Southern California Rapid Transit District
METRO RAIL PROJECT

System Design

Criteria & Standards

VOL. 2

CIVIL/STRUCTURAL

RTD

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SYSTEM DESIGN CRITERIA AND STANDARDS

VOLUME: II SECTION: FOREWORD

REVISION RECORD

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1	None/1	-----	Foreword Summary Contents Vol. II	Replaces 6/30/83 issue. Format corrections and revisions to Contents pages.

FOREWORD

The Metro Rail Project, undertaken by the Southern California Rapid Transit District (SCRTD), will have a significant role in the future development of the Los Angeles region. As part of the 1976 Regional Transportation Development Program, Metro Rail is designed to help solve the increasing transportation problems of Los Angeles' high-density urban center - the regional core.

SYSTEM DESCRIPTION

The Metro Rail line will be a conventional two-track, steel wheel, steel rail system. The initial segment will be approximately 18 miles long and will serve the central business district, Wilshire Boulevard, Fairfax, Hollywood, and North Hollywood areas. On December 20, 1982, SCRTD adopted the route and station locations shown on the following figure.

The initial line is being designed with future line extensions in mind. Seven Metro Rail corridor extensions have been analyzed to estimate the effect of additional travel demand on the initial line. The ultimate regional system under consideration is a 150-mile rapid transit system, to be developed on an incremental basis. Different types of transit - light rail, bus-on-freeway, rail rapid transit - will be evaluated as each extension is planned. The most appropriate type will be selected, but in some cases, the system design will allow upgrading to other types of high-capacity transit as demand increases.

A basic policy of the SCRTD Board of Directors is that the Metro Rail System be designed with the flexibility to connect with any of the seven corridors and be able to accommodate increased patronage from additional future corridors. This policy ensures that the initial 18-mile system will accommodate line extensions without major cost or disruption to existing services.

The Metro Rail system can be described in terms of its four system elements: ways and structures, yard and shops, station, and subsystems.

- <u>Ways and structures</u>: Ways and structures consist of the major fixed facilities of the system, including the tunnels and trackwork. The initial segment will be entirely underground, primarily in mined tunnel.

- <u>Yard and shops</u>: The main yard and shops constitute the facilities required to store and maintain Metro Rail transit vehicles and to provide maintenance to the system's physical plant and equipment. These facilities will be located southeast of Union Station.

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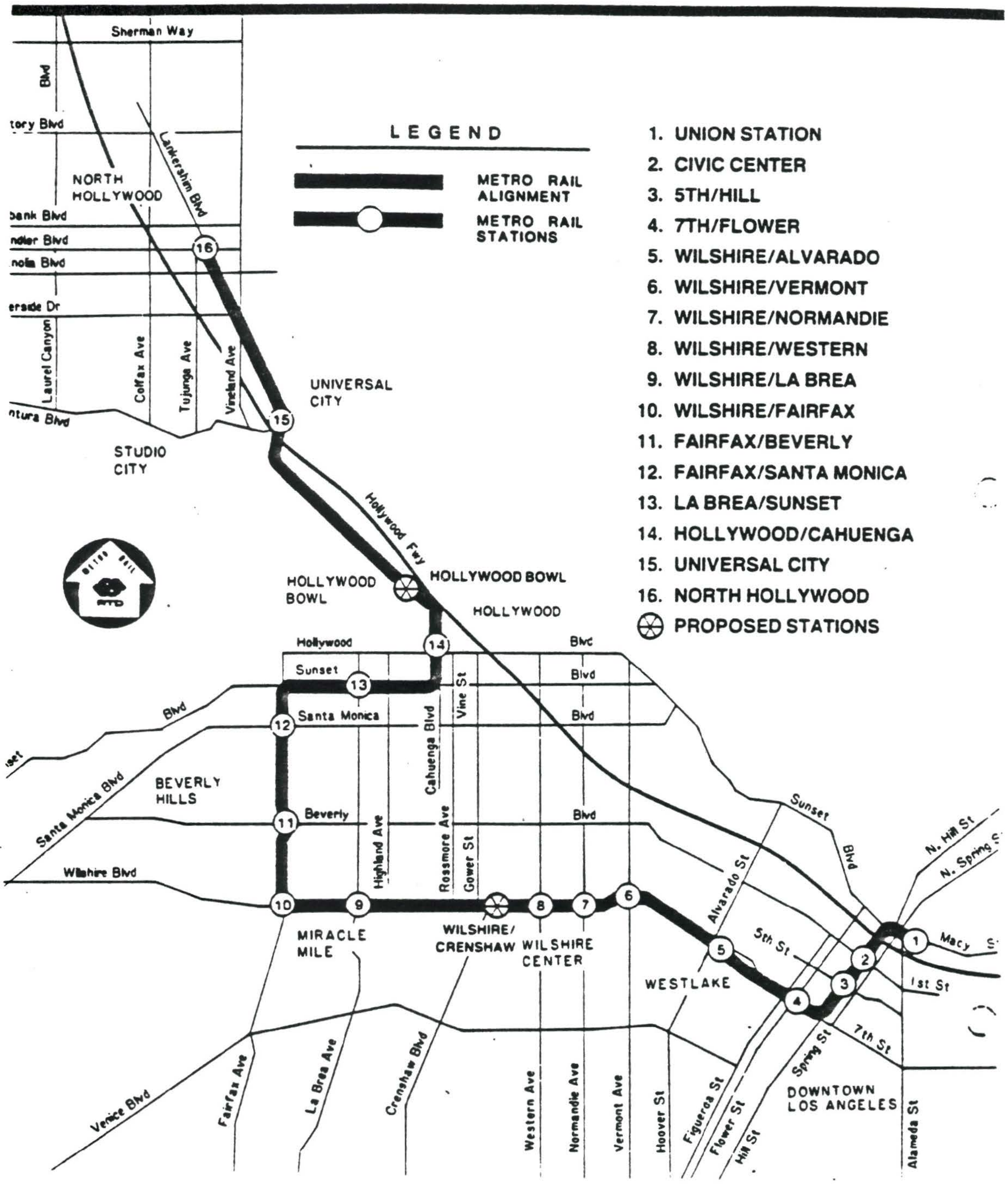
Metro Rail Project



- Stations: Stations provide riders access to the trains from the street level. Stations include stairs, escalators, elevators, a platform area for boarding and leaving trains, and a mezzanine area for fare collection. The stations also provide space for such elements as train control equipment and ventilating equipment. The stations will be constructed by the cut-and-cover method.

- Subsystems: The subsystems are the operating equipment portions of the system, such as the passenger vehicles, train control and communications equipment, traction power, and fare collection equipment. The passenger vehicles will be similar to those currently in use in modern U.S. rail rapid transit systems. It will comfortably carry approximately 76 seated or 94 standing passengers. Trains will consist of up to six passenger vehicles, and will be run by one operator. Automatic devices will be provided for routine operating functions and to ensure safe operations.

PROGRAM DEVELOPMENT

When Metro Rail goes into operation, it will have passed through the five conventional stage of rapid transit development: (1) planning and alternatives analysis; (2) preliminary engineering/environmental impact analysis; (3) final design; (4) construction, manufacturing, and installation; and (5) operational testing.

The first phase ran from 1977 to 1980. Since June 1980, SCRTD has been engaged in the preliminary engineering (PE) phase. This phase has three major objectives: (1) to define and resolve major design and engineering issues; (2) to provide precise location and design data for detailed environmental analysis; and (3) to produce reliable cost estimates. Upon completion of the preliminary engineering phase and the commitment of necessary capital funding, the final design phase will commence. This will be followed by a four-to-six year construction period culminating with system inspection and testing.

One of the major project documents developed during the PE phase is the design criteria. The criteria define detailed functional requirements for all aspects of the Metro Rail System, and will determine the direction taken by the final designers of the various facilities and subsystems elements. The Metro Rail Project System design criteria and standards are presented in five volumes, as follows:

- Volume 1, Systemwide--Contains criteria that affect the whole system, including contract drawing standards, fire/life safety, system safety, security, and system assurance.

- Volume 2, Civil/Structural--Contains civil and structural criteria for all facilities (tunnel, stations, yard and shops), and functional criteria for certain specific elements (trackwork, yard and shops).

- Volume 3, Station--Contains criteria, primarily architectural, for stations.

- Volume 4, Mechanical/Electrical--Contains criteria for mechanical and electrical elements of the facilities' heating, ventilating, and air conditioning; plumbing; facilities electrical; elevators and escalators; and miscellaneous criteria for several other subjects, such as corrosion control, and noise and vibration control.

- Volume 5, Subsystems--Contains functional criteria for the passenger and auxiliary vehicles, train control and communications, traction power and distribution, and fare collection.

It should be recognized that none of these volumes stands alone, and that criteria in more than one volume will apply to the design of any particular system facility or equipment element. A summary table of contents for each individual volume is included in the foreword to that volume as an aid to the designer.

VOLUME II, CIVIL/STRUCTURAL

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SYSTEM DESIGN CRITERIA AND STANDARDS

VOLUME: II SECTION: 1

CIVIL

REVISION RECORD

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SCRTD METRO RAIL SYSTEM DESIGN CRITERIA

Volume 2, Section 1

CIVIL

JUN 30 1983

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VOLUME II, SECTION 1

CIVIL

1.1 SCOPE

1.1.1 This section establishes the basic Civil Engineering Criteria to be used in the design of the Southern California Area Rapid Transit District Metro Rail Project and the related work that:

A. Includes criteria for the design of transit system alignments, trackwork, and drainage and related utility work for determination of rights-of-way, control of access, and service roads

B. Establishes the minimum dimensions required to assure proper clearances between the transit vehicles, or transit structures, and the obstructions involved

C. Specifies the minimum amounts of earth cover to be maintained above the various underground transit system components.

1.2 BASIS FOR CRITERIA

1.2.1 The basic requirement of any transit geometric design is to provide comfortable, economical, and efficient transportation for passengers while maintaining adequate factors of safety with respect to overall operation, maintenance, and vehicle stability.

A. The criteria presented herein relating to the design of operational components emphasize safety and passenger comfort and follow accepted engineering practices used in current operating rapid transit and railroad systems.

B. The criteria relating to other elements of design, such as transit system drainage, and to work items necessitated by transit system construction, such as miscellaneous utility work, are based on the current specifications and practices of the agencies concerned in the jurisdiction involved.

VOLUME II, SECTION 1 CIVIL (Cont'd.)

1.3 SURVEY CONTROL SYSTEM

1.3.1 Horizontal Control

A. All horizontal controls shall be based on the California Coordinate System, Zone 7, as defined beginning at Section 8801 of the Public Resource Code of California as it existed on January 1, 1982.

B. 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," authored by the National Geodetic Survey in February 1974.

1.3.2 Vertical Control

A. Vertical controls for this project shall be based on the National Geodetic Vertical Datum of 1929 as established in Los Angeles County through the 1980 adjustment of the Southern California Cooperative Leveling Net.

B. The accuracy of the vertical ground control and of supporting vertical ground surveys shall be at least 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," authored by the National Geodetic Survey in February 1974.

1.4 HORIZONTAL ALIGNMENT AND SUPERELEVATION

1.4.1 General

A. The parameters for the design of horizontal alignments have been established in accordance with the recommendations of the Manual for Railway Engineering, published by the American Railway Engineering Association, current August 1, 1981 to July 31, 1982. Riding comfort requirements are based on the AREA Joint Committee Report, "Passenger Ride Comfort on

Curved Track," published in Bulletin 516, June-July, 1954.

B. The horizontal alignment of main line tracks shall consist of tangents joined to circular curves by spiral transition curves. Spirals shall not be used in yards and service areas.

C. Curvature and superelevation shall be related to design speed, with consideration for the acceleration and deceleration characteristics of the design vehicle. Whenever possible, the geometrics shall accommodate the maximum design speed of 75 miles per hour, depending on the location of curves, station stop spacings, construction limitations, and the performance characteristics of the design vehicle. The minimum design speed shall be 45 miles per hour.

D. Each route shall be stationed independently along the centerline of the right hand track. Stationing shall be continuous throughout the length of this track, designated Track "R," and shall be the basic control for locating all other system facilities along the route.

E. Separate stationing shall be used for the left hand track, designated Track "L," where tracks are neither parallel nor concentric, where widened track centers are required around curves, or where tracks are in separate structures.

F. Geometrics shall be developed for all tracks.

1.4.2 Track Spacing

A. Track spacing will vary, depending on the type of construction used for the particular section of line structure.

B. Minimum center to center dimensions for parallel tracks shall be 14' - 0".

C. Center to center dimensions for parallel tracks generally will be dependent upon the width of station platform.

VOLUME II, SECTION 1 CIVIL (Cont'd.)

1.4.3 Tangent Alignment

A. Line Structures

1. The desired minimum tangent length shall be determined by the following formula:

$$L = 3V$$

Where L = Minimum tangent length, feet
V = Design speed through the curve, mph

2. The absolute minimum tangent length between curves or spirals shall be 75 feet.

B. Station Structures

1. At rapid transit stations, the desired horizontal alignment shall be tangent for a minimum of 600 feet, beginning 75 feet before the station platform and extending 75 feet beyond the 450-foot length of platform.

2. Formal approval shall be obtained from the District prior to any deviation from the tangent length criteria.

1.4.4 Curved Alignment

A. Circular Curves

1. Circular curves shall be defined by the arc definition of curvature and specified by their radii. Curve functions and abbreviations are shown in Figure II-1-1.

2. For main line tracks, the desired minimum radius shall be 1,000 feet; the absolute minimum radius shall be 750 feet.

3. For secondary tracks, the desired minimum radius shall be 750 feet; the absolute minimum radius shall be 500 feet.

4. For yard tracks, the desired minimum radius shall be 350 feet; the absolute minimum radius shall be 250 feet. Prior to assuming absolute minimum radius for the tracks, underbody characteristics of the car shall be considered for clearance purposes.

VOLUME II, SECTION 1 CIVIL (Cont'd.)

5. The desired minimum length of circular curve shall be determined by the formula:

$$L = 3V$$

Where L = Minimum Length of curve, feet
V = Design speed through the curve, mph

B. Superelevation

1. In the design of horizontal alignments, the allowable speed throughout curved sections shall be determined by passenger comfort as related to superelevation. Superelevation is defined as the height difference in inches between high rail and low rail, and is divided into the following elements:

$$E_r = E_a + E_u$$

Where E_r = Total amount of superelevation required for equilibrium, inches
E_a = Actual superelevation to be constructed, inches
E_u = Unbalanced superelevation, (the difference between the equilibrium superelevation and the actual superelevation), inches.

2. For running track in cut-and-cover, tunnel, and aerial construction, the absolute maximum actual superelevation (E_a) shall be 4 inches. Formal approval must be obtained from the District to exceed E_a = 4 inches.

3. For running track on surface construction, the desired maximum actual superelevation (E_a) shall be 4 inches. However, where the design speed of a section of alignment can be increased by the addition of actual superelevation above 4 inches, an absolute maximum of 6 inches may be used. Formal approval must be obtained from the District to exceed E_a = 4 inches.

4. The absolute maximum unbalanced superelevation (E_u) throughout the system shall be 4-1/2 inches.

VOLUME II, SECTION 1 CIVIL (Cont'd.)

5. Superelevation shall be determined by the formula:

$$E_r = E_a + E_u = 4.011 \frac{V^2}{R}$$

Where V = Design speed through the curve, mph

R = Radius of curve, feet

6. Calculated values for actual superelevation (E_a) shall be rounded to the nearest 1/4 inch. For a calculated total superelevation (E_r) of 1/2 inch or less, no actual superelevation (E_a) shall be applied.

7. 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 top of the inside rail at the profile grade.

8. Yard and secondary tracks shall not be superelevated without prior approval from the District.

C. Spiral Transition Curves

1. Spiral transition curves shall be used in main-line tracks to connect tangents to circular curves or to connect compound circular curves. The spiral used shall be the Barnett spiral. Spiral curve functions and abbreviations are shown in Figure II-1-2.

2. No spirals shall be required for curves with radii 10,000 feet or greater.

3. The desired minimum length of spiral (L_s) shall be the greater of the lengths as determined by the following formulae, but not less than 100 feet:

$$L_s = 1.17\ E_a V$$
$$L_s = 1.22\ E_u V$$

The relationship between superelevation and spiral length is shown in Figure II-1-3.

VOLUME II, SECTION 1 CIVIL (Cont'd.)

4. The absolute minimum length of spiral (L_s) shall be the greater of the lengths as determined by the following formulae, but not less than 100 feet:

$$L_s = 0.98\ E_a V$$
$$L_s = 0.99\ E_u V$$

Approval by the District shall be required for each use of these alternative formulae.

5. Normally, E_u shall be required to vary from 0 inch to a maximum of 4-1/2 inches in the following manner:

   a. For E_a = 4 inches maximum, E_u shall equal 0 inch until E_a = 4 inches is reached. E_a shall then be maintained at 4 inches until the total E_a = E_u is equal to 8-1/2 inches. At this point, a limit shall be placed on the design speed.

   b. For E_a = 6 inches maximum, the same technique shall be used until E_a = 6 inches. E_a shall then be maintained at 6 inches until the total E_a + E_u is equal to 10-1/2 inches. At this point, a limit shall be placed on the design speed.

6. Where insufficient space is available to accommodate the length of spiral required to maintain E_u = 0 until maximum E_a is reached, E_a shall be reduced and E_u increased in order to achieve maximum design speed.

7. Where E_a is reduced and E_u increased, the maximum design speed for a given length of spiral shall be obtained by separating E_r into E_a and E_u as follows:

$$V = \frac{41E_a}{E_u}$$

8. Where spirals are not required, E_a shall be attained linearly over a length equal to 1.5 E_aV (rounded to the next 10 feet) and divided equally between the tangent and the curve.

D. Compound Circular Curves

1. Where compound circular curves are required, a spiral shall be inserted between the circular curves. The minimum length of the spiral shall be the greater of the lengths determined by the following:

$$L_s = 1.17\ (E_{a2} - E_{a1})V$$

Or

$$L_s = 1.22\ (E_{u2} - E_{u1})V$$

Where

L_s = Minimum length of spiral, feet

E_{a1} = Actual superelevation on the first circular curve, inches

E_{a2} = Unbalanced superelevation on the second circular curve, inches

E_{u1} = Unbalanced superelevation on the first circular curve, inches

E_{u2} = Unbalanced superelevation on the second circular curve, inches

V = Design speed through the circular curves, mph

2. The desired minimum length of spiral between compound curves shall be 100 feet.

3. If the calculated minimum length of spiral is 25 feet or less, no spiral will be required. The difference in superelevation shall be attained throughout a length of 25 feet measured back from the PCC within the curve of larger radius.

E. Reverse Curves

1. If the minimum tangent length specified in Article 1.4.3, Paragraph A.2, cannot be accommodated between reverse curves, the transition spiral curves of the two curves shall be extended to meet at the point of reverse curvature. The point of reverse curvature shall be set so that $L_{s1}\ E_{a2} = L_{s2}E_{a1}$. A maximum separation of 3 feet between the spirals is acceptable in lieu of meeting at a point. The superelevation transition through the spirals shall be accomplished by

sloping both rails throughout the entire transition spiral as shown in Figure II-1-4. Through the transition, both rails will be at an elevation above profile grade.

2. This method of superelevation transition presents problems with respect to increased ballast at Point A of Figure II-1-4 and to vehicle clearances. If the alignment permits, reverse curves shall be separated by minimum tangent lengths to avoid these complications.

F. Double Reverse Curves

Double reverse curves shall not be used in the system unless the total length of line between the first and third curves is at least 600 feet, i.e., unless the distance from the ST of the first curve to the TS of the third curve is at least 600 feet. The intent of this criterion is to prevent the head and tail cars in any one train being rotated by superelevation in one direction while the intermediate cars are rotated in the opposite direction.

1.5 VERTICAL ALIGNMENT

1.5.1 General

A. The profile grade shall represent the elevation of the top of the low rail.

B. In areas of curved alignment where profile is given for one track only, the elevations of the second track shall be adjusted uniformly to accommodate the differences in lengths throughout the curves.

1.5.2 Grades

A. Line Structures

1. For standard track installation, the maximum desired sustained grade for mainline and for secondary tracks shall be 3.0 percent; the absolute maximum sustained grade shall be 4.0 percent. For short lengths of track, grades may be increased to, but shall not exceed, 6.0 percent.

2. No minimum grade is specified, but adequate drainage shall be provided for all trackage.

3. For main line track, the desired minimum length of constant profile grade between vertical curves shall be determined by the following formula:

$$L = 3V$$

Where L = Minimum tangent length, feet

V = Design speed in the area, mph

4. The absolute minimum length of constant profile grade between vertical curves shall be 100 feet.

5. Grade adjustments shall be applied to compensate for horizontal curves, where applicable. Where horizontal curves are present, the allowable grade shall be reduced by 229.18 divided by the radius of the horizontal curve.

B. Yard and Shop Tracks

1. For yard track, the absolute maximum grade shall be 1.0 percent; no minimum grade is specified, but adequate drainage at subballast level shall be provided for all trackage.

2. Track located within shop buildings shall be level.

C. Storage Tracks

1. It is desired that the grade of a stub end storage track descend toward the stub end, and, if adjacent to a main line or secondary track, be curved away from such track at its stub end. If it is necessary to grade the storage track up toward the stub end, the grade shall not exceed 0.20 percent. For yard secondary tracks, it is desirable to have a slight grade, maximum 1.0 percent and minimum 0.35 percent, to achieve good drainage at the subballast level.

2. Through storage tracks shall have a sag in the middle of their profile, to prevent rail cars from rolling to either end.

D. Station Structures

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

2. The absolute maximum allowable grade through passenger stations shall be 1.0 percent.

3. Vertical curves shall not encroach within 75 feet of station platforms.

1.5.3 Vertical Curvature

A. Main Line Tracks

1. All changes in grade shall be connected by parabolic vertical curves. For main line tracks the desired minimum length of vertical curve shall be determined by the formula:

$$L = 0.014AV^2 + 2.5V$$

Where L = Length of vertical curve, feet
A = Algebraic difference in grades connected by the vertical curve, percent
V = Design speed in area, mph

Where possible, vertical curves longer than the desired minimum length shall be used.

2. The absolute minimum length of vertical curve for main line track shall be determined by the equation $L = AV$ or 100 feet, whichever is greater, applicable to design speeds less than 60 mph.

3. Reverse vertical curves may be used, provided each vertical curve conforms to requirements stated in Article 1.5.3, Paragraph A.1.

4. Compound and unsymmetrical vertical curves may be used, provided each curve conforms to requirements stated in Article 1.5.3, Paragraph A.1.

B. Combined Horizontal and Vertical Curves

1. Where possible, combining horizontal and vertical curves shall be avoided.

2. Where the combination of horizontal and vertical curves cannot be avoided, the minimum distance between vertical control points (PVC and PVT) and horizontal control points (TS, SC, CS, and ST) shall be 75 feet. Where a vertical curve occurs within a horizontal curve, the length of the

vertical curve shall be increased beyond the minimum desired length defined in Article 1.5.3, Paragraph A.1.

1.6 CLEARANCE AND COVER REQUIREMENTS

1.6.1 Clearance Envelope

The clearance envelope is defined as the space occupied by the dynamic outline of the design vehicle plus an additional running clearance allowance of 2 inches around the dynamic outline.

The following factors shall be considered in developing the clearance envelope:

A. Dynamic Outline

The dynamic outline of the design vehicle shall be developed in accordance with data as described in Volume V, Section 1 - "Passenger Vehicle" of the SCRTD Metro Rail Project Design Criteria, and illustrated in Figure II-1-7.

B. End and Middle Ordinate Displacement

For design purposes, the end overhang and middle ordinate of the vehicle shall be considered. They shall be based on a vehicle 73' - 9" long, centered in the coupling-to-coupling distance of 75' - 0". Use 54' - 0" truck centers-for-center overhang and 52' - 0" truck centers for end overhang clearance requirements. Rounding at car corners shall not be considered.

C. Effect of Superelevation

1. The effect of superelevation shall be considered independently in determining the clearance envelope, and shall be taken into account in establishing the dimensional clearances for the various construction sections. The width of the design vehicle dynamic outline on superelevated track, exclusive for values for midordinate and end overhang, is called the dynamic width. This width includes the dynamic width toward the curve center, and the dynamic width away from the curve

center. These values are measured horizontally from the centerline of track to the widest point on the design vehicle dynamic outline.

2. It is the intent of these criteria to provide facilities which will permit changing the operating speeds of the trains during the life of the System by changing the applied superelevation, E_a. Because some horizontal clearances are a function of superelevation, it is necessary that the facilities be designed for a maximum value of E_a, not to exceed 6 inches, toward the center of the curve, and for a minimum value of E_a away from the center of the curve unless physical conditions restrict the operating speed in a given area.

D. Allowance for Acoustical Treatment

Wherever walls, acoustical barriers, or other surfaces are to be constructed more-or-less parallel to the trackway, the minimum horizontal clearance shall include a 2-inch allowance for the application of acoustical treatment. Without exception, such allowance shall be provided for all subway structures, aerial and at-grade structure acoustical barriers, and retaining walls extending more than 3 feet above the elevation of the top-of-rail profile.

E. Other Factors

Other factors used in sizing the structure, but not included in the clearance envelope, are allowances for chorded construction, construction tolerances, clearances to walls, and overhead clearances required for operations and repairs.

1.6.2 <u>Clearances</u>

A. General

1. Horizontal Clearances

Minimum horizontal clearances measured from centerline of track shall be as follows.

a. Adjacent parallel tracks, 14' - 0" centers

b. Converging Tracks: Clearance distances for two converging tracks shall be determined from the transit car clearance envelope and, where appropriate, shall include the allowances for middle ordinate and end overhand of the transit car.

c. Fixed Structure in Open:

(1) Intermittent columns and point restrictions, 7' - 6" desired. Each such restriction shall be considered independently and submitted for approval.

(2) Retaining walls or continuous restrictions:

Where provision is made for a safety walk, 9' - 0"

Where no provision is made for a safety walk, 6' - 6".

d. Fences parallel to track, 11' - 6".

e. Wall of cut-and-cover structure in subway, on side with safety walk, 8' - 3-3/8"; on side without safety walk, 6' - 5-3/8".

2. Vertical Clearances

Minimum vertical clearances, measured from the top of low rail, shall be as follows.

a. Fixed structure in subway, cut-and-cover section, 14' - 0"

b. Fixed structure in open, 14' - 0".

3. Chorded Construction

a. When chorded construction is specified, walls and walkways shall be constructed in chords whose lengths shall be measured along the inside face of the wall nearest the curve center. The maximum allowable lengths of chord shall be:

For curves with radii 2,500 feet or greater - 50 feet

For curves with radii less than 2,500 feet - 25 feet.

b. Values to be used for allowances for chorded construction in clearance calculations are shown in Figures II-1-5 and II-1-6.

c. In chorded construction, the horizontal dimensions from centerline of track to inside face of wall shall be measured normal to the centerline of track between adjacent chorded elements.

4. Clearance Diagrams

a. Clearance diagrams indicating clearance requirements for various types of structural sections are included as part of these criteria.

b. Abbreviations and definitions used in the clearance diagrams are shown in Figure II-1-8.

c. The design vehicle dynamic outline shall be located within each clearance diagram so as to satisfy the following criteria:

(1) A minimum of 6 inches shall be required between the face of the wall and the clearance envelope.

Allowance shall be made for the construction tolerances and, where applicable, for chorded construction.

(2) A minimum of 3 inches shall be required between any fixed installation and the design vehicle dynamic outline, except that a minimum of 2 inches shall be required between the safety walk and the dynamic threshold.

(3) The design vehicle static outline shall not encroach into the passenger clearance envelope maintained on the walkway

of 1' - 6" at the walking surface, 2' - 0", from 5' - 0" to 5' - 6", and 1' - 6" at 6' - 8" height.

(4) The design vehicle dynamic outline shall not encroach vertical projection of 24 inches width at safety walk to clear height of 6' - 8"

5. Design Tables

Tabulated values for the horizontal dimensions A, T, As and Ts, measured from centerline of track to inside face of wall are included among the figures and are referenced for each type of structure. These values shall be used for sizing the type of structural section referenced. Linear interpolation shall be used for values of radii and superelevation intermediate to those shown in the tables.

6. Widening on Curves

The required increase in width of structure between a tangent section of track and a curved section of track shall be applied or removed linearly over a length equal to the spiral length plus 40 feet, beginning at a point 65 feet before the TS or after the ST. The full width required along the circular curve shall be reached at a point on the spiral 25 feet before the SC and shall be maintained to a point on the spiral 25 feet beyond the CS.

7. Structure Width

The minimum structure width shall be determined by the sum of the dynamic total width, required clearances, construction tolerances, allowance for chorded construction, where applicable, allowance for superelevation of the tracks, where applicable, and requirements for safety walks.

8. Station Clearances

Minimum horizontal clearances within stations shall be as follows:

a. Edge of platform to car body, 3 inches with car standing still

b. Finished face of exterior wall to centerline of track, 6' - 3".

B. Cut-and-Cover Rectangular Sections

1. Construction Tolerances

For design purposes, walls, and roof slabs shall have assumed horizontal and vertical construction tolerances of -0 inch, +2 inches, measured normal to the surface, provided no variation exceeds 1/4 inch in any 10 feet of surface.

2. Clearances

Figure II-1-9 shows the clearance requirements for cut-and-cover sections. Figures II-1-10, II-1-11, II-1-12, II-1-13, and II-1-14 contain the design tables applicable to cut-and-cover sections.

