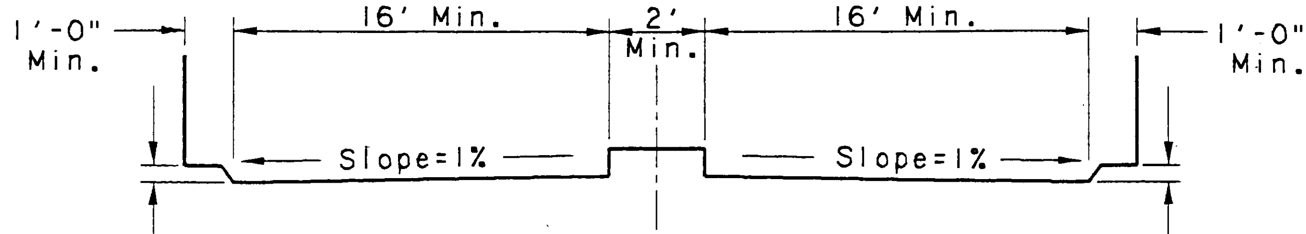
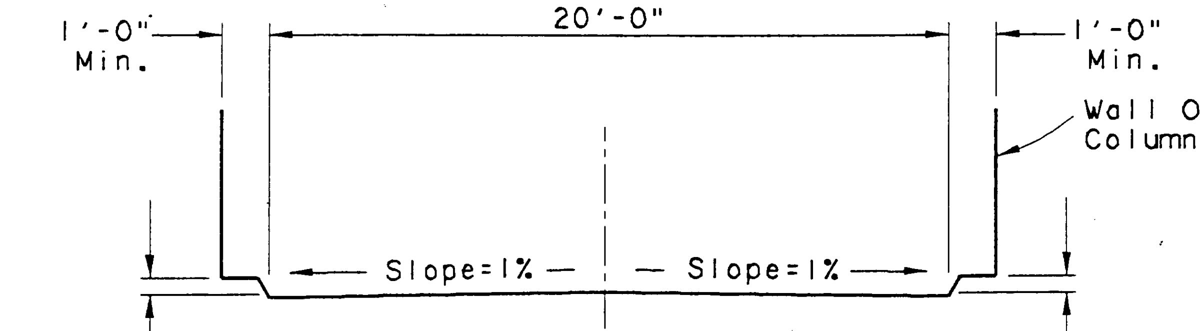
RAMP GRADE TRANSITION

SCALE: NTS

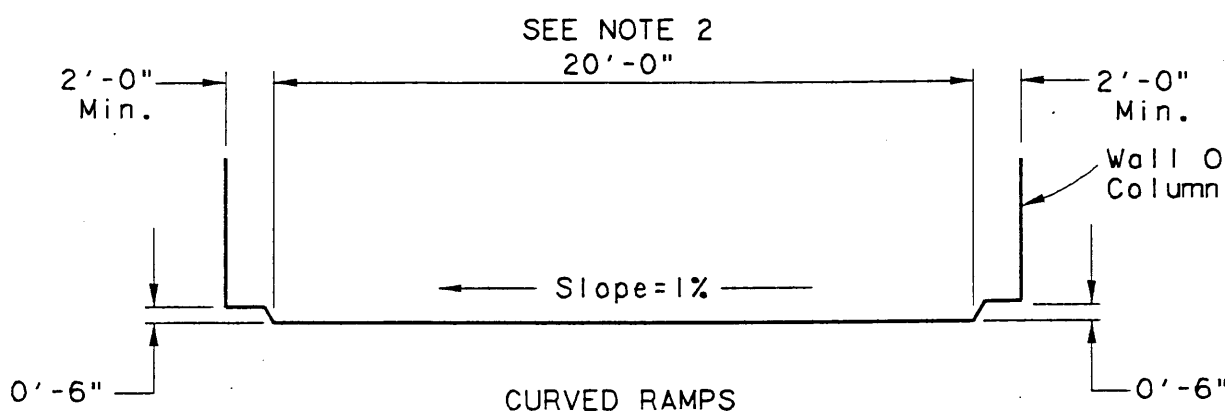
FIGURE: 4-21



2-WAY STRAIGHT RAMPS



1-WAY STRAIGHT RAMPS



CURVED RAMPS

Notes:

1. Provide slope shown on straight and curved ramps for drainage purposes. Slope to inside on curved ramps.

2. Ramp widths and lateral clearance on curved ramps shall be designed based on ramp radius and design vehicle overhang.

3. Curved ramps shall not be superelevated.

ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA RAMP CROSS SECTION-STRAIGHT AND CURVED RAMPS IN PARKING STRUCTURES SCALE: NTS FIGURE: 4-22

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CHAPTER 5 – TRAFFIC CONTROL

5.1 INTRODUCTION

This chapter establishes criteria and standards for the design of traffic control devices for streets, parking lots, and parking structures.

Traffic control devices controlling street traffic shall be owned and maintained by the agency having jurisdiction. Traffic control devices on station, parking, or other sites owned by DART and controlling traffic on these sites shall be owned and maintained by DART.

Replacement of existing facilities to be maintained by others shall be replacement-in-kind. New facilities to be maintained by others shall be designed in conformance with current standards of the agency having jurisdiction, or these criteria if approved by such agency. These criteria and guidelines do not remove the responsibility for proper traffic control from the designer, nor do they supersede more stringent requirements of the Texas Manual on Uniform Traffic Control Devices (TMUTCD) and the Federal Highway Administration's (FHWA) MUTCD. All traffic control devices shall conform to the requirements, principles, and concepts of these manuals.

The objectives of this chapter are:

- o To present ways to provide for the safety of the general public.
- o To establish uniform policies and procedures for traffic functions.
- o To determine that DART's traffic control devices are compatible with those of other agencies.

5.1.1 Codes, Standards, and References

All federal, state, and local jurisdiction codes and standards publications shall govern the design of traffic control systems as appropriate.

The latest available revisions of each publication shall be used to determine compliance with applicable codes and ordinances.

5.1.2 Traffic Control for Facilities Owned by Agencies Other than the Authority

When a traffic control device needs to be placed on a facility owned by an agency other than DART, the section designer shall coordinate the design and location of that device and its proposed operation with the agency having legal jurisdiction and responsibility.

5.1.3 Engineering Study Required

The decision to use a particular traffic control device at or on a DART facility at a particular location shall be made on the basis of an engineering study of that location. The criteria contained in this chapter provide guidelines for the design and application of traffic control devices. These guidelines are not a substitute for engineering judgment.

5.2 SPECIAL DIRECTIVES

5.2.1 All Traffic Control Devices

General. All traffic control devices shall conform with the requirements of the TMUTCD. All special non-standard devices shall conform to the principles and concepts of the TMUTCD and the federal MUTCD and/or Traffic Control Device Handbook in the absence of information in the TMUTCD.

Traffic control devices shall include, but are not limited to, signs, pavement markings, raised pavement markers, signals, islands, grade crossing warning devices, automatic gates and intelligent management system elements.

5.2.2 Signs

Classification of Signs. Traffic control signs for DART facilities shall normally be classified as regulatory signs, warning signs, or guide signs.

Traffic control signs shall be referred to by code number and size. Code numbers shall conform to those found in Texas Standard Highway Signs. When the traffic control signs are available in a choice of right or left to indicate a right or left movement to the motorists, the letter "R" or "L" shall follow the code number. The minimum sign size shall be either "Standard" or "Urban" as defined in Texas Standard Highway Signs.

Standardization of Signs. In situations where messages are required other than those found in the TMUTCD or Texas Standard Highway Signs, the signs shall be of the same shape and color as standard signs of the same functional type.

The basic requirements of a traffic control sign are that it be legible to those for whom it is intended and that it be understood in time to allow a proper response. Sign designs should therefore have high visibility, lettering and symbols of adequate size, and a short legend for quick comprehension by drivers.

Locational Conflicts. Where two or more signs are needed at approximately the same location, Regulatory signs shall take precedence over Warning or Guide signs. Within the regulatory sign group, the sign with the most important regulation supercedes the others. Priority for sign types shall be as follows:

- o Regulatory Signs.

- o Warning Signs.
- o Guide Signs.
- o Emergency Service Signs.
- o Public Transportation Signs.

<u>Posts and Mountings</u>. Sign supports shall be of a suitable breakaway or yielding design, as dictated by the design speed of the traveled way and the agency with jurisdiction, when ground mounted signs cannot be sufficiently offset from the edge of pavement. Concrete bases for sign supports shall be flush with ground level.

When signs can be correctly placed on other supports, such as traffic signal poles, street light poles, or utility poles, such placement shall be considered in order to reduce costs and minimize sidewalk obstruction.

<u>DART Facilities Traffic Control Sign Design.</u>

- o <u>Sign Size.</u> The size of traffic control guide signs for DART facilities shall be a function of legibility distance, required letter size and spacing, and length of message. The length of message shall be as brief as possible to avoid excessively large signs, although driver comprehension should not be compromised as a result of brevity.

Special traffic control guide signs which make course routes to DART facilities shall normally be 24 inches square for use on low speed streets and larger for high speed facilities, as specified in the TMUTCD.

- o <u>Size of Lettering</u>. For traffic control guide signs with varying legends, sign legibility is a direct function of letter size.

Within parking facilities the minimum letter size shall be 4 inches in height. At least 5-inch high letters shall be desirable within parking structures with restricted clearances. At least 6-inch high letters shall be desirable within open parking lots and in parking structures without clearance restrictions.

For traffic control guide signs on circulation roadways and facilities, the minimum letter size shall be as prescribed by the TMUTCD, which is based on the type of highway rather than to variable speeds.

- o <u>Amount of Legend</u>. The legend on traffic control guide signs to be used at or on DART facilities shall be kept to a minimum. Three lines of legend shall be the maximum number of lines per guide sign. Where two or more guide signs are placed at the same location, either on the same mount or close to each other, the amount of legend shall be further reduced to prevent overburdening the driver.

5.2.3 Pavement Markings

Reflectivity of Pavement Markings. Markings that must be visible at night shall be reflectorized unless ambient illumination provides adequate visibility. The reflectivity of pavement markings may be done through the use of reflectorized raised pavement markers, glass-beaded paint, glass-beaded thermoplastic, or other appropriate means.

Parking lot stall marking may be 4" white paint without glass beads.

Removal of Pavement Markings. Pavement markings that are no longer applicable shall be removed or obliterated as soon as practical.

Crosswalks. Minimum crosswalk widths, when crossing public streets or major driveways next to public streets, shall be 6 feet at non-station locations and 10 feet at crossings to DART stations.

5.2.4 Traffic Control Signals

Where DART is proposing new or modified signalization on facilities owned by agencies other than the Authority, such signalization shall be designed in accordance with the design criteria, including specifications used at the time of design by the agency having jurisdiction. Special hardware may be considered if approved by the jurisdictional authority and DART.

5.2.5 Islands

Pedestrian refuge islands located between traffic lanes shall be a minimum of 6 feet wide, measured from face-of-curb-to-face-of-curb, when used at or on DART facilities, and should be sized through a capacity analysis as presented in the current edition of the Highway Capacity Manual. Level of Service "C" shall be the minimum acceptable level of service for pedestrian facilities. The minimum usable length of the island shall be the width of the crosswalk or 20 feet, whichever is greater. All pedestrian refuge islands at or on DART facilities shall be constructed with a raised barrier curb and appropriate ADA access, rather than only pavement markings.

5.3 TRAFFIC CONTROL AT GRADE CROSSINGS WITH STREETS

Traffic control measures shall be provided to permit safe and efficient operation of vehicular, pedestrian, and DART rail traffic at all rail-roadway grade crossings. Such measures shall generally include, but not be limited to: crossbucks, flashers, bells, automatic gates, signs and pavement markings; they may be supplemented by traffic signals, special roadway channelization, turn restrictions, and street or driveway modifications, as appropriate. The section designer shall analyze each grade crossing individually to determine specific traffic control and crossing warning needs and design these provisions accordingly.

5.3.1 Local Agency Requirements and Coordination

At-grade crossing traffic control and warning designs shall incorporate applicable criteria, standards, and specifications of the municipality with jurisdiction, the Texas Department of Transportation, and railroads operating on the same or adjacent trackage or right-of-way as DART. Each proposed design shall be coordinated and reviewed with entities having jurisdiction at or next to the crossing, including any equipment being used in conjunction with crossing warning or traffic control devices.

5.3.2 Reference Manual and Handbook

All traffic control devices used at or in conjunction with at-grade rail crossings shall conform to the Texas Manual on Uniform Traffic Control Devices (TMUTCD) supplemented by the information contained in the Federal Highway Administration's Traffic Control Devices Handbook (FHWA Handbook), and the FHWA MUTCD. In the case of conflict between the documents, the provisions of the TMUTCD shall govern, followed by the FHWA MUTCD. All numerical references to signs correspond to the numbering system contained in the TMUTCD. The suffixes "L" and "R" indicate left or right versions of the signs.

5.3.3 Grade Crossing Warning Devices

As a minimum, the following elements should be provided at public grade crossings of side-running rail and at public mid-block rail grade crossings:

- Automatic gates with crossbucks and flashing light signals.
- Pedestrian warning bells.
- Cantilevered flashing light signals at mid-block crossings where needed for additional emphasis, or for better visibility to approaching traffic, particularly on multi-lane approaches or highways with profile restrictions. If their installation will distract driver attention from nearby traffic signals, supplemental ground-mounted flashing light signals shall be installed, if required, to provide adequate signal visibility.
- Crossing area illumination in conformance with the American National Standards Institute's "Practice for Roadway Lighting", RP-8, available from the Illuminating Engineering Society.
- All other necessary and appropriate traffic control signs and markings included in the TMUTCD and FHWA MUTCD.

Flashing light signals and gates shall not be installed at grade crossings of street-running or median-running rail.

5.3.4 Automatic Gate Requirements

The following requirements shall be followed for automatic gate installation:

- o Gates shall cross adjacent sidewalks. If necessary sidewalks shall be reconstructed such that the gates cover them and pedestrians are not permitted to walk behind the gates. Pedestrian gates shall be used to cover non-vehicle approach quadrants in the proximity of public elementary schools and public parks where children are likely to cross. Pedestrian gates shall also be used to cover the non-vehicle approach quadrant adjacent to operating freight tracks or other locations approved by DART.

- o Gates shall be designed to reach the horizontal position at least 5 seconds before the time the train arrives at the crossing.

- o Automatic gate arms shall extend to the centerline of the roadway on two-lane undivided streets approaching a mid-block or side-running grade crossing.

- o Desirable maximum length for gates shall be 29 feet, but never shall they exceed 40 feet. Where single gate arms would exceed these limits, a second median-mounted automatic gate shall be provided and the median widened to provide adequate clearance. Separate gates may be used to control pedestrian movements to reduce gate length.

- o Fencing or other barriers used in conjunction with gates shall be designed to provide the train operator with adequate sight distance to motorists and pedestrians at the crossing.

- o Gate arms shall extend to within 1-foot of the near curb face of a raised median.

5.3.5 Traffic Signals at or Near Grade Crossings

Traffic signals shall be used to control non-rail vehicular movements at all intersections with median-running rail and at other grade crossings when required, to provide adequate control of vehicular movements. The signals shall be approved by the municipality with jurisdiction. When used at these locations, signals shall conform to the following design guidelines:

- o <u>Signal Design and Details</u> – Shall conform to the requirements of the agency having jurisdiction, as shown in that agency's standard plans unless otherwise agreed in advance by the agency.

- o <u>Pedestrian Capacity and Control</u> – Must be considered.

- o <u>Interconnection and Coordinated Operation</u> – Shall be used with any traffic signals at intersections located within 200 feet of a rail grade crossing, and considered for traffic control signals located more than 200 feet from the crossing based on engineering.

- Optically Programmed or Louvered Signal Lenses – Should be used on signal heads located downstream of the tracks where clearance intervals are used to clear tracks. These clearance signal indications should not be visible to motorists approaching a crossing.

- Mast Arm Poles – Shall be used at far side right locations except at "T" intersections, where the cross street is narrow (i.e. two lanes only), or as indicated in the Typical Traffic Control Layouts shown in Figures 5-1 through 5-10. Pole mounted signals may be used in the Dallas Central Business District and where required by the municipality with jurisdiction.

- Near Side Signals – Shall be installed between the tracks and the cross-street at side-running locations with traffic signals.

- Lens Sizes and Location and Number of Signal Heads – Shall conform to the requirements of the TMUTCD.

- Left-Turn Phasing for Parallel Movements Turning into the Tracks – Shall be protected only. Permissive left-turns shall not be allowed. Two separate red circular signal indications shall be displayed to provide the turn prohibition to motorists. A supplemental "Train Coming" activated Blank-Out warning sign (W10-7) may be used to warn road users turning across the tracks of an approaching parallel LRT vehicle.

- Pedestrian Indications – Shall be provided at all crosswalks controlled by traffic signals and shall be coordinated with vehicular and train movements.

- Pedestrian Crossing Time and Signal Layout – Should generally provide for crossing of the entire street, except that where safe to do so, the pedestrian crossing time can be limited to a pedestrian refuge median or station platform if more efficient operation will result. Where sufficient pedestrian queuing is provided in the median, pedestrian crossing time can be limited to allow pedestrians to reach the median.

- Turn Prohibition or Lane–Use Control Signs – Shall be provided at locations where left turns or right turns are prohibited or required.

- Separate Right-Turn Phasing with Circular Red Indications – Shall be provided at locations with separate right-turn lanes which provide for right turns across rail tracks; right turns shall be prohibited upon the approach of an LRT vehicle by the display of two separate red circular signal indications. A supplemental "Train Coming" activated Blank-Out warning sign (W10-7) may be used to warn road users turning across the tracks of an approaching parallel LRT vehicle.

- Distinct Pedestrian Warning Devices – May be used to warn pedestrians in the ungated quadrant of the crossing at mid-block and side-running crossings.

- o ITS Elements – Shall be provided at specific location as required by the municipality with jurisdiction and tied to their city network in accordance to their criteria, standards and specification.

- o Loop Detectors and Setback Detectors – Shall be provided at specific locations as required by the municipality with jurisdiction.

- o Traffic Controller – Shall be provided at each intersection in accordance with the jurisdictional municipality's standards and specifications. Controller may be interconnected to the municipality's traffic control system.

5.3.6 Signal Coordination

Where the LRT tracks pass through an intersection either:

- o The train control shall be coordinated with the roadway traffic signal system without preempting the normal sequence of roadway intersection signal indications; or

- o The normal sequence of roadway intersection signal indications shall be preempted upon approach of trains.

At each intersection, signals for exclusive LRT use will be provided. These special LRT transit signals are distinct from roadway traffic signals and will be coordinated with the vehicular traffic signal controller. This will require special phases and LRT priority capabilities in the traffic signal control equipment.

All controllers shall have the ability to be operated in either an isolated mode (free), or in a coordinated mode. They shall have the ability to be switched between these two modes by time of day. All signals shall be capable of being coordinated with adjacent signals in both the LRT corridor and on cross streets. The primary method of coordination shall be fixed cycle length coordination via time based coordinators, but the provision of master coordination capabilities as part of the monitoring and programming system is considered a definite advantage.

Signal preemption capability will be provided at each crossing. However, preemption may not actually be operated at all such locations. In general, full preemption by the LRT train will only be used at intersections where the traffic signals operate in an isolated mode. Where intersection traffic signals operate in a coordinated mode with transit priority, special clearance intervals may be used to either advance or extend the green phase needed for the LRT trains.

5.3.7 Vehicular Traffic Control and Restrictions

The following controls and restrictions shall be provided at rail grade crossings of streets:

- o Sufficient Roadway Queuing Capacity – Shall be provided both upstream and downstream from the crossing to ensure queues do not block the LRT crossing or adjacent intersections, and traffic signal phasing and timing are set to clear queues prior to train arrival at the crossing (i.e., neither adjacent intersections nor rail crossings are to be blocked by vehicular queues).

- o Raised Physical Curb – Except within the Dallas Central Business District, shall be provided between the tracks and roadway traffic along street-running rail between intersections. The curb shall be designed to discourage vehicle entry to the track area from the roadway, but to allow errant vehicles which have encroached in the track area to exit to the parallel roadway.

- o Reflectorized Raised Marking Materials – Shall be used to separate the track area from the roadway area at crossings of street-running rail except within the Dallas Central Business District. Such markings are intended to provide visual and tactile information to motorists to discourage entry into the track area. Such markings shall not be located within marked, or other normal, pedestrian paths.

- o 6 Inch High, Non-mountable, Raised Median, with Standard Width of 6 Feet and a Desirable Length of 150 Feet – Shall be constructed between the directions of traffic on undivided streets approaching a mid-block or side-running grade crossing. To provide minimum lane widths, some roadway widening may be necessary with appropriate tapers used to transition the curbs to the widened sections. Where significant physical or right-of-way constraints exist, the median may be reduced to 4 feet. Wider medians may be installed when necessary. The minimum median length shall be 75 feet unless operational considerations require further reduction. On two-lane streets, the median curb shall be mountable. Appropriate fixed obstruction pavement markings shall also be installed. If the appropriate jurisdiction or agency will not permit a raised median on a two-lane, two-way street, a double row of closely spaced 8" pavement buttons may be considered.

- o Left and Right Turns That Will Cross Tracks at Unsignalized Intersections – Shall be prohibited from traffic lanes parallel to the track at side-running rail crossings.

- o No Left Turns – Shall be permitted across tracks from lanes parallel to the rail line at street-running locations at unsignalized intersections.

- o Left Turns Crossing the Tracks at Signalized Intersections – Shall only be allowed from exclusive turn lanes for traffic traveling parallel to the rail line. These left-turns will be allowed on a protected green arrow only with a R10-5L or R10-10L sign installed adjacent to the left turn signal head.

- o Right Turns Crossing the Tracks at Signalized Intersections – Shall be permitted only from exclusive right-turn lanes with a separate right turn signal. Right turns shall be prohibited upon the approach of an LRT vehicle by the display of double red signal indications.

- o <u>Unrestricted Opportunity to Clear the Trackway</u> – Shall be provided for vehicles departing the tracks at side-running crossings without traffic signals.

- o <u>Vehicular Non-Rail Traffic</u>– Shall travel in same direction as trains running on the adjacent track for street or median running tracks. Exceptions may be made when no other opportunities exist to provide local access. In those cases, a physical barrier (e.g., curbed median) shall be installed to prohibit vehicular movements to or from this access across the LRT tracks except in the Dallas Central Business District.

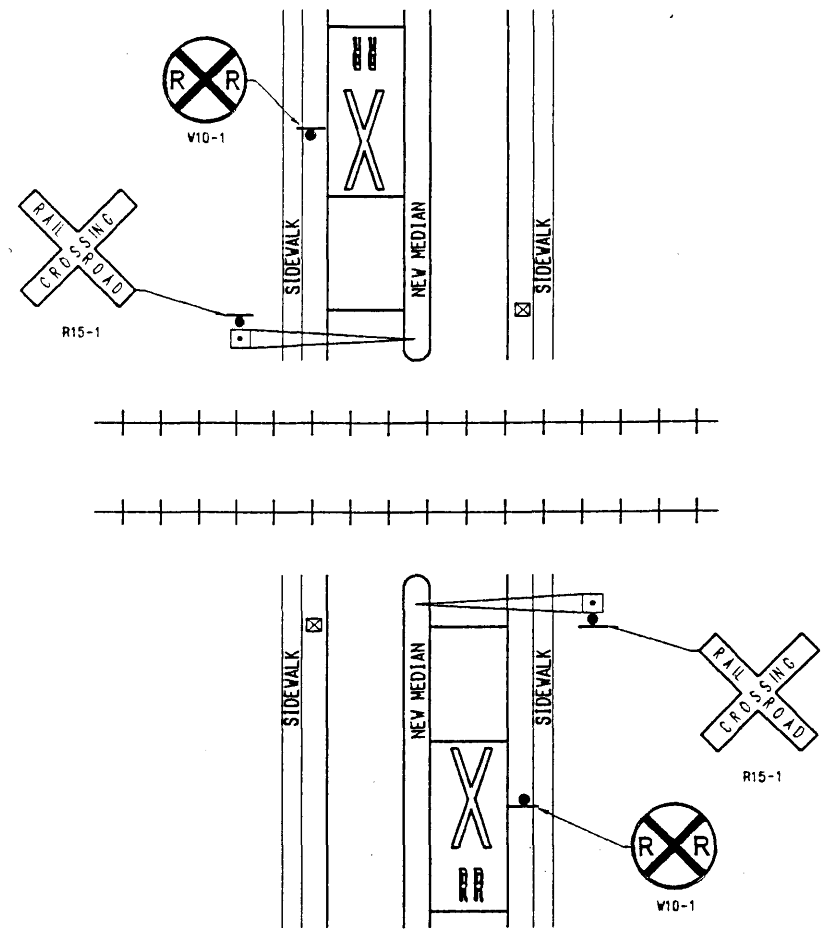
- o <u>Right-Turn-On-Red</u> – May be prohibited from the approach which crosses the tracks prior to the parallel cross-street at crossings of side-running rail.

- o <u>Standard Crossbucks</u> – Shall be used to control vehicular crossings of the track at private crossings (driveways) of side-running rail. Adequate sight distance must be provided along the track in both directions. Standard flashing light signals or gates may be installed at the direction of DART.

- o <u>Railroad Advance Warning Signs (W10-1, W10-2 or W10-3)</u> – Shall be installed in advance of street-running, median-running, and side-running crossing locations. Supplemental Special LRT Warning Signs may be used to alert pedestrians at station crosswalks of the potential of trains coming in both directions (Figure 5-10).

<u>Typical Traffic Control Layouts</u>

Figures 5-1 through 5-9 show typical traffic control layouts for conditions anticipated along DART's proposed LRT extensions. Figure 5-10 displays a Supplemental Special LRT Warning Sign, which may be used to alert pedestrians at station crosswalks of the potential of trains coming in both directions.



REQUIRED ELEMENTS

- STANDARD AUTOMATIC GATE ASSEMBLIES.
- PEDESTRIAN WARNING DEVICES (OPTIONAL) ⊠
- APPROPRIATE SIGNS AND MARKINGS.
- AREA ILLUMINATION
- INSTALL NEW MEDIAN

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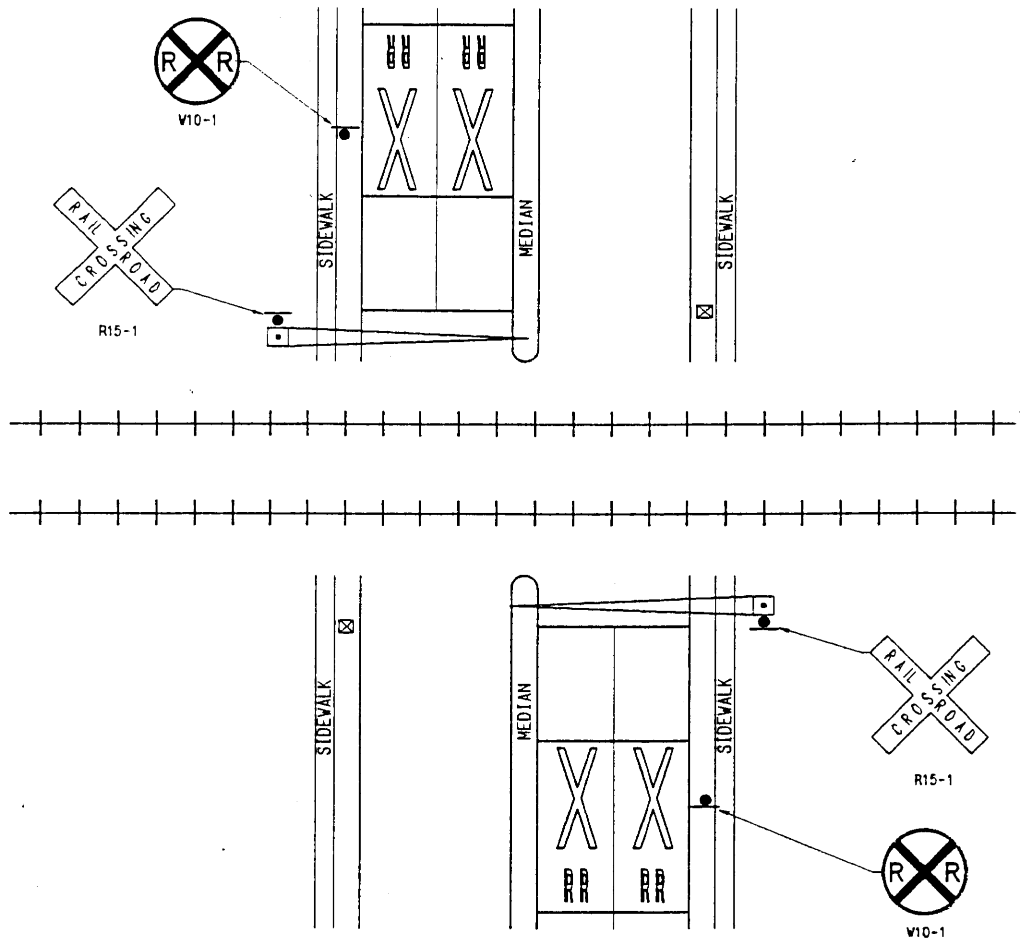
MID-BLOCK CROSSING OF
TWO-LANE UNDIVIDED ROADWAY

SCALE: NONE

FIGURE: 5-1

JAN. 2003, REV 10



REQUIRED ELEMENTS

- STANDARD AUTOMATIC GATE ASSEMBLIES.
- PEDESTRIAN WARNING DEVICES (OPTIONAL) ⊠
- APPROPRIATE SIGNS AND MARKINGS.
- AREA ILLUMINATION

NOTE:

ON APPROACHES WITH FOUR OR MORE LANES, OR WHERE THE GATE ARM LENGTH WOULD EXCEED 40', A SECOND MEDIAN-MOUNTED GATE MAY BE REQUIRED. A SEPARATE GATE MAY BE USED TO CONTROL PEDESTRIANS TO REDUCE GATE ARM LENGTH.

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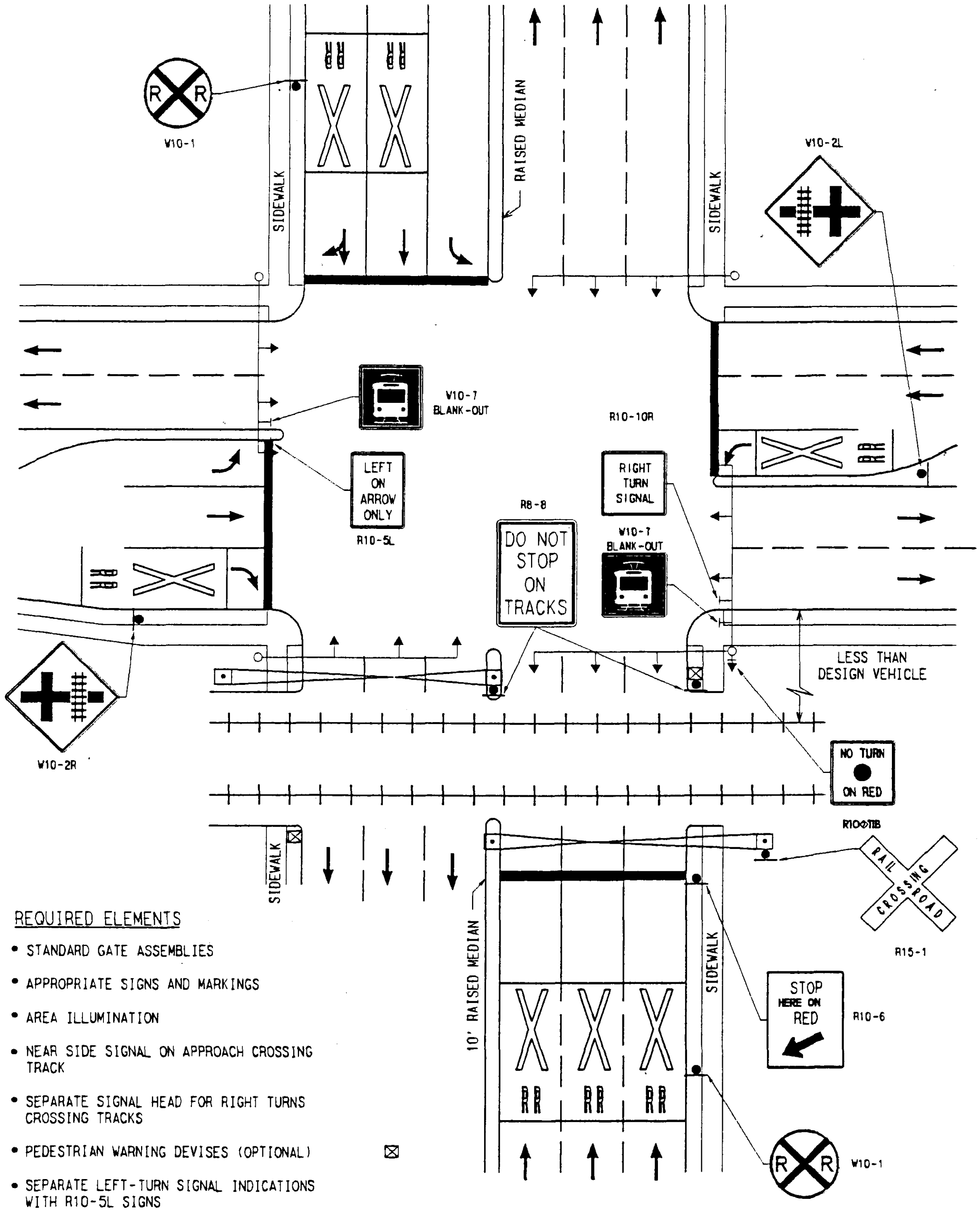
MID-BLOCK CROSSING OF MULTI-LANE DIVIDED ROADWAY

SCALE: NONE FIGURE: 5-2



REQUIRED ELEMENTS

- STANDARD GATE ASSEMBLIES
- APPROPRIATE SIGNS AND MARKINGS
- AREA ILLUMINATION
- NEAR SIDE SIGNAL ON APPROACH CROSSING TRACK
- SEPARATE SIGNAL HEAD FOR RIGHT TURNS CROSSING TRACKS
- PEDESTRIAN WARNING DEVISES (OPTIONAL) ⊠
- SEPARATE LEFT-TURN SIGNAL INDICATIONS WITH R10-5L SIGNS

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SIDE-RUNNING RAIL AT INTERSECTION WITH TRAFFIC SIGNAL

SCALE: NONE

FIGURE: 5-3

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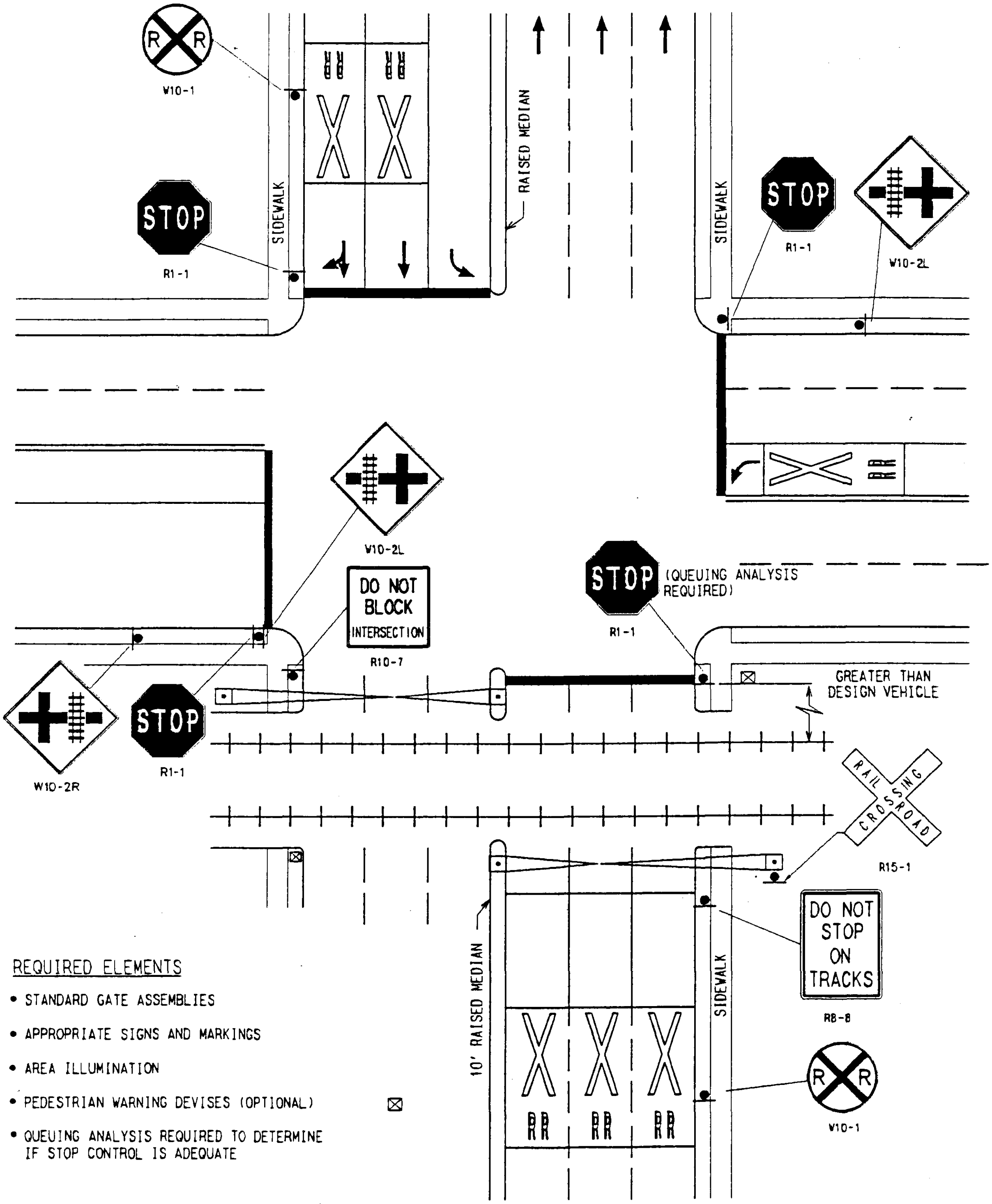

REQUIRED ELEMENTS

- STANDARD GATE ASSEMBLIES
- APPROPRIATE SIGNS AND MARKINGS
- AREA ILLUMINATION
- PEDESTRIAN WARNING DEVISES (OPTIONAL) ⊠
- QUEUING ANALYSIS REQUIRED TO DETERMINE IF STOP CONTROL IS ADEQUATE

ACT21

CARTER BURGESS
JACOBS ENGINEERING
STV INCORPORATED
KAI ALLIANCE

DART PROJECT

DART

DART DESIGN CRITERIA

SIDE-RUNNING RAIL AT INTERSECTION WITHOUT TRAFFIC SIGNAL

SCALE: NONE

FIGURE: 5-4

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Thu Feb 21 09:48:41 2003
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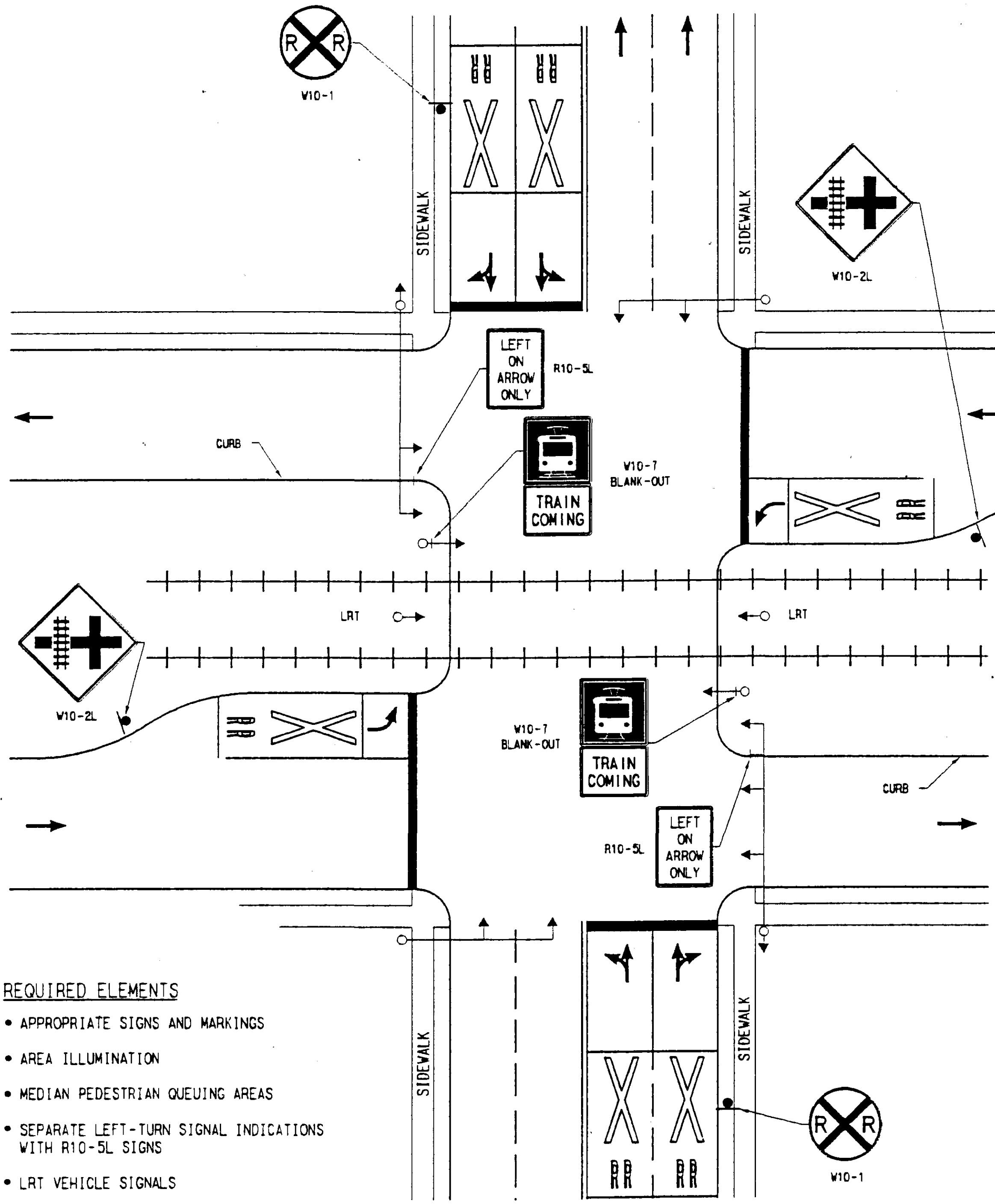

REQUIRED ELEMENTS

- APPROPRIATE SIGNS AND MARKINGS
- AREA ILLUMINATION
- MEDIAN PEDESTRIAN QUEUING AREAS
- SEPARATE LEFT-TURN SIGNAL INDICATIONS WITH R10-5L SIGNS
- LRT VEHICLE SIGNALS

ACT 21

CARTER BURGESS
JACOBS ENGINEERING
STV INCORPORATED
KAI ALLIANCE

DART PROJECT

DART

DART DESIGN CRITERIA

STREET-RUNNING RAIL IN MIDDLE AT INTERSECTION WITH TRAFFIC SIGNAL WITH TURN BAYS

SCALE: NONE

FIGURE: 5-5

JAN. 2003, REV 10

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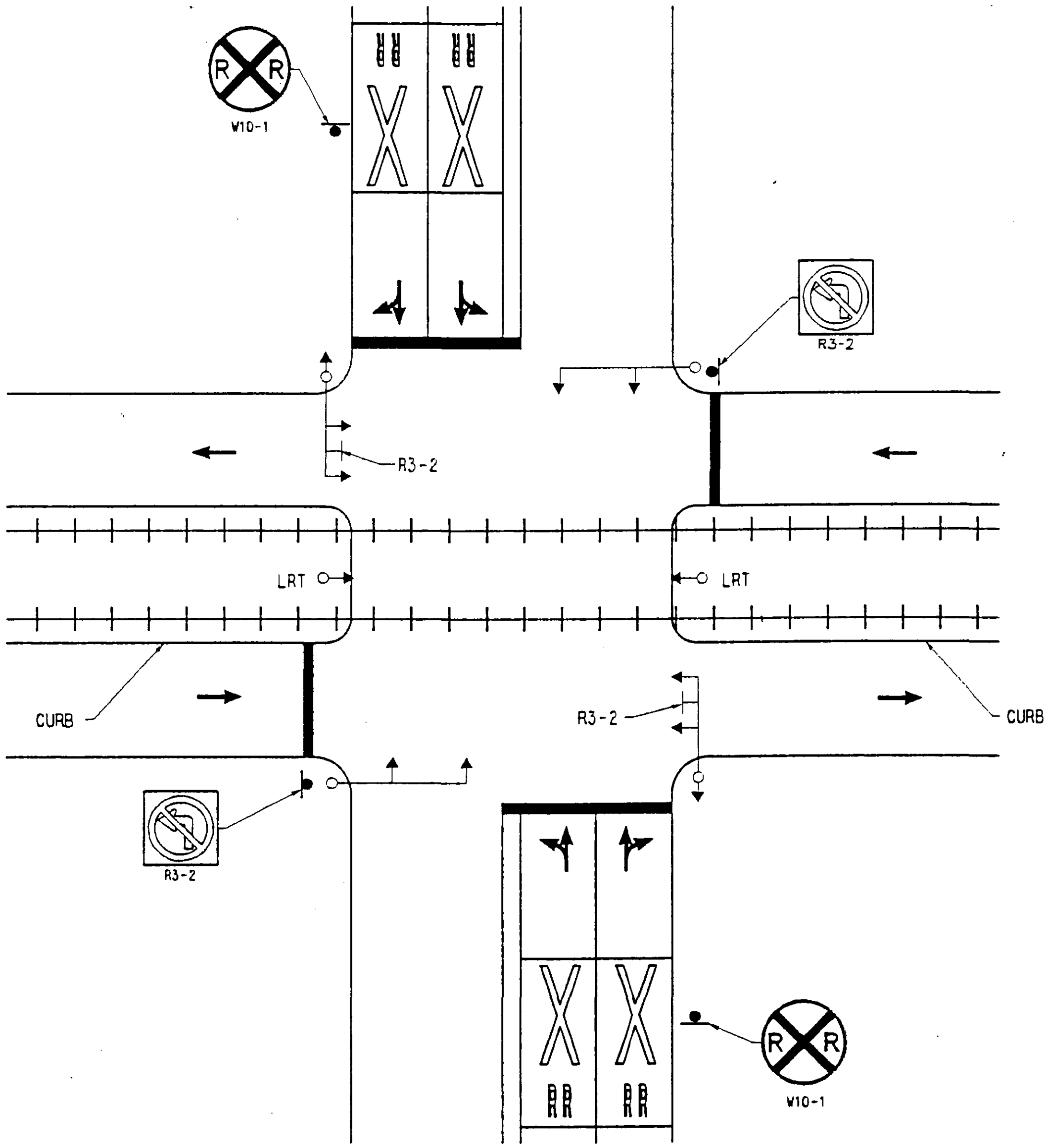


REQUIRED ELEMENTS
- NON-RAIL TRAFFIC MUST TRAVEL IN SAME DIRECTION AS TRAIN ON ADJACENT TRACK.
- NO LEFT TURNS ACROSS TRACKS FROM PARALLEL TRAFFIC LANES.
- R3-2 SIGNS SHALL ALSO BE MOUNTED ON THE APPROPRIATE SIGNAL MAST ARMS.
- RR PAVEMENT MARKINGS NOT REQUIRED IF POSTED VEHICLE SPEED < 40 MPH.
- LRT VEHICLE SIGNALS

NOTE:
LANE USE CONTROL SIGNS MAY BE USED INSTEAD OF TURN PROHIBITION SIGNS IF APPROVED BY THE AGENCY WITH JURISDICTION.

ACT 21

CARTER BURGESS
JACOBS ENGINEERING
STV INCORPORATED
KAI ALLIANCE

DART PROJECT

DART

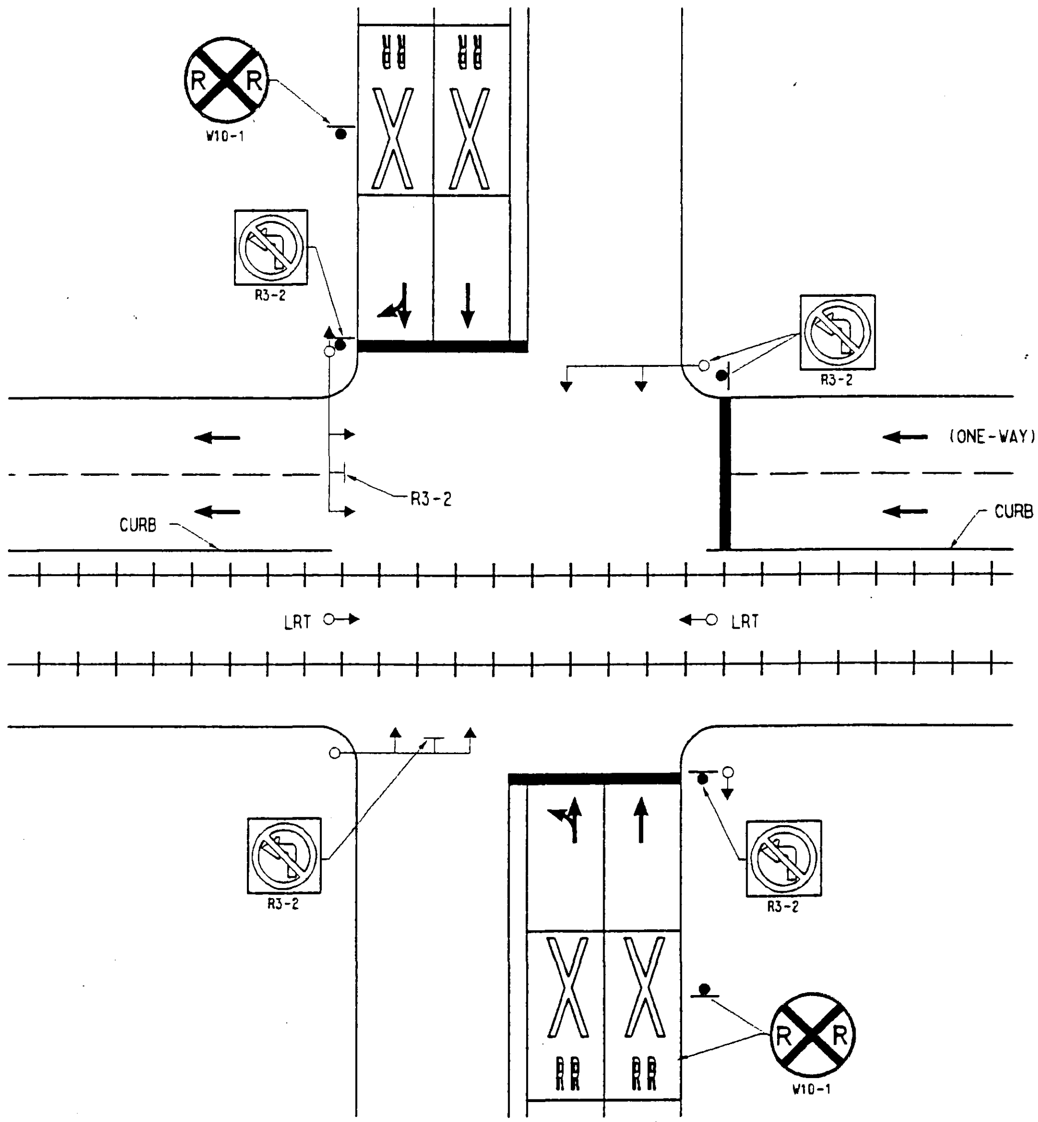
DART DESIGN CRITERIA

STREET-RUNNING RAIL IN MIDDLE AT INTERSECTION WITH TRAFFIC SIGNAL AND NO TURN BAY

SCALE: NONE

FIGURE: 5-6

JAN. 2003, REV 10

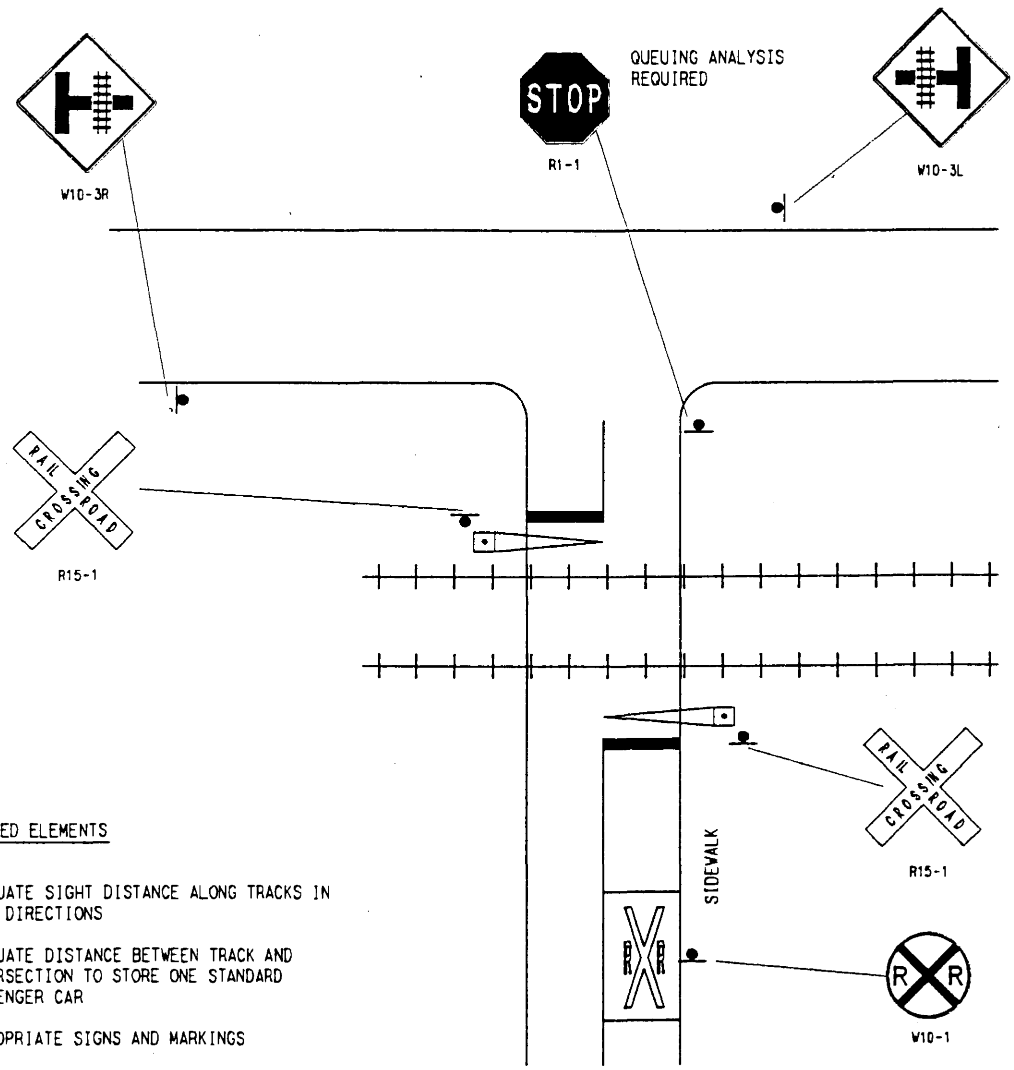


REQUIRED ELEMENTS

- NON-RAIL TRAFFIC MUST TRAVEL IN SAME DIRECTION AS TRAIN ON ADJACENT TRACK.
- NO LEFT TURNS ACROSS TRACKS FROM PARALLEL TRAFFIC LANES.
- R3-2 SIGNS SHALL ALSO BE MOUNTED ON THE APPROPRIATE SIGNAL MAST ARMS.
- RR PAVEMENT MARKINGS NOT REQUIRED IF POSTED VEHICLE SPEED < 40 MPH.
- LRT VEHICLE SIGNALS

NOTE:
LANE USE CONTROL SIGNS MAY BE USED INSTEAD OF TURN PROHIBITION SIGNS IF APPROVED BY THE AGENCY WITH JURISDICTION.

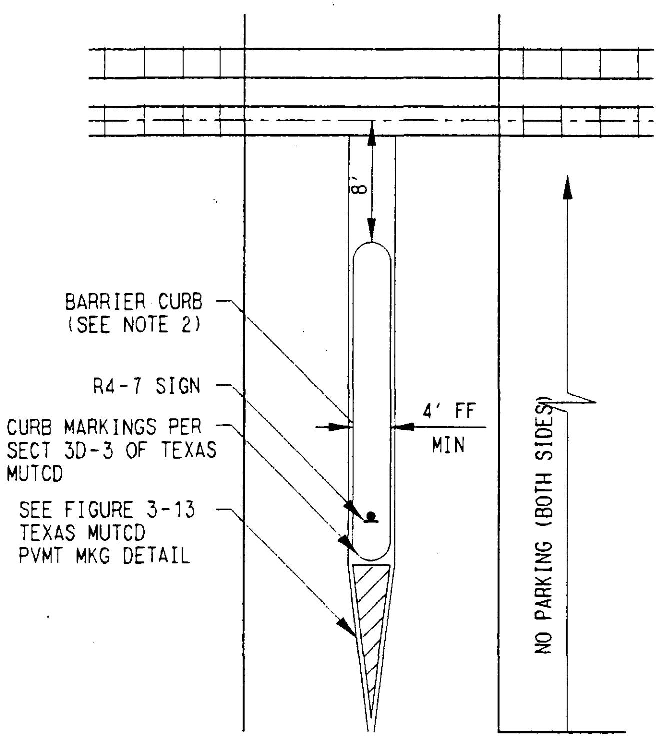
ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA STREET-RUNNING RAIL ADJACENT TO CURB AT INTERSECTION WITH TRAFFIC SIGNAL SCALE: NONE FIGURE: 5-7

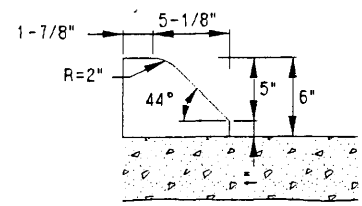


REQUIRED ELEMENTS

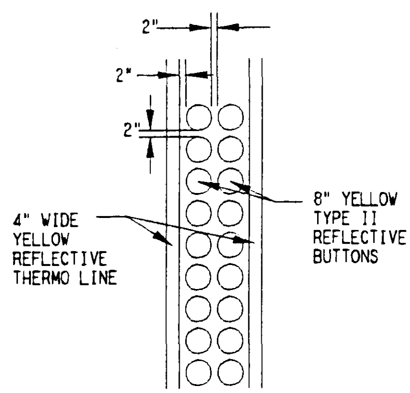
- ADEQUATE SIGHT DISTANCE ALONG TRACKS IN BOTH DIRECTIONS
- ADEQUATE DISTANCE BETWEEN TRACK AND INTERSECTION TO STORE ONE STANDARD PASSENGER CAR
- APPROPRIATE SIGNS AND MARKINGS
- STANDARD FLASHING LIGHT SIGNALS AND GATES MAY BE INSTALLED IF REQUIRED BY DART FOR LRT TRAIN SPEEDS UP TO 35 MPH
- AUTOMATIC GATES AND FLASHING LIGHT SIGNALS REQUIRED WHERE LRT TRAIN SPEEDS EXCEED 35 MPH
- QUEUING ANALYSIS REQUIRED TO DETERMINE IF STOP CONTROL IS ADEQUATE

ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA SIDE-RUNNING RAIL AT PRIVATE (DRIVEWAY) CROSSING SCALE: NONE FIGURE: 5-8





DETAIL 1
(MOUNTABLE CURB)



DOUBLE ROW
BUTTON DETAIL

F-F WIDTHS (FT)

STREET	MEDIAN	LANES (NO)
26-36	4-10	11-13 (2)
44	4	10 (4)

NOTES:

- 1-MEDIAN LENGTH DESIRABLE - 150' MINIMUM - 75' (UNLESS OPERATIONAL CONSIDERATIONS REQUIRE FURTHER REDUCTION)
- 2-FOR TWO (2) LANE STREETS MEDIAN CURB SHOULD BE IN ACCORDANCE WITH DETAIL 1

CARTER BURGESS
JACOBS ENGINEERING
STV INCORPORATED
KAI ALLIANCE

DART PROJECT

DART DESIGN CRITERIA

PROPOSED TYPICAL
GRADE CROSSING LAYOUT

SCALE: NONE

FIGURE: 5-9

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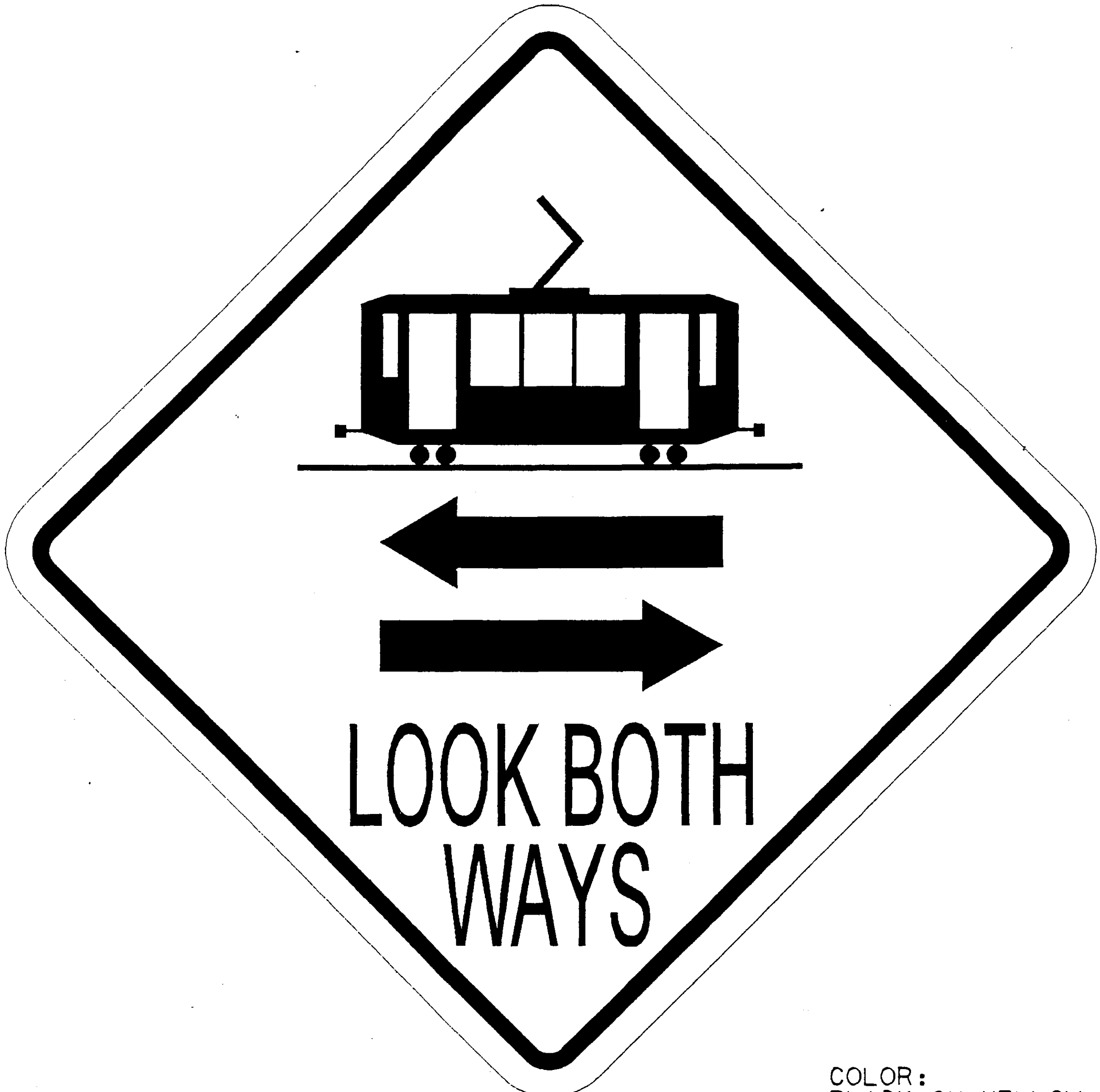


COLOR:
BLACK ON YELLOW
BACKGROUND

ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA SUPPLEMENTAL SPECIAL LRT WARNING SIGN SCALE: NONE FIGURE: 5-10

JAN. 2003, REV 10

CHAPTER 6 - UTILITIES

6.1 INTRODUCTION

This chapter establishes criteria for the design of all relocations to achieve maintenance, support, continued service or modification of existing utilities that will be affected by the construction of the system. The criteria also govern the design of utilities that may be installed on DART right-of-way to provide utility services to DART's facilities.

"Utilities" are defined as the lines, connections and appurtenances forming a transmission, distribution, collection or communication system belonging to governmental agencies, public utility corporations, railroads and privately owned companies for the provision of sewer, water, gas, electrical, telephone, telegraph, and cable television service. Other systems to be included as utilities are street lighting; petroleum pipelines; fire and security alarm systems; vaults; parking meters; postal service facilities; railroad lines and equipment and other communications systems. Included are service connections to adjacent properties and DART-owned utility facilities or communication systems. For purposes of providing requirements provided in this chapter to existing systems, storm sewers and drainage appurtenances will be considered a utility, in as much as these requirements are not provided in Chapter 7 - Drainage.

Terms used in this chapter are intended to have the following meaning:

- "Facilities" - Includes "utilities" as described above. May also include other structures or systems, depending on usage.

- "Owner" - The owner of the utility system or systems in question. The term "utility owner" may also be used for clarity. DART will be considered the owner if the utility in question belongs, or will belong to DART.

- "Railroad, railroad company", or the like" - Used to define railroad companies ownership instead of the term "owner".

- "City" - Used to define a municipality's ownership of items that are traffic and transportation related, as opposed to utility type items, such as streets and bridges, street lighting, and traffic signalization.

The required design and construction of utility relocations due to the impact of DART construction will be performed either under contracts directly with DART or entirely by the affected facility owner. The designer will be required to prepare designs of utility relocations only as specifically directed by DART.

These criteria for utilities relocations shall be used by the designer only to the extent of designing those facilities specifically directed by DART in the `Scope of Work' of the contract. The criteria provided herein are intended to comply with and supplement, relative to DART systems construction, the applicable City codes, ordinances, regulations, standards and specifications for utility relocations and construction. Such City standards shall include the Standard Specifications for Public Works Construction published by the North Central Texas Council of Governments, local amendments thereto, standard details, construction methods, and design policy and procedures of the City. Utility owner standards and criteria that equal or exceed these criteria shall govern. Specific criteria provided herein shall be in addition to utility owner criteria and standards, and shall govern in the absence of applicable criteria issued by the utility owner.

In the performance of utilities relocations, consideration shall be given to the needs of the utility system, the requirements and obligations of the utility owners, traffic requirements, the service needs of adjoining properties, and policies established, or to be established, by DART.

Such consideration shall also include making the following determinations according to criteria provided in Systems Design Criteria Chapter 8 - Corrosion Control and Chapter 9 - System Grounding:

- Utilities which do not generate electromagnetic interference (EMI) or any other interference that would compromise either operations or safety of any element of the system.

- Metallic pipes and casings are protected against corrosion by the use of corrosion-resistant materials, protective coatings, and/or cathodic protection, and are made electrically continuous in accordance with the requirements of Systems Design Criteria Chapter 8 - Corrosion Control and Chapter 9 - System Grounding and the corrosion control standard and directive drawings.

- Utility system design covered by these criteria shall be coordinated with Systems Design Criteria Chapter 8 - Corrosion Control. DART-owned utility structures may require atmospheric, soil and water, and/or stray current corrosion-prevention measures. Utility company structures shall be designed and constructed in accordance with each company's standard corrosion control practices and the provisions of any agreements between DART and the utility owners.

6.1.1 Relocation Alternatives

The necessary relocation of utilities shall be performed by using one of the following alternative procedures:

- Support and maintain impacted utility in place during construction of DART's facility, and continue in service following completion of the DART system facilities.

- o Temporary relocation and maintenance, then, upon completion of the DART system facilities, restoration of the existing facility.

- o Temporary relocation and maintenance, then, upon completion of the DART system facilities, replacement with a new utility facility.

- o Permanent utility relocation beyond the DART construction limits, preferably clear of the DART right-of-way.

- o Replacement with a new utility facility to be supported and maintained-in-place during DART's construction, then continued in service following completion of the DART system facilities.

No relocation of utilities shall be done within DART subways with the exception of DART-owned facilities such as fire mains and chilled water mains.

Utilities service to adjoining properties shall not be interrupted without permission of the facility owner, and, if temporarily relocated, shall be restored upon completion of construction.

6.1.2 Replacements and Relocations Design

Design of replacement or relocation of utility facilities shall be performed generally on a replacement-in-kind basis. However, the minimum replacement or relocation standards and design procedures agreed to by DART and each owner, as listed in Section 6.4, shall govern. If betterments are to be included, they shall be approved by DART in accordance with cooperative and detailed agreements with the applicable agency, utility, or railroad.

All design involving utility relocations and replacements will include maintenance of service, support in place, replacement due to damage and coordination of other utilities work and all designs shall follow the utility owner's design criteria and specifications. The designer shall coordinate their work and submit utilities replacement and relocation designs and plans for review and approval by DART in accordance with their contract and the terms and conditions of the cooperative agreements between DART and the utility owner. Detailed procedures for coordinating with the utility owner will be as established by DART. The designer shall coordinate their work with the other designers of adjacent sections, agencies, utility owners, and private developers to ensure compatibility of the respective replacements or relocations.
Specifications and design standards provided by the utility owners known to be affected shall be obtained directly from them by the designer. The designer shall coordinate the location of existing utilities and the new proposed utilities with the DART facility or related construction.

It is common practice, in the preparation of contract drawings, to specify control elevations for only those utilities that are dependent on proper slopes for their operation, such as gravity sewers. Such practices in the design of the system may result in underground facilities conflicts not resolvable by field engineering. Possible sources of conflict include two or more of the following facilities: footings; sanitary and storm sewers; water, gas, and oil lines; conduits for train control, communications, and auxiliary power systems; conduits for the traction power system; DART electric service ducts; underdrains; retaining wall stems and counterforts; manholes and pull boxes; and structure walls.

Elevations of all utilities shall be corrected to the datum of the U.S. Coast and Geodetic Survey. Where critical to the design, utilities shall be exposed to verify elevations. In particular, the elevations of the inverts of all new manholes and ductbanks shall be clearly shown on the plans and profiles at the center of the manhole and at the break points along the ductbank or at the manhole or junction box, respectively. Other critical elevations and dimensions shall also be highlighted on the plans or profiles to notify the Contractor of any special conditions.

Wherever there is a potential underground facilities conflict in the system, and where required by utility owners, the designer shall design to eliminate the conflict and shall indicate sufficient elevations and horizontal dimensions so that the design is effectively implemented in the construction.

Wherever inclusion of the above data or the number of utilities involved results in the plans becoming congested or difficult to interpret, separate drawings shall be prepared for each utility owner's facilities. Separate utility drawings will be prepared for City-owned utilities in accordance with the City's policies, design criteria, standards and procedures.

Plans prepared for City-owned utilities and drainage facilities will be prepared in accordance with the City's requirements, as published in design manuals, development guidelines, standard construction details, standard specifications, and related documents.

6.1.3 DART Service Connections

Utilities service connections to DART facilities shall be shown on the utilities plans; their design shall be coordinated with other items of the work. The designer shall ensure that service connections from the utility mains are indicated on either their plans or those for the adjacent construction contracts to preclude the cutting of new pavement.

6.2 DART UTILITY DESIGN CRITERIA

The following section is general criteria to be used by the designer in the preparation of construction plans for new utilities and the relocating or replacing of existing utilities parallel to, contiguous with, or across and either on, below or above the surface of DART's right-of-way. The first part of this section discusses requirements for all utilities related to DART's right-of-way. The second part of this section discusses in detail the underground utilities, the overhead utilities and surface utilities.

6.2.1 General Categories

Utilities relocations or replacements are classified into three categories: 1) utilities crossing DART trackways: 2) utilities on DART right-of-way clear of tracks; and 3) utilities clear of DART right-of-way.

Utilities Crossing DART Trackways. Utility crossings of DART system trackways, roadways, and parking lots shall be kept to a minimum. Crossings under special trackwork should be avoided, if possible. Utilities service connections, other than those serving DART's system facilities, shall not cross beneath system at-grade tracks. However, properly constituted and franchised utility agencies and licensees have the right to cross system rights-of-way with transmission and distribution/collection facilities to fulfill their existing service obligations.

Utilities crossings shall be perpendicular to the DART's system trackway or roadway alignment, or as nearly perpendicular as possible. Utilities shall not be placed within drainage culverts, or in any manner or position that might cause damage to, or impair the safety of the facility or the system.

Existing utilities within the system right-of-way shall be relocated to the extent necessary to conform to the criteria prescribed herein, unless specifically excluded from this requirement by DART and the utility owner.

New utilities crossings under operating DART's system trackways shall be made by boring, jacking, or tunneling, and shall be subject to DART approval in each case. Open-trench methods may generally be used under streets, parking lots, and aerial structures.

To facilitate maintenance operations, utility markers shall be provided to indicate the location of underground utility lines, drainage lines, and appurtenances beneath at-grade tracks. Section 6.3, Utility Markers, of this chapter outlines design details and requirements for utility markers.

Flammable or hazardous liquid or gas lines crossing the trackways shall have a valve at each end of the line at the right-of-way for shutoff in emergencies.

Utilities may exist on, or be relocated to cross the right-of-way for subway, at-grade, or aerial trackways. Such utilities may pass above or beneath the DART facilities.

Underground utilities relocations above subways shall be designed according to Section 6.3, Design Criteria for Underground Utilities. Those beneath subways shall be encased as provided in the utility owner's standards or criteria, or as provided in the DART standard drawings.

The designer shall perform their designs so that utilities service will be maintained when required by the facility owner. When practicable, the existing facilities shall be maintained complete-in-place.

Utilities on DART Right-of-Way Clear of Tracks. Utilities extending longitudinally along the trackway shall be limited to those serving DART's facilities. Facility relocations clear of tracks but within theDART right-of-way may be allowed in some instances. When utilities exist within the DART right-of-way and the most feasible and economical solution would be to support or relocate the facility within the right-of-way, the designer shall submit conceptual schematic designs to DART for approval prior to beginning of detailed facility design. Such designs should preclude future disruption to DART operations.

These general criteria govern the design of relocations of utilities that are affected by the DART system and that will be relocated in public or private property clear of the DART right-of-way or beneath DART parking lots.

The design of facility relocations shall be on a replacement-in-kind basis. It is with the understanding that any upgrading in a replacement facility resulting solely from the replacement of devices or materials no longer regularly manufactured, processed, or installed shall be considered as a replacement-in-kind. This is based on provisions that such replacement shall be only to that standard used on other projects financed solely by the utility owner. Minimum replacement standards and methods of design shall be in accordance with the criteria of the utility owner, and as agreed by DART and each facility owner or, for a facility that is to be supported in place during system construction, the standards must be sufficient to provide required structural strength.

Should a utility owner require the upgrading of a facility beyond the standard described above, such upgrading shall constitute a betterment and shall not be included in the work prior to an agreement being reached between DART and the utility owner.

Facilities clear of DART right-of-way shall be supported or relocated to facilitate system construction and meet the requirements of facility owners. The designer shall coordinate their work with all affected utility owners so that the most economic overall solution is obtained according to these requirements. These facilities also include those crossing railroad trackways.

6.3 DART DESIGN CRITERIA FOR UNDERGROUND UTILITIES

The design criteria for underground utilities will include utilities that will cross, parallel or clear of the DART right-of-way. These utilities will consist of storm sewers, sanitary sewers, water mains, gas lines, and petroleum lines. There are several general requirements related to the underground utilities, which need to be addressed as follows:

- Utilities wires or cables installed in conduits crossing under at-grade or subway structures shall be placed in plastic or other approved nonmetallic conduits such as Poly Vinyl Chloride (PVC). The conduits shall be encased in concrete in accordance with the utilities standards. The utility owner may perform the design and installation of encased utility relocations. In this instance, the designer shall provide the owner with plans of the DART facilities and shall coordinate their work with that of the utility owner to ensure that the design conforms to these criteria. The designer shall coordinate the design of the encased utility with other affected facility owners where necessary and shall include the relocation in the utilities plans and construction sequence plans.

- Pipelines crossing under aerial structures need not be placed in casings unless there is danger of damage to the DART facilities. Even if such a danger exists, casings may be omitted if the design of the carrier pipe is specifically approved by DART in each case.

- Pipelines crossing under at-grade sections of the system or beneath subways shall be placed in casings as shown on the utility owner's standards or minimum standards established by DART. Excluded from this requirement are storm sewers that normally operate under intermittent or continuous pressure of less than 10 psi. Construction of casing will be in accordance with the utility owner's standards. The space between casings and carrier pipes shall be plugged so as to prevent the formation of a waterway under the trackway, and casings shall be installed with an even bearing throughout their length.

- Installation of pipeline crossings by open-trench methods shall comply with the requirements for conduit bedding and backfilling as contained in the utility owners standards, or minimum standards established by DART.

- If no casing is required, bored or jacked installations shall have a bored-hole diameter essentially the same as the outside diameter of the approved carrier pipe. If voids should develop or if the bored-hole diameter is greater than the outside diameter of the casing or approved carrier pipe, all voids shall be grouted. Boring operations shall not be stopped if such stoppage would be detrimental to the system.

- Tunneling operations shall be conducted as approved by DART. If voids are caused by the tunneling operations, they shall be filled by pressure grouting or by other approved methods that will provide proper support. Boring, jacking, and tunneling shall be performed according to the utility owners standards or minimum standards established by DART.

- Shut-off valves shall be used as mutually agreed to by DART and the utility owner. Other than drainage or sewer lines, accessible emergency shutoff valves shall be installed in pipelines on each side of DART's system trackway. Wherever possible, such shutoff valves shall be located outside the DART right-of-way. Where pipelines are provided with valved automatic control stations at locations and within distances approved by DART, no additional valves shall be required.

- Utilities may exist in public right-of-way and on private property that will become part of the right-of-way for a DART parking lot. When such utilities are encountered, they will be allowed to remain in place beneath the DART parking lots provided that:
  1) The facility can withstand the construction loading and permanent parking lot loading;
  2) The depth of cover over the facility upon completion of construction will not be less than the minimum cover allowed by the facility owner, greater than the maximum depth used by the facility owner in its own construction, and greater than an existing utility conduit may withstand;
  3) The facility is not located beneath major access roads, or bus stalls;
  4) The facility does not compromise reliability, maintainability, or safety;
  5) The cables are installed in conduit; and
  6) The construction of the parking lot does not violate an existing utility easement, interfere with owners maintenance of utility, or is otherwise unacceptable to the utility owner.

  When a utility facility must be relocated because of parking lot construction, the relocation may be placed beneath the parking lot, provided the section designer shows it is more economical than relocation in the public right-of-way or in right-of-way acquired specifically for the purpose (and approved by the owner). Such facility relocations shall be located clear of the parking lot, major access roads, and bus stalls to minimize possible future disruption to the parking lot by utilities maintenance operations. The criteria used to design utilities relocations beneath DART parking lots shall be those used for the design of each utility.

For underground utilities specific criteria is required by DART and by the individual utility owner. The stricter of the two criteria shall be used which is either DART or the utility owner's criteria for each utility. The DART design criteria is as follows:

Excavation Support. Refer to Chapter 16 - Excavation Support for design of trench excavation and shoring related to all utility facilities.

6.3.1 Storm and Sanitary Sewers

The designer is responsible for the preparation of contract documents for the relocation of all conflicting storm and sanitary sewers. Unless DART and the facility owner agree otherwise, the design and relocation of sanitary and storm sewer facilities that conflict with the system shall be performed without the use of permanent ejectors or pumping stations. Sewer facility relocations shall be designed to conform to the design criteria, standards, and ordinances of the utility owner and applicable regulatory agency requirements. Adequate closed flumes shall be provided to handle the flow of sanitary sewers temporarily removed from service. No sewage shall be discharged into open trench.

Design storm sewers and capacity requirements for storm sewers, and the design of storm sewer facilities, including the relocation of existing facilities, shall be performed according to the requirements of Chapter 7 - Drainage.

Municipal requirements will be incorporated into the design as necessary. Where existing municipal storm sewer facilities cross beneath the DART alignment and must be relocated, the relocated facilities shall be designed to current standards and criteria of the municipality. The pipe size shall be determined by calculating the discharge from the upstream contributory area and considering the future development trends of the area, as set forth in Chapter 7 - Drainage. The resulting flows shall be used to size the complete sewer relocation. Where relocation is an extension of an existing storm sewer, and replacement is not otherwise required, the extension shall be of similar size and shape and of a hydraulic capacity equal to or greater than the existing pipe.

When no additional flow is added to the storm sewer, conditions downstream of the relocation need not be studied. Where increase in flow takes place as a result of construction, conditions downstream shall be evaluated. The extent of this evaluation shall be determined on an individual basis. Should retention/detention be considered a solution to an increased rate of storm water discharge or downstream sewer inadequacy, the retention/detention facility must be in accordance with Chapter 7 - Drainage.

The Designer shall have the following responsibilities to:

1) Provide the sewer utility owner with plans showing the DART facilities and coordinate with the owner to determine the extent of the system impact upon the sewer facilities. The utility owner shall determine which facilities may be abandoned or taken out of service during the utility construction. The utility owner and the designer shall determine which facilities may be supported-in-place during utility construction. The utility owner and the designer,

through DART, shall decide upon locations for the relocation of conflicting sewer facilities that are acceptable to DART, the utility owner, and the owners of other affected facilities.

2) Prepare the design so that service in sanitary and storm sewer facilities is maintained at all times, except in those facilities previously determined to be abandoned as a result of construction.
3) Prepare contract documents for the sewer facility relocations including those betterments requested by the owner and agreed to by DART.
4) Coordinate sewer facility relocations with other utilities owners and local government agencies.
5) Include the sewer facility relocations in the construction sequence plans.
6) Include provisions in the design to maintain service to all properties, which are to remain connected to sanitary or storm sewers affected by the construction.

The Designer shall also consider in his design the following factors related to storm and sanitary sewers:

Location and Cover. The location of sanitary sewers with respect to water supply wells and potable water lines shall follow the regulations of the Texas Department of Health and the criteria and standards of the utility owner. Sanitary sewers shall be located with a minimum of 3 feet of cover in areas not subject to vehicular traffic. No part of a proposed storm sewer shall be designed within the improved subgrade of a proposed pavement. The minimum cover for storm sewers in areas not subject to vehicular traffic is 2 feet, although greater cover is desirable. Where exceptions to these provisions are made necessary due to connection to existing lines or for other causes, special material or bedding may be required. Design of sanitary and storm sewers outside of DART right-of-way shall conform to the design criteria and standards of the respective local public agency involved.

Cross Connections. Physical connections between a public or private potable water supply system and any sewer, drain, facility, or equipment shall not be made, except in strict accordance with applicable plumbing codes and all local or state regulations pertaining to cross connections.

Materials. Materials shall be selected to give best service under local conditions and the requirements of the design. Special consideration shall be given to the character of industrial wastes, possibilities of septicity, exceptionally heavy external loads, abrasion, infiltration and exfiltration, soil conditions, pipe bedding, and similar problems. Unless otherwise approved by DART, reinforced concrete pipes shall be used for storm sewers. Vitrified clay, reinforced concrete or PVC sewer pipe(s) will be used for sanitary sewers. Materials shall comply with utility owners criteria and standards.

Size. The minimum allowable diameter for sanitary sewers shall be 8 inches, 4 inches for residential services, and 6 inches for other than residential services. Sanitary sewer laterals within easements or dedicated right-of-way shall be at least 6 inches in diameter.

Slopes. All sewers shall be designed with slopes sufficient to give mean velocities, when flowing full or half full, of not less than 2.0 feet per second to a maximum of 10 feet per second based on Manning's formula. Sanitary sewer velocities shall be determined using a Manning's "n" of 0.013. Optimum flow velocity is considered to be 3.0 feet per second, and slopes producing less than 3.0 feet per second shall be used only with the approval of the utility owner.

Pipe Size Increases. At manholes where a sanitary sewer is increased in size and any points where a smaller sewer connects into a larger sewer, the invert of the larger sewer shall be at a lower elevation so that the energy gradient is maintained. To achieve this, pipes shall be installed with the crowns at the same elevation.

Alignment. Sanitary sewer mains shall be designed with straight alignment wherever possible. Where curved alignments are required, design shall not exceed the minimum curve radius for pipe material specified, and shall be in accordance with the utility owner's standards.

Manholes. Manholes shall be installed at the end of each sewer line; at all changes in grade, pipe size, junctions, and intersections; at changes in alignment, except where an approved curved alignment is involved, and at other locations as may be required by the utility owner. Manhole spacing shall be in accordance with the utility owner's standards and criteria. Manholes and covers shall be constructed according to the utility owner's criteria, specifications and standard details. The invert elevation of the manhole shall be clearly shown on the plans and profiles at the center of the manhole. Other critical elevations and dimensions shall also be highlighted on the plans or profiles to notify the Contractor of any special conditions. The designer shall have the option to permit precast manholes to be used. The requirements, criteria and details shall be noted on the respective plans and defined in the general notes for the precast manhole.

Inverted Siphons. If no other option exists, and if approved by the utility owner, design of inverted siphons shall follow the utility owners standards and the requirements of the Texas Department of Health.

Force Mains. Force mains shall be constructed of ductile iron or PVC pipe with mechanical or other approved joints, or, if approved by the facility owner, other materials such as prestressed concrete cylinder pipe.

Sanitary Sewer Flows. Where the design of new sanitary sewers is included in the work, such sewers shall be designed according to the utility owner's criteria.

Connections. Connections to existing sanitary sewers shall be by manholes or other construction approved by the utility owner.

Drainage Report. A drainage report for the design of the storm sewer shall be prepared for submittal to the local government agency having jurisdiction. The report shall describe the effect of construction of a section of the DART system upon the existing drainage facilities and shall show that the design conforms to the applicable DART and utility owner's policies, criteria and standards. For further details of drainage report requirements refer to Chapter 7 - Drainage.

Low Pressurized Pipe. Pipelines included in this section are those installed to carry water, or any other nonflammable substance, which, from its nature of pressure, might cause damage escaping on, or in the vicinity of, system property. The following casing requirements apply to storm and sanitary sewer lines and waterlines. Water lines relocations and replacements are discussed in more detail later in this section.

Relocations of storm and sanitary sewer facilities that cross under at-grade system trackways and that normally operate under pressures of less than 10 psi shall be designed according to procedures specified herein and by the utility owner. However, the design shall be checked to provide a safeguard for the system should such facilities become surcharged during a 100-year-frequency storm (Chapter 7 - Drainage). Non-encased facilities shall have watertight joints and the capability of serving for a period of at least 50 years with minimal maintenance. Reinforced concrete pipe meeting ASTM C76 and having "O"-ring rubber gasket joints conforming to ASTM C443 will satisfy these requirements.

Nonflammable Substance Pipelines. Pipelines containing nonflammable substances under low pressure shall be designed as follows:

1) Carrier pipe and joints for lines under system trackways shall be of comparable type, strength, and material to that required by the utility owner for direct burial application or by AREMA Manual, whichever is more stringent. Joints for carrier pipe operating under pressure shall be push-on, mechanical joints, or welded. Carrier pipes shall be in accordance with the utility owner's criteria and standards, except where these requirements are more stringent or have additional requirements.
2) Casing materials shall consist of corrugated metal, steel, or reinforced concrete pipe, all in accordance with the requirements prescribed below. For larger or high-pressure mains that require periodic inspection, and where otherwise appropriate, reinforced concrete utilities tunnels may be used. The standards of the utility owners shall be complied with when more restrictive or stringent.
3) Corrugated metal casing pipe requirements shall be designed according to the latest edition of Corrugated Metal Pipe Culverts - Structural Design Criteria and Recommended

Installation Practices, published by the Federal Highway Administration. For water mains and sanitary sewer casings, the standards of the utility owner for corrugated metal pipe and circular liner plate shall be used.

4) Steel casing pipe requirements shall have a minimum yield strength of 35,000 psi. Wall thickness for steel casing pipe with a protective coating installed in a trench shall conform to Table 6.1. The wall thicknesses shown in Table 6.1 shall be increased by at least 0.063 inch for uncoated casing and by at least 0.063 inch for coated or uncoated casings to be installed by jacking or boring. For water mains and sanitary sewer, the standards of the utility owner will be used, subject to approval by DART, in lieu of the foregoing.
5) Reinforced concrete pipe and fittings requirements shall conform to the requirements of ASTM C76, Class IV, minimum, in accordance with the owner's standards. "O"-ring gaskets shall conform to the requirements of ASTM C443.
6) Casing pipe and joints shall be designed to withstand the imposed loading. Casings shall be sloped to drain. They shall be protected against corrosion in accordance with the requirements of Systems Design Criteria Chapter 8 - Corrosion Control and Chapter 9 - System Grounding and corrosion control standards and directive drawings. Care shall be taken to select materials that will not be damaged through dissimilar metals contact. Where both carrier pipe and casing are metallic, they shall be separated electrically by using insulated spacers. The inside diameter of the casing shall be at least 2 inches greater than the largest outside diameter of the joint or coupling of the carrier pipe and shall also meet the requirements of the utility owner. In any case, the casing shall be large enough to allow pressurized carrier pipe to be removed subsequently without disturbing the casing pipe or trackbed. For water main and sanitary sewer casing pipes, the standards of the utility owner will be used. For sanitary sewer lines, voids between the encasement and carrier pipes shall be grouted.
7) The ends of the casing shall be suitably sealed to protect against the entrance of foreign materials. Utility owner's standard details for seals and drainage shall be used.
8) The limits of the casing pipe unless otherwise approved by DART and the utility owner, casing pipe shall extend to the greater of the following horizontal distances, measured perpendicular to the centerline of track: a minimum distance of 2 feet outside the fenced portion of the system right-of-way or minimum distance of 25 feet from the centerline of the outside track.
9) If additional tracks are constructed in the future, the casing shall be extended correspondingly. Where future additional tracks are planned, utilities shall be installed on a straight line and grade for the appropriate distance to facilitate future casing extension.
10) Minimum cover over uncased pipe or over casings shall be 3 feet at areas subject to vehicular traffic, unlined ditches, and other unpaved surfaces, and 2 feet at lined ditches. Additional cover shall be provided where necessary to comply with the utility owner's policy or local government ordinances. On at-grade DART trackways, the minimum clearance between the top of uncased pipe or top of casing pipe and the base of the

system rails shall be 4 feet 6 inches. The standards of the utility owners will be used if more stringent than the above.

11) Sewer services shall be in accordance with the codes and standards of the utility owner.

TABLE 6-1

MINIMUM WALL THICKNESS FOR STEEL CASING PIPE UNDER DART TRACKWAYS

NOTE: For Coated Casings Installed in a Trench

Height of Cover in Feet	Diameter in inches 10 or less	11 to 20	21 to 30
12 or less	0.250"	0.250"	0.250"
14	0.250"	0.250"	0.250"
16	0.250"	0.250"	0.250"
18	0.250"	0.250"	0.281"
20	0.250"	0.250"	0.312"
22	0.250"	0.250"	0.344"
24	0.250"	0.281"	0.344"
26	0.250"	0.312"	0.375"
28	0.250"	0.312"	0.406"
30	0.250"	0.344"	0.438"
32	0.250"	0.344"	0.469"
34	0.250"	0.344"	0.469"
36	0.250"	0.375"	0.500"
38	0.250"	0.375"	0.500"
40	0.250"	0.406"	0.562"
42	0.250"	0.438"	0.562"

NOTE: For water mains and sanitary sewers, the standards of the utility owner will be used, subject to approval by DART, in lieu of the above table.

NOTE: The above thicknesses pertain to coated pipe casings installed in a trench. A maximum allowable trench width shall be indicated to assure that trench condition loading actually occurs. If casing is to be installed in an embankment and positive projecting installation is anticipated, maximum allowable deflection shall be equal to 0.05 of nominal pipe diameter, and wall thickness shall be determined from Spangler's formula.

6.3.2 Water Mains

Water mains belonging to local government agencies will be affected by construction of the system. The section designer is responsible for the preparation of contract documents for relocation of all conflicting water facilities not performed by the utility owner. Unless DART and the facility owner agree otherwise, the design and relocation of water facilities that conflict with the system shall be performed on a replacement-in-kind basis.

Designer Requirements. It shall be the designer's responsibility to implement the following general requirements for the relocation or replacement of water mains and service lines:

1) Provide the water utility owner with plans showing the DART facilities and coordinate with the owner to determine the extent of the system impact upon the water facilities. The utility owner and the designer shall determine which facilities may be abandoned or taken out of service during DART system construction and which facilities may be supported-in-place during system construction. All water mains with lead joints shall be replaced with ductile iron or PVC pipe having mechanical or push-on joints prior to supporting-in-place. The utility owner and the designer shall decide upon the locations for the relocation of conflicting water facilities which are acceptable to DART, the facility owner, and the owners of other affected facilities.
2) Prepare the designs so that water service is maintained at all times, except in those facilities previously determined to be abandoned as a result of the reconstruction. No water main or fire hydrant shall be out of service without prior approval of the utility owner.
3) Prepare contract documents for the water facility relocations, including those betterments requested by the owner and agreed to by DART.
4) Coordinate water facility relocations with other utilities owners and local government agencies.
5) Include the water facility relocations in the DART construction sequence plans.

The designer shall incorporate into the plans the following design requirements for the following specific items and elements related to the relocation or replacement of water mains and service lines.

1) Water mains, materials and fittings shall be as required by the owner. Relocation alignments must meet the current standards of the utility owner.
2) Depth of cover shall be 4 feet minimum on DART right-of-way or property, and in accordance with the utility owner's criteria in all public right-of-way, DART right-of-way, or utility easement.

3) Fire hydrant installation shall comply with the utility owner's standards. The section designer shall consider both temporary and permanent requirements when designing hydrant relocations. The following pertains to fire hydrant installation:

    a) Spacing:

        - Residential and commercial/central business district areas: Hydrant spacing shall follow utility owner and local fire department requirements.
        - DART stations and other DART facilities: Hydrant spacing shall follow the requirements specified in Chapter 29 - Fire Protection Systems.
        - DART yard facilities: Hydrant spacing shall be a maximum of 300 feet.

    b) Valving for hydrants: Hydrants shall be installed on a 6-inch lateral and shall have a 6-inch gate valve located between the hydrant and the main.

    c) Bracing: Hydrants shall be anchored in accordance with the utilities standards.

4) Valve type and spacing shall be in accordance with the utility owner's criteria and standards.
5) Thrust blocks or approved joint restraint systems shall be provided at bends (horizontal and vertical), tees, and plugs according to the utility owner's criteria and standard details.
6) Casings are required for all water mains crossing under DART tracks. Crossings under DART trackways shall conform to casing requirements detailed under **Storm and Sanitary Sewers.**
7) Crossings under other facilities shall comply with the standards and criteria of the specific facility owner. Where the facility must remain in operation, the use of tunneling or jacking shall be considered for the installation of relocating facilities crossing below.
8) Services taps on new, relocated and replaced water mains shall be installed according to the requirements of the utility owner.
9) All cleaning, pressure and leakage tests, and chlorination for disinfection requirements shall be in conformance with the criteria of the utility owner.
10) Water mains on bridge crossings or structure shall comply with the following requirements:

    a) All pipe joints that are to be aerially supported over or under a bridge or similar structure shall be thoroughly restrained against both longitudinal and lateral movement with a minimum of one restraining device per joint.
    b) Pipe material shall be ductile iron or steel and in accordance with utility owner's requirements.
    c) Each crossing shall have a valve on each side of the bridge and beyond the abutment located in proximity to the crossing. Valves shall not be on the bridge structure.

11) Blow-off valves, air vents or air/vacuum release valves shall be provided when directed by the utility owner, and shall be in accordance with the utility owner's criteria and standards.
12) Pipe insulation, if required for aerially supported or other above grade lines, shall meet or exceed insulation equivalent to the following, and approved by the owner:
    a) Insulating material: 3-inch-thick polyurethane pipe covering, formed to fit the particular pipe diameter.
    b) Outer covering material: 0.016-inch aluminum chiller jacket with moisture shield secured with stainless steel straps.
13) Right-of-way for publicly owned water facilities shall never be placed on private property. Should the area within the public right-of-way be insufficient for facility installation, sufficient right-of-way or an easement shall be provided.
14) Connections to water main shall be shown on the plans. The designer shall prepare plans showing details for the connection of new, relocated or replaced water mains to the existing mains. Such details shall include valves, temporary hydrants, fittings, and temporary and permanent plugs. The connection plan shall delineate the following responsibility for performance of the work: unless specified otherwise, all water main connections shall be constructed by the contractor after necessary valve operation by the utility owner.
15) Service Connections shall be shown on the plans. Commercial and industrial service connections 4 inches and larger shall be detailed on the plans. Residential service connections shall be included by reference on the drawings. Responsibilities for relocation of service connections shall be in accordance with the utility owner's standard procedure and criteria.
16) Water services and meters shall be installed according to the codes and standards of the utility owner.
17) DART fire and domestic water service connections shall be designed by the designer. The size of the domestic connection and meter shall be based upon peak-demand/pressure loss calculations in conjunction with local codes and ordinances. Fire flow and pressure data in the existing water main shall be obtained from the water utility owner.
18) The fire and domestic services in public right-of-way and up to the DART right-of-way shall be installed by DART's contractor. The domestic service meter must be in public right-of-way or in a utility easement granted by DART to the water utility. The utility will install all domestic meters, and either the utility or DART's contractor may install fire service meters.

6.3.3 Gas Facilities

The designer shall comply with the following general requirements as they relate to gas lines and facilities. These requirements will also apply to petroleum lines and lines which carry flammable and highly volatile substances. The designer shall pay close attention to the facilities owner's requirements in the design of the relocation or replacement of these lines.

Pipelines for Flammable Substances. Pipelines included in this section are those installed to carry natural gas, oil, petroleum products, or other flammable or highly volatile substances. They shall be encased under DART tracks and right-of-way in accordance with the following criteria:

1) Carrier pipe:
    a) The following requirements for carrier pipe apply to pipelines crossing under both at-grade and aerial sections of the system. These requirements apply for a minimum horizontal distance of 50 feet from the centerline of the outside track or 25 feet beyond the end of casing when casing is required whichever is greater.
    b) Pipelines carrying oil and other flammable products shall conform to the requirements of the current edition of ANSI B31.4, Liquid Petroleum Transportation Piping Systems, and other applicable ANSI codes.
    c) Wall thickness for carrier pipe shall be based on the design criteria, standards, and specifications used by the facility owner for encased crossings beneath highways or railroads. In no case shall the encased facility be of lesser strength than the adjacent, direct-burial sections.
2) Casing materials: Casing pipe and joints shall be of corrugated metal, steel, ductile iron, or reinforced concrete pipe according to the requirements prescribed for nonflammable carrier pipe, excluding plastic pipe. For large or high-pressure mains that require periodic inspection, reinforced concrete utilities tunnels may be used.
3) Casing design: Casing pipe and joints shall be watertight and shall be capable of withstanding the imposed loading. Casings shall be sloped to drain. They shall be protected against corrosion in accordance with the requirements of Systems Design Criteria Chapter 8 - Corrosion Control and Chapter 9 - System Grounding chapter and the corrosion control standard and directive drawings. Care shall be taken to select materials that will not be damaged through dissimilar metals contact. Where both carrier pipe and casing are metallic, they shall be separated by using insulated spacers. The inside diameter of the casing shall be at least 2 inches greater than the largest outside diameter of the joint or coupling of the carrier pipe. The casing diameter shall always be large enough to allow the carrier pipe to be removed subsequently without disturbing the casing pipe or trackbed. All joints or couplings, supports, insulators, or centering devices for the carrier pipe within a casing shall be taken into account. In addition, casing shall be designed so that its maximum vertical deflection is 5 percent of its diameter and so that no loads from the trackbed, track, traffic, or casing pipe itself are transmitted to the carrier pipe.
4) Ends of casings and vents:
    a) The ends of casings shall not project above ground level. They shall be closed with a liquid-tight seal bushing or bulkhead.

b) Casing pipe shall extend to the greater of the following horizontal distances, measured perpendicular to the centerline of track, unless otherwise approved by DART and the utility owner:
    - o A minimum distance of 2 feet outside the fenced portion of the DART right-of- way.
    - o A minimum distance of 25 feet from the centerline of the outside track, when the casing is sealed at both ends.

c) If additional tracks are constructed in the future, the casing shall be extended correspondingly.

d) Casings shall be vented at each end by vent pipes attached near the ends of the casing and having a minimum diameter of 2 inches. Vents shall project through the ground surface outside the DART right-of-way at a distance of not less than 6 inches from the right-of-way line or not less than 25 feet measured at right angles from the centerline of the nearest track, unless otherwise approved by DART and the utility owner.

e) Vent pipes on DART right-of-way shall extend not less than 4 feet above the ground surface. The top of the vent pipe shall be fitted with a down-turned elbow that shall be screened or fitted with a relief valve. Vents in locations subject to high water shall be extended above the maximum elevation of high water and shall be adequately supported and protected.

f) Vent pipes on DART right-of-way shall terminate at least 8 feet below aerial electric wires carrying 750 volts or less and 12 feet below aerial electric wires carrying over 750 volts.

5) Cover: Minimum cover over uncased pipe or over casings shall be 4 feet in areas subject to vehicular traffic, unlined ditches, and other unpaved surfaces, and 2 feet at lined ditches. Additional cover shall be provided where necessary to comply with the facility owner's policy or local design conditions. On at-grade trackways, the minimum clearance between the top of encased pipe or top of casing pipe and the base of the system rails shall be 5'-6".

Natural gas transmission and distribution facilities belonging to the gas companies will be affected by construction of the system. The gas companies, coordinating through DART and other facility owners, shall decide upon locations for the relocation of affected gas facilities that are acceptable to DART, the companies, and other affected facility owners.

Unless DART and the gas company agree otherwise, the design and relocation of gas facilities that conflict with the system shall be performed on a replacement-in-kind basis by the gas company according to their criteria and standards, and all local, State and federal standards and codes.

Abandoned gas pipe lines within DART right-of-way shall be excavated and disposed of after they have been purged by the gas company.

Designer Requirements. It shall be the designer's responsibility to:

1) Provide the gas company with plans showing the DART facilities.
2) Include the company's requirements for maintenance of gas facilities complete-in-place in the preparation of the DART design.
3) Include the gas facility relocations to be performed by the company in the DART construction sequence plans.

Gas Company Responsibilities. The gas company shall coordinate with the designer through DART to determine the extent of the system impact on the gas facilities, and the company shall:

1) Determine facilities where service may be terminated on a temporary or permanent basis.
2) Delineate those facilities that are to be maintained complete-in-place.
    - Facilities that are to be maintained-in-place above DART subways shall be constructed of steel; facilities of other materials shall be replaced with steel by the gas company prior to system construction.
    - Facilities to be maintained-in-place beneath at-grade DART tracks shall be enclosed in a casing in accordance with the requirements for Pipelines for Flammable Substances.
3) Design and construct new facilities necessary to maintain continuity of service to the company's customers.

6.3.4 Petroleum Products Pipelines

High-pressure fuel and oil transmission pipeline facilities belonging to different privately owned pipeline companies will be affected by construction of the DART system. The design and relocation of pipelines that conflict with the system shall be performed by the facility owner according to company standards and all applicable local, state, and federal standards and codes. The general requirements for pipelines carrying flammable substances shall be implemented on petroleum lines.

Designer Requirements. It shall be the designer's responsibility to:

1) Provide the company with plans showing the DART facilities and proposals for the relocation of other utility facilities so that the company may complete its design.
2) Prepare utility plans showing the work to be performed by the affected company, consider such work in the design, and, where necessary, consider such work in the preparation of the construction sequence plans.
3) Coordinate with the affected company during the design, where appropriate.

Petroleum Company Responsibilities. The petroleum company shall coordinate with the designer through DART to determine the extent of the system impact on the petroleum facilities, and the company shall:

1) Determine facilities where service may be terminated on a temporary or permanent basis.
2) Delineate those facilities that are to be maintained complete-in-place.
   a) Facilities that are to be maintained-in-place above DART subways shall be constructed of steel.
   b) Facilities of other materials shall be replaced with steel by the petroleum company prior to DART construction.
   c) Facilities to be maintained-in-place beneath at-grade DART tracks shall be enclosed in a casing in accordance with the requirements for Pipelines for Flammable Substances above.
3) Design and construct new facilities necessary to maintain continuity of service to the company's customers.

6.4 DART DESIGN CRITERIA FOR UTILITIES BOTH AERIAL AND UNDERGROUND

Aerial utilities, other than DART owned, preferably shall have the supporting poles, towers, and guys located outside the DART right-of-way. Where such location is impractical, a minimum horizontal clearance of 25 feet from the centerline of the outside track shall be provided to any pole, tower, guy, or wire. This clearance may be reduced where approved by DART and the affected utility owner.

Minimum vertical clearances to wires or cables above existing streets, top-of-rail, or other structures shall comply with the requirements of the latest editions of the National Electrical Safety Code and the OSHA regulations for construction clearances. See Figures 6.1, 6.2, and 6.3.

Design of aerial wire and cable arrangements shall be performed by the utility owners. The designer shall coordinate their work with the respective owners through DART to ensure that adequate clearances are provided.

If DART believes it is uneconomical to provide an aerial relocation of an existing aerial wire or cable above the trackway, the facility shall be relocated beneath the trackway in approved conduit encased in concrete.

The designer shall coordinate their work with the utility owner to determine the need for any temporary bypass during any bridge construction. The design of utilities supported on bridges or aerial structures shall be performed by the designer and shall comply with the structural criteria contained in the structural criteria and the criteria and specifications of the facility owner, whichever is the most stringent.

Where it is not practical to accommodate utilities on a bridge that crosses over the tracks, a separate utilities bridge may be considered. However, the designer shall submit comparative cost estimates for aerial and underground relocations and shall obtain DART's approval of the proposed utilities bridge before proceeding with its design.

For aerial utilities such as electricity, telephone, telegraph and cable television lines, these utilities can be located underground. When underground facilities for these utilities are encountered by the designer the following general criteria shall be incorporated in the design in conjunction with the utility's requirements and standards.

<u>Conduit Facilities</u>. Utilities wires or cables placed beneath DART trackways shall be installed in conduits. In the absence of DART criteria and specifications to the contrary or more stringent, conduit facilities shall be designed according to the utility owner's standard details and specifications.

Where jacking or boring must be employed, conduits may be steel, ductile iron, or reinforced concrete.

Where open-trench methods are employed, plastic or approved type of nonmetallic conduits shall be encased in concrete in accordance with the utilities or railroad standards, whichever is more stringent.

1) Sizes:
   a) Conduits shall be a minimum of 4 inches in diameter and shall be on a reasonably straight line and grade beneath the tracks.
   b) Where bends are required, they shall be situated clear of the tracks and shall be of sufficiently large radius to allow the installation of cable without damage.
2) Cover: The clearance between top of conduit encasement and top of rail shall normally be not less than 5 feet. Where savings may be realized by reduction of this clearance, the section designer shall obtain the approval of DART before completing the detailed design.
3) Horizontal clearance:
   a) Manholes shall not be located closer than 25 feet from the centerline of the outside track and shall be located outside any ditch section required at that location. Exceptions may be approved by DART.
   b) Where the distance between DART and railroad near tracks is less than 25 feet, or where there would be no means of access to a manhole located between the DART

tracks and the railroad tracks, the conduits shall be continuous across both the DART and the railroad trackways.

6.4.1 Electrical Power Facilities

Electrical power transmission and distribution facilities belonging to the power company will be affected by construction of the DART system.

The following types of facilities may be encountered:

- o Aerial wires and cables, which may be mounted on wood or metal poles belonging to power company or telephone and telegraph companies.
- o Underground conduit and manhole systems containing electrical power transmission and distribution cables.

Coordinating through DART and other facility owners, the designer shall determine locations for the relocation of affected power facilities that are acceptable to DART, the power company, and other affected facility owners.

Unless DART and the facility owner agree otherwise, the design and relocation of the electrical power facilities that conflict with the system shall be performed on a replacement-in-kind basis by the power company and coordinated with the system construction and the relocation of other facilities.

Electrical power facility relocations shall be designed by the power company according to its in-house criteria and standards.

Designer Requirements. It shall be the designer's responsibility to:

1) Provide the power company with plans showing the DART facilities, and coordinate with the power company to determine the extent of the system impact on the company facilities.
2) Determine, through further coordination, which facilities may be maintained-in-service during system construction. Underground electrical facilities may be maintained-in-service by retaining the facility complete-in-place or by removing the existing conduit structure, placing cables in a new temporary structure, and, ultimately, reinstalling the facility with a concrete encasement on compacted backfill.
3) Prepare the design so that power service shall be maintained at all times, except in those facilities previously determined to be abandoned as a result of DART construction.

Power Company Responsibilities. It will be up to the power company to:

1) Determine those facilities where service may be terminated as a result of DART construction.
2) Design and construct all aerial facility relocations.
3) Design and install all surface, aerial and underground facilities relocations.

6.4.2 Telephone Facilities

Telephone transmission and distribution facilities belonging to telephone and telegraph companies will be affected by the construction of the system.

The following types of facilities may be encountered:

- o Aerial wires and cables that may be mounted on wood or metal poles belonging to a telephone company, power company, or a local government agency.

- o Underground conduit and manhole systems containing telephone and telegraph company cables, and cables belonging to local private and government agencies (such as private security alarm lines and fire alarm lines).

The telephone companies, by coordinating through DART and other facility owners, shall decide upon locations for the relocation of affected telephone facilities that are acceptable to DART, the telephone company, and other affected facility owners.

Unless DART and the facility owner agree otherwise, the design and relocation of telephone facilities that conflict with the system shall be performed on a replacement-in-kind basis by the telephone company and coordinated with the system construction and the relocations of other facilities.

Telephone relocations shall be designed in accordance with the standards and practices of the respective telephone and telegraph company.

The DART contractor shall install conduits for public telephones in DART stations and parking lots from the telephones to the DART property line. The location and elevation of the conduit stub at the property line shall be coordinated with the telephone company by the designers and indicated on the plans.

Designer Requirements. It shall be the designer's responsibility to:

1) Provide the respective telephone company with plans showing the DART facilities, and coordinate with that telephone company to determine the extent of the system impact on telephone facilities.
2) Determine through further coordination, which facilities may be maintained-in-place during DART construction.
3) Consider retaining underground communications facility service by maintaining the facility complete-in-place or by removing the existing conduit structure, placing existing cables in a temporary structure, and, ultimately, encasing the facility with concrete on a compacted backfill based on the requirements previously discussed in underground utilities.

Telephone Company Responsibilities. The telephone facility owner shall be responsible for any necessary coordination and shall:

1) Determine the facilities in which service may be terminated as a result of DART construction.
2) Design and construct all aerial, surface, and underground facility relocations.

6.4.3 Telegraph Facilities

Telegraph facilities belonging to the Western Union Telegraph Company will be affected by construction of the system.

The following types of facilities may be encountered:

- Aerial wires and cables mounted on poles belonging to a telephone company and/or power company.
- Underground conduit and manhole systems containing cables.

Unless DART and Western Union agree otherwise, the design and relocation of telegraph facilities that conflict with the system shall be performed on a replacement-in-kind basis in accordance with the Western Union Telegraph Company Specifications.

Designer Requirements. It shall be the designer's responsibility to:

1) Provide Western Union with plans showing the DART facilities, coordinate with Western Union through DART to determine which telegraph facilities may be abandoned and which must be maintained-in-place on a temporary or permanent basis. Western Union and the designer shall decide upon locations for the relocation of conflicting facilities that are acceptable to DART, Western Union and other affected facility owners.

2) Consider retaining underground communications facilities service mains by maintaining the facility complete-in-place or by removing the existing conduit structure, placing existing cables in a temporary structure, and, ultimately, encasing the facility with concrete on a compacted backfill.

Western Union Telegraph Company Responsibilities. Western Union shall:

1) Perform all design and construction involving cables.
2) Coordinate with DART and other facility relocations.

6.4.4 Cable Television

Cable television facilities belonging to various cable television companies will be affected by construction of the system. With very few exceptions, cable television facilities are aerial and are mounted on utility poles belonging to a power company or a telephone and telegraph company.

Each cable television company shall be responsible for the design and relocation of its facilities which conflict with the system.

Designer Requirements. It shall be the designer's responsibility to:

1) Provide the company with plans showing the DART facilities and proposals for the relocations of other utility facilities so that the affected cable television company may complete its design.
2) Show the location of the existing and relocated cable television facilities on the utility plans and, where necessary, consider such work in the preparation of construction sequence plans.
3) Coordinate through DART with the affected cable television company during the design, when appropriate.

6.5 DESIGN CRITERIA FOR SURFACE FACILITIES

Surface facilities are utilities that are impacted by the DART construction and are facilities that incorporate other utilities. These facilities include traffic signal and appurtenances; street lighting; alarm systems; intelligent transportation systems (ITS); security systems.

6.5.1 Traffic Signalization, ITS and Street Lighting

Street lighting, ITS and traffic control facilities will be affected by construction of the system. Unless DART and the facility owner agree otherwise, the design and relocation of street lighting, ITS and traffic control facilities that conflict with the system shall be performed on a replacement-in-kind basis. Refer to Chapter 5 - Traffic Control for traffic signalization requirements for additional details.

DART-owned street lighting facilities are to be mounted on metal poles and are connected in circuits. Power supply cables may be aerial, attached to the poles, or in metal conduit buried in the sidewalks adjacent to the street curbs. Individual lights can be taken out of service provided doing so does not disrupt service in the circuit. Refer to Chapter 26 - Lighting for requirements within the DART right- of-way.

Design and construction responsibilities will be defined in DART's agreement with the local government having jurisdiction.

Designer Requirements. It shall be the designer's responsibility to:

1) Provide affected facility owners with plans showing the DART facilities, and coordinate with the City to determine the extent of the system impact upon lighting facilities and the City's requirements for facility relocation.
2) Prepare street lighting contract documents for the relocation of City-owned street lighting facilities and connecting conduits, including temporary facilities, where necessary. In the performance of this work, care shall be taken to ensure compatibility among street lighting, DART parking lot lighting, and DART station site lighting.
3) Prepare contract documents for the relocation of the affected signals, ITS elements and traffic control facilities such as control boxes, loop detectors, conduits, electrical boxes, etc.
4) Coordinate with the power company regarding disconnection and restoration of power supplies to lighting facilities, ITS systems and traffic signalization systems.
5) Include temporary lighting, ITS and signal facilities in the construction sequence and traffic control plans.
6) Base the design of lighting, ITS and signalization facilities on the standard drawings, criteria, and specifications of the City.

6.5.2 Fire Alarms and Other Security Systems

Fire alarm facilities belonging to the local fire services and security system facilities owned by private security system companies will be affected by DART construction of the system.

The facilities consist of fire alarm boxes connected in circuits to various fire stations and the fire department central headquarters, and security system circuits to various customers and the security system control room. The fire alarm and security system circuit cables may be aerial, installed on telephone company or power company utility poles, or underground, installed in telephone company duct banks. Fire alarm and security system circuits must be maintained-in-service at all times, unless otherwise approved by the respective authorities or utility owners. The Fire Department and fire alarm and security system owners shall be notified when relocations are being constructed or service is to be interrupted.

<u>Designer Requirements</u>. It shall be the designer's responsibility to:

1) Provide the City and security system owners with plans showing the DART facilities, and coordinate with them through DART to determine the extent of the system impact upon their facilities and whether affected facilities may be abandoned or taken out of service during DART construction. The city, security system owners, and the designer shall decide upon locations for the relocation of conflicting facilities that are acceptable both to DART and the owners of the affected facilities.
2) Prepare the design so that service in fire alarm systems facilities is maintained at all times, except where the facility owner has agreed otherwise.
3) Prepare contract documents for the relocation of affected facilities, as directed by DART.
4) Coordinate plans to relocate or maintain these facilities in-place with the power company or telephone and telegraph companies as necessary to ensure continuity of service.
5) Include above facilities relocations in the DART construction sequence plans.
6) Coordinate with the facility owners, and include in the design provisions to allow adequate and continuous facilities operations during DART construction of the system. Such provisions may include:
    a) All work related to fire alarm systems shall be in accordance with the requirements of the respective facility owner's criteria and standards.
    b) All work related to security and systems owned by private security companies will be performed by themselves or by telephone or other companies providing the service to the security company.

<u>Security Company Responsibilities</u>. The security company shall:

1) Perform all design and construction involving security and alarm facilities.
2) Coordinate with DART and other facility relocations.

6.5.3 U. S. Postal Service

The postal service shall relocate affected facilities prior to DART construction.

<u>Designer Requirements</u>. It shall be the designer's responsibility to:

1) Provide the postal service with plans showing DART facilities and the location of affected collection and distribution boxes.
2) Coordinate through DART with the U.S. Postal Service during design.

U.S. Postal Service Responsibilities. The Postal Service shall:
1) Coordinate with DART for any facility relocations.

6.5.4 Parking Meters

All work related to removal, relocation, restoration, and installation of parking meters shall be in conformance with the requirements of the City. All work shall be coordinated through DART with the City. The City shall remove, store, and install meter heads and DART's contractor shall remove, store, and install meter posts.

Designer Requirements. Where DART facilities will impact parking meters the designer shall:

1) Coordinate impacted parking meters through DART so that adequate data may be furnished to the City for completion of its work.
2) Show the necessary relocations of impacted parking meters on the DART utilities plan.
3) Provide details for the installation of meter posts on the utility plans.

City Responsibilities. The City shall:

1) Perform all removal and store meter heads. The City will reinstall meter head once new posts have been relocated.
2) Coordinate with DART and other facility relocations.

6.6 DESIGN CRITERIA FOR MISCELLANEOUS UTILITIES

6.6.1 Vaults

All remodeling, abandonment, or other work involving private vaults extending from adjoining buildings into public space shall be in accordance with current codes, standards, and practices of the concerned jurisdiction. All work related to private vaults shall be coordinated through DART with the vault owners.

Designer Requirements. The designer shall determine which vaults will be affected by DART construction. Plans shall show, as a minimum, portions of each vault to be removed and the area available for permanent use upon completion of DART construction. This information shall be forwarded to DART at the earliest practical date so prompt action can be taken to avoid delay in construction.

Vault Owner'sResponsibilities. The owner of the vault shall:

1) Perform all design and construction involving cables.
2) Coordinate with DART and other facility relocations.

6.7 DESIGN CRITERIA FOR UNDERGROUND FLAMMABLE AND COMBUSTIBLE LIQUID STORAGE TANKS

The following criteria provide the design requirements for dealing with flammable and/or combustible liquid storage tanks and related appurtenances adjacent to DART trackway running through a subsurface structure or on the surface. Designs shall conform to NFPA 130, Section 3-2.8.1-6. The classification of liquids according to the National Fire Protection Association (NFPA) is given in the following table:

Classification of Liquids

Agency Classification	NFPA Classification	Flash Point
Flammable	Class I	Below 100°F (37.8°C)
Combustible	Class II	100°F to 140°F (37.8°C to 60°C)
	Class III	Above 140°F (60°C)

Underground tanks for Class I flammable and Class II and Class III Combustible liquids and related piping shall not be permitted directly over a subsurface DART structure or within 25 feet (measured horizontally) from its outside wall.

6.7.1 New Underground Storage Tank Installation

Where the tops of underground storage tanks and related piping for Class I flammable liquids and Class II and III combustible liquids are more than 2 feet above the lowest point of excavation for a DART substructure, and where they are within 25 to 100 linear feet from the outside wall of the DART substructure, they shall be installed in accordance with NFPA 130.

6.7.2 Service Stations

Where service stations dispensing Class I flammable liquids, and Class II and III combustible liquids are located in the area within 100 feet (measured horizontally) from the outside wall of subsurface structure, NFPA 130 requirements shall be complied. If service stations are outside the DART right-of-way, the designer shall notify DART so that arrangements for complying with NFPA 130 can be developed.

6.7.3 Existing Tanks

Existing storage tanks for Class I flammable liquids and Class II and III combustible liquids located on DART right-of-way in or under buildings, directly above a subsurface transit structure, or within 25 linear feet from a subsurface transit structure outside wall shall be removed and relocated to outside the prohibited area.

All existing storage tanks, above ground or underground, shall comply with NFPA 130 when located within the distances specified in that standard. Where existing storage tanks for Class I flammable liquids or Class II and III combustible liquids are governed by that standard and outside the DART right-of-way, the designer shall notify DART so that arrangements for compliance can be developed.

6.8 DESIGN CRITERIA FOR UTILITY RELOCATIONS CROSSING RAILROAD TRACKWAYS

Utilities may presently cross railroad trackways, or, because of DART construction, be relocated to cross railroad trackways. Signal and communications lines belonging to railroad companies will be affected by DART construction. The design and relocation of railroad facilities that conflict with the DART system shall be performed by the railroad according to the railroad's standards.

Designer Requirements. Where DART facilities will impact railroad utility facilities, or where relocation of other utility facilities will impact, or possibly affect the operation of railroad facilities, the designer shall:

1) Coordinate work through DART so that adequate data may be furnished to the railroad for completion of its work.
2) Show the necessary relocations of railroad utilities in the DART utilities plan.
3) Coordinate through DART with the affected utility owners to define the limits of existing facilities that are in conflict, and determine the responsibility for the design and construction of relocated facilities that will eliminate such conflicts.
4) Coordinate and furnish data to utility owners who are designing their relocations so that they may complete their design.
5) Review the utility owner's proposals to ensure that they are compatible with the DART design and that of other affected owners.
6) Show such relocated utility alignments on the plans and provide appropriate copies of those plans for distribution to other affected facility owners.

Railroad Company Responsibilities. The railroad company shall:

1) Perform all design and construction involving it utilities.
2) Coordinate with DART and other utility relocations.

6.8.1 Underground Facilities Crossing Railroad Trackways

When building underground facilities, the following items will either be enclosed in casings, or conduits.

- Casings:
  - Pipelines carrying either flammable or nonflammable substances under pressure beneath railroad trackways.
  - All sanitary sewers, whether operating by gravity or under pressure.
- Conduits:
  - Electrical cables.
  - Communications cables.

When an underground facility relocation is designed by the section designer, such design shall provide for installation of the facility in the following manner:

- When utilities must be installed beneath active railroad mainline tracks, such installation shall be by jacking, boring, or tunneling. The section designer shall determine the specific requirements of the railroad for each type of installation, including materials, prior to proceeding with the detailed design.
- When utilities must be installed beneath active railroad secondary tracks, such installation shall be by methods approved by the railroad.
- When utilities must be installed beneath inactive or proposed railroad tracks, such installation preferably shall be by open-trench methods, provided the installation will be more than 25 feet away, or other distance approved by the railroad, from active mainline tracks and beyond existing fill sections or other ditch sections.
- When open-trench methods will be used:

- All installation shall comply with "Installation of Pipe Culverts", Chapter 1, Part 4, of the AREMA Manual for Railway Engineering of the American Railway Engineering and Maintenance-of-way Association (AREMA) and railroad requirements.

- The design shall include details of sheeting and method of supporting the railroad track for utility facilities installation, if appropriate.

o Underground facilities shall:

  - Cross railroad trackway at right angles, where practicable. When this cannot be done, the skew shall in no instance be greater than 45 degrees.

  - Be designed for Cooper E-80 loading as specified in Chapter 15, Part 1, Section 1.3.3 of the AREMA Manual for Railway Engineering and railroad requirements.

Encased Facilities

Utility owner's standard details and specifications shall be used for design, except where these requirements or the railroad criteria and specifications are more stringent. Pipeline encasements shall be designed according to the requirements of Chapter 1, Part 5, of the AREMA Manual for Railway Engineering.

o Casing thickness:

Chapter 1, Part 5, of the AREMA Manual for Railway Engineering provides for steel casings up to 42 inches in diameter. In situations where steel casings larger than 42 inches in diameter are required, the following wall thicknesses shall be used:

Outside Casing Diameter (Inches)	Minimum Wall Thickness (Inches)
44	0.500
46	0.625
48	0.625
50	0.625
52	0.750
54	0.750
60	0.813

An allowance for increased wall thickness shall be made for uncoated pipe having a diameter greater than 42 inches as is required in Chapter 1, Part 5, of the AREMA Manual for Railway Engineering.

- Casing design considerations:

  For large-diameter carrier pipe, it may be necessary to perform installation and routine maintenance from within the casing, in which case appropriate internal clearance shall be provided. Where additional clearance is required, the alternatives of arch and elliptical sections might be considered.

  Extension of an existing casing shall be of similar style and shape and of compatible materials to the existing casing. The extension of an existing casing shall continue the line and grade of the existing casing.

  Where the distance between DART and railroad near tracks is less than 25 feet, or where there would be no means of access to the end of the casing between DART and railroad tracks, the casing shall be continuous across both the DART and railroad trackways. Such casings shall be on a straight grade and alignment, be of uniform strength throughout their length, and conform to either DART or railroad criteria, depending on which is the most stringent.

Nonencased Facilities - Storm Sewers. Casings may be omitted on storm sewers where the facility will normally operate under pressures of less than 10 psi.

Utility owner's standard details and specifications shall be used for design of encased facilities, except where these requirements or the railroad criteria and specifications are more stringent.

- Cover:

  The top of non-encased sewers shall normally be not less than 5 feet 6 inches below the bottom of rail because of possible problems during track maintenance. For sewers with diameters in excess of 84 inches, the minimum cover should be 2 feet greater than one-half the inside diameter. Where substantial savings may be realized by reduction of this clearance, the section designer shall submit studies showing how the relocated facility will withstand railroad loading, and the approval of the railroad shall be obtained before completion of the detailed design.

Strength design of non-encased sewer facilities shall be based on the criteria of Chapter 1, Part 10, of the AREMA Manual for Railway Engineering.

- o Horizontal clearance:

  Manholes shall not be located closer than 25 feet from the centerline of the railroad outside track and shall be located outside the ditch section required at that location.

  Where the distance between DART and railroad near tracks is less than 25 feet, or where there would be no means of access to a manhole located between DART tracks and the railroad tracks, the sewer shall be continuous across both the DART and the railroad trackways. New sewers shall be on a straight grade and alignment, be of uniform strength and material throughout its length, and conform to either DART or railroad criteria, depending on which is the most stringent. Extensions for existing sewers shall be of similar style and shape, of compatible materials, and equal to or greater in hydraulic capacity than the existing sewer.

- o Minimum size:

  Minimum size of sewers beneath railroad tracks shall be 18 inches in diameter.

- o Minimum slope:

  Minimum slope for sewers shall be as set forth in Chapter 7 - Drainage.

Conduit Facilities. Utilities wires or cables placed beneath railroad tracks shall be installed in conduits. Utility owner's standard details and specifications shall be used for design of conduit facilities, except where these requirements or the railroad criteria and specifications are more stringent.

Where jacking or boring must be employed, conduits may be steel, or reinforced concrete.

Where open-trench methods are employed, plastic or approved type of nonmetallic conduits shall be encased in concrete according to the utilities or railroad standards, whichever is more stringent.

- o Sizes:

  Conduits shall be a minimum of 4 inches in diameter and shall be on a reasonably straight line and grade beneath the railroad tracks.

Where bends are required, they shall be situated clear of the tracks and shall be of sufficiently large radius to allow the installation of cable without damage.

- o Cover:

The clearance between top of conduit encasement and top of rail shall normally be not less than 5 feet. Where savings may be realized by reduction of this clearance, the section designer shall obtain the approval of the railroad before completing the detailed design.

- o Horizontal clearance:

Manholes shall not be located closer than 25 feet from the centerline of the outside track and shall be located outside the ditch section required at that location. Exceptions may be approved by the railroad.

Where the distance between DART and railroad near tracks is less than 25 feet, or where there would be no means of access to a manhole located between the DART and the railroad tracks, the conduits shall be continuous across both the DART and the railroad trackways.

Table 6-2
MINIMUM COVER FOR UNDERGROUND UTILITIES
(in feet)

UTILITY	TRAFFIC AREAS UNLINED DITCH OTHER UNPAVED	LINED DITCH	DART ROW & PROPERTY	DART LRT CROSSING	RAILROAD CROSING	NON-TRAFFIC
Sanitary Sewer	3	2		4.5*	4.5*	3
Storm Sewer	2	2		5.5*	5.5*	2
Non-flammable Substance Pipelines	3	2		4.5*	4.5*	3
Water	4	4	4	4.5*	4.5*	4
Gas	4	2		5.5*	5.5*	4
Wiring/Cable Conduits	2	2		5**	5**	2

* Top of pipe, casing or encasement to base of rail.

** Top of pipe, casing or encasement to top of rail.

NOTE: Minimum cover outside DART right-of-way shall comply with standard requirements of the jurisdictional municipality.

6.8.2 Aerial Facilities

Utilities wire or cable facilities may cross aerially above railroad tracks or be relocated to cross aerially above railroad tracks. Such facilities may be owned by a power company, telephone and telegraph companies, cable television companies, or other local agencies.

In the absence of railroad criteria and specifications to the contrary or more stringent, aerial facilities shall be designed according to the following criteria. Design of aerial wire and cable relocations shall be performed by the utility owners. The section designer shall coordinate with the respective utility owners to ensure that adequate horizontal and vertical clearance will be provided.

Horizontal Clearance. Where railroad tracks are paralleled or crossed by overhead lines, the poles shall, if practicable, be located outside railroad right-of-way. If location on railroad right-of-way is necessary, the poles shall be not less than 25 feet from the centerline of the nearest track and outside any ditch section required at that location. The exceptions cited below may be necessary in some instances; they shall not be used, however, unless approved by the railroad before completion of the detailed design.

- o Exception 1:

  At sidings, a 15-foot clearance is preferred. The absolute minimum clearance shall be 10 feet from the track centerline provided sufficient space for a driveway is left where railroad cars are loaded or unloaded.

- o Exception 2:

  Where necessary to provide safe operating conditions that require an uninterrupted view of signals and signs along tracks, the parties concerned shall cooperate in locating poles to provide the necessary clearance.

Vertical Clearance. The minimum vertical clearance of wire or cable above the top of rail shall not be less than specified in Table 6-3.

When warranted by conditions of span length, voltage, and method of supporting the conductors, the vertical clearance of wire or cable above top of rail shall be increased in accordance with Article 232B of the National Electrical Safety Code.

Should it be impractical to provide an aerial relocation of an existing aerial wire or cable above a railroad, the facility shall be relocated beneath the railroad trackway in conduit in accordance with the conduit facilities described in Section 6.8.1.

6.9 UTILITY MARKERS

Markers as shown in the utilities standard drawings shall be used to indicate the location of below-grade utilities installations whether belonging to DART, private utilities companies, or local governments.

6.9.1 Location

Markers shall be placed at the centerline of the facility being marked. Lines beginning or ending within the DART right-of-way shall be marked at their ends. Lines crossing DART right-of-way shall be marked at a point near the edge of the subballast shoulder. Track underdrains shall be marked at changes in direction and at outflows. Markers are not required for underdrains extending along bases or tops of retaining walls. Markers, when required, shall be placed on retaining walls in retained sections.

Where a marker location, as prescribed above, results in a conflict with other underground facilities, the marker shall be placed away from the trackbed at a point near the right-of-way line.

Utility markers are not required, however, for storm drains crossing under the DART trackway when the storm drains can be readily located by trackside catch basins, manholes, or headwalls, or when the storm drains are so deep that they will not be affected by trackway work. The section designer shall indicate the location of utility markers on project plan drawings and shall prepare a schedule of utility markers for facilities in their project, defining the legend for each marker. The schedule shall be on a project drawing.

6.9.2 Description

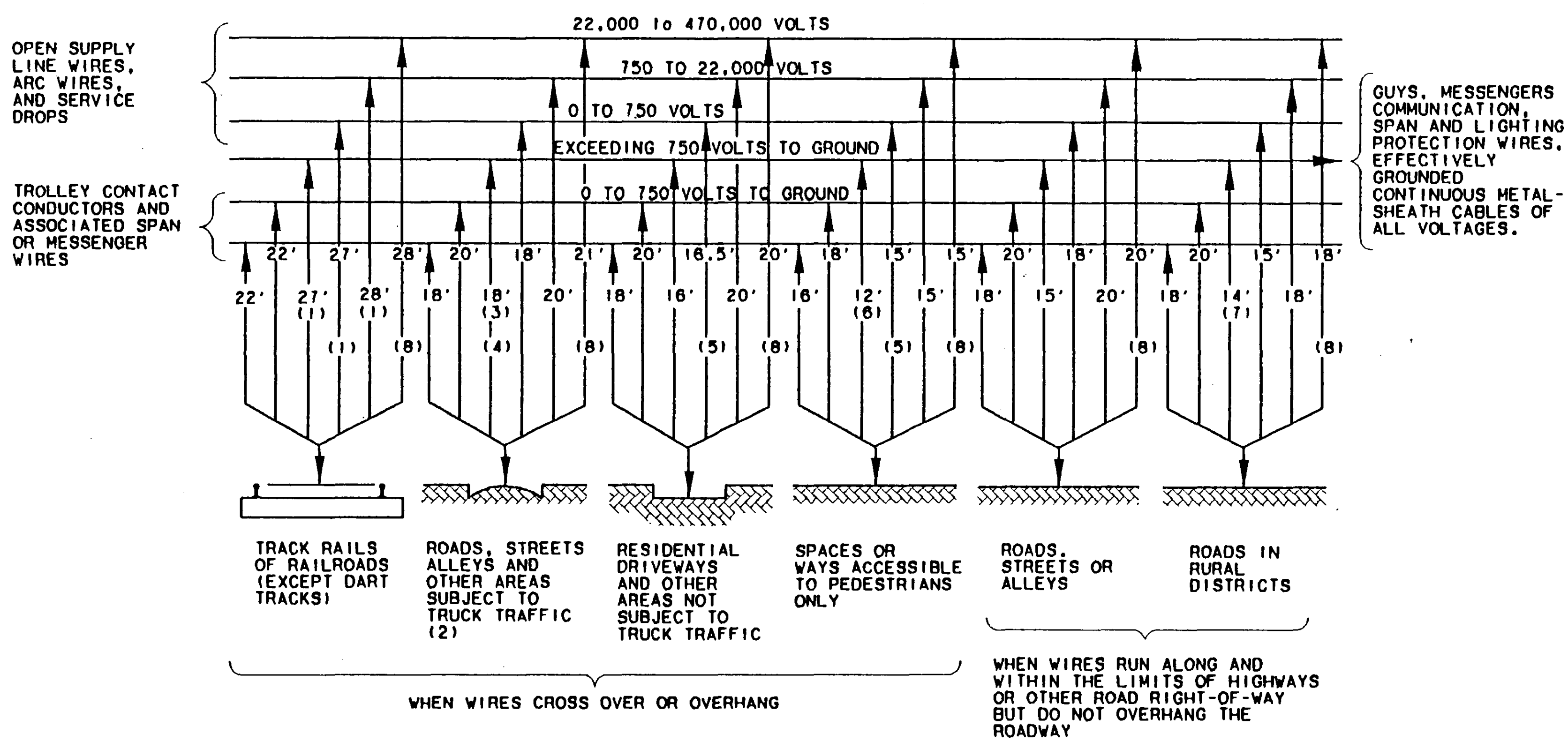
Utilities markers shall consist of a metal target plate mounted vertically on a formed metal post and shall be furnished and installed by the contractor. The front face of the target plate shall be marked as indicated on utilities standard drawings, with the station number, a symbol identifying the type of facility, and the utilities owner. Markers located near the edge of the subballast shoulder shall be oriented so that the front face faces away from the tracks. Markers located away from the trackbed shall be oriented so that the front face faces the tracks.

TABLE 6-3

MINIMUM VERTICAL CLEARANCE OF WIRES AND CABLES ABOVE RAILROAD TOP-OF-RAIL

RAILROADS	Guys; Messengers; Communication, Span, and Lightning Protection Wires; Communication Cable Supply Cable having Effectively Grounded Continuous Metal Sheath, or Insulated Conductors Supported on and Cabled together with an Effectively Grounded Messenger	Open Supply Line Wires, Arc Wires, and Service Drops		
		Less than 750V	750V to 21,999V	22,000 to 50,000V(1)
(Names of the Railroads)				
All Other Railroads in Accordance with National Electrical Safety Code	27 ft.	27 ft.	28 ft.	29 ft.

(1) Over 50,000 volts, add 0.5 inch for each 1,000 volts over 50,000 vol



NOTES:

1. THESE CLEARANCES MAY BE REDUCED TO 25 FT, WHERE PARALLELED BY TROLLEY-CONTACT CONDUCTOR ON THE SAME STREET OR HIGHWAY.
2. THESE CLEARANCES DO NOT ALLOW FOR THE FUTURE ROAD RESURFACING.
3. IF A COMMUNICATION SERVICE DROP OR A GUY WHICH IS EFFECTIVELY GROUNDED CROSSES RESIDENTIAL STREETS AND ROADS. THE CLEARANCE MAY BE REDUCED TO 16 FT. AT THE SIDE OF THE TRAVELED WAY PROVIDED THE CLEARANCE AT THE CENTER OF THE TRAVELED WAY IS AT LEAST 18 FT. THIS REDUCTION IN CLEARANCE DOES NOT APPLY TO ARTERIAL STREETS AND HIGHWAYS WHICH ARE PRIMARILY FOR THROUGH TRAFFIC, USUALLY ON A CONTINUOUS ROUTE.
4. FOR COMMUNICATIONS CABLE SUPPORTED ON A MESSENGER, AND WITH SPAN LENGTHS NOT EXCEEDINIG 150 FT, THE CLEARANCE MAY BE REDUCED TO 17 FT ABOVE OR ALONG LOCAL STREETS OR ROADS. THIS REDUCTION DOES NOT APPLY FOR ARTERIAL STREETS OR HIGHWYS WHICH ARE PRIMARILY FOR THROUGH TRAFFIC, USUALLY ON A CONTINUOUS ROUTE.
5. THIS CLEARANCE MAY BE REDUCED TO 12 FT, FOR SUPPLY CONDUCTORS LIMITED TO 300V TO GROUND.
6. THIS CLEARANCE MAY BE REDUCED TO 10.5 FT FOR INSULATED SERVICE DROPS LIMITED TO 300V TO GROUND.
7. THIS CLEARANCE MAY BE REDUCED TO 13.5 FT FOR COMMUNICATION CONDUCTORS.
8. FOR VOLTAGES EXCEEDING 22,000 VOLTS, THE CLEARANCE SHALL BE INCREASED BY 0.4 INCH FOR EACH 1,000 VOLTS, OR FRACTION THEREOF, IN EXCESS OF 22,000 VOLTS. FOR VOLTAGES IN EXCESS OF 470,000 VOLTS, REFER TO NATIONAL ELECTRICAL SAFETY CODE.

ACT 21
CARTER BURGESS
JACOBS ENGINEERING
STV INCORPORATED
KAI ALLIANCE

DART PROJECT

DART

DART DESIGN CRITERIA

VERTICAL CLEARANCES OF WIRES ABOVE GROUND OR RAILS

SCALE: NOT TO SCALE
FIGURE: 6.1

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no ref logical, *no ref name*, *no ref levels*
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Fri Feb 21 09:48:57 2003
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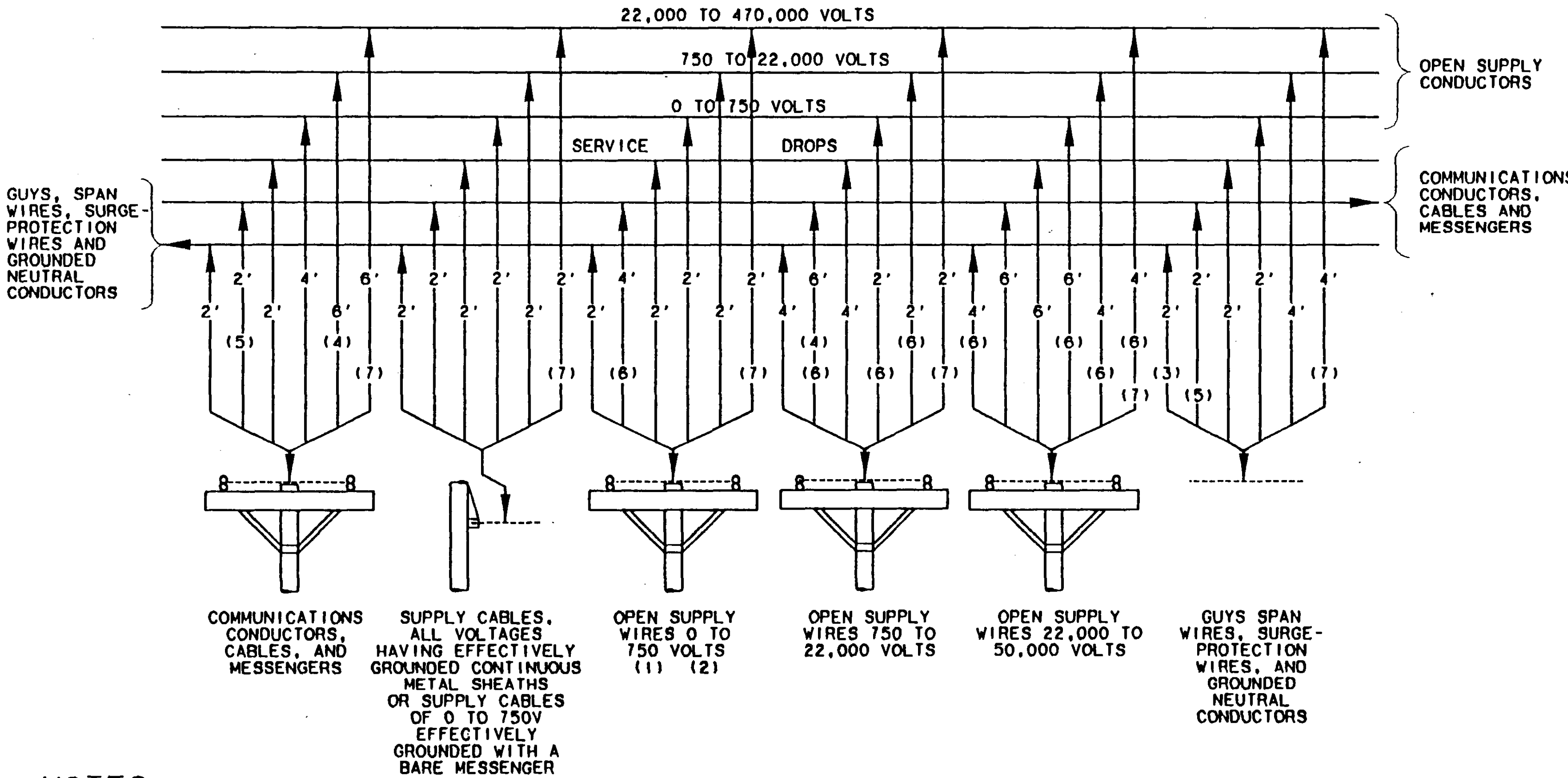

NOTES:

1. FOR CLEARANCE PURPOSES, INSULATED, NON-SHIELDED CABLES CARRYING 750 TO 2,900 VOLTS SUPPORTED ON AND CABLED TOGETHER WITH AN EFFECTIVELY GROUNDED BARE MESSENGER SHALL BE TREATED AS OPEN SUPPLY CONDUCTOR CARRYING 0 TO 750 VOLTS.

2. FOR CLEARANCE PURPOSES, CABLES OF ANY VOLTAGE OVER 750 VOLTS, COVERED WITH A CONTINUOUS AUXILIARY SEMICONDUCTING SHIELD IN COMBINATION WITH SUITABLE METALLIC DRAINAGE AND SUPPORTED ON AND CABLED TOGETHER WITH AN EFFECTIVELY GROUNDED BARE MESSENGER SHALL BE TREATED AS OPEN SUPPLY CONDUCTOR CARRYING 0 TO 750 VOLTS.

3. THIS CLEARANCE MAY BE REDUCED WHERE BOTH GUYS ARE ELECTRONICALLY INTERCONNECTED.

4. THIS CLEARANCE MAY BE REDUCED TO 4 FEET, WHERE SUPPLY CONDUCTORS OF 750V TO 8.7KV CROSS A COMMUNICATION LINE MORE THAN 6 FEET HORIZONTALLY FROM A COMMUNICATION STRUCTURE.

5. THE CLEARANCE OF COMMUNICATION CONDUCTORS AND THEIR GUY, SPAN, AND MESSENGER WIRES FROM EACH OTHER IN LOCATIONS WHERE NO OTHER CLASSES OF CONDUCTORS ARE INVOLVED MAY BE REDUCED BY MUTUAL CONSENT OF THE PARTIES CONCERNED, SUBJECT TO THE APPROVAL OF THE REGULATORY BODY HAVING JURISDICTION, EXCEPT FOR FIRE-ALARM CONDUCTORS AND CONDUCTORS USED IN THE OPERATION OF RAILROADS, OR WHERE ONE SET OF CONDUCTORS IS FOR PUBLIC USE AND THE OTHER IN THE OPERATION OF SUPPLY SYSTEMS.

6. IN GENERAL, THIS TYPE OF CROSSING IS NOT RECOMMENDED.

7. FOR VOLTAGES EXCEEDING 22,000 VOLTS, THE CLEARANCE SHALL BE INCREASED BY 0.4 INCH FOR EACH 1,000 VOLTS OR FRACTION THEREOF, IN EXCESS OF 22,000 VOLTS. IF BOTH UPPER AND LOWER WIRES EXCEED 22,000 VOLTS CALCULATE INCREASES SEPARATELY FOR UPPER AND LOWER WIRES AND ADD BOTH TO CLEARANCE, FOR VOLTAGE MOVE.

ACT 21
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STV INCORPORATED
KAI ALLIANCE

DART PROJECT

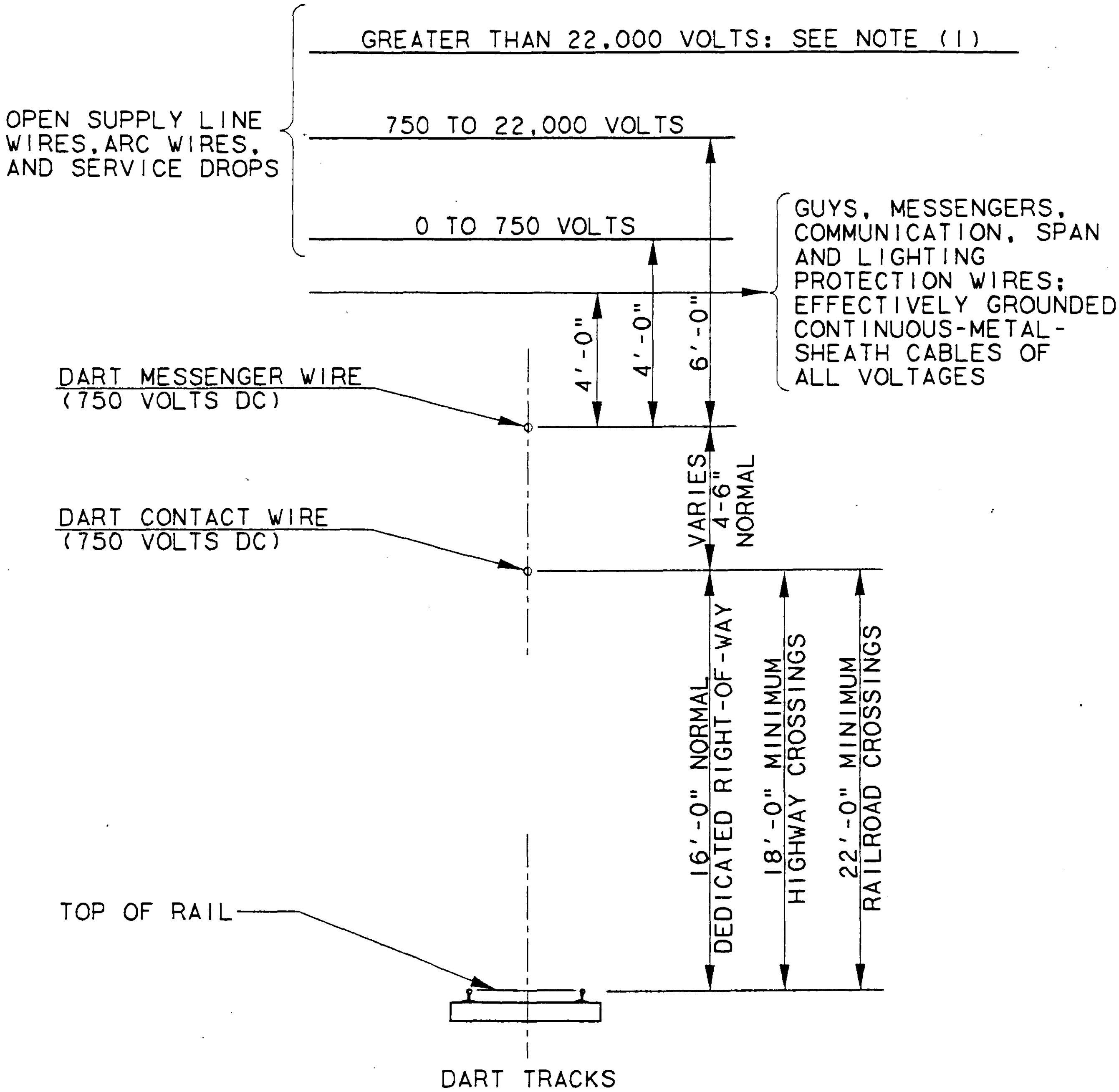
DART DESIGN CRITERIA

WIRE CROSSING CLEARANCE

SCALE: NOT TO SCALE

FIGURE: 6.2

JAN. 2003, REV 10



NOTE (1):

FOR VOLTAGES EXCEEDING 22,000 VOLTS, (UP TO 470,000 VOLTS), THE CLEARANCE SHALL BE INCREASED BY 0.4 INCH FOR EACH 1,000 VOLTS, OR FRACTION THEREOF, IN EXCESS OF 22,000 VOLTS. FOR VOLTAGES ABOVE 470,000, REFER TO NATIONAL ELECTRICAL SAFETY CODE.

ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA VERTICAL CLEARANCES OF WIRES ABOVE DART TRACKS SCALE: NTS FIGURE: 6.3

JAN. 2003, REV 10

CHAPTER 7 - DRAINAGE

7.1 INTRODUCTION

These criteria shall govern the planning, design, construction, and operation of all storm drainage facilities located within the DART right-of-way, as well as those facilities directly affected by DART construction. Design of drainage facilities that are not located within the DART right-of-way and are relocated or modified because of DART construction shall conform to the design and construction criteria of the municipality or public agency having jurisdiction for the affected drainage facility. In general, required relocation of existing drainage facilities shall be "replacement-in-kind" or "equal construction" unless conditions of flow, loading, or operation are altered. If conditions are altered, design(s) shall conform to the design criteria and standards of the public agency involved.

Planning and design of DART-constructed facilities will be in accordance with the criteria and standards of other public agencies having jurisdiction, to the extent they apply to the DART construction. This will apply to drainage facilities constructed within public right-of-way or utility or drainage easements, and any drainage facilities in DART right-of-way or parking lots which will impact on drainage facilities within the public right-of-way. DART's drainage criteria, as provided herein, will apply:

1) In the absence of jurisdiction by another public agency.

2) When additional or more stringent criteria are needed to protect the DART trackway or facilities, and the DART criteria are not inconsistent with the criteria of the agency having jurisdiction.

The DART design criteria provided in this chapter is a compilation of criteria which includes the City of Dallas Design Manual For Storm Drainage Facilities, TxDOT Hydraulic Manual, and other sources. It is the intent of this manual to conform to the requirements of the local jurisdiction, unless DART has need for more stringent requirements to protect any facilities or accommodate passengers. The criteria of the various local, state, or federal agencies having jurisdiction appear in several different documents and would be too voluminous to incorporate in their entirety in these criteria to cover all circumstances. For that reason, these criteria could not be all inclusive with respect to the criteria of other agencies having jurisdiction. The designer will be required to use the criteria of other agencies having jurisdiction and prepare their design in accordance with the most stringent applicable criteria.

These design criteria are intended to protect the DART system and facilities from storm runoff damage, and to protect DART from liability for damage to other property from storm runoff either passing through or caused by construction of the system.

This chapter addresses primarily the hydrology and hydraulic aspects of the drainage design criteria. Chapter 6-Utilities, addresses criteria on the relocation and construction of drainage structures, as well as the variety of utility services, which will be associated with the construction of the DART system. That criteria is not repeated in this chapter. Chapter 6 also discusses plan preparation requirements, including the utilities and drainage facilities requirements of local agencies.

7.1.1 Design Assumptions

Drainage facilities for the system shall be designed so that the proposed improvements will not:

- o Increase the flood or inundation hazard to adjacent property.
- o Raise the flood level of a drainage way.
- o Reduce the flood storage capacity or impede the movement of floodwater within a drainage way.

Drainage facilities shall be designed for a fully developed watershed and existing zoning. If the system alignment crosses a floodplain, alternatives shall be considered to prevent an increase in the flood hazard to adjacent, upstream, or downstream property. Provision of compensatory flood storage is to be considered in each instance where fill reduces the existing flood storage area. When inundation of, or damage to the trackbed resulting from runoffs in excess of the capacities of existing drainage facilities may occur, consideration shall be given to enlargement of the existing system. Detention storage shall be considered as an alternate to enlargement of an existing downstream system. Where detention is used, a surface detention system, subsurface detention system, or infiltration system may be used. The method selected shall generally be one that is the most cost effective, considering costs of property, facility construction, and facility maintenance.

7.1.2 Drainage Report

All drainage designs shall be contained in a drainage report that shall be submitted to DART and the GEC for review and approval. The drainage report shall be in a form to provide the basis for timely and consistent review and shall be made a part of the permanent record for future evaluation.

The drainage report shall contain, as a minimum, the following:

- Description and plan of existing drainage facilities.

- Description and plan of proposed drainage facilities (which may be half size reduction of preliminary or final design plans).

- Drainage area map.

- Consideration and evaluation of alternatives and selection of preferred drainage facilities.

- All calculations for evaluating the existing drainage facilities and designing the proposed facilities using standardized calculation forms (Figures 7-1 through 7-7) or a computer output table(s) with format similar to the standardized calculation forms.

- A certificate signed and sealed by a professional engineer registered in the state of Texas that the design procedure is in full compliance with the requirements of these criteria.

- Fulfillment of all criteria as established by the applicable jurisdiction, where required to obtain governing jurisdiction approval or permits from other than DART.

- Evaluation of maintenance impacts on existing systems and preferred maintenance procedures for the proposed system.

Drainage Area Map. The drainage area map shall have an easily legible scale of 1 inch equals 200 feet or larger, if required, showing street and/or DART right-of-way. The map may be a preliminary version of the 200-scale or larger drainage area map required as a part of the construction drawings. The drainage area map shall show onsite and offsite drainage and any water courses adjacent to the project. The area shall be divided into numbered subareas to determine flow concentration points or inlet location(s). Drainage area maps shall show zoning, zoning boundaries, existing ground elevations on at least 5-foot contours, and be accompanied by a summary table of peak design flows for subareas with acreage, runoff coefficient and intensity shown.

Quantity and direction of design flow within streets, alleys, natural and man-made drainage ways, and at all system intersections shall be shown. Existing and proposed drainage inlets, storm drainage systems, and drainage channels shall be clearly shown and differentiated on the drainage area map. Plan-profile storm sewer or drainage improvements limits shall also be shown, as will public agency existing storm drainage system file or record numbers, if applicable.

Floodplain. Alteration of any floodplain shall require a hydraulic performance analysis and include a compilation of documentation required by the governing regulatory agency(s) for permitting. The required documentation shall be presented to DART for review and approval. DART will then submit the documentation to the governing regulatory agency.

FIGURE 7-1

INLET DESIGN CALCULATIONS, FIGURE 7-1

Column 1	Inlet identification shall be the same as the drainage area designation shown on D.A. Map.
Column 2	Plan center line station where inlet is located and either left or right.
Column 3	Drainage area number from D.A. Map contributing surface flow to the inlet.
Column 4	Storm flow discharge to the inlet, obtained from data on D.A. Map.
Column 5	Carry-over discharge from upstream inlet.
Column 6	Total discharge to the inlet = Q +CO.
Column 7	Reciprocal of the street cross slope (i.e. for a 1/4 inch per foot cross slope Z =12/ ¼ =48) Use the average slope equivalent for parabolic crown.
Column 8	Manning's roughness coefficient, obtained from Table 7-7. Use n = 0.0175 for paved street gutters.
Column 9	Slope of gutter.
Column 10	Depth of flow in feet in the gutter for a given Q, S and z/n and is determined by $Y = \left(\frac{Q}{(0.56)(z/n)(s^{1/2})}\right)^{3/8}$
Column 11	Width of street conveying flow - z(y) and is also called ponding width. Note: If the allowable gutter capacity is exceeded, as determined from Figure 7-10, Figure 7- 11, or Figure 7-12, then relocate the inlet upstream.
Column 12	Gutter depression in feet (vertical distance from normal gutter line to throat of inlet).
Column 13	Rate of flow per foot of inlet for a given depth "y" and depression "a" and is determined from Figure 7-16.
Column 14	Length of curb inlet necessary to intercept all of the discharge Column 6 divided by Column 13.
Column 15	Actual length of inlet selected and shall be not less than 5 feet.
Column 16	Column 15 divided by Column 14.
Column 17	Column 12 divided by Column 10.
Column 18	Ratio of Q_i (intercepted) to Q_a (actual) and is obtained from Figure 7-17.