C. Circular Tunnel Sections

1. Construction Tolerances

a. For design purposes, curved concrete surfaces of mined tunnels shall have assumed construction tolerances of -0 inch, +3 inches, measured normal to the surface of the concrete, provided no variation exceeds 1/2 inch in any 10 feet of surface.

b. Under the terms of the construction contract, the Contractor shall be given the option of making the tunnel larger than is required by the criteria.

2. Clearances

Figure II-1-15 shows the clearance requirements for circular tunnel sections. Figures II-1-16 through II-1-25 contain the design tables applicable to circular tunnel sections.

3. Location of Tunnel Working Point

a. The location of the tunnel centerline (working point) shall be defined by the X_A, X_T and

Y values as shown in Figures II-1-15 through II-1-25. The X_A and X_T values shall be measured horizontally from the centerline of track in the plane normal to the top of the low rail; the Y value shall be measured normal to the top of the low rail.

b. The completed tunnel shall have its center not more than 4 inches in any direction from the designed location on tangent tunnels. For tunnels on curves, the construction tolerance is 3 inches in any direction.

D. Single-Track, Horseshoe Rock Tunnel Sections

1. Construction Tolerances

a. For design purposes, the walls and curved concrete roof shall have assumed construction tolerances of -0 inch, +3 inches, measured normal to the surface of the concrete, with no variation exceeding 1/2 inch in any 10 feet of surface.

b. Under the terms of the construction contract, the Contractor shall be given the option of making the tunnel larger than is required by the criteria.

2. Clearances

Figure II-1-26 shows the clearance requirements for single track horseshoe rock tunnel sections. Figures II-1-16 through II-1-25 inclusive, containing the clearance requirements for circular tunnel, may also be used for single-track, horeshoe rock tunnel sections.

3. Location of Tunnel Working Point

a. The location of the tunnel centerline (working point) shall be defined by the X_A, X_T and Y values as shown in Figures II-1-16 through II-1-25.

b. The completed tunnel shall have its center not more than 4 inches in any direction from the designed location on tangent. For tunnels on curves, the construction tolerance is 3 inches in any direction.

E. Surface Track Sections

1. Construction Tolerances

Allowance shall be made for the following construction tolerances:

a. Fences, piers, columns, light standards, and miscellaneous structures: Horizontal construction tolerance of ±1 inch

b. Overhead structures: Vertical construction tolerance of ±1 inch.

2. Clearances

a. Figure II-1-27 shows the clearance requirements for surface track sections.

Figures II-1-10, II-1-11, II-1-12, II-1-13, and II-1-14 inclusive, containing the design tables for cut-and-cover rectangular sections, are also applicable to surface track sections.

b. The design vehicle dynamic outline shall be located so as to satisfy the following criteria:

(1) A minimum of 6 inches shall be required between the light standards and the design vehicle dynamic outline.

(2) A minimum of 6 inches shall be required between existing adjacent intermittent columns or existing point restriction and the clearance envelope.

(3) For new adjacent intermittent columns and new point restrictions, a minimum of 2' - 0" shall be required between the structure and the clearance envelope. Each restriction shall be considered independently and submitted to the District for approval.

(4) For parallel bridge abutments and piers, a minimum of 2' - 0" shall be required between the structure and the clearance envelope.

(5) A minimum of 14' - 0" shall be required from the top of low rail to the underclearance point of the overhead structure.

(6) A minimum of 14' - 0" shall be required between track centers.

(7) The dynamic outline shall not encroach into the safety walk space defined by a vertical plane along the edge of the safety walk.

F. Retaining Wall Sections

1. Construction Tolerances

Walls and overhead surfaces shall have construction tolerances of ±2 inches, measured normal to the surface, provided that no variation exceeds 1/8 inch in 10 feet of surface.

2. Clearances

a. Figure II-1-28 shows the clearance requirements for retaining wall sections. Figures II-1-10, II-1-11, II-1-12, II-1-13, and II-1-14 containing the design tables for cut-and-cover rectangular sections, are also applicable to retaining wall sections.

b. The design vehicle dynamic outline shall be located so as to satisfy the following criteria:

(1) A minimum of 14' - 0" shall be required between track centers. A minimum 2' - 6"-wide safety walk shall be required between the design vehicle dynamic outline and the face of the retaining wall. Allowance shall be made for construction tolerances and for chorded construction, where applicable.

(2) Where a closed drainage system is to be installed between the track and the face of the retaining wall, the absolute minimum clearance from centerline of track to face of wall shall be 10' - 0".

(3) The design vehicle dynamic outline shall not encroach into the safety walk space defined by a vertical plane along the edge of the safety walk.

G. Aerial Structures

1. General

a. Double-track aerial structures shall have an independent girder for each track with the safety walks located outside of each track. On curved track, each girder shall be superelevated as required by the track geometry.

b. Single-track aerial structures shall have a side safety walk placed on the outside of the girder, on the side opposite the contact rail. On curved track, the girder shall be superelevated as required by the curve geometry.

2. Clearances

Figure II-1-29 shows the clearance requirements for aerial structures. Figures II-1-30, II-1-31, and II-1-32 inclusive, containing a portion of the design tables, are also applicable to aerial structures (A_s and T_s values). For A and T values, see Figures II-1-10, II-1-11, II-1-12, II-1-13, and II-1-14.

H. Turnouts

Turnouts for trackwork shall comply with American Railway Engineering Association - "Portfolio of Trackwork Plans," 1981. Minimum clearances required between the design vehicle dynamic outline and structures or installations adjacent thereto shall be in compliance with the clearance criteria for the particular type of construction involved.

I. Railroad

1. Railroad clearances shall satisfy the requirements of the California Public Utilities Commission.

2. The Designer shall establish minimum requirements acceptable to the railroad in each instance and will report thereon to the District. In the course of consultation with a railroad, existing clearances and conditions shall be considered in order to achieve transit system alignment costs. The study and report to the District shall contain cost comparisons and plans illustrating alignments, construction types, and acquisition alternatives to enable the District to review the alternatives comprehensively prior to negotiating agreements with the railroad. Railroad requirements shall be subject to approval by the District.

J. Highway

1. The following vertical clearances (rapid transit structure over highway) shall apply to possible future developments as well as existing conditions.

   a. Over roadways under California Department of Transportation jurisdiction:

      Minimum vertical clearance, 16' - 6"

   b. Over roadways under City of Los Angeles jurisdiction:

      Minimum vertical clearance, 15' - 3"

   c. Over roadways under Los Angeles County Department of Public Works jurisdiction:

      Minimum vertical clearance, 15' - 6"

   d. The above-listed vertical clearances, vertical clearance requirements in all other jurisdictions, and all horizontal clearance requirements shall be verified with the appropriate authorities. For structures under the jurisdiction of agencies other than those listed above, the design shall be coordinated with the appropriate owner or agency involved.

K. Parking Lots

1. The following vertical clearances shall apply to aerial transit structures through transit system parking lots.

   a. Over Line Structures: Minimum vertical clearance, 15' - 0"

   b. Over Station Structures:

      (1) Minimum vertical clearance at vehicular lanes, bus loops, etc., 15' - 0"

      (2) Minimum vertical clearance at pedestrian ways, 10' - 0".

1.6.3 Depths of Cover

A. General

1. Cover is defined as the distance from the top of underground transit structure to finished surface.

2. Minimum depths of cover over underground transit structures shall be dependent on the method of construction utilized.

3. To avoid conflict with existing and proposed underground utilities, an absolute minimum depth of cover of 8' - 0" shall be used.

B. Minimum Cover

Minimum depth of cover for the various types of underground transit construction are as follows:

1.	Cut-and-Cover	8' - 0"
2.	Rock Tunnel of sound rock cover plus amount of earth to surface	10' - 0"
3.	Earth Tunnel	18' - 0"

1.7 TRACKWAY

1.7.1 General

A. This section establishes criteria for the design of at-grade sections of the transit trackway and provides guidelines for determining right-of-way requirements for line sections of the system.

B. Trackway is defined as that portion of the system's rail line which has been prepared to support the track and its appurtenant structures. Criteria for the design of trackwork are included in Section 1.8 of these criteria.

C. Trackway at-grade is that portion which is neither on aerial structures, in subways, nor in U-wall sections.

D. Trackway at-grade generally includes the entire right-of-way, exclusive of stations, and includes the subballast, subgrade, slopes of cuts and fills, and the drainage systems for diverting or carrying water away from the track area.

E. The trackway may contain longitudinal and transverse ductbanks, electrical conduits, or utilities structures.

1.7.2 Correlation With Other Criteria

These criteria are to be used in conjunction with Section 1.4 "Horizontal Alignment and Superelevation," Section 1.5 "Vertical Alignment," Section 1.6 "Vehicle Clearance Requirements," Section 1.8 "Trackwork," Section 1.10 "Drainage," and Section 2.3 "Earth Retaining Structures." Some dimensions specified in these criteria are also shown on the Trackwork Directives, At-Grade Directives, and At-Grade Standards.

1.7.3 Subballast

A. Subballast is defined as a material that will provide a semi-impervious layer between the ballast and the subgrade to facilitate drainage and distribute loads to the subgrade.

B. The subballast for primary tracks shall consist of a uniform 8-inch-deep layer over the subgrade following the profile and cross section thereof.

C. The subballast for yard tracks shall consist of a uniform 6-inch-deep layer over subgrade following the profile and cross section thereof.

D. Subballast material shall be select crushed aggregate. The quality of the aggregate shall conform to ASTM Designation D-1241, and the gradation shall conform to Chapter 1, Section 2.10, "Specifications for Sub-Ballast," 1980-81 Manual for Railway Engineering.

1.7.4 <u>Subgrade</u>

A. The subgrade is the finished surface of the trackbed below the subballast. The subgrade supports the loads transmitted through the ballast and subballast. The design of the track depends ultimately on the stability of the subgrade. Uniformity is the goal of subgrade design because of its differential settlement, rather than total settlement, that leads to unsatisfactory geometry. The recommendations of the Geotechnical Consultant shall be followed in the design of the subgrade.

1. Configuration

The subgrade shall be crowned and sloped away from the apex on a slope of 24 horizontal to 1 vertical. The location of the apex shall be at the centerline of the track for single track; at a line midway between the two tracks for double track; and at the centerline of the middle track for three tracks. If the track center-to-center spacing is more than 26 feet, each track shall be treated as a single track.

2. Elevation

a. The elevation of the subgrade is determined from the profile grade line (PGL) of the stationed track. The vertical dimensions from the PGL to the subgrade for single, double, and three-track systems are shown in

Figures II-1-33, II-1-34, II-1-35, and II-1-36 and on the Trackwork Directives. Elevations at the apex and shoulders of the subgrade must be calculated from the PGL elevation and the slope of the subgrade.

b. These criteria are based on the assumption that the PGL elevations of the tracks differ by no more than 3 inches through any cross section of track. Where such difference exceeds 3 inches, the elevation of the lowest track shall be used to determine the elevation of the subgrade.

3. 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 herein are based upon a tie length of 8' - 6" and a track gauge of 4' - 8-1/2". The subgrade must be of sufficient width to support the subballast. Widths of top surface of subballast are shown in Figures II-1-33, II-1-34, II-1-35, and II-1-36 and in the Trackwork Directives. A 2 ft minimum shoulder is required between the toe of the ballast and the outer edge of the subballast. Where practical, a 9' - 6" service road shall be provided on one side of the trackway.

a. Single Track: On tangent track the minimum width of the top surface of subballast shall be 23' - 0", plus 7' - 6" additional width for the service road, where provided. For track with a radius of curvature less than 10,000 feet, the width of subballast shall be increased by 1' - 6" on the outside of the curve. See Figure II-1-35.

b. Double Track: On tangent track the minimum width of the top surface of subballast shall be 23' - 0", plus the distance between track centers, where they are 26' - 0" or less, plus 7' - 6" additional width for the service road, where provided. Where track centers are more than 26' - 0", treat the tracks as two single tracks. For tracks with radii of curvature less than 10,000 feet, the width of subballast shall be increased by 1' - 6" on the outside curve. See Figures II-1-33 and II-1-34.

c. Three Tracks: On tangent track the minimum width of the top surface of subballast shall be 52' - 0", plus 7' - 6" additional width where a service road is provided. This assumes track centers of 14' - 0"; where wider track centers are required, treat each situation as a special case. For tracks with radii of curvature less than 10,000 feet, the width of subballast shall be increased by 1' - 6" on the outside of the curve. See Figure II-1-35.

d. Transition: The transition from one subgrade width to another shall take place uniformly throughout the length of the spiral easement curve, and at a rate of 1 foot per 100 feet for other conditions, such as curves without spirals and hi-rail access points.

1.7.5 Slopes

A. Side slopes of earth generally shall be two horizontal to one vertical or flatter. Side slopes of earth steeper than two horizontal to one vertical may be used in special situations to avoid excessive earthwork or right-of-way costs; however, such slopes shall be used only after the Geotechnical Consultant has determined that the slopes will be stable. Steeper slopes may be used in rock cuts if the Geotechnical Consultant concurs. Where sufficient right-of-way is available, consideration shall be given to the use of slopes flatter than two horizontal to one vertical in order to minimize maintenance costs. All slopes shall conform to recommendations of the Geotechnical Consultant unless otherwise approved by the District. Typical treatment of cut-and-fill slopes is shown in Figures II-1-37 and II-1-38.

B. Where the Geotechnical Consultant so recommends, benches shall be provided at the toe of cuts or fills or along the face of the cut. Where the cut is in rock with an overburden of soil, a bench shall be provided at the rock/soil interface. Where such benches are provided they shall have a minimum width of 8 feet to permit maintenance by conventional earth-moving equipment. Access to the benches by such maintenance equipment shall be provided.

C. Permanent erosion control for cut-and-fill slopes shall be provided immediately upon the completion of earthwork. Landscaping shall be provided in accordance with the Landscape Design criteria.

1.7.6 Drainage

A. Stability of track requires that water seeping or flowing toward the track be intercepted and diverted before it reaches the track and that water falling upon the track area be drained quickly. The presence of nonflowing water is deleterious, even at an elevation several feet below the subballast, so the water must be drained away.

1. Side Ditches

a. Side ditches shall be provided parallel to the tracks through sections in cut. Intercepting ditches at tops of slopes and along benches shall be provided where needed.

b. The design of ditches shall conform to criteria given in Section 1.10, "Drainage," and as shown in Figures II-1-37 and II-1-38.

c. Side ditches shall not be used on tops of fills. They shall be used at the bottoms of fills only when necessary to provide continuity of drainage.

2. Drains in Retained Sections

a. Longitudinal perforated drains shall be provided immediately adjacent to the retaining walls and below the surface of the subgrade. The drainage pipe shall be encased in an envelope of suitable filter material contiguous with the wall and shall extend up through the subballast.

b. A cross drain shall be provided at each sag in the track profile. Criteria contained in

Section 1.10 , "Drainage," apply. Also refer to Section 2.3, "Earth Retaining Structures," of these criteria.

B. For subway drainage see Volume II, Section 2.14.

1.7.7 Undertrack Structures

A. Duct banks, conduits, utilities, or other structures may cross or run longitudinally adjacent to the transit track. Any such structures shall be kept clear of the "Clearance Envelope for Structures Below T/R in Ballasted Track" as shown in Figures II-1-33, II-1-34, II-1-35, and II-1-36, and as defined in Figure II-1-39.

B. Duct banks, as specified in these criteria, may run longitudinally along the outside of transit tracks or below the space between racks. These, as well as conduits crossing under the tracks, must be kept clear of the clearance envelope referred to above, and in all cases must be below the surface of the subgrade. Where manholes, pull boxes, or conduit "stub-ups" come to the surface, encroachment within the clearance envelope may be necessary. The extent of this encroachment should be kept to a minimum. In no case shall the duct banks be permitted to affect the drainage system adversely.

1.7.8 Right-of-Way

A. At-Grade Sections

Where space permits, the right-of-way shall be determined by the tops of cuts, toes of fills, drainage structures, service roads, and appurtenances.

1. Right-of-Way Line, Cut Side: The right-of-way line at the cut side of the trackway shall be no less than 10 feet beyond the catch-point. An exception will be where an intercepting ditch is required. In this case, the top edge of the intercepting ditch nearer the tracks shall be no less than 10 feet beyond the catch-point, and the right-of-way line shall be at least 5 feet beyond the opposite top edge of the intercepting ditch.

2. Right-of-Way Line, Fill Side: The right-of-way line at the fill side of the trackway shall

be at least 10 feet beyond the top edge of the ditch farther from the tracks, or, if no ditch is provided, the right-of-way line shall be at least 10 feet beyond the toe of the fill.

3. Right-of-Way Line, Retained Section: Figure II-1-40 shall be used as a guide in establishing permanent and temporary SCRTD right-of-way needs for retained at-grade sections.

B. Subway Sections

Figure II-1-41 shall be used as a guide in establishing permanent and temporary SCRTD right-of-way needs for aerial sections.

C. Aerial Sections

Figure II-1-42 shall be used as a guide in establishing permanent and temporary SCRTD right-of-way needs for aerial sections.

1.7.9 Retained Trackway At-Grade

Where the trackway is constrained by a retaining wall, the width of the subgrade, subballast, and ballast will be governed by the location of the wall.

A. Dimensions

The distance from the track centerline to the wall shall be not less than that shown in Figure II-1-36 and the tables for Section 1.6.2, "Clearances."

B. Drainage

For drainage in retained trackway refer to Section 1.7.6, "Drainage."

1.7.10 Walkways

Walkways are required to provide egress by passengers on those occasions when it becomes necessary to evacuate trains, and to provide access to the track area for maintenance personnel. A walkway shall be provided adjacent to one side of every track. It may be between two tracks to serve both.

A. Unretained Sections

For unretained sections, the subballast shoulder shall be at least 2' - 0" wide and will be the walkway.

B. Retained Sections

For retained sections, the walkway shall be at least 2' - 0" wide and on the same side of the track as the duct bank. Unless otherwise provided in special cases, the duct bank in retained sections may be between the two tracks.

C. At-Grade, Adjacent to Aerial Structure

Where an at-grade section abuts an aerial structure a transition shall be made from the at-grade walkway to the aerial walkway located on top of the conduit rack.

1.7.11 Wayside Access

Access to the trackway at track level must be provided for maintenance and emergency work. This requires provision for highway vehicles carrying men, tools, and material to drive to and along the trackway to the fullest extent possible, and for vehicles equipped with flanged as well as highway wheels (Hi-Rail Equipment) to drive onto the track at strategic locations. Consideration shall be given to accessibility when locating entry points to the SCRTD right-of-way from public streets and highways.

A. Service Roads

Where practicable, a service road on the right-of-way and paralleling the at-grade track shall be provided. This may be on either side of the track and need not be continuous, but access and turnaround facilities shall be considered for each section of road. The feasibility of providing service roads shall be considered for each section of at-grade track. Typical cross sections of such roads are shown in Figures II-1-33 and II-1-34, and in the Trackwork Directives.

B. Highway Vehicle Access Points

Access by highway vehicles shall be provided to the at-grade trackway near subway portals, crossovers, rail line junctions, and any other at-grade points where heavy maintenance requirements are anticipated. Where service roads are not provided, access shall be provided at intervals not exceeding 2 miles, preferably at 1-mile intervals. Consideration shall be given at these access points to vehicle turning requirements and to limited parking space for the transit systems highway equipment.

C. Hi-Rail Vehicle Access Points

At strategic points, hi-rail vehicle set-offs shall be provided as shown in the Trackwork Directives. The locations of these points shall be determined by systemwide overview and furnished to the Designer. Construction access considerations must be given in locating the hi-rail access points so that the usage of this access is maximized.

1.7.12 Special Trackway Conditions

Special trackway conditions may be encountered. Some are listed in this section. Others, not covered in these criteria, should be referred to the District for resolution.

A. 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. Refer to At-Grade Directives and At-Grade Standards for configuration and dimensions of slab.

B. Approach Slab

An approach slab shall be provided at each transition between direct-fixation track and tie-and-ballast track. Refer to Section 1.8.8.B and the Trackwork Directives.

C. Special Trackwork

Where transit tracks diverge through a turnout to a branch or yard, the subgrade shall be widened by

3 feet between a point 8 feet ahead of, and 8 feet behind, the point of switch in order to provide space for switch operating mechanisms. The widening shall take place on the side toward which the turnout track diverges.

D. Yards

The configuration of the subgrade underlying yards requires special consideration. The subgrade shall have lateral slopes of 24:1 for drainage. Six in. of subballast shall be used on top of the subgrade. The ballast depth shall not be less than 8 inches under any tie at a point below the lower rail. Where feasible, due consideration shall be given to combine the sub drain and the storm drain. For corrosion control requirements, refer to Volume IV, Section 5, Corrosion Control Criteria. For location of cleanouts and manholes, follow the local codes and standards.

E. Trackway Adjacent to Railroads, Streets, and Highways

The normal minimum lateral clearance from a structure to the centerline of the nearest track of an adjacent railroad must be verified with the involved company. The minimum lateral clearance for streets and highways normally shall be 8 feet, measured from the face of curb to the SCRTD right-of-way line.

1.7.13 Earthwork Quantity Take-Off Data and Methods

The data required and the methods to be followed in determining earthwork quantities for design estimates shall be as follows:

A. Trackway Cross Section Data

Trackway cross sections shall be perpendicular to the centerline of the "R" track, and generally taken at 50-foot intervals and at sharp breaks in the terrain. In terrain where the difference in elevation between the profile grade line and the ground surface varies uniformly, cross sections may be taken at 100-foot intervals.

B. Method of Computing Volumes

Volumes computed from these criteria, and allowances used as specified herein, are for the purpose of balancing earthwork only and are not for purposes of determining payment. The average-end-area method shall be used to compute earthwork quantities. The volumes obtained shall be corrected for shrinkage or swell. No volume corrections need be made to account for curvature of the control line. Cut and fill volumes for each trackway prism shall be computed and tabulated separately.

C. Shrinkage and Swell Corrections

Allowances for shrinkage or swell in cut volumes shall be made by application of a shrinkage factor (n) as indicated below:

Embankment	=	C(adj) = C(1-0.01n)
Where: C	=	Initial volume to be excavated (cut)
C(adj)	=	Final volume after placing and compacting (adjusted cut)
n	=	Shrinkage factor, percent. This factor shall compensate for the effects of soil and groundwater conditions and for field compaction. It shall be positive for soils which tend to lessen in volume after hauling, placing and compacting, and negative for the soils which tend to have the opposite effect.

D. Mass Diagram Ordinates

Ordinates representing accumulated cut volumes as they appear on the mass diagram shall be shown above the line of zero volume and shall be designated positive. Accumulated fill ordinates shall be shown below the line and correspondingly shall be negative.

1.8 TRACKWORK

1.8.1 General

All transit track construction, including special trackwork shown in the construction plans and specifications, shall comply with this Design Criteria and the District's Trackwork Standards and Directives, which are based on the American Railway Engineering Association (AREA) "Manual for Railway Engineering" and the "Portfolio of Trackwork Plans."

1.8.2 Definition of Trackwork Terms

Trackwork terms will be in accordance with the AREA Definition in the "Portfolio of Trackwork Plans."

1.8.3 Track Structures

Trackwork shall be of two basic types of construction.

A. Tie-and-ballast track structure shall be the primary type used for the trackwork at-grade. It shall consist of crushed rock ballast to a ballast depth of 12 inches and cross ties. For special track conditions (e.g., avoiding short lengths of different track construction) it may be used on aerial structures and bridges (ballasted deck) and in subway structures (ballasted invert). This is the type of track structure to be used in yards.

Wherever ties-and-ballast track construction is to be used, the minimum horizontal clearance shall include an allowance of 4-1/2 inches for primary and 3-1/2 inches for secondary and yard track. These allowances are used to accommodate vehicle yaw and translation due to the following:

a. Wheel flange wear

b. Rail wear

c. Rail fastener loosening and rail cant

d. Track gauge tolerance

e. Wheel gauge/track gauge relationship

f. Track misalignment.

The allowance stated above shall be included wherever intentional track gauge widening is not employed, i.e., where the track gauge is 4' - 8-1/2". Where track gauge widening is employed, the allowance shall be increased by an amount equal to the gauge widening, on the assumption that the entire amount of widening may be effected on one side of the track centerline. This +-1/2-inch allowance does not include the translation effect from the unintentional cross level variance that may be expected in ties-and-ballast track. Such variance may be as great as 1-1/2 inches.

B. Direct-fixation track structure shall be the primary type used for trackwork on aerial structures, bridges, in subway structures, and in at-grade stations. It shall consist of a supporting structural slab (subway invert or aerial structure) and a fastening system to hold the running rails directly to the surface of the concrete surface. For special track conditions or requirements, it also may be used for at-grade sections. Included in this type of track structure are those where cross ties are placed directly on or in the invert of the subway, the top surface of the aerial structure, or the top surface of the at-grade slab.

1.8.4 Gauge

A. The transit system track gauge shall be based on the standard track gauge used in the United States, 4' - 8-1/2", and shall be measured between the gauge (inner) sides of the heads of the two running rails of the track at a distance 5/8 inch below the top of the rails (T/R). Track gauge shall comply with the following:

1. Tangent Track - Gauge, 4' - 8-1/2"

2. On curves with radii greater than 700 feet - Gauge, 4' - 8-1/2"

3. On curves with a radii 700 feet or less, but with radii greater than 500 feet - Gauge, 4' - 8-3/4"

4. On curves with radii of 500 feet or less - Gauge, 4' - 9"

B. The above gauges are based on the use of an AAR multiple wear wheel with a gauge of 4' - 7-11/16" and an axle spacing between 7 feet and 8' - 6" (4-wheel truck).

1.8.5 Rail

A. Standard Rail Section to be used on the transit system shall be the 115 lb/yd AREA section (115 RE), see Figure II-1-43.

B. Rail classification for purpose of design, procurement, and construction shall be in accordance with the requirements of the AREA.

C. Rails to be used shall be control cooled, carbon steel or special rail as described in Section E below. Only No. 1 rails shall be used in main and transfer tracks. No. 2 and "A" rails may be used in yard and secondary tracks in lieu of No. 1 rails.

D. Girder rail will be used in shop buildings and yards where the rail is embedded in pavement. The rail section to be used shall be the AREA Girder Rail Section 128-404.

E. Special rail, providing greater resistance to wear, will be used in areas where heavy rail wear is expected. This rail may be fully heat treated, flame hardened, induction hardened, or of special steel alloy, and shall have the standard rail section. The type of special rail to be used will depend upon initial cost and availability. Its use is to be considered for:

1. Curves in the main track with radii equal to or less than 2,000 feet shall extend into tangent track a minimum of 35 feet beyond the end of the curve.

2. Tangent and larger radius curves on grades greater than 3 percent, or in areas of repeated rapid acceleration and/or deceleration.

3. Within the special trackwork units.

1.8.6 Continuous Welded Rail

All rail on the transit system shall be installed as continuous welded rail (CWR) except as noted below. It is important to recognize that CWR will transfer loads into its supporting structure based on temperature change. These loads for a 50°F temperature differential are 110 kips per rail at the restrained end of the rail.

A. Exceptions - CWR will not be used under the following conditions:

1. Rails, less than 300 feet in length, when exposed to the weather

2. Special trackwork where joints are required

3. Buffer rails adjacent to certain joints or special trackwork used to assist in offsetting the rails' longitudinal forces

4. Curves where rail handling may be a problem

5. Structural Joints - Certain structural design features of tunnels, subways, aerial structures, or bridges may require that the rail be jointed and/or provided with expansion joints.

B. Anchorage for CWR shall be provided by the rail fastening system to deter expansion and contraction of rail ends, and to prevent rail creepage. At critical locations, it may be necessary to relieve expansion and contraction of the rail to prevent damage to the track or to the supporting structure. When the anticipated movement of the rail cannot be relieved by the rail gaps in conventional joint rail, expansion joints for the rail should be considered.

1.8.7 Rail Joints

A. The standard rail joint to be used where CWR cannot be installed shall be the six-hole, 36-inch-long AREA joint bar with AREA recommended rail drillings, bar punching, and track bolts. See AREA "Manual for Railway Engineering," Chapter 4, Part 1.

B. Insulated joints shall be selected and installed at locations that shall be determined in cooperation with the design of the Train Control System. For details of installation and location refer to Volume V - Subsystems Criteria. These insulated joints shall meet the following track requirements:

1. They shall use the same rail drillings as the standard joint.

2. They shall meet the general requirements for a rail joint specified by AREA.

3. In CWR areas, they shall be compatible with the requirements for the CWR, and be able to transfer the longitudinal rail loads when required.

4. They must be compatible with the rail fasteners selected.

5. They should be easily adaptable for use with a restraining rail.

6. Their design shall prevent excessive wear and damage to component parts.

1.8.8 Standard Trackwork

A. At-Grade Track

1. At-grade track will use either precast concrete cross ties or timber ties, to be decided by future economic studies. If concrete cross ties are used, they will be spaced at 30-inch centers. Timber cross ties, if used, will be spaced at 24-inch centers.

2. Timber switch ties shall be used in at-grade special track work and spaced in accordance with the standard drawings which are based on "AREA Portfolio of Trackwork Plans."

B. Direct Fixation Track

1. Direct fixation track will use fasteners under each rail, spaced at 30-inch centers on the main line and 33 inches in the yard. These fasteners shall be placed opposite each other.