Column 19 Discharge intercepted by the inlet. Obtained from multiplying Column 6 by Column 18.

Column 20 Subtract Column 6 from Column 19.

Column 21 Downstream inlet to receive the carry-over flow.

Column 22 Self explanatory.

GUTTER FLOW / INLET COMPUTATIONS

INLET ID	INLET LOCATION	D.A. No.	Q cfs	CO cfs	Qa cfs	z	n	s ft/ft	y ft	w ft	a ft	qL cfs/ft	Lr ft	La ft	La/Lr	a/y	QI/QA	QI cfs	QI-Qa cfs	Carry-over to:	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22

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INLET DESIGN CALCULATIONS

SCALE: N.T.S. FIGURE: 7-1

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FIGURE 7-2

STORM SEWER CALCULATIONS, FIGURE 7-2

Column 1	Upstream station of the section of conduit being designed. Normally, this would be the point of a change in quantity of flow, such as an inlet, or a change in grade.
Column 2	Downstream station of the section of conduit being designed.
Column 3	Distance in feet between the upstream and downstream stations.
Column 4	Drainage subarea designation from which flow enters the conduit at the upstream station.
Column 5	Area in acres of the drainage subarea entering the conduit.
Column 6	Runoff coefficient, obtained from Table 7-2, based on the characteristics of the subarea drainage.
Column 7	Column 5 multiplied by column 6.
Column 8	Obtained by adding the values shown in column 7 to the value shown immediately above in column 8.
Column 9	This time in minutes is transposed from column 19 on the previous line of calculations. The original time shall be equal to the time of concentration as shown on Table 7-3 or Figure 7- 9, whichever value has been used.
Column 10	Design storm frequency.
Column 11	Using the time at the upstream station shown in column 9 and the design storm frequency shown in column 10, this value is taken from Figure 7-8a or 7-8b.
Column 12	Column 8 multiplied by column 11.
Column 13	This slope should be computed from Figures 7-19, 7-22, 7-25 or nomographs in the SDHPT Hydraulic Manual. Normally, the hydraulic gradient will have a slope approximately the same as the proposed conduit and will be located above the inside crown of the conduit.
Column 14	Utilizing the value in column 12, a conduit size should be selected so that the conduit and hydraulic gradient comply with Section 7.5.2.
Column 15	Velocity in the selected conduit based on the values in columns 12, 13, and 14, taken from Figures 7-21, 7-24, and 7-27 for concrete pipe. If pipe is flowing less than full, velocity shall be computed based on actual depth of flow.
Column 16	Minor head loss coefficient obtained from Figure 7-28 or Figure 7-29.
Column 17	Head loss at the upstream junction calculated by mulitplying Column 16 by velocity squared and divided by two times the acceleration due to gravity, g.
Column 19	Sum of columns 9 and 18.

Column 20 Special design comments may be entered here.

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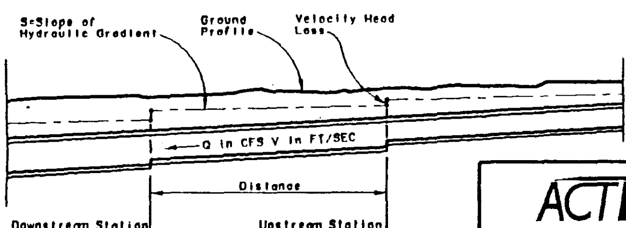
RUNOFF COLLECTION POINT (Inlet or Manhole)		Distance Between Collection Points	INCREMENTAL DRAINAGE AREA				Accum-ulated "CA"	Time at Upstream Station (MIN)	Design Storm Frequency (YRS)	Intensity "I" (Inches/hr.)	Storm Water Runoff "Q" (CFS)	Slope of Hydraulic Gradient "S" (FT/FT)	Selected Storm Sewer Size	Velocity in Sewer Between Collection Points "V" (FPS)	Velocity Head Loss Coeff. KJ	Velocity Head Loss at Upstream Station $Kj\frac{V^2}{2g}$ (feet)	Flow Time in Sewer $\frac{\text{Distance}}{\text{Vx60}}$ (MIN)	Time at Downstream Station (MIN)	REMARKS
UPSTREAM STATION	DOWNSTREAM STATION		Area NO	Drainage Area "A" (Acres)	Runoff Coeff. "C"	Incremental "CA"													
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20



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STORM SEWER CALCULATIONS

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FIGURE: 7-2

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FIGURE 7-3

DRAINAGE RUNOFF CALCULATIONS, FIGURE 7-3

Column 1	Description of runoff collection point.
Column 2	Drainage subarea designation from which flow enters the conduit at the upstream station.
Column 3	Area in acres of the drainage subarea entering the conduit.
Column 4	Runoff coefficient, obtained from Table 7-2, based on the characteristics of the subdrainage area.
Column 5	Column 3 multiplied by column 4.
Column 6	Obtained by adding the value shown in Column 5 to the value shown in column 6, above.
Column 7	The original time shall be equal to the time of concentration as shown on Table 7-3 whichever value has been used. Subsequent times are calculated by using the time of concentration for the subarea drainage or the previous value in column 7 plus the routing time, whichever is greater.
Column 8	Design storm frequency.
Column 9	Using the time at the upstream station shown in Column 9 and the design storm frequency shown in Column 10, this value is taken from Figure 7-8a or 7-8b.
Column 10	Column 6 multiplied by Column 9.

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RUNOFF COLLECTION POINT	INCREMENTAL DRAINAGE AREA				ACCUM-ULATED "CA"	Time of Upstream Station (MIN)	Design Storm Frequency (YRS)	INTENSITY "I" (IN/HR)	Storm Water Runoff "Q" (CFS)
	Area NO	Drainage Area "A"(Acres)	Runoff Coeff. "C"	Incremental "CA"					
1	2	3	4	5	6	7	8	9	10

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DRAINAGE RUNOFF CALCULATIO
(FOR FORMS 7-4a, 7-4b, 7-5
& 7-6

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FIGURE: 7-3

JAN. 2003, REV 10

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FIGURE 7-4a

NATURAL CHANNEL CALCULATIONS, FIGURE 7-4a

Column 1 At each point where a water surface elevation is desired, a cross section must be obtained. The sections are numbered and subdivided according to the assigned roughness coefficient. Sections are stationed in increasing numbers going upstream and drawn looking downstream. Start at the section farthest downstream.

Column 2 Known or assumed water surface elevation at the particular section.

Column 3 Weighted distance along the channel between sections.

$$\left(L = \frac{L1Q1 + LcQc + LrQr}{Q}\right)$$

Q_l, L_l = Left overbank flow and distance
Q_c, L_c = Center channel flow and distance
Q_r, L_r = Right overbank flow and distance

Column 4 Area of subsection calculated from plotted cross sections.

Column 5 Wetted perimeter of each subsection exclusive of the water interfaces between adjacent subsections.

Column 6 Column 4 divided by column 5 (hydraulic radius).

Column 7 Roughness coefficient for Manning's formula from Table 7-7.

Column 8 Column 4 multiplied by 1.486 times column 6 raised to the two-thirds power and the product divided by column 7.

Column 9 The total flow in the total section divided by the sum of column 8 for that section and squared, which is the friction slope.

Column 10 Column 9 multiplied by column 3.

Column 11 Flow from each individual subsection. Varies directly with the conveyance factor shown in column 8. The sum of the values must equal the total flow.

Column 12 Column 11 divided by column 4.

Column 13 Sum of the values in column 12 of a particular section squared and multiplied by column 11 divided by twice the acceleration of gravity and multiplied by the total flow.

Column 14 Algebraic differences in velocity heads between sections.
Note: hv2 applies to the downstream section.

Column 15 Eddy losses are calculated as 10 percent of the value of column 14 when such value is positive, and 50 percent of the value of column 14 when such value is negative.

Column 16 Sum of column 10, column 14 and column 15.

Column 17 The sum of the value shown in column 2 for the previous section and the value in column 16. If the elevations calculated for subsequent sections do not agree within a reasonable limit with the assumed elevations shown in column 2 for that particular section, then the assumed elevations for such sections must be revised and the section properties recomputed until the desired accuracy is obtained. An accuracy of 0.3 foot is considered a reasonable limit.

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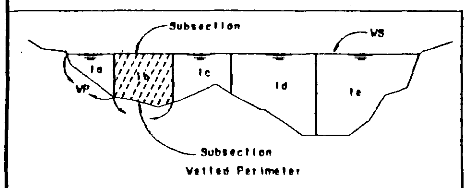
Section and Subsection	Known or Assumed W.S. Elevation	Distance Between Subsection "L" (FT)	Subsection Area "AS" (SQ FT)	Subsection Wetted Perimeter "WP" (FT)	Subsection Hydraulic Radius "R" = $\frac{A_S}{WP}$	Subsection Roughness Coefficient "n"	Conveyance Factor "Y" = $\frac{1.486 A_S}{n}(R^{2/3})$	Friction Slope "S_f" = $\left(\frac{Q_T}{\Sigma Y}\right)^2$ (FT/FT)	Friction Head Loss Between Sections "h_f" = Avg. S_f(L)	Subsection Flow "Q_S" (CFS)	Subsection Velocity "VS" = $\frac{Q_S}{A_S}$ (FPS)	Weighted Velocity Head "h_v" = $\frac{\Sigma V_S^2 Q_S}{2g Q_T}$	Velocity Head Loss "$h_{v\Delta}$" = $h_{v1} - h_{v2}$	Eddy Losses "E_I" = .10(+$h_{v\Delta}$) or .50(-$h_{v\Delta}$) (FT)	Total Loss "ΔH" = (h_f)+($h_{v\Delta}$)+(E_I)	WATER SURFACE ELEVATION	REMARKS
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18



TYPICAL SECTION

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NATURAL CHANNEL CALCULATIONS
MULTI-SECTION METHOD

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FIGURE: 7-4a

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FIGURE 7-4b

CHANNEL CALCULATION, FIGURE 7-4b

Column 1	Downstream limit of the section of channel under consideration.
Column 2	Upstream limit of the section of channel under consideration.
Column 3	Type of channel is entered here.
Column 4	Flow in the section of channel under consideration.
Column 5	Roughness coefficient of the channel cross section taken from Table 7-7.
Column 6	Slope of the channel which is normally set near parallel to slope of the hydraulic gradient.
Column 7	Calculation is made using the values in columns 4, 5, and 6.
Column 8	Assumed width of the bottom of the channel.
Column 9	Assumed depth of flow.
Column 10	Assumed slope of the sides of the channel.
Column 11	Area of flow which is calculated based on columns 8, 9, and 10.
Column 12	Wetted perimeter calculated from columns 8, 9 and 10.
Column 13	Value is calculated from columns 11 and 12.
Column 14	Column 11 times column 13 raised to the two-thirds power. When the value of column 14 equals the value of column 7, the channel has been adequately sized. When the value of column 14 exceeds the value of column 7 by more than 5 percent, then the channel width or depth should be decreased and another trial section analyzed.
Column 15	Calculation is based on the values of columns 4 and 11.
Column 16	Calculation is based on column 15.
Column 17	Remarks concerning the channel section analyzed may be entered here.

Note: Figure 7-4b should be used to size open channels only. Figure 7-4a should be used to calculate stream profile.

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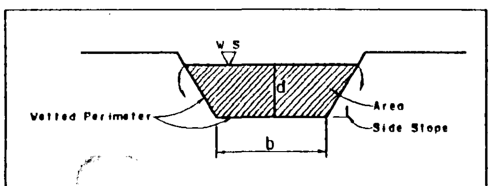
CHANNEL STATION From	CHANNEL STATION To	Channel Type	Flow "Q" (CFS)	Roughness Coeff. "n"	Slope "S" (FT/FT)	$\frac{Q \times n}{1.486 \times S^{1/2}}$	Width "b" (FT)	Depth "d" (FT)	Slide Slope	Area "A" (SQ FT)	Wetted Perimeter "WP" (FT)	Hydraulic Radius "R" = $\frac{A}{WP}$	$A \times R^{2/3}$	Velocity $V = \frac{Q}{A}$ (FPS)	Velocity Head $\frac{v^2}{2g}$ (FT)	REMARKS
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

JAN. 2003, REV 10



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CHANNEL CALCULATIONS

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FIGURE 7-5

CULVERT DESIGN CALCULATIONS, FIGURE 7-5

INFORMATION IN LOWER RIGHT OF SHEET:

Culvert Location -- This is a word description of the physical location.

Length -- The actual length of the culvert.

Total Discharge Q -- Refer to Section 7.2

Design Storm Frequency -- Refer to Section 7.2

Roughness Coefficient, n -- Refer to Table 7-7

Maximum Velocity -- Obtained from Table 7-5.

Tailwater -- This is the design depth of water in the downstream channel and is obtained in connection with the channel design performed on Figure 7-4a or 7-4b.

Downstream Channel Width -- This is the bottom width of the downstream channel obtained from the calculations of Figure 7-4a or 7-4b. The culvert should be sized to approximate this width whenever possible.

Entrance Description -- This is a listing of the actual condition as shown in TxDOT Hydraulic Manual.

Roadway Elevation -- The elevation of the top of curb or top of ballast at the upstream end of culvert.

Upstream Culvert Flow Line -- The flow line of the culvert at the upstream end.

Difference -- The difference in elevations of the roadway and the upstream flow line.

Required Freeboard -- The vertical distance required for safety between the upstream design water surface and the roadway elevation or such other requirements that may occur because of particular physical conditions.

Allowable Headwater -- This is obtained by subtracting the freeboard from the difference shown immediately above.

Downstream Culvert Flow Line -- The flow line elevation of the downstream end of the culvert.

Culvert slope S_0 -- This is the physical slope of the structure calculated as indicated.

Entrance loss coefficient C_e -- Refer to TxDOT Hydraulic Manual.

Columns 1 through 10 deal with selection of trial culvert size and are explained as follows:

Column 1 Total design discharge, Q, passing through the culvert divided by the allowable maximum velocity gives trial total area of culvert opening.

Column 2 Culvert width should be reasonably close to the channel bottom width, W, downstream of the culvert.

Column 3 Lower range for choosing culvert depth is trial area of culvert opening, column 1, divided by channel width, column 2.

Column 4 Allowable headwater obtained from lower right of sheet.

Column 5 Trial depth, D, of culvert corresponding to available standard sizes and between the numerical values of columns 3 and 4.

Column 6, 7, and 8 are solved simultaneously based on providing a total area equivalent to the trial area of opening in column 1.

Column 6 Number of culvert openings.

Column 7 Inside width of one opening.

Column 8 Inside depth of one opening if culvert is box structure, or diameter if culvert is pipe.

Column 9 Column 6 multiplied by column 7 and column 8 if culvert is a box culvert, or column 6 multiplied by the cross-sectional area of one pipe if culvert is pipe.

Column 10 Total discharge divided by number of openings shown in column 6.

Columns 11 through 15 (inlet control) and 16 through 27 (outlet control) deal with headwater calculations which verify hydraulics of trial culvert selected and are explained as follows:

Column 11 Obtained from lower right of sheet.

Column 12 Calculated as per TxDOT Hydraulic Manual.

Column 13 Calculated $\frac{Vc^2}{2g}$ as per TxDOT Hydraulic Manual.

Column 14 Calculated as per TxDOT Hydraulic Manual.

Column 15 Column 12 added to columns 13 and 14.

Column 16 Obtained from TxDOT Hydraulic Manual.

Column 17 For Case IIA, d_c is calculated from TxDOT Hydraulic Manual. For Case IIB, tailwater depth from lower right of sheet.

Column 18 For Case IIA and Case IIB, $\frac{Vc^2}{2g}$ calculated as per TxDOT Hydraulic Manual.

Column 19 For Case IIA, h_e is calculated as per TxDOT Hydraulic Manual. For Case IIB, h_e is calculated as per TxDOT Hydraulic Manual.

Column 20 Lower right of sheet: L multiplied by S_o.

Column 21 Obtained from TxDOT Hydraulic Manual.

Column 22 Column 17 added to columns 18, 19, and 20 minus column 21.

Column 23 Obtained from TxDOT Hydraulic Manual.

Column 24 Obtained from TxDOT Hydraulic Manual.

Column 25 Obtained from lower right of sheet for TxDOT Hydraulic Manual.

Column 26 Same number as column 21.

Column 27 The sum of columns 24 and 25 minus column 26.

Column 28 Enter the larger of the values from either column 15, column 22, or column 27. This determines the controlling hydraulic conditions of the particular size culvert investigated.

Column 29 When the engineer is satisfied with the hydraulic investigations of various culverts and has determined which would be the most economical selection, the description should be entered.

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TRIAL CULVERT										HEADWATER CALCULATION																	The Greater Controlling Head Water (Inlet or Outlet) (FT)	SELECTED CONDUIT SIZE
		DEPTH RANGE D.R.			POSSIBLE CULVERT SIZES					INLET CONTROL					OUTLET CONTROL													
										$HW = d_c + \frac{V_c^2}{2g} + h_e$					CASE I A $HW + d_c + V_2^2/2g + h_e + h_f - LS_o$ B $HW + TW + V_{TW}^2/2g + h_e + h_f - LS_o$							CASE II A $HW + H + TW - LS_o$ B $HW + H + P - LS_o$						
Trial Area Of Opening $A_i = \frac{Q}{V_{max}}$ (SQ FT)	Channel Width "W" (FT)	$\frac{A_i}{W}$ (FT)	AHW (FT)	Try Depth "D" (FT)	No. Openings	Width of Box "B" (FT)	Box Depth or Pipe Dia. "D" (FT)	Total Culvert Area "Ac" (SQ FT)	"Q" Each Opening (CFS)	Entrance Loss Coeff. Ce	d_c (FT)	$\frac{V_2^2}{2g}$ (FT)	h_e (FT)	HW (FT)	Case No.	d_c or TW (FT)	$\frac{V^2}{2g}$ (FT)	h_e (FT)	h_f (FT)	LSo (FT)	HW (FT)	Case No.	H (FT)	TW or P (FT)	LSo (FT)	HW (FT)		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29

SKETCH OF CULVERT

Culvert Location __________

__________ Length, L __________

Total Discharge, Q __________ Design Storm Freq __________

Roughness Coeff, n __________ Max Vel __________

Tailwater __________ D S Channel width __________

Entrance Description __________

Rdwy Elev __________	U S Culv F L __________
U S Culv FL __________	D S Culv F L __________
Difference __________	Difference __________
	Culv Slope, $S_o = \frac{\text{Diff FT}}{\text{Length FT}}$
Req'd Freeboard __________ FT	S_o = __________
Allow Headwater __________ FT	C_o = __________

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CULVERT DESIGN CALCULATIONS

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FIGURE 7-6

BRIDGE DESIGN CALCULATIONS, FIGURE 7-6

Columns 1 and 2 obtained from calculations on Figures 7-3, 7-4a, and/or 7-4b.

Column 3 — Assume an average velocity that is less than the maximum allowable velocity and more than 4 feet per second. Maximum velocities are equal to those specified for open channels. Refer to Table 7-5. Velocity should be approximately the same as the velocity of the main channel of the stream.

Column 4 — Total flow as shown on lower part of sheet divided by column 3.

Column 5 — Column 4 divided by column 2.

Column 6 — Selected bridge length utilizing standard span lengths.

Column 7 — Calculated from bridge and channel geometrics.

Column 8 — Total flow through bridge divided by column 7.

Column 9 — Selected head loss coefficient based upon specific conditions.

Values of K_b normally will vary 0.2 to 0.5 with exact value to be determined by the designer. With a minimum of constriction and change in velocity, a clear span bridge would have a minimum coefficient. It would increase for multispan bridges or with skewed piers not placed perpendicular to the flow.

Column 10 — Calculated by using values in columns 8 and 9; should be less than 0.5 foot.

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Velocity in Downstream channel "V_c" (FPS)	Depth of Flow in Downstream Channel "D" (FT)	Trial Velocity through Bridge "V_T" (FPS)	Trial opening Area "A_T" = $\frac{Q}{V_T}$ (SQ FT)	Trial Length of Opening "L_T" = $\frac{A_T}{D}$ (FT)	Actual Length of Opening "L" (FT)	Actual Area of Opening Below Highwater "A" (SQ FT)	Actual Velocity through Bridge "V" = $\frac{Q}{A}$ (FPS)	Head Loss Coefficient "K_b"	Head Loss through Bridge "h_f" = $K_b\left(\frac{V}{2g}\right)$ (FT)
1	2	3	4	5	6	7	8	9	10

Q=__________ CFS

Location:______________________________

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BRIDGE DESIGN CALCULATIONS

SCALE: N.T.S.

FIGURE: 7-6

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JAN. 2003, REV 10

FIGURE 7-7

DETENTION BASIN STORAGE CALCULATIONS, FIGURE 7-7

Column 1 Obtained from zoning or existing use maps.

Column 2 "C" from Table 7-2.

Column 3 Individual subbasin area Ai, as computed on area drainage map.

Column 4 Product of columns 2 and 3.
Values for existing time of concentration (t_{ce}) and proposed time of concentration (t_{cp}) are determined from Figure 7-9. Weighted coefficients for existing and proposed conditions are determined using the totals in columns 3 and 4. The maximum outflow rates for Q2yr, Q5yr, and Q100yr are computed with t_{ce} and corresponding I from column Q2yr, Q5yr, or Q100yr from Figure 7-8.

Columns 7, 11, 15 Compute V_I for 2-, 5-, and 100-year frequency storm, using:

$$V_I = \frac{CwpiAT}{726}$$

commencing with $T = t_{ce}$.

Columns 8, 12, 16 Compute $V_o = \dfrac{(t_{cp} + T)\, Q_o}{1452}$

Columns 9, 13, 17 Column 7 minus column 8; column 11 minus column 12; and column 15 minus column 16, respectively. Continue computation until Vs reaches a maximum. The larger of the maximum in columns 9, 13, and 17 is to be used as the basic design value.

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	2 - Year Frequency Storm				5 - Year Frequency Storm				100 - Year Frequency Storm			
T (MIN)	I (IN/HR)	V_I (AC-FT)	V_O (AC-FT)	V_S (AC-FT)	I (IN/HR)	V_I (AC-FT)	V_O (AC-FT)	V_S (AC-FT)	I (IN/HR)	V_I (AC-FT)	V_O (AC-FT)	V_S (AC-FT)
5	6	7	8	9	10	11	12	13	14	15	16	17
5	6.00				6.96				10.56			
10	5.04				5.88				8.88			
15	4.30				5.00				7.56			
20	3.87				4.55				6.97			
25	3.45				4.09				6.39			
30	3.02				3.64				5.80			
40	2.66				3.23				5.19			
50	2.31				2.83				4.57			
60	1.95				2.42				3.96			
70	1.82				2.27				3.74			
80	1.68				2.12				3.51			
90	1.55				1.97				3.29			
100	1.42				1.82				3.07			
120	1.15				1.52				2.62			
140	1.04				1.37				2.39			
160	0.94				1.23				2.15			
180	0.83				1.08				1.92			

FORMULAS:

1) V_I (inflow volume) $= \frac{CwpIAT}{726}$

2) V_O (outflow volume) $= \frac{tcp+T}{1452} Qo$

3) V_S (storage volume) $= V_I - V_O$

Pond Location________

Basin Area, A=_____AC

CALCULATION OF WEIGHTED RUNOFF COEFFICIENT, Cw			
1	2	3	4
EXISTING LAND USE	"C"(Table 6-4)	Area, Ai(AC)	CAi
TOTALS			
PROPOSED LAND USE			
TOTALS			

EXISTING TIME OF CONCENTRATION tCE = ________ MIN

PROPOSED TIME OF CONCENTRATION tCP = ________ MIN

EXISTING WEIGHTED COEFFICIENT $C_{WE} \frac{\Sigma CAi}{\Sigma Ai} =$ ______

PROPOSED WEIGHTED COEFFICIENT $C_{WP} \frac{\Sigma CAi}{\Sigma Ai} =$ ______

MAXIMUM OUTFLOW RATE Qo=CweIA

Q 2yr =________CFS

Q 5yr =________CFS

Q 100yr =______CFS

JAN. 2003, REV 10

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DETENTION BASIN STORAGE CALCULATIONS

SCALE: N.T.S.

E: 7-7

7.1.3 Codes and Standards

The latest edition of the following codes and standards shall be used in conjunction with these criteria.

- o City of Dallas, Texas, Design Manual for Storm Drainage Facilities.
- o City of Irving, Texas, Design Criteria for Drainage Projects.
- o Texas Department of Transportation Hydraulic Manual, Austin, Texas.
- o City of Plano, Texas, Storm Drainage Design Manual, Revised August 1982.
- o U.S. Department of Commerce, Weather Bureau, Hydro-35, National Technical Information Service Publication No. PB 272-112, June 1977.
- o U.S. Department of Commerce, Weather Bureau, Technical Paper No. 25, Rainfall Intensity-Duration- Frequency Curves.
- o U.S. Department of Commerce, Weather Bureau, Technical Paper No. 40, Rainfall Frequency Atlas.
- o City of Farmers Branch, Texas, Section III -- Storm Drainage Design Standards.
- o City of Garland, Texas, Consultants Helper.
- o City of Carrollton, Texas, General Design Standards, Volume III, Sanitary Sewer, Water, Paving and Drainage Construction.
- o City of Richardson, Texas, City Resolution 73-13.
- o National Flood Insurance Program, Code of Federal Regulations Parts 59 through 79, Title 44, Emergency Management and Assistance, Chapter 1, Federal Emergency Management Agency (FEMA).
- o City of Dallas, Texas, Hydrology and Hydraulics of Flood Plain Studies for the City of Dallas, January, 1976.
- o U.S. Department of Agriculture, Washington, D.C., National Engineering Handbook, Section 4, Hydrology, March, 1985.

7.1.4 Computer Programs

The following computer programs are acceptable for use by the various agencies within the DART service area as shown in Table 7-1. This list is not intended to be all inclusive and will be subject to modifications and limitations on the use of programs for specific applications. See Document Control Center list of programs authorized for use in the design of DART facilities. Design calculation using computer programs shall be in accordance with System Design Manual Volume 1, Part C, Section 8.0.

- o U.S. Army Corps of Engineers
  Water Resources Center
  Hydraulic Engineering Center
  HEC-1
  Flood Hydrograph Package

- o U.S. Army Corps of Engineers
  Water Resources Center
  Hydraulic Engineering Center
  HEC-2
  Water Surface Profiles

- o Texas Department of Transportation
  Bridge Division File D-5
  THYSYS
  Texas Hydraulic System

- o U.S. Department of Agriculture
  Soil Conservation Service
  Engineering Division
  Technical Release Number 20

- o U.S. Department of Agriculture
  Soil Conservation Service
  Engineering Division
  Technical Release Number 55
  Urban Hydrology for Small Watersheds

- o University of Ottawa
  Department of Civil Engineering
  Ottawa, Canada
  OTTSWMM
  University of Ottawa Storm Water Management Model

- o U.S. Army Corps of Engineers
  Fort Worth District
  NUDALLAS
  Flood Hydrograph Model Adapted
  to Dallas/Fort Worth Area.

- o City of Dallas
  Department of Public Works
  Storm Water Management Section
  WSP
  Water Surface Profile

7.2 HYDROLOGY

7.2.1 Storm Frequency

Figures 7-8(a) and 7-8(b) show anticipated rainfall rates for storm durations from 5 minutes to 24 hours. Interpolation of rainfall rates versus durations from the isopluvial maps contained in

HYDRO-35 was used to prepare Figure 7-8(a) for durations of less than 60 minutes. For durations beyond 60 minutes, the information shown in Figure 7-8(b) was derived from Technical Paper No. 40. The individual curves shown on Figure 7-8(a) labeled 2, 5, 10, 25, 50, and 100 Yr are referred to as "Design Storm Frequency." In figure 7-8(b) the design storm frequency is shown as the "Return Period in Years". Each drainage facility shall be designed to convey the runoff which results from a certain prescribed design storm as shown in Table 7-1.

For runoff computations using the Rational Method, the curves in Figure 7-8(a) derived from Hydro-35 will be used. The curves in Figure 7-8(b) derived from TP-40 will be used for all unit hydrograph methods of runoff computation.

7.2.2 Methods of Determining Runoff

Prior to hydraulic design of drainage facilities, the amount of runoff from the particular drainage area must be determined. Two methods, the rational method and the unit hydrograph method, are used in these criteria for computing volumes of storm water runoff. Data from a Federal Emergency Management Agency Flood Insurance Study or previous flood study of a waterway by the local public agency shall be used in lieu of the rational method or unit hydrograph for determination of drainage and floodway easement elevations and design discharge flows, if such data are available.

Rational Method. The use of the rational method is based on the following assumptions:

- The peak rate of runoff at any point is a direct function of the average rainfall intensity and the duration of the design storm.
- The frequency of the peak discharge is the same as the frequency of the average rainfall intensity.
- The time of concentration is the time required for the runoff to become established and flow from the most remote part of the drainage area to the design point.
- The duration of the design storm is equal to the time of concentration for the point of interest.

The rational method is based on the direct relationship between rainfall and runoff expressed in the following equation:

$$Q = C I A$$

Where "Q" is storm water flow in cubic feet per second, "C" is the runoff coefficient representing the estimated ratio of runoff to rainfall which is a dependent characteristic of the watershed, "I" is intensity in inches per hour of rainfall over the entire watershed, and "A" is the drainage area of the tributary watershed in acres. Values for "C" are obtained from Table 7-2.

The time of concentration is a combination of the inlet time and the flow time in the conduit to the point of concentration. The inlet time shall be determined using Figure 7-9 but shall not exceed the maximum inlet time listed in Table 7-3. The flow time in the conduit is computed by dividing the length of the conduit by the average velocity in the conduit.

Unit Hydrograph Method. For basin areas of 130 acres or larger, a hydrology/hydraulics model based on the unit hydrograph method shall be used to determine peak storm runoffs at the proposed drainage facility. The components of the unit hydrograph method in modeling a direct precipitation-runoff process are precipitation, interception/infiltration, and transformation of precipitation excess to subbasin outflow.

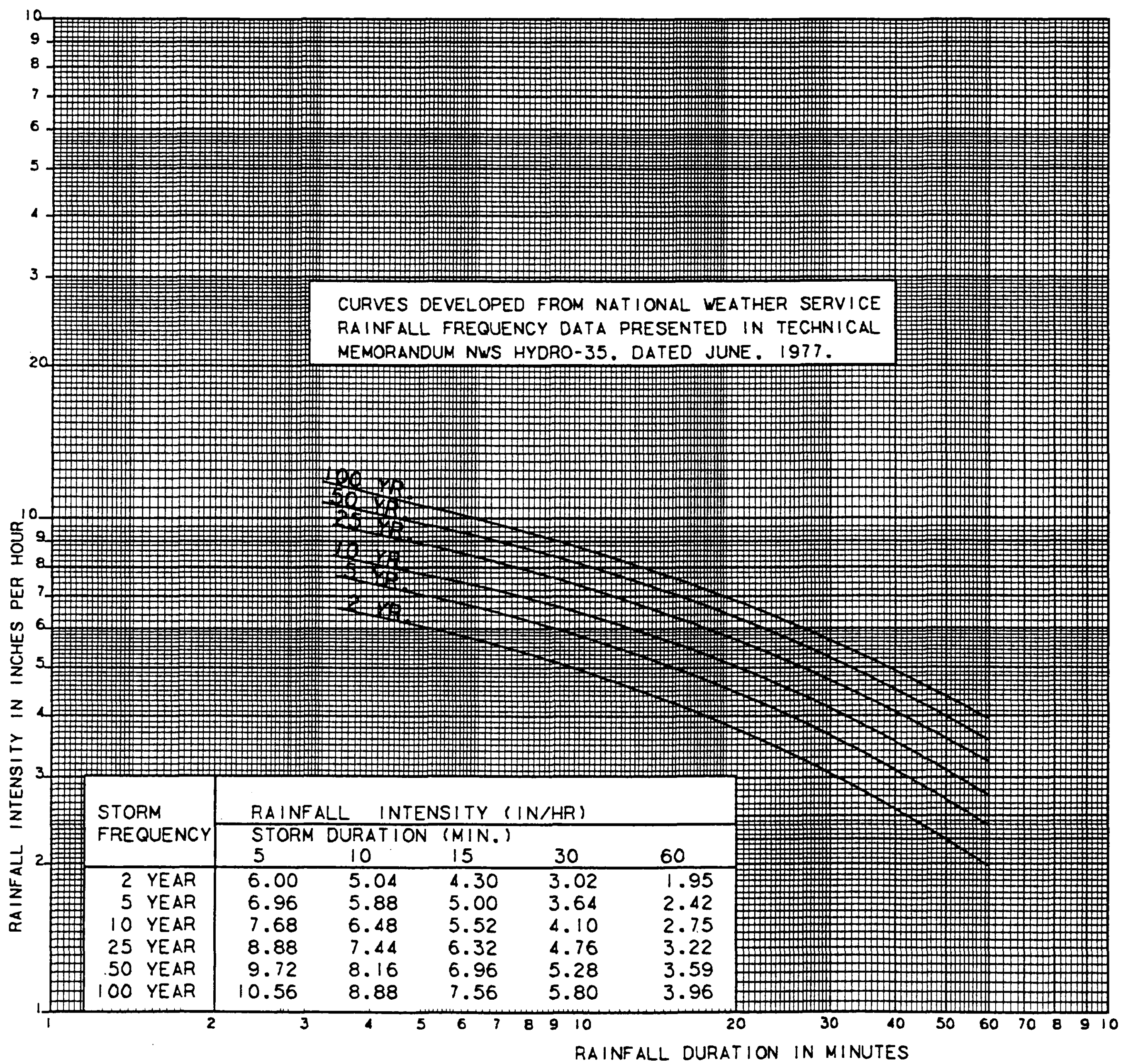
Curves from Technical Paper 40 Rainfall Frequency Data, shall be used to develop a precipitation hyetograph for the basin (or subbasins). The total duration of the precipitation hyetograph shall be long enough to satisfy initial interception/infiltration losses of the basins without a significant impact on the peak storm runoff.

For modeling the interception/infiltration losses of the basin using the HEC-1 model, values of 0.75 inch (initial loss) and 0.07 inch/hour (constant loss rate) should be used. These values are based on the Corps of Engineers determined rainfall/runoff characteristics of basins in the region to be served by DART.

Examples of a synthetic unit hydrograph methodology for determining runoff are the Clark Unit Hydrograph Method (1945), Snyder Unit Hydrograph Method (1938), and the SCS Dimensionless Unit Hydrograph. The selected methodology for determining runoff shall be similar to these methods. A kinematic wave method shall be used to transform precipitation excesses to subbasin outflow when using the HEC-1 model.

The method and model parameters used in determining the design discharge shall be in accordance with criteria established by the agency having jurisdiction. If an existing model is available, that model will be the preferred method and should be investigated for suitability for the current application. In absence of an existing model, the HEC-1 or TR-20 models shall be used, with an SCS type II, 24-hour rainfall distribution.

RAINFALL INTENSITY CHART



STORM FREQUENCY	RAINFALL INTENSITY (IN/HR) STORM DURATION (MIN.) 5	10	15	30	60
2 YEAR	6.00	5.04	4.30	3.02	1.95
5 YEAR	6.96	5.88	5.00	3.64	2.42
10 YEAR	7.68	6.48	5.52	4.10	2.75
25 YEAR	8.88	7.44	6.32	4.76	3.22
50 YEAR	9.72	8.16	6.96	5.28	3.59
100 YEAR	10.56	8.88	7.56	5.80	3.96

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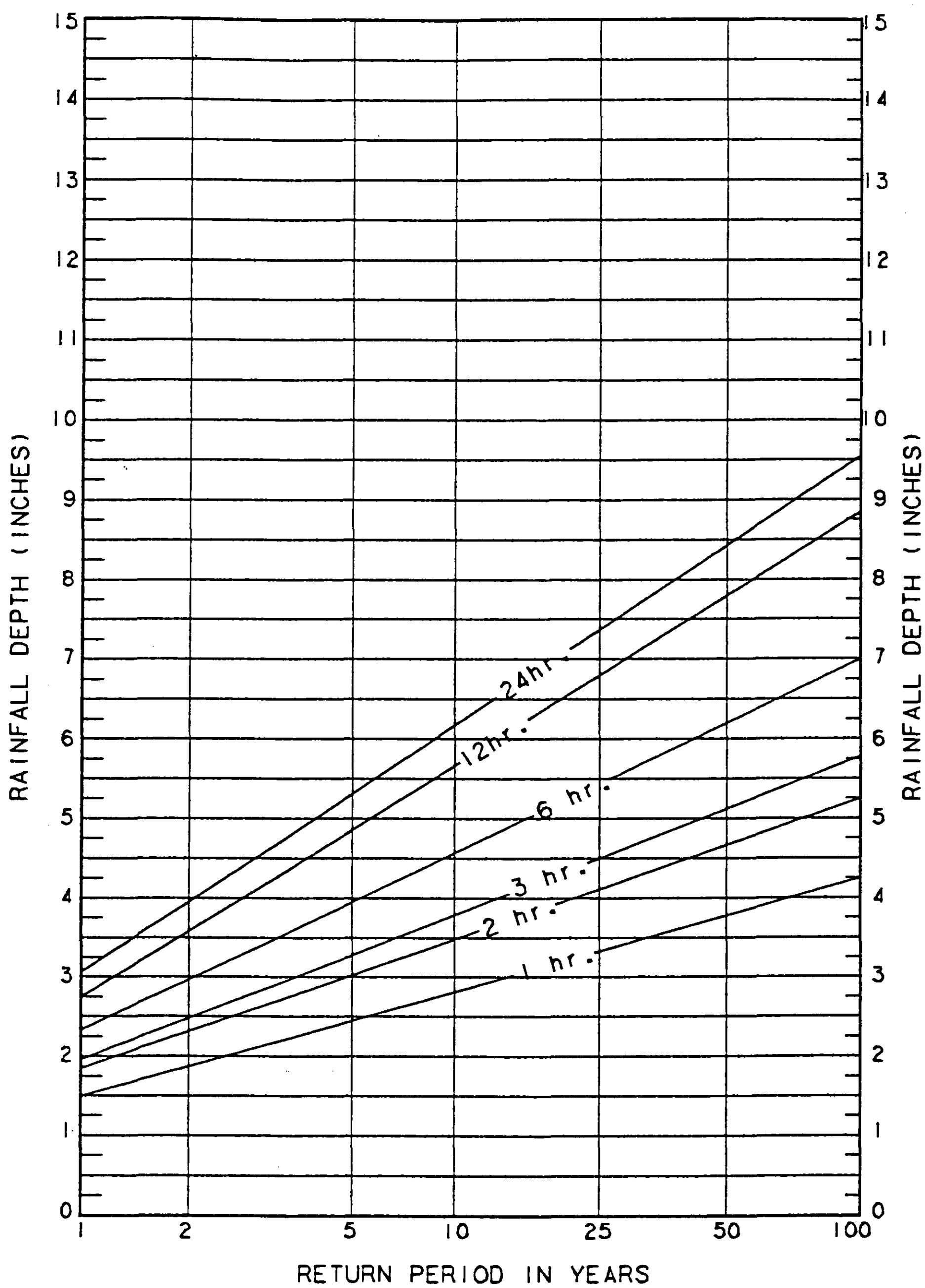
		RAINFALL INTENSITY-DURATION FREQUENCY CURVES
		SCALE: N.T.S. FIGURE: 7-8a

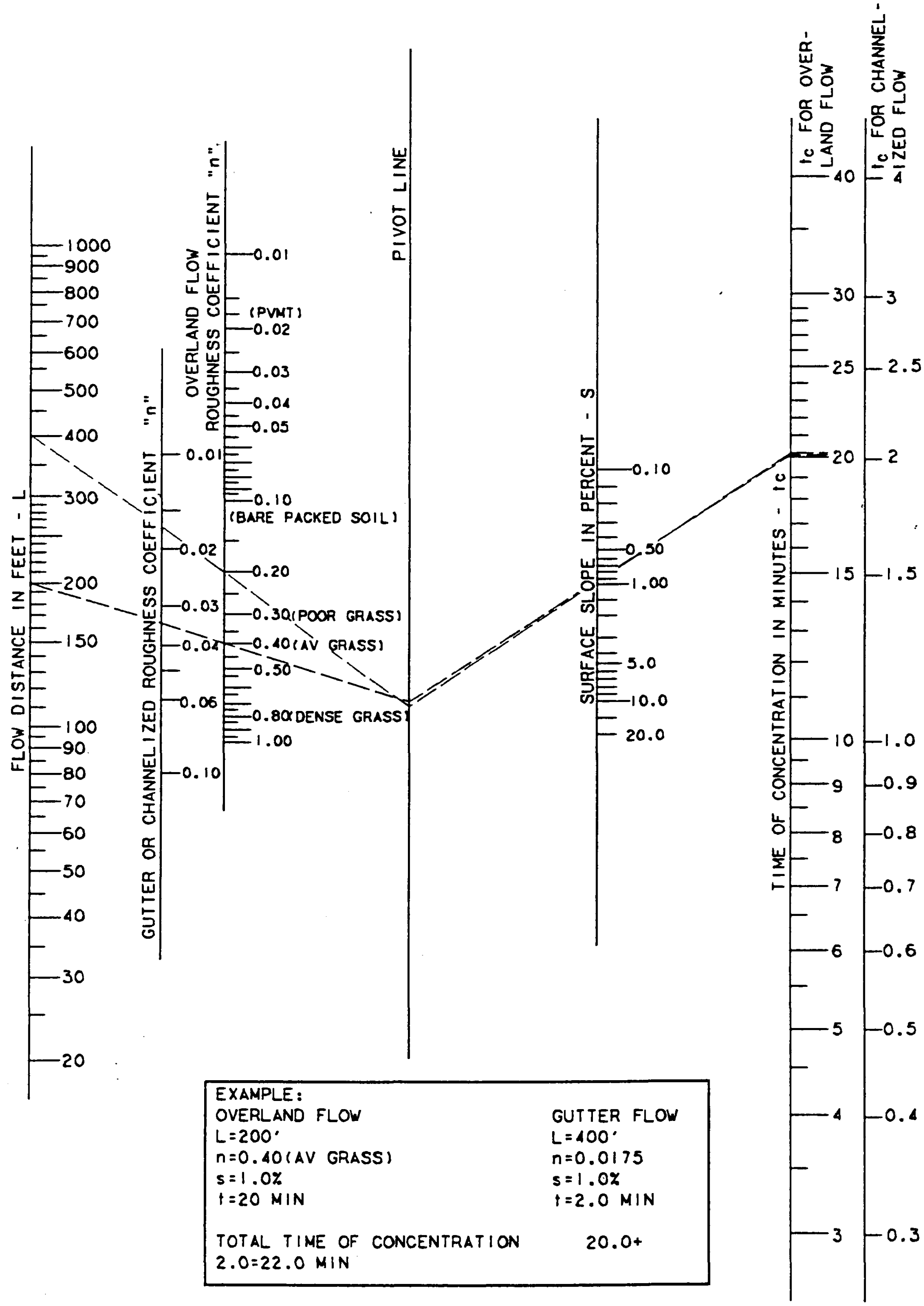


DEVELOPED FROM WEATHER BUREAU, TECHNICAL PAPER NO. 40, DATED MAY, 1961

<u>Rainfall Depth, Duration and Frequency</u>

ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA RAINFALL INTENSITY-DURATIO FREQUENCY CURVES SCALE: N.T.S. FIGURE: 7-8b

JAN. 2003, REV 10



EXAMPLE:

OVERLAND FLOW	GUTTER FLOW
L=200'	L=400'
n=0.40 (AV GRASS)	n=0.0175
s=1.0%	s=1.0%
t=20 MIN	t=2.0 MIN

TOTAL TIME OF CONCENTRATION 20.0+ 2.0=22.0 MIN

TIME OF CONCENTRATION
FOR
SURFACE FLOW

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TIME OF CONCENTRATION NOMOGRAPH FOR SURFACE FLOW

SCALE: N.T.S.

FIGURE: 7-9

JAN. 2003, REV 10

Table 7-1

MINIMUM DESIGN STORM FREQUENCY FOR DART DRAINAGE FACILITIES

DRAINAGE FACILITY	MINIMUM STORM FREQUENCY
Streets	100-Year
Storm sewer when acting in combination with street and/or emergency overflow. (1)	10-Year
Storm sewer without emergency overflow	100-Year
Channels (lined or unlined)	100-Year
Culverts	100-Year
Bridges	100-Year
Pump stations	100-Year
Detention storage areas	100-Year

NOTE: (1) Design storm for pipe when acting in conjunction with street and/or emergency overflow is subject to definition or approval by local jurisdiction.

Table 7-2
RUNOFF COEFFICIENTS

Item	DART	SDH&PT	Highland Park University Park Dallas	City of Irving	Garland	Carrollton*	Farmer's Richardson	Branch	Plano
Single Family, 1 acre	0.45	0.20-0.40	0.45	0.40	0.45	0.45-0.65	0.50	0.50	0.50
Single Family, 1/2 acre & less	0.45-0.65	0.30-0.50	0.45-0.65	0.40	0.45	0.45-0.65	0.50	0.50	0.50
Duplex	0.70	0.40-0.60	0.70	0.70	0.60	0.50-0.70	0.50	0.50	0.50
Townhouse	0.80	0.60-0.75	0.80	0.70	0.60	N/A	0.60	0.80	0.60
Multifamily	0.80	0.50-0.70	0.80	0.70	0.60-0.75	0.55-0.75	0.70	0.80	0.80
Mobile Home	0.55	N/A	0.55	N/A	N/A	N/A	N/A	N/A	N/A
Office	0.90	0.70-0.95	0.90	0.90	0.90	0.80-0.85	0.90	0.90	0.90
Commercial	0.90	0.70-0.95	0.90	0.90	0.90	0.80-0.85	0.90	0.90	0.90
Industrial	0.7-0.9	0.50-0.90	0.70-0.90	0.90	0.90	0.75-0.85	0.90	0.90	0.90
Parking	0.95	0.70-0.95	0.95	0.90	0.90	N/A	0.90	0.90	0.90
Church	0.80	0.50-0.70	0.80	0.40	0.45	N/A	N/A	0.70	0.60
School	0.70	0.50-0.70	0.70	0.40	0.45	0.30-0.45	N/A	0.70	0.60
Parks	0.40	0.20-0.40	0.40	0.40	0.45	0.20-0.35	N/A	0.35	0.40
Ballast Trackway	0.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

* Slope Dependent
(1) For further breakdown by zoning classifications see Dallas Drainage Design Manual

Table 7-3

MAXIMUM INLET TIME

Item	Highland Park University Park DART	SDH&PT	Dallas	Irving	Garland	Carrollton	Richardson	Farmer's Branch	Plano
Single Family Lot, 1 acre	20	None	20	15	15	10	10	15	15
Single Family Lot, 1/2 acre	20	None	20	15	15	10	10	15	15
Single Family Lot, 16,000	15	None	15	15	15	10	10	15	15
Single Family Lot, 13,000	15	None	15	15	15	10	10	15	15
Single Family Lot, 10,000	15	None	15	15	15	10	10	15	15
Single Family Lot, 7,500	15	None	15	15	15	10	10	15	15
Single Family Lot, 6,000	15	None	15	15	15	10	10	15	15
Single Family Lot, 5,000	15	None	15	15	15	10	10	15	15
Single Family Lot, 2,500 & 3,500	15	None	15	15	10	10	10	15	N/A
Duplex	10	None	10	10	10	10	10	15	15
Townhouses	10	None	10	10	10	5	10	10	15
Multifamily	10	None	10	10	10	5	10	10	10
Mobile Home District	15	None	15	10	10	5	10	10	10
Office	10	None	10	10	10	5	10	10	10
Commercial	10	None	10	5	10	5	10	10	10
Industrial	10	None	10	5	10	5	10	10	10
Parks, Open Spaces	20	None	20	None	None	10	None	15	N/A
Schools, Churches, Institutional	10-20	None	N/A	N/A	N/A	N/A	15	15	N/A

7.3 STREETS AND PARKING

Streets. The location of inlets and permissible flow of water in streets should be related to the extent and frequency of interference due to traffic and probability of flood damage to surrounding property. Interference due to traffic is regulated by the permissible spread of water into traffic lanes. Flooding of surrounding property is controlled by limiting the depth of gutter flow to the top of the curb for a 100-year frequency storm. No lowering of the standard height of street crown with respect to the top of curb shall be allowed for the purpose of hydraulic design, unless approved by DART. Design of streets outside of the DART right-of-way shall conform to the design criteria and standards of the public agency involved.

The types of interference due to traffic that should be considered in the design are:

- o Flow spread in streets.
- o Ponding due to grade changes, flat vertical curves, superelevation or the crown of intersecting streets.
- o Significant sheet cross-flow.
- o Reduced gutter capacity.

Parking Areas. Drainage shall be directed away from areas of pedestrian traffic. If storm water cannot be drained away from the curb along roadways and/or parking areas adjacent to station concourse entrances, then drainage facilities shall be designed to prevent the 10-year frequency storm from spreading more than 6 feet from the face of the curb. Inlets shall be placed to intercept storm water before it crosses pedestrian traffic areas.

7.3.1 Maximum Spread of Water

Parking Lots – In large parking lots, designer shall grade parking lots to maximize area that will drain by sheet flows where feasible. If paving swales are necessary, these shall be placed between parked vehicles and not in pedestrian or driving lanes.

The maximum permissible water spread for DART access, circulation and maintenance roadways shall be restricted to provide one 12-foot lane clear. Storm water spread along bus loading zones and pedestrian crossings shall be limited to 1 foot from curb face. In parking areas, the water spread shall be limited to 6 feet from curb face adjacent to pedestrian crossings.

Storm water spread / ponding depth for joint use roadways or on roadways impacted by the DART corridor shall conform to the requirements of the jurisdictional authority sharing the right of way. The most restrictive of water spread or ponding depth will be used for design.

7.3.2 Minimum and Maximum Velocities

Minimum velocity of curb flow is controlled by the minimum street or parking lot slope of 0.5 percent. The maximum curb flow velocity is controlled by the capacity reduction factor, F. See Figure 7- 12.

7.3.3 Design Methodology for Gutter Capacity

Streets with Straight Cross-Slope. Figure 7-10, Capacity of Triangular Gutters, applies to all streets having a straight cross-slope. The cross-slope varies from an allowable minimum of 1/8 inch per foot to a maximum of 1/2 inch per foot.

Alleyways. Figure 7-11 is a nomograph for determining the storm drain capacity of various standard alley sections.

Reduction Factor for Allowable Gutter Capacity. Figure 7-12 is a graph for determining the reduction factor, F, for allowable gutter capacity. For design, the theoretical gutter capacity is reduced by multiplying by the appropriate factor, F, which is a function of street slope to compensate for such parameters as future pavement overlaying, subgrade settlement and swelling, and most important, excessive velocities created by steep slopes.

Table 7-4
PERMISSIBLE SPREAD OF WATER FOR DESIGN STORM

DART access, circulation and maintenance roadways	1 lane clear
Bus loading zones & pedestrian crossings	1' from curb face
Parking areas	6' from curb face adjacent to pedestrian crossings

* For joint right-of-way or where impacted by DART right-of-way corridor use most restrictive of top of curb or spread width.
** Flow to be contained within right-of-way for 100-year frequency storm.
*** 10 yr. frequency for interstate and 5 yr. frequency for all other roadways.

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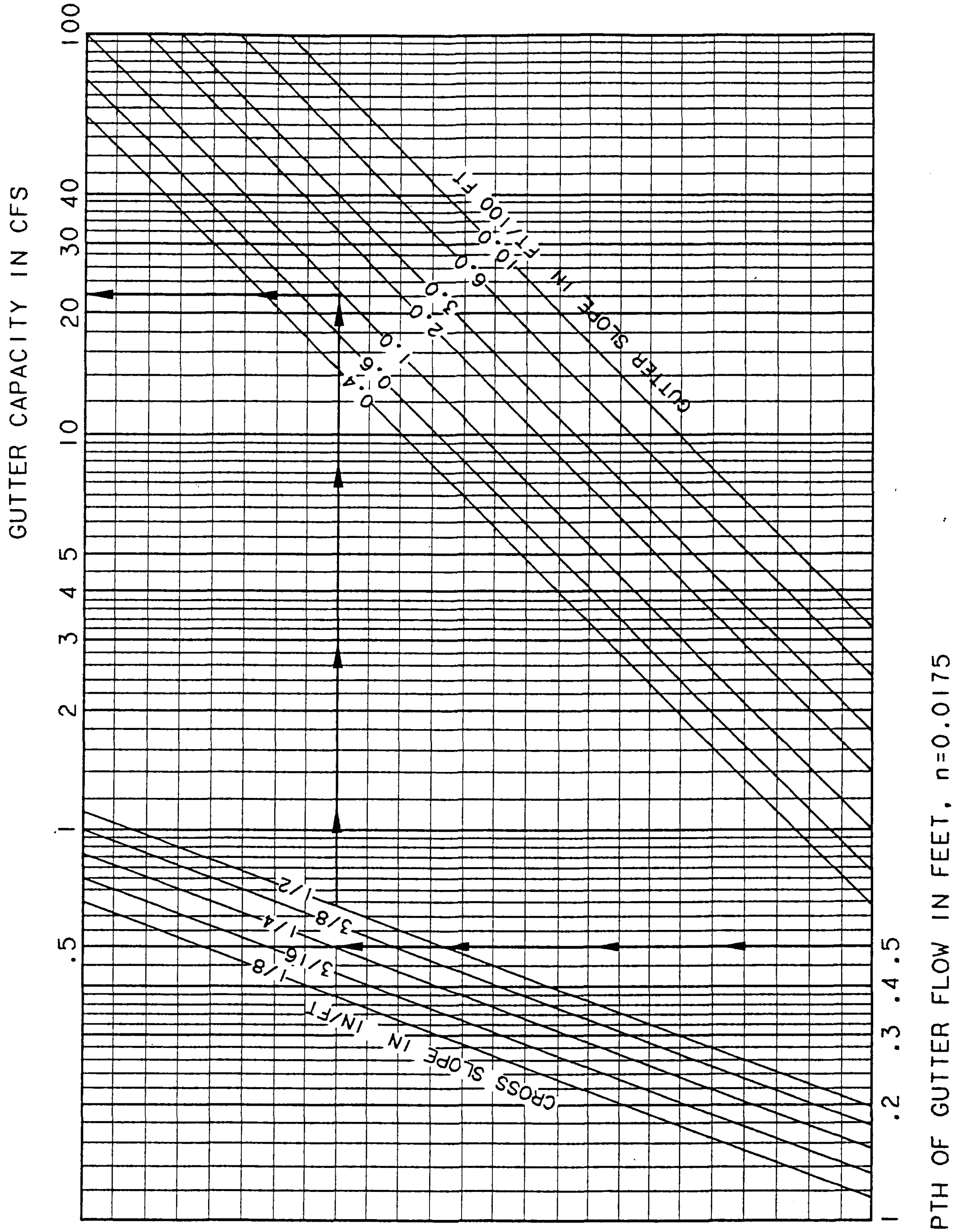

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CAPACITY OF TRIANGULAR GUTTERS

SCALE: N.T.S.

FIGURE: 7-10

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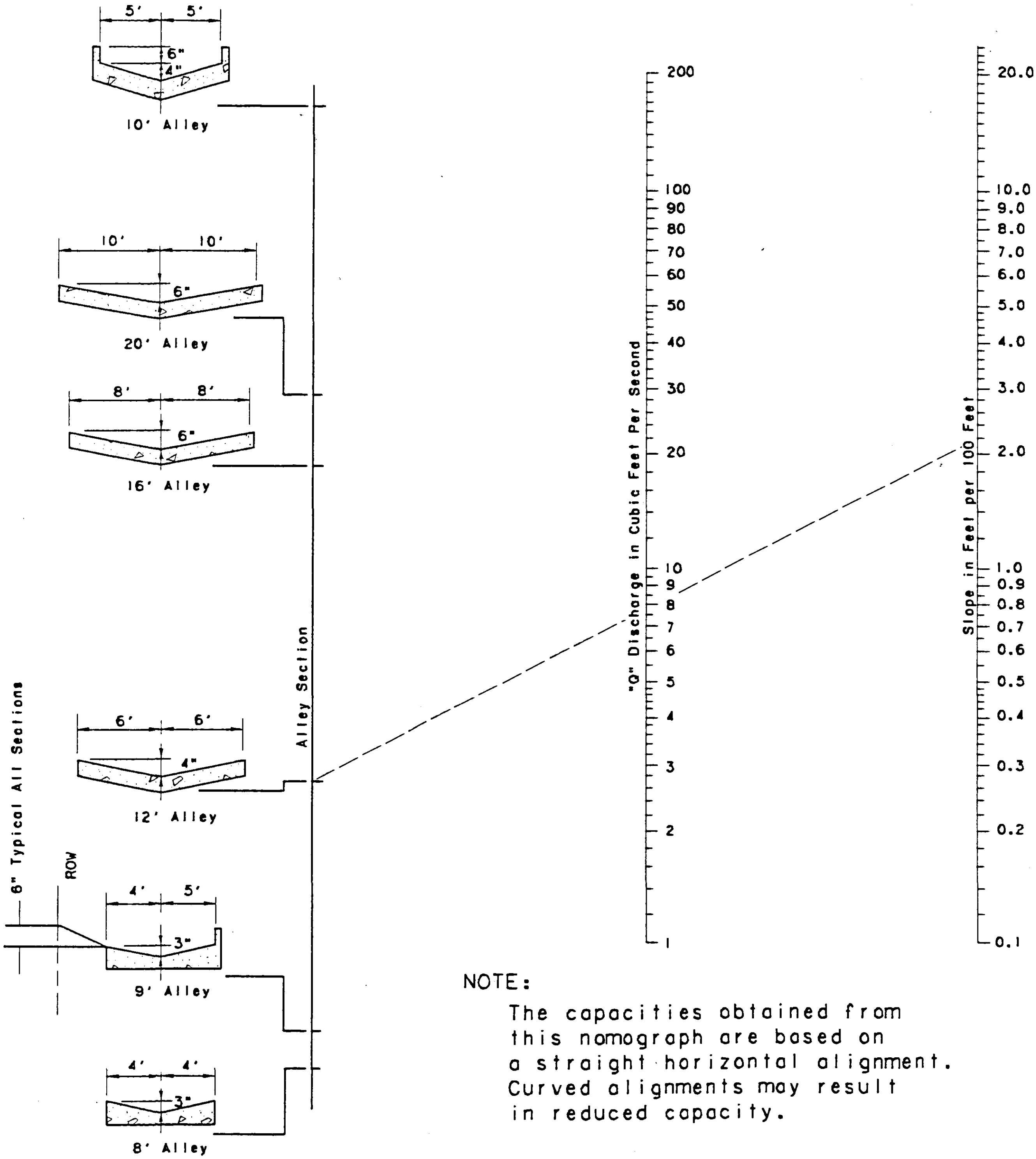

NOTE:
The capacities obtained from this nomograph are based on a straight horizontal alignment. Curved alignments may result in reduced capacity.

EXAMPLE

KNOWN:
Alley Width = 12'
Alley Depression = 4"
Gutter Slope = 2.2%

FIND:
Gutter Flow (Q)

SOLUTION:
Connect the 12' Alley Section with Slope = 2.2%
Read Q = 7.6 CFS

n= 0.0175

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CAPACITY OF ALLEY SECTIONS

SCALE: NOT TO SCALE FIGURE: 7-11

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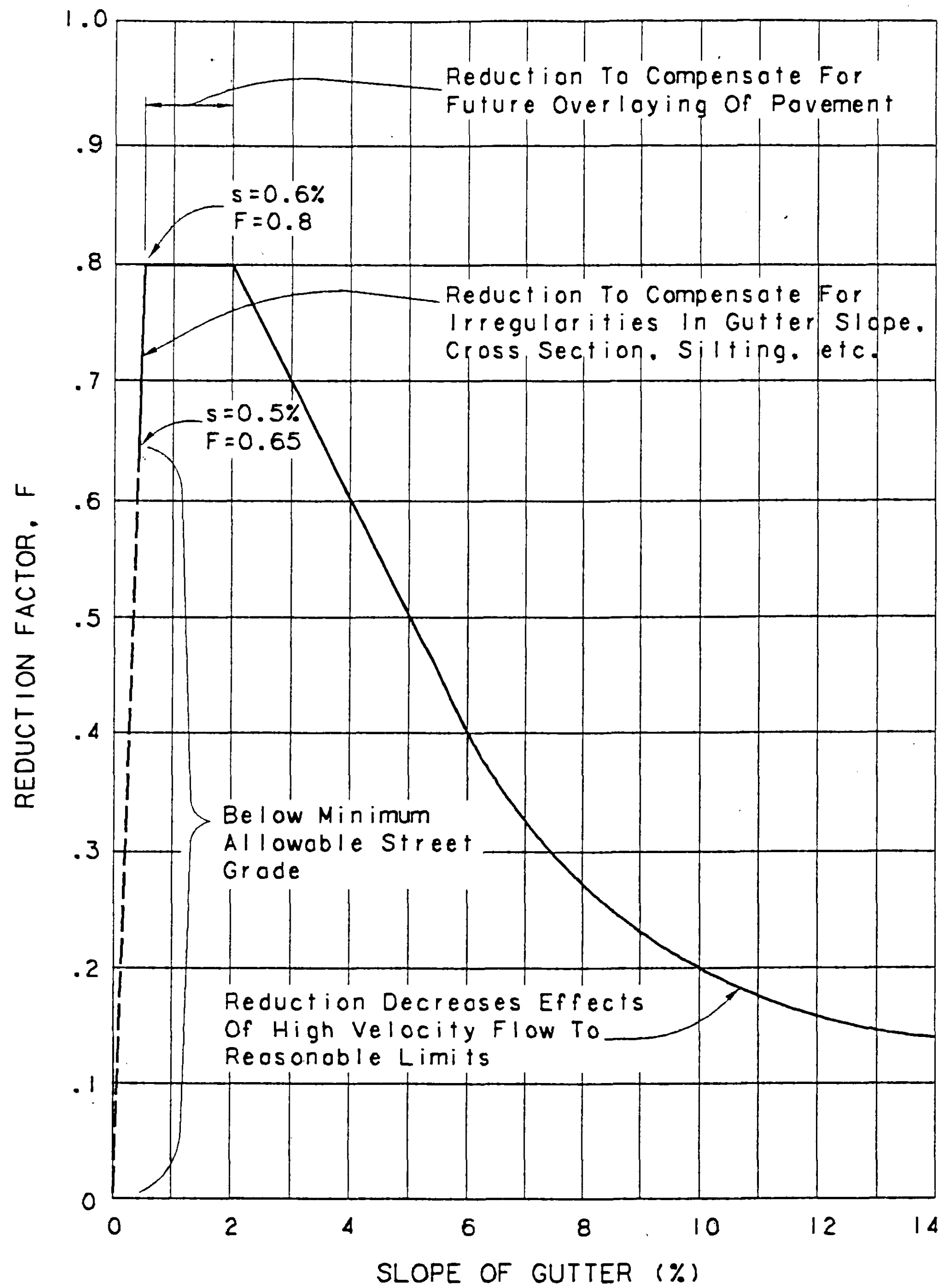


APPLY REDUCTION FACTOR FOR APPLICABLE SLOPE TO THE THEORETICAL GUTTER CAPACITY TO OBTAIN ALLOWABLE GUTTER CAPACITY

ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA REDUCTION FACTOR FOR ALLOWABLE GUTTER CAPACITY SCALE: NOT TO SCALE FIGURE: 7-12

JAN. 2003, REV 10

7.4 INLETS

A storm drain system shall begin at the point where the depth of gutter flow, based on a 100-year frequency storm, which allows for the permissible spread of water for the 100-year frequency storm but not to exceed the top of curb elevation. Theoretical gutter capacity at this point is reduced by application of the appropriate reduction factor, F, based on street grade (See Figure 7-12.). Unless stated otherwise, the preferred inlet type will be the Type I, 5-, 10-, or 14-foot inlet per the at-grade standards for all minor streets, undivided secondary streets, major couplets, and parking facilities. The preferred inlet type will be the Type II, 5-, 10-, or 14-foot inlet for all divided secondary and major streets. For inlets located outside the DART right-of-way, selection of inlet type shall be in conformance with the design criteria of the public agency having jurisdiction. Inlets shall be coordinated with street profile so that no drainage enters the trackway.

7.4.1 Inlet Types

Inlets are classified into six basic types with differentiation made as to whether the inlet is located in a sump (low point) or on a grade. Figures 7-13 and 7-14 summarize the inlet types and the typical locations for usage. See standard drawings for inlet details.

7.4.2 Inlet Capacities

Figures 7-14 through 7-18 shall be used to calculate the capacity of each inlet type. A brief description of each inlet type and the equations used in formulating Figures 7-14 through 7-18 follows.

Type I: Standard Curb Opening Inlet in Sump. Standard curb openings in a sump or low point are considered to operate as a rectangular weir up to a depth (H_1) equal to 1.4 times the height of the opening, and as an orifice for greater depths. Their capacity shall be based on the following equations:

Weir Flow:

$$Q = 2.1\,(L + 1.8\,W)\,(H_1 - H_2)^{1.5}$$

Where: Q=Inlet capture in cfs

L=Length of the inlet in feet
W=Width of depression in feet (measured transversely from face of inlet)
H_1=Depth of flow in the gutter approaching the inlet plus the inlet depression, in feet
H_2=Inlet depression in feet

Orifice Flow:

$$Q = 0.60\ h\ L\ (2_g\ (H_1 - {}^{h}/_{2}))^{0.5}$$

Where: h=height of inlet opening in feet.

Figure 7-15 provides for direct solution of the preceding equation. Because curb opening inlets and drop inlets in sumps have a tendency to collect debris at their entrances, the coefficients in the above equations and Figure 7-15 have been adjusted to accommodate a 10 percent loss in capacity due to clogging.

Type IA: Standard Curb Opening Inlet on Grade. The capacity of standard curb opening inlets on streets with grades of 2 percent or less shall provide one foot of opening for 1.0 cfs of gutter flow. All curb inlets on grades greater than 2 percent shall be calculated using Figures 7-16 and 7-17. To determine the inlet capacity, use the following procedure:

- o Determine depth of gutter flow at proposed inlet (per Figures 7-10 and 7-11 and Section 7.3.1).
- o Determine Q_a/L_a from Figure 7-16 for depth of gutter flow and depth of gutter depression, a.
- o Q_a, Calculate required inlet length for 100 percent capture, L_a for the approach flow.
- o Determine the intercepted flow, Q, from Figure 7-1. Use Figure 7-17 for a proposed inlet with a length, L, that is less than L_a. The bypass flow, Q_b, is equal to the difference of the approach flow, Q_a, and the intercepted flow, Q.

Type II: Recessed Curb Opening Inlet in Sump. The capacity of the recessed curb opening inlet in a sump condition is calculated in the same manner as a Type I standard curb opening inlet in a sump condition. (See Figure 7-15.)

Type IIA: Recessed Curb Opening Inlet on Grade. The capacity of a recessed curb opening inlet on grade is calculated in a similar manner as the Type I standard curb opening inlet. (See Figures 7-16 and 7-17.)

Type III: Combination Inlet in Sump. The capacity of combination inlet Type III, consisting of a grate and curb opening inlet in a sump, shall be considered to be the sum of the capacities obtained from Figures 7-15 and 7-18.

Because combination inlets in sumps have a tendency to clog and collect debris at their entrances, the calculated inlet capacity shall be reduced by 20 percent to allow for this clogging.

Type IIIA: Combination Inlet on Grade. The capacity of combination (curb opening plus grate) inlets on grade shall be considered to be 90 percent of the sum of the capacity of a Type IA inlet (Figures 7-16 and 7-17) and a Type IVA (Figure 7-18) inlet (allowing for reduction due to clogging).

Type IV: Grate Inlet in Sump. The capacity of a grate inlet in a sump shall be based on the following equation:

$$Q = 4.82 A_g Y^{(1/2)}$$

Where:

Q = capacity in cubic feet per second
A_g = area of clear opening in square feet
Y = depth of flow at inlet or head at sump in feet.

The curves shown in Figure 7-18 provide for direct solution of the preceding equation. Because grate inlets in a sump have a tendency to clog, the calculated inlet capacity of grate inlet shall be reduced by 35 percent. The area of grate opening is shown in the at-grade standards.

Type IVA: Grate Inlet on Grade. Capacity of grate inlets on grade shall be determined from Figure 7- 18 and reduced by 25 percent.

Type IVB: Ballast Drain Inlet. The capacity of a ballast drain inlet shall be determined from Figure 7-18 and reduced by 35 percent. The area of grate opening is shown in the track directive standards.

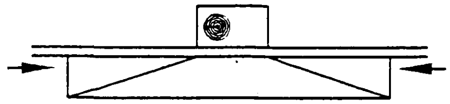
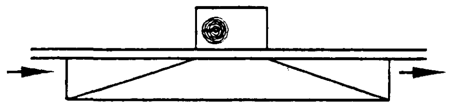
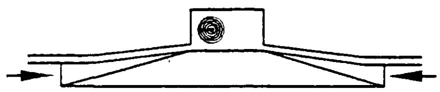
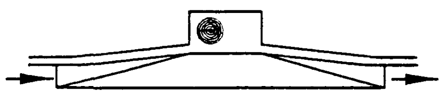
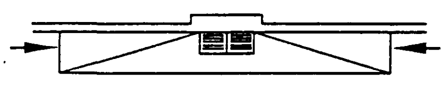
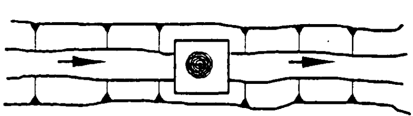
Type V: "Y" Inlet in Sump. The capacity of a type "Y" inlet is calculated in the same manner as a standard curb opening inlet in a sump. (See Figure 7-15.) The calculated inlet capacity shall be reduced by 10 percent to allow for clogging.

Slotted Drains in Sump. The capacity of a slotted drain inlet shall be determined from Figure 7-14 and shall be reduced by 35 percent to allow for clogging.

Slotted Drains on Grade. The capacity of a slotted drain inlet shall be determined from Figure 7-14 and shall be reduced by 25 percent to allow for clogging.

7.4.3 Location Requirements

The type of inlet shall be selected in accordance with Figures 7-13 and 7-14. Where possible, inlets should be placed upstream from an intersection to prevent large amounts of water entering an intersection. Inlets for sag vertical curves shall include an inlet at the low point and inlets at a maximum distance of 100 feet either side of the low point.

INLET TYPE	INLET DESCRIPTION	AVAIL INLET SIZES	WHERE USED
I	 Standard curb opening inlet in sump	5',10' 14'	All Minor Streets, Undivided Secondary Streets, Major Couplets, Streets on DART ROW and Parking Areas. For Capacity - See Figure 7-15
IA	 Standard curb opening inlet on grade	5',10' 14'	All Minor Streets, Undivided Secondary Streets, Majors Couplets, Streets on DART ROW and Parking Areas. Gutter Depression - a = 5 3/4" For Capacity - See Figures 7-16 and 7-17
II	 Recessed curb opening inlet in sump	5',10' 14'	All Divided Secondary and Major Streets. For Capacity - See Figure 7-15
IIA	 Recessed curb opening inlet on grade	5',10' 14'	All Divided Secondary and Major Streets. Gutter Depression - a = 0 For Capacity - See Figures 7-16 and 7-17
III	 Grate Inlet (Curb Type) in sump	Single Double Triple	Combination inlets to be used only where space behind curb prohibits other inlet types and in alleys. For Capacity - See Figures 7-15 and 7-18
IIIA	 Grate Inlet (Curb Type) on grade	Same	Do not use except if space behind curb prohibits other inlet types. Gutter Depression - a = 4 1/2" For Capacity - See Figures 7-15, 7-16 and 7-18
IV & IVA	 Grate Inlets (Gutter Type) Ballast Drain	Single 2 Grate 4 Grate 6 Grate 8 Grate	Type IV - in sump Type IV A - on Grade Type IV B - Ballast Drain in Sump Inlet location with no curb Alleys - Driveways For Capacity - See Figure 7-18
V	 Drop Inlet	"Y"	Open Channel - Ditches For Capacity - See Figure 7-15

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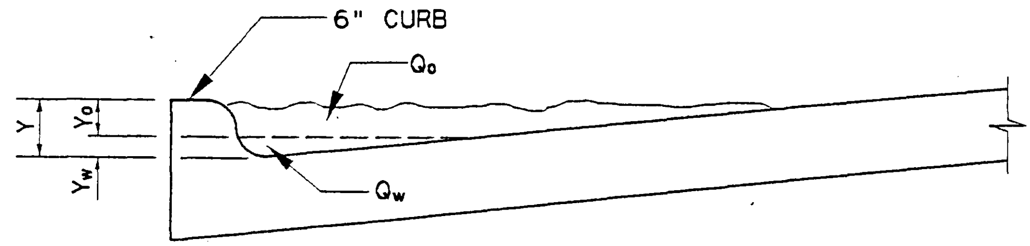
STORM DRAIN INLETS

SCALE: NOT TO SCALE FIGURE: 7-13

JAN. 2003, REV 10

FOR DESIGN OF A SLOTTED DRAIN IN A SUMP OR ON GRADE



Q= GUTTER CAPACITY= $Q_o + Q_w$

$$Q = 0.56\left(\frac{Z}{N}\right) S^{1/2}\ Y^{8/3}$$ OR USE TRIANGULAR CHANNEL FLOW NOMOGRAPH

Z= RECIPROCAL OF CROSS SLOPE
N= ROUGHNESS COEFFICIENT IN MANNING FORMULA (USE N=0.0175)
Y= DEPTH OF FLOW MAX= HEIGHT OF CURB (USUALLY 6")
S= GRADE OF GUTTER IN FT/FT

Q_w=PORTION OF WATER DRAINED BY WEIR FLOW

$$Q_w = 0.56\left(\frac{Z}{N}\right) S^{1/2}\ Y_w^{8/3}$$

Y_o =DEPTH OF WATER CONSIDERED AS WEIR FLOW $\leq$ 0.2'

Q_o PORTION OF WATER DRAINED BY ORIFICE FLOW = $Q - Q_w$

Y_o =DEPTH OF WATER CONSIDERED AS ORIFICE FLOW $\geq$ 0.2'

L_w = LENGTH OF SLOTTED DRAIN NECESSARY TO PICK UP WEIR FLOW(Q_w)

$$L_w = \frac{Q}{C_w\ H_w^{3/2}} = \frac{Q_w}{0.103} = 9.7\ Q_w (Y_w = 0.2')$$

C_w = WEIR COEFFICIENT = 3.26
H_w = AVERAGE DEPTH OF FLOW IN FEET = 0.1'

L_o= LENGTH OF SLOTTED DRAIN NECESSARY TO PICK UP ORIFICE FLOW(Q_o)

$$L_d = \frac{Q_o}{C_o A_o \sqrt{2_g H_o}} = \frac{Q_o}{0.399} = 2.5\ Q_o \text{ (FOR Y=6")}$$

C_o = ORIFICE COEFFICIENT = 0.60
A_o = AREA OF ORIFICE = 0.14 SQ FT/LN FT
g = ACCELERATION OF GRAVITY = 32.2 FT/SEC/SEC
H_o = AVERAGE DEPTH OF FLOW IN FEET = 0.35' FOR Y = 6"

L=ADJUSTED LENGTH OF SLOTTED DRAIN DUE TO GUTTER GRADE

$S \leq 1\%$: NO ADJUSTMENT

$S \geq 1\%$: $L = \dfrac{L_o + L_w}{1 - 4S}$

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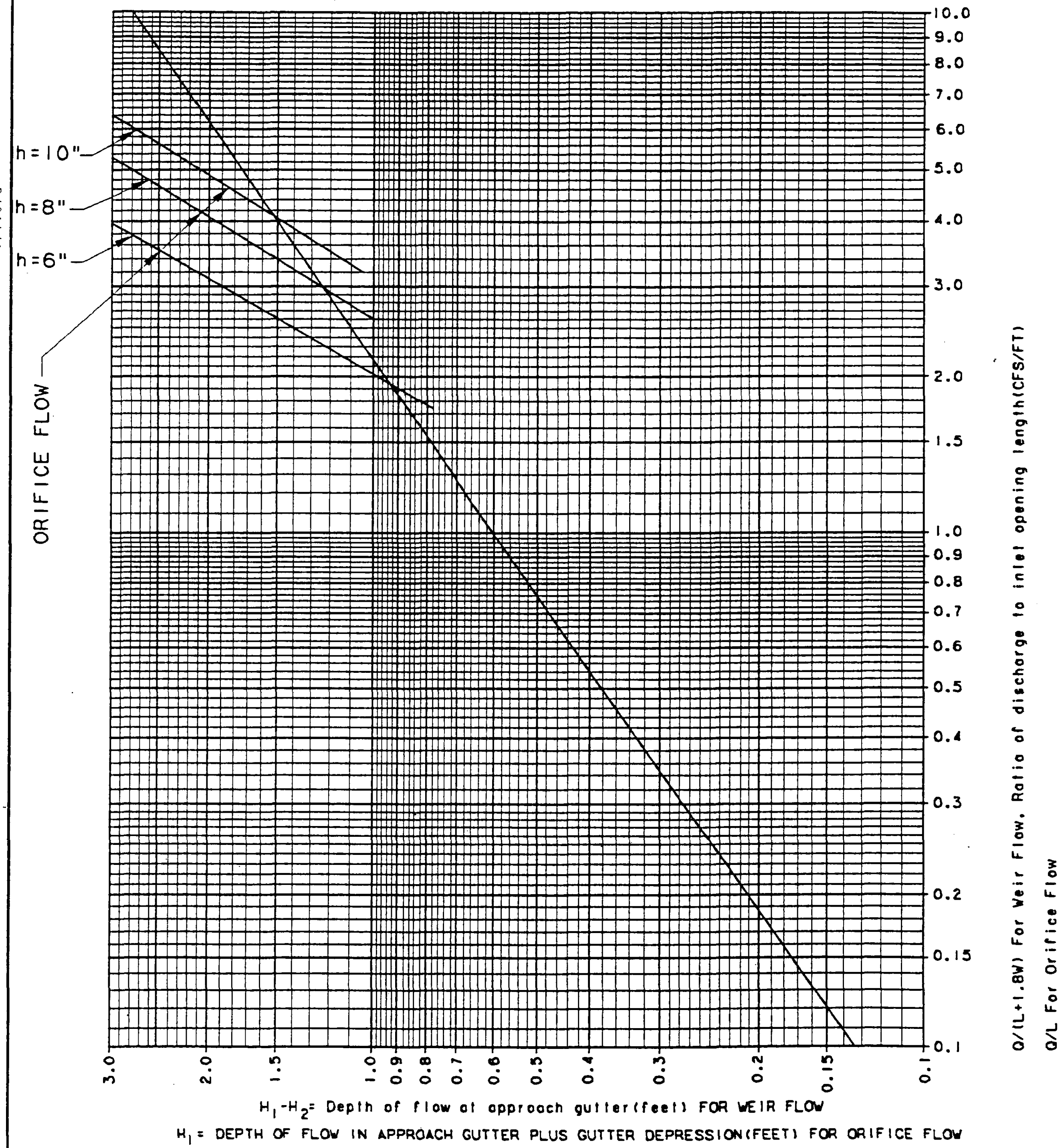
WEIR FLOW

$Q/(L+1.8W)=2.1(H_1-H_2)^{1.5}$



INLET CAPACITY

$Q/(L+1.8W)=2.1(H_1-H_2)^{1.5}$

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	DART	INLET CAPACITY CURVE FOR TYPES I, II, III AND V
		SCALE: NOT TO SCALE — FIGURE: 7-15

JAN. 2003, REV 10

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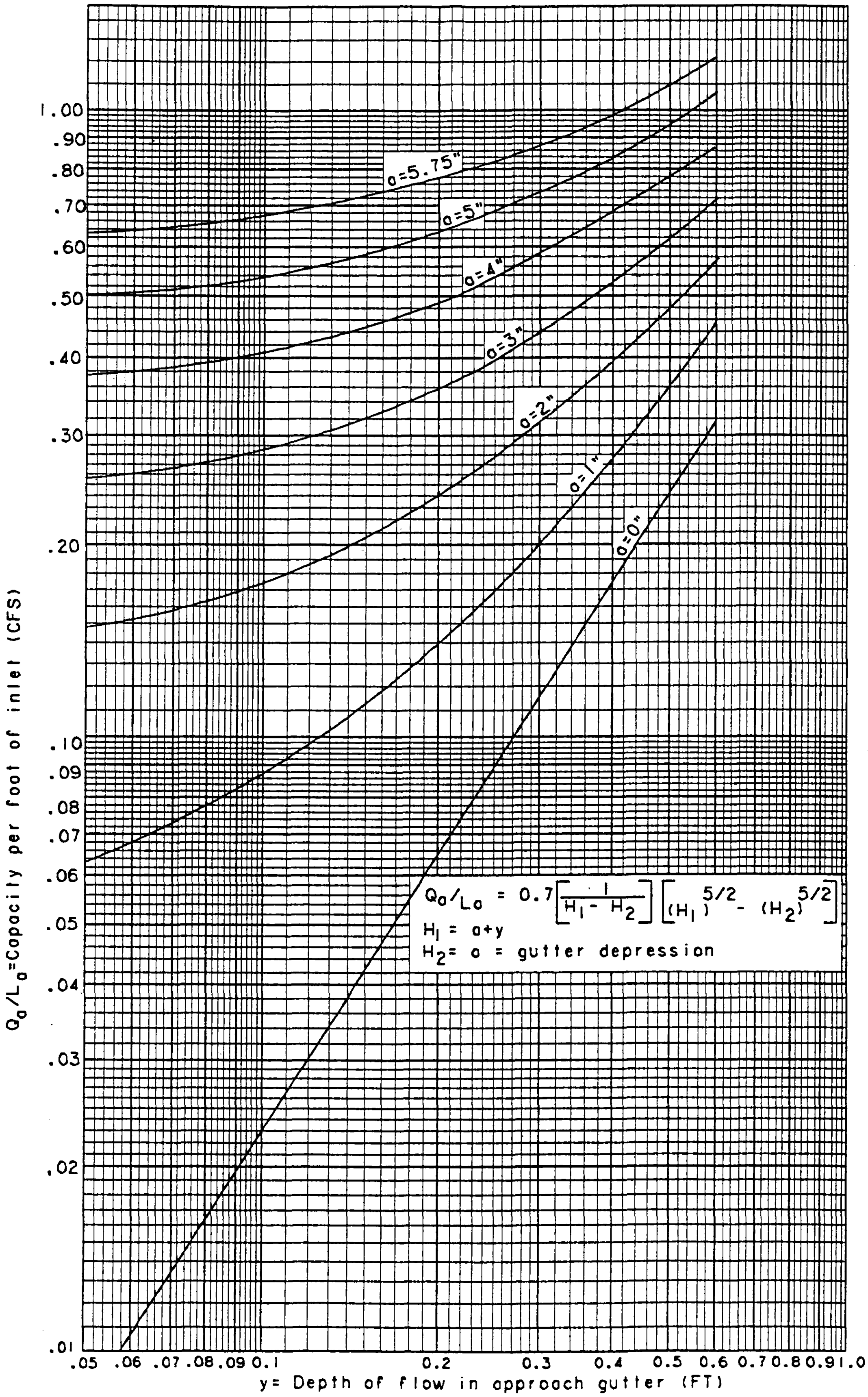

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INLET CAPACITY CURVES FOR TYPES IA, IIA AND IIIA

SCALE: NOT TO SCALE

FIGURE: 7-16

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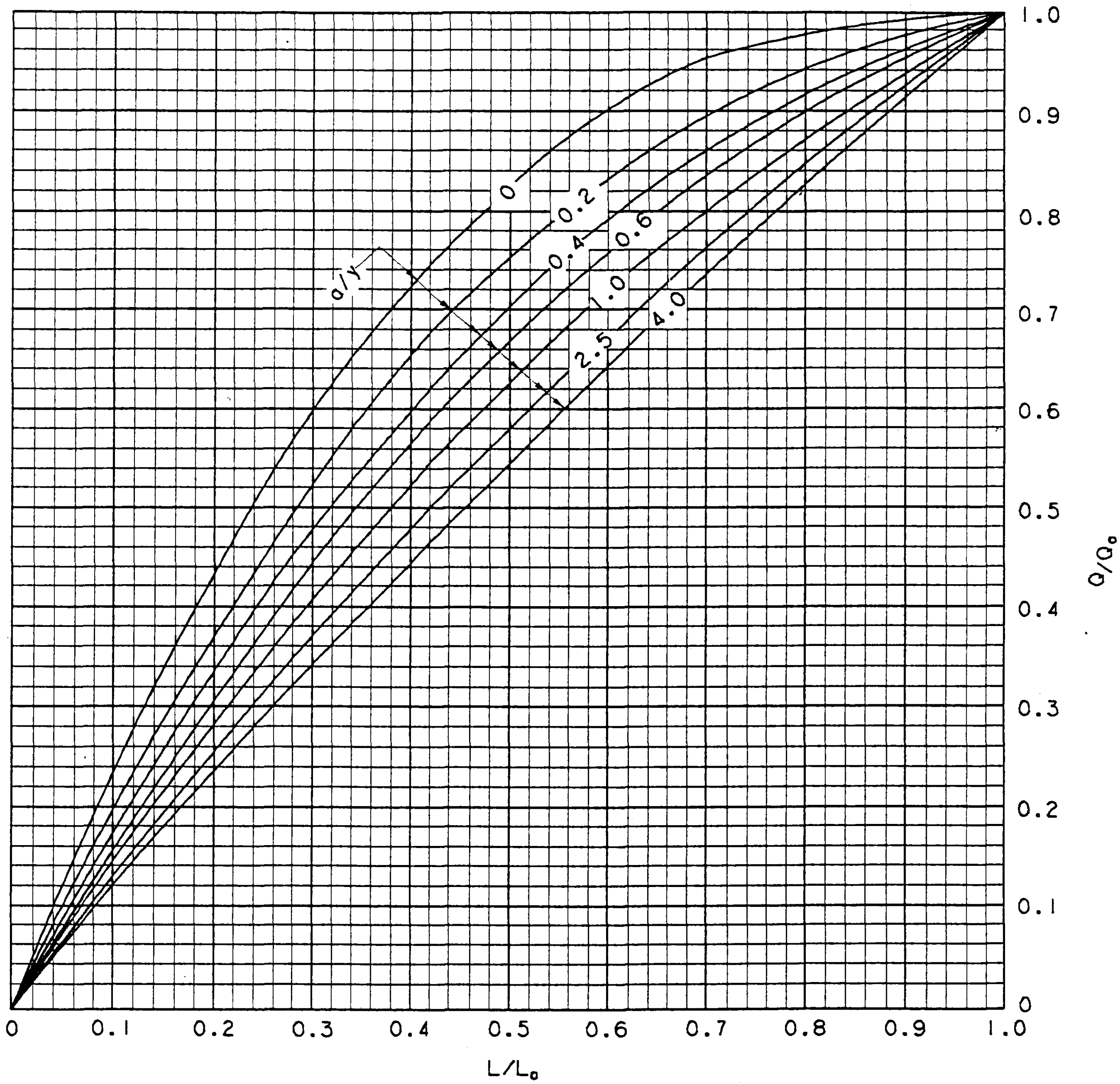

RATIO OF INTERCEPTED TO TOTAL FLOW FOR INLETS ON GRADE

L = Length of curb opening, FT

L_a = Length of curb opening for 100% interception, FT

Q = Flow intercepted by inlet of length "L", CFS

Q_a = Total flow in approach gutter, CFS

a = Gutter depression, FT

y = Depth of flow in approach gutter, FT

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INLET CAPACITY CURVES FOR TYPES IA, IIA AND IIIA

SCALE: NOT TO SCALE

FIGURE: 7-17

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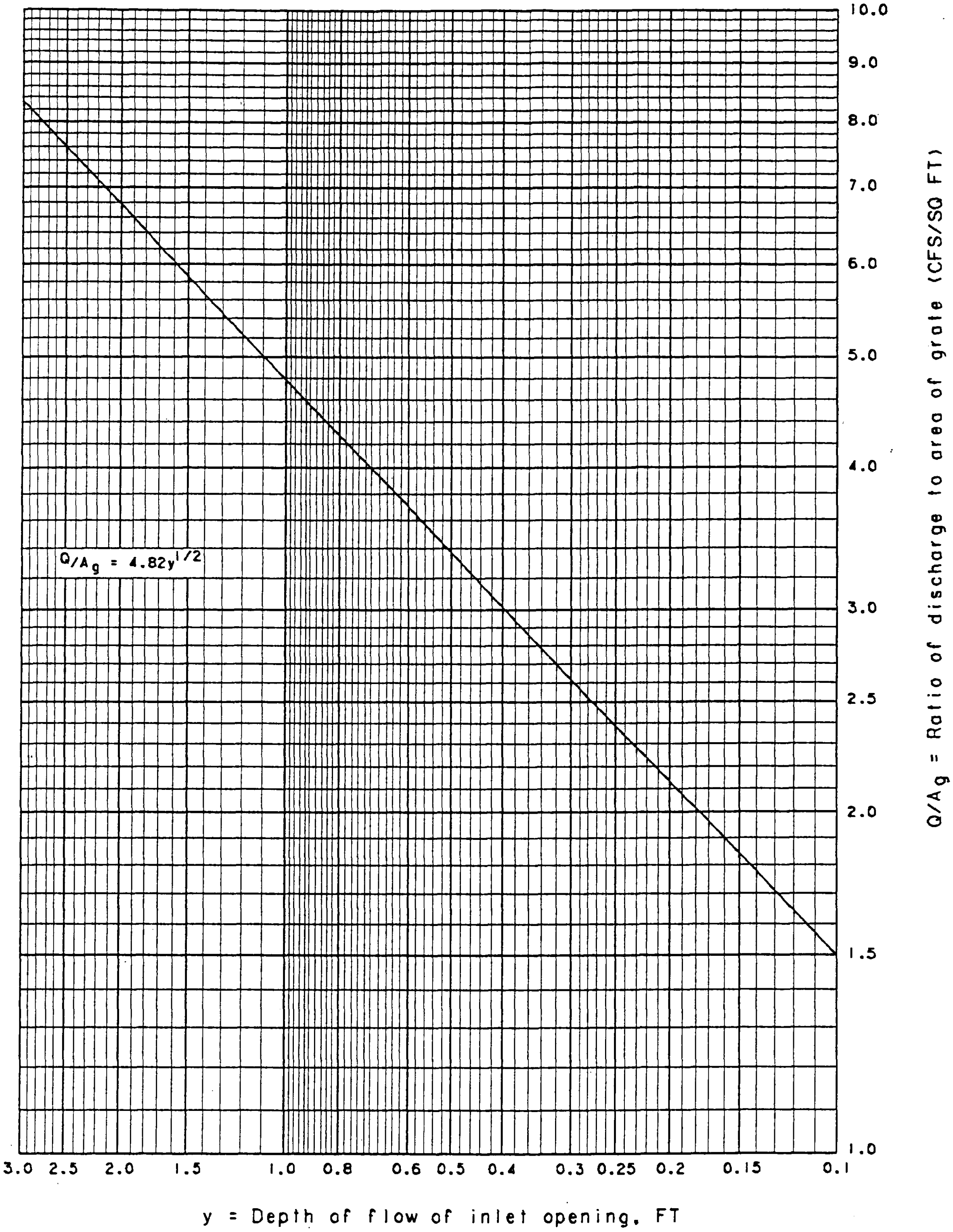

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INLET CAPACITY CURVES FOR TYPES III, IIIA, IV AND IVA

SCALE: NOT TO SCALE

FIGURE: 7-18

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7.5 STORM SEWER

Storm sewer pipes may be designed for less than the 100-year storm when acting in combination with other drainage elements. The storm sewer system, made up of pipes, a street system, (excluding major divided streets and interstate highways) and/or acting in conjunction with an emergency overflow drainage system shall have a combined capacity of a 100-year frequency storm. Storm sewer pipes without an emergency overflow system or acting in conjunction with a major divided street or interstate shall be designed to intercept and transport the 100-year frequency storm. In the preparation of hydraulic designs, a thorough investigation shall be made of all existing drainage structures and their performance on the waterway in question. Storm sewer pipes designed for less than the 100-year storm will be subject to the requirements of and/or approval by the agency having jurisdiction.

The design of a storm drainage system shall be governed by the following five conditions.

Design Storm Runoff. The system must accommodate all surface runoff resulting from the selected design storm without damage to physical facilities or substantial interruption of normal traffic. In public right-of-ways, substantial interruption will be defined by the agency having jurisdiction.

Runoff in Excess of Design Storm. Runoff resulting from a storm exceeding the design storm must be anticipated and disposed of with minimum damage to physical facilities and minimum interruption of normal traffic.

Construction Costs. The construction costs of the system must be reasonable with relationship to the importance of the facilities it protects.

Maintenance. The storm drainage system must require minimum maintenance and must be accessible for maintenance operations.

Future Planning. The storm drainage system must be adaptable to future expansion with minimum additional cost, to the greatest extent possible.

7.5.1 Permissible Velocities in Pipes

A minimum slope of 0.3 percent shall be maintained in the pipe. A minimum velocity of 2.5 feet per second shall be maintained in pipes flowing under surcharged conditions. Table 7-5 shows the maximum allowable outlet velocities from closed conduits. Discharge velocities cannot exceed the maximum permitted velocity of the receiving channel downstream of the outfall.

7.5.2 Design of Closed Conduits

Inlets and laterals shall be designed for the peak flow entering each inlet; however, the storm sewer system is not designed for the sum of the inlet design quantities of all inlets above that section of the system, but is less than the total. This is because as the time of concentration increases, the rainfall intensity decreases.

Recommended Manning's Roughness Coefficient. In selecting a roughness coefficient for concrete pipe, between 0.012 and 0.015, consider the average condition during the useful life of the structure. An "n" value of 0.015 for concrete pipe should be used primarily in analyzing old conduits where alignment is poor and joints have become rough. Any selection of "n" values below the minimum or above the maximum, either for monolithic concrete structures, concrete pipe, or corrugated metal pipe, must have sufficient justification. An "n" value of 0.012 for concrete pipe should be used primarily in designing new systems where alignment and jointing are assumed in good condition. For cast-in-place and precast box culverts an "n" value of 0.012 may be used.

Pipe Flow Calculations. All storm drains shall be designed according to the continuity equation and Manning's equation, either through the direct solutions of the equation as follows, or by the use of appropriate nomographs:

$$Q = AV, \quad \text{and } Q = (1.486\, AR^{(2/3)}\, S_f^{(1/2)})/n$$

Where:

Q = pipe flow (cubic feet per second)
A = cross-sectional area of pipe (square feet)
V = velocity of flow (feet per second)
n = coefficient of roughness of pipe
R = hydraulic radius = A/Wp (feet)
Sf = friction slope in pipe (feet per foot)
Wp = wetted perimeter (feet)

Several general rules shall be observed when designing storm sewer facilities. These rules are as follows:

- o Pipe size and slope shall be selected so that the velocity of flow will increase progressively, or at least will not appreciably decrease, at inlets, bends, or other changes in geometry or configuration.

- Contents of the larger pipe shall not be discharged into a smaller one, even though the capacity of the smaller pipe may be greater due to steeper slope.

- At changes in pipe size, the crown of the two pipes shall be matched rather than matching the flow lines.

- Conduits at the time of their design shall be checked with reference to critical slope; if the slope of the line is greater than critical slope, the unit will likely be operating under entrance control instead of the originally assumed normal flow.

- Conduit slope shall be kept below critical slope if at all possible; this also removes the possibility of a hydraulic jump within the line.

- The pipe shall be designed to intersect any inlet at the center of the inlet.

Figures 7-19 through 7-29 are nomographs for determining flow properties in circular pipe, elliptical pipe, and pipe-arches. The nomographs are based upon a value of "n" of 0.012 for concrete. The charts are self- explanatory, and their use is demonstrated by the example in Figures 7-19 to 7-21.

For values of "n" other than 0.012, the value of Q should be modified by using the formula below:

$$Qc = [Q_n(0.012)]/nc$$

Where:

Qn = flow based upon n = 0.012
Qc = flow based upon nc
nc = value of "n" other than 0.012

Hydraulic Gradient. In storm drain systems flowing full, all losses of energy through resistance of flow in pipes, by changes of momentum, or by interference with flow patterns at junctions must be accounted for by the accumulative head losses along the system from its initial upstream inlet to its outlet. All hydraulic gradient calculations are to begin at the outfall of the system. The following are the criteria for the starting elevation of the hydraulic gradient.

- Starting hydraulic grade at an outfall into a creek or channel should be the 100-year water surface unless an approved flood hydrograph is available to provide a coincident peak.

- o When a proposed storm drain is to connect to an undersized existing storm drain system, the hydraulic gradient for the proposed storm drain should start 1 foot above the top of the existing pipe or at the top of the proposed storm drain, whichever is higher.

- o The starting hydraulic grade elevation at sumps shall be obtained from the agency having jurisdiction.

- o Starting hydraulic gradient at an outlet shall not be below the top of pipe.

- o The starting hydraulic grade elevation at the Trinity River shall be the stage of the river at reservoir release discharge.

The friction head loss for pipes flowing under surcharged conditions shall be determined by direct application of Manning's equation or by appropriate nomographs in this section. Minor losses due to turbulence at structures shall be determined by the procedures for determining minor head losses provided later in this section.

The pipe should be placed at minimum depth in most cases to eliminate excessive excavation. The hydraulic grade line should be approximately parallel to the ground surface and approximately 3 feet below the ground surface for main line sewers to accommodate head loss at lateral junctions and pipe entrance losses at inlets. The hydraulic gradient shall be designed below the throat flowline of the inlet where possible. The minimum difference between the hydraulic gradient and top of curb shall be:

$$\frac{1.5\,V_2^2}{2g}$$ (or 1 foot, whichever is greater.)

Where:

V_2 = the velocity in the lateral
g = gravitational acceleration (32.2 feet per second per second)

For storm sewer systems out of the DART right-of-way, the hydraulic gradient shall be designed in accordance with the public agency having jurisdiction.

Manholes. Manholes shall be located preferably at street intersections, conduit junctions, changes of grade, or changes of alignment. The maximum spacing between manhole openings and/or points of access shall be 500 feet for pipe sizes of 45-inch diameter or less, and 1,000 feet for pipe sizes 48-inch diameter and larger. Manhole diameters shall be large enough to admit all connecting pipes with a minimum of 1 foot between the outside diameter of the pipes.

Maintenance access shall be provided.

The invert elevation of the manhole shall be clearly shown on the plans and profiles at the center of the manhole.

Other critical elevations and dimensions shall be highlighted on the plans or profiles to notify the contractor of any special conditions.

The designer shall have the option to permit precast manholes to be used. The requirements, criteria and details shall be noted on the respective plans and defined in the general notes for the precast manhole.

Pipe Connection. End-to-end connections of pipe shall match at the crown of the pipe unless utility clearance dictates otherwise. A concrete collar shall be constructed at all designated end to end connectors or where a proposed pipe is connected to an existing pipe.

Horizontal and vertical curve design for storm sewers shall take into account joint closure. Half tongue exposure is the maximum opening permitted with tongue and groove pipe. Where horizontal or vertical alignment require greater deflection, radius or beveled pipe shall be used. A grade difference of 3 percent or more shall require the use of an appropriate vertical curve.

Inlet laterals shall intersect the storm sewer at a 60-degree angle unless interference with utilities requires otherwise. No two laterals shall enter the storm sewer at the same point or length of pipe, unless entering at a manhole or junction structure.

All "Y", 10-foot and 14-foot inlets shall have 21-inch diameter minimum laterals, and 5-foot inlets shall have 18-inch diameter minimum laterals. Pipe wyes connecting to the storm sewer shall be made centerline to centerline. Wye connections shall be shown in the main line profile with the size of lateral, flow line of wye, and stationing of storm sewer indicated.

Minor Head Losses. Total energy head losses shall be determined for inlets, manholes, wye branches, or bends in the design of closed circuits. See Figures 7-28 and 7-29 for the appropriate equations for each type of structure.

Head losses (or gains) due to a sudden pipe size change will be calculated by the formulas:

$$hj = (V_2^2 - V_1^2)/2g \qquad \text{Where: } V_2 > V_1$$

$$hj = (V_2^2 - V_1^2)/4g \qquad \text{Where: } V_1 > V_2$$

Where:

V_1 = velocity in upstream pipe in feet per second

V_2 = velocity in downstream pipe in feet per second

The values of the coefficient "Kj" for determining the loss of head due to obstructions in pipes are shown in Table 7-6 and are used in the following equation to calculate the head loss at the obstruction:

$$hj = (KjV_2^2)/2g$$

Conflicts with Existing Utilities. When conflicts arise between a proposed drainage system and a utility system, the resolution of the conflict shall be coordinated with the utility owners.

7.5.4 Pipe Materials and Required Bedding

Pipe and required bedding materials shall be in accordance with the DART standards and specifications of the utility owner, or DART, as applicable.

Table 7-5
RECOMMENDED MAXIMUM PIPE OUTLET VELOCITY

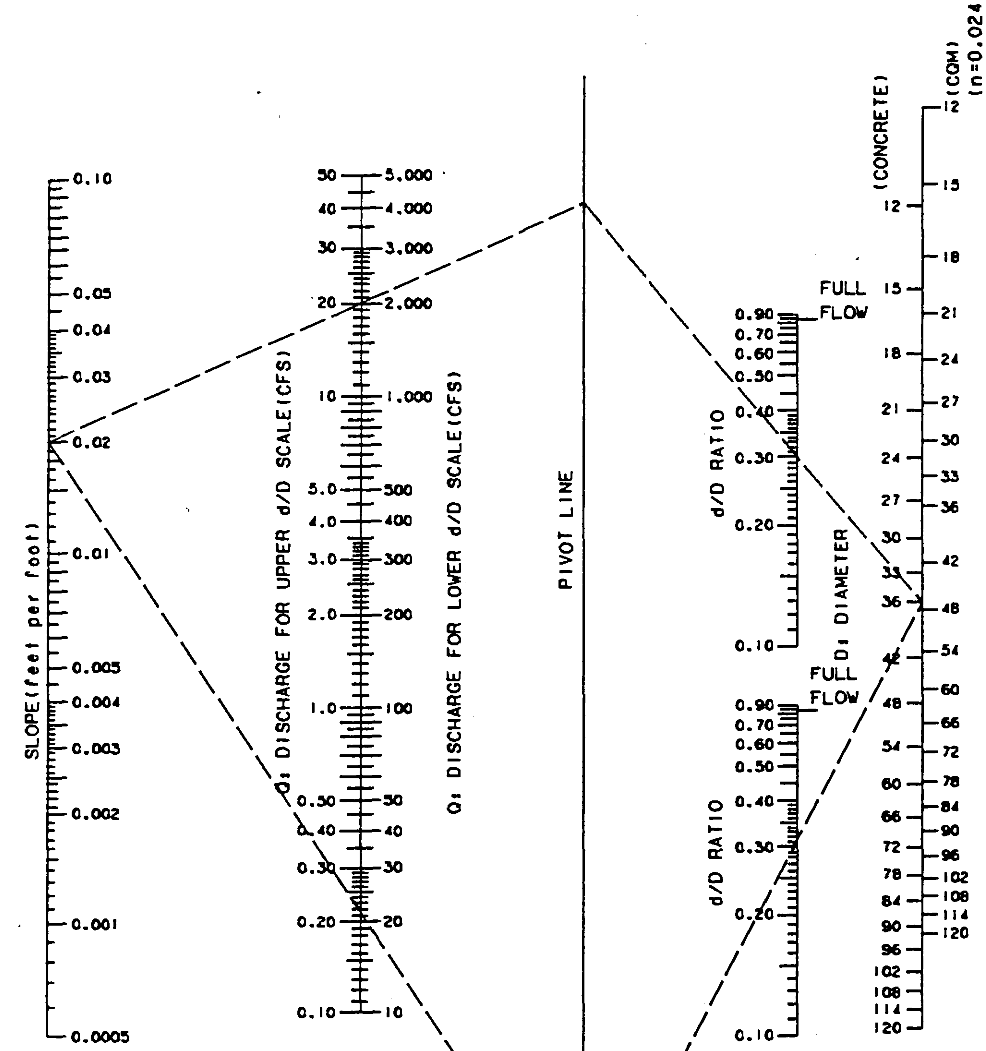
DOWNSTREAM CHANNEL MATERIAL	MAXIMUM OUTLET VELOCITY Feet Per Second
Earth unlined vegetated clay soils	8
Earth unlined vegetated sandy soils	6
Dry riprap (ungrouted)	10
Partially lined	12
Natural rock or finished concrete	15

Maximum outlet velocities in the Escarpment Zone and Geologically Similar Areas are given in the City of Dallas Escarpment Ordinance.

Table 7-6
HEAD LOSS COEFFICIENTS DUE TO OBSTRUCTIONS

A/A'	Kj	A/A'	Kj
1.05	0.10	3.0	15.0
1.1	0.21	4.0	27.3
1.2	0.50	5.0	42.0
1.4	1.15	6.0	57.0
1.6	2.40	7.0	72.5
1.8	4.00	8.0	88.0
2.0	5.55	9.0	104.0
2.2	7.05	10.0	121.0
2.5	9.70		

Note: A/A' = Ratio of area of pipe, A to area of opening at obstruction, A'



EXAMPLE

GIVEN: S = 0.02 FIND: d/D=
Q = 20 CFS d:
D = 36" (CONCRETE)

SOLUTION

d/D = 0.30
d = 0.30x3' = 0.9'

UNIFORM FLOW FOR PIPE CULVERTS

For Full Flow: $Q=35.628\ D^{(8/3)} S_0^{(1/2)}$

Where - D = Pipe Diameter in Feet
S = Slope Of Hydraulic Gradient In Feet Per Foot

n= 0.012

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UNIFORM FLOW FOR PIPE CULVERTS

SCALE: NOT TO SCALE

FIGURE: 7-19

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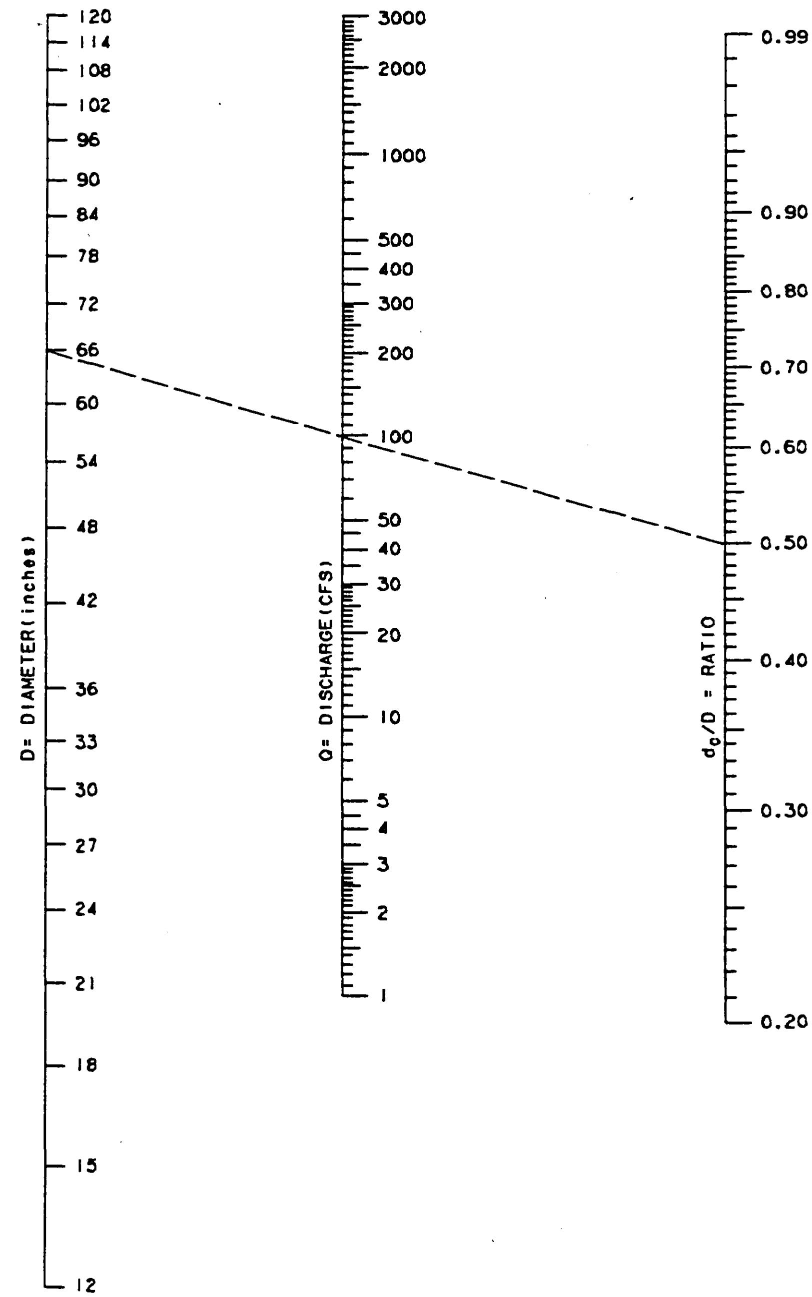
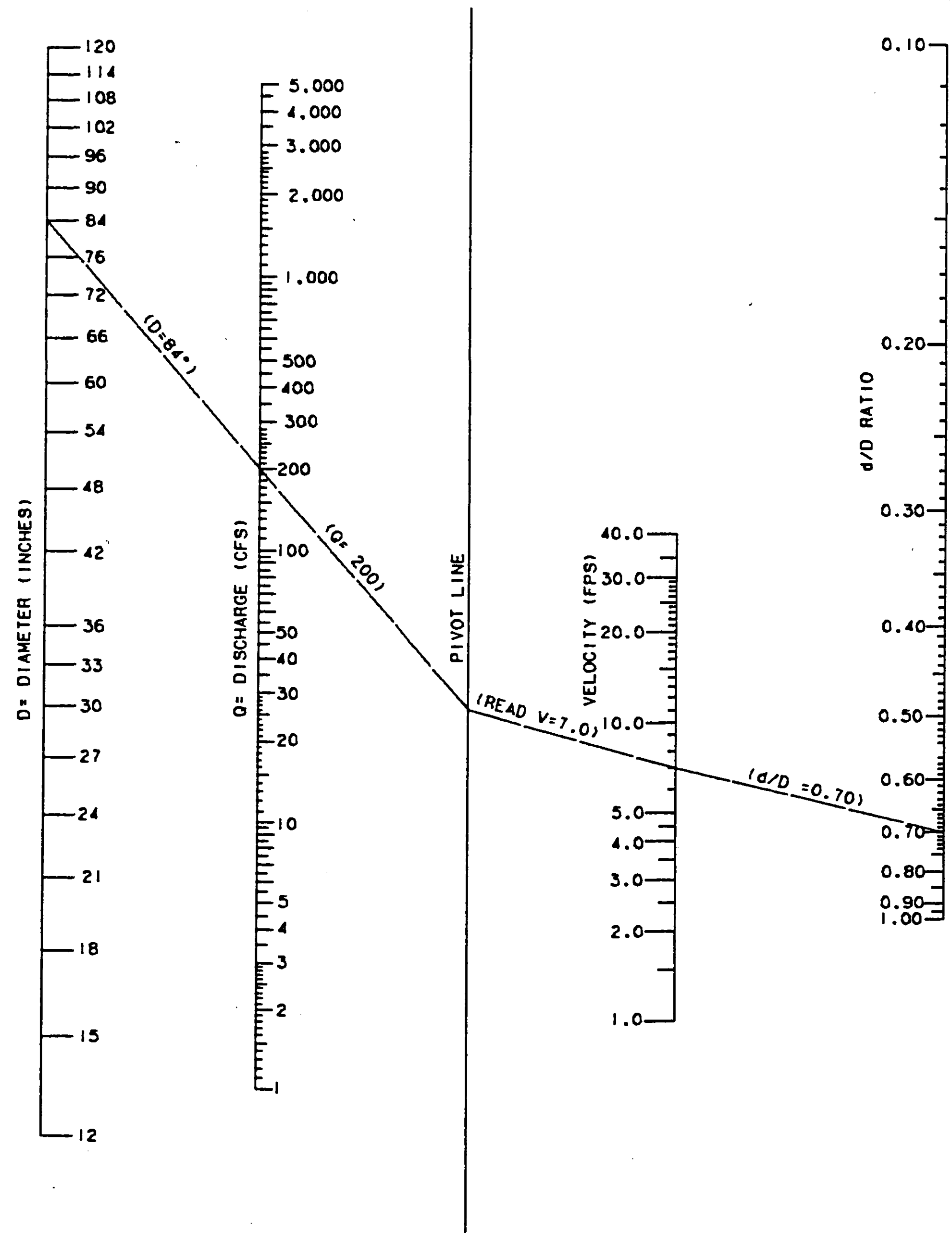


CRITICAL DEPTH OF FLOW
FOR CIRCULAR CONDUITS

n=0.012
CREDIT:TxDOT

ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA CRITICAL DEPTH OF FLOW FOR CIRCULAR CONDUITS SCALE: NOT TO SCALE FIGURE: 7-20

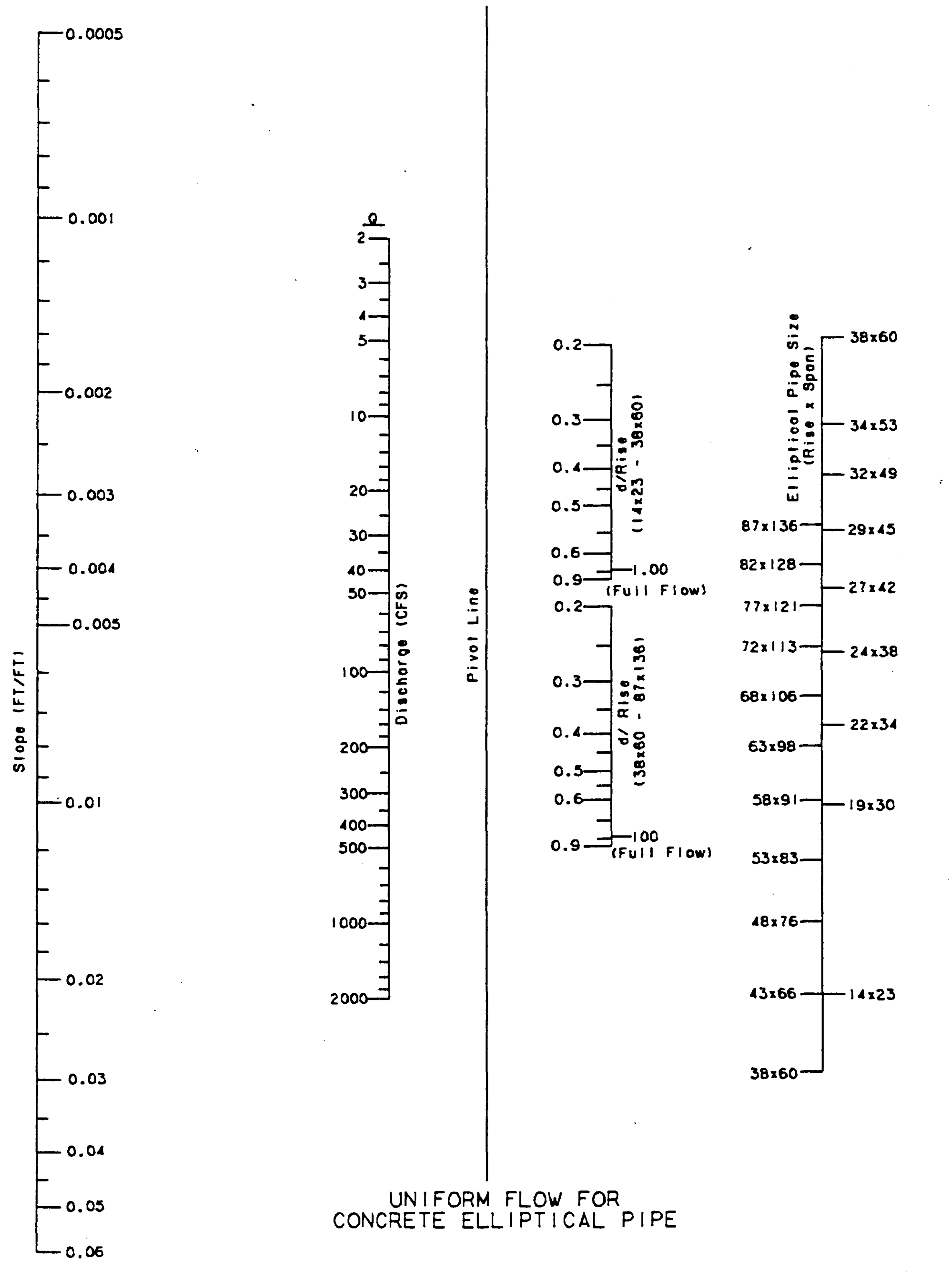
JAN. 2003, REV 10



VELOCITY IN PIPE CONDUITS

n=0.012
CREDIT: TxDOT

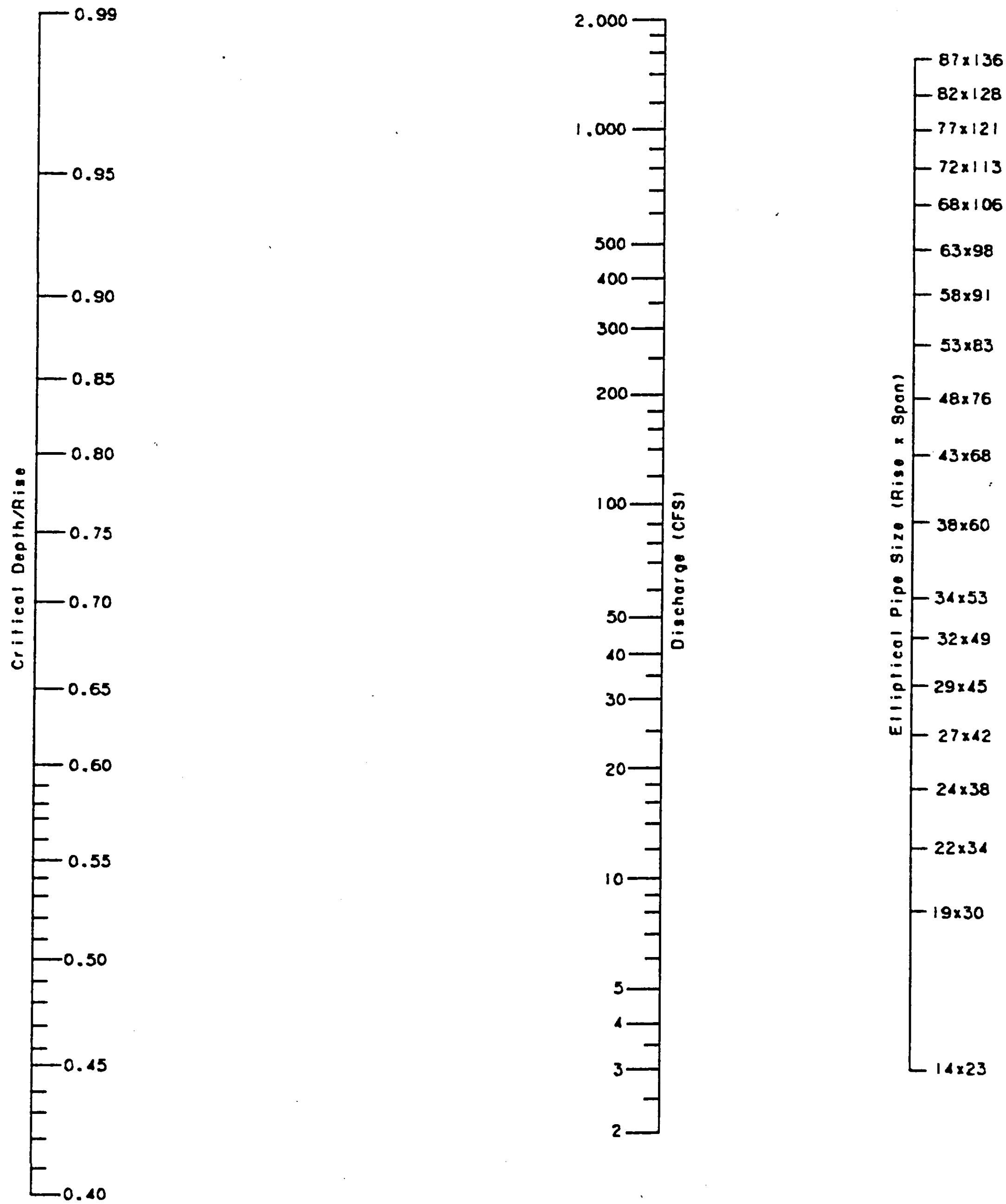
ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA VELOCITY IN PIPE CONDUITS SCALE: NONE FIGURE: 7-21



UNIFORM FLOW FOR
CONCRETE ELLIPTICAL PIPE

n=0.012
CREDIT: TxDOT

ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA UNIFORM FLOW FOR CONCRETE ELLIPTICAL PIPE SCALE: NONE FIGURE: 7-22



CRITICAL DEPTH FOR
ELLIPTICAL PIPE

n=0.012
CREDIT: TxDOT

ACT 21

CARTER BURGESS
JACOBS ENGINEERING
STV INCORPORATED
KAI ALLIANCE

DART PROJECT

DART

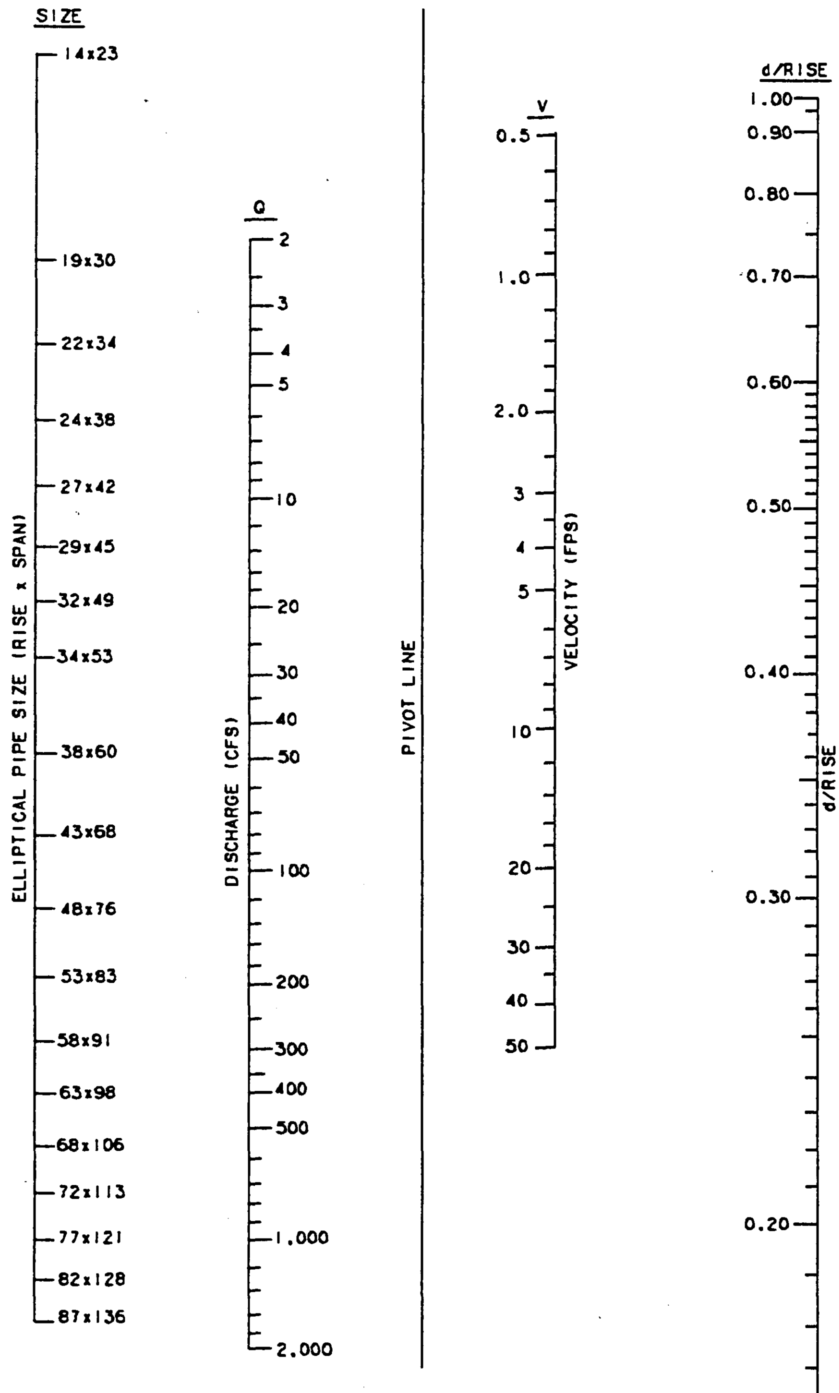
DART DESIGN CRITERIA

CRITICAL DEPTH FOR ELLIPTICAL PIPE

SCALE: NONE

FIGURE: 7-23

JAN. 2003, REV 10

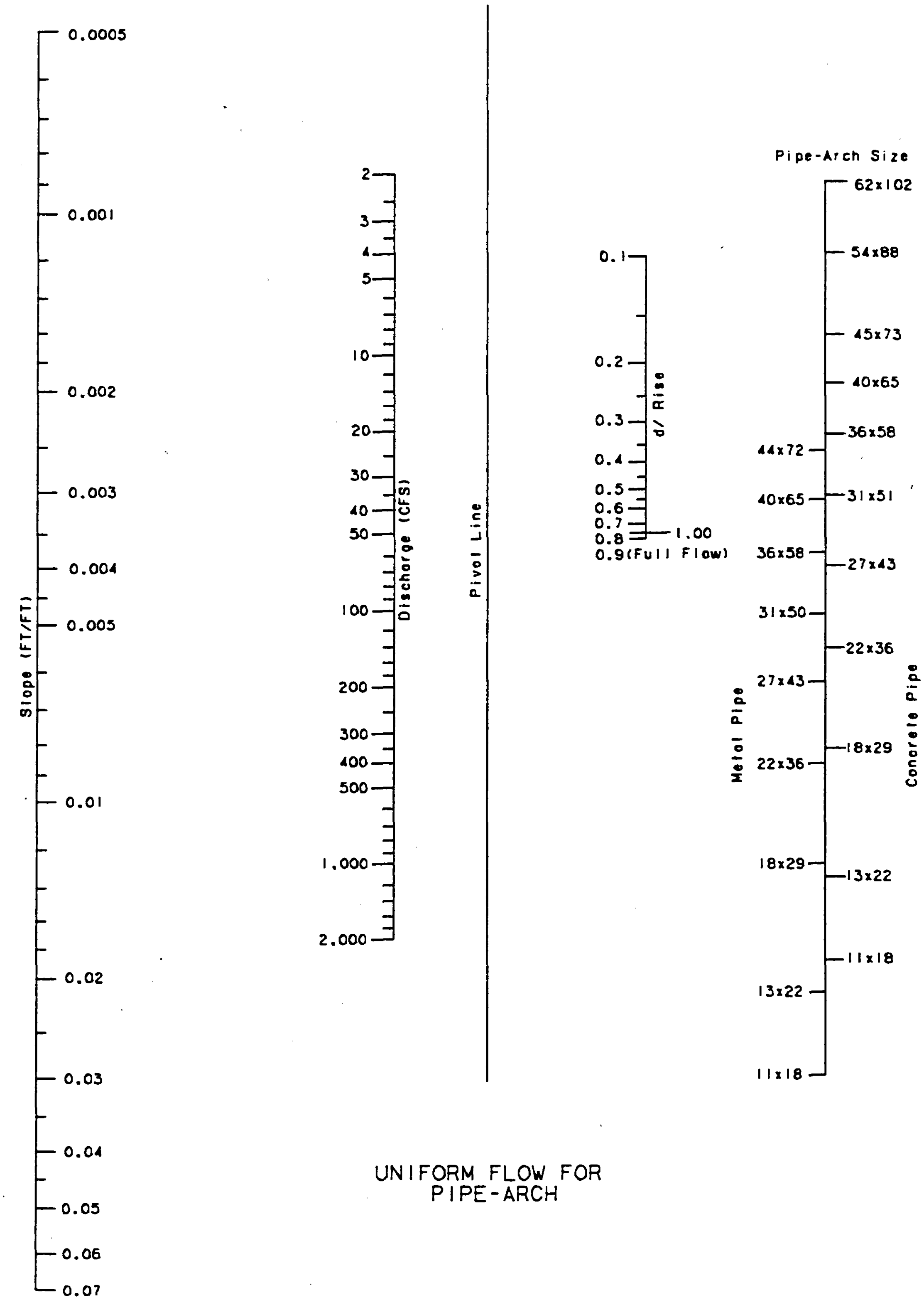


VELOCITY IN ELLIPTICAL PIPE

n=0.012
CREDIT: TxDOT

ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA VELOCITY IN ELLIPTICAL PIPE SCALE: NONE FIGURE: 7-24

JAN. 2003, REV 10



UNIFORM FLOW FOR
PIPE-ARCH

n=0.012
CREDIT: TxDOT

ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA UNIFORM FLOW FOR PIPE - ARCH SCALE: NONE FIGURE: 7-25

JAN. 2003, REV 10

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vrivera

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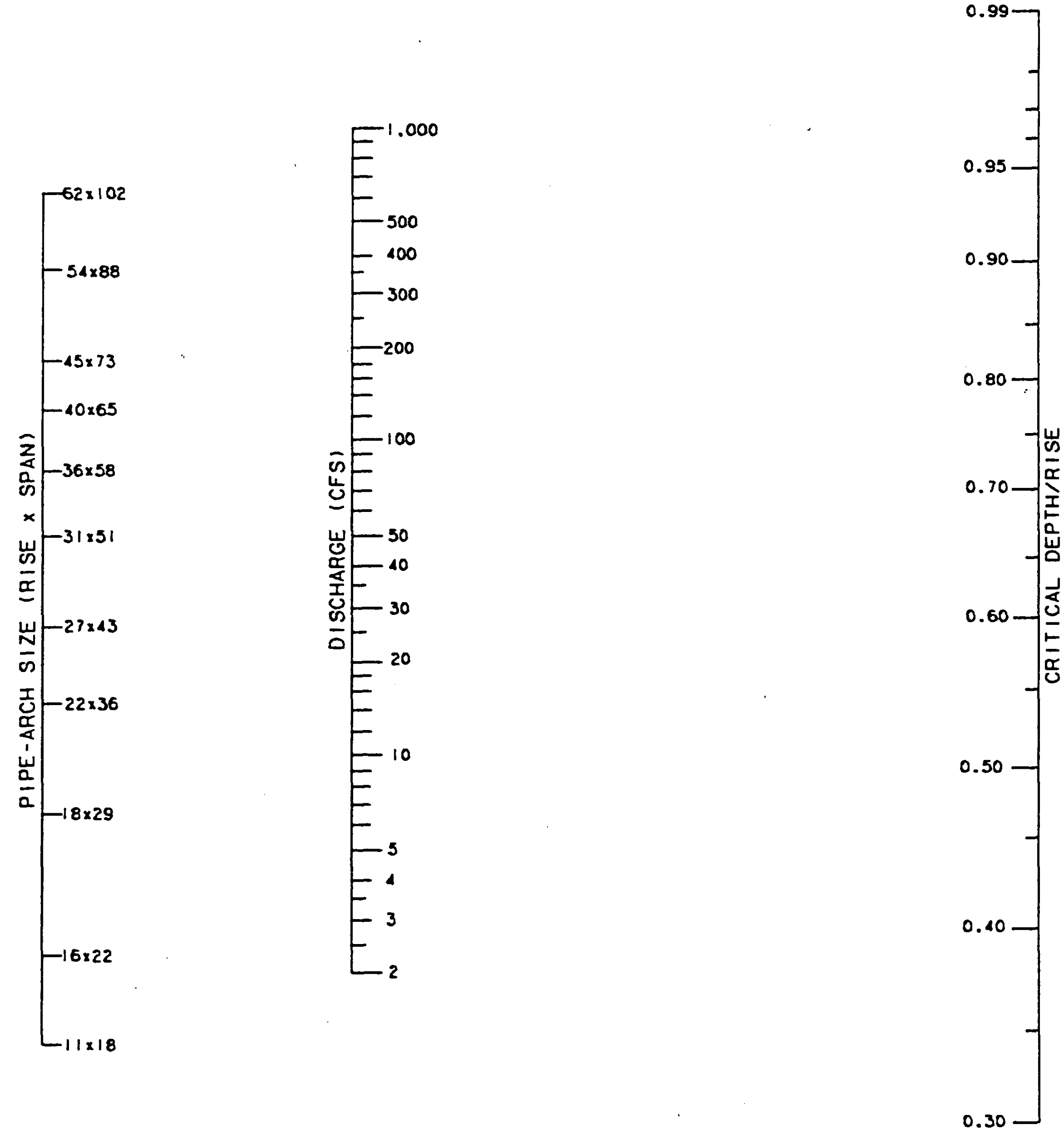

CRITICAL DEPTH OF FLOW
FOR PIPE-ARCH

n=0.012
CREDIT: TxDOT

DART PROJECT

DART DESIGN CRITERIA

CRITICAL DEPTH OF FLOW FOR PIPE-ARCH

SCALE: NONE

FIGURE: 7-26

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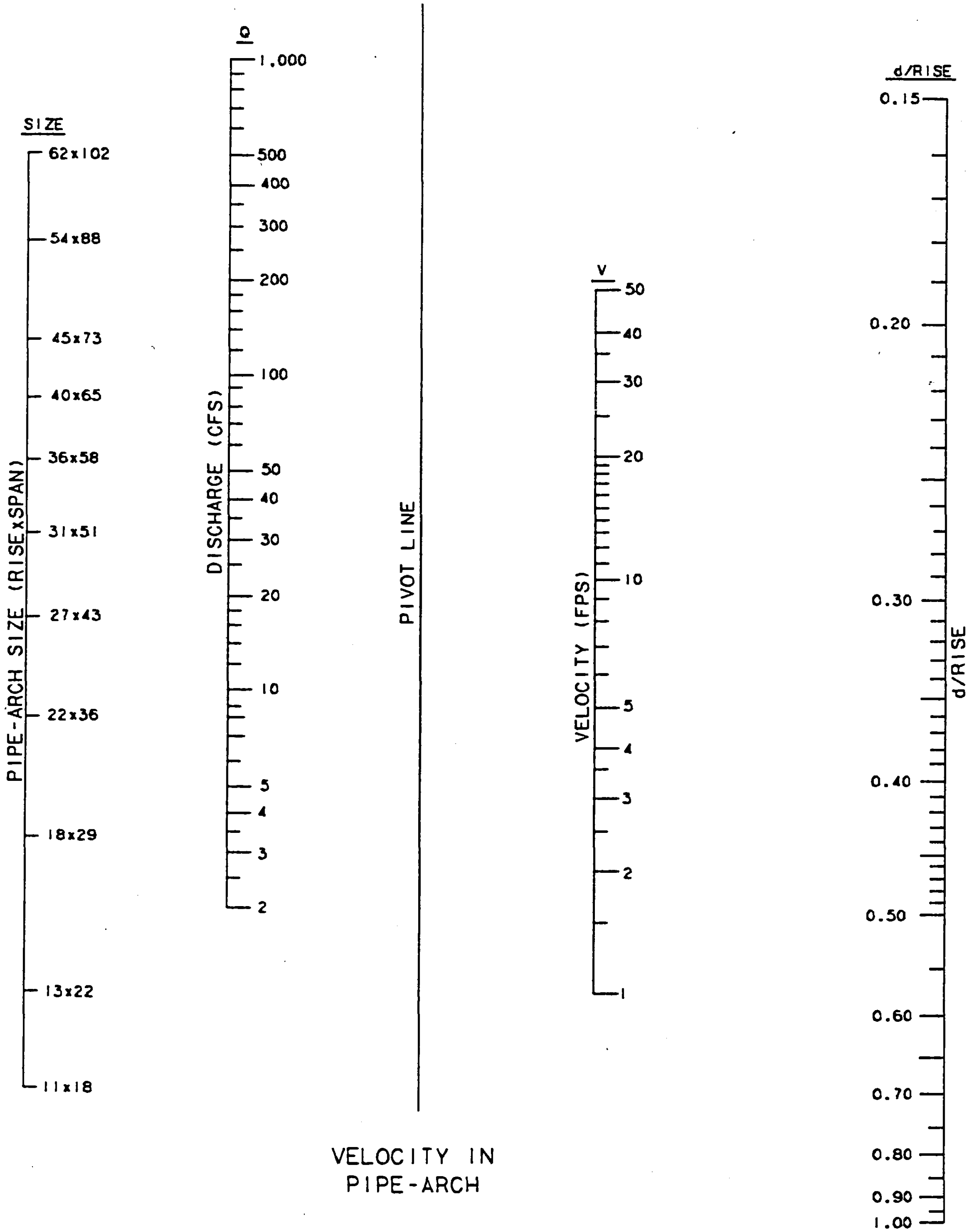
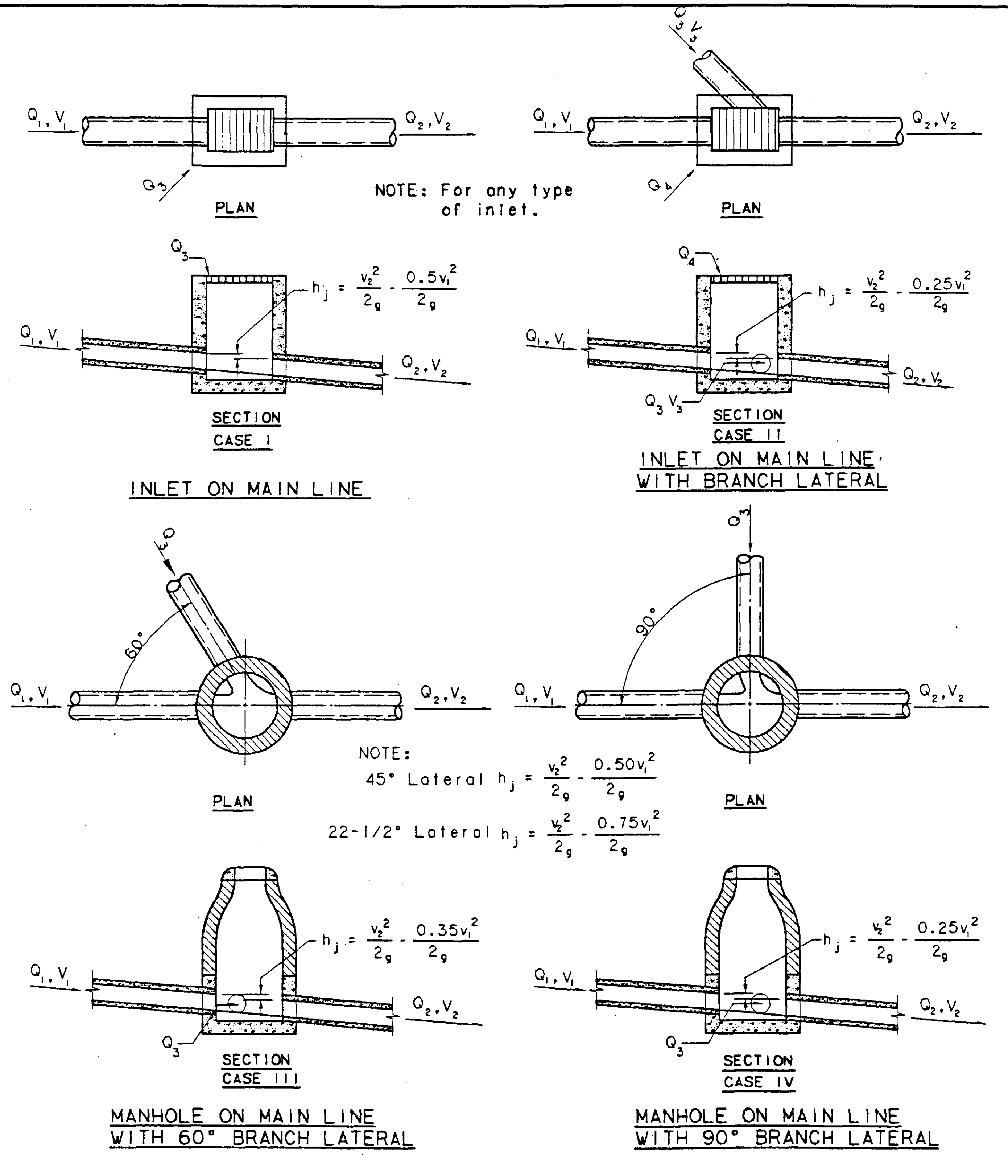


VELOCITY IN
PIPE-ARCH

n=0.012
CREDIT: TxDOT

ACT 21 — CARTER BURGESS, JACOBS ENGINEERING, STV INCORPORATED, KAI ALLIANCE	DART PROJECT	DART DESIGN CRITERIA
	DART	VELOCITY IN PIPE-ARCH
		SCALE: NONE — FIGURE: 7-27



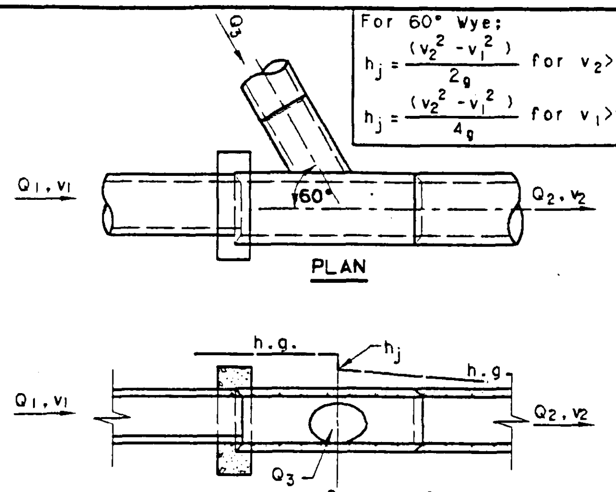
MINOR HEAD LOSSES DUE TO TURBULENCE AT STRUCTURES

ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA MINOR HEAD LOSSES SCALE: NONE FIGURE: 7-28

For 60° Wye:

$$h_j = \frac{(v_2^2 - v_1^2)}{2g} \text{ for } v_2 > v_1$$

$$h_j = \frac{(v_2^2 - v_1^2)}{4g} \text{ for } v_1 > v_2$$



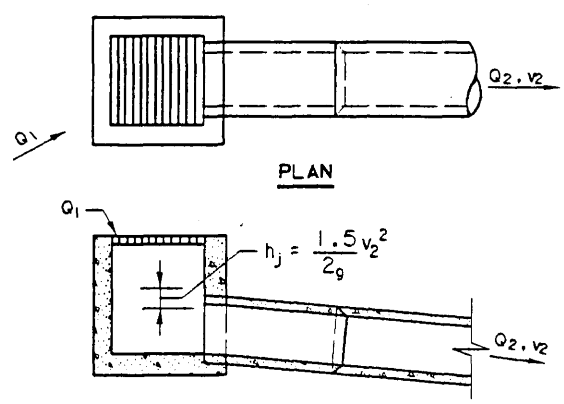
NOTE: For 45° Wye: $h_j = \frac{v_2^2}{2g} - .75\,\frac{v_1^2}{2g}$ for $v_2 > v_1$

$h_j = 0.5\left(\frac{v_2^2}{2g} - .75\,\frac{v_1^2}{2g}\right)$ for $v_1 > v_2$

SECTION

CASE V

60° WYE CONNECTION OR CUT IN

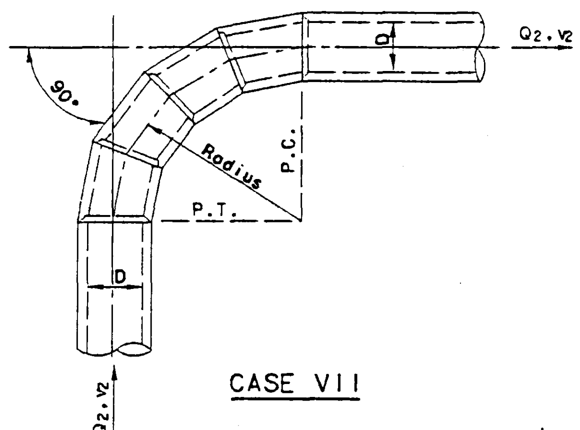


$h_j = \frac{1.5\,v_2^2}{2g}$

SECTION

CASE VI

INLET OR MANHOLE AT BEGINNING OF LINE



CASE VII

CONDUIT ON 90° CURVES *

NOTE: Head loss applied at P.C. for length of curve.

Radius = Dia of Pipe $h_j = 0.50\,\frac{v_2^2}{2g}$

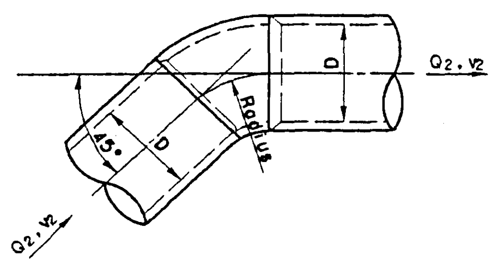
Radius = (2-8)Dia of Pipe $h_j = 0.40\,\frac{v_2^2}{2g}$

Radius = (8-20)Dia of Pipe $h_j = 0.25\,\frac{v_2^2}{2g}$

Radius = Greater than 20 Dia of Pipe $h_j = 0$

*When curves other than 90° are used, apply the following factors to 90° curves

60° curve 85%
45° curve 70%
22-1/2° curve 40%



CASE VIII

BENDS WHERE RADIUS IS EQUAL TO DIAMETER OF PIPE

NOTE: Head loss applied at beginning of bend

90° Bend $h_j = 0.80\,\frac{v_2^2}{2g}$

60° Bend $h_j = 0.60\,\frac{v_2^2}{2g}$

45° Bend $h_j = 0.50\,\frac{v_2^2}{2g}$

30° Bend $h_j = 0.45\,\frac{v_2^2}{2g}$

22-1/2° Bend $h_j = 0.30\,\frac{v_2^2}{2g}$

7.6 CHANNELS

Open channels may be used to convey storm waters when the design storm runoffs exceed the capacity of a 72-inch diameter pipe. Channels (lined or unlined) shall be designed to transport the 100-year frequency storm. A wide variety of lined, partially lined, or unlined channels is permitted except that lined channels in DART right-of-way may not be constructed in single family, multifamily, or townhouse residential developments. If a municipality allows open channels in these residential areas, the new channels on DART right-of-way shall be consistent with the existing channel and submitted for DART approval. In general, the use of existing channels in their natural condition is encouraged. Low-flow pilot-channel lining of earth channels may be permitted in areas where necessary for bottom maintenance.

Roadway and railway roadbeds within the DART right-of-way may be drained by use of ditches designed for a minimum 10-year frequency storm, subject to local approvals. However, flooding potential, however, must be evaluated for the 100-year frequency storm and a suitable emergency overflow must be provided that does not adversely impact adjacent drainage or property. Typically, ditches are grass lined and of smaller geometric configuration than that of an open channel.

7.6.1 Permissible Velocities

Table 7-7 shows the maximum allowable velocities for open channels. When the grade selected results in velocities exceeding the maximum allowable, special drop structures, energy dissipators or flow retarders shall be required. At transitions from lined to unlined channels, velocities must be reduced before reaching the unlined channel, to values at or below the allowable maximum for the unlined or natural channel.

7.6.2 Channel Hydraulic Design

Manning's Equation. The hydraulic characteristics of channels shall be determined by Manning's equation as given for the pipe flow calculations in Section 7.5.2. Roughness coefficients are shown in Table 7-7 for different types of channels.

Water Surface Profiles. On all channels, the water surface elevation profile shall be calculated for the 100-year design storm and shown on the channel profile.

7.6.3 Channel Geometry Design Considerations

Alignment. The use of existing channels in their natural condition is encouraged. If new and improved channels are required, alignments shall be smooth with long radius curves. Generally, curve radii should exceed 10 times the bottom width of the new or improved unlined channel.

Connections of new or improved channels to an existing channel shall match line and grade of the existing channel. All regulations concerning channelization must be carefullly checked, as exhaustive permitting, approval, and construction requirements may be imposed.

Side Slopes. For unlined channel sections, the maximum side slopes are 3:1. For lined low-flow channel sections, the sides may be vertical if the height of the vertical wall does not exceed 3 feet. Paved slopes shall be 2:1 maximum.

Bottom Width. Channels with narrow bottoms are difficult to maintain and are conducive to high velocities during high flows. It is desirable to design open channels such that the bottom width is at least twice the depth. Roadbed drainage ditch bottom width shall be a minimum of 2 feet. (Refer to the at-grade standards.) Any permanent open channels shall have a minimum bottom width of 5 feet, except grass-lined shallow swales. If maintenance vehicles are required to travel the channel bottom, the minimum width shall be 8 feet.

Low Flow Pilot Channel. The low flows, and sometimes base flows, from urban areas must be given specific attention. If erosion of the bottom of the channel appears to be a problem, low flows may be transported in a paved pilot channel which can usually be estimated to carry approximately 5 percent of the design peak flow. Care must be taken in grading the channel bottom to ensure that low flows enter the pilot channel without flow paralleling the pilot channel.

Freeboard. For channels with flow at high velocities, the water surface roughness, wave action, air bulking, splash, and spray are quite erosive along the top of the flow. The height of freeboard shall be a minimum of 2 feet from the design water surface to the top of bank, and 1 foot to top of the channel liner. For deep flows with high velocities, greater freeboard may be required.

If the previously stated minimum curve radius for a channel cannot be met and a sharp curve is required, extra height must be added to the outside bank or wall in the amount:

$$H = \frac{V^2 (T + B)}{2gR}$$

Where:

H = additional height on outside edge of channel (feet)
V = velocity of flow in channel (feet per second)
T = width of flow at water surface (feet)
B = bottom width of channel (feet)
R = centerline radius of turn (feet)
g = acceleration of gravity (32.2 feet/second$_2$)

If R is equal to or greater than three B, additional freeboard is not required.

Freeboard for roadbed ditches shall be the maximum of either 1.0 feet from the shoulder of a road without curb and gutter, or 1.0 feet from top of curb, and 1.0 foot from the bottom of the trackway subballast for the 100-year frequency storm, 1.75 feet from the bottom of the subballast for the 25-year frequency storm, or 1.5 feet from the bottom of the subballast for the 10-year frequency storm.

Channel Drops. The use of channel drops permits adjustment of channel gradients which are too steep for the design conditions. In urban drainage work, it is often desirable to use several low-head drops in lieu of a few higher drops. Special attention must be given to protecting the channel from erosion in the area of channel drops.

The use of sloped drops will generally result in lower cost installations. Sloped drops can easily be designed to fit the channel topography.

Sloped drops shall have roughened faces and shall be no steeper than 2:1. They shall be adequately protected from scour, and shall not cause an upstream water surface drop that will result in high velocities upstream. Protection shall be provided against scour and side cutting downstream of a drop.

The length of the sloped drop, L, will depend upon the hydraulic characteristics of the channel and drop. L may be calculated at one-half of Q/B where Q is the peak design flow in the channel and B is the bottom width of the channel. For example, L would be 15 feet for a Q/B of 30 cubic feet per second per foot. The L should not be less than 10 feet. In addition, riprapping will often be necessary at drops to fully protect the banks and channel bottom.

Erosion/Siltation Control. Potential erosion and/or siltation areas - due to eroding velocities or abrupt changes in velocities - shall be considered in the design process. Preventive measures shall be incorporated in the design.

Energy Dissipator Structures. Baffle chutes may be used to dissipate the energy in the flow at a larger drop. They require no tailwater to be effective. They are particularly useful where the water surface upstream is held at a higher elevation to provide head for filling a side storage pond during peak flows.

Baffle piers are used to prevent undue acceleration of the flow as it passes down the chute. The chute, on a 2:1 slope or flatter, may be designed to discharge up to 60 cubic feet per second per foot of width, and the drop may be as high as structurally feasible. So that degradation of the stream bed does not adversely affect the performance of the structure, the lower end should be protected from the scouring action by use of concrete or grouted riprap and a toe wall of sufficient depth to prevent undermining.

Table 7-7

ROUGHNESS COEFFICIENT FOR OPEN CHANNELS

Channel Description	Roughness Coefficient Minimum	Roughness Coefficient Normal	Roughness Coefficient Maximum	Maximum Velocity
MINOR NATURAL STREAMS				
Moderately Well-Defined Channel				
Grass and Weeds, Little Brush	0.025	0.030	0.033	8
Dense Weeds, Little Brush	0.030	0.035	0.040	8
Weeds, Light Brush on Banks	0.030	0.035	0.040	8
Weeds, Heavy Brush on Banks	0.035	0.050	0.060	8
Weeds, Dense Willows on Banks	0.040	0.060	0.080	8
Irregular Channel with Pools and Meanders				
Grass and Weeds, Little Brush	0.030	0.036	0.042	8
Dense Weeds, Little Brush	0.036	0.042	0.048	8
Weeds, Light Brush on Banks	0.036	0.042	0.048	8
Weeds, Heavy Brush on Banks	0.042	0.060	0.072	8
Weeds, Dense Willows on Banks	0.048	0.072	0.096	8
Flood Plain, Pasture				
Short Grass, No Brush	0.025	0.030	0.035	8
Tall Grass, No Brush	0.030	0.035	0.050	8
Flood Plain, Cultivated				
No Crops	0.025	0.030	0.035	8
Mature Crops	0.030	0.040	0.050	8
Flood Plain, Uncleared				
Heavy Weeds, Light Brush	0.035	0.050	0.070	8
Medium to Dense Brush	0.070	0.100	0.160	8
Trees with Flood Stage Below Branches	0.080	0.100	0.120	8
MAJOR NATURAL STREAMS				
The roughness coefficient is less than that for minor streams of similar description because banks offer less effective resistance.				

Table 7-7 cont.

ROUGHNESS COEFFICIENT FOR OPEN CHANNELS

Channel Description	Roughness Coefficient Minimum	Normal	Maximum	Maximum Velocity
Moderately Well Defined Channel	0.025	---	0.060	8
Irregular Channel	0.025	---	0.100	8
UNLINED VEGETATED CHANNELS				
Mowed Grass, Clay Soil	0.025	0.030	0.035	8
Mowed Grass, Sandy Soil	0.025	0.030	0.035	6
UNLINED NONVEGETATED CHANNELS				
Clean Gravel Section	0.022	0.025	0.030	8
Shale	0.025	0.030	0.035	10
Smooth Rock	0.025	0.030	0.035	15
LINED CHANNELS				
Smooth Finished Concrete	0.013	0.015	0.020	15
*Dry Riprap (Rubble)	0.030	0.040	0.050	10
*Grouted Riprap	0.020	0.025	0.030	15
Partially Lined, Concrete	---	---	---	12

*See Figure 7-33 for minimum stone diameters

7.7 CULVERTS

The function of a drainage culvert is to pass the design storm flow under a roadway or railroad without causing excessive backwater and without creating excessive downstream velocities. The culvert shall be designed to transport the 100-year frequency storm. The designer shall keep energy losses and discharge velocities within reasonable limits when selecting a culvert structure. The standard culvert construction details as prepared by the bridge division of the Texas Department of Transportation shall be used for culvert design.

7.7.1 Permissible Velocities

The maximum permissible velocity in culverts is limited to 15 feet per second. The velocity shall be reduced to within the maximum values provided in Table 7-5 prior to being discharged to an unlined channel.

7.7.2 Culvert Hydraulic Design

Culvert Flow Calculation. Culverts shall be selected based on hydraulic principles, economy of size and shape, and with a resulting headwater depth that will not cause damage to adjacent property. The hydraulic design method detailed in the TxDOT Hydraulic Manual shall be used for design of culverts.

Maximum Allowable Headwater. The maximum allowable headwater shall be the maximum of either 1.5 feet from the shoulder of a road without curb and gutter, 2.0 feet from top of curb, or 1.0 foot below bottom of subballast for the 100-year frequency storm. The preferred headwater may range between 1.2D and 1.5D where D is the inside vertical dimension of the culvert.

7.7.3 Culvert Bedding

Bedding materials, required depths of bedding, and other installation details shall be in accordance with the DART at-grade standards, Department of Public Transportation Standard Details, and DART specifications. In the case of confliction between standards, the more stringent standard shall apply.

7.8 BRIDGES

Bridges shall be designed to accommodate the 100-year frequency storm or highest recorded flood, whichever is greater. After determination of the existing waterway flow characteristics for the design storm, the bridge opening size can be determined.

It should be noted that columns, piers, etc. are not considered in any of the following discussion. Usually, they may be neglected. However, their effect in reducing the waterway opening should not be neglected if they constitute a substantial cross-sectional area themselves. This is particularly true in the case of skewed crossings with normal bents.