2. If resiliently supported precast concrete ties are required, they shall be spaced at 30 inch centers.

3. Special trackwork in direct fixation track areas will be installed directly on the concrete surface using a resilient support system with each fastening device. The spacing of the fasteners in the special trackwork will be as shown in the Directive or Standard Drawings and shall not exceed the spacing for the standard trackwork.

4. Noise and vibration requirements may require special track construction for the direct fixation track structure. Two types of this track construction that can be considered are the floating track slab and the resiliently supported concrete cross tie. Each of these types has certain properties that will meet the reduction requirements.

5. Approach slabs (e.g., subballast slabs) of reinforced concrete shall be used to support the ballast track at the transition to direct fixation track, and at the abutments of ballasted deck bridges as shown in the Directive Drawings. These slabs shall be of Class 3000 Concrete and steel reinforcement as necessary. A minimum depth of ballast of 8 inches will be allowed over such slabs, but 12 inches of ballast is preferred. The end of the approach slab away from the direct-fixation track shall be perpendicular to the centerline of track. The face of the concrete for the direct fixation track shall be perpendicular to the centerline of the track. Special care shall be taken to drain the ballast in all approach slab areas.

1.8.9 Special Trackwork

A. Special trackwork includes turnouts, crossovers, double crossovers, and crossings. This special trackwork shall be located only on tangent track with constant profile grade. Double crossovers shall be used only between parallel tracks. Special trackwork on nonballasted aerial structures shall be avoided wherever possible.

1. Turnouts to be used on this system are divided into three categories based on speed through the turnouts, as shown in Figure II-1-44. The speed restriction through the turnout is for the curved lateral portion. For the tangent portion there is no speed restriction other than the design speed. The categories are:

a. High Speed Turnouts: These are No. 15 and No. 20 turnouts. Their use will be restricted to main tracks where high speeds are required through the curved portion of the turnout. The specific use of these turnouts will be determined by the operating speed required and the location of the turnout. Because of their excessive lengths, they are not recommended for use in underground portions of the system.

b. Intermediate Speed Turnouts: These are No. 10 and No. 8 turnouts. These turnouts can be used on main tracks and in yard and secondary tracks.

c. Low-Speed Turnouts: No. 6 turnouts that will be used only in the yards.

(1) Nos. 6, 8, 10, 15, and 20 turnouts will be the only turnouts used on the system. Design information on these turnouts is shown in the Directive Drawings and in the Standard Plans.

(2) The minimum distance between a turnout's point of switch and TS (or TC) or PVC is shown in Figure II-1-45. The separations between points of intersection of various combinations and directions of turnouts shall be not less than those shown in Figures II-1-46 through II-1-51 inclusive. The minimum tangent distance preceding a point of switch shall be 10 feet.

(3) Turnouts or special trackwork shall not be located within 200 feet of the transition between direct fixation and ballasted track.

2. Crossovers are used to connect essentially parallel tracks where adequate space is available. Their length, and the speed through them, is dependent upon the turnouts used and the geometry of the track connecting them. Their selection and application will be governed by the turnouts used ir the crossover.

3. Double crossovers are used where operations requires the flexibility of two crossovers and space is extremely limited. The length of a double crossover and the speed of operating through it are dependent upon the turnouts used.

Their selection and application will be governed by the turnouts used and by the contact rail configuration in the crossover area. Traction power shall be provided to all trains operating through the crossing of all double crossovers.

When considering the use of a double crossover, every effort shall be made to avoid movable point crossing-frogs and double-slip switch points.

4. Switches to be used in turnouts shall be fabricated with Samson Switch Points, Detail 5100, AREA Plan 221 with the stock rails accordingly. The switches to be used are:

   No. 6 Turnout, 11' - 0" Straight split switch
   No. 8 Turnout, 16' - 6" Straight split switch
   No. 10 Turnout, 19' - 6" Curved split switch
   No. 15 Turnout, 26' - 0" Curved split switch
   No. 20 Turnout, 39' - 0" Curved split switch.

5. Frogs that are to be used with the turnout will be: on main line and yard tracks, railbound manganese steel frogs; and in pavement areas of the yards, solid manganese steel frogs. Where required, frogs will be provided with appropriate guardrails.

6. Switch and lock movements (switch machines) shall be used on the transit system to throw the switch points of the turnouts. Space for these switch and lock movements must be considered and provided.

   a. In subways and tunnels, a space 8 feet long, 4 feet wide, and at least 7 feet high above the plane of the base of rail centered opposite the point of switch will be provided. This space is for maintaining the switch and lock movements. The switch and lock should be placed outside the clearance lines of the car body, the contact rail, and any adjacent tracks.

   b. Where turnouts are mounted by direct fixation to a concrete surface, two troughs 13-1/2-inches deep below top of rail, and 14-inches wide, extending under both running rails to and under the switch and lock movement, shall be provided for the throw rods. Similar troughs under both running rails shall be provided for the switch rods of the turnout.

c. Where turnouts are mounted on resilent pads, switch machines shall be similarly mounted on resilent pads

1.8.10 Derails/Tripping Devices

These devices will be used on the transit system only at those locations specified by the District. The use of tripping devices will be dependent upon the train control system. Since derails will close down a track, and, in all probability, cause some form of physical damage to the guideway and the transit vehicle, further investigation of their use will be coordinated with the District.

1.8.11 Bumping Posts/Sand Boxes

At the end of each stub ended track a stopping device shall be provided. It may be a bumping post whose face is mounted 12 feet from the end of track or a sand box (sand track) that will halt the movement of the train by forcing its wheels to plow through the sand. The device selected will be dependent upon the transit vehicle, its end configuration, and the location of the end of track.

1.8.12 Guardrails

Three types of guardrails will be considered for use on the transit system.

A. Frog guardrails shall be placed opposite all frogs. All main line frogs will be protected with a Tee-Rail guardrail. Guardrails shall be provided in accordance with AREA Plans Nos. 502-71, 504-71, 505-59, and 590-55.

B. Guardrails on curves or restraining rails are to provide guidance for the wheels around short radius curves. They will be installed on the gauge side of the inner rail in the following tracks:

1. All main line tracks with radii less than 780 feet

2. All yard of secondary tracks with radii less than 370 feet

3. No restraining rails will be provided in connection with the curved closure rails in turnouts.

   The guardrail system to be used in curves is the type with a standard off-base, laid on its side on special chairs, mounted on extended running rail support plates. Relayer rail may be used for these guardrails.

C. Inner guardrails are rails or other structures laid parallel with the running rails of a track to keep derailed wheels adjacent to the running rails. They will be installed on all main track bridges. The inner guard rail will be designed and located to retain the wheels of a derailed vehicle traveling at the maximum speed for that location. The striking face of the inner guardrail shall be located a maximum of 15 inches from the gauge line of the running rail.

1. These guardrails shall extend 60 feet ahead of the abutment face on the approach end and 26 feet beyond the abutment on the departure end of each structure. The above lengths do not include the end approaches of the inner guardrails, which will be 16-feet long at each end and tapered to the center of the track.

2. Inner guardrails may be made of running rails, relayer rails, or standard structural shapes. Once a section, either rail or structural, is selected, it will become the standard for the system.

3. Inner guardrails shall be attached on ballasted cross-tie lasted track to every second crosstie and, in direct fixation track, every 5 feet to the slab. If the inner guardrails are continuously welded, the longitudinal forces they can generate shall be considered in the design of the structures and the track.

4. As the inner guardrails are to be made of steel, the Designer shall consider the effects of induced electrical currents in these rails

because of their proximity to rails that will be carrying electrical currents.

5. Inner guardrails shall not be installed within the limits of special trackwork.

1.8.13 Grade Crossings

A. Grade crossings for vehicles shall be limited to yard tracks and to hi-rail access points on the main tracks. They shall be perpendicular to the tracks they cross, if possible. They shall not be placed within the limits of frogs and switch points of special trackwork. They shall be designed to provide an adequate flangeway and to readily allow maintenance of the running rails and their fasteners.

B. Crossings shall not be provided for pedestrians except as required for emergency removal of passengers from the trackways.

1.8.14 Coordination with Electrical Design

Contact rail support. The track structure shall provide for the traction power contact rail assemblies at a standard spacing of 10 feet.

1.8.15 Clearance Envelope

The clearance envelope for structures and other facilities below Top of Rail of tie and ballast track is shown in Figure II-1-39.

1.8.16 Railroad Trackwork

Railroad trackwork for others shall comply with current plans and specifications of the respective railroad, and, in absence of such plans and specifications, shall comply with the AREA "Manual of Railway Engineering" and the "Portfolio of Trackwork Plans."

1.9 UTILITIES

1.9.1 General

A. These criteria shall govern the maintenance, support, restoration, and construction of utilities encountered by, or affected by, construction of the rail transit system, and the restoration of pavement distributed by such construction. In the performance of work, due consideration shall be given to the needs of the transit system, the requirements and obligations of the utility organizations, traffic requirements, and the Master Agreement between the Utility and the District.

1. Utilities include facilities belonging to governmental agencies other than the District, Public Utility Corporations, and private parties, including service lines to adjoining properties.

2. Utilities encountered or close enough to be affected by transit construction shall be:

   a. Supported and maintained complete in place during construction and continued in service following completion of the transit facilities.

   b. Temporarily relocated and maintained; then, upon completion of transit facilities, restored to service.

   c. Temporariliy relocated and maintained; then, upon completion of the transit facilities, replaced by new utilities.

   d. Permanently relocated beyond the immediate limits of transit of construction.

B. Utility service to abutting properties shall be maintained and, if temporarily relocated, shall be restored to its prior location upon completion of work.

C. Replacements for any existing utilities, including government facilities, and pavements shall be designed to provide service equal to that offered by the existing installations.

D. No improvements to utilities shall be included unless specifically directed by the District.

E. All designs involving maintenance, support, and relocation or other utility work shall conform to the applicable specifications, criteria, and standard drawings of the concerned corporations or agencies. When directed by the District, the Designer shall submit utility designs to the concerned corporation or agencies for review and approval.

F. Record elevations of all utilities shall be adjusted to project datum. Pertinent utility elevations and locations shall be checked by field survey, and, where critical to design, by digging test holes at locations approved by the District.

G. The Designer shall consider plans developed, or being developed, by others in adjoining sections to ensure that the overall utilities systems will be consistent with those existing before the start of construction, and that the systems will be compatible with those of the transit system.

1.9.2 Sewers and Storm Drains

A. Codes and Standards

1. All maintenance, relocation, restoration, and construction of sewers and drainage facilities shall conform to the current specifications and practices of the jurisdictions involved.

2. Construction of sewer laterals to abutting properties shall conform to applicable local codes.

B. General

1. Necessary replacements of existing sewers and appurtenances shall provide capacities and services equivalent to those of existing facilities.

2. Services to adjoining properties shall be maintained by supporting in place, by providing alternative temporary facilities, or by diverting to other points.

3. Closed flumes, adequate to handle flows of sewers temporarily removed from service, shall be provided. No sewage shall be discharged onto the project construction sites.

4. No catch basins, utility drains, or subsurface drains shall be connected to sanitary sewers.

5. No surface drains from adjoining areas shall be connected to the transit drainage system.

C. City Jurisdictions

All maintenance, relocation, restoration, and construction of sewers and drainage facilities shall conform to the approved standard drawings, specifications, and design criteria as submitted by the local jurisdictions.

D. Los Angeles County

All maintenance, relocation, restoration, and construction of sewers and drainage facilities shall conform to the approved standard drawings, specifications, and design criteria as published by the controlling agency of the County of Los Angeles, including the County Sanitation District and the County Flood Control District.

1.9.3 Water

A. Codes and Standards

1. All maintenance, relocation, restoration, and construction of water mains and appurtenances shall conform to current specifications and practices of the agencies concerned.

2. Construction of water services to abutting properties shall conform to applicable local codes.

B. General

1. Necessary replacement of existing water mains and appurtenances shall provide capacities and services equivalent to those of existing facilities.

2. Services to adjoining properties shall be maintained by supporting in place, by providing alternative temporary facilities, or by diverting from other points.

1.9.4 Gas

A. Codes and Standards

All work on, or adjacent to, gas lines shall conform to regulations and standards of the agencies concerned.

B. General

1. After consultation with the District, the Designer shall inform the gas company if and where the design for the transit system will affect the company's plant.

2. Removal, installation, and connection of temporary or permanent gas mains shall be performed in accordance with the Master Agreement between the Utility and the District.

3. Protection and support of steel gas mains, existing or installed prior to transit system construction, may be performed by the Contractor or by the gas company, as provided for in a Master Agreement to be developed between the companies and the District. Consideration shall be given to the more efficient and economical of these options for this project.

4. The Contractor shall permit inspections of the construction site by authorized personnel of the gas company to determine, among other things, the presence of, and source of, any gas in the atmosphere.

5. Upon completion of work, steel gas mains shall be suported permanently on compacted backfill.

1.9.5 Electric

A. Codes and Standards

All maintenance, relocation, and restoration of electric lines throughout the transit system shall conform to the current practices of the electric company involved, the requirements of the Electrical Code of the concerned jurisdictions and agencies, and the National Electrical Safety Code.

B. General

1. Design shall include the following, and the Contractor shall:

   a. Maintain and support duct banks, manholes, and vaults, where required.

   b. Install split ducts and temporary manholes and support same when existing ducts, manholes, and vaults cannot be maintained.

   c. Construct new ducts, manholes, and vaults where required.

   d. Provide concrete foundations beneath facilities maintained or supported in place.

   e. Furnish concrete encasement around cables enclosed in split duct upon completing work.

   f. Provide special backfill around any pipe conduit carrying high-voltage cable.

2. Design shall include the following based on the Master Agreement with the Electric Utility Company:

   a. Remove existing duct structures and manholes where live cables in these facilities must be kept in service.

   b. Perform all cable work, including removal of existing cable.

   c. Furnish all conduits (split or whole), spacers, couplings, end bells, manhole frames, manhole covers, manhole gratings, and manhole pulling-in-irons for installations.

      (1) Design shall indicate what work will be performed by the Electric Utility Company.

      (2) In general, design shall provide that any electric lines maintained or installed within the limits of transit system excavation shall be supported permanently on compacted backfill.

Should conditions warrant, posting to roof of transit structure may be specified. Any encasement or other protection of duct lines shall be as shown on the utility's standard drawings insofar as they are applicable.

(3) Pipelines carrying high-voltage lines shall be supported during construction. Upon completion of work, pipes shall be supported permanently on compacted backfill and surrounded by acceptable thermal sand.

(4) The prepartion of designs shall be coordinated with the electric utility company in whose jurisdiction the work occurs, and with any concerned governmental agencies.

(5) Work on street and traffic lights shall conform with the standard drawings, specifications, and design criteria of the local jurisdictions.

1.9.6 Telephone

A. Codes and Standards

All maintenance, relocation, and restoration of telephone lines throughout the transit system shall conform to current practices of the Pacific Telephone and Telegraph Company and General Telephone of California, wherever their respective facilities are incorporated.

B. General

1. Design shall indicate which telephone lines are to be maintained complete in place; which ducts are to be removed, cables supported temporarily during work and, upon completion of work, replaced by a new system of ducts and cables; and any rerouting or new construction. Abandoned lines, and those to be abandoned, shall also be indicated.

2. Design shall indicate what work, primarily pulling and cutting-over new cables, will be performed by the affected telephone company.

3. In general, design shall provide that any telephone lines maintained or installed within in limits of transit system excavation shall be supported permanently on compacted backfill. Should conditions warrant, posting to roof of the transit structure may be specified. Any encasement or other protection of duct lines shall be as shown on the utility's standard drawings where applicable.

4. Preparation of designs shall be coordinated with the involved telephone company and any concerned governmental agencies.

1.9.7 Telegraph

A. Codes and Standards

All restoration of Western Union lines shall conform to existing plans.

B. General

1. Design shall include manholes equal in size to existing manholes. Concrete may be used instead of brick.

2. Pipes and conduits shall be supported temporarily during work and, upon completion of work, placed on compacted backfill.

1.9.8 Miscellaneous Communications Cables

In the event of design involving maintenance, relocation, or restoration of miscellaneous communications cables, such as cables belonging to AT&T, Western Union, coaxial TV cables, National Defense Cables, and private alarm systems, Designer shall verify ownership, and after consultation with the owners, shall perform the necessary design work in accordance with the approved codes and standards of the companies and agencies affected.

1.9.9 Fire and Police Alarm Systems

Codes and Standards - Except for required support and protection of cables and restoration of ducts by the

Contractor, all work along the corridor will be performed by the respective owners of such systems, unless otherwise set forth in the Master Agreement.

1.9.10 Parks

A. Codes and Standards

All relocation and restoration of underground utility lines, water mains, sewers, drains, catch basins, sprinkler systems, lights, pavements, and other improvements shall conform to requirements of the several governmental agencies and utility companies involved as stipulated elsewhere in these criteria.

B. General

Design for the various facilities shall be submitted for approval to the Department of Recreation and Parks of the concerned local authority.

1.9.11 Street and Traffic Lights

A. Codes and Standards

All relocations, temporary or permanent, and restoration of these facilities shall conform to the practices of the agencies involved.

B. General

1. Relocation, restoration, and other work involving streetlights and traffic lights shall meet the standards of the affected City or County and the California Department of Transportation.

2. The Designer shall coordinate the work with the California Department of Transportation and the affected City or County Department of Public Works to assure jurisdictional compliance.

1.9.12 Parking Meters

A. Codes and Standards

Does not apply, since work will involve only removal and restoration of existing facilities.

B. General

Within their jurisdictions the affected agencies will remove and restore meter heads; the Contractor shall remove, store, and reinstall posts unless noted otherwise in the Master Agreement.

1.9.13 Vaults

A. Codes and Standards

All remodeling, abandonment, or other work involving private vaults extending from adjoining buildings into public space shall conform to the rules, regulations and practices of the jurisdictions involved.

B. General

1. The Designer shall determine which vaults will be affected by transit construction. Details shall show the portion of each vault to be excavated; new walls required to permit continued use of vaults outside construction limits; new walls to accomplish complete abandonment of vaults, where required; the work required to restore vaults, including delivery chutes and freight elevators and the area available for permanent occupancy by the original owner upon completion of transit facilities.

2. The Designer shall determine what goods or facilities must be removed from the vault; how deliveries will be made to properties when existing vault entrances must be abandoned; and the time required to take each of the above enumerated steps. This information shall be forwarded to the District at the earliest practical date to avoid possible construction delay, and the District will arrange for permission to occupy the vault and make the necessary alterations.

1.9.14 Oil Pipe Lines, Steam Lines, Etc.

A. Codes and Standards

All work involving oil transmission lines, steam lines, and similar types of installations shall be performed by the owner of the installation unless stated otherwise in the Master Agreement.

B. General

After consultation with the District, the Designer shall inform the pipeline company where the design of the transit system will affect the company's installation and shall coordinate the transit system design with the pipeline company to assure safety and compatibility.

1.9.15 Paving

A. Codes and Standards

All pavement restoration in public streets shall conform to the current specifications and practices of the several jurisdictions and agencies involved.

B. General

Restored pavements shall be of materials and shall conform to widths existing prior to transit construction, except that if an existing street is found to be based on obsolete paving materials, such as wood block or brick, replacement will not be in kind, and current specifications and practices will control.

1.9.16 Landscape Areas and Street Trees

A. Codes and Standards

All work involving street trees and landscaped areas shall conform to specifications, criteria, and practices of the agencies involved.

B. General

1. Street trees and landscaped areas shall be preserved wherever practicable. Trees in the construction area which are to remain shall be protected.

2. If they cannot be maintained during construction, landscaped areas shall be restored after construction to the original condition to the extent possible, with street trees to be replaced with the minimum size permitted under applicable codes and standards of the locality involved.

1.9.17 <u>Street Signing</u>

A. Codes and Standards
All work involving relocation, restoration, and temporary installation of street signing shall conform to current standards of local authorities and of the California Department of Transportation.

B. General

After consultation with the District, the Designer shall coordinate with concerned authorities to assure compatibility of street signing with transit construction staging.

1.9.18 <u>Maintenance of Traffic</u>

A. Codes and Standards

Traffic maintenance shall be coordinated with, and subject to approval by, local authorities.

B. Design shall include:

1. Traffic staging and detours necessary to assure proper maintenance of traffic

2. Street and sidewalk areas to be decked for the duration of construction.

1.10 DRAINAGE

1.10.1 <u>General</u>

A. Transit system drainage criteria shall apply only to the drainage of areas under the authority of the District. Drainage of other areas and connections to other drainage systems shall be designed in accordance with the criteria of the particular jurisdiction involved.

B. Invert elevations and locations of transit system drainage piping at each end of the Contract shall be coordinated with other concerned Designers. Elevations and locations of drainage facilities shall be determined by the Designer and shall be submitted to the District for approval.

C. Where practical, drainage shall be by gravity flow. Where necessary, pumping stations shall be installed.

D. No sanitary outfall shall be permitted to enter the track drainage system.

1.10.2 Location of Drains

A. In the track sections, manholes or drainage inlets shall be provided at 350-foot centers or less.

B. Cleanouts shall be provided at 120-foot centers or less along all drainage lines. A cleanout shall be required for 90°-bends and for each two 45°-bends.

C. Underdrains shall be located in areas where it is anticipated that groundwater may interfere with the stability of trackbeds, roadbeds, and side slopes. Their use shall be supported by thorough field explorations prior to design. In general, they may be used in the following places:

1. Along the toe of a cut slope to intercept seepage

2. Along the toe of a fill on the side from which groundwater emanates

3. Across the roadway at the downhill end of a cut

4. Along the periphery of any paved area under which the groundwater is likely to collect.

Underdrains shall also be provided to collect trackbed surface drainage along trackbeds, in retained cuts, on retained embankments, or where several sets of tracks are adjacent, e.g., in yards.

D. Underdrain Configuration

1. Underdrains for the trackbed and behind retaining walls shall consist of a perforated pipe surrounded by a singularly graded aggregate, 3/4-inch crushed stone, wrapped in a geotextile having openings comparable to those of a No. 100 sieve. A column of filler material shall be placed immediately above the wrapped aggregate and shall extend upward to the top of the subballast for the trackbed and to within 3 feet of the finished grade behind retaining walls.

2. Underdrain pipe material selection should be based on strength, durability, and ability to resist corrosion. Concrete, vitrified clay, polyvinyl chloride, and bituminous fiber are acceptable materials. Galvanized corrugated pipe shall not be used for underdrain pipe. Where differential settlement is likely to occur, concrete and vitrified clay pipe shall not be used.

1.10.3 Drainage Volumes

The volumes of water to be handled by each drainage system shall be calculated as follows:

A. Surface and Aerial Construction

1. Drainage of all open areas shall be calculated by means of the formula:

$$Q = CIA$$

Where: Q = Volume of water in ft^3/sec
C = Coefficient of runoff
I = Intensity of rainfall as derived from approved Los Angeles County intensity charts. (Parking lots and appurtenances shall be based on 10-year frequency curve, all other areas shall be based on 50-year frequency curve.)

A = Drainage area in acres.

2. The time of concentration shall be computed and entered into the chart to determine the intensity of rainfall "I." Time of concentration is the time required for water to flow from the most remote part of the drainage area to the point under consideration. This time is the combination of time of overland flow and flow in swales, gutters, ditches, and pipes. (See Figures II-1-52 and II-1-53). Use curve "K" for all elements of starter line (line A) except that portion of the line between Hollywood Bowl station and the North Hollywood station cross-over, including the site at Hollywood Bowl but not at North Hollywood where curve "L" is to be used.

3. In computing flow to any point under consideration, the runoff coefficient shall be a composite of the "C" factors for all the areas tributary to the point. The "C" factor shall be computed using the following values:

Impervious Areas - 0.90
Grass - 0.25 - Slopes 7% and flatter
- 0.35 - Slopes steeper than 7%

B. Underground Sections in Earth

Drainage for underground sections in earth shall be designed to exclude groundwater and shall be based on the formula:

$$q = \frac{a}{30} + \frac{L}{500}$$

Where q = Volume of water, in gal/min
a = Horizontal projected area of all subway openings in ft^2, i.e., station entrances, fan shifts, etc.

L = Linear feet of structure in the drainage system.

C. Underground Sections in Rock

Drainage for underground sections in rock shall be designed to collect groundwater in order to relieve hydrostatic pressure, and shall be based on the formula:

$$q = \frac{a}{30} + \frac{L}{50}$$

1.10.4 Size of Drains

A. Sizes of open channels and closed conduits shall be established primarily by the relationship Q = av where:

Q = Volume of water in ft^3/sec
a = Required area in ft^2
v = Velocity as determined by the Manning Formula

B. Adjustments to sizes of closed conduits thus determined shall be made if warranted by the hydraulic gradients.

1.10.5 Grades

A. The following minimum grades shall apply:

Pipe Diameter (Inches)	Minimum Grade
4	2.0% or 1/4 inch/foot
6	1.0% or 1/8 inch/foot
8	0.65%
12 and greater	0.25%

B. For the design of main drains, the Designer shall consider the economics of increasing the size of the drain to permit as close a correlation as possible between the drain profile and top of rail profile.

C. Main drains shall be designed in such a manner that the grades produce a minimum velocity of 2-1/2 feet per second with the pipe flowing 50 percent full.

1.10.6 Selection of Drainage Structures

A. Standard Drainage Structures, except for parking lots, shall be designed special structures which satisfy the conditions.

B. Drainage structures for parking shall be selected from the standard storm drain details of the jurisdiction in which the parking lot is to be constructed.

C. A sufficient number of inlets shall be provided to intercept the surface drainage. Inlets on grade shall be designed to intercept 85 percent or more of the design flow. Inlets in sump areas shall be designed to intercept 100 percent of the design flow. The amount of flow intercepted by an individual inlet shall be determined by the procedures outlined in the manual entitled "Design of Stormwater Inlets," published by the Johns Hopkins University, Department of Sanitary Engineering and Water Resources, in June 1956.

1.10.7 Materials

A. Closed Conduit

1. Below is a list of the materials acceptable for storm drain construction. Accompanying each material is the roughness coefficient to be used in the solution of the Manning Formula.

Material	Manning "n"	
Cast Iron Pipe	(CIP)	0.013
Polyvinyl Chloride Pipe	(PVC)	0.011
Reinforced Concrete Pipe	(RCP)	0.014

2. Main drains of 12 inches diameter and smaller shall be PVC and 48 inches diameter and larger shall be RCP. Main drains 15 through 42 inches in diameter shall be PVC- or RCP-based on an economic study to be made by the Designer. Drain connections in structural walls and floors shall be CIP.

B. Open Channel

Below is a list of the treatments acceptable for open channel storm drainage. Accompanying each treatment is the roughness coefficient to be used in the solution of the Manning Formula and the maximum allowable velocity.

Material	Manning "n"	Max. Velocity ft/sec
Concrete	0.015	20
Sod on clay soil	0.025	8
Sod on clay and sand mixed	0.025	6
Sod on sandy soil	0.025	4

1.10.8 Hydraulic Gradient

The hydraulic gradient is a line connecting points to which water will rise in manholes, inlets, and pipes throughout the system during the design flow. The hydraulic gradient shall be determined starting at the downstream end of the proposed drainage system. The elevation of the hydraulic gradient at this point shall be taken as the crown of the proposed drain, the hydraulic gradient of the system to which the proposed drain is being connected, or the tailwater elevation, whichever is the highest. Next, the friction loss in the drain to the next structure shall be added. Then, the loss in the upstream end of the proposed drainage system shall be determined by adding a series of friction losses in each section of drain and in structures. The hydraulic gradient shall not be above a point 1' - 6" below the finished grade nor more than 6 feet over the crown of the pipe. The Designer shall coordinate with the District so that full consideration may be given to the possible future extension of the system.

1.10.9 Structural Considerations

Class of pipe and concrete encasement shall be determined from foundation conditions, depth of cover, and loading conditions.

1.10.10 Parking Lots

Parking lots shall be designed so that storm water is removed by overland flow to a gutter or curb and gutter, then to an inlet where the water will enter the closed drainage system. Overland flow shall be on a 1 percent grade, at least, and shall not run for more than 75 feet. The maximum permissible spread for gutter flow shall be 12 feet.

1.10.11 Flood Control

A. Flood protection shall involve station entrances, vent and fan shafts, power substations, and any other facilities and openings into the system, such as electric conduits or other pipes.

B. Where pertinent, the design for the District shall include protection against storm surge flooding of rivers.

C. The design of the transit system shall take into consideration the protection of the system against local flooding resulting from stream overflows and surface flooding. Based on field investigations, consultations with local authorities, studies of any recorded data, and analyses of existing and proposed drainage systems, the Designer shall submit findings and recommendations to the District for approval while in the preliminary stages of work. Final design shall not be undertaken prior to receipt of such approval.

1.11 RIGHT-OF-WAY

1.11.1 General

A. Right-of-way is the composite total requirement of all interests and uses of real property needed to construct, maintain, protect, and operate the transit system. Some right-of-way requirements are temporary and reversionary in nature, while other requirements are permanent as dictated by operating needs. The philosophy of the District is to acquire and maintain the minimum right-of-way required consistent with the requirements of the system and good right-of-way practices. Because right-of-way plans approved by the District are used as a basis for acquisition of property, all interests and uses required shall be shown on the right-of-way plans together with the detailed property dispositions.

B. The taking envelope is influenced by the topography, drainage, ditches, retaining walls, service roads, utilities, the nature of the structure and side slopes selected.

C. The limits of permanent right-of-way shall be shown on the right-of-way plans as an unbroken line utilizing simple curves and tangents. Spiral curves will not be used in right-of-way descriptions. Chords may be used in lieu of curves under special conditions approved by the District.