For the hydraulic design of bridges, cross sections that are 90 degrees to the direction of stream flow at flood stage shall be used. If the crossing is skewed to the stream flow at flood stage, all cross sections shall be normalized before proceeding with bridge design. If the skew is severe and the floodplain is wide, elevations in the normalized section may require adjusting to offset the effects of elevation changes in the point displacement between the skewed section and the normalized section.

7.8.1 Bridge Hydraulic Design

The bridge hydraulic design method detailed in the TxDOT Hydraulic Manual shall be used for design of bridge structures to serve DART facilities. The design shall comply with the following criteria:

- o Minor head loss due to the structure is allowed; normal losses due to channel cross sections are allowable.
- o Excavation of the natural channel is not normally allowed as compensation for loss of cross sectional area.
- o Channelization upstream or downstream of the proposed bridge will normally not be permitted.

7.8.2 Bridge Geometric Design Considerations

Freeboard. A 2-foot freeboard is required between the design water surface and the lowest point on the superstructure for the 100-year frequency storm. A 1-foot freeboard is allowed for bridge crossings over sump areas off the primary stream channel for the 100-year frequency storm.

Spur Dikes. Spur dikes are beneficial at sites where the distance of the flow travel along the embankment is in excess of 600 feet. Spur dikes are also advantageous for improving the characteristics of flow through a single structure. They function by directing along-embankment flow away from the bridge opening. This causes any parallel embankment velocity to be removed from the embankment itself and serves to greatly reduce the under-bridge turbulence usually caused by intersecting flow vectors. If scour is a problem, the end of the spur dike is eroded and not the bridge header. The top of the spur dike elevation should be a minimum of 2 feet above design high-water elevation. Also, it is desirable for natural vegetation to be left around the end of the spur dike.

Scour. A scour study shall be made for piers within water flow areas.

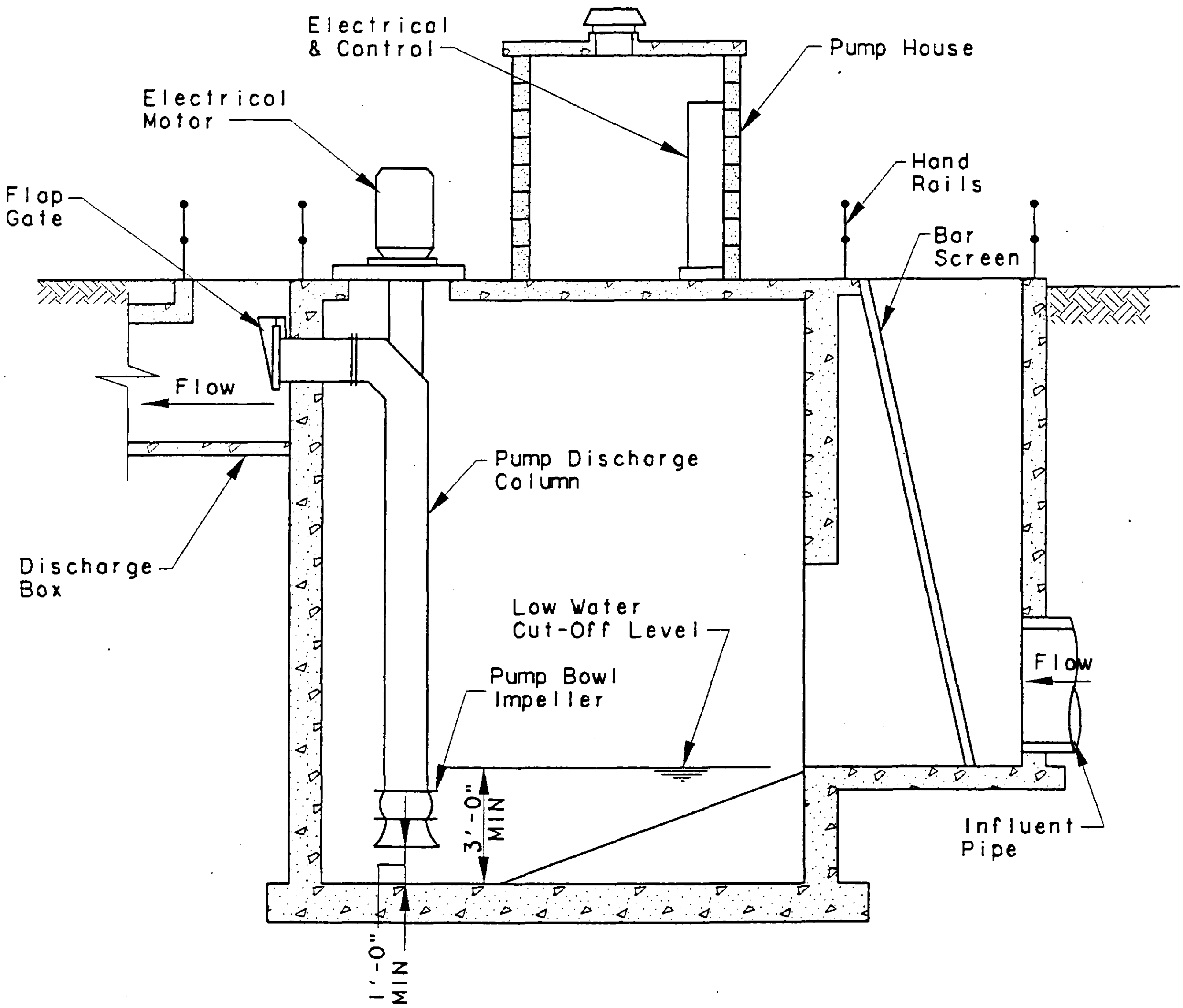
7.9 STORM WATER PUMP STATIONS

Where feasible, the use of a storm water pumping station shall be avoided. The feasibility of storm water pumping stations shall be based on both the initial outlays for pumping versus gravity drainage systems and future operating and maintenance costs of each system. Where pumping stations are required, they shall conform to the following general guidelines, to the standards of the city in which they are located, and be sized to accommodate the previously defined design storm runoff.

This section provides general guidance to the designer for an acceptable storm water pump station design. In addition, pump manufacturers and electrical equipment vendors can provide helpful design information. Contacts are also necessary through DART with representatives of the utility firms that might supply power to the station (electricity, natural gas, or diesel fuel).

The term "pump station" refers to the entire facility required for mechanically lifting the storm water a predetermined distance from a gravity inflow to a gravity outfall. The basic features of a typical storm water pump station (Figure 7-30) include a wet well sump, pumps, screening facilities, appurtenances, pump house, and motors and/or engines.

Storm water pump stations typically shall consist of vertical wet-pit pumps suspended from the pump floor into the wet well. The pumps shall be protected by a bar screen.



ACT 21

CARTER BURGESS
JACOBS ENGINEERING
STV INCORPORATED
KAI ALLIANCE

DART PROJECT

DART

DART DESIGN CRITERIA

EXAMPLE PUMP STATION

SCALE: NOT TO SCALE

FIGURE: 7-30

7.9.1 Design Features

Design of storm water pump stations shall be in conformance with the architectural design criteria. Refer to the TxDOT Hydraulic Manual for a detailed example of a pump station design.

7.10 DETENTION STORAGE

Detention storage shall be considered as an alternate to upgrading existing facilities if the peak storm runoff for the design storm exceeds the capacity of the existing downstream system.

Retention and detention are two generalized types of storm runoff storage used to control flooding. Retention storage refers to storm runoff collected and stored for a significant period and released or used after the storm runoff has ended. Retention storage usually consists of "wet reservoirs" which often have agricultural, recreational, and/or aesthetic value. Detention storage consists of reducing the peak rate of runoff by controlling the discharge through an outlet structure and by extending the period of runoff.

7.10.1 Types of Detention Storage

Detention Basin Storage. Detention basin storage may be used to reduce the peak storm runoff. Detention basins shall be designed according to these criteria.

Channel Storage. Although all channels inherently store water, channels can be made to attenuate runoff by altering their hydraulic characteristics in a way that will reduce peak flows. Side channels that run essentially parallel to the main stream channel are also a means of temporarily storing water during excessive rainfall.

7.10.2 Hydraulic Design of Detention Storage Areas

The rate of inflow to a storage facility (inflow hydrographs) and all hydrologic consideration must assume ultimate development of the site's contributing area.

Detention storage areas shall be designed to accommodate the inflow of a 100-year frequency storm. The detention storage area shall be checked for the 2-year and 5-year frequency storms. The maximum allowable release rate from a detention storage area shall be determined by considering the following items:

- The peak flow rate for the basin prior to the DART improvements.

- The capacity of downstream drainage facilities for the 100-year frequency storm.

- Compliance with a master plan for the watershed (if one exists).
- Problems, if any, that are created on-site by the detention storage.
- Problems, if any, created downstream if the on-site detention storage area is full, and the excess runoff flows overland into downstream areas.

The outfall or outlet structures shall be designed on the basis of inlet or outlet control, whichever is applicable. The structures shall be capable of safely and properly passing the storm runoff from the 2-year, 5-year, and the 100-year storm without causing downstream flooding or exceeding the maximum allowable release rate for each frequency storm.

Modified Rational Method. The modified rational method analysis manipulates the rational method to reflect the fact that storms with durations greater than the normal time of concentration for a basin could result in a larger volume of runoff even though the peak discharge is reduced. This method may be used for sizing a detention storage area with a drainage basin of less than 130 acres.

The modified rational method shall be used to develop a range of hydrographs for the 2-year, 5-year, and 100-year storm frequencies to evaluate the effect of resultant flooding that might occur. The example solution shown in Figure 7-31 determines the required storage volume for a given basin and analyzes the effects of the 2-year, 5-year and 100-year storm frequencies.

Unit Hydrograph Method. An inflow-storage-outflow-hydrograph-based methodology similar to the techniques specified in the unit hydrograph method detailed in Section 7.2 shall be used to determine the required detention storage for basin areas greater than or equal to 130 acres. The storm duration and design frequency to be used shall be the combination requiring the greatest detention storage volume.

Freeboard and Emergency Spillway. Where earth embankments are used to temporarily impound the required detention, the top of the embankment shall be a minimum of 2.0 feet above the maximum 100-year pool level. In addition, an emergency spillway or overflow area shall be provided at the maximum 100-year pool level to ensure that the 500-year frequency event does not overtop the embankment.

If the emergency spillway capacity is to be provided over the embankment, it must be structurally designed to prevent erosion and consequent loss of structural integrity. If the capacity is to be provided in a vegetated earth spillway separate from the embankment, the required width for a trapezoidal spillway with a control section can be estimated by the equation:

$$Bw = \frac{0.36Q}{D^{3/2}} - 0.7ZD$$

Where:

Bw = bottom width
Q = emergency spillway capacity (cubic feet per second)
D = design depth above spillway crest (feet)
Z = side slope, i.e., horizontal distance to 1 foot vertical

The minimum width for this type of spillway is 4.0 feet.

Earth Embankment Design. The steepest side slope permitted for a vegetated earth embankment is 4:1 and 2:1 for a rock dam. The minimum crown width is as follows:

Total Height of Embankment (feet)	Minimum Crown Width (feet)
14 or less	8
15 to 19	10
20 to 24	12
25 to 34	14

Outflow Structure. Where the outflow structure conveys flow through the embankment in a conduit, the conduit shall be reinforced concrete designed to support the external loads with an adequate factor of safety. The structure shall withstand the internal hydraulic pressures without leakage under full external load or settlement. It must convey water at the design velocity without damage to the interior surface of the conduit.

Basin Grading. Detention basins to be excavated must provide positive drainage with a minimum grade of 0.3 percent. The steepest side slope permitted for an excavated slope not in rock is 4:1.

Earth Embankment Specifications. Earth embankments used to temporarily impound required detention volume must be constructed according to specifications for fill, equal to that required for levee embankments. Where permanent impoundment is to be provided, more stringent specifications may be required based on a geotechnical investigation for the site.

Maintenance Provisions. Detention basin design must provide access for periodic desilting and debris removal. Basins with permanent storage must include dewatering facilities to provide for maintenance. Detention basins with a drainage area of 320 acres or more must include a desilting basin in the upstream pool area.

Fencing. Security fencing with a minimum height of 6 feet shall encompass the basin area due to potential safety hazards created by prolonged storage of floodwaters. The fencing shall not restrict the inflow or outfall of the basin. Adequate access for maintenance equipment shall be provided. In basins to be used for recreation areas during dry periods, pedestrian access may be provided with approval by DART.

7.11 UNDERDRAINS

Underdrains carry away any storm water or lateral seepage flow that infiltrates the subgrade. Underdrains could be located beneath the DART ballasted trackbed or under paved or unpaved areas. Lateral seepage flow interception shall be considered only when there are indications of high groundwater. For this situation, an analysis of the expected quantity of lateral seepage flow shall be made and considerations shall be given to the use of an aggregate drainage course in conjunction with a filter fabric. Their use should be supported by thorough field explorations prior to design.

7.11.1 Usages of Underdrains

Underdrains generally may be used in the following areas:

- Along the toe of a cut slope to intercept seepage.
- Along the toe of a fill on the side from which groundwater emanates.
- Across the roadway at the lower end of a cut section.
- Along the periphery of any paved area under which groundwater is likely to collect.
- Along trackways where side ditches are not possible.

7.11.2 Filter Medium

The filter medium surrounding the underdrain shall be in accordance with the DART standards and specifications and shall extend upward to the top of the subballast for the trackbed and to within 2 feet of the finished grade behind retaining walls. (Refer to the at-grade standards.).

7.11.3 Pipe Material and Configuration

The underdrain pipe shall conform to the DART at-grade standards and specifications.

The DART trackbed underdrain systems shall be located in a manner consistent with the trackwork directive standards.

7.11.4 Design of Underdrain

Required Size. The minimum diameter DART trackbed underdrain shall be 8 inches. Outlets shall be provided at intervals not to exceed 1,000 feet for each 20,000 square feet of trackbed area. The size of each leg of pipe network should be determined from Figure 7-32. This figure is based upon Manning's equation for smooth PVC pipe (n = 0.010) and perforated PVC pipe (n = 0.013). Pipes manufactured from other materials should be sized using Manning's equation and appropriate "n" factors.

Underdrain design for groundwater control shall be coordinated with a soils engineer's recommendations and/or field observations and local experience.

Separation of Drainage. Pipes carrying surface water shall not discharge into underdrains.

Grades and Outlets. Underdrain grades, except behind retaining walls, shall not be less than 0.5 percent. Underdrain outlets shall be unobstructed and placed well above the maximum expected water surface at the point of discharge. Underdrain junctions within the trackbed area shall be made at a man-accessible structure. Ballast screen and grated cover shall be provided if structure is within ties-and-ballast trackbed.

Cleanouts. Terminal cleanouts shall be provided at the upper ends of all trackbed underdrains and shall consist of a section of pipe (unperforated) brought to the ground surface. Intermediate cleanouts (unperforated) shall be placed at intervals not greater than 250 feet. Both intermediate and terminal cleanouts shall be in accordance with the at-grade standards.

7.12 EROSION CONTROL

A baseline Storm Water Pollution Prevention Plan (SW3P) shall be prepared in accordance with the most current Construction Storm Water regulations (NPDES or TPDES) and reflect the General Construction Storm Water Permit Checklist, published by EPA. All construction and related activities shall comply with the requirements of NPDES or TPDES. All temporary and permanent erosion controls shall comply with the latest revision of Storm Water Quality Best Management Practices Manual for Construction, prepared by the North Central Texas Council of Governments.

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T (MIN)	2 - Year Frequency Storm				5 - Year Frequency Storm				100 - Year Frequency Storm			
	I (IN/HR)	V_I (AC-FT)	V_O (AC-FT)	V_S (AC-FT)	I (IN/HR)	V_I (AC-FT)	V_O (AC-FT)	V_S (AC-FT)	I (IN/HR)	V_I (AC-FT)	V_O (AC-FT)	V_S (AC-FT)
5	6	7	8	9	10	11	12	13	14	15	16	17
5	6.00				6.96				10.96			
10	5.04	3.88	1.82	1.56	5.88	3.95	2.12	1.83	8.88	5.96	3.20	2.76
15	4.30	4.33	2.28	2.05	5.00	5.03	2.65	2.39	7.56	7.61	4.00	3.61
20	3.80	5.10	2.73	2.37	4.43	5.95	3.16	2.77	6.79	9.11	4.80	4.31
25	3.35	5.62	3.19	2.43	3.98	6.68	3.70	2.97	6.15	10.32	5.60	4.72
30	3.02	6.08	3.64	$\boxed{2.44}$	3.64	7.32	4.23	$\boxed{3.09}$	5.80	11.67	6.40	5.27
40	2.57	6.90	4.55	2.35	3.15	8.46	5.29	3.16	5.02	13.48	8.00	$\boxed{5.47}$
50	2.20				2.70	9.06	6.35	2.71	4.45	14.93	9.60	5.33
60	1.95				2.42				3.96			
70												
80												
90												
100												
120												
140												
160												
180												

FORMULAS:

1) V (inflow volume) = $\frac{CwpIAT}{726}$

2) V (outflow volume) = $\frac{tcp + T}{1452}$

3) V (storage volume) = $V_I - V_O$

Pond Location EXAMPLE

Basin Area, A = 58.0 AC

CALCULATION OF WEIGHTED RUNOFF COEFFICIENT, C_W			
1	2	3	4
EXISTING LAND USE	"C"(TABLE 7-3)	AREA, AI (AC)	CAi
RESIDENTIAL	0.65	15.0	9.75
COMMERCIAL	0.90	13.0	11.70
PARK	0.40	30.0	12.0
TOTALS		58.0	38.45
PROPOSED LAND USE			
TRANSFER STATION w/PARKING	0.90	50.0	45.0
PARK	0.50	8.0	4.0
TOTALS		58.0	49.0

EXISTING TIME OF CONCENTRATION tcE = 15 MIN

PROPOSED TIME OF CONCENTRATION tcp = 10 MIN

EXISTING WEIGHTED COEFFICIENT $Cwe \frac{\Sigma CAI}{\Sigma AI} = 0.58$

PROPOSED WEIGHTED COEFFICENT $Cwp \frac{\Sigma CAi}{\Sigma Ai} = 0.84$

MAXIMUM OUTFALL RATE Qo = CwEIA

Q 2 yr = 132.2 CFS
Q 5 yr = 153.7 CFS
Q 100 yr = 232.4 CFS

JAN. 2003, REV 10

ACT 21
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JACOBS ENGINEERING
STV INCORPORATED
KAI ALLIANCE

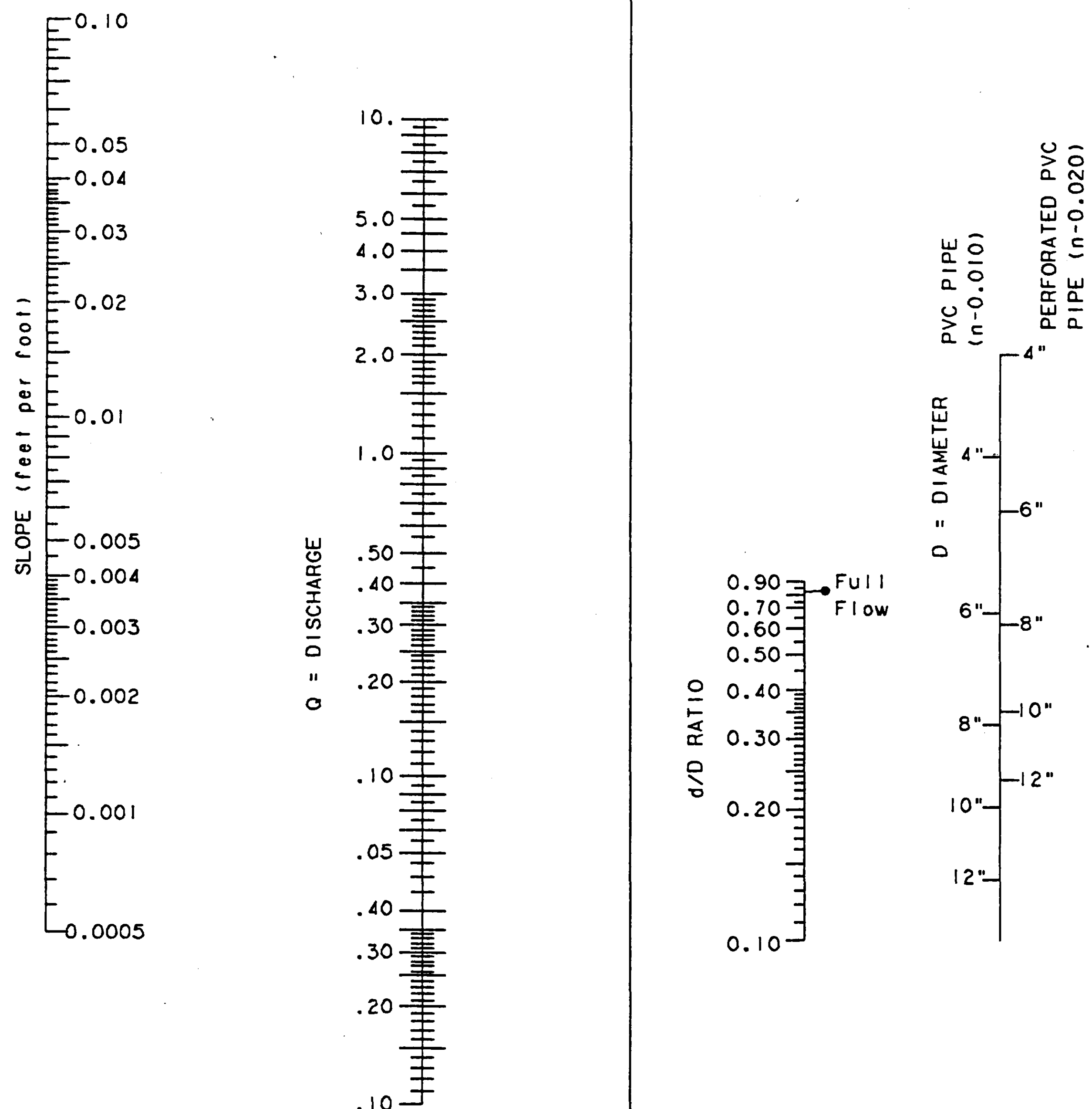
DART PROJECT

DART

DART DESIGN CRITERIA

DETENTION BASIN STORAGE CALCULATIONS - EXAMPLE

SCALE: NONE FIGURE: 7-31



UNIFORM FLOW FOR
SMALL CONDUITS

ACT 21

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DART PROJECT

DART

DART DESIGN CRITERIA

UNIFORM FLOW FOR SMALL CONDUITS

SCALE: NONE

FIGURE: 7-32

JAN. 2003, REV 10

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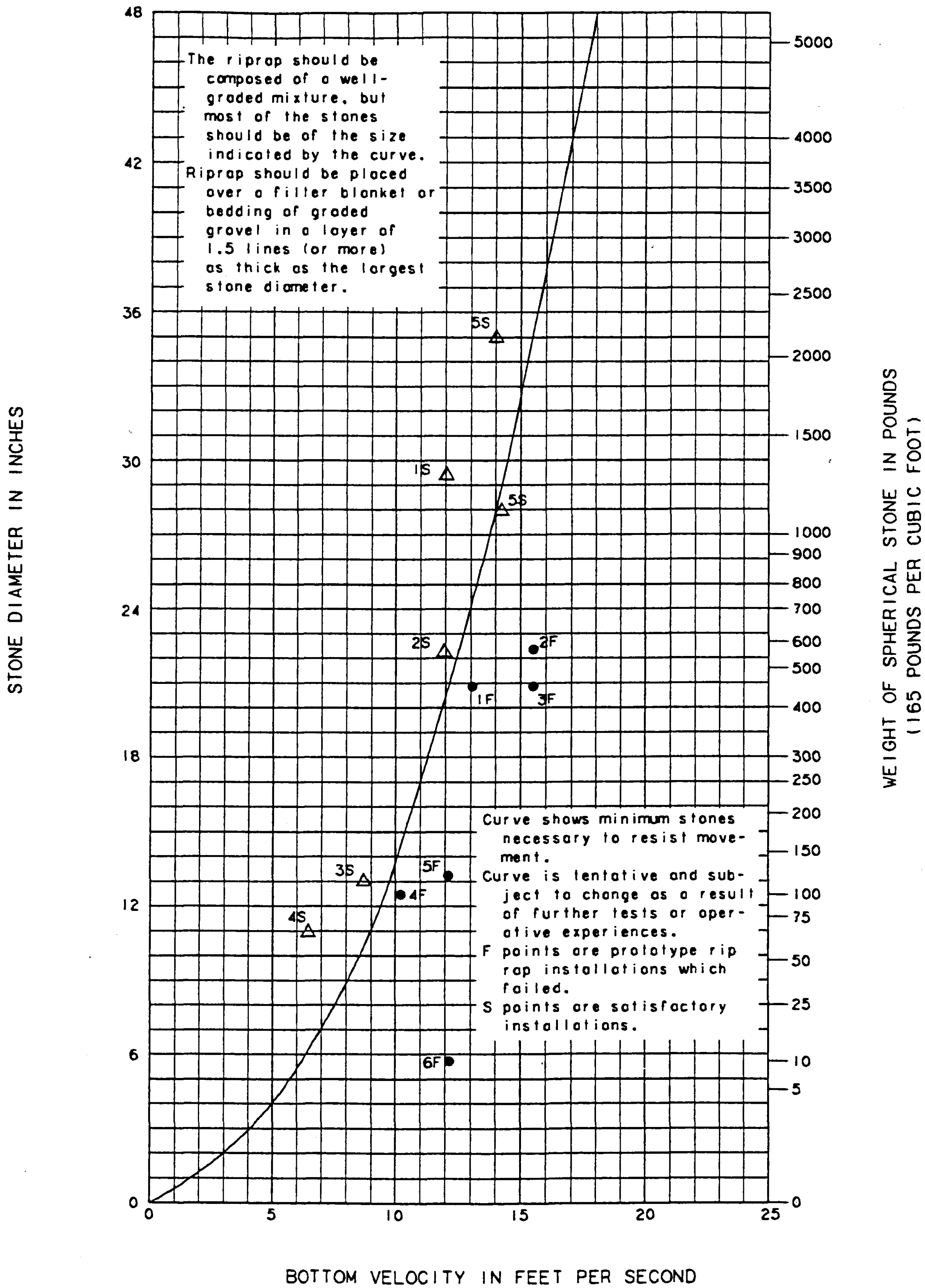

ACT 21

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KAI ALLIANCE

DART PROJECT

DART

DART DESIGN CRITERIA

MINIMUM RIPRAP DIAMETER FOR STREAM VELOCITIES

SCALE: NONE

FIGURE: 7-33

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CHAPTER 8 - STRUCTURAL MATERIALS

8.1 INTRODUCTION

The design criteria contained in this chapter shall relate to the design of structures constructed as part of the Dallas Area Rapid Transit (DART) Rail System. Structural design shall be governed by these criteria in addition to the codes, standards, and specifications referenced in Appendix 1. The full titles of all references in this chapter are listed in the Structural section of Appendix 1. In the event of a conflict between criteria in this chapter and information referenced in Appendix 1, the more restrictive criteria shall govern. If, in the opinion of the designer, significant economies can be achieved by the use of different materials other than those specified while providing the same or a better level of performance and durability, the designer may substitute alternate material standards after receiving written approval from DART. All materials not covered in the appendix of these design criteria shall conform to the procedures and specifications as mentioned in the current manuals of the American Society for Testing and Materials (ASTM), as applicable.

The Design of all structures associated with underground, aerial, and at-grade guideways and stations and their appurtenances shall conform to NFPA 130 – Standards for Fixed Guideway Transit and Passenger Rail Systems, and the International Building Code (IBC). Where more than one code standard or Criterion is applicable, the most restrictive requirement shall govern.

Construction for underground facilities shall be not less than Type I construction. Construction for At-grade or elevated transit facilities shall be not less than Type I or Type II or a combination of Type I and Type II, approved fire resistive construction as defined in the above codes and standards.

In addition to the requirements contained in this chapter, corrosion protection shall conform to the provisions of Systems Design Criteria Chapter 8 - Corrosion Control.

8.1.1 Material Properties

The following properties shall be used in all design calculations:

Modulus of Elasticity

Structural Steel and Steel reinforcement	E_s = 29,000,000 pounds per square inch (psi)
Concrete	$E_c = (W_c^{1.5})\ 33(f'c)^{1/2}$ psi

Where:

W_c = unit weight of concrete between 90 and 155 pounds per cubic foot (pcf)

and:

f'c = specified compressive strength of concrete (psi)

Prestressing Steel. In the event that more accurate data cannot be obtained from manufacturers or from tests, the following values shall be used for the modulus of elasticity of prestressing steel:

Cold drawn wire	29,000,000 psi
Seven wire strand	27,500,000 psi
Strand of more than seven wires	25,000,000 psi
High strength bars	26,500,000 psi

Poisson's Ratio

Concrete	0.20

Coefficient of Thermal Expansion and Contraction

Normal Weight Concrete	0.0000060 per degree Fahrenheit
Steel	0.0000065 per degree Fahrenheit

8.1.2 Loadings

Load factors and loading combinations shall conform to the provisions of the respective chapters of these design criteria:

- Chapter 9 Loads
- Chapter 13 Aerial Structures
- Chapter 14 Earth Retaining Structures
- Chapter 15 Cut and Cover Structures
- Chapter 16 Excavation Support
- Chapter 17 Deep Foundations
- Chapter 18 Mined Tunnels and Stations

8.2 STEEL

Unless otherwise specified, structural steel and related materials shall conform to the following:

- Bridge Structures – Standard Specification For Structural Steel for Bridges (ASTM A709) grade 36 or 50 as required by design.

- Structures other than Bridges – Standard Specification for Structural Steel (American Society for Testing and Materials (ASTM); ASTM A36 here in sited as such.
- High Strength Bolts – Standard Specification for High Strength Bolts for Structural Steel Joints (ASTM A325). The use of bolts conforming to Specifications for Heat Treated Steel Structural Bolts 150-ksi Minimum Tensile Strength (ASTM A490) shall be subject to prior written approval from DART.
- Anchor Bolts – Standard Specification for Low Carbon Steel Externally and Internally Threaded Standard Fasteners (ASTM A307), or ASTM A36 (listed above).
- Weld Material – All weld Material shall comply with AWS D-1.5 and be compatible with the base materials.

The designer shall investigate the use of high strength steels where their use would result in design economies.

8.2.1 Structures Subject to DART Loading

Steel aerial and bridge structures subject to DART train loading, individual structural steel elements and other structures as specifically directed by DART shall be designed in accordance with Chapter 13 – Aerial Structures of these criteria and in accordance with the provisions of the "Strength Design Method" of Section 10 of the Standard Specification for Highway Bridges (American Association of State Highway and Transportation Officials, AASHTO; hereafter sited as such). For bridge structure on curved alignment the design shall comply with the provisions of "Guide Specifications for Horizontally Curved Highway Bridges" of AASHTO.

8.2.2 Structures Not Subject to DART Loading

Steel structures not subject to DART train loading and individual structural steel elements of DART structures not subject to DART train loading shall be designed, unless otherwise directed in the design criteria, in accordance with the requirements of Load and Resistance Factor Design Specification for Structural Steel Buildings (American Institute of Steel Construction, AISC; hereafter cited as such). All steel structures subject to highway loading shall be designed according to Section 10 of AASHTO. All steel structures subject to railroad loading other than DART trains shall be designed in accordance with Chapter 15 of the Manual for Railway Engineering (American Railway Engineering and Maintenance of Way Association [AREMA]).

8.2.3 Fatigue Stresses

The requirements of Section 10.3 of AASHTO shall apply. All structures carrying DART train loading shall be designed on the assumption of their being subject to over 2,000,000 applications of the standard DART loading over the life of the structure. See Chapter 9 - Loads of these criteria for a description of the standard DART load. For structures not subject to the DART train loading fatigue cycles shall be based on a 75-year design life.

8.2.4 Deflections

Sections 10.6.2 and 10.6.3 of AASHTO shall be modified as follows: "vibration and deflection limitations shall be determined in accordance with the provisions of Chapter 13 - Aerial Structures of these criteria."

8.2.5 Splices and Connections

Field splices and connections shall be designed as high-strength bolted connections unless otherwise approved by DART. All splices and connections shall be designed not only for strength but also to fulfill deflection requirements. Use of field welding will not be allowed unless specifically approved by DART. All shop connections are to be welded and all welding shall be in accordance with the current specification of the American Welding Society (AWS).

8.2.6 Diaphragms, Cross Frames, and Lateral Bracing

In addition to the requirements of Sections 10.20 and 10.21 of AASHTO, refer to Sections 10.30.5 and 10.30.6. Unless approved by DART and effectively connected to both flanges, the lateral bracing of compression chords shall be as deep as the chords. In addition to the shear from lateral forces, the lateral bracing of the compression chords of trusses, and the flanges of deck girders shall be proportioned for a transverse shear in any panel equal to 2.5 percent of the axial stress in both members in that panel.

8.2.7 Structural Steel Accessibility of Parts

Members, fastners, and other structural and non-structural parts inaccessible by normal maintenance shall be permanently protected against corrosion, by way of coatings or other means approved by DART.

8.2.8 Camber

Girders shall be cambered to compensate for dead load deflections and for any vertical curvature required by profile grade.

8.3 REINFORCED CONCRETE

Unless otherwise specified by DART, all structural concrete shall have a specified compressive strength (f'c) of 4,000 psi. All reinforcement shall be ASTM A615 Grade 60, with yield strength

(f_y) of 60,000 psi as described in Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement (ASTM A615).

8.3.1 Structures Subject to DART Loading

Reinforced concrete aerial and bridge structures subject to DART train loading shall be designed in accordance with Chapter 13 - Aerial Structures of these criteria and Section 8 of AASHTO, except as modified in the design criteria. Combined shear and torsion shall be designed in accordance with Section 11.6 of Building Code Requirements for Reinforced Concrete (American Concrete Institute ACI 318; hereafter cited as such). Cut-and-cover box structures, station structures, and at-grade reinforced concrete structures shall be designed according to these criteria and ACI-318 (excluding ACI-318 Sections 8.3, 8.6, and 8.7).

8.3.2 Structures Not Subject to DART Loading

Reinforced concrete structures and other structures not subject to DART train loading, as well as individual reinforced concrete structural elements not subject to DART train loading, shall be designed (unless otherwise directed in these design criteria) in accordance with the "Strength Design Method" of ACI 318. All reinforced concrete structures subject to highway loading shall be designed according to Section 8 of AASHTO. All reinforced concrete structures subject to railroad loading other than DART trains shall be designed in accordance with Chapter 8 of the Manual for Railway Engineering (American Railway Engineering and Maintenance of Way Association [AREMA]).

8.3.3 Details of Reinforcement

Reinforcement details shall conform to those outlined in Chapter 7 of ACI 318 and in the ACI Detailing Manual (ACI SP-66) except as modified or revised in these criteria. The spacing of reinforcement for all DART structures shall be a multiple of even inches. Main reinforcement spacing, however, shall not exceed 12 inches. Secondary reinforcement spacing shall not exceed 18 inches and shall be compatible with the main bar spacing. The length of lap splices for distribution, temperature, and shrinkage reinforcement shall not be less than 24 bar diameters nor less than 12 inches. The provisions for controlling flexural cracking described in Section 10.6 of ACI 318 or in Section 8.16.8.4 of AASHTO shall apply as a minimum for distribution of flexural reinforcement.

8.3.4 Creep and Shrinkage

Short and long term creep and shrinkage shall be accounted for in the design of reinforced concrete structures and shall be considered when calculating camber and deflection. The design of superstructures, using prestressed girders and composite concrete decks with direct rail attachment, shall account for the long term effects of creep over time to avoid exceeding the limits of adjustment for direct rail fasteners.

8.3.5 Frame Analysis and Continuous Girders

For structures not subject to DART loadings, ACI 318, Sections 8.3 Methods of Analysis, 8.6 Stiffness, 8.7 Span Length, and 8.9 Arrangement of Live Load shall not apply. All structures shall apply a rigorous method of elastic analysis approved by DART for the design of continuous girders, rigid frames, and other statically indeterminate structures. For the purpose of determining the theoretical span length of a beam or girder, monolithic with its support, the support point shall be either the centerline of the supporting element or a point one-half the depth of the beam (measured at the face of support) inward from the face of said support, whichever gives the lesser span. When the width of the monolithic supporting member is more than twice the depth of the beam or girder, the portion of the beam over the support shall be considered as infinitely rigid, and the frame shall be designed accordingly.

The moments for beams or girders monolithic with their supports shall be increased proportionately from the negative design moments theoretically occurring at the face of the support to those occurring at a distance inward from the face equal to 1/6 the depth of the beam or girder or 1/6 the width of the supporting member, whichever gives the lesser distance.

8.3.6 Distance Between Lateral Supports

Provisions of Section 10.4.1 of ACI 318 when applied to members subject to impact and vibration other than DART loading shall be revised as follows:

Spacing of lateral supports for a beam shall not exceed 36 times the least width b of compression flange or face. When the spacing exceeds 24 times b, then the allowable stress shall be reduced. The allowable stress reduction shall vary proportionally from 0 to 50 percent for spacings between 24 b and 36 b, respectively.

8.3.7 Columns

In addition to complying with the provisions of Section 10 of ACI 318, particular attention shall be paid to confining the column concrete in and near beam-column joints. This shall include the use of ties within the joints where complete restraint is not provided by the structural configuration.

8.3.8 Composite Concrete Flexural Construction

For structures not subject to DART loading, the permissible horizontal shear stresses under the condition of Section 17.5.4 of ACI 318 shall be reduced by 20 percent. Shear connections between precast structural elements may be designed by the shear-friction method in accordance with Section 11.7 of ACI 318.

Effective Concrete Flange Width. Section 10.38.3 of AASHTO shall be modified as follows: Unless a finite element analysis or other rigorous analysis approved by DART is performed to determine stresses in the cross section of a composite girder, the effective width of the slab as flange in composite girder construction shall not exceed the least of the following:

- Independent Single-Cell Box Girders:
  - One-fourth the span length of the girder.
  - Twice the distance from the centerline of the girder to the nearest edge of the slab.
  - Twice the width of the box, measured at the intersection of the bottom of the top slab and the outside faces of the webs.
  - Six times the least slab thickness on the outer side of each web plus six times the least slab thickness on the inner side of each web.
- Multiple Single-Cell Box Girders:
  - One-fourth the span length of the girder.
  - For an interior girder, the center-to-center distance of girders; for an exterior girder, twice the distance from the centerline of the girder to the nearest edge of the slab, or a point midway between the exterior girder and the adjacent girder, whichever is less.
  - Six times the least slab thickness on the outer side of each web plus six times the least slab thickness on the inner side of each web.
- Interior T-Beam Girders:
  - Refer to Section 10.38.3.1 of AASHTO.
- Exterior T-Beam Girders with Overhanging Flanges:
  - The above limitations for interior girders.

- The distance from slab edge to exterior girder (not exceeding six times the least thickness of the slab) plus 1/2 the center-to-center distance to the next girder (not exceeding six times the thickness of the slab).

Composite Box Girders. Replace Sections 10.39.1 and 10.39.2 of AASHTO with the following criteria: "Steel-concrete composite box girders shall be designed by rigorous analytical methods with due regard to torsional and other stresses imposed when the rails do not lie in the plane of the webs. Thorough analysis shall be made of the lateral distribution of DART train loads."

8.4 PRESTRESSED CONCRETE

Unless otherwise specified by DART, all prestressed concrete shall have a specified 28-day compressive strength (f'c) of 5,000 psi and a minimum initial compressive strength when prestress is applied of 4,000 psi. Prestressing reinforcement shall be high-strength steel wire, high-strength seven-wire strand, or high-strength alloy bars. High-strength steel wire and bar shall conform to the following:

- Specifications for Uncoated Stress-Relieved Steel Wire for Prestressed Concrete (ASTM A421; hereafter cited as such).

- Specifications for Steel Strand Uncoated Seven-Wire for Prestressed Concrete (ASTM A416; hereafter cited as such), including low-relaxation strand.

- Standard Specification for Uncoated High-Strength Steel Bar for Prestressing Concrete (ASTM A722; hereafter cited as such). Bars with greater minimum ultimate strength, but otherwise produced, tested, and meeting the requirements of ASTM A722, may be used as long as they are approved by DART.

Lightweight concrete shall not be used on any main-load-carrying members. Consideration shall be given to fatigue stresses whenever steel coupling or splicing devices are used. See Chapter 9 - Loads for fatigue loading. Stresses of all prestressed concrete members shall be checked to cover all loading conditions at every stage of prestressing, including construction and erection.

8.4.1 Structures Subject to DART Loading

Prestressed concrete structures subject to DART train loading, individual prestressed concrete structural elements subject to DART train loading, and other structures as specifically directed in the design criteria shall be designed according to the provisions of Section 9 of the AASHTO, except as modified in these criteria. The use of cantilevered prestressed beams with a drop in span is prohibited without prior written approval from DART.

8.4.2 Structures Not Subject to DART Train Loading

Prestressed concrete structures not subject to DART train loading and individual prestressed concrete structural elements of DART structures not subject to DART train loading shall be designed, unless otherwise directed in these design criteria, in accordance with the requirements of ACI 318. All prestressed concrete structures subject to highway loading shall be designed according to Section 9 of AASHTO. All prestressed concrete structures subject to railroad loading other than DART trains shall be designed in accordance with Chapter 8 of the Manual for Railway Engineering (American Railway Engineering and Maintenance-of-Way Association [AREMA]). The use of cantilevered prestressed beams with a drop-in span is prohibited without prior written permission from DART.

8.4.3 Allowable Stresses

See Section 9.15 of AASHTO, Chapter 18 of ACI and Chapter 8 of AREMA as applicable.

8.4.4 Loss of Prestress

Calculation of prestress losses shall be in accordance with Section 9.16 of AASHTO for structures subject to DART loading or highway structures, in accordance with Section 8.17 of AREMA for railroad structures and in accordance with Section 18.6 of ACI for structures not subject to previous loadings. Calculation of prestress losses shall include:

- Anchorage seating losses.
- Elastic Shortening of Concrete.
- Creep of concrete.
- Shrinkage of concrete.
- Relaxation of prestressing steel stress.
- Friction loss due to intended or unintended curvature of the post-tensioning tendons.

The mean annual ambient relative humidity used in calculations of losses due to shrinkage shall be 65 percent.

8.4.5 Camber and Deflection

Creep and shrinkage shall be accounted for in the design of pretested concrete structures and shall be considered when calculating camber and deflections. All calculations shall be done utilizing the PCI multipliers as defined in Chapter 4 of the PCI Design Handbook for Precast and Prestressed Concrete, 5th Edition.

The design of superstructures, using prestressed girders and composite concrete decks with direct rail attachment, shall account for the long term effects of creep over time to avoid exceeding the limits of adjustment for direct rail fasteners.

8.4.6 Shear and Torsion

The required area of shear and torsion reinforcement shall conform, where applicable, to the requirements of Chapter 11 of ACI 318, except that lightweight concrete shall not be used in any main-load-carrying members.

8.4.7 Anchorage Zones

Refer to the provisions of Sections 9.21 and 9.27 of AASHTO, and Sections 18.13, 18.14, and 18.15 of ACI.

8.4.8 Cover and Spacing of Steel in Prestressed Concrete

In addition to the provisions of Section 9.26 of AASHTO, the following shall also apply:

Corrosion Protection. Anchorages and end fittings of prestressing steel shall be permanently protected against corrosion with a minimum concrete cover of 2 inches.

Fire Protection. To conform to the relevant code requirements, additional concrete cover may be required in structural members with potential fire exposure hazards.

8.5 TIMBER

Temporary and permanent structures shall be in accordance with AASHTO, Chapter 13 for highway loading, and Chapter 7 of the Manual for Railway Engineering (AREMA) for railroad or transit loading, using the appropriate allowable stresses.

8.6 REINFORCED SHOTCRETE

Unless otherwise approved by DART, all structural shotcrete shall have a specified compressive strength (f'c) of 5,000 psi at 28 days. All welded wire fabric (WWF) shall conform to Welded Steel Wire Fabric for Concrete Reinforcement (ASTM A185) if made of smooth wire, or Welded Deformed Steel Wire Fabric for Concrete Reinforcement (ASTM A497) if made of deformed wire. ASTM yield strength is 65,000 psi for A185 and is 70,000 psi for A497. Unless otherwise specified, welded wire fabric conforming to ASTM A185 shall be used.

CHAPTER 9 - LOADS

9.1 INTRODUCTION

The transit and general loads contained in this chapter refer to the loads generated as a direct result of construction, operation, and maintenance of the system. They shall be considered as the minimum design loads. The dead loads derived from various construction materials are also indicated. Modification of these loads necessary for the design of the various structures associated with the DART system are indicated in their respective chapters. The full title of all references in this chapter are listed under the Structural section of Appendix 1.

In addition to the design guidelines contained in this volume the DART structures shall generally be designed according to the following:

Transit, Highway, and Railroad Structures

- o Structures supporting transit and highway loads shall be designed according to Standard Specifications for Highway Bridges (American Association of State Highway and Transportation Officials, AASHTO; hereafter cited as such).

- o Structures supporting railroad loads shall be designed according to the Manual for Railway Engineering (American Railway Engineering and Maintenance-of-Way Association, AREMA; hereafter cited as such).

Sound Barriers

- o At-grade and structure-mounted sound barriers shall be designed in accordance with the AASHTO Guide Specifications for Structural Design of Sound Barriers, AASHTO.

All Other Structures

- o Structures supporting non-transit or non-highway loads shall be designed according to the requirements of Minimum Design Loads for Buildings and Other Structures, ASCE 7-98 (American Society of Civil Engineers, ASCE; hereafter cited as such).

- o International Building Code (International Conference of Building Officials, UBC, hereafter cited as such).

- o Concrete structures supporting non-transit or non-highway loads shall be designed according to Building Code Requirements for Reinforced Concrete (American Concrete Institute, ACI 318; hereafter cited as such).

- Steel structures supporting non-transit or non-highway loads shall be designed according to the requirements of Load and Resistance Factor Design Specification for Structural Steel Buildings (American Institute of Steel Construction, AISC; hereafter cited as such).

Prior to commencing design work, the section designer shall submit to DART for approval the list of codes and specifications to be used, indicating the areas where they will be used.

9.2 DEAD LOAD (D)

Dead load shall constitute all loads, which by their nature are fixed and immovable. The dead load shall consist of the actual or estimated weight of the entire structure, such as trackwork, walls, foundations, partitions, electrification, service walks, parapet walls, pipes, equipment, conduits, cables, and other utilities services. Some of these loads are indicated below.

Unless the designer can substantiate other estimates of the weights of materials and installations, the following unit weights shall be used in computing the dead load:

Material	Pounds per Cubic Foot
Steel	490
Cast iron	450
Aluminum alloys	175
Asphaltic concrete	150
Portland cement concrete, plain, reinforced, or prestressed	150
Compacted sand, earth, or gravel	130
Ballast, including ties	130
Timber (treated or untreated)	50
Parapet, or Acoustical Barrier	365 lbs./lin. ft., per side
Track rails, Guardrails, and Fasteners	200 lbs./lin. ft.
Cables - Single or Double Track	100 lbs./lin. ft.

Cable weights include attachment hardware and cables for electric, traction, communication, and signal systems.

9.3 LIVE LOAD (L)

The designer shall determine the vehicle configuration and arrangement to determine the maximum loading conditions for the member under consideration, based on the loadings below. Other maintenance or construction loads shall not exceed these load limits. These limitations shall be noted on all designs.

9.3.1 Standard DART Loading

Standard DART loading, for design purposes, is defined as the axle spacing, axle loading and car spacing shown in Figure 9.1. Any one train may consist of one, two, three, or four cars. The standard DART loading shall be used for all stress, deflection, and stability calculations. The weight of the railcar used in any loading combination to produce maximum stress shall be based on the AW3 - "Crush Loading" condition as defined in the System Criteria.

9.3.2 Track Maintenance Live Load

A special live load used during maintenance of the track shall be considered in the design of all structures subject to DART loading. The loading will consist of a 45-ton locomotive pulling one, two, three, or four 20-ton ballast cars. They shall be placed on the structure in a position to produce maximum stress. The axle spacing, axle loading, and car spacing, for design purposes, are shown in Figure 9.2.

The fatigue design of structures need not consider the loading from a track maintenance live load.

9.3.3 Construction Live Load

Construction Live Loads shall be considered in the design of all structures subject to DART, AASHTO or AREMA Loadings. The live load shall be equivalent to an AASHTO HS-25 loading. No other live load or fatigue need to be considered in combination with the construction load. Load combinations can be limited to AASHTO groups I, II, and III, as defined in AASHTO Table 3.22.1A and modified in Table 9.1 of these Criteria. Impact shall be accounted for according to AASHTO 3.8.2.

9.4 IMPACT (I)

The standard DART loading and the track maintenance live load shall be increased for dynamic, vibratory, and impact effects for those structures, or parts of those structures, listed in Section 9.4.1. The increase in loading shall not apply for those structures, or parts thereof, listed in Section 9.4.2.

9.4.1 Items Where Vertical Impact Applies

Vertical impact should be applied to the design of piers and superstructure elements, but need not be applied to the design of foundations or elastomeric bearings.

9.4.2 Items Where Vertical Impact Does Not Apply

- Abutments, retaining walls, wall-type piers, and portions of piles below the ground.
- Foundations and footings, including base slabs in subways and tunnels.
- Service walks.
- Culverts and other buried structures having a cover of 3 feet or more.

9.4.3 Vertical Impact Force (I_v)

The vertical impact force, I_v, shall be determined in accordance with the provisions of Section 3.8.2.1 of Standard Specifications for Highway Bridges, (AASHTO). The vertical impact force is additive to the standard DART loading. The vertical force (I_v) for the track maintenance live load shall be limited to a maximum of 10% regardless of span length.

For spans longer than 125 ft., a minimum vertical impact factor of 20 percent shall be used.

9.4.4 Transverse Horizontal Impact Force (I_h)

Provision shall be made for a transverse horizontal impact force, I_h, equal to 10% of the standard DART loading and 5% of the track maintenance live load. This force shall be applied horizontally in the vertical plane containing each axle and shall be assumed to act, normal to the track, through a point 3.5 feet above the top of the low rail. The horizontal force component transmitted by an axle to the rails and supporting structure shall be concentrated at the rail having direct wheel-flange-to-rail-head contact.

9.5 CENTRIFUGAL FORCE (CF)

In horizontal curves, a centrifugal force (CF) shall be applied horizontally in the vertical plane containing each axle. The force shall be assumed to act through a point which is on a line perpendicular to the plane of the tops of the rails and midway between the rails, and at a distance along said line 3.5 feet above the plane of the tops of the rails. The effects of superelevation shall be considered when applying centrifugal force to the structure. The magnitude of the centrifugal force shall be computed as follows:

$$CF = (\text{Axle Load}) \times 0.0668V^2/R$$

Axle Load = As per Figure 9.1 or 9.2, in kips.

Where:

V = Design speed in miles per hour, and

R = Radius of curvature of the track center line in feet.

If the design speed is unknown at the time of design, use V max of 70 MPH for radii of 2,150 feet and greater; for radii less than 2,150 feet use the following equation to determine maximum speed:

$$V = (2.27R)^{1/2}$$

9.6 LONGITUDINAL FORCES (LF)

Provision shall be made for the longitudinal force (LF) due to train acceleration and deceleration. The magnitude of the longitudinal force shall be computed as follows:

- For decelerating trains, LF shall be equal to 28 percent of standard DART loading.
- For accelerating trains, LF shall be equal to 16 percent of standard DART loading.

This force shall be applied to the rails and supporting structure as a uniformly distributed load over the length of the standard DART train in a horizontal plane at the top of low rail.

Consideration shall be given to combinations of acceleration and deceleration forces on structures where there is more than one track.

For double-track structures, three longitudinal-loading cases shall be considered, each acting in either direction:

- Single Track Loaded. Longitudinal force acting, applicable forces on supporting structure.

- Both Tracks Loaded. One train accelerating, one decelerating. Maximum longitudinal forces acting, applicable forces on supporting structure.

- Both Tracks Loaded. Both trains accelerating or decelerating. Longitudinal forces acting in opposite directions, applicable forces on supporting structure.

9.7 HUNTING FORCE (HF)

The hunting (or nosing) force (HF) is caused by the lateral interaction of the vehicle and the guideway due to the oscillation of the vehicle back and forth between rails. For rail and structure design, the hunting force shall be applied at the top of the rail head at the lead axle of the train only, with a magnitude equal to 12.5% of the vehicle live load (excluding impact). Hunting forces shall be applied to one track only of any tangent dual-track structure. On horizontal curves the more critical of hunting force or centrifugal force shall be applied.

9.8 RAIL FORCES (T)

Provisions shall be made for transverse (radial) and longitudinal rail/structure interaction forces due to temperature variations in the rail and superstructure. These forces shall be applied in a horizontal plane at the top of low rail as follows:

- o Transverse Force. The transverse force shall be applied in each direction. Its magnitude per linear foot of structure per rail shall be determined by the designer.

- o Longitudinal Force. The magnitude of the longitudinal rail forces shall be determined by a rigorous analysis of the total structural system: rails, rail fasteners, girders, bearings, and substructure.

- o Forces Due To Rail Restraints. Wherever a continuous welded rail is terminated, provisions shall be made to fully restrain its end. This restraint will introduce a significant longitudinal force. The continuous welded rail shall not be terminated on the aerial structure unless it is designed to withstand the imposed load.

  Termination, as used in the above paragraph, means absolute termination. The continuous welded rail is not considered to be terminated at a turnout or crossover.

- o Replacement and Broken Rails. Loads due to broken or replacement rails shall be treated as thermal load for the derailment load group combination as described in Section 9.9. Aerial structures shall be designed for the interactive force between the continuously welded rail and the structure and, to accommodate the temporary loads associated with rail replacement. In addition, the aerial structure shall be capable of adequately sustaining a single broken rail. The structure shall be capable of having the rail installed at any ambient temperature between 10°F and 110°F. The zero thermal stress temperature of the rail is 85°F (+10°-5°).

  When considering the effects of broken rail or rail replacement in combination with other loading conditions, the percentage of Basic Unit Stress shown in Table 9.1 is applicable.

9.9 DERAILMENT LOAD (DR)

Derailment load shall be that produced by the standard DART train loading placed with its longitudinal axis parallel to the track, with a minimum distance from the centerline of track of 1 foot 6 inches and a maximum distance of 3 feet 0 inches. The derailment load, DR, shall be as follows:

$$DR = L + ID$$

or

$$DR = L + I + RB$$

Where: L = Standard DART loading (see Fig. 9.1)

ID = Derailment Impact, 100 percent of the axle load to be applied to any two adjacent axles at a time and normal vertical impact factor for all other axles, which produces critical loading condition for the structures.

RB = Loads on structure due to single broken rail.

9.10 MISCELLANEOUS LIVE LOADS (M)

The live loads on elements of DART transit structures shall be taken as follows:

- o Service Walkways - Service walkways and their immediate supports shall be designed for a live load of 85 pounds per square foot of walkway area, or a concentrated load of 500 pounds acting on an area measuring 1 foot by 1 foot and placed in a position that will cause maximum stress. Except for aerial structures and pedestrian bridges, all members supporting 50 square feet of walkway or more may be designed for a reduced live load of 60 pounds per square foot of walkway area.

- o Stairs - 100 pounds per square foot, or a concentrated load of 600 pounds per stair tread located so as to produce a maximum stress condition, whichever gives the higher stress.

- o Equipment Rooms - Equipment load or 250 pounds per square foot, whichever produces the greater stress.

- o Storage spaces and rooms - Shall be designed for the loading to which they may be subjected, but not less than 250 pounds per square foot.

- o Floors, and all other areas not specified herein - 150 pounds per square foot, or a concentrated point load of 2,000 pounds acting on a 2½ foot-square area, located so as to produce a maximum stress condition, whichever gives the higher stress.

- o Railing - Shall be designed for a horizontal and vertical force of 50 pounds per linear foot acting simultaneously on each longitudinal member. Further, all handrails shall be designed for a force of 200 pounds applied in any direction at any point.

- o Design of structures - Account shall be taken of all loading resulting from the method and route to be taken for the installation and subsequent removal and replacement of the various items of plant and equipment.

Areas not specified herein shall be determined on an individual case basis and shall be approved by DART.

9.11 EARTH PRESSURE (E or H)

Loads From Existing and Proposed Structures. Existing non-DART structures which are to remain in place shall not be supported or in any way impose loading on DART structures without specific approval in writing by DART. The magnitude of loading of approved adjacent structures or portions of structures on DART structures shall be individually evaluated.

Unless otherwise specifically determined by DART, future non-DART construction shall not be considered to impose any additional loading on DART at-grade structures.

Soil and Rock Pressures. Soil pressures to be used for final structural design shall be based upon the information referred to in Chapter 10 - Geotechnical Information for the design section involved. This information should be reviewed by the designer in the light of any changes in design or construction concepts between preliminary and final design phases. Allowances shall be made for both dry and submerged earth pressures, for hydrostatic pressure, and for the influence of physical and chemical characteristics of soils adjacent to DART structures. The effects of specified construction methods, such as flexible and rigid bulkheads, bracing procedures, and so forth on the development of lateral pressures shall be considered, together with the effects of compaction on construction lateral soil pressures.

The effects of hydrostatic pressure shall be considered whenever the presence of groundwater is indicated. It shall be computed at 62.5 pounds per square foot per linear foot of depth below groundwater table. Where hydrostatic pressures pertain, lateral earth pressures shall be based upon the submerged unit weight of the soil and in accordance with the geotechnical information referred to in the geotechnical chapter of these criteria. The possibility of future significant changes in groundwater elevation shall be considered. Full hydrostatic pressure shall be assumed to act on all external structural members for the maximum likely height of the water table, unless specific permanent provisions to remove these effects are included in the overall design of the structural members.

See Chapter 15 - Cut and Cover Structures, Chapter 16 - Excavation Support, and Chapter 18 - Mined Tunnels and Stations for additional design requirements regarding earth pressures for each respective structure type in these design criteria.

9.12 BUOYANCY (B or F)

Hydrostatic Pressure and Buoyancy (B). The effects of hydrostatic pressure and buoyancy shall be considered whenever the presence of groundwater is indicated. The possibility of future major changes in groundwater elevation shall be considered. The elevation of groundwater shall be controlled so that the calculated total weight of structure and backfill shall always exceed the calculated uplift due to buoyancy by 10%. The design shall take into account the effect of hydrostatic pressures pertaining to construction sequence. The backfill shall be considered as the volume contained within vertical planes defined by the outside limits of the structure. No value shall be assigned to contact soil friction.

The effects of buoyancy shall be considered in the structural design.

9.13 SHRINKAGE AND CREEP (S)

In concrete structures, provisions shall be made for movement and stresses resulting from concrete shrinkage and creep in accordance with Chapter 8 - Structural Materials. The shrinkage coefficient for normal weight concrete shall be assumed to be 0.0002 inch per inch. For the purpose of calculating effects of creep due to sustained load, the modulus of elasticity of the concrete may be assumed to be 1/3 the value given in Section 8.5 of ACI 318 for the design strength of the specified concrete.

9.14 THERMAL (T)

Provisions shall be made for movements and stresses resulting from temperature variations. The normal temperature shall be taken as 65°F. The ambient temperature variation during construction shall be taken as plus or minus 45°F for concrete structures and 60°F for steel structures. The average temperature of all interior members of the complete structures shall be assumed to vary plus or minus 20°F.

9.15 STREAM FLOW (SF or F)

See Chapter 13 - Aerial Structures of these design criteria.

9.16 WIND LOADS (W)

For wind loads on aerial structures, see Paragraph 13.3.3 - Wind Loads of these design criteria.

For air pressure (wind) loads for cut and cover structures, see paragraphs 15.2.2 - Air Pressure Loads of these design criteria.

Wind loads for all other structures (excluding structures subjected to the DART train loading, highway loading, or railway loading) shall be in accordance with the provisions of Section 6 - Wind Loads of Minimum Design Loads for Buildings and Other Structures, ASCE 7-98. Basic design wind speed shall be 90 mph. The minimum design wind load for the main wind-force resisting systems shall not be less than 10 psf multiplied by the projected area (vertical plane normal to the wind direction) of the building or structure.

9.17 EARTHQUAKE (EQ)

9.17.1 Seismic Design of Aerial Structures

DART aerial structures shall be classified Seismic Performance Category A, acceleration coefficient $A \leq 0.09$, in accordance with AASHTO Seismic Design, Division I-A. As such, aerial structures do not require a seismic analysis. Design forces and displacements shall be determined and accommodated for in accordance with "Section 5 - Design Requirements for Bridges in Seismic Performance Category A" of AASHTO Seismic Design, Division I-A. The use of restrainer pins shall not be used at bridge expansion bearings to provide a mechanical connection as described in AASHTO Division 1-A, Section 5.2. Concrete shear key restrainers shall be used in lieu of the restraining pins.

9.17.2 Seismic Design of Other Structures

Earthquake Loads for all other structures (excluding structures subjected to the DART train loading, highway loading, or railway loading) shall be in accordance with the provisions of "Section 9 - Earthquake Loads" of Minimum Design Loads for Buildings and Other Structures, ASCE 7-98 for Seismic Performance Category B. Effective peak velocity-related acceleration shall be $Av \geq 0.05$. In lieu of rigorous analysis, all design shall utilize the Equivalent Lateral Force Procedure of ASCE 7 - 98, Section 9.2.3.

9.18 LOADING COMBINATIONS

9.18.1 Transit Loading Combinations

The following load combinations represent various combinations of loads and forces to which components of the DART structures may be subjected due to the standard DART train loading. These should also include temporary construction loads. Each part of the structure shall be proportioned for all combinations of these loads multiplied by the load combination factor and coefficients indicated in Table 9.1 and Table 9.2.

All structures shall be analyzed utilizing group combination VIII or H for a temporary overload condition. The axle spacing, axle loading as well as cars and locomotive spacing shall be as shown in Figure 9 - 2.

Elements Supporting Two Tracks. For elements supporting two tracks with both tracks loaded simultaneously, the value of CF, LF and horizontal impact may be reduced by 25 percent in all applicable load groups when applying these loads on both tracks.

Group VIII or H loading combinations only applicable to single track loading from track maintenance live loading described in Paragraph 9.3.2.

Service Load Design. The design of prestressed concrete members, stability and deflection calculations, and soil bearing pressures shall be based on the following loading combinations shown in Table 9.1.

TABLE 9.1 SERVICE LOAD DESIGN
Load Combination Coefficients

GROUP	FACTOR	D	L+IM	CF or HF	E	B	SF		W	WL	LF	S+T	DR	Percentage of Basic Unit Stress
I	1	1	1	1	K	*	1	1	0	0	K	0	0	100%
II	1	1	0	0	0	1	1	1	1	0	0	0	0	125%
III	1	1	1	1	K	*	1	1	0.3	1	K	0	0	125%
IV	1	1	1	1	1	*	1	1	0	0	0	1	0	125%
V	1	1	0	0	0	1	1	1	1	0	0	1	0	140%
VI	1	1	1	1	K	*	1	1	0.3	1	K	1	0	140%
VII	1	1	0	0	1	1	1	0	0	0	1	0	1	150% **
VIII	1	1	1	1	1	*	1	1	0	0	0	0	0	125%

Where maximum stresses are produced in any member by loading a number of tracks simultaneously, the following K factors shall be used in view of the improbability of coincident maximum loading:

K = 1.0 for single track loading.
K = 1.0 for multiple track loading less than 1000 feet from stations.
K = 0.75 for multiple track loading greater than 1000 feet from stations.

* = 0.5 or 1.0 for lateral loads on rigid frames. (Check both loadings and use the one which governs)
* = 1.0 for vertical loads and lateral loads on all other structures.
** = Prestressed concrete girders shall be checked against loading by train derailment. The stress of prestressed strand shall not exceed 0.85 fpu, and concrete shall not exceed 0.6 f'c, in lieu of 150 percent as shown in the table.

The minimum allowable strengths for various materials are given in Chapter 8 - Structural Materials of these criteria.

Strength Design. Reinforced concrete members and structural steel members shall be designed by the strength method. Prestressed concrete members shall be checked using the strength method. Reinforced concrete, structural steel, and prestressed concrete members shall have the capacity of resisting any of the load groups listed in Table 9.2.

TABLE 9.2 STRENGTH DESIGN
Load Combination Coefficients

GROUP	FACTOR	D	L+I	M	CF or HF	E	B	SF	W	WL	LF	S+T	DR
A	1.3	1	1.67	1.67	K	*	1	1	0	0	K	0	0
B	1.3	1	0	0	0	*	1	1	1	0	0	0	0
C	1.3	1	1	1	K	*	1	1	0.3	1	K	0	0
D	1.3	1	1	1	1	*	1	1	0	0	0	1	0
E	1.25	1	0	0	0	*	1	1	1	0	0	1	0
F	1.25	1	1	1	K	*	1	1	0.3	1	K	1	0
G	1.25	1	0	0	1	*	1	0	0	0	1	0	1
H	1.3	1	1	1	1	*	1	1	0	0	0	0	0

For values of K, refer to the service load design section above.

* = 1.3 for lateral earth pressure for retaining walls, and rigid frames excluding rigid culverts.
* = 0.5 for lateral earth pressure when checking positive moment in either rigid frames.
* = 1.0 for vertical earth pressure.
A multiplier 0.75 shall be applied to D, in all the load groups, when checking members for minimum axial load and maximum moment or maximum eccentricity. (Column Design)

Where:

D	=	Dead Load
L	=	Live Load
I	=	Impact
CF	=	Centrifugal Force
LF	=	Longitudinal Force
DR	=	Derailment Load
M	=	Miscellaneous Live Loads
E	=	Earth Pressure
B	=	Buoyancy
S	=	Shrinkage and Creep Forces
T	=	Thermal Forces
EQ	=	Earthquake
HF	=	Hunting Force

The loading criteria adopted for the design of each structure or structural element shall be clearly stated on the structural drawings.

9.18.2 Non-Transit Loading Combinations

The following load combinations represent various combinations of loads and forces to which components of DART structures may be subjected excluding structures subjected to the DART train loading, highway loading, or railway loadings. These structures include but are not limited to the following:

- o Stations and associated ancillary structures. (Including elevated stations.)
- o Traction substations.
- o Maintenance workshops.
- o Entrance structures.
- o Ventilation shafts.
- o Plant and equipment rooms.
- o Storage structures.
- o Lighting masts and poles.
- o Signal and communication bungalows.

<u>**Service Load Design**</u> The design of prestressed concrete members, stability and deflection calculations, and soil bearing pressures shall be based on the group of loading combinations shown in Table 9.3.

TABLE 9.3 SERVICE LOAD DESIGN
Load Combination Coefficients

FACTOR GROUP		D	L	F	H	T	(L_r or S or R)	(W or EQ)
I	1	1	0	0	0	0	0	0
II	1	1	1	1	1	1	1	0
III	1	1	0	0	0	0	0	1
IV	1	1	1	0	0	0	1	1

The most unfavorable effects from both wind and earthquake loads shall be investigated, where appropriate, but they need not be assumed to act simultaneously. When structural effects due to two or more loads in combination with dead load, but excluding earthquake load, are investigated in the above load combinations, the combined effects shall comply with both of the following requirements: (a) The combined effects due to the two or more loads multiplied by 0.75 plus effects due to dead loads shall not be less than the effects from the load combination of the dead load plus the load producing the largest effects; and (b) the allowable stress shall not be increased to account for these combinations.

Strength Design Reinforced concrete members and structural steel members shall be designed by the strength method. Prestressed concrete members shall be checked using the strength method. Reinforced concrete, structural steel, and prestressed concrete members shall have the capacity of resisting any of the load groups listed in Table 9.4.

TABLE 9.4 STRENGTH DESIGN

FACTOR GROUP		D	L	F	H	T	(L_r or S or R)	W	EQ
A	1	1.4	0	0	0	0	0	0	0
B	1	1.2	1.6	1.2	1.6	1.2	0.5	0	0
C	1	1.2	0.5	0	0	0	1.6	0	0
D	1	1.2	0	0	0	0	1.6	0.8	0
E	1	1.2	0.5	0	0	0	0.5	1.3	0
F	1	1.2	0.5	0	0	0	0.2S	0	1.0
G	1	0.9	0	0	0	0	0	0	1.0
H	1	0.9	0	0	0	0	0	1.3	0

Exception: The load factor on L in combinations C-F shall equal 1.0 for garages, areas occupied as places of public assembly, and all areas where the live load is greater than 100/sq ft (pounds-force per square foot).

Each relevant strength limit state shall be investigated. Effects of one or more loads not acting shall be investigated. The most unfavorable effects from both wind and earthquake loads shall be investigated, where appropriate, but they need not be considered to act simultaneously.

Where:

D	=	Dead Load
EQ	=	Earthquake Load
F	=	Load due to fluids with well-defined pressures and maximum heights
F_a	=	Flood Load
H	=	Load due to the weight and lateral pressure of soil and water in soil;
L	=	Live Load
L_r	=	Roof Live Load (See ASCE 7-95)
R	=	Rain Load (See ASCE 7-95)
S	=	Snow Load (See ASCE 7-95)
T	=	Self-straining force; (Shrinkage, creep and thermal forces)
W	=	Wind Load

For the definition of the above loads, see these criteria and Minimum Design Loads for Buildings and Other Structures, ASCE 7-95.

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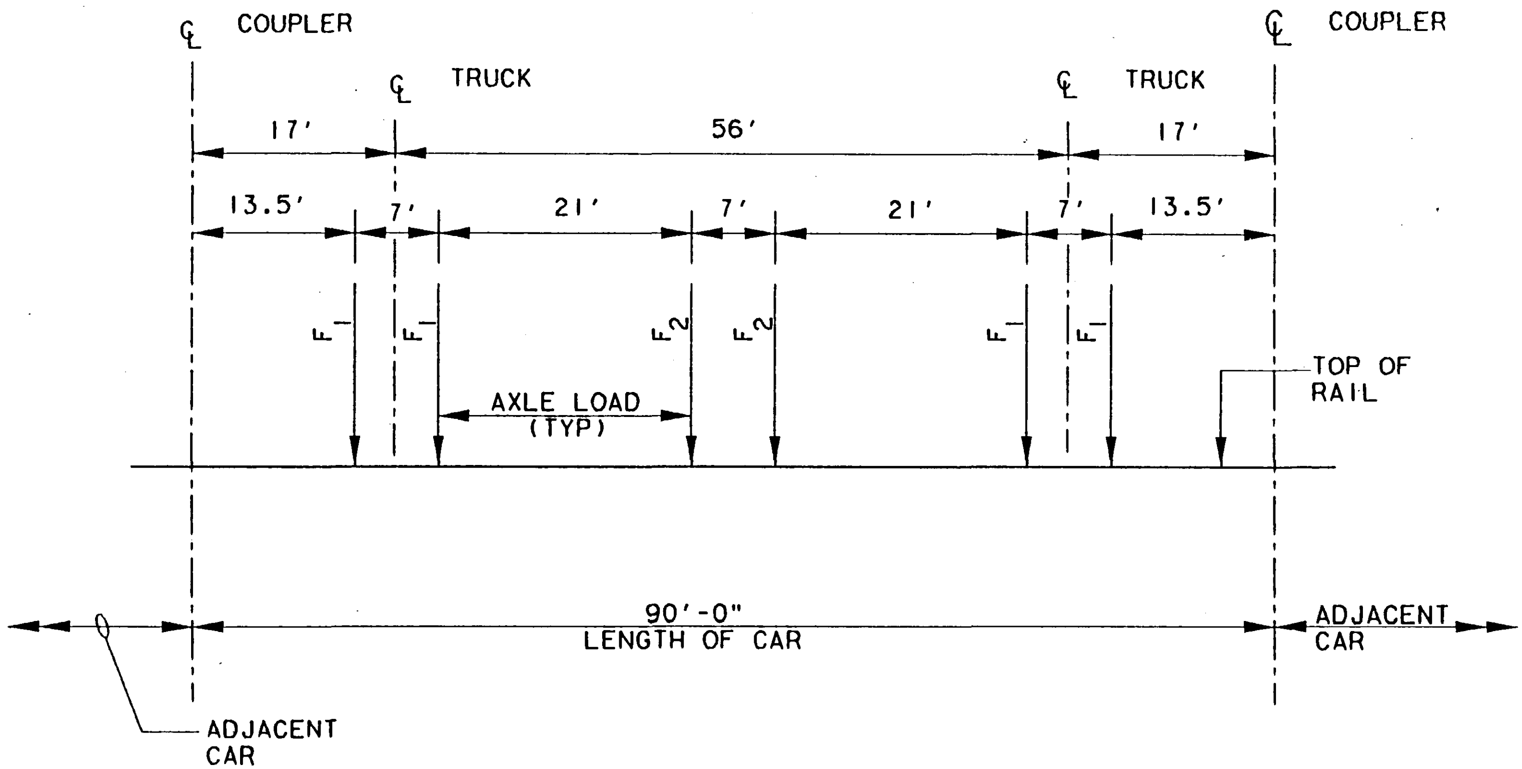

	CRUSH LOADED 20%	CRUSH LOADED 30%
F_1 (MOTOR TRUCK)	30K	26.5K
F_2 (ARTICULATION)	15K	22K

NOTES:

FOR TRACKWORK GAUGE REFER TO TRACKWORK DESIGN CRITERIA.
MAXIMUM LOAD MAY CONSIST OF TWO 4-CAR TRAINS ON EACH TRACK.

ACT 21
CARTER BURGESS
JACOBS ENGINEERING
STV INCORPORATED
KAI ALLIANCE

DART PROJECT

DART

DART DESIGN CRITERIA

STANDARD DART TRAIN LOADING

SCALE: NOT TO SCALE

FIGURE: 9.1

JAN. 2003, REV 10

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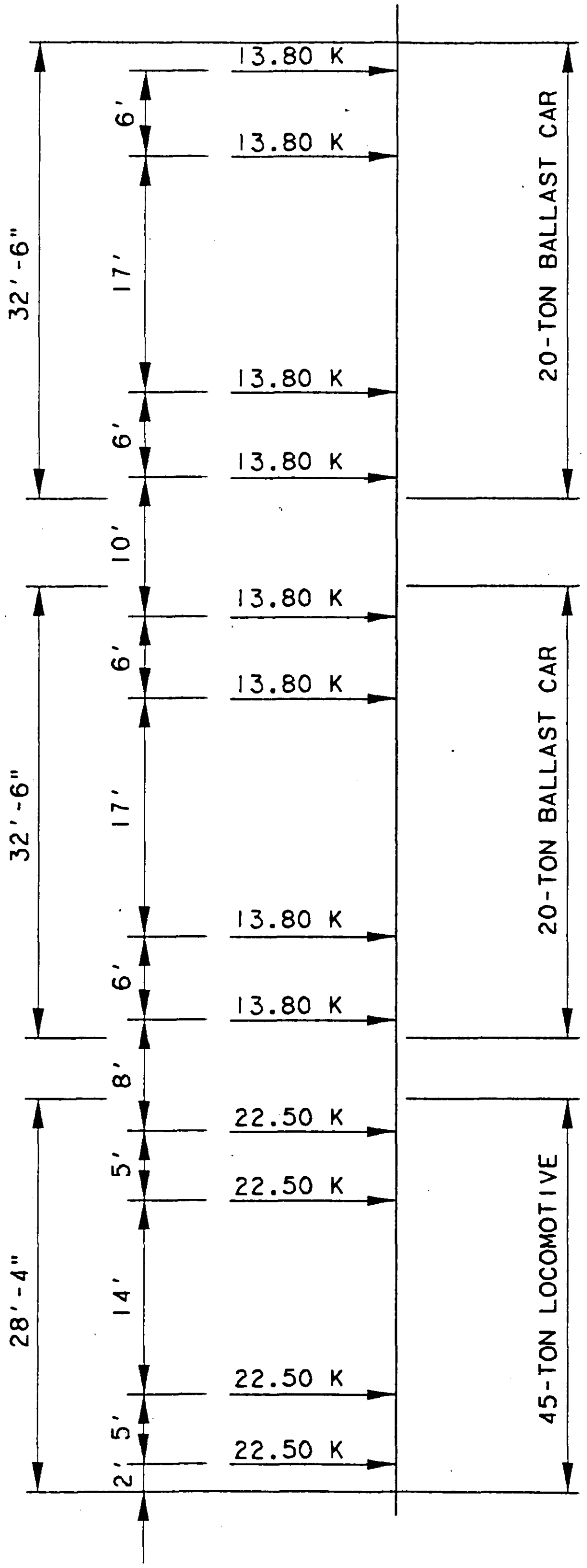

NOTES:

MAXIMUM LOAD MAY CONSIST OF ONE 45-TON LOCOMOTIVE AND FOUR 20-TON BALLAST CARS. WEIGHT OF EMPTY BALLAST CAR IS 15,000 LBS.

ACT 21
CARTER BURGESS
JACOBS ENGINEERING
STV INCORPORATED
KAI ALLIANCE

DART PROJECT

DART

DART DESIGN CRITERIA

TRACK MAINTENANCE
LIVE LOADING

SCALE: NOT TO SCALE

FIGURE: 9.2

CHAPTER 10 - GEOTECHNICAL INFORMATION

10.1 INTRODUCTION

This chapter provides an overview of the geotechnical aspects that relate to the design of the DART system. Besides the various design phases, the chapter covers the role of geotechnical data and its importance to the design. It also covers the application of geotechnical criteria and discusses types of reports that may be required throughout this phase of system development.

10.2 SUBSURFACE INVESTIGATION PROGRAMS

10.2.1 Conceptual/Preliminary Design

During the conceptual design stage, an investigation program will be implemented to provide a general indication of geology, subsurface conditions, and general geotechnical parameters. Subsurface conditions should be identified that could impact the design, such as soft ground conditions that could limit the height of retaining walls, soils with high soluble sulfates or highly active clays that could require special subgrade treatments, and groundwater conditions that could impact construction and operation costs. The findings from this initial program will be summarized in a subsurface investigation report.

Following the refinement and completion of the conceptual design (depending on the level of preliminary design anticipated) it may be necessary to implement a supplementary program to support the completion of the preliminary design effort.

The typical subsurface investigation program for conceptual/preliminary design of cut-and-cover box and mined-tunnel construction should consist of test borings on an average spacing of 600 linear feet with one test boring located at each major structure such as stations. Test borings typically should extend to a minimum depth of 20 feet below the invert of proposed construction.

The typical subsurface investigation program for conceptual/preliminary design of at-grade or aerial construction and retained cuts and fills will have an average test boring spacing of 750 linear feet. Test borings for at-grade construction and shallow retained cut should extend to a depth of 25 feet or 5 feet into unweathered rock, whichever is less. Depths of test borings for deep retained cut or fill should extend to a depth of 60 feet in soil or 20 feet into unweathered rock, whichever is less. For aerial structures, test borings should extend 20 feet into unweathered rock.

Depending on geology, access or other specific requirements, the actual spacings and depths of the test borings will vary.

10.2.2 Final Design

As a part of the section designer's proposal, an assessment of the additional subsurface investigation required to support the final design effort shall be included. This assessment shall take into account the existing information and shall identify, in general, the additional test borings, laboratory testing, and any special tests or analyses the section designer deems necessary.

If the section designer concludes that the existing information from completed investigations is sufficient for final design, no additional investigation program will be conducted. In the case where additional investigation is needed, the section designer shall, within a reasonable time of notice to proceed, and considering any constraints imposed by the design schedule, submit a written request for enumerating specific parameters, tests, and any other information required for the proposed subsurface investigation program.

Following approval of the proposed investigation program by DART, additional geotechnical investigations will be implemented by the section designer. The completed investigation will be summarized in a subsurface investigation report prepared by the section designer. The report shall include the boring logs and testing data. During the preparation of this report, the section designer shall submit to DART its recommendations for approval.

10.3 GEOTECHNICAL INPUT TO DESIGN

Geotechnical input to design will be based upon geotechnical data derived from the aforementioned subsurface investigation programs, along with other available data, and will be commensurable with the corresponding design level. Subsurface investigations for conceptual/preliminary design, in general, will provide similar information, such as: groundwater levels; soil and rock unit weight; bearing capacity; angle of internal friction; coefficients of active, passive, and at-rest pressures; swelling potential; modulus of elasticity, Poisson's ratio; compressive and tensile strengths; consolidation; pH; and resistivity and chemical tests. Other routine test information will include grain size, Atterberg limits, and moisture contents. The basic difference between the two levels of investigation is that the investigation in support of conceptual/preliminary design may be based upon limited testing, whereas the investigation in support of final design provides more detailed site-specific information.

For seismic design, the Soil Profile Type shall be classified in accordance with 2000 International Building Code, 1615.1.1 Site Class Definitions. Geotechnical input to design shall consider seismic effects on retaining walls, cut-and-cover structures, excavation support, deep foundations as well as mined tunnels and stations.

10.4 GEOTECHNICAL DESIGN CRITERIA

General geotechnical criteria outlined in this chapter shall be applied where referenced in Chapters 12 - 18 of these criteria: At-Grade Structures, Aerial Structures, Retaining Structures, Cut-and-Cover Structures, Excavation Support, Deep Foundations, and Mined Tunnels and Stations. The geotechnical criteria, where included in these chapters, may not always consider the specifics that apply to each unique design. Due to the variability of earth, rock, and hydrostatic pressures on underground structures, foundation elements of other structures, and earth retaining structures with geographic location and depth, the design parameters shall be derived based upon material properties developed from site-specific subsurface investigation.

10.5 GEOTECHNICAL BASIS OF DESIGN REPORT

For each mined tunnel and mined station contract, the section designer will prepare a report entitled "Geotechnical Interperative Report." When required by DART, a report shall be prepared for other underground structural design contracts. The reports are to describe the geologic conditions anticipated along the subject contract segments of the DART Light Rail System and the influence of these anticipated geological conditions upon design and construction. A geotechnical report will be prepared by the section designer that provides geotechnical recommendations to guide the design and construction of surface structures and underground utilities. These reports will become a part of the contract documents in order to assist prospective bidders in evaluating ground conditions and requirements for the initial support of excavations, to assist the contractor in planning their work, and to assist the resident engineer in reviewing the contractor's submittals.

CHAPTER 11 - NOISE AND VIBRATION

11.1 INTRODUCTION

This chapter provides design criteria for noise and vibration control in the construction and operation of the DART rail system. It excludes the transit vehicle noise and vibration specifications that are contained in Section 2.05 of the DART Rail Vehicle Performance Specifications.

The basic goals of these criteria are to create designs that will:

- o Provide transit system patrons with an acoustically comfortable environment by maintaining, within acceptable limits, noise and vibration levels in vehicles along the way and in stations.
- o Minimize the adverse impact of system operation and construction on the community by controlling the transmission of noise and vibration to adjacent properties.
- o Provide noise and vibration control consistent with economic constraints and appropriate technology.

Community acceptance of a rail rapid transit system requires control of airborne noise and vibration from transit train operations, transit ancillary areas and facilities such as yard operations, vent and fan shafts of the ventilation systems, electrical substations, emergency service buildings, and air conditioning chiller plants. The design should also provide for any required control of ground-borne noise and vibration caused by transit vehicle operations.

Airborne noise from train operations generally can be controlled with the use of sound barrier walls located adjacent to the alignment. Noise from ancillary facilities can often be controlled through the use of sound absorption materials installed within rooms or shafts. Ground-borne noise and vibration from train operations can be reduced with the use of "soft" direct fixation fasteners, resiliently supported ties, ballast mats or floating slab trackbeds.

Community acceptance of construction noise and vibration requires that the contractors use machinery and equipment with efficient noise and vibration suppression devices and that other noise and vibration abatement measures be employed for the protection of both employees and the public.

Construction noise and vibration generally can be reduced by using sound barrier walls around the construction site, using drilled rather than driven piles, limiting the charge sizes during blasting, and so forth.

Providing a satisfactory and comfortable acoustical environment for patrons in station areas requires use of sound absorption materials near platform areas and in walls and ceilings. Overall control of station noise also requires including maximum noise limits in equipment specifications.

The criteria presented in this document are based upon scales which most closely correlate with the objective evaluation of noise. For most typical noise sources, it has been found that the A-weighted sound level provides excellent correlation with the subjective evaluation of response to noise. Thus, the A-weighted sound level, which can be read directly from a sound level meter, has been selected as the basic noise unit in descriptors for evaluating the response of people to the noise created by transit system construction and operation.

In addition, these criteria are based on those contained in the U. S. Federal Transit Administration (FTA) publication, Transit Noise and Vibration Impact Assessment and the American Public Transit Association (APTA) publication, Guidelines for Design of Rapid Transit Facilities (see Appendix 1) with certain revisions and additions based on the Dallas City Development Code.

Definitions of many of the terms used in this chapter are contained in Appendix 3 - Glossary.

11.2 MEASUREMENT PROCEDURES AND ASSUMPTIONS

Unless otherwise indicated, all noise levels are expressed in decibels referenced to 20×10^{-6} Pascals (Pa) (0.0002 microbar) as measured with the A-weighting network of a standard sound level meter, abbreviated dBA. All noise levels or measurements refer to the use of A- weighting and "slow" response of an instrument complying with the Type 2 requirements of the latest revision of American National Standard (ANSI) S1.4-1983, Specification for Sound Level Meters. (See Appendix 1.)

Vibration levels are expressed in decibels in terms of vibration velocity level referenced to 10^{-6} in./sec. as measured with a velocity transducer or accelerometer with suitably integrated output.

11.2.1 Transit System Wayside Noise and Vibration Measurements

Transit system wayside noise criteria are based on measurements taken at appropriate distances and performed at a specified height above ground away from vertical reflective or shielding surfaces. Unless otherwise indicated, vibration guidelines are based on measurements of vibration in the vertical direction on the ground surface, or on building floors.

11.2.2 Construction Noise and Vibration Measurements

Construction noise shall be measured in accordance with section 11.2. All impulse or impact noise levels or measurements shall refer to use of an impulsive sound level meter complying with the criteria of IEC 179 (see Appendix 1) for impulse sound level meters. As an alternative procedure, a Type 2 General Purpose sound level meter using C-weighting and "fast" response may be used to estimate the peak values of impulsive or impact noises.

Determining construction noise and vibration levels:

- o Noise levels at buildings affected acoustically by the contractor's operations: Refer to measurements at points between 3 and 6 feet from building facades or building setback lines, or a distance of 200 feet from the construction limits (whichever is closer).

- o Vibration levels at buildings affected by construction operations: Refer to vertical direction vibration on the ground surface or building floor, or 200 feet from the construction limits (whichever is closer).

- o Vibration levels at buildings affected by blasting operations: Refer to the 3-axis vector sum of vibration velocity on the ground surface or building floor, or 200 feet from the construction limits (whichever is closer).

11.3 WAYSIDE NOISE AND VIBRATION

11.3.1 Community Land Use Categories and Relation to Criteria

A wayside community noise impact criterion provides a basis from which to determine the type and extent of noise reduction measures necessary to avoid annoyance in the community. The wayside noise criteria are related to the type of activity taking place in the building or community and to the ambient noise levels in the absence of transit system noise.

Wayside noise impact is based on the criteria defined by the Federal Transit Administration (FTA Report DOT-T-95-16, April 1995). These criteria group noise-sensitive land uses into the three categories described in Table 11.1. As indicated in the table, the Day-Night Sound Level (Ldn) is used to characterize noise exposure for residential areas (Category 2). For other noise-sensitive land uses (Categories 1 and 3), the maximum one-hour Equivalent Sound Level (Leq) during the operating period of the facility is used. The one-hour Leq is a single noise level with the same sound energy as the fluctuating noise level over a one-hour period, and the Ldn is a 24-hour Leq with a 10 dBA penalty applied to noise that occurs between 10:00 p.m. and 7:00 a.m. to account for heightened sensitivity to noise at night in residential areas.

Table 11-1 Land Use Categories and Metrics for Transit Noise Impact Criteria		
Land Use Category	Noise Metric (dBA)	Description of Land Use Category
1	Outdoor $L_{eq}(h)$*	Tracts of land where quiet is an essential element in their intended purpose. This category includes lands set aside for serenity and quiet, and such land uses as outdoor amphitheaters and concert pavillions, as well as National Historic Landmarks with significant outdoor use.
2	Outdoor L_{dn}	Residences and buildings where people normally sleep. This category includes homes, hospitals and hotels where a nighttime sensitivity to noise is assumed to be of utmost importance.
3	Outdoor $L_{eq}(h)$*	Institutional land uses with primarily daytime and evening use. This category includes schools, libraries, and churches where it is important to avoid interference with such activities as speech, meditation and concentration on reading material. Buildings with interior spaces where quiet is important, such as medical offices, conference rooms, recording studios and concert halls fall into this category. Places for meditation or study associated with cemeteries, monuments, and museums. Certain historical sites, parks and recreational facilities are also included.
*L_{eq} for the noisiest hour of transit-related activity during hours of noise sensitivity.		

Source: U.S. Federal Transit Administration, April 1995

11.3.2 Airborne Noise from Above-Ground Train Operations

Table 11-2 presents criteria for airborne noise exposure from transit train operations for the noise-sensitive land use categories listed in Table 11-1. The first column in this table shows the existing (ambient) noise exposure and the remaining columns show the added noise exposures from the transit operations that define the thresholds of "impact" and "severe impact." The future noise exposure would be the combination of the existing noise exposure and the additional noise exposure caused by the transit operations. Table 11-3 gives the information from Table 11-2 in terms of the maximum allowable increase in cumulative (i.e. existing plus transit) noise exposure as a function of existing noise exposure. Although Table 11-2 indicates that higher levels of transit noise are allowed in areas with high levels of existing noise, Table 11-3 shows that smaller increases in total noise exposure are allowed as existing noise levels increase.

For severe impact areas, noise mitigation is required if at all practical. For moderate impact areas, other project-specific factors must be considered to determine the need for mitigation. These other factors can include the predicted increase over existing noise levels, the types and number of noise-sensitive land uses affected, existing outdoor-to-indoor sound insulation and the cost-effectiveness of reducing the noise to more acceptable levels. Refer to Section 2.05, "AUDIBLE NOISE AND

VIBRATION," of the DART Rail Vehicle Performance Specification for information on the noise and vibration expected from the vehicle.

Table 11-2

FTA Noise Impact Criteria

Existing Noise Exposure Leq or Ldn	Project Noise Exposure Impact Thresholds, Leq or Ldn (dBA)			
	Category 1 or 2 Sites		Category 3 Sites	
	Impact	**Severe Impact**	**Impact**	**Severe Impact**
<43	Amb.+10	Amb.+15	Amb.+15	Amb.+20
43	52	58	57	63
44	52	59	57	64
45	52	59	57	64
46	52	59	57	64
47	52	59	57	64
48	53	59	58	64
49	53	59	58	64
50	53	60	58	65
51	54	60	59	65
52	54	60	59	65
53	54	60	59	65
54	55	61	60	66
55	55	61	60	66
56	56	62	61	67
57	56	62	61	67
58	57	62	62	67
59	57	63	62	68
60	58	63	63	68
61	58	64	63	69
62	59	64	64	69
63	60	65	65	70
64	60	66	65	71
65	61	66	66	71
66	61	67	66	72
67	62	67	67	72
68	63	68	68	73
69	64	69	69	74
70	64	69	69	74
71	65	70	70	75
72	65	71	70	76
73	65	72	70	77
74	65	72	70	77
75	65	73	70	78
76	65	74	70	79
77	65	75	70	80
>77	65	75	70	80
Note: Ldn is used for land uses where nighttime sensitivity is a factor: Maximum 1-hour Leq is used for land use involving only daytime activities.				

Source: U.S. Federal Transit Administration, April 1995

Table 11-3
Cumulative Noise Level Increase Allowed by FTA Criteria

Existing Noise Exposure Leq or Ldn	Impact Threshold for Increase in Cumulative Noise Exposure (dBA)			
	Category 1 or 2 Sites		Category 3 Sites	
	Impact	Severe Impact	Impact	Severe Impact
45	8	14	12	19
46	7	13	12	18
47	7	12	11	17
48	6	12	10	16
49	6	11	10	16
50	5	10	9	15
51	5	10	8	14
52	4	9	8	14
53	4	8	7	13
54	3	8	7	12
55	3	7	6	12
56	3	7	6	11
57	3	6	6	10
58	2	6	5	10
59	2	5	5	9
60	2	5	5	9
61	1.9	5	4	9
62	1.7	4	4	8
63	1.6	4	4	8
64	1.5	4	4	8
65	1.4	4	3	7
66	1.3	4	3	7
67	1.2	3	3	7
68	1.1	3	3	6
69	1.1	3	3	6
70	1.0	3	3	6
71	1.0	3	3	6
72	0.8	3	2	6
73	0.6	2	1.8	5
74	0.5	2	1.5	5
75	0.4	2	1.2	5
Note: Ldn is used for land uses where nighttime sensitivity is a factor: Maximum 1-hour Leq is used for land use involving only daytime activities.				

Source: U.S. Federal Transit Administration, April 1995

11.3.3 Ground-Borne Vibration and Noise from Train Operations

Table 11-4 presents the criteria for maximum ground-borne vibration and noise due to transit train operations based on land use and train frequency. There are some buildings, such as concert halls, recording studios and theaters, which can be very sensitive to vibration but do not fit into any of the three categories listed in Table 11-4. Due to the sensitivity of these buildings, they usually warrant special attention during the design of a transit project. Table 11-5 gives criteria for acceptable levels of ground-borne vibration and noise for various types of special buildings.

It should be noted that ground-borne noise is the "rumble" that can be radiated from the motion of room surfaces in buildings due to ground-borne vibration. Although expressed in dBA, which emphasizes the more audible middle and high frequencies, the criteria are set significantly lower than for airborne noise to account for the annoying low-frequency character of ground-borne noise. Because airborne noise often masks ground-borne noise for above ground (i.e. at-grade or elevated) rail systems, ground-borne noise criteria are primarily applied to subway operations and to buildings with sensitive interior spaces that are well insulated from exterior noise.

Table 11-4
Ground-Borne Vibration and Noise Impact Criteria

Land Use Category	**Ground-Borne Vibration Impact Levels (VdB Re 1 micro Inch/sec)**		**Ground-Borne Noise Impact Levels (dB re 20 micro Pascals)**	
	Frequent Events[1]	**Infrequent Events[2]**	**Frequent Events[1]**	**Infrequent Events[2]**
Category 1: Buildings where low ambient vibration is essential for interior operations.	65 VdB[3]	65 VdB[3]	-[4]	-[4]
Category 2: Residences and buildings where people normally sleep	72 VdB	80VdB	35 dBA	43 dBA
Category 3: Institutional land uses with primarily daytime use.	75 VdB	83 VdB	40 dBA	48 dBA

Notes:
1. "Frequent Event" is defined as more than 70 vibration events per day. Most rapid transit projects fall into this category.
2. "Infrequent Events" is defined as fewer than 70 vibration events per day. This category includes most commuter rail systems.
3. This criterion limit is based on levels that are acceptable for most moderately sensitive equipment such as optical microscopes. Vibration sensitive manufacturing or research will require detailed evaluation to define to acceptable vibrations levels. Ensuring lower vibration levels in a building often requires special design of the HVAC systems and stiffened floors.
4. Vibration-sensitive equipment is not sensitive to ground-borne noise.

Source: U.S. Federal Transit Administration, April 1995

Table 11-5
Ground-Borne Vibration and Noise Impact Criteria for Special Buildings

Type of Building or Room	Ground-Borne Vibration Impact Levels (VdB Re 1 micro Inch/sec)		Ground-Borne Noise Impact Levels (dB re 20 micro Pascals)	
	Frequent Events[1]	Infrequent Events[2]	Frequent Events[1]	Infrequent Events[2]
Concert Halls	65 VdB	65 VdB	25 dBA	25 dBA
TV Studios	65 VdB	65 VdB	25 dBA	25 dBA
Recording Studios	65 VdB	65 VdB	25 dBA	25dBA
Auditoriums	72 VdB	80 VdB	30 dBA	38 dBA
Theaters	72 VdB	80 VdB	35 dBA	43 dBA

Notes:

1. "Frequent Events" is defined as more than 70 vibration events per day. Most transit projects fall into this category.
2. "Infrequent Events" is defined as fewer than 70 vibration events per day. This category includes most commuter rail systems.
3. If the building will rarely be occupied when the trains are operating, there is no need to consider impact. As an example consider locating a commuter rail line next to a concert hall. If no commuter trains will operate after 7 pm, it should be rare that the trains interfere with the use of the hall.

Source: U.S. Federal Transit Administration, April 1995

11.4 NOISE AND REVERBERATION CONTROL IN SUBWAY STATIONS

The purpose of this section is to define the criteria and the acoustical treatment which will result in a desirable acoustical environment in and around stations throughout the DART rail system. The use of sound absorption material installed on the ceilings and walls of enclosed areas is usually necessary for the control of noise and reverberation. Where appropriate and applicable, noise control can also be achieved through limitations on permissible noise emanating from equipment. These design features are required because it is essential that acoustical control be included in the design of modern transit system facilities to provide a satisfactory and attractive environment for transit system patrons and to minimize impact on the neighboring community.

The inclusion of acoustical treatment in the design of transit system stations accomplishes three major purposes:

- o Control and reduction of noise from transit vehicle operations.

- o Control of noise in enclosed areas generated by patrons and/or exterior sources.
- o Assistance in the control of noise from station air handling equipment, vertical circulation equipment, and any other station mechanical equipment.

Control of these noises will provide transit system patrons with an acoustically comfortable environment and aid the intelligibility of announcements from the public address system.

Acoustical treatment of the stations accomplishes these objectives by the absorption of sound energy as it impinges on the interior surfaces of the station, thus preventing multiple reflections and the build-up of reflected or reverberant sound energy. The amount of control of reverberation and the consequent reduction of noise obtained is dependent on the area of the acoustical treatment, the absorption coefficient, and the placement of the treatment. To obtain the most economical and appropriate design for the station acoustical treatment, a set of criteria for determining the appropriate areas, absorption coefficients, and placements of the acoustical material has been derived.

The criteria were developed to be consistent with the design goal maximum noise levels presented in Table 11-6. The noise levels inside the stations are dependent on the design of the transit cars and station mechanical equipment, and on the acoustic treatment in stations. The criteria and designs for the acoustic treatment take into account the general architectural characteristics expected of the DART stations and the expected noise to be radiated by the transit cars and other noise sources.

TABLE 11-6

UNDERGROUND STATION MAXIMUM NOISE LEVELS

On platform, trains entering and leaving*	80 dBA
On platform, trains passing through*	85 dBA
On platform, trains stationary*	75 dBA
On platform or in mezzanine areas with only station ventilation system and auxiliaries operating	55 dBA
On platforms or other public areas of stations with ventilation fans operating in emergency status	85 dBA
In tunnels with tunnel ventilation fans operating in emergency status	100 dBA
In station attendants' booths or offices	50 dBA

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* Measured at center of platform, 10 feet from edge of platform (or 16 feet from centerline of track).

Table 11-9 summarizes the criteria for reverberation time and acoustical treatment of the various areas of underground stations:

TABLE 11-7

ACOUSTICAL DESIGN CRITERIA

	Areas Exposed to Street Traffic	Enclosed Concourse Areas	Train Rooms
Maximum Reverberation Time (500 Hz)	1.2 to 1.4 sec.	1.2 sec.	1.5 sec.
Maximum Mechanical Equipment Noise	--	55 dBA	55 dBA*
Treatment: Minimum ceiling only	70-100%	85-100%	85-100%
Treatment Properties: Minimum 500 Hz absorption coefficient	0.6	0.6	0.6**
Minimum.NRC0.60.60.6**			

* 50 dBA maximum in station attendants' booths.

11.4.1 Station Interior Acoustical Design

The architectural design of a station includes treatment for enclosed areas. Among the considerations in the design are four basic steps:

- o Determine required reverberation times and quantities of absorption.
- o Determine locations that will provide maximum control of noise.
- o Select appropriate absorption coefficients for the treatment materials.
- o Select acoustical materials and design material installations.

Reverberation Time and Absorption Quantity. As summarized in Table 11-7, the acoustical criteria for stations include the maximum reverberation time at 500 Hz, the minimum areas for treatment, and the minimum absorption properties.

- Train Rooms (Station Platform Areas). The optimal treatment for underground train rooms is obtained with a reverberation time of about 1.3 seconds. The reverberation time in the train rooms shall be no greater than 1.5 seconds.

  The acoustical treatment shall be continuous and uniform for the entire length of the enclosed space. When the train rooms have a relatively constant cross-section, it is most appropriate to define the quantity of treatment in terms of treatment per foot of station platform length. From this, the thickness of treatment required as a function of the absorption coefficient of the material can be determined.

- Mezzanines and Passageways. The reverberation time shall not exceed 1.2 seconds for enclosed concourse areas such as mezzanines, fare collection areas, and corridors.

- Station Areas At or Above Grade. Areas exposed to street noise can be increased to the range of 1.2 to 1.4 seconds at 500 Hz.

- Ancillary Areas. Ancillary areas include service rooms, toilets, mechanical/electrical equipment rooms, and train control and communications equipment rooms. Spaces used for fans and other potentially noisy equipment shall be separated from public areas as much as possible. Access to these noisy areas shall be through double doors or sound-treated doors. Any of these areas used by the public or next to public spaces shall receive appropriate acoustical treatment.

Location of Absorption Material. Continuous treatment of the surfaces at platform level is essential for the effective control of train noise, since most train noise originates in this area. It is especially effective to treat the side walls opposite the platform.

The basic design criteria call for a coverage of 85 to 100 percent of the total ceiling area, or 35 percent of the wall and total projected ceiling area, with acoustical treatment in addition to the platform treatment. The preferred locations for acoustical treatment in stations are listed below in order of priority:

- Platform Areas - Enclosed Station Train Rooms:

  - Train room ceilings.
  - Side walls, especially near tracks.

o Mezzanine and Corridor Areas:

- Ceilings. Between structural members or directly on the ceiling surface for flat ceilings.

- Walls. Appropriate panel assemblies or direct wall-mounted materials.

- Concourse, Mezzanines, and Passageways. All enclosed public areas of the station shall receive acoustical treatment equal to a minimum of 85 to 100 percent of the projected ceiling area, or alternately, 35 percent of the projected wall and ceiling area. Acoustical material in public areas shall be placed a minimum of 9 feet from floor surfaces, or shall have protective facing to prevent vandalism.

- Entrances. Entrance enclosures shall have acoustical treatment on a minimum of 70 to 100 percent of the projected ceiling area, or 20 to 25 percent of the wall and ceiling area.

- Openings. For the purpose of calculation, large openings in enclosed spaces may be considered as acoustical treatment.

Acoustical Materials and Installations. This section covers the selection and application of appropriate acoustical materials for stations. Acoustical treatment for transit system stations consists of three elements:

o The sound absorption material.

o A protective covering.

o An architectural or trim facing.

Flammability. All acoustical materials shall be in accordance with NFPA-130 (see Appendix 1).

Materials. Absorption treatments for wall and ceiling shall be selected from available materials which meet the specified mechanical and acoustical requirements. Among the candidate materials are glass fiber blankets wrapped in close-weave glass cloth or other non-flammable sheeting not to exceed 0.004 inch thickness, and sprayed-on cementitious material which meets the criteria in Table 11-7.

Installation.

Wherever perforated metal or slit-and-slat facings are used, the open area shall be at least 30 percent of the total area. Expanded metal or perforated metal facing can be attached with metal brackets. Air space should be provided around the edges of panels in enclosed stations to allow free circulation of air to prevent loading of the acoustical material panels due to air pressure transients created by the train movements. Panels with perforated metal or slit-and-slat facings--either for ceiling or wall installations--shall have a dimensional screen placed between the metal facing and the face of the acoustic blanket to establish an air space of approximately 0.5 inch thickness between the perforated facing and the blanket or glass-cloth bag.

If a continuous panel acoustical system or a suspended acoustical tile ceiling is used, openings shall be provided to permit free air flow between the panels and the concrete surface behind. This shall be done to prevent loading of the acoustical panel by the air pressure transients created by train piston action on the air. All acoustical systems shall have positive mechanical anchorage designed to resist the shock of transient air pressure produced by the movement of a train moving through a station at maximum speed. If sprayed-on cementitious material is used, it must be applied to clean, primed surfaces. Where thickness greater than one inch is required to meet sound absorption criteria of Table 11-7, the installer may be required to use mechanical support such as expanded metal sheeting.

11.4.2 Noise Intrusion from Traffic and Railroad Operations

Where feasible and practical, the following areas in DART rail stations shall be shielded from street, highway, and railroad vehicle noise:

- Entrance areas.
- Stairs from street level.
- Elevators from street level.
- Escalators from street level.
- Vent shafts from street level.

The reverberation time of these enclosed areas shall be in the range of 1.2 to 1.4 seconds at 500 Hz when the area is unoccupied.

Acoustical Treatment. Acoustical treatment should be placed on a minimum of 20 to 25 percent of any cross-sectional perimeter, or 70 to 100 percent of the ceiling area. The treatment can consist of an absorptive wall panel system, an acoustical absorption assembly applied to the ceiling, or a combination of these. The acoustical treatment shall have a Noise Reduction Coefficient (NRC) of at least 0.60, and a minimum sound absorption coefficient of 0.60 in the 500 Hz octave band.

11.4.3 Enclosed Concourse Areas

The maximum noise level from mechanical and electrical equipment shall not exceed 55 dBA in the absence of occupants for the following areas:

- o Fare collection areas.
- o Stairs.
- o Escalators.
- o Corridors.

The reverberation time of the areas shall not exceed 1.2 seconds at 500 Hz when the area is unoccupied.

Acoustical Treatment. The acoustical treatment shall cover not less than 35 percent of the combined surface area of ceiling and walls, or the equivalent, including coverage of at least 50 percent of the ceiling area where possible. In narrow spaces, the treatment can be concentrated on the ceiling, covering 70 to 100 percent of the ceiling area. The acoustical treatment shall have an NRC of at least 0.60 and a minimum sound absorption coefficient of 0.60 in the 500 Hz octave band.

11.4.4 Train Rooms

The maximum noise level on platforms due to the station ventilation system or other operating auxiliaries shall not exceed 55 dBA. The maximum noise level on platforms with ventilation systems operating in single track congestion status shall not exceed 70 dBA. The maximum noise level on platforms with ventilation systems operating in emergency status shall not exceed 75 dBA. The reverberation time of the platform area shall not exceed 1.5 seconds at 500 Hz when the area is unoccupied.

Acoustical Treatment. Acoustical treatment with a minimum NRC of 0.60 and a minimum 500 Hz sound absorption coefficient of 0.60 shall cover the surface areas of ceiling and wall as required. The underside of the platform overhang and the wall of the underplatform overhang space shall be covered with an acoustical material having a minimum absorption coefficient of 0.40 at 250 Hz and 0.65 at 500 Hz.

11.4.5 Ancillary Areas

If possible, spaces for noisy ancillary equipment shall be located away from public spaces. Noisy ancillary spaces opening directly to public spaces shall have sound-rated or double-entrance doors. Acoustical treatment for each area listed below depends on location, type of noise, and occupancy. The areas to be considered are as follows:

- Toilet and service rooms.
- Electrical equipment rooms.
- Train control and communications equipment rooms.
- Mechanical equipment rooms.
- Traction power equipment rooms.

Acoustical Treatment Guidelines. As required, toilet, locker and service rooms shall have acoustical treatment applied to the ceilings for control of reverberation and noise. The acoustical absorption material shall have an NRC of at least 0.55. As required, electrical equipment rooms, train control equipment rooms, and traction power equipment rooms with noise generating equipment shall have acoustical treatment covering the ceiling. The acoustical material shall be an equipment room ceiling/wall treatment, 1-inch-thick-glass fiber boards, for example, and shall have an NRC of at least 0.65. Mechanical equipment rooms housing fans, pumps, and other equipment that generates high sound levels shall have a sound absorption treatment equivalent to a 2-inch-thick glass fiber board or blanket (minimum NRC of 0.75) applied to cover the ceiling and wall areas as required. In other spaces with equipment which generates only low or moderate noise, the acoustical treatment shall be as indicated above for electrical equipment rooms.

11.4.6 Vertical Circulation Equipment

For all normal operating conditions for escalators and elevators located in public areas, the noise level at 3 feet from the equipment shall not exceed 55 dBA for steady-state noise, and transient noise shall not exceed 60 dBA as measured using the fast meter response.

Escalators. Noise produced by escalators operating individually in either direction under no load and maximum load in the station environment shall not exceed 55 dBA 5 feet above the tread at the entrance combs at both ends of the escalator.

Elevators. Steady-state noise produced by elevators or associated equipment shall not exceed 55 dBA in public spaces 3 feet or more from the elevator (or associated equipment), or within the elevator cab at any location 5 feet above the floor and 1 or more feet from any wall. Transient noise produced by elevators or associated equipment, not including entrance door operations, shall not exceed 60 dBA (using the fast meter response) in public spaces 3 feet or more from the elevator (or associated equipment), or within the elevator cab at any location 5 feet above the floor and 1 or more feet from any wall. Transient noise produced by the operation of the elevator door shall not exceed 65 dBA (using the fast meter response) 3 feet or more from the elevator door inside or outside the elevator cab.

11.4.7 Ventilating Equipment

Fan and Equipment Rooms. Spaces for fans and other potentially noisy equipment shall be separated from public areas whenever possible. If direct access into such rooms from public areas cannot be avoided, sound rated doors necessary to achieve the noise levels specified in Table 11-6 shall be provided. Sound transmissions through other openings shall be controlled by such appropriate means as acoustically lined ducts or shafts.

Fan Equipment. Fans shall have certified sound/power levels measured in accordance with the AMCA test code. (See Appendix 1.) The fan sound/power levels shall not exceed those shown on the drawings or listed in the fan procurement documents.

Vibration Isolation. Because of the nature of subway station and other transit facility structures, it may not be necessary to provide spring-type vibration isolators for fans and other equipment in the same manner as in office or other general purpose buildings. Subway station structures are of heavy concrete construction, and the fans and equipment are generally separated from public areas. As a minimum, however, simple rubber support pads shall be required between the concrete mounting surface and the machine or device.

Except as noted below, in subway structures, substation structures, and in any separate mechanical equipment or plant structures, vibration isolation consisting only of standard ribbed rubber pads or 1/2-inch-thick neoprene pads shall be provided between the mounting feet or bracket and the support surface for the following items:

- Fans.
- Pumps.
- Emergency generators.
- Elevator motors, motor generators, DC power converters and hydraulic power units.

- o Electrical equipment containing reactors or choppers.

Except for hydraulic elevator power units, flexible connectors should be provided in pipes and ducts only as necessary to prevent street or load concentration, or to provide for alignment tolerance. Each hydraulic elevator power unit output line shall have a muffler in the line and two flexible connectors at right angles to each other and separated by at least 4 feet of line. The connectors can be on each side or on the same side of the muffler, but they should be close to the hydraulic power unit.

In any location where fans are placed in a room that is located directly above a public area, spring isolators shall be provided for support of the fan, and flexible connectors shall be used for connecting the fan to the ductwork. Rubber pads of 1/2 inch thickness shall be provided between the spring foot and the support surface. In all cases where anchor bolts pass through the rubber support pads, a neoprene sleeve and washer shall be used to separate the anchor bolt shank and head (or nut) from the machine support foot or bracket.

11.5 NOISE CONTROL IN ABOVE-GROUND STATIONS

Table 11-8 lists the design maximum noise levels for above-ground stations. Many of the provisions of section 11.4 are applicable to the enclosed areas of the above-ground stations and are not repeated here. Specific reference is made to material selection and location contained in section 11.4.1, the provisions of 11.4.3 for enclosed concourse areas, the provisions of section 11.4.5 for ancillary areas, and the provisions of section 11.4.6 for vertical circulation equipment.

TABLE 11-8

MAXIMUM NOISE LEVELS IN ABOVE-GROUND STATIONS

On platform, trains entering and leaving -	
ballast-and-tie trackbed	80 dBA
concrete trackbed	85 dBA
On platform, noise from traffic on nearby streets, highways or expressways	70 dBA L_{eq} (peak hour)
On platform, noise from any ancillary mechanical or vertical circulation equipment	55 dBA
Noise in station attendants' booths or offices due to ventilation system and booth equipment	55 dBA

11.5.2 Acoustical Design Criteria

In fully enclosed station platforms, the reverberation time of the platform area shall be between 1.2 to 1.5 seconds at 500 Hz when the area is unoccupied.

11.5.3 Station Areas Related to Noise from Street Traffic, Highway Traffic and Railroad Operations

Where feasible and practical, the following areas shall be shielded from street, highway, and railroad vehicle noise:

- o Entrance areas.
- o Stairs.
- o Escalators.
- o Elevators.
- o Platforms.
- o Corridor and mezzanine areas.

Open areas, particularly platforms, shall have sound barrier walls blocking the line-of-sight between significant noise sources and the patron areas.

Acoustical Treatment. Enclosed areas such as stairs, corridors, or mezzanines shall have sound absorption treatment applied as described in sections 11.4.2 and 11.4.3.

11.6 AIRBORNE NOISE FROM TRANSIT ANCILLARY FACILITIES

11.6.1 Transient and Continuous Noise

There are sources of community noise from a subway or above-grade transit system other than trains. The two basic types of airborne noise from ancillary facilities are transient and continuous. For example, transient noise occurs when trains pass by and this noise is transmitted from vent shaft openings. Power substations, chiller plants and fan noise may be characterized as continuous ancillary equipment noise. These noises can be obtrusive due to their tonal and continuous nature. The appropriate noise level criterion depends on the activities of occupants as well as the background noise in the area. The acceptable levels of transient and continuous noises are different. Transient noises are acceptable at higher levels than continuous noises, particularly continuous noises containing pure tones. Table 11-9 presents the design criteria for the transit system ancillary facility noises in various zoning districts. These criteria are based on the nighttime noise limits included in Part II of the Dallas City Development Code (Article VI, Section 51A-6.102, Noise Regulation). The code prohibits creating noise levels that exceed the specified limits or that exceed the background noise level (in terms of Leq averaged over an 8-minute period of time) by five (5) dBA, whichever is greater. The criteria in Table 11-9 shall be applied at the setback line of the nearest building or occupied area.

Table 11-9
Dallas City Nighttime Noise Limits for Ancillary Equipment

Zoning District	Noise Limit, dBA*	
	Transient Noise	Continuous Noise
Residential	59	49
Commercial	66	56
Light Industrial	68	58
Heavy Industrial	73	63
*Use specified values or background Leq + dBA, whichever is greater.		

Transient noise design goals apply to short-duration events such as noise transmitted through shaft openings from passing trains. Continuous noise design goals apply to noises such as fans, cooling towers, or other long duration noises (except electrical transformer hum). The design goals for transformer noise and other sources of noise with tonal components shall be 5 dBA less than given in Table 11-9. Sound attenuation may not be required for emergency exhaust fans except in cases where they are used as part of a station ventilation system, or if regular tests of the fans occur at night.

The designer is advised to use caution making estimates of the noise from ancillary equipment. A safety factor of at least 5 dB in octave bands 1 and 2 (63 and 125Hz) and 3 dB in octave bands 3 through 8 (250,500,1000,4000 and 8000 Hz) should be used.

11.6.2 Fan and Vent Shafts

For fan and vent shafts with surface gratings or openings, the noise shall be limited in accordance with the criteria for exterior noise from ancillary facilities listed in Table 11-9.

Vent shaft noise reduction shall be achieved by using similar absorption treatment in the shafts that is applied to station walls and ceilings. Fan shaft noise reduction shall be achieved by using standard duct attenuators in shafts where the fans are near surface gratings. For shafts with fans located remotely from the grating, the noise reduction shall be achieved by using standard attenuators and sound absorption treatment applied to the fan room and shaft walls and ceilings with the combination to achieve the total attenuation required.

11.6.3 Substations and Emergency Power Generation

Substation and emergency power generation equipment noise shall be limited to sound level 5 dBA less than those listed for continuous noise in Table 11-9. As applicable to the individual facility or unit design, the reduction of noise from these sources shall be achieved, using barriers, enclosures, sound absorption materials, and mufflers.

11.6.4 Chiller Plant Noise

Chiller plant noise levels shall comply with the design criteria listed for continuous noise in Table 11-9. As applicable to the individual facility or unit design, the reduction of noise from chiller plants shall be achieved by barriers, enclosures, and sound absorption materials.

11.7 NOISE IN SUBWAY TUNNELS

High-speed train operations in tunnels can generate excessive noise levels. Noise abatement techniques shall be used to reduce the noise to an acceptable level. The maximum interior car noise at maximum tunnel operating speeds shall not exceed 80 dBA. To meet this design goal, an acoustical absorption system may be employed in the tunnel, or additional sound insulation may be provided on the cars. Tunnel sound absorption treatment can, for instance, provide 5 dBA or more reduction of noise levels inside the car. Reducing tunnel noise by installing an acoustical absorption system in the tunnels improves the acoustical environment for system employees and aids in complying with the statutory noise limits set by OSHA. (See reference 7 under Section 1.5

in Appendix 1.) With tunnel ventilation fans operating in emergency status, noise levels in tunnels shall not exceed 100 dBA.

11.8 SHOP EQUIPMENT NOISE

To avoid excessive noise exposure for employees, shop equipment noise shall comply with OSHA standards.

11.8.1 Miscellaneous Habitable Areas

Recommended background noise levels due to operation of mechanical/electrical equipment and from intrusive exterior noise, are tabulated in Table 11-10 for habitable areas. Note that these criteria apply to unoccupied spaces, with all systems operating.

TABLE 11-10

BACKGROUND NOISE LEVELS

Type of Area	Recommended Background Noise Levels - dBA
General Offices	40-45
Private Offices	35-40
Cafeterias	45-50
Equipment Rooms	50-60
Lockers	50-55
Open Work Areas	50-60
Repair Shops	
1) Metal	50-60
2) Electronic	40-50
Conference Rooms	30-35
Lecture Rooms	30-35

11.9 VIBRATION ISOLATION OF TRANSIT STRUCTURES

Vibration isolation shall be provided at any point where a subway, vent shaft, aerial structure column, aerial structure girder, or other structure is in direct contact with, supported on, or supporting a building structure. Vibration isolation also shall be provided at any point where a subway structure, station structure, or vent shaft is close to or directly against a building structure or building foundation element.

To prevent the direct transmission of noise and vibration to buildings, vibration isolation in the form of a resilient element shall be provided between transit structure elements and building structure elements.

11.9.1 Isolation Elements

For underground transit structures near or at buildings, the resilient element between the two structures shall consist of intervening soil of at least 2 feet thickness or depth, or shall be an elastomer pad between the subway structure and building. The elastomer pad shall be a 1- to 2-inch-thick closed-cell expanded neoprene selected to give proper support of hydraulic or structural loads. Deflection of this elastomer pad shall not exceed 10 to 20 percent of pad thickness.

For aerial structure columns or girders, the transit structures shall be separately founded from buildings. Resilient bearing pads or elastomer separation elements shall be provided between the transit structures and the building. There shall be no direct or rigid connection between the building elements and the transit structure elements.

11.10 CONSTRUCTION NOISE AND VIBRATION CONTROL

Construction operations shall be performed in a manner to minimize noise and vibration. Working machinery and equipment shall be provided with efficient noise suppression devices, and other noise and vibration abatement measures necessary for protection of both employees and the public. In addition, working hours shall be restricted and operations scheduled in a manner that will minimize to the greatest extent feasible the disturbance to the public in areas adjacent to the work. In accordance with the requirements of the Occupational Safety and Health Act of 1970 and the current statutory noise limits set by OSHA, employees and the public shall be protected against noise exposure. The contractor shall also be responsible for compliance with state and local ordinances, regulations, and other chapters of these design criteria.

11.10.1 Special Requirements

Compliance with the requirements of this section will require the use of machines with effective mufflers or enclosures and the selection of quieter alternative procedures. Compliance may also require the use of complete enclosures (tongue-and-groove plywood or sheathing) around work sites or a combination of closed boarding and effective mufflers or enclosures. Haul routes shall be arranged to minimize noise and vibration at residential sites, and it may be necessary to place operating limitations on machines and trucks if suitable routes cannot be found. Shop drawings of work sites and haul routes showing provisions for the control of construction noise shall be submitted to the resident engineer for approval.

11.10.2 Monitoring

Work operation noise and vibration levels shall be monitored so that they comply with the noise and vibration limitations contained in this chapter. Records of these noise and vibration measurements shall be retained for inspection by the resident engineer. The resident engineer shall be informed of any complaints received from the public regarding noise and vibration. The contractor shall describe the remedy proposed and the schedule for implementation, and shall subsequently inform the resident engineer of the results.

11.10.3 Definitions

Daytime/Nighttime. Daytime refers to the period from 7:00 a.m. to 10:00 p.m. local time, daily except Sundays and legal holidays. Nighttime refers to all other times, including all day on Sunday and all day on legal holidays.

Construction Limits. The right-of-way lines, construction easement boundary lines, or property lines as indicated on the drawings.

Special Zones or Special Construction Sites. These may be designated outside of the construction site by the agency having jurisdiction where the construction site is located. These specially designated zones shall be treated by the contractor as if they were within the construction limits.

11.10.4 Noise Level Restrictions

Noise Level Restrictions in All Areas. In no case shall the public be exposed to construction noise levels exceeding:

- 90 dBA (slow) or to impulsive noise levels with a peak sound pressure level exceeding 140 dB as measured on an impulse sound level meter.

- 125 dBC maximum transient level as measured on a general purpose sound level meter on "fast" meter response.

Noise Level Restrictions at Affected Structures. Construction activities shall be conducted so that the noise levels 200 feet from the construction limits or at the nearest affected building, whichever is closer, do not exceed the levels listed below and in Tables 11-11 and 11-12.

Continuous Noise. Noises from stationary sources, parked mobile sources, or any combination of sources producing repetitive or long-term noise lasting more than one hour shall be prevented from exceeding the limits of Table 11-11. In urban areas with very high ambient noise levels, continuous noise levels shall not exceed existing ambient plus 10 dB.

Intermittent Noise. Noises from non-stationary mobile equipment operated by a driver or from any source of non-scheduled, intermittent, non-repetitive, short-term noises not lasting more than one hour shall be prevented from exceeding the limits of Table 11-12.

Special Zone or Special Construction Site. In areas outside of construction limits, but for which the contractor has obtained designation as a special zone or special construction site from the agency having jurisdiction, the noise limitations for buildings in industrial areas apply.

In zones designated by the local agency having jurisdiction as special zones, the noise level and working time restrictions imposed by the agency shall apply. These zones and work hour restrictions shall be obtained by the contractor from the local agency.

More Than One Limit Applicable. Where more than one noise limit is applicable, the more restrictive requirement for determining compliance shall be used.

11.10.5 Noise Emission Restrictions

Only equipment meeting the noise emission limits listed in Table 11-13 as measured at a distance of 50 feet from the equipment shall be used. The measurements shall be in accordance with the latest revisions of SAE J366b, SAE J88, and SAE Ja52b (Appendix 1) or in accordance with the measurement procedures specified in this chapter.

TABLE 11-11

CONTINUOUS CONSTRUCTION NOISE LIMITS

Affected Structure or Area	Maximum Allowable Continuous Noise Level, dBA	
Residential	Daytime	Nighttime
Single family residence, multi-family residential areas, including hospitals and hotels	65	55
Commercial	Daytime	Nighttime
Mixed residential/commercial areas, including schools	75	65
Commercial areas with no nighttime residency	75	75
Industrial		
All locations	85	85

TABLE 11-12

INTERMITTENT CONSTRUCTION NOISE LIMITS

Affected Structure or Area	Maximum Allowable Intermittent Noise Level, dBA	
Residential	Daytime	Nighttime
Single family residence, multi-family residential areas, including hospitals and hotels	85	75
Commercial	Daytime	Nighttime
Mixed residential/commercial areas, including schools	90	80
Commercial areas with no nighttime residency	90	90
Industrial		
All locations	90	90

TABLE 11-13

CONSTRUCTION NOISE EMISSION LIMITS

TYPE OF EQUIPMENT	MAXIMUM NOISE LIMIT*
Impact and Vibratory Pile Drivers	95 dBA
Mounted Impact Hammers and Concrete Saws	90 dBA
Backhoes, Front End Loaders, Compressors, Compactors and Vibrators	80 dBA
All Other Equipment with Engines Larger than 5HP	85 dBA

11.10.6 Vibration Level Restrictions

Vibration Limits in All Areas. Construction activities shall be conducted so that vibration levels at a distance of 200 feet from the construction limits or at the nearest affected building (whichever is closer) do not exceed root-mean-square (rms) vibration velocity levels of 0.1 inches per second in any direction over the frequency range of 1 to 100 Hz. For residential zones and for manufacturing zones with vibration-sensitive processes (e.g. semiconductor production), a reduced vibration limit of 0.02 inches per second shall apply based on Part II of the Dallas City Development Code (Article VI, Section 51A-6.105).

Special Zones. In zones designated by the local agency having jurisdiction as a special zone, special premise, or special facilities, the vibration level and working time restrictions imposed by the agency shall apply. These zones and work hour restrictions shall be obtained by the contractor from the local agency.

11.10.7 Noise and Vibration Control Requirements

Although this chapter specifies specific noise and vibration level limitations, the noise and vibration control measures listed below shall be used to minimize to the greatest extent feasible the noise and vibration levels in all areas outside the construction limits. Examples of noises and vibrations and measures to be used are as follows:

- o Transmission of noise: Shields, impervious fences, or other physical sound barriers.

- Noise producing equipment: Sound retardant housings or enclosures.

- Internal combustion engines and compressors: Intake and exhaust mufflers.

- Hoppers, storage bins, and chutes: Linings, or a covering made of sound-deadening material.

- Air or gasoline driven saws: Use of these tools should be minimized.

- Truck loading, unloading, and hauling operations: Shall be conducted to minimize noise and vibration.

- Construction equipment and vehicles carrying tunnel spoils, concrete, or other materials: Shall be routed over streets and routes that will cause the least disturbance to residents. (Before securing a permit from the local government, the resident engineer shall be advised in writing of the proposed haul routes.)

- Stationary equipment: Shall be placed to minimize noise and vibration impact on the community. (Subject to approval by the resident engineer.)

- Vibrating pile drivers or auguring for setting piles: Shall be used instead of impact pile drivers where feasible. If impact pile drivers must be used, their use shall be restricted from 8:00 a.m. to 5:00 p.m. weekdays in residential and semi-residential/commercial areas.

11.11 BLASTING NOISE AND VIBRATION CONTROL

Blasting operations shall be performed in a manner to minimize noise and vibration. Blasting mats shall be used along with other abatement measures necessary for the protection of employees and the public. In addition, working hours and schedule operations shall be restricted in a manner that will minimize to the greatest extent feasible the disturbance to the public in areas adjacent to the work and to the occupants of buildings in the vicinity of the work. Compliance by the contractor with the requirements of this section will not relieve the contractor from responsibility for compliance with state and local ordinances, regulations, or other chapters of these criteria.

11.11.1 Monitoring

Noise and vibration levels of work operations shall be monitored so that the limitations contained in this chapter are complied with and records of measurements are retained for inspection by the resident engineer. The resident engineer shall be promptly informed of any complaints received from the public regarding noise or vibration. The action proposed and the schedule for implementation shall be described and the resident engineer shall be promptly informed of the results of the action.

11.11.2 Time of Blasting

Blasting shall be restricted to daytime hours between 7:00 a.m. and 7:00 p.m. daily except Sundays and legal holidays.

Emergency. In the event that logistics, safety or emergency considerations require blasting during nighttime hours between 7:00 p.m. and 7:00 a.m. and Sundays and legal holidays, blasts may be fired at such times subject to prior notice to and approval by the resident engineer, and subject to the restrictions of section 11.11.3, Emergency Blasting.

Special Considerations. In addition to these restrictions, if situations and circumstances require, blasting shall be restricted to within reasonably safe distances of noise-and-vibration sensitive premises or facilities. Blasting in these sensitive areas shall be restricted to specific daytime periods determined by the resident engineer. Each shot shall be scheduled and coordinated with the resident engineer.

11.11.3 Ground Vibration Due to Blasting

Blasting operations shall be conducted to avoid damage to structures or buildings and to prevent peak particle velocity of blast-induced motion from exceeding 2.0 inches per second on or in the nearest structure, on the ground at the nearest structure, or 200 feet from the construction limits, whichever is closer. At residential structures, a reduced vibration limit of 0.5 inches per second shall apply. Peak particle velocity is defined as the instantaneous maximum vector sum of the velocity vectors in three mutually perpendicular directions at the point of interest.

Emergency Blasting. Emergency blasting required during nighttime to protect the safety of the project shall be controlled to prevent peak particle velocity of ground vibration from exceeding 0.2 inch per second at the nearest building having nighttime occupancy, or 200 feet from the construction limits, whichever is closer. Notwithstanding the above, if an emergency arises from an inability of the contractor to fire loaded holes within the daytime period solely due to unavoidable conditions, peak particle velocity of ground vibration may exceed 0.2 inch per second, but they shall not exceed 2.0 inches per second.

New Concrete. Blasting operations shall be conducted to prevent peak particle velocity of ground vibration from exceeding 1.0 inch per second at concrete less than 3 days old or 2.0 inches per second at concrete less than 7 days old. Blasting within 25 feet of concrete less than 76 days old is prohibited unless a satisfactory plan has been submitted in writing and has been accepted by the resident engineer.

11.11.4 Noise (Overpressure) Due to Blasting

Daytime blasting shall be conducted so that instantaneous peak overpressure is limited to 0.01 psi at the nearest building or 200 feet from the construction limits, whichever is closer. All instrumentation must be linear in response with a range of at least 5 Hz to 200 Hz.

Emergency. Nighttime blasting shall be conducted in such a manner that instantaneous peak overpressure is limited to 0.0004 psi at the nearest building or 200 feet from the construction limits, whichever is closer.

Overpressure Control Measures. Notwithstanding the limitations specified in this chapter, control measures such as those listed below shall be used to minimize to the greatest extent feasible the blasting overpressure in all areas outside the construction limits. These control measures are as follows:

- Weighted covers on vertical and inclined shafts: Shall be utilized to contain blasting overpressure.
- Blasting mats: Shall be used where feasible at the excavation.
- Charge per delay: Shall be minimized.
- Covers and excavation: Shall be arranged to maximize underground volume exposed to blast pressure.

11.11.5 Test Blasts

At least one small-charge test blast shall be performed at each new drill-and-blast excavation site prior to the commencement of production blasting to establish local ground-borne vibration and airborne overpressure propagation characteristics and anomalies. This data will aid in the placement of efficient charges that will not cause the ground-borne vibration and airborne overpressure limits to be exceeded. The scheduling of each test blast shall be coordinated with the resident engineer.

11.11.6 General Precautions in Blasting Operations

All parties owning or operating subsurface utilities shall be notified a minimum of 72 hours before blasting operations commence. The resident engineer's approval for the daily blasting schedule shall be obtained. Controlled blasting techniques shall be used to minimize fracturing the rock outside the neat lines of the excavation. Sizes and arrangements of explosive charges and detonation methods shall be used that will reduce the magnitude of vibration resulting from the explosion to the limits specified in previous sections of this chapter. This shall be done to prevent damage to the constructed works as well as to services, buildings, or property in the neighborhood, and to minimize nuisance to nearby residents.

All necessary and satisfactory means of protection shall be employed. These may include temporary bridges, staging, chains, rope-nets, mats, timber and so forth, to prevent any stones, rock fragments or other materials from being shot or thrown out of any excavation. As the excavation proceeds, and immediately after each blast, the roof and walls shall be tested and loose and shattered rock shall be scaled. At least every 48 hours, similar checks on previously excavated sections shall be performed.

Blasting in ground that, in the opinion of the resident engineer is loose or liable to slips, shall be prohibited. Wedging and barring shall only be allowed in such ground.

Before blasting within 15 feet of an existing line of water, gas, or sewer pipes, or within 50 feet of any completed part of the rail system, a plan shall be submitted to and approved by the resident engineer. The plan shall show the relative positions of the existing service, or the completed part of the works and the area to be blasted, and the blasting technique to be employed.

CHAPTER 12 - AT-GRADE STRUCTURES

12.1 INTRODUCTION

The design criteria contained in this chapter shall relate to the design of at-grade structures constructed as part of the Dallas Area Rapid Transit (DART) Rail System. Structural design shall be governed by these criteria in addition to the codes, standards, and specifications referenced in Appendix 1.

The full titles of all references in this chapter are listed in the Structural section of Appendix 1. In the event of a conflict between criteria in this chapter and information referenced in Appendix 1, the more restrictive criteria shall govern.

At-grade structures include the following:

- Stations and associated ancillary structures.
- Traction substations.
- Maintenance workshops.
- Entrance structures.
- Ventilation shafts.
- Plant and equipment rooms.
- Storage structures.
- Lighting masts and poles.
- Signal and communication bungalows.
- Catenary pole foundation.

Emergency egress shall be provided for patrons to evacuate a train at any point along the guideway and proceed to an exit or the nearest station or await evacuation. These egress provisions shall include the following: 1) ballast shall be considered a walkway surface for exit purposes for at-grade areas only; and 2) a transition in the walkway shall be provided at all grade-to-aerial guideway and all underground-to-at-grade abutments. There shall be adequate provisions for access and egress by emergency rail vehicles and crews to at-grade guideways.

12.1.1 Structural Interfaces

The at-grade portions of both underground and aerial structures shall be designed according to the criteria contained in this chapter, with allowance for the prevailing conditions at the structural interfaces.

12.2 LOADS

The structural components shall be designed to resist the Loads of Chapter 9 - Loads of these criteria except as modified herein this chapter.

12.2.1 DART System Live Loads (L)

Standard axle spacings and loadings, centrifugal force, and longitudinal force shall be as prescribed in Chapter 9 - Loads. The vertical impact factor shall be taken as 30% for slabs on grade. Wheel loads shall be considered as concentrated loads when considering loads applied directly to the top of the subway structure.

12.2.2 Wind Loads (W)

See Chapter 9 - Loads of these design criteria. For wind loads on special type structures such as canopy roof for station buildings, the designer is referred to "Wind Forces on Structures", Paper No. 3269, reprinted 1972, by American Society of Civil Engineers.

12.3 STRUCTURAL DESIGN

Those portions of the building and ancillary structures located below ground level shall be designed to resist the loads and forces as specified in the relevant chapters of these criteria, together with the full imposed dead and live loads of the above-ground portion of the structure. Those portions of DART structures considered to form aerial structures shall be designed according to the relevant chapters of these design criteria.

Relevant structural components shall also be checked according to the requirements for deep beams per ACI 318, Chapters 10 and 11. Structural elements which involve cantilevered designs shall also be checked under the provisions for corbels as stated in ACI 318, Chapter 11 and AASHTO, Section 8.

12.3.1 Analysis and Design Assumptions and Methods

All materials shall comply with the requirements of the materials chapter of these design criteria. Design calculations for prestressed concrete shall be based on working loads and allowable unit stresses; prestressed concrete design shall also be checked for ultimate loads. The design of steel structures shall be per load resistance factor design and reinforced concrete structures shall be based on the ultimate strength design method. Framed structures shall be analyzed by rational elastic methods which consider the effects of relative stiffness of connected members, relative displacement, rotation of joints, and the effects of axial deformations.

Particular consideration shall be given to the variations in elastic properties and stress distribution of complex frameworks resulting from different construction sequences. Any limitations on construction operations inherent in the design assumptions shall be noted on the project drawings and specified in the special provisions. Conversely, advantage may be taken of specified construction procedures or sequences to effect a more favorable distribution of loads or stresses.

12.3.2 Design Strengths

See Chapter 8 - Structural Materials of these criteria for minimum material requirements.

12.3.3 Crack Control

The limitations of the chapter on structural materials on the design stress in reinforcing steel is aimed at reducing the cracking of concrete. In addition, the reinforcing steel in the exterior face of concrete members in contact with the ground that are not protected by an impermeable waterproofing barrier shall not exceed bar size designation number 11.

12.3.4 Soil and Rock Bearing Capacity

The allowable bearing capacity of soil and rock shall be determined by the designer in accordance with the geotechnical information specified in Chapter 15 - Cut-and-Cover Structures. For at-grade structures founded in soil, the bearing capacity shall be investigated by the designer for adequacy, with due consideration of groundwater elevation and its potential variation, together with the effects of soil stress relief attributable to reduced overburden pressures. For deep foundations, such as drilled shafts, variations in seasonal moisture, and the influence of possible uplift loads on the shafts and caps shall be fully evaluated.

12.3.5 Joints

Expansion Joints. Provisions for expansion shall be made in all DART at-grade structures. Where a structural element is partially underground and partially above-ground, and where an above-ground element is attached to an underground element, particular care shall be taken in detailing to accommodate differential thermal movements.

Reinforcing steel shall not be continuous through the joint. Shear forces shall be transferred across the joint preferably by a key; alternatively, smooth dowels may be embedded on one side of the joint and provisions made on the other side to break the dowel bond and to provide space for dowel movement. All expansion joints in base and roof slabs and in walls against earth shall contain a nonmetallic waterstop with a minimum width of 9 inches. Thorough consideration shall be given to ensuring structural integrity and watertightness. Expansion joint locations shall be indicated in drawings.

Contraction Joints. To control shrinkage stresses in concrete slabs and walls and to minimize cracking, contraction joints shall be provided in at-grade structures at intervals not greater than 32 feet. They shall also be provided at locations of major change in structural section. A closer spacing shall be used if appropriate to the framing system. Provisions for contraction also shall be made in the above- ground portions of subway structures. Contraction joints shall be unbonded joints and designed not to transmit the forces perpendicular to the joint that may occur under any design condition, and shall be designed according to the criteria described above for expansion joints.

Construction Joints. Construction joint locations may be indicated by the designer to divide the structure into convenient working units for concrete placement. Such joints shall be detailed in the plans, together with an indication of whether they are optional or mandatory. They shall be designed to transmit all the forces that may occur under any design condition. Construction joints through which no moment is transferred may be detailed as either expansion joints or contraction joints.

Construction joints through which moment is transferred shall be bonded joints; that is, prior to placing concrete in the adjacent pour, the joint shall be cleaned by abrasive cleaning, high-pressure water jetting, or other means to remove loose material and to expose clean aggregate. Reinforcement shall be continuous through the joint. A key or other positive means shall be provided where required for the transfer of shear forces. Construction joints in base and roof slabs and in exterior walls against soil and rock shall contain a nonmetallic waterstop with a minimum width of 9 inches. Thorough consideration shall be given to structural integrity and watertightness.

Joints in Steel Frames. Provisions shall be made in structural steel frameworks of at-grade structures for the temporary accommodation of fabrication and erection tolerances without introducing significant distortions in the frame. If required, temporary joints shall be permanently connected after the entire framework has been plumbed and aligned. They shall be designed to accommodate all design loads.

12.3.6 Temporary Works

The designer shall consider the influence of temporary works on the design of the permanent works for at-grade structures. In particular, the detailing of watertightness and the penetration of structural steel into structural concrete (for example, temporary bracing) shall be evaluated. At least 4 inches of concrete cover to temporary works left in place shall be provided on the inside face of the structure. A minimum concrete cover of 4 inches to cast-in temporary works shall be provided to the exterior face of permanent works.

12.3.7 Foundations

The design of foundations for at-grade structures shall be in accordance with the geotechnical information referred to in Chapter 15 - Cut-and-Cover Structures. For deep foundations, refer to Chapter 17 - Deep Foundations. Slabs on grade shall be analyzed in accordance with the requirements for elastic foundation design with due consideration of any potentially expansive soils located below the foundation level.

12.4 SURFACE STRUCTURES

12.4.1 Roof Drainage

Roofs of all above-grade and at-grade structures shall be sloped for drainage a minimum of 1/4 inch per foot under any ambient condition. Beams and girders shall be cambered for dead load. For additional requirements see the architectural design criteria.

12.4.2 Surface Finish

All internal and external faces of at-grade structures shall have a surface finish in accordance with the architectural design.

12.4.3 Drainage

The recommendations of Chapter 30 - Plumbing and Drainage Systems shall be used in the design of at-grade structure drainage systems.

12.4.4 Noise and Vibration

The recommendations of the DART consultant shall be used for those portions of at-grade structures subject to vibration loads, other than those resulting from plant vibration that shall be designed according to Chapter 11 - Noise and Vibration.

12.4.5 Waterproofing

Waterproofing shall be provided in accordance with the structural standard and directive drawings and the guide specifications.

12.4.6 Walkways

Safety Walkway minimum width shall be 22 inches, with 24 inch desirable.

12.5 CATENARY POLES AND FOUNDATIONS

The design criteria catenary poles and foundations for overhead catenary system of the DART rail system is in Volume 2 - Systems Design of the DART Design Criteria Manual.

CHAPTER 13 - AERIAL STRUCTURES

13.1 INTRODUCTION

The design criteria contained in this chapter shall relate to the design of aerial structures constructed as part of the Dallas Area Rapid Transit (DART) Rail System. Structural design shall be governed by these criteria in addition to the codes, standards, and specifications referenced in Appendix A.

The full titles of all references in this chapter are listed in the Structural section of Appendix A. In the event of a conflict between criteria in this chapter and information referenced in Appendix A, the more restrictive criteria shall govern.

These criteria are for use in the design of aerial guideway structures and structural elements of aerial stations which are subjected to the standard DART train loading. In addition, this chapter includes vibration, and deflection limitations for pedestrian structures and station platforms.

Ballasted-deck structures shall be designed in accordance with these criteria and also shall comply with the track requirements of these criteria. Catenary poles, mounted on aerial structures, shall be designed in accordance with Volume 2 – System Design, Chapter 3 – Traction Electrification.

Emergency egress shall be provided for patrons to evacuate a train at any point along the guideway and proceed to an exit or the nearest station or await evacuation. These egress provisions shall include the following: 1) ballast shall be considered a walkway surface for exit purposes for at-grade areas only; and 2) a transition in the walkway shall be provided at all grade-to-aerial guideway and all underground-to-at-grade abutments. There shall be adequate provisions for access and egress by emergency rail vehicles and crews to aerial guideways. Aerial structures shall comply with the requirements of the NFPA 130 standard for fixed guideway transit and passenger rail systems.

13.2 GENERAL DESIGN FEATURES

13.2.1 Clearances

The minimum clearances between the aerial structure and the DART standard vehicle shall conform to the provisions of the transit vehicle design criteria. The clearances between the aerial structure and privately or publicly owned streets, highways, railways, utility lines, and other structures or property shall be those prescribed by the agencies involved.

13.2.2 Vibration and Deflection Limitations

Aerial structures shall be designed for vibration, verifying limitations set forth in these design criteria are not exceeded. Special consideration is required for Continuous Welded Rail (CWR)/Structure interaction, including the use of 3-D models where appropriate.

Track Girders. All structures supporting DART trains shall be designed so that the unloaded natural frequency of the first mode of vibration of the longitudinal girders is not less than 2.5 cycles per second. Furthermore, no more than one span in any series of three consecutive spans shall have a first mode frequency less than 3.0 cycles per second.

Designers may find that compliance with the above criterion necessitates the inefficient use of certain materials, particularly where the girders are of structural steel and the span lengths are relatively long. Where such a finding is made, the proposed design shall be discussed with DART to determine, for that particular instance, whether a lower natural frequency may be acceptable.

Members having simple or continuous spans shall be designed so that the deflections due to live load plus impact does not exceed 1/1000 of the span length. The deflection of cantilever arms due to live load plus impact shall be limited to 1/375 of cantilever arm.

Pedestrian Structures. Pedestrian structures shall be designed to meet the span/depth ratio and deflection criteria contained or cited in the structural materials chapter of these criteria. In addition, the following limitations shall apply:

- Structures Supporting Pedestrian Traffic Only. The natural frequency of the unloaded structure shall be not less than 2.0 cycles per second. The calculated pedestrian live load deflection shall be limited to:

$$L_o = \frac{L}{67} \leq 1 \text{ in (1 inch absolute maximum)}$$

Where:

L_o = allowable live load deflection, in inches

L = span length, in feet

- Platform Girders in Aerial Stations. Primary longitudinal supports of the platforms shall be structurally independent of the track girders. Where this does not prove possible, the calculated static deflection due to train live load shall be limited to:

$$L_o = L^3/900{,}000$$

Where:

L_o = allowable live load deflection, in inches
L = track girder span, in feet

- o Transverse Station Supports. Transverse frames or girders in aerial stations that support both pedestrian traffic and train loads shall be designed so that the calculated static deflection of any support point for pedestrian traffic is not greater than that calculated by (a) or (b) below:

(a) $L_o = L/67 \leq 1$ in (1 inch absolute maximum)

Where:

L_o = allowable deflection, in inches, due to pedestrian loads only
L = span length of transverse girder, in feet

b) $L_o = L^3/900{,}000$

Where:

L_o = allowable deflection, in inches, due to train loads only
L = average length of track girder supported by adjacent transverse girder, in feet

13.2.3 Alignment

Horizontal Alignment. Except where tracks diverge or converge, the edges of the aerial structure deck slab shall be parallel to the DART system control line.

Vertical Alignment and Camber. Girders supporting the superstructure shall be cambered to compensate for deflection due to its own dead load and all superimposed dead loads. In superstructures supported on prestressed girders, the camber both short and long term, induced by the prestressing forces, shall be included. In concrete superstructures the design shall limit total creep movements to avoid exceeding the limits of adjustment for the direct rail fastners. Track rail supports and fastenings shall contain provisions for correcting the long-term effects of creep.

13.2.4 Electrification

Space shall be provided for the installation of the catenary support system, signals and communications systems, auxiliary power transmission system, primary power distribution system (in some locations), and other electrical appurtenances.

13.2.5 Trackwork

Where the rails are to be fastened to the superstructure deck by direct-fixation methods, adequate provisions shall be made in the design of the deck for the mounting of the rails. See the trackwork directive drawings and the trackwork chapters 1 - 3, of these design criteria for more information.

13.2.6 Service Walkway

A continuous service walkway shall be provided along the aerial structure. For a height of 6 feet above the top of the walkway, the service walkway shall have a clear width of 24 inches beyond the dynamic clearance envelope of the vehicle. Conduits, pipes, fixtures, and other appertances shall not extend more than 2 inches into the walkway envelope. The service walkway shall be readily accessible from the superstructure deck. The service walkway shall have a cross slope for drainage unless otherwise directed. The service walkway will carry all system cables and conduits, and shall be designed for this additional load (see Chapter 9 - Loads).

13.2.7 Aerial Structures Drainage

The superstructure deck shall be designed to provide both longitudinal and transverse drainage. Transverse drainage shall be secured by suitable cross slopes, and longitudinal drainage by camber or gradient of the deck or gutter. Runoff shall be computed in accordance with the civil design criteria using a runoff coefficient of 0.90. Collected water from a storm of 100-year frequency shall be carried from the deck by a system of inlets and down spouts at each pier.

Inlets and down spouts shall be rattle-proof and made of non-corrosive material. Down spouts shall be rigid, have a minimum inside dimension of 4 inches, and be provided with suitable clean-outs and splash blocks.

The concrete decks shall be provided with drip notches.

13.2.8 Aerial Station Drainage

The superstructure deck in the vicinity of the aerial station shall be designed to accommodate drainage requirements from the adjacent station structure. Drains shall be watertight and carry water to desired exit points. These requirements will be in addition to those specified in section 13.2.7.

13.2.9 Approach Slabs

Except where the abutting at-grade trackbed consists of a track slab, an approach slab shall be provided at each abutment to ensure a smooth transition from the at-grade section to the aerial structure. The approach slab shall have a length of not less than 20 feet.

Approach slabs shall have ballast checks to minimize ballast creep, and provisions shall be made to prevent the scatter of ballast onto the superstructure deck; refer to the trackwork standard drawings.

13.2.10 Noise Considerations

At locations identified by DART or its noise and vibration subconsultant, an acoustical barrier shall be provided along one or both edges of the aerial structure deck to limit noise transmission to noise-sensitive developments along the wayside. At locations where no acoustical barrier is identified, provisions shall be made to the deck, superstructure, and substructure for the future installation of a barrier.

At locations identified by DART or its noise and vibration subconsultant, certain steel girders may require sound damping panels to minimize their propagation of low frequency vibrations. Where required, DART will provide the section designer with sound damping details. All noise and vibration designs shall meet the requirements provided in Chapter 11 - Noise and Vibration of these design criteria.

13.2.11 Pedestrian Railings

Wherever the edge of the deck or aerial structure is not protected by an acoustical barrier, pedestrian railing shall be provided. Pedestrian railing shall meet the requirements of <u>Standard Specifications for Highway Bridges</u> (American Association of State Highway and Transportation Officials, AASHTO) for protection of open-sided platforms except, that no toe board is required.

13.2.12 Identification

At each crossing of an aerial line structure over a highway or major street, a sign shall be placed on the superstructure, over the highway or street centerline, identifying the DART structure. For sign details, see the architectural standard drawings. Locations will be specified by DART.

13.3 LOADS

The structural components shall be designed to resist the loads of Chapter 9 - Loads of these criteria except as modified herein this chapter.

13.3.1 Buoyancy (B)

The effects of buoyancy shall be considered in the design of the substructure, including piling.

13.3.2 Stream Flow (SF)

The effects of stream flow and drift on bridge substructures shall conform to the provisions of Section 3.18.1 of AASHTO.

The design of waterway crossings shall be performed in accordance with Hydraulics of Bridge Waterways (U.S. Department of Transportation (DOT)) and local agency requirements. The effects of bridge backwater and the stability of the stream bed and bank beneath the structure shall be considered in footing design.

13.3.3 Wind Loads

The aerial structure shall be designed to withstand wind loads of uniform pressure acting upon the superstructure, the substructure, and the live load.

Wind Load on Superstructure (W). A horizontal, uniform wind load of the intensities given by Sections 3.15.1.1.1 and 3.15.1.1.2 of AASHTO shall be applied at the centroids of the exposed areas. In addition to the horizontal wind loads, an upward load shall be applied at the windward quarter point of the transverse width of the superstructure in accordance with Section 3.15.3 of AASHTO.

Wind Load on Live Load (WL). Provision shall be made for a transverse horizontal wind load of 100 pounds per linear foot of train and a longitudinal horizontal wind load of 40 pounds per linear foot of train. These loads shall be based on the length of the train as seen in elevation normal to the longitudinal axis of the structure and shall be applied simultaneously. The transverse wind load shall be applied to the train as concentrated loads at the axle locations in a plane 7 feet above the top of low rail, and normal to the track. The horizontal force component transmitted to the rails and superstructure by an axle shall be concentrated at the rail having direct wheel-flange-to-rail-head contact. The longitudinal force shall be applied to the rails and superstructure as a uniformly distributed load over the length of the train in a horizontal plane at the top of low rail. Minimum train length shall be four cars.

Wind Load on Substructure (W). The substructure shall be designed to withstand the above loads applied to the superstructure as they are transmitted to the substructure and the wind loads applied directly to the substructure as follows:

A uniform transverse pressure of 40 pounds per square foot shall be applied to the exposed area of the substructure as projected onto a vertical plane perpendicular to the axis of the superstructure.

13.3.4 Uplift

Aerial structures shall be designed so that under dead load conditions anchor bolts attaching the superstructure to the substructure are not in tension.

Anchor bolts shall be provided or other provisions shall be made for adequate attachment of the superstructure to the substructure to resist uplift from transit loads, including the derailment load, as per the section on transit loads of these criteria in addition to the requirements of Section 3.17 of AASHTO.

13.3.5 Thermal Forces (T)

Provisions shall be made for stresses and movements resulting from temperature variations. The maximum and minimum temperature and the coefficients of thermal expansion shall be taken as follows:

Material		**Thermal Coefficient**
Concrete:		0.0000060 in/in-degree F
Maximum Temperature	110° F.	
Minimum Temperature	20° F.	
Steel Plate and Girders:		0.0000065 in/in-degree F
Maximum Temperature	110° F.	
Minimum Temperature	5° F.	
Steel Rail:		0.0000065 in/in-degree F
Maximum Temperature	135° F.	
Minimum Temperature	-5° F.	

The neutral rail laying temperature is 90° F.

13.3.6 Pedestrian Loadings (L)

Aerial Structure Walkways. Walkways and their immediate supports shall be designed for a pedestrian live load of 85 pounds per square foot of walkway area. Girders, trusses, arches, and other members shall be designed for the following walkway live loads:

Spans 0 to 25 feet in length 85 lb./ft.^{2}
Spans 26 to 100 feet in length 60 lb./ft.^{2}
Spans over 100 feet in length according to the formula:

$$P = \left(30 + \frac{3{,}000}{L}\right)\frac{(55 - W)}{50}$$

Where:

- P = live load per square foot, max. 60-lb. per sq. ft.
- L = loaded length of sidewalk in feet
- W = width of sidewalk in feet

In calculating stresses in structures that support cantilevered sidewalks, the sidewalk shall be fully loaded on both sides or only one side of the structure to determine which condition produces maximum stress.

Pedestrian Bridges. Pedestrian bridges shall be designed for a pedestrian live load of 85 pounds per square foot of walkway surface. The loading shall be placed either over the entire surface or over portions of the surface, whichever is required to produce the greatest stress in the member being considered.

13.4 TRANSIT VEHICLE LOAD DISTRIBUTION

13.4.1 Load Distribution on Slabs and Beams

In the absence of an elastic analysis, the following empirical methods of load distribution may be employed. These methods are limited to monolithic concrete deck slabs on skews of less than 20 degrees. The skew angle is defined as the angle intersected by a horizontal line parallel to the pier or abutment and a horizontal line perpendicular to the girder centerline. These methods are applicable for unballasted track only. For ballasted bridges, the effects of the ballast in distributing the wheel loads may be considered. For the effects of ballast on distribution of live load, refer to Section 8-2-3 of the Manual for Railway Engineering, American Railway Engineering and Maintenance-of-Way Association (AREMA)).

Contact Area. Under service condition, each wheel load shall be dispersed through the running rail to produce an effective contact area of six inches (measured parallel to rail) by 12 inches measured at the bottom of the elastomeric bearing pad under the rail fastener.

Under derailment condition, each derailed wheel in direct contact with the deck slab shall be assumed to make a groove 0.25 inch to 0.50 inch deep with a wheel-to-concrete contact area 2 inches wide by 8 inches long.

One-Way Slabs (Excluding Cantilever Slabs).

- o Dispersion of Loads Along the Span. The effective length of the slab on which a wheel load acts shall be taken as equal to the dimension of the contact area in the direction of the span plus twice the depth of the slab measured to the centerline of the bottom reinforcement of the slab.

- Effective Width of Slab Resisting Bending Moment and Shear. A solid one-way slab supported on two opposite edges shall be designed to resist the maximum bending moment and shear force caused by the applied loads. Such bending moment and shear force shall be assumed to be resisted by an effective width of slab E (measured parallel to the supported edges, in feet) according to the following empirical formula:

Case 1. Main Reinforcement Perpendicular to the Track (Spans 2 to 24 feet inclusive):

$E = KX(1 - X/L) + W$ but should not exceed 7.0 feet

Where:

X = distance in feet from the center of gravity of the wheel load to the near face of support

L = the effective span as defined in Section 3.24.1.2 of AASHTO in the case of simply supported slabs, and the clear span in the case of continuous slabs

K = 2.5 for simply supported slabs

K = 2.2 for continuous slabs over three or more supports

W = spacing of the rail fasteners

W = 2.0 feet for a derailed wheel load in direct contact with the slab

In the case of a load near the unsupported edge of a slab, E should not exceed the above value nor half the above value plus the distance from the load to the unsupported edge.

Case 2. Main Reinforcement Parallel to the Track

The effective width (in feet) of the slab resisting a wheel load should be taken as:

$E = 4 + 0.06L$ but not to exceed 5.0 feet.

Full edge beams shall be provided for all slabs having main reinforcement parallel to the track. The beam may consist of a slab section with additional reinforcement, a beam integral with and deeper than the slab, or an integral reinforced section of slab and curb.

For simple spans, the edge beam shall be designed to resist a minimum live load moment of $M = 0.10\,(PL)$ where P is the wheel load and L is the span length. For continuous spans, 80 percent of the above calculated value shall be used for both positive and negative moments, unless a greater reduction can be justified based on a rigorous analysis.

Two-Way Slabs. Two-way slabs are those supported on all four sides and reinforced in both directions. For rectangular slabs simply supported on all four sides, the proportion of the load carried by the short span of the slab may be estimated by the following equations:

For load uniformly distributed:

$$P = \frac{L_2^4}{L_1^4 + L_2^4}$$

For load concentrated at center:

$$P = \frac{L_2^3}{L_1^3 + L_2^3}$$

Where:

P = proportion of load carried by short span

L_1 = length of short span of slab

L_2 = length of long span of slab

In cases where L_2 exceeds 1.50 (L_1), the slab shall be designed as a one-way slab spanning in the short direction (span L_1).

For a concentrated load, the effective slab width, E, for the load carried in either direction shall be determined as specified above for one-way slabs.

The moments obtained shall be used in designing the center half of the short and long spans. The reinforcement steel in the outer quarters of both short and long spans may be reduced 50 percent.

Cantilever Slabs.