1.11.2 Types of Right-of-Way

A. Fee Simple

1. Full ownership of property. It should provide sufficient space for the construction, operation, protection, and maintenance of the transit system.

2. Fee simple should always be the first type of right-of-way to be considered for any surface or aerial construction. If this is not practical, another type of right-of-way should be used.

B. Permanent Surface Easement With an Upper Limit

1. An easement that provides space for the transit structures, and for the future maintenance of structures, which support aerial facilities located on private property. This easement also is applicable where structures, such as railroad bridges, pass over transit facilities. The easement shall have definite upper and lateral limits which shall be described by the Designer. Where required, lower limits will be described.

2. The recommended easement width must include basic track width, drainage, supporting slopes, and utilties, and must consider the overall effect on the affected property.

C. Permanent Underground Easement

An easement that encompasses the total transit facility located beneath the surface of the ground. It shall have definite upper and lateral limits which shall be described by the Designer. Lower limits will be described only where special limiting features exist.

D. Permanent Aerial Easement

An easement that completely envelopes the aerial portion of the transit facility. Its upper, lower, and side limits shall be described by the Designer.

E. Temporary Construction Easement

An easement, temporary in nature, that provides sufficient space to allow for the use of the property by the Contractor during construction.

F. Utility Easements

Utility easements which are required shall be treated as right-of-way. Bearings and distances along the centerline shall be shown as well as the lengths and widths of the easements and ties to the limits of right-of-way. All easements shall be in accordance with local and utility regulations.

1.11.3 Right-of-Way Criteria

A. Right-of-Way-Limits

The following criteria are provided for establishing the limits of the right-of-way. The dimensions are given for minimum conditions and must be modified where engineering requirements dictate additional needs. All right-of-way limits shall be vertical or horizontal planes.

1. Rock Tunnel

a. Upper Limit: The limit of the right-of-way is described by elevations of horizontal planes, stepped as required, co-locating the steps with existing property lines or prominent suitable topographical features. Ten ft. above the high point of the structure is the minimum required vertical distance to the horizontal plane of the envelope. Allowances shall be made for rock bolting which may be required.

b. Lateral Limit: Vertical planes 10 feet outside the inside finish surface of the tunnel. Where necessary, allowances shall be made for rock bolting or other required special construction. With formal approval of the District, the right-of-way lateral limit may be set at the existing property line if the normal lateral limit of the right-of-way encroaches upon the existing property by no more than 3 feet.

c. Lower Limit: Where used, the lower limit shall be configured in a manner similar to that for the upper limit. Lower limits normally are not defined for rock tunnels.

2. Earth Tunnel

a. Upper Limit: The limit of the right-of-way is described by elevations of horizontal planes, stepped as required, co-locating the steps with existing property lines or prominent suitable topographical features. Ten feet above the high point of the structure is the minimum required vertical distance to the horizontal plane of the envelope.

b. Lateral Limit: 5 feet beyond the outside face of each tunnel structure.

c. Lower Limit: Where required by local conditions, a lower limit shall be configured in a manner similar to that of the upper limit, using a minimum vertical distance of 10 feet below the low point of the structure, where possible.

3. Cut-and-Cover Construction

a. Upper Limit: 10 feet above the high point of the structure. The limit shall be delineated by elevations of horizontal planes, stepped as required, co-locating the steps with existing property lines or prominent suitable topographical features.

b. Lateral Limit: 5 feet beyond the outside faces of the structure.

c. Lower Limit: Where required by local conditions, the lower limit shall be configured in a manner similar to that of the upper limit, using a minimum vertical distance of 10 feet below the low point of the structure, where possible.

4. Aerial Construction

a. Upper Limit: Where required by local conditions, the upper limit is delineated by elevations of horizontal planes, stepped as required, co-locating the steps with existing property lines or prominent suitable topographical features. The minimum required vertical distance from top of rail to the horizontal plane is 15 feet.

b. Lateral Limit: 25 feet outside the centerline of each track. Easements shall be required for maintenance of and repairs to structures.

c. Lower Limit: Where required by local conditions and specifically directed by the District, the lower limit will be the ground level with specified use restrictions, except where crossing other rights-of-way.

5. At-Grade Construction

a. Upper Limit: Normally, an upper limit is not required. When an upper limit is required, the limit shall be described by the elevations of horizontal planes, stepped as required, and co-locating the steps with existing property lines or prominent suitable topographical features. The minimum required vertical distance from top of rail to the horizontal plane is 15 feet.

b. Lateral Limit: On exclusive right-of-way, the minimum allowable distance from the centerline of the nearest track to the limit of right-of-way is 13 feet.

c. On restrictive rights-of-way, such as in highway and railroad corridors, the minimum rights-of-way shall be as approved by the District and by the agencies, jurisdiction, or the owner involved.

d. Additional distances required, such as for service road and drainage ditches, shall be added to the above. In superelevated sections, the minimum allowable exclusive right-of-way is 15' - 0" from the line of the nearest track on the high side.

e. In retained cuts or on retained fills, the minimum right-of-way required is measured laterally to the outside edge of the retaining wall footings. Allowances shall be made for pile encroachments. In side cuts, unretained open cuts, or fills, the slopes shall be included in the right-of-way.

f. Lower Limit: When required, the lower limit shall be defined in a manner similar to that for the upper limit, using a minimum vertical distance of 10 feet below top of rail, where possible.

6. Storm Drainage

a. Open Ditches: The minimum width for surface drainage easements shall be governed by local agency requirements, but in no case shall be less than 6 feet for paved ditches and channels and 8 feet for unpaved ditches.

b. Underground Drainage: Easement widths for underground drainage systems shall be approved by the local agency involved. As a guideline, the minimum easement width is 10 feet with 2 feet minimum clearance from outside edge of structure to right-of-way line.

7. Stations

a. Right-of-way required for stations shall include space needed for platforms, ticketing, waiting rooms, access to stations ancillary rooms and accommodations, and for the structure.

b. In addition to the structural, mechanical, and electrical requirements for space, the requirements for pedestrian circulation space must be observed. A 15-foot-wide longitudinal walk strip on one side of the finished escalator portal is required. A 20-foot distance from the newels of the escalators must also be preserved for pedestrian circulation. Minimum head room is 8 feet.

8. Substations and Tie Breaker Stations

Substations and tie breaker stations at-grade require a minimum 15-foot access strip. The requirement for land varies. The land should be contiguous to the right-of-way for the transit system, where possible, with 5 feet provided between the limit of the right-of-way and the face of the structure for maintenance purposes.

9. Vent and Fan Shafts

Vent and fan shafts shall be located in public space, where possible. When located on private property, the limit of right-of-way is 3 feet from the outside face of the structure. Access to the shaft is required.

B. Right-of-Way Information Requirements

1. Curve Data

The Designer shall reduce all spirals to circular curves at the limits of the right-of-way. Circular curves are the only types of curves acceptable for recording purposes. Curve data shall be shown on the right-of-way plan sheet in a table of curve data. Tangent sections be used in lieu of curves to show the limits of the right-of-way when curves are extremely flat.

2. Continuous Right-of-Way

Although the District may not require acquisition of public space, all plans shall show the right-of-way envelope as being continuous crossing public as well as private space. Such private space shall be identified.

3. Isolated Right-of-Way

The boundary for the easement areas supporting all new construction, such as fan and vent shafts, substations, escalators, and chiller plants, shall be defined geometrically with ties shown wherever the location is not contiguous to the right-of-way.

4. Vaults

a. Vaults affected by transit construction shall be shown and their disposition shall be noted. The vaults shall be labeled as follows:

(1) Category "A" - vaults which must be removed during construction.

(2) Category "B" - vaults which lie within the influence line of construction, but may not require removal.

b. The influence line generally may be considered to project outward on a 1:1 slope from the lowest point of excavation nearest the property line. Vaults not in Category "A," but within the influence line, could experience cracking, and utility lines may be subject to rupture. The owner may be required to abandon use of such vaults during construction.

5. Multilevel Easements

Multilevel easements, such as at station entrances located in buildings, may be required by the District. In such instances, the Designer shall prepare a separate detailed drawing showing all interests on each floor level proposed for use by for the District. The following requirements shall be met:

a. Each floor level affected by the transit facility shall be so noted and separately illustrated. A separate entry in the property disposition table is required for each level.

b. Each type of easement on a floor level shall be dimensioned and symbolized properly. All column locations shall be shown.

c. The elevations of each floor easement shall be given and shall be referenced to the project datum. Elevations normally shall be from the underside of the floor structure to the underside of the next higher floor structure.

6. Explanatory Notes

   The Designer should use explanatory notes, where applicable, to aid in clarifying the right-of-way takings.

7. Projections in Public Space

   The Designer's right-of-way plans shall show all vaults, fire escapes, signs, display windows, footings, foundations, and other projections in public space which must be removed to accommodate the construction of the transit system. The projections into public space affected by the construction will be identified in terms of location and type of projection and reported separately to the District as soon as possible. In areas where projections are numerous, a chart shall be provided on the plans for clarification.

8. Underpinning

   The Designer shall provide detailed plans of the right-of-way necessary for any underpinning required in his scope of work. Separate drawings showing the easements required for the Contractor shall be prepared and referenced. The underpinning details shall show the dimensions of the easements and tie the easements to the transit system right-of-way. The property line and all the supporting columns of the structure shall be shown. Proposed access and location of dust walls shall be shown.

9. Street Closings

   The Designer shall provide separate drawings showing the areas of public property to be closed and utilized for the transit system. These drawings shall be prepared in accordance with local requirements.

1.11.4 <u>Surveys and Monumentation</u>

A. Any Land Surveyor or any Civil Engineer registered in California before 1982 may conduct surveys and prepare drawings for recording in California. Civil Engineers registered in 1982 and thereafter may conduct surveys only if they have passed the Land

Surveyor's examination and are duly registered as Land Surveyors.

B. Using field surveys, record information, and computations, the Designer shall prepare individual plats of survey in accordance with requirements. The final plats shall comply with the recording requirements of Los Angeles County. The Transit System's right-of-way envelope shall be described by metes and bounds, insuring that the pertinent portions of all tracts, subdivisions, U.S. lands, parcels and other areas which are affected by the envelope are similarly described. Coordinates and elevations further describing the right-of-way and existing property corners shall be shown on the plans. Coordinates shall be provided for all angle and curve points along the limits of the right-of-way.

C. Monuments, as shown in Figure II-1-54, will be used wherever monumentation is required and where it can be utilized in the form shown. Monuments shall be placed at each PC and PT of right-of-way line curves, and, as necessary, to satisfy involved jurisdictions. Where monument locations are such that use of the above-described monument is not practical, other suitable monuments may be used, subject to approval of the District and the jurisdictions involved.

1.12 CONTROL OF ACCESS

1.12.1 General

The rapid transit right-of-way shall be protected in such a manner as to prohibit public vehicular or pedestrian traffic from the right-of-way except at points of passenger entrance and egress, such as at stations and parking areas.

1.12.2 Crossings

All crossings of the right-of-way, except for SCRTD maintenance roads, shall be grade separated.

1.12.3 Right-of-Way Barriers

A. Throughout the system, fencing or other suitable barriers shall be provided to prevent the public from gaining access to the tracks. See Figures II-1-55, II-1-56, and II-1-57 for acceptable barriers.

B. The design of the transit system shall take into consideration the protection of the system against local flooding resulting from stream overflows and surface flooding. Based on field investigations, consultations with local authorities, studies of any recorded data, and analyses of existing and proposed drainage systems, the Designer shall submit findings and recommendations to the District for approval while in the preliminary stages of work. Final design shall not be undertaken prior to receipt of such approval.

1. Pedestrian Barriers

   Acceptable forms of pedestrian barriers include fences, walls, and elevation differences of appropriate magnitude. A deterrent in the form of barbed wire or equal physical obstruction, approved by the District, shall be mounted on fences or walls. Where the transit right-of-way is crossed by a pedestrian walkway, the barrier shall prevent objects from being dropped or thrown into the transit right-of-way.

2. Vehicular Barriers

   Acceptable vehicular barriers include highway guardrails, barrier curbs, structural walls, or earth embankments. Wherever vehicular access to areas adjacent to the transit right-of-way is possible, each possibility must be evaluated, including accidential entry by runaway vehicles.

3. Safety Railings

   Where elevation differences alone constitute a sufficient pedestrian or vehicular barrier, safety railings must be provided for the protection of both the public and the rapid transit personnel.

4. Temporary Barriers

   All construction sites and Contractors' areas shall have temporary fencing and suitable barricades, where required, to protect pedestrians and vehicles. It shall be noted on the plans that the Contractor is required to fence only the area he will need to conduct his operations. Dimensions of fencing may be scaled.

1.13 SERVICE ROADS

Service roads shall be provided for transit system construction at grade on exclusive right-of-way wherever land use permits and wherever real estate and construction costs make their inclusion economically feasible. The decision to include or exclude a service road shall be made by the District upon receipt of the Designer's evaluation of feasibility.

1.14 STREETS, PARKING FACILITIES, AND SITE WORK

1.14.1 General

This chapter establishes criteria and standards for the design of streets, parking lots, parking structures, pedestrian facilities, and driveways, including signing and marking, all of which are to be maintained by SCRTD. 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 standards of the agency having jurisdiction, or criteria contained herein if approved by such agency.

1.14.2 Basic Goals

The basic goals of this chapter are:

- o To provide for the safety of SCRTD patrons while arriving at or departing from the station site
- o To establish convenient traffic circulation patterns for vehicular and pedestrian movement
- o To provide parking facilities which are safe, convenient, attractive, and easily maintained
- o To provide for the reconstruction of local roads and streets disturbed by SCRTD construction.

1.14.3 Traffic Modes

A. Patrons will arrive at, and depart from stations in as many as six basic modes, as follows:

1. Pedestrian

2. Bicycle

3. Bus-and-ride

4. Kiss-and-ride

5. Motorcycle

6. Park-and-ride.

B. Facilities to park bicycles, motorcycles, and cars as well as off-street and kiss-and-ride facilities will be incorporated at selected stations.

C. The maximum possible separation between modes of transportation shall be provided.

1.14.4 SCRTD System Streets Design Elements

A. Vehicular Entrances to Station Sites

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

1. Vehicular entrances from public streets shall be from minor streets where possible, with provisions for sufficient stacking space provided at intersections with major streets.

2. Entrances, where feasible, should be so located that a vehicle approaching the station from any direction, missing one entrance, will find a second available without circuitous routing.

3. The number of vehicular entrances along any one street shall be minimized. Entrances shall be at least 150 feet apart. Sufficient number of entrances shall be provided so that the volume per lane entering station sites does not exceed 300 vehicles per hour.

4. 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 considered.

B. Traffic Lanes

All roadways other than those used mainly for service or maintenance purposes shall have a least one traffic lane for each direction of travel. The number of traffic lanes provided on these roadways shall be sufficient so that the vehicular volume per lane does not exceed 300 vehicles per hour. Where these roadways are one-way and have only a single traffic lane, the traveled way width shall be 20 feet with either a gutter or shoulder on each side giving a clear distance of at least 24 feet between constraints. Lane width for roadways of more than one lane, exclusive of gutter or shoulder width, should be 12 feet but shall be not less than 11 feet.

C. Parking Lanes and Curb Loading Zones

1. Placement of loading zones on access roadways shall reflect the following order of preference with respect to proximity of the loading zone to the station concourse:

   a. Buses

   b. Passenger cars (kiss-and-ride)

   c. Taxi reservoirs.

2. Parking on SCRTD System roadways preferably shall be parallel to the curb. Lane width prescribed herein for parking and loading zones includes the gutter width.

D. Loading Zones for Buses and Taxis

1. The required bus (or taxi) design capacity for a station shall be determined by the General Architectural Consultant based on the individual requirements for each station.

2. Loading zones for buses and taxis shall be located to provide the most direct and safest intermodal transfer.

3. The following designs show standard layout for various types of bus loading zones.

   a. Recessed Bus Bays: Where the volume of passenger cars or buses is sufficient on roads used jointly by cars and buses, the bus loading zone shall be recessed from the through traffic lane.

      (1) Recessed bus bays shall be designed parallel to and close enough to the curb so that passengers may enter and leave any door by an easy step to the curb. Upon leaving, the merging lane will enable the bus an easy re-entry into the through traffic lane.

      (2) The loading zone shall have a 10-foot wide lane, and the total length for a two-bus loading area should be 120 feet long with a 40-foot tapered section at each end. For each additional bus required, an additional 80-feet length shall be added at curbside.

   b. Parallel-to-Curb Bus Bays: Parallel to curb base shall have 10-foot-wide lanes and a length of 80 feet.

   c. Sawtooth Bus Bays: Sawtooth bus bays will reduce the length of loading zone, but will increase the width of roadway. The critical movement in this layout is the operation of moving a bus out and around a parked bus at the loading zone.

      (1) The minimum roadway width is determined as follows:

23 ft - 8 in.	Clearance path of bus
2 ft - 0 in.	Additional clearance
3 ft - 4 in.	High point
29 ft - 0 in.	Nominal roadway width

      (2) The nominal roadway width is the average of the high and low points of the

sawtooth and allows a direct comparison with the parallel-to-curb bus bays.

d. Taxi zones shall have a minimum lane width of 8 feet. Parking spaces for taxis shall be 25 feet long and shall be no closer than 20 feet to a crosswalk.

1.14.5 Kiss-and-Ride Facilities

A. Capacity

The required design capacity for a station shall be determined by the General Architectural Consultant and will be based on the individual requirements of each station. The kiss-and-ride lot may be used for reserved (short-term) parking (shoppers, etc.) during the day, but must be cleared from 6:00 A.M. to 9:00 A.M and from 4:00 P.M. to 7:00 P.M.

B. Location

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

1. Parking facilities located off-street, in a parking lot, shall be as near to the station concourse entrances as practicable and shall be physically separated so as not to appear as an integral part of long-term parking areas within the parking lot or parking structure.

2. Kiss-and-ride facilities shall be located off-street, as near to the main station entrance as practical, and shall be physically separate from long-term parking areas and bus-and-ride facilities. Loading is preferred on the right-hand side of the car. The location should, if possible, be such that a driver can view the station entrance to see an exiting passenger for whom he is waiting.

3. A parking area for persons waiting to pick up handicapped persons shall be provided as required by installing appropriate pavement markings and signs.

4. All kiss-and-ride parking spaces shall be delineated by signs or curb markings as being limited to short-term use.

5. Kiss-and-ride parking stalls shall be 9 feet wide and preferably at a 60 degree angle.

1.14.6 Parking General (See Figures II-1-59 through II-1-70)

A. Parking Stall Dimensions

1. Stall Angle

Stall Dimension			(Parallel)	45°	60°	90°
Normal Car	-	width	10.0 ft	9.0 ft	9.0 ft	9.0 ft
	-	length	22.0 ft	18.0 ft	18.0 ft	18.0 ft
Handicapped Stall						
	-	width*		14.0 ft	14.0 ft	14.0 ft
	-	length		18.0 ft	18.0 ft	18.0 ft
Small Car	-	width		8.0 ft	8.0 ft	8.0 ft
	-	length		14.0 ft	14.0 ft	14.0 ft
Clear Aisle	-	width (Roadway)		13.0 ft	19.0 ft	27.0 ft

2. Small-car stalls shall be used only in locations where full-size stalls will not fit. Small-car stalls shall be adequately signed.

3. Handicapped stalls shall be located as near as possible to the main station entrance, and shall be adequately signed as being only for handicapped persons. Reference Section 2-7102 Title 24, California Administrative Code (CAC). (See Figure II-1-63.)

B. Multilevel Parking Structures

1. Ground levels shall contain entrances and exits, reservoir areas and internal ramps, and locations for obtaining parking tickets on entry and toll booths on exit, as well as parking areas. Kiss-and-ride areas shall be located outside the parking structure unless this is impossible.

*Reference figures for detailed requirements for single and multiple handicapped-parking space requirements.

Upper levels and/or underground levels shall contain only ramps and as many parking stalls as possible.

2. Traffic circulation within parking structures shall be designed to minimize vehicular travel distances and number of turns.

3. Columns will be located to provide uniform spans for the structure as much as is possible. Columns must not encroach on the clear dimensions noted for cars, unless a small-car stall can be created. Columns shall be located not closer than every third stall.

4. Where site conditions permit, adjoining street grades shall be used to minimize the need for ramps between parking levels.

5. Internal ramps shall be placed as far as practicable from entrances and exits. The ramps shall be so placed that they do not constitute a direct and natural path for pedestrian travel to the station concourse. Internal ramps shall be designed for one-way travel. Parking stalls shall not be located on curved internal ramps.

6. External ramps may be used where appropriate. The ramps shall be designed for one-way travel and shall merge directly into, or diverge directly from streets.

   Whenever practicable, a grade separation of pedestrians and vehicles shall be provided where external ramps cross pedestrian walkways. Parking stalls shall not be located on external ramps.

7. The design capacity of ramps shall be 200 vehicles per lane per hour.

8. Ramp grades shall be kept as low as practicable, and excluding areas of transition, shall not exceed 6 percent on ramps with parking or 12 percent on ramps without parking.

9. Traveled ways, other than parking aisles and ramps, shall be 24 feet wide for two-way travel and 16 feet wide for one-way travel. The minimum vehicular inside turning radius shall be 16 feet, and the minimum outside turning radius shall be 26 feet.

1.14.7 <u>Site Work Criteria</u>

A. Grades

1. Parking lots

   a. Maximum 6 percent with parking

   b. Maximum 12 percent ramps without parking

   c. Desirable maximum 5 percent (except ramps w/o parking)

   d. Minimum desirable 1 percent

   e. Minimum 0.5 percent.

2. Streets

   a. Maximum 6 percent

   b. Desirable 5 percent

   c. Minimum 0.5 percent

   d. Desirable 1 percent

   e. Cross-slope 2 percent

   f. Crown cross section except on curves where 2 percent continuous cross-slope toward center of curve may be used.

3. Maximum Grade Differential

   a. Crest Vertical Curve 9 percent

   b. Sag Vertical Curve 6.5 percent.

NOTE: Crest and Sag Curves at top and bottom of ramps without parking may exceed these differentials, but must use a vertical curve 20 feet in length or more.

B. Design Speeds

1. In parking lots - not applicable

2. On SCRTD streets - 30 mph

C. Clearances

1. SCRTD Streets

a. Vertical, 14' - 6"

b. Horizontal, 2' - 6" from face of curb to fences, light standards, and pedestrian barriers.

2. Parking Lots

a. Vertical, 7' - 0"

b. Horizontal, 2' - 6"

D. Vertical Curves on SCRTD Streets

1. Crest Curves - Lmin = 28 A

2. Sag Curves - Lmin = 35 A

Where: Lmin = minimum vertical curve length

A = Algebraic difference in grades
No vertical curves shall be less than 20 feet.

E. Curb Returns

Parking Lots and Areas

1. For cabs, 20 feet

2. For buses, 30 feet minimum, (inside radius) (50 foot minimum outside radius clear).

F. Sight Distance at Intersections

To comply with "A Policy on Geometric Design of Rural Highways," 1965, published by the American Association of State Highways and Transportation Officials (AASHTO).

G. Curbs and Gutters

All SCRTD streets and parking lots shall have curbs and gutters. Curbs shall be 6-inch-high, barrier-type, with sloping face of 1 inch horizontal to 6 inches vertical. Gutters shall be 18 in., sloped to roadway or parking lot cross-slope and grade. Curbs and gutters shall be cast-in-place, Class A concrete.

H. Side Slopes

Cut-and/or-fill-slopes shall be as flat as possible, and shall not exceed a slope of 2:1 (horizontal to vertical). Tops of cut slopes shall be rounded.

I. Drainage

Drainage runoff shall be calculated in accordance with:

1. Surfaces shall be sloped to drain away from areas where pedestrians will walk.

2. Catch basins will not be located in pedestrian walkways.

1.14.8 Ventilation Grating Opening

Ventilation grating openings shall be located to minimize any adverse effect on existing features of landscaping, improvements, and environment. Such gratings may be located either in raised median strips, or in other public land outside the traveled way. Where location in other preferred areas is not possible, ventilation grate openings will be authorized at an approved location immediately behind the street curbs, provided the width of grating does not exceed 50 percent of the sidewalk width of 5 feet, whichever is greater. Where possible, gratings will be located outside of the far tangent points at street intersections and will not be located in any crosswalk area. Covered openings, such as mechanical access openings, may be permitted in sidewalk is permissible. Sidewalk and street gratings for subway vent and fan shafts shall be steel grating with bar sizes and spaces to be designed considering the type of traffic to be imposed.

1.14.9 Traffic Control Devices

A. General Criteria

(The paragraphs which follow prescribe the criteria to be used for signs and for pavement and curb markings in streets, parking lots, and parking structures.)

The application of any traffic control device shall:

1. Fulfill an important need

2. Be located in such a manner as to command attention and provide adequate time for response

3. Command respect and gain compliance

4. Convey a clear, simple, and appropriate message

5. Complement a good design, rather than attempt to compensate for an inadequate design.

B. Signs

1. Signs shall be displayed only for the specific purpose and under the specific conditions prescribed in these criteria.

2. Signs shall not be used to confirm well known or universally recognized rules of the road. They shall be used where special regulations apply at specific places or at specific times only, or where hazards are not self-evident. Care shall be taken not to install too many signs, especially those of the regulatory or warning types, which, if used to excess, tend to lose effectiveness. On the other hand, a frequent display of directional signs will not lessen their value.

CIRCULAR CURVES

I = TOTAL INTERSECTION ANGLE

Δ = CENTRAL ANGLE OF CIRCULAR CURVE = $I - 2\theta_s$ (EQUAL SPIRAL LENGTHS)

Δ = CENTRAL ANGLE OF CIRCULAR CURVE = $I - (\theta_{s1} + \theta_{s2})$ (UNEQUAL SPIRAL LENGTHS)

Dc = DEGREE OF CURVE (ARC DEFINITION) = $\frac{5729.58}{R} = \frac{18,000}{\pi R}$

R = RADIUS OF CIRCULAR CURVE

T = TANGENT LENGTH OF CIRCULAR CURVE = $R\tan\frac{\Delta}{2}$

T_I = TANGENT LENGTH FROM P.C. TO P.I. $T_I = R\tan\frac{I}{2}$

Lc = LENGTH OF CIRCULAR CURVE = $\frac{\Delta R}{57.2958} = \frac{\Delta \pi R}{180}$

E = EXTERNAL DISTANCE = $R(\text{EXSEC}\frac{\Delta}{2})$

PC = POINT OF CURVE

PT = POINT OF TANGENCY

TS = TANGENT TO SPIRAL

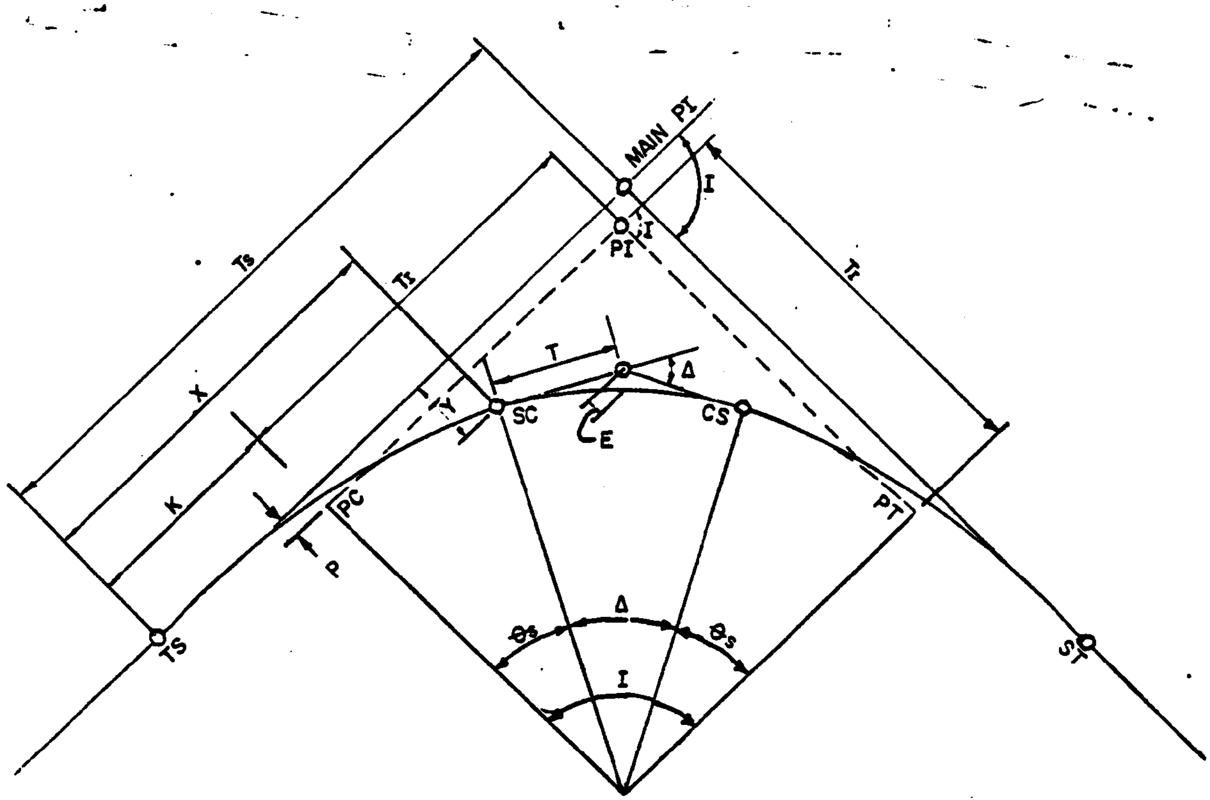
SC = SPIRAL TO CURVE

CS = CURVE TO SPIRAL

ST = SPIRAL TO TANGENT

PI = POINT OF INTERSECTION

NOTE: SEE FIGURE II-1-2 FOR SPIRAL CURVE FUNCTIONS AND ABBREVIATIONS.



CIRCULAR CURVES
FUNCTIONS & ABBREVIATIONS
FIGURE II-1-1

SPIRAL TRANSITION CURVE

Ls = LENGTH OF SPIRAL

θs = SPIRAL ANGLE = $\frac{90 L_s}{\pi R}$, $\delta s = \frac{L_s}{2R}$

$X = L_s \left(1 - \frac{\delta s^2}{10} + \frac{\delta s^4}{216} - \frac{\delta s^6}{9360} + \frac{\delta s^8}{685{,}440}\right)$

$Y = L_s \left(\frac{\delta s}{3} - \frac{\delta s^3}{42} + \frac{\delta s^5}{1320} - \frac{\delta s^7}{75{,}600} + \frac{\delta s^9}{6{,}894{,}720}\right)$

$P = Y - R(1 - \cos \theta s)$

$K = X - R \sin \theta s$

Ts = TANGENT LENGTH FROM T S TO MAIN P I (EQUAL SPIRAL LENGTHS) = $(R + P)\tan\frac{I}{2} + K$

$T_{s1} = T_I + K + \frac{P_2 - P_1 \cos I}{\sin I}$

(UNEQUAL SPIRAL LENGTHS)

$T_{s2} = T_I + K + \frac{P_1 - P_2 \cos I}{\sin I}$

$ST = \frac{Y}{\sin \theta s}$

$LT = X - \frac{Y}{\tan \theta s}$

$LC = \sqrt{X^2 + Y^2}$

Δ = CENTRAL ANGLE OF CIRCULAR CURVE

δs = θs EXPRESSED IN RADIANS

θc, θs, Δ & I ARE IN DEGREES

Eo = ACTUAL SUPERELEVATION IN INCHES

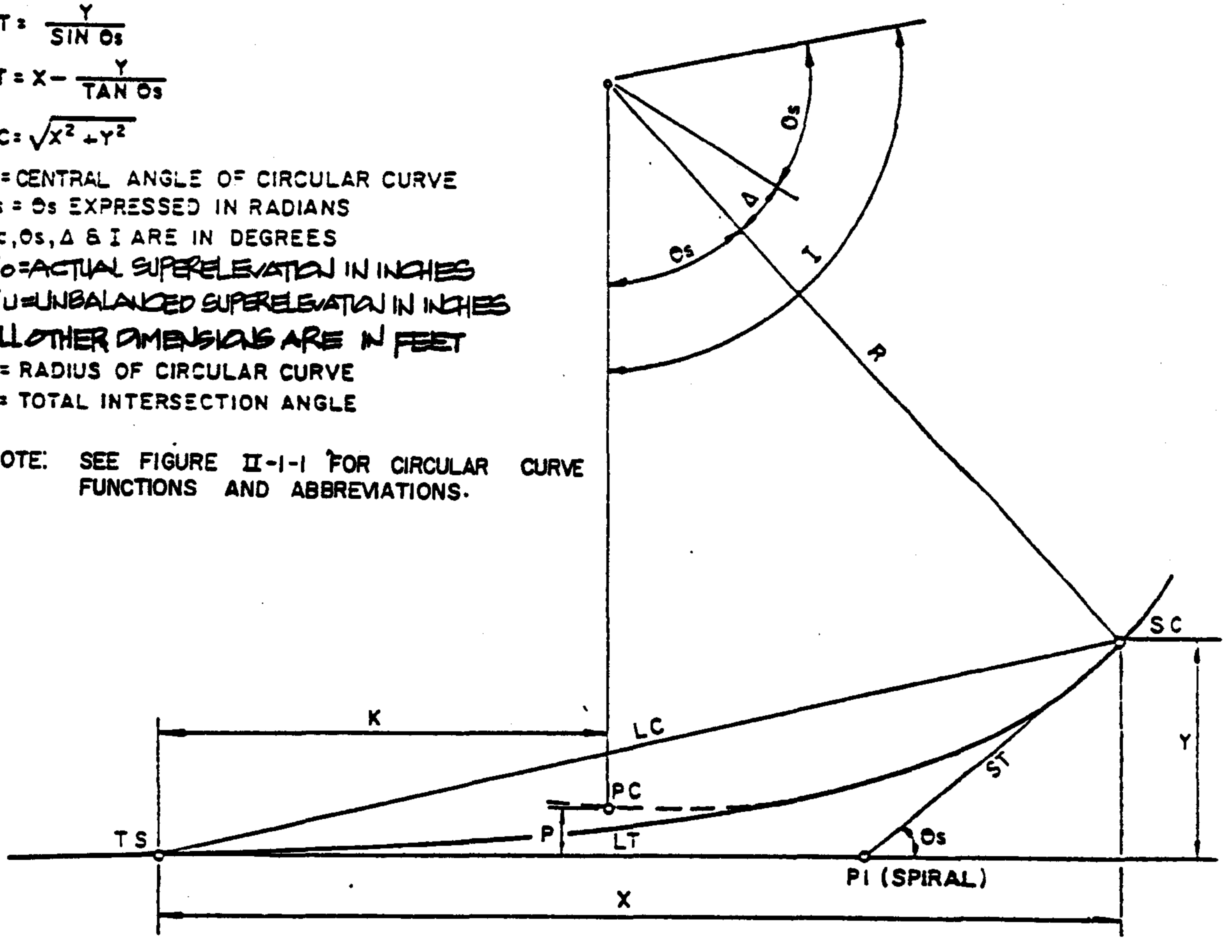
Eu = UNBALANCED SUPERELEVATION IN INCHES

ALL OTHER DIMENSIONS ARE IN FEET

R = RADIUS OF CIRCULAR CURVE

I = TOTAL INTERSECTION ANGLE

NOTE: SEE FIGURE II-1-1 FOR CIRCULAR CURVE FUNCTIONS AND ABBREVIATIONS.

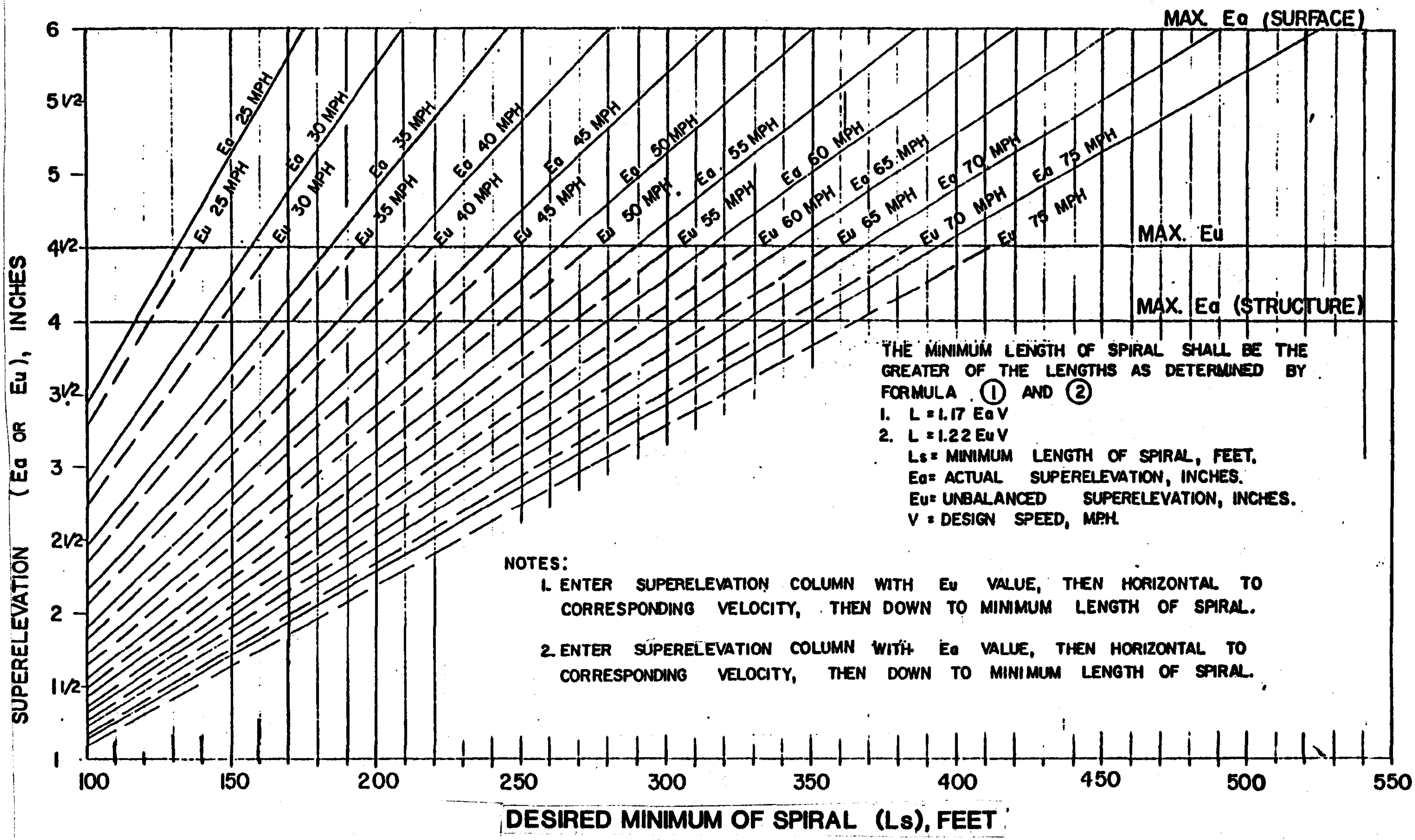


SUPERELEVATION

ACTUAL SUPERELEVATION (Eo) WILL BE ATTAINED AND REMOVED LINEARLY THROUGHOUT THE FULL LENGTH OF THE SPIRAL TRANSITION CURVE

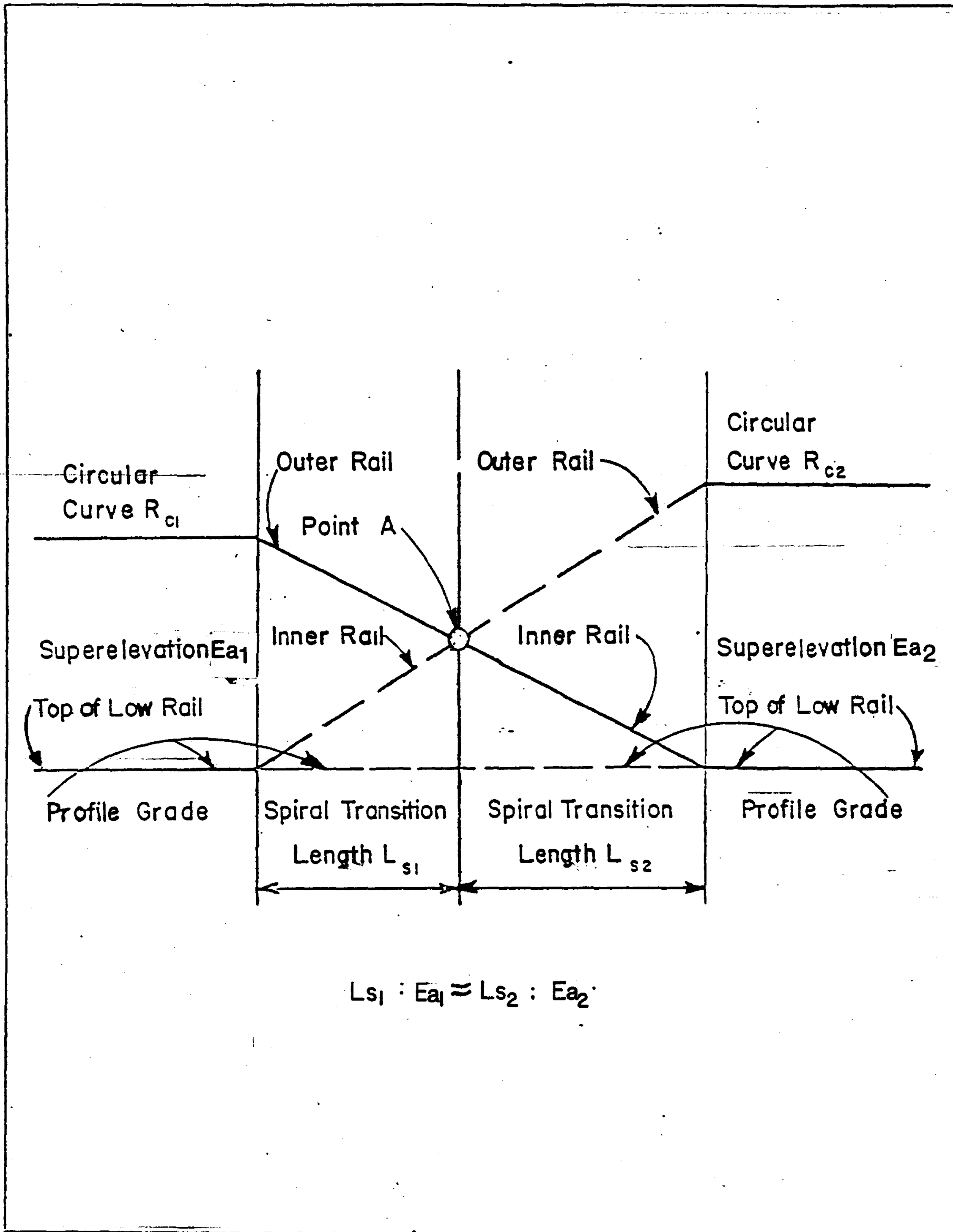
SPIRAL CURVES FUNCTIONS & ABBREVIATIONS

FIGURE II-1-2



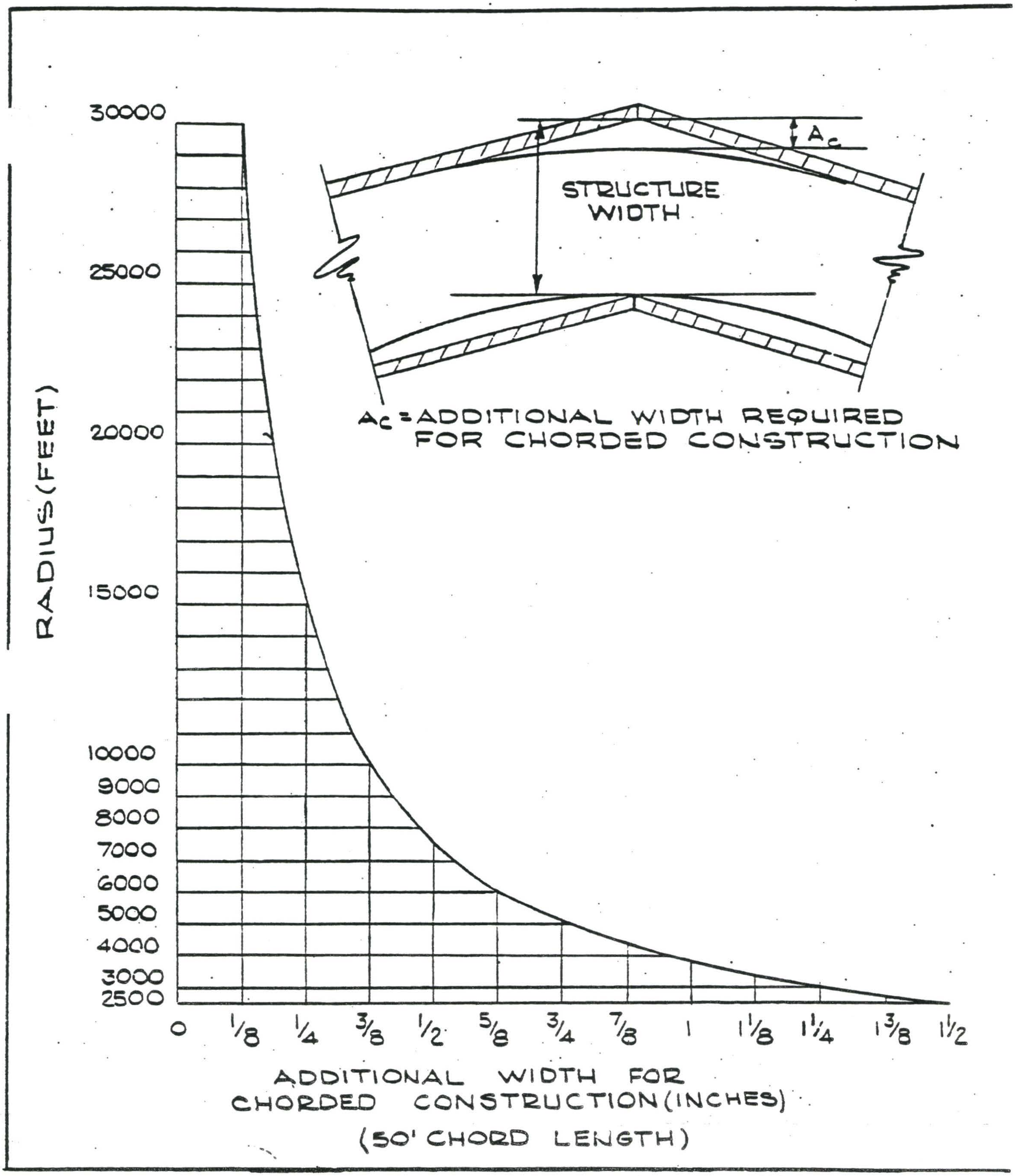
SPIRAL LENGTH CHART

FIGURE II - 1 - 3

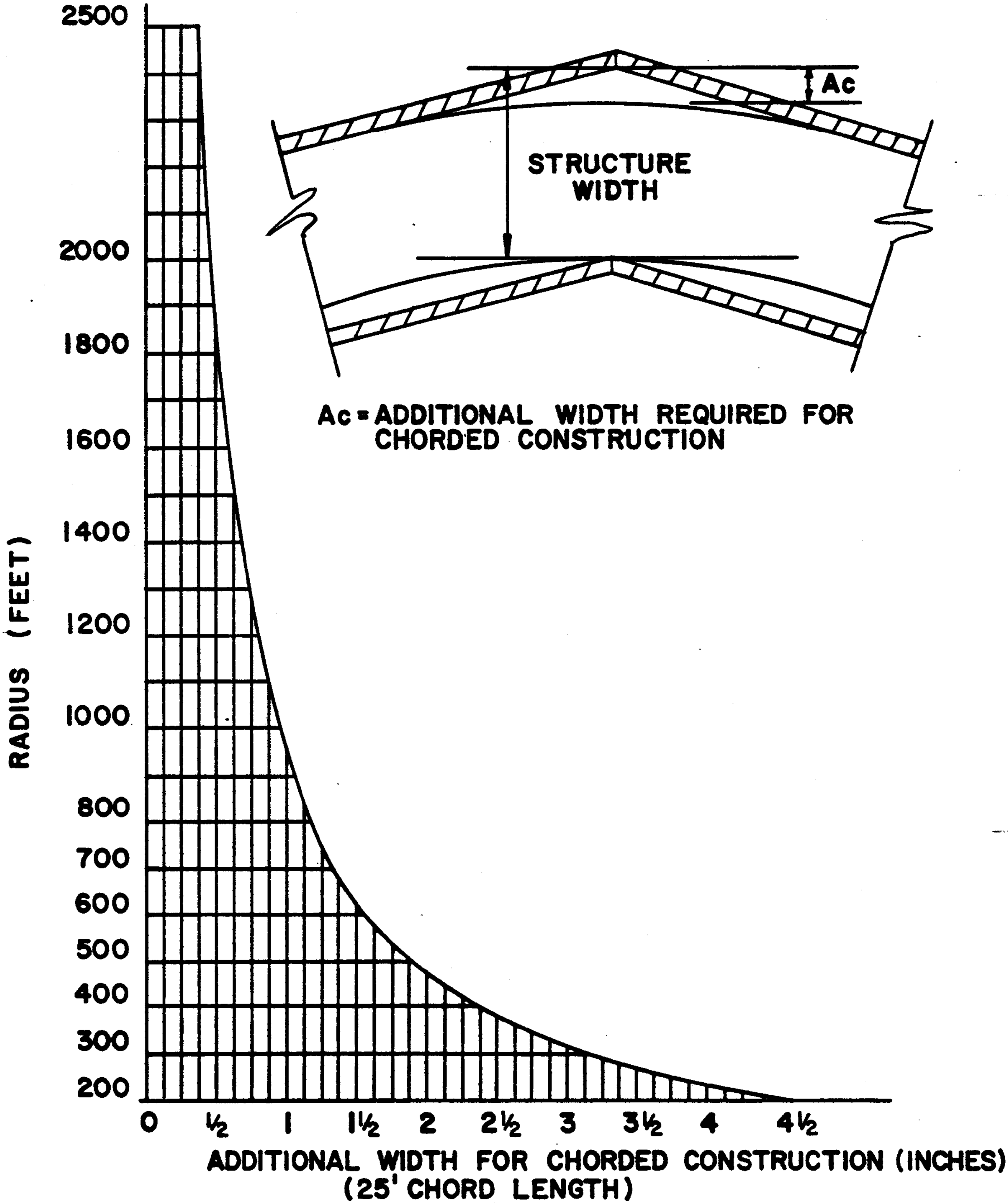


REVERSE CURVES SUPERELEVATION TRANSITION THROUGH SPIRALS PROFILE

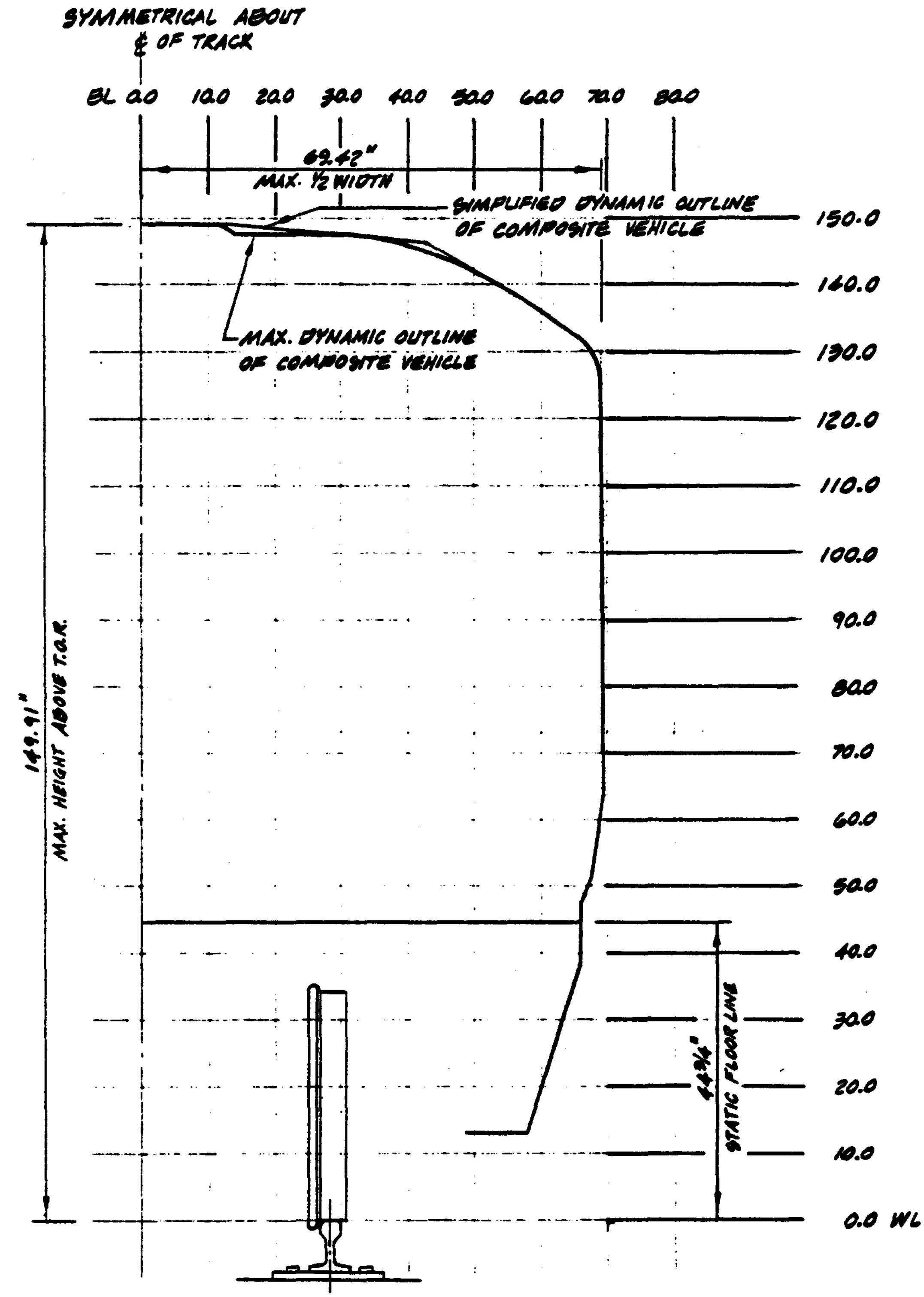
FIGURE II-1-4



ADDITIONAL WIDTH FOR CHORDED CONSTRUCTION
CURVE RADII - 2500' TO 30,000'
FIGURE II - 1 - 5



ADDITIONAL WIDTH FOR CHORDED CONSTRUCTION
CURVE RADII - 200' TO 2500'
FIGURE II - 1 - 6



MAXIMUM DYNAMIC OUTLINE

DESIGN VEHICLE
DYNAMIC OUTLINE DIAGRAM
TANGENT TRACK

FIGURE II-1-7

SW = SAFETY WALK

X_A = OFFSET OF ℄ OF TUNNEL FROM ℄ OF TRACK, AWAY FROM CURVE CENTER.

X_T = OFFSET OF ℄ OF TUNNEL FROM ℄ OF TRACK, TOWARDS CURVE CENTER.

Y = VERTICAL DISTANCE FROM TOP OF RAIL TO ℄ OF TUNNEL

T/R = TOP OF RAIL

H_W = DISTANCE FROM ℄ OF TRACK TO EDGE OF SERVICE WALK

SE = SUPERELEVATION - THE DIFFERENCE IN INCHES BETWEEN THE HIGH RAIL AND LOW RAIL.

A_C = ALLOWANCE FOR CHORDED CONSTRUCTION (SECTION 1.6.2.A.3)

RC = RUNNING CLEARANCE (SECTION 1.6.1)

WC = WALL CLEARANCE (SECTION 1.6.2.A.4.C (1)

CT = CONSTRUCTION TOLERANCE (SECTION 1.6.2.A.4.C(1))

DW_A = DYNAMIC WIDTH OF VEHICLE AWAY FROM CURVE CENTER (SECTION 1.6.1.C.1)

DW_T = DYNAMIC WIDTH OF VEHICLE TOWARD CURVE CENTER (SECTION 1.6.1.C.1)

E_O = END OVERHANG (SECTION 1.6.1.B.1)

M_O = MIDDLE OVERHANG (SECTION 1.6.1.B.1)

A = DISTANCE FROM TRACK CENTER TO FACE OF STRUCTURE AWAY FROM CURVE CENTER

= $DW_A + E_O + A_C + RC + WC + CT$

A_S = DISTANCE FROM TRACK CENTER TO FACE OF STRUCTURE AWAY FROM CURVE CENTER INCLUDING SAFETY WALK.

= $DW_A + E_O + A_C + SW + CT$

T = DISTANCE FROM TRACK CENTER TO FACE OF STRUCTURE TOWARD CURVE CENTER.

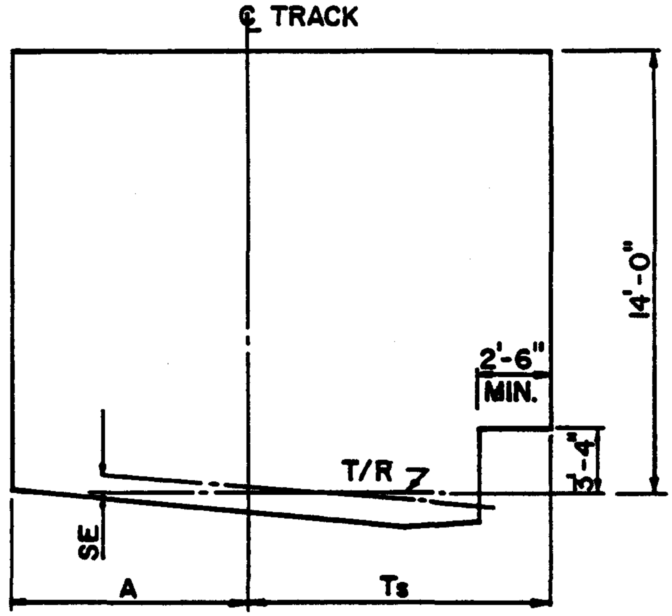
= $DW_T + M_O + RC + WC + CT$

T_S = DISTANCE FROM TRACK CENTER TO FACE OF STRUCTURE TOWARD CURVE CENTER INCLUDING SAFETY WALK.