- Wheel Load. In the design of a cantilever deck slab in which the main reinforcement is perpendicular to the track, a concentrated wheel load may be assumed to be uniformly distributed over an effective width E of the slab, not exceeding 7.0 feet:

  $E = 0.8X + 3.75$ for service condition
  $E = 0.8X + 3.00$ for derailed condition

where X = distance in feet from the load to the face of cantilever support.

- Railing, Acoustical Barrier or Parapet Load. Loads transmitted from railing, barrier or parapet attachments to a cantilever deck slab shall be distributed over the effective width E as specified above for wheel loading under service condition, except that X is the distance in feet from the railing or parapet support to the point along the cantilever that is under investigation, and E shall be limited to the longitudinal spacing of the railing or parapet supports.

Unsupported Edges, Transverse. The design assumptions of the sections on one-way and two-way slabs above do not provide for the effect of loads near unsupported edges. Therefore, at points where the continuity of the slab is broken, the edges shall be strengthened by diaphragms, or other suitable means, and shall be designed to resist the full moment and shear produced by the applied wheel loads.

Longitudinal Beams. In calculating bending moments in longitudinal beams, no longitudinal distribution of the DART vehicle axle loads shall be assumed. The axle loads shall be taken as concentrated loads and shall be placed to cause the maximum bending moment in the longitudinal beams.

Distribution of Wheel Load on the Girders Due to Derailment. For the purpose of calculating the distribution of the wheel load on the girders due to the derailment load, the following shall be used:

- Deck slab shall be assumed to be simply supported between the girders when the load falls in between the girders.

- Deck slab shall be assumed to be continuous over the girders when the load falls on the cantilevered portion of the slab.

13.5 SUBSTRUCTURE

Substructure design shall be in accordance with Section 7 of AASHTO and in compliance with geotechnical recommendations.

Substructure components such as pier caps and caps for drilled piers, shall be checked in accordance to the requirements for deep beams per ACI 318-02 Section 10.7 and 11.8. Additionally, all substructure elements which involve cantilever designs, including pier caps, shall be checked under the provisions for corbels as stated in ACI 318-02 Section 11.9.

13.5.1 Piers

Where the aerial structure crosses streets, highways, or railways, the spacing and location of piers shall be controlled by clearance requirements of the roadways or railways, as well as the necessity of avoiding existing improvements, such as underground utilities whose relocation is not feasible. The minimum horizontal and vertical clearances between the structure and privately or publicly owned streets, highways, utility lines, and other structures or property shall satisfy the requirements of the owners. The minimum horizontal clearance for streets and highways shall preferably include a minimum of 3 feet of lateral clearance between the face of pier and the street right-of-way line.

In addition, crash protection for piers (i.e., traffic barriers, posts, or guardrails, and so forth) against accidental vehicle collision shall be implemented next to those piers adjacent to street right-of-way. For piers adjacent to railroad right-of-way see AREMA.

Lateral Displacement of Pier. The following criteria shall be used to establish maximum lateral displacement of piers consisting of a cap beam supported directly on column and drilled shaft.

- The deformation of the soil shall not exceed the elastic limits.

- Unsupported column height H in feet for pier design shall be the lesser value of the following two:

  - H = (EL @ bot of pier cap) - (EL of finish grade) + 5 feet - 0 inches + 2 x D (drilled shaft diameter)

  - H = (EL @ bot of pier cap) - (EL @ top of rock)

  For definition of H, see Figure 13.1

  Rock is defined as unweathered shale or unweathered limestone.

- The absolute displacement at top of pier shall not exceed H/300.

Piers in Waterways. For those piers located in waterways, special considerations shall be given in the following conditions:

- Piers in Non-Navigable Waterway. In addition to the design loads specified herein, the piers shall be designed to withstand forces caused by the impact of floating objects in stream velocity of 8 feet per second or higher. The design of bridge piers shall be in compliance with Section 7 of AASHTO. Additionally, the pier design should also recognize that considerable debris can accumulate on piers and exert significant lateral loading on the piers.

- o Piers in Navigable Waterway. In addition to the loadings pertaining to the design of piers in non-navigable waterway, the design of the pier protection system for bridge piers in navigable waterway shall be in accordance with Chapter 8, Part 23 of the Manual for Railway Engineering (AREMA). The vessel mass and speed used to determine the collision forces (unless otherwise approved by DART) for the design of piers and its protection system shall not be less than the following dimensions:

  - Vessel mass: 195 feet long by 35 feet wide, with a minimum water displacement depth of 8.5 feet.

  - Vessel speed: 8 feet per second.

  The design of bridge piers shall consider bridge clearance and the base of pier to accommodate the additional excavation of channel bottom to meet ultimate navigational criteria.

13.5.2 Abutments

Abutments founded on spread footings shall be designed so that the resultant load falls within the middle third of a footing resting on soil and the middle half of a footing resting on rock. The abutments shall be designed with the following factors of safety:

- o Overturning about the toe of footing resting on soil: 2.0.
- o Overturning about the toe of footing resting on rock: 1.50.
- o Sliding on the footing base: 1.50.

In computing stresses in an abutment, the weight of fill material directly over the inclined or stepped rear face, or over a reinforced concrete spread footing extending back from the rear face of the wall, may be considered as part of the effective weight of the abutment. Provisions shall be made to effectively drain the fill material behind abutments. The effects of temperature, creep and shrinkage on the superstructure shall be considered in the design.

Pile and drilled pier foundations shall be designed to carry the entire superimposed load, including the weight of the footing and overlying loads supported by the footing. Pile foundations shall be designed for the combination of loads and forces, which produce maximum load in accordance to these criteria. Pile and drilled-pier supported abutments designed to resist earth pressures greater than active pressures shall be investigated under conditions of only active pressures to ensure that the rear piles or drilled piers are not overloaded if only active pressures are produced.

13.5.3 Drilled Shafts

The design of drilled shafts for the piers, abutments, and other structures shall be based on the soil parameters obtained from the geotechnical subconsultant.

13.5.4 Spread Footings and Pile Footings

In addition to the provisions of Chapter 15 of Building Code Requirements for Reinforced Concrete (American Concrete Institute (ACI) ACI 318) and Section 4 of AASHTO, the following shall also apply:

Overstress Allowance. Maximum soil pressures and maximum pile loads shall be permitted to exceed their corresponding allowables by percentages indicated in the Service Load Design table in Section 9.18, **Loading Combinations**, of this Design Criteria.

Minimum Footing Thicknesses. Total concrete thickness of an aerial structure footing shall be equal to or greater than 2 feet 6 inches for a spread footing, and 3 feet 6 inches for a pile or drilled-pier cap. Footing thicknesses shall be specified in increments of 6 inches.

13.5.5 Foundation Settlement

Simple Span Aerial Structure. The differential settlement between two adjacent aerial structure piers shall not exceed 1/2400 times the sum of the length of the connecting span and the shorter of the two adjacent spans.

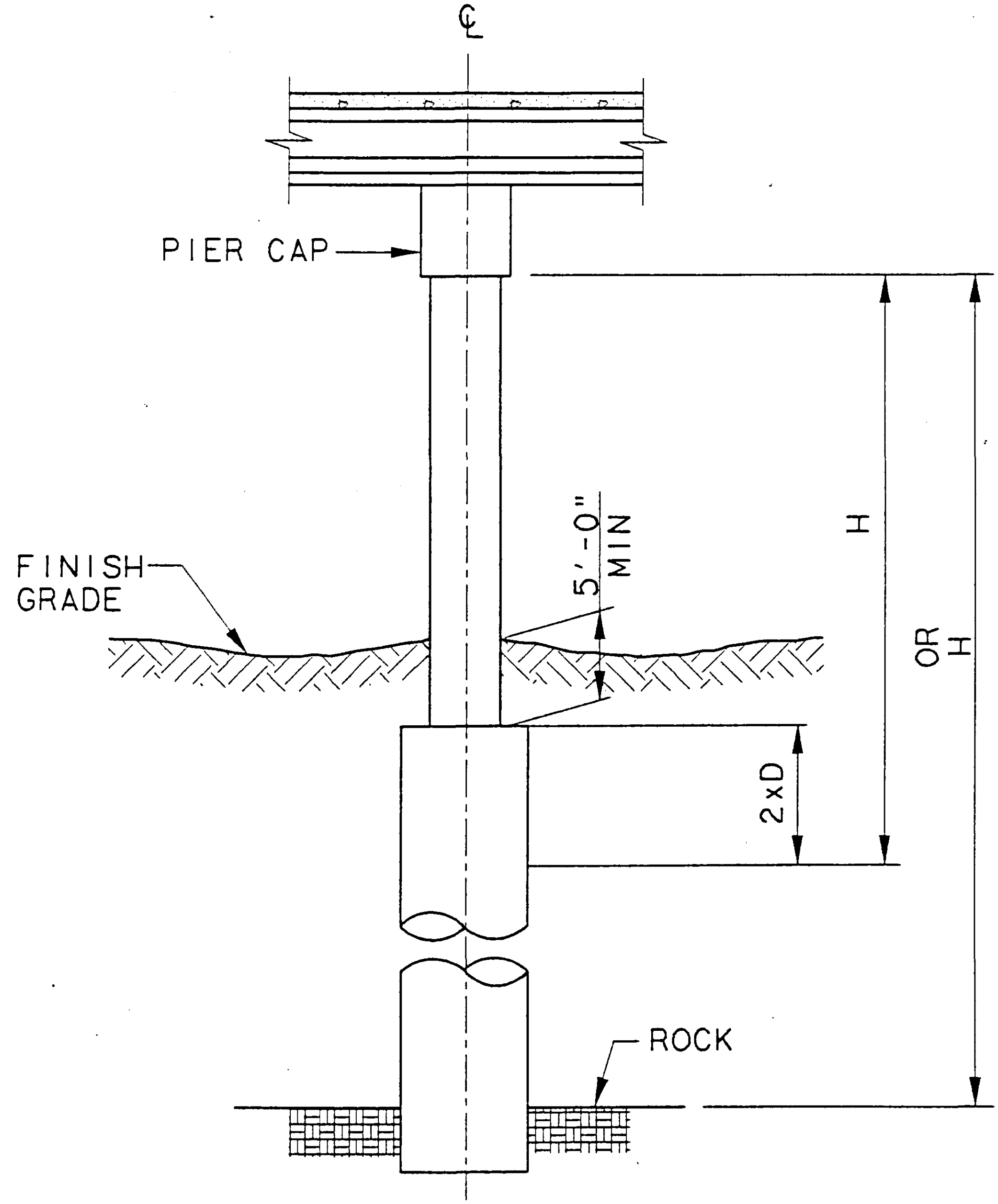
Continuous Span Aerial Structure. The designer shall investigate the differential settlement and design accordingly. In any case the differential settlement shall not be more than that described in the preceding paragraph.

13.6 CORROSION CONTROL

For criteria relating to provisions for minimizing, monitoring, and controlling stray currents in aerial structures, see Systems Design Criteria Chapter 8 - Corrosion Control and Chapter 9 - Systems Grounding.

13.7 FIRE PROTECTION

Refer to Fixed Guideway Transit Systems (NFPA 130) or the applicable local code for fire protection requirements.



LEGEND

D = DRILLED SHAFT DIAMETER
H = UNSUPPORTED COLUMN HEIGHT

ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA PIER DESIGN UNSUPPORTED COLUMN HEIGHT SCALE: NOT TO SCALE FIGURE: 13.1

CHAPTER 14 - EARTH RETAINING STRUCTURES

14.1 INTRODUCTION

The design criteria contained in this chapter shall relate to the design of earth retaining structures constructed as part of the Dallas Area Rapid Transit (DART) Rail System. Structural design shall be governed by these criteria in addition to the codes, standards, and specifications referenced in Appendix 1.

The full titles of all references in this chapter are listed in the Structural Section of Appendix 1. In the event of a conflict between criteria in this chapter and information referenced in Appendix 1, the more restrictive criteria shall govern.

This chapter establishes criteria for the design of abutments, retaining walls, and other earth-retaining structures, which are required for the construction of the system.

Structures that are owned by local governments or other entities shall be designed according to the criteria specified by each owner unless specific approval of the use of the criteria contained herein is obtained from the owner.

Abutments and wingwalls for DART bridge construction shall be designed in accordance with AASHTO, Sections 7 and 8, Division 1. Retaining walls for DART-related work shall be designed to meet the requirements of Section 5, Division 1 of AASHTO, and as noted in this chapter.

14.2 DESIGN PROCEDURES

Where particular retaining structure is not covered by these criteria, the designer shall submit in writing his proposed structure for advance approval from DART. Relevant published references should also be included with the request. Particular attention should be given to the possibilities of differential settlement or deep-seated slope failures affecting earth-retaining structures.

14.2.1 Structural Material Properties

See Chapter 8 - Structural Materials of these criteria for minimum material strengths.

Soldier piles shall be W or HP shapes as designated in the AISC manual Load and Resistance Factor Design Specification for Structural Steel Buildings consisting of steel as defined in Specifications for Structural Steel (American Society for Testing and Materials, ASTM A36). Permanent concrete in pre-drilled holes below the bottom level of lagging shall have a specified compressive strength (f'_c) equal to 3,000 pounds per square inch (psi). Pre-drilled holes above the bottom level of lagging shall be filled with lean concrete with f'_c equal to 1,000 psi. Materials for the construction of gabions shall be submitted to DART for approval in writing.

14.2.2 Soil Properties

Soil properties, including allowable bearing capacities, shall be established by using Chapter 10 - Geotechnical Information of these criteria.

14.2.3 Backfill Material

Backfill material for cantilever walls shall be suitable well-drained earth material that will form a stable embankment. Section Designers need to consider the engineering and economic impact of using a high quality backfill in lieu of the standard. High quality backfill will have an internal friction angle greater than 28°. For MSE walls see section 14.10 of the Design Criteria.

14.3 LOADS

The structural components shall be designed to resist the loads of Chapter 9 - Loads of these criteria except as modified herein this chapter.

Walls shall be designed to resist earth pressures resulting from retained earth and by any live loads, which may occur behind the wall. The minimum live load surcharge shall be the equivalent of 2 foot of soil, unless actual conditions or engineering judgment warrant a greater surcharge. Earth pressure loadings shall be defined on the assumption that the retained earth is well drained, that hydrostatic pressures on the wall can be ignored, and that the soils can be represented by an equivalent material that can be defined by its unit weight and angle of internal friction, that is, unless site-specific conditions prohibit drainage or require consideration of in-situ earth and groundwater conditions. Live load surcharge shall not include the effects of impact. Effects of temporary construction loads shall also be investigated.

Any departure from these design assumptions shall be approved by DART and shall be fully reflected in the individual wall designs. All assumptions shall be clearly indicated in the structural drawings.

14.4 STABILITY

The evaluation of wall stability and the associated factors of safety for overturning, sliding, and overall stability of slopes shall be in accordance with AASHTO Paragraph 5.5.5 and Paragraph 5.2.2.3.

Where non-DART railroad tracks occur behind a wall, a stability shall be determined in accordance with the Manual for Railway Engineering (AREMA), as supplemented by the criteria of the railroad owner.

14.5 STRUCTURES ON DRILLED-SHAFT FOUNDATIONS

Drilled-shaft foundations shall be designed to resist the design loadings associated with the wall structure under consideration. The capacity of drilled shafts shall be determined as prescribed in Chapter 17 - Deep Foundations of these criteria. Drilled shafts supporting earth-retaining structures shall be designed with sufficient lateral capacity to accommodate forces resulting from variations in the design earth pressure.

If the retaining wall system is relatively unyielding, horizontal earth pressures in excess of the active pressure condition can act on the wall. The design shall consider such variations in lateral wall pressures based upon the wall structural configuration and the geotechnical information contained in the geotechnical chapter of these criteria.

14.6 DEEP-SEATED FAILURE INVESTIGATION

For both spread footings and drilled-shaft foundations, calculations shall be made for the possibility of deep-seated failures.

14.7 CAST-IN-PLACE-WALLS

Cast-in-place walls shall be designed in accordance with the current AASHTO Division 1, Section 5. See Figure 14.1 for typical geometric values.

14.7.1 Joints

Maximum spacing of joints shall be as indicated in Figure 14.1. Construction joints in stems of cantilever walls and in face slabs of counterfort walls shall contain a non-metallic waterstop with a minimum width of 9"; the waterstop shall extend from an elevation not less than 1 foot below finished grade in front of the wall to an elevation 6 inches below the top of the stem or face slab.

In addition to the contraction and expansion joints indicated in Figure 14.1, full stem height joints shall be placed as follows:

1) Footing steps less than 1 foot – no additional joint needed
2) Footing steps between 1 foot and 2 foot – contraction joint
3) Footing steps exceeding 2 foot – expansion joint

14.7.2 Wall Stem

A special transition panel will be designed at locations of wall type changes or where the retaining wall abuts other structures. The design shall take into account differences in wall stiffness and will provide a smooth front face to match geometric differences.

The top-of-wall profile shall be designed by the section designer to be free of irregular changes in slope. Design drawings shall show absolute top-of-wall elevations at intervals of approximately 32 feet and at any changes in slope, abrupt change in top-of-wall profile or horizontal profile.

14.7.3 Footings

The bottom of footings shall be placed against undisturbed earth, compacted fill, or non-structural concrete. The face of the toe of spread footing shall not bear against ballast or subballast.

14.7.4 Architectural Treatment of Wall Face

Where the face of a retaining wall is exposed to public view by other than DART train-borne patrons and extends more than 4 feet above the ground line, it shall be architecturally treated. Walls tapering in height to less than 4 feet shall be treated for their entire length. The Designer is referred to the architectural sections, Chapters 19 - 24 of these design criteria.

14.8 CORROSION CONTROL

Where retaining walls run more or less parallel to the DART track way, the longitudinal reinforcing steel shall be suitably bonded to provide a continuous path for stray electrical currents. Refer to Systems Design Criteria Chapter 8 - Corrosion Control and Chapter 9 - System Grounding.

14.9 DRAINAGE

A system of drainage shall be provided for all walls to prevent water accumulation in the backfill and to eliminate forces on the walls due to hydrostatic and pore pressures.

14.9.1 Surface Drainage

A concrete gutter or a trackbed subdrain shall be provided at the top of all walls where flow of water may occur. In addition, an impervious layer of soil should be placed on top of the backfill wherever possible to reduce the amount of water which may seep into the backfill. A splash block shall be provided at all gutter drain outlets at the face of the wall.

14.9.2 Backfill Drainage

Except at those locations where drainage through weep holes is prohibited by the owner of property on the discharge side of the weep holes, backfill drainage shall be provided for all walls by means of 4-inch-minimum diameter weep holes located 1 foot above the ground surface at the exposed face and spaced at intervals no greater than 8 feet. Where drainage through the weep holes would discharge onto sidewalks or other pedestrian ways, provisions shall be made to prevent the drainage flowing across these walking surfaces. For additional information, see the retaining wall directive drawings.

14.10 MECHANICALLY STABILIZED EARTH (MSE) STRUCTURES

Earth-retention structures of mechanically stabilized earth may be used in the DART project at those locations where wall heights are less than 20 feet. Otherwise, for walls greater than 20 feet, MSE walls shall only be used as recommended by the section designer and approved by DART.

Similarly, modular block walls typically using precast concrete block facing and plastic geogrid reinforcing behind the wall, shall not be used to support track or structures. They may be used as retaining walls to introduce a distinct grade differential or as landscape walls.

14.10.1 Specifications

Specifications for the construction of mechanically stabilized earth structures are in the standard specifications for the project. The specifications are generally based upon the design and construction recommendation given in AASHTO Standard Specifications for Construction for Highway Bridges, AASHTO Task Force 27 Report, In Soil Improvement Techniques and TxDOT Standard Construction Specifications. Guideline specifications shall be modified by the final designers as required for each particular project.

14.10.2 Standard Drawings

DART has prepared standard drawings for Mechanically Stabilized Earth Retaining Walls. They should be included in construction documents where MSE walls are required.

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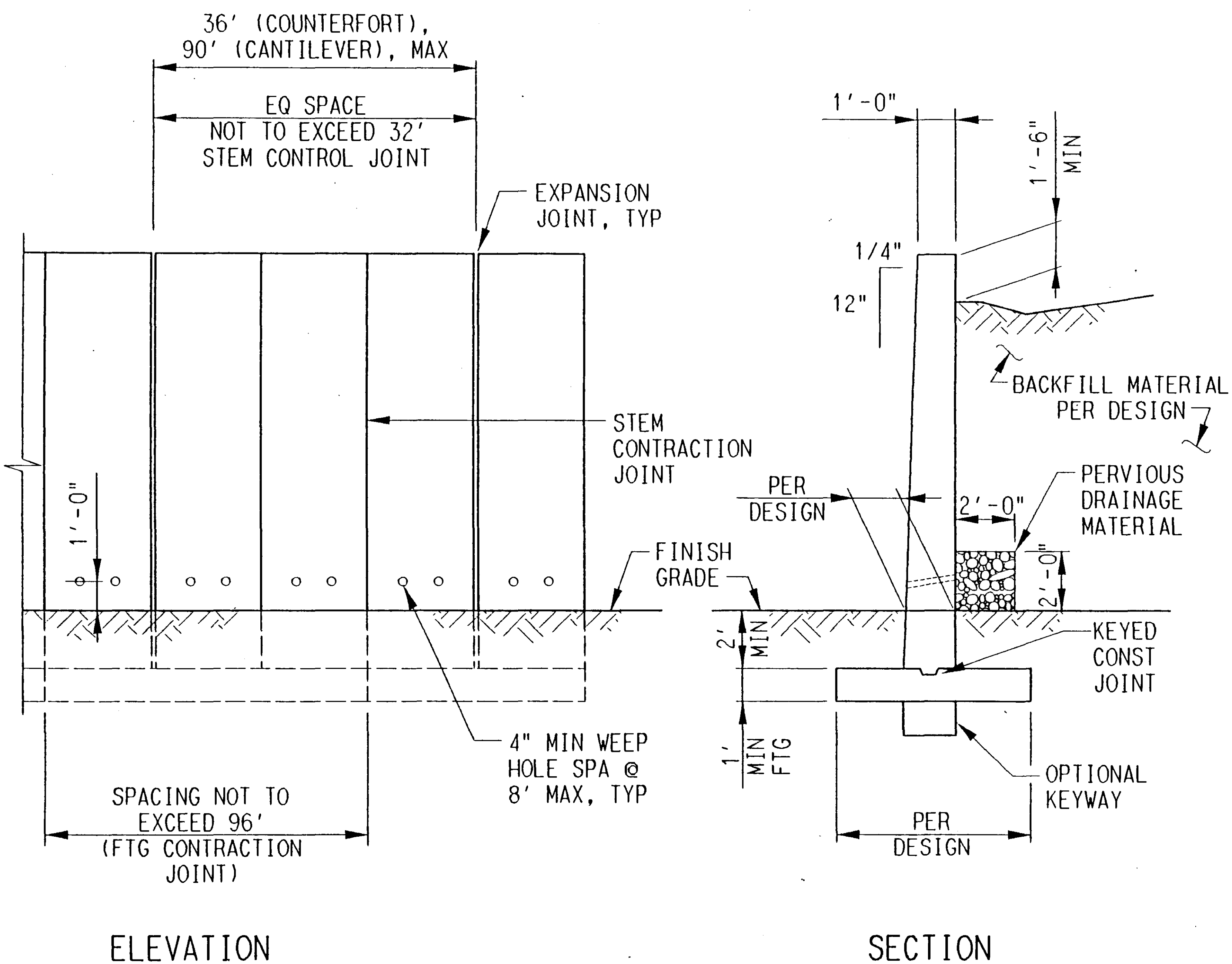

ACT 21
CARTER BURGESS
JACOBS ENGINEERING
STV INCORPORATED
KAI ALLIANCE

DART PROJECT

DART

DART DESIGN CRITERIA

C-I-P RETAINING WALL

SCALE: NOT TO SCALE

FIGURE: 14.1

JAN. 2003, REV 10

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CHAPTER 15 - CUT-AND-COVER STRUCTURES

15.1 INTRODUCTION

The design criteria contained in this chapter shall relate to the design of cut-and-cover structures constructed as part of the Dallas Area Rapid Transit (DART) rail system. Structural design shall be governed by these criteria in addition to the codes, standards, and specifications referenced in Appendix 1.

The full titles of all references in this chapter are listed under the structural section of Appendix 1. In the event of a conflict between criteria in this chapter and information referenced in Appendix 1, the more restrictive criteria shall govern.

DART cut-and-cover structures shall be designed to sustain the most severe combination of dead and live loads along with hydrostatic and earth pressures to which they may reasonably be subjected. This should include the effects of erection and any other temporary loads occurring during construction.

Emergency exits to the surface shall be provided at intervals not exceeding 1,250 feet when trackways are not separated by 2 hour firewall solid walls or when the trackways are not accessible from each other due to individual tunnel profiles. Travel speed and capacity of walkways and/or walking surfaces shall be in accordance with Section 2-5.3 of Fixed Guideway Transit Systems (National Fire Protection Association, NFPA 130) hereafter cited as such.

The design of DART underground station structures shall be in accordance with these design criteria together with any supplementary criteria provided and/or approved by DART.

15.2 LOADS

The structural components shall be designed to resist the loads of Chapter 9 - Loads of these criteria except as modified herein this chapter.

15.2.1 Transit Loads

Standard axle spacings and loadings, centrifugal force, and longitudinal force shall be as prescribed in Chapter 9 - Loads of these criteria. Wheel loads shall be considered as concentrated loads in accordance with section 15.3.3 when considering loads applied directly to the top of the subway structure.

15.2.2 Air Pressure Loads (W)

The following air pressure loads shall be considered as wind loads for service load and strength design load groups. In lieu of these forces, the designer may use loads developed from a detailed ventilation/pressure analysis. These loads apply to members within the stations and along the tunnels.

Supports for fans and vent shaft dampers shall be designed to withstand a force, reversible in its direction, of 40 pounds per square foot (psf).

Walls, doors, ceilings, and ceiling fixtures shall be designed to withstand a force, reversible in its direction, based on vehicle velocity and free tunnel area as follows:

	55 MPH		70 MPH	
FREE TUNNEL AREA (sq.ft.)	FATIGUE LOADING (PSF)	MAXIMUM LOADING (PSF)	FATIGUE LOADING (PSF)	MAXIMUM LOADING (PSF)
200	18.1	50.4	29.4	81.6
220	16.3	40.2	26.4	65.2
240	14.9	33.5	24.1	54.2
260	13.7	28.6	22.2	46.4
280	12.8	25.0	20.7	40.5
300	11.9	22.2	19.3	36.0
320	11.2	20.0	18.2	32.3
340	10.6	18.1	17.2	29.4
360	10.0	16.6	16.3	26.9
380	9.6	15.3	15.5	24.8
400	9.1	14.2	14.7	23.0

Fatigue loading shall be assumed to occur 100,000 times per year.

The following air pressure loadings, within the stations, shall be designed for:

	Maximum	Fatigue
Station Platform	25 psf	10 psf
Mezzanine Levels	15 psf	10 psf

15.2.3 Earth Loads (E)

Vertical soil and rock loads to be used for preliminary final structural design shall be based upon the information obtained in accordance with Chapter 10 - Geotechnical Information of these criteria. This information shall be reviewed by the designer in the light of any changes in design or construction concepts prior to the final design phases. Allowances shall be made for both dry and submerged earth pressures, for hydrostatic pressure, and for the influence of physical and chemical characteristics of soils adjacent to DART structures. Consideration shall be given to multilayered effects where substantial differences in soil and rock properties occur over the depth of the structure. The effects of specified construction methods such as flexible and rigid bulkheads, bracing procedures, and so forth on the development of lateral pressures shall be considered, together with the effects of construction compaction on lateral soil pressures due to construction.

Lateral loads due to soil and rock shall be considered both for temporary and permanent structural design works. The magnitude and resultant direction of all rock loads shall be based upon the information referred to in the geotechnical chapter of these criteria for the relevant design section. Changes in either temporary or permanent work design methods or construction sequences shall be fully evaluated together with due allowance for both short-term and long-term hydrostatic pressures which may exist adjacent to the rock/structure interface.

Railroad Surcharge Loads. Structures or structural elements supporting railroad loads shall be designed in accordance with the requirements of the railroad owner and the Manual for Railway Engineering (AREMA).

Where railroad loads are carried on fill over cut-and-cover structures, the loading on the structure shall be as specified in Part 16 of Chapter 8 of the Manual for Railway Engineering (AREMA), including the impact loading therein prescribed.

Roadway and Sidewalk Surcharge Loads. Live load surcharge shall be applied at the ground surface both over and adjacent to the cut-and-cover structure to simulate possible roadway and sidewalk live loads. While these live loads may not be realized, the cut-and-cover structure shall be designed for the eventuality that such live loads may occur. Future construction adjacent to the structure may result in both permanent and temporary loads from construction equipment and the stockpiling of construction materials, or from the deposition of excavated earth. It is also possible that high loads may be applied inadvertently to the cut-and-cover structure due to the characteristics of this structure type. The surcharge load shall be applied to all cut-and-cover line and station structures, unless the following conditions are met:

- o Positive and recognizable means are provided at the ground surface to prevent the above types of loading from occurring.

- DART specifically permits, in writing, the application of a surcharge of lesser magnitude.

Surcharge Vertical Intensity. A 400 pound per square foot surcharge shall be considered as a static uniform load applied at the ground surface. Its vertical intensity at any depth below the ground surface shall be constant.

The surcharge load shall be applied in addition to all known dead and live loads, except that the surcharge shall not be applied when the alternative wheel loading described in the following section is applied.

Wheel Loading. On existing and planned roadways, wheel loading for depths of cover of 5 feet or less shall be distributed at the surface with the width and length as set forth in Division 1, Section 3.30 of AASHTO. The width and length of the distribution area shall be increased 1/2 foot for each foot of depth.

Loads from Existing and Proposed Structures:

- Structures over the Subway. Existing structures that are to remain in place over the subway shall be underpinned in such a manner as to avoid any transfer of load onto the subway section, or the section shall be designed to support the structure directly. Non-DART structures shall be supported directly on DART structures only if specific approval in writing is received from DART.

- Structures Adjacent to the Subway. The subway structure shall be designed for excess loading from existing adjacent buildings or structures unless they are either founded or permanently underpinned to a depth below the zone of influence of the subway structure.

- Building Loads. Each existing building or structure adjacent to the cut-and-cover construction shall be considered on its own merits when evaluating dead and live loads.

The foundation loading shall be estimated based on the actual construction and use of the building, but shall not be less than required by local codes or IBC. Horizontal building loads shall be based upon recommendations contained in the Geotechnical Chapter of these criteria.

Proposed Construction. Unless otherwise determined by DART, future construction will not be presumed to exert vertical and lateral pressures exceeding those due to natural ground conditions by more than the surcharge allowances prescribed in this section. The provisions of DART agreements with property owners, railroads, and other agencies regarding special loadings for portions of subway structures that pass beneath or adjacent to their properties or facilities shall be considered in establishing the loading conditions for such subway structures.

Special Surcharge and Minimum Surcharge and Overburden. Besides the surcharge due to railroad, roadway, sidewalk, and buildings mentioned in sections 15.2.7, surcharge generated by any other loads shall be evaluated by a recognized method of analysis. All underground structures shall be designed to resist a minimum surcharge pressure of 300 psf together with 8 feet of earth overburden.

15.2.4 Buoyancy and Hydrostatic Pressure (B)

Hydrostatic Pressure. The effects of hydrostatic pressure shall be considered whenever the presence of groundwater is indicated. It shall be computed at 62.5 pounds per square foot per foot of depth below groundwater table. Where hydrostatic pressures pertain, lateral earth pressures shall be based upon the submerged unit weight of the soil. The possibility of future significant changes in groundwater elevation shall be considered. Full hydrostatic pressure shall be assumed to act on all external structural members for the maximum likely height of the water table, unless specific permanent provisions to remove these effects are included in the overall design of the structural members.

Buoyancy. Adequate resistance to flotation shall be provided at all sections for full hydrostatic uplift pressure on the structure foundation based on the 10-year high ground water table. For the completed structure, such resistance shall consist of the dead weight of the completed structure plus the weight of backfill overlying the structure which is located within vertical planes drawn through the outer edges of the structure roof and through all joints separating adjacent structural sections. The submerged unit weight of soil below the groundwater table may be taken as 68 pounds per cubic foot unless otherwise recommended by DART's geotechnical subconsultant.

When evaluating buoyancy loads, unless indicated otherwise in the geotechnical information of these design criteria, the compacted dry weight of soil above the roof slab level shall be taken as 130 pounds per cubic foot. The weight of street pavement and live loads shall be neglected for the purposes of calculating uplift. The factor of safety against uplift under the above conditions, neglecting side wall soil and rock friction effects, shall not be less than 1.10.

Rotational effects due to buoyancy shall be considered where the main structure is markedly asymmetrical. Local asymmetry need not be considered unless the section is isolated by structural joints.

A construction sequence, together with all temporary measures necessary to provide adequate safeguards against flotation during all stages of construction, shall be indicated. The possibility of lowering the groundwater table, if necessary, may also be considered in special cases to minimize buoyancy forces during construction, if such dewatering does not result in ground settlements.

Dewatering during the construction stage shall be considered in the cut-and-cover structures design.

15.3 LOAD APPLICATION

All loading combinations in accordance with Section 15.2 that can reasonably occur must be investigated and shall include, but not be limited to, the following:

15.3.1 Symmetrical Loading

For symmetrical loading conditions, the design shall satisfy the following three loading conditions:

Condition I - Long-term Condition. Full vertical loading including dead load, live loads, surcharge loads, and hydrostatic pressure combined with maximum lateral pressures due to soil and rock loads, ground water, and surcharge loads. See Figure 15.1.

Condition II - Short-term, Construction Condition. Vertical loading of dead load only, assuming no live load, no earth cover, and no surcharge, combined with maximum lateral pressures due to soil and rock loads, surcharge, and groundwater. Include hydrostatic pressure in vertical loading where applicable to reflect local ground water conditions and design assumptions. See Figure 15.2.

Condition III - Intermediate Condition. Maximum available vertical loading of dead load, live load, and surcharges combined with horizontal active pressures from soil and rock with no lateral live load, surcharge, or hydrostatic pressures. See Figure 15.2.

15.3.2 Asymmetrical Loading

For asymmetrical loading, the design shall satisfy the following load conditions due to possible adjacent construction:

Condition I - Overhead Surcharge Added. Maximum lateral pressures due to groundwater, soil, or rock loads applied to one side of the structure only, together with a reduced level of groundwater, soil, and rock loads, shall be applied to the opposing side of the structure. Maximum vertical loads due to dead load, live load, surcharge, and hydrostatic pressures shall be applied. See Figure 15.3.

Condition II - Overhead Surcharge Not Added. As for Condition I above, except the minimum vertical loads of dead load and earth cover only shall be applied. See Figure 15.3.

Condition III – Short Term Adjacent Construction Condition. As for Condition II above, except a 25 foot deep excavation, 5 feet from the face of the box shall be assumed for future building construction. This loading shall be used wherever adjacent or joint development is anticipated. See Figure 15.4.

15.3.3 Concentrated Loads

See Chapter 13 - Aerial Structures in these design criteria for calculation of effective width.

15.3.4 Invert Slabs

Invert slabs shall be designed as structural members on elastic foundations, and include the effects of hydrostatic pressure. See Chapter 10 - Geotechnical Information in these criteria.

15.4 SOIL AND ROCK BEARING CAPACITY

Bearing stresses shall not exceed the allowable bearing capacity of the soil or rock in accordance with Chapter 10 - Geotechnical Information of these criteria.

15.5 STRUCTURAL DESIGN

15.5.1 Analysis and Design Assumptions and Methods

Design calculations for prestressed concrete shall be based on working loads and allowable unit stresses. Prestressed concrete design shall also be checked by the strength design method. The design of steel and reinforced concrete structures shall be based on the strength design method. Framed structures shall be analyzed by rational elastic methods which consider the effects of the relative stiffness of connected members, relative displacement, rotation of joints, and the effects of axial deformations.

Particular consideration shall be given to the variations in elastic properties and stress distribution of complex frameworks resulting from different construction sequences. Any limitations on construction operations inherent in the design assumptions shall be noted on the project drawings and specified in the special provisions. Conversely, advantage may be taken of specified construction procedures or sequences to effect a more favorable distribution of loads or stresses.

Unbalanced lateral loadings shall be investigated. In cases where passive resistance might be mobilized to resist the horizontal load on the opposite side of the structure, the horizontal sway shall be considered in the analysis.

Where there is a portion of a continuous box structure without restraint on one side (such as at entrances), a horizontal sway shall be assumed and the horizontal slabs shall be investigated for their capacity to transfer load by diaphragm action from the portion of the structure with unbalanced load to the restrained ends of the structure. The capacity of the soil at the ends of the structure shall also be investigated to determine whether it provides sufficient passive resistance to sustain the loads being transferred thereto.

If required as part of station underground design, the requirements of the following chapters in these criteria shall apply: Chapter 17 - Deep Foundations, Chapter 14 - Earth Retaining Structures, and Chapter 16 - Excavation Support.

15.5.2 Structural Material Properties

See Chapter 8 - Structural Materials of these criteria.

15.5.3 Crack Control

The limitation shown in the structural materials chapter on the design strength of reinforcing steel is intended to reduce the cracking of concrete. In addition, the reinforcing steel in the exterior face of concrete members in contact with the ground and not protected by an impermeable waterproofing barrier shall not exceed bar size designation number 11.

15.5.4 Foundation Pressures

Vertical pressures on foundation slabs may be divided into hydrostatic and earth pressure components. The hydrostatic component shall be distributed across the width of the foundation in proportion to the depth of each portion of the base slab below the design groundwater table. Distribution of the earth pressure component shall be based on specified construction procedures and on elastic foundation effects. Swelling pressures should be considered when appropriate. The extent of swelling pressures shall be determined based on geotechnical testing results and other pertinent information.

15.5.5 Global Loads

The loads for cut-and-cover construction shall consist of the total weight of the completed permanent structure, including the weight of secondary elements permanently supported by the structure, together with the weight of the supported earth cover. The depth of earth cover shall be measured from the ground surface or roadway crown, or from the officially proposed street grade (whichever is higher) to the top of subway roof. In lieu of the unit weight of earth specified in Chapter 8 - Structural Materials, compacted earth cover over the subway shall be assumed to have a design weight of 130 pounds per cubic foot. In those cases where full hydrostatic pressure below the groundwater table is used as a design load, a design unit weight of 68 pounds per cubic foot shall be used for the submerged earth below ground water level in lieu of specific recommendations contained in the geotechnical reports referred to in Chapter 10 - Geotechnical Information.

Resistance to flotation shall be provided at all sections. See Section 15.2.4 for a description of buoyancy and hydrostatic pressure.

15.5.6 Joints

Joint Locations. Joints in areas of special trackwork must be located in such a way as to avoid placement under movable parts and track fasteners.

Expansion Joints. In view of the relatively constant internal temperature in underground structures, no permanent expansion joints need be provided in the underground portions of subway structures 90 feet beyond the portals, as long as contraction joints are provided in accordance with the contraction joints section below. Expansion joints shall be provided at the juncture of a U-wall line structure with an underground line structure. Provisions for expansion shall be made in the above-ground portions of cut-and-cover structures. Where a structural element is partially underground and partially above-ground, and where an above-ground element is attached to an underground element, particular care shall be taken in detailing to accommodate differential thermal movements at the interface.

Where expansion joints are required, they shall be provided in accordance to Figure 14.1 of these Design Criteria. Reinforcing steel shall not be continuous through the joint. Shear forces preferably shall be transferred across the joint by a key; alternatively, smooth dowels may be embedded on one side of the joint and provisions made on the other side to break the dowel bond and to provide space for dowel movement. All expansion joints in base and roof slabs and in walls against earth shall contain a nonmetallic waterstop with a minimum width of 9 inches. Thorough consideration shall be given to ensuring structural integrity and watertightness.

Contraction Joints. To control shrinkage stresses and minimize cracking in concrete slabs and walls, contraction joints shall be provided in the underground portions of subway structures at intervals not greater than 50 feet. They shall also be provided at locations of major change in structural section, such as between subway line structure and station structure. A closer spacing shall be used if appropriate to the framing system. Provisions for contraction shall also be made in the above-ground portions of subway structures.

Contraction joints shall be unbonded joints, designed not to transmit the forces perpendicular to the joint that may occur under any design condition. Reinforcing steel shall not be continuous through the joint. Shear force preferably shall be transferred by a key across the base slab and the invert contraction joints, and across contraction joints in walls and roofs. Alternatively, smooth dowels may be embedded on one side of the joint and provisions made on the other side to break the dowel bond. All contraction joints in base and roof slabs and in exterior walls against soil and rock shall contain a nonmetallic waterstop with a minimum width of 9 inches. Thorough consideration shall be given to ensuring structural integrity and watertightness.

Construction Joints. Construction joint locations may be indicated by the designer to divide the structure into convenient working units for concrete placement. Such joints shall be detailed in the plans with an indication of whether they are optional or mandatory. They shall be designed to transmit all the forces that may occur under any design condition.

Construction joints through which no movement is transferred may be detailed as either expansion joints or contraction joints.

Construction joints through which movement is transferred shall be bonded; that is, prior to placing concrete in the adjacent pour, the joint shall be cleaned by abrasive cleaning, high-pressure water jetting, or other means to remove loose material and to expose clean aggregate. Reinforcement shall be continuous through the joint. A key or other positive means shall be provided where required for the transfer of shear forces. Construction joints in base and roof slabs and in exterior walls against soil and rock shall contain a nonmetallic waterstop with a minimum width of 9 inches. Thorough consideration shall be given to structural integrity and watertightness.

Joints in Steel Frames. Provisions shall be made in the structural steel frameworks of cut-and-cover station structures for the temporary accommodation of fabrication and erection tolerances without introducing significant distortions in the frame. Temporary joints, if required, shall be permanently connected after the entire framework has been plumbed and aligned. They shall be designed to accommodate all design loads.

15.5.7 Portals

When locating portals and determining the ends of cut-and-cover construction, consideration shall be given to providing protection against flooding resulting from highwater levels near bodies of water, from tributary watercourses, and from local storm runoff.

Adequate provisions shall be made for resistance to hydrostatic uplift. Portals shall be designed to provide a factor of safety of at least 1.1 against uplift when subjected to minimum global dead loads (see section 15.5.5) and maximum hydrostatic uplift pressure. Adequate provisions shall be made for the immediate and effective removal of water from rainfall, drainage, groundwater seepage, or any other source.

Attenuation of sudden changes in air pressure and noise levels due to transit trains passing into or out of enclosed box structures shall be provided for.

15.5.8 Temporary Decking Systems

Temporary decking systems, including decking, beams, piles, lagging, bracing, struts, railings, curbs, sidewalks, and other elements, shall be designed by the contractor in accordance with the requirements established by the designer and these design criteria. The design shall be prepared by an engineer registered in Texas. In general, primary bracing members shall be prestressed to approximately 50 percent of their design load. This is to minimize movement of the retained soils and reduce the possibility of damage to adjacent buildings, sewers, utilities, or other structures (see Chapter 16 - Excavation Support). In open localities where there are no adjacent buildings, that could be damaged and where it is anticipated that there are no sewers, water lines, or other utilities that could be affected, the requirement for 50 percent pre-loading may be reduced upon receiving written approval from DART.

Emphasis shall be placed by the designer on the adequate design and detailing of member connections. Web stiffeners should be specified at all strut-to-wale connections and other points of concentrated forces.

The designer shall indicate in the contract drawings, as well as cover comprehensively in the specifications, any detailed arrangements for traffic diversions, allowable restrictions (including noise and vibration), and necessary construction stages which have been approved by the public authorities. Acceptable locations also shall be indicated for construction access ramps or any other construction facility that affects the temporary street decking system design.

15.6 WATERPROOFING

Waterproofing shall be provided in accordance with the structural standard and directive drawings. Special consideration shall be given to details and specifications for the reduction of cracking and the promotion of concrete density and impermeability.

Adequate provisions shall be made to collect and drain water seeping through cut-and-cover subway roofs, walls, and floors, regardless of whether they are waterproofed. Design details shall be shown on the drawings and be such as to minimize leakage through both waterproofed and non-waterproofed structural elements. Concrete mix and placement specifications shall require a concrete which is dense and impermeable.

Where station appendages such as concourse wings, entrances, and elevator shafts are to be constructed before the rise of the water table, differential vertical movements of the station body and the appendages as a result of ground re-expansion may cause cracking at indeterminate places.

To minimize the opening of cracks, the project drawings and specifications shall call for a gradual return of the groundwater and an appropriate construction sequence. Properly designed joints between such appendages and the station body shall include complete detailing of the waterproofing.

15.7 SUBWAY STRUCTURES

15.7.1 Roof Slabs

Line Structures. Transverse construction joints in the roof of cut-and-cover subway line structures shall be detailed as contraction joints. The top of the roof slab shall have a gradient of 1/4 inch per foot, measured at the center line of the structure to determine adequate drainage cross-fall. The roof slab shall be waterproofed and covered by protection board. A 2-inch layer of lean concrete course shall be placed on top of the protective board. The extent of the membrane waterproofing shall be shown in the project drawings; the boundary conditions and the treatment around roof penetrations shall be completely detailed.

The roof waterproofing shall be brought down the exterior line-structure wall to an elevation at least 1 foot below that of the longitudinal construction joint at the roof-wall intersection, and shall be terminated with a suitable seal.

Station Structures. Station roofs shall be completely waterproofed with elastomeric membrane waterproofing using not less than two 1/8 inch thick layers. The membrane shall be covered by protection board and a 2-inch layer of lean concrete. The extent of the waterproofing shall be shown on the project drawings; the boundary condition, the treatment of changes in elevation, and the treatment around roof penetrations shall be completely detailed. The top of structural concrete to the roof slab shall have a gradient of 1/4 inch per foot, measured at the center line of the structure to allow for adequate drainage cross-fall.

The roof waterproofing shall be brought down the exterior station wall to an elevation at least 1 foot below that of the longitudinal construction joint at the roof-wall intersection, and shall be terminated with a suitable seal.

15.7.2 Walls

Transverse joints in the exterior walls of cut-and-cover subway line structures shall be detailed as contraction joints. Longitudinal construction joints normally shall be bonded joints. The extent of the waterproofing shall be shown in the project drawings; the boundary conditions and the treatment around wall penetrations shall be completely detailed.

In public areas of stations, the inside face of exterior structural walls against earth shall not be used as finished surfaces. Finish walls shall be constructed inside such exterior walls to create a cavity. The cavity depth normally shall not be less than 4 inches; a greater depth may be required if the cavity is used as a chase for electrical and mechanical systems. Provisions shall be made in the cavity for the collection and drainage of seepage water. Drainage systems shall be positive and capable of being maintained. If the finish wall is fastened to the structural wall, provisions shall be made to prevent seepage to the finish wall along the fastening; fasteners shall be non-corrodible.

15.7.3 Invert Slabs

Invert slabs need not be waterproofed. Any water infiltration through the invert slab shall be directed toward a longitudinal track drain and carried to suitable outlets.

15.7.4 Appendages

Where station appendages such as vent and elevator shafts and entrances are to be constructed before the rise of the water table, differential vertical movements of the structure and the appendages as a result of subsequent ground movements shall be accommodated in the design to avoid cracking or distress at the structural interface.

To minimize the opening of cracks, the project drawings and specifications shall call for a gradual return of the groundwater and an appropriate construction sequence. Properly designed joints between such appendages and the station body shall include a complete detailing of the waterproofing.

15.7.5 Structural Steel Penetrations

Permanent structural steel placed in the surrounding soil shall not penetrate concrete slabs or walls communicating with the station interior. At least 4 inches of concrete shall protect the permanent steel from contact with ground. Temporary bracing steel left in place shall be embedded in the concrete and have at least 4 inches of concrete cover over the embedded steel at each face of the concrete.

15.8 EQUIPMENT ROOMS

15.8.1 Waterproofing

Where the waterproofing of an exterior wall is achieved by external means, and where electrical panels, cabinets, or other equipment is to be mounted on such a wall, consideration shall be given to interior waterproofing. When hydrostatic pressure is low, such interior waterproofing may include cement plaster, or the provision of a cavity wall where the hydrostatic pressure is high. The floors of equipment rooms shall have adequate slope-to-drainage outlets.

15.9 WATERSTOPS

Nonmetallic waterstops shall be provided in all expansion, and construction joints in exterior roofs, walls, and floors of cut-and-cover subway structures.

15.10 FIREPROOFING

All structures shall have a fire rating in accordance with the system safety program plan and fire protection system design criteria. All structural metallic elements that support loads shall be covered with not less than 2 inches of concrete with a minimum 28-day strength of 3,000 psi, or with an approved alternative fireproofing material providing an equal fire resistance rating.

15.11 DEWATERING

In certain areas, the lowering of the groundwater for construction may cause settlement of buildings both adjacent to and some distance from the excavation. Recommendations for construction and dewatering shall be prepared for these areas. Such limitations and control measures shall be incorporated in the design studies and shall be included as appropriate in the contract plans. See Chapter 16 - Excavation Support in these design criteria.

15.12 PROTECTION OF EXISTING STRUCTURES

See Chapter 16 - Excavation Support for the protection of structures adjacent to DART structures.

15.13 EXCAVATION SUPPORT

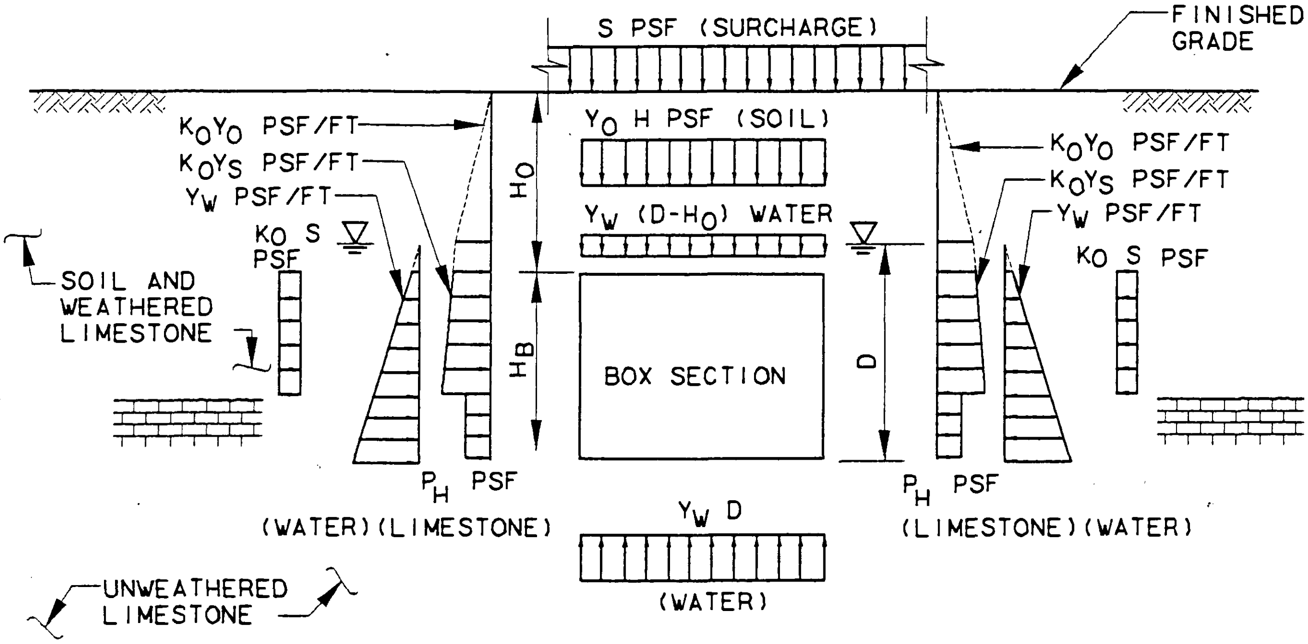
The methods and design of excavation support for underground stations shall be as described in Chapter 16 - Excavation Support of these criteria.

15.14 CORROSION CONTROL

For criteria relating to provisions for minimizing, monitoring, and controlling stray currents in subway structures, refer to Systems Design Criteria Chapter 8 - Corrosion Control and Chapter 9 - Systems Grounding.

15.15 GROUND-BORNE VIBRATIONS AND NOISE

DART or its vibration consultant will identify locations where the transmission of ground-borne noise and vibrations from the subway to adjacent existing structures may be objectionable. Subway design in these locations shall incorporate "floating slab" inverts or other vibration and noise control measures approved by DART. (Also see Chapter 11 - Noise and Vibration of these criteria.)



SYMMETRICAL LOADING-CONDITION I

LEGEND:

Y_O	UNIT WT OF SOIL
Y_S	UNIT WT OF SUBMERGED SOIL
Y_W	UNIT WT OF WATER
K_O	COEFFICIENT OF LATERAL EARTH PRESSURE AT REST
K_A	COEFFICIENT OF ACTIVE LATERAL EARTH PRESSURE
S	VERTICAL INTENSITY OF SURCHARGE
H_O	DEPTH OF OVERBURDEN
H_B	HEIGHT OF OVERBURDEN
P_H	LATERAL PRESSURE OF UNWEATHERED LIMESTONE
D	DEPTH OF WATER LEVEL TO THE BOTTOM OF BOX SECTION

NOTES:

FOR DEFINITION OF LOADING CONDITIONS. SEE SECTION 15.3.1 OF DESIGN CRITERIA.

DEAD LOAD AND LIVE LOAD ARE NOT INCLUDED IN DIAGRAMS. THIS SHOULD BE CONSIDERED IN DESIGN.

ACT 21

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JACOBS ENGINEERING
STV INCORPORATED
KAI ALLIANCE

DART PROJECT

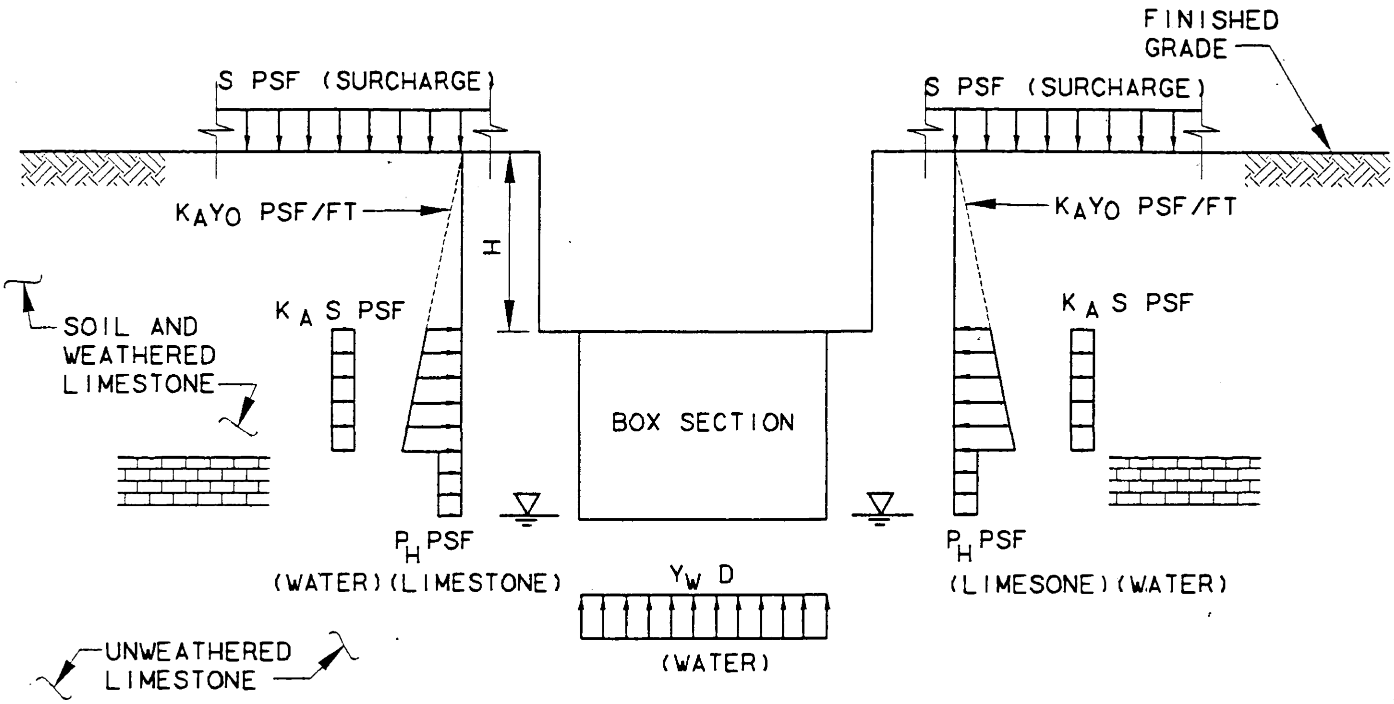
DART

DART DESIGN CRITERIA

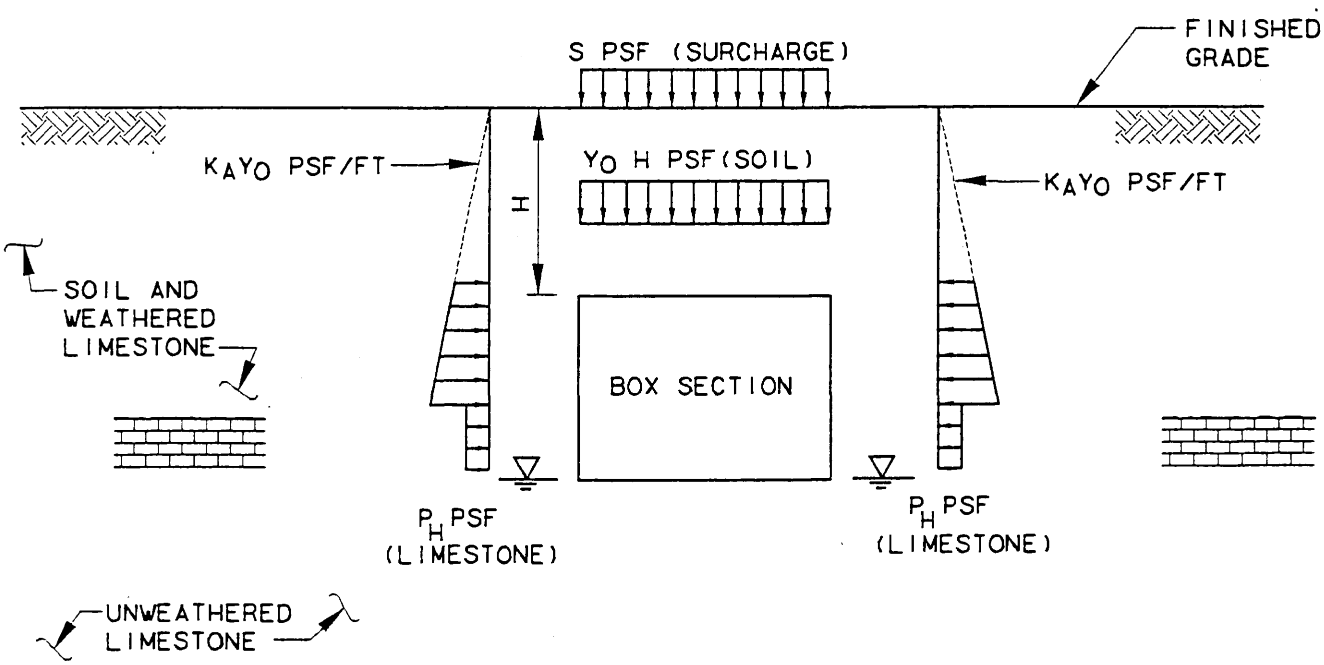
CUT AND COVER STRUCTURES LOADING CONDITIONS

SCALE: NOT TO SCALE

FIGURE: 15.1



SYMMETRICAL LOADING-CONDITION II

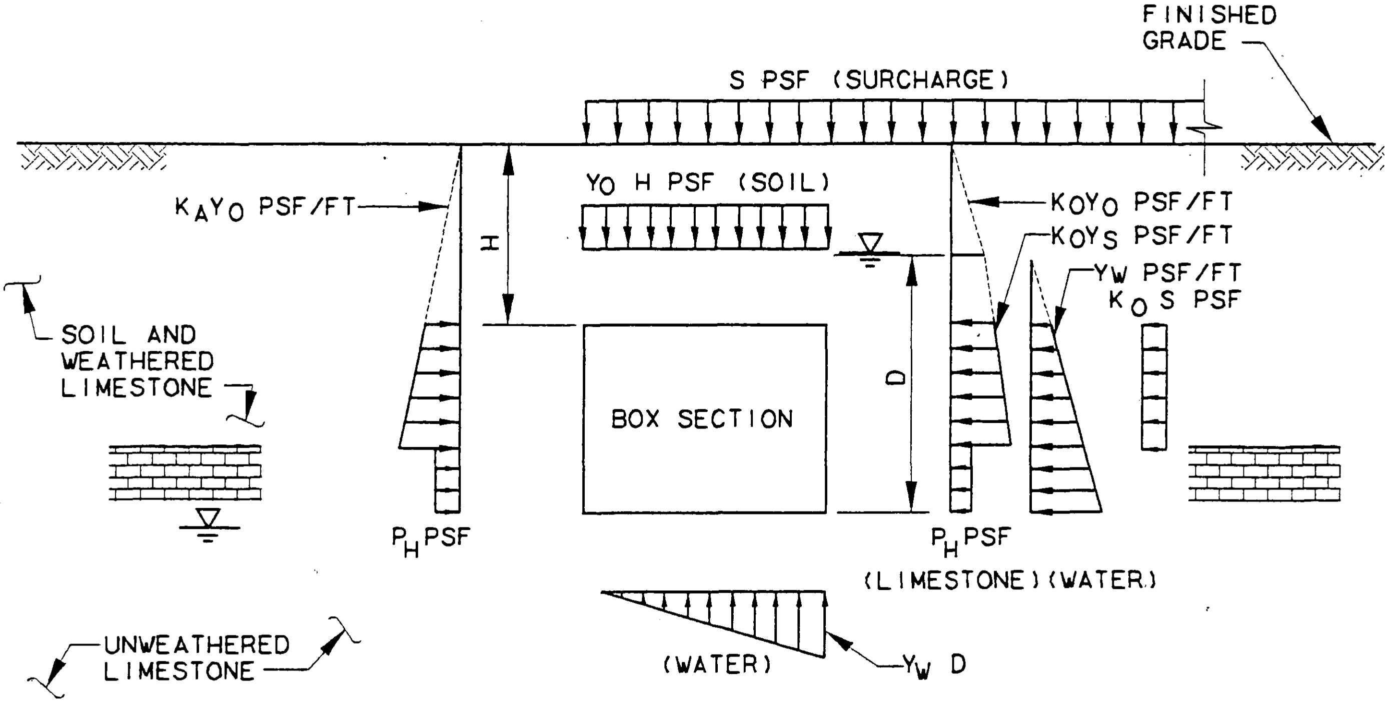


SYMMETRICAL LOADING-CONDITION III

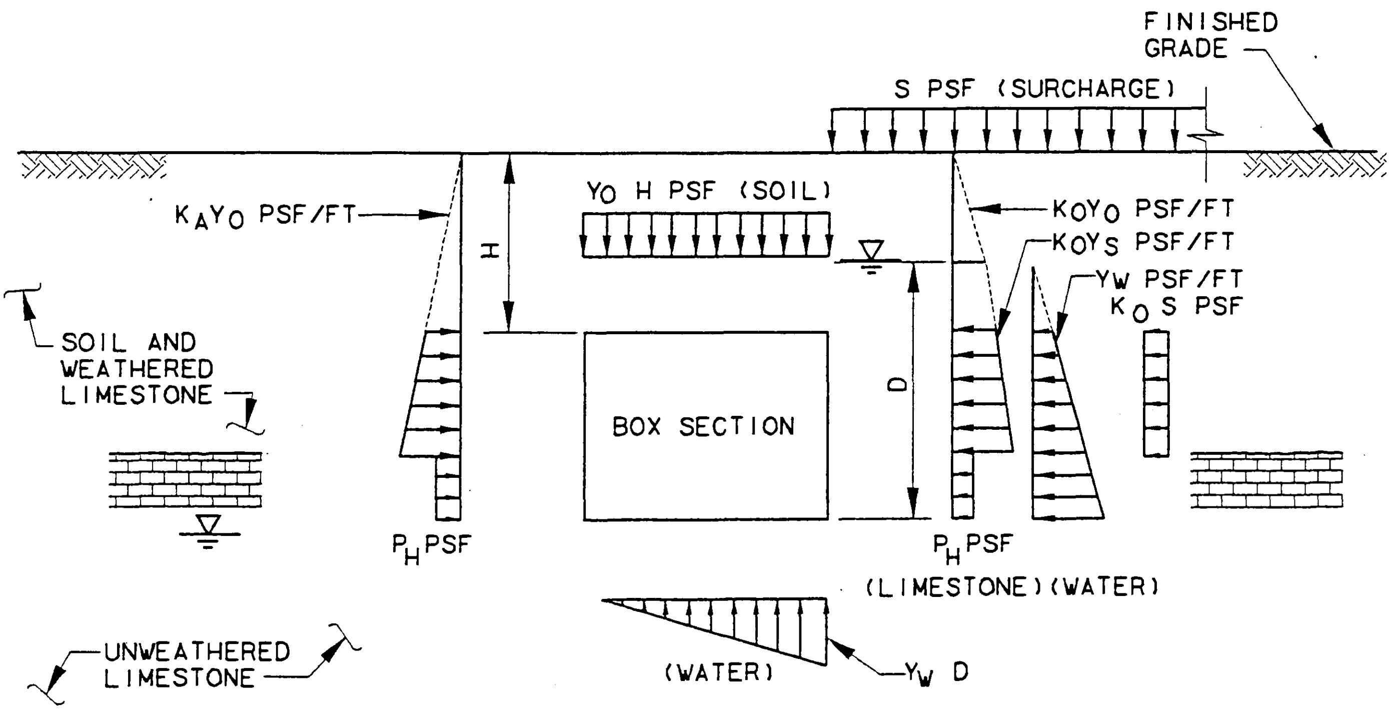
NOTE: SEE FIGURE 15.1 FOR LEGEND AND NOTES.

ACT21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA CUT AND COVER STRUCTURES LOADING CONDITIONS SCALE: NOT TO SCALE FIGURE: 15.2

JAN. 2003, REV 10



UNSYMMETRICAL LOADING-CONDITION I

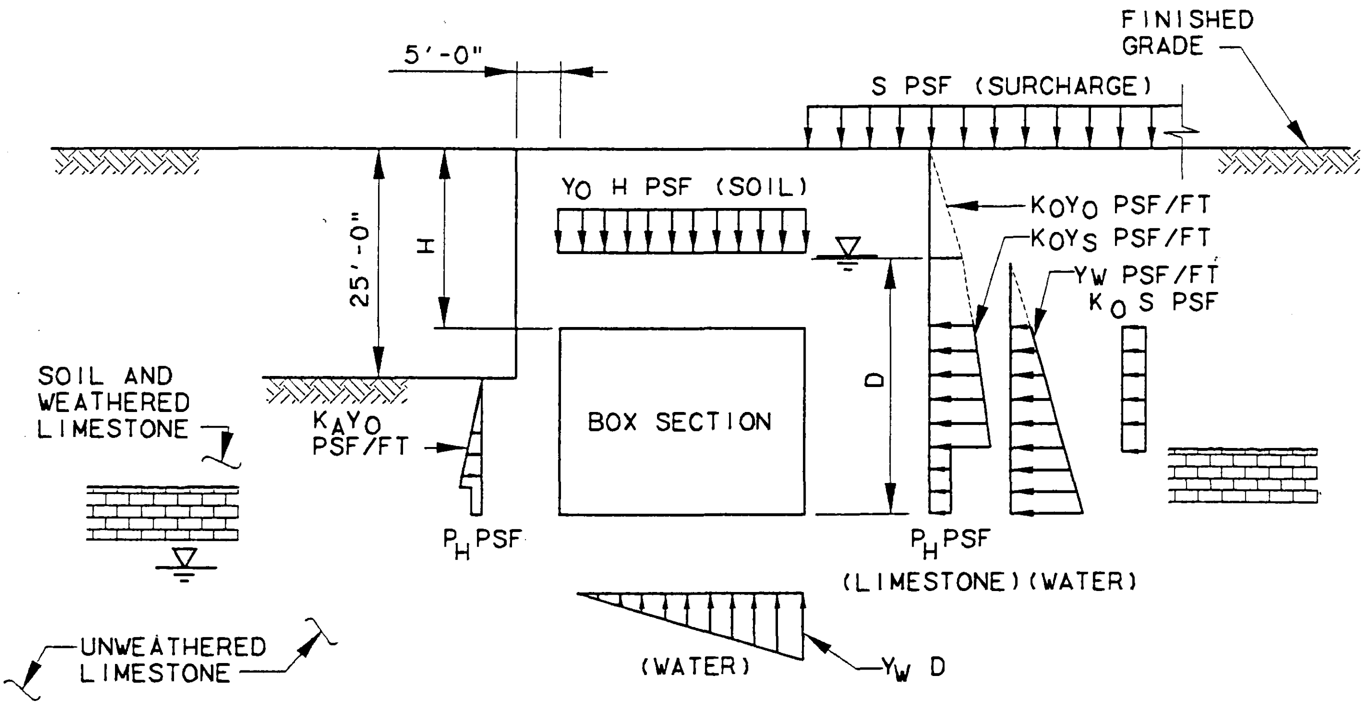


UNSYMMETRICAL LOADING-CONDITION II

NOTE: SEE FIGURE 15.1 FOR LEGEND AND NOTES.

ACT 21 CARTER BURGESS JACOBS ENGINEERING STV INCORPORATED KAI ALLIANCE	DART PROJECT DART	DART DESIGN CRITERIA CUT AND COVER STRUCTURES LOADING CONDITIONS SCALE: NOT TO SCALE FIGURE: 15.3

JAN. 2003, REV 10



UNSYMMETRICAL LOADING-CONDITION III

NOTE: SEE FIGURE 15.1 FOR LEGEND AND NOTES.

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DART

DART DESIGN CRITERIA

CUT AND COVER STRUCTURES LOADING CONDITIONS

SCALE: NOT TO SCALE

FIGURE: 15.4

JAN. 2003, REV 10

CHAPTER 16 - EXCAVATION SUPPORT

16.1 INTRODUCTION

The design criteria contained in this chapter shall relate to the design of excavation support systems for the construction of the Dallas Area Rapid Transit (DART) Rail System. The excavation support system shall include support wall systems, wall restraints, tie-back anchors, trench shoring, dewatering, and protection of existing structures during excavation. Excavation support systems shall be designed to sustain the most severe combination of dead and live loads to which they may be subjected. The deflection of support systems should be limited to the local requirements. Structural design shall be governed by these criteria in addition to the codes, standards, and specifications referenced in Appendix 1. In addition to the design guidelines contained in this volume, the DART structures shall generally be designed according to the following:

- o Structures supporting transit and highway loads shall be designed according to Standard Specifications for Highway Bridges (American Association of State Highway and Transportation Officials, AASHTO; hereafter cited as such).

- o Concrete structures supporting non-transit or non-highway loads shall be designed according to Building Code Requirements for Reinforced Concrete (American Concrete Institute, ACI 318; hereafter cited as such).

- o Steel structures supporting non-transit or non-highway loads shall be designed according to Load and Resistance Factor Design Specification for Structural Steel Buildings (American Institute of Steel Construction, AISC; hereafter cited as such).

- o Structures supporting railroad loads shall be designed according to the Manual for Railway Engineering (American Railway Engineering and Maintenance of Way Association, AREMA; hereafter cited as such).

- o Welding shall be designed according to Bridge Welding Code or Structural Welding Code - Steel (American Welding Society AWS; hereafter cited as such).

- o Timber structures shall be designed according to National Building Code - Timber (American Institute of Timber Construction (AITC); hereafter cited as such).

Prior to commencing work on construction documents, the Section Designer shall submit to DART for approval a list of codes, standards and specifications to be used, indicating the areas where they will be used, to guide the design of the excavation support system(s). The design of the excavation support system(s) is the sole responsibility of the Contractor. Design of the excavation support system(s) shall be in accordance with the codes, standards and specifications, and the minimum design criteria as set forth in this chapter. Prior to the start of any excavation, structural drawings, calculations, and a Certificate of Design, each signed and sealed by the Contractor's engineer, shall be submitted to DART for approval. The Contractor's engineer who signs and seals the documents, shall be a Professional Engineer registered in the State of Texas whose qualifications include 10 years of documented experience in the design and construction of excavation support systems.

Monitoring and inspection of the excavation support system(s) installation and performance shall include, at a minimum, weekly inspections of the system(s) by the Contractor's engineer. The Contractor shall obtain from his engineer and submit to DART, no later than the 5th day of each month, a signed and sealed certification that the excavation support system work performed during the previous month was installed and is performing substantially as designed. Any changes or deviations from the design, and the basis for such changes shall be documented in the certification.

The full titles of all references in this chapter are listed under the structural section of Appendix 1. In the event of a conflict between criteria in this chapter and information referenced in Appendix 1, the design criteria in this chapter shall govern.

16.2 SUPPORT WALL TYPES

Based on the relative rigidity of the wall and the resultant deflection due to excavation loads, temporary excavation support wall systems shall be identified as either flexible or semi-rigid wall systems.

16.2.1 Flexible Wall Systems

Typical flexible wall systems for DART excavation support shall include the following:

Soldier Piles and Lagging. The lagging shall consist of either wooden, steel, or concrete planks of suitable shape and strength. The soldier piles shall be either steel H-sections or structural equivalents, placed at 3- to 10 foot intervals, with the web aligned perpendicular to the excavation face being supported. The soldier piles shall be placed in pre-drilled holes unless otherwise approved by DART. In order to strengthen the soldier pile or prevent ground movement and settlement which will influence the adjacent structures due to pre- drilled holes, the Contractor shall consider filling the hole with sand, cement grout, or lean concrete. The location of the soldier piles shall be placed to assure that the expected line of deviations during driving will not result in the soldier pile encroaching on the envelope defined by planned permanent structures. Particular attention shall be paid to supporting the walls during excavation. The wall system shall be designed such that any pile deflections will not result in unacceptable movement or loss of ground. The walling system shall not be used where unacceptable groundwater drawdown adjacent to the excavation will occur.

Interlocking Steel Sheet Piles. Particular attention shall be paid to adequately supporting the walls during excavation and to ensuring that pile deflections and water leakage will not be such that unacceptable movement, loss of ground, or significant groundwater drawdown will occur adjacent to the excavation.

16.2.2 Semi-Rigid Wall Systems

Typical semi-rigid wall systems shall include the following:

Soldier Pile and Tremie Concrete. A soldier pile and tremie concrete wall is constructed prior to placing soldier piles, excavating the slot between the piles, and forming a panel by filling the slot with concrete. The soldier piles shall be similar to the soldier pile and lagging wall system described above. As required, steel reinforcing bars or structural steel sections may be included as part of the panel design.

Cast-in-place Reinforced Concrete (Slurry) Walls. The sequence of panel construction, the watertightness of the vertical panel joints, and the support of the walls during excavation shall be considered during design.

16.2.3 Alternative Support Systems

Other methods of temporary excavation support not specifically mentioned in these design criteria may be submitted for approval. The submission shall provide full structural calculations and details relating to the strength and stability of the proposed support, together with the influence on the existing groundwater regime and adjacent structures and services.

16.2.4 Temporary Walls for Permanent Works

For the design of temporary walls considered by the designer to form an integral structural part of the permanent works design, consideration shall be given to the long-term behavior, performance, appearance of the wall, and corrosion protection of steel elements of temporary walls incorporated into permanent works.

16.3 SUPPORT WALL RESTRAINT TYPES

Wall restraints shall be designed to provide support to the wall system and shall bear directly on the wall or on a horizontal wale, or any bearing surface built for that purpose. Struts, rakers and tie-back anchors shall be preloaded. Typical restraints shall include the following:

16.3.1 Struts

Struts shall generally consist of horizontal steel pipe or H-section structural members, extending from one side of the excavation to the other. Struts shall be designed to resist load combinations outlined in 16.4.2, including all fabrication and construction tolerances and temperature loads. Allowance for pre-loading of the strutting system shall be included in the strut fabrication and design. Struts shall be installed at adequate spacing and shall have adequate stiffness to minimize support wall deflections and rotations. Struts shall be monitored so that they comply with design load assumptions. The system for monitoring struts shall be approved by DART.

16.3.2 Rakers

Rakers shall be defined as inclined structural elements that bear against the excavation wall and the excavation foundation level. With due allowance for the upward load imparted to the wall system, the bearing stresses at the wall, and the safe bearing capacity at the excavation foundation level, the rakers may be fabricated from steel pipe or H-sections. Rakers should be designed to accommodate all temporary dead and live loadings, including fabrication, temperature, and pre-loading stresses. Adequate stiffness and spacing shall be provided so that support wall deflections and associated adjacent structural movements are minimized.

16.3.3 Tie-Back Anchors

Tie-back anchors shall be formed in a downward-inclined hole into the soil or rock behind the wall beyond the failure plane, forming a grouted anchor at the end of the hole and extending a steel bar or tendon from the anchor to the wall. Alternatively, anchors may be formed by installing a steel bar or tendon from a deadman to the wall in a horizontal trench. The deadman shall be located beyond the failure plane for the retained material. All tie-backs shall be the subject of a DART-approved testing program. In general, they shall be tested as follows: a load 50% greater than the maximum design load shall be placed on the tie-backs, which must be able to sustain this test load for 15 minutes without any loss of stress. (See section 16.5.3 of this chapter.) Suitable precautions shall be taken so that there is resistance to corrosion of the anchor and anchor head. (See Systems Design Criteria Chapter 8 - Corrosion Control and Chapter 9 - Systems Grounding.) Consideration must be given to the right-of-way required when designing and costing the use of tie-back anchors. (See the DART Project Right-of-Way Manual (DART)).

16.3.4 Compression Members

In certain instances, such as in the design of shafts or bulkheads, it may be necessary to provide lateral restraint via a system of internal frames, such as a ring beam. This structural member shall be constructed of cast-in-place reinforced concrete, or structural steel. With due consideration of the bearing stresses imposed at the load-structure interface, it shall be designed to resist all imposed dead and live loads experienced during construction.

16.4 LOADS AND FORCES

16.4.1 Notation

All components of the excavation support structures shall be proportioned to withstand the most severe combination of dead and live loads to which they may be subjected. The service load design method shall be used in all analysis and design calculations. The following loads and forces shall be considered in the design of the excavation support systems. See the referenced sections for detailed descriptions.

A. DL = Dead Loads - (see section 16.4.3).

B. Transit Loads:

LL = Live Loads including transit and highway loads (see section 16.4.4 of these criteria)

I = Impact
CF = Centrifugal Force
LF = Longitudinal Forces

C. Other Loads:

M = Miscellaneous live loads (see section 16.4.5)
WS = Wind load on structure
WL = Wind load on live load
E = Earth loads (see section 16.4.6)
V = Ground-borne vibrations (see section 16.4.7)
B = Buoyancy and hydrostatic pressure (see section 16.4.8)
S = Shrinkage and creep forces (see section 16.4.9)
T = Thermal forces (see section 16.4.10)

The loading criteria adopted for the design of each structure or structural element shall be clearly stated on the structural drawings.

16.4.2 Loading Combinations

<u>**Minimum Design Loads**</u>. The design of temporary steel excavation supports, reinforced concrete members, prestressed concrete members, stability and deflection calculations, and soil bearing pressures shall be based on the following minimum design loads:

MINIMUM DESIGN LOADS

STRUCTURE	VERTICAL LOADS		HORIZONTAL LOADS (E) AND (B)	DESIGN LOADING COMBINATIONS AND ALLOWABLE UNIT STRESSES	
	DEAD LOADS (DL)	LIVE LOADS (LL)		FLEXIBLE WALL SYSTEMS	SEMI-RIGID WALL SYSTEMS
Wall system (elements in contact with retained earth except lagging)	Weight of wall Deck loads including weight of deck Reactions from bracing system including vertical load components of inclined tiebacks or rakers	Reactions from all live loads including AASHTO HS20-44 loading and applicable construction equipment loading	Loads from lateral earth pressure and lateral surcharge pressures (E) and hydrostatic pressure (B) Axial loads from end walls (E) + (B), where applicable	100% of DL + LL + B + 80% of E at 100% of allowable unit stresses	100% of DL + LL + E + B at 100% of allowable unit stresses
Primary bracing members (members carrying direct loads including wales, struts and tiebacks)	Weight of primary bracing member plus deck loads, where applicable		Loads from wall system (E) + (B) Axial loads from end walls (E) + (B), where applicable	For wales: 100% of DL + LL + B + 80% of E in bending + 100% of E in compression For other primary bracing members: 100% of DL + LL + E + B All at 100% of allowable unit stresses	For all primary bracing members 100% of DL + LL + E + B at 100% of allowable unit stresses
Secondary bracing members (posts, lacing, etc.)	Weight of secondary bracing member plus weight of supported primary bracing member, where applicable	Axial load equal to 3% of the design axial load in the more heavily loaded adjacent primary bracing member		100% of allowable unit stresses	100% of allowable unit stresses

In selecting critical loading combinations, consideration shall be given to appropriate combinations of maximum vertical loads with minimum horizontal loads (and vice versa), and to asymmetrical loads.

16.4.3 Dead Loads (DL)

The magnitude of unit weight applicable to each structural element for computing dead load shall be in accordance with Chapter 9 - Loads of these criteria for the construction material under consideration. The unit weight of proposed construction materials not listed in Chapter 8 - Structural Materials shall be in accordance with the manufacturer's literature, as approved by DART.

16.4.4 Live Loads (LL)

Live Loads shall include, but not be limited to, transit and highway loads. Standard axle spacings and loadings, centrifugal force, and longitudinal force shall be as prescribed in the loads chapter of these criteria. The vertical impact factor shall be taken as 30 percent for suspended trackway slabs and slabs on grade. Highway loads shall include AASHTO HS20-44 loading and applicable construction equipment.

16.4.5 Miscellaneous Live Loads (M)

The live loads on elements of DART excavation support structures shall be taken as follows:

- <u>Service walks</u> - See Chapter 9 - Loads of these criteria.

- <u>Stairs</u> - 100 pounds per square foot (psf), or a concentrated load of 600 pounds on one stair tread located so as to produce a maximum stress condition, whichever gives the higher stress.

- <u>Floors, and all other areas not specified herein</u> - 150 psf, or a concentrated point load of 2,000 pounds located so as to produce a maximum stress condition, whichever gives the higher stress.

- <u>Railing in excavation support structures</u> - Shall be designed for a horizontal force of 50 pounds per linear foot (plf) and vertical force of 50 plf at their top. Railings in equipment rooms and working areas shall be designed for a force of 200 pounds applied in any direction at any point.

- o Design of excavation support structures - Account shall be taken of all loading resulting from the method and route to be taken for the installation and subsequent removal and replacement of the various items of plant and equipment.

16.4.6 Earth Loads (E)

Soil pressures to be used for design shall be based upon the information for the design section involved provided in Chapter 10 - Geotechnical Information. Allowances shall be made for both dry and submerged earth pressures, for hydrostatic pressure, and the influence of physical and chemical characteristics of soils adjacent to DART structures. Consideration shall be given to multilayered effects where substantial differences in soil and rock properties occur over the depth of the subway structure. The effects of specified construction methods such as flexible and rigid bulkheads, bracing procedures, and so forth, on the development of lateral pressures shall be considered, together with the effects of compaction, on construction lateral soil pressures.

Lateral pressures due to rock loads shall be considered both for temporary and permanent structural design works. The magnitude and resultant direction of all rock loads shall be based upon the information referred to in the geotechnical chapter of these criteria for the relevant design section. Changes in either temporary or permanent work design methods or construction sequences shall be fully evaluated, together with allowance for both short-term and long-term hydrostatic pressures which may exist adjacent to the rock/structure interface.

Railroad Surcharge Loads. Structures or structural elements supporting non-DART railroad loads shall be designed according to AREMA using Cooper E 80 loading.

Where railroad loads are carried by excavation support structures, the loading on the structure shall be as specified in Part 16 of Chapter 8 of AREMA, including the impact loading therein prescribed.

Roadway and Sidewalk Surcharge Loads. Live load surcharge shall be applied to or adjacent to the excavation support structure to simulate possible roadway and sidewalk live loads. Construction adjacent to the structure may result in both permanent and temporary loads from construction equipment and the stockpiling of construction materials, or from the deposition of excavated earth.

Surcharge Vertical Intensity. The surcharge shall be considered as a static uniform load applied at the ground surface. Its vertical intensity at any depth below the ground surface shall be a constant force 400 psf.

The surcharge load shall be applied in addition to all known dead and live loads except that the surcharge shall not be applied when the alternative wheel loading described in the following section is applied.

Wheel Loading. On existing and planned roadways, wheel loading for depths of cover of 5 feet or less shall be distributed at the surface with the width and length as described in AASHTO, Division 1, Section 3.30. The width and length of the distribution area shall be increased 1/2 foot in each direction for every foot of depth.

Loads from Existing and Proposed Structures:

- Structures over the Subway. Existing structures that are to remain in place over the subway shall be underpinned in such a manner as to avoid any transfer of load onto the subway section, or the section shall be designed to support the structure directly. Non-DART structures shall be supported directly on DART structures only if specific approval in writing is received from DART.

- Structures Adjacent to the Subway. The excavation support structure shall be designed for loading from existing adjacent buildings or structures unless they are either founded or permanently underpinned to a depth below the zone of influence on the subway structure.

- Building Loads. Each existing building or structure adjacent to the cut-and-cover construction shall be considered on its own merits when evaluating dead and live loads.

For adjacent structures founded on piles or drilled shafts taken to rock, lateral surcharge shall be considered to act upon the subway structure in accordance with Chapter 10 - Geotechnical Information of these criteria.

Proposed Construction. Unless otherwise determined by DART, future construction will not be presumed to exert vertical and lateral pressures exceeding those due to natural ground conditions by more than the surcharge allowances prescribed in this section. The provisions of Authority agreements with property owners, railroads, and other agencies regarding special loadings for portions of support structures that pass adjacent to their properties or facilities shall be considered in establishing the loading conditions for such structures.

Load at Interfaces. The Contractor's Engineer shall be aware of the schedule, sequence, and type of all respective construction. Support of excavation shall be designed with consideration of the load variation due to those constructions.

Special Surcharge and Minimum Surcharge and Overburden. Besides the surcharge due to railroad, roadway, sidewalk, and buildings mentioned in sections 16.4.6, 16.4.7, and 16.4.8, surcharge generated by any other loads shall be evaluated by a recognized method of analysis. All underground structures shall be designed to resist a surcharge pressure of not less than 300 psf together with 8 feet of earth overburden.

16.4.7 Ground-borne Vibrations (V)

DART or its vibration consultant will identify locations where the transmission of ground-borne vibrations from existing structures must be considered in design.

16.4.8 Buoyancy and Hydrostatic Pressure (B)

Hydrostatic Pressure. The effects of hydrostatic pressure shall be considered whenever the presence of groundwater is indicated. It shall be computed at 62.5 pounds per square foot per foot of depth below groundwater table. Where hydrostatic pressures pertain, lateral earth pressures shall be based upon the submerged unit weight of the soil and in accordance with the geotechnical information referred to in the geotechnical chapter of these criteria. The possibility of future significant changes in groundwater elevation during construction shall be considered. Full hydrostatic pressure shall be assumed to act on all external structural members for the maximum likely height of the water table, unless specific permanent provisions to remove these effects are included in the overall design of the structural members.

Buoyancy. If the excavation support structure provides for free drainage, buoyancy need not be considered, otherwise adequate resistance to flotation shall be provided for full hydrostatic uplift pressure on the structure foundation based on the probable maximum height of the water table. For the excavation support structure only, such resistance shall consist of the dead weight of the structure. Provision shall be made in the design, or a construction sequence shall be specified, to prevent buoyancy which might result from a rise in the water table before all backfill is placed. The submerged unit weight of soil below the groundwater table may be taken as 68 pounds per cubic foot unless otherwise noted in Chapter 10 - Geotechnical Information of these criteria.

When evaluating buoyancy loads on excavation support, sidewall soil and rock friction may be included with the weight of the structure. Unless indicated otherwise in the geotechnical information of these design criteria, the compacted dry weight of soil above the roof slab level shall be taken as 120 pounds per cubic foot. The weight of street pavement and live loads shall be neglected for the purposes of calculating uplift. The factor of safety against uplift under the above conditions, neglecting side wall soil and rock friction effects, shall not be less than 1.10.

Rotational effects due to buoyancy shall be considered where the support structure is markedly asymmetrical. Local asymmetry need not be considered unless the section is isolated by structural joints.

A construction sequence together with all temporary measures necessary to provide adequate safeguards against flotation during all stages of construction shall be indicated. The possibility of lowering the groundwater table, if necessary, may also be considered in special cases to minimize buoyancy forces during construction, if such dewatering does not result in ground settlements.

Dewatering during the construction stage shall be considered in the underground structures design.

16.4.9 Shrinkage and Creep (S)

Provisions shall be made for movements and stresses resulting from concrete shrinkage and creep. See Chapter 8 - Structural Materials of these criteria.

16.4.10 Thermal Effects (T)

Provisions shall be made for movements and stresses resulting from temperature variations. See Chapter 8 - Structural Materials of these criteria.

16.5 DESIGN

Excavation support structures shall be designed according to good structural and geotechnical engineering practices carried out in accordance with the codes and specifications referenced in Section 16.1 of these criteria, or as specified by the applicable local authority having jurisdiction.

Excavation structures shall be analyzed for all conditions that might occur during the various stages of construction, including plant loading installation, relocation, and removal of bracing; soil removal and dewatering of excavation; and concreting of the excavation bottom. Where the lateral loading conditions on opposite sides of a cut are not equal and cross-lot bracing is used, the design of the wall system and bracing shall be undertaken using the larger loading. As construction of the permanent structure proceeds upwards, no reduction in the intensities of the pressure diagrams shall be allowed. A design shall be prepared for the staged removal of bracing to suit the sequence of concrete placement. In open cuts, bottom stability shall be fully evaluated, including piping and shear failure at the base of the excavation. In the design of the bracing system, the items in the following sections also shall be considered.

16.5.1 Wall System

Soldier piles, where used, shall be assumed to be fully braced against buckling in the plane of the lagging. In the plane perpendicular to the lagging, the column length shall be taken as the distance between braced points. Soldier piles and bearing piles may be assumed to be fully braced in both planes at a depth of three pile diameters, or computed equivalent diameters, into unweathered rock, when founded in rock. Based upon the geotechnical chapter of these criteria, the Contractor's Engineer shall verify these assumptions using site-specific design parameters.

Vertical members of flexible wall systems shall be designed on the assumption that they are hinged at braced levels and at the bottom of excavation. Vertical members of rigid wall systems may be assumed continuous over intermediate supports and hinged at the top-braced-level and at the bottom of excavation. Elements supporting vertical loads as well as lateral pressures shall be analyzed as structures subjected to combined axial load and bending. Voids between the lagging and the supported soil shall be backfilled with compacted granular or other suitable material as soon as practicable at each stage of excavation and prior to the pre-loading of the bracing at the level under consideration. Backfill between soil and lagging shall be done in a manner to prevent unraveling.

Where the vertical member of the wall system cantilevers above the uppermost brace level, a fully continuous moment shall be taken for the cantilever portion only. To account for the concentration of soil pressures at struts and tie-back locations, the bending moments taken from the pressure diagrams (hydrostatic pressure excluded) may be reduced by 20 percent when calculating flexure requirements for vertical members and flexible wall system wales.

In calculating the required penetration of the wall system below the excavation invert, the moment of forces about the lowest brace shall verify static equilibrium by assuming a hinge point at the brace level. Any bending resistance offered by the wall at the brace elevation shall be ignored. Penetration shall be sufficient to develop the design passive resistance with a minimum safety factor of 1.5. Penetration calculations for benched excavations shall consider the effects of benching on the passive resistance of material. See Chapter 10 - Geotechnical Information of these criteria.

16.5.2 Wall Restraints (Bracing)

Bracing members shall be constructed of structural steel. Permanent bracing may be constructed using reinforced concrete construction. Tie-backs should be constructed using high-strength steel tendons or rods.

In a bracing system where wales are not used and a direct strut-to-soldier-pile connection is used, additional provisions for bending stress due to the eccentricity of lateral loading shall be considered in the design of the strut member. All bracing splices shall have full moment and shear stress connections, with additional allowances for misalignment stresses. The maximum slenderness ratio of struts shall not exceed 120. The slenderness ratio of secondary bracing elements shall not exceed 200.

For the calculation of strut loads, the wall shall be assumed to act as several independent simple beams supported at brace levels, but their continuity effects shall be ignored. The sum of reactions at each support shall be used as the design brace load. The full loading on cantilevered wall sections should be considered as acting directly on the supporting brace level. A fictitious strut shall be assumed to exist below the lowest level of the excavation when evaluating strut loads. Full account shall be taken of the temporary excavation stages when evaluating maximum strut loads.

Struts shall be prestressed to a minimum of 25 percent of their total design compressive load. Stresses due to temperature variations shall be taken into account in the design of the struts. Provisions shall be made to protect struts against excessive deformations and stress variations induced by temperature fluctuations.

16.5.3 Tie-Back Anchors

A check shall be made on the overall stability (sliding, rotational, and so forth,) of the soil block forming the anchoring mass of earth. In performing this sliding stability analysis, the width of the resisting surface should not be taken greater than the distance from the support wall back to the vertical plane passing through the end of the shortest anchor. For rotational analysis, the slip circle method of design shall use a yield factor of safety of 1.5 based on applicable loading, and site-specific soil and rock properties.

Anchor Length. For purposes of determining the effective length of anchors, the failure plane of the soil or rock mass behind the wall shall be taken at a maximum angle measured from a vertical line extending from the bottom of the excavation. The failure plane angle shall be calculated from site-specific geotechnical design parameters. Anchors shall be considered as receiving resistance from only the soil or rock mass acting beyond the indicated failure plane. Consideration shall be given to increasing the extent of the failure zone due to high surcharge loads. The determination of the approximate failure plane for the purposes of effective anchor length shall be checked by the Culmann or other similarly approved methods of analysis.

The allowable value of shear stress between the soil and the anchor to be used in design of effective embedded length for each individual anchor in various strata shall be derived by the Contractor's Engineer. The value of overburden pressure used for these calculations should not include surcharge loads or live loads. The effective length thus found shall be increased by a minimum of 10 percent to make allowance for unforeseen field variables.

Angle of Anchor. The angle between the direction of the anchor and the horizontal line perpendicular to the excavation wall shall be generally within a range of 15-45 degrees. Account shall be taken of the effects of resulting load vectors and the associated structural implications arising from these, particularly toe penetration and bearing capacity requirements.

Anchors generally shall be installed in pre-drilled holes and grouted so they make firm contact with the surrounding soil. Pre-drilling beneath adjacent buildings may only be undertaken with the express consent of DART in writing and with the permission of the property owner. For drilled-in anchors, the total anchor load shall be developed in bond between steel and grout acting within effective length of the anchorage. Where high-strength tie rod steel is used, the final working stress shall not usually exceed 60 percent of the ultimate tensile strength of the steel.

Tie-Back Spacing. The design spacing of tie-backs shall be such that no overlap of resisting soil or rock stress bulbs exists when assuming full value of anchorage for each tie-back. If such an overlap exists, a reduction factor shall be used for affected ties. Regardless, in any one plane the anchors shall have a minimum clear distance of 5 feet between them. Those tie-backs having overlapping soil stress bulbs shall be pre-tested using a minimum of three adjacent anchors. Tie-backs shall not be placed closer than 10 feet to foundation structures of existing buildings unless approved in writing by both DART and the property owner.

16.5.4 Connections

Connection between struts, wales, and the wall system shall be designed for a tensile and shearing load equal to at least 10 percent of the design compressive strut load. Filler plates or an approved equivalent shall be used to obtain a tight fit. Struts shall be pre-loaded so that the supporting system is in firm contact with the ground at all times. Upon completion of the wall system bracing and supports, no further driving of wall piles shall be undertaken. When tendon anchors are used, the lock-off wedges shall be of the same or greater hardness as the tendon.

Unless specifically designed for in the connection details, the wale-strut connection shall not be capable of moment transfer. The effective length of a strut shall be taken as the total length of the strut plus twice the width of the wale, and the strut shall be designed with a pinned connection.

16.6 TRENCH EXCAVATION AND SHORING

Trench excavation for utility facilities or other purposes shall meet the requirements of this chapter, the Occupational Safety and Health Act, and as set forth by the Texas Legislature. For sloping of sides of excavation, appropriate slope angle shall be determined based on the geotechnical information supplied by DART. (See Chapter 10 - Geotechnical Information for more information.) The Contractor's Engineer shall indicate the specific type of shoring or trench slope lay-back required for every trench deeper than 5 feet, or as required by DART.

16.7 DEWATERING

This section covers the evaluation and control of groundwater associated with excavations and construction activities. The existing groundwater regime is subject to geographical and seasonal variations. The Contractor's Engineer, therefore, shall consider each excavation on an individual basis.

16.7.1 Groundwater Control

Groundwater lowering may result in ground and structural settlement due to the increased effective stress within the soil. The Contractor's Engineer shall estimate the magnitude of groundwater lowering at various distances from the excavation, and also estimate the amount of settlement associated with the groundwater lowering. The section designer shall evaluate the integrity of any existing structure that may be influenced by dewatering activities. They shall investigate its ability to accommodate absolute as well as differential settlements and rotations associated with these activities. When considering dewatering activities, safety of personnel, equipment, and structure shall be paramount.

The section designers shall develop an allowable movement profile (Displacement Limits) on a case-by-case basis for all structures affected by dewatering activities. Methods shall be based on stability, serviceability, and structural integrity, and shall be approved by DART. For settlements or rotations of a structure outside the allowable movement profile, suitable methods of reducing dewatering settlements shall be considered and evaluated.

16.8 PROTECTION OF EXISTING STRUCTURES

16.8.1 Design Guidelines

This section deals with the protection of existing structures from ground movements and subsequent settlement and/or rotation that results from excavation or tunneling activities associated with the construction of DART structures.

The section designer, in conjunction with the geotechnical consultant, shall determine the influence of existing structures on excavation or tunneling activities. In addition, the influence of excavation or tunneling activities on the settlement and/or rotation and stability of existing structures shall be analyzed. Based on these evaluations the section designer shall establish design parameters for the allowable settlement, differential settlement, and rotation of each building affected by excavation or tunneling activities. Also, the allowable horizontal displacement of excavation support shall be analyzed on a case by case basis.

The ground movements associated with excavation or tunneling activities generally may be placed in two categories: (1) lateral and vertical ground movements due to either the inward movement and rotation of the excavation support system or movement of earth associated with tunneling; and (2) ground settlements associated with groundwater lowering. The protection of existing structures shall be accomplished by using protection walls around the excavation, underpinning the existing structure, or a combination of these two methods.

When determining the appropriate protection for an existing structure the designer shall consider the sequence of construction and the effect of the placement of protection on other phases of construction and vice versa. Consideration shall also be given to the right-of-way requirements of different protection techniques, especially tie-back anchors in conjunction with protection walls.

16.8.2 Protection Walls

The elected method of excavation support shall be designed to resist the loading combinations outlined in section 16.4. The individual struts shall be designed to resist the additional load due to any pre-loading.

Soil and rock anchors may be used to support protection walls during construction. When designing wall tie-backs, the following items shall be considered: effects of installation, creep, yield of the tendon or bar, and shear strength of the soil-grout interface. Tie-back anchor design shall include a detailed method of monitoring and testing anchors during the time the anchors are in place. All methods of monitoring shall be approved by DART.

The designer, in conjunction with the geotechnical consultant, shall determine acceptable limits of groundwater seepage and ground loss on a site-by-site basis. All necessary means shall be taken to keep ground loss and seepage within these limits. Seasonal groundwater table variations shall be studied in addition to the analysis of past case histories in the vicinity of the construction area.

Attention shall be paid to the effects that the sequence of construction, placement of struts, depth of excavation below each level of struts, and control of groundwater level within the excavation have on wall loads. Particular attention shall be paid to groundwater seepage. The effects of on-site soil permeability on soil flow and excavation dewatering to prevent the migration of fines through the support wall shall be clearly shown on design drawings.

The Contractor's Engineer shall estimate the amount of settlement, differential settlement, and/or rotation of an existing structure based on the particular excavation support design under consideration. The need to keep settlements to a minimum will be an important factor in selecting the type of excavation support.

16.8.3 Underpinning, Support and Restoration of Structures

Underpinning of an existing structure shall be considered only if estimated movement of the structure, if protection walls were used, would be in excess of that allowable. The allowable settlement shall be determined for each structure as outlined in 16.8.1 and in conjunction with the building owner. Some structural settlement shall be anticipated in conjunction with most underpinning systems. These settlements should be taken into account when analyzing the effects of construction activities on an existing structure.

The following methods are recommended for consideration:

- o Pit piers.
- o Jacked piles.
- o Column pick-up.
- o Micro piles.
- o Foundation grouting.

The Contractor shall be responsible for restoration, defined as the correction by repair or replacement, of structures damaged or altered as a result of the Contractor's operations. Restoration shall be to the equivalent condition existing prior to the start of Contract work and shall be to the satisfaction of DART.

The Contractor shall submit to DART for approval the method for underpinning, temporary support, or maintenance system installation for each existing structure. The submission shall include a detailed analysis of both the structure and the soil/structure support system, the installation method and sequence, and estimates of structural movements associated with the proposed method.

CHAPTER 17 - DEEP FOUNDATIONS

17.1 INTRODUCTION

The design criteria contained in this chapter shall relate to the design of structures constructed as part of the Dallas Area Rapid Transit (DART) light rail system. Structural design shall be governed by these criteria in addition to the codes, standards, and specifications referenced in Appendix 1. In addition to the design guidelines contained in this volume, the DART structures shall generally be designed according to the following:

- Structures supporting transit and highway loads shall be designed according to Standard Specifications for Highway Bridges (American Association of State Highway and Transportation Officials, AASHTO; hereafter cited as such).

- Concrete structures supporting non-transit or non-highway loads shall be designed according to Building Code Requirements for Reinforced Concrete (American Concrete Institute, ACI 318; hereafter cited as such).

- Steel structures supporting non-transit or non-highway loads shall be designed according to the requirements of Load and Resistance Factor Design Specification for Structural Steel Buildings (American Institute of Steel Construction, AISC; hereafter cited as such).

- Structures supporting railroad loads shall be designed according to the Manual for Railway Engineering (American Railway Engineering and Maintenance of Way Association, AREMA; hereafter cited as such).

Prior to commencing design work, the section designer shall submit to DART for approval the list of codes and specifications to be used, indicating the areas where they will be used.

The full titles of all references in the chapter are listed in the Structural section of Appendix 1. In the event of a conflict between criteria in this chapter and information referenced in Appendix 1, the design criteria in this chapter shall govern.

As defined for use in the DART light rail system, deep foundations shall include driven piles and drilled shafts. A deep foundation shall be used when a shallow foundation cannot be designed to carry the applied loads economically. Even though the bearing capacity of the soil is sufficient to make practical the use of a shallow foundation, deep foundations shall be used where scour, erosion, or unacceptable settlement may occur.

17.1.1 Principles of Design

A deep foundation shall be whatever depth required to attain the necessary load-carrying capacity. A drilled shaft or pile that penetrates a soft upper stratum overlaying a stiff stratum shall attain the design capacity wholly within the stiff stratum.

17.2 DEEP FOUNDATION TYPES

The following paragraphs present alternative kinds of deep foundations that may be used for DART structures.

17.2.1 Precast Concrete Piles

Because of the characteristics of the subsurface soils in the DART service area, it is not anticipated that precast, prestressed concrete piles will be used. Details of pile construction, driving method, and location may be submitted for DART's consideration, however.

17.2.2 Timber Piles

Timber piles shall not be used for permanent DART structures.

17.2.3 Steel H-Section Piles

Steel H-section piles may be employed as part of temporary construction works. Steel H- section piles shall be constructed from rolled structural steel with a minimum web thickness of 0.40 inch and with adequate capacity to accommodate driving stresses. Pile splices shall be adequate to develop the full driving capacity of the pile. The web and flanges shall be spliced by a full-penetration butt weld. Bolted splices shall only be used when approved in writing by DART and fully detailed in the working drawings.

Bearing caps shall be in accordance with AASHTO, Section 4. When their need is proven, bearing caps shall be designed to withstand a compression load at least equal to the pile capacity.

Steel H-section piles subject to uplift shall be provided with adequate pile cap anchorage. This can include studs welded to the pile or reinforcement passed through the section to resist the design uplift load. When evaluating uplift capacity, the bond between the H-pile steel surface and the surrounding concrete shall not be included. Lugs, scabs, and core- stoppers may be used to increase the bearing capacity of steel H-section piles. They may consist of structural shapes or plates suitably welded between the pile flanges.

17.2.4 Steel Pipe Piles

Steel pipe piles shall have a wall thickness of not less than 0.25 inches. Where difficult driving is anticipated, a thicker shell shall be specified by the designer to prevent buckling of the shell. The piles may be of uniform section, tapered, or a combination thereof. To prevent the entry of soil and water, steel pipe piles may have the lower end closed with a steel plate. They may be either driven or placed in holes drilled to a predetermined depth. Steel pipe piles with heads embedded in concrete and subject to uplift loads shall be provided with sufficient anchorage devices to withstand design uplift loads. (For example, studs welded to the exterior of the pile). In the evaluation of the pile uplift resistance, no allowance for the bond between the concrete and the steel surface of the pile shall be permitted.

A driven steel pipe shall be of sufficient thickness and strength so that it holds its original form after it and adjacent piles have been driven. Steel pipe piles shall be filled with concrete after placement of the casing. (Also see section 17.2.5.) Pipe piles with sufficient wall thickness to withstand the applied loads and resist the anticipated corrosion may remain unfilled only with the written permission of DART. Piles shall be spliced to develop the full capacity of the section of the pile, using either butt welding or welded sleeves. Splices shall be fully detailed on the working drawings.

17.2.5 Cased Piles

Cased piles shall consist of concrete-filled steel shells. The concrete, plain or reinforced, shall be cast in the pre-placed steel shell, which shall remain permanently in place. The shells may be either driven or placed in holes drilled to a pre-determined depth and diameter then driven for seating. They may be of uniform section, tapered, or a combination thereof. Prior to the placement of concrete, the interior of the shells shall be fully cleaned out and free of groundwater ingress.

Those portions of the pile not supported laterally shall be designed as reinforced concrete columns. The reinforcing steel shall extend 10 feet below the plane where the soil provides adequate lateral restraint. When the steel shell thickness is more than 0.12 inch after deducting the allowance for corrosion (see section 17.2.9), it may be considered as reinforcement. Interior reinforcing steel, when used, shall not be placed within 1 inch of the inner face of the steel shell.

A driven shell and any associated jointing shall be of sufficient thickness and strength to retain its original form and show no harmful distortion after driving. If a mandrel is used, there shall be no harmful distortion to the driven shell and jointing after the mandrel has been withdrawn and after the adjacent shells have been driven.

17.2.6 Drilled Shafts

Drilled shafts are likely to be employed in foundations. These drilled shafts shall include those members constructed with or without a temporary steel casing, or alternative methods of temporary ground support as determined by the designer with regard to local geological conditions. The concrete may be either plain or reinforced. The holes may be of either constant diameter or have belled ends. Reinforcement, when used, shall be detailed in accordance to the requirements of ACI 336.1. Special care shall be used when determining cover and clear space requirements in the splice locations. The portion of the drilled shaft that is not supported laterally by the adjacent ground shall be designed as a reinforced concrete column in accordance with Chapter 8 - Structural Materials. The reinforcing steel shall extend at least 10 feet below the plane where the soil provides adequate lateral restraint. The use of slurry or other hydrostatic support methods shall be considered in adverse soil conditions only with the written approval of DART.

17.2.7 Auger-Cast Piles

Auger-cast piles shall be constructed by rotating a continuous flight hollow-shaft auger into the soil or rock to a specified founding depth and placing Portland cement mortar under pressure into the hole through the hollow shaft as the auger is withdrawn. While auger-cast piles are generally unreinforced, a single piece of reinforcement may be placed at the pile center through the hollow shaft of the auger, or reinforcement may be provided near the pile top by placing it before the mortar has obtained its initial set. Auger piles may be either friction or end-bearing piles. They will generally have a diameter of between 12 and 16 inches and will be constructed from cement mortar with a 28-day compressive strength greater than 2,000 psi.

As structural members, auger-cast piles have a low lateral resistance and shall not be used to resist lateral design loads without a complete design proof that the pile has adequate capacity. Since auger-cast piles also have low resistances to tensile forces, they shall not be used to resist uplift forces without sufficient prior evidence that sufficient effective tensile reinforcement can be provided to transmit uplift forces from the footing or pile cap through the pile to the surrounding ground.

17.2.8 Other Types of Deep Foundations

At the discretion of the designer, alternative designs for deep foundations not presented in these criteria may be submitted to DART for approval. The submission shall include the full structural and geological conditions under which the foundations are to be used. It should be accompanied by detailed drawings, construction method statements, testing procedures, and a frequency of testing schedule.

17.2.9 Corrosion Protection

Where corrosive conditions are anticipated, encasement or a coal tar epoxy protective coating shall be used on steel piles and shells or as recommended in Systems Design Criteria Chapter 8 - Corrosion Control. If encasement or a coating is not provided, a 1/16-inch thickness shall be deducted from all exposed surfaces when computing the area of steel in the piles and shells.

17.3 DESIGN

The designers shall select a foundation type based upon conditions prevailing at the site and on cost, availability, and the desire to achieve competition among the suppliers of alternative materials.

Drilled piles and piers are preferred for use near existing facilities where the impact from pile driving might result in damage, where noise and vibration restrictions may prohibit pile driving, and where subsurface conditions or restraints might impede pile driving.

Deep foundations shall be designed to withstand the loads and forces transmitted thereto. They shall be designed to carry the entire applied load, including any surcharge load above the footing. The material immediately under a footing supported on deep foundations shall be assumed to have no capacity to support vertical loads.

17.3.1 Uplift

In the design of deep foundations, the possibility of uplift loads shall be investigated. In addition to any hydrostatic uplift or expansive soil pressure, provisions shall be made to resist uplift should any loading or combination of loadings, when increased by 100 percent of the design live load, produce uplift on any deep foundation or portion thereof. Design live load shall be understood to include any surcharge loads applied to simulate any undefined live loads that may exist at the ground surface.

Provided proper structural provisions are made for the anchorage at the pile or shaft head, deep foundations may be considered to resist uplift forces. In the case of a pile group, the uplift resisting capacity of the group shall not exceed the weight of material (buoyancy considered) within the group.

The uplift capacity of pile foundations shall be established by the designer based upon geotechnical design parameters recommended by the geotechnical subconsultants. Deep foundations shall not be required to sustain uplift from sustained f(dead) loads. The factors of safety for both individual piles and for pile groups shall be provided by the geotechnical subconsultants.

17.3.2 Lateral Resistance

Consideration shall be given to the ability of deep foundations to adequately resist lateral loads. When the lateral resistance of the soil surrounding piles is inadequate to counteract the horizontal forces transmitted to the foundation, or when increased rigidity of the entire structure is required, battered piles may be used in the foundation. Piles shall not be battered more than 1 (horizontal) to 3 (vertical). Where battered piles are used, consideration shall be given to prevent the possibility of such battered piles encroaching on property outside the DART right-of-way.

The axial loads on deep foundation groups shall be determined by the static analysis of the moment-resistant group, the method of elastic center, or by any other satisfactory method. In addition to the horizontal component of the axial load on battered members, each reinforced member, vertical or battered, in a deep-foundation group may be assumed to have a lateral resistance capacity equal to the least of the following values:

- Resistance capacity computed by the designer based upon the subsurface material properties.
- Capacity of the pile or shaft as a structural member.

Because an unreinforced concrete structural element has essentially no moment capacity, it shall be assumed to have no lateral capacity as a structural member. Unless a pile or other deep foundation structural member is driven or founded at a depth in competent material sufficient to develop full fixity, its capacity to resist lateral loads in bending must be analyzed.

17.3.3 Settlement

Based upon site-specific subsurface conditions, the designer shall give full consideration to the long-term settlement and lateral displacement of deep foundations.

17.3.4 Pile Length

The "Estimated Tip Elevation" shall be indicated on the contract drawings only to show the basis for quantity estimates. The length and carrying capacity of piles shall be determined by the application of the appropriate test loads or formulas.

17.3.5 Spacing, Clearances, and Embedment

Deep foundations shall be spaced at a center-to-center minimum of 3 feet. A minimum of 9 inches shall be provided from the edge of the footing to the edge of any pile. In no case shall the distance from the edge of the footing to the center of any pile be less than 1 foot 6 inches, however. The minimum spacing of drilled shafts shall be designed in accordance with the subsurface characteristics of the site. (See Chapter 10 - Geotechnical Information.)

Where deep foundations involve caps, the tops of deep foundations shall be embedded at least 6 inches into concrete footings or caps, and reinforcing steel shall be extended to develop a suitable anchorage. The tops of steel piles shall be embedded at least 6 inches into concrete footings or caps. The bond between the embedded length of a steel pile and the footing concrete shall not by itself be considered effective in the transfer of either compressive or uplift loads. (See sections 17.2.3 and 17.2.4.) For all piles, plumb and battered, the embedment length shall be measured vertically.

17.3.6 Test Piles and Shafts

Based upon the DART Facilities Standard Specification, the location and frequency of testing drilled piles or piers shall be determined by the designer. The testing program shall include both load testing and material integrity testing so that any variations in pile and shaft capacity and in geological conditions will be encountered and evaluated.

17.4 DESIGN CAPACITY

The design capacity of a deep foundation shall be the least of the values determined below. The values determined by the application of each of these criteria shall be estimated by using parameters defined by subsurface investigations. Sufficient tests to justify the assumed design values used for the particular condition of support under consideration may also be used to determine these values.

Consideration shall also be given to:

- The difference between the supporting capacity of a deep foundation member and that of the foundation group.
- The capacity of the underlying strata to support the load on the deep foundation group.
- The effects of foundation installation and the influence of loads on adjacent structures.
- The possibility of scour and its effects on foundation capacity.
- The effects of negative skin friction.
- The method of construction/driving and the time-dependent load capacity.
- The effects of loads from existing adjacent structures.

Deep foundations shall be designed as structural columns. Concrete structural members, and steel piles shall be designed according to the column provisions of Chapter 8 - Structural Materials, except that the allowable unit stresses may be increased 20 percent for concrete-filled steel pipes. For steel-cased piles, the area of the shell shall be included in determining the value of the percentage of reinforcement where the shell is more than 0.12 inch in thickness (after deducting the 1/16-inch thickness allowance for corrosion specified in section 17.2.9).

End-Bearing. A deep foundation shall be considered to be end-bearing when placed or driven on or into a material capable of developing the design load by direct bearing at the tip. (Whether or not a deep foundation is end-bearing shall be determined by investigating the site as described in Chapter 10 - Geotechnical Information.) The load at the tip of the deep foundation shall not exceed the following:

- Concrete members. The capacity at the tip.

- Steel piles. 10,000 psi multiplied by the net cross-sectional area of the pile tip.

Friction. A deep foundation shall be considered to be frictional if its tip does not rest on or in a material capable of supporting the full design load by direct bearing at the tip. Where a deep foundation is socketed into rock and obtains some of its capacity from friction between the concrete and rock, the capacity attributable to such frictional resistance shall be determined by the designer after consideration of the site-specific geotechnical data. (See Chapter 10 - Geotechnical Information.)

The load-carrying capacity of friction foundations shall be estimated by one or more of the following methods:

- The installation and loading of test foundations.

- Previous installation experience in the vicinity. When piles are designed on the basis of experience in the vicinity, consideration shall be given to the variation in their types and lengths and in the variation of the soil strata. Where possible, the complete installation records of all deep foundations in the vicinity shall be examined and compared to the installation records of the proposed foundations.

- Adequate testing of the soil strata through which the foundation is to be installed. The designer shall request tests to determine friction values for design. If possible, the tests should be projected and compared to tests of similar material through which deep foundations of known capacity have been installed.

Combined Friction and End-Bearing. Depending upon the structural arrangement, and if indicated by geotechnical design parameters, a deep foundation may be considered to derive its load-carrying capacity from a combination of end-bearing and skin friction. Suitable safety factors for each element of load capacity shall be used.

Required Geotechnical Investigations. In general, geotechnical investigations shall be in accordance with the geotechnical chapter. The capacity of the ground to support the load delivered by the deep foundation shall be determined from site-specific geotechnical investigations. (See Chapter 10 - Geotechnical Information.)

17.4.1 Pile or Drilled Pier Group Loading

Single Pile or Drilled Shaft. A single row of piles or drilled piers shall not be considered to act as a group if the piles or piers are center-to-center spaced more than three times their nominal diameter or dimension. In those cases where piles are installed in groups, a definite allowance shall be made for the difference between the carrying capacity of a single pile and that of a group of piles.

End-Bearing Piles or Drilled Shafts. In the case of grouped end-bearing piles or drilled piers resting on bedrock with a center-to-center spacing of at least three times their nominal diameter or dimension, it shall be assumed that a group of "n" piles or piers will safely carry "n" times the carrying capacity value of a single pile or pier, provided the bearing capacity of the base material is not exceeded.

Friction Piles. Where the carrying capacity of a group of friction piles installed into plastic materials is not determined by test loading, the following Converse-Labarre formula is suggested as one method of determining the capacity of the pile group:

$$P = Pi \ mn - \left(\frac{A}{90}\right)(m(n-1) + n(m-1))$$

and

$$A = \text{Arctan}(d/s)$$

Where:

P = total capacity of pile group
Pi = capacity of individual pile
n = the number of piles in each row
m = the number of rows in each group

A is numerically equal to the angle expressed in degrees
d = the average diameter of the pile, and
s = the center-to-center spacing of the piles.

17.5 PROCEDURES AND SEQUENCES OF INSTALLATION

Any limitations on construction operations inherent in the design considerations and assumptions shall be approved by DART in addition to being noted on the contract drawings and referenced in the special provisions. These are especially important when the work to be done is near existing buildings or roads.

CHAPTER 18 - MINED TUNNELS AND STATIONS

18.1 INTRODUCTION

This chapter provides criteria for the design and construction of DART subway tunnels constructed by boring or mining methods. Except at such access points as portals and shafts, these tunnels do not break the ground surface. In addition to the design guidelines contained in this volume, the DART structures shall generally be designed according to the following:

- o Structures supporting transit and highway loads shall be designed according to Standard Specifications for Highway Bridges (American Association of State Highway and Transportation Officials, AASHTO; hereafter cited as such).

- o Concrete structures supporting non-transit or non-highway loads shall be designed according to Building Code Requirements for Reinforced Concrete (American Concrete Institute, ACI 318; hereafter cited as such).

- o Steel structures supporting non-transit or non-highway loads shall be designed according to the requirements of Load and Resistance Factor Design Specification for Structural Steel Buildings (American Institute of Steel Construction, AISC; hereafter cited as such).

- o Structures supporting railroad loads shall be designed according to the Manual for Railway Engineering (American Railway Engineering Association, AREA; hereafter cited as such).

Prior to commencing design work, the section designer shall submit to DART for approval the list of codes and specifications to be used, indicating the areas where they will be used.

18.2 SUBSURFACE INVESTIGATIONS

At the beginning of detail design, the section designer shall evaluate the existing subsurface information. If additional information is required, the designer shall submit a request in writing to DART for that information. The request shall include the proposed locations of additional borings or other explorations and the types and locations of associated tests, measurements, or observations.

18.3 ROCK TUNNELS

This section applies to tunnels constructed entirely within the Austin chalk limestone formation (which can sometimes contain shale or shaley layers). To qualify as a rock tunnel segment, a running tunnel segment shall have at least half a diameter of unweathered and unaltered rock (competent rock) around the excavated tunnel above the invert slab, and at least 5 feet of competent rock under the excavated invert.

Where unfavorable conditions exist, such as clustered fractures, bentonitic seams, or any other unfavorable conditions occur within the zone of influence of the tunnel, either the distance to the excavated tunnel shall be increased appropriately or the support system shall be intensified. The zone of influence of the tunnel corresponding to these unfavorable conditions shall be determined by the designer based on the site-specific conditions.

18.3.1 Design Parameters

All parameters considered pertinent by the designer shall be used. These include the effects of geology and the groundwater regime; e.g., the impermeability of the intact rock and the transmissivity characteristics of the discontinuities. These discontinuities include faults, fractures, or special conditions such as bentonitic seams. Attention shall be given to the number, location, attitude, and characteristics of any discontinuities.

18.3.2 Excavation Methods

Excepting special circumstances, mechanical excavation in the form of tunnel boring machines (TBMs) or roadheaders will be used. As a result of using mechanical excavation, both overbreak and major abrupt local peripheral offsets will be minimal. Blasting will not be permitted.

18.3.3 Cross-Section

The tunnel configuration shall be selected by considering the prevailing stress conditions and ground mass strength in association with simplicity of construction. The finished internal dimensions of permanent tunnels on tangent alignment shall not be less than those shown on the standard and directive drawings. The effect of horizontal alignment curvature, track super-elevation, chorded construction, car dynamic outline, and so forth shall be in accordance with Chapter 1 - Track Alignment.

18.3.4 Groundwater Control

Groundwater intrusion from individual water-bearing discontinuities should be treated on an individual basis. All such discontinuities shall be drained to the invert drainage system. Consideration shall be given to possible fines in groundwater when evaluating perimeter drainage design.

18.3.5 Stabilization Systems - Design Concept and Support Methods

Designers shall investigate the stability of tunnels and the loading conditions on tunnels in three ways. First, the stresses at conditions of equilibrium after excavation shall be evaluated with respect to rock strength. Second, based on established empirical rock mass classification systems, estimates of rock support shall be evaluated. Third, the conditions of potential rock wedges and roof blocks shall be evaluated. Based on these analyses, the designer shall propose stabilization system designs for each tunnel reach by using a rock reinforcement system, a direct rock support system, or a combination thereof.

Rock Reinforcement. The use of untensioned rock dowels and shotcrete individually or in combination shall be designed to interact with the rock mass and provide an adequate structural unit. In special situations, the use of pretensioned rock bolts may be warranted.

Direct Rock Support. Structural elements (i.e., steel ribs and lagging, precast concrete segments, lattice girders and shotcrete, or steel liner plates) shall be used to provide direct support of the unstable rock around the opening.

In typical single-track tunnel conditions, shotcrete may not be required for stabilization purposes. However, a fiber-reinforced or wire-reinforced typical shotcrete liner of 2-inch nominal thickness shall be provided to maintain the quality of the in-situ rock surface and conditions.

18.3.6 Rock Pillars

Except where tracks must converge, for example at crossovers, tunnel transitions, or approaching stations, the minimum clear distance between tunnels shall not be less than one excavated tunnel diameter. In such cases, the rate of convergence is a factor. The absolute minimum rock pillar width shall be 5 feet and may be used only when the pillar walls are converging at a rate equal to or greater than 1 foot in 5 feet. This equates to a number 10 double crossover. Elsewhere the minimum pillar width shall be 10 feet. Where exceptions to the latter are necessary in special situations, the pillar stresses, including stress concentrations, shall be investigated and maintained at a level considered safe by the designer.

18.4 SOFT GROUND TUNNELS

Ground incapable of supporting itself for any period of time, which therefore needs essentially immediate and continuous support, shall be classed as soft ground. Such ground may be non-cohesive (e.g., clean sand), partially cohesive (e.g., silty sand), or cohesive (e.g., clay). Moderately to heavily weathered rock that has lost most or all of its self- supporting capability shall be considered as soft ground.

18.4.1 Construction Methods

All soft ground tunnels shall be shield-driven tunnels unless specifically approved otherwise by DART.

18.4.2 Groundwater Control

Tunnels shall be designed so that the infiltration of groundwater into the tunnel shall not exceed 0.2 gpm in any 250 linear feet nor more than 0.1 gpm in any 50 linear feet for a single track tunnel. Twin-track tunnels may have twice the above amount.

18.4.3 Design of Support System

Design Method. The support system shall be designed to maintain the stability of the excavated tunnel and to minimize ground subsidence. Tunnel lining design shall use analytical and numerical methods that consider ground-support interaction by evaluating the stiffness of the lining and the stress/strain characteristics of the surrounding soil mass. For the design of initial support, the allowable compressive stress can be increased by 25 percent. Where possible, designers shall incorporate the initial support system in the final lining and shall recommend appropriate corresponding reductions to the final design load conditions. If steel rib beams are used, shotcrete between beams shall be considered only for bridge action. If lattice girders are used, however, composite action between lattice girders and shotcrete can be considered.

Loadings. Factors to be considered during tunnel design shall include the following:

- Overburden.
- Water pressure.
- Surface surcharge.
- Adjacent tunnels.
- Adjacent existing structures or future construction.
- Construction loads (including the possibility of damaging the tunnel lining due to TBM jack forces).

Support System. A support system in soft ground tunnels may consist of the following:

- Steel ribs and lagging as initial support, with a cast-in-place concrete lining as a final lining;
- Precast concrete segments;
- Shotcrete, with or without cast-in-place concrete as a final lining; or
- Steel liner plates.

18.4.4 Tunnel Spacing

The clear spacing between twin tunnels generally shall be one excavated diameter. The absolute minimum clear spacing shall be 0.4 excavated diameters at the ends of a double crossover, and 0.6 excavated diameters for total tapers flatter than 1:5. This equates to a number 10 double crossover.

18.5 MIXED-FACE TUNNELS

Mixed-face is normally defined as the presence of both soft ground and rock in the excavation face. This definition shall be expanded to include ground of two or more types requiring markedly different excavation procedures; for example, limestone and water-sensitive shale in a rock formation.

The design of mixed-face tunnels shall be site specific and shall be appropriate to the conditions encountered. Potential shrinkage and swelling problems in shale and clays shall be addressed. To minimize the potential weathering of the shale, the design shall include provisions for protecting the surface of the shale from air and moisture within 4 hours of exposure.

18.6 STATION CAVERNS

This section applies only to station caverns mined entirely within the Austin chalk limestone formation. It also may be applied, with appropriate modifications, to the single-span portion of double crossovers and vent chambers.

18.6.1 Waterproofing

Groundwater control in station caverns shall be executed in the same manner as described in section 18.3.4 of this chapter. In addition, because stations are public areas, more positive groundwater control measurements shall be implemented. Architectural finishes such as precast concrete panels shall be installed in the public areas of stations. Special waterproofing treatment shall be applied to the architectural finish and connection joints.

18.6.2 Cross-Section

All caverns shall have an arched roof. The rise-to-span ratio generally shall not be less than 1:3. Consideration may be given to reducing the rise-to-span ratio if analyses indicate tunnel stability.

18.6.3 Support System Design

For design of the support system for station caverns, refer to section 18.3.5.

18.6.4 Construction

Shotcrete shall be used in conjunction with a furred-out architectural finish or a cast-in-place concrete final lining in station caverns.

18.7 MISCELLANEOUS

18.7.1 Catenary Support

Provision shall be made in all tunnel designs for the overhead catenary support. For the location of the catenary feeders in tunnels, see the tunnel directive drawings.

18.7.2 Tunnel Appurtenance Installation

Provision shall be made for the fixing of all cables, signal equipment, pump mains, and other fixed equipment in the locations directed by the standard and directive drawings and these criteria.

18.7.3 Tunnel Drainage

Tunnel drainage sumps shall be provided at or near the lowest point of each section. Tunnel sumps shall be designed according to Chapter 30 - Plumbing and Drainage Systems and System Design Criteria Chapter 7 - Drainage. Where a mined tunnel connects to an open-cut approach, a drain shall be provided in the tunnel invert approximately 30 feet from the portal.

18.7.4 Ventilation Shaft

The loadings imposed on the shaft by the surrounding ground shall be determined by the designer in accordance with the subsurface investigation and the shaft configuration.

18.7.5 Portal

Portals between tunnels and open-cut box sections shall be designed in a manner to minimize the rate of change of air pressure (the piston effect) from a train passing through the portal.

18.7.6 Settlement

The effects of possible differential settlement at existing adjacent buildings, bridges, sewer tunnel, roadway, and so forth due to tunneling shall be taken into account in the design.

18.7.7 Heave

The effects of heave can be ignored in single-track tunnel configurations when there are more than 5 feet of limestone (including any transition zone) below the excavated invert. Elsewhere, when there is a depth of limestone below the excavated invert equal to or less than 5 feet, the effects of heave due to stress relief or other factors shall be considered.

18.7.8 Stress Concentrations

Special attention shall be taken of the stress concentrations of all tunnel intersections.

18.7.9 Cross Passages

The distance between tunnel crosspassages shall not exceed 800 feet.

18.7.10 Corrosion Control

Corrosion control measures shall be included as detailed in Systems Design Criteria Chapter 8 - Corrosion Control.

18.8 INSTRUMENTATION

Contract documents shall contain requirements for a subsurface monitoring system.

18.8.1 Techniques and Equipment

Designers shall propose a detailed instrumentation program to monitor the behavior of subsurface structures during construction and operations. The program may include the appropriate types and number of monitoring instruments, some of which may be as follows:

- o Convergence pins within the tunnel to monitor the relaxation of the soil, rock, support system, and lining.
- o Borehole extensometers installed from either inside the tunnel or from the surface to monitor rock and soil mass displacements.
- o Surface survey monuments to measure tilt and vertical deformation of the ground surface and adjacent structures.
- o Inclinometer casings installed from the surface to monitor the development of subsurface lateral displacements caused by the horizontal relaxation of the soil or rock mass into the tunnel.
- o Piezometers to monitor local groundwater levels during construction.
- o Strain gauges to monitor the development of deformation within the shotcrete or reinforced concrete lining and to indicate the time rate and distribution of load around the tunnel.
- o Load cells to measure loads exerted on the liner, as well as loads within the liner.

- Vibrational measurements to monitor the effect of excavation operations on adjacent structures.

18.9 ALTERNATE DESIGN

If the designer determines that overall construction economy can be achieved through the preparation of an alternate design for a particular tunnel, the designer shall recommend this design to DART.

18.9.1 Design Approach

The designer shall consider the various construction methods appropriate to the contract under design. Where applicable, alternatives shall be provided by the designer.

18.10 EMERGENCY ACCESS/EGRESS PROVISIONS

There shall be adequate provisions for access and egress by emergency rail vehicles and crews and other emergency personnel to and from the guideways. Emergency egress shall be provided to allow patrons to evacuate a train at any point along the guideway and either proceed to an exit at the nearest station or await evacuation. The emergency egress shall consist of fire-resistive stairways and passageways supplementary to access for underground guideways at stations and portals. A transition in the walkway shall be provided at all underground-to-at-grade abutments. Emergency exit stairways shall be provided throughout the tunnels, spaced so that the distance to an emergency exit shall not be greater than 1,250 feet, unless otherwise approved by the authority having jurisdiction. Where trainways in tunnels are divided by minimum two-hour rated firewalls, or where trainways are in twin bores, such an arrangement shall be deemed to afford adequate protection for the passenger via crosspassageways between the trainways. These arrangements may, therefore, be used in lieu of emergency exit stairways to the surface. The travel speed and capacity of walkways and/or walking surfaces shall be in accordance with Section 2.5.3 of Fixed Guideway Transit Systems (National Fire Protection Association (NFPA) Standard 130, latest edition).

CHAPTER 19 - STATION SITE REQUIREMENTS

19.1 INTRODUCTION

This chapter establishes guidelines for the design of DART light rail stations. The major goal for this section is to create a site design for each station that satisfies operational demands. The station should also contribute to the aesthetics of its location. Site design shall follow the architectural concept of a systemwide cost-effective approach to design.

The locations and boundaries of station sites, adjacent street improvements, and station locations have been established by DART and are shown on the Preliminary Engineering Drawings for each station. Provisions for handling the pedestrian and traffic flow are reflected on the Preliminary Engineering Drawings. For additional information, see Chapter 4 - Streets, Highways, and Parking. Functional consistency shall be assured for the benefit of system patrons.

19.2 STREETS, PARKING FACILITIES, AND SITEWORK

19.2.1 Mode-of-Access Priorities

Since all modes of access to a station cannot be given equal priority, a hierarchy has been established.

1) Pedestrians. All patrons accessing the stations become pedestrians at some point. For reasons of safety, the pedestrian mode shall be given first priority.

2) Bus Areas. The total public transportation network envisioned includes both rail and buses. Since feeder buses will play a crucial role in determining the ultimate success of Light Rail Transit, buses shall be given priority over other vehicular modes of access. Bus bays in the site shall be located as close as possible to the platform or station entrance. Bus access to and egress from the site shall not be compromised by other modes of transportation.

3) Kiss-and-Ride Area. Kiss-and-ride spaces allow high volumes of patrons to access stations in short periods with relatively few special facilities provided. Kiss-and-ride and drop-off spaces convenient to the station entrance or platform will provide incentive not to stop on adjacent public streets. Therefore, second vehicular priority shall be given to the kiss-and-ride facility. Kiss-and-ride spaces shall be as close as possible to the station platform without interfering with the bus facilities. Waiting time in the afternoons and evenings is considerable greater, since the person driving will usually arrive at the station before the transit patron. Right-hand drop-off, usable by the handicapped, shall be provided where possible to promote better morning service and to provide for effective use by taxis. Head-in parking may be utilized when space is limited or less than 3 Kiss-and-Ride spaces are required provided spaces are 10 foot minimum in width.

Kiss-and-Ride spaces are to be provided based on the one space per 450 daily boardings, with no less than 3 provided.

4) Park-and-Ride Area. If required by site conditions, park-and-ride areas, whether at-grade or structured, shall be located at a greater distance from the station entrance than bus bays or kiss-and-ride areas. The recommended walking distance from the station entrance to the most remote parking space shall be 600 feet; 1,000 feet shall be the maximum, unless approved by DART. Designated motorcycle spaces shall be provided. If necessary, these could be converted into regular parking spaces in the future. Parking spaces and aisles should be designed to allow efficient and safe pedestrian access to the station.

19.2.2 Pedestrian Access

Depending on the location and function of a station, the relative importance of pedestrian access will vary. In all cases, however, pedestrian access to the station shall be as direct and safe as possible.

Approaches. Pedestrian crosswalks shall be emphasized with an obvious contrasting change in paving material, surface texture, or color. The width of the crossing shall be at least equal to the width of the adjacent pedestrian walk, but not less than 6 feet. Pedestrian crosswalks shall have good visibility for both pedestrians and drivers. No pedestrian ramp within the station site shall have a slope greater than 5 percent. Parking areas shall be arranged to minimize the number of pedestrian crossings of streets, access roads, and vehicular circulations aisles. Pedestrians shall have the right-of-way over vehicles at all crossings for internal circulation.

Walkways. Isolated and remote or hidden pedestrian walkways shall be avoided. Where avoidance is not feasible, they shall be as open and well-lighted as possible. The effective width of exterior walks shall be equal to the total width minus obstacles such as parking meters, poles, fire hydrants, and trash cans. An additional 1- to 1-1/2-foot fringe area per side shall be subtracted due to the tendency of people to avoid walking close to walls or barriers. The actual minimum walkway width within the station site is 6 feet. Walks shall have a continuing common surface not interrupted by steps or abrupt changes in level. Wherever walks cross other walks, driveways, or parking lots, they shall merge to a common level.

At-Grade Platform Crosswalks. Pedestrian track crosswalks shall be required at most at-grade stations. Crosswalks shall meet the following conditions:

- From the crosswalk (outside of the train dynamic envelope), there must be good transit-patron visibility for 600 feet in both directions along the tracks. (Refer to Systems Design Criteria Chapter 4 - Signals System for warning signs and devices and Chapter 12 – Systems Safety.)

- Crosswalks must be emphasized with an obvious contrasting change in paving material, surface texture, or color. Warning strips complying with ADA requirements must border the track crosswalk at the platform. The width of the crossing shall not be less than 10 feet.

- Except at tracks, crosswalks shall have a continuing common surface. Where possible, they shall not be interrupted by steps or abrupt changes in level.

- Crossings shall be lighted to a minimum of 2 foot-candles, but the lighting must not interfere with track visibility.

- The number of crossings shall be minimized.

- Crossings shall be at consistent locations at each station.

19.2.3 Bus Facilities

As stated in section 19.1.1, buses shall be given priority in terms of vehicular access.

__Bus Lanes__. Bus lanes shall be one-way only through the station site and shall be a minimum of 24 feet wide to allow buses in motion to pass stopped buses. The minimum outside turning radii of bus lanes shall be as indicated in Chapter 4 - Streets, Highway, and Parking, plus and extra 5 feet to allow for the front overhang of buses. Bus lanes shall be 30 feet in width where the lane also serves as Fire Department access.

__Bus Bays__. To alleviate the necessity of buses backing up to maneuver around other buses and to reduce the length required by in-line bus bays, shallow sawtooth bus bays shall be used wherever possible. (See the project definition drawings for dimensions, quantities, and configuration.) Bus bays shall be designed to allow the loading and unloading of passengers from the right side of the bus to pedestrian paths. Bus bays shall be oriented so that bus patrons do not need to cross traffic to reach a station platform or entrance, unless approved by DART.

19.2.4 Kiss-and-Ride Facilities

Convenience and safety are prime design objectives. Kiss-and-ride facilities shall have second priority in vehicular access and, where possible, shall have separate access points.

__Access Roads__. Access roads shall be single lane with a minimum width of 20 feet to allow space to maneuver around a stopped vehicle. When possible, the kiss-and-ride traffic shall not be routed through the park-and-ride areas, but instead should use the circulation roads or the access roads. Kiss-and- ride traffic circulation through the station shall be one way wherever possible.

Configuration. Wherever possible, kiss-and-ride spaces should be oriented so that the waiting driver can watch the station exit or platform. Since drive-through spaces promote better circulation, they shall always be considered as the first configuration choice. Site constraints will determine whether drive-through or head-end spaces are provided. (See the Preliminary Engineering drawings for additional information.) Drop-off zones shall be incorporated into the kiss-and-ride areas to promote better morning service and for taxis in the nonpeak hours when they cannot use the kiss-and-ride spaces. Drop-off zones shall be parallel to the curb at the passenger side. Angle parking of 45 degrees to the direction of travel is preferred, but up to 60 degrees is acceptable. Parallel parking may be used if land constraints demand. Wherever possible, use single direction (one way) aisles should be used.

19.2.5 Park-and-Ride Facilities

Park-and-ride facilities will be defined in the Preliminary Engineering drawings. The amount of parking space at a particular station will depend upon the traffic potential, the ability of the street system to feed the station, and the availability of land. (See the project definition drawings for specific station requirements.) The siting of parking facilities shall be in accordance with the local ordinances.

The minimum parking space width is 8'-6". No compact parking spaces are allowed. Handicapped parking is to be provided in accordance with the Texas Accessibility Standards (TAS) and the ADA Accessibility Guidelines.

Parking facilities may be at-grade initially with provisions for structured parking in the future, or structured parking with expansion capability. (Refer to Preliminary Engineering Drawings for park-and-ride requirements.) Whenever possible, two access/egress points shall be provided.

If paid parking is incorporated in the park-and-ride areas, slot boxes are the preferred method of fee collection. If gates are to be installed, provisions shall be made to allow for parking payment to occur either on entering or exiting the site area. Although the installation of control devices may not be made initially, the ability to have paid parking at or near the parking stalls or upon entry/exit shall be designed into all park-and-ride facilities.

The park-and-ride facilities shall be designed for self-parking. Ninety-degree parking is preferred. Motorcycle spaces shall be 4 feet wide by 8 feet long. Concrete paving is required. Aisles shall be two-way for 90-degree parking and one-way for angled parking.

DART Maintenance Parking. Provision for a minimum of one maintenance vehicle parking space shall be made at each station. Vehicles shall be able to access the facilities without impeding bus or pedestrian traffic.

At-Grade Parking. Large parking lots shall be subdivided into sections to reduce the scale. Walkways and landscaping shall be used for this purpose, but vehicular movement between sections shall not be restricted. Although landscaped, the parking areas shall be open enough to allow good surveillance by DART security personnel.

Parking Garages. Parking garages shall be concrete structures and shall conform to the criteria set forth in the first four paragraphs of this section. Elevators shall be provided in parking structures that exceed three levels (two levels above-grade), and as required for handicapped patrons or employees. Elevator locations shall be as close as practical to the platform or station entrance. (Refer to the vertical circulation and architectural project definition drawings for these and other site-specific considerations.) Parking structures shall conform to the following:

o Minimum vehicular clearance height:	7 feet 6 inches.
o Ramp grades:	
- Parking on ramp	5 percent maximum.
- No parking on ramp	5 percent desirable; 8 percent maximum.
o Width of entrance/exit lanes	12 feet.
o Width of one-way entrance/exit lane	16 feet.
o Aisle turning radii	16 feet inside; 30 feet outside.
o Curb height	6 inches.

Parking garage design shall be simple, functional, economical, and with minimal ornamentation. Architectural compatibility with the station shall be achieved through similarity of materials, conservation, and landscaping.

19.2.6 Vehicular Access

Refer to Chapter 4 - Streets, Highways, and Parking. Access to and exit from parking facilities shall be in accordance with local building and fire codes.

Separation of Modes of Access. Due to the differing circulation needs and priorities assigned to buses, kiss-and-ride, and park-and-ride facilities, the separation of vehicular modes of access shall be provided wherever possible.

19.2.7 Bicycle Facilities

Provisions shall be made for access to and egress from stations by bicycles, and space should be provided at station sites for their storage. Bicycle racks shall be placed near the platform or station entrance. Bicycle lockers, if used, shall be similarly placed, or shall be placed in parking structures. Their placement shall not compromise pedestrian walkways nor detract from the architectural quality of the station.

Bicycle Paths. Bicycle paths shall be provided as an integral part of the sitework. When bicycle paths meet with station areas where pedestrians are encountered, they shall remain separate from pedestrian walks. When separation is not possible, cyclists will be expected to walk their bicycles. Special provisions for cyclists, such as wide turning radii, shall NOT be made in these pedestrian/bicycle areas. Bicycle paths shall be a minimum of 8 feet wide. Turning radii shall be a minimum of 15 feet, but 30 feet is preferable.

Bicycle Parking. Provisions shall be made for parking of bicycles in the station area. A minimum of 1 bicycle rack to accommodate a minimum of 7 bicycles shall be provided. A minimum of 1 bicycle locker accommodating 2 bicycles shall be provided. Additional racks/lockers shall be provided as required by local ordinances or at the request of the community.

19.2.8 Facilities for the Elderly and Handicapped

These provisions are intended to make all station sites and facilities used by the public accessible and functional for the physically handicapped and elderly.

Parking Spaces. Elderly and handicapped parking spaces shall allow room for individuals in wheelchairs, with braces, or on crutches to get in and out of an automobile and onto a level surface suitable for wheeling and walking. Care shall be exercised in planning walkways so that those individuals are not compelled to wheel or walk behind parked cars. Parking spaces as close as practical to the platform or station entrance shall be set aside and identified in the park-and-ride and kiss-and-ride areas for use by individuals with physical disabilities as required by the Americans with Disabilities Act (ADA) and the Texas Accessibility Standards (TAS).

Walkways. Ramps and curb cuts shall be furnished as required to provide safe and convenient circulation by the elderly and handicapped to and from the station. Ramps shall be located so that they are not obstructed by parked vehicles and are not intruding into vehicular traffic lanes. For curb cut details refer to Chapter 4 - Streets, Highways, and Parking. Walkways shall not have a gradient greater than 5 percent or a cross slope greater than 2 percent.

19.3 LANDSCAPING

19.3.1 Basic Requirements

These landscape architectural design criteria have been established to provide the designer with the landscape requirements that will allow the development of unified DART stations. They establish specific plant and material uses and provide a "palette" of design devices that allows for the development of low-maintenance landscape areas. Each station design will be site specific, but the design shall fall within the parameters of the basic goals.

The basic goals of these landscape architectural design criteria are the following:

- o Create a pedestrian environment projecting a sense of quality and visual identification of the DART station. Landscaping shall be designed to provide mitigation of adverse visual impacts where applicable and appropriate.

- o Provide a safe and vandal resistant station.

- o Assist the pedestrian in making the logical choices and progressions through the station. Promote safe pedestrian movements by providing appropriate barriers and directional control.

- o Create a station setting that becomes a part of the particular neighborhood and compliments the established streetscape/surroundings, expressing local historical and cultural information while conforming to all applicable codes and regulations.

- o Provide landscape architectural components that are standardized to the extent that system-wide elements have continuity, but that individual stations have unique characteristics.

- o Provide compatibility of landscape architectural elements with the architecture of the stations, graphics and lighting to create a harmonious and unified rail system.

- o Provide the proper grading and drainage criteria in conjunction with civil engineer input.

- o Make provisions for the design guidelines to fit within the budget allocations for planting/irrigation/hardscape at each station.

- o Utilize site elements, both in terms of vegetative materials and hardscape features that have a high probability of survival. Utilize indigenous/adaptable plants and local construction materials to attain this goal.

- Provide landscaping with low maintenance requirements and plant materials that are non-toxic.

- Define landscape spaces where art and the site are woven together to create a sense of arrival, destination, and excitement in the user. These landscape spaces shall guide the flow of the patron and automobile and function as public gathering spaces.

19.3.2 General Criteria

Based on the above goals and in light of the unique environmental conditions of the DART Service Area, the following landscape design criteria ensures the cohesiveness of the final design form.

Climate Control. The placement of the plant materials (Shrubs, trees, ground cover, grass, and so forth) and landscape elements shall create a beneficial microclimate regarding sun and shade patterns. Desirable and undesirable winds and breezes shall be utilized and baffled as much as possible. Landscape elements, such as walls and berms with planting, shall promote noise reduction in areas of heavy traffic.

Height Requirements. Landscaping other than trees should not exceed three (3) feet in height for both security and safety reasons. The only exceptions will be taller hedges required per landscape ordinance requirements or to address neighborhood concerns and Art and Design committee requests.

Movement Control. The patrons must have unobstructed access to the transit system. There shall be a clearly defined separator/landscape area from bus and auto traffic wherever possible. Waiting areas at bus stops and kiss-and-ride areas shall be pleasant and comfortable for short-term use with shade trees, but shall be visibly open for security reasons. Patrons must never feel trapped or unsafe. Bicycle patrons must not be encouraged to create hazardous conditions for pedestrians or vehicular patrons. Physical barriers such as bollards, fences, railings, and planting may be used where appropriate to separate and control movement. Bollards, boulders or similar devices may be used to prevent bus and other vehicles from damaging landscaping at inside turning movements.

Pavement and Surfaces. Users must feel at ease when walking or sitting in transit areas. Walking surfaces must be slip resistant and seating surfaces must not have sharp or heavily textured edges that could damage clothing. For system unity, plaza surfaces shall be coordinated with station architectural elements. Pedestrian movement shall be directed by an emphasis on pavement differentiation. Trees and plant materials should be of the type that will not interfere with pedestrian use of walks and platform surfaces and that contribute a minimum of leaf, fruit/seed and sap litter.

Grading and Drainage. Planting and other landscape elements shall provide for positive drainage away from platforms, sidewalks and other structures and shall be reviewed by the

Section Designer Drainage Engineer. Water retention areas shall be coordinated with other site elements to create a positive environmental impact.

Lighting and Signage Interface. Plant selection and location must be coordinated with lighting placement clearances and with the lighting and visibility limits of the sign and the luminaire palette. Plant materials selected should not be dependent on excessive trimming to keep lighting and/or signage free of obstruction. Light poles should be shown on the planting plans to minimize conflict.

Irrigation. The landscape for all DART stations shall be fully irrigated. Design techniques shall be used that provide 100 percent coverage. The designer shall carefully coordinate the location of irrigation components for minimal accessibility to the public. Plants with low water requirements shall be selected to minimize water usage. Where irrigation is to be done as part of future construction, pipes for irrigation lines shall be placed under all paved surfaces as part of initial construction.

Platform Planting. The main area of special use will be the platform area. A limited palette of special area plants shall be utilized for this area. On the platforms, this modified range of plant materials may be utilized in the correct situations/site specific locations. Trees on the platforms needs to have an upright character and allow free pedestrian access to a minimum of 7' –0" clearance above the platform. Their adjacency to curb, bus bay, canopy and trackway need to be reviewed and approved by the Site Design Engineer

Preserving Existing Plant Materials. Every effort shall be made to retain existing trees and vegetation. Construction techniques and site layouts shall dictate which trees and vegetation are able to be saved. Trees removed due to construction shall be replaced within the framework of the proposed landscape design prepared for each specific site. Tree removal must meet municipal requirements for mitigation.

Relationship of the Park and Ride Facility to the Platform. The stated goal is to create attractive pedestrian spaces for users waiting for trains, buses and rides. These people oriented spaces, although designed for heavy traffic flow, will provide the pedestrian with a waiting space to be utilized for a limited duration. Linear edge treatment for the Park and Ride side of the station will allow entry to the station along the platform length. Clear access should be maintained to the Entry/Fare Vending Functions on the platform. The specific design elements for Park and Ride façade of the station are:

The massing of trees and vertical elements to emphasize and define pedestrian flow.

Trees within tree grates to provide shade, visual relief and definition.

Raised planters/wall to define pedestrian areas and function as seating walls in certain site-specific areas.

Enriched pavement at parking lot edge/platform and at specific points of access.

Placement of plants shall be in raised planters as opposed to at grade planters because of greater probability of survival, if site conditions dictate.

Use of walls, earth sculpturing, and level changes to create visual interest while maintaining handicap accessibility.

Use of landscape elements as opportunities for art that are integral to the station design. I.e., wall design, seating, berms, tree grates, lighting, trellis, etc.

Isolate grass and ground cover areas where they are contained by hardscape elements such as walks and other paving.

None of the above design elements shall block visibility into station or provide hiding areas.

Parking Lot (Park and Ride). The parking lot will be broken up with landscape and islands containing shade trees adding visual impact and assisting directional flow of vehicular and pedestrian users. Interior landscape areas shall meet municipal landscape ordinance.

Bus Drop-Off to the Platform. High volume of traffic will preclude use of large planting areas at the bus bays. (Station design provides bus bays adjacent to the train platform, with passengers from each bus seeking a direct, unobstructed route to platform.) Softscape development to occur between ingress/egress points; it is likely that tree grates or regularly spaced planters will be utilized; formulated contingency planning of shortened space between bus drop-offs and platform where buses are only a few feet away from the platform.

Kiss and Ride Relationship to the Platform. In the prototypical station, users pass through the bus drop-off to get from Kiss and Ride to station; bar island controlling traffic flow can be used for trees and plant materials to break up expanse of concrete parking.

Train Approach to Platform. This will signify arrival; identify station, accommodate level change of rail with sloping ballasts to level grade crossing configuration at station. Identity of each station will be addressed at train approach to platform. The train approach to the platform shall utilize plant material below three feet in height to maximize visibility from the train operator to the pedestrians on the platform.

Train Sight Distance to Streets and Drives. Landscaping should be limited to grass or low groundcover in the visibility corridor from the train to the street/drive intersection. The visibility corridor is measured from the intersection of the track with the pavement to a point 200 feet towards the approaching train. The visibility corridor shall extend forty feet either direction of the near track center line along the street/drive. See Figure 19 –1.

Planting and Irrigation along track ROW -
When planting is required along the ROW due to residential betterments, LEA requirements or sound mitigation, planting shall be placed to minimize conflict with train operations. Planting shall not encroach upon the train envelope. Refer to Section 12, Systems Safety, Volume 2 of

the DART Systems Design Criteria. A minimum clearance of 12 feet from the near track center line is required.

Gates along the ROW fencing should be placed approximately 1,000 feet apart for landscape maintenance access. Gate location should be coordinated with track and systems engineers and DART project and maintenance personnel.

The plant palette should consist of materials that do not require shearing or frequent pruning or other maintenance activity. Plants that require low water amounts and are drought tolerant are highly recommended.

Irrigation controllers should be either battery or solar powered as approved by DART personnel. The use of drip irrigation is encouraged if suitable to the planting and site conditions.

Seeding and sodding along the ROW is placed primarily for erosion control. Refer to DART Specification Section 02930 for grass seed mixes to be used along the track guideway. Sodding is specified on slopes equal to or greater than 2:1. The Seeding and sodding specification should be reviewed, edited as needed and coordinated with the civil engineer for the guideway.

Planting and Irrigation at TPSS –
Planting at the Traction Power Substations is requested by municipalities to screen the building, using evergreen shrubs. The height and location of the shrubs should be reviewed and approved by the Systems Engineer so as not to interfere with the operation of the substation nor to hinder visibility of the train operator. Caution should be exercised in planting and irrigation layout since an electrical grid exists under the gravel yard.

The power source for the irrigation controller can be tapped from the TPSS and coordinated with the Systems Engineer. If electrical power is not available, then the controller should be battery or solar powered. The use of drip irrigation is encouraged at these sites.

Station Envelope/Individual Site Conditions. The main objective is to set the station in a visual park-like atmosphere with low maintenance considerations studied. Grass area, especially in proximity to the platform, will be minimized to the maximum extent possible and will be used primarily where required by ordinance, for visual mitigation, or in areas so large that other materials are not cost effective/practicaliper. Additional objectives are the preservation of any existing trees on specific sites where possible, and station design that will encourage user comfort and promote the reduction of vandalism.

Local Landscape Ordinance.
All DART facilities shall be designed to meet local landscape ordinance requirements.

Vehicular Sight Distance Triangles.
Plant material shall not obstruct sight distance triangles for vehicular traffic. Plant materials should not block site visibility triangles. All drive intersections should use a 25'-0" site visibility triangle. Major roadway intersections and/or interface with highway service roads should use a 45'-0" site visibility triangle. Refer to Section 4.3.7. Sight distance triangles must also comply with municipal requirements.

Ancillary Facilities. Plant material should not obstruct access to communication interface cabinets, electrical panels, tower fences or maintenance buildings. Maintain 6' clear zone at all entrance/service locations.

19.3.4 Landscape Standards

Standard landscape details shall be used systemwide to simplify construction details. These drawings shall be used by all final designers, who will either use the drawings as is, or will indicate any required changes. All changes must be reviewed by DART prior to usage.

19.3.5 Security Considerations

Placement of plantings, raised planters, hardscape structures and similar landscaping elements shall be accomplished in such a manner as to not provide spaces for loiterers or persons intending to hide behind such features. Ease of surveillance for security patrol cars shall be considered when locating shrubs taller than eye level.

19.3.6 Design Standard for Planter Walls/Landscape Walls

No planter wall shall exceed 24" in height so as to promote visibility into site and service dual function as a seating wall. The exception will be the screening wall i.e., property line with residential adjacency.

An ideal seating wall for user comfort shall be 12" to 20" wide and 17" to 22" in height.

Materials for planter walls shall be durable and compatible with architectural materials used at the station.

19.3.7 Design Standards for Paving/Paving Enhancement

Paving design changes in texture, scale, and color should delineate pedestrian areas and paths for improved safety.

Track crossing at unauthorized points is discouraged. Paving definition will promote defined crosswalk areas and increase user safety.

Paving pattern and alignment of walks shall respond to the function of directing large numbers of users to particular functions on the platform.

Refer to Section 4 for additional paving requirements.

19.3.8 Design Guidelines for Irrigation

The design shall be zoned so that shrub and groundcover areas are not on the same valve as turfgrass. The irrigation design should be coordinated with the landscape design so that plants of similar water requirements are on the same zone. Each valve should be labelled to reflect the valve size and number and the gallons per minute. The valve number should indicate the zone placement in the watering sequence and the type of plant material being watered (e.g. B for Bubblers at trees; T for turfgrass areas; S for Shrub, groundcover, perennial areas; L for low water plantings). The areas adjacent to the highest pedestrian use should be watered first, e.g. platform area; the parking lot area should be watered last.

Each irrigation system shall show the available pressure and design pressure on the irrigation drawing. The plan should distinguish the type of head to be used by indicating quarter, half, three-quarter, and full heads.

The irrigation design shall place all valve boxes in bed areas as much as possible including valves for turf, bubbler and shrub/groundcover. Drip irrigation shall be utilized in areas where applicable and where it will not be visible, e.g. long, linear planters or planting beds away from pedestrian areas. Quick coupling valves should be provided at appropriate places on the site. Master valves should be provided for repair and to flush the main line. The irrigation water meter should be located near a fire hydrant.

19.3.9 Irrigation Sleeving

Sleeving shall be sized and indicated on drawings. The main line shall be placed in 6 inch Schedule 40 PVC pipe; lateral lines shall be placed in 4 inch Schedule 40 PVC pipe. Main line placed under the track shall be placed five feet under the track using Schedule 80 PVC pipe.

Control wiring shall be placed in separate sleeves of minimum 2 inch Schedule 40 PVC pipe.

19.3.10 Hose Connections for the Platform

Hose connections will be provided on the main irrigation line at the ends of the platform. Refer to the standard drawings for details for the hose bibb connection.

19.3.11 Design Guidelines for Topsoil

The Landscape Architect shall prepare topsoil drawings for each facility site and planting areas along the R.O.W. Topsoil drawings are not required for grassed areas along the track R.O.W.

The drawings shall indicate excavation in parking lot islands to a depth of 18 inches below the top of adjacent paving to remove lime stabilized material. Tree pits at tree grates shall be excavated to a depth of five feet below the adjacent paving.