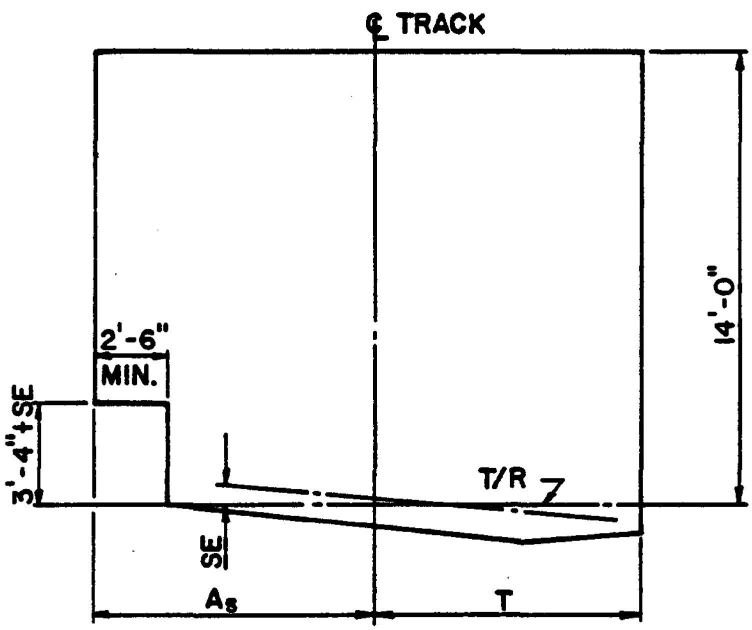
= $DW_T + M_O + SW + CT$

ABBREVIATIONS AND DEFINITIONS
CLEARANCE DIAGRAM

FIGURE II-1 - 8



SAFETY WALK TOWARDS
CURVE CENTER



SAFETY WALK AWAY
FROM CURVE CENTER

FOR ABBREVIATIONS SEE FIGURE II-1-8
FOR A_S, A, T_S & T SEE FIGURES: II-1-10, 11, 12, 13, & 14

CUT AND COVER RECTANGULAR SECTION CLEARANCE DIAGRAM

FIGURE II-1-9

RADIUS	SUPERELEVATION = 0"				SUPERELEVATION = 1/2"			
	A	Ts	As	T	A	Ts	As	T
250	8-1 7/8	9-9	9-11 7/8	7-11	8-1 3/8	9-9 3/4	9-11 3/8	7-11 3/4
300	7-10 5/8	9-6	9-8 5/8	7-8	7-10	9-6 3/4	9-8	7-8 3/4
400	7-6 3/8	9-2 3/8	9-4 3/8	7-4 3/8	7-5 7/8	9-3 1/8	9-3 7/8	7-5 1/8
500	7-3 7/8	9-0 1/8	9-1 7/8	7-2 1/8	7-3 1/4	9-1	9-1 1/4	7-3
600	7-2 1/8	8-10 3/4	9-0 1/8	7-0 3/4	7-1 5/8	8-11 1/2	8-11 5/8	7-1 1/2
700	7-0 7/8	8-9 5/8	8-10 7/8	6-11 5/8	7-0 3/8	8-10 1/2	8-10 3/8	7-0 1/2
750	7-0 3/8	8-9 1/4	8-10 3/8	6-11 1/4	6-11 7/8	8-10	8-9 7/8	7-0
800	7-0	8-8 7/8	8-10	6-10 7/8	6-11 3/8	8-9 5/8	8-9 3/8	6-11 5/8
900	6-11 1/4	8-8 1/4	8-9 1/4	6-10 1/4	6-10 3/4	8-9	8-8 3/4	6-11
1000	6-10 3/4	8-7 3/4	8-8 3/4	6-9 3/4	6-10 1/8	8-8 5/8	8-8 1/8	6-10 5/8
1100	6-10 1/4	8-7 3/8	8-8 1/4	6-9 3/8	6-9 5/8	8-8 1/8	8-7 5/8	6-10 1/8
1200	6-9 7/8	8-7 1/8	8-7 7/8	6-9 1/8	6-9 1/4	8-7 7/8	8-7 1/4	6-9 7/8
1300	6-9 1/2	8-6 3/4	8-7 1/2	6-8 3/4	6-8 7/8	8-7 1/2	8-6 7/8	6-9 1/2
1400	6-9 1/4	8-6 1/2	8-7 1/4	6-8 1/2	6-8 5/8	8-7 3/8	8-6 5/8	6-9 3/8
1500	6-9	8-6 3/8	8-7	6-8 3/8	6-8 3/8	8-7 1/8	8-6 3/8	6-9 1/8
1600	6-8 3/4	8-6 1/8	8-6 3/4	6-8 1/8	6-8 1/8	8-6 7/8	8-6 1/8	6-8 7/8
1800	6-8 3/8	8-5 7/8	8-6 3/8	6-7 7/8	6-7 3/4	8-6 5/8	8-5 3/4	6-8 5/8
2000	6-8 1/8	8-5 5/8	8-6 1/8	6-7 5/8	6-7 1/2	8-6 3/8	8-5 1/2	6-8 3/8
2500	6-8 5/8	8-5 1/8	8-6 5/8	6-7 1/8	6-8 1/8	8-6	8-6 1/8	6-8
3000	6-8 1/8	8-4 7/8	8-6 1/8	6-6 7/8	6-7 1/2	8-5 5/8	8-5 1/2	6-7 5/8
4000	6-7 1/2	8-4 1/2	8-5 1/2	6-6 1/2	6-6 7/8	8-5 1/4	8-4 7/8	6-7 1/4
5000	6-7	8-4 1/4	8-5	6-6 1/4	6-6 1/2	8-5 1/8	8-4 1/2	6-7 1/8
6000	6-6 3/4	8-4 1/8	8-4 3/4	6-6 1/8	6-6 1/4	8-4 7/8	8-4 1/4	6-6 7/8
7000	6-6 5/8	8-4	8-4 5/8	6-6	6-6	8-4 7/8	8-4	6-6 7/8
8000	6-6 3/8	8-4	8-4 3/8	6-6	6-5 7/8	8-4 3/4	8-3 7/8	6-6 3/4
9000	6-6 3/8	8-3 7/8	8-4 3/8	6-5 7/8	6-5 3/4	8-4 5/8	8-3 3/4	6-6 5/8
10 000	6-6 1/4	8-3 7/8	8-4 1/4	6-5 7/8	6-5 5/8	8-4 5/8	8-3 5/8	6-6 5/8
15 000	6-6	8-3 3/4	8-4	6-5 3/4	6-5 3/8	8-4 1/2	8-3 3/8	6-6 1/2
25000	6-5 3/4	8-3 5/8	8-3 3/4	6-5 5/8	6-5 1/8	8-4 3/8	8-3 1/8	6-6 3/8
TANGENT	6-5 3/8	8-3 3/8	8-3 3/8	6-5 3/8				

CLEARANCE TABLES

CUT AND COVER RECTANGULAR SECTIONS

FIGURE II-1-10

RADIUS	SUPERELEVATION = 1"				SUPERELEVATION = 1 1/2"			
	A	Ts	As	T	A	Ts	As	T
250	8-0 3/4	9-10 7/8	9-10 3/4	8-0 7/8	8-0 1/8	9-11 7/8	9-10 1/8	8-1 7/8
300	7-9 1/2	9-7 7/8	9-7 1/2	7-9 7/8	7-8 7/8	9-9	9-6 7/8	7-11
400	7-5 1/4	9-4 1/2	9-3 1/4	7-6 1/4	7-4 3/4	9-5 3/8	9-2 3/4	7-7 3/8
500	7-2 3/4	9-2	9-0 3/4	7-4	7-2 1/8	9-3 1/8	9-0 1/8	7-5 1/8
600	7-1	9-0 5/8	8-11	7-2 5/8	7-0 3/8	9-1 5/8	8-10 3/8	7-3 5/8
700	6-11 3/4	8-11 1/2	8-9 3/4	7-1 1/2	6-11 1/4	9-0 5/8	8-9 1/4	7-2 5/8
750	6-11 1/4	8-11 1/8	8-9 1/4	7-1 1/8	6-10 3/4	9-0 1/4	8-8 3/4	7-2 1/4
800	6-10 7/8	8-10 3/4	8-8 7/8	7-0 3/4	6-10 1/4	8-11 7/8	8-8 1/4	7-1 7/8
900	6-10 1/8	8-10 1/8	8-8 1/8	7-0 1/8	6-9 1/2	8-11 1/4	8-7 1/2	7-1 1/4
1000	6-9 1/2	8-9 5/8	8-7 1/2	6-11 5/8	6-9	8-10 3/4	8-7	7-0 3/4
1100	6-9 1/8	8-9 1/4	8-7 1/8	6-11 1/4	6-8 1/2	8-10 3/8	8-6 1/2	7-0 3/8
1200	6-8 5/8	8-8 7/8	8-6 5/8	6-10 7/8	6-8 1/8	8-10	8-6 1/8	7-0
1300	6-8 3/8	8-8 5/8	8-6 3/8	6-10 5/8	6-7 3/4	8-9 3/4	8-5 3/4	6-11 3/4
1400	6-8	8-8 3/8	8-6	6-10 3/8	6-7 1/2	8-9 1/2	8-5 1/2	6-11 1/2
1500	6-7 3/4	8-8 1/4	8-5 3/4	6-10 1/4	6-7 1/4	8-9 1/4	8-5 1/4	6-11 1/4
1600	6-7 5/8	8-8	8-5 5/8	6-10	6-7	8-9 1/8	8-5	6-11 1/8
1800	6-7 1/2	8-7 3/4	8-5 1/2	6-9 3/4	6-6 7/8	8-8 7/8	8-4 5/8	6-10 7/8
2000	6-6 7/8	8-7 1/2	8-4 7/8	6-9 1/2	6-6 3/8	8-8 5/8	8-4 3/8	6-10 5/8
2500	6-7 1/2	8-7	8-5 1/2	6-9	6-7	8-8 1/8	8-5	6-10 1/8
3000	6-7	8-6 3/4	8-5	6-8 3/4	6-6 3/8	8-7 7/8	8-4 3/8	6-9 7/8
4000	6-6 1/2	8-6 3/8	8-4 1/2	6-8 3/8	6-5 3/4	8-7 1/2	8-3 3/4	6-9 1/2
5000	6-5 7/8	8-6 1/8	8-3 7/8	6-8 1/8	6-5 3/8	8-7 1/4	8-3 3/8	6-9 1/4
6000	6-5 5/8	8-6	8-3 5/8	6-8	6-5	8-7 1/8	8-3	6-9 1/8
7000	6-5 1/2	8-5 7/8	8-3 1/2	6-7 7/8	6-4 7/8	8-7	8-2 7/8	6-9
8000	6-5 1/4	8-5 7/8	8-3 1/4	6-7 7/8	6-4 3/4	8-6 7/8	8-2 3/4	6-8 7/8
9000	6-5 1/8	8-5 3/4	8-3 1/8	6-7 3/4	6-4 5/8	8-6 7/8	8-2 5/8	6-8 7/8
10 000	6-5 1/8	8-5 3/4	8-3 1/8	6-7 3/4	6-4 1/2	8-6 7/8	8-2 1/2	6-8 7/8
15 000	6-4 7/8	8-5 5/8	8-2 7/8	6-7 5/8	6-4 1/4	8-6 5/8	8-2 1/4	6-8 5/8
25000	6-4 5/8	8-5 1/2	8-2 5/8	6-7 1/2	6-4	8-6 1/2	8-2	6-8 1/2
TANGENT								

CLEARANCE TABLES

CUT AND COVER RECTANGULAR SECTIONS

FIGURE II-1-11

RADIUS	SUPERELEVATION = 2"				SUPERELEVATION = 2 1/2"			
	A	Ts	As	T	A	Ts	As	=T
250	7-11 5/8	10-1	9-9 5/8	8-3	7-11	10-2 1/8	9-9	8-4 1/8
300	7-8 1/4	9-10 1/8	9-6 1/4	8-0 1/8	7-7 3/4	9-11 1/8	9-5 3/4	8-1 1/8
400	7-4 1/8	9-6 3/8	9-2 1/8	7-8 3/8	7-3 1/2	9-7 1/2	9-1 1/2	7-9 1/2
500	7-1 5/8	9-4 1/4	8-11 5/8	7-6 1/4	7-1	9-5 3/8	8-11	7-7 3/8
600	6-11 7/8	9-2 3/4	8-9 7/8	7-4 3/4	6-11 1/4	9-3 7/8	8-9 1/4	7-5 7/8
700	6-10 5/8	9-1 3/4	8-8 5/8	7-3 3/4	6-10	9-2 3/4	8-8	7-4 3/4
750	6-10 1/8	9-1 1/4	8-8 1/8	7-3 1/4	6-9 1/2	9-2 3/8	8-7 1/2	7-4 3/8
800	6-9 3/4	9-1	8-7 3/4	7-3	6-9 1/8	9-2	8-7 1/8	7-4
900	6-9	9-0 3/8	8-7	7-2 3/8	6-8 3/8	9-1 3/8	8-6 3/8	7-3 3/8
1000	6-8 3/8	8-11 7/8	8-6 3/8	7-1 7/8	6-7 3/4	9-0 7/8	8-5 3/4	7-2 7/8
1100	6-7 7/8	8-11 1/2	8-5 7/8	7-1 1/2	6-7 3/8	9-0 1/2	8-5 3/8	7-2 1/2
1200	6-7 1/2	8-11 1/8	8-5 1/2	7-1 1/8	6-6 7/8	9-0 1/4	8-4 7/8	7-2 1/4
1300	6-7 1/8	8-10 7/8	8-5 1/8	7-0 7/8	6-6 5/8	8-11 7/8	8-4 5/8	7-1 7/8
1400	6-6 7/8	8-10 5/8	8-4 7/8	7-0 5/8	6-6 1/4	8-11 5/8	8-4 1/4	7-1 5/8
1500	6-6 5/8	8-10 3/8	8-4 5/8	7-0 3/8	6-6	8-11 1/2	8-4	7-1 1/2
1600	6-6 3/8	8-10 1/4	8-4 3/8	7-0 1/4	6-5 7/8	8-11 1/4	8-3 7/8	7-1 1/4
1800	6-6 1/8	8-9 7/8	8-4 1/8	6-11 7/8	6-5 1/2	8-11	8-3 1/2	7-1
2000	6-5 3/4	8-9 5/8	8-3 3/4	6-11 5/8	6-5 1/8	8-10 3/4	8-3 1/8	7-0 3/4
2500	6-6 3/8	8-9 1/4	8-4 3/8	6-11 1/4	6-5 3/4	8-10 1/4	8-3 3/4	7-0 1/4
3000	6-5 7/8	8-8 7/8	8-3 7/8	6-10 7/8	6-5 1/4	8-10	8-3 1/4	7-0
4000	6-5 1/8	8-8 5/8	8-3 1/8	6-10 5/8	6-4 5/8	8-9 5/8	8-2 5/8	6-11 5/8
5000	6-4 3/4	8-8 3/8	8-2 3/4	6-10 3/8	6-4 1/8	8-9 3/8	8-2 1/8	6-11 3/8
6000	6-4 1/2	8-8 1/4	8-2 1/2	6-10 1/4	6-3 7/8	8-9 1/4	8-1 7/8	6-11 1/4
7000	6-4 1/4	8-8 1/8	8-2 1/4	6-10 1/8	6-3 3/4	8-9 1/8	8-1 3/4	6-11 1/8
8000	6-4 1/8	8-8	8-2 1/8	6-10	6-3 1/2	8-9 1/8	8-1 1/2	6-11 1/8
9000	6-4	8-8	8-2	6-10	6-3 1/2	8-9	8-1 1/2	6-11
10000	6-3 7/8	8-7 7/8	8-1 7/8	6-9 7/8	6-3 3/8	8-9	8-1 3/8	6-11
15000	6-3 5/8	8-7 3/4	8-1 5/8	6-9 3/4	6-3 1/8	8-8 7/8	8-1 1/8	6-10 7/8
25000	6-3 1/2	8-7 5/8	8-1 1/2	6-9 5/8	6-2 7/8	8-8 3/4	8-0 7/8	6-10 3/4
TANGENT								

CLEARANCE TABLES

CUT AND COVER RECTANGULAR SECTIONS

FIGURE II -1-12

RADIUS	SUPERELEVATION = 3"				SUPERELEVATION = 3½"			
	A	Ts	As	T	A	Ts	As	=T
250	7-10⅜	10-3⅛	9-8⅜	8-5⅛	7-9⅞	10-4¼	9-7⅞	8-6¼
300	7-7⅛	10-0¼	9-5⅛	8-2¼	7-6½	10-1⅜	9-4½	8-3⅜
400	7-2⅞	9-8⅝	9-0⅞	7-10⅝	7-2⅜	9-9⅝	9-0⅜	7-11⅝
500	7-0⅜	9-6⅜	8-10⅜	7-8⅜	6-11¾	9-7½	8-9¾	7-9½
600	6-10⅝	9-4⅞	8-8⅝	7-6⅞	6-10⅛	9-6	8-8⅛	7-8
700	6-9½	9-3⅞	8-7½	7-5⅞	6-8⅞	9-5	8-6⅞	7-7
750	6-9	9-3½	8-7	7-5½	6-8⅜	9-4½	8-6⅜	7-6½
800	6-8½	9-3⅛	8-6½	7-5⅛	6-7⅞	9-4⅛	8-5⅞	7-6⅛
900	6-7¾	9-2½	8-5¾	7-4½	6-7¼	9-3⅝	8-5¼	7-5⅝
1000	6-7¼	9-2	8-5¼	7-4	6-6⅝	9-3⅛	8-4⅝	7-5⅛
1100	6-6¾	9-1⅝	8-4¾	7-3⅝	6-6⅛	9-2⅝	8-4⅛	7-4⅝
1200	6-6⅜	9-1¼	8-4⅜	7-3¼	6-5¾	9-2⅜	8-3¾	7-4⅜
1300	6-6	9-1	8-4	7-3	6-5⅜	9-2⅛	8-3⅜	7-4⅛
1400	6-5¾	9-0¾	8-3¾	7-2¾	6-5⅛	9-1⅞	8-3⅛	7-3⅞
1500	6-5½	9-0½	8-3½	7-2½	6-4⅞	9-1⅝	8-2⅞	7-3⅝
1600	6-5¼	9-0⅜	8-3¼	7-2⅜	6-4⅝	9-1½	8-2⅝	7-3½
1800	6-4⅞	9-0⅛	8-2⅞	7-2⅛	6-4¼	9-1⅛	8-2¼	7-3⅛
2000	6-4⅝	8-11⅞	8-2⅝	7-1⅞	6-4	9-0⅞	8-2	7-2⅞
2500	6-5¼	8-11⅜	8-3¼	7-1⅜	6-4⅝	9-0½	8-2⅝	7-2½
3000	6-4⅝	8-11⅛	8-2⅝	7-1⅛	6-4	9-0⅛	8-2	7-2⅛
4000	6-4	8-10¾	8-2	7-0¾	6-3⅜	8-11¾	8-1⅜	7-1¾
5000	6-3⅝	8-10½	8-1⅝	7-0½	6-3	8-11⅝	8-1	7-1⅝
6000	6-3¼	8-10⅜	8-1¼	7-0⅜	6-2¾	8-11⅜	8-0¾	7-1⅜
7000	6-3⅛	8-10¼	8-1⅛	7-0¼	6-2½	8-11⅜	8-0½	7-1⅜
8000	6-3	8-10⅛	8-1	7-0⅛	6-2⅜	8-11¼	8-0⅜	7-1¼
9000	6-2⅞	8-10⅛	8-0⅞	7-0⅛	6-2¼	8-11¼	8-0¼	7-1¼
10000	6-2¾	8-10⅛	8-0¾	7-0⅛	6-2⅛	8-11⅛	8-0⅛	7-1⅛
15000	6-2½	8-9⅞	8-0½	6-11⅞	6-1⅞	8-11	7-11⅞	7-1
25000	6-2¼	8-9¾	8-0¼	6-11¾	6-1⅝	8-10⅞	7-11⅝	7-0⅞
TANGENT								

CLEARANCE TABLES

CUT AND COVER RECTANGULAR SECTIONS

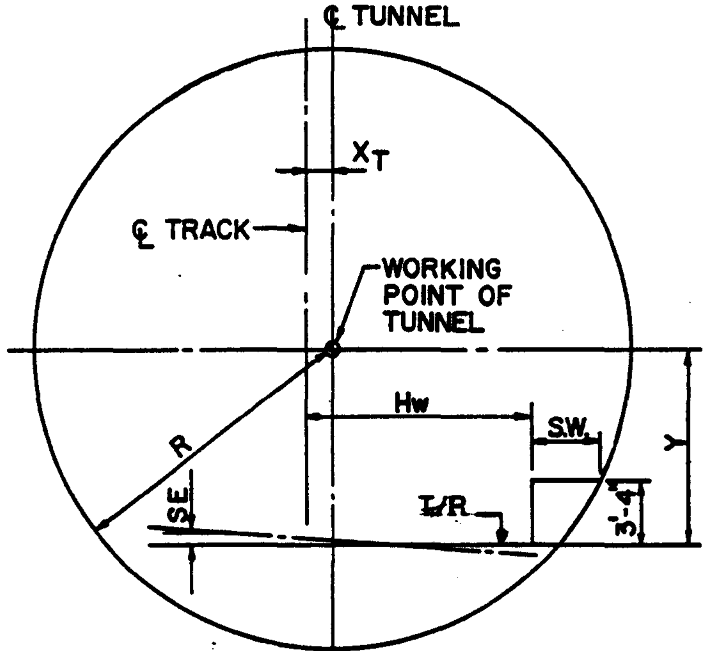
FIGURE II-1-13

RADIUS	SUPERELEVATION = 4"				SUPERELEVATION =			
	A	Ts	As	T	A	Ts	As	=T
250	7-9 1/4	10-5 3/8	9-7 1/4	8-7 3/8				
300	7-5 7/8	10-2 3/8	9-3 7/8	8-4 3/8				
400	7-1 3/4	9-10 3/4	8-11 3/4	8-0 3/4				
500	6-11 1/4	9-8 1/2	8-9 1/4	7-10 1/2				
600	6-9 1/2	9-7 1/8	8-7 1/2	7-9 1/8				
700	6-8 1/4	9-6	8-6 1/4	7-8				
750	6-7 3/4	9-5 5/8	8-5 3/4	7-7 5/8				
800	6-7 3/8	9-5 1/4	8-5 3/8	7-7 1/4				
900	6-6 5/8	9-4 5/8	8-4 5/8	7-6 5/8				
1000	6-6	9-4 1/8	8-4	7-6 1/8				
1100	6-5 1/2	9-3 3/4	8-3 1/2	7-5 3/4				
1200	6-5 1/8	9-3 3/8	8-3 1/8	7-5 3/8				
1300	6-4 7/8	9-3 1/8	8-2 7/8	7-5 1/8				
1400	6-4 1/2	9-2 7/8	8-2 1/2	7-4 7/8				
1500	6-4 1/4	9-2 3/4	8-2 1/4	7-4 3/4				
1600	6-4	9-2 1/2	8-2	7-4 1/2				
1800	6-3 3/4	9-2 1/4	8-1 3/4	7-4 1/4				
2000	6-3 3/8	9-2	8-1 3/8	7-4				
2500	6-4	9-1 1/2	8-2	7-3 1/2				
3000	6-3 1/2	9-1 1/4	8-1 1/2	7-3 1/4				
4000	6-2 3/4	9-0 7/8	8-0 3/4	7-2 7/8				
5000	6-2 3/8	9-0 5/8	8-0 3/8	7-2 5/8				
6000	6-2 1/8	9-0 1/2	8-0 1/8	7-2 1/2				
7000	6-1 7/8	9-0 3/8	7-11 7/8	7-2 3/8				
8000	6-1 3/4	9-0 3/8	7-11 3/4	7-2 3/8				
9000	6-1 5/8	9-0 1/4	7-11 5/8	7-2 1/4				
10000	6-1 5/8	9-0 1/4	7-11 5/8	7-2 1/4				
15000	6-1 1/4	9-0 1/8	7-11 1/4	7-2 1/8				
25000	6-1 1/8	9-0	7-11 1/8	7-2				
TANGENT								

CLEARANCE TABLES

CUT AND COVER RECTANGULAR SECTIONS

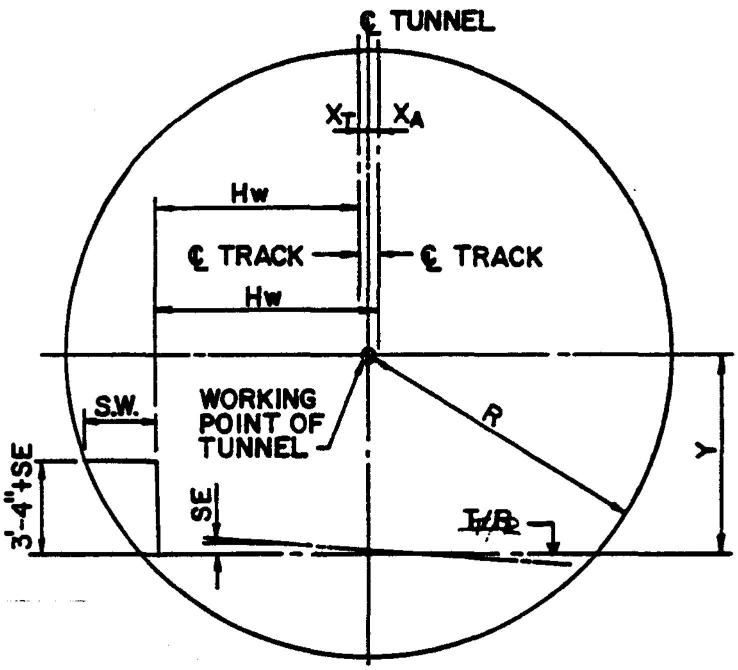
FIGURE II-1-14



SAFETY WALK TOWARDS CURVE CENTER

FOR ABBREVIATIONS SEE FIGURE II-1-8

FOR X_T, X_A, Y, Hw & S.W. VALUES SEE FIGURES II-1-16 THRU II-1-25



SAFETY WALK AWAY FROM CURVE CENTER

CIRCULAR TUNNEL CLEARANCE DIAGRAM FIGURE II-1-15

SW TOWARD CURVE CENTER

RADIUS	SE 10" Y	SE 10" Xr	SE 10" Xa	SE 10" SW	SE 10" HW	SE 10 1/2" Y	SE 10 1/2" Xr	SE 10 1/2" Xa	SE 10 1/2" SW	SE 10 1/2" HW
900	5'10 3/4"	5 1/2"		2'6"	6'0 3/4"	5'10 3/4"	5 3/4"		2'6"	6'1 1/8"
1000	5'9 5/8"	4 3/4"		2'6"	6'0 1/4"	5'9 5/8"	5"		2'6"	6'0 5/8"
1100	5'8 5/8"	4"		2'6"	5'11 7/8"	5'8 3/4"	4 3/8"		2'6"	6'0 1/8"
1200	5'8"	3 5/8"		2'6"	5'11 1/2"	5'8"	3 3/4"		2'6"	5'11 7/8"
1300	5'8"	3 1/8"		2'6"	5'11 1/4"	5'8"	3 1/2"		2'6"	5'11 5/8"
1400	5'8"	2 7/8"		2'6"	5'11"	5'8"	3 1/4"		2'6"	5'11 3/8"
1500	5'8"	2 3/4"		2'6"	5'10 3/4"	5'8"	3"		2'6"	5'11 1/8"
1600	5'8"	2 5/8"		2'6"	5'10 1/4"	5'8"	2 7/8"		2'6"	5'11"
1800	5'8"	2 5/8"		2'6"	5'10 5/8"	5'8"	2 7/8"		2'6"	5'11"
2000	5'8"	2 3/8"		2'6"	5'10 3/8"	5'8"	2 3/4"		2'6"	5'10 3/4"
2500	5'8"	2 3/8"		2'6"	5'10 3/8"	5'8"	2 5/8"		2'6"	5'10 3/4"
3000	5'8"	2 3/8"		2'6"	5'10 3/8"	5'8"	2 5/8"		2'6"	5'10 3/4"
4000	5'8"	2 1/4"		2'6"	5'9 7/8"	5'8"	2 5/8"		2'6"	5'9 5/8"
5000	5'8"	2 1/8"		2'6"	5'9 3/8"	5'8"	2 3/8"		2'6"	5'9 1/2"
6000	5'8"	2"		2'6"	5'9"	5'8"	2 1/4"		2'6"	5'9 3/8"
7000	5'8"	2"		2'6"	5'9"	5'8"	2 1/8"		2'6"	5'9 1/4"
8000	5'8"	2"		2'6"	5'9"	5'8"	2 1/8"		2'6"	5'9 1/8"
9000	5'8"	2"		2'6"	5'9"	5'8"	2"		2'6"	5'9 1/8"
10,000	5'8"	2"		2'6"	5'9"	5'8"	2"		2'6"	5'9 1/8"
15,000	5'8"	2"		2'6"	5'9"	5'8"	2"		2'6"	5'9 1/8"
25,000	5'8"	2"		2'6"	5'9"	5'8"	2"		2'6"	5'9 1/8"
TANGENT	5'8"	2"		2'6"	5'9"	—				