19.3.12 Design Guidelines for Drainage at Trees in grates, Planters, Parking Lot Islands

Drainage shall be provided for trees in grates, raised planters and parking lot islands. The drain lines shall exit into the site/storm drainage system. Refer to the standard drawings for details.

19.3.13 Design Guidelines for Planting at Facilities

Landscape design shall use native species and low maintenance plant materials that provide a comfortable station and one that is an asset to the neighborhood. Planting design should utilize xeriscape principles as much as possible. Plants with similar water requirements should be placed in the same irrigation zones, i.e. dry plant zones versus wet plant zones.

Trees are to be placed so their limbs will not overhang the trackway. Plants and trees are to be placed so that vegetation is no closer than 12 feet to the adjacent track centerline when full grown. Trees shall not be placed in vehicular or train visibility triangles. Refer to conceptual design drawings for more information.

Maintenance of overhead power lines is critical to light rail operations. Trees are to be selected and placed to minimize the opportunity for leaves or limbs to fall or blow onto trackway or overhead power system. Planting plans must comply with TXU requirements and receive TXU approval when plant material falls within TXU right-of-way.

Maintain 6' clear zone in front of access points to all electrical cabinets, communication interface cabinets, irrigation controllers and building entrances.

Maintain 6' clear zone in front of access points to all electrical cabinets, communication interface cabinets, irrigation controllers and building entrances.

Annual/seasonal flowers or other plant material shall not be used on DART properties. However, the use of perennial flowering plants is permitted.

Any berms used for parking lot screening shall not exceed 3:1 slope maximum.

19.3.14 Landscape Maintenance

Landscape maintenance specifications should be reviewed, edited and issued for each DART facility. (Refer to Sections 02980, 02981 and 02982 for maintenance of guideway and facilities.) The landscape contractor who installs the planting will be obligated to maintain the plantings for one year after final acceptance of the installation. Confirm with project engineer and DART project manager and maintenance personnel regarding extent of scope of work and budget for landscape maintenance.

19.3.15 Master Plant List

The Master Plant List provides an alphabetical listing of all trees, shrubs, groundcovers, vines, and grasses which may be used on DART facilities and guideway. Unless specific approval to vary from the list has been granted by DART, the landscape architect shall use only those plants listed. Only those trees listed for use at the platform may be used as shade trees at the LRT platforms. The Master Plant List follows:

A. SHADE TREES FOR PLATFORM:
Specify 200 gallon container for platform trees.

	Common Name	Botanical Name	Minimum Size
1.	Caddo Maple	*Acer barbatum*	4" caliper
2.	Ginkgo	*Ginkgo biloba*	4" caliper
3.	Sweetgum	*Liquidambar styraciflua*	4" caliper
4.	Fruitless Sweetgum	*Liquidambar styraciflua 'Rotundiloba'*	4" caliper
5.	Chinese Pistachio	*Pistacia chinensis*	4" caliper
6.	Bald Cypress	*Taxodium distichum*	4" caliper
7.	Red Oak	*Quercus shumardii*	4" caliper
8.	Live Oak	*Quercus virginiana*	4" caliper
9.	Cedar Elm	*Ulmus crassifolia*	4" caliper
10.	Winged Elm	*Ulmus alatus*	4" caliper

B. SHADE TREES FOR SITE:
(Container or Balled and Burlapped may be specified.)

	Common Name	Botanical Name	Minimum Size
1.	Caddo Maple	*Acer barbatum*	4" caliper
2.	Red Maple "October Glory" or "Autumn Flame"	*Acer rubrum* 'Autumn Flame' or *Acer rubrum* ' October Glory'	4" caliper
3.	Trident Maple	*Acer rubrum* var. *trilobum*	4" caliper
4.	Chittamwood	*Bumelia lanuginosa*	2" caliper
5.	Raywood Ash	*Fraxinus oxycarpa*	4" caliper
6.	Marshall Seedless Ash	*Fraxinus pennsylvanica cv.*	4" caliper
7.	Texas Ash	*Fraxinus texensis*	4" caliper
8.	Ginkgo	*Ginkgo biloba*	4" caliper

9.	Honey Locust	*Gleditsia triacanthos*	3" caliper
10.	Kentucky Coffeetree	*Gymnocladus dioica*	4" caliper
11.	Eastern Red Cedar	*Juniperus virginiana*	2" caliper
12.	Sweetgum	*Liquidambar styraciflua*	4" caliper
13.	Fruitless Sweetgum	*Liquidambar styraciflua 'Rotundiloba'*	4" caliper
14.	Magnolia And cultivars	*Magnolia grandiflora*	4" caliper
15.	Chinese Pistachio	*Pistacia chinensis*	4" caliper
16.	Mesquite	*Prosopis glandulosa*	4" caliper
17.	Durrand Oak	*Quercus durandii*	4" caliper
18.	Bur Oak	*Quercus macrocarpa*	4" caliper
19.	Chinquapin Oak	*Quercus muehlenbergii*	4" caliper
20.	Red Oak	*Quercus shumardii*	4" caliper
21.	Texas Red Oak	*Quercus texensis*	4" caliper
22.	Live Oak	*Quercus virginiana*	4" caliper
23.	Black Locust	*Robinia pseudoacacia*	3" caliper
24.	Western Soapberry	*Sapindus drummondii*	4" caliper
25.	Bald Cypress	*Taxodium distichum*	4" caliper
26.	Winged Elm	*Ulmus alata*	4" caliper
27.	Cedar Elm	*Ulmus crassifolia*	4" caliper
28.	Lacebark Elm	*Ulmus parvifolia*	4" caliper
29.	Zelkova	*Zelkova serrata*	4" caliper

C. ORNAMENTAL TREES:

Common Name	Botanical Name	Minimum Size
1. Texas Redbud	*Cercis canadensis Texenis*	2” caliper
2. Chitalpa	*Chilopsis X chitalpa*	2" caliper
3. Desert Willow	*Chilopsis linearis*	3" caliper
4. Texas and Washington Hawthorns	*Craetagus cv.*	2” caliper
5. Texas Persimmon	*Diospyros texana*	2” caliper
6. Foster’s, Savannah, East Palatka Holly	*Ilex x attenuata* *Ilex opaca cv.*	2" caliper
7. Possumhaw	*Ilex decidua*	2" caliper
8. Tree Yaupon and cultivars, e.g. Weeping	*Ilex vomitoria*	8’ height
9. Crapemyrtle use powdery mildew resistant varieties	*Lagerstroemia indica*	8’ height
10. Little Gem Magnolia	*Magnolia grandiflora 'Little Gem'*	2" caliper
11. Southern Wax-myrtle	*Myrica cerifera*	8’ height
12. Eldarica (Mondell) Pine	*Pinus eldarica*	2" caliper
13. Austrian Pine	*Pinus nigra*	2” caliper
14. Purple Plum	*Prunus cerasifera*	2” caliper
15. Mexican Plum	*Prunus mexicana*	2" caliper
16. Eve’s Necklace	*Sophora affinis*	2" caliper
18. Pond Cypress	*Taxodium distichum*	2" caliper

19. Rusty Blackhaw Viburnum	*Viburnum rufidulum*	2" caliper
20. Vitex	*Vitex agnus-castus*	2" caliper

D. LARGE SHRUBS: (4' height and greater)

Common Name	Botanical Name	Minimum Size
1. Abelia	*Abelia grandiflora*	5 gallon
2. Bamboo	*Bambusa cv.*	5 gallon
3. Agarita	*Berberis trifoliolata*	5 gallon
4. American Beautyberry	*Callicarpa americana*	5 gallon
5. Althea	*Hibiscus syriacus*	5 gallon
6.. Willowleaf Holly	*Ilex cornuta cv.*	5 gallon
7. Dwarf Burford Holly	*Ilex cornuta burfordii nana*	5 gallon
8. Nellie Stevens Holly	*Ilex cornuta 'Nellie R. Stevens'*	5 gallon
9. Yaupon Holly	*Ilex vomitoria*	5 gallon
10. Juniper varieties	*Juniperus cv.*	5 gallon
11. Texas Sage	*Leucolphyllum frutescens*	5 gallon
12. Variegated Ligustrum	*Ligustrum sinensis*	5 gallon
13. Wax Myrtle	*Myrica cerifera*	5 gallon
14. Dwarf Wax myrtle	*Myrica pusilla*	5 gallon
15. Nandina domestica	*Nandina domestica*	5 gallon
16. Bright n tight Cherry Laurel	*Prunus daroliniana 'Bright n tight'*	5 gallon
17. Indian Hawthorne (tall varieties)	*Raphiolepis indica*	5 gallon
18. Evergreen sumac	*Rhus virens*	5 gallon
19. Vitex	*Vitex angus-castus*	5 gallon

E. SMALL SHRUBS: (less than 4' height)

	Common Name	Botanical Name	Minimum Size
1.	Red Barberry	*Berberis thunbergii atropurpurea*	5 gallon
2.	Boxwood	*Buxus microphylla*	5 gallon
3.	Horsetail	*Equisetum hyemale*	5 gallon
4.	Red Yucca	*Hesperaloe parviflora*	5 gallon
5.	Dwarf Burford Holly	*Ilex cornuta Burfordii nana*	5 gallon
6.	Dwarf Chinese Holly	*Ilex cornuta rotunda*	5 gallon
7.	Italian Jasmine	*Jasminum humile*	5 gallon
8.	Tamarix Juniper	*Juniperus sabina Tamarisciffolia*	5 gallon
9.	Compact Texas Sage	*Leucophyllum frutenscens 'compacta'*	5 gallon
10.	Dwarf Wax myrtle	*Myrica pusilla*	5 gallon
11.	Compact Nandina	*Nandina domestica compacta*	5 gallon
12.	Indian Hawthorn	*Raphiolepis indica cv.*	5 gallon
13.	Coralberry	*Symphoricarpos orbiculatus*	5 gallon
14.	Soft leaf Yucca	*Yucca arkansana*	5 gallon

F. GROUND COVER:

	Common Name	Botanical Name	Minimum Size
1.	Horseherb	*Calyotocarpus vialis*	4" pot
2.	False Stawberry	*Duchesnea indica*	4" pot
3.	Purple Wintercreeper	*Euonymous fortunei*	4" pot

	coloratus	
4. English Ivy	*Hedera helix*	4" pot
5. Creeping Juniper	*Juniperus horizontalis or procumbens*	1 gallon
6. Green Liriope	*Liriope muscari 'Big Blue'*	4" pot
7. Creeping Liriope	*Liriope spicata cv.*	4" pot
8. Purple Honeysuckle	*Lonicera japonica 'purpurea'*	4" pot
9. Monkey Grass	*Ophiopogon japonicus*	4" pot
10. Frogfruit	*Phyla nodiflora*	4" pot
11. Asian Jasmine	*Trachelospermum asiaticum*	4" pot
12. Vinca	*Vinca major or minor*	4" pot

G. VINES:

Common Name	Botanical Name	Minimum Size
1. Crossvine	*Bignonia capreolata*	1 gallon
2. Trumpet Vine	*Campsis radicans*	1 gallon
3. Carolina Jessamine	*Gelsemium sempervirens*	4" pot
4. English Ivy	*Hedera helix*	4" pot
5. Coral Honeysuckle	*Lonicera sempervirens or heckrottii*	1 gallon
6. Virginia Creeper	*Parthenocissus quinquefolia*	1 gallon
7. Boston Ivy	*Parthenocissus tricuspidata*	1 gallon
8. Passion Vine	*Passiflora incarnata*	1 gallon
9. Chinese Wisteria	*Wisteria sinensisa*	5 gallon

H. ORNAMENTAL GRASSES/PERENNIALS

Where appropriate, the planting plan may include perennial grasses and flowering plants. The use of low maintenance, native plant material and introduced plants that are proven in the Texas environment are encouraged.

I. TURFGRASS

Solid sod is preferred method of establishment using Buffalograss cultivar or Texturf 10, Tif 419, or Sahara Bermudagrass. Alternate turfgrass includes Palisades or Cavalier Zoysia.

In areas requiring hydroseed/hydromulch application, bermudagrass should be specified. Sprigging of bermudagrass may be utilized.

For shade areas, seed Fescue cultivars.

Turfgrass areas shall be overseeded with ryegrass during fall and winter.

CHAPTER 20 - STATION LAYOUT

20.1 INTRODUCTION

This chapter covers design requirements for the layout of DART light rail stations. The importance of designing functional, visible, easy-to-identify and easy-to-use stations is stressed.

Stations will range in complexity from a simple at-grade platforms to complex and aerial subway stations. Besides their integral relationship to system operations, stations are the interchange points for transportation modes. They can help to determine the effectiveness of the entire multi-modal regional transportation system.

Rail transit stations consist of the following basic elements: patron access, boarding platforms (low level and handicapped), fare vending, passenger information and passenger amenities. A mezzanine level or concourse may be required to improve the distribution of pedestrian traffic between station entrance/exit points and boarding platforms at specified grade separated stations.

Stations shall be side-loading type platforms unless otherwise indicated on Preliminary Engineering drawings. A fare vending area shall be provided at entry level in the path of patrons accessing the platform or on the station platform. Low-level primary platforms are to be used throughout the system with provisions for special use high-level boarding platforms accessible by ramp for mobility impaired patrons. (Refer to Chapter 22 - Station Operational Requirements for additional information).

The design of all stations should exercise considerable discretion in design regarding the physical conditions and amenities of the site and the operating characteristics of the system, while providing for patron safety, comfort, and convenience. Prototypes for each station type are defined in the Directive Drawings. These drawings will require modifications for site adaptation.

20.2 AT-GRADE STATIONS

At-grade stations shall be designed in accordance with local codes and ordinances and guidelines of the National Fire Protection Association (NFPA) Standard 130 and all applicable codes and regulations. Refer to all applicable chapters of this criteria and Appendix 1 for additional information. Stations shall be located so that the end of the platform (310' envelope) is no closer than 50' from any cross street or access drive. Provisions shall be made for a 100' expansion of the 310' platform from either end of the station. No ancillary elements, streets or other obstructions may be located in this area. See Figure 20-1.

20.2.1 Relationship To Environment

The following objectives shall be used to achieve a successful integration of the system into the community environment:

- o Minimize neighborhood disruption by recognizing and reflecting existing and planned land-use trends and community activity patterns.
- o Assist or complement the implementation of community goals and objectives.
- o Provide opportunities to accommodate joint development, and transit oriented development.
- o Provide for the possibility of transit stations becoming nodes of activity and gateways to areas.
- o Support the safety of the patron and community through appropriate design, lighting and visibility.

Respect for the existing neighborhood shall be demonstrated in the following ways: lighting that does not intrude into surrounding areas, proper screening of selected visual elements, noise attenuation, preservation of desirable views and vistas to and from the station sites, and the development of an element in a neighborhood that will support civic pride.

20.2.2 Site Development

The locations and approximate boundaries of station sites will be established by DART and will be set forth in the Preliminary Engineering Drawings for each station. Parking areas, where required, and landscaped areas will also be included in these plans.

The platform configuration and the standard station functional elements will be shown on the Directive Drawings for each station.

The site layout and traffic flow shall relate to the surrounding area and its traffic patterns. Provisions for handling patrons arriving and departing on foot, on bicycles, on buses, by car, and at kiss-and-ride drop-offs shall be based on requirements included in Chapter 19 - Site Requirements.

Where required by the conceptual design for the station, the DART property surrounding the station will be used for parking lots or parking structures. At some stations, parking lot layouts must provide for possible future construction of multi-story parking structures to handle increased patron loads or joint development.

20.2.3 Access to Platforms.

Vertical access to at-grade station platforms shall be by ramp if required. Where stations are located on retained earth fills or cuts (grade separated), elevators may also be required when differences in elevation make use of ramps impractical. Escalators may be utilized for enclosed (subway) stations with DART approval. (Refer to Section 20.3 Grade Separated Stations.)

20.2.4 Platform

Station platforms shall be approximately 310 feet long, capable of handling a three-car train with provisions for expansion to four-car trains. They shall be primarily side platform configuration with center platform loading used only at terminal stations and special conditions, as shown in the Preliminary Engineering Drawings. A roof or canopy covering approximately one-third the length of each platform shall be located and designed as required to provide shelter for patrons at the platform. Both covered and uncovered portions of platforms require lighting and a public address system and visual message display. No columns or other obstructions will be permitted closer than 7 feet 0 inches from the train side edge of the platform.

Wind and weather screens shall be provided, as required to shelter waiting patrons from wind and wind-driven rain and snow. Such screens shall be designed to resist wind loads in accordance with governing codes. Platform seating shall be incorporated on the platform in conjunction with windscreens. See Directive Drawings for locations.

A high-level special use platform shall be provided at each station for elderly and handicapped passengers and others requiring boarding assistance. The high-level platform will be accessible by ramp. Mechanical wheelchair lifts may be used only at special stations with DART approval where conditions prohibit use of ramps. The use of wheelchair lifts require approval of the Texas Accessibility Standards agency by means of a variance if the lift is used to access the high-level platform.

Platforms shall be provided with provisions for Public Address (PA), Visual Message Boards (VMB), Passenger Emergency Call (PEC) and CCTV surveillance.

20.2.5 Canopy

Station platforms shall be designed to allow the placement of a canopy structure which will provide protection against reasonably adverse weather conditions such as direct sun or wind driven rain. The canopy shall be approximately one third the length of the platform. The handicapped special use platform shall be provided with a canopy structure for weather protection.

Canopy support columns shall be placed in compliance with platform clearance requirements. Columns shall be used for placement of drainage pipes and electrical conduit. All electrical conduits and drainage pipes shall be concealed from patron view. The canopy shall drain away from the train edge to minimize water spill-over on patrons accessing the trains or provide for a gutter system at the canopy edge. For additional information refer to standard and directive drawings. Weather protection shall be provided for bus loading areas. Where bus loading is remote from the station separate bus shelters shall be provided.

20.2.6 Heating, Ventilating, and Air Conditioning

Except as noted below, public spaces in at-grade stations, including platform areas and any concourse areas, will not be provided with heating or cooling. Such spaces will not be fully enclosed but shall be partially protected by canopies and wind and weather screen walls, permitting natural ventilation with minimal intrusion of rain or snow. In stations where a high percentage of bus transfers is anticipated climate controlled enclosures may be provided as directed by DART.

At those stations requiring operational support facilities such as crew rooms, provisions shall be made for heating, ventilating, and cooling systems. Toilet rooms and custodial rooms, where required, shall be provided with heating and ventilating systems only. Other enclosed spaces will not be provided with heating or cooling but will be ventilated. For further information, see Chapter 25 - Heating, Ventilation, and Air Conditioning Systems.

20.2.7 Ancillary Space Requirements

Ancillary spaces shall be provided in at-grade stations as shown on the conceptual design drawings. Specific requirements for train and station-operation-related spaces and for police emergency phones and fire protection equipment are described in the systems design criteria.

20.3 GRADE SEPARATED STATIONS

Grade Separated stations, where required, shall be designed in accordance with local codes and ordinances of the National Fire Protection Association (NFPA) Standard 130 and all applicable codes and regulations. Refer to all applicable chapters of this criteria and Appendix 1 for additional information.

20.3.1 Relationship To Environment

The high visibility of elevated structures requires a sensitive area design approach to achieve the successful integration of the system into the urban fabric and to help define the opportunities and constraints for enhancing the established urban landscape. See Section 20.2.1 of this chapter for objectives. In addition, visual screening may be required at Aerial Stations to mitigate site-line issues at adjacent properties.

20.3.2 Site Development

Refer to Section 20.2.2 of this chapter. See Chapter 19 - Station Site Requirements.

20.3.3 Concourse Area

A concourse area may be required at specified stations to monitor and contain fare vending equipment and vertical circulation to the train loading platforms. Depending on site specific conditions and station configuration, the concourse may be elevated or at-grade level. Concourse configuration for specific stations shall be indicated on conceptual design drawings.

20.3.4 Access to Platforms

Vertical access to platforms of grade separated stations shall be by stairway and elevator and where appropriate, escalator. Elevators shall be provided for elderly and handicapped patrons. Ramps and horizontal walkways shall be used as necessary for each station location to provide access to vertical circulation from the site.

20.3.5 Platform

Station platforms shall be approximately 410 feet long as required for four-car trains with no provisions for future expansion. Refer to section 20.2.4 for additional platform information.

20.3.6 Canopy

Refer to section 20.2.5 of this chapter.

20.3.7 Heating, Ventilating, And Air Conditioning

Refer to section 20.2.7 of this chapter and Chapter 25 - Heating, Ventilating, and Air Conditioning.

20.3.8 Ancillary Space Requirements

Ancillary spaces shall be provided where required in grade-separated stations as shown on the Preliminary Engineering and Standard & Directive drawings. Specific requirements for each of these areas are described in other chapters of these criteria.

20.4 SUBWAY STATIONS

Subway stations shall be designed according to local codes and ordinances of the National Fire Protection Association (NFPA) Standard 130 and all applicable codes and regulations. Refer to all applicable chapters of this criteria and Appendix 1 for additional information.

Particular care should be taken to provide for a pleasant environment. Areas shall be spacious, well-lighted and comfortable. Spatial relationships and circulation patterns shall be as clear as possible so the patron can pass through the station easily and pleasantly. Color and texture can be very significant and should be considered carefully.

20.4.1 Site Development

In the urban center, the new traffic patterns established by station entrances may seriously conflict with existing pedestrian and vehicular movement. Organization of external station areas in concurrence with governing authorities will minimize these conflicts to the greatest extent feasible.

The street level and underground pedestrian walkway systems shall serve, as much as possible, as primary "organizers" by sorting people according to their destinations before they actually enter the stations. This will help reduce conflicting circulation flows at the lower levels.

20.4.2 Entrances

Some public entrances to the system will be "on-street" elements, with stairs and/or escalators leading directly from the sidewalk to the fare-vending areas at a lower level.

Plaza-type entrances or sidewalk arcade entrances will be considered by DART wherever possible. These "off-street" entrances, planned as open, landscaped areas, will relate to existing business and urban activities. Where there are existing or planned underground pedestrian passages, or where plans are underway for extensive redevelopment of the whole street, additional public entrances for the system will be designed in conjunction with these facilities. Development of such entrances will be initiated by DART.

It is assumed that various business enterprises located near the stations will wish to have direct access from the stations to their properties. Any such entrances will be financed and maintained by the private enterprises and will have lockable closedown doors. While such entrances will be considered as valuable elements they will not take the place of any of the required station entrances.

The number of entrances to any subway station depends upon a series of factors. First, they must handle the expected patron loading; second, they must relate to the site itself and respect the direction of the patron loading; and third, they must be sufficient to handle the egress requirements from other levels. Exits shall be designed in accordance with NFPA 130 and 101 as well as other authorities listed in Appendix 1. All entrances shall be designed so that the station can be secured by DART for scheduled or emergency closing. At least one entrance shall have direct egress to a public open area.

20.4.3 Access to Platforms

Access to platforms shall be by stairs and where appropriate, escalators. In addition, elevators shall be provided for elderly and handicapped patrons.

20.4.4 Platform

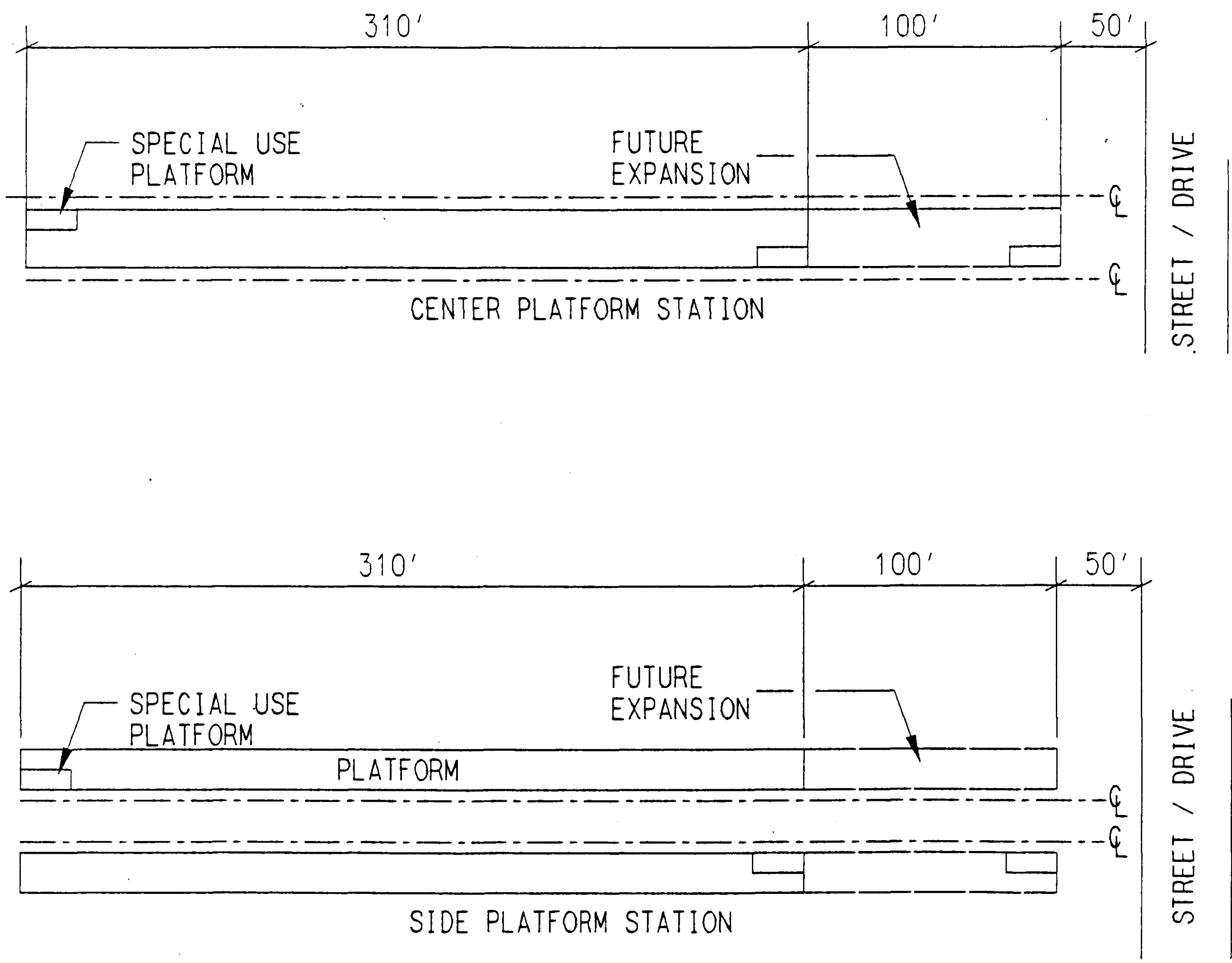
Station platforms will either be of the side- or center-loading type as indicated in the Preliminary Engineering drawings. Clearance from edge of platform to columns or other obstructions shall be as indicated in section 20.2.4 of this chapter. Subway station platforms will be designed to accommodate four-car trains. Provisions for CCTV surveillance, PA, PEC and VMB shall be incorporated into platform and fare vending areas.

20.4.5 Heating and Ventilation: Fire Protection and Plumbing

Provisions for environment control will be made as outlined in Chapter 25 - Heating, Ventilating, and Air Conditioning Systems. For additional information, refer to Chapter 29 - Fire Protection and Chapter 30 - Plumbing and Drainage.

20.4.6 Ancillary Space Requirements

Ancillary spaces shall be provided in subway stations as shown on the Preliminary Engineering drawings. Specific requirements for spaces are described in other chapters of these criteria. Spaces such as sewage ejector rooms, sump pump rooms, and valve rooms for fire protection water systems shall be provided as required and shall be an appropriate size to house the required equipment. Access shall be provided for personnel and equipment. For additional information refer to the mechanical standard drawings.



ACT 21
CARTER BURGESS
JACOBS ENGINEERING
STV INCORPORATED
KAI ALLIANCE

DART PROJECT

DART

DART DESIGN CRITERIA

STATION EXPANSION
AT-GRADE STATIONS

SCALE: NOT TO SCALE

FIGURE: 20.1

JAN. 2003, REV 10

CHAPTER 21 - STATION FUNCTIONAL REQUIREMENTS

21.1 INTRODUCTION

The purpose of this chapter is to outline and define the criteria for the design of the functional aspects of DART rail system stations. The information in these sections will help the section designer design safe, functional, attractive and cost-effective stations. The chapter includes guidelines for choosing materials and finishes that will provide convenience, comfort, and attractiveness, as well as safety, durability and economy. Additionally, requirements are summarized for planning patron circulation patterns and vertical circulation systems.

The overall goal of the following sections is to assist the section designer in designing safe, functional, attractive, and cost-effective stations.

21.2 REFERENCE DATA

21.2.1 Environmental Impact Statement

The Environmental Impact Statement will provide guidance on environmentally sensitive design issues and specify mitigation items which shall be incorporated into the final design of each station.

21.2.2 Patronage Analysis

The key to the organization of a station is its relationship to the surrounding area in terms of vehicular and pedestrian movement. It is essential that all such movement data pertaining to the area immediately surrounding the proposed station be studied prior to the development of any design. Patronage analysis studies, based on recent projections of future employment, population, building development, and other activities in areas adjacent to the stations have been prepared by DART. Station patronage will define ridership for peak periods and daily use for each station. DART will provide design data by mode of arrival for the peak periods that will be used for station design guidance. The patronage analysis will be furnished by DART to the designer as part of the Preliminary Engineering design package.

21.2.3 Project Definition Design

The section designer shall prepare documents for review and approval by DART based on the Preliminary Engineering design work provided by DART.

21.2.4 Final Design Specifications

DART will provide standard specifications to the section designer to be included in the final design documents for construction contracts. Certain specialized sections or special provisions may not be included, and will require preparation by the final designer in conformance with the standard specifications.

21.2.5 Station Program

The station program will be provided to the section designer, defining scope, stages of design and submittals, budget, and schedules.

21.2.6 Utility Locations

Since the location of underground utilities may influence the station area design, all available information on utilities in the project area should be studied. Utility drawings and required information for the various sites will be made available to DART.

21.2.7 Construction

The minimum type of construction for train stops and passenger stations shall be Type II as described in the Uniform Building Code and International Building Code, Types of Building Construction (National Fire Protection Association (NFPA) NFPA 220), and Safeguarding Construction, Alteration, and Demolition Operations (NFPA 241). Other local ordinances and amendments may also apply.

21.2.8 Other General Data

Master plans, Station Area Plans, urban renewal plans, ordinances, and plans for specific future projects in the proposed station area should be reviewed for pertinent information that might influence design possibilities.

21.3 STATION CAPACITIES

Station general capacities are listed in this chapter. For more specific requirements, see the Patronage Analysis and the Definitive Design Program.

21.3.1 Station Patronage

The station patronage for each station shall be taken from the patronage estimates outlined in the operations and maintenance plan. Estimates of station patronage are prepared for the morning and evening peak hours. For design purposes, the greatest peak patronage volume shall be used. For emergency egress purposes the peak 15 minutes shall be used, this factor will be provided in the operation and maintenance plan. The sizing of station elements will be established by DART. Bus bay and kiss-and-ride parking lot capacity shall be identified on the project definition drawings.

21.3.2 Platform Area

The Preliminary Engineering Drawings will provide the section designer with the station platform size for specific site requirements. The design of platforms shall be coordinated with the vehicle design to assure that the static horizontal gap between the platform and vehicle step does not exceed 3 inches nominal.

21.3.3 Station Capacity

Operating Conditions. All station elements such as ramps, escalators, elevators, stairs, corridors, doors, and gates shall be sized to accommodate the peak 15-minute patronage levels established in the vertical circulation subsection of section 21.8. Platform areas shall be sized to accommodate a maximum density of 15 square feet per person during the peak 15 minute period.

Emergency Conditions. All stations must meet requirements for emergency evacuation as established in Fixed Guideway Transit Systems (NFPA 130), in the "System Safety Program Plan" of the DART Systems Assurance Manual (DART), and in Chapter 29 - Fire Protection Systems of these criteria and Systems Design Criteria Chapter 12 - Safety Systems.

Public Occupancy Areas. Passenger station public occupancy areas consist mainly of those areas open to the public during normal system operating hours. However, under emergency or special circumstances, emergency exits, passageways, and other areas required for emergency egress shall become public occupancy areas. Commercial occupancies, such as shops, restaurants, or garages integrated into stations are also considered public occupancy areas; as such, special fire/life safety design measures shall be established for these facilities.

21.4 DESIGN GUIDELINES

All rail transit stations will have certain elements that are standardized for reasons of safety, clarity, and economy. Issues such as code and life-safety compliance, patron circulation patterns, operational systems, maintenance procedures, and joint-development requirements shall be determinants for systemwide uniformity or continuity in design.

Each station design responds to the unique characteristics of its specific site and alignment conditions, entrance considerations, projected patronage requirements, linkages to other DART systems, and the surrounding neighborhood. (Refer to Section 21.5 for more information.)

The following concepts shall be considered by the section designer in the development of the individual station designs:

- Architectural concepts shall use a cost-effective basis for design.

- Station design and materials shall provide for ease of maintenance.
- Station design shall be sensitive to the local environment of the area and use indigenous landscaping materials.
- Station circulation shall be simple and direct.
- Station size shall be based upon projected patronage.
- Major functional areas shall be spatially and visually related.
- Design consideration should be given to the needs of the elderly and handicapped.
- Design consideration shall be given to patron comfort, weather protection, safety, and security.
- Specified materials and finishes shall be used in a consistent manner throughout the station complex.
- Special conditions shall be avoided through standardization and the use of repetitive elements.

Standard criteria deviations proposed by the section designer will be considered only if they are proven to be in the best interest of the project. It is the section designer's responsibility to justify any deviations from the criteria standards and to secure any necessary approvals as the work progresses.

21.4.1 Site Development

Refer to Chapter 19 - Station Site Requirements for site development information.

21.4.2 Patron Circulation

Passenger traffic is composed of two distinct groups: regular patrons, and infrequent users. Once passenger flows have been established and the majority of patrons have become familiar with the process, many directional problems will be eliminated.

Some basic principles that should be considered in planning station circulation are as follows:

- People tend to keep to the right. For this reason, righthand flows are recommended.

- Cross-flow of passengers must be avoided. The layout should encourage the separation of passenger flows moving in the opposite direction.

- Dead-end conditions should be avoided wherever possible. Where some are unavoidable, they shall comply with governing code.

- Patrons will tolerate longer delays in entering than in exiting the system. Station design should attempt to eliminate waiting at exits.

- Circulation patterns and station layouts should enable patrons to know where they are and where they are going at all times.

- Provide good visibility from adjacent areas and avoid blind corners wherever possible.

21.4.3 Internal Space Organization

Platform. The platform shall provide a visually open and unobstructed boarding and alighting area for patrons. Elements such as seating, windscreens, signage and lighting shall be located as to not obstruct waiting and circulation areas. Ticket Vending Machines, System Maps and user information shall be centrally located and be as consistent in location as practicable between stations.

Concourse. Depending on the site and above-ground or subway conditions, the concourse area, if required, may be at street level or at a mezzanine between levels. This concourse will function as a transition area between the points of entry into the station and the accessways to the train platforms. The concourse may provide space for various functions. These include the entire fare-vending process, directional and informational signing, and patron amenities. If no concourse is used, the space required for these functions must be provided at street level or on the platform. The subway station concourse space will also enable the patron to move horizontally to that point in the station where stairs, escalators, or elevators will take him or her directly to an exit, a bus stop, or a train platform. In addition, private entrances from various adjacent buildings may be accommodated along the length of a concourse.

Access. Routine access shall be provided to all areas of train platforms and passenger stations by the normal egress routes. Separate access and egress routes may be considered on a site specific basis, providing the overall safety of the station is assured. Open areas shall be provided around all passenger stations for emergency response and fire department equipment access as required by local codes. Exits shall be provided from nonpublic areas of passenger stations in accordance with the International Building Code (IBC). Refer to the project definition design drawings for site-specific station access.

Surge Space. Adequate space must be provided around the fare-vending machines to allow patrons to buy their tickets without undue crowding. Section 21.4.6, **Queuing Distance Requirements,** contains the minimum dimensions to be used in determining these surge or queuing spaces. Consideration must also be given for exiting through this space in case of emergency.

Emergency Conditions. The organization of circulation within the station must be planned to meet all emergency situations. In emergencies, it must be possible to move patrons efficiently and rapidly from the trains, platforms, and other parts of the station to an area of safety. For further information, refer to Chapter 29 - Fire Protection Systems of these criteria and the "System Safety Plan" of the Systems Assurance Manual (DART).

Handicapped Patrons. All public station facilities must be accessible and functional for the handicapped and elderly in accordance with ADA Guidelines Section 4 and Section 10, Transportation Facilities, and Texas Accessibility Standards. Provisions for these patrons shall include special use boarding platforms, elevators, ramps, curb cuts, nonslip floor materials, and doors with a clear opening width of no less than 32 inches. Elevators will be provided as indicated in the vertical circulation subsection of section 21.8 and in Chapter 31 - Elevators and Escalators. A tactile warning strip in accordance with ADA shall be used to allow visually handicapped persons to discern the platform edge.

Clearances. In all public areas, minimum accessible overhead clearance to obstructions shall be 9 feet 0 inches above finish floor, with 10 feet 0 inches desirable. At localized critical points, however, clearance may be reduced to not less than 8 feet 0 inches.

Emergency Access to Station. Access to station entrances or platforms and emergency egress locations shall be from public streets, or from a surface suitable for vehicular access having a width of at least 20 feet and an overhead clearance of at least 14 feet. Where a fire lane is jointly used as a bus drop off area a 30' minimum lane is required. An access road to a station shall be continuous from a public street. If longer than 100 feet, it shall end in a configuration conforming to the Dallas fire lane turnaround designation defined in the local Fire Department. The fire department inlet connections for automatic sprinkler and standpipe system shall be located within 50 feet of vehicular access. Hydrant spacing and locations shall be by local codes. A key lock box system and location acceptable to the local fire department shall be established and keys necessary for access to all parts of the station shall be provided.

21.4.4 Ancillary Space Requirements

Ancillary spaces shall be provided in subway and other specified stations as shown on the project definition drawings. Specific space requirements for train and station operations are described in other chapters of these criteria. Spaces such as sewage ejector rooms, sump pump rooms, and valve rooms shall be provided as required, and shall be of a size to house the required equipment. Appropriate access shall be provided. Means of egress shall be arranged in accordance with NFPA

130 and the Uniform Building Code or International Building Code, except that for the purpose of this criteria, exits from station ancillary occupancy areas into station public occupancy areas shall be considered as discharging into a protected passageway leading directly to a point of safety.

21.4.5 Safety and Security

Refer to Chapter 27 - Fire and Intrusion Alarm Systems and Chapter 29 - Fire Protection Systems, to all other applicable chapters of these criteria, and to the Safety Program Plan of the Systems Assurance Manual.

21.4.6 Queuing Distance Requirements

Table 21-1 shows minimum queuing distance requirements.

TABLE 21-1

MINIMUM QUEUING DISTANCE REQUIREMENTS

Ticket Vending Machine	8' - 0"
Escalator	20' - 0"
Elevator	12' - 0"
Stair	15' - 0"

21.5 ELEMENTS OF CONTINUITY/VARIABILITY

To accomplish the total design process, the work is divided into three phases: prototype/conceptual design, Preliminary Engineering design, and final design. During the first two phases of design, DART and its architectural consultant will be responsible for the general layout of the station. They will develop the total station architectural and engineering work program. For the final design phase, architectural/engineering (A/E) firm section designers will be selected for each station to prepare design and construction contract documents.

While reflecting the unique characteristics of its immediate surroundings, the design of stations shall take into consideration systemwide application requirements. A basic functional and structural design for each station will be established as a part of the Standard & Directive drawings. This will be done to provide the necessary degree of standardization throughout the system for patronage convenience and acceptability, ease of circulation, function, safety, economical vehicle and systems interfacing, and overall system identity and continuity. By providing for variable design elements, the station design shall address the specific site and area requirements to achieve a coherent placement of the station in the community. The site specific design of the elements of variability will be addressed in final design as part of the community Art and Design Program.

Design elements will be divided into two classifications by DART: elements of continuity and elements of variability. These are defined below:

- o Elements of system continuity (s = standard). Established by DART for purposes of functional consistency, safety, patron recognition, and reduction of capital, and maintenance cost.

- o Elements of variability (n = non-standard) or (p = palette). Established by DART, they define the areas wherein individual design within specified parameters is permitted or encouraged.

The design of all elements should anticipate a service life that will minimize future replacement and maintenance. Considering the anticipated growth and longevity of the system, careful consideration must be given to each station's compatibility with future development in the surrounding neighborhood.

TABLE 21-2

CONTINUITY/VARIABILITY
SYSTEMWIDE PROCUREMENT ITEMS

N = No Standard
S = Standardized
P = Palette/Range

Information Devices (All signs/graphics)

Station identifications (exterior and interior)	S
Map cases--system station vicinity, bus information	S
Signing and graphics (exterior and interior)	
Directional	S
Identification	S
Regulatory	S

TABLE 21-2 (continued)

Vertical Movement	
Escalators	S
Elevators	S
Out-of-service barricade/devices	S
Safety/security signing (elevators and escalators)	S
Communications	
Visual Message Board	S
Public address speakers/enclosures	S
Public address amplifiers	S
Radiax cable	S
Wayside Telephones	S
Coaxial cable	S
Passenger emergency call (PEC)	S
DART telephones (wayside phones)	S
Public telephones	S
Elevator emergency telephone	S
Station Control and Security	
Closed-circuit television (CCTV) equipment	S
Intrusion detection system	S
Facilities RTU subsystem	S
Fare Vending Equipment	
Fare vending machines & validators	S
Parking fee collection devices	S
Money changing devices	S
Fire and Life Safety (Subway)	
Emergency egress gates	S
Emergency equipment cabinet	S
Fire hose cabinet	S
Warning devices (horns, signs, etc.)	S
Fire detection equipment	S
Fire management panel	S
Local fire pulls	S
Fire extinguishers	S

TABLE 21-3

CONTINUITY/VARIABILITY
MATERIALS, BUILDING COMPONENTS, AND FIXTURES INTEGRAL WITH STATION CONSTRUCTION

N = No Standard
S = Standardized

P = Palette/Range

Site Development		
	Paving	N
	Street curb and gutter (city standards)	S
	Walkway	N
	Retaining wall	P (Site Specific)
	Bollards, bumpers	P
	Handrails/railings	N
	Fences (Chain Link)	S
	Benches	N
	Bus stop shelters (free-standing)	S
	Trash receptacles	S
	Planters	N
	Lighting (pedestrian and vehicular)	S
	Bicycle racks & lockers	S
	Bus bays (dimensional)	S
	Pavement markings	S
	Signage	S
Station		
	Platform paving	P
	Platform seating	S/P
	Trash receptacles	S
	Canopies	P
	Roof deck	P
	Windscreens/Seating	S
	Special Use Platform	S
	Warning Strip	S
	Public address speaker housing	S
	Doors and gate - hardware	N
	Floor, wall and ceiling finishes-public areas	P
	Hose bibbs	S
	Lighting fixtures (above grade)	S
	Lighting fixtures (below grade)	N

TABLE 21-3 (continued)

Entrance gates	N
Acoustical materials and details (controlled)	P
Signage	S
Visual Message Board	S
Stairs	N
Electrical outlets	S
Platform edge	S
Platform end gates	N
Fire hose cabinet and Fire/emergency telephone	N
Crowd control devices	N
Elevators	S
Escalators	S
Conduits/wiring/outlets/etc.	S
Structural mounts for communications subsystems	S
CCTV outlets (subway)	S
Ventilation fan systems	N
Sump pump system	N
Grounding of Structural	S

Auxiliary Rooms/Facilities Integral with Stations

Supervisors Booth	S
Substations	S
Auxiliary electrical rooms (Aerial)	S
Auxiliary electrical rooms (Subway)	N
UPS/Battery room	N
Miscellaneous auxiliary rooms	N
Toilet rooms - fixtures, accessories materials	S
Custodial room	N
Crew room	S
Security room	S
Fan room	N
Building maintenance storage rooms	N
Utility boxes	N
Doors - hardware (master key)	S
Crowd control devices	N
Revenue storage room	N
Elevator machine room	N
Mechanical grates, louvers, and grills	N

TABLE 21-3 (continued)

Structural Framing Systems	S
HVAC Distribution Systems	S
Artwork	N

21.6 MATERIALS/FINISHES

The purpose of this section is to specify criteria that have been established for the finish of public areas within the system. While convenience, comfort, and attractiveness will be considered in the selection and application of these finishes, the finishes must also be safe, durable and economical. The specific characteristics and installation methods for all materials will be addressed in the specifications.

The following outlines basic goals for choosing materials and finishes to use on the DART Light Rail System.

Safety. Hazard from fire shall be reduced by using materials with minimum burning rates, smoke generation, and minimum toxicity characteristics for stations finishes. The materials should be consistent with code requirements and should be in compliance with NFPA 130. Dislodgement hazards due to temperature change, vibration, impact, wind, aging, or other causes shall be eliminated by using proper attachments, attachment techniques, and adequate bond strength. Surfaces shall minimize protrusions and sharp edges. Floor materials with nonslip qualities shall be used to increase pedestrian safety and accommodate the needs of the handicapped and infirm. Entrances, stairways, platform edge strips and areas around equipment should have high nonslip properties.

Durability. Long and economical service shall be provided by using materials with wear, strength, and weathering qualities consistent with their initial and replacement costs, and their location in the station. The materials must maintain their good appearance throughout their useful life and must be colorfast. Materials that require trim shall be avoided. Monolithic materials may be used if they have inherent soil-hiding characteristics. Monolithic materials need adequate control and expansion joints at the proper spacing to prevent surface cracking. Edges shall be of profiles that do not easily dent or chip.

Ease of Maintenance. Cleaning costs shall be reduced by using materials which do not soil or stain easily, which have surfaces that are easy to clean in a single operation, and on which minor soiling is not apparent. Materials shall be cleanable with standard equipment and cleaning agents. All material shall be as graffiti resistant as possible, with sealers being used on porous surfaces. Maintenance costs shall be reduced by using materials which, if damaged, are easily repaired or replaced without undue interference with operations. All exposed framing shall be designed to preclude ledges allowing for nesting of birds. Spare materials shall be provided for tile and other unit materials in a quantity of approximately 2 percent of the total used. The station designer shall provide a manual detailing maintenance requirements for all materials used.

Resistance to Vandalism. Materials shall be provided and details designed that do not encourage vandalism and that are difficult to deface, damage, or remove. All surfaces exposed to the public are to be finished in such a manner that the results of casual vandalism can be readily removed with normal maintenance techniques. As part of the maintenance manual described above, station designers are required to describe the procedures for removal of more serious defacement for each finish in public areas and within 8 feet of the floor surface.

Aesthetic Qualities. Stations shall be designed to create a feeling of warmth, attractiveness, and quality, and to instill in transit patrons a civic pride that will encourage good housekeeping and good behavior.

21.6.1 General Criteria

Certain general criteria for finish materials are indicated to achieve the goals outlined above, as well as those that would result in a high level of illumination, good cleanliness levels, and the appearance of high cleanliness. Those criteria are outlined below.

Surface. Materials should be hard, dense, non-porous, non-staining, and acid and alkali resistant, for long life and low maintenance. Surfaces within reach of the public - up to 8 feet above the floor - should be more resistant to damage than is necessary for surfaces above that point.

Color. Colors should be predominantly light in tone to aid in maintaining high illumination levels, but with sufficient contrasts and accents to provide visual interest and warmth, as well as to conceal minor soiling.

Texture. Smooth surfaces are preferred over rough ones for ease in cleaning and because they are less prone to catch settling dust. Rough surfaces are desirable where a nonslip feature is important. Rough surfaces are also acceptable for surfaces that are difficult to reach, and therefore unlikely to be cleaned very frequently, because even though these surfaces may accumulate dust, they will not appear dusty.

Unit Size. Units should be large enough to reduce the number of joints, yet small enough to facilitate replacement if damaged. Monolithic materials may be used if they have inherent soil-hiding characteristics and can be easily repaired in an unnoticeable fashion.

Joints. Small, flush joints shall be provided. Since joints are a major source of maintenance problems, they shall be limited in number and shall be of the best possible materials. Horizontal joints should not be raked but should be flush or tooled concave. To prevent cracking, monolithic materials should have adequate control joints and expansion joints at proper spacings. The use of easily damaged joint covers or soft joint filler materials shall be avoided.

Cost. Costs should be within the budget to the station and should be consistent with long life, frequency and expense of maintenance, convenience, replacement considerations, and overall aesthetic and functional qualities.

Availability. Materials should be provided in sufficient quantity that their delivery and/or installation, whether for one or several stations with concurrent completion schedules, will not involve cost penalties or delays for either materials or labor.

Non-Proprietary Materials. To obtain competitive bids, proprietary items should be used only where it is established that no other materials exist which would meet the particular design requirements or where specific materials are required for systemswide consistency. All other items should be specified on a "performance specification" basis.

Installation Standards. Materials shall be detailed and specified to be installed according to industry standards and the manufacturer's printed directions for long-life, low-maintenance installations.

Flammability. Interior finishes shall meet the requirements of the Uniform Building Code (UBC), Chapter 42, as well as NFPA 130 and all other applicable codes. (See the architectural section of Appendix 1 for more information.) The finishes for all exitways shall be Class I as defined by the UBC and Class A as defined by NFPA 130. Platforms, concourses, corridors, stairways, and vestibules shall be considered exitways. Finishes in all other areas shall be Class II as defined by the UBC and Class B as defined by NFPA 130. Combustible adhesives and sealants may be used when they meet the requirements stated above.

21.6.2 List of Finish Materials

This list will apply to all areas of public use and contact at entrance, concourse, and platform levels, but not to those areas used by DART rail personnel only. The use of items listed as "acceptable" is subject to the consideration of the location and environment of the installation.

Floor Materials:

- o Acceptable:
  - Monolithic materials.
  - Concrete--Broom or similar finish to achieve a nonslippery surface and sealed with soil-resistant solution.
  - Unit Materials (large units).

- Granite (restrictive locations).
- Quarry tile--non-slip.
- Paver brick (dense hard).
- Porcelain Tile (non-slip).
- Precast concrete.
- Concrete pavers.

o Not Acceptable:

- Monolithic materials.
- Bituminous toppings.
- Synthetic resin toppings.
- Unit Materials.
- Resilient tile and sheet products.
- Wood products.
- Ceramic Tile.

<u>Column/Wall Materials</u>:

o Acceptable:

- Monolithic materials.
- Concrete (with sufficient surface texture to conceal minor soiling and damage without complicated maintenance procedures, or to constitute a hazard to clothing or skin of patrons).
- Unit Materials.
- Structural glazed facing tile.
- Unglazed ceramic mosaic tile.
- Ceramic facing veneers.
- Granite (restricted locations).
- Glazed and unglazed brick.
- Precast concrete.
- Solid glass block.
- Structural glazed faced concrete masonry units (restricted locations).
- Stainless steel.
- Surface-applied finishes.
- Heavy duty standard paints (restricted locations) non-public areas.

o Acceptable for use over 8 feet above floor only:

- Rough concrete.
- Concrete masonry units (acoustical and standard).

- o Not Acceptable:

  - Monolithic materials:

    - Rough concrete (within 8 feet of floor).
    - Plaster.
    - Exposed steel.

  - Unit materials:

    - Gypsum board.
    - Plastics.
    - Wood.

  - Surface-Applied Finishes:

    - Vinyl wall covering.

Ceiling Materials:

- o Acceptable:

  - Monolithic materials.
  - Smooth concrete.
  - Unit materials.
  - Heavy-gauge metal panels.
  - Metal panels with large perforations, and wrapped acoustical material.
  - Precast concrete.

- o Not Acceptable:

  - Surface-applied materials.
  - Sprayed acoustic materials (such as plaster, vermiculite).
  - Gypsum plaster.
  - Cement plaster.
  - Unit Materials.
  - Acoustic tile (ceramic and mineral, glass and wood fiber).
  - Gypsum board.

Door Materials and Schedule. Doors, frames, doorway panels, and exterior louvers shall meet the requirements of the system security criteria.

- o Acceptable:

    - Flush hollow metal, galvanized steel.
    - Steel style with tempered plate glass (at selected locations).
    - Tempered plate or safety glass.
    - Anodized aluminum overhead rolling doors.
    - Anodized aluminum overhead rolling grilles.
    - Stainless steel overhead grilles.

- o Not Acceptable:

    - All upward-acting sectional doors.
    - All non-tempered glass.

Hardware and Schedule. Finish hardware shall be US32D-stainless steel, satin finish. Locksets shall be heavy duty mortise type (non-ferrous) with stainless steel trim and knobs. Electric latching and alarms shall be provided as required for safety and security. Hinges in public areas shall be three-knuckle, fixed-pin stainless steel type. Closers shall be heavy-duty surface-mounted types in simple rectangular cases finished to approximate lockset finish. Stops, not overhead hold-opens, shall be provided for all doors. Floor stops shall be located out of traffic. Wall stops rather than floor stops shall be provided where possible. Some doors will require hold-open hooks on the stops. In no case shall a door that swings 180 degrees have its swing interrupted by the projecting masonry at the door opening.

Window Materials:

- o Acceptable:

    - Frames:

        - Stainless steel.
        - Anodized aluminum.
        - Coated steel.

    - Glazing:

        - Tempered plate glass.
        - Laminated safety glass.
        - Tempered, insulating glass
        - Plastic glazing sheet, (special hard, in areas inaccessible to public).

- Annealed glass, sized for twice the design load and installed out of public reach.

Open Railings Materials:

- o Acceptable:

  - Stainless steel.
  - Coated Steel.

- o Not Acceptable:

  - Color anodized aluminum.
  - Painted steel.

Interior Finishes. Finishes of surfaces exposed to the interior operations and maintenance facilities, including movable walls, partitions, columns, ceilings and other public areas shall meet Code for Safety to Life from Fire in Buildings and Structures (NFPA 101) requirements for Class A and B interior finishes and the Uniform Building Code (ICBO), Chapter 42, Class I and II requirements as follows:

- o Interior finishes shall be Class A and Class I for all exit routes.

- o Interior finishes in all other areas shall meet Class A or B NFPA 101 requirements and Class I or II Uniform Building Code requirements.

21.7 FIRE AND LIFE SAFETY

Refer to the DART System Safety Plan (part of the Systems Assurance Manual) and Chapter 29 - Fire Protection Systems of these criteria.

21.8 VERTICAL CIRCULATION

This section lists the main principles and standards relevant to the design of vertical circulation at specified stations, including escalators, elevators, stairs, and pedestrian ramps. (For further information, refer to Chapter 31 - Elevators and Escalators.) In grade separated stations, the basic means of vertical transportation will be by the elevators and stairs and or escalators when approved by DART. Escalators and stairs must be situated so that they carry patrons directly to a location on the platform convenient for boarding trains. Changes of direction should be avoided when possible. These vertical elements must be carefully located at all levels to make this direct route possible.

The ultimate quantity of stairs and escalators required in the foreseeable future shall be shown on the project definition drawings. Although only some of these escalators may be installed now to accommodate present loading, the station design must permit the ultimate quantity to be installed. All stairs should be provided in the original construction. Elevators from street level to concourse level and from concourse level to platform level or levels shall be provided as required to make the system accessible to the handicapped and for use by DART employees.

The basic goals of vertical circulation design are as follows:

- o Safety shall be achieved through the proper relationship of basic vertical circulation elements and construction details.
- o Maximum convenience for patrons shall be achieved through the establishment of uniform circulation patterns throughout the system.
- o Comfort shall be achieved through the proper sizing and layout of the vertical circulation elements.
- o All facilities shall be designed to serve the physically handicapped.
- o High quality standard design shall be provided to facilitate security and maintenance systemwide.

21.8.1 Layout Requirements

All grade-separated stations must have at least one main entrance/exit to the street level plus either one additional entrance/exit for regular use or one emergency exit. Where changes in level occur (rise), elevators, escalators and stairs shall be provided in accordance with the following minimum criteria:

- o 0 foot to 12 foot rise - 1 stair and 2 elevators or ramp.
- o 12 foot to 30 foot rise - 2 elevators and 1 stair, 1 up-down escalator according to peak hour flow, and 1 stair, or (Interior conditions only, with DART approval).
- o Over 30 foot rise – 2 elevators and 2 stairs or 2 escalators, 1 up and 1 down (reversibles), and 1 stair. (Interior conditions only, with DART approval)

Additional stairs and escalators shall be provided between the platform and street levels to clear the platform of detraining passengers prior to the arrival of the next train, based on patronage forecasts and emergency egress requirements. Emergency egress requirements and the capacities of vertical circulation elements shall be determined on the basis of NFPA 130.

An unobstructed run-off or queue space shall be provided at each end of all stairs and escalators. This space shall be as outlined in the queuing distance section and Table 21-1 of this chapter. Where stairs and/or escalators oppose one another at the same level, the total unobstructed run-off/queue space may be reduced by 25 percent. All vertical circulation elements shall comply with the codes and standards referenced in Appendix 1 and NFPA 130.

To provide access for those patrons who would have difficulty using stairs or escalators, and for maintenance equipment, elevators or ramps will be required in all stations having a change in level between the station entrance and the platform.

21.8.2 Stairs

General Requirements. Noncombustible materials shall be used for stair construction. All treads, landings, and nosings shall have nonslip surfaces. At least one shallow sloping trough shall be provided at the side of each public stair to facilitate cleaning. The bottom of the trough shall be a minimum of 1-1/2 inch clear below the tread. Treads of stairs exposed to the weather shall have a 1 percent slope downward toward the nosing.

Standard Stair Widths (Minimum).

- For public use: 5 feet, 8 inches.
- For service stairs (staff use only): 3 feet, 8 inches.
- Emergency stairs: 3 feet, 8 inches.

Stair Landings. For a straight-run stair, the minimum and recommended length of the landing shall be 5 feet. For a return stair, the minimum width of the landing must be at least equal to the width of the stair. Concealed reverse landings should be avoided in public stairs.

Tread and Risers. Public stairs running parallel to and adjoining escalators shall have a tread and riser relationship with a component of 30 degrees. All other public stairs shall have a tread and riser relationship with a component within 30 to 35 degrees. The maximum height of risers on public stairs shall be 7 inches. A riser height of 6-1/2" inches is recommended. The number of risers in any one run of public stairs shall not exceed 18. Solid treads and risers shall be used. In any one stair, tread and riser dimensions shall be uniform. Treads shall have closed backs and rounded nosings. The minimum allowable number of risers is three. Where a change in elevation is less than 18 inches, a ramp shall be used. The minimum headroom at public stairs measured vertically from the line of nosings shall be 9 feet. Continuous soffits, without obstructions, should be held to 10 feet. Emergency and staff stairs shall be a maximum 7-inch riser and a minimum

11-inch tread. The number of risers in any one run of stairs shall not exceed 20. The minimum headroom shall be not less than 7 feet 6 inches measured perpendicular to the tread nosing.

The ratio of risers to treads shall fall within the following limits: $2R + T = 24$ to 25.

Where: R = Riser
T = Tread

Handrails. Measured vertically from the top of the tread at the nosing to the top of the handrail, the height of handrails shall be 2 feet 10 inches. Handrails may extend a maximum of 3-1/2 inches into the required stair width. Except for center handrails, handrails shall be continuous through landings for the full length of the stair. Handrails shall extend a minimum of 12 inches beyond the top riser and 12 inches plus the width of 1 tread beyond the bottom riser. Handrails must be provided on both sides of all stairs. The maximum allowable stair width without a center handrail is 7 feet 4 inches. Center handrails shall be provided on narrower stairs where needed or required to aid circulation. All stairs (except monumental stairs) in excess of 7 feet 4 inches wide must have center handrails spaced no more than 7 feet 4 inches apart. Where a balustrade is not solid, the distance between balusters must be in accordance with the Uniform Building Code and local ordinances. Handrail ends shall be returned to the wall, or where freestanding, curved down 90 degrees. Handrail material shall be brushed stainless steel or coated steel.

21.8.3 Pedestrian Ramps

Pedestrian ramp slope preferably shall not exceed 1 foot in 20 feet (5 percent). Maximum slope shall not exceed 1 foot in 12 feet 6 inches (8 percent). If for use by the handicapped, slopes and widths must comply with the Texas Accessibility Standards and ADA Accessibility Guidelines. The surface of ramps shall be nonslip. A cleaning trough is not required for ramps.

21.8.4 Escalators

General Requirements.

- Direction. All escalators will be furnished and installed under a separate systemwide contract. Exact dimensional requirements will be furnished after the station design contract is awarded.

- Width. Unless otherwise shown on general plans, all escalators shall have a 48-inch nominal width.

- Speed and capacity. All escalators shall be dual-speed, 90- and 120-feet-per-minute (fpm) in both up and down directions. They shall be capable of operating 24 hours each day under full load conditions.

- Rise and slope. Rise (H) is the true vertical distance between working points (W.P.). All escalators shall be installed with the line of step nosing 30 degrees from the true horizontal.

- Structural considerations. A slip connection at the head of escalators in above-ground stations and at the foot of escalators in below-ground stations will be provided by the escalator manufacturer to allow for movement (such as deflection and torsion) due to the load on the station's structure caused by the train as it moves in and out of the station. Escalator trusswork and other structural members are not to receive loads other than those imposed by the normal functions of the escalator itself.

- Floor slope. Landing plates must be level. Adjacent floors shall be sloped away from the escalator.

- Space and safety requirements for escalator machine space. All escalator machinery shall be contained within the escalator truss. All machine pits shall be provided with removable covers over the full area of the machine pit. Covers shall be removable by one person without use of special equipment. Escalator finish materials shall be brushed stainless steel. The moving handrail shall be black rubber. Additional lighting shall be provided at landings.

- Noise attenuation requirements. Refer to Chapter 11 - Noise and Vibration for requirements.

- Balustrades. All escalators shall have solid balustrades clad with rigid stainless steel or glass balustrade in accordance with the standard drawings. Exterior cladding shall be coated steel. All cladding shall be procured as part of the escalator contract.

- Escalator treads. All Class A escalators (vertical rise of less than 20 feet) and Class B escalators (vertical rise of 20 feet or more) shall have a minimum of three level treads exposed to form a horizontal platform at "fade out," at both the upper and lower landings.

- Escalator pit. All escalators in grade-separated stations shall contain a lower pit as indicated on the architectural directive drawings. The escalator pit shall contain either a sump pit or a floor drain.

- Escalator machinery location. All machinery that is required for both Class A and Class B escalators in grade-separated stations shall be contained within the escalator truss and its enclosure. This shall apply to all escalators, whether their drive mechanisms are contained within the truss on the incline or at the upper landing.

21.8.5 Elevators

Planning Requirements. Elevators shall be installed in all stations between platform level and street level, or between each platform and the concourse and between the concourse and the street. Elevators at street level shall be located near a loading zone. In stations with parking facilities, parking for the handicapped shall be located near the elevator.

Elevator cab finish materials shall be brushed stainless steel on all opaque wall surfaces, doors, frames, sills, and trim. Floor and ceiling materials are to be as specified. Transparent surfaces shall be laminated safety glass and as required by applicable codes.

Elevator hoistway enclosure finish material shall be stainless steel on all opaque walls, or other acceptable materials as indicated in the materials list with coated or stainless steel roof and ceiling. Doors, frames and sills shall be stainless steel. Transparent surfaces shall be as described above. The elevator hoistway shall be located and sized as indicated on the architectural project definition drawings and directive drawings, and shall comply with ANSI elevator safety code A17.1A requirements. It shall contain a pit providing a maximum bottom cab clearance of 4 feet and a cab over-run clearance of 4 feet at the top of the hoistway. The elevator pit shall contain a sump pit or floor drain.

To the maximum extent possible, both the elevator cab and the elevator hoistway enclosure shall be constructed of glass. This will allow security to observe activity in the elevators at all times and will help to prevent criminal activity and vandalism.

Elevator Cab. All elevator cabs shall be equipped with mat hooks to secure protective wall mats for maintenance and service use. Cabs with a single center-opening entrance shall be designed and sized to accommodate an ambulance-type stretcher or a large commercial floor scrubber, and to permit the turning of a wheelchair. Cab controls shall meet handicapped requirements according to ANSI standards.

Elevator Machine Room. The elevator machine room shall be located and sized as indicated on architectural project definition and directive drawings. For additional information, refer to Chapter 31 - Elevators and Escalators.

21.9 VEHICLE DATA AND CLEARANCES*

*Note: Rail vehicle data and clearance criteria are provided in Systems Design Criteria Chapter 2 - Light Rail Vehicles. Refer to Systems Design Criteria Chapter 2 - Light Rail Vehicles, Chapter 1 - Track Alignment of these criteria, and the architectural standard drawings for rail vehicle requirements and track data necessary for determining station configuration.

21.9.1 Bus Description

For information on bus dimensions, weights and other pertinent data, refer to Chapter 4 - Streets, Highways, and Parking.

21.10 ACOUSTICS

The purpose of this section is to provide and define criteria that will result in a desirable environment at and around stations throughout the system. The amount of control of sound energy and the consequent reduction of noise obtained is dependent upon the area of the acoustical treatment, the absorption coefficient, and the placement of the treatment. For further information, refer to Chapter 11 - Noise and Vibration.

The basic goals of these acoustical design criteria are as follows:

- To control and reduce noise from rail transit operations.
- To provide for clarity of announcements from the public address (PA) system.
- To control general crowd noise generated by patrons speaking and walking.
- To control noise from exterior sources.
- To assist in the control of noise from station mechanical and electrical equipment.

21.10.1 General Criteria

No long-distance echoes should be audible in public spaces when they are nearly empty. Flutter echo between parallel surfaces should be minimized. Consideration must be given to the effect of noise generated by the DART Rail System on the area surrounding the lines and stations, and of street, highway, and railroad operation noises entering the station.

21.10.2 Specific Criteria

Subway Station Areas Directly Related to Street Traffic Noise. The areas affected are entrances, stairs from street level, elevators, escalators, and vent shafts from street level, and mezzanine levels (if applicable). Where practicable, these areas should assist in reducing the traffic noise transmitted into the station. Unless it becomes indispensable, entrance portals from grade to mezzanine-level passageways shall have no acoustical treatment. The acoustical coverage of mezzanine-level passageways shall be as indicated in Chapter 11 - Noise and Vibration. Wall acoustical treatment shall be avoided. All acoustical material shall be mechanically fastened.

__Concourse Areas__. Areas affected include the fare vending areas, stairs and escalators, and corridors. The maximum noise level for these concourse areas should not exceed 55 A-weighted decibels (dBA) in the absence of occupants. Acoustical coverage on the underside of the mezzanine-level floor slabs shall be as indicated in Chapter 11 - Noise and Vibration. Sidewall coverage shall be avoided. All acoustical material shall be mechanically fastened.

__Areas Related Directly to Rail Transit Noise__.

- o Subway Stations. For design purposes, refer to Chapter 11 - Noise and Vibration for on-platform train noise level requirements.

- o Ventilating and Air Conditioning Equipment. Spaces for fans and other potentially noisy equipment shall be separated as much as possible from public areas. If direct access into these rooms from public areas cannot be avoided, doors shall be provided that have a suitable sound rating. Sound transmission through other openings shall be controlled by appropriate means.

For additional information refer to Chapter 11 - Noise and Vibration.

21.11 ADVERTISING

Advertising is permitted in the DART Rail System on a carefully controlled basis. Marketable advertising space should be provided in the design of DART rail stations consistent with the locations and assemblies shown on the Standard and Directive drawings.

To produce significant revenues for the DART system, DART will carry out the following:

- o Establish controlled advertising programs that will provide an attractive, informative, and enjoyable environment for its patrons.

- o Provide that advertising, by its placement and treatment, does not interfere with orderly and efficient patron circulation. The placement of advertising on or adjacent to escalators, stairs, system graphics, or clocks will not be permitted.

- o Discourage defacement or damage by the placement and the form of advertising. Merchandise display cases will not be permitted due to their potential for being vandalized.

21.11.1 General Criteria

All advertising space in the system shall conform to the national standard sizes of advertising in general use in the United States. The selected standard sizes shall be coherent with station design.

Advertisements will be located adjacent to, but not in conflict with, areas of heavy traffic. To prevent defacement, advertisements should, where possible, be located out of public reach or be protected by laminated safety glass. No advertising will be visible from outside the system. For related information, refer to the signing section in Chapter 22 - Station Operational Requirements. No special lighting will be provided by DART for advertising displays, however, back lighted advertising displays will be considered. All advertising display designs and locations shall be coordinated with and approved by DART.

21.12 ART PROGRAM (including Artworks)

The purpose of this section is to describe the goals and criteria of the DART Art and Design Program, dated June 1990, as it relates to the station and site design, and to outline a procedure to be followed by each designer. Each station design will be site specific but certain opportunities for art are intrinsic to all stations. The areas within the station complex and station site that lend themselves to integral or individual artwork are identified in this section and in the Art and Design Handbook.

The basic goals of the Art Program are as follows:

- o To enhance the everyday act of commuting and expand the public experience of art through the commissioning of the highest quality of art in public places.
- o To enrich the rail transit system for both residents and visitors by creating a unique visual identity for each station through works of art that reflect a sense of community identity and pride.
- o To incorporate artwork as part of the initial station designs, thus integrating it into the architecture and/or sites, maximizing the effectiveness of the budget, and of the sense of context of each location.
- o To foster public involvement in the design process of each station identity and art project.
- o To recognize the multicultural nature of the Dallas metroplex by promoting diversity and pluralism in the art projects, thus reflecting as wide a range of expression as possible.
- o To express commitment to artists residing in Texas by focusing the program toward Texas artists, thus encouraging the business of art as it in turn helps develop the local economy.

21.12.1 General Criteria

Based on the above goals the following criteria take into consideration the elements necessary to ensure the proper implementation of the DART Art and Design Program.

- Aesthetic excellence - The art projects shall strive to be of the highest aesthetic quality and enduring value.
- Site specific - Relationship of art and site shall be considered in terms of integration of art and architecture with landscape, social dynamics, local character, and surrounding urban context.
- Durability of design and materials - Art projects shall be designed with consideration to minimum maintenance requirements and maximum resistance to vandalism. All art project components are to be designed with suitable durability to maintain their integrity for 20 years with minimal maintenance. All operable components must have standard replacement parts.

21.12.2 Artists Involvement

Artists from a variety of sources will be involved in the Art and Design Program. It will be necessary to coordinate each participant in the facility process. Each of the artists will have a separate and distinct role in the program.

DART's objective as stated in the Art and Design Program is to establish and maintain an effective transit Art and Design Program. To accomplish this objective, in addition to the Lead Artist Consultant, each section will have Local Station Design artist working with each of the professional design teams to participate in design elements of the specific facility designs. In addition, the artist will work as a member of the design team and with the community in determining the theme or attitude of the station and in recommending the ways in which the art budget should be spent.

Specific project artists may then be selected to create and install art projects in the stations and on the sites, once proposals for final design are developed and approved by the Site Specific Committee and the Board Art and Design Committee.

21.12.3 Integration of Schedules

In order to ensure the careful coordination of the Art Project(s) with the various phases of the facility development, an integration schedule has been established. As described in the DART Art and Design Program dated June 1990, the objective is to match the development of the art projects design and construction with the stages of development of the art projects for those facilities. The objective is to define and develop art projects at the most critical and effective point of the facility design process and integrate the project into the space and construction of the facility.

21.12.4 Budgets and Funding

The budget to develop and implement art projects for the light rail stations is based on an assessment of $50,000 per station or facility as determined by the Art and Design Program dated June 1990. The per facility amount may be summed by each transit corridor to produce a total corridor budget which will be distributed for art projects at stations and other facilities within that corridor.

Opportunities have been identified for the prototype station that enhance the facility's capital budgets. For example, a floor or wall in the facility budget could be developed from the overall facility budget and not Art Program funds. Such coordination would allow for more art possibilities at that station or in that corridor.

In order to enhance the Art and Design Program budget, funds external to DART revenues will be sought by both staff and committees. These external funds will be through local and national foundations, as well as joint development contributions as related to station facility development.

21.12.5 Security Considerations

Art projects shall be placed where they do not provide spaces for loiterers or persons intending to hide behind such features. Ease of surveillance for security patrol cars shall be considered when locating all projects.

21.12.6 Art Opportunities

I. System wide - Art opportunities exist which could be incorporated into prototypical elements within the system or corridor. For example:

    Tree grates or tree-protectors.
    Pavement Designs.
    Banners or windsocks.
    Ornamental frames for advertising, maps or temporary art displays.
    Benches.
    Drinking fountains.
    Trash receptacles.
    Lighting fixtures.
    Landscape Areas.

II. Prototypical Stations-Art opportunities for art projects that might be modified to give site specific identity to each station. For example:

A. Intrinsic Design Opportunities:

Column clading-bas relief, mosic.
Windscreens-holograms, photographs, stained glass, videos, murals.
Lighting fixtures.
Benches or seating.
Railings/Fencing.
Entrance/Platform paving.
Planters or planter area.
Bollards.

B. Individual art opportunities:

Clocks.
Neon designs.
Mobiles or hanging art works from arched trusses.
Windchimes or wind sculptures.
Banners.
Sound or light installations.
Message center-thought provoking messages.
Drinking fountains.

C. Station Landscape Area:

Tree grates or tree protectors.
Sculptures.
Seating.
Hardscape.
Plantings.
Mitigation elements-visual screening, sound screening.
Enhanced pedestrian paving.
Raised planters.

III. Station Site - Art opportunities exist that could be incorporated into station sites. For example:

A. Landscape buffer zones:

Earth berms, earth sculptures.

Water features.
Visual screening.

B. Entry Areas:

Plantings.
Sculptures.
Gateways.
Banners.

C. Parking Lots:

Parking Lines-painted designs.
Bollards.
Hardscape paving patterns.

D. General Site:

Banners, windsocks, wind sculpture.
Fences.
Poles.
Lighting fixtures.
Retaining walls.
Mitigation walls.
Sundials.
Interactive sculpture.
Clock towers.
Stage area.

21.13 CONCESSIONS

DART policy on concessions has not yet been established. The criteria below is included for discussion purposes only, and is based on the policies of other transit properties.

It will be the policy of DART to establish controlled concession programs to provide for patron convenience, while at the same time maintaining an attractive, functional, and enjoyable environment for its patrons. Accordingly, all concessions permitted by DART shall conform to the general standards set forth below:

o To provide facilities and spaces for concessions.

- o To provide that concession operation does not result in security, litter, or pest infestation problems.

- o To provide that concession operation does not interfere with patron circulation and transit operation, and that the visual impact of concessions is complementary to station design.

- o To generate revenue.

21.13.1 General Criteria

Concessions shall be located on the concourse level. No concessions shall be allowed on the platforms. No food or drink concessions shall be permitted.

21.13.2 Specific Criteria

Coin-Operated Equipment. Public telephones will be provided in all stations as indicated in Systems Design Criteria Chapter 5 - Communications. Fare vending machines will be as indicated in Chapter 22 - Station Operational Requirements of these criteria. Coin-operated newspaper vending machines may be authorized for selected stations. They will be systemwide, standardized machines designed for either mounting in wall recesses or as freestanding units.

21.14 SANITATION AND MAINTENANCE

This section provides the station designer with general standards for station sanitation and maintenance facilities. DART will provide all necessary maintenance equipment and facilities regardless of whether the maintenance work forces consist of DART rail employees or contract personnel. Maintenance crews will be based at the maintenance-of-way (MOW) facility, and possibly at other off-station locations. A maintenance room for storage of some equipment, materials, and supplies shall be provided at selected stations. The size of this room will vary with each station.

Station maintenance activities are classified under three general categories: service and inspection, preventive maintenance, and corrective maintenance. Work under the first two categories will be performed on a prescheduled, routine basis. Work under the third category will be provided on an as-needed basis.

Most station maintenance activities will be performed during revenue hours. Only those activities that would seriously disrupt revenue operations will be performed during nonrevenue hours. Truck access to maintenance areas shall be provided with minimum disruption to station functions. For data relative to the maintenance of those areas of the station complex beyond the exterior surfaces of the station building (or buildings), including canopies and other appendages, and within the boundaries of the station site, see the DART Rail System maintenance plan.

The basic goals of the design criteria for DART sanitation and maintenance facilities are as follows:

- To create environments throughout the system with an easily maintained high level of cleanliness.

- To create environments which will instill pride and encourage patronage.

- To provide facilities for a cost-effective maintenance program.

- To integrate maintenance elements in the stations as a part of station design without detracting from the appearance of the stations.

- To provide uniform interchangeable facilities within each station or between stations, where possible, to simplify the replacement of damaged items.

21.14.1 General Criteria

Maintenance and operation programs requiring the use of trainway areas and equipment should be avoided. Although some intrusion into the trainway may be necessary, every such intrusion will cause either additional programming problems with revenue operations or result in high costs from having to provide services for limited times during premium hours.

Horizontal ledges should be avoided to minimize the collection of dust. Wherever possible in above-grade stations, the exposed top surfaces of areas such as outriggers, beams, parapets, and window ledges shall have a minimum slope of 30 degrees to horizontal in order to prevent the collection of dust and debris and to discourage birds from roosting in station structures. All alcove areas are to be sealed to prevent trash accumulation and bird roosting.

Bases should be flush with walls or recessed. If recessed, the configuration must not preclude the use of a vacuum scrubber to clean the floor within the recess. Cove bases shall be provided. Wherever possible, these shall be integral with the floor and not less than 6 inches high at all points of intersection between floors and walls, partitions, columns, and other surfaces in all public areas, as well as in toilet, custodial, trash, and battery rooms.

Handrails, door pulls, and other protruding elements should have a 1-1/2-inch minimum clear space behind them. Signs, advertising panels, and artwork should be designed and located to require limited maintenance. Cleanouts and access panels should be inconspicuously located and (where possible) placed in pipe chases and nonpublic areas.

Wall-mounted items of equipment (including movable equipment) should be flush with the wall. This equipment must be accessible to the handicapped, including those in wheelchairs. Any notches in walls for flush-mounted equipment should not extend down to the floor unless necessary to provide access for the handicapped. The bottoms of these notches should be not less than 6 inches above the adjacent floor at any point. Where equipment is freestanding, it should have its own integral base fitted tight to the floor. Where equipment is grouped, flush closure strips should be used to cover the spaces between units.

Structural and architectural elements which must project from walls should be held at least 12 inches above the floor for easy cleaning. Where an element must project more than 3 inches from a wall, it first must be verified that the floor and wall surfaces below or adjacent to the projecting element are accessible for cleaning using standard equipment.

Items such as signs, handrails, and benches should be securely anchored with tamperproof screws or bolts. If heads must be exposed, flush spanner-head screws shall be used. Allen-head screws shall be used if heads are concealed from view. The use of concealed fasteners is preferred.

21.14.2 Specific Criteria

Entrance. Provisions should be made at each entrance for a 110-volts alternating current (VAC) weatherproof outlet and a 3/4-inch hose bibb in an adjacent locked box. Covered trash receptacles should be located at all entrances, bus drop-off areas, and kiss-and-ride areas. Steel grating floor mats in drained recesses shall be provided, under cover, across the full width of all station patron entrances.

Concourse. Pairs of locked utility boxes consisting of a 3/4-inch hose bibb and a 110-VAC weatherproof outlet shall be provided throughout public and ancillary spaces. These shall be located so that no portion of a floor area is more than 100 feet from such a pair. Pairs located in public areas shall be installed in separate but adjacent flush-mounted stainless-steel boxes; one containing the hose bibb and the other containing the electrical outlet.

Trash and ash receptacles should be located in pairs at key points where people stop, such as at vending machines, gates, and seating areas as indicated on the directive drawings. There will be no ash receptacles in station areas, which are designated as "no smoking" areas. Ash and trash receptacles will be furnished and installed by a DART rail supplier on a systemwide basis.

Custodial Room. This room is to be located as near as possible to an elevator. One such facility is required at each subway station, preferably at mezzanine or concourse level, and at selected stations shown on the Preliminary Engineering drawings. Items in this area should include:

- Mop sink.

- o Hot and cold water, single spout with pail hook at 3 feet above bottom of mop sink, equipped with a 4-foot-long, low-pressure hose.
- o Floor drain.
- o 110-VAC weatherproof outlet directly adjacent to a scrubber storage space.
- o Two adjustable shelves, 10 feet wide (minimum) by 1 foot deep, for storage of cleaning supplies.
- o Two adjustable shelves, 6 feet wide (minimum) by 1 foot 6 inches deep, for storage of toilet supplies.
- o 10 sets of stainless steel, cam-action, tool-holding clips.
- o Space for a double bucket and a vacuum-scrubber machine.

Trash Room. This room is required at each subway station and (as required) at selected stations as directed by DART. It shall be preferably located at the mezzanine level adjacent to the elevator. Items in this area should include:

- o 110-VAC weatherproof outlet.
- o Cold water hose bibb, 3 feet above the floor.
- o Floor drain under the hose bibb.
- o Mechanical ventilation as described in Chapter 25 - Heating, Ventilation, and Air Conditioning Systems.
- o Sprinkler system (see Chapter 29 - Fire Protection Systems).
- o 3 foot 6 inch by 7 foot access door.

Platform. Pairs of locked utility boxes for hose bibbs and electrical outlets shall be located throughout the platform area. The description and spacing shall be as established for concourse areas above, except that one of the required pairs must be located in the centroid portion of each platform as shown on the directive drawings. A trash receptacle should be placed at all central waiting areas.

CHAPTER 22 - STATION OPERATIONAL REQUIREMENTS

22.1 INTRODUCTION

This chapter describes the supervision, administration, safety, security, and monitoring requirements of passenger stations. It examines how they may be fitted in the station design as presently anticipated. This includes various types of communications systems; from closed circuit television to telephones and portable radios. Other operational areas covered are fare vending machine locations and placement of informational signs to guide patrons through stations quickly and easily.

The basic goals of this section are to present ways to:

- o Provide for public safety.
- o Provide efficient operation of the station and optimum service to patrons.
- o Deter crime and vandalism.

Ideally, the above will be accomplished with a minimum of manpower by using unique design techniques, automatic devices, and remote control equipment.

22.2 STATION CONTROL

22.2.1 Planning Considerations

Except for emergencies, to activate or reverse elevators, or to secure for shutdown, all stations shall be designed so that once set in operation a station attendant will not be required. At-grade stations will have no provisions for shutdown during nonoperating hours. All subway and grade-separated entrances, including entrances to pedestrian bridges, grade- level entrances to subway stations must be capable of being closed each day. To minimize surveillance problems, the station design should eliminate nooks, recesses, and corners wherever possible. Stations should be secured at their outermost points.

Station supervision and administration functions will be monitored from the operations control center (OCC) by remote control systems, closed circuit television (CCTV), passenger emergency call intercom, fire alarms, intrusion alarms, and public address systems and related visual message board.

22.2.2 Station Functions Monitored by the Operations Train Control Center

The OCC will monitor all stations. Responsibilities will include:

- Supervision of passenger activity:

  - Monitoring and controlling (where provided) CCTV.
  - Providing information and assistance to patrons.
  - Acting in emergencies such as illness or assault.
  - Monitor security alarms.
  - Responding to passenger emergency calls.
  - Monitoring platform loading conditions.
  - Monitoring fare vending machine malfunctions.

- Supervision of station operation and security:

  - Monitoring stations for undesirable and illegal acts against patrons, DART rail personnel, and station facilities.

  - Directing unlocking and opening of stations by DART rail roving supervisory or security personnel at the commencement of the day's operations.

  - Directing station close-down and locking by DART rail roving security or supervisory personnel at the end of the day's operations.

  - Directing activities of the DART rail system roving security force by a security radio system, and directing the activities of DART rail system personnel in stations by CCTV and the DART rail system telephone system.

  - Monitoring the station intrusion alarm system.

22.2.3 Staff/Security Room in Stations

Selected stations will have a staff/security room used principally by security personnel, located directly off the concourse or platform. The room should be inconspicuous yet afford, if possible, a view of the fare-vending area. The staff/security room shall accommodate a desk and three chairs and have provision for CCTV monitoring.

22.2.4 Barriers and Fences

The barriers and fences used for station security enclosures shall be as follows:

- Heights of fences shall be not less than 9 feet.

- Barriers shall be visually open to provide for ease of surveillance.

- Where bars, slats, or pickets are used, the maximum spacing shall be a 5-inch clear opening.

- Fences shall be a non-climbable type with horizontal members near the top and bottom only, except at ceiling high fences.

22.2.5 Station Closedown

It is not standard practice to secure (lock-down) DART grade-separated stations when the station or the entire system is shut down. However, as directed by DART, the need to secure certain grade-separated stations may arise. Under these circumstances, provisions shall be made in the design to provide adequate means of limiting access to these stations. These means shall be in the form of doors, gates, rolling doors, roll-down shutters or grilles that are controlled from either side of the entrance by devices to be specified by DART. Consideration shall not be given to providing means of securing at-grade stations. It should also be noted that subway stations, by nature of their construction, are inherently capable of being secured and do not require detailing of additional lock-down methods. Each secured station must have at least one means of emergency egress in accordance with applicable code requirements for each municipality. Each station must have at least one access door for use by DART rail personnel when the station is secured. This requirement could be combined with the emergency egress door requirement by providing for a key-operated alarm bypass from both sides. Security-closure doors and grilles should be located to eliminate places of concealment accessible from the street after closedown.

22.2.6 Private Entrances

Entrances to the concourse from non-DART rail structures such as stores, hotels, and office buildings will be provided with closure similar in function to closedown closures. The closure will be equipped with a security lock keyed as required by specific station entrance configuration. If emergency egress is required at the closure location, special provisions shall be made to comply with the applicable codes for each municipality.

22.2.7 Security Alarms and Locks

All station-related ancillary spaces shall be protected by locks. Selected spaces shall be provided with intrusion alarms to alert OCC or station personnel to intrusion, tampering, or unauthorized use. Refer to Chapter 27 - Fire and Intrusion Alarm Systems for more specific requirements. As many ancillary spaces as possible, which will normally require locks and alarms, shall be clustered along a corridor entered by a doorway from the station concourse. This corridor doorway will be equipped with a lock and intrusion alarm that will take the place of individual alarms and locks at doors to these rooms. Ancillary spaces in this category include electric closets, elevator machine rooms, fan rooms, and pump/valve rooms.

Secure rooms and auxiliary electric rooms will require individual locks and intrusion alarms whether or not they are located off a secured corridor. Secure rooms will be separately keyed and access to these rooms will be monitored from the OCC.

All grade-separated and subway station entrances that are locked during non-revenue hours shall be in accordance with 22.2.5 and shall be equipped with an alarm signal audible at the entrance and directly connected to the OCC. Included in this category are:

- o Entrances giving direct access to a station.
- o Entrances to pedestrian bridges leading to stations.
- o Grade-level entrances to subway stations.
- o Emergency egress doors for use during non-revenue hours.
- o DART rail personnel access doors for use during non-revenue hours.

The entrances referred to above shall have manual locking capability from either side. All entrances shall be operable by a station entrance master key, except the non-revenue-hours personnel entrance, which shall be separately keyed. The non-revenue-hours emergency egress door shall be equipped with panic hardware.

22.2.8 Security Areas

Station areas have been classified by level of security as a basis for determining requirements for protection:

- o Level A - Open to the public during system operating hours.
- o Level B - Open to system employees at all times and to the public under emergency or special circumstances.
- o Level C - Controlled access for system employees only.

Security provisions for station areas and appropriate levels of security shall be as shown in Table 22-1.

22.3 COMMUNICATIONS

This section identifies the general requirements for the installation of communications systems and equipment to be provided in stations, and establishes the minimum provisions necessary to accommodate them. For equipment information, refer to System Design Criteria Chapter 5 - Communications. Architectural standard and directive drawings will provide enclosures, and location and installation details for all communications equipment as it applies to each station type.

The basic goals for this section are to alert the designer to systems that must be accommodated in each station to provide:

- o Proper allocation of space to house and maintain equipment.
- o Proper arrangement of the spaces to minimize electromagnetic interference from electrical systems and to avoid costly and inefficient layout of equipment.
- o That housings, trim, and architectural elements exposed to public view are properly located, design coordinated, and aesthetically pleasing, and that their impact on the surrounding community is minimized.

22.3.1 Communications System

The communications system will include all apparatus required to transmit information and data within and outside the DART system.

Table 22-1

SECURITY LEVELS AND PROVISIONS

	Security Level	CCTV Surveillance	Sensing Devices	2-Way Audio	Security Latching	Special Key	High Light Level
Station Closure at Ground Level	A		o		o	o	o
Entrance Elevator	A	o			o	o	o
Mezzanine Area	A	o					o
Fare Vending Equipment	C	o	o		o	o	
Toilets Entry	B	o				o	
Emergency Gates	B	o					
Mezzanine Elevator	A	o		o	o	o	o
Ancillary Space Main Entrance	C	o	o		o	o	
Ancillary Space	C		o		o	o	
Platform	A	o		o			
Parking and Bus Area	A	o		o			

The OCC will be the hub of all operations-oriented communications subsystems. It will also act as the alarm center for fire and emergency systems. OCC security functions will be synonymous with those of police department precincts. The primary functions include: passenger/employee security, passenger assistance, and crowd control. (Refer to Systems Design Criteria Chapter 6 - Operations Control Center for additional information.)

Interfacing equipment and provisions for the communications system, such as handset and speaker enclosures, mounting for emergency call units, microphones, CCTV cameras, cabinets, and conduit, shall be provided under station construction contracts. Telephone sets, police emergency call units, microphones, and wiring will be provided under a separate contract. (Refer to Systems Design Criteria Chapter 5 - Communication for interface details.)

Wayside Telephone Subsystem. This subsystem will provide voice communication between police, fire department, DART employees, DART patrons and the OCC for the reporting of emergency situations. Handsets will be provided on the aerial station platform, aerial structures and elevated guideway areas in excess of 2,500 feet, in elevators, in subway tunnel cross-passageways and at the departing ends of terminal at-grade station platforms.

The sets for the aerial station platforms have been located in the "proto-typical" aerial station layout. The final line section designer shall develop the station design with these wayside telephone locations. If there becomes a case as an individual station design is developed, where a particular phone location is in conflict, the section designer should review any proposed modifications with DART's Manager Rail Systems Safety. The station platform includes two wayside phones, one at the ramp entrance of each special use platform. An emergency phone is located so that any part of the platform will be no further than 300 feet from the set. Telephone sets can also be installed in the fare vending machine area of aerial stations for emergency purposes.

Passenger Emergency Call Subsystem. This subsystem will provide voice communication between patrons and the operations control center for emergency assistance. One Passenger Emergency Call unit shall be installed in each subway station mezzanine and fare vending area. Two units shall be installed on each station platform with one in the proximity at the fare vending machine. A unit may be installed in each elevator in lieu of an emergency telephone.

Elevator Emergency Phones. All elevators shall be equipped with emergency phones in accordance with ANSI A17.1.

Blue Light Stations. Emergency phones (Blue Light Stations) will be provided at all grade separated stations. Blue Light Stations shall be located within a maximum travel distance of 300' from any point on the boarding platform. Ref. Systems Design Criteria Volume 2, Chapter 12.

DART Telephone Subsystem. This subsystem will provide voice communication links for DART rail system personnel. Telephone sets shall be installed at each staff room and equipment room.

Public Telephone Service. Public telephones shall be provided at selected stations in cooperation with the local telephone company. Provisions for service, the number and location of sets, and the size of required equipment space will be determined by DART in consultation with the local telephone company. The total number of telephones will be determined by DART. All telephones will be suitable for use by the handicapped. Terminal cabinets should be located in a telephone equipment closet and, where possible, should be located to provide direct access for telephone company employees without the necessity of entering secured ancillary spaces.

Public Address. The public address subsystem will be used by OCC staff to make general announcements and to give fire alarms and evacuation instructions at selected stations and in station bus-loading areas. Central control can communicate with any or all of the stations equipped with public address systems. Loudspeakers should be located at intervals frequent enough to provide intelligible speech in public and ancillary areas. Spacing and locations will be established in the preliminary design drawings and will be established according to the provisions of the Systems Design Criteria Chapter 5 - Communications. Where speaker enclosures are practical the enclosure for each speaker will e an acoustically treated, non-corrosive metal box no larger than 12 inches by 12 inches by 6 inches deep with a grille providing 75 percent free opening. The speaker enclosure shall be recessed and mounted flush with ceiling or wall surface.

Electronic Visual Display. (Visual message Board) Provisions will be made at each station for display of general patron information and train status to supplement the PA system.

Radio Subsystem. The radio subsystem, which will be furnished and installed under a systemwide contract, will include maintenance, yard, train, transit police, local police and fire department radios. There shall be a distributed antennae system (lossy line) within all subway structures to allow constant communication between the train operator and the OCC.

Although this distributed antennae system will be furnished and installed under a separate systemwide contract, provisions for this installation must be made in station designs as follows:

- o One line will be required for each track through the station area and located so that it is in line of sight and within 50 feet of the vehicle antenna and portable radios on the belt of any personnel on the platforms.
- o Lines will be required through mezzanines and ancillary areas so that they are within 50 feet and in line of sight of portable radios on the belts of any personnel in the area.
- o The lines must run through a station area continuously, without any breaks.
- o The lines may be sleeved through structural members under certain conditions which must be separately evaluated for each station design.
- o Provisions must be made for a connection between the lines and the station communications bungalow.
- o The location of the antenna shall be coordinated and integrated with overall station design.

- The minimum forming radius for the distributed antennae (lossy line) is 15 inches. Provisions must be made for supporting the line at intervals no greater than 5 feet. The line will be suspended on non-conductive brackets to be furnished and installed by the line's installer. These brackets will hold the line a minimum of 3 inches from adjacent construction. Provisions to be made in the station design and construction will consist of internally threaded cast-in-place sleeves or threaded bolts set in concrete, or welded or bolted equivalents, if the structure is steel.

- Lossy line will be concealed in stations with covers or other means which will not interfere with radio transmission between the line and the train.

- Additional data will be furnished by DART on request as needed.

Closed Circuit TV (CCTV) Subsystem. (Refer to Section 22.2 of this chapter for general details and requirements.) The purpose of closed-circuit television will be for use as a means of maintaining surveillance over subway and other selected station areas from the OCC. DART will establish approximate locations of cameras, and the section designer will develop their precise locations in coordination with other equipment locations such as lighting, public address speakers, and signing. The section designer will make provisions for attachment, and provide conduit runs and outlet boxes for power and control for the system, as a part of the station contract.

- Camera Locations. The following is a list of those facilities requiring special supervision. They should be within direct range of a closed-circuit television camera.

    - Station Mezzanine.

    - Fare vendors/change machines.

    - End of vertical circulation elements (stairs, escalators, elevators).

    - Station Platforms.

These cameras will be placed to cover the areas at the ends of vertical circulation elements and as much of the platform area as possible.

Cameras shall be out of reach and all conduits shall be concealed. The designer shall determine that the average lighting levels are adequate.

Fire Detection/Intrusion Alarm Annunciator Equipment. The fire detection and intrusion alarm systems are defined in Chapter 27 - Fire and Intrusion Alarm Systems.

Communication Transmission Subsystem (CTS). The CTS shall link the stations and other primary areas with each other. It shall transmit signals for telephone, public address, data transmission service, radio, television, and miscellaneous remote-control equipment. For design criteria and requirements, refer to Systems Design Criteria Chapter 5 - Communications.

22.4 FARE VENDING

The ticket-vending system will be a self-service type. The layout of the fare vending equipment (ticket vending machines), should be such that the equipment can be used easily and quickly. Spacing shall be adequate to allow for separate queuing for each machine without impacting other machines or patron flow. (For additional information, see Systems Design Criteria Chapter 7 - Fare Collection.)

To monitor the payment of correct fare, passenger fares will be checked throughout the DART rail system by roving fare inspectors.

All necessary patron information relating to the fare vending/checking procedure will be included in station signing and incorporated in the vending panels or adjacent to the panel. (Refer to section 22.5 of this chapter for detailed requirements.)

Ticket Vending Machines shall be located at a consistent centralized location between stations. This location will also contain system maps and patron information.

The basic goals for this section are to present ways to:

- o Control passenger movement and DART system usage in such a way that a self-service fare collection system operates smoothly, economically, and with greatest passenger convenience.
- o Allow sufficient flexibility in station layout for future expansion or changes in the fare vending system.

22.4.1 Fare Card Equipment

Location and Description. The fare vendors (ticket vending machines) and validators will typically be located on the station platforms located in concourses, mezzanines, and areas that are adjacent to or lead to platforms; specified stations may have fare vending. The fare vendors must be clearly visible upon entry to the station but placed to avoid impeding the direct flow of passenger traffic or sight lines important to passenger safety. All fare vendors shall be freestanding or built-in, having front panels flush with wall surfaces, or as required by station type. Fare vendors shall have front access for maintenance and servicing. Vending machines will have built-in security alarm systems. Fare-vendor design and location shall be integrated and coordinated with overall station design. (Refer to the preliminary design drawings for more information.)

Quantities and Dimensions. The disposition of fare vendors within each station should reflect the loads at the various stations projected by the patronage analysis and station layout. The quantity of vendors required for initial installation will be determined by DART, but shall not be less than space for 2 vendors per station or one per platform for side platform stations. Wall recesses shall be provided for vending machines to fit selected equipment dimensions and mounted on a 6-inch-high base or free standing units may be utilized. Knock-out closure panels shall be provided for machine spaces over and above the initial installation.

22.4.2 Transfers

The following is assumed for station layout. There must be space for a minimum of two ticket validators dispensers in each station. The total number of transfer dispensers shall be as directed by DART for each specific station. Such equipment should be located where practical. In conjunction with ticket vending machines, near station entrances, but out of the direct flow of passengers. For passengers transferring from feeder buses to trains, transfer tickets will be issued on the feeder vehicles. The approximate dimensions of the validator are described in Systems Design Criteria Chapter 7 - Fare Collection. These units will be of the freestanding console type or recessed in the fare vending console.

22.4.3 Money Collection Provisions

Money will be collected from fare vending machines and money changers of a type to be determined. Collection procedures and method of change supply shall be determined by DART.

22.5 SIGNING

This section lists the main principles and basic requirements for station signing throughout the DART rail system. Standards for all system signage is addressed in the Sign Standards Manual and Standard Drawings. Signs will be standard throughout the system and will be designed, furnished, and installed under a separate, systemwide contract. The dimensions and mounting heights of signs will be determined by DART. Sign supports and locations will be standardized. As the individual station design is developed, a station-adapted signing layout will be prepared by the section designer in accordance with the Standard and Directive drawing and Sign Standards Manual. The coordination of supports for all signs and provision of electrical power, where required, will be the responsibility of the section designer unless otherwise specifically noted. In areas where possible conflicts may occur, signing will take precedence over the work specified in the artwork section of Chapter 21 - Station Functional Requirements. Artwork shall be coordinated with signing by the section designer unless otherwise specified. Artwork and signing must be approved by DART.

The goals for designing signs for the DART System shall be as follows:

- To guide patrons through the station area in the most efficient manner.
- To provide orientation and information required by the patron to aid directional decision making.
- To provide a safe trip for patrons and to warn patrons and non-patrons of potential system hazards.
- To provide fast, safe exit in case of emergency.
- To allow patrons to recognize origin and destination points at all times.

22.5.1 General Requirements

Signs should be kept to the minimum necessary for passenger guidance. Signs should reinforce architectural elements in identifying areas such as entrances and exits. The message on each sign will be concise, clear, and simple for easy understanding. Standard symbols will be employed for regulatory signs such as "Handicapped", "Do Not Enter", and "No Smoking", in compliance with jurisdictional requirements. Signs should be located at key points of separation and at intervals frequent enough to allow patrons to find their way confidently. Sign design and placement will be uniform systemwide to aid in immediate recognition by the patron. Directional signs should have priority over others to achieve the prime goal of efficient movement of patrons. These signs should include those directing the patron to trains, to normal and emergency exits, and all other directional signs. This priority may be achieved by differences in size of copy, color, or location of signs. Major signs will have optimum visibility and dominance over lesser signs which may occur in the same field of view. Site signs require similar design considerations. Identification signs such as door numbers for personnel use shall also be provided in the systemwide contract.

Signs shall be designed and placed in accordance with applicable codes of the local jurisdiction and NFPA 130. Refer to the Sign Standards Manual, Standard Drawings and the conceptual design drawings for additional information.

Station Platform "Walk/Don't Walk" Safety Signage. The line section designer shall consider the placement of illuminated, "Walk/Don't Walk" safety signage provided at the center crosswalk, for situations where sight distances are reduced, to warn DART patrons and employees of approaching rail vehicles. This safety sign is a train activated sign.

An audible warning device will be used with the "Walk/Don't Walk" sign, with on-off timer capabilities. The audible alarm should be of a typical AAR gong type. The selection process for the appropriate audible device should be flexible to allow consideration of new technologies in this area. Provisions for the sign/audible device installation will require design interface with the LRT Signal system for advance warning activation, circuit assignments and audible alarm time limits.

Refer to Volume 2; Systems Design Criteria Manual, Chapter 4 and 12, for additional requirements and sign interface coordination and control.

The exact location of the sign, sign with support members and/or pedestrians, electrical connections and conduits and the audible warning device with timer to be provided by the Station construction contract. These dual mode warning/devices are currently in use at Station Platforms with similar sight distance situations within the existing LRT System. The station design team should survey the installations as a pre-requisite for initiating design on the "Walk/Don't Walk" audible warning devices.

CHAPTER 23 - ARCHITECTURE OF OPERATIONS AND MAINTENANCE FACILITIES

23.1 INTRODUCTION

This chapter outlines the basic requirements and criteria for the design of the DART rail project operations and maintenance facilities. It is the basic goal of this chapter to create designs that will provide facilities that are safe and functional for the use of DART employees and the general public.

23.2 REFERENCE DATA

23.2.1 Facilities Criteria

For information related to specific requirements of each facility, refer to the following chapters and sections of the Systems Design Criteria:

- o Transit Vehicle.
- o Operations Control Center.
- o Maintenance Facilities.
- o Substations.
- o Yards.
- o Service Station Facilities.
- o Guideways.
- o The applicable sections of other criteria chapters describing the facility need for:

  - Parking and loading zones.
  - HVAC.
  - Lighting.
  - Fire and intrusion alarms.
  - Electrical requirements.
  - Fire protection.
  - Plumbing and drainage.
  - Elevators.
  - Signal systems.
  - Communication requirements.
  - System security.

23.2.2 DART Rail Transit Vehicle Technical Specification

The DART rail transit vehicle technical specification includes the following:

- Dimensions.
- Clearance requirements.
- Acoustic, vibration, and impact criteria.
- Materials.
- Design loads and stresses.
- Vehicle weights.
- Jacking requirements.
- Power requirements.

23.3 CODES AND STANDARDS

Due to the unique nature of rail transit, variances from existing specific codes and standards may be required for certain functional elements of the operation and/or maintenance facilities. If a condition is found that is not covered by the codes, regulations, and criteria outlined in this and other chapters, the designer should refer the matter to DART for guidance in reaching an acceptable solution.

23.3.1 Applicable Codes and Standards

Compliance. The design of all operations and maintenance facilities shall comply in all respects with all applicable codes and standards. Refer to Appendix 1 for list of codes and regulations. These codes and standards shall in each instance be the latest edition or issue, and the most recent revision, amendment, or supplement in effect at the date of notice. Where the requirements of more than one code or standard are applicable, the more restrictive shall govern.

23.4 DESIGN PARAMETERS/CONSTRUCTION REQUIREMENTS

The purpose of this section is to define the architectural design parameters and establish criteria for the architectural design of the operations and maintenance facilities and to meet operational needs as defined in the operations plan. If a transit system facility or structure is located adjacent to unusual or high-hazard occupancies or facilities (such as flammable liquid or gas storage, lumber yards, toxic or corrosive material storage), then greater separation distances may be required. Urban Development Siting with Respect to Hazardous Commercial/Industrial Facilities (U.S. Department of Housing and Urban Development) may be used as a guide, along with Standards for Fixed Guideway Transit Systems (NFPA 130).

The basic goals for designing and constructing operations and maintenance facilities are as follows:

Aesthetic Qualities. The overall goal is to provide facilities which meet the functional requirements of the design program while providing a work environment that is sensitive to employees' needs. The facilities should present an uncluttered appearance. Building massing and scale are to be appropriate to the intended use and to the character of the surrounding neighborhoods. Fenestrations and other major elements are to reflect the requirements of the design program. Roof penetrations and roof-mounted equipment are to be carefully placed to prevent visual disorganization and to enhance the goal of an uncluttered appearance.

Future Expansion Capabilities. Maintenance facilities are to be designed to allow future expansion in an organized fashion. A consistent module is to be established for the arrangement and dimensioning of all major elements of the building. Modular exterior wall materials (concrete tees, tilt-up concrete panels, or preformed metal panels) are to be an even incremental module of the structural framing.

Economy. The facilities are to be designed in a manner that promotes both economical construction and building maintenance while providing maximum durability.

Ease of Maintenance. The facilities are to be designed in a manner that promotes ease of maintenance. Construction details are to minimize potential dirt traps and horizontal ledges which are not readily accessible to cleaning equipment. Where feasible, ledges shall be sloped and other surfaces, connections, and appurtenances designed to minimize dirt buildup and nesting of birds or rodents.

Space Requirements. The space requirements for specific functions and activities directly related to a facility are identified in the pertinent facility chapter. Additional spaces such as toilets, first aid/medical room, lunch room, wash room, locker rooms, and other personnel convenience spaces shall be required at some facility buildings. The quantity, location, and size of these spaces shall be determined on the basis of the needs of each facility.

Special Requirements. Due to frequent use of forklifts and other moving heavy duty equipment within maintenance facilities, bumpers and other protecting devices for walls and machinery shall be provided for protection.

Emergency Conditions. All rail project operations and maintenance facilities must also meet requirements for emergency evacuation as established in Fixed Guideway Transit Systems (National Fire Protection Association (NFPA) NFPA 130; hereafter cited as NFPA 130), in the "System Safety Program Plan" of the DART Systems Assurance Manual (DART) and in Chapter 29 - Fire Protection Systems of these criteria.

- o Access and Egress. Emergency access to and emergency exiting from DART rail project operations and maintenance facilities shall meet the requirements of the fire code of the affected local jurisdiction and the Uniform Building Code (ICBO). In the event of a conflict, the local code shall govern.

- Emergency Lighting and Exit Signs. Emergency lighting and exit signs shall be provided for all egress routes from and throughout all rail project operations and maintenance facilities in accordance with the Uniform Building Code (ICBO), local codes, and NFPA 130.

Site Development. Landscaping shall be provided in accordance with local ordinances. Ingress/egress from parking location to all maintenance building entrances should be unobstructed by shrubs or trees. Provide site and security lighting as required by Chapter 26.

23.4.1 Fire Protection

In buildings supplied with sprinkler systems, permanent draft stops shall be installed in structures having a height of more than 25 feet to the top of the roof trusses, as required by the Uniform Building Code (International Conference of Building Officials (ICBO)). Draft stops shall be constructed of rigidly supported, noncombustible material.

Graphics and Signs. Graphics and signs within the rail system will be provided for in the Signage and Graphics Manual.

23.5 VERTICAL CIRCULATION

This section lists the main principles and standards relevant to the design of vertical circulation including stairs and elevators. Protection of vertical openings shall be in accordance with the Group B, Division 2 occupancies of Type II-N construction Uniform Building Code (ICBO).

The basic goals to be considered in designing vertical circulation are as follows:

- Safety, achieved through proper relationship of basic vertical circulation elements and the details of construction.
- Maximum convenience for employees.
- Ease of access, achieved through proper sizing and layout of the vertical circulation elements.
- Facilities designed to provide for the physically handicapped.
- Standard design to facilitate maintenance.
- Compliance with all appropriate codes and standards.

23.5.1 Stairs

Non-combustible materials shall be used for stair construction, and all treads, landings, and nosing shall have nonslip surfaces. The design of stairway(s) must allow a live load five times the expected normal load and not less than 1,000 pounds. All stairways shall be in compliance with applicable codes referenced in Appendix 1.

Standard Stair Widths (Minimum). The standard width for service stairs shall be 3 feet-8 inches; for Emergency stairs: 3 feet-8 inches.

Stair Landings. For straight-run stairs, the minimum and recommended length of landing shall be 4 feet. For return stairs, the minimum width of the landing must be at least equal to the width of the stair. Concealed reverse landings should be avoided.

Tread and Risers. Stairs shall have a tread-and-riser relationship with a component within the comfort range of from 30 degrees to 35 degrees. The maximum height of the riser on service stairs shall be 7 inches. A riser height of 6-1/2 inches is recommended. Treads shall have closed backs and rounded nosings. Tread and riser dimensions shall be uniform in any one stair. The minimum allowable number of risers is three. Where a change in elevation is less than 18 inches, a ramp shall be used. The minimum headroom at service stairs measured vertically from the line of nosings shall be 9 feet. Continuous soffits, without obstructions, should be held to 10 feet. Emergency stairs shall have a maximum 7-inch riser and a minimum 11-inch tread. The number of risers in any one run of stairs shall not exceed 18. The minimum headroom shall be not less than 7 feet 6 inches measured perpendicular to the tread nosing. The ratio of risers to treads shall fall within the following limits: $2R + T = 24$ to 25.

Handrails. The height of handrails shall be 2 feet 10 inches measured vertically from the top of the tread at the nosing, to the top of the handrail. Handrails may extend a maximum of 3-1/2 inches into required stair width. Handrails, except center handrails, shall be continuous through landings for the full length of the stair. Handrails should extend a minimum of 12 inches beyond both sides of all stairs. The maximum allowable stair width without a center handrail is 7 feet 4 inches. Center handrails should be provided on narrower stairs where needed or required to aid circulation. All stairs (except monumental stairs) in excess of 7 feet 4 inches wide must have center handrails spaced no more than 7 feet 4 inches apart. Handrails outside diameter shall not be smaller than 1-1/4 inches and larger than 2 inches. The space between the handrail and the supporting wall shall not be less than 1-1/2 inches. Where a balustrade in public areas is not solid, the clear distance between vertical balusters must be in accordance with UBC and local ordinances. Handrail ends shall be returned to wall, or curved down 90 degrees where freestanding.

Pedestrian Ramps. Slope or ramp of pedestrian ramps shall preferably not exceed 1 foot per 20 feet (5 percent), with a maximum slope of 1 foot in 12-feet 6-inches (8 percent). The run of ramp between landings shall not exceed 30 feet. General requirements for ramp widths, landings, railings, and handrails are as noted for stairs. In addition, refer to ANSI Standard A117.1 and the "Elimination of Architectural Barriers Act" for provisions for the physically handicapped. Ramp surfaces shall be nonslip.

23.5.2 Elevators

Elevators shall be installed in operations and maintenance facilities as required to meet the following needs:

- o Vertical movement of materials, components, or equipment.
- o Accessibility for handicapped employees.
- o Accessibility for all employees to working spaces more than 30 feet above ground floor.

Freight elevators shall have a load capacity of 8,000 pounds. If heavy workshops are located in upper floors (not recommended) the capacity of at least one elevator shall be 5,000 pounds. Parking facilities for the physically handicapped shall be provided near elevators designed to be accessible to the physically handicapped. If a separate elevator is required for passenger use only, it does not need to exceed 3,500 pounds capacity.

23.6 MATERIALS/FINISHES

The purpose of this section is to identify basic requirements and criteria for the finish of operations and maintenance facilities within the DART rail system. These criteria are intended as a guideline for design and material selection. Refer to the DART Master Specifications for information on material specifications and installation methods.

23.6.1 General Criteria

Surfaces. For long life and low maintenance, materials should be hard, dense, non-porous, non-staining, and acid and alkali resistant. Floor surfaces in shop areas must be able to withstand impact from tools and equipment and to withstand the movement of forklifts, rail car lifts and other equipment.

Color. Colors should be predominantly medium to light in tone to aid in maintaining high illumination levels without creating high levels of glare. Accent colors should be provided to add visual interest.

Texture. Smooth surfaces are preferred in areas where cleanliness is important. Floors in all working areas, especially between and next to tracks, shall have nonskid surfaces.

Unit Size. Units should be large enough to reduce the number of joints, yet small enough to facilitate replacement if damaged. Monolithic materials may be used if they have inherent soil-hiding characteristics and can be easily repaired without the repair being noticeable.

Joints. Refer to the DART Master Specifications for joint materials and methods of application. Monolithic materials should have adequate contraction joints and expansion joints at the proper spacing in order to prevent surface cracking. The use of easily damaged joint covers or soft joint filler materials should be avoided.

Cost. Material selection should consider initial cost as well as maintenance and replacement costs.

Availability. Specified materials must be readily available in sufficient quantity to meet schedules that will be met without cost penalties for materials or labor arising from delays in either delivery or installation. Standard materials should be used for ease of future replacement.

Non-Proprietary Materials. To obtain competitive bids, proprietary items should be used only where it is established that no other materials exist that would meet the particular design requirements. Such items should be specified on a "performance specification" basis, with the name of proprietary item as an example.

23.6.2 List of Finish Materials

This list applies to all areas accessible to the public and/or DART personnel. Due to the diversity of functional spaces encountered, some materials may be acceptable for one type of space but not acceptable in others.

Floor Materials

- o Shop areas:
  - Concrete with smooth-troweled hardened finish and nonskid coating. Acid/Electrolyte resistant finish in battery area.
- o Shop offices:
  - Concrete with smooth-troweled finish.
  - Vinyl tile with cove vinyl base.
  - Carpet, where required.
- o Non-shop offices:
  - Carpet with straight vinyl base.

- Vinyl tile with cove vinyl base.

- o Toilets, locker rooms, and other similar areas requiring plumbing service:
  - Quarry tile with nonslip surface and matching cove base.
  - Unglazed ceramic mosaic tile and matching cove base.

- o Storage Rooms:
  - Concrete with smooth trowel finish.

- o Operations Control Center:
  - Carpet.
  - Resilient Flooring.

- o Basement/working pit:
  - Cast-in-place concrete with smooth-troweled hardened finish and nonskid coating.

Exterior Wall Materials

- o Monolithic materials:
  - Cast-in-place concrete.
  - Materials specified in the DART standard construction specifications to be used as applied fireproofing materials.

- o Unit materials:
  - Precast concrete double tees with aggregate finish.
  - Tilt-up precast concrete panels.
  - Concrete masonry units.
  - Brick veneer.
  - Insulated metal panel. (Not approved below 8 feet above finish floor.)

Interior Partitions

- o Shop areas:
  - Concrete masonry units with coated surfaces.

- o Shop offices:

  - Concrete masonry units.
  - Gypsum drywall with smooth finish on metal studs with acoustical treatment where required.

- o Non-shop offices:

  - Concrete masonry units.
  - Gypsum drywall with smooth finish on metal studs with acoustical treatment where required.

- o Toilets, locker rooms, and other similar areas requiring plumbing service:

  - Concrete masonry units with coated surfaces.
  - Glazed ceramic tile.

- o Storage Rooms:

  - Concrete masonry units.
  - Gypsum drywall with smooth finish on metal studs.

- o Operations Control Center:

  - Gypsum drywall with smooth finish on metal studs with acoustical treatment.
  - Concrete masonry units with acoustical treatment.

Roofing Materials

- o Built-up asphaltic (minimum 1/4 inch per foot pitch).

- o Single ply membrane (minimum 1/4 inch per foot pitch).

- o Standing seam metal panel (minimum 1 inch per foot pitch).

Ceiling Materials

- o Monolithic materials:

  - Exposed concrete floor slabs in shop areas.
  - Exposed roof deck in shop areas.

- Materials specified in the DART standard construction specifications to be used as applied fireproofing materials.

- Unit materials:

  - Acoustic tile (ceramic and mineral, glass and wood fiber) with a 2 feet by 2 feet or 2 feet by 4 feet lay-in grid system.
  - Gypsum drywall with smooth finish.

- Not acceptable:

  - Unit materials smaller than 2 feet by 2 feet.
  - Concealed spline grid systems.

Door Materials

- Acceptable:

  - Coated flush hollow metal.
  - Coated flush solid core metal where required to meet fire rating or achieve acoustic separation.
  - Anodized-aluminum with tempered and/or laminated safety glass at main entrances.
  - Anodized-aluminum overhead rolling doors.
  - Anodized-aluminum overhead rolling grilles.
  - Steel overhead rolling doors.
  - Steel overhead rolling grilles.
  - Solid-core wood doors at non-shop offices.
  - Solid-core metal bi-fold or tri-fold shop vehicular entry.

- Not acceptable:

  - All upward-acting sectional doors.
  - All non-tempered or non-safety glass.

Window Materials

- Frames:

  - Anodized aluminum.
  - Coated steel.

- Glazing:

    - Tempered glass.
    - Laminated safety glass.
    - Insulating, reflective, or tinted glass.

Skylights

- Acceptable materials are similar to those for windows with the added limitation of all applicable codes.

- Glazing:

    - Tempered glass.
    - Laminated safety glass.
    - Wire glass.

Interior Finishes. Finishes of surfaces exposed to the interior operations and maintenance facilities, including movable walls, partitions, columns, ceilings, and other public areas, shall meet Code for Safety to Life from Fire in Buildings and Structures (NFPA 101) requirements for Class A and B interior finishes and the Uniform Building Code (ICBO), Chapter 42, Class I and II requirements as follows:

- Interior finishes shall be Class A and Class I for all exit routes.

- Interior finishes in all other areas shall meet Class A or B NFPA 101 requirements and Class I or II Uniform Building Code requirements.

23.7 SUBSTATIONS

Traction power substations in subway shall be a minimum of type II-N construction in accordance with the Uniform Building Code (ICBO). Substations located beneath the trainway or beneath passenger station platforms (above ground) shall have Class A or non-combustible roof coverings as defined by the Uniform Building Code (ICBO). Refer to Systems Design Criteria Chapter 3 - Traction Electrification for additional information.

Substation doors shall be monitored by a security system. Entry by unauthorized persons shall be prevented by locks with special keying. The use of bays shall not be required at egress. Substations shall have provisions for intrusion alarms.

23.8 OPERATIONS CONTROL CENTER

The operations control center (OCC) shall be a controlled space for housing electronic equipment, personnel, and supporting facilities to be used for operation and supervision of the transit system through signaling, communication, and fire and security management. The facility will be used for data processing, status reporting, and transit system supervision. The facility shall be equipped to permit 24-hour operation. Refer to Systems Design Criteria Chapter 6 - Operations Control Center for additional information.

23.8.1 Construction

The OCC facilities shall comply with type II-N construction requirements (including height and area limitations) of the Uniform Building Code (ICBO) for Group B, Division 2 occupancy. All structural assemblies and building appurtenances in the OCC shall be of noncombustible material.

Fire-rated assemblies protecting openings in fire-rated separations shall be automatic or self-closing and shall be installed according to Chapter 43 of the Uniform Building Code. Activation of assemblies shall be by smoke detectors at the opening and by means of a fixed temperature device. Assemblies may be released by fixed temperature device alone when a separate smoke barrier is provided.

The OCC and other related occupancies shall be protected by 2 hour fire-rated enclosures as recommended by NFPA 130.

23.9 MAINTENANCE FACILITIES

Maintenance facilities shall provide occupancy separations as required by the City of Dallas Building Code. All overhead cranes installed in maintenance facilities shall comply with the standard for cranes and monorails, as described in Article 610 of the National Electric Code (NFPA 70).

Emergency. Warning lights and signs shall be located at power distribution areas in the vehicle maintenance facilities. Adequate warning shall be given to alert personnel that power is going to be applied to a vehicle.

23.10 YARD

Emergency Access. Emergency access shall be provided to transit system facilities within the yard area through public streets or access roads. Access gates in the yard security fencing shall have openings a minimum of 15 feet wide.

Full access to the inside perimeter of the passenger vehicle yard and maintenance facility area, including storage yards, shall be by access roads. Access roads shall be a minimum of 20 feet paved width. Minimum vertical clearance shall be 14 feet. Dead ends greater than 100 feet shall be provided with cul-de-sac or "T" turnaround provisions as described in the City of Dallas fire codes. Access road pavement design shall provide for all weather use.

23.11 SERVICE STATIONS

Service stations for road or hi-rail vehicles shall conform to Chapter 9 of the Uniform Building Code (ICBO), Division 79, Division IX of the Uniform Plumbing Code (ICBO), and the City of Dallas Building Code.

23.12 GUIDEWAY ACCESS

Emergency exit discharge will normally be one of the following:

- Vertical exit door in a surface kiosk or an adjacent building. Such a door shall be equipped with panic hardware on the emergency exit stairway side and shall have a minimum fire rating of 1-1/2 hours. The force to open the door shall not exceed 15 pounds applied at the latch side. Entrance from the outside shall be provided by a key or wrench. The type of key will need to be coordinated with the local fire department.

- Horizontal exit door or hatch flush with surface level. The flush exit doors shall be of solid steel and shall be counterweighted or spring loaded so that they will open when pressure is put on a panic release bar on the emergency exit stairway side. The force required to open the hatch shall not exceed 15 pounds applied at the latch side. To preclude accidental closure, the latch shall be equipped with a hold-open device which shall automatically latch the door in the open position. Entrance from the surface side shall be provided by a key or wrench. Where the hatch is in a position subject to pedestrian traffic, an automatic warning bell at the surface shall be activated by foot traffic in the stairwell below the hatch.

Exit doors at the surface shall be at locations acceptable to local authorities and shall not be provided in areas subject to vehicular traffic or where opening them suddenly would create a hazard to pedestrians. Emergency access to underground guideway (tunnels) shall be through passenger stations, portals, and enclosed emergency exit stairways. The stairway shall be designed to be in accordance with the Class A designation described in NFPA 130.

CHAPTER 24 - STATION ARCHITECTURE – MECHANICAL/ELECTRICAL SYSTEMS

24.1 INTRODUCTION

This chapter provides an overview of the mechanical and electrical systems to be installed at DART Light Rail stations. Among the areas covered: Climate control systems, plumbing and drainage, electrical systems, and lighting.

24.2 HEATING, VENTILATING AND AIR CONDITIONING

This section describes the minimum criteria for the heating, ventilating, and air-conditioning (HVAC) of enclosed station spaces. Individual station designs will require specific solutions to achieve the basic goals. (Refer to Chapter 25 - Heating, Ventilating, and Air Conditioning Systems for more specific requirements.)

The basic goals for designing HVAC systems for station spaces are as follows:

- To provide temperature, ventilation, and draft control to achieve a physical environment that provides maximum comfort with minimum capital and maintenance costs.
- To provide necessary environmental conditions, where required, for the proper operation of all mechanical, train control, electrification, lighting, and auxiliary electrical systems.
- To provide for the safety of public and employees.
- To provide necessary environmental conditions where required for the proper operation of all mechanical , train control, electrification, lighting and auxiliary electrical systems.

24.2.1 General Criteria

Provisions must be made for the rapid purging of smoke from all areas in case of fire, in both public and non-public areas. Refer to NFPA 130 and applicable codes in Appendix 1 for specific requirements.

Items such as controls, vents, and louvers shall be flush and smooth, providing no sharp or projecting edges or natural hazards to the public or maintenance crews. In public areas, all such devices must be installed with theft-proof attachments and tamper-proof guards.

To reduce airborne pollution, outdoor air shall be filtered where necessary. Air intakes should be located to avoid the introduction of dirt, debris, fumes, flammable liquids, odors, noise, and irritants from traffic and other external sources into the DART station. Air intakes shall also be located to avoid the "short circuiting" of exhaust air.

Depending on external factors such as site configuration and availability of real estate, the locations of intake and exhaust shaft outlets in order of preference shall be as follows:

- Opening 10 feet or more above grade.

- Opening above grade located in street medians, at off-street locations which are not pedestrian ways, or in planters.

- Shaft openings in sidewalks or other pedestrian ways. In sidewalks, locate gratings covering such openings immediately behind the street curb. The extent of sidewalk width occupied by these gratings shall conform to the following limitations:

  - Sidewalk width from 0 feet to 6 feet: No grating allowed.
  - Sidewalk width from 6 feet to 10 feet: 4 feet maximum.
  - Sidewalk width 10 feet or more: 40 percent of sidewalk width.
  - Grating shall be designed to avoid tripping (including that caused by high heels).

Outdoor intake and exhaust shaft openings shall be fitted with birdscreen and storm-proof louvers or offsets and drains to prevent the intrusion of storm water. All shafts terminating at or near grade shall be equipped with gratings suitably designed to accommodate the anticipated loads. Surfaces shall be pitched away from openings to provide proper drainage. Openings shall be located to avoid the potential of intrusion of toxic fumes or combustible or flammable fumes or liquids.

All HVAC units located in ceiling or plenum areas shall incorporate ducted ventilation to prevent overheating of the units.

Within stations, air supply outlets should be located a minimum of 8 feet above floor level and should be designed and located to minimize dirt deposit on adjacent surfaces.

Indoor air quality (IQA) shall be provided to meet the requirements of ASHRAE Standards 62-89.

Sound attenuators should be provided in HVAC systems, as required, to meet the requirements of Chapter 25 - Heating, Ventilating, and Air Conditioning Systems and Chapter 11 - Noise and Vibration.

24.2.2 Specific Criteria

<u>Station Public-Area Air Conditioning</u>. (Refer to Chapter 25 - Heating, Ventilating, and Air Conditioning Systems for air conditioning requirements at subway station public areas.)

Ancillary (Non-Public) Areas. Refer to Chapter 25 - Heating, Ventilating, and Air Conditioning Systems for specific requirements for the following spaces in enclosed stations:

- o Staff Room: Provide heating and air conditioning.
- o Toilets: Provide heating and mechanical ventilation.
- o Battery Rooms: Provide exhaust mechanical ventilation. Heating and/or air conditioning as required by equipment.
- o Auxiliary Electrical Rooms: Provide mechanical ventilation. Heating and/or air conditioning as required by equipment.
- o All Other Ancillary Rooms: As required by the HVAC chapter.
- o Chiller Plants: Provide mechanical ventilation.

Mechanical Equipment Rooms. Station mechanical equipment rooms, sized to house the required equipment, shall be located to minimize duct runs. Convenient and safety controlled maintenance access shall be provided. Equipment access shall be sized for the installation and removal of each factory-built item of equipment through doors, hatches, removable panels, or shafts directly to the exterior. Where provisions of such doors, hatches, removable panels, or shafts are not feasible, openings may be provided into the trainway for removal of equipment by work train. Room sizes and locations will be shown in the preliminary design drawings. Unobstructed access shall be provided to all components of mechanical units.

24.3 PLUMBING AND DRAINAGE

This section describes minimum standards for plumbing and drainage at all stations. For further information, refer to Chapter 30 - Plumbing and Drainage Systems.

The basic goals for designing plumbing and drainage systems at stations are as follows:

- o To provide toilet facilities for system staff with provisions for emergency access by patrons at selected stations.
- o To minimize maintenance, operations, and security requirements.
- o To standardize plumbing fixtures and fittings throughout the system.
- o To standardize toilet room accessories throughout the system.

- o To standardize station drainage throughout the system.
- o To allow for the provision of facilities accessible to the handicapped.

24.3.1 Toilet and Locker Facilities

The quantity and type of toilet and locker facilities in staff areas to be provided is to be determined by DART. To accommodate the handicapped, refer to the American's with Disabilities Act Accessibility Guidelines and Texas Accessibility Standards for additional information and requirements. Toilet rooms shall have the following:

- o One toilet stall that is 3 feet wide by 5-feet 6-inches deep, with a 32-inch wide outswinging door with capability of staff access.
- o Grab bars conforming to code requirements, mounted at 2 feet-9 inches above the floor.
- o Toilet room doors equipped with delayed action-closer and raised graphics.
- o Fixtures mounted at special heights.
- o Interior lock with capability of staff access.

Additional toilet fixtures beyond these basic requirements need not meet the provisions necessary for handicapped patrons.

Each toilet room shall have the following accessories:

- o Combination paper dispenser and waste receptacle.
- o Soap dispenser.
- o Toilet tissue dispenser.
- o Sanitary napkin-tampon dispenser (women's room only).
- o Sanitary napkin disposal (women's room only).
- o Mirror and shelf.
- o Coat hook.

- o Toilet partition.
- o Urinal screen (men's room only).
- o Lockers (for staff members only).

24.3.2 Toilet Fixtures

General Requirements. Water closet, urinals, and lavatories shall be installed with chair carriers.

Specific Requirements. Fixtures to be used shall be uniform system wide. For more information see Chapter 30 - Plumbing and Drainage Systems.

- o Water Closet. Water closets shall be a wall-mounted, elongated bowl type with an integral back spud. One water closet in each toilet room shall be mounted with the seat 18 inches above the floor. Additional water closets, if required, shall be mounted at standard height.

- o Urinal. Toilet rooms used by men shall have a wall-mounted, projecting bowl with an integral trap urinal. One urinal in each men's toilet room shall be mounted with the opening of the basin 17 inches above the floor. Additional urinals, if required, shall be at standard mounting heights.

- o Lavatory. One lavatory in each toilet room shall be of the type designed for wheelchair individuals with front overflow and concealed arm support at a 30 inch mounting height. Additional lavatories, if required, shall be of a standard type mounted at standard height.

- o Trim for Water Closets and Urinals. Large diaphragm flush valves shall be provided for water closets and for urinals.

- o Hose Bibb. Recessed polished chrome brass hose bibbs shall be provided in chrome plated brass boxes, with the lid flush with the wall surface and keyed similarly to other accessory items.

- o Floor Drain. A galvanized iron body with a stainless steel top shall be provided. The drain should be sized according to the area serviced.

24.3.3 Toilet Room Accessories

General Requirements. All necessary items shall be fully recessed into the wall. The maximum projection from the finished wall should not be greater than 5/8 of an inch. All accessories shall be constructed of Type 302 or 304 stainless steel, heavy gauge unless otherwise noted. Exposed surfaces shall have No.4 satin finish. Doors shall be double-pan-back construction and have full-length stainless steel piano hinges and key operated tumbler locks, with all items keyed alike. Toilet room equipment which requires manual operation by the handicapped, such as toilet paper racks, towel dispensers and disposer units, shall be mounted no more than 40 inches from the floor.

Specific Requirements. Actual accessories to be used shall be uniform system wide.

24.3.4 Drinking Fountain

A wall-mounted drinking fountain accessible to the handicapped will be provided in the staff area. Public drinking fountains will be provided as directed by DART and located as shown on conceptual design drawings.

24.3.5 Drainage in Stations

Entrances. At entrances to subway stations, the first 25 feet (minimum) of floor under cover should be sloped at a minimum of 1 percent to drain toward the steel grating floor mat at the entrance. Recesses for flush-mounted steel grating floor mats should be provided under cover at all subway station entrances. The length of the grating should equal the width of the entrance. A drain shall be provided in each recess. Drainage at aerial and at-grade stations shall be accomplished by sloping floors to drain toward the outside at a 1-percent slope.

Concourse. Except at entrances, interior ramps, and where the subway mezzanine is open to the sky, subway mezzanine floors should be level in the transverse direction and level or sloped to align with the structure in the longitudinal direction. Floor drains shall be provided at all hose bibb locations. At aerial and at-grade stations, floors shall be sloped toward the concourse perimeter at a 1-percent slope.

Platforms. Platforms exposed to weather should be pitched to drain away from the tracks at a 1 percent slope. All other platforms should be level, at right angles to the track, and parallel with the structure in the longitudinal direction. Floor drains should be provided at all hose bibbs located at platforms. Floors within 3 feet of hose bibb should be pitched towards a drain at a 1-percent rate.

Roof Areas. Within the station, all roofs shall be pitched to roof drains or gutters. Subway station structural ceilings shall be pitched at a 2-percent minimum to provide for drainage. Water should not be allowed to spill over the edge of exterior roofs, but shall be carried away by concealed leaders to the storm drainage system.

24.4 FACILITY ELECTRICAL SYSTEMS

In this section, minimum criteria for electrical system spaces in stations are presented. Individual stations will require specific solutions to achieve basic goals. (Refer to Chapter 28 - Facilities

Electrical Requirements for more specific requirements.) The basic goal of this section is to design facility electrical systems to provide space of correct size and location to accommodate all required station electrical equipment.

24.4.1 General Criteria

These systems will provide power to all facility equipment and lighting within and adjacent to each station. These systems are separate and distinct from the traction power system which is described in Systems Design Criteria Chapter 3 - Traction Electrification. They are also separate from the signal and communication systems, but will serve to provide power to those systems.

24.4.2 Specific Criteria

Facility Electrical Rooms. Facility electrical rooms will be required at specified stations, as indicated by conceptual design drawings. These rooms, together with any associated battery rooms, must be provided with acoustic controls adequate to be compliant with provisions in Chapter 11 - Noise and Vibration. Space for wall-mounted panelboards and wall-mounted or freestanding emergency power system equipment shall be provided where required.

Battery Room. A battery room may be required in subway stations for batteries which supply the emergency power system, and shall be located adjacent to an auxiliary power room. The size of the battery room shall be as indicated on standard drawings. Access to the battery room shall be via a 3-foot-wide by 7-foot-high door. An eye wash unit shall be provided. The floor finish shall be acid resistant, waterproof, and slip resistant, and carried to a 6-inch height along the walls. The battery room shall have mechanical ventilation (see Chapter 25 - Heating, Ventilating, and Air Conditioning Systems for more details). Provisions will be made in this room for the grounding of equipment. The battery room shall not be located below, or adjacent to, any means of egress.

Traction Power. All traction power substations will be housed in separate bungalows on the surface. (Refer to Systems Design Criteria Chapter 3 - Traction Electrification for more information.)

Signals and Communications. Separate bungalows will be provided for these facilities. (Refer to Systems Design Criteria Chapter 4 - Signals System and Chapter 5 - Communications for additional information.)

24.5 LIGHTING

A unified lighting system shall be provided for all DART stations and sites to strengthen the identity of the DART rail system and create a hospitable environment for the rider. It is the goal of this lighting design criteria to guide the station section designer in attaining the maximum aesthetic and functional effects. DART-provided drawings, together with this criteria, form the basis for design.

24.5.1 General Station/Site Lighting

Lighting will maximize the aesthetic effect of the interrelation between the station illumination system and the urban environment. Lighting will define the station/site at night and be a visible architectural element during daylight hours. Lighting must be located and focused to provide a clear visual path for station monitoring.

24.5.2 Specific Lighting Requirements By Area

The following station areas should be provided with light necessary to achieve visual clarity:

Station Site Areas. The site lighting system will produce a visual landmark announcing the facility to potential users and identifying each station site. A hierarchy of lighting levels will produce a natural lead-in, guiding both driver and pedestrian to the station entrance. It shall not interfere with or cause annoyance to persons on neighboring property, and it shall meet all lighting/glare performance standards. Lighting must emphasize the bus loading/unloading, kiss-and-ride, and park-and- ride areas to deter incidents and accidents due to vehicular/pedestrian congestion. All areas must be lighted to reflect true colors. Parking areas should be made brighter by placing additional luminaries between ranks of automobiles allowing for the orientation and identification of persons or intentions. Pedestrian access lighting shall define walkways, crosswalks, ramps, stairs, and bridges to facilitate movement and recognition at night. Plazas should be provided with a diffused illumination to define and organize the site. Luminaries, coordinated with the urban surroundings, should highlight major traffic ways, seating and waiting areas, and provide a comfortable and pleasant environment. (Refer to Chapter 26 - Lighting for vehicular access lighting requirements.) Lighting in tunnels shall be designed so either the walkway or the invert can be used as an evacuation path in case of emergency.

Station Entrance. Entries should have the highest apparent brightness within the station area, creating a quickly recognizable destination focus. Open entrances, located either off-street, within a sidewalk right-of-way, or in conjunction with station plazas, should be lit using systemwide elements to give prominence to the open well. Covered entrances, special or storefront, within public or private buildings, shall be lit to stress the stair head and run. To clearly feature them as a DART element, elevator entrances are to be given a special consideration.

Patron Circulation. Illumination shall be provided for all elements of circulation to simplify directional decisions. Escalators, elevators and stairs shall be lit to emphasize open circulation wells and transitional components - run-off areas and entrances. Passageways shall be lit to define a direct path from the station entry to the interior.

Station Boarding Areas (Platform). Lighting should help create immediate recognition of position and orientation. It should emphasize system graphics, information messages, and fare-vending equipment. The platform shall be provided with an overall ambient lighting level which expands peripheral vision and reduces the time required to detect potential hazard. The concourse/mezzanine, if provided, shall be illuminated to distinguish the preferred circulation paths. All areas must be lighted to reflect true colors.

Ancillary Facilities. Lighting shall be provided for all subsidiary areas as noted in Chapter 26 - Lighting.

24.5.3 Tables of Illuminance Values for Station Areas

Refer to the following tables in Chapter 26 - Lighting for normal and emergency required lighting levels.

- Table 26-1: Site Area Illumination Levels.
- Table 26-2: Passenger Station Illumination Levels.
- Table 26-4: Miscellaneous Areas Illumination Levels.

CHAPTER 25 - HEATING, VENTILATING, AND AIR-CONDITIONING SYSTEMS

25.1 INTRODUCTION

This chapter describes the functional and design requirements for the environmental control systems (ECS) to provide heating, ventilating, and air-conditioning (HVAC) for Dallas Area Rapid Transit (DART) Rail Project facilities. It is intended to promote uniformity of design and to standardize the type and location of DART Rail Project ECS equipment.

These criteria cover ECS functional requirements, operation, and control for the following elements of the DART rail system:

- Service and inspection shops.
- Service and Inspection (S & I) Facility.
- Operations Control Center (OCC).
- Yard control tower.
- Traction power substations in facilities structures.
- Ancillary spaces.
- At-grade and aerial stations.
- Subway stations.
- Subsurface line sections.

The ECS requirements for the transit vehicle, signaling bungalows, communication bungalows, and prepackaged traction power substations are respectively prescribed in Systems Design Criteria Chapter 2 - Light Rail Vehicles, Chapter 4 - Signal Systems, Chapter 5 - Communication and Chapter 3 - Traction Electrification.

25.1.1 System Interface

The ECS design shall interface with the design parameters set forth in these criteria for other systems as appropriate.

25.1.2 Codes and Standards

As applicable, the ECS design shall comply with the local, state, and national codes set forth for the mechanical/electrical chapters in Appendix 1. The section designer's attention is directed to the requirements of the National Fire Protection Association (NFPA) Standard 130, Fixed Guideway Transit Systems. Section designers shall consult the referenced codes and publications and provide ECS in accordance with the most stringent of the applicable codes and/or industry practices.

25.2 ENVIRONMENTAL CONTROL SYSTEM (ECS)

The ECS to control temperature, air velocity, rate of air pressure change, dust, odors, and the direction of spread of smoke during fire emergencies shall be provided as prescribed below:

Yards and Shops. ECS systems for offices, employee areas, and vehicle preparation shall be provided with spot cooling in maintenance rooms and shop areas. Ventilation for paint booths, hazardous and flammable materials storage rooms, and ancillary rooms shall be provided.

Yard Control. ECS systems for offices, employee areas, control rooms, and miscellaneous equipment rooms shall be provided.

Operations Control Center (OCC). HVAC systems for offices, employee areas, operation control center, computer, and miscellaneous electronics equipment rooms shall be provided.

Traction Power Substations. ECS systems shall be provided for traction power substation structures and rooms which are not included in the systemwide contracts. Refer to Systems Design Criteria Chapter 3 - Traction Electrification for HVAC systems for prepackaged traction power substation bungalows.

Miscellaneous Wayside Structures. ECS systems shall be provided for the ancillary rooms in DART miscellaneous wayside structures.

At-Grade and Aerial Stations. ECS systems shall be provided for the ancillary rooms and for concession areas. ECS will not be provided for patron areas unless:

- The architecture of the station requires ventilation for smoke control.
- The ECS is part of a joint development project.

Subway Stations. ECS systems for concession areas, and the ancillary rooms shall be provided.

Subway. A ventilation shaft that terminates at or above grade at each end of the station shall be provided as indicated on the project definition drawings. The ventilation shafts shall be equipped with reversible fans, fan dampers, sound attenuators, and bypass dampers for forced ventilation during congested or emergency operations.

25.3 FUNCTIONAL REQUIREMENTS

25.3.1 HVAC Systems

HVAC systems for the offices, ancillary rooms, concourse areas, and concession areas with spot cooling for shops and maintenance shall maintain an acceptable environment for patrons and operating and maintenance personnel. These HVAC systems shall also prolong the life of equipment through proper control of temperature, pressure, and humidity. The HVAC functional requirements to maintain this acceptable environment are set forth below.

25.3.2 Subway Station Trackways and Tunnel ECS

Operations are considered `normal' when trains are moving through the system according to schedule and when passengers are traveling smoothly through stations to and from transit vehicles. Since this is the predominant category of operations, considerable effort should be made to optimize performance of the ECS during normal operations.

Congested operations result from delays or operational problems which prevent the free flow of trains through the system. Trains may wait in stations, or stop at predetermined locations in tunnels. Delays usually range from 30 seconds to 20 minutes, although longer delays may occasionally be experienced. Passenger evacuation or exposure of passengers to danger does not occur during congested operations.

Emergency operations generally result from a malfunction of the transit vehicle. The most serious emergency is a stopped train on fire in a tunnel, disrupting traffic and requiring passenger evacuation. The ventilation system is designed to maintain a single evacuation path from the train that is clear of smoke and hot gases. Maintaining such a path during a fire emergency enhances passenger safety.

The subway station and tunnel ECS is the collection of ventilation systems that provides comfort to the patrons during normal and congested operations. It also provides the ventilation of the stations and tunnels during emergencies (e.g.,fires).

During an emergency in a subway line section or station, especially if a fire occurs, the ventilation system shall supply outside air into the selected evacuation path and exhaust any smoke from the system. In a station fire emergency, station ventilation shall be achieved by drawing in outside air through the entrances, sweeping it through the public area, and exhausting it through the tunnel ventilation shafts located at both ends of the station. Tunnel ventilation shall be achieved by using a "push-pull" system of operating fans during emergencies. On one side of the affected area, the fans shall be operated to supply fresh air while fans on the other side are operated to exhaust smoke and hot gases. Thus, a longitudinal air movement shall be produced in the affected tunnel to allow passengers to be evacuated toward the supply of outside air.

25.4 DESIGN PARAMETERS

25.4.1 Outside Conditions

The outside conditions prescribed herein are for determining the required capacities of HVAC systems. The system equipment shall be suitable for continuous operation (at degraded capacity) during extreme weather conditions. The ventilation, heating, cooling, and refrigeration equipment shall continue to operate if the outside temperature reaches 115 degrees Fahrenheit (°F) or drops to 0°F.

<u>Summer Peak Design Conditions</u>:

- Maintenance shops and yards:

  102° F dry bulb (DB) and 75° F wet bulb (WB) temperatures (1 percent occurrence).

- Ancillary spaces:
  102° F DB and 75° F WB (1 percent occurrence).

- Operations Control Center:
  102° F DB and 75° F WB (1 percent occurrence).

- Enclosed concession areas (at-grade, aerial, and subway stations):
  102° F DB and 75° F WB (1 percent occurrence).

- Subway station air-conditioned spaces:
  97° F DB and 75° F WB (5 percent occurrence).

- Subway station trackways and tunnels:
  102° F DB and 75° F WB (1 percent occurrence).

<u>Winter Minimum Design Condition</u>:

- 18° F DB (1 percent occurrence).

25.4.2 Inside Conditions for Normal and Congested Operations

Ventilation Rate. The number of air changes per hour (total air circulated) shall be based on the requirements of applicable codes, heating and cooling loads, or odor control (whichever is greater), but shall not be less than four air changes per hour. The ventilation systems shall be designed to provide cross ventilation. The outside air requirement shall be a minimum of 7-1/2 cubic feet per minute (cfm) per person for all occupied spaces being heated, ventilated, or air-conditioned.

Indoor Design Conditions. Tables 25-1 through 25-3 detail indoor design conditions for yards and shops, the OCC. Ancillary rooms with solid state equipment such as ECS controls, remote terminal units (RTUs), telephone electronics, and printed circuit boards may impose more stringent ventilation and cooling requirements. Section designers shall analyze each room individually, and shall furnish an environmental control system that will provide a room temperature suitable for optimum equipment operation.

Table 25-1*

INDOOR DESIGN CONDITIONS
YARDS AND SHOPS

Space	Winter[1] (°F)	Summer[2] (°F DB)	(% RH)
General Offices	72	75	50
Open Shops	68	85*	--
Enclosed Shops	68	85*	--
Lunch Rooms	72	75	50
Locker Rooms	72	75	50
Staff Room	72	75	50
Conference Room	72	75	50
Training Room	72	75	50
Crew Room	72	75	50
Toilets	70	--	--
Showers	72	--	--
Storage Areas	60	--	--
Custodial Room	68	--	--
Electrical Equipment Room	60	112	--
Mechanical Equipment Room	60	112	--
Battery Room	68	85	--
Computer Room	72	72	50
UninterruptiblePower Supply (UPS) Room	60	85	--
Standby Power Generator Room	60	112	--
Electronic Equipment Room	72	78	50
Yard Control Room	72	78	50

* Spot cooling provided.

***Notes for Tables 25-1 through 25-3**

[1] Winter temperatures are based on the following parameters:

- o Rooms occupied by physically sedentary personnel: 72°F.
- o Rooms occupied by physically active personnel: 68°F.

- o Rooms requiring the temperature to be maintained well above freezing to avoid maintenance problems: 60°F.
- o Rooms requiring no heating: no value provided. These rooms may be ventilated by transfer air.

[2] Summer temperatures are based on the following parameters:

- o Rooms occupied by personnel dressed in office attire: 75°F.
- o Rooms occupied by personnel in work clothing: 85°F.
- o Rooms with solid state electronic equipment: 85°F (to avoid maintenance problems).
- o Rooms which may be cooled by ventilation only: 112^{oF} (ambient +10°F).
- o Rooms requiring no cooling: no value provided. These rooms may be ventilated by transfer air.

Where:

°F	= Degrees Fahrenheit
°F DB	= Degrees Fahrenheit dry bulb
% RH	= Percentage relative humidity

Computer room HVAC systems shall also be capable of maintaining room temperatures of 75° F on a 115° day and on a 0° F day. Uninterruptible power supply (UPS) and battery room HVAC systems shall also be capable of maintaining a room temperature of 90° F on a 115° F day. For rooms or spaces having no humidistat, the design relative humidity listed in Tables 25-1, 25-2 and 25-3 shall have a range of ±10 percent. Rooms having a humidistat, such as computer rooms and tape storage rooms, shall have range of ±3 percent.

Storage and equipment rooms temperature requirements shall be based on material and equipment requirements.

Table 25-2*

INDOOR DESIGN CONDITIONS
OPERATIONS CONTROL CENTER

Space	Winter[1] (°F)	Summer[2] (°F DB)	Summer[2] (% RH)
General Offices	72	75	50
Reception Area	72	75	50
Staff Rooms	72	75	50
Conference Room	72	75	50
Training Room	72	75	50
Crew Room	72	75	50
Main Control Room	72	72	50
Tape Storage Room	72	72	50
Computer Room	72	72	50
Electronics Shops	72	72	50
Storage Areas	60	--	--
Locker Rooms	72	75	50
Showers	72	--	--
Toilets	68	--	--
Custodial Rooms	68	--	--
Electrical Equipment Room	60	112	--
Mechanical Equipment Room	60	112	--
Electronic Equipment Room	72	72	50
UPS Room	60	85	--
Standby Power Generator Room	60	--	--
Closed Circuit Television Room	72	72	50
Security Control Room	72	72	50
Battery Room	68	85	--

* Notes listed under Table 25-1 are also applicable to this table.

Table 25-3*

INDOOR DESIGN CONDITIONS ANCILLARY ROOMS

Space	Winter[1] (°F)	Summer[2] (°F DB)	(% RH)
Electronic Equipment Rooms	72	72	50
Traction Power Substations	--	112	--
Electrical Equipment Rooms	60	112	--
Mechanical Equipment Rooms	60	112	--
Elevator Machine Rooms	--	note 3	--
Telephone Equipment Rooms	--	75	--
Battery Rooms	68	85	--
Toilets	68	--	--
Custodial Rooms	68	--	--
Trash Rooms	60	--	--
Storage Rooms	60	--	--
Water Meter Vaults	60	--	--
Valve Rooms	60	--	--
Pump Rooms	60	--	--
Sewage Ejector Rooms	60	--	--
Computer Room	72	75	50
UPS Room	60	85	--
Standby Power Gen. Rm.	60	--	--
Station ECS Control Room	60	85	--
Multipurpose Room	72	75	50

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* Notes listed under Table 25-1 are also applicable to this table.

3. Cool and heat elevator equipment rooms per manufacturers requirements.

<u>**Indoor Design Conditions - Other Facilities**</u>.

- <u>At-Grade and Aerial Stations Platform Areas</u>. Ambient conditions.

- o <u>At-Grade and Aerial Station Enclosed Concession Areas</u>. Summer dry bulb temperature: 75°F, relative humidity: 50 percent; winter: 72°F.

- o <u>Subway Station Platform and Mezzanine Areas</u>. Averages are over a time interval of one train headway.

  - Dry bulb temperatures:

    Summer: 81°F.
    Winter: Heating will not be provided. Temperatures down to 0°F could occur in locations adjacent to the portals or surface if the system were not operated.

  - Humidities:

    Summer: Less than 60 percent.
    Winter: Less than 100 percent.

  - Horizontal air velocity:
    (Platform, mezzanine, horizontal entranceways)

    Average: Not greater than 600 feet per minute (fpm).
    Maximum: Not greater than 1,000 fpm.

  - Sloping air velocities:
    (Escalators, stairways)

    Upward flow average: Not greater than 600 fpm.
    Upward flow maximum: Not greater than 1,000 fpm.
    Downward flow average: Not greater than 600 fpm.
    Downward flow maximum: Not greater than 1,000 fpm.

  - Air Pressure Transients: The criterion for rapid pressure changes, applicable when the total change in pressure is greater than 0.10 pounds per square inch (psi) (2.8 inches per water gauge) (in. wg), is that no person (either patron or employee) shall be subjected to a rate of pressure greater than 0.06 psi per second (1.7 in. wg. per second).

- o <u>Subway Station Enclosed Concession Areas</u>:

  - Summer: 75°F dry bulb temperature, 50 percent relative humidity.
  - Winter: 72°F.

- Subway Tunnels:

  - Dry bulb temperature (maximum). The requirements for the DART rail vehicle heating and A/C systems are prescribed in Systems Design Criteria Chapter 2 - Light Rail Vehicles. The vehicle air conditioning system can operate at its design capacity when the condenser air inlet temperature is less than or equal to 115°F, and at a reduced capacity when the condenser air inlet temperature is greater than 115°F but not exceeding 125°F. The other systemwide and facilities equipment in the tunnel can continuously operate at full capacity at temperatures up to 104°F without a decrease in life expectancy and can operate for short periods at temperatures up to 125°F. Therefore, the capacities of station and tunnel environmental control equipment shall be selected to limit the tunnel dry bulb temperatures to the ambient temperature plus 10°F for normal and congested operations during periods of warm and hot weather.

  - Dry bulb temperature (minimum). Heating will not be provided. Temperatures down to 0°F could occur in locations adjacent to the portals or surface if the transit system were not operated.

  - Humidity. Dehumidification is not required.

  - Air Velocity. Unoccupied tunnels: No control.
    Occupied ancillary rooms: 600 fpm maximum.

  - Air Pressure Transients. The criterion for rapid pressure changes, applicable when the total change in pressure is greater than 0.10 psi (2.8 inches water gauge), is that no person (either patron or employee) shall be subjected to rate of pressure change greater than 0.06 psi per second (1.7 inches water gauge per second).

- Rail Vehicles. Braking resistors and A/C compressors and condensers will be located on the vehicle capacity for normal and congested operations. For specific guidance, refer to Systems Design Criteria Chapter 2 - Light Rail Vehicles. For location of rail vehicle system refer to vehicle criteria.

25.4.3 Normal Operations Train Frequency

Refer to Systems Design Criteria for the train frequency in each direction. The passenger loadings shall be the latest available hourly flows. The station dwell times shall be those derived from the latest hourly flows.

25.4.4 Design Conditions for Emergency Operations

The design emergency scenarios are as follows: a stopped train on fire in the tunnel or a stopped train on fire in a subway station, or a collision between 2 trains. The size of the emergency ventilation system, the number of fans activated in an emergency situation, the type of ventilation equipment provided, and the built-in system reliability shall be designed to meet these scenarios. Exhaust outlets shall be of sufficient distance from evacuation exit supply intake and exits, to prevent recirculation. During a design case subway fire that involves a single- or multiple-car train, the following design parameters shall apply:

Vehicle Fire Heat Load. In British Thermal Units (BTU/Hr) per car as determined in accordance with NFPA 259.

Train Fire Heat Release Rate. In British Thermal Units (BTUs) per hour as determined in accordance with NFPA 259.

Station. The maximum air temperature in the evacuation route shall be 140°F or less, ignoring radiant heating.

Tunnels. Tunnel design conditions are for the evacuation route only. For tunnel fires, sufficient mechanical ventilation shall be provided to move smoke in one direction or the other as required to maintain tolerable conditions in a single evacuation route from one side of the fire. The maximum temperature in the evacuation route shall be 140°F or less, ignoring radiant heating.

The minimum air velocity in the evacuation path shall not be less than that required to control the spread of smoke and hot gases from the fire into the evacuation path. The maximum air velocity in the evacuation path shall be 2,200 fpm.

25.4.5 Design Velocities for Air Distribution Systems

Design velocities shall be selected to provide the required system performance and to minimize pressure loss and energy consumption, air-borne noise generation, draft, and the intake of dust particles. The design velocities in air distribution systems are described below.

Sheet Metal Ducts. Sheet metal supply and return-air duct sizes shall be determined in accordance with the requirements prescribed for low-velocity air-distribution systems in the duct design chapter of the Fundamentals (American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE), latest edition).

Concrete Ducts/Plenums/Shafts. Tunnel ventilation shafts shall have a nominal air velocity of 1,800 fpm and a maximum air velocity of 2,200 fpm. Other concrete ducts, plenums and shafts shall have a nominal air velocity of 1,500 fpm and a maximum air velocity of 1,800 fpm.

Air Outlets and Intakes. Supply registers shall be selected for throw and noise criteria. (Noise criteria is stated in Paragraph 25.4.6. Throw must be consistent with room architecture).

Variable Air Volumes (VAV) Terminals. VAV terminals shall be selected for required air flow, pressure, and noise criteria.

Diffusers. Diffusers shall be selected for throw and noise criteria.

Exhaust and Return Grilles. Exhaust and return grilles shall have a capacity based on maximum velocity of 500 fpm over gross area.

Transfer Grilles. Transfer grilles shall have a maximum velocity of 250 fpm over gross area.

Transfer Louvers. Transfer louvers shall have a maximum velocity of 250 fpm over gross area.

Tunnel Ventilation Fan Dampers. Tunnel ventilation fan dampers shall have a maximum air velocity of 1,800 fpm over gross area.

Tunnel Ventilation Fan Sound Attenuators. Tunnel ventilation fan sound attenuators shall have a maximum air velocity of 1,800 fpm over the gross area.

Isolation Dampers. Isolation dampers shall have a maximum velocity of 2,000 fpm over gross area; damper areas will be provided by DART.

Bypass Dampers. Bypass dampers shall have a maximum velocity of approximately 500 fpm over gross area; damper areas will be provided by DART.

25.4.6 Noise Criteria

A proper acoustical environment is as important for human comfort as any of the other environmental factors controlled by ECS. The ECS equipment can create an unacceptable acoustic environment. The primary objective of ECS acoustical design is to achieve acceptable sound levels for all activities and people involved; this does not necessarily mean the lowest possible sound levels, however. Because of the wide range of activities, appropriate indoor acoustical design levels will vary considerably from room to room and acceptable outdoor levels will depend on local ambient sound conditions. Proper sound levels at various listener locations shall be achieved by controlling the sound generation of the various sources and the sound transmission from the sources to the listeners.

The maximum permissible sound levels of ECS shall be as prescribed in Chapter 11 - Noise and Vibration. Sound control for environmental control systems shall be designed according to the procedures outlined in the noise and vibration chapter of these criteria and the Sound and Vibration Control chapter of the Handbook of Systems and Applications (ASHRAE, latest edition).

25.5 SYSTEMS AND EQUIPMENT

25.5.1 HVAC Systems for Maintenance Shops and Yards

The concepts described in these criteria are applicable to HVAC systems, equipment, operation, and controls in the indicated areas. Outside and indoor summer and winter design conditions shall conform to the requirements prescribed in section 25.4 of this chapter.

General Office Areas and Shops. The HVAC system shall consist of unitary or split-package air-conditioners with an air-distribution system, controls, drives, and accessories. The condensing units for split package system shall be roof- or ground-mounted, and air-handling units (AHUs) shall be located in the mechanical equipment room or within the space as required. Unitary packages shall be roof mounted. A gas-fired furnace or electric heating coil shall be included in each air handler for heating supply air. If a gas-fired furnace is provided, the flue gases shall be vented outdoors as required by the applicable codes. All air-conditioning systems, except where noted otherwise, shall be designed so that they can modulate from the minimum outside air required for ventilation to 100 percent outside air. A ducted return air system shall be provided with registers located in each air-conditioned office space. The operation of the HVAC system shall be thermostatically controlled. If spot cooling is not used in the shop areas, then air circulation fans shall be used.