FIGURE II-1-16

CLEARANCE TABLES
CIRCULAR TUNNEL

SW TOWARD CURVE CENTER

RADIUS	SE = 1"				
	Y	X_T	X_A	SW	HW
900	5'10¾"	5⅞"		2'5¾"	6'1⅜"
1000	5'9⅝"	5⅜"		2'6"	6'0⅞"
1100	5'8¾"	4⅝"		2'6"	6'0½"
1200	5'8⅛"	4⅛"		2'6"	6'0¼"
1300	5'8"	3⅞"		2'6"	5'11⅞"
1400	5'8"	3⅝"		2'6"	5'11⅝"
1500	5'8"	3⅜"		2'6"	5'11½"
1600	5'8"	3⅜"		2'6"	5'11½"
1800	5'8"	3¼"		2'6"	5'11⅜"
2000	5'8"	3"		2'6"	5'11⅛"
2500	5'8"	3"		2'6"	5'11⅛"
3000	5'8"	3"		2'6"	5'11⅛"
4000	5'8"	3"		2'6"	5'10"
5000	5'8"	2¾"		2'6"	5'9¾"
6000	5'8"	2⅝"		2'6"	5'9⅝"
7000	5'8"	2½"		2'6"	5'9½"
8000	5'8"	2⅜"		2'6"	5'9⅜"
9000	5'8"	2⅜"		2'6"	5'9⅜"
10,000	5'8"	2⅜"		2'6"	5'9⅜"
15,000	5'8"	2⅛"		2'6"	5'9¼"

RADIUS	SE = 1½"				
	Y	X_T	X_A	SW	HW
900	5'10¾"	6¼"		2'5¾"	6'1¾"
1000	5'9¾"	5¾"		2'6"	6'1¼"
1100	5'8⅞"	5"		2'6"	6'0⅞"
1200	5'8¼"	4½"		2'6"	6'0½"
1300	5'8"	4⅛"		2'6"	6'0¼"
1400	5'8"	3⅞"		2'6"	6'0"
1500	5'8"	3¾"		2'6"	5'11¾"
1600	5'8"	3¾"		2'6"	5'11¾"
1800	5'8"	3⅝"		2'6"	5'11¾"
2000	5'8"	3⅜"		2'6"	5'11½"
2500	5'8"	3⅜"		2'6"	5'11⅜"
3000	5'8"	3⅜"		2'6"	5'11¾"
4000	5'8"	3⅜"		2'6"	5'10⅞"
5000	5'8"	3⅛"		2'6"	5'10⅛"
6000	5'8"	3"		2'6"	5'10"
7000	5'8"	2⅞"		2'6"	5'9⅞"
8000	5'8"	2¾"		2'6"	5'9⅞"
9000	5'8"	2¾"		2'6"	5'9¾"
10,000	5'8"	2⅝"		2'6"	5'9¾"
15,000	5'8"	2½"		2'6"	5'9⅝"

FIGURE II-1-17

CLEARANCE TABLES
CIRCULAR TUNNEL

SW TOWARD CURVE CENTER

Radius	SEq = 2"					SEq = 2 1/2"				
	Y	XT	XA	SW	HW	Y	XT	XA	SW	HW
900	5'10 3/4"	6 5/8"		2'5 3/4"	6'2 1/8"	5'10 3/4"	7"		2'5 3/4"	6'2 1/2"
1000	5'9 3/4"	6"		2'6"	6'1 5/8"	5'9 1/2"	6 1/2"		2'6"	6'2"
1100	5'9"	5 3/8"		2'6"	6'1 1/4"	5'9"	5 3/4"		2'6"	6'1 5/8"
1200	5'8 1/4"	4 7/8"		2'6"	6'0 7/8"	5'8 3/8"	5 1/4"		2'6"	6'1 1/4"
1300	5'8"	4 1/2"		2'6"	6'0 5/8"	5'8"	4 7/8"		2'6"	6'1"
1400	5'8"	4 1/4"		2'6"	6'0 3/8"	5'8"	4 5/8"		2'6"	6'0 3/4"
1500	5'8"	4 1/8"		2'6"	6'0 1/8"	5'8"	4 3/8"		2'6"	6'0 1/2"
1600	5'8"	4"		2'6"	6'0 1/8"	5'8"	4 1/4"		2'6"	6'0 3/8"
1800	5'8"	4"		2'6"	6'0"	5'8"	4 1/8"		2'6"	6'0 1/4"
2000	5'8"	3 3/4"		2'6"	5'11 3/4"	5'8"	4 1/8"		2'6"	6'0 1/8"
2500	5'8"	3 1/2"		2'6"	5'11 1/2"	5'8"	3 3/4"		2'6"	5'11 7/8"
3000	5'8"	3 1/2"		2'6"	5'11 1/2"	5'8"	3 3/4"		2'6"	5'11 7/8"
4000	5'8"	3 1/2"		2'6"	5'11 1/2"	5'8"	3 3/4"		2'6"	5'11 3/4"
5000	5'8"	3 1/2"		2'6"	5'10 1/2"	5'8"	3 3/4"		2'6"	5'10 7/8"
6000	5'8"	3 1/4"		2'6"	5'10 3/8"	5'8"	3 5/8"		2'6"	5'10 3/4"
7000	5'8"	3 1/4"		2'6"	5'10 1/4"	5'8"	3 1/2"		2'6"	5'10 5/8"
8000	5'8"	3 1/8"		2'6"	5'10 1/8"	5'8"	3 1/2"		2'6"	5'10 1/2"
9000	5'8"	3 1/8"		2'6"	5'10 1/8"	5'8"	3 3/8"		2'6"	5'10 1/2"
10,000	5'8"	3"		2'6"	5'10"					

FIGURE II-1-18

CLEARANCE TABLES
CIRCULAR TUNNEL

SW TOWARD CURVE CENTER

RADIUS	$SE_q = 3"$ Y	Xr	Xa	SW	HW	$SE_q = 3\frac{1}{2}"$ Y	Xr	Xa	SW	HW
900	5'10¾"	7¼"		2'5¾"	6'2¾"	5'10¾"	7⅝"		2'5¾"	6'3¼"
1000	5'10"	6⅞"		2'6"	6'2⅜"	5'10"	7⅛"		2'6"	6'2⅝"
1100	5'9⅛"	6⅛"		2'6"	6'2"	5'9¼"	6⅝"		2'6"	6'2¼"
1200	5'8½"	5⅝"		2'6"	6'1⅝"	5'8⅝"	6"		2'6"	6'2"
1300	5'8"	5¼"		2'6"	6'1¼"	5'8"	5⅝"		2'6"	6'1⅝"
1400	5'8"	5"		2'6"	6'1⅛"	5'8"	5⅜"		2'6"	6'1⅜"
1500	5'8"	4¾"		2'6"	6'0⅞"	5'8"	5⅛"		2'6"	6'1¼"
1600	5'8"	4⅝"		2'6"	6'0⅝"	5'8"	5"		2'6"	6'1"
1800	5'8"	4⅜"		2'6"	6'0½"	5'8"	4¾"		2'6"	6'0⅞"
2000	5'8"	4⅜"		2'6"	6'0⅜"	5'8"	4¾"		2'6"	6'0⅞"
2500	5'8"	4⅛"		2'6"	6'0¼"	5'8"	4⅜"		2'6"	6'0½"
3000	5'8"	4⅛"		2'6"	6'0¼"	5'8"	4⅜"		2'6"	6'0½"
4000	5'8"	4⅛"		2'6"	6'0¼"	5'8"	4⅜"		2'6"	6'0½"
5000	5'8"	4⅛"		2'6"	5'11¾"	5'8"	4⅜"		2'6"	6'0½"
6000	5'8"	4"		2'6"	5'11"	5'8"	4⅜"		2'6"	5'11⅞"
7000	5'8"	3⅞"		2'6"	5'11"	—				
8000	5'8"	3⅞"		2'6"	5'10⅞"	—				

CLEARANCE TABLES
CIRCULAR TUNNEL

FIGURE II-1-19

SW TOWARD CURVE CENTER

RADIUS	SEQ = 4"				
	Y	XT	XA	SW	HW
900	5'10¾"	8"		2'5¾"	6'3½"
1000	5'10"	7½"		2'6"	6'3"
1100	5'9¼"	6⅞"		2'6"	6'2⅝"
1200	5'8¾"	6½"		2'6"	6'2¼"
1300	5'8¼"	6"		2'6"	6'2"
1400	5'8"	5¾"		2 6"	6 1¾"
1500	5'8"	5½"		2'6"	6'1⅝"
1600	5'8"	5⅜"		2'6"	6'1⅜"
1800	5'8"	5"		2'6"	6'1⅛"
2000	5'8"	4¾"		2'6"	6'0⅞"
2500	5'8"	4¾"		2'6"	6'0¾"
3000	5'8"	4⅜"		2'6"	6'0½"
4000	5'8"	4"		2'6"	6'0⅛"
5000	5'8"	3⅞"		2'6"	5'11⅞"

FIGURE II-1-20

CLEARANCE TABLES
CIRCULAR TUNNEL

SW AWAY FROM CURVE CENTER

RADIUS	SEq=0"					SEq=0 1/2"				
	Y	X_T	X_A	SW	HW	Y	X_T	X_A	SW	HW
900	5'10 1/8"		4 3/8"	2'5 1/2"	6'0 3/8"	5'10 5/8"		4 1/4"	2'5 1/2"	6'0"
1000	5'9 5/8"		4 3/8"	2'6"	5'11 7/8"	5'10"		4"	2'6"	5'11 5/8"
1100	5'8 7/8"		3 5/8"	2'6"	5'11 1/2"	5'9 7/8"		3 3/8"	2'6"	5'11 1/4"
1200	5'8"		3 1/8"	2'6"	5'11 1/4"	5'8 7/8"		2 3/4"	2'6"	5'10 7/8"
1300	5'8"		2 7/8"	2'6"	5'11"	5'8"		2 3/8"	2'6"	5'10 5/8"
1400	5'8"		2 3/4"	2'6"	5'10 3/4"	5'8"		2 1/4"	2'6"	5'10 3/8"
1500	5'8"		2 1/2"	2'6"	5'10 5/8"	5'8"		2"	2'6"	5'10 1/4"
1600	5'8"		2 3/8"	2'6"	5'10 1/2"	5'8"		2"	2'6"	5'10 1/8"
1800	5'8"		2 3/8"	2'6"	5'10 3/8"	5'8"		2"	2'6"	5'10 1/8"
2000	5'8"		2 1/4"	2'6"	5'10 1/4"	5'8"		2"	2'6"	5'10 1/8"
2500	5'8"		2 1/4"	2'6"	5'10 1/4"	5'8"		2"	2'6"	5'10 1/8"
3000	5'8"		2 1/4"	2'6"	5'10 1/4"	5'8"		2"	2'6"	5'10 1/8"
4000	5'8"		2 1/4"	2'6"	5'9 3/4"	5'8"		2"	2'6"	5'10 1/8"
5000	5'8"		2"	2'6"	5'9 1/2"	5'8"		2"	2'6"	5'9"
6000	5'8"		2"	2'6"	5'9"	5'8"		2"	2'6"	5'9"
7000	5'8"		2"	2'6"	5'9"	5'8"		2"	2'6"	5'9"
8000	5'8"		2"	2'6"	5'9"	5'8"		2"	2'6"	5'9"
9000	5'8"		2"	2'6"	5'9"	5'8"		2"	2'6"	5'9"
10,000	5'8"		2"	2'6"	5'9"	5'8"		2"	2'6"	5'9"
15,000	5'8"		2"	2'6"	5'9"	5'8"		2"	2'6"	5'9"
25,000	5'8"		2"	2'6"	5'9"	5'8"		2"	2'6"	5'9"
TANGENT	5'8"		2"	2'6"	5'9"	—				

FIGURE II-1-21

CLEARANCE TABLES
CIRCULAR TUNNEL

SW AWAY FROM CURVE CENTER

RADIUS	SEa = 1"					SEa = 1 1/2"				
	Y	X_T	X_A	SW	H_W	Y	X_T	X_A	SW	HW
900	5'11 1/8"		3 3/4"	2'5 1/2"	5'11 5/8"	5'11 1/4"		3"	2'5 1/4"	5'11 3/8"
1000	5'10 1/2"		3 5/8"	2'6"	5'11 1/4"	5'10 3/4"		2 7/8"	2'5 3/4"	5'10 7/8"
1100	5'9 1/2"		2 7/8"	2'6"	5'10 7/8"	5'9 7/8"		2 1/2"	2'6"	5'10 1/2"
1200	5'8 3/4"		2 3/8"	2'6"	5'10 5/8"	5'9 1/8"		2"	2'6"	5'10 1/4"
1300	5'8 1/4"		2"	2'6"	5'10 1/4"	5'8 1/2"		1 5/8"	2'6"	5'10"
1400	5'8"		1 3/4"	2'6"	5'10 1/8"	5'8"		1 1/4"	2'6"	5'9 3/4"
1500	5'8"		1 1/2"	2'6"	5'9 7/8"	5'8"		1"	2'6"	5'9 1/2"
1600	5'8"		1 3/8"	2'6"	5'9 3/4"	5'8"		0 7/8"	2'6"	5'9 3/8"
1800	5'8"		1 1/4"	2'6"	5'9 5/8"	5'8"		0 3/4"	2'6"	5'9 1/4"
2000	5'8"		1 1/4"	2'6"	5'9 5/8"	5'8"		0 5/8"	2'6"	5'9 1/4"
2500	5'8"		1"	2'6"	5'9 3/8"	5'8"		0 1/2"	2'6"	5'8 7/8"
3000	5'8"		1"	2'6"	5'9 3/8"	5'8"		0 1/2"	2'6"	5'8 7/8"
4000	5'8"		1"	2'6"	5'9 1/8"	5'8"		0 1/2"	2'6"	5'8 7/8"
5000	5'8"		1"	2'6"	5'8 7/8"	5'8"		0 1/2"	2'6"	5'8 5/8"
6000	5'8"		1"	2'6"	5'8 3/4"	5'8"		0 1/2"	2'6"	5'7 7/8"
7000	5'8"		1"	2'6"	5'8 3/4"	5'8"		0 1/2"	2'6"	5'7 7/8"
8000	5'8"		1"	2'6"	5'8 3/4"	5'8"		0 1/2"	2'6"	5'7 7/8"
9000	6'8"		1"	2'6"	5'8 5/8"	5'8"		0 1/2"	2'6"	5'7 7/8"
10,000	5'8"		1"	2'6"	5'8 5/8"	5'8"		0 1/2"	2'6"	5'7 7/8"
15,000	5'8"		1"	2'6"	5'8 5/8"	5'8"		0 1/2"	2'6"	5'7 7/8"
	—									
	—									

FIGURE II-1-22

CLEARANCE TABLES
CIRCULAR TUNNEL

SW AWAY FROM CURVE CENTER

RADIUS	SEq = 2"					SEq = 2½"				
	Y	XT	XA	SW	HW	Y	XT	XA	SW	HW
900	5'11 5/8"		2 5/8"	2'5 1/4"	5'11"	5'11 3/4"		1 7/8"	2'5"	5'10 5/8"
1000	5'11 1/8"		2 1/2"	2'5 3/4"	5'10 1/2"	5'11 1/4"		1 7/8"	2'5 1/2"	5'10 1/4"
1100	5'10 3/8"		2 1/4"	2'6"	5'10 1/8"	5'10 3/4"		1 7/8"	2'6"	5'9 7/8"
1200	5'9 1/2"		1 5/8"	2'6"	5'9 7/8"	5'10"		1 3/8"	2'6"	5'9 1/2"
1300	5'8 7/8"		1 1/4"	2'6"	5'9 5/8"	5'9 1/4"		0 7/8"	2'6"	5'9 1/4"
1400	5'8 3/8"		0 7/8"	2'6"	5'9 3/8"	5'8 3/4"		0 1/2"	2'6"	5'9"
1500	5'8"		0 5/8"	2'6"	5'9 1/4"	5'8 1/4"		0 1/4"	2'6"	5'8 7/8"
1600	5'8"		0 3/8"	2'6"	5'9"	5'8"	0 1/8"		2'6"	5'8 3/4"
1800	5'8"		0 1/8"	2'6"	5'8 3/4"	5'8"	0 5/8"		2'6"	5'8 5/8"
2000	5'8"	0 1/8"		2'6"	5'8 5/8"	5'8"	0 5/8"		2'6"	5'8 1/4"
2500	5'8"	0 1/8"		2'6"	5'8 1/2"	5'8"	0 5/8"		2'6"	5'8 1/8"
3000	5'8"	0 1/8"		2'6"	5'8 1/2"	5'8"	0 5/8"		2'6"	5'8 1/8"
4000	5'8"	0 1/8"		2'6"	5'8 1/2"	5'8"	0 5/8"		2'6"	5'8 1/8"
5000	5'8"	0 1/8"		2'6"	5'8 1/2"	5'8"	0 5/8"		2'6"	5'8 1/8"
6000	5'8"	0 1/8"		2'6"	5'8 1/2"	5'8"	0 5/8"		2'6"	5'8 1/8"
7000	5'8"	0 1/4"		2'6"	5'7 1/2"	5'8"	0 5/8"		2'6"	5'8 1/8"
8000	5'8"	0 1/4"		2'6"	5'7 3/8"	5'8"	0 5/8"		2'6"	5'7"
9000	5'8"	0 1/4"		2'6"	5'7 3/8"	5'8"	0 5/8"		2'6"	5'7"
10,000	5'8"	0 1/4"		2'6"	5'7 3/8"	—				
15,000	—					—				
25,000										

CLEARANCE TABLES
CIRCULAR TUNNEL

FIGURE II-1-23

SW AWAY FROM CURVE CENTER

RADIUS	SEq = 3" Y	SEq = 3" X_T	SEq = 3" X_A	SEq = 3" SW	SEq = 3" HW	SEq = 3½" Y	SEq = 3½" X_T	SEq = 3½" X_A	SEq = 3½" SW	SEq = 3½" HW
900	5'11⅞"		1½"	2'5"	5'10¼"	5'11⅞"		0⅞"	2'5"	5'9⅞"
1000	5'11⅝"		1½"	2'5½"	5'9⅞"	5'11⅝"		0⅝"	2'5¼"	5'9½"
1100	5'11¼"		1½"	2'6"	5'9½"	5'11¼"		0⅝"	2'5¾"	5'9⅛"
1200	5'10⅜"		0⅞"	2'6"	5'9⅛"	5'10⅝"		0½"	2'6"	5'8¾"
1300	5'9⅝"		0½"	2'6"	5'8⅞"	5'10"	0	0	2'6"	5'8½"
1400	5'9⅛"		0⅛"	2'6"	5'8¾"	5'9⅜"	0⅜"		2'6"	5'8¼"
1500	5'8⅝"	0¼"		2'6"	5'8½"	5'8⅞"	0¾"		2'6"	5'8⅛"
1600	5'8⅛"	0½"		2'6"	5'8⅜"	5'8½"	1"		2'6"	5'7⅞"
1800	5'8"	0¾"		2'6"	5'8⅛"	5'8"	1⅜"		2'6"	5'7⅝"
2000	5'8"	1"		2'6"	5'7⅞"	5'8"	1⅝"		2'6"	5'7⅜"
2500	5'8"	1½"		2'6"	5'7⅝"	5'8"	2"		2'6"	5'7"
3000	5'8"	1½"		2'6"	5'7⅜"	5'8"	2"		2'6"	5'7"
4000	5'8"	1⅝"		2'6"	5'7¼"	5'8"	2¼"		2'6"	5'6¾"
5000	5'8"	1⅞"		2'6"	5'7"	5'8"	2⅜"		2'6"	5'6⅝"
6000	5'8"	2"		2'6"	5'6⅞"	5'8"	2⅝"		2'6"	5'6½"
7000	5'8"	2⅛"		2'6"	5'6¾"	–				
8000	5'8"	2¼"		2'6"	5'6¾"	–				

FIGURE II-1-24

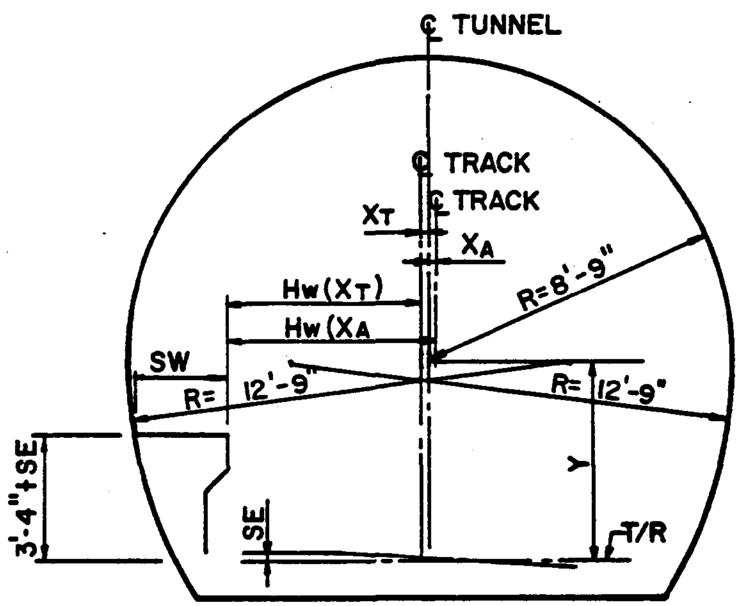
CLEARANCE TABLES
CIRCULAR TUNNEL

FIGURE II-1-25

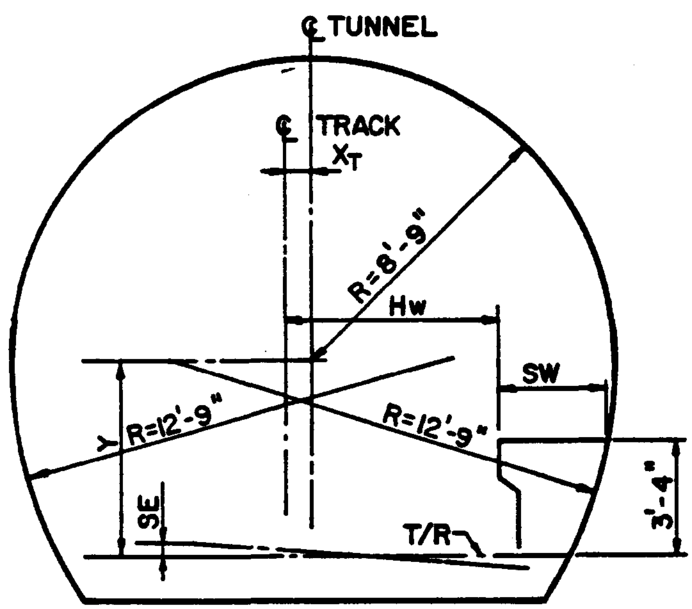
SW AWAY FROM CURVE CENTER

RADIUS	$SE_q = 4''$				
	Y	X_T	X_A	SW	HW
900	5'11 3/4"		0 3/8"	2'5"	5'9 1/2"
1000	5'11 7/8"		0 1/8"	2'5 1/4"	5'9"
1100	5'11 1/2"		0 1/8"	2'5 3/4"	5'8 5/8"
1200	5'11"	0	0	2'6"	5'8 3/8"
1300	5'10 1/4"	0 1/2"		2'6"	5'8 1/8"
1400	5'9 5/8"	0 7/8"		2'6"	5'7 7/8"
1500	5'9 1/8"	1 1/4"		2'6"	5'7 5/8"
1600	5'8 3/4"	1 1/2"		2'6"	5'7 1/2"
1800	5'8"	1 3/4"		2'6"	5'7 1/4"
2000	5'8"	2 1/8"		2'6"	5'7"
2500	5'8"	2 1/4"		2'6"	5'6 5/8"
3000	5'8"	2 1/2"		2'6"	5'6 5/8"
4000	5'8"	2 3/4"		2'6"	5'6 3/8"
5000	5'8"	3"		2'6"	5'6 1/8"

CLEARANCE TABLES
CIRCULAR TUNNEL



SAFETY WALK AWAY FROM CURVE CENTER



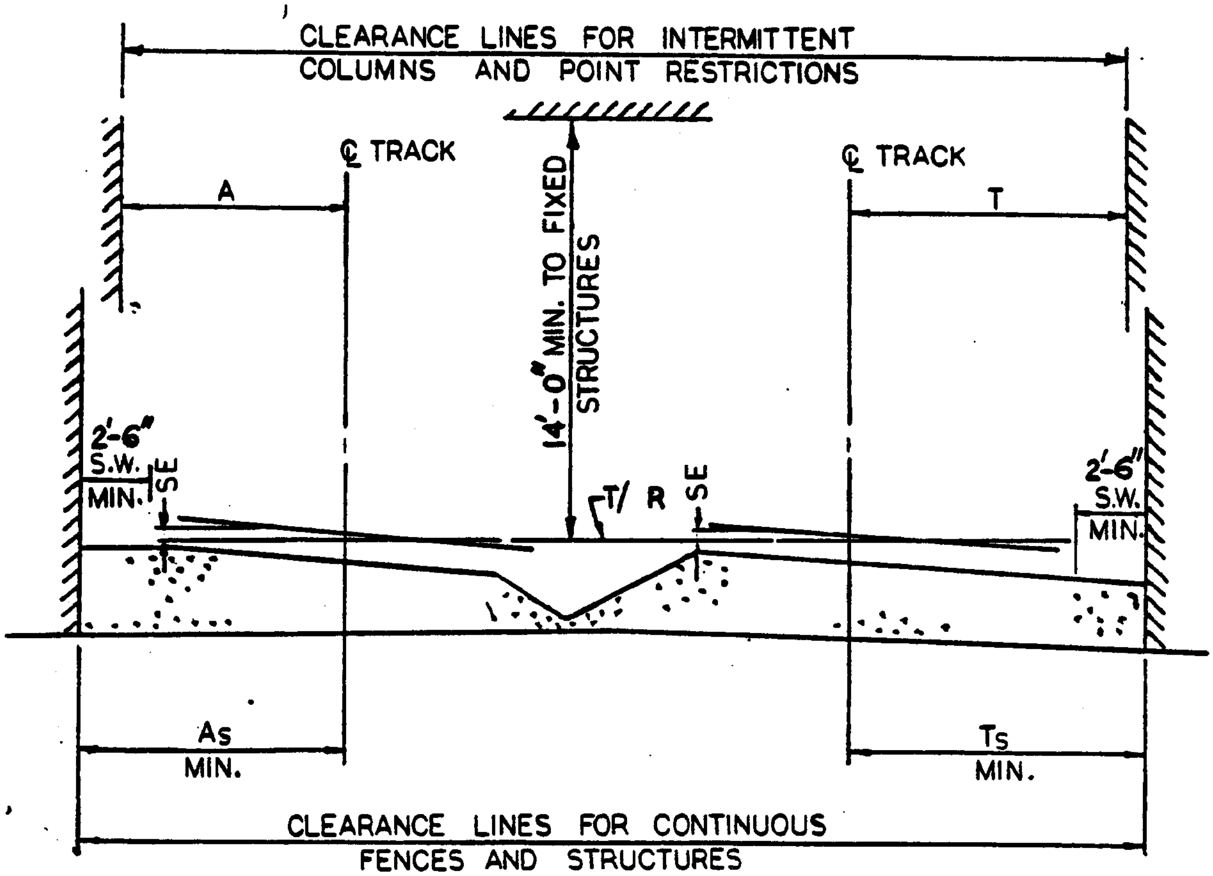
SAFETY WALK TOWARDS CURVE CENTER

FOR ABBREVIATIONS SEE FIGURE II-1-8

FOR X_A, X_T, Hw & Y VALUES SEE FIGURES II-1-16 THRU II-1-25

SINGLE TRACK HORSESHOE ROCK TUNNEL CLEARANCE DIAGRAM

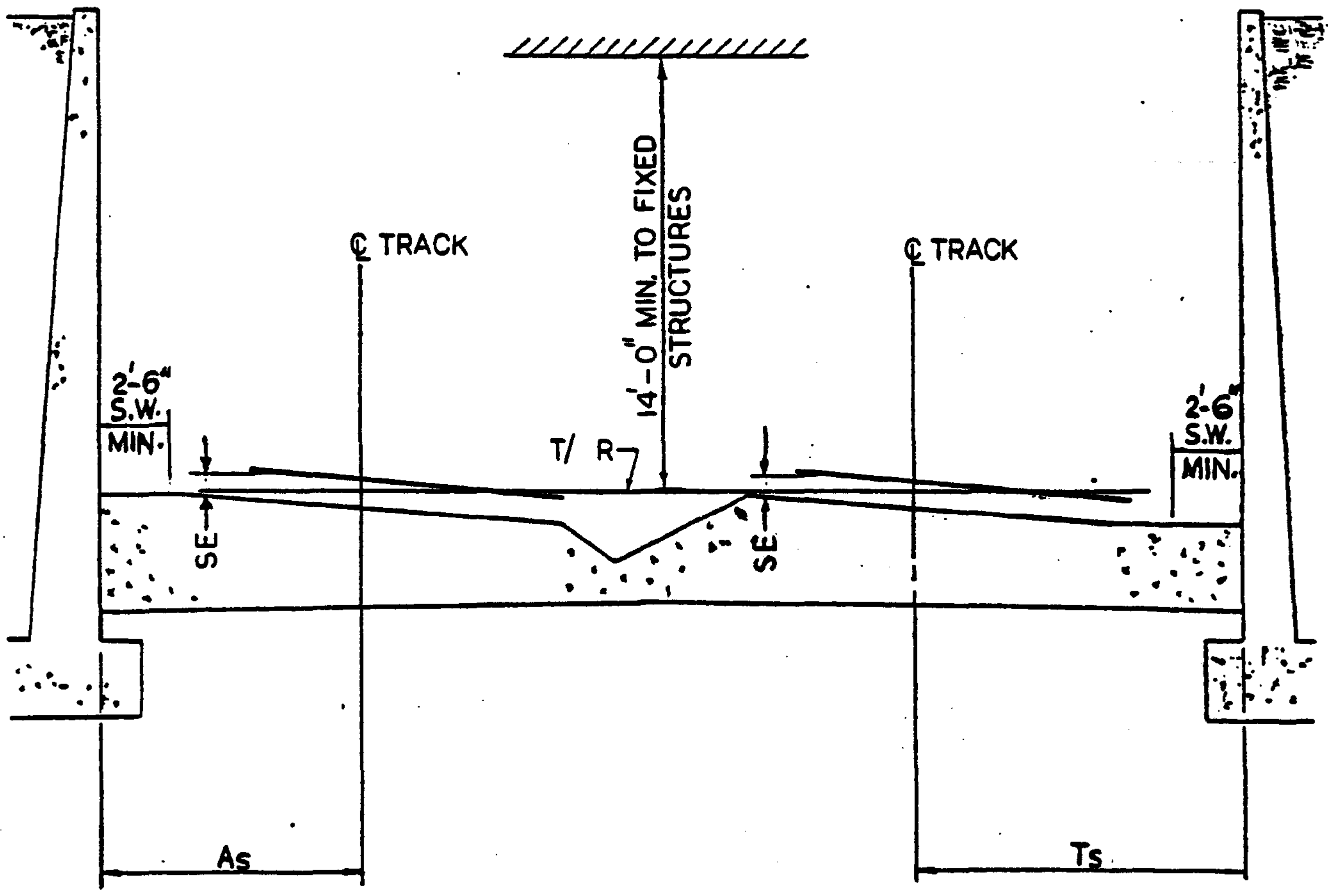
FIGURE II-1-26



FOR ABBREVIATIONS SEE FIGURE II - 1 - 8

FOR As,A,Ts & T VALUES SEE FIGURES II-1-10,11,12,13 & 14

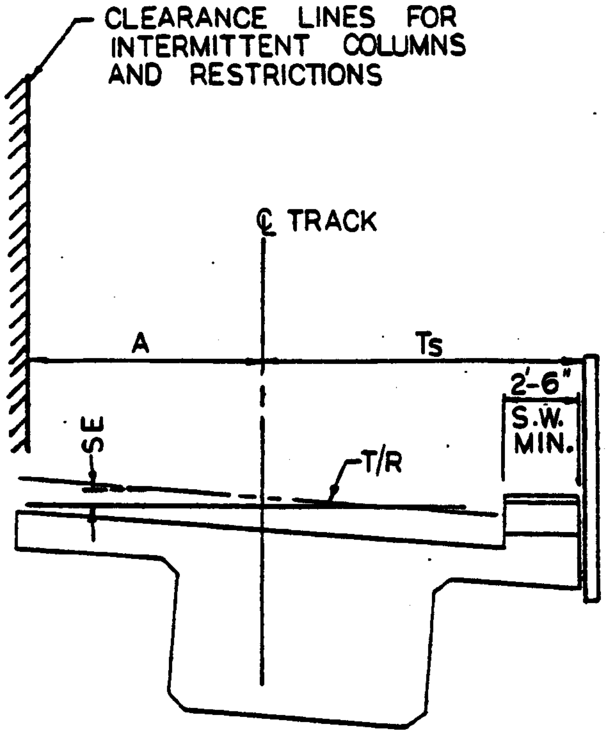
SURFACE TRACK SECTION
CLEARANCE DIAGRAM
FIGURE II-1-27