If a source of chilled water is conveniently available at a maintenance facility, then the cost-effectiveness of cooling with purchased chilled water shall be analyzed. The HVAC system with purchased chilled water shall include chilled water circulating pumps, air handling units relief systems, return-air fans, etc. The air distribution ductwork and controls for the general office area HVAC systems shall be separated from the air distribution ductwork and from the controls for the shop HVAC systems. The section designer may propose a variable air volume (VAV) system for general office spaces as an alternate design. This alternative design must include a system description and a cost comparison with the constant volume system.

The cooling load shall be based on a summation of the following heat gains:

- o Occupancy.
- o A lighting load of 3 watts per square foot (W/sq ft) (or actual lighting load when available) and power requirements of 1 W/sq ft of space (or actual load when available).

- Ventilation make-up air.

- Solar and transmission gains (where applicable).

- Equipment heat rejection based on usage factor.

The heating load shall be based on a summation of the transmission heat loss and ventilation air heat load, and equipment heat loads as applicable.

Air-handling units for split packages shall include the following components:

- Mixing Plenum.

- Outside and Return Air Dampers of the Opposed-Blade Type. Damper operators shall be pneumatic or electric.

- Air Filter Section.

- Direct Expansion (DX) Coils Section. DX coils shall have a maximum face velocity of 550 fpm. The number of fins per inch shall not be greater than eight.

- Centrifugal Fans With Non-Overloading Motors. Each fan shall be complete with electric motor, vibration isolators for mounting the fan, and motor base and belt guard. Electric motors for each fan unit shall be selected so that the fan power requirement at any point on the fan power-capacity curve does not exceed the horsepower rating of the motors. For belt-drive fans, an adjustable sheave V-belt drive shall be provided.

- Controls. Controls for units shall consist of the following:

  - Across-the-line, circuit-breaker-type magnetic motor starters.
  - Local manual on/off/automatic fan switches.
  - Remote control terminals from the space thermostat.
  - Terminals for remote monitoring and control.

Sufficient access around A/C and air handling units shall be provided for the maintenance of fans, coils, and air filters and to facilitate coil and filter removal and reinstallation as recommended by the equipment manufacturers.

The refrigeration system shall include the following:

- Air-Cooled Condensing Units. Each unit shall consist of the following: semi-hermetic reciprocating type compressors; condensing coils with integral subcooling;

supporting casing with stand; direct-drive, propeller-type fans; motors; and head pressure control. Units shall be factory packaged. With ambient air at 102°F dry bulb entering the condenser with 15°F subcooling, the saturated suction temperature shall be 42°F at a condensing temperature of 120°F.

HVAC system with chilled water shall include the following:

- Air Handling Units. Air handling units shall conform to the requirements for air handling units for split packages (excluding the requirement for condensing coils). Cooling coil section shall consist of water coils having a maximum face velocity of 550 fpm. There shall not be more than eight fins per inch. The velocity of water in the tubes shall be a maximum of 8 feet per second (fps). Where velocities less than 2 fps are encountered, a method of turbulation shall be provided. Cooling coils shall be designed for a maximum water temperature rise of 12°F for ice storage and chilled water storage systems, and 12°F for a manufactured chilled water system. Chilled water lines shall be arranged to permit air venting and drainage of the water system and to facilitate removal of the cooling coils from the unit casing.

- Heating. Heating in the shops shall be provided by ceiling-suspended gas-fired unit heaters. Heating for office areas, and so forth shall be by electric heating coils.

- Chilled Water Pumps. Chilled water pumps shall be double-suction, centrifugal, horizontally split case, flexible-coupling, mechanical-seal, and base-mounted. They shall have the following characteristics:

  - Maximum pump speed: 1,800 revolutions per minute(rpm).
  - Operating efficiency at design flow: within 5 percent of maximum efficiency.
  - Pump type: non-overloading.

- Water Treatment. Chilled water and condenser water shall be chemically treated to prevent scale and algae buildups, to prolong the system's lifespan, and to maintain system efficiency. The water treatment systems shall satisfy the requirements of Systems Design Criteria Chapter 8 - Corrosion Control. Their operation should not require the stoppage of chilled water or condenser water circulation.

- Operation and Control. Individual thermostats located in the space that they serve shall be provided for each packaged or split air-conditioning system to control space temperatures. Each system shall have economizer capabilities through the use of return-air and modulating dampers in outside air and exhaust ducts.

Paint Spray Area. To maintain negative pressure in paint spray booths, the ventilation system for the paint spray area shall be sized so that the supply air volume is 5 percent less than the air volume exhausted by the paint spray booth exhaust. The number of air changes per hour (the ventilation rate) shall be as recommended by the spray paint equipment supplier, but the number of changes shall not be less than the rate required by any of the applicable codes as referenced in Appendix 1. The filtration of supply and exhaust air shall be provided as recommended by the spray paint equipment supplier and as required by the applicable codes. Exhaust air filters shall be capable of removing paint and dust. Exhaust fan motors and temperature control equipment shall be of explosion-proof construction.

Mechanical Equipment Room. Ventilation and heating shall be as that described in section 25.5.3 for the ancillary rooms.

Locker Rooms. The locker rooms shall receive heat and conditioned air from the general office HVAC unit described in the General Office Areas, and Shops section above. If HVAC cannot be provided from the general office area, a packaged HVAC unit shall be provided.

Toilets. In the maintenance shop area, toilet rooms shall be heated with secondary air transferred from adjacent locker rooms. Toilet rooms located within a general shop area shall be heated and ventilated. The toilet room exhaust fan shall be controlled by the light switch, with a time delay on light off. In the general office area, toilet rooms shall receive heat and air-conditioned air from the general office unit described in the General Office Areas, and Shops section above. The toilet room exhaust fans shall operate continuously when offices are occupied. The toilet room exhaust fans shall maintain a negative pressure in the toilet room.

Electrical Equipment Rooms. Ventilation system shall be as that described in section 25.5.3 for the ancillary rooms. Where required to prevent condensation, electrical equipment rooms shall be heated by transferring secondary air from adjacent heated areas. Where additional heating is required, electric heaters controlled by a room thermostat shall be provided.

Train Operators' Lounge and Lunch Room. The train operators' lounge and lunch room shall be provided heat and A/C from the general office unit described in the **General Office Areas, and Shops** section above, or it shall have its own package HVAC unit.

Under Car Cleaning Facility. Under car cleaning is dirt and grease removal using steam for routine service and inspection access reasons and not to be confused with long-term cleaning, which occurs at intervals greater than one service and inspection cycle. The Section Designer will confirm the adequacy of the below criteria with the authorities having jurisdiction prior to beginning final design.

- System Concepts. A supply and exhaust ventilation system shall be furnished to provide safety and comfort to the operating personnel and to remove airborne dust resulting from cleaning of under-carriage equipment of the vehicles.

- Ventilation Requirements. General ventilation at the rate of 10 air changes per hour shall be provided for the total enclosed area. Exhaust or air extraction rate for pit area shall be four cubic feet per minute (cfm) per square foot. Make-up or supply air shall be less than the exhaust air.

- Equipment and Accessories. Roof-mounted exhaust fans and packaged or unitary HVAC type make-up air units shall be used to provide the required ventilation. If the booth is within the maintenance building, the exhaust fans shall be mounted on the maintenance building roof, and split-package HVAC type make-up air units shall be mounted on the booth roof. Air-cooled condensers for the split-package HVAC units shall be mounted on the building roof. Exhaust air grilles shall be located near the booth floor and the pit floor, with a minimum face velocity of 175 feet per minute (fpm). Make-up air shall be introduced at the roof level and near the work platforms. Appropriate air distribution ductwork, air filters, and automatic temperature controls shall be provided.

- Operation and Control. Supply and exhaust ventilation systems shall be thermostatically controlled. A cooling-heating switch and a fan on-off-auto switch, controlling both the make-up air and exhaust systems, shall be provided. In the heating position, the heating system shall operate. While in the cooling position, the refrigeration system shall operate. When the space temperature exceeds 85°F, the refrigeration circuit shall be energized. When temperatures drop below 68°F, the heating system shall be energized.

All Other Areas. HVAC criteria for all other areas shall conform as applicable to the requirements of section 25.5.3 of this chapter.

25.5.2 Operations Control Center

The concepts described in these criteria are applicable to the heating, ventilation, and air-conditioning systems, equipment, operation, and controls in the operations control center (OCC). Both outside and indoor peak design conditions for summer and winter shall conform to the requirements prescribed in section 25.4.

A/C System Concepts. If conveniently available, the OCC shall be cooled using chilled water. The HVAC system shall include air handling units, chilled water circulating pumps, and exhaust and relief fans. The primary unit shall be capable of providing 100 percent of the total cooling load, and the back-up unit shall be capable of maintaining an 80°F room temperature until the primary unit is brought back on line. As a minimum, the main control room, the security control room, the closed-circuit television (CCTV) room, the communications equipment room, and the computer equipment room shall be provided with a backup air-conditioning system. The backup air-conditioning system shall consist of a split-package A/C unit with a remote air-cooled condenser. Each system shall be complete with refrigerant piping, controls, drives, and accessories. The air distribution ductwork shall be common. Outside air for ventilation shall be provided as required.

In accordance with the requirements of Halon 1301 Fire Extinguishing Systems (NFPA Standard 12A), provisions shall be made to extract decomposition products of Halon. The halon extraction system shall also be suitable for smoke removal.

A/C Equipment and Accessories.

- o Indoor Units. Each unit shall be completely pre-piped and prewired internally. Compressors shall be a heavy-duty, semi-hermetic type with vibration isolators, high/low pressure switches, and pump-down controls. The fans shall be centrifugal and belt-driven with forward-curved blades and double inlets. Fan motors shall have an adjustable mount and an adjustable sheave to vary the fan speed. Evaporator coils shall consist of copper tubes, copper or aluminum fins, and a stainless steel drip pan. Humidifiers shall be stainless steel. An immersion-type heating element shall be used. The reheating apparatus shall be electric and shall be sized to maintain room dry-bulb conditions when the system is calling for full dehumidification. Air filters shall be provided for pre-filter and final-filter.

- o Outdoor Units. Condensers shall have ample capacity to handle the compressors' total heat rejection and maintain adequate condensing temperature for an ambient air temperature range of 0°F to 115°F. Air-cooled condensers shall have direct-driven propeller fans.

HVAC chilled water systems shall include the following:

- o Air Handling Units. See 25.5.1, "Air Handling Units".

- o Chilled Water Pumps. See Section 25.5.1, "Chilled Water Pumps".

- o Cooling Towers. Cooling tower type shall be either counterflow, induced, or forced draft. The selection of one of these three types shall be based on the following design parameters:

  - Water flow rate: 3 gallons per minute (gpm) per ton.

- Water temperature: 95°F entering, 85°F leaving.

- Entering air: 78°F WB.

The sump shall be provided with an electric immersion heater and a controlling aquastat shall be installed in the tower basin so that the sump and basin do not have to be drained during freezing weather. Electric heaters shall be connected to the standby power supply system.

Sound attenuation shall be provided, if necessary, to preclude the possibility of cooling tower noise levels rising above the levels indicated in Chapter 11 - Noise and Vibration. Provisions shall be made for the elimination of any water plume formation at the discharge of cooling towers where such a plume would interfere with the visibility of vehicular traffic, pedestrian movements, or building operations.

Operation and Control. To maintain step control for temperature and humidity conditions, a solid state control system shall be used. The indoor temperature and humidity sensing elements shall be located in the space that they serve. To provide two stages of cooling and up to three stages of reheat as required to maintain close room temperature tolerances, the dry-bulb temperature control shall consist of a multi-step proportional sequencer. The humidity controller shall consist of one stage of humidification and one stage of dehumidification. The outside air sensors shall be provided in the fresh air intake duct. System operating mode configurations shall range from full cooling with minimum outside air to maximum free cooling with 100 percent outside air. The air-conditioning system shall automatically shut down if fire or smoke detected.

Standby Power. Air-conditioning equipment serving the OCC shall be wired to the standby power supply as prescribed in Chapter 28 - Facilities Electrical Requirements.

25.5.3 Ancillary Space HVAC Systems

The concepts described in this section are applicable to the HVAC systems, equipment, operations, and controls in the indicated areas. Outside and indoor summer and winter peak design conditions shall conform to the requirements prescribed in section 25.4.

Communication and Signaling Rooms. The ECS requirements for prepackaged communications and signal equipment bungalows shall be as prescribed in Systems Design Criteria Chapter 4 - Signals System and Chapter 5 - Communications. The requirements prescribed below are applicable to communication and signaling (C&S) rooms located in subway stations, or at major repair shops, and service and inspection shops.

- System Concepts. The air-conditioning system shall be designed so that an air-conditioning unit shall modulate from minimum outside air required for ventilation to 100 percent outside air. Approximately 90 percent of the supply air shall be either recirculated or exhausted to outside, and 10 percent of the supply air shall be exhausted by exfiltration to maintain positive pressure within the space. Outside air shall be introduced into the room through motorized dampers in the outside air intake duct. Supply air shall be filtered. In accordance with Halon 1301 Systems (NFPA Standard 12A), a provision shall be made to purge Halon after a fire emergency.

- Cooling Load. The cooling load shall be calculated based on a summation of the following heat gains:

  - Internal equipment load.

  - Lighting load of 3 W/sq ft (or actual lighting load if available).

  - Outside air load.

  - Solar and transmission gains (where applicable).

- Equipment and Accessories. Air-handling unit equipment shall be of the DX split-system type, with an air-handling unit in the room adjacent to or within the C&S room. Air-handling units shall include disposable filters, DX cooling coils, a centrifugal fan, and a condensate drain pan. Installation shall include automatic temperature controls and a remote, air-cooled condensing unit. Although not essential, a system with dual compressors (each with 50 percent capacity), is preferred. Air-cooled condensing units for C&S rooms in subway stations shall be located within mechanical equipment rooms for subway stations, with air ducted to subway line sections or (where possible) grade level. A condensing unit for at-grade and aerial C&S rooms shall be located outdoors. A condensing unit may be part of the air-handling unit, or it may be remote from it. Where chilled water is conveniently available, an air handling unit with chilled water coils shall be provided.

- Operation and Control. The operation of the HVAC system shall be controlled by a room thermostat. The ventilation system shall be automatically shut down if fire or smoke is detected within the communications and signaling rooms. The system shall have provisions so that high-temperature and dirty-filter indicators can each transmit a summary fault indication to the OCC.

Computer Rooms. The concepts described in section 25.5.2 for HVAC systems for the OCC are applicable to HVAC systems for computer rooms.

Auxiliary Electrical Rooms.

- o System Concepts. A supply and exhaust ventilation system shall be provided to remove and discharge to the outdoors heat produced by transformers, switchgear, the uninterruptible power supply unit, lights, etc. Ventilation air shall be obtained from the outdoors. Air filtration shall be provided at the air intake to the space and a positive pressure shall be maintained when the system is in operation. Heating and/or air conditioning may be required depending on specific equipment requirement.

- o Ventilation Capacity. The ventilation capacity shall be based on a summation of the following internal heat gains:

  - 3 percent of the installed transformer capacity.

  - Heat rejected by the electrical equipment.

  - Solar and transmission gains (where applicable).

  - A lighting load of 3 W/sq ft (use actual lighting load when available).

- o Equipment and Accessories. The system shall consist of one or more supply and exhaust fans, distribution ductwork and devices, air filters, automatic temperature controls, and intake and exhaust louvers. Air shall not be drawn from or discharged into tunnels through these louvers.

- o Operation and Control. Supply and exhaust fans shall be controlled by an adjustable electric thermostat located within each auxiliary electrical room. For example, the fans shall start when the space temperature rises to 86°F or above and stop when the temperature falls to 80°F or below. Local manual control via a time switch shall be provided for operation of the ventilation system during human occupancy of the room. The ventilation system shall be automatically shut down if fire or smoke is detected within the room. A positive pressure within the room shall be maintained when the system is in operation.

Traction Power Substations. The ECS requirements for prepackaged traction power substation bungalows at grade shall be as prescribed in Systems Design Criteria Chapter 3 - Traction Electrification. The requirements prescribed in this section are applicable to traction power substations located in subway tunnels and in permanent masonry buildings.

- o System Concepts. A ventilation system is required in all enclosed traction power substations to remove heat generated by the electrical equipment, and to limit the operating temperatures within substations to the design operating conditions prescribed in section 25.4.2. A central ventilation system shall be provided to supply filtered, 100 percent outdoor air to traction power substations and exhaust hot air from the space to outdoors.

- Ventilation Capacity. The ventilation capacity shall be based on a summation of the following internal heat gains:

  - Lighting load of 3 W/sq ft. (Use actual lighting load when available).

  - Solar and transmission gains (where applicable).

  - Heat rejected by the electrical equipment.

- System Arrangement and Associated Equipment. The system shall consist of two identical supply fans with motorized dampers. It shall have filters, an air distribution system, and automatic temperature controls. The design of supply and exhaust ducts shall be based on two-fan operation. Ventilation air shall not be taken from the subway or exhausted into the subway. A positive pressure shall be maintained within the room when the ventilation system is in operation. Fans shall be selected with sound power levels such that with both supply fans in operation the noise level in the substation does not exceed the maximum allowable noise level as prescribed in Chapter 11 - Noise and Vibration.

- Operation and Control. The operation of the fans shall be controlled by adjustable thermostats located within the substation. For example, when the space temperature rises to 86°F, the first (or lead) fan will start. On a continued rise to 96°F, the second (or lag) fan will start. On a fall in temperature to 95°F, the lag fan will stop. On a continued fall in temperature to 80°F, the lead fan will stop. By means of an alternator, the lead fan of one cycle will become the lag fan on the next cycle. This will keep the number of starts and hours of operation approximately equal. Local manual control (a time switch) shall be provided so that the fans can be turned on during human occupancy of the substation. The ventilation system shall be automatically shut down if fire or smoke is detected within the traction power substation. The system shall have provisions so that high-temperature and dirty-filter indicators can each transmit a system fault indication to the OCC.

Battery Room. Maintenance-free batteries will be used. Exhaust ventilation, heating and/or air conditioning shall be provided at a minimum of one air change per hour as recommended by the battery manufacturers.

Miscellaneous Ancillary Rooms.

- System Concepts. Exhaust ventilation shall be provided for each ancillary room shown on the project definition drawings. Air shall be discharged to outdoors. Ventilation air shall be provided as required and shall be taken from adjacent areas or outside as applicable. Ventilation air, if taken from outdoors, shall be filtered. Each ventilation system shall be shut down automatically if fire or smoke is detected within the area served.

- Operation and Control. In toilets, the ventilation system shall operate only when associated lighting is energized, with a time-delay on the light "off" switch. The ventilation system shall operate continuously in the following rooms: custodial rooms, trash rooms, sewage ejector or pump rooms, battery rooms, and storage rooms. The telephone equipment rooms and elevator machine rooms shall be provided with air conditioning. In the electrical equipment rooms, the ventilation system shall be controlled by a room thermostat and by manual override. The ventilation system shall be automatically shut down if fire or smoke is detected within the room.

25.5.4 Concession Area HVAC Systems

The concepts described in these criteria are applicable to HVAC equipment systems and their operation and control of concession areas where provided at at-grade, aerial, and subway stations. Ambient and indoor summer and winter design conditions shall conform to the requirements prescribed in section 25.4.

At-Grade and Aerial Stations

- System Concepts. The HVAC system for concession spaces provided at aerial and at-grade stations shall consist of a split-packaged or self-contained air conditioning units complete with an air distribution system, controls, drives, and accessories. An electric heating coil shall be provided where required for the heating of supply air.

- Equipment. The HVAC equipment and operating controls shall conform to the requirements prescribed in section 25.5.1.

- Operation and Control. The operation of the HVAC system shall be controlled by a space thermostat and by a manual override.

- Metering Devices. Metering devices shall be provided for domestic water and electricity consumption.

Subway Stations

- System Concepts. A chilled-water HVAC system shall be used for concession spaces at subway stations. Each system shall be complete with air handling or fan-coil units, air distribution systems, air terminals, controls, drives, and accessories. Air handling or fan coil units shall be equipped with a chilled water cooling coil and an electric heating coil. Chilled water shall be obtained from the station chilled water distribution system. Fresh air/exhaust air connections to the station air distribution system shall be as shown on the project definition drawings.

- Equipment. Air handling and fan coil units shall conform to the requirements prescribed in Section 25.5.1 for identical HVAC equipment.

- Operation and Control. The operation of the HVAC system shall be controlled by space thermostat and by manual override. The ventilation system shall be automatically shut down in the event of fire or smoke detection within the room.

- Metering Devices. Metering devices for chilled water, domestic water, and electric power consumption shall be provided.

25.5.5 Tunnel ECS

The concepts described in these criteria are applicable for subway stations and tunnels. Ambient and indoor summer and winter design conditions shall conform to the requirements described in Section 25.4. Provisions for emergency ventilation for protection of passengers and employees from fire or generation of smoke shall conform to NFPA 130.

System Concepts. The tunnel ventilation system shall be designed to achieve the objectives established for emergency situations. The primary relevant fire emergencies include fire and smoke in subway station concourses, in platform areas, in ancillary rooms, in subway line sections, or onboard a rail vehicle. In any of these situations, the function of the tunnel ventilation system is to maintain a relatively safe path of egress in case it becomes necessary to evacuate persons from the DART rail system. The ventilation system will also assist emergency rescue and fire-fighting personnel in gaining access to the source of the emergency by minimizing the spread of smoke in their path sufficiently to mitigate backlayering of smoke.

For achieving the above objectives, the basic concept of operation and control of the tunnel ventilation system is that the tunnel ventilation fans should be operated to provide a source of fresh air into the evacuation path and to keep smoke and heat away. The ventilation system shall be capable of moving air in either direction in the tunnel at the required air velocity.

Vehicle locations, fire locations, and passenger evacuation routes are the three factors that affect the operating mode (supply or exhaust) of each of the tunnel ventilation fans, and (in certain situations) even the mode of station ventilation fans. Fan dampers and bypass dampers must be interlocked such that the former open and the latter close when their respective fan is started. Also, the "power-off" mode for damper positions shall be "open" for fan dampers and "closed" for bypass dampers.

During congested operations, the movement of air in the tunnels caused by the train piston effect ceases. The heat given off by the train air conditioners and the residual heat from the train propulsion system will then cause the tunnel air temperatures to increase. The temperatures can increase to the point where the related increase in the train A/C condenser pressures would cause the train A/C system to stop. Therefore, during congested operations the tunnel ECS shall act to limit the temperature rise by moving air past the stopped trains(s). The tunnel ventilation fans shall be operated in a push-pull mode with a fan at one end of the affected tunnel supplying air and a fan at the other end of the tunnel exhausting hot air. In the event two parallel tunnels are congested then the two fans in each of the contiguous ventilation shafts shall be operated.

System Arrangement. For a typical two-track subway station, a total of four fans shall be provided - two at each end of the station. A tunnel ventilation shaft shall be provided at each end of the station. Where required, mid-tunnel ventilation shafts (in addition to tunnel ventilation shafts located adjacent to stations) shall be provided approximately midway between adjacent stations or a station and its adjacent portal. Typical arrangements for tunnel ventilation shafts shall be as indicated on the project definition drawings. Mid-tunnel ventilation shafts shall be equipped with a minimum of two fans.

Fans shall be housed in fan rooms adjacent to the trackway and shall be arranged horizontally or vertically. Fan dampers and bypass dampers shall be provided in the structure separating the fan room from the trackway. Bypass dampers shall be provided for all fans and shall be located nearest to the vent shafts extending to grade.

Fan motor starters and related operating control devices shall be isolated from the ventilation airflow by a separation having a fire resistance rating of one hour or more. Emergency ventilation fans shall be connected to two power feeds from separate sources.

Equipment and Accessories. All system components located in the airstream, including fans, isolation, fan and bypass dampers, shall be capable of operating in an ambient air stream temperature of 300°F for a minimum of 1 hour.

- o Tunnel Ventilation Fans. Tunnel ventilation fans (TVFs) shall be of the axial-flow type with an internally mounted, direct-drive motor. Fans shall be reversible within a 60-second time interval so as to either supply or exhaust air to or from the trackway.

Fans shall have adjustable-pitch blades to permit a change in pressure versus air flow capacity for either system balancing or for future system modification. The minimum acceptable reverse (supply) air flow capacity shall be 90 percent of the forward (exhaust) air flow capacity. Fans shall be selected to have a total fan efficiency of not less than 60 percent in the forward (exhaust) flow mode.

Each fan shall be provided with modular, rectangular sound attenuators approximately 7 feet long on both inlet and discharge sides. The exact length of sound attenuators shall be based on the dynamic insertion loss (DIL) levels to be provided to the section designer. With prior approval, additional sound lining shall be provided as required on fan room and vent shaft walls so that the maximum noise levels from the ECS do not exceed the allowable limits for interior or outdoor noise levels prescribed in Chapter 11 - Noise and Vibration.

Isolation dampers, fan dampers, and bypass dampers shall be the heavy duty, industrial, parallel-blade type. All damper components shall be designed to withstand an ambient temperature of 300°F for a minimum of 1 hour. Dampers and their associated structural supporting members shall be capable of withstanding a maximum differential static pressure across the dampers of 16 inches water gauge; and minimum differential static pressure of 6 inches of water gauge for 2,000,000 reversals. Each damper module will have two end switches. One end switch will indicate the fully open position and the other end switch will indicate the fully closed position.

- Ductwork. Air distribution ductwork shall conform to the requirements prescribed in section 25.6.

- Operation and Control - Normal Operation. During normal operations, the tunnel ventilation fans will not be operated and their associated fan dampers will be closed. The isolation dampers will be open. Depending on the season, the bypass dampers will be either opened or closed. During the summer, the bypass dampers will be closed to prevent the heat of the outside air (which can be greater than the train heat) from entering the system. During the extreme winter, the bypass dampers will be closed to allow train heat to warm the system. The bypass dampers will be opened during the spring and autumn so that the entry of cooler outside air.

- Instrumentation and Controls. The control system shall have capability of controlling all operating modes of tunnel ventilation fans and dampers, both remotely from OCC and locally from respective ventilation shafts and stations. Local control panels at stations and ventilation shafts shall control fans and dampers located on the premise. Fan and damper positions in all operating modes shall be annunciated to OCC and at local control panels. The local controls shall be located in a secured area and shall be capable of overring the OCC.

o Operation and Controls - Emergency Operation. The emergency ventilation system consists of a number of tunnel ventilation fans, motorized dampers, and associated equipment. If an emergency involving fire or smoke occurs within the subway, the coordinated operation of this equipment is required to provide sufficient ventilation to the affected area. (The DART Project Ventilation Operations Matrix detailing the operational sequence of commands necessary to implement emergency ventilation within the subway will be provided to the designer during final design.) Controls shall be "fail safe" in the case of power failure and shall indicate this condition to the OCC.

The primary control of the ventilation equipment is from the OCC, which serves as the control center for the entire DART rail system. The OCC operator has three sources of information: a display of track circuit occupancy information showing the location of trains, telephone communication to local telephones, and two-way radio communication with the vehicle operators. After receiving information from the train operator, the operator at the OCC must make an assessment of the situation and, if appropriate, activate the emergency ventilation system.

Before activating the emergency ventilation system, the evacuation route must be selected. The following information is needed for this decision:

- From train operator: Location of disabled train
  Location of fire on train
  (front car/rear car, if any)

- From the train control board: Location of other trains
  near disabled train

The operator at the OCC, in consultation with the vehicle operator, would use the information to determine the safest evacuation route. After determining the evacuation route, the appropriate emergency ventilation mode would be activated by the operator at the OCC.

The response time for determining and implementing the proper ventilation mode for a given emergency will be reduced through the use of computers. The computers would store the operating modes of the ventilation equipment as a function of each anticipated emergency. The computers will be redundant and will include a monitor to guide the operator in the proper activation of the required ventilation elements. In essence, this control system will function as follows:

Input information (voice communication at the scene of the incident) would advise the OCC operator of the following:

- The location of the train in the system.

- The relative location of the fire (if any).

- The proposed evacuation route.

The OCC operator would then input the above three points of information into the computer. In response, the computer would display the following on the CRT:

- Input information inserted by the OCC operator.

- A schematic display of the subway system, indicating all of the ventilation elements to be activated and their proposed mode of operation.

Upon examination of the display by the OCC operator to assure the reasonableness of the displayed decision, the operator would then instruct the computer to proceed. This would operate (in the manner indicated and in the proper sequence) each of the displayed ventilation elements. It is not intended to have the CRT display and the microprocessor fully automate the emergency operation of the ventilation system, but rather to minimize the response time needed to implement the decision.

o Operation and Control - Congested Operations. Procedures for the operation of the tunnel ventilation system will be provided during final design.

For further descriptions of control system operation and hardware refer to Systems Design Criteria Chapter 6 - Operations Control Center.

25.6 AIR DISTRIBUTION SYSTEM DESIGN

All air-distribution duct systems shall be designed based on recommendations and in accordance with information contained in the latest edition of the Handbook of Fundamentals (ASHRAE). Supply duct sizes shall be selected for an equal pressure drop or static regain method as appropriate. Maximum velocities shall not exceed those described in section 25.4.5. Air-distribution ductwork for ancillary area ventilation systems shall be so arranged that air is not exhausted into or obtained from station public occupancy areas.

All sheet metal ducts shall be constructed of galvanized steel with airtight joints. Air distribution ductwork for battery rooms shall be of stainless steel or fiberglass construction. Aluminum ductwork shall be used in ejector rooms, sump pump rooms, and other similar rooms which have a high moisture content in the air. All ducts shall be sufficiently stiffened and supported to avoid sagging and vibration.

In general, the ductwork fabrication shall be in accordance with Low Pressure or Medium Pressure Duct Construction Standards (Sheet Metal and Air-Conditioning Contractors National Association, Inc. (SMACNA) as appropriate, except for the tunnel ventilation systems, where ductwork fabrication shall be in accordance with High Pressure Duct Construction Standards.

25.6.1 Pressure Losses

Pressure loss calculations shall be performed according to the Handbook of Fundamentals (ASHRAE, latest edition). The static pressure differential across any supply or return air terminals shall not exceed 0.15 inches water gauge when the system is operating at full capacity.

25.6.2 Supply Air Registers and Diffusers

All supply air registers and diffusers shall be selected to provide the required throw and spread with the least amount of draft and noise. All registers shall be provided with adjustable and double-deflection louvers and spin taps or opposed-blade adjustment volume dampers. Volume dampers shall be key-operable through the face of the register. All ceiling diffusers shall be the square, rectangular, circular, or linear type. They shall have adjustable throw, opposed-blade adjustable volume dampers, and adjustable air extractors. Utilize spin taps with dampers whenever possible to reduce requirement of opposed blade dampers at diffusers. (Close coordination with the architectural and lighting designs shall be required.)

25.6.3 Variable Air Volume Terminals

If provided, variable air volume (VAV) terminals, and fan powered terminals (FPVAV) with electric reheat for perimeter zones shall be pressure-independent and shall reset a volume as determined by the space thermostat regardless of any changes in system air pressure. Terminals shall be system powered and shall require no more than 1 inch water gauge static pressure regardless of air quantity. The casing shall be of double shell construction meeting SMACNA standards with sandwiched "foamed in place" insulation. Terminals shall be complete with factory furnished system powered actuators, controls, and thermostats.

25.6.4 Exhaust and Return Air Grilles

Either all exhaust and return air grilles shall be equipped with fixed, non-see-through blades or louvers, or the duct behind them shall be painted matte black. All exhaust grilles shall be equipped with opposed-blade, adjustable-volume dampers key-operated through the face.

25.6.5 Volume Dampers

Adjustable, opposed-blade volume dampers shall be provided for all branch ducts serving multiple outlets. All dampers shall be equipped with locking quadrants with blades sufficiently stiffened at the edges to effectively close off the duct. Under all conditions of operation, they shall be free from vibration.

25.6.6 Splitter Dampers

Splitter dampers shall be used in multiple duct fittings for initial balancing in place of individual opposed-blade volume dampers in each branch of the multiple duct fitting. These splitters should be adjustable through locking quadrants and shall be single-bladed. The blades shall have edges sufficiently stiffened to avoid vibration under all conditions of operation.

25.6.7 Fire Dampers

Fire dampers shall be provided in ducts which pass through fire-rated floors, walls, and barriers. All fire dampers shall be Underwriters Laboratories, Inc. (UL) listed.

25.6.8 Backdraft and Relief Dampers

Backdraft or motorized shutoff dampers shall be used on exhaust fans where more than a single fan discharges into a common exhaust. Weighted relief dampers shall be used in exhaust ducts and openings where a positive pressure is required to be maintained by a forced air supply and relief exhaust. All backdraft and relief dampers shall be the multi-bladed gravity type with neoprene cushioning on blade edges.

25.6.9 Air Extractors

Air extractors shall be used in branch duct connections and for registers and diffusers where there is inadequate space for installing multi-bladed volume dampers. All air extractors shall be the movable blade, pivoted type.

25.6.10 Turning Vanes

All elbows shall have a full centerline radius at least 1.5 times the width of the duct. Where full-radius curves are not feasible, elbows shall be provided with turning vanes. All turning vanes shall be the double radius type.

25.6.11 Access Doors

Access doors shall be provided in ducts and plenums to service fans, dampers, fire dampers, turning vanes, coils, filters, etc. Access doors in plenums shall be hinged and furnished with latches operable from both inside and outside, and door edges shall rest against neoprene gaskets to form an airtight enclosure. Duct access doors shall rest against felt or neoprene gaskets and shall be hinged or fastened by toggle tabs or wing nuts. Access doors in insulated ducts and plenums shall be insulated using sheet metal-insulation-sheet metal construction.

25.6.12 Flexible Duct Connectors

Flexible duct connectors shall be used on all fan and air handling units to connect units to ductwork. The length of each joint shall be selected to adequately accommodate both horizontal and vertical deflections of the fan units. The flexible material shall not be less than 4 inches, however. Flexible duct connectors for tunnel ventilation fans shall be capable of withstanding an air temperature of 300°F for 1 hour.

25.6.13 Insulation

The insulation on indoor ductwork shall be composite insulation with a Kraft facing. The adhesive used to adhere a jacket or facing to the insulation shall meet fire and smoke hazard ratings as tested by the American Society for Testing Materials (ASTM) E84 procedure, the NFPA 255 procedure, NFPA 90A, NFPA 90B, and the Underwriters Laboratories, Inc. (UL) 723 procedure. In addition to meeting these ratings, the adhesive shall not exceed a flame spread of 25, a fuel contribution of 50, and a smoke development of 50. Accessories such as adhesives, mastics, cement, tapes, and cloths for fittings shall have similar component ratings. The acceptance of the liner material shall be evaluated on a case-by-case due to IAQ questions and standards.

Insulation shall be provided for the following:

- Heating and A/C supply and return ducts.
- Outside air intake ducts subject to condensation.
- Emergency generator exhaust flue.

25.7 VENTILATION SHAFTS AND AIR TERMINALS AT GRADE

The maximum air velocity through a grating or louver shall be computed using the gross free face area of the grating or louver, exclusive of any supports. All ventilation shafts and terminals at or above grade shall be sized, designed, and spaced in accordance with the following sections.

25.7.1 Normal Operations

For discharges at the sidewalk level, the peak outflow air velocity shall not exceed 500 fpm. For discharge 8 feet or more above sidewalk level or away from public areas, the peak discharge velocity shall be limited by the noise criteria but shall not provide a pressure loss greater than 0.50 inches water gauge. For supply air intakes 8 feet or more above grade or away from public areas, the peak intake air velocity shall not exceed 1,200 fpm. For supply air intakes less than 8 feet above grade, the peak intake air velocity shall not exceed 1,000 fpm.

25.7.2 Emergency Operations

For discharges at the sidewalk level, the peak outflow air velocity shall not exceed 1,000 fpm. For discharges 8 feet or more above sidewalk level or away from public areas, the peak discharge velocity shall be limited by the noise criteria. Pressure losses shall not exceed 0.75 inches water gauge, however.

25.7.3 Shafts and Terminal Locations

Ventilation intake and discharge terminals at street level shall be located to avoid pedestrian and vehicle crossings and to minimize the danger of flooding from the sidewalk or street. When located in sidewalks, they shall not occupy more than 40 percent of the sidewalk width. Where possible, they shall be located in median strips or in off-street locations, and shall be suitably screened with planters or other decorative treatments. Under no circumstance shall ventilation shaft openings be located in roadways, driveways, near motor vehicle stops, or anywhere fuel, fuel fumes, or high concentrations of exhaust fumes can be drawn into the ventilation shafts. At-grade surfaces shall be sloped away from the gratings of shafts to minimize the flow of water into the shafts.

25.7.4 Shaft Design

Shafts shall be designed so that sudden transitions in the shaft cross section are avoided and the minimum number of bends and elbows are used. Turning vanes may be used to reduce pressure losses, and the streamlining of obstructions in fan shaft passages shall be undertaken where required. Air passages shall be constructed of smooth concrete or sheet metal ductwork. Exhaust air shafts may be combined into a common shaft, as may outside air intake shafts.

Under no circumstances, though, shall exhaust and intake shafts be combined into a common shaft. Ventilation air intake and discharge facilities shall be designed so that an adequate distance is provided between intake and exhaust to prevent recirculation. The following formula shall be used to calculate the minimum horizontal distance between adjacent ventilation shaft openings to the surface at the same elevation:

$$d = b \times (L_1 + L_2)$$

Where:

d = the minimum distance in feet between edges of the adjacent openings.

L_1 and L_2 = lengths in feet of the adjacent parallel sides of the openings.

$b = 0.25$ If one shaft is a tunnel ventilation shaft and the other is a station exhaust shaft.

$b = 0.50$ If one shaft is a station fresh intake shaft and the other is a station exhaust shaft.

$b = 0.25$ If one shaft is a tunnel ventilation shaft and the other is a station fresh air intake shaft.

Ventilation shaft terminals at grade level shall be separated by a minimum horizontal distance of 40 feet from the closest station entrance or the closest surface emergency stair doorway. Where this is not practical, the horizontal distance may be reduced to 15 feet if the closest ventilation shaft terminal is raised a minimum of 8 feet above the top of the station entrance door or emergency stair doorway.

25.8 PIPING

All piping systems shall be designed to meet the requirements of American National Standards Institute (ANSI) B.31 (all applicable sections). All pipe fittings, flanges, valves, and accessories shall comply with ANSI B16 (all applicable sections for dimensional requirements). All piping systems shall be designed and arranged for neat appearance. They shall be properly sloped for drainage and venting, and properly supported, guided, and anchored to provide complete flexibility and to maintain the integrity of all systems without any damage or leaks under all operating conditions. All valves and accessories shall be installed in a systematic manner in places accessible for operation without the use of chains or additional operating platforms. Sleeves and escutcheons shall be provided wherever pipes pass through walls.

25.8.1 Pipe Unions or Flanges

To facilitate easy removal for servicing, unions or flanges shall be provided on both the inlets and the outlets of all apparatus, isolation valves, control valves, and accessories. Wherever two pipes made of dissimilar metals are connected, a dielectric union shall used to isolate the two pipes from each other. Dielectric unions and flanges may also be required for cathodic protection.

25.8.2 Valves

Isolation valves shall be provided on both sides of such apparatus as chillers, cooling towers, pumps, heating coils, control valves, multiple installations, and piping branches. The installation of all valves shall be designed to give a neat appearance and provide easy grouping with all parts accessible for operation and maintenance. Valve stems shall be horizontal wherever possible.

25.8.3 Piping Accessories

To assure the trouble-free operation of all piping systems, all required piping accessories shall be provided. These accessories should include strainers, vent cocks, dirt-and-drip legs with drain-and-flush connections, expansion tanks, liquid flow indicators, balancing cocks, relief valves, and pressure and temperature gauges, etc. All piping accessories requiring maintenance or replacement of parts shall be installed in accessible places. All dials of gauges and indicators shall be of sufficient size and arranged to be easily seen and read.

25.8.4 Pipe Expansion Joints

The use of pipe expansion joints shall be avoided wherever possible. Pipe systems shall be arranged to have sufficient offsets and expansion loops to accommodate thermal expansion and vibration. Pipe expansion joints may be used only where pipe expansion loops are impractical. All such expansion joints shall be of stainless steel or monel metal. They shall be the double-compensating type with an anchor in the middle. These shall be guided on both sides in strict accordance with the manufacturer's recommendation. All expansion joints shall be flanged to facilitate easy and quick replacement.

25.8.5 Flexible Pipe Connectors

The use of flexible pipe connectors to connect piping to heating and cooling apparatus shall be restricted to cases where providing piping offsets for flexibility is impractical. Where flexible pipe connectors are used, such as on resiliently mounted air-handling units and pumps, these flexible pipe connectors shall be of stainless steel or monel construction with flanged ends for quick and easy dismantling from the pipe systems. They shall be of sufficient length to provide an overall stiffness less than the resilient mounts used for supporting the apparatus.

25.8.6 Pipe Supports, Hangers, Guides, and Anchors

Pipe supports, hangers, guides, and anchors shall be designed to assure proper alignment of all pipes for operating conditions. The forces caused by the motion of the fluid; the weight of the fluid, piping, valves and insulation and thermal expansion/contraction shall be considered as appropriate. All hangers and supports shall be so arranged as to prevent the transmission of vibration from the piping to the structure. Anchors and guides shall be designed to allow pipes to expand and contract without a build-up of excessive stress. Pipe rollers shall be used with all hangers where pipe movement due to expansion or contraction exceeds 0.5 inch. Spring hangers of constant or variable load types, as the case requires, shall be used when piping is connected to vibrating equipment and where supporting vertical pipes.

25.8.7 Insulation

Composite insulation with a metal jacket or Kraft facing shall be used on indoor piping as appropriate. The adhesive used to adhere the jacket or facing to the insulation shall meet the fire and smoke hazard ratings as tested by procedures ASTM E84, NFPA 255, NFPA 90A, NFPA 90B and UL 723. In addition, this adhesive shall not exceed a flame spread of 25, a fuel contribution of 50, and a smoke development of 50. Accessories such as adhesives, mastics, cements, tapes, and cloths for fittings shall have similar component ratings. Insulation for chilled water supply and return piping, and cooling tower condenser return (to water chiller) piping shall be two-piece, heavy density, sectional insulation jacketed with an embossed vapor barrier laminate. Insulation for refrigeration suction piping shall be a 2-inch thick (minimum) slip-on-type premolded cellular glass.

25.8.8 Freeze Protection

The section designers shall analyze the piping installation at each station and other unheated spaces for the potential of water lines freezing during winter months. If required, electric-resistance tape shall be provided in addition to insulation. Provisions shall also be made to allow for drainage of piping that will be subject to freezing temperatures.

25.8.9 Pumps

As conditions dictate, pumps shall be either single- or double-suction. Pumps shall be arranged so that they can be serviced without any removal of the piping system. This shall include any disconnection of piping from the pumps. Pumps shall have the following characteristics:

- o Maximum Pump Speed: 1,800 rpm.

- o Operating Efficiency at design flow rate: Within 5 percent of maximum efficiency.
- o Pump Type: Non-overloading.

25.9 EQUIPMENT FOUNDATIONS

All floor-mounted equipment shall be placed on reinforced concrete housekeeping pads at least 4 inches high.

25.10 EQUIPMENT ACCESS

Provisions shall be made for the installation and removal of each completely factory-built item of equipment. All ventilation shafts extending up to grade, opening into shafts, hatches, hatchways, removable grating, access plates, and doors intended for use in the installation and removal of mechanical equipment shall be sized, with adequate clearances, so that it can be moved between grade and its location without special disassembly. The installation and removal of equipment from underground mechanical equipment rooms preferably shall be accommodated by providing hatches in slabs and/or providing removable grating at grade. Where this is not feasible or economical, the installation and removal of equipment may be accommodated by providing openings above or adjacent to the trackway.

25.11 EQUIPMENT HANDLING

Provisions shall be made in the form of monorails, lifting hooks, and removable panels for the installation and removal of equipment. Structural openings shall be sized so that each complete factory-built item of equipment can be installed or removed without disassembly or special construction/demolition.

25.12 VIBRATION ISOLATION

All equipment which produces vibrations shall be isolated from the structure by spring or rubber-in-shear vibration isolators. All piping and ducts attached to rotating and oscillating equipment shall be isolated from such equipment by flexible connections. Inertia blocks shall be provided as required. The maximum permissible vibration levels of ECS shall be as prescribed in Chapter 11 - Noise and Vibration. Vibration control for environmental control systems shall be designed according to the procedures outlined in Chapter 11 - Noise and Vibration and the Sound and Vibration Control chapter of the Handbook of Systems and Applications (ASHRAE, latest edition).

25.13 AIR FILTRATION

Cartridge or bag filters shall be provided for all supply air units with a capacity of 10,000 cfm or more. Filters shall be replaceable units. The filter media shall have a minimum of 80 percent efficiency on the National Bureau of Standards Cotterell and Lint Type Test at rated capacity, and shall have an initial pressure drop not exceeding 0.20 inch water gauge. It shall not have a maximum pressure drop greater than 0.50 inch water gauge. Filter material shall be rated UL Class I. Where available, media may be rated UL Class II.

Supply air units with air volumes less than 10,000 cfm shall have replaceable (throwaway) media filter sections arranged in banks as appropriate. At rated capacity, the replaceable filter media shall have an efficiency of not less than 80 percent on the National Bureau of Standards Cotterell and Lint Type Test, and shall not have an initial pressure drop greater than 0.20 inch water gauge. Air filter material shall be rated UL Class I.

25.14 DRAIN SYSTEM

No mechanical equipment drain shall be connected directly into any drain system. Indirect drain connectors with an air gap shall be used. Oil separators shall be installed where required by code. (Refer to the requirements of Chapter 30 - Plumbing and Drainage Systems for more information.)

25.15 ROUGHING-IN

In buildings and stations that are to be constructed in stages under separate contracts, sleeves and block-outs shall be provided in the early stage structures to accommodate fan, piping, and ductwork installation by later-stage contractors. The locations and sizes of the sleeves and block-outs shall be accurately dimensioned to facilitate the subsequent piping and ductwork installation under later-stage contracts and shall be coordinated with other items such as raceways, sprinklers, lighting fixtures, etc. Pipe sleeves in exterior walls shall be sized to provide sufficient space for watertight sealing around carrier pipes.

CHAPTER 26 - LIGHTING

26.1 INTRODUCTION

This chapter defines the basic minimum requirements for the design and operation of lighting for subway, aerial and at-grade stations, at-grade and roadway crossings, station parking lots, as well as yards and shop facilities of the system. It is the goal of this chapter to create a design that shall provide lighting luminaires that are properly selected and located to achieve the required illumination levels in each facility area for safe, reliable, and continuous operation of the facilities' systems, as well as to promote safety and comfort for all transit patrons and DART employees. These criteria are intended to promote a uniformity in the design approach and to aid the designer in attaining effective and efficient lighting for each specific area in addition to attaining the aesthetic effects of quality lighting design. The criteria in this chapter establish the standards for design and selection of lighting equipment. Luminaires and lamps shall be selected from those indicated on the standard drawings, or selected by the section designer for those areas where luminaires and lamps are not shown on the standard drawings.

26.2 SYSTEM INTERFACES

The lighting design of facilities shall interface with the chapters on station operational requirements, station mechanical and electrical systems, controls and instrumentation, architecture of shops and other facilities, and facilities electrical requirements. Conduits, wires, and cables for lighting shall comply with the requirements of the National Electrical Code, (National Fire Protection Agency (NFPA) NFPA 70; hereafter cited as NFPA 70) and with Chapter 28 - Facilities Electrical Requirements of these criteria.

26.3 CODE REQUIREMENTS

Unless otherwise indicated in this chapter, the design of lighting systems shall conform to the latest editions of all appropriate and applicable codes, local ordinances, regulations, standards, and recommendations. See Appendix 1 for applicable codes.

26.4 DAYLIGHT

The use of daylight for energy conservation is preferred. Where daylight is used to supplement electric lighting, an evaluation shall be made to determine lighting zones and their photoelectric control schemes, to minimize required electric lighting.

26.5 DESIGN REQUIREMENTS

The following documents shall be prepared for approval:

- o Illumination level calculations for each facility area. (With the exception of mechanical and electrical ancillary spaces, computer calculations shall be used to determine illumination levels for all rooms 500 square feet or greater. Illumination level tables are shown under Section 26.7 of this chapter.)

- o Lighting layouts indicating luminaire types and mounting methods.

- o Luminaires schedule.

26.5.1 Lighting Calculations

Calculations of average maintained illumination levels in interior spaces shall conform to the average illumination calculations method described in the latest edition of the Illuminating Engineering Society (IES) Lighting Handbook. Average values shall not be less than those listed in this chapter and in the document referenced. Average illumination calculations are applicable only if the luminaires are spaced to obtain acceptable illumination uniformity.

Calculations of minimum maintained illumination levels in tunnels and exterior areas shall employ the point-by-point calculation method as described in the latest edition of the IES Lighting Handbook.

26.5.2 General Requirements

The following general requirements shall be incorporated in the design of lighting for each facility:

- o The lighting system is to provide the intended quality and quantity of light required for each individual area.

- o Lighting shall sufficiently define the decision/transition points and areas of potential hazard.

- o The lighting system installation shall be designed to minimize initial capital costs as well as frequency and expense of maintenance.

- o Lighting fixture locations shall permit accessibility for relamping and periodic cleaning.

- o Lighting shall be designed to avoid interference with the railroad signal system.

- Lighting shall be designed to satisfy security requirements and to provide a pleasant environment.

- Lighting shall emphasize directional signage indicating preferred circulation paths and the informational signage that provides for quick recognition of danger and decision points.

- Any required illumination shall be arranged so that the failure of any single lighting unit shall not leave the area in total darkness.

26.5.3 Specific Lighting Requirements By Area

Each area shall be provided with an illumination system that achieves the following functional and aesthetic requirements.

Station Public Areas. Incandescent lamps are not permitted unless approved by DART. Luminaires and lamps to accentuate specific architectural features or special requirements shall be selected by the designer from the prepared palette, or as directed by DART.

Non-Public Areas. In control and equipment rooms, as well as substations, particular attention shall be given to the illumination of vertical surfaces such as cathode-ray tube (CRT) screens, control panels, switches, and meters. Supplementary lighting may be used to achieve proper visibility and minimize shadows and reflections in glass faces.

In battery rooms, light fixtures and switches shall have enclosures approved for Class 1, Division 2 locations in accordance with NFPA 70.

Parking Lots and Yard Areas. The lighting of parking lots and similar areas shall consider the following:

- Maximum energy efficiency.

- Avoidance of "spill" light and objectionable glare.

- Proper scale of the pole heights with relation to site and surrounding area.

- Safety of pedestrians on walkways, especially at crossings of driveways and streets.

- High mast lighting poles mounted in airport flight paths shall conform to Federal Aviation Administration warning light requirements.

To avoid interference with light reaching the parking lot surface and, thereby, to establish continued efficient use of the lighting system, the placement of poles shall be coordinated with the proposed tree locations and estimates of anticipated tree growth.

Lighting poles shall be located generally along the parking barriers and/or the parking lot perimeter. The placement of poles shall present a minimum obstruction to movement and parking of cars.

Lighting poles located in paved areas of parking lots or less than 3'-0" from the edge of parking lot paving shall be mounted on concrete bases which are 2'-6" above finished grade.

Plazas. Lighting of outdoor plazas, station sites, pedestrian walkways, and similar areas shall be accomplished by using luminaires on low poles. Security lighting shall be provided for parking lots, plazas, and entrance and exit roadways. Security lighting may use the same fixtures as used for normal lighting.

Adjacent Properties. Special care shall be taken to avoid "spill" light and objectionable glare which might affect adjacent properties and roadways. This is particularly important in residential areas. Typical preventive measures include:

- Care in positioning of luminaires.
- Addition of internal and/or external shielding as part of the luminaire.
- Coordination with barriers created by architectural structure and/or landscaping features.
- Evaluation of appropriate pole heights and luminaire wattage.
- Consultation with zoning officials in each municipality to determine current regulations governing mounting heights and other restrictions. (Regulations are subject to change, and may vary in different areas of the same jurisdiction.)

Vehicular Roadways. Illumination shall be provided for vehicular traffic areas within the station boundary lines. A hierarchy of lighting levels as areas within the station boundary interrelate, shall provide a natural lead-in to the bus loading/unloading, auto drop-off, and parking areas. The illumination on all access and egress roads shall be graduated up or down to the illumination of the "feeder" street or highway.

At-Grade and Roadway Crossings. Crossing lighting shall be as recommended by the IES Lighting Handbook.

The illumination level on the track shall be sufficient to identify the railway crossing to drivers on the roadway, to provide visual recognition of traffic and warning signs, and to determine presence or absence of a train in the crossing. The illumination level on the track within 100 feet on each side of the crossing shall be 1.0 foot candles (fc) minimum, or twice the level of the adjacent area of the same roadway, whichever is greater.

Trackway Lighting. Illumination of subway trackways shall be sufficient for the safety of personnel performing normal maintenance. It shall define a path for the prompt, safe, and orderly movement of patrons and employees required to evacuate the system under emergency conditions. Illumination levels are shown in Section 26.7, Table 26-3.

No additional tunnel lighting fixtures would be required if the train tunnel lighting (see following paragraph) provides for sufficient trackway lighting. At-grade and aerial trackways will be illuminated by portable equipment when night work is required, and are excluded from this criteria.

Train Tunnel Lighting. Train tunnel lighting shall be as shown on the project definition drawings and as recommended in Proposed American National Standard Practice for Tunnel Lighting (IES).

Tunnel lighting shall have an average-to-minimum uniformity ratio per IES recommendation.

Luminaires shall be placed in the tunnel so they will not infringe on train clearances. They should be located above the walkway several feet below the crown of the tunnel to minimize the possibility of obstruction by stratified smoke during a fire. The luminaires shall be spaced as shown on the project definition drawings. With the exception of tunnel portals, these spacings and locations have been selected to avoid critical flicker frequencies (5 to 10 Hertz), and to avoid direct horizontal glare and obscuration by smoke. At the proposed maximum speed of 65 mph, a spacing of 19.1 feet will result in 5 Hertz flicker. Therefore spacing of luminaires must exceed 19.1 feet.

Additional lighting shall be provided near the portals for daytime use only. This additional lighting shall be used to soften the contrast between day light and tunnel light. It will give operator's eyes more time to adapt to the change when entering and leaving the tunnel. At night the additional lighting shall be turned off, leaving lights similar to those in the interior of the tunnel.

Tunnel lighting design shall be based on the assumption of tunnel interior temperature range between 40° and 90°F. The tunnel portal temperature will range between 0° and 115°F.

Blue lights shall be used to distinguish emergency phones in accordance with Fixed Guideway Transit Systems (National Fire Protection Association (NFPA), NFPA 130; hereafter cited as NFPA 130). Colored lights shall be used for crosspassages and for informational and/or directional signage, and shall be as indicated in the project definition drawings.

An engine-generator power supply with an automatic transfer switch shall provide power to tunnel lighting if both utility company feeders fail. This system is described in Chapter 28 - Facilities Electrical Requirements.

Tunnel Walkways. Tunnel walkways and tunnel invert for passenger evacuation and normal system maintenance shall have a lighting system that defines both of these paths for the prompt, orderly, and safe movement of patrons and maintenance personnel.

Tunnel Entrances and Exits. Refer to the project definition drawings for lighting standards.

Special Track Areas in Tunnel. Areas containing switches and other equipment requiring maintenance shall be provided with higher lighting levels for the safety and convenience of personnel performing normal duties. Luminaires may be staggered on both sides of the tunnel, where they are accessible for relamping.

Subway Pedestrian Passageway Lighting. Luminaires in subway passageways shall be surface mounted and shall provide the required illumination for the visual monitoring of the passageway.

Maintenance Facilities. Illumination levels shall be in accordance with Occupational Safety and Health Administration (OSHA) and Illuminating Engineering Society (IES) lighting criteria. Adequate lighting with minimum glare and shadows shall be provided.

26.5.4 Emergency Lighting

General Requirements. Emergency lighting shall be provided in accordance with NFPA 130. In stations, it shall be supplied by a percentage of normally burning luminaires and during normal power failure define a path of egress to assist in safe and orderly evacuation. All public areas of subway stations, including platforms, shall have emergency lighting.

The means of egress from station to street level, including main entrances, emergency refuge areas, emergency exits, and public areas that are essentially enclosed or located under station aerial structures, shall be provided with emergency lighting.

Emergency lighting for stairs and escalators shall be designed to emphasize illumination on the top and bottom steps and landings. All newel and comb lighting on escalator steps shall be on emergency power circuits. Emergency lighting shall be in accordance with applicable portions of NFPA 101: Life Safety Code, the Uniform Building Code (International Conference of Building Officials (ICBO)), and with all local requirements. Emergency lighting systems shall be installed and maintained in accordance with NFPA 70, Article 700 "Emergency Systems," and shall provide a minimum illuminance level of 1 footcandle measured at the walking surface. Such lighting shall also be provided for the operations control center (OCC), fan rooms, facility electrical rooms, maintenance facilities, and traction power substations.

Train tunnels shall have emergency lighting sufficient for safe evacuation of patrons in conformance with NFPA 130. The same fixtures shall supply normal lighting and emergency lighting in the tunnel. All fixtures must operate to meet emergency requirements.

Tunnel emergency exits for egress to points of safety shall be illuminated. The lighting system shall provide for immediate recognition of these points to assist in the safe evacuation of passengers.

A blue light station, in conformance with NFPA 130, shall be located adjacent to each exit from tunnels.

Each blue light station shall contain the following:

- A blue light connected to emergency power for identification of its function.
- Information provided at the blue light station which clearly identifies the route and location of the exit, and the distance to the next station in each direction.
- A traction power emergency disconnect device at the option of the Authority.
- A wayside telephone.

The wayside telephone shall have two modes. The user may select a direct connection to the dispatcher's desk at the operation control center, or dial any number as from a conventional telephone. For further information, see Systems Design Criteria Chapter 5 - Communications.

Emergency Lighting Power Source. Engine-generator sets and batteries shall supply emergency power as described in Chapter 28 - Facilities Electrical Requirements. Selected emergency lights and lighted exit signs in subway stations shall be supplied by battery and inverter during startup of the generator. Emergency lighting circuits shall be separated from all non-emergency circuits and shall be connected to emergency distribution panels. These and other emergency circuits shall be protected from physical damage and fire by encasement and by routing through areas of least hazard. Engine-generator sets shall be on line within 10 seconds after failure of normal power, and emergency battery sources within one second.

The power sources for tunnel lighting loads shall be divided between the two adjacent stations.

Exclusions. The following spaces do not need provision for emergency lighting:

- At-Grade Station - Entire station.
- Public spaces -- Kiss-and-ride areas and parking lots.

- Non-public spaces -- Spaces such as custodial rooms, storage rooms, telephone closets, trash rooms.

Luminaires. If practical, luminaires that are used for normal lighting shall be provided with dual wiring, for both normal and emergency lighting sources, or with integral battery and charger for emergency lighting. Otherwise, separate emergency lighting luminaires shall be used where normal lighting fixtures are impractical for emergency use.

26.5.5 Exit Sign Lights

Station signs that indicate exits or routes to exits shall be provided in accordance with information contained in the station architecture-operational requirements chapter, and illuminated signs chapter of the architectural design criteria. Such signs shall be internally illuminated. All internally illuminated exit signs shall have two sources of power, one normal power and one emergency power as described in the illuminated signs section of Chapter 28 - Facilities Electrical Requirements. Where permitted, selected exit signs may be of the self-illuminous type provided they are used in accordance with limitations of viewing distance and manufacturer's instructions. These signs shall be in accordance with Life Safety Code (NFPA 101) and OSHA regulations. Use of self-luminous signs is to be limited to applications where it is impossible or impractical to provide electric power.

26.5.6 Light Control Systems

General Requirements. The lighting system shall be controlled to effectively coincide with system operation. The lighting system is expected to operate continuously and rely on both automatic and manual controls to provide efficient use of energy and reduce operational costs.

Lighting of mezzanines and platforms in at-grade, and/or aerial-station areas shall be photocell controlled to operate whenever the light level for the area falls below the minimum, due to cloudiness or the approach of dusk. Photocell sensitivity shall be adjustable so that higher outdoor ambient lighting levels, based on an established differential with minimum illumination levels for interior space can be used to activate lighting for specific station areas.

Control System Requirements. Switches shall be installed to control normal lighting in all non-public areas except the emergency equipment room. Switches shall be located inside the individual rooms near the doors. Switches and control components shall have engraved nameplates identifying lights or equipment controlled (except where identification is obvious, such as in a room with a single light switch).

Lighting contactors shall be of the electrically held type in locations where the humming noise of the magnet will not disturb passengers or employees. Mechanically held contactors may be used where magnet noise would be a problem. Contactors may be located within lighting panelboards with a split bus where practical, or in separate cabinets placed adjacent to lighting panelboards.

Controls shall be designed so that lighting circuits will be energized whenever the control circuit fails.

Where outdoor ambient light will adequately illuminate station public areas, photocell control shall be used for normal and emergency lighting. In all other station public areas, time-clock or photocell control shall be used for normal lighting. The emergency lighting is controlled by transfer from loss of normal power to emergency power source.

Lighting for all public areas, within and adjacent to the station, shall be controlled locally from the station lighting control panel.

Proper controls shall be designed to achieve the required nighttime illumination in each area.

Depending on the outside light levels, the illumination level in the train tunnel portal area shall be automatically controlled by switching selected fixtures actuated by light sensors.

Exterior Areas. All parking lot, plaza, walkway and at-grade station (other than enclosed areas) lighting shall be controlled automatically by photocell and time-clock switch. Lighting circuits for security lighting shall be designed so that approximately 15 to 25 percent of normal parking area and roadway entrance lighting is controlled by photocells. The remainder of exterior lighting shall be turned on by photocells and turned off by time-clock switches.

26.6 LIGHTING PANELBOARDS

Lighting panelboards are designated for function and service voltages as described in Chapter 28 - Facilities Electrical Requirements.

26.7 ILLUMINATION LEVELS

Average maintained illumination levels for various areas shall be as indicated in the following tables (based on IES recommendation) or higher illumination if required. Maintained footcandle values shall be measured as follows:

- o For trainways, in a horizontal plane at the tunnel floor or at the serviceway, as applicable.
- o For site and above grade station areas, in a horizontal plane on grade.
- o For all other areas, in a horizontal plane 30 inches above the finished floor.

TABLE 26-1 - SITE AREA ILLUMINATION LEVELS

AREA	MAINTAINED ILLUMINATION LEVELS, FOOTCANDLES	
	Minimum Normal	Minimum Emergency
Vehicular Access Roadways	2	NA
Bus Loading/Unloading	2	NA
Kiss-and-Ride	2	NA
Open Parking	2	NA
	Average Normal	
Underguideway Parking	2	NA
Covered Parking Structures:		
Entrances	2	2
Traffic Lanes	2	1
Storage	1	1
Pedestrian Ways:		
Walkways, Ramps and Bridges	2	NA
Tunnels and Passageways	5	1
On-Grade Crossings	10	1
Plazas	5	1
Yards	2	NA

TABLE 26-2 - PASSENGER STATION ILLUMINATION LEVELS

AREA	MAINTAINED ILLUMINATION LEVELS, FOOTCANDLES	
	Average Normal	Minimum Average Emergency
Aerial Station Platforms	5	2
Subway Station Platforms	20	2
At-Grade Platforms	5	NA
Concourse and Mezzanine Area	20	2
Subway and Aerial Fare Collection, Fare Vending and Concession Areas	30	1
At-Grade Fare Collection, Fare Vending, and Concession Areas	30	NA
Stairs, Escalators and Passageways	15	3
Elevators	15	2
Entrance Lobbies	10	2
Facility Power Substations, Electrical Equipment Rooms, Mechanical Equipment Rooms	30	3
Traction Power Substations	50	5
Storage and Custodial Rooms	10	NA
Cleaner's and Service Rooms	15	NA
Washrooms, Toilets	10	2
Battery Rooms	30	2
Dispatch and Trainmen's Rooms	30	2
Station Control Room	30	3
Signal/Communication Bungalows	50	5

TABLE 26-3 - TUNNEL ILLUMINATION LEVELS

AREA	MAINTAINED ILLUMINATION LEVELS IN FOOTCANDLES		
	Normal Conditions:		Emergency Condition:
	Average*	Minimum	Minimum
Subway Pedestrian Passageways	15	10	2
Train Tunnels	1.5	0.25	0.25
Train Tunnel Portals:			
Daytime	10	0.25	0.25
Nighttime	1.5	0.25	0.25
Emergency Exits			1
Special Track Areas	3	1	0.25
Tunnel Paths of Emergency Egress:			
Serviceway	1.5	1	1
Tunnel Floor between Rails	1.5	1	1

* "Average" values listed are the lowest acceptable values. They may be exceeded if necessary to achieve the "minimum" values listed.

TABLE 26-4 - MISCELLANEOUS AREAS ILLUMINATION LEVELS

AREA	MAINTAINED ILLUMINATION LEVELS, FOOTCANDLES	
	Average Normal	Minimum Emergency
Operations Control Center	50	5
Maintenance Shops:		
Repairs, open area	100	1
Repair/grease pits	100	2
Lounge areas/group training	50	2
Active Traffic Areas	20	1

CHAPTER 27 - FIRE AND INTRUSION ALARM SYSTEMS

27.1 INTRODUCTION

This chapter defines the functional and design requirements of the fire and intrusion alarm systems for the DART Light Rail project. Each facility of the system shall be provided with fire and intrusion alarm systems if indicated on the project definition drawings. Such systems shall include all devices, controls, conduits, and panels necessary for the detection and reporting of fire and intrusion.

The criteria prescribed in this chapter are intended to promote uniformity of design and to standardize the type of fire and intrusion alarm equipment and materials, and their location throughout the system. Design of the installations will require close coordination of the section designers with systems design.

These criteria cover the fire and intrusion alarm systems for the following:

- Operation control center.
- Maintenance shops and yards.
- Repair facilities.
- Service and inspection shops.
- Traction power substations and tie stations in subway areas.
- Miscellaneous wayside structures.
- Station ancillary spaces.
- At-grade and aerial stations.
- Subway stations.
- Subsurface line sections.
- Yard control center.

The fire and intrusion alarm systems for the operations control center (OCC) are described in Systems Design Criteria Chapter 6 - Operations Control Center. Signals and communications bungalows are described in Systems Design Criteria Chapter 4 - Signals System and Chapter 5 - Communications. Traction electrification substations and tie-breaker stations (non-subway) are described in Systems Design Criteria Chapter 3 - Traction Electrification. Refer to the general plans, standards and directives, and communications interface drawings for additional details.

27.2 SYSTEM INTERFACES

The design of fire and intrusion alarm systems shall interface with the design criteria for all appropriate systems. A single point of System/SCADA access shall be provided at all facilities with alarm systems.

27.3 CODES AND STANDARDS

The fire and intrusion alarm systems shall comply with all applicable local codes of the city and county to which they pertain, and with the State of Texas and national codes. See Appendix 1 for a representative list of applicable codes.

In addition, the design of fire and intrusion alarm systems shall comply, unless otherwise prescribed in this chapter, with applicable standards and recommended practices of all appropriate organizations.

The designer's attention is directed to the requirements of the National Fire Protection Association (NFPA) Standard 130, Fixed Guideway Transit Systems.

The designer shall consult the appropriate codes and publications, and provide fire and intrusion alarm systems according to the most stringent of the applicable codes and/or industry practices.

27.4 FIRE DETECTION AND ALARM SYSTEMS

27.4.1 Functional Requirements

The fire detection and alarm systems shall detect presence and provide warning of smoke, excessive heat, rapid temperature increase, or water flow in the sprinkler system in the following areas: any enclosed space in stations (including mezzanine and platform areas in subway stations, equipment rooms, storage rooms, attendant's room, and toilets), facility power supply room, traction power substations, tie stations, communication bungalows, signal bungalows, maintenance facilities, rooms with Halon systems, and other buildings and facilities, or as designated in the project definition drawings. Train stops and passenger stations without ancillary space do not require fire detection, alarm, or control systems.

27.4.2 System Description

The fire detection and alarm systems shall be electrically supervised, closed circuit, selectively coded, and continuously self-monitoring. System components shall conform to applicable codes and standards.

The system shall include provisions for automatic activation of local alarm devices, shutdown of air conditioning and ventilation systems, closing of fire doors, and performance of other functions as required in the area of an alarm. Public areas of enclosed stations and all enclosed areas of stations and other facilities shall be protected.

The communications transmission subsystem, where provided, shall be used to transmit alarms to the OCC, except for the maintenance and yard facilities. An alarm indication shall be transmitted for each zone in a station or other facility. A summary indication of system malfunction also shall be provided from each station or other facility to the OCC. Alarms shall be transmitted simultaneously to the local control panel and to the OCC. To the extent feasible, water flow detectors in sprinkler systems shall be used in lieu of other detectors, to indicate presence of fire. Provision shall be made to test the system from the OCC.

Subway Stations. The fire detection and alarm system for each subway station shall be broken down and limited to several zones consisting of multiple sub-zones as required. It shall be a proprietary system as defined in NFPA 72D, monitored at the OCC.

The activation of a fire detector at a subway station shall, through the fire alarm control panel, cause the display of an alarm indication at the station fire management panel, which shall show the zone where the alarm condition exists. The system shall provide additional outputs as follows:

- To equipment or devices providing alarm signals audible and visual to all persons in the station.
- To any station environmental control equipment and other station equipment to cause the required operation in a fire situation, including shutdown of air conditioning equipment, homing of elevators, and operation of certain dampers and fans, in conformance with applicable codes.
- To the remote terminal unit in the facility for transmission of a fire indication for each zone to the OCC.

The visual indication shall remain until the detection system is reset, and the audible alarm shall continue until acknowledged at the fire alarm control panel.

A malfunction on any detector circuit, or an input power failure, shall cause a display on the fire management panel of an indication showing the zone in which the detector circuit has malfunctioned, or type of other malfunction. It also shall cause an output to the remote terminal unit in the facility of a consolidated malfunction indication for transmission to the OCC and to an auxiliary visual and audible indicator in the station attendant's room, where one is provided. Emergency fan control and status communication circuits also shall be supervised by the fire alarm control panel, and malfunction indications transmitted to the OCC. The visual indication shall remain until the malfunction is corrected. The audible signal shall continue until acknowledged at the fire alarm control panel, and shall be restarted by subsequent malfunctions prior to correction of the initial malfunction.

<u>At-Grade and Aerial Stations</u>. All enclosed spaces in at-grade and aerial stations shall be equipped with a fire protection alarm system as prescribed in this chapter.
Exception: Standard crew room structures for at-grade stations.

<u>Maintenance Shops, Service and Repair Facilities</u>. Zoning of the fire alarm system shall be as directed and as follows:

The activation of a fire detector in a maintenance shop and service and repair facilities shall, through the fire control panel, cause the sounding of alarm signals audible to all persons in the facility and the display of an alarm indication at the building fire management panel showing the zone in which the alarm condition exists. Additionally, the system also shall provide outputs to any environmental control and other equipment to cause the required operation in a fire situation, including shutdown of air conditioning equipment, homing of elevators, closing of fire doors, and operation of certain dampers and fans.

A malfunction of any detector circuit, or an input power failure, shall cause a display on the fire management panel of an indication showing the zone in which the detector circuit has malfunctioned, or type of other malfunction. It also shall cause, in a central location to be defined on a site-specific basis, an audible signal that shall sound until acknowledged at the panel, and a visual indication that shall remain visible until the malfunction is corrected. Any subsequent malfunctions occurring after the initial malfunction, and before it has been corrected, shall restart the audible malfunction signal.

<u>Bungalows</u>. Signal and communications bungalows shall have their own individual fire detection, Halon, and alarm system. Each shall be connected to an adjacent fire detection system as a single zone, providing both local alarm and malfunction indications with summary alarms being returned to the OCC. In addition, where location permits, each bungalow will also extend their summary alarms to the station facility fire detection equipment. Each bungalow shall have its own zone in the station fire detection system, identified as such.

27.4.3 Equipment

Fire detection equipment and material shall conform to all applicable federal, state, and local laws, codes, and standards.

<u>Fire Alarm Control Panels</u>. Each facility shall be provided with a fire alarm control panel (FACP), which shall house all necessary supervisory and monitored circuits. The panel shall provide for external monitoring and control circuits.

Each fire alarm system shall use an alphanumeric system of identification. All signals shall be summarized in the fire alarm control panel (FACP) and actuate dry contacts in an interface terminal cabinet for each zone designated for this purpose. Closed contacts shall indicate a normal condition; open contacts shall indicate a trouble or fire condition.

Fire Management Panels. The fire alarm control panel (FACP) at each subway station, and at other stations and facilities as required, shall be associated with a fire management panel (FMP), which shall present a graphic display of the station or facility.

- o Location - The FMP shall be located in coordination with the fire department having jurisdiction so that it will provide first-arriving firefighters visual mapping for access to various areas of the station. The FMP shall be placed in an area that is readily accessible and protected.

- o Graphic Display - The graphic display shall be a graphic rendition of all public and non-public areas of the station. It shall depict all circulation elements and the means by which firefighters may reach the area indicating a fire condition.

- o Annunciation - Each area provided with fire detection shall be shown on the FMP graphic display. When the control and monitor systems at the FACP detect a fire condition, the FMP shall mimic that condition. Every zone annunciated at the FACP shall be represented at the FMP on the graphic display.

- o Communications and Control - The FMP or a separate panel adjacent to the FMP shall be provided with an emergency telephone and a microphone for public address system capture, with pre-amplifier as required. The emergency phone shall be a "hotline" to the OCC. The power for alarm lights shall be supplied from two independent sources: one uninterruptible or battery, and one normal source, as described in the illuminated signs section of Chapter 28 - Facilities Electrical Requirements.

- o Display - The panel shall display visual indications as follows:

  - Zone in which fire alarm condition is detected.
  - Zone in which there is a malfunction of a detector circuit.
  - Malfunction of an audible alarm circuit.
  - Alternating current (AC) power failure.
  - Battery voltage.
  - Battery charging current.

Manual Fire Alarm Stations. DART system manual fire pull stations shall be provided at maintenance shops, service and repair facilities, the OCC, and subway station entrances.

DART system manual pull stations shall be provided within 100 feet of parking facilities. As an alternative, a telephone (not coin operated) may be provided. A fire department manual pull station will meet this requirement if it is within 100 feet.

Manual fire alarm stations shall be finished in fire engine red color with the word "FIRE" in molded raised white letters, as well as operating instructions in a contrasting color such as white. The use of a key or wrench shall be required to reset the station. The fire alarm stations shall be an approved type. All manual stations shall be located so as to be accessible to physically handicapped persons as outlined in the "Elimination of Architectural Barriers" Act of the State of Texas.

Fire Detectors. The following lists the different types of fire detectors that shall be used on the DART system. It should be noted, where Halon 1301 fire suppression systems are installed, smoke or heat detection devices shall be provided.

- Fixed-Temperature Detectors - Fixed-temperature detectors shall be of the twist/lock plug-in type, which will operate when the temperature of the surrounding air exceeds 190°F in areas that are not air conditioned, or 135°F in air-conditioned areas. Units for installation in signal bungalows, communications bungalows, facility power substations, electrification substations, and tie stations shall include an alarm light emitting display (LED) that shall remain lit after activation until manually reset. The detectors shall be Underwriters Laboratories, Inc. (UL) listed.

- Combination Rate of Rise and Fixed Temperature Detectors - Combination rate of rise and fixed temperature detectors shall be of the twist/lock plug-in type, which will operate when the rate of rise of the temperature of the surrounding air exceeds 15°F per minute, or the temperature of the surrounding air exceeds 190°F. Units for installation in signal bungalows, communications bungalows, facility power substations, electrification substations, and tie stations shall include an alarm LED that shall remain lit after activation and until manually reset. The detectors shall be UL listed.

- Smoke Detectors - Photoelectric smoke detectors shall be of the twist/lock plug-in type. Sensitivity shall be factory set. Monitoring of detector sensitivity shall be possible without removal of the detector head from its base. Units shall be installed in signal bungalows, communications bungalows, facility power substations, electrification substations, tie stations, and elevator shafts. The detectors shall include an alarm LED that shall remain lit after activation and until manually reset. Sensitivity of these detectors shall be adjusted to compensate for the presence of dust, and shall meet the requirements of NFPA 72E. Detectors in restrooms shall be photoelectric type. The detectors shall be UL listed.

- o Beam Smoke Detectors – Projected beam type or reflective beam type smoke detectors shall be installed in subway or underground stations in addition to the other kind of standard smoke detectors. These beam detectors shall be 4 wire, 24 volt DC and include both the transmitter and the receiver or reflector. Features shall include automatic compensation for signal drift, dirty lens, and shall have a minimum of three field adjustable sensitivity settings in addition to factory set sensitivities. These smoke detectors shall be UL listed and meet the requirements of NFPA 72. The detectors shall be capable of operating between a range of 15 to 330 feet and a temperature range of 220°F to 1310°F.

- o Duct Detectors - Photoelectric-type duct detectors shall be used in the supply and return air ducts of all heating, ventilation, and air-conditioning (HVAC) systems. For requirements of duct detectors, refer to Chapter 25 - Heating, Ventilating, and Air Conditioning Systems. These detectors shall be designated by the letter "D" inside a diamond. The detectors shall be UL listed. Sensitivity of the duct detectors shall meet the requirements of NFPA 72E.

- o Ionization Detectors - Ionization detectors shall be of the dual-chamber unit, twist/lock plug-in type. This type of detector shall be used in all other non- public areas not covered by one of the other types and in conjunction with other types where good practice dictates. One detector shall be provided for a maximum of 900 square feet of area, with consideration given to ceiling configuration. Detector placement shall be coordinated with the architectural drawings. The detectors shall be UL listed. Sensitivity of the detectors shall meet the requirements of NFPA 72E.

- o Base Assemblies - Detector base assemblies shall be of twist/lock design with screw clamp terminals. The base shall use self-wiping contacts for circuit connection to the detector which shall be directly interchangeable with other compatible plug-in detectors. Security locks shall be provided on bases to be installed in areas where tamper-resistant installation is required in accordance with the approved final design. The detector base assemblies shall be UL listed.

Water Flow Switches. Water flow switches to detect flow of water in wet sprinkler systems are described in Chapter 24 - Fire Protection Systems. These switches shall be equipped with two snap-action double-pole, double-throw switches, with contacts rated at 10 amps at 125 volts alternating current (VAC), 0.5 amp at 125 volts direct current (VDC), and 0.25 amp at 250 VDC. The fire detection system shall be capable of providing the interface required.

End-of-Line Devices. End-of-line devices for each detector and alarm circuit shall provide a fully supervised system. The type and characteristics of these devices shall be in strict accordance with the manufacturer's recommendations.

Audio/Visual Alarms. Alarm units shall be combination horn and light units. Audible alarms shall be of the horn type, operating on 18-30 VDC. For outdoor and below-grade installations, they shall be in waterproof enclosures. Measured at 10 feet, the horns shall provide an output rating of no less than 15 decibels above ambient noise level. The tone of the alarm shall be that normally used for fire alarms. The visual signal shall be from a xenon strobe light.

Exit Signs. All lighted exit signs shall flash when the system is in an alarm condition, in accordance with the "Elimination of Architectural Barriers" Act of the State of Texas.

Auxiliary Visual Indicators. Auxiliary lamp panels shall be provided as required. The lamps shall operate on 18-30 VDC. They shall be of the LED type.

Equipment Module. Each fire alarm control panel and fire management panel shall be associated with an integral or separate equipment module which is capable of operating the complete fire detection system. The equipment module shall include the following:

- Sealed storage battery with capacity to carry the system on standby for 24 hours with the AC power off.
- Battery charger operating on 120 VAC single phase, providing 24 VDC, capable of recharging the battery from full discharge to full charge in 24 hours, while carrying the normal system load.
- Circuit supervision, detection, and indication modules as required by final design.
- Output modules of the proper rating to provide the required outputs to alarms, auxiliary indicators, public address equipment, air conditioning equipment, the communications transmission subsystem, and any other interface required by final design.
- A module indicating battery voltage and charging current.

Conduits, Wires, and Cables. Conduits, wires, and cables for the fire alarm system shall comply with the requirements of the National Electrical Code (NEC) as well as those described in Chapter 28 - Facilities Electrical Requirements.

27.5 INTRUSION DETECTION AND ALARM SYSTEMS

27.5.1 Functional Requirements

The intrusion detection and alarm systems shall detect and provide warning of entry into the following areas: subway ancillary spaces, equipment and storage rooms in stations, emergency exits, operations control center, maintenance shops, major repair, service and repair facilities, and, when stations are closed, the station entrances and rolling grilles, as well as in other buildings and facilities as designated by DART.

27.5.2 System Description

The intrusion detection and alarm systems shall be electrically supervised, closed circuit, selectively coded, and continuously self-monitoring. System components shall conform to applicable codes and standards.

The zoning of intrusion alarm systems shall be as indicated on the project definition drawings and as follows:

The communications transmission subsystem shall be used to transmit alarms to the OCC. An alarm indication shall be transmitted for each station or other facility. A summary indication of detectors deactivated shall also be provided from each station or other facility. Alarms and system malfunction shall be provided through a remote terminal unit in the facility. Provisions shall be made to test the system from the OCC.

At-Grade and Aerial Stations. All enclosed spaces, except spaces leased to non-DART entities, in at-grade and aerial stations shall be equipped with an intrusion alarm system as prescribed in this chapter.
Exception: Standard crew room structures for at-grade structures.

Subway Stations. The activation of an intrusion detector at a subway station shall cause a display of an alarm indication at the station intrusion alarm indicator panel adjacent to the station fire management panel. It will show the zone in which the alarm condition exists and shall provide additional outputs as follows:

- To the remote terminal unit in the facility, an intrusion indication for transmission to the operations control center.
- To an audible alarm outside the station when the station is closed.
- To an auxiliary visual and audible alarm indicator in the station attendant's room, where one is provided. The visual indication shall remain until the detection system is reset, and the audible alarm shall continue until acknowledged at the panel, or the detection device is reset or disabled. The audible signal shall be restarted by any subsequent intrusion signal, whether the first detection device has reset or not. The audible alarm shall be separate from the audible alarm for the fire detection system, and shall have a different sound frequency.

The local and remote reporting of an intrusion shall not take place until after a pre-selected elapsed time has occurred. This time shall be adjustable from 10 seconds to 3 minutes and shall normally be set for 30 seconds. An "acknowledge" key-operated switch shall be provided. It shall cancel alarms if actuated.

A malfunction on any detector circuit or an input power failure shall cause a display on the station intrusion alarm indicator panel of an indication showing the zone in which the detector circuit has malfunctioned, or indicating an input power failure. It also shall cause an output to the remote terminal unit in the facility of a consolidated malfunction indication for transmission to the OCC, and to an auxiliary visual and audible indicator in the station attendant's room, where one is provided. The visual indication shall remain until the malfunction is corrected. The audible signal shall continue until acknowledged at the panel and shall be restarted by subsequent malfunctions prior to correction of the initial malfunction. The audible signal shall be provided by the same device which provides the audible malfunction signal for the fire detection subsystem.

A key-operated switch, or digital or other access control device inside the entrance to each zone within a station, shall be provided to disable the intrusion detection devices for that zone. With a switch in the disable position, a visual indication shall be displayed at the local intrusion alarm indicator panel showing the zone that is disabled. It also shall cause to be displayed a consolidated zone disabled indication on the auxiliary panel in the station attendant's room, if one is provided. This disable status shall not be transmitted to the OCC.

A key-operated switch inside the main station entrance shall be provided to disable the outside alarm and the intrusion detection devices for the station, but not the zones within the station. With the switch in the disabled position, a station-disabled indication shall be transmitted to the OCC. After zone or station detectors are enabled, the system shall allow sufficient time for a person to leave the zone or station before indicating an alarm.

Rolling Grilles at Passenger Stations. Rolling grilles and other doors shall have door position indicators and audible alarms. The exterior junction box associated with each door or grille shall house only the audible alarm. (There shall be no interior junction box with a pushbutton associated with these doors or grilles.)

In order to open these doors without transmitting an intrusion alert and simultaneously activating the associated audible alarm, an alarm bypass control shall be provided within the protected space. The bypass control shall be housed in a separate and distinct intrusion alarm junction box and shall be operated by a key switch. Actuation of the key switch shall nullify all the individual audible alarms and the summary intrusion alert for as long as the key switch is in the bypass position and a light shall indicate that the system is in bypass.

Maintenance Shops, Service and Repair Facilities. The activation of an intrusion detector in a maintenance shop, service and repair facilities building, and designated offices shall sound an audible alarm in the protected area and cause a display of an alarm indication at the intrusion alarm indicator panel in the facility security office showing the zone in which the alarm condition exists. The visual indication shall remain actuated until acknowledged at the panel and the detection device is reset or disabled. The audible alarm shall continue until acknowledged at the panel or the detection device is reset or disabled. The audible alarm shall have a different sound from that indicating a fire.

The local and remote reporting of an intrusion shall not take place until after a pre-selected elapsed time has occurred. This time shall be adjustable from 10 seconds to 3 minutes and shall normally be set for 30 seconds.

Inside the entrance to each zone within a facility and in the facility security office, key operated switches shall be provided to disable the intrusion detection devices for each zone. With a switch in the disable position, a visual indication shall be displayed at the intrusion alarm indicator panel in the facility security office showing the zone that is disabled.

Inside the main facility entrance and at the facility security office, key-operated switches shall be provided to disable the intrusion detection devices for the general facility area but not the zones within it. With the switch in the disabled position, a disabled indication shall be displayed on the intrusion alarm indicator panel in the facility security office. After zone or facility detectors are enabled, the system shall allow sufficient time for a person to leave the zone or facility before indicating an alarm.

Tunnel Cross Passage Door Indication. Provision shall be made to indicate door position at each tunnel cross passage. An alarm shall be initiated if more than one door is open at a time. An indication and alarm shall be received at the OCC, and at other locations as directed.

27.5.3 Equipment

Intrusion detection equipment and material shall conform to all applicable codes and regulations, including the Underwriters Laboratories, Inc. (UL) Electrical Construction Materials Directory and the UL Automotive Burglary Protection Mechanical Equipment Directory.

All units of each type provided for each location shall be fully interchangeable with all units of the same type throughout the system. Detectors shall be capable of operating on 2-wire circuits.

Intrusion Alarm Control Panel. The principal components of the intrusion alarm control panel (IACP) shall be local indicator panels, tapes, switches, other automatic intrusion detection devices, end-of-line devices, common equipment, local audible and visual alarms, and cable.

Local Intrusion Alarm Indicator. A local intrusion alarm indicator panel sized for the number of intrusion detection zones in the facility shall be provided for each facility. The panel shall display visual indications as follows:

- Zone in which intrusion alarm condition is detected.
- Zone in which there is a malfunction of a detector circuit.
- Zone in which detectors have been disabled.
- AC power failure.
- Battery voltage.
- Battery charging current.

Auxiliary Visual Indicators. Auxiliary lamp panels as required shall be provided. The lamps shall operate on 18-30 VDC. They shall be of the LED type.

Intrusion Detection Tape. Intrusion detection tape, where required, shall be of standard manufacture attachable to glass or installed in other locations where it would be broken by a person intruding into the area.

"Door and Window Open" Detector Switches. "Door and window open" detector switches shall be of the micro-switch or magnetic type. They shall be capable of sustaining frequent operation without failure over a minimum period of ten years.

Electronic Surveillance Devices. Electronic surveillance devices shall use light sources and photoelectric cells or other electronic means to detect movement or presence. These devices shall be of standard manufacture with a proven performance history.

Detector Deactivation Switches. Key-operated detector deactivation switches shall be in tamperproof housings for wall mounting. Individual housing shall be provided for each switch except for shop and office building security offices, where only one housing for all switches at a location shall be provided. Switches for installation in subway ancillary spaces shall be arranged so that the key cannot be removed when the switch is in the deactivated position. The type of keying provided shall be systemwide standard..

End-of-Line Devices. End-of-line devices shall be furnished for each detector and alarm circuit to provide a fully supervised system. The type and characteristics of these devices shall be in strict accordance with the manufacturer's recommendations and applicable codes.

Audible Alarms. Audible alarms shall be of the horn type operating on 18-30 VDC. The tone shall be different from that of fire alarms. Alarms for outside installation shall be provided in weatherproof enclosures. Measured at 10 feet, the horns shall provide an output rating of no less than 15 decibels above ambient noise level. The tone of the alarm shall be that normally used for intrusion alarms.

Equipment Modules. Equipment modules shall be furnished in each intrusion indicator panel to provide a complete operating intrusion detection subsystem. This equipment shall include the following:

- Sealed maintenance-free storage battery with capacity to carry the system on standby for 24 hours with the AC power off.
- Battery charger operating on 120 or 240 VAC single phase, providing 24 VDC capable of recharging the battery from full discharge to full charge in 24 hours, while carrying the normal system load.
- Circuit supervision, detection and indication modules as required by the approved final design.
- Output modules of the proper rating to provide the required outputs to alarms, auxiliary indicators, the communications transmission subsystem, and any other interface required by the approved final design.
- A module indicating battery voltage and charging current.

Communication Transmission Medium. The communication transmission medium shall be as described in Systems Design Criteria Chapter 5 - Communications.

Conduits, Wires, and Cables. Conduits, wires, and cables for intrusion detection and alarm systems shall comply with the requirements of the NEC and Chapter 28 - Facilities Electrical Requirements of these criteria.

27.6 EQUIPMENT INTERFACE

27.6.1 Fire Detection and Alarm System

Communications System Interface. Alarm and malfunction indications in the form of circuit openings shall be connected to the remote terminal units (RTUs) described in Systems Design Criteria Chapter 6 - Operations Control Center. These connections shall be made at a communications interface cabinet, from which they are extended to the RTU.

Interface with OCC equipment may be in the form of digital messages through computer equipment.

<u>Facility Equipment Interface</u>. Outputs shall be connected as required to initiate automatic shutdown or other operation of facility equipment as necessary in a fire emergency. The location of the interface shall be coordinated with the facility designer.

27.6.2 Intrusion Detection and Alarm System

<u>Communications System Interface</u>. Except in shop and office buildings, alarm, malfunction, and detector deactivated indications in the form of circuit openings shall be connected to the station facilities RTUs described in the operations control center performance specifications. These connections shall be made directly to the RTU interposing/interface relay cabinet.

27.7 DRAWINGS

In addition to plan and riser drawings, which shall locate all monitors and control points, fire and intrusion alarm drawings shall be provided with detail design of the fire and intrusion alarm systems.

27.7.1 Fire Alarm Systems

A logic diagram shall be developed in single line form to depict all zones, fan shutdown requirements, and summing requirements, and the zones to be presented at the interface terminal cabinet.

27.7.2 Intrusion Alarm Systems

A wiring diagram shall be developed that shall show in detail which doors and which points require intrusion detection.

CHAPTER 28 - FACILITIES ELECTRICAL REQUIREMENTS

28.1 INTRODUCTION

This chapter defines the functional and design requirements of the electrical systems for the underground, aerial, and at-grade stations, and yards and shops facilities of the system. Electrical standard requirements and applicable local codes shall be used to supplement these criteria.

The goal for this phase of system design is to determine that electrical spaces are properly located and sized to facilitate the installation and maintenance of equipment. The design of the facilities electrical systems shall provide for their safe, reliable, and continuous operation. Accessibility shall be provided to permit removal and replacement of major equipment. These criteria are intended to promote a uniformity in the design approach and to standardize the type of equipment and its location throughout the Dallas Area Rapid Transit (DART) system.

These criteria include facilities electrical requirements for the following:

- Electrical distribution systems.
- Lighting.
- Heating, ventilating and air conditioning systems (HVAC).
- Emergency power substation systems.
- Traction power subway substation auxiliary power connections.
- Maintenance yards and shops.
- Elevators and escalators.
- Fare vending.
- Illuminated signing.
- Public telephones.
- Grounding system.
- Lightning protection system.
- Supervisory and control systems.
- Raceway systems.
- Power to signal and communications bungalows (Bungalows at some locations may use facilities power and those at other locations may use power supplied by traction power substations. The choice will be based on DART's operating and maintenance plans.)
- Provision for cables in communication and signaling system (cables to be provided and installed by system contractor).

28.2 SYSTEM INTERFACES

The facilities electrical design shall interface with all appropriate design criteria. Section designers shall coordinate with systems design group.

28.3 CODE REQUIREMENTS

The design shall conform to the latest editions of all appropriate applicable standards and codes, including the governing agencies building/electrical codes. (See Appendix 1 for more information.)

28.4 DESIGN REQUIREMENTS

28.4.1 Design Calculations

The section designer shall prepare short-circuit and voltage-drop calculations. Calculations shall be in sufficient detail to permit evaluation of the basis of design for the electrical distribution system.

Short-circuit calculations shall be completed for the electrical distribution system based upon an assumed short-circuit capacity of maximum mega-volt amperes (MVA) available from the power company at the electric service entrance into the unit substation or at the secondary terminals of the station electric service transformer. Results of calculations shall be placed at pertinent locations on a single line drawing of the electrical distribution system.

Voltage drop calculations shall be completed for all maximum loads or long run circuits and feeders. Motor circuit calculations shall be based on an 85 percent lagging power factor. Capacitor banks should be considered to improve the power factor as required.

28.4.2 Basis for Design

Supply Voltages. Nominal electric supply voltages to the facilities shall be 120/240 volts (V), single phase, 208Y/120V three phase, and 480Y/277V three phase. Dry-type transformers shall be used for all indoor power transformations. Pad-mount transformers, if used in outdoor applications, may be oil filled. Oil filled transformers shall be enclosed within a curbing to contain oil in event of a rupture, or non-flammable liquid may be used instead of oil. Voltage regulation shall conform to the National Electrical Code (National Fire Protection Association (NFPA) NFPA 70).

Utilization Voltages. Electric utilization voltages generally shall be according to the following, with variations as may be required by local conditions:

Equipment	Voltage
Advertising dioramas	120 volts, single phase
CCTV cameras	120 volts, single phase

Equipment	Voltage
Communications equipment	120 volts, single phase
Convenience outlets	120 volts, single phase
Exit signs	120 or 277 volts, single phase
Emergency power systems	480/277volts, three phase
Fare vending	120 volts, single phase
Heaters, to 2900 watts	120 volts, single phase
Heaters, 2901 to 5500 watts	208 volts, single phase
Heaters, 5501 watts and up	480 volts, three phase
Lighting, ballasted types	*277 volts, single phase
Lighting, incandescent	120 volts, single phase
Motor controls	120 volts, single phase
Motors, 1/2 hp and smaller	120 volts, single phase
Motors, larger than 1/2 hp	480 volts, three phase
Station signing	277 volts, single phase
Cathodic protection rectifiers	120 volts, single phase
Special power outlets	As required

*Note: 120 volts may be used if applicable codes prohibit use of 277 volts.

Voltage Drop. Branch circuit voltage drop from 480 volt or 208V switchboards to point of utilization shall not exceed the following:

Equipment	Percentage
Fluorescent lighting	5 percent
Incandescent lighting	5 percent
High-intensity discharge lighting	3 percent
120- to 240-volt motors	4 percent
460-volt motors	5 percent
Receptacles	5 percent
Electric heaters	5 percent
Other loads	5 percent

Demand Factors. N.E.C. recognized demand factors shall be used for selecting switchboards, switchboard feeder breakers, panel boards, feeders, and transformers.

Safety Considerations. Ground fault protection shall be provided on branch circuits that have equipment or outlets for which personnel protection is required by either the NEC or engineering judgment. Ground fault tripping shall be at the Underwriters Laboratories, Inc. (UL) Class A level (5 milliamperes).

Heavy-duty disconnect switches shall be provided as required by the NEC as a means to disconnect equipment from its feeder when equipment is not within the sight of either the feeder breaker or motor controller, or where advantageous to separate feeder from electrical loads to be supplied by others. In general, disconnect switches shall be of the non-fusible type and shall plainly indicate whether they are in the open (off) or closed (on) position. They shall have the means of being locked in the open position. Where fuses must be used, they shall be of the current limiting type (UL Class J for 600 amperes and less, Class L for 601 amperes through 6,000 amperes.)

Overcurrent elements which (a) are designed to protect conductors serving emergency equipment motors (fans, dampers, pumps, and so forth), emergency lighting, and communications equipment, and (b) which are located in spaces other than the main distribution system equipment rooms, shall not depend upon thermal properties for operation (per NFPA 130).

Switches, electrical outlets, and lighting fixtures installed in areas where batteries are installed/charged shall have enclosures approved for Class 1, Division 2 locations in accordance with the National Electrical Code (NFPA 70).

28.5 INCOMING ELECTRIC SERVICE

The required electrical energy for the auxiliary power and lighting systems of DART facilities will be furnished by one or two utility power sources. Two primary feeders shall serve each subway station, tunnel ventilation facility, and the operations control center (OCC). One primary feeder shall serve each aerial and at-grade facility. Power metering shall be installed as required by the applicable electric utility company and DART. Each passenger station shall have a facility power supply room. Traction power substations will be separate from facility power substations. At some locations they may be serviced by the same utility company feeders, but there will be separate transformers and switchgear for traction power and for facilities power.

28.5.1 Duct Bank

Each incoming primary service duct bank shall consist of three 4-inch polyvinyl chloride (PVC) or fiberglass reinforced epoxy (FRE) conduits per feeder and shall extend from the auxiliary electrical room through the outside wall or foundation for extension to a point on the right-of-way to interface with the power company substation conduits. Refer to the utilities chapter of the civil design criteria for specific guidance. The power company will furnish and install duct bank from its substations to the DART facilities duct bank. DART or the utility company will furnish and install the primary feeder cables to the auxiliary electrical room. Design and installation of the duct banks shall be coordinated through DART to determine compliance with power company requirements and regulations.

28.6 FACILITY POWER SUPPLY ROOM

Facility power supply rooms in the subway stations shall include unit substations, including primary transformers where required, secondary transformers, lighting and power distribution panel boards, motor control centers, control panels, and space for adding one future secondary switchboard section to the unit substation. An auxiliary electrical room in subway stations shall include the emergency power system described in section 28.6.3 of this chapter, with the associated batteries placed in an adjoining mechanically ventilated room.

Refer to Chapter 25 - Heating, Ventilating and Air Conditioning Systems, Section 25.4, design parameters paragraph. The conditions described in this chapter shall be used for determining the rating requirements of the electrical systems. The transformers, switchgear, switchboards, panelboards, and so forth shall continue to operate when the outside temperature reaches 115°F and shall continue to operate when the outside temperature drops to zero °F.

28.6.1 Electrical Loads

Electrical loads connected to auxiliary power equipment shall be defined as either non- essential or emergency.

Non-Essential Loads. Non-essential loads are those loads which, if de-energized, would have minor effect on patron safety and none on system safety. This load classification includes all non-essential station loads and part of all station lighting.

Essential Loads. Essential loads are those loads which, if lost, would have a detrimental effect on patron and/or system safety. Included are those loads required for the fixed guideway transit systems to be maintained in the event of a total facility power failure. See National Fire Protection Association (NFPA) Standard 130 for more information. Specific essential loads are identified in the essential power load paragraph of this chapter.

28.6.2 Electrical Distribution

Distribution of facilities power will be at nominal 480/277 volts or less. Where power is delivered by the utility company at higher voltage, it shall be transformed at a DART facilities power substation.

Unit Substations. There are several possible configurations of facilities power unit substations, according to the type facility to be served, and the voltage supplied by the utility company.

- o Subway stations and tunnel ventilation facilities - The electrical load will be relatively large, and the need to avoid power interruptions will be urgent. A double-ended substation with two utility company feeders (with separate transformers if transformation is required) and an automatic tie breaker will be required. The two utility company feeders must be routed separately and must be fed from different utility company substations. An emergency generator will also be required.

- o Grade-level and elevated substations - Power requirements are relatively low, and there is less concern over occasional power interruptions. These stations will be single-ended with one feeder and no emergency generator or UPS.

Transformation will be required at each substation if supply voltage is other than that required by the facility. It is possible that some small facilities may be served more efficiently at less than 480/277 volts: either 208/120 volts, three phase; or 240/120 volts; single phase.

Unit Substation for Subway Stations. Each service entry from the utility company shall contain a primary-fused disconnect switch or a circuit breaker for the utility primary of either 13.8 Kilovolt (kV) or 4.16kV to a 480/277 volt dry-type transformer. Where it is feasible, 480/277 volt 3-phase power can be supplied from the utility company directly to the switchgear without the need of transformers. The 480 volt switchgear shall consist of main breakers, tie breaker, and switchboards with distribution feeder breakers. The tie breaker shall close automatically after either one of the main breakers opens or is under-voltage. The tie breaker shall open after restoration of normal voltage to the main breaker. The transformers shall be equipped with forced air cooling by thermostat control and shall be provided with two-stage over-temperature device with alarm contracts. (Refer to Chapter 25 - Heating, Ventilating, and Air Conditioning Systems for space ventilation.)

Unit Substation Transformers. Each unit substation transformer shall have self-cooled rating of not less than the sum of the following:

- o Total connected load of the substation and other areas serviced from the substation multiplied by the diversity factor determined by using the demand factors provided in this chapter.

- o A spare load not less than 10 percent of the connected load of the substation.

Unit Substation Capacity. The substation shall be designed to carry the forced-air-cooled rating of the transformer. Each unit substation 480 volt switchboard shall have approximately 20 percent of total usable space bussed and ready to accept future breakers, unless such provision requires an additional section, in which instance space shall be provided for the additional section. In addition, each substation shall be provided with space for a future main power breaker, equal in size to the largest main breaker used.

Unit Substation Power Breakers. At substations of 4160 volts and higher, the main secondary breakers and tie breakers shall be electrically operated drawout air circuit breakers with a solid state tripping system. The main secondary breakers shall be provided with protective relays and a time delay before opening, after an undervoltage condition occurs. The main and tie breakers shall be electrically interlocked to prevent simultaneous breaker operation. Substations not equipped with electrically operated circuit breakers may use contactors in lieu of tie breakers. The tie contactors shall operate in a similar manner to the tie breakers: loss of power at either main breaker shall cause the tie contactor to close and another contactor to open, disconnecting the malfunctioning service. Restoration of power shall cause the contactor to open. Time delays shall be used as with the tie breaker.

Unit Substation Feeder Breakers. At substations of 4160 volts and higher, the feeder breakers shall be the draw-out air circuit type, electrically operated.

Switchboard Feeder Breakers. Switchboard feeder breakers shall be the molded case type. Breakers may be used in conjunction with current-limiting fuses (UL class H) if molded case breakers cannot provide the required short-circuit protection. If smaller frame size breakers are used in conjunction with current-limiting fuses, they shall be rated not less than 120 percent of that required by the load.

Ground Fault Protection. Secondary ground fault-sensing protection shall be provided as required by the National Electrical Code. Ground fault interrupters shall be interlocked to provide maximum coordination so that a ground fault will trip at the first upstream breaker from the fault and not cause tripping of another breaker before a preset time delay.

Station Control Power. Main breakers in subway stations shall operate with 120-volt alternating current (AC) control power with capacitor trip devices to actuate each breaker in the event of a failure of control power.

Metering. Each 480-volt switchgear assembly shall include a metering section consisting of voltmeter, ammeter, kilowatt-hour meter, and demand meter with peak indicator, and required switches, protective fusing and sensors.

Utility metering shall be coordinated with the utility company.

28.6.3 Facilities Emergency Power Systems

Operations Control Center. The emergency power system for the OCC shall meet the requirements of Central Station Signaling Systems (NFPA 71) and use an uninterruptible power supply (UPS). The system shall consist of a UPS capable of delivering a rated load at 480/277 volts, three-phase; and a step-down transformer and distribution panels for 208/120 volt, single-phase and three-phase loads to meet the requirements for the OCC. UPS batteries shall be capable of supplying a rated load for a minimum of 5 minutes.

A natural-gas or diesel powered standby generator will be provided for the OCC. It shall have automatic startup capabilities upon failure of normal power, and retransfer with adjustable time delays upon restoration of normal power. It shall be capable of supplying all essential OCC loads, including input to the UPS, for a minimum of 24 hours.

Subway Stations. Subway stations shall include the following emergency power systems:

- An uninterruptible power supply to the remote terminal units (RTU) where required.

- An interruptible power supply (IPS) as shown to supply a part of the emergency lighting (in the public areas of station only), including emergency exit stair lights and exit signs. It must function within one second of a power interruption. Its purpose is to eliminate complete blackout during engine-generator startup.

- A standby engine-generator capable of supplying essential power loads, all emergency lighting in the station, and all tunnel lighting normally supplied from that station (with exception as described below).

All tunnel lighting fixtures (except special lighting at portals and at special track) will be required to meet the minimum emergency lighting level requirement. The UPS and IPS described above may have batteries capable of supplying loads for a short time (about 15 minutes) only, since the standby generator will supply power to them when it begins generating.

Maintenance Yards and Shops. Emergency lighting shall be provided for all means of egress in the maintenance facilities and for entire areas of the yard control tower and associated equipment rooms. Interior areas shall be equipped with selected emergency lighting equipment (containing battery, battery charger, and automatic transfer switch) to provide safe egress from the buildings in case of a complete power failure. Units shall provide illumination for a minimum of 90 minutes.

Essential Power Distribution. Distribution panels for essential power shall be located near concentrated loads or in the auxiliary electrical room. Dry type transformers shall be located in the auxiliary electrical room where transforming essential power to 208Y/120-volt-utilization voltage is desired.

Essential Power Loads. The following loads shall be connected to emergency power systems in all subway passenger stations:

- Part of station emergency lighting.
- All internally illuminated exit signs.

- Fan room access shaft emergency lighting.
- Emergency exit stair lights.
- CCTV cameras.
- UPS for remote terminal unit.
- Fire/life safety systems.
- Fire alarm control and management panel.
- Intrusion alarm control panel.
- Blue lights in tunnel.
- Public address system.
- Power to elevator cab lights and elevator equipment room receptacles.
- Tunnel lighting (Exception: those fixtures providing additional light near portals and at special track).

28.7 PANELBOARDS

28.7.1 Placement

Panelboards shall be placed near or central to their loads. They shall be located in the auxiliary electrical rooms, electrical closets or suitable ancillary rooms provided they are easily accessible to maintenance personnel.
Exception: Panelboards mounted in electrical enclosures for at-grade stations.

28.7.2 Circuit Identification

All branch circuits or feeders shall be identified on the drawings with the panelboard identity and device protecting the individual circuit or feeder.

28.7.3 Spares

Panelboards shall be equipped with minimum 25 percent spare bus work and spaces. Sufficient panelboard sections shall be added to each panelboard to accomplish these spare capacity requirements.

28.7.4 Service Voltages

Panelboards shall be designed for function and service voltage as follows:

	Recommended Panel Designation
480/277 volts	
Lighting panel	LP1, LP2, LP3, etc.
Distribution panel	DP1, DP2, DP3, etc.
Motor control center	MCC1, MCC2, MCC3, etc.
Emergency panel	EP1, EP2, EP3, etc.
Emergency distribution panel	ED1, ED2, ED3, etc.
Transformer panel	TP1, TP2, TP3, etc.
208/120 Volts	
Lighting, convenience outlet and miscellaneous power	LL1, LL2, LL3, etc.
Distribution panel	DD1, DD2, DD3, etc.
Emergency panel	EE1, EE2, EE3, etc.
120/240 Volts	
Miscellaneous power	MP1, MP2, MP3, etc.

28.8 MOTORS, STARTERS AND CONTROLS

In general, motor control centers with motor-circuit-protector combination-starters shall be used for 460-volt motors. Control centers shall be equipped with either a main circuit breaker or a fused main switch with the main busses adequately braced to withstand the available short-circuit current. Individually mounted motor circuit protector combination starters may be used where electrically advantageous and where they can be located in a physically secure area.

28.8.1 Motor Starters

All motors shall normally use across-the-line starters, provided the voltage drop at the motor terminals at the time of starting does not exceed the allowable rating. In certain specific applications, solid state "soft start" (reduced voltage and current) starters, or solid state variable frequency drives should be used, where appropriate, for reduced energy costs, more precise control, and/or improved equipment performance. Each individually mounted starter shall use a 120-volt control transformer with primary and secondary fusing. All three-phase motor starters shall be equipped with three magnetic overload relays properly sized for the load. Single-phase 120-volt motors shall use a manual or automatic motor starter.

28.8.2 Ventilation Fans and Sump Pumps

It is essential that the tunnel ventilation fans, under platform exhaust fans (if used), tunnel booster fans (if used) and sump pumps shall be provided with a maximum reliable source of power supply. Two sources (substations) of supply from two feeders, separated physically to the best extent possible, shall be provided for each emergency fan. The starters shall be located in a control room that has a controlled environment and is protected from unauthorized entry. The starters for the tunnel fans shall be provided. The ventilation fans shall be locally and remotely controlled. Tunnel ventilation fans and pumps located in the vicinity of a station shall be supplied from each of the buses of the substation. Ventilation fans and pumps located between stations shall be supplied from both stations.

28.8.3 Motor Control Center and Motor Starter Construction

Motor control centers and individually mounted motor starters shall be National Electrical Manufacturers Association (NEMA) Type 1, 4, or 12, depending on location as required.

28.9 ELECTRICAL SERVICE REQUIREMENTS

28.9.1 Wires and Cables

Fixture wires shall be Type AF. Minimum size conductors shall be No. 16 AWG for fixture wires, No. 14 AWG for control circuits. No. 12 AWG of insulation type as indicated shall be used for branch circuits unless otherwise specified. Wire and cable for branch circuits (600 volts and below) and feeders shall conform to the requirements of the National Electrical Code (NFPA 70), and the Insulated Cable Engineers Association (ICEA). They shall be UL listed.

Feeder, branch circuits and control circuit conductors shall be 98% annealed copper. Conductors No. 16 AWG and larger shall be stranded.

All conductors shall be insulated. Ground wires may be bare except where insulated wires are called for on the drawings or in the specifications. All insulations shall conform to Article 310 of the National Electrical Code (NFPA 70). Insulations shall be moisture and heat resistant types with temperature ratings corresponding to the conditions of application, but in no case lower than 194°F (90°C). Insulation for general use shall be type THHN/THWN or type XHHW. Types THHN/THWN and XHHW shall not be used in subways, tunnels, or underground stations.

Wire and cable used in operating vital power circuits to emergency fans, lights, and so forth, shall pass the flame propagating criteria of Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations (Institute of Electrical and Electronics Engineers (IEEE) IEEE 383, page F-9, 1974 Edition, Table 2.5). Such tests shall be performed with the wire and/or cables protected as they will be when installed.

Wire and cable used in subway, tunnel, and underground station applications shall meet all requirements described above, and also shall be fabricated of "low smoke" materials to keep quantity and toxicity of smoke to the lowest attainable levels in the event of fire. Refer to Fixed Guideway Transit Systems, NFPA 130.

Conductors for emergency lighting, communication, and so forth, shall be protected from physical damage by transit vehicles or other normal transit system operations, and from fires in the transit system. This shall be accomplished by suitable embedment or encasement, or by routing the conductors through areas of low fire potential (light hazard).

28.9.2 Raceways for Facilities

Purpose. The following paragraphs describe conduit materials, special installation methods, conduit identification and specific design requirements for systemwide conduits.

28.9.3 Raceway Materials

Raceways may be of the following types:

Type	Abbreviation
Galvanized rigid steel conduit	GRS
Fiberglass reinforced epoxy conduit	FRE
Polyvinyl chloride conduit conforming to NEMA TC-6* and ASTM F-512*	PVCC
Electrical Metallic Tubing	EMT
Cable tray (galvanized rigid steel)	-
Flexible conduit	FLEX

(*See the list for references for Chapter 28 in Appendix 1 for the full citation.)

Conduit types shall be selected for the different conditions in accordance with the following schedule:

- o Underground installations more than two feet from foundation wall: Galvanized rigid steel conduit or schedule 80 PVCC conduit. GRS conduit in contact with the ground shall be coated with polyvinyl chloride (40 mil minimum thickness).

- o Installations in or under concrete slab, or underground within two feet of foundation wall: Galvanized rigid steel conduit or schedule 40 PVCC conduit (GRS conduit in contact with the ground shall be coated with polyvinyl chloride - 40 mil minimum thickness).

- o Final connections to vibrating equipment, light fixtures in lay-in ceilings and transformer primaries secondaries: flexible conduit.

- o In slab above grade: Galvanized rigid steel conduit.

- o Exposed outdoor locations: Galvanized rigid steel conduit with weathertight fittings.

- o Wet interior locations: Electrical metallic tubing with weathertight fittings or water tight flexible conduit where allowed in specifications.

- o Concealed dry interior locations: Electrical metallic tubing or flexible conduit where allowed in specifications.

- o Exposed dry interior locations: Electrical metallic tubing.

- o Interior locations where physical damage (including vandalism) is possible: Substitute rigid steel conduit where electrical metallic tubing is listed.

- o In stations (above, at, or below grade) and trainways below grade: Galvanized rigid steel conduit.

Materials manufactured for use as conduits, raceways, ducts and their surface finish materials, when installed in stations above, at, or below grade, and trainways below grade, shall be capable of being subjected to temperatures up to 932°F (500°C) for an hour, and shall not support combustion. All conduit in these areas shall be GRS. When encased in concrete, other materials are acceptable. Raceways shall conform to the National Electrical Code (NFPA 70). They shall also conform to the codes of the National Electrical Manufacturers Association (NEMA), the American National Standards Institute (ANSI), and Underwriters Laboratories, Inc. Expansion fittings shall be provided in all conduit runs where they cross expansion joints, and as required by the NEC for longer runs.

28.9.4 Line Section Design

Wayside Cables. All power cables shall be in conduit or cableway. In tunnels, the conduits shall be either attached to tunnel walls, directly buried or in cableway. On elevated structures, conduits shall be attached to, or embedded in the structure. Where the track is at ground level, the conduits shall be in concrete duct banks below grade or directly buried.

In tunnels and on elevated structures, a cableway shall be provided by others, adjacent to the track.

The top of the cableway (known as the serviceway) shall consist of removable covers suitable for walking over.

The serviceway shall be used by maintenance personnel and shall be available as a path of emergency egress. The cableway is to be used for systems cables only--no facility power cable shall be placed in the cableway. Wiring to lights and power outlets in the tunnel shall be in conduits mounted on the tunnel wall, or enbedded within the wall.

Wayside Duct Banks. Wayside cables may be direct burial, placed in prefabricated trenches or in duct banks as required. Where duct banks are used, they shall be configured as required at the specific locations. Manholes, pullboxes, junction boxes and cable vaults shall be spaced for ease of cable pulling, and shall meet applicable codes and operational requirements, without exceeding cable pulling tensions. Underground duct banks shall be sloped toward a manhole or box from which water may be drained or pumped. The design must be carefully coordinated with underground utilities to assure safe access within the right-of-way. The routing of utility company feeder conduits within the right-of-way shall be coordinated and approved by DART to avoid interference with the transit system duct bank. Refer to Chapter 6 - Utilities for more information. Project drawings shall include duct bank profiles and other details to show underground utilities or other obstructions.

Bends in conduits within a duct bank shall be minimum 3-foot radius, regardless of size, unless otherwise shown.

Wayside duct banks, where used beyond tunnel sections and cut-and-cover constructed sections, shall be installed for pulling cables from the cableway in the tunnels to the points of terminations in the stations. To facilitate cable pulling, splicing, and transitioning, pull boxes shall be installed at intervals consistent with system requirements.

As directed in at-grade sections of the transit system, underground duct banks, prefabricated trenches, or direct burial cables shall be installed between adjacent tracks or in adjacent right-of-way. To facilitate cable pulling, splicing and transitioning, manholes or pull boxes shall be installed at appropriate intervals to accommodate the system requirements.

Cable transition details shall be shown on the drawings for cable transition from at-grade to aerial structures and from at-grade to tunnel sections.

Where prefabricated trenches are used, the trench walls and cover must be designed to support the weight of all maintenance machinery used along the right-of-way.

Conduit Transitions. Conduit transitions are needed when changing from one wayside cableway location or configuration to another and to provide conduit access from the wayside cableway to system wayside facilities, such as signals/signal systems equipment, traction power equipment, track switches, and tunnel emergency telephone stations.

Manholes for duct banks shall have sufficient working room for cable-pulling and required equipment. Wayside junction boxes, pull boxes, and manholes, designed to accommodate both power, signals/signal systems and communication system cables, shall incorporate protective barriers as required to separate power, control and communication circuits. Barriers shall comply with NEC requirements for separating different classes of power circuits and shall be designed to not interfere with installation of systemwide cabling.

Where conduit transition, pull or junction boxes, or manholes might collect water, drainage shall be provided.

Manholes, Pullboxes and Vaults. Each manhole or pullbox shall contain cable pulling irons, cable racks, ladder and/or rungs as required, and accessible ground rod. Aerial structure wireways of metal shall be individually grounded by means of ground cable(s) welded to the wireway every ten feet and at intersections. The ground cable shall be extended to the nearest manhole or transition box at a station and connected to the station facility ground system. The manhole shall be designed such that the auxiliary power conduits can be divided from the system train control and communication conduits entering the manhole. Where possible, wayside conduits shall enter the manhole at the same elevation as those conduits on the wayside. Sudden changes in conduit elevations should be avoided in the vicinity of the cable vault.

A manhole or pullbox shall be provided at the end of each facilities contract limit if no provisions have been made in the adjoining contract.

Manhole and pullbox for access to under-platform area shall conform to the architectural requirements.

Cable vaults shall be used to integrate wayside duct banks with the station conduit system. The size and shape of these vaults shall be adapted to station conduit configuration and shall include sufficient working room for one worker and cable-pulling equipment.

Installation Considerations. All DART electrical facilities conduit pull boxes, manholes, and so forth shall be installed on DART right-of-way. If this is not possible, the additional required right-of-way shall be identified and coordinated with DART within 4 weeks after the notice to proceed has been issued.

Concrete-encased wayside duct banks shall have a 2-1/2 inch minimum protective cover on all sides. Encased PVC and FRE conduits shall be coupled to GRS conduit before the conduit emerges from an encasement and becomes exposed. Conduits of dissimilar metals shall not be joined without insulating provisions to prevent galvanic corrosion. Refer to Systems Design Criteria Chapter 8 - Corrosion Control and Chapter 9 - System Grounding.

28.9.5 Conduit Identification

Conduit Feeder Schedule. The conduit schedule shall identify all feeder conduits to be installed, using symbols and annotations. Conduits that are to enclose circuits installed by others shall be clearly indicated. Installation specifications shall require pull wire and permanent tagging of each conduit access.

Schedule Content. Conduit and feeder schedules shall include the following information:

- Conduit identification
- Circuit identification
- Conduit from
- Conduit to
- Indication of multiple runs
- Conduit size
- Conduit type
- Conductor description
- Conductor quantity
- Drawing reference

28.9.6 Design Approach

Raceway designs shall include all required runs between equipment and panel boards in electrical rooms, bungalows, and so forth, and shall be shown on drawings with cross references to other drawings that detail the conduit routing in ceilings, walls or floor slabs as required in areas where routing is critical. Conduits shall be extended from these secondary distribution points to the associated equipment. Conduit runs that may exceed the 270-degree bend limitation and conduit runs in excess of 100 feet shall be detailed in the project drawings. Details shall include junction box locations, bends and potential obstructions, such as mechanical ducts and piping. Conduit routing and locations of pull boxes and junction boxes shall be subject to change as necessary during construction.

28.9.6.1 Train Control

Communications and Signaling. Conduits for communications and signal circuits are part of the wayside duct bank, or cable troughs and transitions discussed in Section 28.9.4 entitled "Wayside Duct Banks" and "Conduit Transitions" in this chapter. Conduit designations, locations and circuit assignments shall be indicated on the design drawings.

Conduits for wayside telephones, maintenance telephones, and signaling devices shall be provided from wayside cable trough, wireways, manholes, junction boxes, or cable vaults, as applicable, where such devices are to be installed.

Traction power substations require communications conduit for telephones, maintenance telephone jacks, and miscellaneous monitor/control functions. Typically, these will require conduits from the cable trough (one from each trough) in the tunnels, or junction box nearest the traction substation.

A radio antenna feed cable conduit shall be extended from the communications equipment in the station control room to each feed point of the lossy line designed for the station.

All station communications devices (except public telephones) shall be connected and run via conduits, cable troughs, or wireways, as applicable, to the communications equipment or the communications interface cabinet in the station control room. From the station control room, conduits shall extend to both wayside cable troughs or directly to the communications bungalow. A branch trough or duct shall be provided from each wayside cable trough to each signal bungalow. Where there is no station communications equipment, conduit shall be provided from station communication devices to the wayside cable trough(s) or to an adjacent communications bungalow. Signal devices shall run to the signal bungalow in the designated signal conduits.

28.9.7 Conduit Location Summary

This section provides a menu of conduit ductbank, and CIC interface requirements that may be part of a specific project. These are not additional requirements and are included only to aid in the design of conduit systems. Facilities conduits for common services, such as lighting and exhaust fans, have been omitted for clarity.

Communications and Signal Bungalows. Section designers shall provide conduits from each wayside cable trough to each signal bungalow and communications bungalow. Conduits shall be provided for bungalow power feeds. Blockouts in the cable troughs for cables from wayside telephones and signal devices to the communications and signal bungalows shall be provided and shown on the design drawings.

Specific conduit and cut-out requirements will be coordinated with the section designers, and the systems contractor by DART. For communications system conduit functional needs, refer to the Systems Design Criteria.

Station Control Room. Section designers shall provide conduits from each station control room to each wayside cable trough, or conduits to the adjacent communications bungalow rooms. Conduits shall also be included in the design from the station control room to accommodate wires and cables to the following:

- Auxiliary power connectors.
- Station electronic private-access branch exchange (EPABX) telephones.
- Station fire hot line telephone.
- Station passenger emergency call (PEC) units.

- o Elevator emergency telephones or PEC units.
- o Supervisory and control circuits to facility equipment.
- o Public address speakers.
- o Public address control points.
- o Fire detection devices, alarms, and panels.
- o CCTV cameras.
- o Public Telephones

Wireways and cable troughs may be used in lieu of conduit where appropriate. Spare conduits or capacity in wireways and cable toughs shall be provided.

Subway Traction Power Substations Auxiliary Services. The following summary shall be used for the required substation conduits:

- o Auxiliary power connections (see the "Traction Auxiliary Power" section in this chapter).
- o Station fire and intrusion common detection conduits.
- o Supervisory, control circuits and PABX telephone.
- o Normal and emergency lighting.
- o Traction power positive and negative feeders.
- o Utility primary feeder conduits.
- o Corrosion control conduit.
- o Spare conduits to tunnel walkway cable trough.

Elevator Machine Rooms. The following summary shall be used for the required elevator equipment room conduits:

- o Auxiliary power feeders.
- o Communications bungalow conduits for emergency telephone.
- o Public address system speakers.
- o Fire detection devices.
- o Corrosion control.

Escalator Equipment Space. The following summary shall be used for the required escalator equipment conduits:

- o Auxiliary power feeders.
- o Fire detection devices.
- o Corrosion control.

Where an escalator is not adjacent to a stairway or another escalator, conduit(s) shall be provided to connect escalator controls with station exit sign controls.

28.9.8 Installation Guidelines

The following provides general installation guidelines for conduits:

- Minimum conduit size shall be 3/4 inch or as specified.

- Flexible conduit shall not be used to extend rigid conduit to fixed pull, junction, or outlet boxes.

- Conduits in non-public areas may be installed exposed on the surface of walls or ceiling.

- Raceways installed on subgrade walls or ceilings that are earth retaining shall be installed with not less than 1/2-inch air space between mounting surface and raceway.

- Pull and junction boxes shall be placed only in accessible areas and in a manner that their covers can be removed without requiring other conduits or objects to be moved.

- For grounding or isolating of conduits, refer to Systems Design Criteria Chapter 8 - Corrosion Control and Chapter 9 - System Grounding.

- All conduits and other raceways in public areas shall be concealed from public view. Underfloor raceway locations and sizes for initial and future equipment shall be provided.

- Except in ancillary or other nonpublic areas, when installed in stations and trainways all conductors (excluding radio antenna and overhead traction power catenary) shall be entirely enclosed in armor sheaths, conduits, or enclosed raceways, boxes, and cabinets. Conductors in conduits or raceways may be embedded in concrete or run in concrete electrical duct banks, but they shall not be installed, exposed, or surface-mounted in those air plenums that could carry high-temperature air during a fire.

Conduit Bends. Conduits shall have no more than the equivalent of three 90-degree bends (270 degrees) between an outlet or service point, and pullbox, manhole, or outlet box.

Minimum bend radii shall be per applicable codes and as follows:

- Antenna lossy line and lead-in conduits leaving communication or signal bungalow or room shall be 3-inch conduit with 48-inch minimum bend radius.

- Wayside duct bank conduits including those routed to the signal bungalow shall have 48- inch minimum bend radius. Where space limitations exist, use a pullbox having one side as a removable cover and a length equal to eight times the diameter of the largest conduit entering the box shall be used. Conduits entering the box shall have bushings to reduce risk of cable damage during installation.

28.9.9 Tunnel Lighting

Galvanized rigid steel conduits with watertight junction boxes and with lighting fixtures spaced as shown shall be installed in each tunnel. The conduit shall be located above the walkway surface as shown on drawings. Refer to Chapter 26 - Lighting for additional requirements. Junction boxes and lighting fixtures shall also be installed in each emergency exit and at each crosswalk to an adjacent passageway for emergency exit.

28.9.10 Electrical Boxes and Cabinets

When installed in stations and trainways, materials manufactured for use as boxes, cabinets, and equipment enclosures (including the surface finish materials of these objects), shall be capable of being subjected to temperatures up to 932°F (500°C) for 1 hour and shall not support combustion. When encased in concrete, other materials are acceptable.

Raceway Boxes. Outlet, junction and pull boxes shall be indicated on the drawings where they are required to facilitate the pulling, supporting, or connecting of wires and cable. Junction and pull box locations shall be subject to change as necessary during construction.

Interface Boxes. Facility design shall include special boxes and cabinets with terminal blocks to enable cross connection between the installations of the station contractor and those of other contractors.

A communication interface cabinet (CIC)) shall be located in each elevator and escalator equipment area.

In each communications station equipment room or enclosed area, the mountings for communications interface cabinets (CIC) shall be furnished and installed by the systems contractor. These shall be either:

- o CIC 1 as described in this chapter.
- o CIC 2 as described in this chapter.

Cables and wires from public address subsystem speakers and control locations will be terminated directly on terminals in the public address equipment to be furnished and installed by the systems contractor, in the communications station equipment room or enclosed area.

28.9.11 Grounding

General Grounding Criteria. Refer to Systems Design Criteria Chapter 8 - Corrosion Control and Chapter 9 - System Grounding. The NEC and Institute of Electrical and Electronic Engineers (IEEE) publications identified in the appendix of these criteria contain regulations pertaining to system and equipment grounding applicable to the facilities and equipment to be constructed and installed on the system. The codes are to be considered as the minimum requirement for the protection of life and property and should be carefully reviewed during the course of system design.

Hazardous Conditions. The types of hazardous conditions which can develop in a transit electrical system are:

- o Single-phase-to-ground faults.
- o Multiple-phase-to-ground faults.
- o Phase-to-phase faults.
- o Three phase faults.
- o Arcing faults, which may cause burndown.
- o Abnormal hazards, including:
  - Lightning.
  - Switching surges.
  - Static.
  - Contact with a high-voltage system.
  - Line-ground faults.
  - Resonant conditions.
  - Restriking ground faults.
  - Catenary-to-ground fault.
  - Cable fire.
  - Large stray currents.
  - Catenary-to-running rail faults.

Protective Measures. The facilities' electrical systems shall be grounded and designed to limit the voltage imposed by lightning, line surges, or unintentional contact with higher voltage lines and to stabilize the voltage to earth during normal operation.

- o To limit the potential difference between uninsulated conducting objects in a facility and the ground.

- o To isolate faulted equipment and circuits when a fault occurs.

- o To limit over-voltages appearing on the system under abnormal and hazardous conditions.

Normal Operating Conditions. Under normal operating conditions, persons who are within a passenger station or other areas shall not be exposed to a leakage current of more than 0.3 milliampere.

Abnormal Conditions. The following measures shall be taken to protect transit passengers and personnel under the abnormal condition of a ground fault:

- o Provide a ground grid under each facility.
- o Provide a low-resistance path to ground for ground-fault current.
- o Provide means to disconnect the station supply transformer from incoming power in a one- half second or less.

A design objective of the ground grid is to limit touch potentials to 50 volts maximum.

Grounding Electrode System. A ground electrode system shall be provided for each facility. The grounding electrode system shall consist of buried ground conductors and electrodes interconnected to form a grid and shall be capable of maintaining a resistance to ground as specified.

Facility Ground Grid System. The grounding system shall consist of ground rods and horizontally interconnected longitudinal and lateral bare conductors forming a grid of a rectangular pattern. The ground grid shall be designed to provide safe step and touch potentials throughout the facility during a maximum available fault current on the electric power system which shall not exceed the recommended safety limits of IEEE Standard 80. The buried conductors used to form the ground grid shall be copper bare cable interconnected at each crossover point (node) by exothermic welding process. The ground grid shall be connected to ground rods as required. Grids shall be buried in filled trenches or laid on earth and overlaid with at least 18 inches of backfill. Landscaping plans shall be consulted to avoid conflicts with tree roots. Grid locations shall be coordinated with underground utilities and sewer installations to avoid any direct electrical connection to these systems. Taps from the ground grid for equipment grounding shall be insulated copper conductors where they penetrate and/or run along structural concrete floors and walls. All connections and interconnections shall be coated with coal tar epoxy or equivalent waterproof coating.

Grounding Conductor Sizing. Each of the conductors shall be sized so it can safely pass the maximum ground fault current without melting or fusing before the circuit breakers or protective relays disconnect the source of the fault current.

Ground Rods. When ground rods are used as the ground electrode they shall be minimum 3/4-inch diameter, 10 foot length, copper clad. Driven ground rods shall be placed along the periphery of the ground grid and at nodes as required to meet the specified overall resistance of maximum 25 ohms. Rods shall be connected to the grid by the exothermic welding process, with coal tar epoxy or equivalent waterproof coating over the weld. The installation of chemical ground rods is acceptable where the presence of rock prevents ground rods from being driven to the required depth.

Grounding Electrode Conductor. Conductors between the ground electrode system and the grounded system shall be insulated copper wire or cable in nonmetallic conduit. The conductor shall be sized to preclude fusing under the maximum fault current for that equipment but in no case smaller than permitted by the NEC. Each conductor shall be exothermically welded to the ground grid at a node. All connections shall be coated with coal tar epoxy or equivalent waterproof coating to prevent corrosion of the connection.

Supplemental Grounding Electrode System. When it is advantageous, steel piling that will remain after construction shall be incorporated into the ground grid system to lower the resistance of the grounded system to earth. Steel reinforcement in the station platform area and in floors of transformer substation rooms shall be connected to the ground grid system to reduce touch potentials to a minimum as calculated for these areas.

Connection to Utilities. There shall be no connection between the grounding system and any utility line (including water) outside the dielectric coupling which is used to isolate facilities from utilities outside the building line or tunnel.

Auxiliary Equipment Grounding. The transformer case and alternating current switchgear enclosures for auxiliary power shall be solidly grounded to the facility ground grid system using copper grounding conductors. The spiral metallic tape covering of medium voltage cables 5 kv and above shall also be solidly grounded at both ends to the facility ground grid system.

Power Transformer Grounding. The neutral of the power transformer secondary shall be solidly grounded through a copper grounding conductor bonded to the facility ground grid system. Grounding conductors from the secondary switchboards shall be grounded to the same grounding conductor.

Distribution Transformer Grounding. Distribution transformers used for secondary power distribution shall have their secondary neutrals solidly grounded. Neutral conductors from secondary panelboards served by 480-volt transformers shall be grounded to the same conductor to assure single point grounding of neutral conductors.

Safety Ground. Raceways for lighting and power feeders to motor, lighting and receptacle loads shall contain a separate green safety insulated grounding conductor. The safety grounding conductors for feeder circuits shall each be bonded at one end to the substation ground bus and at the other end to the ground bus of a panelboard or to a motor control center ground bus. Each branch circuit shall have a safety-insulated grounding conductor extended from the ground bus of the panelboard or motor control center to the device it is serving.

Equipment Restrictions. Metal cabinets or equipment containing electrically operated lights, motors, or mechanisms shall not be permanently located closer than eight feet from the platform edge. Electrical tools, including power cleaning equipment, if used in the platform area, will be double insulated to prevent possible injury.

Equipment Separation Requirements. A distance of five feet shall be maintained between grounded surfaces and the case of the ungrounded rectifier and DC switchgear. All AC equipment housings shall have provisions for grounding.

Ground Plates-General. Ground plates for electrical and communication equipment shall be provided such that no potential equipment location within a station facility is more than 30 feet from the nearest plate. The grounding conductor shall be welded or bolted to the plate for visible inspection of the connection. Additional grounding conductors shall be provided for major equipment at specified locations.

Signal Reference Ground Plates. A signal reference ground plate shall be installed in each subway communication equipment room and room for signal and communications. Except for a single point of interconnection to the ground grid, each signal reference network shall be insulated from other networks and elements of the facility ground grid system.

Equipment Power Ground. All AC power cables terminated in cabinets and chassis shall include a green safety wire grounding conductor. One end of this wire shall be connected to the chassis or cabinet and the other end shall be connected to the ground bus in the circuit breaker panel. In subway areas, connections to the grounding system shall be made available to signal and communications bungalow, rooms and other signal locations. Ground plates shall be installed in electrical switchgear room, traction power substation and other rooms with electrical equipment as required.

Pull Boxes, Manholes, Cable Vaults and Conduit. All metallic conduit pull boxes, manholes and cable vaults shall be grounded to the station ground system or to a ground electrode if remote from the station ground system.

Fence Grounding. Fences shall be grounded in accordance with the National Electrical Safety Code and (ANSI). Spacing of ground electrodes shall be every 150 feet and on either side of a gate or other opening in the fence. The fence shall be bonded at gate hinges and other openings to form a continuous path. The grounding conductor shall be exothermically welded to the fence post and the other end of the grounding conductor exothermically welded to the driven ground electrode. Welds shall be waterproofed with a coating of coal tar epoxy or equivalent.

Equipment Grounding. The non-current-carrying parts of all electrical equipment, devices, panelboards and metallic raceways shall be connected to the ground bus. The main bonding jumpers between the unit substation ground bus and auxiliary power equipment shall be routed in the most direct and mechanically protected manner. The transformer neutrals of wye-connected transformers shall be solidly grounded together through a grounding conductor connected to the facility ground grid system.

Metalwork Grounding. All exposed metalwork such as handrails, stairways, and escalators shall be connected to the station ground system or separate ground system. Handrails on special-use platforms shall not be grounded and shall be electrically isolated from ground. Free-standing station amenities such as windscreen, trash racks, and seats do not require grounding. All handrails on bridges and retaining walls shall be grounded.

Subway Traction Power Substation Grounding. Each traction power substation and tie station which is located in the subways shall be furnished with a ground grid to provide safety to personnel and to protect equipment. The ground grid shall be provided by the station contractor and shall comply with all of the requirements in the facility ground grid system section. All other requirements under this grounding section apply equally to this subsection.

Shop, Yard, and Storage Track Grounding. Grounding in these areas shall be in accordance with Systems Design Criteria Chapter 8 - Corrosion Control and Chapter 9 - System Grounding.

Traction Power Negative Return. Traction power negative return system is ungrounded. Care shall be taken to assure that all other ground grid system ground cables will not contact the negative return system at any point.

Corrosion Control. Coordination of grounding and corrosion control requirements shall be completed as detailed in Systems Design Criteria Chapter 8 - Corrosion Control.

28.9.12 Convenience Receptacles

Type and Location. Receptacles for general use shall be of the duplex 20-amp minimum rating, grounded type. In public areas they shall be spaced not more than 100 feet apart and be located flush in a wall or column. In station non-public areas, receptacles may be surface-mounted and shall be spaced not more than 20 feet apart. They shall be supplemented, where needed, for fixed equipment. Receptacles in restrooms, outdoors, in tunnels, and in wet areas shall be provided with ground fault protection locally at the receptacle. (Exception: if all receptacles on a circuit are close together and all require GFP, the GFP may be at the circuit breaker.) Receptacles shall be connected so that a local GFP will not affect other receptacles. Receptacles of other voltages, amperages, and phase arrangements shall be provided in locations as required.

Tunnel Receptacles. In tunnels, 120V, 20-amp, 1-phase duplex, weatherproof receptacles shall be installed on nominal 150-foot intervals. The receptacles shall be located on the tunnel wall above the service walkway below the lighting fixture. Where voltage drop at 120 volts may be excessive, receptacles shall be fed from 480V panels located at the station and through a mini power center consisting of 480-120V transformer and branch circuit breakers located at each cross-passageway. One receptacle shall be provided at each cross-passageway.

Switch Machine Receptacle. A 120V, 20-amp receptacle shall be provided at each switch machine on the inside tunnel wall.

Track Lubricator Receptacle. At locations shown on track directive drawings for all trainways, a 120V, 20-amp receptacle shall be provided at each track lubricator.

Hose Bibb Receptacles. A flush-mounted receptacle box with duplex outlet with ground fault protection shall be provided close to the hose bibbs.

Vent Fan and Access Shaft Receptacles. Receptacles shall be located so that any point in a vent fan or access shaft can be reached with a 50-foot electrical cord. These receptacles shall be of the GFP type.

Site Maintenance Receptacles. A receptacle with duplex outlet with ground fault protection shall be provided approximately ten feet from any site maintenance outlet box where required.

Circuit Allocation. In public areas, no more than six duplex outlets shall be connected to a branch circuit. In ancillary or service areas, no more than five duplex outlets shall be connected to a branch circuit.

28.9.13 Specific Power Requirements

Elevators. The power supply to each elevator shall be 480 volt, 3-phase, terminated in a fused disconnect switch or circuit breaker in the elevator machine room. Ampacity and fuse characteristics shall be selected according to information from the elevator supplier.

A 208Y/120-volt, 3-phase, 20-amp emergency power service shall be provided for hoistway lighting and receptacles in accordance with the applicable code requirements.

A 120-volt, 20-amp service shall be provided for cathodic protection circuit in the elevator machine room.

Escalators. The power supply for each escalator shall consist of a 480-volt, 3-phase supply terminated in a fused disconnect switch or circuit breaker in the escalator machine space. Ampacity and circuit breaker characteristics shall be selected according to information from the excalator supplier. A 208Y/120-volt, 3-phase, 20-amp service is required for each escalator for maintenance lights, light switch, and receptacle in the machine space. This service is not to be connected to emergency power. Escalator control connections to exit signs and roll-down gates shall be provided. Refer to the Illuminated Sign section of this chapter.

An audible alarm shall be provided at each escalator. The alarm shall sound when the cover over the escalator emergency stop button is open, and shall cease sounding when the cover is closed.

Fare Vending. Provisions for fare vending shall be made as required in the general plans, and in the standard and directive drawings. The equipment shall be fed from a panelboard located in the electrical room.

Retail Spaces in Subway Stations. Retail or other leased spaces in subway stations shall receive power from the station power supply. This will avoid possible complications that might arise if the utility provided a separate feeder to each tenant. Each enclosed lease space shall have feeder, watthour meter, and panelboard serviced from the station distribution panel. Leaseholders shall make payments for electric power to DART, and not to the utility company. Leased counters in general public areas (e.g. foyers or corridors) shall not have individual meters or panelboards--their rent shall include an allowance for electric power consumed.

Illuminated Signs. The number and location of patron direction and information signs and whether internally or indirectly illuminated, shall be as shown on architectural general plans and as described in the station architecture, operational requirements chapter of the architectural design criteria. Exit signs for passenger stations shall be provided in accordance with the above reference and Chapter 26 - Lighting of these criteria. In subway line sections, an exit sign shall be provided at each emergency exit from the subway to the surface and on each side of the dividing wall between cells of the subway at those crosswalks or cross passages that are to be used for emergency exiting. Selected signs that indicate exits or ways of exit shall have two or more extended-life type lamps, with automatic transfer to emergency power if normal power fails. Sign lighting control relays shall be part of each sign. For escalators having no adjacent stairway, associated directional signs shall be interlocked with the escalator controller via an escalator communication interface cabinet (CIC) in the escalator machine space.

Maintenance Facilities. The installation of electrical wiring, lighting, and power in structures, and the installation of all electrical devices not supplying traction power within all maintenance facilities, shall be in accordance with the National Electrical Code (NFPA 70), the National Electric Safety Code (ANSI C2), Installation, Maintenance, and Use of Proprietary Protective Signalling Systems (NFPA 72D), and applicable local codes.

Installation of all electric equipment and wiring used in connection with overhead cranes and hoists shall conform to Article 610 of NFPA 70. To prevent contact with movable maintenance platforms, ladders, or mobile cranes, protected or recessed overhead AC/DC power bus systems shall be provided. Catenary system conductors shall not be protected or recessed, however.

Traction Auxiliary Power. Subway traction power substations provide their own auxiliary power supply. Lighting, receptacles, and panelboard connections shall be by others unless otherwise indicated on the preliminary design drawings.

28.9.14 Telephone Support

Station Access. The incoming telephone service entrance duct bank, consisting of two 2-inch conduits (or as directed by the telephone company), shall extend from the DART property line to the station public telephone equipment space. The telephone company will provide all cables from its facilities, through DART-provided conduit, and terminate in the station public telephone equipment space. The exact location on the property line for termination of DART provided conduit will be determined during design.

Tunnel Emergency Telephones. A telephone shall be located in tunnels at the points where the blue light is located, and for each exit stairway and at crosspassageways, as shown on drawings. The telephone shall be connected to the OCC for emergency calls. (Refer to Systems Design Criteria Chapter 5 - Communications.)

Public Telephone Conduits. Conduit requirements for the public telephone system in passenger stations are:

- 1-inch conduit and wiring installed from the nearest 208Y/120-volt panelboard to each telephone location for convenience outlet requirements.

- 1-inch conduit from the public telephone equipment space to the closest telephone in each multiple telephone location, with provision for distribution from that telephone to the remaining telephones in the same vicinity.

Network Access. Provisions for access to the DART intranet and internet shall be provided at all subway station maintenance offices.

28.10 FACILITY MONITOR AND CONTROL REQUIREMENTS

These criteria describe the facility requirements and interfacing hardware necessary to enable the operations control center to have remote monitor and control capability. The following sections provide the basis for identifying functions that are to be remotely monitored or controlled. Project drawings shall be prepared to show specific information as a guide.

28.10.1 Local Monitor and Control Requirements

Equipment controls, such as those for escalators, elevators, fans, and pumps, shall be in accordance with NEMA criteria related to the prescribed equipment.

Control Cabinets and Panels. The following cabinets and panels shall be furnished and installed as part of the facility project.

- Communications Interface Cabinet No. 2 shall provide housing and terminal block for low voltage control and dry contact monitoring devices.
- Lighting contactor cabinets (LCC) and lighting flasher control cabinets (FCC) shall be provided to house lighting contactors where required. These cabinets shall be located adjacent to the power or lighting panelboards that supply power for controlled circuits.

Lighting Control. Lighting controls shall be provided in accordance with Chapter 26 - Lighting.

Control Voltages. 120 volts AC shall be used for panel controls interfaced with systemwide functions incorporated within CIC No. 2. Motor controls shall be 120 volts AC, as provided by individual control transformers with fused secondary. Draw-out switchgear control shall be 120 volts AC with a capacitor trip device for each breaker (to operate the breaker in the event of failure of control power).

Station Entrances. Key operated controls shall be used for station entrances. Station entrance controls shall be inside and outside the station within line-of-sight.

28.10.2 Remote Monitor and Control Requirements

The facility equipment and systems that are remotely monitored and controlled shall have individual circuits extended from their installed locations to the communication bungalow by facility-provided conduit, cable, wire, and interface terminal boxes described below. (Refer to the Communications Interface Drawings.) Where the communications equipment is located in an exterior bungalow, the interface cabinets shall be located in the station adjacent to the entry point of the cables from the communications bungalow.

Communications Interface Cabinet (CIC) No. 1. CIC No. 1 shall be used to terminate:

- All station telephones (except public telephones).

- o Circuits between the communications transmission subsystem and the public address equipment.

- o All police emergency call units.

- o Circuits between the communications transmission subsystem and the station facilities remote terminal unit.

- o CCTV camera video circuits.

- o Radio antenna.

Communications Interface Cabinet (CIC) No. 2. CIC No. 2 shall be used to terminate the following functions as indicated by the General Plans and the Communications Interface Drawings:

- o Monitor Functions:

  -Auxiliary power substation.
  -Battery room exhaust fan.
  -Auxiliary electrical high temperature alarm.
  -Miscellaneous equipment.
  -Fans.
  -Pumps.
  -Emergency trip.
  -Fire and intrusion alarms.

- o Control Functions:

  -Fans.
  -Pumps.
  -Miscellaneous equipment.
  -Spares.

Communications Interface Cabinet Wiring. Communications interface cabinet (CIC) wiring shall comply with the following:

- o Terminations shall be identified by number and physically positioned on the design drawings.

- o Where monitor or control circuits are to be summarized to reduce monitor points extended to another location, each circuit first shall be terminated on the facility side of the terminal block in the interface terminal cabinet (IFTC) No. 2, depending on site specific conditions. Terminals shall have capability to be used for multiple circuits as required.

- o Three types of terminal blocks shall be used:
  - Protector Blocks. Used when terminating cable or wire that is external to the station or that may otherwise be subjected to high current surges.
  - Slotted, Wire-Insertion-Type Connector Blocks. Used for telephone cables, 22 AWG and smaller.
  - Dual-Strip Screw-Terminal Blocks. Used for all other wire and cable.
- o Radio signal and CCTV video coaxial cable shall be terminated by means of suitable bulkhead connectors.

28.11 LIGHTNING PROTECTION

Lightning protection systems and equipment shall be installed, where required, to provide protection of persons, equipment, and facilities against the hazards posed by lightning-related currents and voltages.

28.11.1 Structures Requiring Protection

Lightning-protection systems shall be provided for DART at-grade and aerial passenger stations that are more than 14 feet above average terrain and outside of the cone of protection provided by nearby structures. In addition, lightning protection shall be provided for other similarly exposed DART buildings or structures for which the probability of a direct strike exceed .01 per structure per year. According to the U. S. Weather Bureau (in cooperation with the U. S. Army Corps of Engineers) the probability of lightning in Dallas is 50 thunderstorms per year. The designer shall refer to NFPA 78, Lightning Protection Code.

28.11.2 Design Requirements

Conductor Systems. Reference shall be made to the Lightning Protection Code (NFPA 78). Down-conductors shall be sized by weight according to the height of the structure being protected. For structures under 75 feet, down-conductors of copper must weigh at least 187.5 pounds per 1000 feet of perimeter. For structures over 75 feet, down-conductors are required at diagonally opposite corners for buildings with perimeters less than 250 feet. An additional down-conductor is required for each additional 100 feet increase in perimeter. For structures over 75 feet in height, down-conductors must weigh at least 375 pounds per 1000 feet. When steel columns are used as down conductors, spacing is reduced to every other steel column or 60 feet, whichever is less. The down-conductors shall be connected to the facility ground system or a separate ground system, as required. All connections shall be made by the exothermic welding process.

Non-Use of Utilities. Connections of down-conductors shall not be made to water lines or other utilities outside utility isolation couplings.

Air Terminal Placement. The placement of air terminals and the routing of conductors shall consider appearance as well as protection requirements. Air terminals shall be placed to take advantage of any protection afforded by adjacent structural features. For air terminals 12 inches in height, spacing shall be 20 feet maximum; for air terminals 2 feet in height, spacing shall be 25 feet. On large roof areas additional air terminals shall be installed at a 50-foot-grid spacing in mid-roof areas.

Down-Conductor Conduit. When it is necessary to enclose the down-conductors in conduit, the conduit shall be of a non-conductive material. Where conductive conduit must be used, the conduit shall be bonded to the down-conductor at each end. Ferrous conduit shall not be used to enclose lightning down-conductors. Down-conductor conduit shall be concealed from public view and access.

28.12 ELECTRICAL FACILITIES LOCATIONS

All electrical equipment, such as cables, and duct banks, shall be located within DART right-of-way. If acquisition of additional right-of-way should become necessary, the section designer shall notify DART immediately.

28.13 SYSTEMS POWER AND CONTROL FACILITIES

Systems power and control facilities (communications, traction electrification, signal, and OCC systems) shall be provided by the DART systems contractor. The section designer shall make provisions for the equipment as indicated in these criteria and as further detailed in the general plans, standards, directives and interface drawings.

CHAPTER 29 - FIRE PROTECTION SYSTEMS

29.1 INTRODUCTION

This chapter describes the functional and design requirements for the fire protection systems. It is intended to promote uniformity of design and standardize the type and location of fire protection equipment throughout the system.

These criteria cover the fire protection systems for at-grade, aerial and subway stations, subway tunnels, yards, shops, major repair shops, service and inspection shops, operations control center (OCC), traction power substations, and miscellaneous wayside ancillary spaces. All piping and equipment pertaining to the plumbing and drainage systems are described in Chapter 30 - Plumbing and Drainage Systems, but drainage systems pertaining to indirect waste from fire protection systems are included in this chapter. Fire protection systems for signal bungalows and communications bungalows shall be in accordance with the requirements described in other chapters of these criteria. Fire and intrusion alarm system requirements are described in the Chapter 27 - Fire and Intrusion Alarm Systems.

29.1.1 Codes and Standards

The fire protection systems design shall comply with all applicable local codes of the city to which they pertain, and with all applicable State of Texas codes. Unless otherwise prescribed in this chapter, fire protection systems design shall comply with the applicable standards and recommended practices of the appropriate professional organizations. (See Appendix 1, the mechanical/electrical section, for a representative list of these standard codes and references.)

The section designer's attention is further directed to the requirements of the standard for Fixed Guideway Transit and Passenger Rail Systems, NFPA 130, hereafter cited as NFPA 130. Section designers shall consult all appropriate codes and publications listed in Appendix 1 and provide fire protection systems in accordance with the most stringent of the applicable codes and industry practices.

29.1.2 Fire Protection Provisions

The following types of fire protection systems shall be provided:

- o Automatic sprinkler systems (wet and dry).
- o Standpipe systems (wet and dry).
- o Firehose cabinets.
- o Portable fire extinguishers.
- o FM200 Systems.

29.2 AUTOMATIC SPRINKLER SYSTEMS

29.2.1 Design Requirements

Sprinkler systems shall include: main water supply, backflow preventer, fire department inlet connections (Siamese), all piping from inlet connections and water supply mains to sprinkler heads, sprinkler heads, drain lines, provisions for connection to remote alarm devices, pipe fittings, valves, hangers, inserts, sleeves, escutcheons, necessary tools, and appurtenances. Where piping is subject to freezing temperatures, a dry pipe sprinkler system of the pre-action type with deluge valve activated through smoke/heat detectors shall be provided. Sprinkler systems shall be provided in the ancillary spaces at stations, maintenance shops, and other locations as described herein. The sprinkler system shall not be combined with the standpipe system.

Automatic sprinkler systems shall comply with the standard for the Installation of Sprinkler Systems NFPA 13, current edition, Chapter 38 of the Uniform Building Code (UBC), or Chapter 9 of the International Building Code (IBC) as applicable, and the following design criteria:

Office Areas, Locker Rooms, and Lounges. A minimum 0.10 gallons per minute (GPM) per square foot over the hydraulically most remote 1,500 square feet or largest room, whichever is less, with a maximum sprinkler spacing of 225 square feet per sprinkler.

Concession Stand and Restaurant Service Areas. A minimum 0.16 GPM per square foot over the hydraulically most remote 1,500 square feet or largest room, whichever is less, with a maximum sprinkler spacing of 130 square feet per sprinkler.

Storage Areas, Workshops, and Trash and Mechanical and Electrical Rooms. A minimum 0.21 GPM per square foot over the hydraulically most remote 1,500 square feet or largest room, whichever is less, with a maximum sprinkler spacing of 130 square feet per sprinkler.

29.2.2 At-Grade and Aerial Stations

Automatic sprinklers are not required in public or nonpublic areas.

29.2.3 Subway Stations

Automatic sprinkler systems shall be provided in all nonpublic areas, in all escalator steel truss areas and escalator pits, elevator shafts, and in concession areas where such facilities are provided within passenger stations. For office areas, locker rooms, concession stands, storage areas, trashrooms, and all other spaces requiring sprinkler protection, the systems shall be designed according to the requirements prescribed in section 29.2.1.

Electronic equipment rooms, such as radio repair, telephones, and computers have no sprinklers. These rooms shall be provided with a FM200 protection system.

29.2.4 Maintenance Facilities

Automatic sprinkler systems shall be provided in all areas of maintenance buildings. The sprinkler systems shall be for light, ordinary, or extra hazard classification, as appropriate, and shall be hydraulically designed according to all applicable codes. Portions of sprinkler systems in areas that are unheated or subject to freezing shall be freeze-protected as prescribed in section 29.2.1. Sprinkler heads in paint spray booths shall be protected from overspray. Sprinkler heads subject to damage shall have protective cages.

Electronic equipment rooms such as radio repair, telephones, and computers shall have no sprinklers. These rooms shall be provided with a FM200 protection system.

29.2.5 Operations Control Center

An automatic sprinkler system shall be provided throughout the OCC excluding the areas protected by FM200 systems. The design of the sprinkler system shall be coordinated with Systems Design Criteria Chapter 6 - Operations Control Center. If the OCC is in a building having occupancy not directly related to transit system operations, the automatic sprinkler system shall be supplied from an independent connection to the municipal water supply. The OCC computer room, data archive room, and other electronic equipment rooms as indicated on project definition drawings shall be protected with FM200 systems. Sprinklers shall not be provided in these rooms.

29.3 STANDPIPE SYSTEMS

Standpipe systems shall conform to the requirements of Installation of Standpipe and Hose Systems (NFPA 14) and as delineated and specified by class type in Chapter 38 of the Uniform Building Code, or Chapter 9 of the International Building Code as applicable to the local municipality. Standpipe systems shall include: fire department inlet connections (siamese), main water supply, piping from inlet connections to mains, hose valves, fire hose cabinets, drain lines, pipe fittings, control valves, hangers, sleeves, tools, and appurtenances as required for a complete and working system. Standpipe systems shall be provided at subway stations, tunnels, service and inspection facility, OCC, and other locations described below. Wet standpipe systems shall not be combined with sprinkler systems.

29.3.1 At-Grade and Aerial Stations

All areas of passenger stations shall be within 300 feet of a fire hydrant connected to a public water supply. Fire hydrants and water supply mains shall be in accordance with applicable codes. Aerial and open-air below-grade stations shall not be provided with a dry standpipe system.

29.3.2 Subway Stations

A Class III standpipe system shall be provided throughout the station entranceways and platforms. Firehose outlets shall be located so that any point may be reached with a maximum of 100 feet of hose and 30 feet of water stream, including in and around any transit vehicles which may be stopped at the station.

At crossing subway stations, a cross-connection pipe of a minimum size of 4 inches in diameter shall be provided between the standpipe system of each station so that supply water to any standpipe system can be used throughout the entire system.

29.3.3 Service and Inspection Facilities

In addition to the automatic sprinkler system described above, a wet standpipe system (including fire hoses) shall be provided in all areas of major repair, and service and inspection shops, with the spacing and location of the hose connections as required by applicable codes.

29.3.4 Operations Control Center

In addition to the automatic sprinkler system and FM200 protection systems, a wet standpipe system (including fire hoses) shall be provided in all areas, with spacing and location of the hose connections as required by applicable codes.

Standpipe water supply shall meet the requirements of applicable codes. If the OCC is within a building having occupancies not directly related to transit system operations, the OCC standpipe shall be supplied from an independent connection to the municipal water system. A separate fire department connection, clearly marked with its intended use, shall be provided within 150 feet of a street hydrant and within 100 feet of vehicular access.

29.3.5 Guideways

Aerial and at-grade guideways shall not be provided with standpipes, unless required by the authority having jurisdiction.

Dry standpipe systems shall be provided at portals and in guideway tunnels. The system shall have hose outlet connections at 200-foot intervals. Each hose connection shall consist of a 2.5-inch angle valve equipped with a 2.5-inch to 1.5-inch reducer-adapter to facilitate the connection of a 1.5-inch fire hose to a 2.5-inch valve. The system shall be sized to supply 250 gallons per minute at the hydraulically most remote outlet. Sectionalizing valves shall be provided to isolate portions of the standpipe system subject to damage due to vehicle derailments. Fire department connections at-grade shall be within 50 feet of vehicular access and within 150 feet of a street hydrant. The zones supplied by each connection shall be clearly identified by identification plates attached to the fire department connections. Identifying numbers shall also be provided at each hose valve in tunnels in accordance with the requirements of NFPA 130.

29.4 FIRE HOSE VALVE CABINETS

Fire hose valve cabinets, equipped as required, shall be provided to achieve coverage of all the areas specified below. This coverage shall be in accordance with Installation of Standpipe, Private Hydrant, and Hose Systems (NFPA 14). Each cabinet (except in subway stations) shall be equipped with a 1.5-inch angle valve with 100 feet of 1.5 inch fire hose, hose rack, a combination spray/stream/off nozzle, a 2.5-inch angle valve with a capped outlet for a hose connection, and a fire extinguisher. Each cabinet in the guideway tunnels and stations shall be equipped with a 1.5-inch angle valve and a 2.5-inch angle valve, and each of these valves shall be equipped with a capped outlet for a hose connection and a fire extinguisher. Cabinets in guideway tunnels and stations shall not be equipped with fire hoses.

Fire hose valve cabinets shall be located in the following areas:

- Subway stations: mezzanine, platform, and concessions.
- Service and inspection facilities: all areas.
- Operations control center: all areas.

29.5 UNDERCAR DELUGE SYSTEMS (Section Deleted)

29.6 FIRE HYDRANTS

29.6.1 Lines and Stations

If not already existent, a fire hydrant of the type approved by the local authority having jurisdiction shall be provided at each of the following locations:

- o Within 300 feet of each location where the Dallas Area Rapid Transit (DART) guideway crosses over a traveled way or access road.
- o Within 150 feet of each fire department connection to a standpipe or sprinkler system.
- o Within 150 feet of each subway station entrance or access point.

The above 150-foot limits are maximal; it is desirable that a fire hydrant be located as close as possible but not closer than 50 feet to each of the points indicated above.

29.6.2 Operations Control Center

Fire hydrants shall be provided along the access road to the OCC at a maximum spacing of 300 feet, if the OCC is an at-grade free-standing building.

29.6.3 Maintenance Shops and Yards

Fire hydrants shall be provided at a maximum spacing of 300 feet along the access roads to the yard and shop facilities.

In the yards, fire hydrants shall be spaced not farther than 300 feet apart and not closer than 50 feet to any building in accordance with the standard for the Installation of Private Fire Service Mains and their Appurtenances (NFPA 24). The piping shall be installed with a post indicator valve to form a loop with the feed connection to the municipal water supply. Where post indicator valves cannot be used, underground gate valves may be used, provided their locations and direction of turning to open are plainly marked. Operating tools for underground valves shall be provided.

29.6.4 Fire Hydrant Reflectors

As described in Chapter 5 - Traffic Control, blue fire hydrant reflectors (reflective pavement markers) shall be installed at the centerline of the roadway opposite to each fire hydrant.

29.7 WATER SUPPLY

29.7.1 System Requirements

A water supply system separate from a domestic water supply system shall be provided for all automatic sprinkler and standpipe systems.

The adequacy of water supply shall be determined by flow tests or other suitable means. Where flow tests are made, the flow rate in gallons per minute, together with the static and residual pressures, shall be indicated on the plans.

Street mains, that is, the mains from the local municipality supplying water service for fire protection, shall be sized to carry the fire protection water design flow, but in no case shall they have a diameter of less than 8 inches. Where both sprinkler and standpipe systems are served, the building fire main shall not be less than 6 inches in diameter. Where only standpipe systems are served, the building fire main shall not be less than 4 inches in diameter.

No pressure-regulating valves shall be used in fire protection water supply mains. Where such devices are judged to be necessary, the section designer shall obtain special permission from the local authority having jurisdiction. Unless otherwise required by the owner of the water supply system, meters shall not be installed in fire protection water supply mains to DART rail facilities.

Where connections are made to a public water system, it shall be necessary to guard against possible contamination of the public water supply. The requirements of the local jurisdiction shall be met. As a minimum, however, a backflow preventer with detector check shall be provided on fire protection water mains on the discharge (or load) side of the main shutoff valve and immediately inside the building wall.

29.7.2 Fire Pump

As a single source of water supply, an automatically controlled fire pump taking water from a water main of adequate capacity may, under certain conditions, be acceptable to the local authority having jurisdiction.

Where a pump is the only means of supplying water, the pump shall be centrifugal and shall be provided with supervisory service from an approved proprietary system or equivalent. This supervisory system shall provide the means for a positive indication that the pump has operated normally. This arrangement shall be in addition to the supervision of power supply and any other features required by the local authority having jurisdiction.

The fire pump shall be connected to an essential power source or an emergency power generation source, and shall have its own auto-transfer switch. Overload relays to protect the pump motor shall not be provided.

As required by the local authority having jurisdiction, provisions shall be made to test the fire pump on a periodic basis. If hose outlets are provided for this purpose, they shall be located outdoors and their intended use clearly marked. The location and type of testing facility shall be coordinated with the architect.

29.8 FIRE DEPARTMENT CONNECTIONS

One or more connections shall be provided through which the local fire department can pump water into the sprinkler, standpipe, or other system furnishing water for the fire protection system. There shall be no shutoff valve between the fire department connection and the system feed mains.

In each fire department connection line, an approved silent check valve shall be installed. The valve shall be located as close as practicable to the joint where it joins the system.

The sprinkler pipe and standpipe systems between the check valve and the fire department connection shall be equipped with an approved automatic drip arranged to discharge to a proper place. In subway line sections the discharge shall be extended to track level.

The fire hose screw threads for the fire department hose connection shall comply with the local fire department's hose threads.

Fire department connections shall be provided at the access-road side of buildings and shall be located and arranged so that hose lines can be readily and conveniently attached to the inlets without interference with any nearby objects, including buildings, fences, posts, other fire department connections, or street traffic.

Fire department connections shall be designated by a sign having raised letters at least 1 inch in size and cast on a plate or fitting reading "AUTO-SPKLR," "OPEN SPKLR," or "STANDPIPE," whichever is appropriate. The sign shall also indicate the buildings or structures, or parts thereof, served by the connection. The connections shall have a chrome finish. The DART logo shall be cast-in on all siamese connections. The location of fire department connections shall be as indicated on project definition drawings.

29.9 PIPING

29.9.1 Design Requirements

All pressure piping systems shall be designed to meet the requirements of the Code of Pressure Piping (American National Standards Institute (ANSI) B.31). All pipe fittings, flanges, valves, and accessories shall comply with Face-to-Face and End-to-End Dimensions of Valves (ANSI B16.10), all applicable sections, for dimensional requirements. All piping systems shall be designed and arranged for neat appearance, properly sloped for drainage and venting, properly supported, guided, anchored to provide complete flexibility, and designed to maintain the integrity of all systems without any damage or leaks during extreme operating conditions. Unless embedment is unavoidable because of architectural or structural requirements, piping shall be accessible and shall not be embedded in concrete structures. All valves and accessories shall be arranged in a systematic manner in places accessible for operation without the use of chains or additional operating platforms. Valves for drainage shall be provided at all low points of the piping system. For low points in piping in spaces under the station platform, drains shall be extended to trackway area. Valves for such drains shall be provided with signs indicating the intended purpose. Sleeves and escutcheons shall be provided wherever pipes pass through structures.

Corrosion control measures for the piping shall be in accordance with the requirements of Systems Design Criteria Chapter 8 - Corrosion Control and Chapter 9 - Systems Grounding.

29.9.2 Piping Accessories

All piping accessories shall be of sufficient size and provided to assure the trouble-free operation of piping systems. These accessories shall include strainers, vent cocks, drains, liquid flow indicators, tamper switches, and pressure gauges. All piping accessories requiring maintenance or replacement shall be located in accessible places. All dials of gauges and indicators shall be of sufficient size and arranged to be easily seen and read from operating floor levels. Piping expansion joints shall be selected to provide for not less than 150 percent of the calculated traverse. All valves shall be tagged and charted.

29.9.3 Valve Monitoring Requirements

All control valves in water supply piping to the automatic sprinkler and standpipe systems shall be continuously monitored with the use of tamper-proof switches which are Underwriters Laboratories, Inc. (UL) listed and Factory Mutual (FM) approved. The closure of control valve(s) or the removal of switches shall be annunciated to the operations control center, as shown in the applicable standard, directive, and project definition drawings.

Liquid flow indicators (flow switches) shall be provided in building fire main or branch piping feeding sprinkler loops. The operation of fire pumps and the activation of pre-action deluge valves shall be monitored. Except for the maintenance facilities, the detection of water flow to a sprinkler system and the activation of deluge valves for a pre-action dry pipe system shall be annunciated to the OCC as shown in the applicable standard, directive, and project definition drawings. By annunciating all alarms locally, maintenance facility personnel shall monitor their own sprinkler systems.

29.9.4 Insulation and Freeze Protection

Section designers shall analyze wet sprinkler and standpipe systems at each location for possible freezing of water lines. All portions of the wet piping system subject to freezing temperatures shall be insulated, and if required, taped with electric-resistance heat tape. Provisions shall be made to drain the portions of piping subject to freezing. The requirement of freeze protection shall be based on the outdoor ambient air temperature of 0° F.

29.10 PORTABLE FIRE EXTINGUISHERS

Portable fire extinguishers with a minimum rating of 4A: 60B:C, and UL approved shall be provided in accordance with the standard for Portable Fire Extinguishers (NFPA 10) and as modified by these criteria.

Fire extinguishers shall be mounted in cabinets in finished rooms. Extinguishers shall be surface mounted in unfinished rooms. Recessed cabinets in public areas of the station platform and concourse shall be provided for the installation of fire extinguishers. The locations of such recesses shall be as indicated on project definition drawings.

Section designers shall make provisions for installation and shall show on the contract drawings the locations of portable fire extinguishers.

Portable fire extinguishers shall be located in the following areas:

- o Underground Guideways: At cross-passages.
- o Aerial and At-Grade Stations: In ancillary spaces.
- o Underground Stations: At each fire hose location on station platforms and at other locations as required by hazard type and space utilization. The maximum travel distance to the nearest extinguisher shall not exceed 75 feet in public areas.
- o Operations Control Center: Installed throughout. In addition, clean agent fire extinguishers shall be installed in the operations control room, computer room, and the areas protected by FM200 systems.
- o Service and Inspection Facilities: Throughout and at each emergency phone in the facility. Certain shop areas such as welding, battery rooms and paint booths may require special extinguishers to suit specific hazardous conditions. In addition, clean agent fire extinguishers shall be installed in all areas protected by FM200 extinguishing systems.
- o Other locations as required by local codes and safety requirements.

29.11 FM-200 SYSTEMS

29.11.1 Suppression System Description

FM-200 protection systems include those that provide total flooding, with heptafluoropropane, FM-200, to extinguish fire within a hazard area. The system is a fixed installation with equipment designed and installed to provide fire-extinguishing capability for ordinary combustibles. Such systems shall comply with NFPA 2001, *Standard on Clean Agent Fire*

Extinguishing Systems, 2000 Edition, and the manufacturer's installation requirements. The system will provide total flooding of at least a 7 percent FM-200 concentration by volume, in a maximum ten seconds between the dropped ceiling and finished floor at 70 degrees F. At least a six percent design concentration within hazard area will be retained for at least 10 minutes.

A sufficient amount of FM-200 liquid to convert into FM-200 vapor will be provided. When computing the required agent volume several factors shall be considered. These factors include the volume of hazard area; the specific volume of FM-200 vapor; additional quantities of FM-200 required to compensate for uncloseable openings, pipe losses, and nitrogen dilution; forced ventilation, fan coast down time, and damper actuation time; mechanical smoke control systems, if provided; and other special conditions affecting extinguishing efficiency. The amount of agent in the system primary agent supply shall be at least sufficient for the largest single hazard protected or group of hazards to be protected simultaneously. Where required, a reserve agent supply shall consist of as many multiples of the primary agent supply as the authority having jurisdiction considers necessary. Where uninterrupted protection is required, both the primary and the reserve agent supplies shall be permanently connected to the distribution piping and arranged for easy changeover.

In the design of a total flooding system, the characteristics of the protected enclosure shall be considered. The area of uncloseable openings in the protected enclosure shall be kept to a minimum. To prevent loss of agent through openings to adjacent hazards or work areas, openings shall be permanently sealed or equipped with automatic closures. Where reasonable confinement of agent is not practicable, protection shall be expanded to include the adjacent connected hazards or work areas, or additional agent shall be introduced into the protected enclosure using an extended discharge configuration. Forced-air ventilating systems shall be shut down, or closed automatically, where their continued operation would adversely affect the performance of the fire extinguishing system or result in propagation of the fire. Completely self-contained recirculating ventilation systems shall not be required to be shut down. When determining the quantity of agent, the volume of the ventilation system and associated ductwork shall be considered as part of the total hazard volume. Ventilation systems, necessary to ensure safety, are not required to be shut down upon activation of the fire suppression system. Under these circumstances, an extended agent discharge shall be provided to maintain the design concentration for the required duration of protection.

The protected enclosure shall have the structural strength and integrity necessary to contain the agent discharge. If the developed pressures present a threat to the structural strength of the enclosure, venting shall be provided to prevent excessive pressures. Designers shall consult system manufacturer's recommended procedures relative to enclosure venting.

Storage containers and accessories shall be located and arranged so that inspection, testing, recharging, and other maintenance activities are facilitated and interruption of protection is held to a minimum. Storage containers shall be located as close as possible to, or within, the hazard or hazards they protect. Agent storage containers shall not be located where they can be rendered inoperable or unreliable due to mechanical damage, exposure to chemicals, harsh weather conditions, or by any other foreseeable cause. Where container exposure to such conditions is unavoidable then suitable enclosures or protective measures shall be employed. Storage containers shall be securely installed and secured according to the manufacturer's installation manual, and in a manner that provides for convenient individual servicing. Where storage containers are connected to a manifold, automatic means, such as a check valve, shall be provided to prevent agent loss and to ensure personnel safety if the system is operated when any containers are removed for maintenance.

Detection, actuation, alarm, and control systems shall be installed, tested, and maintained in accordance with NFPA 72, *National Fire Alarm Code*, NFPA 70, *National Electrical Code*, or other nationally recognized standards. An adequate and reliable primary, as well as a minimum 24-hour standby, source of energy shall be provided for operation of the detection, signaling, control, and actuation components of the system.

Automatic detection and automatic actuation of the system shall is required. Initiating and releasing circuits shall be installed in raceways. Alternating current (ac) and direct current (dc) wiring shall not be combined in a common conduit or raceway, except ac and dc wiring may be combined in a common conduit or raceway where shielded and grounded. Automatic detection shall utilize smoke detectors located within the protected area and under raised floors.

The detectors shall be cross-zoned so that detection in two zones is necessary for actuation of the FM-200 system. When a single smoke detector from one zone recognizes an alarm condition, the FM-200 control panel shall activate a pre-discharge warning. The operation of a smoke detector in the second zone shall activate appropriate auxiliary devices, such as release of door hold-open devices, shut down of ventilation systems, and the FM-200 discharge warning. Manual operation shall utilize the same sequence as the operation of a single detector from each zone, and shall be designed to discharge the FM-200 system in the same manner.

For FM-200 extinguishing systems, a pre-discharge alarm and time delay, sufficient to allow personnel evacuation prior to discharge, shall be provided. The system shall be design to delay for a pre-determined interval, normally 20 to 30 seconds, before activating the FM-200 discharge. For hazard areas subject to fast growth fires, where the provision of a time delay would seriously increase the threat to life and property, a time delay may be eliminated. Time delays shall be used only for personnel evacuation or to prepare the hazard area for discharge. Time delays shall not be used as a means of confirming operation of a detection device before automatic actuation occurs.

Operating devices shall include agent releasing devices or valves, discharge controls, and shutdown equipment necessary for successful performance of the system. Operation shall be by listed mechanical, electrical, or pneumatic means. An adequate and reliable source of energy shall be used. All devices shall be designed for the service they will encounter and shall not readily be rendered inoperative or susceptible to accidental operation. Devices normally shall be designed to function properly from -20°F to 130°F, or marked to indicate temperature limitations. All devices shall be located, installed, or suitably protected so that they are not subject to mechanical, chemical, or other damage that would render them inoperative.

A means of manual release of the system shall be provided. Manual release shall be accomplished by a mechanical manual release, or by an electrical manual release when the control equipment monitors the battery voltage level of the standby battery supply, and will provide a low battery signal. The release shall cause simultaneous operation of automatically operated valves controlling agent release and distribution. The normal manual control(s) for actuation shall be located for easy accessibility at all times, including at the time of a fire. The manual control(s) shall be of distinct appearance and clearly recognizable for the purpose intended. Operation of any control shall cause the complete system to operate in its normal fashion. Manual controls shall not require a pull of more than 40 pounds, nor a movement of more than 14 inches, to secure operation. At least one manual control for activation shall be located not more than 4 feet above the floor. Where gas pressure from the system or pilot containers is used as a means for releasing the remaining containers, the supply and discharge rate shall be designed for releasing all of the remaining containers. All devices for shutting down supplementary equipment shall be considered integral parts of the system and shall function with the system operation. All manual operating devices shall be identified as to the hazard they protect.

The electrical control equipment shall supervise the actuating devices and associated wiring and, as required, cause actuation. The control equipment shall be specifically listed for the number and type of actuating devices utilized, and the compatibility of the devices shall be listed.

Where pneumatic control equipment is used, the lines shall be protected against crimping and mechanical damage. Where installations could be exposed to conditions that could lead to loss of integrity of the pneumatic lines, special precautions shall be taken to ensure that no loss of integrity will occur. The control equipment shall be specifically listed for the number and type of actuating devices utilized, and the compatibility of the devices shall be listed.

Alarms or indicators, or both, shall be used to indicate the operation of the system, hazards to personnel, or failure of any supervised device. The type (audible, visual, or olfactory), number, and location of the devices shall be such that their purpose is satisfactorily accomplished. The extent and type of alarms or indicator equipment, or both, shall be approved. Audible and visual pre-discharge alarms shall be provided within the protected area to give positive warning of impending discharge. Operation of the warning devices shall continue, after agent discharge, until positive action has been taken to acknowledge the alarm and proceed with appropriate action. Alarms indicating failure of supervised devices or equipment shall give prompt and positive indication of any failure, and shall be distinctive from alarms indicating operation or hazardous conditions.

Abort switches generally are not recommended, however, where provided, the abort switches shall be located within the protected area and shall be located near the means of egress. An abort switch shall not be operated unless the cause for the condition is known and corrective action can be taken. The abort switch shall be of a type that requires constant manual pressure to cause abort. The abort switch shall not be of a type that would allow the system to be left in an aborted mode without someone present. In all cases, the normal and manual emergency control shall override the abort function. Operation of the abort function shall result in both audible and distinct visual indication of system impairment. The abort switch shall be clearly recognizable for the purpose intended.

A means of disconnecting the power to all electrical equipment in the room, except lighting and computer equipment shall be provided at an accessible location at designated exit doors from the rooms or areas. This disconnect shall be installed in accordance with the parameters described in NFPA 75, *Standard for the Protection of Electronic Computer/Data Processing Equipment*, 1999 Edition.

Means shall be provided for ventilation of the decomposition products of FM-200 from the protected areas to the outdoors. Warning and instruction signs at entrances to and inside protected areas shall be provided.

29.11.2 Passenger Stations

Station control rooms and electronic equipment rooms in all subway passenger stations shall be protected by a FM200 system.

29.11.3 Service and Inspection Facilities

Electronic equipment rooms, such as radio repair, telephones, and computers shall be provided with FM200 fire protection systems.

29.11.4 Yard Control Tower

A FM200 fire protection system shall be provided in each control room and electronic equipment room of the yard control tower.

29.11.5 Operations Control Center

A FM200 fire protection system shall be provided for the under-floor areas, the electronic equipment rooms and enclosures, and the operations control rooms in the OCC.

Consoles shall be protected with the associated room and under-floor space. FM200 system protection also shall be provided for all other areas in the OCC containing critical communication and operations control equipment, as well as for tape storage rooms and inverter rooms.

29.11.6 Traction Power Substations

A fire protection system shall not be provided in traction power substations.

29.12 ROUGHING-IN

In buildings and stations that are to be constructed in stages under separate contracts, sleeves and block-outs shall be provided in the early stage structures to accommodate equipment and piping installations by later-stage contractors. The locations and sizes of the sleeves and block-outs shall be accurately dimensioned under structural contracts to facilitate the later-stage equipment and piping installations.

CHAPTER 30 - PLUMBING AND DRAINAGE SYSTEMS

30.1 INTRODUCTION

These criteria describe the functional and design requirements for the facilities plumbing and drainage systems. They are intended to promote uniformity of design and to standardize the type of plumbing and drainage equipment and its location throughout the system.

This chapter covers the facilities plumbing and drainage systems for at-grade, aerial, and subway stations, subway tunnels, yards and maintenance shops, operations control center (OCC), and miscellaneous wayside ancillary spaces. In addition, they prescribe the requirements for sewage systems for human waste and other waste-fluids to the public sewers.

The design of all piping and plumbing pertaining to the fire protection system shall be in accordance with the requirements described in Chapter 29 - Fire Protection Systems.

The design of site drainage for buildings, parking lots, park-and-ride facilities, and for aerial and at-grade portions of the system shall be in accordance with the requirements described in Chapter 7 - Drainage.

30.2 SYSTEM INTERFACES

The design of the plumbing and drainage system shall interface with all appropriate design criteria for all systems.

30.3 CODES AND STANDARDS

The plumbing and drainage systems design shall comply with all applicable local codes of the city and county to which they pertain and with the State of Texas codes. In addition, the plumbing and drainage systems design shall comply with applicable standards and recommended practices of all appropriate organizations. Refer to Appendix 1 for additional information.

Section designers shall consult the codes and publications listed in Appendix 1 and provide plumbing and drainage systems in accordance with the most stringent of the applicable codes and/or industry practices.

30.4 FUNCTIONAL REQUIREMENTS

All plumbing and drainage systems shall be designed for the functional requirements listed in the following two sections.

30.4.1 Water Distribution

Water shall be collected and conveyed from public utility distribution and/or storage points to stations, buildings, and other consumption and service points.

30.4.2 Waste Return

Storm drainage shall be collected and conveyed to the public storm sewer system, and sanitary sewage to the public sanitary sewer system from stations, buildings, and subsurface line sections.

30.5 WATER SERVICE

30.5.1 Potable Cold Water Systems

The domestic water service connection to each facility shall be sized for the total peak demand. The domestic water service connection to each underground station shall be a minimum of 2 inches in diameter. Each service shall have a main shutoff valve and backflow preventer immediately inside the structure wall of station or building. Remote meter reading facilities at street level shall be provided for subway stations and mid-tunnel ventilation shafts.

Stations, mid-tunnel ventilation shafts, and buildings having plumbing fixtures shall be served with water mains sized for the total plumbing fixture demand, plus 10 percent for future expansion. Minimum fixture service requirements as per Uniform Plumbing Code/International Plumbing Code shall be calculated from the following fixture unit values:

Water Closet, flush value	10 fixture units
Urinal, flush valve	5 fixture units
Lavatory	2 fixture units
Service Sink	4 fixture units
Drinking fountain	2 fixture units
Shower	4 fixture units
Hose bibb	3 fixture units
Sink (washup, each set of faucets)	2 fixture units
Sink (washup, circular spray)	4 fixture units

The service requirements of such outlets as cooling tower make-up water, which are likely to impose additional demand, shall be estimated separately and added to the above fixture service requirements to determine the required total service connection capacity.

Water service connection at each facility for fire protection systems shall be separate from that for domestic water systems. Refer to Chapter 29 - Fire Protection Systems for further information.

The domestic water service shall be provided with a pressure reducing valve when city pressure at the lowest point of use inside the structure is higher than 60 pounds per square inch (psi). The pressure-reducing valve shall be generally located on the discharge side of the main shutoff valve immediately inside the building wall, except for deep underground stations, where a pressure-reducing valve shall be located at the lowest level of distribution. Sizing of the domestic water distribution lines shall be based on maintaining uniform pressure at all plumbing fixtures located at the same level, to minimize shock and water hammer, and to maintain a minimum of 15 psi pressure at each flush valve. All pipe lines shall be run in a systematic manner, parallel and at right angles with walls, and properly pitched for drainage. Water hammer arresters shall be provided for long pipe runs, and branches with flush valves. In addition to the main shutoff valve, isolation valves shall be provided in branch lines and for each floor level to facilitate maintenance in individual areas without losing service for the entire facility. Pressure-reducing valves and backflow preventers shall be provided where automatic makeup for heating, ventilating, and air conditioning (HVAC) equipment is connected to the potable water system.

30.5.2 Potable Hot Water Systems

Potable hot water systems for facilities having lavatories, showers, and service sinks shall include water heaters, circulating hot water pumps where required, hot water distribution piping, and pipe accessories. All hot water pipes serving more than a single fixture shall be sized for the simultaneous fixture demand with a minimum pipe size of 3/4 inch. All pipes shall be arranged in a systematic manner, and provisions made for thermal expansion and drainage. All hot water pipes shall be insulated. Isolation valves shall be provided for all branches to facilitate maintenance.

30.6 PLUMBING FIXTURES

Location and type of plumbing fixtures shall be fully coordinated with the architectural requirements. Fixture types are shown on the Standard and Directive Drawings.

30.6.1 Fixtures

Water closets shall be wall-hung, of the siphon-jet, elongated-bowl type, and provided with a flush valve. Urinals shall be wall-hung, of the siphon-jet type, and provided with a flush valve. Lavatories shall be wall-hung. All wall-hung fixtures shall be supported by standard chair supports. Service sinks shall be of stainless steel or monolithic precast terrazzo equipped with a stainless steel rimguard. Water-coolers shall be wall mounted, and shall have bubbler of vandal-proof design. The service sink in the battery room shall be acid-resistant and supplied with a wall hanger, rim-guard, and standard trap. Showers shall have private compartments complete with partitions, receptors, curtain rails and curtains. The wash fountain shall be of precast terrazo, circular or semi-circular and foot-operated with supplies from below, and shall have a vent-off drain, powdered soap dispenser, with chrome finish hardware.

30.6.2 Fixtures for Handicapped Persons

In stations and other facilities having more than one toilet (for each sex), plumbing fixtures in one toilet for each sex shall be installed to accommodate physically handicapped persons in wheelchairs. In stations and other facilities having only one toilet, plumbing fixtures shall be installed to accommodate physically handicapped persons in wheelchairs in accordance with ADA, ANSI handicapped codes and Texas Accessibility Standards.

30.6.3 Hose Bibbs and Box Hydrants

Hose bibbs shall be provided in the following areas: toilet and trash rooms, battery rooms, in the vicinity of the elevator and escalator pits, in at-grade, aerial, and subway station platforms, at station entrances, and in the concourse areas of stations and other areas where periodic cleaning is required. For station platform areas, a 3/4-inch hose bibb as close as practicable to the centroid of each platform, and additional hose bibbs as required, shall be provided so that any point of the platform (excluding the trackway) is not more than 75 feet from a hose bibb. All hose bibbs inside buildings and subway stations with side platforms shall be installed in walls in stainless steel boxes with flanges flush with the wall. All exterior hose bibbs shall be installed in exterior walls in brass boxes with flanges flush with the wall. Hose bibbs for at-grade and aerial stations and subway stations with center platforms shall be brass box hydrant type and shall be installed in platforms with flanges flush with the finished floor. All exterior hose bibbs and box hydrants in unheated areas shall be a non-freeze type. Hose bibbs in battery rooms shall have an acid-resistant finish.

30.6.4 Water Supply

All water supplies to fixtures in public areas shall have key-operated service valves. Each connection shall be designed for the pressure as recommended by the fixture manufacturer, but not less than 15 psi for flush valves and not less than 8 psi for other fixtures. Water supply to lavatories and flush-valve fixtures shall have water-shock-absorbing provisions. Vacuum breakers shall be provided on all outlets with hose bibb connections and submerged inlets.

30.6.5 Plumbing Fixture Connections

All services and piping connections for plumbing fixtures shall be selected according to Table 30-1.

TABLE 30-1

SERVICES AND PIPING CONNECTIONS FOR PLUMBING FIXTURES

(All dimensions are inches)

Fixture	Fixture Symbol	Soil or Waste	Trap Size	Vent Pipe	HW Pipe	CW Pipe	Remarks
Water Closet	P-1	4	Integral	2	no	1	Wall Mounted
Urinal	P-2	2	1-1/2	1-1/2	no	1/2	Wall Mounted
Lavatory	P-3	2	1-1/4 x 1-1/2	1-1/2	3/8	3/8	Wall Mounted
Mop Service Basin	P-4	3	3	1-1/2	1/2	1/2	Floor Mounted
Drinking Fountain	P-5	1-1/2	1-1/4 x 1-1/2	1-1/2	no	3/8	Wall Mounted
Hose Bibb	HB	no	no	no	no	3/4	Flush with Walls
Floor Hydrant	FH	no	no	no	no	3/4	Flush with Floors
Floor Drain	FD	3 minimum	3	1-1/2	no	*	
Eye Wash/Body Shower	P-6	3	no	no	no	1-1/4	

* Primed traps shall be provided where judged to be necessary and as required by local codes.

30.7 DOMESTIC WATER HEATERS

Domestic water heaters of 30 gallons or less capacity shall be electric and shall not have water softeners. Above 30 gallons capacity, all water heaters shall be a natural gas fired type if natural gas is available. Where natural gas is not conveniently available, such as underground facilities, the water heaters may be electric regardless of capacity. Water heaters shall be properly sized for the plumbing fixture demand and shall be Underwriters Laboratories, Inc. (UL) listed and bear the American Society of Mechanical Engineers (ASME) stamp of approval. Dielectric couplings shall be provided between dissimilar metal piping connections. The requirements for water softeners and their type shall be determined by the source water quality.

30.7.1 Gas Fired Water Heaters

All gas fired water heaters shall be of storage type, with approximately 100°F recovery capacity sized for the demand of plumbing fixtures to be served by each heater. Heaters shall be provided with electronic ignition. Heaters shall be glass-lined and equipped with temperature and safety controls, a temperature and relief valve, and thermal insulation. Where judged to be necessary, a hot water return pump shall be provided for circulation. The operation of the hot water return pump shall be controlled with an aquastat located in the hot water return piping, immediately before the heater.

30.7.2 Electric Water Heaters

Electric water heaters with a capacity of 10 gallons or less shall be the instantaneous type. All electric water heaters with a capacity above 10 gallons shall be the storage type, with approximately 100°F recovery capacity sized for plumbing fixture demand served by the heater. Heaters shall be glass-lined and equipped with fast acting dual element immersion heating, temperature and safety controls, a temperature and relief valve, and thermal insulation. Units with heating elements of 2,900 watts or less shall be suitable for a 120 volt/1-phase power supply. Units with heating elements of 5,500 watts or less shall be suitable for a 208 volt/1-phase power supply, if available. Units with heating elements above 5,500 watts shall be suitable for a 480 volt/3-phase power supply, if available. Where judged to be necessary, a hot water return pump shall be provided for circulation. The operation of the hot water return pump shall be controlled with an aquastat located in the hot water return piping immediately before the heater.

30.8 EYEWASH FACILITIES

Emergency eyewash facilities shall be provided within, or immediately adjacent to, each battery room.

In passenger stations and other buildings with water service, each battery room located more than 25 feet from any water outlet (such as lavatory, drinking fountain, or hose bibb) shall have one wall-mounted emergency eye-and-face-wash fixture, with bowl, connected to the cold-water piping system and with a direct drain to the sanitary sewer system. No separate floor drain is required. Where compliance with this criterion necessitates an extension of more than 150 feet of either cold-water piping or waste pipe, the capability for eye lavage may be provided by a portable eyewash apparatus. Where the battery room is located in a facility without water service, the capability for eye lavage shall be provided by a portable eyewash apparatus. In addition, a portable eyewash of 32 ounce capacity shall be provided in each battery room.

30.9 DRAINS

All floor, area, and roof drains shall be of bottom outlet type wherever possible. Where space is not adequate to use bottom outlet drains, drains with side outlet may be substituted. All drains used in membrane waterproof floors and roofs shall be provided with flashing collars securely clamped to the waterproof membranes or flashing. Floor drains in public areas shall be bronze or stainless steel finish. Finish is to be determined by floor material, which must be coordinated with the architectural requirements. Floor drains in public spaces shall be installed with vandal-proof screws.

30.9.1 Floor Drains

Floor drains shall be provided at building and station entrances, underneath walk-off mats, in escalator and elevator pits, in emergency exit stairwells, in toilets, trash rooms, and custodial rooms, and in all ancillary rooms in at-grade, aerial and subway stations and subsurface line sections. Drainage provisions at station main entrances, building entrances, as well as approach areas of elevators and escalators at at-grade level, shall be of trench-drain type. Drains shall be provided in all ancillary rooms and spaces having automatic sprinklers. Primed traps shall be provided where judged to be necessary or required by local codes. Floor drains in battery rooms shall be acid resistant and drain into a neutralizing pit. Floor drains in spaces beneath station platforms, ventilation shafts, ventilation grating areas, and other areas subject to clogging shall have bronze dome strainers.

Floor drains shall be provided immediately beneath all hose bibbs located inside buildings and subway stations. Station platforms that have a slope toward the trackway of at least one percent do not require floor drains beneath the hose bibbs. Platforms with a lesser slope shall be provided with a floor drain immediately beneath each hose bibb.

30.9.2 Area Drains

Area drains shall be provided at station and building entrance areas and emergency exits, exterior elevators, and escalators.

30.9.3 Roof Drains

Roof drainage systems shall be designed to handle the rainfall intensity for 100-year frequency.

Roof drains shall be of cast iron, copper, or other approved corrosion-resistant material. Roof drains passing through the roof into the interior of a building shall be made watertight at the roof line by the use of a suitable flashing material. Refer to architectural standards for details.

Roof drains shall be equipped with strainers extending not less than 4 inches above the roof surface. Drains shall have a minimum inlet area 1-1/2 times the area of the pipe to which they are connected.

Roof deck drain strainers for use on parking decks and similar occupied areas may be of an approved flat-surface type which is level with the deck. Such drains shall have an inlet area not less than 2 times the area of the pipe to which they are connected. The strainers shall be suitable for the anticipated maximum traffic load.

30.9.4 Trackway Drains

Trackway drains inside subway stations, subsurface line sections, shop aprons at doors, and at portals shall consist of concrete drainage slots, concrete catch basins, and concrete manholes with cast-iron gratings. No traps or vents shall be provided for the track drainage system. Trackway drains need to be coordinated with Track Designers and Civil Engineers.

30.10 TRAPS

All traps shall be of plain pattern having a seal of not less than 2-1/2 inches and not greater than 4 inches. All traps shall be of the same material as that for the piping system to which they are connected. All exposed traps in toilet rooms shall have chrome finish. Trap primers shall be provided where floor drains are not used frequently and as required by local codes.

All floor drains connected to the sanitary sewer system shall be provided with a trap. A building or house trap with cleanout shall be provided at the building drain before connection to the building sewer.

30.11 CLEAN-OUTS

Clean-outs shall be provided on all soil, waste, and drain lines for each pair of 45-degree bends, for each 90-degree bend, and for each 50 feet of straight run, except track drainage for which maintenance of the drainpipes will be through the catch basins. All clean-outs brought to finished floors shall terminate with removable cleanout brass covers at paver tile floors, or stainless steel cover on concrete floors, flushed with the floor. Clean-outs shall be the same size for 2-1/2" and smaller pipes; and a 3" cleanout for 3" to 4" pipes; and a 3-1/2" cleanout for larger pipes. No floor clean-outs in public areas shall be provided. Floor clean-outs from public areas shall be extended to nonpublic areas.

30.12 SOIL AND WASTE SYSTEMS

The soil and waste system for facilities shall include soil and waste piping from all plumbing fixtures and floor drains, sewage ejector stations, and ejector discharge piping for subway stations. All soil and waste pipes shall be sized for fixture demand, and as required by applicable plumbing codes and ordinances.

30.13 VENT SYSTEMS

Complete vent systems shall be provided for all soil and waste systems and sized in compliance with applicable plumbing codes and ordinances. All horizontal vent pipes shall be kept as short as possible, pitched at 1/4 inch per foot toward soil and waste pipes, then rise to the outside in the most direct way. Each vent riser shall be properly flashed at roof penetration. Vent risers terminating in planting areas at street level shall be provided with vandal-proof and rodent-proof caps.

30.14 SEWAGE EJECTION SYSTEMS

Consideration shall be given to performance, noise, durability, standardization, and handling characteristics when selecting equipment for the sewage ejection systems. All equipment selected for the sewage ejection systems shall be manufacturer's standard products suitable for competitive bidding. For corrosion control requirements refer to Systems Design Criteria Chapter 8 - Corrosion Control and Chapter 9 - Systems Grounding.

30.14.1 Ejector Stations

Subway stations and other subsurface facilities having toilets shall be provided with sewage ejector stations. Sewage ejector stations shall be of electric duplex vertical centrifugal wet pit sump pumps or pneumatic type using duplex ejector units (see Sections 30.17.6 and 30.17.7). Wet sump systems are preferred over pneumatic ejector systems. Prior DART approval is required for pneumatic ejector systems. Each pneumatic ejector unit shall be equipped with a cast iron sewage receiver, an air-cooled air compressor, interconnecting air piping and controls, sewage inlet and discharge piping with corrosion resistant check valves and isolation valves, air exhaust piping and controls, mechanical level controls, electric controls, and interlocks for the air compressor. All interconnecting air piping, control valves, sewage inlet and discharge valves, piping, and accessories shall be supplied by the ejector equipment manufacturer in subassemblies for field installation.

30.14.2 Ejector Size and Capacity

The size and capacity of each ejector shall be based on the total load and dynamic head calculated for one ejector unit operating. The minimum size of any unit shall be 30 gallons per minute (GPM) capacity with 4 inches minimum sewage discharge line. Each pneumatic ejector unit shall operate automatically from local mechanical level controls and shall be provided with means to be supervised from the OCC. Air exhaust piping shall be 2 pipe sizes larger than the exhaust valve size, or 2 inches minimum, and shall be vented to the atmosphere.

30.14.3 Receiver

Receivers for pneumatic ejectors shall be cast iron and shall be designed for a working pressure of 200 psi. They shall be hermetically sealed and provided with a minimum 16-inch manhole in the top cover plate.

30.14.4 Air Compressor

Air compressors for pneumatic ejectors shall be of the positive displacement type and shall be air cooled. The compressor control shall be independent of the ejector operation.

30.14.5 Air Storage Tank

Air storage tanks for pneumatic ejectors shall be of welded steel, shall conform with ASME requirements and bear the ASME stamp, and shall be equipped with drain valve, pressure relief valve, pressure gauge, and low pressure alarm with provisions for remote indication.

30.14.6 Electrical Characteristics

Motors for pneumatic ejectors shall be of the drip-proof type, and shall be non-overloading at normal operating conditions. Motors 1/2 horse power (HP) and smaller shall be suitable for 120 volts, single-phase. Motors larger than 1/2 HP shall be suitable for 480 volts three-phase. Magnetic starters shall be of the across-the-line type in National Electrical Manufacturers Association (NEMA) 4 enclosures. Selector switches shall be of the hand-off-automatic type. An adjustable automatic pressure switch and circuit-breaker shall be provided. A disconnect shall be located adjacent to the motor, within line of sight.

30.14.7 Ejector Discharge

Ejectors shall discharge to the nearest sanitary sewer and shall have a minimum diameter of 4 inches. Discharge velocity shall be 2-1/2 feet-per-second minimum, and 7 feet-per-second maximum. Check and gate valves shall be provided in discharge piping from the ejector units. Connections to discharge header shall be made with Y-connections.

30.14.8 Level Control

Level control for pneumatic ejectors shall be of the mechanical type. A local high-level alarm and provisions for remote indication of high water condition shall be provided.

Where units are installed in a concrete pit, the depth of each shall be selected to allow the upper-flanged opening on the sewage receiver (the opening provided for the mechanical level control) to project above the rim of the pit. All automatic control devices, valves, and accessories requiring maintenance or replacement shall be located above the rim of the ejector pit.

30.14.9 Sewage Return Sump Pump

The bottom of the pneumatic ejector pit shall be sloped to one corner where a sump and a submersible centrifugal sump pump shall be provided to return any leakage back to the sewage discharge pipe. The sewage return sump pump shall be controlled automatically by a mechanical float and through a local "on-off-automatic" switch.

30.15 GREASE, OIL, AND SAND INTERCEPTORS

Grease, oil, and sand interceptors shall be provided as required by environmental standards for effluent to public waters. Interceptors shall conform to all local codes that govern the installation.

Floor drainage systems serving maintenance shops, vehicle storage areas and non-revenue vehicle wash areas shall be provided with oil and grease separators, and sand traps for extraction of oil, grease, sand, and other substances that are harmful or hazardous to the structure or to public drainage systems. Separators and traps shall have sufficient capacity to retain all sludge between cleanings.

30.16 DRAINAGE

The criteria of this section pertain to the design of subway drainage facilities. The following shall apply:

- o Invert elevations and the location of drainage facilities at the interface between contract units shall be coordinated with related section designers.
- o To the best extent possible, drainage shall be by gravity flow. Where collection points are below the elevation of gravity outfalls, pumping stations shall be provided.

- To the best extent possible, surface drainage (except from platforms and seepage water in subway stations and tunnels) from entrances, ventilation shafts, and similar openings, shall not be conveyed to the trackway drainage systems. This drainage shall be intercepted before it enters into the track drainage system and diverted to the public sewer system in accordance with the requirements of Chapter 7 - Drainage.

- No sanitary sewage shall be permitted to enter the track drainage system.

30.16.1 Location of Drains

- Drainage pumps shall be provided at all low points that cannot be drained by gravity.

- In subsurface line sections, invert drainage slots shall carry drainage to pumping stations at the low point. Drainage slot inlets or sumps shall be provided at a maximum interval of 300 feet so that the drainage inlet spacing also satisfies the spacing requirements for cleanouts or manholes.

- In stations, drainage slot inlets or sumps shall be provided at a maximum interval of 100 feet along each trackway.

- Gravity drainage from the low point in the space under platforms shall be provided and shall be connected to the storm or track drainage system. Where a wall divides the space under the platform, sleeves shall be provided through the wall, at the top of the base slab, to permit inter-space flow to the low point.

- Where gravity drainage from the low point in the spaces under platforms to the storm or track drainage system is not possible, the drainage shall be collected in a sump. These sumps shall be equipped with automatic duplex sump pumps and check valves to discharge the collected drainage into the storm or track drainage system. A backwater valve shall be provided in the pump discharge line immediately at the connection to storm or track drainage system.

- Where the provision for gravity drainage to the sanitary drainage system with oil interceptor is impractical, a drainage sump 24 inches square by 18 inches deep, without outlet, shall be provided in each escalator pit, elevator pit, and elevator machine room. Provisions shall be made for inspection and periodic emptying by means of portable pump.

- Clean-outs shall be provided at maximum intervals of 50 feet along all drainage lines, except track drainage. A clean-out shall be provided for each 90-degree bend and for each two 45- degree bends.

30.16.2 Drainage Fittings

The following fittings shall be provided:

Manhole Frame and Cover. A manhole frame and cover shall be provided at each access to the main track drain.

Drain Inlet. A drain inlet, made of cast iron grating, shall be provided at each drainage inlet, with a connection to the main track drain.

Scupper Drain. A scupper drain shall be provided at the drain inlet from fan shafts and vent shafts.

Clean-Out. Clean-outs with cover shall be provided where access to the drainage piping is required for clean-out purposes, and at prescribed intervals.

30.16.3 Drainage Piping

Piping for drainage systems shall be provided as follows:

- Drainage piping for both the open-track and subsurface sections shall be designed according to the requirements as prescribed below.

- The following lists drainage pipe sizes, materials, and uses:

Diameter (inches)	Material	Use
4	Extra-heavy-weight cast iron	Drain connections in structural walls and floors
6	Extra-heavy-weight cast iron	Drain connections in structural walls and floors
6	Extra-heavy-weight cast iron underground	Branch connections in structures and

8	Polyvinyl chloride (PVC) sewer pipe schedule 80	Station track drain and subsurface line track drainage
10	PVC sewer pipe schedule 80	Station track drain and subsurface line track drainage

30.16.4 Drainage Volumes

The volumes of water to be handled by each system shall be as required by Chapter 7 - Drainage.

30.16.5 Grades

Drainage piping shall have the following minimum grades:

Pipe Diameter (Inches)	Minimum Grade
4	2.0 percent or 0.25 inch per foot
6	1.0 percent or 0.125 inch per foot
8	1.0 percent or 0.125 inch per foot
10	1.0 percent or 0.125 inch per foot

For the design of main drains, the section designer shall consider the economics of increasing the size of the drain line to permit as close a correlation as possible between the drain profile and the top of the rail profile.

Main drain lines shall be designed in such a manner that the grades produce a minimum velocity of 2.5 feet per second with the pipe flowing 50 percent full.

30.16.6 Sanitary Facilities

All drains from mop sinks, lavatories, water closets, and other miscellaneous drains/sanitary waste shall be run by gravity where feasible to existing public sanitary sewers. If a gravity run cannot be accomplished, drains/sanitary waste lines shall be run to sewage ejector pits equipped with pneumatic duplex ejector pumps or a sump equipped with non-clog duplex vertical centrifugal wet pit sump pumps. The discharge shall then be pumped to the nearest public sanitary sewer line(s).

For corrosion control requirements refer to Systems Design Criteria Chapter 8 - Corrosion Control and Chapter 9 - Systems Grounding.

30.16.7 Pumping Stations

Each track drainage or sewage sump pump station shall consist of a concrete wet well with two non-clog vertical centrifugal wet pit pumps, or a wet well with two submersible pumps. In addition, a seepage water (interceptor) pump at each track drainage pumping station shall be provided. Water level controls shall be provided with remote indication of high water condition, electric pump "on-off-automatic" switch, lead lag control, electric alternators, level rise indicator, and connections to street mains.

Pump Type. Sump pumps shall be fully sealed to exclude moisture, abrasive materials, corrosive gases, and all other matter that may contribute to wear. Pumps shall be the non-clog sewage, vertical centrifugal or submersible, wet basin type. Impellers shall be grinding type, with clearance adequate to pass 3-inch solids.

Pump Capacity. Each pump shall have a capacity equal to 100 percent of the calculated drainage volume including infiltration and seepage. The minimum capacity of each track drainage pump in pumping station at the low point shall be 500 GPM; the minimum capacity of each seepage water or interceptor pump at the low point in the track drainage system shall be 150 GPM.

The minimum capacity of each sewage sump pump shall be 30 GPM with 4 inches minimum sewage discharge line.

Pump Head. The pump head (total dynamic head) shall suit the static and friction heads of each installation; the friction head shall be calculated with two pumps operating. In determining the pump head, an investigation of existing sewers shall be made. If the existing sewer is liable to be overcharged, the pump discharge shall be increased to exceed the overcharge head.

Electric Motors. Motors shall be nonoverloading at any point of pump curve. Motors for trackway drainage pumps shall be of explosion-proof construction.

Motors 1/2 HP and smaller shall be suitable for 120 volts, single-phase power supply. Motors larger than 1/2 HP shall be suitable for 480 volts three-phase power supply.

Level Control. Level controls shall be mechanical or electrical type. A local high-water alarm and provisions for remote indication of high-water condition shall be provided. Provisions for manual testing of such level controls shall be located adjacent to pump controllers.

Piping. Pump connections to discharge header shall be made with Y-connections or lateral. A check valve and gate valve shall be provided in each pump discharge line. Provisions shall be made by automatic ball drip or motorized valve to drain the standing water from the discharge line back into the sump after the pumps are deenergized, in order to prevent freezing.

30.17 VALVES

Isolation valves shall be provided on both sides of each water heater, on each pressure main at buildings and at stations, on each branch of distribution mains, at each plumbing fixture (except where several units are installed in a battery, for which one isolation valve shall be adequate), on both sides of in-line accessories, and on equipment that requires removal or isolation from pressure for maintenance. All valves for water and compressed air shall be made of bronze, with screwed ends for up to 2-inch sizes, and with flanged ends for 2-1/2 inches and larger sizes. Valves shall be tagged and charted.

30.18 PIPING

30.18.1 Design Requirements

All pressure piping systems shall be designed to meet the requirements of the Code of Pressure Piping, American National Standards Institute (ANSI) A21, B31 and B125, in all applicable sections. All pipe fittings, flanges, valves, and accessories shall comply with the requirements of ANSI B16, in all applicable sections, for dimensional requirements. All piping systems shall be designed and arranged for neat appearance, properly sloped for drainage and venting, properly supported, guided, and anchored to provide complete flexibility, and to maintain the integrity of all systems without any damage or leaks during extremes of operating conditions. Piping shall be accessible and shall not be embedded in concrete structures unless embedment is unavoidable because of architectural or structural requirements. Embedded piping shall be provided with adequate cleanouts or access points. Piping in public areas of stations shall not be exposed. All valves and accessories shall be arranged in a systematic manner in places accessible for operation without the use of chains or additional operating platforms. Where necessary to install valves above 6 feet, they shall be chain operated. Sleeves and escutcheons shall be provided wherever pipes pass through structures. Battery room drainage piping shall be acid resistant and flow through neutralizing tanks prior to merging with sanitary mains. The requirements for exterior piping beyond 5 feet of the building line are described in Chapter 6 - Utilities. Corrosion control measures shall be provided in accordance with the requirements prescribed in Systems Design Criteria Chapter 8 - Corrosion Control and Chapter 9 - Systems Grounding.

30.18.2 Piping Accessories

All required piping accessories shall be of sufficient size and provided to assure trouble-free balancing, control, access, and operation of all piping systems.

These accessories shall include, but not be limited to: strainers, vent cocks, dirt and drip legs with drain and flush connections, liquid flow indicators, vacuum breakers, backwater valves, backflow preventers, pressure reducing valves, shock absorbers and water-hammer arresters, drain and drip legs for gas and compressed air systems, moisture traps for compressed air systems, balancing cocks, relief valves, isolation valves, and pressure and temperature gauges. All piping accessories requiring maintenance or replacement shall be located in accessible places. All dials of gauges and indicators shall be of English or English/International System of Units (SI) units of measurement and shall be of sufficient size and arranged to be easily seen and read from operating floor levels. Piping expansion joints shall be selected to provide for not less than 150 percent of the calculated traverse movements. All valves shall be tagged and charted.

30.18.3 Pipe and Fittings

All station track drainage and subsurface line track drainage pipes shall be PVC sewer pipe. All waste and soil pipes shall be service-weight cast-iron pipe with bell and spigot fittings. Soil pipe from fixtures shall have a slope of 0.25 inch per foot (2 percent slope) in the direction of flow, except that soil pipe running the length of the station shall have a slope of 0.125 inch per foot (1 percent slope) in the direction of flow.

Vent pipes shall be galvanized steel threaded pipe, service-weight cast iron pipe with bell and spigot fittings or hubless, properly pitched, and shall exit the structure.

Cold-water piping embedded in structures shall be hard-drawn copper tubing type "K"; all other hot- and cold-water piping shall be hard-drawn copper tubing type "L" with wrought brass or copper fittings. Copper tubing type "K" and "L" shall be as per American Society for Testing Materials (ASTM) B88.

Force mains shall be of ductile iron pipe with joints of a type approved by the local authority having jurisdiction.

Water service piping shall be ductile iron with dual mechanical-joint type for pipe 2 inches and above, and type 'K' copper with wrought fittings for pipe sizes less than 2 inches.

Hose bibbs shall be provided with integral vacuum breaker. Hose bibbs in public areas shall be installed in recessed boxes, operated with keys. Hose bibbs in areas subject to freezing temperatures shall be non-freeze type. Hose bibb boxes shall be coordinated with the architectural requirements.

The minimum diameter of waste pipe installed underground or embedded in structural slabs shall be 4 inches.

Dielectric couplings shall be provided for the connection of pipes of dissimilar metals and in all metallic piping entering a facility.

30.19 INSULATION AND FREEZE PROTECTION

30.19.1 Insulation

The following piping shall be insulated:

- o Hot water piping.
- o Portions of all water piping subject to freezing temperatures.
- o Portions of drainage and cold water piping subject to sweating.

30.19.2 Freeze Protection

Designers shall analyze the piping installation at each station and other unheated spaces for possible freezing of water lines during winter months. Requirement for freeze protection shall be based on outdoor ambient air temperature of $0^{o}F$. If required, electric-resistance tape shall be provided in addition to insulation. Provisions shall also be made to drain the portions of piping subject to freezing temperatures. Drains provided at low points in water lines installed in spaces under station platforms shall be extended to trackway area so that they are easily accessible. Each drain shall have a valved connection.

30.20 EQUIPMENT HANDLING

Provisions shall be made in the form of monorail, guide rail, lifting hooks, and removable panels for the installation and removal of pumping equipment. Structural openings shall be sized so that each complete factory-built item of equipment can be installed without disassembly or special construction.

30.21 VIBRATION ISOLATION

All equipment that produces vibrations shall be isolated from the structure by vibration isolators. All piping attached to rotating equipment shall be isolated from such equipment by flexible connections. Inertia blocks shall be provided as required.

30.22 ROUGHING-IN

In stations and buildings that are to be constructed in stages under separate contracts, sleeves and block-outs shall be provided in the early stage contracts to accommodate plumbing fixtures and piping installations by later-stage contractors. The locations and sizes of the sleeves and block-outs shall be accurately dimensioned for the structural contracts to facilitate the subsequent plumbing fixtures and piping installations under later-stage contracts. Sleeves shall be 2 inches larger than proposed pipe diameter.

CHAPTER 31 - ELEVATORS AND ESCALATORS

31.1 INTRODUCTION

These criteria describe the functional and design requirements for elevators and escalators that will be furnished and installed under a separate systemwide systems contract.

These criteria are intended to familiarize the section designer with the type of elevators and escalators to be provided, and to emphasize the importance of the coordinating efforts required to facilitate their installation during the execution of facilities contracts.

These criteria cover the elevators and escalators for aerial and subway stations, the operations control center (OCC), and other similar facilities and structures throughout the system. The design of elevators and escalators shall interface with design criteria for all related systems. Support functions will be included in the procurement specification. These include quality assurance, manuals, maintenance program, reliability, availability, maintainability, and safety.

31.2 CODES AND STANDARDS

The design of elevators and escalators shall comply with all local codes of the city and county to which they pertain, as well as with the State of Texas codes. In addition, the design shall comply, unless otherwise prescribed, with industry standards and recommended practices. (Refer to Appendix 1 for applicable codes and industry standards.)

The section designer's attention is directed to the requirements of the National Fire Protection Association (NFPA) Standard 130 (latest edition), <u>Standard For Fixed Guideway Transit Systems</u>. In addition, the section designer's attention is directed to the American National Standard Safety Code for Elevators, Dumbwaiters, Escalators, and Moving Walks, American National Standards Institute (ANSI)/American Society of Mechanical Engineers (ASME) A17.1-1981, and Supplements ANSI/ASME A17.1a-1982, ANSI/ASME A17.1b-1983, 1984, 1985, 1986.

The section designer shall consult the applicable codes and publications listed in Appendix 1, and provide the interface facilities for elevators and escalators in accordance with the most stringent of codes and industry practices.

31.3 VERTICAL CIRCULATION ELEMENTS

All vertical circulation elements shall be designed to meet the requirements imposed by considerations of fire safety and patronage. The requirements for stairs, walkways, and ramps are described in Chapter 21 - Station Functional Requirements and Chapter 23 - Architecture of Operations and Maintenance Facilities.

31.4 COORDINATION REQUIREMENTS

The location of elevators and escalators will be shown on the project definition drawings.

31.5 ELEVATORS

31.5.1 Design and Location

Elevators shall be fully automatic, hydraulically operated. The rated capacity of each elevator shall be 3,500 pounds to accommodate wheelchairs, stretchers for emergencies, or maintenance equipment. The minimum speed shall be 125 feet per minute (FPM). **(Note: These criteria will be revised to include electric elevators should they be required.)**

Elevators shall be provided between each platform and street level, or between each platform and the mezzanine and between the mezzanine and the street. Elevators at street level shall be located near a passenger vehicle loading zone. In stations with parking facilities, elevators shall be located near the parking for the handicapped. Elevator and escalator locations will be indicated on the preliminary design drawings.

Overall cab dimensions shall be a minimum as required by the Texas handicapped code and ANSI. Controls shall be located to satisfy the ANSI handicapped standards.

31.5.2 Elevator Casings and Guide Rails

Casings. Casings shall be structural steel piling pipe. Casing bottoms shall be closed and waterproofed. Casing length shall be as required based on length of travel and additional safe distance, per standard industry practice. See Systems Design Criteria Chapter 8 - Corrosion Control for additional corrosion protection measures.

Guide Rails. Guide rails shall be standard steel tees conforming to ANSI/ASME A17.1. Guide rails shall be securely fastened to hoistway framing. The car stile shall be fitted at top and bottom with adjustable-swivel guide shoes. Buffers shall be spring type conforming to ANSI/ASME A17.1.

31.5.3 Hoisting Equipment

Construction. The jack unit shall be designed according to the requirements of ANSI/ASME A17.1. It shall be of sufficient size to lift the gross load to the height specified and shall be factory tested to demonstrate adequate strength and freedom from leakage.

__Jack Unit Protection__. The casing shall be double wrapped with an approved coating designed to protect it from electrolytic and chemical corrosion. Underground piping shall be similarly protected. See Systems Design Criteria Chapter 8 - Corrosion Control for additional protection measures.

__Wiring__. All wiring shall be furnished and installed in the hoistway in accordance with the National Electrical Code (NEC) and with applicable chapters of these criteria.

31.5.4 Signal Equipment

__Alarm Bell__. An emergency alarm bell shall be provided in conformance to the requirements of ANSI/ASME A17.1 and shall be connected to a plainly marked pushbutton in the car operating panel.

__"Door Open" Bell__. A "Door Open" bell shall be provided on the car. It shall be connected to the direction buttons in the car and landing pushbutton stations. The bell shall ring when any button is pressed if any door is open.

__"In Use" Lights__. Each landing station shall contain "In Use" signal lights to indicate that the car is in motion and that it cannot be called until it has completed the registered call, at which time the signal light will be extinguished and the car will be available to answer the next call registered. Car and landings shall be equipped with illuminated pushbuttons.

31.5.5 Communication Equipment

A pushbutton-activated intercom-type system shall be provided in each elevator cab for use by the public and Dallas Area Rapid Transit (DART) employees. The phone equipment shall be fully recessed in cab panels and located to provide communication capability between the operations control center (OCC) and the elevator cab. The communication system shall become active with momentary pressure on the pushbutton. For specific guidance, refer to Systems Design Criteria Chapter 5 - Communications.

31.5.6 Power Unit

__Oil Pumping and Controls__. The oil pumping and control mechanism shall be of compact design with all of the components combined in a self-contained unit.

__Pump__. The pump shall be designed for oil-hydraulic elevator service. It shall be of the positive displacement type, designed for steady discharge with minimum pulsations to give smooth and quiet operation.

Motor. The motor shall be designed for oil-hydraulic elevator service and of duty rating to comply with specified speeds and loads. The motor shall be designed for operation from a nominal 480 volt, 3-phase, 60 hertz (Hz) power source.

Oil Control Unit. The electric controller shall be of the magnetic type or solid state integrated circuitry. Silver-to-silver contacts shall be used on all relays and contactors. Overload relays shall be provided to protect the motor in each phase.

31.5.7 Failure Protection

The electrical control circuit shall be designed so that if a malfunction should occur due to motor starter failure, low oil volume or loss of pressure in the system, or the car failing to reach a landing in the up direction within a pre-determined time, the elevator car will automatically descend to the lowest terminal landing. The doors will automatically open when the car reaches that landing to allow passengers to depart. The doors will then automatically close and control buttons, except the "door open" button in the car station, shall be made inoperative. A car top inspection station with an "Emergency Stop" switch and with constant pressure "up-down" direction buttons shall make the normal operating devices inoperative and give the inspector complete control of the elevator.

31.5.8 Cars and Entrances

Platforms. The platform shall have a frame of structural steel shapes, gusseted, and rigidly welded. A ceramic tile finish flooring shall be provided on top of the car platform. The underside of platform shall be fireproofed.

Car Enclosures. The elevator cab shall be of a design developed especially for DART needs and architectural requirements. Details of the cab design will be shown on the architectural standard drawings.

Car Light. Flourescent light fixtures shall be furnished in the car above the ceiling and shall be recessed type. The light shall be controlled by a key-operated switch in the car operating panel.

Doors. The car entrance shall be provided with horizontal sliding doors. Doors shall be hung on sheave hangers with tires running on a track and guided at the bottom by nonmetallic shoes sliding in threshold groove. Hoistway doors shall be installed at each landing. Car and hoistway doors shall be operated simultaneously. Door movements shall be electrically controlled and cushioned at both limits of travel, and the door operating mechanism shall be arranged for manual operation in event of power failure. The leading edge of the car door shall have a retractable reversal edge arranged to automatically return the car and hoistway doors to the open position if the doors are obstructed during the closing cycle. Doors shall then resume closing cycle. Doors shall automatically open as the car arrives at the landing and shall automatically close after an adjustable interval or when the car is dispatched to another landing.

31.5.9 Operation

Operation shall be "selective-collective" automatic pushbutton without attendant.

The elevator shall be controlled automatically by pushbuttons in the car numbered to correspond to floors served, for registering car stops and by "Call" pushbuttons at landings.

When a call is registered by momentary pressure on any car or hall button, the button shall become illuminated and shall dispatch the operated car if all car and hoistway doors are closed. The car shall travel to its destination in the direction chosen without interference.

After the car has been placed in motion, all other pushbuttons (except "Emergency Stop") shall become inoperative until the car has reached its designated landing.

An adjustable time delay, non-interference feature shall be incorporated in the control circuit to allow ample time for opening the car and hoistway doors before the car can be dispatched to another landing.

An emergency stop switch shall be provided in the car pushbutton station which, when in the off position, will render the elevator inoperative, and which will enable the passenger to stop the car at any point during its travel.

Automatic Terminal Limits. Electric limit switches shall be placed in the hatchway near the terminal landings and be designed to cut off the electric current, stop the car, and sound an alarm should it run beyond either terminal landing.

Automatic Self-Leveling. The elevator shall be provided with a self-leveling feature that will automatically bring the car to the floor landings. Car doors shall not open until the car is level with the landing. Within its zone the self-leveling shall be entirely automatic and independent of the operation device and shall correct for overtravel or undertravel. The car shall be maintained approximately level with the landing irrespective of the load.

Interlocks. Each hoistway entrance shall be equipped with an interlock. The interlock shall be designed to prevent operation of the car away from the landing until the doors are locked in the closed position and shall prevent opening the door from any landing on the corridor side unless the car is at rest at that landing. Unlocking devices shall be provided to permit authorized persons to gain access to the hoistway.

__Retiring Cams__. Retiring cams shall conform to the requirements of ANSI/ASME A17.1. The cams shall operate in conjunction with the door interlocks.

31.5.10 Ventilation

Ventilation shall be supplied by a single-speed exhaust blower located above the plenum and mounted to the car top. The ceiling grille shall match finished ceiling surface.

31.5.11 Noise Levels

Elevators and associated equipment shall not produce steady-state and transient noise levels in excess of the noise levels prescribed for elevators in Chapter 11 - Noise and Vibration.

31.6 ESCALATORS

31.6.1 Design Requirements

Escalators shall be of a type designed for use in public transportation terminals suitable for outdoor installations where applicable. The escalator design shall be of such finishes, materials, and components as to deter and resist vandalism.

The escalators shall conform to the following:

__Type__. The width of each escalator shall be a nominal 48 inches, measured at a point between the balustrade, 27 inches above the nose line of the step treads.

__Speed and Reversibility__. Escalators shall have two speeds, 90/120 FPM, and shall be fully reversible, as well as capable of operating under full load as defined by ANSI/ASME Code A17.1 in either an up or down direction.

__Capacity__. Escalators shall have a rated capacity of 8,000 people per hour (PPH) when operating at 90 feet per minute (FPM) and 10,700 PPH when operating at 120 FPM. Patronage calculations shall assume an actual capacity of 4,800 PPH at 90 FPM and 6,000 PPH at 120 FPM.

__Maintenance Access__. Escalator maintenance access shall be from above.

31.6.2 Escalator Classification

Escalators to be furnished shall have three classifications: A, B, and C, which are applied to the wellway structure design.

The classes of escalators are based on the following ranges of rise:

Class A: 0-20 feet
Class B: 20-35 feet
Class C: Over 35 feet

All escalators shall have, at both upper and lower landings, three level treads exposed to form a horizontal platform at fade-out. In addition, all escalators shall have the drive machine and controller located within the escalator truss.

31.6.3 Escalator Truss

The structural truss shall be designed to rigidly maintain the tracks and moving parts of the escalator and to safely carry the passenger capacity, the load of the mechanism, the balustrades, and the weight of exterior truss covering. The truss shall have a design safety factor as described by the latest editions of the American National Standard Safety Code for Elevators, Dumbwaiters, Escalators and Moving Walks, ANSI/ASME A17.1-1981, and Supplements ANSI/ASME A17.1a-1982, ANSI/ASME A17.1b-1983, 1984, 1985, and 1986.

31.6.4 Drip Pans

Oil-tight drip pans shall be provided in the truss for the entire length of the truss and machinery space. The machinery space and truss pans shall be of sufficient strength to support the weight of workers. The drip pans shall be designed to slide, to provide access to the wellway surface under the drip pan.

31.6.5 Tracks

The axle wheel straight track, curved back track, and trailor wheel roller track shall be designed and fabricated to support and safely retain the steps and running gear under the load requirements and speeds indicated. The curved back track for returning steps to opposite end of escalator shall be automatic and self adjusting.

31.6.6 Drive Machine

The drive machine shall be of a helical gear or worm and gear type. The drive machine shall be mounted within the escalator truss. Drive chains between drive machine and main drive shaft shall be self adjusting to maintain even chain tension during operation.

31.6.7 Step Chain

The step chains shall be an endless, precision roller or flat-link type; one chain located on each side of the steps. The chains shall be designed to prevent up-thrust bucking at lower end return.

31.6.8 Step Assembly

The step frame and/or cast aluminum unit step shall be braced to carry the step treads and the maximum rated load per step under eccentric loading conditions without distortion. In addition, step assemblies and/or cast aluminum unit steps shall be designed for easy replacement.

Step treads shall be designed to mesh with the comb plates. Step risers shall form an interlocking unit with the step tread of the adjacent step to minimize seizure of articles between the riser of one step and the tread of the following step.

Safety demarcation lines or strips shall be provided in step treads to assist demarcation between treads when they are level at top and bottom landings.

31.6.9 Comb Plate Assembly

Comb plate assemblies shall have an anti-slip surface. The comb shall have closely spaced teeth arranged so that the step tread cleats pass between the teeth with minimum clearance.

Comb teeth shall be made in sections so that any damaged or worn sections can be readily replaced without disturbing the main comb plates. The comb teeth shall have a continuation of the comb plate non-slip surface.

Step demarcation lights shall be provided at both the lower and upper ends of each escalator immediately outboard of the comb plate.

31.6.10 Landings

The landing plates shall have an anti-slip surface at the upper and lower landings to cover the entire area within the outline of the truss. Removable sections of the landing plate shall be provided at the upper and lower ends for maintenance access.

31.6.11 Handrails

Handrail Drives. A handrail drive shall be provided with a self-adjusting handrail tension device to take up the stretch. The handrail drive mechanism shall provide motion to the handrails to obtain the same rate of speed and direction of travel as the escalator steps.

Handrail Guides. The handrail shall run on guides to allow easy movement of the handrail. The guides shall be shaped to prevent the handrail from being thrown off the guides.

Handrails. The handrail shall be constructed to form a smooth, endless loop. It shall have white inserts molded into it as a non-separating integral part. At least one insert shall be visible at all times as the handrail turns around the newel extensions.

31.6.12 Balustrades

Balustrades shall be extended newel-type consisting of moldings, deck covers, interior panels, and skirt panels. Stainless steel adjuncts of the same material, backing, and finish as the balustrade deck covers may be used to provide full closure. Adjuncts shall be of equal width installed on two sides to maintain a uniform escalator appearance around the centerline of the step tread. Balustrade interior panel and skirt panel edges shall be sealed against moisture.

31.6.13 Brakes and Sequence of Operation

All brakes shall be failsafe and applied and released in accordance with ANSI/ASME Standard A17.1. Deceleration and stopping shall be smooth and without shock. The brakes shall be adjustable for stopping at various speeds.

Each escalator shall have an electrically released, mechanically applied emergency brake capable of stopping the up or down traveling escalator with any load up to rated load upon activation of any normal stop control, "EMERGENCY STOP" button, or safety device, or upon loss of power.

The activation of any safety device or "EMERGENCY STOP" button, or the loss of electric power, shall operate the emergency brake. The emergency brake shall be electrically interlocked with the motor circuits. If the escalator is stopped for any reason, a key switch shall be capable of starting the escalator after the safety device has been reset.

Controls for re-starting an escalator that has stopped shall not be accessible to the public.

31.6.14 Operating Devices

Each escalator shall have operating switches with the respective controls on a control panel located at upper and lower landings in the level portion of the balustrade deck cover outside the handrails.

31.6.15 Emergency Stop Button

The emergency stop button shall be a red, momentary-contact, manually operated pushbutton. The button shall be protected against accidental operation. The button shall be located opposite the control panel adjacent to the handrail return at the upper and lower landings. The cover for the button shall be marked "EMERGENCY STOP" in white letters. The cover shall be provided with a switch to initiate an audible alarm when the cover is lifted. When pressed, the "EMERGENCY STOP" button shall stop the escalator. The alarm shall stop automatically when the cover is released and returned to the closed position.

31.6.16 Safety Devices

The safety devices specified in the latest edition of ANSI/ASME A17.1-1981 and Supplements shall be provided, including the following:

Speed Governor. A speed governor shall be provided to cause the interruption of power to the driving machine if the speed of the steps exceeds more than 40 percent above the rated speed.

Broken Step-Chain or Step-Link Device. A broken step-chain or step-link device shall be provided, to cause the interruption of power to the drive machine if a step-chain or step- link breaks.

Broken Drive-Chain Device. When the driving machine is connected to the main drive shaft by a chain, a device shall be provided to cause the application of the brake on the main drive shaft if the drive chain breaks.

Skirt Obstruction Device. A device shall be provided to open the power circuit to the escalator driving machine motor and brake should an object become wedged between the step and the skirt panel as the step approaches either the upper or lower landing.

Reversal Stop Device. A device shall be provided to open the power circuit to the driving machine motor and operate the brake in case of accidental direction reversal while the escalator is operating in the ascending direction.

31.6.17 Noise Levels

Escalators and associated equipment shall not produce noise levels in either free-running or under full load conditions in excess of the noise levels prescribed for escalators in the noise and vibration chapter of these criteria.

31.7 ROUGHING-IN

In buildings and stations which are to be constructed in stages under separate contracts, block-outs for equipment, and sleeves for hydraulic, fire protection and drainage piping, and conduit shall be provided in the early stage structures to accommodate equipment and piping installations by later stage contractors. The locations and sizes of the sleeves and block-outs shall be accurately dimensioned under structural contracts to facilitate the subsequent equipment piping and conduit installations under later-stage contracts.

APPENDIX A

CODES, STANDARDS, AND REFERENCE PUBLICATIONS

APPENDIX A

CODES, STANDARDS, AND REFERENCE PUBLICATIONS

The following codes and standards are provided as an aid to designers and other subconsultants, and are not to be considered a comprehensive list. DART's position remains that it is the responsibility of the professional consultant or contractor to comply with all appropriate and applicable codes and standards, based upon his professional judgment. Contractors or consultants wishing to use standards other than those referenced in this appendix or in the text of these design criteria should be a comparison of the proposed standard and the referenced standards. The comparison shall demonstrate that DART is being given designs or materials equal to or better than that specified. The comparison shall be certified as being accurate by an engineer licensed in Texas. If the alternative standard is not originally published in English, the contractor shall certify through an independent translator that the translation is complete and correct. Specified test results will not be accepted in translated form unless the exact test procedures using calibrated test equipment accompanies them. The contractor also will require to certify in writing that compliance with all codes, standards, and reference documents has been achieved.

Unless otherwise specified, all consultants and contractors shall comply in all respect with these codes and standards, which shall be the latest edition or issue, and the most recent revision, amendment, or supplement in effect at the date of notice to proceed with each specific project. Where the requirements of more than one code or standard apply (excepting the variances described in the criteria), the consultant or contractor shall determine which code is in the best interest of safety and cost-effectiveness. All such potential conflicts should be presented to DART for resolution.

Due to the unique nature of rail transit, variances from existing specific codes and standards must be provided for certain functional elements. If a condition is found which is not covered by the codes, regulations, or criteria, the consultant or contractor shall refer the matter to DART for guidance in reaching and acceptable solution.

The first part of this appendix is organized by criteria chapter and/or section. The second part provides an alphabetical listing or referenced organizations, with addresses.

CIVIL - TRACK

Chapter 1 - Track Alignment

American Association of State Highway and Transportation Officials (AASHTO) Station Specifications for Highway Bridges.

American Railway Engineering and Maintenance-of-Way Association (AREMA) Joint Committee Report, "Passenger Ride Comfort on Curved Track," Bulletin 516, June-July 1954.

AREMA Manual for Railway Engineering.

AREMA portfolio of Trackwork Plans.

Federal Railroad Administration Track Safety Standards on Track Geometry.

National Geodetic Survey Classification, Standards of Accuracy and General Specifications of Geodetic Control Stations.

Texas Revised Civil Statutes Annoted, Articles 6559 a-f, Statutes Relating to Railroad Clearances.

Texas Department of Transportation (TxDOT), Operation and Procedures Manual.

Chapter 2 - Trackwork

American Railway Engineering and Maintenance-of-Way Association (AREMA) Manual for Railway Engineering.

Ibid., "Specifications for Preservatives," Volume 1, Chapter 3, Part 7.

Ibid., "Specifications for Rail Drillings, Bar Punchings and Track Bolts," Volume 1, Chapter 4, Part 1.

Ibid., "Specifications for Steel Rail," Volume 1, Chapter 4, Part 2.

Ibid., Specifications for Timber Cross Ties, "Volume 1, Chapter 3, Part 1.

Ibid., "Specifications for Timber Switch Ties," Volume 1, Chapter 3, Part 2.

Ibid., "Specifications for Treatment," Volume 1, Chapter 3, Part 9.

AREMA Portfolio of Trackwork Plans.

Ibid., Plan No. 1005, "Beveling of Rail Ends for Special Trackwork."

Ibid., Plan No. 221-62, point detail 5100, "Details for Switch Points."

Ibid., Plan No. 820-68, "Graph Showing Limitations for the Use of Crossings With Rigid Center Frogs."

Texas Department of Transportation (TxDOT), Standard Specifications for Construction of Highways, Streets and Bridges, "Specifications for Flexible Base in 249."

Chapter 3 - Trackway

Refer to codes and standards listed for chapters 1 and 2.

CIVIL

Chapter 4 - Streets, Highways, and Parking

American Association of State Highway and Transportation Officials (AASHTO), A Policy on Geometric Design of Highways and Streets.

AASHTO, A Policy on Design Urban Highway and Arterial Streets.

AASHTO Guide for Design of Pavement Structures.

City of Carrollton, Texas, General Design Standards, Volume III, "Sanitary Sewer, Water, Paving and Drainage Construction."

City of Dallas of Public Works, Paving Design Manual.

City of Farmers Branch, Texas, Engineering Design Standards, Section IV, Paving Design Standards."

City of Garland, Texas, Consultant's Helper.

City of Irving, Texas, Construction Details.

City of Plano, Texas, Ordinance No. 86-11-17, Ordinance No. 80-7-5.

City of Richardson, Texas, City Ordinance 2562-A.

North Central Texas Standard Specification for Public Works Construction (NCT-SSPWC), together with all revisions, amendments, and deletions.

National Research Council, Transportation Research Board Special Report 209, Highway Capacity Manual.

Occupational Safety and Health Act (OSHA).

Texas Department of Transportation (TxDOT) Highway Design Division Operations and Procedures Manual (THDOPM).

TxDOT, current design manuals, specifications, and standard drawings, together with all revisions, amendments, and deletions.

TxDOT, Texas Manual on Uniform Traffic Control Devices for Streets and Highways (TMUCTD).

Vernon's Texas Civil Statutes, Architectural Barriers Act, Article 7, Article 601b., Texas Accessibility Standards (TAS) of the Architectural Barriers Act Article 9102, Texas Civil Statutes.

CIVIL

Chapter 5 - Traffic Control

American Association of State Highway and Transportation Officials (AASHTO), Guide for Selecting, Locating, and Designing Traffic Barriers.

Federal Highway Administration (FHWA), U.S. Department of Transportation, Standard Alphabets for Highway Signs.

FHWA, Standard Alphabets for Highway Signs and Pavement Markings, metric edition.

FHWA, Traffic Control Devices Handbook.

FHWA, Traffic Control Systems Handbook.

National Research Council, Transportation Research Board Special Report 209, Highway Capacity Manual.

Texas Department of Transportation (TxDOT), Highway Design Division Operations and Procedures Manual.

TxDOT, Standard Specifications for Construction of Highways, Streets, and Bridges.

TxDOT, Texas Manual on Uniform Traffic Control Devices (TMUTCD).

TMUTCD, Traffic Control Standard Sheets.

TxDOT, Traffic Control Standard Sheets.
City code of each municipality served by the Dallas Area Rapid Transit Authority.

CIVIL

Chapter 6 - Utilities

American Association of State Highway and Transportation Officials (AASHTO), Standard Specification for Highway Bridges.

American National Standards Institute (ANSI) A21.50, Thickness Design for Ductile Iron Pipe.

ANSI A21.51, Ductile Iron Pipe Centrifugally Cast in Metal Molds or Sand-Lined Molds for Water or Other Liquids.

ANSI B31.4, Liquid Petroleum Transportation Piping Systems.

ANSI B31.8, and Addenda 31.8b, Gas Transmission and Distribution Piping Systems.

American Petroleum Institute (API) Standard 1104, Gas Transmission and Distribution Piping Systems.

American Railway Engineering and Maintenance-of-Way Association (AREMA) Manual for Railway Engineering, Chapter 15, Part 1, Section 1.3.3.

Ibid., Chapter 1, Part 5.

Ibid., Chapter 1, Part 10.

American Society for Testing and Materials (ASTM) C76, Specifications for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe.

ASTM C443, Specifications for Joints for Circular Concrete Sewer and Culvert Pipe, Using Rubber Gaskets.

ASTM C478, Specifications for Precast Reinforced Concrete Manhole Sections.

ASTM D2310, Classification for Machine-Made Reinforced Thermosetting Resin Pipe.

ASTM 2321, Practice for Underground Installation of Flexible Thermoplastic Sewer Pipe.

American Water Works Association (AWWA) C600, Installation of Ductile-Iron Water Mains and Their Appurtenances.

National Fire Protection Association (NFPA) 70, National Electrical Code (NEC).

NFPA 30. Flammable and Combustible Liquids Code.

Occupational Safety and Health Act (OSHA).

Natural Gas Pipe Line Safety Act, U.S. Department of Transportation Code of Federal Regulation, Minimum Federal Safety Standards Part 192-Title 49, "Transportation of Natural and Other Gas by Pipe Lines.

U.S. Department of Transportation Hazardous Materials Regulations Board, Title 49, Chapter 1, Part 195.

Western Union Telegraph, Specifications for Underground Construction.

Gas company operations procedure manual covering operating procedures, instruction and standards.

City codes and standards of each municipality served by the Dallas Area Rapid Transit Authority.

Where appropriate, refer to the utility plans of the following:

American Telephone and Telegraph Company (AT&T).

Exxon Pipeline Company.

GTE-Sprint Communications.

LDX Net, Inc.

MCI Telecommunications (MCI).

North Texas Municipal Water District.

Southwestern Bell.

Texas Municipal Power Agency.

Texas Department of Transportation.

Texas Utilities Corporation (TXU)

TU Electric

United Gas Pipeline Company.

Western Union Telegraph Company (WU).

Where appropriate, the codes and standards of the following organizations shall apply:

Association of American Railroads (AAR).

American Association of State Highway and Transportation Officials (AASHTO).

American Concrete Institute (ACI).

American Institute of Steel Construction (AISC).

American Iron and Steel Insutitute (AISI).

American National Standards Insutitute (ANSI).

American Plywood Association (APA).

American Petroleum Institute (API).

American Railway Engineering and Maintenance-of-Way Association (AREMA).

American Society for Testing and Materials (ASTM).

American Wood Preservers Institute (AWPI).

American Welding Society (AWS).

American Water Works Association (AWWA).

Concrete Reinforcing Steel Institute (CRSI).

United States Environmental Protection Agency (EPA).

Federal Highway Administration (FHWA).

National Association of Corrosion Engineers (NACE).

National Bureau of Standards (NBS).

North Central Texas Council of Governments (NCT COG).

National Electrical Safety Code (NESC).

National Fire Protection Association (NFPA).

National Geodetic Survey (NGS).

Prestressed Concrete Institute (PCI).

Urban Mass Transportation Administration (UTMA).

United States Coastal and Geodetic Survey (USC&GS).

Water Pollution Control Federation (WPCF).

CIVIL

Chapter 7 - Drainage

City of Carrollton, Texas, General Design Standards, Volume III, "Sanitary Sewer, Water, Paving and Drainage Construction."

City of Dallas, Texas, Design Manual for Storm Drainage Facilities.

City of Farmers Branch, Texas, Engineering Design Standards, Section III, "Storm Drainage Design Standards."

City of Garland, Texas, Consultant's Helper.

City of Irving, Texas, Design Criteria for Drainage Projects.

City of Plano, Texas, Storm Drainage Design Manual.

City of Richardson, Texas, City Resolution 73-13.

Federal Emergency Management Agency (FEMA), National Flood Insurance Program, Code of Federal Regulations Part 59 through 79, Title 44, Emergency Management and Assistance Chapter1.

North Central Texas Council of Governments, Stormwater Management Handbook.

Texas Department of Transportation (TxDOT), Hydraulic Manual.

U.S. Department of Commerce, Weather Bureau, Hyfdro-35, National Technical Information Service Publication No. PB 272-112.

U.S. Department of Commerce, Weather Bureau, Rainfall Frequency Atlat, Technical Paper No. 40.

U.S. Department of Commerce, Weather Bureau, Rainfall Intensity-Duration-Frequency Curves, Technical Paper No. 25.

STRUCTURAL

Chapters 8, 9, 12, 13, 14, 15, 16, 17

American Association of State Highway and Transportation Officials (AASHTO), Standard Specifications for Highway Bridges, including all subsequent AASHTO Interim Specifications for Bridges.

American Association of State Highway and Transportation Officials (AASHTO), Guide Specifications for Horizontally Curved Highway Bridges.

American Concrete Institute (ACI) 318, Building Code Requirements for Reinforced Concrete, including commentary.

American Society of Civil Engineers, ASCE 7-95 Minimum Design Loads for Buildings and Other Structures.

ACI SP-66, Manual of Standard Practice for Detailing Reinforced Concrete Structures.

ACI 209 R-82, Prediction of Creep, Shrinkage and Temperatures Effects in Concrete Structures.

ACI 336.3R, Suggested Design and Construction Procedures for Pier Foundations.

American Institute of Steel Construction (AISC), Load and Resistance Factor Design Specification for Structural Steel Buildings.

American Institute of Timber Construction (AITC), National Building Code-Timber.

American National Standards Institute (ANSI), American Standard Building Code.

American Railway Engineering and Maintenance-of-Way Association (AREMA) Manual for Railway Engineering.

American Society for Testing and Materials (ASTM), current manuals.

ASTM A36, Specification for Structural Steel.

ASTM A185, Specifications for Welded Steel Wire Fabric for Concrete Reinforcement.

ASTM A307, Specifications for Low-Carbon Steel Externally and Internally Threaded Standard Fasteners.

ASTM A325, Specifications for High-Strength Bolts for Structural Steel Joints.

ASTM A416, Specifications for Uncoated Seven-Wire Stress-Relieved Steel Strand for Prestressed Concrete.

ASTM A490, Specifications for Heat-treated Steel Structural Bolts, 150 ksi Minimum Tensile Strength.

ASTM A497, Specifications for Welded Deformed Steel Wire Fabric for Concrete Reinforcement.

ASTM A572, Specifications for High-Strength Low-Alloy Columbium-VA Nadium Steels of Structural Quality.

ASTM A615, Specifications for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement.
ASTM A709, Specifications for Structural Steel for Bridges.

ASTM A722,Specifications for Uncoated High-Strength Steel Bar for Prestressing Concrete.

American Welding Society (AWS), Welding Handbook.

City code of each municipality served by DART.

Federal Highway Administration (FHWA) Standard Specifications for Construction of Roads and Bridges of Federal Highway Projects, FF-74.

International Conference of Building Officials (ICBO), Uniform Building Code.

National Fire Protection Association (NFPA) Standard 130, Fixed Guideway Transit Systems.

Texas Department of Transportation (TxDOT), Bridge Division Operations and Planning Manual, D-5.

TxDOT, current design manuals and standards drawings, together with all revisions, amendments, and deletions.

TxDOT, Standard Specifications for Highways, Streets and Bridges, D-8.

U.S. Department of TranspU.S. Department of Transportation, Hydraulics of Bridge Waterways

STRUCTURAL

Chapter 11 - Noise and Vibration

Air Moving and Conditioning Association (AMCA) Test Code for Sound Rating Air Moving Devices, Standard 300-67.

American National Standards Institute (ANSI) S1.4-1983, Specification for Sound Level Meters.

American Public Transit Association (APTA) Guidelines for Design of Rapid Transit Facilities.

International Electro-Technical Commission (IEC), Precision Sound Level Meters, Publication 179 (1973).

National Fire Protection Association (NFPA) 130, Standard for Fixed Guideway Transit Systems.

Occupational Safety and Health Act (OSHA).

Society of Automotive Engineers (SAE) J366b, Exterior Sound Level for Heavy Tracks and Buses, 1973.

SAE J88, Exterior Sound Level Measurement Procedure for Earthmoving Machinery, 1979.

SAE J95 2b, Sound Levels for Engine Powered Equipment, 1973.

U.S. Department of Labor, Occupational Noise Exposure Standard, 29CFR Part 1910.

U.S. Environmental Protection Agency (EPA) Technical Document 500/9-74-004, Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety, March 1974.

Chapter 18 - Mined Tunnels and Stations

References pending completion of chapter.

ARCHITECTURAL

Chapters 19, 20, 21, 22, 23, and 24

American Institute of Timber Construction (AITC), National Building Code-Timber.

American National Standards Institute (ANSI), 17.1A, Supplement to Safety Code for Elevators and Escalators.

Americans with Disabilities Act (ADA) Department of Justice Title III Regulation 28 CFR Part 36.

ANSI Standard A117.1, Buildings and Facilities - Providing Accessibility and Usability for Physically Handicapped People.

American Plywood Association (APA)

American Society for Testing and Materials (ASTM).

American Welding Society (AWS), Welding Handbook.

City code of the municipality having jurisdiction.

City landscaping regulation used by the municipality having jurisdiction.

Fruin, John J., Pedestrian Planning and Design.

International Conference of Building Officials (ICBO), Uniform Building Code. (UBC)

International Conference of Building Officials (ICBO), International Building Code (IBC)

National Fire Protection Association (NFPA) Standard 130, Fixed Guideway Transit Systems.

Occupational Safety and Health Act (OSHA).

Texas Department of Transportation (TxDOT) design manuals and standard drawings.

Texas Accessibility Standards (TAS) of the Architectural Barriers Act Article 9102, Texas Civil Statutes.

MECHANICAL/ELECTRICAL

Chapter 25 - Heating, Ventilating, and Air-Conditioning Systems

Air Moving and Conditioning Association, Inc. (AMCA).

AMCA Standard 210, Laboratory Methods of Testing Fans for Aerodynamic Performance Rating.

AMCA Standard 300, Reverberant Room Method for Sound Testing of Fans

AMCA Standard 301, Methods for Calculating Fan Sound Ratings from Laboratory test Data.

AMCA Standard 500, Laboratory Methods of Testing Louvers for Rating.

American National Standards Institute (ANSI).

ANSI B16.10, Face-to-Face and End-to-End Dimensions of Ferrous Valves.

ANSI B31, Code for Pressure Piping.

American Public Transit Association (APTA), Rapid Transit Design Guidelines.

American Refrigeration Institute (ARI).

American Society for Testing and Materials (ASTM).

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE).

ASHRAE Handbook of Systems and Equipment.

ASHRAE Handbook of Fundamentals.

ASHRAE Handbook of Refrigeration.

ASHRAE Handbook of Systems and Applications.

ASHRAE 15, Safety Code for Mechanical Refrigeration.

American Society of Mechanical Engineers (ASME).

American Welding Society (AWS).

Building Officials and Code Administrators International, Inc. (BOCA).

Dallas City and County Building Codes.

Dallas City and County Fire Protection Codes.

Dallas City and County Mechanical Codes.

Dallas City and County Plumbing Codes.

Dallas City and County Energy Codes
Other applicable city, county, and state codes.
Factory Mutual.

International Association of Plumbing and Mechanical Officials (IAPMO), Uniform Plumbing Code (UPC).

IAPMO, National Plumbing Code.

National Building Code (NBC).

National Fire Protection Association (NFPA).

NFPA National Fire Codes.

NFPA Standard 130, Fixed Guideway Transit Systems.

NFPA 12A, Halon 1301 Fire Extinguishing Systems.

NFPA 70, National Electrical Code (NEC).

NFPA 90A, Installation of Air Conditioning and Ventilating Systems.

NFPA 90B, Installation of Warm Air Heating and Air Conditioning Systems.

NFPA 91, Installation of Blower and Exhaust Systems for Dust, Stock and Vapor Removal or Conveying.

Occupational Safety and Health Act (OSHA).

Sheet Metal and Air-Conditioning Contractors National Association, Inc. (SMACNA).

SMACNA High Pressure Duct Construction Standards.

SMACNA Low Pressure or Medium Pressure Duct Construction Standards.

Standard Handbook for Mechanical Engineers, Theodore Baumeister, Editor; McGraw-Hill Book Company.

Underwriters Laboratories, Inc. (UL).

U.S. Department of Transportation, Subway Environmental Design Handbook, Volume 1, "Principles and Applications," second edition, NTIS 254788.

U.S. Government Printing Office, Military Specifications, Grounding, Bonding and Shielding, MIL-STD-188-124.

MECHANICAL/ELECTRICAL

Chapter 26 - Lighting

American National Standards Institute (ANSI).

American Public Transit Association (APTA) Guidelines for Design of Rapid Transit Facilities.

Illuminating Engineering Society (IES) Lighting Handbook.
IES CP-13, Proposed American National Standard Practice for Tunnel Lighting.

International Conference of Building Officials (ICBO) Uniform Building Code (UBC).

MECHANICAL/ELECTRICAL

Chapter 27 - Fire and Intrusion Alarm Systems

American National Standards Insutitute (ANSI).

American Society for Testing and Materials (ASTM).

City of Dallas Building Code.

City of Dallas Fire Code.

Applicable Building and Fire Codes For Other Jurisdictions.

Factory Mutual.

International Conference of Building Officials, Uniform Building Code (UBC).

National Fire Protection Association (NFPA).

NFPA 70, National Electrical Code.

NFPA 72A, National Fire Alarm Code

NFPA 130, Fixed Guideway Transit Systems.

Occupational Safety and Health Act (OSHA).

Underwriters Laboratories, Inc. (UL) Automotive Burglary Protection Mechanical Equipment Directory.

UL Electrical Construction Materials Directory.

MECHANICAL/ELECTRICAL

Chapter 28 - Facilities Electrical Requirements

American National Standards Institute (ANSI).

American Society for Testing and Materials (ASTM).

Institute of Electrical and Electronics Engineers (IEEE).

IEEE Standard 80, Guide for Safety in Substation Grounding.

IEEE C2, National Electrical Safety Code.

Insulated Cable Engineers Association (ICEA).

National Electrical Manufacturers Association (NEMA).

National Fire Protection Association (NFPA) 101, Life Safety Code.

NFPA 130, Fixed Guideway Transit Systems.

NFPA 70, National Electrical Code.

NFPA 78, Lightening Protection Code.

Occupational Safety and Health Act (OSHA).

Underwriters Laboratories, Inc. (UL).

U.S. Government Printing Office, Military Specification MIL-STD-188-124, Grounding, Bonding and Shielding.

Applicable local and state codes.

MECHANICAL/ELECTRICAL

Chapter 29 - Fire Protection Systems

American National Standards Institute (ANSI).

ANSI B31, Code of Pressuring Piping.

American Society for Testing and Materials (ASTM).

American Society of Civil Engineers (ASCE).

American Society of Mechanical Engineers (ASME).

American Society of Plumbing Engineers (ASPE).

American Water Works Association (AWWA).

American Welding Society (AWS).

City of Dallas Building Code.

City of Dallas Fire Code.

City of Irving Building Code.

City of Irving Fire Code.

City of Richardson Building Code.

Applicable Water Quality Requirements for Each Local Jurisdiction

City of Richardson Fire Code.

Factory Mutual.

International Association of Plumbing and Mechanical Officials (IAPMO), Uniform Plumbing Code.

Applicable Plumbing Cods for Each Local Jurisdiction

IAMPO, National Plumbing Code.

International Conference of Building Officials, Uniform Building Code (UBC), Chapter 38.

National Fire Protection Association (NFPA).

NFPA 10, Portable Fire Extinguishers.

NFPA 11, Low Expansion Foam and Combined Agent Systems.

NFPA 12A, Halon 1301 Fire Extinguisher Systems.

NFPA 13, Installation of Sprinkler Systems.

NFPA 14, Installation of Standpipe, Private Hydrants and Hose Systems.

NFPA 15, Water Spray Fixed Systems for Fire Protection.

NFPA 16, Installation of Deluge Foam-Water Sprinkler Systems and Foam-Water Spray Systems.

NFPA 20, Installation of Stationary Pumps for Fire Protection

NFPA 24, Installation of Private Fire Service Mains and Their Appurtenances.

NFPA 70, National Electrical Code.

NFPA 75, Protection of Electronic Computer/Data Processing Equipment.

NFPA 130, Fixed Guideway Transit Systems.

NFPA 291, Fire Flow Testing and Marking of Hydrants.

NFPA Fire Protection Handbook.

Underwriters Laboratories, Inc. (UL).

MECHANICAL/ELECTRICAL

Chapter 30 - Plumbing and Drainage Systems

American National Standards Institute (ANSI).

ANSI B31, Code for Pressure Piping.

ANSI handicapped codes.

American Society for Testing and Materials (ASTM).

ASTM B88, Specifications for Seamless Copper Water Tube.

American Society of Civil Engineers (ASCE).

American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE).

American Society of Mechanical Engineers (ASME).

American Society of Plumbing Engineers (ASPE).

ASPE handbooks, current editions.

ASPE Handbook of Fundamentals of Plumbing Design.

ASPE Handbook of Special Plumbing System Design.

American Society of Sanitary Engineering (ASSE).

American Water Works Association (AWWA).

American Welding Society (AWS).

National Electrical Manufacturers Association (NEMA).

National Fire Protection Association (NFPA).

National Sanitation Foundation (NFPA).

National Sanitation Foundation (NSF).

Underwriters Laboratories, Inc. (UL).

U.S. Environmental Protection Agency (EPA).

MECHANICAL/ELECTRICAL

Chapter 31 - Elevators and Escalators

American Society for Testing and Materials (ASTM).

American Society of Mechanical Engineers (ASME).

American Society of Mechanical Engineers (ASME)/American National Standards Institute (ANSI) A17.1, Safety Code for Elevators and Escalators; Supplement A17.1A-1985; Supplement A17.1B-1985; Supplement A17.1C-1986.

ANSI handicapped standards.

City of Dallas Building Code.

City of Dallas Fire Code.

International Conference of Building Officials (ICBP), Uniform Building Code (UBC).

National Elevator Industry, Inc.

National Fire Protection Association (NFPA) 13, Installation of Sprinkler Systems.

NFPA 70, National Electrical Code.

NFPA 130, Fixed Guideway Transit Systems.

Underwriters Laboratories, Inc. (UL).

State of Texas Elevator Requirements

TXU Energy

TXU Gas

APPENDIX B

ABBREVIATIONS

APPENDIX B - ABBREVIATIONS

This appendix includes only those abbreviations that appear in the text of this DART Rail Project Design Criteria. A more complete list of abbreviations can be found in the DART Drafting Standards Manual.

AAR	Association of American Railroads
AASHTO	American Association of State Highway and Transportation Officials
AC	Alternating Current
A/C	Air Conditioning
ACI	American Concrete Institute
A/E	Architect/Engineer
AHU	Air Handling Unit
AISC	American Institute of Steel Construction
AMCA	Air Moving and Conditioning Association
ANSI	American National Standards Institute
API	American Petroleum Institute
APTA	American Public Transit Association
AREMA	American Railway Engineering and Maintenance-of-Way Association
ASCE	American Society of Civil Engineers
ASHRAE	American Society of Heating, Refrigerating & Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATC	Automatic Train Control
ATP	Automatic Train Protection
AWWA	American Water Works Association
BTU	British Thermal Unit
CBD	Central Business District
CCS	Central Control System
CCTV	Closed Circuit Television
CFM	Cubic Feet Per Minute
CIC	Communication Interface Cabinet
CMP	Corrugated Metal Pipe
CRT	Cathode Ray Tube
C&S	Communications and Signals
CTS	Communications Transmission Subsystem
CW	Cold Water
CWR	Continuous Welded Rail

DART	Dallas Area Rapid Transit
DB	Dry Bulb
dB	Decibel
dBA	A-weighted Sound Level in Decibels
DC	Direct Current
DIL	Dynamic Insertion Loss
DTS	Data Transmission System
DX	Direct Expansion
ECS	Environmental Control System
EEP	Elevator Emergency Telephone
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EPA	Environmental Protection Agency
EPABX	Electronic Private Automatic Branch Exchange
F	Fahrenheit
FACP	Fire and Intrusion Alarm Control Panel
FC	Fiber Conduit
FHP	Fire Hotline Telephone
FHWA	Federal Highway Administration
F/M	Factory Mutual
FMP	Fire Management Panel
FPM	Feet per Minute
FPS	Feet per Second
FRE	Fiberglass Reinforced Epoxy Conduit
FT	Foot or Feet
FTA	Federal Transit Administration
GEC	General Engineering Consultant
GFP	Ground Fault Protector
GPM	Gallons per Minute (U.S. gallons)
GRS	Galvanized Rigid Steel
HP	Horsepower
HR	Hour
HVAC	Heating, Ventilating & Air Conditioning
H/W	Hot Water
Hz	Hertz (cycles per second)
IACP	Intrusion Alarm Control Panel
ICEA	Insulated Cable Engineers Association
ID	Inside Diameter

IEEE	Institute of Electrical and Electronics Engineers, Inc.
IES	Illuminating Engineering Society
IFTC	Interface Terminal Cabinet
IMC	Intermediate Metal Conduit
IN.	Inch
K	Kip
kHz	Kilohertz
kV	Kilovolt
LB	Pound
LCC	Lighting Contactor Cabinet
L_{dn}	Day-Night Sound Level
LED	Light Emitting Diode
L_{eq}	Energy Equivalent Level
LLRU	Lowest Line Replaceable Unit
LOS	Level of Service
MAX	Maximum
MBTU	Million British Thermal Units
MBTU/H	Million British Thermal Units per Hour
mHz	Megahertz
MIN	Minimum
MIS	Management Information System
mm	Millimeter
MOW.	Maintenance-of Way
MPH	Miles Per Hour (also mph)
MVA	Megavolt-Ampere
N/A	Not Applicable
NBC	National Building Code
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NESC	National Electrical Safety Code
NFPA	National Fire Protection Association
NGS	National Geodetic Survey
NRC	Noise Reduction Coefficient
OSHA	Occupational Safety and Health Act
PA	Public Address
PABX	Private Automatic Branch Exchange
PBDC	Parsons Brinckerhoff Centec, Inc./Deleuw, Cather & Company

PEC	Passenger Emergency Call
PGL	Profile Grade Line
PLF	Pounds Per Linear Foot
ppm	Parts Per Million
PSF	Pounds Per Square Foot
PSI	Pounds Per Square Inch
PVCC	Polyvinyl Chloride Conduit
PVCP	Polyvinyl Chloride Pipe
RMS	Root Mean Square
ROW	Right-of-Way
RPM	Revolutions Per Minute
RTU	Remote Terminal Unit
SAE	Society of Automotive Engineers
SES	Subway Environment Simulation
S&I	Service and Inspection
SI	International System of Units
SMACNA	Sheet Metal and Air Conditioning Contractor National Association, Inc.
SPKLR	Sprinkler
Sq Ft	Square Feet
TBD	To Be Determined
TCC	Train Control Center
TMUTCD	Texas Manual of Uniform Traffic Control Devices
T/R	Top-of-Rail
TxDOT	Texas Department of Transportation
TUE	TU Electric
TVF	Tunnel Ventilation Fan
TWC	Train to Wayside Communications
UBC	Uniform Building Code
UL	Underwriters Laboratories, Inc.
UMTA	Urban Mass Transportation Administration
UPE	Underplatform Exhaust
UPS	Uninterruptible Power Supply
V	Volt
VAC	Volts Alternating Current
VAV	Variable Air Volume
VDC	Volts Direct Current

W	Watt
WB	Wet Bulb
WP	Work Point

APPENDIX C

GLOSSARY

APPENDIX C - GLOSSARY

This glossary provides common definitions to be used throughout the DART project. The publishing of this glossary does not imply any degree of finality. Terminology, as with language in general, is never static; it responds to use and the environment as well as other factor. This glossary, therefore, is an evolving document, and shall reflect similar changes in language and usage.

As other project documents develop, many of them will incorporate "definitions" within the text to promote ease of interpretation and use. For convenience, it is expected that such definitions may paraphrase or extract from the language contained herein. Users are requested to minimize this practice. However, in cases where the practice is pursued, it is expected that any definition will retain the intent and purpose of this document. Where conflict is encountered between this document and the intended application of the language, glossary users are requested to bring such matters to the attention of the configuration manager for resolution.

Above Grade - The portion of the system that is located above the surrounding finished ground elevation level.

Acceleration Level - Frequently called vibration acceleration level. Vibration acceleration is the rate of change of speed and direction of a vibration. An accelerometer generates an electronic signal that is proportional to the vibration acceleration of the surface to which it is attached. The acceleration level is 20 times the logarithm to the base 10 of the ratio of the RMS value of the acceleration to a reference acceleration. The generally accepted reference vibration acceleration is 10^{-6}g (10^{-5} m/sec).

Accelerometer - A vibration-sensitive transducer that responds to the vibration acceleration of a surface to which it is attached. The electronic signal generated by an accelerometer is directly proportional to the surface acceleration.

Acceptance Testing - The testing concerned with the verification of contractor-furnished items prior to placing in Authority use.

Accident - An event or occurrence which results in personal injury or property damage.

Acknowledgement - The positive confirmation of the completion of a specific action, event or function.

Active Redundancy - See Parallel Redundancy.

Aerial Structure - A system structure or configuration longer than 300 feet which carriers tracks and related elements, including stations, above the adjacent finished or final surface. The adjacent surface may be earth, water, or man-made structure. In trackwork applications, it is a bridge or elevated structure with a concrete deck designed to accommodate direct-fixation or ballasted track.

Air Cushion - A means of supporting and moving an item on thin films of air rather than on wheels.

Alarm Signal - A signal indicating an emergency requiring immediate action.

Alignment - The horizontal location of the guideway or roadway as described by curves and tangents which define its position with respect to the surrounding area. See Profile.

Ambient Noise - The prevailing general noise existing at a location or in a space, which usually consists of a composite of sounds from many sources, near and far.

American Public Transit Association (APTA) - An association of North American transit properties which promotes common transit goals in the United States and Canada.

Ancillary Facilities - Subsidiary locations for personnel or equipment pertaining to Authority activities. These are usually located at designated stations or shops.

Annunciate - To indicate by visual or audible means a condition or status determined by a detector designed for that purpose. See Supervisory and Control.

Approach Signal - A fixed-signal aspect of the train signaling system used in connection with one or more signals given to govern the approach to a particular control zone.

Approach Slab - A reinforced concrete slab to transfer load from rigid support, such as at the end of a subway invert or aerial structure, to the less rigid, adjacent earth structure. A similar slab is used for roadway bridges.

Arcaded Entrances - An entrance to a below-ground station with the head of the stair or public sidewalk and the stair run within a private building structure.

Arterial Street - A type of street, either divided or undivided, that has the main function of carrying non-local traffic at medium speeds.

Aspect - See Signaling.

Assembly - A grouping of components or piece parts that may be permanently or semi-permanently connected and that performs a definable function.

At-Grade - At permanent ground level. When describing transitways relative to streets, the intersecting transitways and streets are at the same elevation and occupy the same space.

Authority - See Dallas Area Rapid Transit.

Authority Having Jurisdiction - The duly authorized representative or agency having legal enforcement responsibility in numerous matters such as those dealing with building codes, NFPA codes, and ordinances. In the case of the Building Code, it is the building official or designated authority. The "authority having jurisdiction" is the organization, office, or individual responsible for approving equipment, and installation, or a procedure. (The phrase "authority having jurisdiction" is used in NFPA standards in a broad manner since jurisdiction and "approval" agencies vary, as do their responsibilities. Where public safety is primary, the "authority having jurisdiction" may be a federal, state, local or other regional department, health department, building official, electrical inspector, or other having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his delegated agent assumes the roles of the authority having jurisdiction. (At government installations, the commanding officer or departmental official may be the authority having jurisdiction.)

Automatic - A term applied to a system, subsystem, or device which has the inherent capability to function without direct manual participation.

- Automatic Block Signaling - In train signaling, a series of consecutive blocks governed by block signals, cab signal, or both, and actuated by train movement or by certain conditions, such as track switch positions, affecting the use of a block.

- o Automatic Fare Collection - A system which permits collection of transit fares of validation of trip passes without the involvement of operating personnel.

- o Automatic Train Dispatcher - A programmable device whose function is to dispatch trains on a predetermined schedule.

- o Automatic Train Protection - The subsystem within the train control system which maintains safe train operation through a combination of train detection, train separation control, interlocking control, and speed limit enforcement.

- o Automatic Train Protection Gate - The guideway boundary of an interlocking which is open or closed to traffic, depending on the status of interlocking circuit elements. When open, the gate allows entry through appropriate ATP aspect display by a train from outside the interlocking. When close, it prevents entry except by a prescribed sequence of unlocking steps.

Availability, Mathematical - The probability that a system element will be operational when scheduled. Mathematically, the ratio of the mean time between failures to the sum of mean time between failures plus mean down time for the system element.

Availability, Applied - The ratio of the actual fleet operating time to the scheduled fleet operating time, excluding preventive maintenance and administrative down time.

Availability, Car - The ratio of the number of cars available at the time of dispatch for the A.M. peak hour service to the number required for that service.

Avoirdupois Weight (AW) - Abbreviation used with designator -0, -1, -2,... to specify empty weight and then succeeding loaded conditions for the transit vehicle.

A-Weighted Sound Level - The sound pressure level, in decibels, as measured on a sound level meter using the internationally standardized A-weighting filter or as computed from sound spectral data to which A-weighting adjustments have been made. A-weighting de-emphasizes the low and very high frequency components of the sound in a manner similar to the response of the average human ear. A-weighted sound levels correlate well with subjective reactions of people to noise and are universally used for community noise evaluations.

Backup System - The general composite non-recognizable noise from all distant sources, not including nearby sources or the source of interest. Background noise generally consists of a large number of distant noise sources and can be characterized by L_{90} or L_{99}.

Ballast - An integral part of the track structure composed of crushed stone in which crossties are embedded for the following purposes:

- o Transmit and distribute the load of the track and rolling equipment to subgrade;

- o Restrain the track laterally, longitudinally, and vertically under dynamic loads imposed by rolling equipment and thermal stress exerted by the track; and

- o Maintain proper track cross-level, surface, and alignment.

Ballast, Electrical - Resistive or inductive impedance used in an electrical circuit to stabilize voltage to an operating element.

Ballast Leakage - The rack circuit current that inadvertently passes through the ballast from one rail of a track circuit to the other, thereby bypassing the intended track circuit current path.

Baseline - The foundation document defined by document control as the basis upon which all further related work is accomplished. Also may be used to define reference work point for survey, construction, and the like.

Below-Ground Station - See Station, Underground.

Berthing - A final positioning of train at a passenger station platform.

Block - A length of track of defined signal system limits.

Blowdown Track - A track within a yard which contains facilities for blowing compressed air or high-pressure steam against parts of the transit vehicle underbody to remove dirt and dust prior to entering the shop.

Body Hoist - Apparatus, either electro-mechanical or hydraulic, generally used in conjunction with a truck lift, for elevating a vehicle car body.

Body Support - Apparatus, either electro-mechanical or hydraulic, generally used in conjunction with a truck lift, to support the transit vehicle body at defined structural points. Often called jacking pads.

Bond

- Cross (Equalizing) Bonds - An electrical connection from one track to another track to distribute traction electrification return currents.

- Impedance Bond - An iron coil of low resistance and relatively high reactance used as follows: to provide a continuous path for the return propulsion current around insulated joints for power frequency track circuits; to equalize the return current for audio frequency track circuits in continuously welded rail; to confine the signaling energy to its own track circuit.

- Propulsion Bond - A conductor of low resistance providing a path for the return propulsion current at non-insulated joints.

- Rail Bond - An electrical connection between adjacent lengths of rails.

- Signal Bond - A conductor of low resistance providing a path for track circuit current across bolted rail joints.

Book of Rules - A set of codified regulations and procedures by which operating personnel are governed.

Box Anchoring - The process of applying rail anchors to both sides of the rail on the same tie, thereby restricting longitudinal rail movement in either direction.

Brake - The means of providing a retarding force to reduce vehicle speed.

- Brake Application - The activation of brakes to achieve deceleration.

- Brake Assurance - The function provided by a subsystem within the automatic train protection system that will cause the brakes of a vehicle to be applied when the actual braking rate of the vehicle is less than the minimum braking rate require by the train signaling system design.

- Brake Cutout - A device which disables all or a portion of the brakes in a released position.

- Brake Shoe (Pad) - The non-rotating, sacrificial portion of a tread or disc brake assembly.

- Dynamic Brake - A method of train braking whereby the kinetic energy of a moving train is used to generate electric current at the traction motors, which is them dissipated through banks of resistor grids or returned to the catenary system.

- Friction Brake - A means of providing a primary retarding force by units applying a friction- producing material to the running wheel tread surface or to a disk rigidly attached to the axle.

- Parking Brake - A manually controlled brake used to prevent movement of the vehicle once it has stopped. Often called a hand brake.

- Track Brake - A form of friction brake that applies a sacrificial element to the running rail through a mechanism attached to the transit vehicle truck.

Braking

- Braking, Blended - Braking achieved by applying a combination of electric and friction brakes to obtain the required retarding force.

- Braking, Closed-Loop - Braking under continuous direction of the propulsion control system to achieve a retarding force proportioned to the commanded stopping rate.

- Braking, Emergency - Irrevocable, open-loop, maximum reliability braking to a stop.

- Braking Rate - The rate of change of speed of a vehicle attributable to the action of its braking system.

- Dynamic braking - See Dynamic Brake.

- Full-Service Braking - A non-emergency, and therefore revocable, brake application which obtains the maximum brake rate consistent with the design of the primary brake system(s).

Buffer - A storage device used to compensate for a difference in rate of flow of information or time of occurrence of events when transmitting information from one device to another.

Bumping Post - A device located near the end of a rail segment designed to meet a transit vehicle anticlimber and resist further movement. Normally capable of absorbing only very low speed energy.

Bus - (1) A rubber-tired vehicle used as a conveyance for transporting people on a public highway or busway. (2) A means of providing a continuous electrical connection between separate points in an electrical system. Also called bus bar.

Busway - Typically, a one or two-lane roadway dedicated for the exclusive use of buses (and possible multi-occupancy automobiles) with grade-separated or signal-protected crossings.

Cab - the compartment of a transit vehicle from which control is achieved.

Cab Signal Display - See Signal.

Cam Control - A propulsion-control method using mechanical cams to introduce variable resistance into the power control circuit to modulate propulsion and electric braking on a transit vehicle.

Canopy - An overhanging roof structure covering a portion or all of the platform protecting patrons from rain or sun.

Capacity -

- Line Capacity - The number of vehicles per unit time, or passengers per unit time, that can be accommodated in one direction between two points along a transit line.

- Vehicle Capacity - The passenger capacity pertinent to specified loading conditions.

Capital Cost - The cost of all facilities construction, rolling stock, equipment system procurement and installation, right-of-way, engineering and architectural services, administration and legal services, tests, pre-operating program, and contingencies.

Capital Inventory - That class of inventory which, through rebuilding, can be returned to specified operating condition rather than consumed.

Carbody - That portion of a vehicle that carrier people or loads and that supports all equipments except the truck assemblies.

Carborne Equipment - The train control equipment installed on the transit vehicle.

Car Spot - Location within a shop or a yard of sufficient length and width to hold one car for a specific beneficial purpose.

Catenary - The combination of conductors, hanger, and in-span hardware of the overhead conductor system, not including supports and crossarms.

Central Business District - The downtown area of a city usually contained within defined boundaries.

Central Control Facility - See Train Control Center.

Central Line Supervision - The subsystem within the train control system which monitors and directs the operation of a system of trains in order to maintain intended schedules and system stability. Consists of remote communication equipment, data transmission systems between remote locations and central control, and the central control information processing and display equipment.

Centralized Traffic Control (CTC) - A specific type of rail traffic control system in which the signal and switches for a designated section of track are controlled from a remotely located, centralized traffic control machine.

Chopper Control - A propulsion control method which uses solid-state thyristors to modulate propulsion and electric braking on a transit vehicle.

Circuit - Any assembly of wires, relays, and electrical/electronic components.

- Non-Vital Circuit - Any circuit the function of which does not directly affect the safety of train operations.

- Track Circuit - An electrical circuit of which the rails of the rack form a part and which detects the presence of a train and provides speed codes for transmittal to trains operating within the boundaries of the track circuit.

- Vital Circuit - Any circuit which affects the safety of train operations and therefore, must be a failsafe design.

Cleaning Platform - A platform elevated to vehicle floor height for easy access to car interiors for personnel and equipment.

Clearance Envelope or Diagram - An envelope or diagram which defines the maximum vertical and horizontal excursions of a rail-borne vehicle and establishes the minimum safe distance between all points on a moving vehicle and fixed wayside structures or appurtenances. Usually defined for the worst combination of equipment wear, failure and speed.

Clearance - The distance between specified points; in transit, generally used to define distance between specified points along the tracks and specified points on moving vehicles.

Clearance Point - The location on a turnout at which required clearance is provided between vehicles on diverging tracks.

Closed Loop - The principle of feedback control in which the response of a system is continuously compared with the controlling signal to generate an error signal.

Code, Standard - The operating, block signal, and interlocking rules of the Association of American Railroads.

Collector-Feeder-Distribution System - A public transit system operating in localized zones to connect patronage generated in different areas of the transit system.

Communications System - A system containing an information source, and information sick or user, and a communications link for moving the information, intelligence, or control between the source and sink.

- Closed Circuit Television (CCTV) Subsystem - Authority owned and supervised television subsystem with cameras installed in locations requiring surveillance and viewing monitors located at TCC.

- Communications Transmission System (CTS) - A system which provides communication channels throughout the transit system.

- Electronic Private Automatic Branch Exchange (EPABX) Telephone Subsystem - The DART owned system of telephone instruments, equipment cabinets, video display printer and other equipment used to provide the switched telephone service to support the operating maintenance communications requirements of the DART rail system.

- Emergency Telephone Subsystem (ETS) - The DART provided system of emergency telephones and related equipment, cables and the like in tunnels, elevators and at the fire hot-line locations.

- o Fire Detection Subsystem - That portion of the FAS provided in the systems contractor pre-packaged bungalows, substations and tie stations. Alson the interface with the facility FAS equipment.
- o Intrusion Detection Subsystem - That portion of the IAS similar to the Fire Detection Subsystem described above.
- o Passenger Emergency Call (PEC) Subsystem - The DART provided system of PEC units at stations, control equipment at TCC and associated cable, wire and interconnections that allows passengers to communicate to obtain emergency assistance.
- o Public Address Subsystem (PAS) - The system of speakers, electronics/amplifiers, microphones and associated wiring providing a means to inform patrons and authority personnel in selected stations and maintenance facilitates.
- o Radio Subsystem - The DART owned, two-way radio subsystem designed to provide communications throughout the DART rail area, including subway, stations, maintenance facilities and surface locations.

Community Noise Equivalent Level - the L_{eq} A-weighted noise level over a 24-hour period wit a 4 dBA penalty applied to noise levels between 7 p.m. and 10 p.m. and a 10dBA penalty applied to noise levels between 10 p.m. and 7 a.m.

Component - The smallest grouping of piece part in an operating element to which identification and isolation of a fault condition is possible.

Component Repair Shop - A facility specifically designed to repair, overhaul, and test electrical, mechanical, hydraulic, or pneumatic parts, modules assemblies, or subsystems. Comparable to a manufacturer's service repair shop. It may be a separate building or part of another shop.

Conceptual Design - Drawings and written documents prepared for each facility to define the special limitations governing both design and development. Conceptual designs show, by means of small-scale plans, elevations, and cross sections, the essential configuration of each facility. No attempt is made to define structural, mechanical or electrical components, or the materials and equipment to be used. Only the size, shape, and arrangement of physical elements is shown to describe the facility "footprint" and functional characteristics. Simple perspective sketches or mass models can be produced from these drawings, and they are adequate to allow a rough cost estimate based on a takeoff of major areas of construction.

Concourse - The public area which lies between the station entrances for patrons and the platform or platforms. It can be at-grade or at a mezzanine level.

Construction Documents - Drawings and written documents prepared by the designer that, approval of the Authority, are ready for issuance to construction contractors for construction.

Consumable Inventory - That class of material that, once used completely or for some predetermined unit of time or distance, is replaced and discarded, such as lubricants, filters, brake shoes, and lighting elements.

Contact - A conducting part which co-acts with another conducting part to open or close an electrical circuit.

Contact Wire - The lower overhead wire of a catenary system from which a transit vehicle collects power via the pantograph for both propulsion and auxiliary power.

Contract Maintenance - The repair, overhaul and testing of parts, modules, and assemblies under contract to other than Authority personnel. The work may be done on or off Authority property. In addition, the term can apply to tasks such as facilities janitorial work and landscaping. It is often used for specific items such as elevators, escalators, motors, and bearings, which are generally impacted by labor agreements.

Contraflow Lane - A highway or street lane on which, during certain hours of the day, public mass transit or other specially designated vehicles operate in a direction opposite to that associated with the normal flow of traffic on that lane during the remainder of the day.

Control

- Central Control - See Train Control Center.
- Deadman Control - A pressure- or activity-actuated device that detects inattention or disability of a train operator, resulting in an alarm to the operator and, in the event of no response to the alarm, automatic brake application.
- Emergency Control - The automatic or manual generation of priority control signals within the system in direct response to abnormal conditions.

Corridor - A geographic area comprising a broad band following a general directional flow connecting major sources of traffic. A corridor may have several alternative routes within it.

Crash Wall - See Deflection Wall.

Crashworthiness - The capacity of a vehicle to act as a protective container and energy absorber during impact conditions.

Criteria - Design requirements prepared for designers, usually contained in a series of documents composed of sketches, requirements statements, and usually interpreted to include standard drawings.

Critical Defect - A fault or imperfection that judgment and experience indicate is likely to result in an unacceptably hazardous condition for individuals using, maintaining, or depending on the product, or likely to prevent an important function in the end item.

Critical Function - A function which, if degraded or lost, has a major impact on system performance, such as loss of vehicle movement and control.

Crossing, At-grade - See at-grade.

Crossing, Movable Point - A structure placed where two tracks intersect, with an angle below the permissible minimum for rigid frogs.

Crossing, Rigid - A structure placed where two tracks intersect, consisting of four frogs.

Crossover, Double - Two single crossovers which intersect between the connecting tracks.

Crossover, Single - Two turnouts, with rail between the frogs arranged to form a continuous passage for track mounted vehicles between two nearby and parallel tracks.

Crosstie - A transverse member of the track structure to which the rails are spiked or otherwise fastened to provide proper gauge and to cushion, distribute, and transmit the stresses of traffic to the ballast.

Crosstown Feeder - Bus service that originates in neighborhoods and collects riders on a convenient route and schedule as it traverses one neighborhood to another.

Current of Traffic - See Direction, Normal Running.

Dallas Area Rapid Transit - The authority responsible for the planning and implementation of the rail and bus mass transit system in the metropolitan Dallas geographical area.

DART - See Dallas Area Rapid Transit.

DART Rail Project - The rail transit system which includes all right-of-way, easements, tracks, structures, vehicles, and other equipment and appurtenances required for conduct and support of revenue operations.

Data Transmission System - An element of the communication system designed with characteristics to assure reliable transfer of data sets between locations.

Day-Night Sound Level (L_{dn}) - The L^{eq} of the A-weighted noise level over a 24-hour period with a 10 dBA penalty applied to noise levels between 10 p.m. and 7 a.m.

Daytime Entrance - Any entrance to a station (usually a below-ground station which is open from early morning only until the time of night when stores and theaters close.

D. C. Feeder Breaker - A direct-current circuit breaker with associated load-sensing devices, the purpose of which is to provide energization to, or remove energization from, a section of catenary. The feeder breaker may operate as a tie feeder or as a radial feeder, or both.

Dead Section - A section of track, either within a track circuit or between two track circuits, the rails of which are not part of a track circuit.

Decibel - A measure on a logarithmic scale of the magnitude of a particular quantity (such as sound pressure, sound power, and sound intensity) with respect to a standardized reference quantity.

Deenergize - To remove operating current from an electro receptive device.

Defect - A fault or imperfection.

Deflection Wall - A sturdy wall, usually of concrete or retained earth, or ballast, built in such proximity to the running rail to protect other facilities and equipment from potential damage in the event of train derailment.

Degradation - Falling from an initial level to a lower level in quality or performance.

Demonstration Test - A test performed to establish that a fabricated system or a unit of equipment meets predetermined requirements.

Departure Test - Operational test made on the complete train in a yard or on a transfer track before permitting the train to operate in cab signal mode on the main line.

Dependent Failure - See Failure, Dependent.

Derail - A device designed to cause rolling equipment to leave the rails. Sometimes used in storage track areas where the consequences of a tracked vehicle continuing to travel in a predetermined direction are determined to be more hazardous than a deliberate derailment.

Design

- Design Deficiency - Any design characteristic which does not meet specified criteria or standards.

- Design Safety - Acceptably low hazard probability achieved by the integration of hazard mitigation measures with the basic system functional features.

Design Peak-Hour Load - The total estimated number of passengers using the station during the most heavily traveled hour of the day either in the morning or evening commuter period.

Designated Authority - The titled position charged with responsibility for supervising, authorizing, directing, and controlling train movements and other facets of operations, often from a central location.

Detector - Any device designed to sense a specific condition or status.

- Detector Track Circuit - A track circuit, within an interlocking, which when occupied by a train prevents the position of a track switch from being changed.

- Point Detector - A circuit controller which is part of a switch operating mechanism to indicate that the point is within a specified distance of the stock rail. See Switch Point.

- Ionization Detector - Part of the fire alarm system located in areas where invisible products of combustion may be sensed before heat or visible evidence of combustion is present. When sensed, the detector sends a signal to the alarm system.

- Rate of Rise Detector - Part of the fire alarm system that detects a rapid change in temperature and signals the alarm system when such a condition exists.

- Photo-Optical Detector - A device that uses a light beam and sensor to detect the presence of a foreign object in the air path. Sometimes used in fire and intrusion detection systems.

Diagnostic Test Equipment - Pre-programmed automatic-test sets used to check car circuitry and subsystems. Usually for use in shops, but may refer to portable sets on cars, trains, or wayside equipment.

Direct Fixation Fastener - The fastening system used to secure the running rails directly to the concrete track bed, replacing ties and ballast with a fixture secured to the concrete by use of threaded inserts, bolts, or similar devices and containing means to accept rail fasteners. See Rail Fastener.

Direction

- Normal Direction or Normal Running - The designed predominant direction of train traffic for a given track as specified by the operating rules. Also see Current of Traffic.

- Reverse Direction or Reverse Running - Train movement against the predominant direction of traffic, for a given track.

Directive Drawings - Drawings defining the arrangement or configuration of components and facilities. They provide direction to the designer but shall not be used as contract drawings.

Discrepant Component - A component which does not perform its intended function.

Dispatching - The process of starting a train into service from a terminal, yard, or transfer track.

Drop and Insert (D/I) - The technique of removing from a digital bit stream representing a group of communications channels the bits representing one or more channels, and inserting other bits in their place, without decoding the entire bit stream.

Drop-Table - A built-in or portable shop device for removing and replacing components from vehicles. Sometimes requires that the car be elevated on a running tack or by jacking/hoisting, or may be used with the vehicle on tracks at the shop floor level.

Duplex - Capable of transmitting and receiving simultaneously.

Dummy Trucks - Trucks consisting only of structural members, wheels and axles, and body support points but without such items as motors, brakes, electric wiring, pneumatic, and hydraulics; used to support and move carbodies under repair or storage in shop and yard areas. In addition, may be used for emergency truck replacement under extreme main line conditions.

Dwell - The time period starting when a train berths in a station and ending when the train resumes motion.

Dynamic Outline - See Clearance Envelope.

Effective Daily Shop Capacity - A measure of the number of units a shop could handle over a three-shift day if every car spot were used on an average time/car/spot.

Effectiveness - The standard of performance realized when the item performance characteristics and human operational and safety features are used to their fullest capabilities.

Elastomeric Bearing - A synthetic bearing pad with tough, elastic properties used to reduce vibrations or to provide resilient mounting or connections.

Electrical Noise - Interference within a dynamic electrical system produced by undesirable or casual electrical occurrences.

Electronics Department - That functional unit within the maintenance organization that generally has responsibility for signals, communication systems, fare collection, automatic control subsystems, and shop repair.

Electropneumatic - A means of providing power by compressed air (or other gas) whose application is electrically controlled.

Emergency Egress - A continuous and unobstructed way of exit travel from any point in a structure to a public way in addition to the normally provided egress.

Emergency Procedures Plan - A plan for information, guidance, and use prior to, during, and when recovering from an emergency situation.

Emergency Telephone System - Telephone system connected directly from the instrument to the Train Control Center requiring no dial-up access and designated for emergency use.

Encoder - A device that transforms the format of detected or commanded data into a different format or code required for transmission or processing.

End-Loaded Platform - Any platform arranged whereby vertical access to the platform is provided at either one or both ends of the platform.

Energy Equivalent Level (L_{eq}) - The level of a steady noise which would have the same energy as the fluctuating noise level integrated over the time period of interest. L_{eq} is based on the logarithmic or energy summation, and places more emphasis on high noise-level periods than does L_{50} or a straight arithmetic average of noise level over time. This energy average is not the same as the average of sound pressure levels over the period of interest, but must be computed by a procedure involving summation or mathematical integration.

Environment - The aggregate of all conditions which externally influence the performance and life of an item.

Equipment Reliability - The characteristic which describes the ability of a component, subsystem or system to perform its specified function without failure and within prescribed application limits, expressed as a probability or failure rate per unit of time.

Express Bus, Express Train, Express Service - A method of a bus or train along a designated route when the vehicles do not stop at all stations or bus stops but operate nonstop between selected stations or destinations.

Express/Limited Stop Service - Bus service operating through corridor zones in which the bus makes convenient stops in its originating zone and runs express through other zones and at least one-half of route miles are in express (non-stop, freeway) running.

Expressway - A divided arterial highway for through traffic with full or partial control of access, and generally with grade separations at major intersections.

Facing Point Switch - See Switch, Facing Point.

Fail Operational/Fail-Safe Design - A design principal in which each of the parts, components, and assemblies that make up a system is analyzed to determine the potential consequence of failure of that element with the goal of continuing operation in a possibly degraded, but defined not to be unsafe, mode.

Fail-Safe (Safety) - A characteristic of an equipment system assuring that any failure or malfunction will cause the system to revert to a state that is no less safe than before the failure or malfunction incident.

Fail-Safe Design - A design principle in which each of the parts, components, and assemblies that make up a system is analyzed to determine the potential consequence of failure of that element, alone or in combination with any or all other elements of the system, to assure that a failure combination of failures will not result in a state or condition less safe than that existing before the failure. The prior condition is generally defined to be safe.

Failure - The inability of an item to perform an intended function when used in the intended manner.

- Failure Analysis - The logical, systematic examination of failure events to identify, analyze and report the causes, consequences and costs of potential and real failures.

- Failure, Critical - A failure which could result in a major impact on system performance (major damage to or loss of a system) or major injury or fatality to people.

- Failure, Dependent - A failure which occurs as the consequence of another failure (also commonly defined as a secondary failure).

- Failure, Independent - A failure which occurs during normal use and cannot be associated with a prior equipment malfunction. Commonly defined as a primary failure.

- Failure, Man - Failure due to human error.

- Failure Management - Decisions, policies, and planning which identify and reduce or eliminate potential and real failures as well as provide means and methods for dealing with failures when they occur in order to minimize revenue service impact.

- Failure Mode - The particular manifestation or reaction of an item of equipment failure; the manner of failing.

- Failure Mode and Effect Analysis (FMEA) - An inductive bottom-up procedure in which potential malfunctions of an item are identified for their possible effect.

- Failure Mode, Effect and Criticality Analysis - An extension of an FMEA in which each failure effect is assigned a criticality index, which reflects both the effect and the subjective probability of the occurrence of the effect in terms of loss in performance, reliability, maintainability, and safety.

- Failure, Primary - See Failure, Independent.

- Failure Rate - The number of failures of an item per unit measure of life (such as cycles, time, miles, or events, as applicable for the item).

- Failure, Secondary - See Failure, Dependent.

- Failure, Service - A failure which not only prevents the unit from performing its intended function, but also disrupts or delays scheduled service.

- Failure, Single Point - A failure of a piece, part, component, or assembly which by itself will cause a failure of the system or equipment.

False Occupancy - Indication of track circuit occupancy when no train is present.

Fare - The amount charged for entry into and use of the transit system.

- Barrier-Free Fare Collection System - An arrangement of facilities and equipment where there is no fare barrier or fare gate between station access and train access points, such as paid and unpaid areas.

- Fare Barrier - The separation device between the station paid area and the free area in conjunction with the fare gates.

- Fare Collection System - A system at stations which includes all personnel, equipment, wiring, controls, enclosures, and instruction to provide the means for collection of money from patrons.

- Flat Fare - A fare structure in which the cost of a trip is the same between any two stations in the system.

- Graduated Fare - A fare structure in which the fare paid is proportional to the distance traveled.

- Paid Fare Area - In a system using fare barriers, that portion of the public space occupied only by persons who have passed through the fare barrier to access a train.

- Self-Service Fare Collection - A fare collection system in which no Authority personnel are present or necessary for the patrons to pay fare and access the system. Barriers may or may not be utilized.

- Unpaid (free) Fare Area - In a system using fare barriers, that portion of the station public space where fare vending equipment and related devices are located.

Fault Tree Analysis - A deductive top-down system assessment in which hazards are identified and then analyzed as to their potential causes.

Feeder Bus - Any publicly or privately operated bus which carries patrons to or from rail or bus transit stations or transfer centers.

Fiber Optics (FO) - An assembly of transparent fibers assembled in a bundle and used for light transmission. By the use of appropriate signal generators and receivers, an FO bundle may transmit optical, audio or coded intelligence.

Final Design - Drawings and specifications prepared by the designer in conformance with a preliminary design. Final design provides enough information about the proposed facility and its site to permit competitive bidding by contractors and to guide construction. In addition, it includes final and detailed definition of the architectural character or appearance of the facility; completely developed structural, mechanical, and electrical systems; and a detailed specification of all materials, finishes, equipment, and construction processes. Larger scaled and fully dimensioned drawings, including numerous details and schedules, are provided. Any interface with adjacent private development is fully defined. From this information, detailed color renderings and models can be produced, and a refined cost estimate can be made on the basis of a precise takeoff of material quantities.

Fire Detection and Alarm System (FAS) - A system of automatic fire detectors designed to detect the presence of fire and initiate action.

Fire Load - The average quantity, expressed in heating value, of the combustible contents of a facility space or transit vehicle, including the building materials, furnishings, and equipment.

Fire Management Panel (FMP) - Panel containing a display of FAS detector locations, a manual pull and access to local communications systems. Intended for use by fire/emergency personnel and usually located close to a facility entrance.

Fire-Resistance Rating - An hourly rating assigned to a tested element or assembly by Underwriters Laboratories, Inc., or other recognized authority.

Fire/Smoke Emergency - Fire or the development of smoke or fumes that calls for immediate action to correct or alleviate the condition or situation.

Fixed Gate (End of Cab Signal/Train Control Territory) - The limit of an interlocked route past which automatic operation of trains is never permitted.

Fleeting - Manually established signal selection allowing successive trains running in the same direction to operate over the established route.

Foreign Currents - Stray electrical currents which may affect a signaling system, but which are not a part of the system.

Fouling Point - The location near the intersection of two converging tracks beyond which adequate clearance does not exist for concurrent passage of on-rail equipment.

Free Areas - All areas of the station outside the paid area which are accessible to the public without paying transit fare. See Fare.

Freeway - An expressway with full control of access.

Frequency - The number of oscillations per second of a periodic noise or vibration, expressed in hertz. Frequency in "hertz" is the same as cycles per second. Also used in describing transit service by identifying the rate at which a conveyance passes a passenger pick-up delivery location.

Friction Buffer - A device located at a stub end track to serve as a means of retarding a train to a stop while keeping the train on the running rails and minimizing physical damage. Similar to a bumping post, but using dynamic energy absorbing elements.

Frog - A track structure used at the intersection of two running rails to provide support for wheels and passageways for their flanges, permitting wheels on either rail to cross the other.

- <u>Movable Point Frog</u> - A frog equipped with points which are movable in the same manner as the points of a switch.

Frog Number - The number used to designate the size of a frog, and being equal to one-half the cotangent of one-half the frog angle.

Gate - In signaling, the entrance to a block or route where signal information is conveyed.

Gauge - The distance between the inside faces of running rails of a track measured at right angles at a point 5/8 inch below the top of rail. Also, a generic measurement of nominal or standard size or thickness.

Gauge Line - A line on the rail head used as the reference for measuring track gauge and located 5/8 inch below the horizontal plane of the top of the running rail head along that side which is nearer the center of the track.

General Engineering Consultant (GEC) - The authorized representative retained by the Authority to provide the planning, architectural and engineering services for the integrated bus/rail project. Also may include construction and procurement management services as deemed desirable by the Authority.

General Plans - Preliminary designs for stations. Also see preliminary design.

Grade - The ratio of the vertical change in elevation of a line with its length. For example, a 3 percent grade is a rise of 3 feet in a distance of 100 feet.

- o Grade Crossing - A term used to describe a physical arrangement of two transportation routes where there is possible physical interference between vehicles on each route. A railroad crossing a street, for example, that requires the automobiles to stop to let a train pass or that requires the train to stop for autos to pass is a grade crossing.

- o Grade Separated - A term used to describe a physical arrangement of two transportation routes which permits them to cross each other without any actual physical interference. When a railroad, for example, crosses a highway on an overpass, it is said to be grade separated.

Guard Rail (Track) - See Rail.

Guideway - The structure and its appurtenances upon which the transit vehicle will be traveling and guided.

Hand-Throw Switch - See Switch.

Hazard - Any real or potential condition that can cause injury, death, damage to property, or loss of equipment.

- o Hazard Analysis - An analysis performed to identify hazardous conditions.

- o Hazard Level - A qualitative measure of hazards stated in relative terms:

  - Category I (Critical) - Can result in a mishap, the worst-case effects of which are death or severe personal injury and/or major damage to equipment or property.

  - Category II (Marginal) - Can result in a mishap, the worst-case effects of which are minor personal injury and/or minor damage to equipment or property.

  - Category III (Negligible) - Worst-case effects are less than minor personal injury and/or minor damage to equipment or property.

Headway - The time separation between two trains, both traveling in the same direction on the same track, measured from the time the head end of the leading train passes a given reference point to the time the head end of the train immediately following passes the same reference point.

Headway Control - The means by which the desired headway is maintained.

Hi-Rail - Attachments to make rubber-tired vehicles (such as trucks or autos) capable of operating on rails.

Hi-Rail Switcher - A self-powered road-rail vehicle used for moving transit vehicles.

Hostler - An operating employee whose duties involve moving cars/trains, usually within a yard boundary; sometimes called yard attendant or yard operator.

Hostling - Movement of transit vehicles within yards or storage areas.

Hostling Panel - A panel enclosed by a locked cover or a portable unit that can be connected to a vehicle or the vehicle end not equipped with an operator cab for the purpose of moving the vehicle within a yard/shop or storage area.

Impedance - The elements within an electrical or electronic circuit that limit the current when a voltage potential is applied to the circuit.

- o Ballast Impedance - The impedance to track circuit current due to the condition of the ballast. See Ballast Leakage.

- o Shunt Impedance - The impedance between rails presented by a train's wheels and axles and the wheel/rail interface that provides a parallel (shunt) path for the track circuit current.

In Approach of a Signal - The signaled territory to which a signal aspect is conveyed.

Inbound Track - The track or tracks upon which a train normally approaches a station headed toward the CBD; if on a branch line, toward a branch line/trunk line junction.

Incident - An unforeseen event or occurrence.

Indicator

- o Approach Indicator - An annunciator used to report the approach of a train.

- o Cab Indicator - Audible - An alerting device, located in a transit vehicle cab equipped with cab signals, designed to sound when a cab signal changes to a more restrictive aspect.

- o Switch (Position) Indicator - An indicator used to indicate the position of switch points.

In-House Maintenance - The repair, overhaul, and testing services provided by Authority employee in its own facilities.

Inspection - The checking or testing for condition, performance, and safety of equipment and construction against established standards.

Insulated Joint (Track) - A joint placed between abutting rail ends to electrically insulate them from each other.

Integrated Test - Test program planned and managed by the Authority and supported by equipment/facility contractors for purposes of verifying form, fit and functional compatibility of two or more system elements.

Intercommunication System - An element of the communication system designed for limited communication between two points.

Interface - The defined common boundary between two systems or subsystems. A point where the characteristics of the systems or subsystems are common. An interface may be electrical, mechanical, functional, or contractual.

Interlocking - An arrangement of signals and signal appliances, interconnected so that their movements must succeed each other in proper sequence, permitting train movements over controlled routes only if safe conditions exist.

Intrusion Detection and Alarm System (IAS) - A system of detectors, cabling, signal conditioner, and communication interfaces arranged to identify and remotely annunciate, via the CTS, the presence of unauthorized personnel or objects in Authority premises.

Item - Unit of complexity, such as an element part, component, subsystem, or system.

Jerk (Transit Vehicle) - The time rate of change of acceleration or deceleration.

Joint Bar - Device bolted in place and used to join the abutting ends of contiguous rails.

- o Joint Bar, Bonded - Special joint bar shaped with maximum surface-to-rail contact for adhesion to rail with epoxy adhesive. Used for joining continuous welded rail strings due to their high tensile strength and their ability to prevent any longitudinal movement of the rails at the joint, thereby eliminating any rail gap.

- o Joint Bar, Bonded, Insulated - Special joint bar shaped with maximum surface-to-rail contact for adhesion of epoxy adhesive and containing insulating coatings to arrest the flow of electric current between contiguous rails.

- o Joint Bar, Compromise - A joint bar used to connect contiguous rails of different cross sections.

- o Joint Bar, Insulated - A joint bar used to arrest the flow of electric current between contiguous rails.

Key-By - A device that is operated to negate a trip stop in order to pass a signal displaying a stop indication. The term is derived from the use of the operator's key to actuate the mechanism to negate the trip stop.

Key Telephone Unit - A unit which interconnects a group of pushbutton telephones for local and systemwide communication.

Kiss-and-Ride - The vehicle mode whereby a patron is driven to the transit station, discharged from the delivery vehicle, and the vehicles-stopping duration is limited to the relatively brief discharge time.

L_1, L_{10}, L_{50}, L_{90} and L_{99} - The noise or vibration levels that are exceeded for 1%, 10%, 50%, 90% and 99% of a specified time period, respectively. Environmental noise and vibration data are often described in these terms.

Lay-Up (Storage) - The act of storing cars of a train.

Level of Service - A term or letter designation used to describe the relative quality of the service provided by various transit alternatives. It will usually encompass a consideration of travel times, frequency of service, and passenger-carrying capacity. (Grades A through F according to the Texas Highway Capacity Manual.)

Line, Route - The alignment followed by a scheduled transit vehicle as a part of a transit system.

Line Supervision (Automatic Train Control) - The subsystem within the automatic train system which monitors system status and provides the appropriate control to direct the operation of a train in order to maintain intended traffic patterns and minimize the effect of train delays on the operating schedule.

Line Supervision (Communications) - The monitoring of a line (circuit) to determine the state of its integrity and ability to perform in its prescribed manner.

Local Service - An operation involving frequent stops and low speeds to deliver and pick up transit passengers as close as possible to their points of destination or origin.

Local Street - A street that provides access to adjacent properties.

Locking - The electrical or mechanical establishment of a condition for a switch, interlocked route, speed limit, or automatic function so that its state cannot be altered except by a prescribed and inviolate sequence of unlocking.

- Approach Locking - Electrical locking of any switch, movable point frog, or derail in the route governed by the signal that occurs whenever a train approaches, within a specified distance of that signal displaying an aspect to proceed (until after the expiration of a predetermined time interval after such signal has been caused to display its most restrictive aspect); and which prevents a conflicting aspect from being displayed for any conflicting route.

- Detector (Occupancy) Locking - A method of locking which prevents the movement of a track switch while certain track circuits are occupied by a train.

- Electric Locking - The combination of one or more electric locks and controlling circuits by means of which levers of an interlocking machine, or switches or other units operated in connection with signaling and interlocking, are secured against operation under certain conditions.

- Indication Locking - Electric locking which prevents manipulation of levers that would result in an unsafe condition for a train movement if a signal, switch, or other operative unit fails to make a movement corresponding to that of its controlling lever, or which directly prevents the operation of a signal, switch, or other operative unit, in case another unit which should operate first fails to make the required movement.

- Occupancy Locking - In the signaling system, a method of locking which prevents the movement of a track switch while the track circuits surrounding that switch detect the presence of a train.

- Route Locking - Electric locking, effective when a train passes a signal displaying an aspect for it to proceed, which prevents the movement of any switch, movable point frog, or derail in the train's cleared route in advance of the train.

- Section Locking - For the signal system, locking that is effective when a specific route section is occupied by a train and that prevents any change in position or status of the operating devices and interlocking circuits affecting the safety of the occupying train.

- Time Locking - Interlocking protection which prevents the position of a switch, movable point frog, or derail from being changed, until a predetermined time has elapsed, after a signal governing movements over the device has been restored to stop.

- Traffic Locking - Electric locking which prevents the actuation of devices for changing the direction of traffic on a section of track while that section is occupied, or while the signal displays an aspect for a movement to proceed into that section.

- Trailing Release of Locking - Locking arranged so that when a train clears a track section of the route that the locking affects, that section is release.

Logistics - The system management function which deals with procurement, maintenance, and transportation of material, facilities, and personnel.

Lossy Line Antenna - See Radiating Coaxial Cable.

Lowest Line Replaceable Unit - The smallest element of an equipment item to which a malfunction can be isolated and that can be removed without severing a connection by cutting, melting, heating, or other destructive means.

Lubrication - The application of lubricants, generally on a scheduled basis, to equipment and machinery.

Main Bay - That portion of a vehicle shop equipped for normal, day-to-day lubrication, servicing, inspection, and maintenance of transit vehicles.

Main Line - All track constructed for the purpose of carrying revenue passengers.

Main Shop - A transit facility specifically designed for heavy maintenance, overhaul, and testing of transit vehicles and equipment.

Main Track - A track extending through yards and between stations, upon which trains are operated by rule.

Maintainability - The probability that when a corrective maintenance action is required, the system will be restored to an operable condition within a specified downtime, when the maintenance action is performed in accordance with prescribed procedures.

Maintenance

- <u>Corrective Maintenance</u> - The action taken to restore a malfunctioning item of equipment to an operable state.
- <u>Maintenance of Way and Structures Department</u> - The functional unit within a maintenance organization that has responsibility for the maintenance of all track and the track support system.
- <u>Maintenance Planning System</u> - A system of cost, work and manpower planning, scheduling, and control, either manual or automated, and generally part of a total management information system.
- <u>Preventive Maintenance</u> - The actions taken in an attempt to retain an item in a specified condition by providing systematic inspection, detection, and prevention of incipient failure.
- <u>Scheduled Maintenance</u> - Programmed preventive maintenance.
- <u>Unscheduled Maintenance</u> - Unprogrammed corrective maintenance.

Maintenance Facility - See Yard and Shop Facilities.

Major Defect - A condition other than critical, that is likely to result in a failure or materially the usability of the unit or product for its intended purpose.

Malfunction - Any defect where the system, subsystem, or component fails to function as intended.

Manual Train Control - An operating mode in which the train responds to the actions of its operator through manipulation of the master controller.

- <u>Manual With Cab Signal</u> - Manual train control wherein the operator responds to a cab signal aspect displayed in the cab to control vehicle speed. See Cab Signal Display.

Married Pair - Two cars that make up an operable transit vehicle unit with a cab at each extreme, and generally sharing certain equipment such as battery and power supply. A car of a married pair cannot function alone and the pair is generally connected on a semi-permanent basis.

Mass Transit - Transportation systems which provide for movement of a relatively large number of persons in shared vehicles. Mass transit includes rail transit, buses on exclusive roadways or on public streets, and collector-feeder-distribution systems.

Master Controller - The device which generates local and trainlined control signals to the propulsion system or brake system of a transit vehicle.

Material Review Board - The group charged with assessing the suitability of items not the precise specification requirements, but which may satisfy the functional requirements in the existing form.

Maximum Load Point - The point on a route where the total number of passengers carried is a maximum. The total, generally, is for a 24-hour period in both directions. The maximum load point can also refer to peak- hour and a one-direction flow.

Mean

- <u>Mean Cycles Between Failure</u> - The arithmetic mean of the number of cycles between successive failures.
- <u>Mean Distance Between Failures</u> - The arithmetic mean of the distance traveled between successive failures.
- <u>Mean Downtime</u> - The arithmetic mean of the time that the device remains in an inoperable state after it has failed.
- Mean Life - The arithmetic mean of time to failure of all items in the sample of population.
- <u>Mean Time Between Failures</u> - The arithmetic mean of the time between successive failures.
- <u>Mean Time Between Service Failures</u> - The arithmetic mean of the time between successive service failures.
- <u>Mean Time to Repair</u> - The arithmetic mean of active repair time.

Median, Median Strip - The portion of a divided highway which separates opposing flows of traffic.

Messenger Wire - Part of the overhead conductor system. The uppermost conductor that assumes the approximate form of a catenary curve between support points and in turn supports the contact wire with hangars of variable length. The messenger also distributes power to the trolley wire.

Mezzanine Level - An intermediate level within the station, between grade and platform level(s).

Mixed Face - The presence of both soft ground and rock in the excavation face. This definition may be expanded to include ground of two or more types that require markedly different excavation procedures. An example of this would be limestone and an expansive water-sensitive shale in a rock formation.

Modal Split - The percentage of inter/intra-zonal trips using some mode of mass transit as opposed to the use of private automobile. The choice or "split" between modes can be modeled as a function of variables which describe both the transportation alternatives and the socioeconomic characteristics of those who would avail themselves of the alternatives.

Model - The representation of a system or system feature having properties and operations that represent those of the original system for the characteristics of interest.

Modem - A contraction of "modulator-demodulator." Equipment that connects data terminal equipment to a communication line.

Movement

- Facing Movement - The movement of a train over a switch in a direction away from the point and toward the frog.

- Trailing Movement - The movement of a train over a switch in a direction away from the frog and toward the point.

Muldem - A contraction of "multiplexer-demultiplexer." Equipment that combines several digital bit streams into one bit stream for transmission and separates a combined bit stream into its component segments in the reverse direction.

Multiple Unit Operation, Control - A method of controlling the actions of the propulsion, braking, and other systems of two or more cars of the train from a single cab.

Multiplexer - A device that allows the interleaving of two or more digital signals to a single line or terminus.

Noise Reduction Coefficient - A measure of the acoustical absorption performance of a material, calculated by averaging its sound absorption coefficients at 250 Hz, 500 Hz, 1,000 Hz, and 2,000 Hz.

Nonconformance - Those characteristics which do not conform to stated requirements for the characteristic.

Objective Evidence of Quality - Any recorded statement of fact pertaining to the quality product, process, or operation which is founded on observations, measurements, or tests can be fully checked or verified. Such statements may be recorded on a written or pre-printed document or tag, and are authorized with a signature or stamp identifiable to the person making the statement of fact.

Occupational Safety and Health Act - Federal standards defining minimum requirements for industrial and commercial work place safety. Standards influence operation and maintenance facility design and DART construction.

Off-Street Entrance - An entrance to a station in which the point of access to the vertical circulation elements is located within an adjacent property, at-grade plaza, alley, or area other than the sidewalk.

Operating Characteristics - Those quantitative, measurable parameters pertinent to a specific system, subsystem, device, or component that provide definition of performance.

Operating Costs - All annual service costs, including salaries, energy, maintenance of equipment, supplies, and administrative expenses.

Operating Personnel - Those employees of a transit system having direct and supervisory responsibility for the movement of trains, the manning of stations, and the maintenance of facilities, embodying both onboard and wayside duties.

Operating Revenue - The gross income from operation of the transit system, including basic and special fares, as well as income from charters, concessions, and advertising. It does not include items such as interest from securities or non-recurring income from sales of capital assets.

Operation Control Center - DART operating office headquarters.

Operations Department - That function within the Authority that generally has responsibility for the transportation and maintenance activities.

Overhaul - The heavy repair or rebuilding of components and complete vehicles, equipment, and machinery to restore to "like-new" condition.

Overhead Conductor System - That part of the overhead line equipment comprising the catenary, catenary supports, foundations, counterweights and other equipment and assemblies that delivers electric power from the traction power sub-station to the transit vehicle.

Outbound Track - The tack or tracks upon which a train normally departs a station headed away from the CBD or a trunk line/branch line junction.

Overspeed Protection Control - That portion of the carborne train control system which, in a fail-safe manner, enforces speed limits. See Automatic Train Protection.

Paid Area - The portion of public space within a station structure which lies inside the fare-collection barrier on a system employing gates controlled by fare media.

Pantograph - A device for collecting current from an overhead conductor, consisting of a diamond or half-diamond-shaped jointed frame, operated by springs or compressed having a suitable trolley-wire contact surface at the top.

Parallel Redundancy - Two or more methods operating continuously, each of which is capable of providing the required functional/operational output independently or collectively.

Park-and-Ride - A parking facility designed for the use of mass transit patrons. A term used to describe a change in travel mode in which passengers park their cars, ride the DART system, and return to their cars at a later time.

Parsons Brinckerhoff Centec, Inc./Deleuw Cather and Company (PBDC) - A joint venture of the two named companies serving as the General Engineering Consultant to DART for the transit project.

Part - See Piece Part.

Passageway - An enclosed space or structure traversing over or under traffic or other barriers for the convenient passage of patrons entering or exiting the system. It may connect from public or private property.

Peak-Hour Load (A.M. or P.M.) - The peak hour is the 60-minute period during an average weekday when the maximum total estimated number of people travel past a specific point in one direction on a specified route. The A.M. or P.M. peaks are in the morning or afternoon when demand for transportation service is heaviest.

Peak-Hour-Only Entrance - An entrance to a station which is open only during rush hours in the morning and evening.

Penalty Stop - The stop effected by the carborne ATP equipment that automatically applies service brakes if imposed restrictions are ignored.

Performance Level (Train) - The combination of vehicle acceleration and speed characteristics that determine point-to-point running time. Performance-level modification may be achieved by train operator selection or ATC command and allows selection of different modes for energy efficiency r schedule adjustment.

Piece Part - The smallest element of equipment or hardware that is uniquely identified by some functional attribute that will be destroyed if the part is further disassembled. Further disassembly is generally only possible by destructive means.

Pit - An area below the maintenance-area floor level between running rails and/or tracks for undercar lubrication, inspection, and maintenance.

Plan - A scheme or program for making, doing, or arranging something, such as project, design, or schedule.

Platform - That portion of the station directly adjacent to the tracks, where trains stop to load and unload passengers. The full platform is the length of the trains which ultimately operate at peak hours. There are two basic types of platform: center platform, with a platform between inbound and outbound track; and side platform, with a platform on each side of an adjacent pair of tracks.

Platform Edge - The continuous portion of the platform adjacent to the train and distinguishable by color, texture, or a combination of both, for the purpose of warning patrons of proximity to the trainway.

Plaza Entrance - An entrance to a below-ground station, opening directly from an off-street plaza, which may be at the street or mezzanine level of the station.

Pocket Track - See Track, Pocket.

Point Detector - See Detector.

Point - See Switch Point.

Portable Car Jacks - Specially designed jacks (usually in a set of four) for raising a single car at specific lifting points established in the car design. They may be used anywhere at floor level where built-in jacks or hoists are not warranted or cannot be installed.

Power Department - That functional unit of the maintenance organization that is responsible for a transit system's power distribution, including substation, overhead conductor system, circuit breakers, and batteries.

Pre-Award Survey - An evaluation of a prospective contractor's capability to perform under the terms of a proposed contract.

Preliminary Design - A continuation of design work following conceptual design. Preliminary design has specific meaning as applied to the DART project. Its scope will vary according to the type of station, facility or other structures involved, and depending on whether there is joint development potential. In general, it involves the development of more detailed, larger-scale, "hardline" plans, elevations, and sections, showing all significant elements of the facility, including structures, site, etc., with appropriate allocation of space for mechanical and electrical systems. Important dimensions are given and principal construction materials may be suggested graphically or by note. All major alternatives have been evaluated and coordination between utilities, adjacent properties and design elements is complete.

Preliminary Engineering - The engineering and architectural services necessary to develop the information required prior to commencing detail or final design.

Private Branch Exchange - A telephone exchange serving a single organization and having connections to a public telephone exchange.

Procedural Safety - Acceptable hazard mitigation achieved or enhanced by compliance with administrative or operational restrictions.

Product Assurance - A methodology used to ensure that the design will perform its intended functions if constructed and operated as expected.

Profile - The vertical location of a guideway or a roadway as described by curves and tangents defining its position with respect to the surrounding area. See Alignment.

Profile Grade Line - A line, based on a vertical datum (reference), which defines the vertical alignment of the track, applied at the top of the low rail.

Qualification Test - A one-time performed by a manufacturer to demonstrate the ability of an item to function in accordance with specified requirements. Sometimes identified as a "proof of design" test.

Quality

- <u>Quality</u> - The as-built degree of optimization of an item or material to the required attributes.

- <u>Quality Assurance</u> - The activities that apply engineering techniques to monitor, measure, evaluate, control, and improve all design, construction, manufacturing, and inspection, with the objective of providing an acceptable level of confidence that the end item will perform as required.

- <u>Quality Assurance/Control Inspector</u> - Engineering inspector authorized to accept or reject items such as materials, systems, structures, components, equipment, or operations, and to test on the basis of non-conformance with pre-defined attributes or inspection plans.

- <u>Quality Assurance Program</u> - All those planned and systematic actions defined to provide confidence that structures, system, components, parts, or materials are designed, erected, manufactured, or installed in accordance with applicable criteria drawings, specifications, and codes.

- Quality Control - The discipline which involves the examination of characteristics of a structure, system material, component, or part and which assures the construction, fabrication or manufacture of uniform end products within specified tolerance limits, in accordance with design drawings and/or specifications.

Queuing Space - Adequate space provided in the approach sides of fare-vending machines, fare gates, escalators or other service elements to prevent undue crowding of patrons.

Radiating Coaxial Cable - An antenna formed by modifying a radio frequency transmission cable to allow it to receive or transmit energy along its entire length. Used in locations shielded from normal antenna radiation such as subway or building structure. Also called a "lossy line".

Radio Base Station - A land station in the land-mobile service carrying on a radio communication service with portable, mobile, and fixed stations.

Radio Satellite Receiver - An auxiliary radio receiver at a fixed location used in conjunction with a radio base station to extend the area of satisfactory signal reception from portable and mobile stations. Typically located in a outer portion of the base station's area of coverage from which reception at the base station of signals from portable and mobile stations would be marginal.

Rail

- Closure Rails - The rails between the parts of any special trackwork layout, such as the rails between the switch and the frog in a turnout; in addition, the rails connecting the frogs of a crossing or of adjacent crossings, but not forming parts.

- Continuous Welded Rail - A number of rails welded together into a single length.

- Guard Rail - A rail installed parallel to and inside of the running rails of a track to hold wheels in correct alignment to prevent their flanges from striking the points of turnout, or crossing frogs, or the points of switches. The term as sometimes applied to other track structures is more properly referred to as restraining rail.

- Head-Hardened Rail - Tee rail which has a Brinell hardness between 321 and 388 on the head of the rail, which is achieved by induction or flame methods.

- Inside Rail - On a curved track, the rail closer to the curve center; the rail with the shorter radius. On a curved track which is superelevated, it is sometimes referred to as the "low rail."

- Outside Rail - On a curved track, the rail farther from the curve center; the rail with the longer radius. On a curved track which is superelevated, it is sometimes referred to as the "high rail."

- Premium Rail - Tee rail which has a Brinell hardness between 321 and 388, which is achieved by heat treating or by manufacturing using magnesium or chromium steel alloys.

- Restraining Rail - See Guard Rail.

- Running Rail - The steel beam that carries the load and guides the flanged wheel of a steel- wheeled vehicle.

- Standard Rail - Tee rail manufactured using an alloy of elements prescribed by the AREMA.

- Stock Rail - The fixed running rail that the switch point bears against at a turnout.

- Tee Rail - The common class of steel rail for track construction which is symmetrical in section and resembles an inverted letter "T." The term "standard" is commonly associated with tee rail sections.

- Rail Anchor - A device which clamps to the base of a rail and bears against the side of a cross tie thereby restraining longitudinal rail movement.

- Rail Fastener - A device used to secure the running rails to cross ties or concrete trackbed for proper lateral and longitudinal support of the rail.

- Rail Operations Controller (RO) - An operating person, within a control center, whose function it is to dispatch trains, monitor train operation, and to intervene in the event of disruption of schedule, or when any change in service or routine is required.

Rail Transit System - An electrified fixed-guideway transportation system, using steel rails, operating for the mass movement of passengers within a city or metropolitan area and consisting of its guideway, transit vehicles and other rolling stock, power, communications and control systems, maintenance facilities, and other stationary and movable apparatus and equipment, as well as its operating practices and personnel.

Rail Transit Vehicle - An electrically propelled passenger-carrying rail vehicle characterized by high acceleration and braking rates for frequent stops and high rates of loading and unloading.

Rapid Transit - A public transit facility operating on exclusive, grade separated fixed right-of-way. Buses operating on exclusive, grade separated roadways are included in this definition.

Rate

- Acceleration Rate - Positive time rate of change of speed of a vehicle.

- Brake Rate - See Braking.

Records Center - An office of an operating department responsible for operation and maintenance data collection and dissemination of such activities as maintenance, schedule vehicle and equipment histories, failure reports, warranty reports, and standards.

Regeneration - The process of supplying the energy generated during dynamic braking into the primary traction electrification distribution system.

Regulator, Speed - An onboard vehicle subsystem, generally but not necessarily a part of the automatic train operation system, which controls acceleration and braking effort for the vehicle to reach and maintain a desired speed within a desired tolerance.

Relay - An electromagnetic device that is operated by a variation in the conditions of one electric circuit to affect the operation of other devices in the same or another electric circuit.

Relay Zone - A grouping of tracks and switches used for temporary routing of cars during a consist change.

Reliability - The ability of a part component, assembly, element, subsystem, system element, or the system to perform its intended function within the design limits and time and without failure, expressed as a probability.

- o Achieved Reliability - The reliability level which has actually been attained at some point in time.
- o Reliability Block Diagram - A schematic representation which portrays item operation by showing all possible success paths.

Remote Communications Terminal - Communications apparatus at a passenger station, yard, or shop.

Remote Station - A station physically removed from a master station where units of switchgear or other equipment are controlled by supervisory control or from which supervisory indication or selected telemeter readings are obtained.

Repair - The maintenance activity which restores a malfunctioning item to an operable state.

Repairable - The condition of a malfunctioning item that can be restored to an operable state regardless of cost.

Reparable - The condition of a malfunctioning item that can be economically restored to an operable state.

Response Time - The time used by equipment, operator, or both, that elapses between the moment an action is called for and when the desired result occurs.

Retrofit - As applied to vehicles and facilities, to equip with new parts or equipment to modify the original design (as contrasted with overhaul or replacement-in-kind).

Revenue Operations - Movements of vehicles and operation of associated apparatus for the purpose of carrying passengers in scheduled service, including the movements of vehicles to and from regular storage locations.

Revenue Service - The transportation of passengers.

Reverberant Field - The region in a room where the reflected sound dominates, as opposed to the region close to the noise source, where the direct sound dominates.

Reverberation - The continuation of sound reflections within an enclosed space after the sound source has stopped.

Reverberation Time - The time taken for the sound-pressure level in a room to decrease to one-millionth (60 dB) of its steady-state value after the source of sound energy is suddenly interrupted. It is a measure of the persistence of a sound in a room and of the amount of acoustical absorption present inside the room.

Reversible Track - A section of track on which the prescribed direction of running can be reversed.

Ridership - The number of persons using the transit system within any given time period.

Right-of-Way - All land purchased, leased, or otherwise acquired by the Authority for the development and operation of the DART project.

Risk Management - The evaluation of safety effects of potential hazards and the acceptance, control, or elimination of such hazards with respect to expenditure of resources.

Roadbed - The earth bed or foundation which supports the subballast, ballast, ties, and rail of a ballasted track structure, sometimes referred to as subgrade.

Rock - Ground capable of supporting itself for either a limited or unlimited period. The lower strength boundary of rock may be as low as 100 pounds per square inch (psi), provided considerable continuity exists in the form of massiveness or cementation.

Rock Bolts - Steel bars inserted into the ground surrounding the tunnel to maintain or increase its self-supporting capability. The bars are inserted into predrilled holes and held in place by encapsulation with a resin or cement grout. Rock bolts may be pre-tensioned to a specific value to increase their binding value and the stress in the ground. Rock dowels are rock bolts with pre-tension.

Rock Stabilization - Controlling the tunnel configuration by whatever method necessary. The term includes steel sets or lattice girders which support the ground, and rock bolts or shotcrete which reinforce the rock.

Rolling Stock - A term generally referring to transit and maintenance vehicles.

Route - A succession of contiguous track blocks between two controlled gates or interlocked signals.

- o Conflicting Route - Two or more routes, opposing, converging or intersecting, over which movements cannot be made simultaneously without possibility of collision.
- o Route Request - The registration at an interlocking of a desired interlocked route.

Runoff Space - Adequate space provided in the exiting areas of fare gates, entrances, and escalators to prevent undue crowding of patrons.

Rush Hour - See Peak Hour.

Safe - Free from or having an acceptably low probability of exposure to defined danger or loss.

Safety Critical - A designation placed on a system, subsystem, element, component, device, or function denoting that satisfactory operation of such is mandatory to ensure patron, personnel, equipment, or facility safety. Such a designation dictates incorporation of special safety design features.

Secondary Tracks - See Yard and Secondary Tracks.

Section Designer - Individual engineering or architectural-engineering firms retained to prepare the design, contract drawings, specifications, and cost estimates for certain sections of the rapid transit system.

Service Aisles - Paved aisles in yards between storage tracks for movements of service vehicles and their personnel and equipment. Such vehicles may include electric carts, forklifts, and specially designed cleaning crew vehicles.

Service Brake - The primary train brake system(s).

Service Brake Application - Any non-emergency brake application.

Service Dependability - The combination of reliability and operating characteristics of a system that describes on-time system performance probability.

Service Gate - A gate controlled by the station attendant through which materials and personnel may pass to circumvent the fare gates in a barrier-equipped system.

Shop Facilities - Facilities, usually located within or adjacent to a storage yard, for the maintenance of transit vehicles and vehicle components, and which may include facilities for the maintenance of fixed plant and wayside systems and equipment.

Shotcrete - Pneumatically applied concrete. Steel fiber, plastic fiber, or fiberglass fiber may be mixed in the shotcrete for crack control.

Shunting Sensitivity (Track Circuit) - The maximum impedance in ohms which, when measured at the most adverse shunting location, will cause the track circuit to detect the presence of a train.

Sidewalk Entrance - An entrance to a transit station located in the sidewalk right-of-way, between the building line and the street curb line, and usually adjacent to the curb line.

Signal - A means of communicating information.

- o Signal Aspect - The appearance of a fixed signal conveying an indication as viewed from the direction of an approaching train; the appearance of a cab signal conveying an indication of signal-system status and viewed by an observer in the cab.

- o Audible Signal - A sound-producing device used for attracting attention.

- o Block Signal - A fixed signal at the entrance to a block used to govern trains entering and using that block.

- o Bumping Post Signal - A signal to advise that a bumping post is ahead at a temporary or permanent end of the track.

- o Cab Signal - A visual indicator in the train operator's cab which conveys the automatic block aspects indicating the prevailing speed command.

- o Call-on-Signal - An interlocked signal aspect which permits a train to enter an occupied block at restricted speed.

- o Cleared Signal - A signal which has been caused to display an aspect to proceed.

- o Color Light Signal - A signal which displays aspects by means of lighted color lenses.

- o Dwarf Signal - A wayside aspect at an elevation below the eye level of the train operator.

- o Fixed Signal - A signal of fixed location indicating a condition affecting the movements of a train.

- o Flashing-Light Signal - A highway crossing signal, the indication of which is given by two horizontal red lights flashing alternately at predetermined intervals, or a fixed signal in which the aspects are given by color and by the flashing of one or more of the signal lights.

- o Hand Signal - Any signal given by an individual located at trackside to govern trains.

- o Home Signal - A fixed signal at the entrance of a route or block.
- o Impulse Signal - An automatic signal, not displaying a visible aspect, which is read and automatically responded to by carborne equipment, thereby regulating train movement.
- o Interlocking Signal - A wayside signal which governs movements into or within interlocking limits.
- o Opposing Signals - Wayside signals which govern train movements in opposite directions n the same track.
- o Proceed Signal - A wayside, hand, or cab signal displaying any aspect which conveys indication that permits a train to move.
- o Repeater Signal - A wayside signal used to provide a mimic of the control aspect in areas of restricted sight distance.
- o Signal Indication - The information conveyed by the aspect of a signal.
- o Wayside Signal - A device located along the wayside providing a visual indication to train operators relative to allowable train speed or routing.

Simulation - The exercising or operation of a model of an item in lieu of operating the item itself. The item model may be scale hardware of systems, a breadboard model, or a mathematical representation that can be operated manually or with the use of a computer.

Single Unit - A self-contained transit vehicle capable of running as a single car as opposed to one car in a multiunit consist. Control cabs are located at both ends. Single units are easily and quickly connected to and disconnected from other cars.

Skip Stop (Station Run Through) - An operating procedure in which a train intentionally passes through a station without stopping.

Slide (Wheel) - The condition where the wheel tread speed is less than train speed.

Soft Ground - Ground incapable of supporting itself for any period of time, and which therefore needs immediate and continuous support. Such ground may be non-cohesive (e.g., clean sand) partially cohesive (e.g., silty sand) or cohesive (e.g., clay). Moderately to heavily weathered rock which has lost much or all of its self-supporting capability is considered soft ground.

Sound Absorption Coefficient ( ) - The absorption coefficient of a material is the ratio of the sound absorbed by the material to that absorbed by an equivalent area of open window. The absorption coefficient of a perfectly absorbing surface would be 1.0 while that for concrete or marble slate is approximately 0.01 (a perfect reflector would have an absorption of 0.00).

Sound-Pressure Level - The sound-pressure level of a sound in decibels is 20 times the logarithm to the base of 10 of the ratio of the RMS value of the sound pressure to the RMS value of a reference sound pressure. The standard reference sound pressure is 20 micro-pascals as indicated in ANSI S1.8-1969, "Preferred Reference Quantities for Acoustical Levels."

Source Inspection - Inspection performed at a supplier's plant.

Special Entrance (Public or Private) - An entrance to a subway or other station from a store, office building, or other public or private building. Usually at mezzanine level.

Special Trackwork - A generic term referring to switches and rail crossings.

Speed

- Civil Speed Limit - The maximum speed allowed in a specified section of track as determined by physical limitations of the track structure, train design and passenger comfort (based on 2- inch superelevation unbalance).

- Command Speed - That speed limit being imposed upon a train at a given pint in time by the automatic train protection system.

- Maximum Authorized Speed (MAS) - The highest speed limit which is ever authorized in a given track section by the signal system or operating rules.

- Operating Speed Limit - See Civil Speed Limit.

- Reduced Speed - The order to proceed slowly and be prepared to stop short of another train or obstruction. Any speed less than MAS.

- Restricted Speed - The order to proceed slowly, and be prepared to stop short of another train, obstruction, maintenance activities or switch not properly aligned, and to look out for broken rail, at a speed established by operating rules and procedures. Train rules may be imposed by written instruction or the signaling system.

- Safety Speed Limit - The maximum speed allowed in a specified section of track as determined by physical limitations of the track structure, train design and passenger safety (based on 4- inch superelevation unbalance).

- Schedule Speed - The speed called for to comply with the train operating schedule.

Speed Distance Profile - A graphical representation of speed against distance traveled.

Spin (Wheel) - The condition wherein the wheel tread speed is greater than the transit vehicle speed. Commonly called wheel slip.

Spin-Slide System - The transit-vehicle-borne system for detecting and minimizing a spin or slide condition.

Spotting - Placing a train in a designated location for loading, unloading, storage, or maintenance.

Standard Drawings - Drawings defining facilities or equipment configurations that will be repetitively used throughout the DART system. Standard drawings may be used as drawings. No modifications may be made to details on standard drawings to fit specific requirements of the project without prior approval of the Authority.

Standard Times - The average times required to perform a given maintenance or operations task. These times are usually estimated originally and constantly refined to reflect experience and progress. They are a measure of production and most useful in estimating personnel, material, and budget requirements as well as for cost control.

Standby Redundancy - Parallel elements, one of which is not activated until its operation is required as a result of prior element failures.

Stand-up Time - The time the excavated ground is capable of self-support. Ravelling from crown and sidewall is permitted, provided it is not so extensive that chimneying (substantial loss of ground overhead) or running (loss of ground in the face) become a threat.

Station

- o Station - The complex of structures and platforms and surrounding access areas, including parking areas within the boundaries of the station site to enable patrons to enter and leave the transit system.

- o Station, Above-Ground - A station located entirely on grade or an aerial structure.

- o Station, Aerial - Any DART station in which the tracks and platforms are located on aerial structures.

- o Station, At-Grade - Any DART station in which the tracks rest directly on grade. Grade may be the natural grade, an open cut or retained fill.

- o Station Attendant - An Authority representative at the station who has constant contact with the public and whose responsibilities include carrying out most of the station operational functions of supervision, administration, and communication.

- o Station Attendant's Booth - The enclosed space located at stations occupied by a station attendant. Sometimes called a kiosk.

- o Station Trainway/Trackway - That portion of a station through which trains run.

- o Station, On-Line - A station area in which transit vehicles on the route must pass.

- o Station Program - An outline of the work of the designer defining scope, states of design at submittals, budget, and schedules.

- o Station, Underground - A station in which the major portion of the structure is located below the finished grade and is completely enclosed.

Statistical Distribution Terms for Noise and Vibration

- o L_{99} and L_{90} are descriptors of the typical minimum or "residual" background noise vibration) levels observed ruing a measurement period, normally made up of the summation of a large number of sound sources distant from the measurement position and not usually recognizable as individual noise sources. The most prevalent source of this residual noise is distant street traffic. L_{99} and L_{90} are not strongly influenced by occasional local motor vehicles passing by. They can be influenced by stationary sources such as air conditioning equipment, however.

- o L_{50} represents a long-term statistical median noise level over the measurement period and does reveal the long-term influence of local traffic.

- o L_{10} describes typical or average levels for the maximum noise levels occurring; for example, during nearby passbys of trains, trucks, buses and automobiles, when there is relatively steady traffic. Thus, while L_{10} does not necessarily describe the typical maximum noise levels observed at a point, it is strongly influenced by the momentary maximum noise level occurring during vehicles passing by at most locations.

- L_1, the noise level exceeded for 1 percent of the time, is representative of the occasional, isolated maximum or peak level which occurs in an area. L_1 is usually strongly influenced by maximum short-duration noise level events that occur during the measurement time period. It is often determined by aircraft or large vehicles passing by.

Stopping Distance - The maximum distance on any portion of any railroad which any train, operating on such portion of railroad at its maximum authorized speed, will travel during a full-service application of the brakes, between the point where such application is initiated and the point where the train comes to a stop.

Storage Life - The length of time an item can be stored under specified conditions and still meet specified operational requirements. Also known as shelf life.

Subballast - A material that will provide a semi-impervious layer between the ballast and the subgrade to facilitate drainage and distribute lads to the subgrade.

Subgrade - The finished surface of the roadbed below the level of subballast or track slab.

Substation - A facility containing electrical equipment, such as transformers and switchgear, which provides electric power to stations, vehicles, and guideways.

Subsystem - A defined portion of a system which is in turn composed of equipment components, assemblies or parts. The public address system, for example, is a subsystem of the communications system.

Subway - That portion of a transit line which is constructed beneath the ground surface, regardless of its method of construction.

Subway Environment Simulation - A complex model of subway system elements including heat sources, profile and alignment, stations, and line sections, use to determine subway ventilation requirements under normal and abnormal conditions.

Subway Station - See Station, Underground.

Superelevation - The difference in vertical height, measured at the centerline of the tops of rails, between the outer rail and the inner rail.

Superstructure - All those parts of an aerial structure or bridge which extend above the bridge seats, tops of piers, haunches or rigid frames, or the spring lines of arches.

Supervisory and Control - A system for remote electrical control and indication of remote located units over one or more common interconnecting channels or lines.

Supervisory Control Point, Control, and Indication - A control point permitting remote control of an end device with report and display of its status.

Switch - A track structure with movable rails to divert rolling stock from one track to another.

- <u>Electropneumatic Switch</u> - A track switch operated by an electropneumatic switch and lock movement.
- <u>Hand-Operated Switch</u> - A switch which can only be operated manually.
- <u>Interlocked Switch</u> - A track switch within the interlocking limits the control of which is interlocked with other functions of the interlocking.

- o Normal Switch Position - The position of a track switch and its control when corresponding to the defined track layout for predominant traffic routing.

- o Reverse Switch Position - The position of a track switch and its controls when opposite to the normal position.

- o Switch and Lock Movement (Switch Machine) - A device which performs the functions of unlocking, operating and locking a switch, movable point frog, or derail.

- o Switch, Facing Point - A track switch, the points of which face traffic approaching the direction for which the track is signaled.

- o Switch Indicator - An indicator used to indicate the position of switch points.

- o Switch Point - A movable tapered track rail, the point of which is designed to fit against the stock rail.

- o Switch, Point of - The end of a switch rail farthest from the frog.

- o Switch Point, Undercut - A switch in which the stock rails are undercut to mate with or nest the switch rails, so that the actual point of the switch rail does not protrude beyond the original outline of the rail head of the stock rails, and its effective width at the point is zero. Consequently, the vertex of the switch angle is located at the actual point of switch rather than ahead of it. The undercut switch point is as per detail 5100 of AREMA Plan Basic No. 221, "Details For Switch Points."

- o Switch Rail (Switch Point) - The tapered rail of a split switch.

- o Switch, Split - A switch consisting essentially of two movable switch rails.

- o Switch, Track - A pair of switch points with their fastenings and operating rods providing the means for establishing a route from one track to another.

- o Switch, Trailing Point - A track switch, the points of which face away from traffic approaching in the direction for which the track is signaled.

System - The composite of facilities and equipment, personnel, and procedures of the transit system, such as the vehicle, train control, communications, electrification, fare collection, and stations, which, when used together as an entity, is capable of performing the required function.

- o System Assurance - The technical activities performed within the disciplines of quality assurance, reliability, maintainability, system safety, system security, and human factors that assure and verify the design, construction, operations, and maintenance of a system.

- o System Description - A top-level document which defines the overall system and subsystems, and identifies their functions, relationships, interfaces, and requirements.

- o System Safety - The application of operating, technical, and management techniques and principles to the safety aspects of a system throughout its life, to reduce hazards to the lowest level possible through the most effective use of available resources.

- o System Safety Engineering - The application of scientific and engineering principles during the design, development, manufacture, and operation of a system to meet or exceed established safety goals.

- o System Safety Management - The organized planning, controlling and integration of all efforts directed toward system safety.

- o System Safety Verification - A written statement testifying to the fact that the operating transit system is considered to be safe for operation, within the state-of-the-art, for patrons, employees, emergency service personnel, the general public, and property, and that such a condition is attested to by the developing authority.

  "Safe" in this connotation refers to four different but overlapping concerns:

  - Fire/Life Safety - Elimination, minimization, or control of potential hazards to patrons, employees, and emergency service personnel, and the protection of property from damage by fire or explosion.

  - Occupational Safety - Elimination, minimization, or control of potential hazards to employees and emergency service personnel.

  - Human Factors and Design Accommodations for Elderly and Handicapped People - Elimination, minimization, or control of potential hazards to patrons and employees, particularly the elderly and handicapped, caused by the interface of people with system hardware and operation.

  - System Safety - Elimination, minimization, or control of potential hazards to patrons and the general public, and the protection of property from damage.

- o System Security - The actual or perceived protection of the public, transit system employees, and the transit system from crime and vandalism.

Tangent - Any portion of the railway alignment without horizontal curvature.

Telephone Channel - A communication channel suitable for the transmission of voice or tone signals.

Test Track - A length of non-revenue service track of sufficient length to safely operate a car or train through a performance cycle (start, accelerate, run at constant speed, decelerate, and stop). The track may be equipped with all the system safety features to include track circuits and cab signals for automatic train protection.

Throat - That portion of a yard that connects the storage area to the main line lead tracks.

Ticket Vendor - Machine located at a transit system station to dispense tickets.

Time Release - A device used to prevent the operation of a piece of equipment until after the expiration of a predetermined time interval after the device has been actuated.

Top-of-Rail - The profile line representing the elevation f the top of the running surface of rails. Where superelevation exists, the top-of-rail profile represents the inside or lower running rail, unless otherwise indicated.

Track

- o Track, Ballasted - Track constructed of rails, ballast, and cross ties. It is the predominant form of track constructed at-grade, but it may also be used on bridges.

- Track Block - Generally, a length of track of defined limits. For DART, a track section equipped to detect train occupancy anywhere in the section and to transmit the same speed command to a train anywhere in the section.

- Track Concrete - The leveling course of reinforced concrete used in all direct-fixation track. Frequently called a second pour.

- Track, Direct-Fixation - Track constructed of rail, elastomeric rail fasteners, associated hardware and track concrete, where fasteners are attached to track concrete by means of anchor bolts.

- Track, Drill - A track connecting with the ladder track, over which cars move back and forth in switching.

- Track, Ladder - A track connecting successively the body tracks of a yard.

- Track, Lead - An extended track connecting either end of a yard with the main track. Also see Track, Transfer Zone.

- Track, Main Line - Track constructed for the primary purpose of carrying passengers.

- Track, Pocket - A track auxiliary to the main track for meeting, passing, turnback or storing trains. Usually accessible from both main tracks on a double-track transit line. May be single ended or double ended.

- Track, Repair Shop - A track on which cars are placed for repairs.

- Track, Running - A track reserved for movement through a yard.

- Track Slab - The reinforced concrete foundation that supports the track itself, generally in conjunction with direct-fixation track; can be the deck of a bridge on the invert slab of a subway structure. Frequently called the first pour.

- Track, Storage - Each of the parallel tracks of a yard upon which cars are stored.

- Track, Tail - A track section connected to the main track beyond the limits of revenue service. May be used to provide overrun space for accommodating maximum stopping distance or in some configurations, may accommodate reversing moves or out-of-use train storage.

- Track, Transfer Zone - A length of defined limit track connecting the main line track with the yard track and used to transfer control between main line operation and yard operation.

- Track, Wayside Storage - One or more tracks off the main for storing equipment or cars.

Trackway - The foundation on which the track is constructed. It usually consists of an earthen roadbed. In addition, it may be a track slab for support of direct-fixation track; or it may be a ballasted bridge deck or direct-fixation bridge deck. In ballasted track the trackway surface is the subgrade or roadbed/subballast interface. In direct-fixation track, the trackway surface is the track slab on which the track structure including the track concrete is constructed.

Trackwork Directive Drawings - Drawings of trackwork elements including typical ballasted and direct-fixation track sections which provide preliminary design guidance for preparation of final detail design f trackwork and interfacing elements. They convey design criteria in graphical or plan form.

Trackwork Standard Drawings - Drawings of standard trackwork elements including special trackwork, grade crossings, ballast and direct-fixation track sections, anchoring patterns, and spiking patterns. They are procurement, fabrication, and construction drawings developed during detail design for all standard trackwork installations.

Traction Electrification System - The substations, feeder cables, catenary system and other equipment that provide electrical power for movement of trains.

Traction Motor - Motor on-board the transit vehicle that propels the vehicle.

Traction Power Substation - An electrical facility for conversion of high voltage AC power to DC power at the design voltage to power transit vehicles.

Traffic Direction - The designed predominant direction of train traffic as specified by the book of rules.

Train

- Train - A consist of one or more transit vehicles combined into an operating unit.
- Train Berth - The space designated for a train of given length to occupy7 when it is stopped at a station platform, in a terminal, on transfer track, or at some designated place.
- Train Control Center (TCC) - The offices of the system in which communications, traction electrification, signals, and closed-circuit television are operated and monitored. In addition, it is the area where all emergency and malfunction alarms are annunciated and recorded. May include additional system functions as appropriate.
- Train Control Receiver - A device on a vehicle placed in a position to be influenced inductively or actuated by an automatic train control or cab signal roadway element.
- Train Detection - A method by which the presence of a train in a block is known.
- Train Identification - A method of identifying trains using information such as number, destination, length, or a combination of these elements. May be accomplished electronically for such functions as routing.
- Train Length - The number of units (transit vehicles) in a train; its overall length in dimensions of distance.
- Train Number - Numerical designation of a train.
- Train Operations - The function involving the authorized operation of trains over main line routes and within yard limits according to established schedules, rules, and procedures.
- Train Operator - An Authority employee in service on board a train whose principal duties are to operate the cab controls, oversee safety, provide required security, and assist in emergency operation.

- o Train Start Lights - Indicators at terminal stations which, in conjunction with manual or automatic train dispatchers, are used to maintain scheduled train operation.

- o Train Washer (Car Washer) - An automatic apparatus made up of brushes, spray arches, solution tanks, water reclamation system, and controls to wash cars or trains passing through the apparatus.

Transducer - Any device used to transmit the energy of one power system in predetermined proportions to that of another.

Transfer Level - The level, immediately above the platforms of adjoining stations, which is common to each station and facilities transfer of patrons between transit lines.

Transfer Table - A device for transferring cars from one track to another parallel track, consisting of a bridge- like structure carrying a section of track, and fitted with flanged wheels at each end that roll on steel rails laid along either side of a long pit. May be configured to serve as a turntable.

Transfer Ticket - Ticket issued to a transit passenger who is changing from one transit vehicle to another.

Transit Agency - Identification of the group who will assume overall authority and responsibility for the development and operation of the rapid transit system. See DART.

Transit Mall - A public street or way dedicated to the exclusive use of mass transit operations, whether bus or rail; used in conjunction with pedestrian malls to facilitate the circulation of transit patrons and general public pedestrian traffic.

Transit System - See System.

Transit Vehicle - A passenger-carrying vehicle propelled by motor or engine, designed for fast loading and unloading of passengers and frequent starting and stopping.

Tread Brake Unit - A unit composed of brake shoe and apparatus to apply the brake shoe to wheel tread.

Trip - The one-way movement of one person between point of origin and point of destination; includes walking to and from the means of transportation.

Trip Cock - A train-mounted mechanical or electro-mechanical device which, when activated by a trip stop, results in a brake application.

Trip Distribution - The procedure of estimating the geographic orientation in distance and direction of the travel demand from a specific analysis area.

Trip Generation - The procedure of estimating the amount of travel demand for various purposes for a specific analysis area.

Trip Stop - A mechanical or electrical device located on the wayside which initiates a brake application on a train which passes the device.

Trip Time - The total time required for a passenger to make a one-way trip between designated origin/destination points on the system, including access time, waiting time, corridor travel time, and transfer time.

Trolley Wire - See contact wire.

Truck - A major transit vehicle assembly which includes structural members, wheels and axles, motors, gearboxes, brakes, collectors, cable, and piping.

Truck Hoist - Apparatus, either electro-mechanical or hydraulic, generally used in conjunction with body hoists, for raising transit vehicles for inspection and maintenance.

Truck Lift - Similar to garage auto lifts, usually hydraulic, used to position separate car trucks at various elevations for maintenance.

Tunnel - An underground or underwater passageway.

Turnback - The operation in which the running direction of a train is reversed, usually at a terminal station, and the movement is in the "normal" direction of travel for the scheduled track.

Turnback Time - The time required to reverse train direction at a terminal station or intermediate turnback location, excluding station dwell time.

Turnout - See Switch.

- Turnout, Equilateral - A turnout in which the diversion, due to the angle of the turnouts, is equally divided between the track from which the turnout is made.
- Turnout, Lateral - A turnout in which the diversion, due to the angle of the turnout, is entirely on one side of the track from which the turnout is made.
- Turnout Number - The number corresponding to the number of the frog used in the turnout.

Turntable - A device built into the maintenance track system for turning separated or disconnected trucks for removal from or installation on a transit vehicle; or a larger version for turning complete transit vehicles. The device may be electro-mechanical or air cushion.

Unpaid Area - That portion of a station which lies outside the fare collection barrier.

Vehicle Maintenance Shop - An all-purpose facility performing the different levels of maintenance of transit vehicles generally split between service and inspection shops and main shops.

Velocity Level - Frequently called the "vibration velocity level". Vibration velocity is the rate of change of displacement of a vibration. The velocity level is 20 times the logarithm to the base 10 of the ratio of the RMS value of the velocity tot he reference velocity. The reported vibration velocity levels are all referenced to 10^{-6} in/sec. Above approximately 10 Hz, human response to vibration is more closely correlated to the velocity level than the acceleration level.

Vertical Circulation Element - Escalator, elevator, stair, ramp, handicap lift, and any other station elements used by patrons to change levels.

Video Matrix Switcher (VMS) - A device consisting of two or more switches or their electronic equivalent capable of handling video signals by which each input signal to the device may be connected to any output of the device without interfering with similar connections being made simultaneously for all other input signals. Typically used at a video monitoring or control center to connect the incoming signals to video monitors and recorders.

Video Sequential Switcher (Sequencer) - A device providing for the connection in turn of one of two or more video signals to a single output. Typically used at a remote location such as a transit station to connect in turn the signals from each camera at the location to a single video transmission path to the monitoring center.

Weighted Velocity Level - The vibration velocity level which a weighting factor has been added. The weighing deemphasizes the low frequencies in a manner similar to human response to vibration.

Vital Component or Circuit - Any device, circuit, or software module used to implement a vital function.

Vital Function - A system, subsystem, component or equipment that provides a function critical to safety.

Vital Relay - A relay, meeting certain stringent specifications, designed so that the probability of failure is so low as to be considered, for all practical purposes, nonexistent.

Wayside - A term generally used to refer to the area along the path of a transit vehicle.

Wheel Grinding Machine - A machine built into a shop track system for removing flat spots or metal buildup from wheel treads by use of abrasive stones.

Wheel Press - A machine used o press wheels, discs, or gear boxes on and off axles. The machine is generally equipped with a pressure recording device. It is usually located near a truck repair area.

Wheel Spinning Jacks - Mechanical or hydraulic devices, built-in or portable, used for raising a wheel set or sets clear of running rail so the wheels may be rotated under power.

Wheel Truing Machine - A machine built into the shop track system for returning the steel wheel profile to original contour using a milling cutter or a single point lathe.

Wire Train - A train composed of work cars pulled by a prime mover, specifically designed for the installation and maintenance of the overhead contour system.

Work Cars - Generally specially-built, special-purpose type cars such as ballast cars, flat cars, rail cars, and wheel cars.

Work Flow - The system of plans and procedures to develop the logical sequence of work tasks required.

Work Train - A train composed of work cars pulled by a prime mover, generally a locomotive, and normally used for maintenance purposes or functions.

Yard - A system of tracks within defined limits for making up trains and storing cars.

Yard Control Tower - An airport-like structure overlooking as much of a yard as possible, housing the personnel and equipment required to control movement of trains and work vehicles both throughout the yard and into and out of the yard from main line tracks.

Yardmaster - An operations employee, generally the supervisor of a yard's transportation activity. Frequently called yard dispatcher.

Yard and Secondary Tracks - All tracks constructed for the purpose of switching, storing or maintaining transit vehicles not carrying revenue passengers.

Yard and Shop Facilities - A network of tracks and support facilities within defined limits designed to provide for making up trains, storing transit vehicles, and maintaining elements of the rapid transit system.

Zone - A length of track of defined limits, the use of which by trains is governed by block signals, cab signals, or both.

Zoned-Fare System - A fare structure in which the cost of a trip is a function of the number of geographical zones traveled.

APPENDIX D

CLEARANCE CRITERIA & METHODS

Developed by PSD – Huitt-Zollars, Inc.
March 25, 1996

CLEARANCE CRITERIA & METHODS

DART Light Rail Starter System

DART

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A discussion of the criteria and methods used to determine acceptability of design and as-built clearances at specific locations.

CLEARANCE CRITERIA & METHODS

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3-25-96

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CLEARANCE CRITERIA & METHODS

TABLE OF CONTENTS

INTRODUCTION

The purpose of this report is to document the locations, analysis and result of clearance issues between the light rail vehicle and certain fixed objects. These locations have been identified during design development of DART's Light Rail Starter System in numerous meetings with DART, the Systems designer (Morrison Knudsen Engineers), the Systems Integration consultant (Transportation and Distribution Associates), and the Principal Section Designer (Huitt-Zollars Inc.). Analysis performed by the Principal Section Designer (PSD) utilized DART Design Criteria and actual static and dynamic data for the Kinkisharyo vehicle.

CLEARANCE ISSUES AND LOCATIONS

The following list comprises the locations and issues where clearance between the light rail vehicle and various fixed objects were of concern to DART. Each item on this list enjoys a detailed discussion of relevant parameters and the final resolution of the issue.

- 15'6" Track Centers with Center Catenary Poles
- 14'0" Track Centers without Center Catenary Poles
- 14'0" Track Centers with Center Catenary Poles for SOC-2
- Roof Shroud of the Kinkisharyo Vehicle
- Bottom of Mirror of the Kinkisharyo Vehicle
- Safety Walkway Envelope for the Trinity River Bridge and the NC-1 Tunnels
- Street Regulatory Signs in SOC-2
- Train Signals in SOC-2
- Catenary Poles in Curve Spirals in SOC-2
- Clearances for certain As-Built Facilities
- Clearance between Kinkisharyo Vehicle Shroud to CBD Station Canopies
- NC-1 Tunnel Clearances
- Special Use Platform Clearance
- Locations of "No Clearance" Signs
- Underbody Kinkisharyo Vehicle Clearance

BASE DOCUMENTATION

DART's ***Design Criteria Manual*** is the base document for settling issues regarding clearance requirements and acceptability[1].

A. Volume 1, <u>Paragraph 1.3.4</u>, "Track Spacing", defines normal track centers with and without center catenary poles as 15'6" and 14'0", respectively.

[1] Volume 1, Chapter 1 of the DART Design Criteria Manual is attached as Appendix A of this report.

B. Volume 1, Paragraph 1.10.1, "Static, Dynamic and Car Dynamic Envelope", does the following:

1. Establishes use of the vehicle static and dynamic envelope as presented in Figure 1.3 of the Design Manual.

2. Defines the track tolerance values to be used in addition to the vehicle static and dynamic envelope – 4 inches for ballasted track or 2 inches for direct fixation track.

3. Permits DART to approve actions to disregard the mirror as a point to be considered when using the vehicle envelope. This revision to the criteria permits the special case of 14-foot track centers with center poles in the SOC-2 Lancaster Road corridor.

C. Volume 1, Paragraph 1.10.2, "Variations of the Clearance Envelope due to Curvature and Superelevation," gives equations describing the amount clearances and/or track centers must be increased for superelevation and curvature. These apply to points on the body of curves, i.e., in the area of constant radius and superelevation. This paragraph also introduces curvature- and superelevation-dependant equations defining the required distances "C1", "C2", "C3", and "C4" from track centerlines to pole centerlines and walls, as pictured in Design Manual Figures 2-8 and 2-9,.

D. Volume 1, Paragraph 1.10.3, "Horizontal and Vertical Clearances and Tolerances",

1. Sets allowances for construction tolerances,

2. Defines the requirements for and dimensions of the service walkway,

3. States minimum and desirable track centers for various types of track,

4. States minimum and desirable clearances to various types of fixed objects,

5. Establishes platform to track centerline distances for both low level and high level (special use) platforms,

6. Specifies minimum and desirable vertical clearances, and

7. Defines certain clearance criteria and sources for other clearance criteria pertaining to interface points between the LRT and streets or railroads.

E. Figure 1.3, "Car Dynamic Envelope", shows an approximation of the tangent track car envelope.

F. Figures 1.4 through 1.9 show clearance widening requirements to allow for trains going through turnouts of various sizes.

G. Table 2-1 defines track construction tolerances for different types of track construction[2].

H. Volume 2, Chapter 2, Paragraph 2.16 includes the LRT Vehicle Clearance Tables developed by Systems Engineering[3]. These extensive tables provide the X-Y coordinates of the dynamic envelope at 24 points around the "Design Manual Vehicle". They show those coordinates for combinations of curvature and superelevation ranging from 82-foot to 100,000-foot radii and from 0 to 6 inches superelevation.

BACKUP FOR BASE DOCUMENTATION

A. All of the references to clearances written into the DART Design Criteria Manual are based on an assumed "Design Manual Vehicle" which defines the largest vehicle which could have been considered for this project. That design vehicle has a width of 9'6" at the side of car, with an additional 8" allowance for the mirrors at a height which is 9.80' above top of rail. The roofline of the design manual vehicle is assumed to be at the 10'6" height, while the lower corners of the car are 8" above top of rail. All these static dimensions are then transformed to dynamic envelope values by the imposition of a 4° roll (from a point of rotation on the centerline of vehicle, 15" above top of rail) and a lateral shift described in the next paragraph. The design manual vehicle is a 95-foot long articulated car with three sets of trucks. One truck is centered over the articulation point in the center of the car, while the other two trucks are assumed to be 31.76' from that center truck, leaving overhangs of 15.74' on the ends of the vehicle.

B. The dynamic envelope values allow for a possible lateral shift of the centerline of vehicle relative to the centerline of track. That allowance includes tolerances for:

Lateral Wheel Wear	0.25"	
Lateral Rail Wear	0.30"	
Wheel/Rail Clearance ...	0.125"	
Truck Suspension Motion	1.50"	
Skew	2.16"	Applies to points at overhanging end of car.
Total Lateral Shift	4.335"	
	= 0.36'	

[2] Appendix B.

[3] Appendix C.

All of these lateral amounts are figured into and included, where applicable, in the LRT Vehicle Clearance Tables in Volume 2, Chapter 2, of the DART Design Criteria Manual.

C. Track tolerances used in clearance calculations are determined by the following track safety standards:

ITEM	STANDARD	EFFECT AT ROOFLINE
Gauge Tolerance	+1" to -1/2"	1 inch
Alignment Tolerance	±3/4"	3/4 inch
Cross-Level Tolerance	±1"	2-1/4 inch
	TOTAL	4 inches

The effect at roofline for cross-level is arrived at by multiplying the cross-level tolerance by the height of that roofline divided by track gauge.

For direct fixation trackwork, the assumed tolerances are twice as tight, so a total of 2 inches of track tolerance is assumed for that and similarly rigid track structures, such as paved track and track constructed using dual block ties embedded in concrete.

Track construction tolerances are tighter than the condemning track safety standards. Total ballasted track construction tolerance is computed at 7/8 inch and direct fixation track construction tolerance is figured at 5/8 inch. Both of these values are significantly less than the standards, which, therefore, control. Construction tolerances merely set the limits to which new construction must apply on the day of acceptance; they must be considered as a portion of the total track deviation allowed before track maintenance must occur and are, therefore, not added to the track safety standard's condemning limits.

D. The LRT Vehicle Clearance Tables in Volume 2, Chapter 2, of the DART Design Criteria Manual were developed by the Systems Engineering group to define the maximum amount the vehicle itself could extend from centerline of track. The tables account for the lateral shift (Paragraph II.B) and the effect of maximum vehicle roll applied to the design manual vehicle, plus end or mid-ordinate overhang of the vehicle due to curvature and the effect of superelevation.

To re-create any of the values in the tables, one must first identify the static coordinates of the point on the car being evaluated. The point is then "rotated", using trigonometry by the 4° roll angle applied from the vehicle rotation point, which is on the centerline of vehicle, 15 inches above top of rail, and then moved laterally by the values shown in Paragraph II.B, above. The resultant XY coordinates represent the tangent value for the dynamic vehicle at that point on the vehicle. To obtain values for that point on a curve, adjustments are made by adding effects of mid-ordinate or end overhang, whichever applies, and adding or subtracting the effect of superelevation.

The following example illustrates this method:

EXAMPLE:

Compute XY coordinates of Point P4 for a 1000' radius curve with 2 inches superelevation:.

Static value of P4: (5.42, 9.40)

Roll 4° to right:

$$X = 5.42 * \cos(4°) + (9.80 - 1.25) * \sin(4°) = 6.00$$

$$Y = -5.42 * \sin(4°) + (9.80 - 1.25) * \cos(4°) + 1.25 = 9.40$$

(6.00, 9.40)

Adding Lateral Shift: (6.36, 9.40)

As shown in table: (6.35, 9.40) — Point P10, 100,000'R, 0" Ea, Rolled Left

Adding effect of vehicle overhang:

$$X = 6.35 + \sqrt{(R * \cos(\sin^{-1}(15.88/R)))^2 + (15.88 + 15.74)^2} - R = 6.72$$

(6.72, 9.40)

Subtracting effect of superelevation:

$$X = 6.72 - \frac{9.40}{4.71} * \frac{Ea}{12} = 6.39$$

$$Y = 9.40 + (\frac{1}{2} + \frac{6.72}{4.71}) * \frac{Ea}{12} = 9.72$$

(6.39, 9.72)

As shown in table: (6.37, 9.69) — Point P4, 1,000'R, 2" Ea

This is a reasonably close validation of the tables; clearly, not every value in the tables can be matched exactly by this method, either due to rounding or slight differences in assumptions.

E. The 15'6" track centers with center poles criterion was established by adding the following:

Max. Tangent Mirror Offset	6.35'
Track Tolerance	0.33'
Running Clearance	0.05'
Half-width of 18" pole ...	0.75'
Pole Tolerance	0.17'
Pole Deflection	0.08'
Track to Pole (centerlines)	7.73'
Rounded	7.75'
Times two (2 tracks)	15.50'

F. The 14'0" track centers without center poles criterion was set by adding the following:

Max. Tangent Mirror Offset	6.35'
Track Tolerance	0.33'
	6.68'
Times two (2 tracks)	13.36'

Clearly, that computation does not justify 14'0" minimum track centers for areas without center poles. Accounting for a center walkway may, however:

Max. Tgt. Roofline Offset	5.70'
Track Tolerance	0.33'
Running Clearance	0.05'
Desirable Walkway ÷ 2 ..	1.00'
	7.08'
Times two (2 tracks)	14.16'

Substituting the Absolute Minimum Walkway Width of 22" for the 24" Desirable Minimum Width used above saves us the 2 inches necessary to justify minimum track centers with center walkway of 14'0". Applying the criteria to direct fixation track saves another 4 inches total in track center requirements, thereby easily justifying the track centers on the Trinity River Bridge with a full walkway width but no catenary poles between tracks.

G. The approval of special 14'0" track centers with center poles on the SOC-2 Lancaster Road corridor was arrived at by the following reasoning:

Max. Tgt. Roofline Offset	5.70'
Track Tolerance	0.33'
Running Clearance	0.05'
Half-width of 12" pole ...	0.50'
Pole Tolerance	0.17'
Pole Deflection	0.08'
Track to Pole (centerlines) .	6.83'
Times two (2 tracks)	13.66'

Note that only 12" wide poles are used here.

Thus, 14'0" track centers with center poles are acceptable from the perspective of the vehicle rooflines. The mirrors require a special exemption, however, as shown in the following:

Max. Tangent Mirror Offset	6.35'
Track Tolerance	0.33'
Running Clearance	0.05'
Half-width of 12" pole ...	0.50'
Pole Tolerance	0.17'
Pole Deflection	0.08'
Track to Pole (centerlines)	7.48'
Times two (2 tracks)	14.96'

Clearly, the mirrors would impact the poles if all these tolerances were used at the same time and place, i.e.,

> if the mirror is extended fully,
> <u>and</u> the vehicle is rolled to its maximum amount ,
> <u>and</u> the track is at its maximum amount of misalignment and wear,
> <u>and</u> if the pole was built too close to the track by the maximum tolerable amount,
> <u>and</u> if the pole is deflected toward the track, <u>the mirror will strike the pole</u>.

For the special circumstances of the Lancaster Road corridor, this relatively remote possibility was considered to be an acceptable risk and the mirrors were considered to be a "sacrificial" component of the vehicles as a trade-off for otherwise excessive right-of-way costs.

NEW CLEARANCE ISSUES NOT COVERED BY DART DESIGN CRITERIA MANUAL

A. The procured vehicle, manufactured by the Kinkisharyo Corporation, requires a couple of changes to the clearance envelope.

1. The Kinkisharyo vehicle is equipped with a roof shroud which is above the roof line and outside the pantograph envelope. This previously-undefined element has caused restudy of clearances at certain facilities, such as pole mounted signals and station canopies. For those special cases, PSD has calculated dynamic envelope points defining the maximum reach of the roof shroud. For tangent track, these points are:

   Bottom of Shroud: (4.95, 10.11)

   Top of Shroud . (4.31, 12.27)

   Systems Engineering had proposed (MKD-3701, 11/14/94)[4] use of Points P5 and P9 to define the bottom of shroud and Points P5a and P9a to define the top of shroud. Defining that item by those tables, however, was much more conservative than even the Kinkisharyo vehicle, resulting in would-be rejection of all the CBD canopies. For that reason, PSD is currently utilizing the values shown above for the tangent dynamic envelope of the roof shroud.

2. Although vehicle specifications defined the maximum height and width of the dynamic envelope at the mirror, they did not define the bottom of the mirror. During preliminary and final facilities design of this project, the low point of the mirror was assumed to be 12 inches below Points P4 and P10. The Kinkisharyo car, while not exceeding the height or width restrictions at the top of mirror, does have a mirror whose bottom is lower than that assumption by 4-3/4 inches.

   This led PSD to establish Points P4b and P10b at the bottom of Kinkisharyo mirror (tangent values shown, before application of curvature and superelevation effect):

   P4b . . . . (6.16, 7.61)

   P10b . . . . (-6.16, 7.61)

   The height of the bottom of mirrors is significant when considering the top of the walkway envelope. Where safety walks are elevated 8 inches above top of rail, such as on the Trinity River Bridge or within the NC-1 tunnels, the paint striping contract had to be designed to reflect these values.

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[4] Appendix D.

3. In conjunction with the discovery of the low Kinkisharyo mirror and the design of the paint stripe location, the height of safety walkway envelope had to be adjusted for the Trinity River Bridge and NC-1 Tunnels. To allow pedestrians to clear that 7.61' mirror bottom while they are standing atop a 0.67' high walkway, the maximum walkway envelope height was reduced to 6'8-1/2" from the current 7'0" maximum height.

B. The proximity of traffic lanes to the light rail tracks in the SOC-2 Lancaster Road corridor created several special clearance conditions to be accommodated:

1. Where curblines are only 7'6" from centerline of adjacent track, necessary street regulatory signs such as "One Way →" and "No Left Turn" signs at T intersections must fit in a narrow area between the back of curb and the LRV clearance envelope. Equations were derived to define the available space for these signs for any combination of curvature and superelevation. Those equations were then applied to all the curves on the Lancaster Road corridor in order to establish generalized minimum values throughout that corridor. The result is a single page guideline ("Min. Envelope to Clear Street Signs on Lancaster Road", attached to PSD #4653, Sosebee to Brown, 8/12/93)[5] which dictates that, for levels less than 7'6" above top of rail, no part of a sign or post may be closer to the track centerline than 6'0" (or 6'3" on Curves SOC-2W, SOC-2EE, and SOC-2XX). Above the 7'6" level, the guideline limits any part of a sign or post from being any closer than 6'10" (7'1" on Curves SOC-2W and SOC-2XX). The 7'6" height is so designated because it is the level above which the LRV mirror controls, rather than the side of vehicle.

   The above criterion was created before it was discovered that the Kinkisharyo car has a lower mirror than previously assumed. It is suggested that the 7'6" level be reduced to 7'2" for all curves except SOC2-W, SOC2-EE, and SOC2-XX, for which it should be reduced to 7'0". Above 7'0", the required horizontal distance can be reduced to 6'10" on Curve SOC2-EE and 7'0" on Curves SOC2-W and SOC2-XX.

2. Train Signals mounted on catenary or "Type 3A" poles between the tracks were investigated for clearance from the pantograph dynamic envelope. The envelope is defined from 11' to 15' above top of rail but of varying width due to site-specific curvature and superelevation. The signal locations and their PSD-requested maximum widths were identified in a 10/26/93 computation,[6] "Traffic Signals Along Track," by KEK, Sheet 7 of 7, although it is not known whether the data in that computation were ever transmitted or used by signal designers.

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[5] Appendix E

[6] Appendix F.

3. There is no designated safety walkway area in the median of Lancaster Road. Pedestrians will be expected to use sidewalks along the two curb lanes of the street.

C. Catenary Pole Clearances at Places with Varying Curvature

Since the published criteria for setting pole offsets referred to only track alignment tangents and circular curves, a trial and error method was established to ascertain the advisable pole offsets in spirals and other alignment transition areas.

PSD used a series of worksheets to calculate the exact location of the design manual vehicle's truck centers which would create the most severe clearance at a catenary pole. Where applicable, this was done for spotting either the front and back of the vehicle or the midpoint between trucks at a point opposite the pole.

This exercise was done for the design locations of pole, assuming the following:

Dynamic Mirror	6.35'	
or Dynamic Roofline		5.70'
Track Tolerance	0.33'	0.33'
Running Clearance	0.05'	0.05'
Half-Width of Pole	0.75'	0.75'
Pole Tolerance	0.17'	0.17'
Pole Deflection	0.08'	0.08'
TOTAL OFFSET REQUIRED:	7.73'	7.08'

These minimum dimensions were reduced by 0.25' for all of SOC-2 and wherever else catenary poles are known to be of only 12" width. Since mirror impact is taken as an acceptable risk in the SOC-2 corridor, a total of 9 inch reduction in the clearance at the roofline is assumed. That value includes the already mentioned 3 inch reduction due to smaller pole dimensions in that corridor. Clearances to the vehicle roofline must still be met, however. This brings the minimum acceptable vehicle centerline to pole centerline dimension in SOC-2 to 6.98' where mirror offsets control, or 6.83' where the roofline controls, which happens only in certain curves.

For direct fixation track, 2 of the 4 inches of track tolerance can be deleted from the requirement.

These required minimum dimensions are then compared to the actual vehicle centerline to pole centerline dimensions computed by the trial and error method mentioned above.

D. Clearance Requirements at As-Built Catenary Poles and Other Objects:

Where poles or their foundations are already in place, the method in the previous section of text is also used to check clearances, although the 2 inch pole tolerance dimension can be deleted from the required clearance dimension used for that check.

In cases where as-built poles fail to meet the design manual clearance requirements, rational arguments can be made to justify their remaining in place if,

1. the track is a low speed and/or non-revenue line, or

2. the remaining clearance is still as good as that expected on the SOC-2 Lancaster Road corridor, or

3. the combination of vehicle roll, track tolerance, etc. still only indicates the possibility of a mirror impact, not an impact of the actual vehicle to the object even under those extreme conditions.

The choice to accept any constructed item which deviates from criteria remains with the agency.

E. Clearance to Shroud from As-Built CBD Station Canopies:

The location of the dynamic envelope of the Kinkisharyo car's shroud was compared to the surveyed XY coordinates of corners of the West End Station canopies, both with and without maximum deflection (0.11' vertically and 0.03' horizontally, toward the vehicle). The canopies were accepted since they cleared by more than the 0.22' required (2" for track tolerance in paved track plus 5/8" for running clearance).

F. Tunnel Clearances:

For the NC-1B tunnels, the lowest dynamic envelope of the pantograph was used, defined by Points P6, P8, P13, and P14 of the Design Manual tables. A minimum of 4 inches was required around those points for electrical clearance, plus 3 inches construction tolerance and 2 inches track tolerance.

The other controlling dimensions were the bottom corner the of car on the side opposite the walkway and the minimum walkway width itself (24" desired, 22" absolute minimum, from edge of paint stripe to foot of wall. The paint stripe set-back was set by the following equation, which corresponds to a 6'8-1/2" maximum height, 24" walkway width, and a 3" taper in the envelope above the 6'0" level:

$$X = X_{P4b} - \frac{3}{8.5} \cdot Y_{P4b} + 2.5849$$

for $Y_{P4b} \le 7.5938$,

$$X = \max(X_{P3}, X_{P2}) + 0.2188$$

and for $Y_{P4b} > 7.5938$,

where Point P4b is the dynamic envelope point at the bottom of the Kinkisharyo car's mirror as defined in Paragraph III.A.2 of this document, Points P2 and P3 are from the Design Criteria Manual tables, and distance X represents in feet the required offset from centerline of track to back edge of paint stripe.

These equations were also used to determine the back edge of safety paint striping on the Trinity River Bridge center walkway.

G. Special Access Platform Clearance:

An exception to the published design criteria is essential for the high block special access platforms or lifts at every station. At a height of 36-1/2" above top of rail on tangent track, the design criteria would require 5.61' of horizontal distance from centerline of track to edge of platform, while the actual design set-out is 5'-2-1/2". This is another subjective choice which the owner has made to risk the unlikely event of the fully rolled car traveling along the maximum defect track and striking the platform. The assumption made is that the track will not be allowed to deteriorate to the point where it is 4 inches out of alignment at this critical and obvious location and that, if a vehicle is in such bad condition that it would be at its maximum 4° roll, it would be on a slow-ordered dead-head move back to the shops rather than in a revenue train at normal speed.

H. "No Clearance" Signs:

Locations have been designated for placement of "No Clearance" signs along the LRT routes. Although that was a topic of discussion in July and August, 1993, final resolution of these locations are not available to PSD at this time.

I. Underbody LRV Clearance:

MKD-889 (Gustafson to Larkin, 1/15/92)[7] discussed clear distances under the body of the Light Rail Vehicle, asking whether any fixed facilities 2 inches or more above top of rail are located within 45-1/4" of the centerline of track anywhere on the system. PSD found no such items within that area, although it cautioned in PSD #2339 (Sosebee to Brown, 7/17/92)[8] that there are items higher than the top of rail, such as the paving blocks in the CBD, the guarding flange of the girder rail,

[7] Appendix G.

[8] Appendix H.

restraining rail, and, when maintenance suffers, crossing panels. At one time during the design, extra shims were attached to the restraining rail assembly which may possibly have infringed upon the subject area.

The PSD letter referred to in the previous paragraph cautions that no portion of the vehicle which is within 2 inches of top of rail can be subjected to the maximum vehicle roll or be at the end of the vehicle, since the roll or vehicle end overhang could otherwise bring the component in contact with pavement.

J. Curved Platforms:

During preliminary engineering, DART and its PSD and Systems design teams jointly decided to allow a curved center platform at the Mockingbird Station. The decision to allow curved tracks and platform edges at that station allowed for special trackwork as well as the station platform within the relatively short distance between the NC-1 tunnel portals and the Garland Line Junction. Earlier design iterations with an entirely tangent platform showed right-of-way requirements or alignment compromises which were deemed untenable.

Preliminary drawings of the LRV by Systems Engineering were used to determine the gap which would result from various track curve radii. Calculations based on these drawings's estimated locations of the vehicle doors and trucks determined that the gap between the vehicle and the platform edge at the doors would increase by a maximum of 1" for a track radius of 3,820', assuming that the track to platform edge distance was increased to guarantee a minimum gap of 2" at the end or midpoint of the vehicle.[9] Based on these calculations and experience gleaned from the practices of other transit systems, consensus established a minimum radius of 4,000' for track radii in station platform areas. For whatever radius is selected for track at a given platform edge, that edge would then be designed with an offset increased to allow for the additional end overhang or mid-ordinate requirement.

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[9] End overhang controls on convex curves, i.e., those curves where the platform edge is on the outside of the curve. Mid-ordinate controls on concave curves, or those where the platform edge is on the *inside* of the curve. For all practical purposes, end overhang is defined by the equation "$e=(370/R)$" and mid-ordinate by the equation "$m=125/R$" where R is the track centerline radius and all dimensions are in feet.

APPENDIX A

Volume 1, Chapter 1 of the DART Design Criteria Manual.

(See Chapter 1 Rev. 4.0)

APPENDIX B

Table 2-1 from Volume 1, Chapter 2 of the DART Design Criteria Manual.

(See Chapter 2 Rev. 4.0)

APPENDIX C

Section 2.16 from Volume 2, Chapter 2 of the DART Design Criteria Manual.

2.14 SIGNALS (Wayside Signals, Trip Stops) AND TRAIN-TO-WAYSIDE COMMUNICATIONS

The signal system will consist of a wayside colored light system, trip stops and train-to-wayside communications equipment. All on board equipment will be supplied by DART and provided to the vehicle contractor for installation on the light rail vehicle. The vehicle contractor will be required to provide space and power hook-ups for all of this equipment in addition to interfacing it with the on-board systems as appropriate.

2.15 FLAMMABILITY & SMOKE EMISSIONS

All of the materials selected for use in the DART light rail vehicle will meet the current USDOT "Recommended Fire Safety Practices for Rail Passenger Car Materials Selection - January 1989" as contained in 54CFR10, pages 1837-1840. Additionally, the requirements of NFPA 130 will be observed.

2.16 CLEARANCES

2.16.1 Clearance Assumptions

The clearance tables are based on the largest vehicle that is permitted by DART Policy. The basic dimensions that were used are as follows:

Length:	95 FT
Width:	9.5 FT
Width Mirrors:	10.8 FT
Height Mirrors:	9.8 FT
Roll:	± 4 DEG
Truck Spacing:	Selected to meet clearance requirements.

2.16.2 Clearance Table Instructions

The Clearance tables combine the effects of carbody roll, superelevation and curve displacement into a single "X, Y" coordinate that defines the position of the selected point in space from the Origin, "0,0", of the system which is at Top of Rail on the centerline of the trackway.

Directions for the use of the tables are as follows:

a) Select the point on the vehicle or pantograph that is to be checked from Fig 1-1; P2 to P24

b) Go to the table that corresponds to the selected point. Each table provides the information for one point on the carbody and is identified with the "Location" of that point, P2 to P24, in the upper left corner of the table.

c) Define the track conditions, curve radius and superelevation, that shall be used to determine the clearance information for the selected point.

d) Find the curve radius in the left column of the table. If there is not an exact match in the table, round the curve radius "down" to the nearest value in the table. For example: a curve radius of 1200 FT should be "rounded down" to the table value of 1000 FT.

e) Read across the table to the superelevation column that corresponds to the defined conditions. If there is not an exact match in the table, round the superelevation value "up" to the nearest table value. For example: a superelevation of 5.25 IN should be "rounded up" to 5.5 IN.

f) The "X and Y" values that are in the box at the intersection of the "selected curve row" and the "selected superelevation column" define the coordinates of the selected point on the carbody, from track centerline.

2.16.3 Reference Drawing and Clearance Tables

Attached are Fig 1-1 showing the 24 different reference points on the carbody that are used for the table calculations. Each table represents the displacement for one point on the reference drawing.

2.17 LOAD DISTRIBUTION

Figures 1-2 and 1-3 present typical axle load distribution diagrams for three car trains. Figure 1-2 represents the shortest, 90 FT, vehicle allowed by DART Policy and Fig. 1-3 represents the longest vehicle, 95 FT truck spacing, axle spacing and end overhang for the two different vehicle lengths reflect typical values for an articulated vehicle. Each drawing has a table showing the expected axle loads, "F1" for motor truck axles and "F2" for articulation truck axles, for the following conditions:

a) Empty Car - Ready to run condition: 110,000 LB

b) Crush Loaded Car - 250 passengers at 155 LB per passenger

c) 20% Load on Articulation Truck - 40% Load on Motor Trucks (2)

d) 30% Load on Articulation Truck - 35% load on Motor trucks (2)

REV

A

LOCATION:

P2 LOWER CORNER OF CARBODY - OUTSIDE OF CURVE

SUPERELEVATION LEFT WITH ROLL LEFT (TOWARD INSIDE)

COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

LENGTH: 95 FT DOORS CLOSED

WIDTH: 9.5 FT

W MIRROR 10.8 FT

	X	Y
P1 - ROLL POINT OF VEHICLE	0	1.26 FT

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
82	8.01	0.67	8.04	1.00	8.03	1.07	8.01	1.13	8.00	1.19	7.98	1.25	7.96	1.32	7.95	1.38	7.93	1.44	7.91	1.50	7.89	1.56	7.87	1.62	7.85	1.69	7.83	1.75
100	7.53	0.67	7.56	1.00	7.55	1.07	7.53	1.13	7.52	1.19	7.50	1.25	7.48	1.32	7.47	1.38	7.45	1.44	7.43	1.50	7.41	1.56	7.39	1.62	7.37	1.69	7.35	1.75
150	6.76	0.67	6.79	1.00	6.77	1.07	6.76	1.13	6.74	1.19	6.73	1.25	6.71	1.32	6.69	1.38	6.67	1.44	6.66	1.50	6.64	1.56	6.62	1.62	6.60	1.69	6.58	1.75
200	6.35	0.67	6.38	1.00	6.37	1.07	6.35	1.13	6.34	1.19	6.32	1.25	6.30	1.32	6.29	1.38	6.27	1.44	6.25	1.50	6.23	1.56	6.21	1.62	6.19	1.69	6.17	1.75
250	6.11	0.67	6.13	1.00	6.12	1.07	6.10	1.13	6.09	1.19	6.07	1.25	6.06	1.32	6.04	1.38	6.02	1.44	6.00	1.50	5.98	1.56	5.96	1.62	5.94	1.69	5.92	1.75
300	5.94	0.67	5.97	1.00	5.95	1.07	5.94	1.13	5.92	1.19	5.90	1.25	5.89	1.32	5.87	1.38	5.85	1.44	5.83	1.50	5.81	1.56	5.79	1.62	5.77	1.69	5.75	1.75
350	5.82	0.67	5.84	1.00	5.83	1.07	5.81	1.13	5.80	1.19	5.78	1.25	5.77	1.32	5.75	1.38	5.73	1.44	5.71	1.50	5.69	1.56	5.67	1.62	5.65	1.69	5.63	1.75
400	5.72	0.67	5.75	1.00	5.74	1.07	5.72	1.13	5.71	1.19	5.69	1.25	5.67	1.32	5.66	1.38	5.64	1.44	5.62	1.50	5.60	1.56	5.58	1.62	5.56	1.69	5.54	1.75
450	5.65	0.67	5.68	1.00	5.67	1.07	5.65	1.13	5.64	1.19	5.62	1.25	5.60	1.32	5.58	1.38	5.57	1.44	5.55	1.50	5.53	1.56	5.51	1.62	5.49	1.69	5.47	1.75
500	5.59	0.67	5.62	1.00	5.61	1.07	5.59	1.13	5.58	1.19	5.56	1.25	5.54	1.32	5.53	1.38	5.51	1.44	5.49	1.50	5.47	1.56	5.45	1.62	5.43	1.69	5.41	1.75
550	5.55	0.67	5.58	1.00	5.56	1.07	5.55	1.13	5.53	1.19	5.51	1.25	5.50	1.32	5.48	1.38	5.46	1.44	5.44	1.50	5.42	1.56	5.41	1.62	5.39	1.69	5.36	1.75
600	5.51	0.67	5.54	1.00	5.52	1.07	5.51	1.13	5.49	1.19	5.48	1.25	5.46	1.32	5.44	1.38	5.42	1.44	5.40	1.50	5.38	1.56	5.37	1.62	5.35	1.69	5.32	1.75
650	5.47	0.67	5.50	1.00	5.49	1.07	5.47	1.13	5.46	1.19	5.44	1.25	5.42	1.32	5.41	1.38	5.39	1.44	5.37	1.50	5.35	1.56	5.33	1.62	5.31	1.69	5.29	1.75
700	5.45	0.67	5.47	1.00	5.46	1.07	5.44	1.13	5.43	1.19	5.41	1.25	5.40	1.32	5.38	1.38	5.36	1.44	5.34	1.50	5.32	1.56	5.30	1.62	5.28	1.69	5.26	1.75
750	5.42	0.67	5.45	1.00	5.44	1.07	5.42	1.13	5.40	1.19	5.39	1.25	5.37	1.32	5.35	1.38	5.34	1.44	5.32	1.50	5.30	1.56	5.28	1.62	5.26	1.69	5.24	1.75
800	5.40	0.67	5.43	1.00	5.41	1.07	5.40	1.13	5.38	1.19	5.37	1.25	5.35	1.32	5.33	1.38	5.31	1.44	5.30	1.50	5.28	1.56	5.26	1.62	5.24	1.69	5.22	1.75
850	5.38	0.67	5.41	1.00	5.39	1.07	5.38	1.13	5.36	1.19	5.35	1.25	5.33	1.32	5.31	1.38	5.29	1.44	5.28	1.50	5.26	1.56	5.24	1.62	5.22	1.69	5.20	1.75
900	5.36	0.67	5.39	1.00	5.38	1.07	5.36	1.13	5.35	1.19	5.33	1.25	5.31	1.32	5.29	1.38	5.28	1.44	5.26	1.50	5.24	1.56	5.22	1.62	5.20	1.69	5.18	1.75
950	5.35	0.67	5.38	1.00	5.36	1.07	5.35	1.13	5.33	1.19	5.31	1.25	5.30	1.32	5.28	1.38	5.26	1.44	5.24	1.50	5.22	1.56	5.20	1.62	5.18	1.69	5.16	1.75
1000	5.33	0.67	5.36	1.00	5.35	1.07	5.33	1.13	5.32	1.19	5.30	1.25	5.28	1.32	5.27	1.38	5.25	1.44	5.23	1.50	5.21	1.56	5.19	1.62	5.17	1.69	5.15	1.75
1500	5.25	0.67	5.27	1.00	5.26	1.07	5.24	1.13	5.23	1.19	5.21	1.25	5.20	1.32	5.18	1.38	5.16	1.44	5.14	1.50	5.12	1.56	5.10	1.62	5.08	1.69	5.06	1.75
2000	5.20	0.67	5.23	1.00	5.22	1.07	5.20	1.13	5.18	1.19	5.17	1.25	5.16	1.32	5.13	1.38	5.12	1.44	5.10	1.50	5.08	1.56	5.06	1.62	5.04	1.69	5.02	1.75
5000	5.12	0.67	5.15	1.00	5.14	1.07	5.12	1.13	5.10	1.19	5.09	1.25	5.07	1.32	5.06	1.38	5.04	1.44	5.02	1.50	5.00	1.56	4.98	1.62	4.96	1.69	4.94	1.75
10000	5.09	0.67	5.12	1.00	5.11	1.07	5.09	1.13	5.08	1.19	5.06	1.25	5.04	1.32	5.03	1.38	5.01	1.44	4.99	1.50	4.97	1.56	4.95	1.62	4.93	1.69	4.91	1.75
50000	5.07	0.67	5.10	1.00	5.09	1.07	5.07	1.13	5.06	1.19	5.04	1.25	5.02	1.32	5.01	1.38	4.99	1.44	4.97	1.50	4.95	1.56	4.93	1.62	4.91	1.69	4.89	1.75
100000	5.07	0.67	5.10	1.00	5.08	1.07	5.07	1.13	5.05	1.19	5.04	1.25	5.02	1.32	5.00	1.38	4.99	1.44	4.97	1.50	4.95	1.56	4.93	1.62	4.91	1.69	4.89	1.75

REV B

LOCATION:

COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

P3 INTERDIMATE POINT OF CARBODY - OUTSIDE OF CURVE

SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)

LENGTH: 95 FT DOORS CLOSED

WIDTH: 9.5 FT

W MIRROR 10.8 FT

	X	Y	
P1 - ROLL POINT OF VEHICLE	0.	1.25	FT

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
82	8.01	7.00	7.60	7.32	8.34	6.72	8.27	6.79	8.21	6.85	8.14	6.91	8.07	6.98	8.01	7.04	7.94	7.10	7.87	7.17	7.80	7.23	7.73	7.29	7.66	7.35	7.59	7.41
100	7.53	7.00	7.12	7.32	7.86	6.72	7.79	6.79	7.73	6.85	7.66	6.91	7.59	6.98	7.53	7.04	7.46	7.10	7.39	7.17	7.32	7.23	7.25	7.29	7.18	7.35	7.11	7.41
150	6.76	7.00	6.35	7.32	7.08	6.72	7.02	6.79	6.95	6.85	6.89	6.91	6.82	6.98	6.75	7.04	6.69	7.10	6.62	7.17	6.55	7.23	6.48	7.29	6.41	7.35	6.34	7.41
200	6.35	7.00	5.94	7.32	6.68	6.72	6.61	6.79	6.55	6.85	6.48	6.91	6.41	6.98	6.35	7.04	6.28	7.10	6.21	7.17	6.14	7.23	6.07	7.29	6.00	7.35	5.93	7.41
250	6.11	7.00	5.69	7.32	6.43	6.72	6.37	6.79	6.30	6.85	6.23	6.91	6.17	6.98	6.10	7.04	6.03	7.10	5.96	7.17	5.89	7.23	5.82	7.29	5.75	7.35	5.68	7.41
300	5.94	7.00	5.52	7.32	6.26	6.72	6.20	6.79	6.13	6.85	6.07	6.91	6.00	6.98	5.93	7.04	5.86	7.10	5.79	7.17	5.72	7.23	5.66	7.29	5.59	7.35	5.51	7.41
350	5.82	7.00	5.40	7.32	6.14	6.72	6.08	6.79	6.01	6.85	5.94	6.91	5.88	6.98	5.81	7.04	5.74	7.10	5.67	7.17	5.60	7.23	5.53	7.29	5.46	7.35	5.39	7.41
400	5.72	7.00	5.31	7.32	6.05	6.72	5.98	6.79	5.92	6.85	5.85	6.91	5.78	6.98	5.72	7.04	5.65	7.10	5.58	7.17	5.51	7.23	5.44	7.29	5.37	7.35	5.30	7.41
450	5.65	7.00	5.24	7.32	5.98	6.72	5.91	6.79	5.85	6.85	5.78	6.91	5.71	6.98	5.64	7.04	5.58	7.10	5.51	7.17	5.44	7.23	5.37	7.29	5.30	7.35	5.23	7.41
500	5.59	7.00	5.18	7.32	5.92	6.72	5.85	6.79	5.79	6.85	5.72	6.91	5.66	6.98	5.59	7.04	5.52	7.10	5.45	7.17	5.38	7.23	5.31	7.29	5.24	7.35	5.17	7.41
550	5.55	7.00	5.13	7.32	5.87	6.72	5.81	6.79	5.74	6.85	5.68	6.91	5.61	6.98	5.54	7.04	5.47	7.10	5.40	7.17	5.33	7.23	5.27	7.29	5.20	7.35	5.13	7.41
600	5.51	7.00	5.10	7.32	5.83	6.72	5.77	6.79	5.70	6.85	5.64	6.91	5.57	6.98	5.50	7.04	5.43	7.10	5.36	7.17	5.29	7.23	5.23	7.29	5.16	7.35	5.09	7.41
650	5.47	7.00	5.06	7.32	5.80	6.72	5.73	6.79	5.67	6.85	5.60	6.91	5.53	6.98	5.47	7.04	5.40	7.10	5.33	7.17	5.26	7.23	5.19	7.29	5.12	7.35	5.05	7.41
700	5.45	7.00	5.03	7.32	5.77	6.72	5.71	6.79	5.64	6.85	5.57	6.91	5.51	6.98	5.44	7.04	5.37	7.10	5.30	7.17	5.23	7.23	5.16	7.29	5.09	7.35	5.02	7.41
750	5.42	7.00	5.01	7.32	5.75	6.72	5.68	6.79	5.61	6.85	5.55	6.91	5.48	6.98	5.41	7.04	5.35	7.10	5.28	7.17	5.21	7.23	5.14	7.29	5.07	7.35	5.00	7.41
800	5.40	7.00	4.99	7.32	5.72	6.72	5.66	6.79	5.59	6.85	5.53	6.91	5.46	6.98	5.39	7.04	5.32	7.10	5.26	7.17	5.19	7.23	5.12	7.29	5.05	7.35	4.98	7.41
850	5.38	7.00	4.97	7.32	5.70	6.72	5.64	6.79	5.57	6.85	5.51	6.91	5.44	6.98	5.37	7.04	5.31	7.10	5.24	7.17	5.17	7.23	5.10	7.29	5.03	7.35	4.96	7.41
900	5.36	7.00	4.95	7.32	5.69	6.72	5.62	6.79	5.56	6.85	5.49	6.91	5.42	6.98	5.35	7.04	5.29	7.10	5.22	7.17	5.16	7.23	5.08	7.29	5.01	7.35	4.94	7.41
950	5.35	7.00	4.93	7.32	5.67	6.72	5.61	6.79	5.54	6.85	5.48	6.91	5.41	6.98	5.34	7.04	5.27	7.10	5.20	7.17	5.13	7.23	5.07	7.29	5.00	7.35	4.92	7.41
1000	5.35	7.00	4.93	7.32	5.67	6.72	5.61	6.79	5.54	6.85	5.48	6.91	5.41	6.98	5.34	7.04	5.27	7.10	5.20	7.17	5.13	7.23	5.07	7.29	5.00	7.35	4.92	7.41
1500	5.33	7.00	4.92	7.32	5.66	6.72	5.59	6.79	5.53	6.85	5.46	6.91	5.39	6.98	5.33	7.04	5.26	7.10	5.19	7.17	5.12	7.23	5.05	7.29	4.98	7.35	4.91	7.41
2000	5.25	7.00	4.83	7.32	5.67	6.72	5.51	6.79	5.44	6.85	5.37	6.91	5.31	6.98	5.24	7.04	5.17	7.10	5.10	7.17	5.03	7.23	4.96	7.29	4.89	7.35	4.82	7.41
5000	5.20	7.00	4.79	7.32	5.63	6.72	5.46	6.79	5.39	6.85	5.33	6.91	5.26	6.98	5.19	7.04	5.13	7.10	5.06	7.17	4.99	7.23	4.92	7.29	4.86	7.35	4.78	7.41
10000	5.12	7.00	4.71	7.32	5.45	6.72	5.38	6.79	5.31	6.85	5.25	6.91	5.18	6.98	5.11	7.04	5.05	7.10	4.98	7.17	4.91	7.23	4.84	7.29	4.77	7.35	4.70	7.41
50000	5.09	7.00	4.68	7.32	5.42	6.72	5.35	6.79	5.29	6.85	5.22	6.91	5.16	6.98	5.09	7.04	5.02	7.10	4.95	7.17	4.88	7.23	4.81	7.29	4.74	[illegible]	4.67	7.41
100000	[illegible]	7.00	4.66	7.32	5.40	6.72	5.33	6.79	5.27	6.85	5.20	6.91	5[illegible]	[illegible]98	5.07	7.04	5.00	7.10	4.93	7.17	4.86	7.23	4.79	7.29	4.7[illegible]	[illegible]	4.65	7.41

REV LOCATION:

A

P4 UPPER CORNER OF MIRROR - OUTSIDE OF CURVE

SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)

COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

LENGTH: 95 FT DOORS CLOSED

WIDTH: 9.5 FT

W MIRROR 10.8 FT

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	FT

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
82	9.86	9.80	9.25	10.16	10.35	9.47	10.26	9.55	10.17	9.62	10.08	9.69	9.99	9.76
100	9.20	9.80	8.59	10.16	9.69	9.47	9.60	9.55	9.51	9.62	9.42	9.69	9.33	9.76
150	8.13	9.80	7.52	10.16	8.63	9.47	8.54	9.55	8.44	9.62	8.36	9.69	8.26	9.76
200	7.57	9.80	6.96	10.16	8.06	9.47	7.97	9.55	7.88	9.62	7.79	9.69	7.70	9.76
250	7.22	9.80	6.61	10.16	7.72	9.47	7.63	9.55	7.54	9.62	7.45	9.69	7.35	9.76
300	6.99	9.80	6.38	10.16	7.48	9.47	7.39	9.55	7.30	9.62	7.21	9.69	7.12	9.76
350	6.82	9.80	6.21	10.16	7.31	9.47	7.22	9.55	7.13	9.62	7.04	9.69	6.95	9.76
400	6.69	9.80	6.08	10.16	7.18	9.47	7.09	9.55	7.00	9.62	6.91	9.69	6.82	9.76
450	6.59	9.80	5.98	10.16	7.08	9.47	6.99	9.55	6.90	9.62	6.81	9.69	6.72	9.76
500	6.51	9.80	5.90	10.16	7.00	9.47	6.91	9.55	6.82	9.62	6.73	9.69	6.64	9.76
550	6.44	9.80	5.83	10.16	6.94	9.47	6.85	9.55	6.76	9.62	6.67	9.69	6.58	9.76
600	6.39	9.80	5.78	10.16	6.88	9.47	6.79	9.65	6.70	9.62	6.61	9.69	6.52	9.76
650	6.34	9.80	5.73	10.16	6.84	9.47	6.75	9.55	6.66	9.62	6.57	9.69	6.47	9.76
700	6.30	9.80	5.69	10.16	6.80	9.47	6.71	9.55	6.62	9.62	6.53	9.69	6.43	9.76
750	6.27	9.80	5.66	10.16	6.76	9.47	6.67	9.55	6.58	9.62	6.49	9.69	6.40	9.76
800	6.24	9.80	5.63	10.16	6.73	9.47	6.64	9.55	6.55	9.62	6.46	9.69	6.37	9.76
850	6.21	9.80	5.60	10.16	6.70	9.47	6.61	9.55	6.52	9.62	6.43	9.69	6.34	9.76
900	6.19	9.80	5.58	10.16	6.68	9.47	6.59	9.55	6.50	9.62	6.41	9.69	6.32	9.76
950	6.16	9.80	5.55	10.16	6.66	9.47	6.57	9.55	6.48	9.62	6.39	9.69	6.30	9.76
1000	6.14	9.80	5.63	10.16	6.64	9.47	6.55	9.55	6.46	9.62	6.37	9.69	6.28	9.76
1500	6.02	9.80	6.41	10.16	6.52	9.47	6.43	9.55	6.34	9.62	6.25	9.69	6.15	9.76
2000	5.96	9.80	6.35	10.16	6.45	9.47	6.36	9.66	6.27	9.62	6.18	9.69	6.09	9.76
5000	5.86	9.80	6.24	10.16	6.34	9.47	6.26	9.65	6.16	9.62	6.07	9.69	5.98	9.76
10000	5.81	9.80	6.20	10.16	6.30	9.47	6.22	9.65	6.12	9.62	6.03	9.69	5.94	9.76
50000	5.78	9.80	6.17	10.16	6.28	9.47	6.19	9.55	6.09	9.62	6.01	9.69	5.91	9.76
100000	5.78	9.80	6.17	10.16	6.27	9.47	6.18	9.65	6.09	9.62	6.00	9.69	5.91	9.76

	3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
82	9.90	9.83	9.81	9.90	9.71	9.97	9.62	10.03	9.52	10.10	9.43	10.16	9.33	10.23
100	9.24	9.83	9.15	9.90	9.05	9.97	8.96	10.03	8.86	10.10	8.77	10.16	8.67	10.23
150	8.17	9.83	8.08	9.90	7.98	9.97	7.89	10.03	7.80	10.10	7.70	10.16	7.61	10.23
200	7.61	9.83	7.52	9.90	7.42	9.97	7.33	10.03	7.24	10.10	7.14	10.16	7.04	10.23
250	7.26	9.83	7.17	9.90	7.08	9.97	6.98	10.03	6.89	10.10	6.79	10.16	6.70	10.23
300	7.03	9.83	6.94	9.90	6.84	9.97	6.76	10.03	6.65	10.10	6.56	10.16	6.46	10.23
350	6.86	9.83	6.77	9.90	6.67	9.97	6.64	10.03	6.48	10.10	6.39	10.16	6.29	10.23
400	6.73	9.83	6.64	9.90	6.54	9.97	6.45	10.03	6.38	10.10	6.26	10.16	6.17	10.23
450	6.63	9.83	6.54	9.90	6.44	9.97	6.35	10.03	6.26	10.10	6.16	10.16	6.07	10.23
500	6.55	9.83	6.46	9.90	6.36	9.97	6.27	10.03	6.18	10.10	6.08	10.16	5.99	10.23
550	6.48	9.83	6.39	9.90	6.30	9.97	6.20	10.03	6.11	10.10	6.02	10.16	5.92	10.23
600	6.43	9.83	6.34	9.90	6.24	9.97	6.16	10.03	6.06	10.10	5.96	10.16	5.86	10.23
650	6.38	9.83	6.29	9.90	6.20	9.97	6.10	10.03	6.01	10.10	5.91	10.16	5.82	10.23
700	6.34	9.83	6.25	9.90	6.16	9.97	6.06	10.03	5.97	10.10	5.87	10.16	5.78	10.23
750	6.31	9.83	6.21	9.90	6.12	9.97	6.03	10.03	5.93	10.10	5.84	10.16	5.74	10.23
800	6.28	9.83	6.18	9.90	6.09	9.97	6.00	10.03	5.90	10.10	5.81	10.16	5.71	10.23
850	6.25	9.83	6.16	9.90	6.06	9.97	5.97	10.03	5.88	10.10	5.78	10.16	5.69	10.23
900	6.22	9.83	6.13	9.90	6.04	9.97	5.94	10.03	5.85	10.10	5.76	10.16	5.66	10.23
950	6.20	9.83	6.11	9.90	6.02	9.97	5.92	10.03	5.83	10.10	5.74	10.16	5.64	10.23
1000	6.18	9.83	6.09	9.90	6.00	9.97	5.90	10.03	5.81	10.10	5.72	10.16	5.62	10.23
1500	6.06	9.83	5.97	9.90	5.88	9.97	5.78	10.03	5.69	10.10	5.60	10.16	5.60	10.23
2000	6.00	9.83	5.91	9.90	5.81	9.97	6.72	10.03	5.63	10.10	5.63	10.16	5.44	10.23
5000	5.89	9.83	5.80	9.90	5.70	9.97	6.61	10.03	5.61	10.10	5.42	10.16	5.32	10.23
10000	5.86	9.83	5.76	9.90	5.60	9.97	6.67	10.03	5.48	10.10	5.38	10.16	5.29	10.23
50000	5.82	9.83	5.73	9.90	5.63	9.97	6.64	10.03	5.45	10.10	5.35	10.16	5.20	10.23
100000	5.82	9.83	5.72	9.90	5.63	9.97	6.64	10.03	5.44	[illegible]				

REV A

LOCATION:

COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

P5. UPPER CORNER OF CARBODY - OUTSIDE OF CURVE

LENGTH: 95 FT DOORS CLOSED
WIDTH: 9.5 FT
W MIRROR 10.8 FT

SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	FT

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
82	8.01	10.50	7.36	10.81	8.55	10.21	8.46	10.28	8.36	10.35	8.26	10.41	8.16	10.48	8.06	10.54	7.97	10.60	7.87	10.67	7.77	10.73	7.67	10.79	7.57	10.85	7.46	10.90
100	7.53	10.50	6.88	10.81	8.07	10.21	7.98	10.28	7.88	10.35	7.78	10.41	7.68	10.48	7.58	10.54	7.49	10.60	7.39	10.67	7.29	10.73	7.19	10.79	7.09	10.85	6.98	10.90
150	6.76	10.50	6.10	10.81	7.30	10.21	7.20	10.28	7.10	10.35	7.01	10.41	6.91	10.48	6.81	10.54	6.71	10.60	6.61	10.67	6.51	10.73	6.41	10.79	6.31	10.85	6.21	10.90
200	6.35	10.50	5.70	10.81	6.89	10.21	6.80	10.28	6.70	10.35	6.60	10.41	6.50	10.48	6.41	10.54	6.31	10.60	6.21	10.67	6.11	10.73	6.01	10.79	5.91	10.85	5.81	10.90
250	6.11	10.50	5.45	10.81	6.64	10.21	6.55	10.28	6.45	10.35	6.35	10.41	6.26	10.48	6.16	10.54	6.06	10.60	5.96	10.67	5.86	10.73	5.76	10.79	5.66	10.85	5.56	10.90
300	5.94	10.50	5.28	10.81	6.48	10.21	6.38	10.28	6.28	10.35	6.19	10.41	6.09	10.48	5.99	10.54	5.89	10.60	5.79	10.67	5.69	10.73	5.59	10.79	5.49	10.85	5.39	10.90
350	5.82	10.50	5.16	10.81	6.35	10.21	6.26	10.28	6.16	10.35	6.06	10.41	5.97	10.48	5.87	10.54	5.77	10.60	5.67	10.67	5.57	10.73	5.47	10.79	5.37	10.85	5.27	10.90
400	5.72	10.50	5.07	10.81	6.26	10.21	6.17	10.28	6.07	10.35	5.97	10.41	5.87	10.48	5.77	10.54	5.68	10.60	5.58	10.67	5.48	10.73	5.38	10.79	5.28	10.85	5.18	10.90
450	5.65	10.50	5.00	10.81	6.19	10.21	6.09	10.28	6.00	10.35	5.90	10.41	5.80	10.48	5.70	10.54	5.61	10.60	5.51	10.67	5.40	10.73	5.31	10.79	5.21	10.85	5.10	10.90
500	5.59	10.50	4.94	10.81	6.13	10.21	6.04	10.28	5.94	10.35	5.84	10.41	5.74	10.48	5.65	10.54	5.55	10.60	5.45	10.67	5.35	10.73	5.25	10.79	5.16	10.85	5.06	10.90
550	5.55	10.50	4.89	10.81	6.09	10.21	5.99	10.28	5.89	10.35	5.80	10.41	5.70	10.48	5.60	10.54	5.50	10.60	5.40	10.67	5.30	10.73	5.20	10.79	5.10	10.85	5.00	10.90
600	5.51	10.50	4.85	10.81	6.05	10.21	5.95	10.28	5.85	10.35	5.76	10.41	5.66	10.48	5.56	10.54	5.46	10.60	5.36	10.67	5.26	10.73	5.16	10.79	5.06	10.85	4.96	10.90
650	5.47	10.50	4.82	10.81	6.01	10.21	5.92	10.28	5.82	10.35	5.72	10.41	5.62	10.48	5.53	10.54	5.43	10.60	5.33	10.67	5.23	10.73	5.13	10.79	5.03	10.85	4.93	10.90
700	5.45	10.50	4.79	10.81	5.98	10.21	5.89	10.28	5.79	10.35	5.69	10.41	5.60	10.48	5.50	10.54	5.40	10.60	5.30	10.67	5.20	10.73	5.10	10.79	5.00	10.85	4.90	10.90
750	5.42	10.50	4.76	10.81	5.96	10.21	5.86	10.28	5.77	10.35	5.67	10.41	5.57	10.48	5.47	10.54	5.37	10.60	5.27	10.67	5.17	10.73	5.07	10.79	4.97	10.85	4.87	10.90
800	5.40	10.50	4.74	10.81	5.94	10.21	5.84	10.28	5.74	10.35	5.65	10.41	5.55	10.48	5.45	10.54	5.35	10.60	5.25	10.67	5.16	10.73	5.05	10.79	4.95	10.85	4.86	10.90
850	5.38	10.50	4.72	10.81	5.92	10.21	5.82	10.28	5.72	10.35	5.63	10.41	5.53	10.48	5.43	10.54	5.33	10.60	5.23	10.67	5.13	10.73	5.03	10.79	4.93	10.85	4.83	10.90
900	5.36	10.50	4.71	10.81	5.90	10.21	5.80	10.28	5.71	10.35	5.61	10.41	5.51	10.48	5.41	10.54	5.32	10.60	5.22	10.67	5.12	10.73	5.02	10.79	4.92	10.85	4.81	10.90
950	5.35	10.50	4.69	10.81	5.89	10.21	5.79	10.28	5.69	10.35	5.60	10.41	5.50	10.48	5.40	10.54	5.30	10.60	5.20	10.67	5.10	10.73	5.00	10.79	4.90	10.85	4.80	10.90
1000	5.33	10.50	4.68	10.81	5.87	10.21	5.78	10.28	5.68	10.35	5.58	10.41	5.48	10.48	5.38	10.54	5.29	10.60	5.19	10.67	5.09	10.73	4.99	10.79	4.89	10.85	4.78	10.90
1500	5.25	10.50	4.59	10.81	5.78	10.21	5.69	10.28	5.59	10.35	5.49	10.41	5.40	10.48	5.30	10.54	5.20	10.60	5.10	10.67	5.00	10.73	4.90	10.79	4.80	10.85	4.70	10.90
2000	5.20	10.50	4.54	10.81	5.74	10.21	5.64	10.28	5.55	10.35	5.45	10.41	5.35	10.48	5.25	10.54	5.15	10.60	5.05	10.67	4.95	10.73	4.86	10.79	4.76	10.85	4.66	10.90
5000	5.12	10.50	4.46	10.81	5.66	10.21	5.56	10.28	5.47	10.35	5.37	10.41	5.27	10.48	5.17	10.54	5.07	10.60	4.97	10.67	4.87	10.73	4.78	10.79	4.67	10.85	4.67	10.90
10000	5.09	10.50	4.44	10.81	5.63	10.21	5.54	10.28	5.44	10.35	5.34	10.41	5.24	10.48	5.15	10.54	5.05	10.60	4.95	10.67	4.85	10.73	4.76	10.79	4.65	10.85	4.66	10.90
50000	5.07	10.50	4.42	10.81	5.61	10.21	5.52	10.28	5.42	10.35	5.32	10.41	5.22	10.48	5.12	10.54	5.03	10.60	4.93	10.67	4.83	10.73	4.73	10.79	4.[illegible]	[illegible]85	4.62	10.90
100000		10.50	4.41	10.81	5.61	10.21	5.51	10.28	5.42	10.35	5.32	10.41	[illegible]	[illegible].48	5.12	10.54	5.02	10.60	4.92	10.67	4.82	10.73	4.72	10.79	4[illegible]	[illegible]5	4.62	10.90

REV A LOCATION:

P6 END OF PANTOGRAPH - OUTSIDE OF CURVE

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)

COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

LENGTH: 95 FT DOORS CLOSED
WIDTH: 9.5 FT
W MIRROR 10.8 FT

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	FT

INCLUDES .18 FT LATERAL MOTION TO OUTSIDE

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	3.43	13.25	2.59	13.45	4.14	13.05	4.02	13.11	3.89	13.16	3.77	13.21	3.65	13.26	3.53	13.32	3.41	13.37	3.28	13.41	3.16	13.46	3.03	13.51	2.91	13.55	2.78	13.60

REV A LOCATION

P7 CENTER OF PANTOGRAPH

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)

SYMETRICAL WITH ROLL LEFT

COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

LENGTH: 95 FT DOORS CLOSED
WIDTH: 9.5 FT
W MIRROR 10.8 FT

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	FT

LATERAL MOTION "+ OR -" 0.18 FT FROM CENTER

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	0.00	14.25	-0.91	14.22	0.78	14.25	0.64	14.27	0.51	14.30	0.38	14.32	0.25	14.35	0.11	14.37	-0.02	14.39	-0.15	14.41	-0.28	14.43	-0.41	14.45	-0.55	14.46	-0.68	14.48

REV A LOCATION

P8 END OF PANTOGRAPH - INSIDE OF CURVE

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL LEFT (TOWARD INSIDE)

COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

LENGTH: 95 FT DOORS CLOSED
WIDTH: 9.5 FT
W MIRROR 10.8 FT

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	FT

INCLUDES .18 FT LATERAL MOTION TO INSIDE

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	-3.43	13.25	-4.26	12.99	-4.38	12.98	-4.50	12.96	-4.62	12.94	-4.74	12.92	-4.86	12.90	-4.98	12.88	-5.10	12.86	-5.22	12.84	-5.34	12.81	-5.45	12.79	-5.57	12.76	-5.69	12.73

REV LOCATION:

A

P9 UPPER CORNER OF CARBODY - INSIDE OF CURVE

SUPERELEVATION LEFT WITH ROLL LEFT (TOWARD INSIDE)

COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

LENGTH: 95 FT DOORS CLOSED

WIDTH: 9.5 FT

W MIRROR 10.8 FT

	X	Y
P1 - ROLL POINT OF VEHICLE	0	1.25 FT

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
82	-6.48	10.50	-7.11	10.15	-7.21	10.12	-7.30	10.09	-7.40	10.06	-7.49	10.03	-7.59	10.00
100	-6.20	10.60	-6.83	10.16	-6.93	10.12	-7.02	10.09	-7.12	10.06	-7.21	10.03	-7.30	10.00
150	-5.77	10.50	-6.41	10.15	-6.60	10.12	-6.60	10.09	-6.69	10.06	-6.78	10.03	-6.88	10.00
200	-5.56	10.50	-6.19	10.15	-6.29	10.12	-6.38	10.09	-6.48	10.06	-6.57	10.03	-6.67	10.00
250	-5.43	10.60	-6.07	10.15	-6.16	10.12	-6.26	10.09	-6.35	10.06	-6.45	10.03	-6.54	10.00
300	-5.35	10.60	-5.98	10.15	-6.08	10.12	-6.17	10.09	-6.27	10.06	-6.36	10.03	-6.46	10.00
350	-5.29	10.60	-5.92	10.16	-6.02	10.12	-6.11	10.09	-6.21	10.06	-6.30	10.03	-6.40	10.00
400	-5.25	10.60	-5.88	10.16	-5.97	10.12	-6.07	10.09	-6.16	10.06	-6.26	10.03	-6.35	10.00
450	-5.21	10.60	-5.84	10.15	-5.94	10.12	-6.03	10.09	-6.13	10.06	-6.22	10.03	-6.32	10.00
500	-6.18	10.50	-5.82	10.15	-5.91	10.12	-6.01	10.09	-6.10	10.06	-6.19	10.03	-6.29	10.00
550	-5.16	10.60	-5.79	10.15	-5.89	10.12	-5.98	10.09	-6.08	10.06	-6.17	10.03	-6.27	10.00
600	-5.14	10.60	-5.77	10.15	-5.87	10.12	-5.96	10.09	-6.06	10.06	-6.15	10.03	-6.25	10.00
650	-5.12	10.50	-5.76	10.16	-5.85	10.12	-5.95	10.09	-6.04	10.06	-6.14	10.03	-6.23	10.00
700	-5.11	10.50	-6.74	10.15	-5.84	10.12	-5.93	10.09	-6.03	10.06	-6.12	10.03	-6.22	10.00
750	-5.10	10.60	-6.73	10.15	-5.83	10.12	-5.92	10.09	-6.02	10.06	-6.11	10.03	-6.20	10.00
800	-5.09	10.50	-5.72	10.16	-5.82	10.12	-5.91	10.09	-6.01	10.06	-6.10	10.03	-6.19	10.00
850	-5.08	10.60	-5.71	10.15	-5.81	10.12	-6.90	10.09	-6.00	10.06	-6.09	10.03	-6.18	10.00
900	-6.07	10.60	-6.70	10.16	-5.80	10.12	-5.89	10.09	-5.99	10.06	-6.08	10.03	-6.18	10.00
950	-5.06	10.60	-5.70	10.16	-6.79	10.12	-5.89	10.09	-5.98	10.06	-6.07	10.03	-6.17	10.00
1000	-5.06	10.60	-6.69	10.16	-5.78	10.12	-6.88	10.09	-6.97	10.06	-6.07	10.03	-6.16	10.00
1500	-5.01	10.60	-6.65	10.15	-6.74	10.12	-5.84	10.09	-6.93	10.06	-6.03	10.03	-6.12	10.00
2000	-4.99	10.60	-6.63	10.16	-6.72	10.12	-6.82	10.09	-6.91	10.06	-6.00	10.03	-6.10	10.00
5000	-5.01	10.60	-6.65	10.16	-6.74	10.12	-6.84	10.09	-5.93	10.06	-6.03	10.03	-6.12	10.00
10000	-5.04	10.60	-6.67	10.16	-6.77	10.12	-5.86	10.09	-6.96	10.06	-6.05	10.03	-6.16	10.00
50000	-6.06	10.60	-6.70	10.16	-6.79	10.12	-6.89	10.09	-6.98	10.06	-6.07	10.03	-6.17	10.00
100000	-6.07	10.60	-6.70	10.16	-6.79	10.12	-6.89	10.09	-6.98	10.06	-6.08	10.03	-6.17	10.00

	3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
82	-7.68	9.97	-7.77	9.94	-7.87	9.90	-7.96	9.87	-8.05	9.84	-8.16	9.80	-8.24	9.76
100	-7.40	9.97	-7.49	9.94	-7.59	9.90	-7.68	9.87	-7.77	9.84	-7.86	9.80	-7.95	9.76
150	-6.97	9.97	-7.07	9.94	-7.16	9.90	-7.25	9.87	-7.34	9.84	-7.44	9.80	-7.53	9.76
200	-6.76	9.97	-6.85	9.94	-6.95	9.90	-7.04	9.87	-7.13	9.84	-7.22	9.80	-7.32	9.76
250	-6.64	9.97	-6.73	9.94	-6.82	9.90	-6.92	9.87	-7.01	9.84	-7.10	9.80	-7.19	9.76
300	-6.55	9.97	-6.64	9.94	-6.74	9.90	-6.83	9.87	-6.92	9.84	-7.01	9.80	-7.11	9.76
350	-6.49	9.97	-6.58	9.94	-6.68	9.90	-6.77	9.87	-6.86	9.84	-6.95	9.80	-7.06	9.76
400	-6.45	9.97	-6.54	9.94	-6.63	9.90	-6.73	9.87	-6.82	9.84	-6.91	9.80	-7.00	9.76
450	-6.41	9.97	-6.50	9.94	-6.60	9.90	-6.69	9.87	-6.78	9.84	-6.87	9.80	-6.97	9.76
500	-6.38	9.97	-6.48	9.94	-6.57	9.90	-6.66	9.87	-6.75	9.84	-6.85	9.80	-6.94	9.76
550	-6.36	9.97	-6.45	9.94	-6.55	9.90	-6.64	9.87	-6.73	9.84	-6.82	9.80	-6.91	9.76
600	-6.34	9.97	-6.43	9.94	-6.53	9.90	-6.62	9.87	-6.71	9.84	-6.80	9.80	-6.90	9.76
650	-6.33	9.97	-6.42	9.94	-6.51	9.90	-6.60	9.87	-6.70	9.84	-6.79	9.80	-6.88	9.76
700	-6.31	9.97	-6.40	9.94	-6.50	9.90	-6.59	9.87	-6.68	9.84	-6.77	9.80	-6.87	9.76
750	-6.30	9.97	-6.39	9.94	-6.49	9.90	-6.58	9.87	-6.67	9.84	-6.76	9.80	-6.86	9.76
800	-6.29	9.97	-6.38	9.94	-6.47	9.90	-6.57	9.87	-6.66	9.84	-6.75	9.80	-6.84	9.76
850	-6.28	9.97	-6.37	9.94	-6.47	9.90	-6.56	9.87	-6.65	9.84	-6.74	9.80	-6.83	9.76
900	-6.27	9.97	-6.36	9.94	-6.46	9.90	-6.55	9.87	-6.64	9.84	-6.73	9.80	-6.83	9.76
950	-6.26	9.97	-6.36	9.94	-6.45	9.90	-6.54	9.87	-6.63	9.84	-6.73	9.80	-6.82	9.76
1000	-6.26	9.97	-6.35	9.94	-6.44	9.90	-6.54	9.87	-6.63	9.84	-6.72	9.80	-6.81	9.76
1500	-6.22	9.97	-6.31	9.94	-6.40	9.90	-6.49	9.87	-6.60	9.84	-6.68	9.80	-6.77	9.76
2000	-6.19	9.97	-6.29	9.94	-6.38	9.90	-6.47	9.87	-6.60	9.84	-6.66	9.80	-6.76	9.76
5000	-6.22	9.97	-6.31	9.94	-6.40	9.90	-6.49	9.87	-6.60	9.84	-6.66	9.80	-6.77	9.76
10000	-6.24	9.97	-6.33	9.94	-6.43	9.90	-6.52	9.87	-6.61	9.84	-6.70	9.80	-6.80	9.76
50000	-6.26	9.97	-6.36	9.94	-6.45	9.90	-6.54	9.87	-6.63	9.84	-6.73	9.80	-6.82	9.76
100000	-6.27	9.97	-6.36	9.94	-6.45	9.90	-6.55	9.87	-6.64	9.84	-6.[illegible]	[illegible]	-6.82	9.76

REV A

LOCATION:

P10 UPPER CORNER OF MIRROR - INSIDE OF CURVE

SUPERELEVATION LEFT WITH ROLL LEFT (TOWARD INSIDE)

COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

LENGTH: 95 FT DOORS CLOSED

WIDTH: 9.5 FT

W MIRROR 10.8 FT

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	FT

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
82	-6.48	9.80	-7.06	9.40	-7.15	9.37	-7.24	9.34	-7.33	9.30	-7.42	9.27	-7.50	9.23	-7.59	9.19	-7.68	9.16	-7.76	9.12	-7.85	9.08	-7.93	9.04	-8.02	9.00	-8.10	8.96
100	-6.20	9.80	-6.78	9.40	-6.87	9.37	-6.96	9.34	-7.05	9.30	-7.13	9.27	-7.22	9.23	-7.31	9.19	-7.39	9.16	-7.48	9.12	-7.57	9.08	-7.65	9.04	-7.74	9.00	-7.82	8.96
150	-5.77	9.80	-6.36	9.40	-6.44	9.37	-6.53	9.34	-6.62	9.30	-6.71	9.27	-6.80	9.23	-6.88	9.19	-6.97	9.16	-7.05	9.12	-7.14	9.08	-7.23	9.04	-7.31	9.00	-7.40	8.96
200	-5.56	9.80	-6.14	9.40	-6.23	9.37	-6.32	9.34	-6.41	9.30	-6.50	9.27	-6.58	9.23	-6.67	9.19	-6.76	9.16	-6.84	9.12	-6.93	9.08	-7.01	9.04	-7.10	9.00	-7.18	8.96
250	-5.43	9.80	-6.02	9.40	-6.11	9.37	-6.19	9.34	-6.28	9.30	-6.37	9.27	-6.46	9.23	-6.54	9.19	-6.63	9.16	-6.72	9.12	-6.80	9.08	-6.89	9.04	-6.97	9.00	-7.06	8.96
300	-5.35	9.80	-5.93	9.40	-6.02	9.37	-6.11	9.34	-6.20	9.30	-6.28	9.27	-6.37	9.23	-6.46	9.19	-6.55	9.16	-6.63	9.12	-6.72	9.08	-6.80	9.04	-6.89	9.00	-6.97	8.96
350	-5.29	9.80	-5.87	9.40	-5.96	9.37	-6.05	9.34	-6.14	9.30	-6.22	9.27	-6.31	9.23	-6.40	9.19	-6.49	9.16	-6.57	9.12	-6.66	9.08	-6.74	9.04	-6.83	9.00	-6.91	8.96
400	-5.25	9.80	-5.83	9.40	-5.92	9.37	-6.00	9.34	-6.09	9.30	-6.18	9.27	-6.27	9.23	-6.36	9.19	-6.44	9.16	-6.53	9.12	-6.61	9.08	-6.70	9.04	-6.78	9.00	-6.87	8.96
450	-5.21	9.80	-5.79	9.40	-5.88	9.37	-5.97	9.34	-6.06	9.30	-6.14	9.27	-6.23	9.23	-6.32	9.19	-6.41	9.16	-6.49	9.12	-6.58	9.08	-6.66	9.04	-6.75	9.00	-6.83	8.96
500	-5.18	9.80	-5.77	9.40	-5.85	9.37	-5.94	9.34	-6.03	9.30	-6.12	9.27	-6.20	9.23	-6.29	9.19	-6.38	9.16	-6.46	9.12	-6.55	9.08	-6.63	9.04	-6.72	9.00	-6.81	8.96
550	-5.16	9.80	-5.74	9.40	-5.83	9.37	-5.92	9.34	-6.01	9.30	-6.09	9.27	-6.18	9.23	-6.27	9.19	-6.35	9.16	-6.44	9.12	-6.53	9.08	-6.61	9.04	-6.70	9.00	-6.78	8.96
600	-5.14	9.80	-5.73	9.40	-5.81	9.37	-5.90	9.34	-5.99	9.30	-6.08	9.27	-6.17	9.23	-6.25	9.19	-6.34	9.16	-6.43	9.12	-6.51	9.08	-6.60	9.04	-6.68	9.00	-6.77	8.96
650	-5.19	9.80	-5.78	9.40	-5.86	9.37	-5.95	9.34	-6.04	9.30	-6.13	9.27	-6.22	9.23	-6.30	9.19	-6.39	9.16	-6.47	9.12	-6.56	9.08	-6.64	9.04	-6.73	9.00	-6.82	8.96
700	-5.23	9.80	-5.82	9.40	-5.91	9.37	-5.99	9.34	-6.08	9.30	-6.17	9.27	-6.26	9.23	-6.34	9.19	-6.43	9.16	-6.52	9.12	-6.60	9.08	-6.69	9.04	-6.77	9.00	-6.86	8.96
750	-5.27	9.80	-5.85	9.40	-5.94	9.37	-6.03	9.34	-6.12	9.30	-6.21	9.27	-6.29	9.23	-6.38	9.19	-6.47	9.16	-6.55	9.12	-6.64	9.08	-6.72	9.04	-6.81	9.00	-6.89	8.96
800	-5.30	9.80	-5.89	9.40	-5.97	9.37	-6.06	9.34	-6.15	9.30	-6.24	9.27	-6.32	9.23	-6.41	9.19	-6.50	9.16	-6.58	9.12	-6.67	9.08	-6.76	9.04	-6.84	9.00	-6.93	8.96
850	-5.33	9.80	-5.91	9.40	-6.00	9.37	-6.09	9.34	-6.18	9.30	-6.26	9.27	-6.35	9.23	-6.44	9.19	-6.53	9.16	-6.61	9.12	-6.70	9.08	-6.78	9.04	-6.87	9.00	-6.95	8.96
900	-5.35	9.80	-5.94	9.40	-6.03	9.37	-6.11	9.34	-6.20	9.30	-6.29	9.27	-6.38	9.23	-6.47	9.19	-6.55	9.16	-6.64	9.12	-6.72	9.08	-6.81	9.04	-6.89	9.00	-6.98	8.96
950	-5.38	9.80	-5.96	9.40	-6.05	9.37	-6.14	9.34	-6.23	9.30	-6.31	9.27	-6.40	9.23	-6.49	9.19	-6.57	9.16	-6.66	9.12	-6.75	9.08	-6.83	9.04	-6.92	9.00	-7.00	8.96
1000	-5.40	9.80	-5.98	9.40	-6.07	9.37	-6.16	9.34	-6.25	9.30	-6.33	9.27	-6.42	9.23	-6.51	9.19	-6.59	9.16	-6.68	9.12	-6.77	9.08	-6.85	9.04	-6.94	9.00	-7.02	8.96
1500	-5.62	9.80	-6.11	9.40	-6.19	9.37	-6.28	9.34	-6.37	9.30	-6.46	9.27	-6.55	9.23	-6.63	9.19	-6.72	9.16	-6.81	9.12	-6.89	9.08	-6.96	9.04	-7.06	9.00	-7.16	8.96
2000	-5.69	9.80	-6.17	9.40	-6.26	9.37	-6.35	9.34	-6.43	9.30	-6.52	9.27	-6.61	9.23	-6.70	9.19	-6.78	9.16	-6.87	9.12	-6.95	9.08	-7.04	9.04	-7.12	9.00	-7.21	8.96
5000	-5.70	9.80	-6.28	9.40	-6.37	9.37	-6.46	9.34	-6.55	9.30	-6.63	9.27	-6.72	9.23	-6.81	9.19	-6.89	9.16	-6.98	9.12	-7.07	9.08	-7.16	9.04	-7.24	9.00	-7.33	8.96
10000	-5.74	9.80	-6.32	9.40	-6.41	9.37	-6.50	9.34	-6.58	9.30	-6.67	9.27	-6.76	9.23	-6.85	9.19	-6.93	9.16	-7.02	9.12	-7.10	9.08	-7.19	9.04	-7.27	9.00	-7.36	8.96
50000	-5.77	9.80	-6.35	9.40	-6.44	9.37	-6.53	9.34	-6.61	9.30	-6.70	9.27	-6.79	9.23	-6.88	9.19	-6.96	9.16	-7.05	9.12	-7.13	9.08	-7.22	9.04	-7.30	9.00	-7.39	8.96
100000	-5.77	9.80	-6.35	9.40	-6.44	9.37	-6.53	9.34	-6.62	9.30	-6.70	9.27	-6.79	9.23	-6.88	9.19	-6.97	9.16	-7.05	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

REV LOCATION: COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

B

P11 INTERMEDIATE POINT OF CARBODY - INSIDE OF CURVE

LENGTH: 95 FT DOORS CLOSED

WIDTH: 9.5 FT

SUPERELEVATION LEFT WITH ROLL LEFT (TOWARD INSIDE)

W MIRROR 10.8 FT

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	FT

RADIUS	LEVEL X	LEVEL Y	ROLL LEFT X	ROLL LEFT Y	0.5 INCH X	0.5 INCH Y	1.0 INCH X	1.0 INCH Y	1.5 INCH X	1.5 INCH Y	2.0 INCH X	2.0 INCH Y	2.5 INCH X	2.5 INCH Y	3.0 INCH X	3.0 INCH Y	3.5 INCH X	3.5 INCH Y	4.0 INCH X	4.0 INCH Y	4.5 INCH X	4.5 INCH Y	5 0 INCH X	5 0 INCH Y	5.5 INCH X	5.5 INCH Y	6.0 INCH X	6.0 INCH Y
82	-6.48	7.00	-6.87	6.65	-6.94	6.63	-7.00	6.60	-7.06	6.58	-7.13	6.55	-7.19	6.52	-7.25	6.50	-7.32	6.47	-7.38	6.44	-7.44	6.41	-7.50	6.38	-7.56	6.35	-7.63	6.32
100	-6.20	7.00	-6.59	6.65	-6.65	6.63	-6.72	6.60	-6.78	6.58	-6.84	6.55	-6.91	6.52	-6.97	6.50	-7.03	6.47	-7.09	6.44	-7.16	6.41	-7.22	6.38	-7.28	6.35	-7.34	6.32
150	-5.77	7.00	-6.16	6.65	-6.23	6.63	-6.29	6.60	-6.35	6.58	-6.42	6.55	-6.48	6.52	-6.54	6.50	-6.61	6.47	-6.67	6.44	-6.73	6.41	-6.79	6.38	-6.85	6.35	-6.92	6.32
200	-5.56	7.00	-5.95	6.65	-6.01	6.63	-6.08	6.60	-6.14	6.58	-6.21	6.55	-6.27	6.52	-6.33	6.50	-6.39	6.47	-6.46	6.44	-6.52	6.41	-6.58	6.38	-6.64	6.35	-6.70	6.32
250	-5.43	7.00	-5.82	6.65	-5.89	6.63	-5.95	6.60	-6.02	6.58	-6.08	6.55	-6.14	6.52	-6.21	6.50	-6.27	6.47	-6.33	6.44	-6.39	6.41	-6.45	6.38	-6.52	6.35	-6.58	6.32
300	-5.35	7.00	-5.74	6.65	-5.80	6.63	-5.87	6.60	-5.93	6.58	-5.99	6.55	-6.06	6.52	-6.12	6.50	-6.18	6.47	-6.25	6.44	-6.31	6.41	-6.37	6.38	-6.43	6.35	-6.49	6.32
350	-5.29	7.00	-5.68	6.65	-5.74	6.63	-5.81	6.60	-5.87	6.58	-5.93	6.55	-6.00	6.52	-6.06	6.50	-6.12	6.47	-6.19	6.44	-6.25	6.41	-6.31	6.38	-6.37	6.35	-6.43	6.32
400	-5.25	7.00	-5.63	6.65	-5.70	6.63	-5.76	6.60	-5.83	6.58	-5.89	6.55	-5.95	6.52	-6.02	6.50	-6.08	6.47	-6.14	6.44	-6.20	6.41	-6.27	6.38	-6.33	6.35	-6.39	6.32
450	-5.21	7.00	-5.60	6.65	-5.66	6.63	-5.73	6.60	-5.79	6.58	-5.85	6.55	-5.92	6.52	-5.98	6.50	-6.04	6.47	-6.11	6.44	-6.17	6.41	-6.23	6.38	-6.29	6.35	-6.35	6.32
500	-5.18	7.00	-5.57	6.65	-5.64	6.63	-5.70	6.60	-5.76	6.58	-5.83	6.55	-5.89	6.52	-5.95	6.50	-6.02	6.47	-6.08	6.44	-6.14	6.41	-6.20	6.38	-6.26	6.35	-6.33	6.32
550	-5.16	7.00	-5.55	6.65	-5.61	6.63	-5.68	6.60	-5.74	6.58	-5.80	6.55	-5.87	6.52	-5.93	6.50	-5.99	6.47	-6.06	6.44	-6.12	6.41	-6.18	6.38	-6.24	6.35	-6.30	6.32
600	-5.14	7.00	-5.53	6.65	-5.59	6.63	-5.66	6.60	-5.72	6.58	-5.78	6.55	-5.85	6.52	-5.91	6.50	-5.97	6.47	-6.04	6.44	-6.10	6.41	-6.16	6.38	-6.22	6.35	-6.28	6.32
650	-5.12	7.00	-5.51	6.65	-5.58	6.63	-5.64	6.60	-5.71	6.58	-5.77	6.55	-5.83	6.52	-5.90	6.50	-5.96	6.47	-6.02	6.44	-6.08	6.41	-6.14	6.38	-6.21	6.35	-6.27	6.32
700	-5.11	7.00	-5.50	6.65	-5.56	6.63	-5.63	6.60	-5.69	6.58	-5.75	6.55	-5.82	6.52	-5.88	6.50	-5.94	6.47	-6.01	6.44	-6.07	6.41	-6.13	6.38	-6.19	6.35	-6.25	6.32
750	-5.10	7.00	-5.49	6.65	-5.55	6.63	-5.62	6.60	-5.68	6.58	-5.74	6.55	-5.81	6.52	-5.87	6.50	-5.93	6.47	-5.99	6.44	-6.06	6.41	-6.12	6.38	-6.18	6.35	-6.24	6.32
800	-5.09	7.00	-5.48	6.65	-5.54	6.63	-5.61	6.60	-5.67	6.58	-5.73	6.55	-5.80	6.52	-5.86	6.50	-5.92	6.47	-5.98	6.44	-6.05	6.41	-6.11	6.38	-6.17	6.35	-6.23	6.32
850	-5.08	7.00	-5.47	6.65	-5.53	6.63	-5.60	6.60	-5.66	6.58	-5.72	6.55	-5.79	6.52	-5.85	6.50	-5.91	6.47	-5.98	6.44	-6.04	6.41	-6.10	6.38	-6.16	6.35	-6.22	6.32
900	-5.07	7.00	-5.46	6.65	-5.52	6.63	-5.59	6.60	-5.65	6.58	-5.71	6.55	-5.78	6.52	-5.84	6.50	-5.90	6.47	-5.97	6.44	-6.03	6.41	-6.09	6.38	-6.15	6.35	-6.21	6.32
950	-5.06	7.00	-5.46	6.65	-5.52	6.63	-5.58	6.60	-5.64	6.58	-5.71	6.55	-5.77	6.52	-5.83	6.50	-5.90	6.47	-5.96	6.44	-6.02	6.41	-6.08	6.38	-6.14	6.35	-6.21	6.32
1000	-5.06	7.00	-5.45	6.65	-5.51	6.63	-5.57	6.60	-5.64	6.58	-5.70	6.55	-5.76	6.52	-5.83	6.50	-5.89	6.47	-5.95	6.44	-6.02	6.41	-6.08	6.38	-6.14	6.35	-6.20	6.32
1600	-5.01	7.00	-5.40	6.65	-5.47	6.63	-5.53	6.60	-5.60	6.58	-5.66	6.55	-5.72	6.52	-5.79	6.50	-5.85	6.47	-5.91	6.44	-5.97	6.41	-6.03	6.38	-6.10	6.35	-6.16	6.32
2000	-4.99	7.00	-5.38	6.65	-5.45	6.63	-5.51	6.60	-5.57	6.58	-5.64	6.55	-5.70	6.52	-5.77	6.50	-5.83	6.47	-5.89	6.44	-5.95	6.41	-6.01	6.38	-6.08	6.36	-6.14	6.32
5000	-5.01	7.00	-5.40	6.65	-5.47	6.63	-5.53	6.60	-5.60	6.58	-5.66	6.55	-5.72	6.52	-5.79	6.50	-5.85	6.47	-5.91	6.44	-5.97	6.41	-6.03	6.38	-6.10	6.36	-6.16	6.32
10000	-5.04	7.00	-5.43	6.65	-5.50	6.63	-5.56	6.60	-5.62	6.58	-5.69	6.55	-5.75	6.52	-5.81	6.50	-5.88	6.47	-5.94	6.44	-6.00	6.41	-6.06	6.38	-6.12	6.36	-6.19	6.32
50000	-5.06	7.00	-5.45	6.65	-5.52	6.63	-5.58	6.60	-5.64	6.58	-5.71	6.55	-5.77	6.52	-5.83	6.50	-5.90	6.47	-5.96	6.44	-6.02	6.41	-6.08	6.38	-6.14	[illegible]	-6.21	6.32
100000	[illegible]	7.00	-5.45	6.65	-5.52	6.63	-5.58	6.60	-5.65	6.58	-5.71	6.55	[illegible]	[illegible]	-5.84	6.50	-5.90	6.47	-5.96	6.44	-6.02	6.41	-6.09	6.38	[illegible]	[illegible]	-6.21	6.32

REV A

LOCATION:

COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

P12 LOWER CORNER OF CARBODY - INSIDE OF CURVE

SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)

LENGTH: 95 FT DOORS CLOSED
WIDTH: 9.5 FT
W MIRROR 10.8 FT

P1 - ROLL POINT OF VEHICLE X 0 Y 1.25 FT

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
82	-6.48	0.67	-6.43	0.72	-6.52	0.98	-6.54	0.96	-6.55	0.94	-6.57	0.92	-6.58	0.89	-6.59	0.87	-6.61	0.85	-6.62	0.83	-6.63	0.80	-6.64	0.78	-6.66	0.76	-6.67	0.74
100	-6.20	0.67	-6.15	0.72	-6.24	0.98	-6.26	0.96	-6.27	0.94	-6.28	0.92	-6.30	0.89	-6.31	0.87	-6.32	0.85	-6.34	0.83	-6.35	0.80	-6.36	0.78	-6.37	0.76	-6.39	0.74
150	-5.77	0.67	-5.72	0.72	-5.82	0.98	-5.83	0.96	-5.84	0.94	-5.86	0.92	-5.87	0.89	-5.88	0.87	-5.90	0.85	-5.91	0.83	-5.92	0.80	-5.94	0.78	-5.95	0.76	-5.96	0.74
200	-5.56	0.67	-5.51	0.72	-5.60	0.98	-5.62	0.96	-5.63	0.94	-5.65	0.92	-5.66	0.89	-5.67	0.87	-5.69	0.85	-5.70	0.83	-5.71	0.80	-5.72	0.78	-5.74	0.76	-5.75	0.74
250	-5.43	0.67	-5.38	0.72	-5.48	0.98	-5.49	0.96	-5.51	0.94	-5.52	0.92	-5.53	0.89	-5.55	0.87	-5.56	0.85	-5.57	0.83	-5.59	0.80	-5.60	0.78	-5.61	0.76	-5.62	0.74
300	-5.35	0.67	-5.30	0.72	-5.39	0.98	-5.41	0.96	-5.42	0.94	-5.44	0.92	-5.45	0.89	-5.46	0.87	-5.48	0.85	-5.49	0.83	-5.50	0.80	-5.51	0.78	-5.53	0.76	-5.54	0.74
350	-5.29	0.67	-5.24	0.72	-5.33	0.98	-5.35	0.96	-5.36	0.94	-5.38	0.92	-5.39	0.89	-5.40	0.87	-5.42	0.85	-5.43	0.83	-5.44	0.80	-5.45	0.78	-5.47	0.76	-5.48	0.74
400	-5.25	0.67	-5.19	0.72	-5.29	0.98	-5.30	0.96	-5.32	0.94	-5.33	0.92	-5.34	0.89	-5.36	0.87	-5.37	0.85	-5.38	0.83	-5.40	0.80	-5.41	0.78	-5.42	0.76	-5.43	0.74
450	-5.21	0.67	-5.16	0.72	-5.25	0.98	-5.27	0.96	-5.28	0.94	-5.29	0.92	-5.31	0.89	-5.32	0.87	-5.33	0.85	-5.35	0.83	-5.36	0.80	-5.37	0.78	-5.39	0.76	-5.40	0.74
500	-5.18	0.67	-5.13	0.72	-5.23	0.98	-5.24	0.96	-5.25	0.94	-5.27	0.92	-5.28	0.89	-5.29	0.87	-5.31	0.85	-5.32	0.83	-5.33	0.80	-5.34	0.78	-5.36	0.76	-5.37	0.74
550	-5.16	0.67	-5.11	0.72	-5.20	0.98	-5.22	0.96	-5.23	0.94	-5.24	0.92	-5.26	0.89	-5.27	0.87	-5.28	0.85	-5.30	0.83	-5.31	0.80	-5.32	0.78	-5.33	0.76	-5.35	0.74
600	-5.14	0.67	-5.09	0.72	-5.18	0.98	-5.20	0.96	-5.21	0.94	-5.22	0.92	-5.24	0.89	-5.25	0.87	-5.26	0.85	-5.28	0.83	-5.29	0.80	-5.30	0.78	-5.32	0.76	-5.33	0.74
650	-5.12	0.67	-5.07	0.72	-5.17	0.98	-5.18	0.96	-5.20	0.94	-5.21	0.92	-5.22	0.89	-5.24	0.87	-5.25	0.85	-5.26	0.83	-5.27	0.80	-5.29	0.78	-5.30	0.76	-5.31	0.74
700	-5.11	0.67	-5.06	0.72	-5.16	0.98	-5.17	0.96	-5.18	0.94	-5.19	0.92	-5.21	0.89	-5.22	0.87	-5.23	0.85	-5.25	0.83	-5.26	0.80	-5.27	0.78	-5.29	0.76	-5.30	0.74
750	-5.10	0.67	-5.05	0.72	-5.14	0.98	-5.16	0.96	-5.17	0.94	-5.18	0.92	-5.20	0.89	-5.21	0.87	-5.22	0.85	-5.24	0.83	-5.25	0.80	-5.26	0.78	-5.27	0.76	-5.29	0.74
800	-5.09	0.67	-5.04	0.72	-5.13	0.98	-5.14	0.96	-5.16	0.94	-5.17	0.92	-5.19	0.89	-5.20	0.87	-5.21	0.85	-5.23	0.83	-5.24	0.80	-5.25	0.78	-5.26	0.76	-5.27	0.74
850	-5.08	0.67	-5.03	0.72	-5.12	0.98	-5.14	0.96	-5.15	0.94	-5.16	0.92	-5.18	0.89	-5.19	0.87	-5.20	0.85	-5.22	0.83	-5.23	0.80	-5.24	0.78	-5.25	0.76	-5.27	0.74
900	-5.07	0.67	-5.02	0.72	-5.11	0.98	-5.13	0.96	-5.14	0.94	-5.15	0.92	-5.17	0.89	-5.18	0.87	-5.19	0.85	-5.21	0.83	-5.22	0.80	-5.23	0.78	-5.25	0.76	-5.26	0.74
950	-5.06	0.67	-5.01	0.72	-5.11	0.98	-5.12	0.96	-5.13	0.94	-5.15	0.92	-5.16	0.89	-5.17	0.87	-5.19	0.85	-5.20	0.83	-5.21	0.80	-5.23	0.78	-5.24	0.76	-5.25	0.74
1000	-5.06	0.67	-5.00	0.72	-5.10	0.98	-5.11	0.96	-5.13	0.94	-5.14	0.92	-5.15	0.89	-5.17	0.87	-5.18	0.85	-5.19	0.83	-5.21	0.80	-5.22	0.78	-5.23	0.76	-5.24	0.74
1500	-5.01	0.67	-4.96	0.72	-5.06	0.98	-5.07	0.96	-5.09	0.94	-5.10	0.92	-5.11	0.89	-5.13	0.87	-5.14	0.85	-5.16	0.83	-5.18	0.80	-5.18	0.78	-5.19	0.76	-5.20	0.74
2000	-4.99	0.67	-4.94	0.72	-5.04	0.98	-5.05	0.96	-5.06	0.94	-5.08	0.92	-5.09	0.89	-5.10	0.87	-5.12	0.85	-5.13	0.83	-5.14	0.80	-5.16	0.78	-5.17	0.76	-5.18	0.74
5000	-5.01	0.67	-4.96	0.72	-5.06	0.98	-5.07	0.96	-5.09	0.94	-5.10	0.92	-5.11	0.89	-5.13	0.87	-5.14	0.85	-5.16	0.83	-5.17	0.80	-5.18	0.78	-5.19	0.76	-5.20	0.74
10000	-5.04	0.67	-4.99	0.72	-5.08	0.98	-5.10	0.96	-5.11	0.94	-5.13	0.92	-5.14	0.89	-5.15	0.87	-5.17	0.85	-5.18	0.83	-5.19	0.80	-5.20	0.78	-5.22	0.76	-5.23	0.74
50000	-5.06	0.67	-5.01	0.72	-5.11	0.98	-5.12	0.96	-5.13	0.94	-5.15	0.92	-5.16	0.89	-5.17	0.87	-5.19	0.85	-5.20	0.83	-5.21	0.80	-5.23	0.78	-5.24	0.76	[illegible]	[illegible]
100000	-5.07	0.67	-5.01	0.72	-5.11	0.98	-5.12	0.96	-5.14	0.94	-5.15	0.92	-5.16	0.89	-5.18	0.87	-5.19	0.85	[illegible]	[illegible]								

REV A LOCATION COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

P13 INTERMEDIATE POINT OF PANTOGRAPH - OUTSIDE OF CURVE

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)

LENGTH: 95 FT DOORS CLOSED
WIDTH: 9.5 FT
W MIRROR 10.8 FT

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	FT

INCLUDES .18 FT LATERAL MOTION TO OUTSIDE

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	2.43	14.25	1.52	14.39	3.20	14.09	3.07	14.14	2.94	14.19	2.81	14.24	2.68	14.28	2.54	14.33	2.41	14.37	2.28	14.41	2.15	14.45	2.02	14.49	1.88	14.53	1.75	14.5[illegible]

REV A LOCATION COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

P14 INTERMEDIATE POINT OF PANTOGRAPH - INSIDE OF CURVE

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL LEFT (TOWARD INSIDE)

LENGTH: 95 FT DOORS CLOSED
WIDTH: 9.5 FT
W MIRROR 10.8 FT

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.26	FT

INCLUDES .18 FT OF LATERAL MOTION

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	-2.43	14.25	-3.33	14.04	-3.46	14.03	-3.59	14.02	-3.72	14.01	-3.85	14.00	-3.98	13.98	-4.11	13.97	-4.23	13.95	-4.36	13.93	-4.49	13.91	-4.62	13.89	-4.75	13.87	-4.88	13.[illegible]

REV A LOCATION COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

P15 END OF PANTOGRAPH - OUTSIDE OF CURVE

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)

LENGTH: 95 FT DOORS CLOSED
WIDTH: 9.5 FT
W MIRROR 10.8 FT

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.26	FT

INCLUDES .18 FT LATERAL MOTION TO OUTSIDE

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	[illegible]	Y	X	Y
ALL	[illegible]43	17.00	2.32	17.19	4.37	16.79	4.21	16.85	4.06	16.91	3.90	16.9[illegible]	[illegible]5	17.01	3.59	17.07	3.44	17.12	3.28	17.16	3.12	17.21	2.96	17.26	[illegible]	17.30	2.65	17.[illegible]

REV A LOCATION

COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

P16 INTERMEDIATE POINT OF PANTOGRAPH - OUTSIDE OF CURVE

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)

LENGTH: 95 FT DOORS CLOSED

WIDTH: 9.5 FT

W MIRROR 10.8 FT

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	FT

INCLUDES .18 FT LATERAL MOTION TO OUTSIDE

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	2.43	18.00	1.26	18.13	3.43	17.84	3.27	17.89	3.10	17.94	2.94	17.99	2.77	18.03	2.61	18.08	2.44	18.12	2.28	18.16	2.11	18.20	1.95	18.24	1.78	18.28	1.61	18.32

REV A LOCATION

COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

P17 CENTER OF PANTOGRAPH

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)

LENGTH: 95 FT DOORS CLOSED

WIDTH: 9.5 FT

W MIRROR 10.8 FT

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.26	FT

LATERAL MOTION "+ OR -" .18 FT FROM CENTER

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	0.00	18.00	-1.17	17.96	1.00	17.99	0.84	18.02	0.67	18.05	0.51	18.07	0.34	18.10	0.18	18.12	0.01	18.14	-0.15	18.16	-0.32	18.18	-0.48	18.20	-0.65	18.21	-0.82	18.23

REV A LOCATION

COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

P18 INTERMEDIATE POINT OF PANTOGRAPH - INSIDE OF CURVE

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL LEFT (TOWARD INSIDE)

LENGTH: 95 FT DOORS CLOSED

WIDTH: 9.5 FT

W MIRROR 10.8 FT

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.26	FT

INCLUDES .18 FT OF LATERAL MOTION

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ALL	-2.43	18.00	-3.50	17.78	-3.75	17.77	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

REV A LOCATION

P19 END OF PANTOGRAPH - INSIDE OF CURVE

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL LEFT (TOWARD INSIDE)

COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

LENGTH: 95 FT DOORS CLOSED

WIDTH: 9.5 FT

W MIRROR 10.8 FT

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	FT

INCLUDES .18 FT OF LATERAL MOTION

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	-3.43	17.00	-4.52	16.73	-4.67	16.72	-4.83	16.70	-4.98	16.68	-5.13	16.65	-5.29	16.63

	3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	-5.44	16.60	-5.59	16.58	-5.74	16.55	-5.89	16.52	-6.04	16.49	-6.19	16.46	-6.35	16.43

REV A LOCATION

P20 END OF PANTOGRAPH - OUTSIDE OF CURVE

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)

COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

LENGTH: 95 FT DOORS CLOSED

WIDTH: 9.5 FT

W MIRROR 10.8 FT

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	FT

INCLUDES .18 FT OF LATERAL MOTION

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	3.43	22.00	1.97	22.18	4.67	21.78	4.47	21.84	4.27	21.90	4.08	21.96	3.87	22.01

	3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	3.67	22.07	3.48	22.12	3.27	22.16	3.07	22.21	2.87	22.26	2.67	22.30	2.47	22.3

REV A LOCATION

P21 INTERMEDIATE POINT OF PANTOGRAPH - OUTSIDE OF CURVE

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)

COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

LENGTH: 95 FT DOORS CLOSED

WIDTH: 9.5 FT

W MIRROR 10.8 FT

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	FT

INCLUDES .18 FT OF LATERAL MOTION

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	[illegible].43	23.00	0.91	23.12	3.73	22.83	3.63	22.88	3.32	22.93	3.11	22.98	[illegible]	23.03

	3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	2.69	23.08	2.48	23.12	2.27	23.16	2.06	23.20	1.85	23.24	[illegible]	[illegible]28	1.43	23.31

REV A LOCATION

P22 CENTER OF PANTOGRAPH - OUTSIDE OF CURVE

COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)

LENGTH: 95 FT DOORS CLOSED

WIDTH: 9.5 FT

W MIRROR 10.8 FT

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	FT

LATERAL MOTION "+ OR -" .18 FT FROM CENTER

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	0.00	23.00	-1.52	22.95	1.31	22.98	1.10	23.01	0.89	23.04	0.68	23.07	0.47	23.09

	3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	0.26	23.12	0.05	23.14	-0.16	23.16	-0.37	23.18	-0.58	23.20	-0.79	23.21	-1.00	23.22

REV A LOCATION

P23 INTERMEDIATE POINT OF PANTOGRAPH - INSIDE OF CURVE

COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL LEFT (TOWARD INSIDE)

LENGTH: 95 FT DOORS CLOSED

WIDTH: 9.5 FT

W MIRROR 10.8 FT

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	FT

INCLUDES .18 FT OF LATERAL MOTION

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	-2.43	23.00	-3.94	22.77	-4.15	22.76	-4.35	22.74	-4.56	22.72	-4.77	22.70	-4.97	22.68

	3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	-5.18	22.65	-5.38	22.63	-5.59	22.60	-5.80	22.57	-6.00	22.54	-6.20	22.50	-6.41	22.47

REV A LOCATION

P24 END OF PANTOGRAPH - INSIDE OF CURVE

COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL LEFT (TOWARD INSIDE)

LENGTH: 95 FT DOORS CLOSED

WIDTH: 9.5 FT

W MIRROR 10.8 FT

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	FT

INCLUDES .18 FT OF LATERAL MOTION

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	-3.43	22.00	-4.87	21.72	-5.07	21.70	-5.26	21.68	-5.46	21.65	-5.66	21.63	-5.85	21.60

	3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	-6.05	21.57	-6.25	21.54	-6.44	21.50	[illegible]	[illegible]	[illegible]	[illegible]				

APPENDIX D

MKD-3701, 11/14/94.

MORRISON KNUDSEN CORPORATION

TRANSPORTATION AND WATER RESOURCES GROUP
1701 N. MARKET STREET, SUITE 404
DALLAS, TEXAS U.S.A. 75202
PHONE: (214) 761-9491/FAX: (214) 761-9497

November 14, 1994
MKD-3701
File No. 11.3.0
1.2.8

Mr. Tom Larkin
Senior Vice President
Dallas Area Rapid Transit
1401 Pacific Avenue
P.O. Box 660163
Dallas, Texas 75266-7209

Attention: Mr. Ron. Swindell

Reference: CBD Transit Way Mall

Subject: **West End Station Canopy Clearances: LRV Design Criteria - Additional Points Describing Roof Shroud**

Dear Mr. Larkin:

This is in response to the request by the Principal Section Designer for the clearance coordinates for the roof mounted equipment on the current LRV.

Systems is pleased to attach two (2) clearance tables, dated November 10, 1994, which describe the clearance coordinates for the roof mounted equipment.

The two new points are "P5a" and "P9a", and correspond respectively to the top outboard corner of roof mounted equipment/shroud above the existing points "P5" and "P9".

The Clearance Tables of "P5a" and "P9a" should be added to the existing Design Criteria Clearance Tables, to further define the clearance envelope for a 9'-6" Light Rail Vehicle.

The points describe a roof mounted shroud which will conceal the roof mounted equipment. The allowable height of roof mounted equipment is 12'-6", per the design criteria, and the horizontal displacement of the shroud is defined such that at a 4° roll, the point does not exceed the vertical line through the top corner of the carbody. This means that the shroud is slanted 4° in, towards the center of the vehicle.

The top corner of the LRV carbody, defined by the points "P5" or "P9", specifies the maximum horizontal movement of the vehicle. Thus the configuration of the shroud and roof equipment has been designed such that the roof mounted equipment does not exceed the horizontal movement of points P5 or P9 in DART's Design Criteria.

We understand that DART's Design Criteria has not changed, and does not allow any wayside equipment to be installed as follows:

- "Under" the vehicle
- Above top of rail
- Extend "over" the vehicle below the minimum pantograph operating height of 13'-6".

Also, we understand that DART's Design Criteria requires that, with the exception of the low level platforms, all wayside equipment and Facilities will be located outside the clearance envelope of the Design Criteria vehicle, which is 9'-6" wide.

As stated above, the roof shroud/equipment on the current LRV will not exceed the horizontal movement of the top corner of the carbody, "P5" or "P9". Also, it is lower than the minimum operating height of the pantograph.

Hence the exact location and dynamic movement of the roo shroud/equipment on the current LRV should not be a determinin factor in the acceptance of the installation of the Facilities wayside equipment.

The Kinkisharyo drawings (Nos. A1D0037 Sheet 1 and Sheet 2) which we submitted October 25, 1994, (MKD-3627) provide all of the dimensions and maximum movements of the current DART LRV.

Please let us know if anything further is required.

Sincerely,

Peter J. Valentine
Project Manager

PJV/JFM/sv

Enc.

cc: R. Rodriguez	(w/enc)		A. Murphy	(w/enc)
DART EDC	(w/enc)		J. F. Miller	(w/enc)
C. Santa Cruz	(w/o)		F0659 Rev. 1	(w/enc)
C. Johnson	(w/enc)		J. Morgan	(w/enc)
M. Sanders	(w/enc)		A. Sosebee	(w/enc)

LOCATION: P5a – UPPER CORNER OF [illegible] F SHROUD – OUTSIDE OF CURVE

REV: 0 (11/07/04) Point P5a defines the extreme vertical and horizontal location of all roof mounted equipment (excluding Pantograph)

DOORS CLOSED

LENGTH:	85 FT
WIDTH:	9.5 FT
W MIRRORS:	10.8 FT

COORDINATE SYSTEM ORIGIN, (0,0) IS LOCATED AT CENTERLINE OF TRACKWAY, TOP OF RAIL (TOR)

VEHICLE – ROLL POINT

P1	X	Y
	0	1.25

	LEVEL		ROLL LEFT		SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)																							
					0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
82	7.99	12.50	7.20	12.79	8.65	12.22	8.54	12.29	8.42	12.35	8.31	12.42	8.19	12.48	8.08	12.54	7.96	12.60	7.84	12.67	7.73	12.73	7.61	12.78	7.49	12.84	7.37	12.90
100	7.40	12.50	6.60	12.79	8.06	12.22	7.94	12.29	7.83	12.35	7.72	12.42	7.60	12.48	7.48	12.54	7.37	12.60	7.25	12.67	7.13	12.73	7.01	12.78	6.90	12.84	6.78	12.90
150	6.62	12.50	5.83	12.79	7.28	12.22	7.17	12.29	7.05	12.35	6.94	12.42	6.82	12.48	6.71	12.54	6.59	12.60	6.47	12.67	6.36	12.73	6.24	12.78	6.12	12.84	6.00	12.90
200	6.22	12.50	5.42	12.79	6.88	12.22	6.76	12.29	6.65	12.35	6.53	12.42	6.42	12.48	6.30	12.54	6.19	12.60	6.07	12.67	5.95	12.73	5.83	12.78	5.71	12.84	5.59	12.90
250	5.97	12.50	5.17	12.79	6.63	12.22	6.51	12.29	6.40	12.35	6.28	12.42	6.17	12.48	6.05	12.54	5.94	12.60	5.82	12.67	5.70	12.73	5.58	12.78	5.46	12.84	5.35	12.90
300	5.80	12.50	5.00	12.79	6.46	12.22	6.34	12.29	6.23	12.35	6.12	12.42	6.00	12.48	5.88	12.54	5.77	12.60	5.65	12.67	5.53	12.73	5.41	12.78	5.30	12.84	5.18	12.90
350	5.68	12.50	4.88	12.79	6.34	12.22	6.22	12.29	6.11	12.35	5.99	12.42	5.88	12.48	5.76	12.54	5.65	12.60	5.53	12.67	5.41	12.73	5.29	12.78	5.17	12.84	5.05	12.90
400	5.56	12.50	4.79	12.79	6.24	12.22	6.13	12.29	6.02	12.35	5.90	12.42	5.79	12.48	5.67	12.54	5.55	12.60	5.44	12.67	5.32	12.73	5.20	12.78	5.08	12.84	4.96	12.90
450	5.51	12.50	4.72	12.79	6.17	12.22	6.06	12.29	5.94	12.35	5.83	12.42	5.71	12.48	5.60	12.54	5.48	12.60	5.36	12.67	5.25	12.73	5.13	12.78	5.01	12.84	4.89	12.90
500	5.46	12.50	4.66	12.79	6.12	12.22	6.00	12.29	5.89	12.35	5.77	12.42	5.66	12.48	5.54	12.54	5.42	12.60	5.31	12.67	5.19	12.73	5.07	12.78	4.95	12.84	4.83	12.90
550	5.41	12.50	4.61	12.79	6.07	12.22	5.95	12.29	5.84	12.35	5.73	12.42	5.61	12.48	5.49	12.54	5.38	12.60	5.26	12.67	5.14	12.73	5.02	12.78	4.91	12.84	4.79	12.90
600	5.37	12.50	4.57	12.79	6.03	12.22	5.91	12.29	5.80	12.35	5.69	12.42	5.57	12.48	5.45	12.54	5.34	12.60	5.22	12.67	5.10	12.73	4.99	12.78	4.87	12.84	4.75	12.90
650	5.33	12.50	4.54	12.79	5.99	12.22	5.88	12.29	5.77	12.35	5.65	12.42	5.54	12.48	5.42	12.54	5.30	12.60	5.19	12.67	5.07	12.73	4.95	12.78	4.83	12.84	4.71	12.90
700	5.31	12.50	4.51	12.79	5.97	12.22	5.85	12.29	5.74	12.35	5.62	12.42	5.51	12.48	5.39	12.54	5.28	12.60	5.16	12.67	5.04	12.73	4.92	12.78	4.80	12.84	4.68	12.90
750	5.28	12.50	4.49	12.79	5.94	12.22	5.83	12.29	5.71	12.35	5.60	12.42	5.48	12.48	5.37	12.54	5.25	12.60	5.13	12.67	5.01	12.73	4.90	12.78	4.78	12.84	4.66	12.90
800	5.26	12.50	4.46	12.79	5.92	12.22	5.81	12.29	5.69	12.35	5.58	12.42	5.46	12.48	5.34	12.54	5.23	12.60	5.11	12.67	4.99	12.73	4.88	12.78	4.76	12.84	4.64	12.90
850	5.24	12.50	4.44	12.79	5.90	12.22	5.79	12.29	5.67	12.35	5.56	12.42	5.44	12.48	5.32	12.54	5.21	12.60	5.09	12.67	4.97	12.73	4.86	12.78	4.74	12.84	4.62	12.90
900	5.22	12.50	4.43	12.79	5.88	12.22	5.77	12.29	5.65	12.35	5.54	12.42	5.42	12.48	5.31	12.54	5.19	12.60	5.07	12.67	4.96	12.73	4.84	12.78	4.72	12.84	4.60	12.90
950	5.21	12.50	4.41	12.79	5.87	12.22	5.75	12.29	5.64	12.35	5.52	12.42	5.41	12.48	5.29	12.54	5.18	12.60	5.06	12.67	4.94	12.73	4.82	12.78	4.71	12.84	4.59	12.90
1000	5.19	12.50	4.40	12.79	5.85	12.22	5.74	12.29	5.62	12.35	5.51	12.42	5.39	12.48	5.28	12.54	5.16	12.60	5.04	12.67	4.93	12.73	4.81	12.78	4.69	12.84	4.57	12.90
1500	5.11	12.50	4.31	12.79	5.77	12.22	5.65	12.29	5.54	12.35	5.42	12.42	5.31	12.48	5.19	12.54	5.07	12.60	4.96	12.67	4.84	12.73	4.72	12.78	4.60	12.84	4.48	12.90
2000	5.06	12.50	4.27	12.79	5.72	12.22	5.61	12.29	5.49	12.35	5.38	12.42	5.26	12.48	5.15	12.54	5.03	12.60	4.91	12.67	4.79	12.73	4.68	12.78	4.56	12.84	4.44	12.90
3000	4.98	12.50	4.19	12.79	5.64	12.22	5.53	12.29	5.41	12.35	5.30	12.42	5.18	12.48	5.07	12.54	4.95	12.60	4.83	12.67	4.71	12.73	4.60	12.78	4.48	12.84	4.36	12.90
5000	4.95	12.50	4.16	12.79	5.61	12.22	5.50	12.29	5.39	12.35	5.27	12.42	5.16	12.48	5.04	12.54	4.92	12.60	4.81	12.67	4.69	12.73	4.57	12.78	4.45	12.84	4.33	12.90
10000	4.93	12.50	4.14	12.79	5.59	12.22	5.48	12.29	5.36	12.35	5.25	12.42	5.13	12.48	5.02	12.54	4.90	12.60	4.78	12.67	4.67	12.73	4.55	12.78	4.43	12.84	4.31	12.90
100000	4.93	12.50	4.13	12.79	5.59	12.22	5.48	12.29	5.36	12.35	5.25	12.42	5.13	12.48	5.01	12.54	4.90	12.60	4.78	12.67	4.66	12.73	4.55	12.78	4.43	12.84	4.31	12.90

APPENDIX E

Attachment to PSD #4653, 8/12/93.

Project SOC-2

Client DART

Task MIN. ENVELOPE TO CLEAR STREET SIGNS ON LANCASTER ROAD

HUITT ZOLLARS INCORPORATED CONSULTING ENGINEERS

Job No. 04-0222-(

By KEK Date 8/1?/

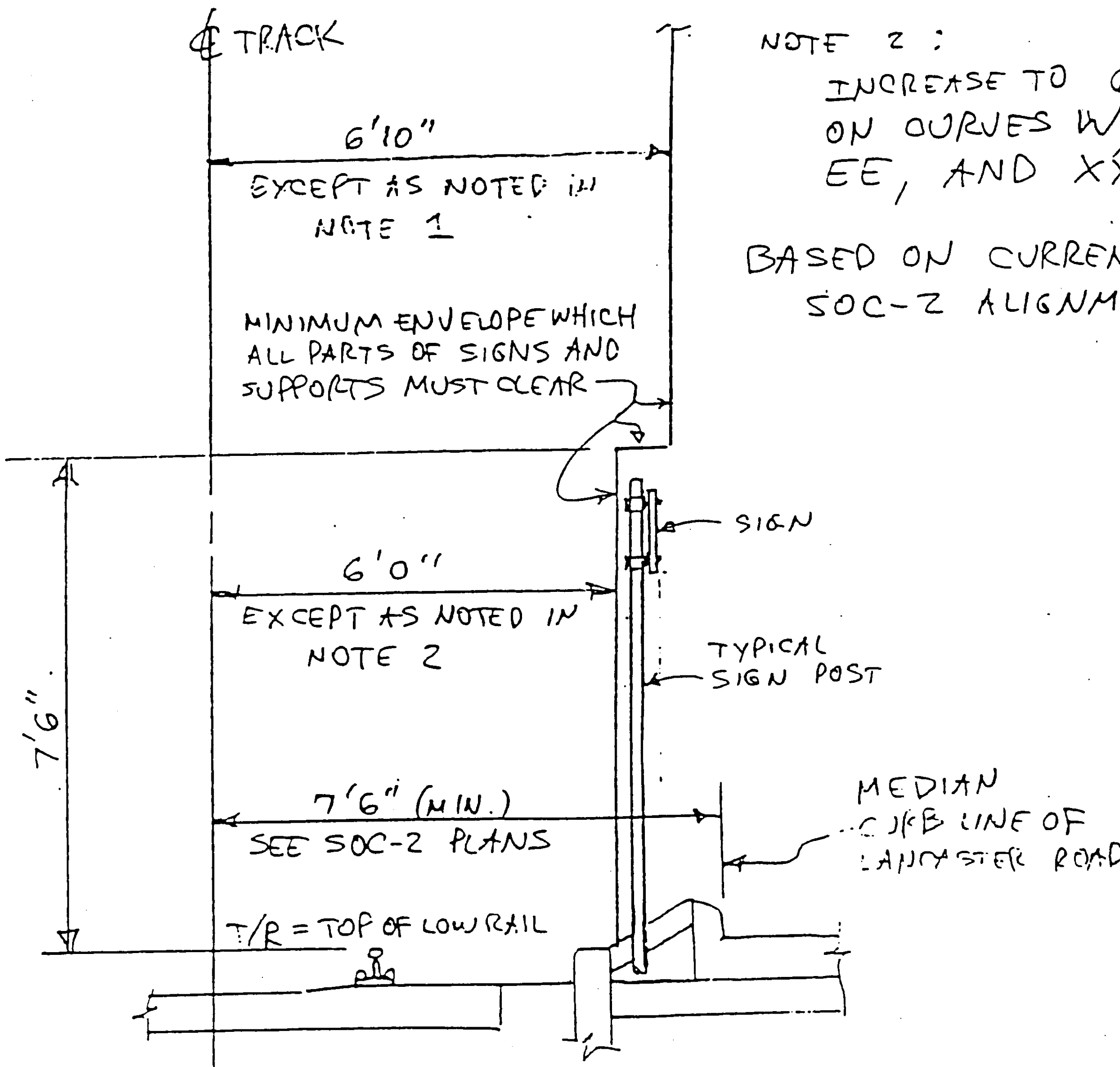
Chkd ______ Date ______

Sheet 1 of 1

NOTE 1 :
INCREASE TO 7'1" ON CURVES W AND XX .

NOTE 2 :
INCREASE TO 6'3" ON CURVES W, EE, AND XX .

BASED ON CURRENT SOC-2 ALIGNMENTS



SCALE : 3/8" = 1'
SIGN IS NOT TO SCALE .

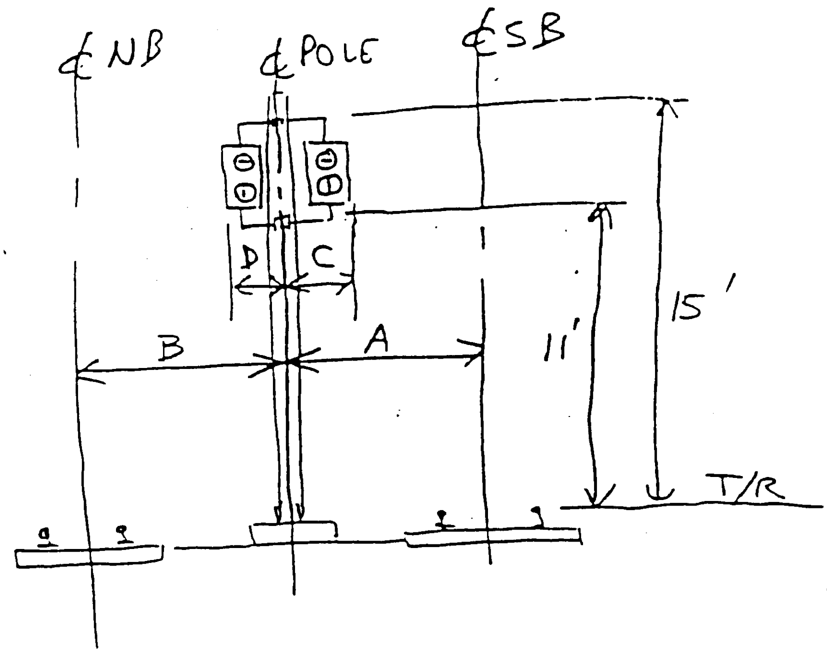
APPENDIX F

Traffic Signals Along Track," calculation, 10/26/93.

Project SOC-2A
Client DART
Task TRAFFIC SIGNALS ALONG TRACK

HUITT ZOLLARS INCORPORATED CONSULTING ENGINEERS

Job No. 04-0222-0
By KEK Date 10/
Chkd ____ Date ____
Sheet 7 of 7



STA	A	B	C	D	COMMEN
390+35	7'9"	7'9"	20"	20"	TYPE 3
391+50	7'0"	8.45'	18 ½"	20"	CAT PO
404+32	7'0"	7'0"	18 ½"	18 ½"	TYPE
405+50	7'0"	7'0"	17"	19"	CAT POL
422+70	7'0"	7'0"	18 ½"	18 ½"	CAT POL
424+70	7'9"	9.24'	20"	20"	CAT PO
439+50	7'0"	7'0"	18 ½"	18 ½"	TYPE 3
440+40	7'0"	7'0"	18 ½"	18 ½"	TYPE 3

"C" & "D" DIMENSIONS SET TO ALLOW CLEARANCE FOR PANTOGRAPH, INCLUDING DYNAMIC ENVELOPE, 4" ELECTRICAL CLEARANCE, 4" TRACK TOLERANCE, 2" POLE TOLERANCE, AND 1" POLE DEFLECTION.

APPENDIX G

MKD-889, 1/15/92.

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

DART SYSTEM DESIGNERS
1701 NORTH MARKET STREET, SUITE 404
DALLAS, TEXAS U.S.A. 75202
PHONE: (214) 761-9491
FAX: (214) 761-9497

January 15, 1992
MKD-889/71
File No. 1.1.4, 1.2.8

Mr. Tom Larkin
Director, Systems Design
DALLAS AREA RAPID TRANSIT
601 Pacific Avenue
Dallas, Texas 75202

Contract No: C-90-0000-23 With Morrison Knudsen Engineers Inc.

Subject: LRV Wayside Clearances

Dear Mr. Larkin,

During the recent meetings with Bidders for supply of LRV's for the DART system there was discussion of the interferences and clearance limitations in the area surrounding the trucks. To close the issue the following interface information is required from the Facilities Design Group:

- What facilities are located or planned to be in the area 17 inches outboard of the gauge face of the running rails, 45.25 inches from track center line, from 2 inches above top of rail up to the existing clearance diagram for the vehicle.

This area is not presently included in the vehicle clearance tables. The existing clearance tables for the vehicle cover the area 57 inches from track center line from 8 inches above top of rail to the top of the vehicle.

If no equipment or facilities are planned in this new area the clearance tables for the vehicle should be modified to include this additional area. This action would address comments that were received from the Bidders.

The clearance tables and the Technical Specification for the vehicles will not be modified until direction is received from DART on this issue.

If you have any questions or desire further information please contact J.S. Gustafson or G. James Morgan at 214-761-9491.

Sincerely,

John S. Gustafson
Project Manager

JSG/GJM/sm

cc: R. Krisak, DART
T. Branson, DART
C. Johnson, DART
A. Daniels, MKE San Francisco
S. Jacimovic, MKE San Francisco
J.R. Vollmar, LTK Blue Bell
R. Andreassen, LTK Dallas
G.J. Morgan, LTK Dallas

APPENDIX H

PSD #2339, 7/17/92.

HUNT-ZOLLARS

Hunt-Zollars, Inc. / Consulting Engineers / 3131 McKinney Avenue / Suite 600 / LB 105 / Dallas, Texas 75204-2416 / 214-871-3311 / FAX 214-871-0757

July 17, 1992

HZ:PSD #2339

Contracting Officer's Representative
Dallas Area Rapid Transit
Attn: Mr. Richard A. Brown
601 Pacific Avenue, Suite 600
Dallas, Texas 75202

RE: Under-Body LRV Clearance
DART Contract C-90000039
Principal Section Design
HZI Job #04-0201-01

Dear Mr. Brown:

This letter is in response to the question raised in MKE's letter of January 15, 1992 (Gustafson to Larkin, MKD-889), which was:

> *What facilities are located or planned to be in the area 17 inches outboard of the gauge face of the running rails, 45.25 inches from track centerline, from 2 inches above top of rail up to the existing clearance diagram for the vehicle?*

No facilities have been planned within that area under the vehicle. The closest item to this area would be restraining rail on curved track, which is one inch higher than the top of rail, leaving another inch to the nearest point on the underside of the vehicle. The guarding flange of GGR-118 girder rail would, if used, also be 1/4" above top of rail. The non-planar superelevated cross-section at Thanks-Giving Square would also have a 1/4" incursion into the area above the top of rail (but still 1-3/4" below the vehicle).

Certain cautions are advised, however:

Grade crossing and paved track materials, be they rubber, wood, or asphalt, are designed to be flush with or a little under the tops of rail. The major concern with those items would be their state of maintenance - if portions of the car are within 2 inches of the top of rail, it is obvious that the combination of track deterioration and crossing defects cannot be allowed to close the 1-3/4" to 2" design gap between facility and underside of vehicle.

Whatever objects placed under the car within two inches of the top of rail cannot be subject to the 4° roll assumed for the body of the vehicle, as that amount of roll would cause a 3-1/8" drop 45-1/4" out from the centerline of vehicle. If those objects were subjected to roll, they would scrape even well maintained grade crossings or transitway mall pavement.

The subject letter does not specify the length of the area where objects may be placed 2" above top of rail, although it does state that they are intended for the "area surrounding the trucks." Right at the trucks, they should not be a problem, unless subjected to roll. However, the further they are located away from the trucks, the more likely it is that they may be effected by vertical curvature of the track. The sharpest vertical curves allowed on the project have a rate of change of 6% per 100' station, which is essentially equivalent to the 1640' minimum radius set by the vehicle specifications. On the sharpest crest vertical curve, the reduction in underbody clearance at the midpoint between trucks would be 7/8". On the sharpest sag vertical curve, the reduction of underbody clearance at the end of the car would be 2-3/4". Thus, an object at the very end of the car 2" above the top of tangent profile rail would definitely scrape pavement on a sharp sag curve, and one at that elevation at the midpoint between trucks would scrape if the pavement and track were not well-maintained.

Providing the objects under the car are in the truck area, not subject to roll, and that the track and pavement are maintained reasonably well, there should not be a problem with placement of objects on the vehicle as close as 2" from the top of rail.

If you have any questions or need additional information, please advise.

Very truly yours,

HUITT-ZOLLARS, INC.
Consulting Engineers

J. Anthony Sosebee

J. Anthony Sosebee, P.E.
Vice President
Project Manager

JAS/kk:mm

cc: Mr. James Battie, DART Contract Administration
Mr. Ronnie Smith, DART WOC-2 Project Manager
Additional Copies (4)