FOR ABBREVIATIONS SEE FIGURE II - 1 - 8

FOR As & Ts VALUES SEE FIGURES II - 1 -10,11,12,13, & 14

RETAINING WALL SECTION
CLEARANCE DIAGRAM
FIGURE II - 1 -28

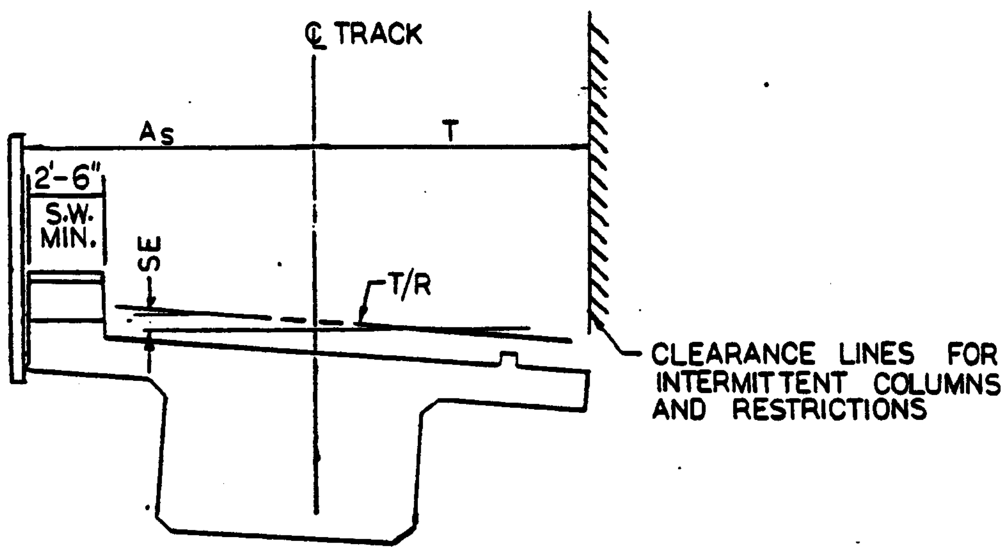


SAFETY WALK TOWARDS CURVE CENTER

FOR ABBREVIATIONS SEE FIGURE II-1-8

FOR A&T VALUES SEE FIGURES II-1-10,11,12,13,&14

FOR As &Ts VALUES SEE FIGUIRES II-1-30,31,&32



SAFETY WALK AWAY FROM CURVE CENTER

AERIAL STRUCTURE

CLEARANCE DIAGRAM

FIGURE II-1-29

RADIUS	SUPERELEVATION							
	0"		1/2"		1"		1 1/2"	
	A_s	T_s	A_s	T_s	A_s	T_s	A_s	T_s
1000'	8'-10 3/4"	8'-9 3/4"	8'-10 1/8"	8'-10 5/8"	8'-9 1/2"	8'-11 5/8"	8'-9"	9'-0 3/4"
1200'	8'-9 7/8"	8'-9 1/8"	8'-9 1/4"	8'-9 7/8"	8'-8 5/8"	8'-10 7/8"	8'-8 1/8"	9'-0"
1400'	8'-9 1/4"	8'-8 1/2"	8'-8 5/8"	8'-9 3/8	8'-8"	8'-10 3/8"	8'-7 1/2"	8'-11 1/2"
1600'	8'-8 3/4"	8'-8 1/8"	8'-8 1/8"	8'-8 7/8"	8'-7 5/8"	8'-10"	8'-7"	8'-11 1/8"
1800'	8'-8 3/8"	8'-7 7/8"	8'-7 3/4"	8'-8 5/8"	8'-7 1/4"	8'-9 3/4"	8'-6 5/8"	8'-10 7/8"
2000'	8'-8 1/8"	8'-7 5/8"	8'-7 1/2"	8'-8 3/8"	8'-6 7/8"	8'-9 1/2"	8'-6 3/8"	8'-10 5/8"
2500'	8'-8 5/8"	8'-7 1/8"	8'-8 1/8"	8'-8"	8'-7 1/2"	8'-9"	8'-7"	8'-10 1/8"
3000'	8'-8 1/8"	8'-6 7/8"	8'-7 1/2"	8'-7 5/8"	8'-7"	8'-8 3/4"	8'-6 3/8"	8'-9 7/8"
4000'	8'-7 1/2"	8'-6 1/2"	8'-6 7/8"	8'-7 1/4"	8'-6 1/4"	8'-8 3/8"	8'-5 3/4"	8'-9 1/2"
5000'	8'-7"	8'-6 1/4"	8'-6 1/2"	8'-7 1/8"	8'-5 7/8"	8'-8 1/8"	8'-5 3/8"	8'-9 1/4"
6000'	8'-6 3/4"	8'-6 1/8"	8'-6 1/4"	8'-6 7/8"	8'-5 3/8"	8'-8"	8'-5"	8'-9 1/8"
7000'	8'-6 5/8"	8'-6"	8'-6"	8'-6 7/8"	8'-5 1/2"	8'-7 7/8"	8'-4 7/8"	8'-9"
8000'	8'-6 3/8"	8'-6"	8'-5 7/8"	8'-6 3/4"	8'-5 1/4"	8'-7 7/8"	8'-4 3/4"	8'-8 7/8"
9000'	8'-6 3/8"	8'-5 7/8"	8'-5 3/4"	8'-6 5/8"	8'-5 1/8"	8'-7 3/4"	8'-4 5/8"	8'-8 7/8"
10,000'	8'-6 1/4"	8'-5 7/8"	8'-5 5/8"	8'-6 5/8"	8'-5 1/8"	8'-7 3/4"	8'-4 1/2"	8'-8 7/8"
15,000'	8'-6"	8'-5 3/4"	8'-5 3/8"	8'-6 1/2"	8'-4 7/8"	8'-7 5/8"	8'-4 1/4"	8'-8 5/8"
25,000'	8'-5 3/4"	8'-5 5/8"	8'-5 1/8"	8'-6 3/8"	8'-4 5/8"	8'-7 1/2"	8'-4"	8'-8 1/2"
TANGENT	8'-5 3/8"	8'-5 3/8"						

CLEARANCE TABLES
AERIAL STRUCTURES
FIGURE II-1-30

RADIUS	SUPERELEVATION							
	2"		2½"		3"		3½"	
	As	Ts	As	Ts	As	Ts	As	Ts
1000'	8'-8 3/8"	9'-1 7/8"	8'-7 3/4"	9'-2 7/8"	8'-7 1/4"	9'-4"	8'-6 5/8"	9'-5 1/8"
1200'	8'-7 1/2"	9'-1 1/8"	8'-6 7/8"	9'-2 1/4"	8'-6 3/8"	9'-3 1/4"	8'-5 3/4"	9'-4 3/8"
1400'	8'-6 7/8"	9'-0 5/8"	8'-6 1/4"	9'-1 5/8"	8'-5 3/4"	9'-2 3/4"	8'-5 1/8"	9'-3 7/8"
1600'	8'-6 3/8"	9'-0 1/4"	8'-5 7/8"	9'-1 1/4"	8'-5 1/4"	9'-2 3/8"	8'-4 5/8"	9'-3 1/2"
1800'	8'-6 1/8"	8'-11 7/8"	8'-5 1/2"	9'-1"	8'-4 7/8"	9'-2 1/8"	8'-4 1/4"	9'-3 1/8"
2000'	8'-5 3/4"	8'-11 5/8"	8'-5 1/8"	9'-0 3/4"	8'-4 5/8"	9'-1 7/8"	8'-4"	9'-2 5/8"
2500'	8'-6 3/8"	8'-11 1/4"	8-5 3/4	9'-0 1/4"	8'-5 1/4"	9'-1 3/8"	8'-4 5/8"	9'-2 1/2"
3000'	8'-5 7/8"	8'-10 7/8"	8'-5 1/4"	9'-0"	8'-4 5/8"	9'-1 1/8"	8'-4"	9'-2 1/8"
4000'	8'-5 1/8"	8'-10 5/8"	8'-4 5/8"	8'-11 5/8"	8'-4"	9'-0 3/4"	8'-3 3/8"	9'-1 3/4"
5000'	8'-4 3/4"	8'-10 3/8"	8'-4 1/8"	8'-11 3/8"	8'-3 5/8"	9'-0 1/2"	8'-3"	9'-1 5/8"
6000'	8'-4 1/2"	8'-10 1/2"	8'-3 7/8"	8'-11 1/4"	8'-3 1/4"	9'-0 3/8"	8'-2 3/4"	9'-1 3/8"
7000'	8'-4 1/4"	8'-10 1/8"	8'-3 3/4"	8'-11 1/8"	8'-3 1/8"	9'-0 1/4"	8'-2 1/2"	9'-1 3/8"
8000'	8'-4 1/8"	8'-10"	8'-3 1/2"	8'-11 1/8"	8'-3"	9'-0 1/8"	8'-2 3/8"	9'-1 1/4"
9000'	8'-4"	8'-10"	8'-3 1/2"	8'-11"	8'-2 7/8"	9'-0 1/8"	8'-2 1/4"	9'-1 1/4"
10,000'	8'-3 7/8"	8'-9 7/8"	8'-3 3/8"	8'-11"	8'-2 3/4"	9'-0 1/8"	8'-2 1/8"	9'-1 1/8"
15,000'	8'-3 5/8"	8'-9 3/4"	8'-3 1/8"	8'-10 7/8"	8'-2 1/2"	8'-11 7/8"	8'-1 7/8"	9'-1"
25,000'	8'-3 1/2	8'-9 5/8"	8'-2 7/8"	8'-10 3/4"	8'-2 1/4"	8'-11 3/4"	8'-1 5/8"	9'-0 7/8"

CLEARANCE TABLES
AERIAL STRUCTURES
FIGURE II - 1 - 31

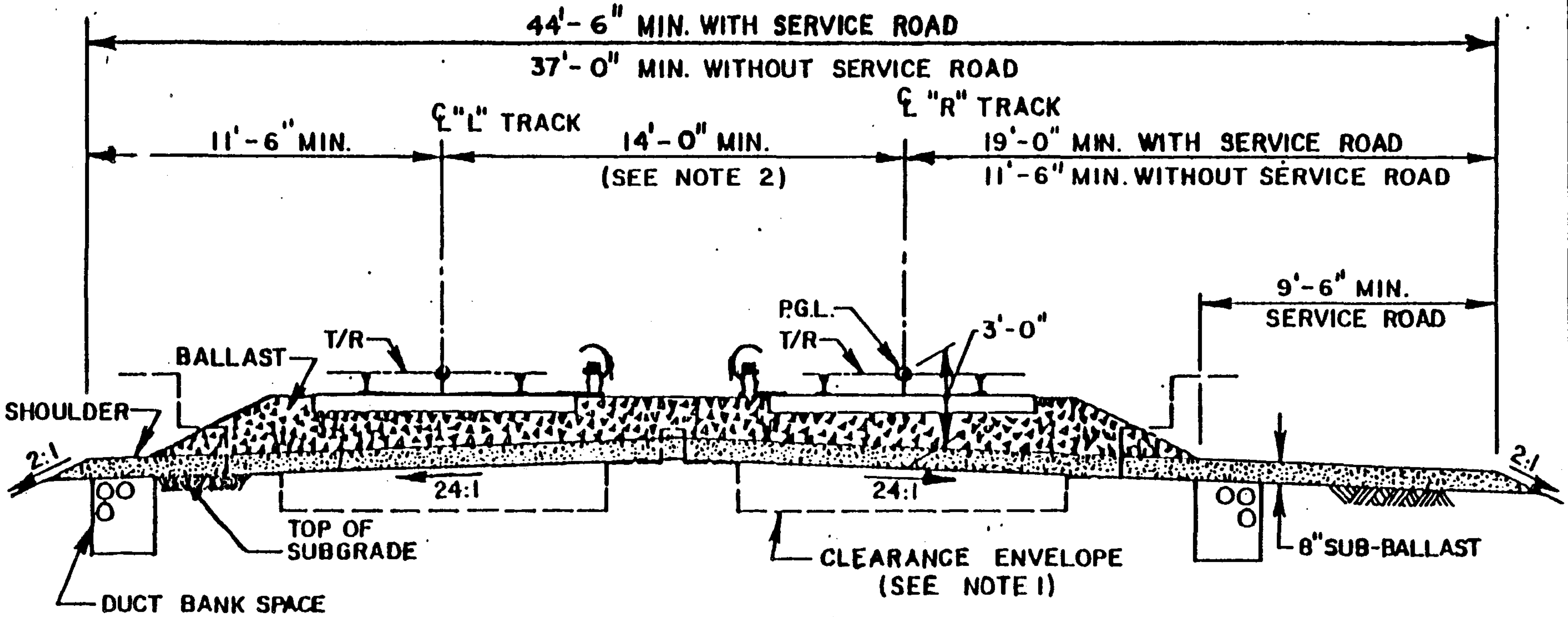
RADIUS	SUPERELEVATION							
	4"							
	A_s	T_s	A_s	T_s	A_s	T_s	A_s	T_s
1000'	8'-6"	9-6 1/8						
1200'	8-5 1/8	9-5 3/8						
1400'	8-4 1/2	9-4 7/8						
1600'	8-4	9-4 1/2						
1800'	8-3 3/4	9-4 1/2						
2000'	8-3 3/8	9-4						
2500'	8-4	9-3 1/2						
3000'	8-3 1/2	9-3 1/4						
4000'	8-2 3/4	9-2 7/8						
5000'	8-2 3/8	9-2 5/8						
6000'	8-2 1/8	9-2 1/2						
7000'	8-1 7/8	9-2 3/8						
8000'	8-1 3/4	9-2 3/8						
9000'	8-1 5/8	9-2 1/4						
10,000'	8-1 5/8	9-2 1/4						
15,000'	8-1 1/4	9-2 1/8						
25,000'	8-1 1/8	9-2						

CLEARANCE TABLES

AERIAL STRUCTURES

FIGURE II - 1 - 32

TYPICAL AT - GRADE TANGENT TRACK
FIGURE II - 1 - 33

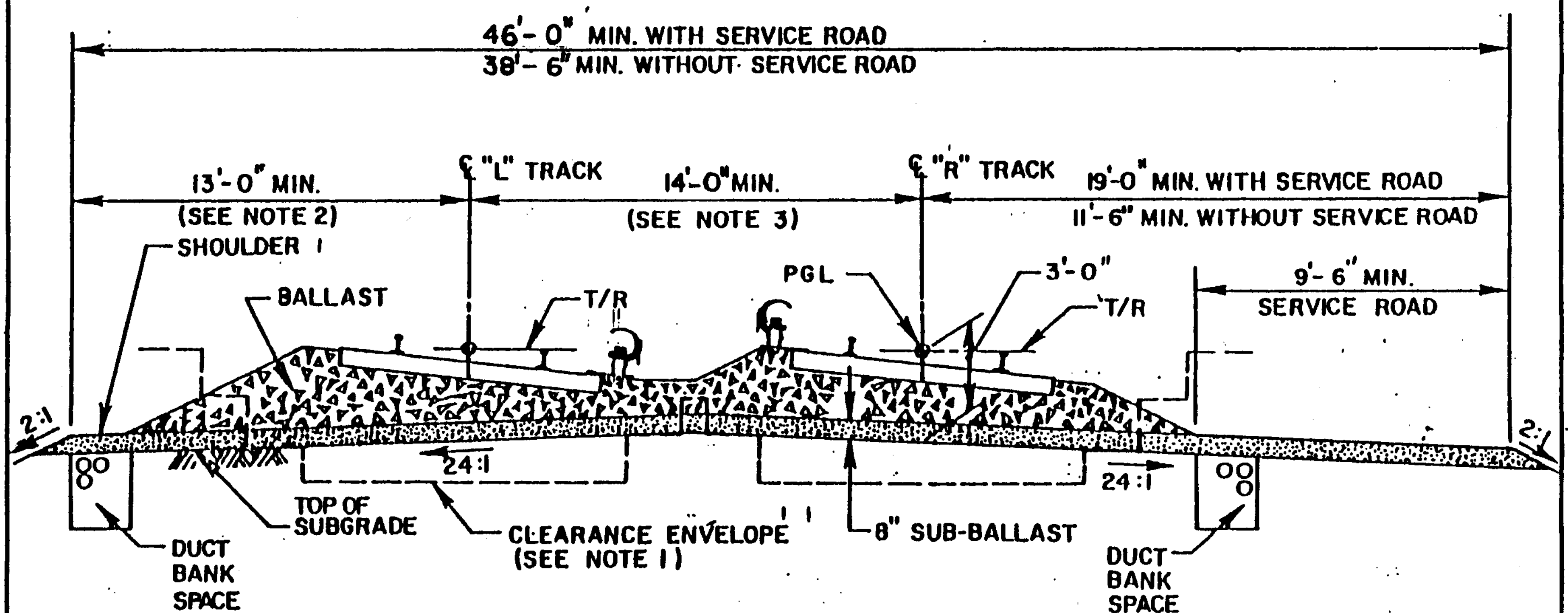


NOTE:

1. REFER TO FIGURE II-1-39 FOR CLEARANCE ENVELOPE DIMENSIONS.
2. WHERE GREATER THAN 26'-0", TREAT AS 2 SINGLE TRACKS.

NOT TO SCALE

TYPICAL AT - GRADE
CURVED TRACK
FIGURE II-1-34



NOTE:

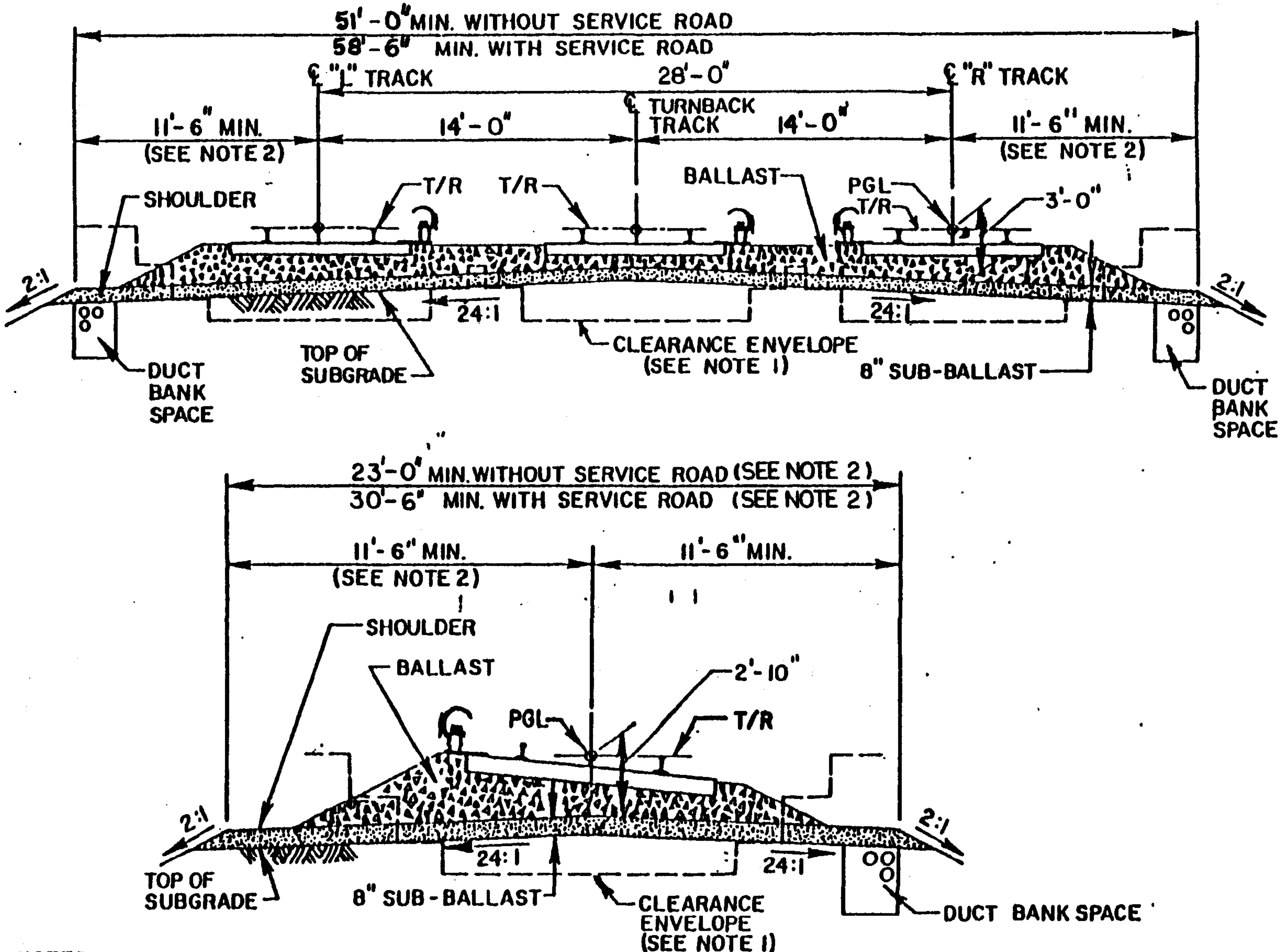
1 REFER TO FIGURE II-1-39 FOR CLEARANCE ENVELOPE DIMENSIONS.

2. THIS DIMENSION IS FOR CURVED TRACK RADII LESS THAN 10,000 FEET. THIS DIMENSION SHALL BE 11'-6" FOR TRACK RADII EQUAL TO OR GREATER THAN 10,000 FEET.

3. WHERE GREATER THAN 26'-0", TREAT AS 2 SINGLE TRACKS.

NOT TO SCALE

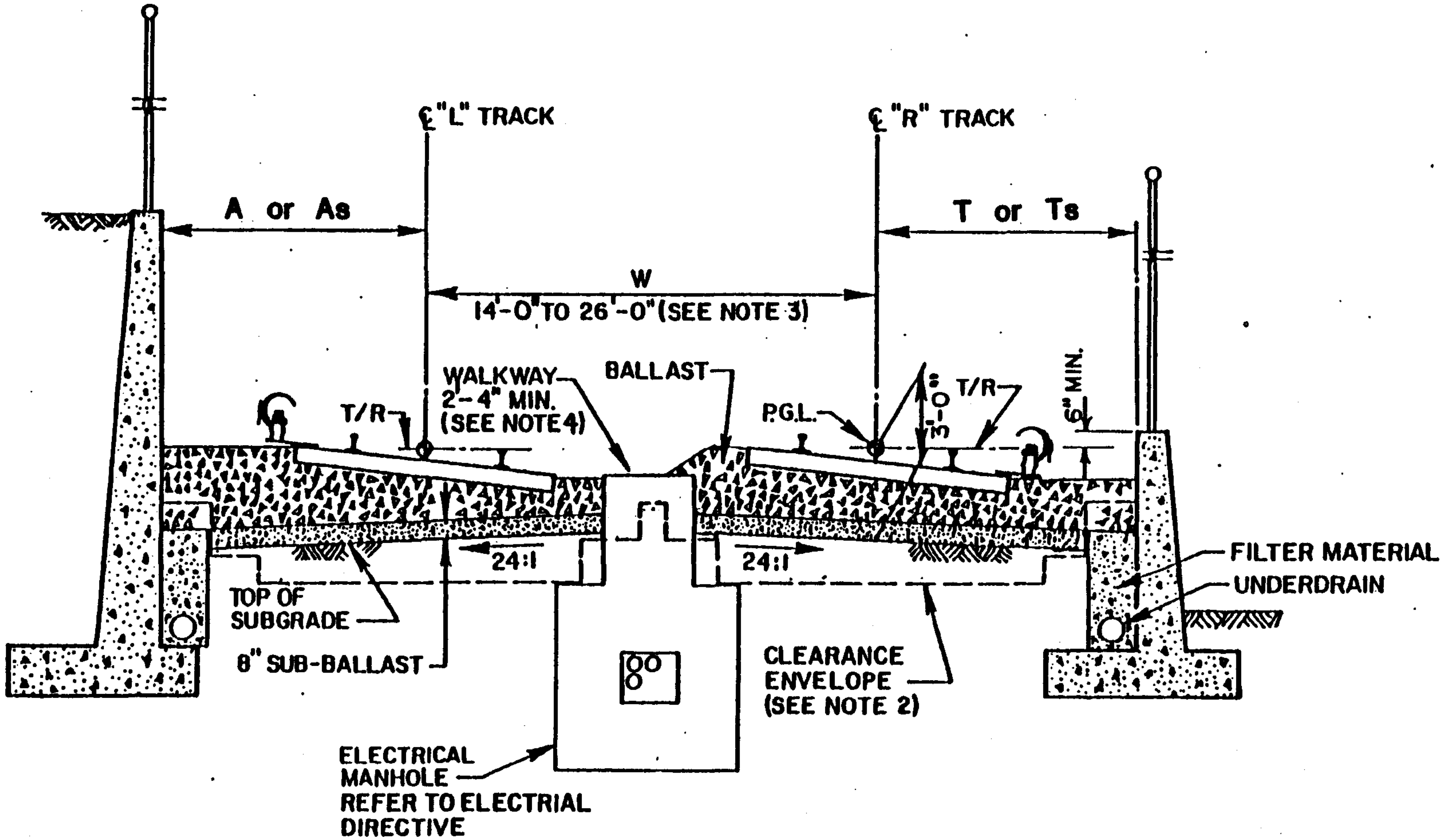
TYPICAL AT-GRADE SINGLE AND TRIPLE TRACK
FIGURE II-1-35



NOTES:

1. REFER TO FIGURE II-1-39 FOR CLEARANCE ENVELOPE DIMENSIONS.
2. THIS DIMENSION IS FOR TANGENT TRACK AND CURVED TRACK WHERE THE RADIUS IS EQUAL TO OR GREATER THAN 10,000 FEET. FOR CURVE TRACK WHERE THE RADIUS IS LESS THAN 10,000 FEET THIS DIMENSION ON THE OUTSIDE OF THE CURVE SHALL BE MINIMUM 13'-0."

NOT TO SCALE

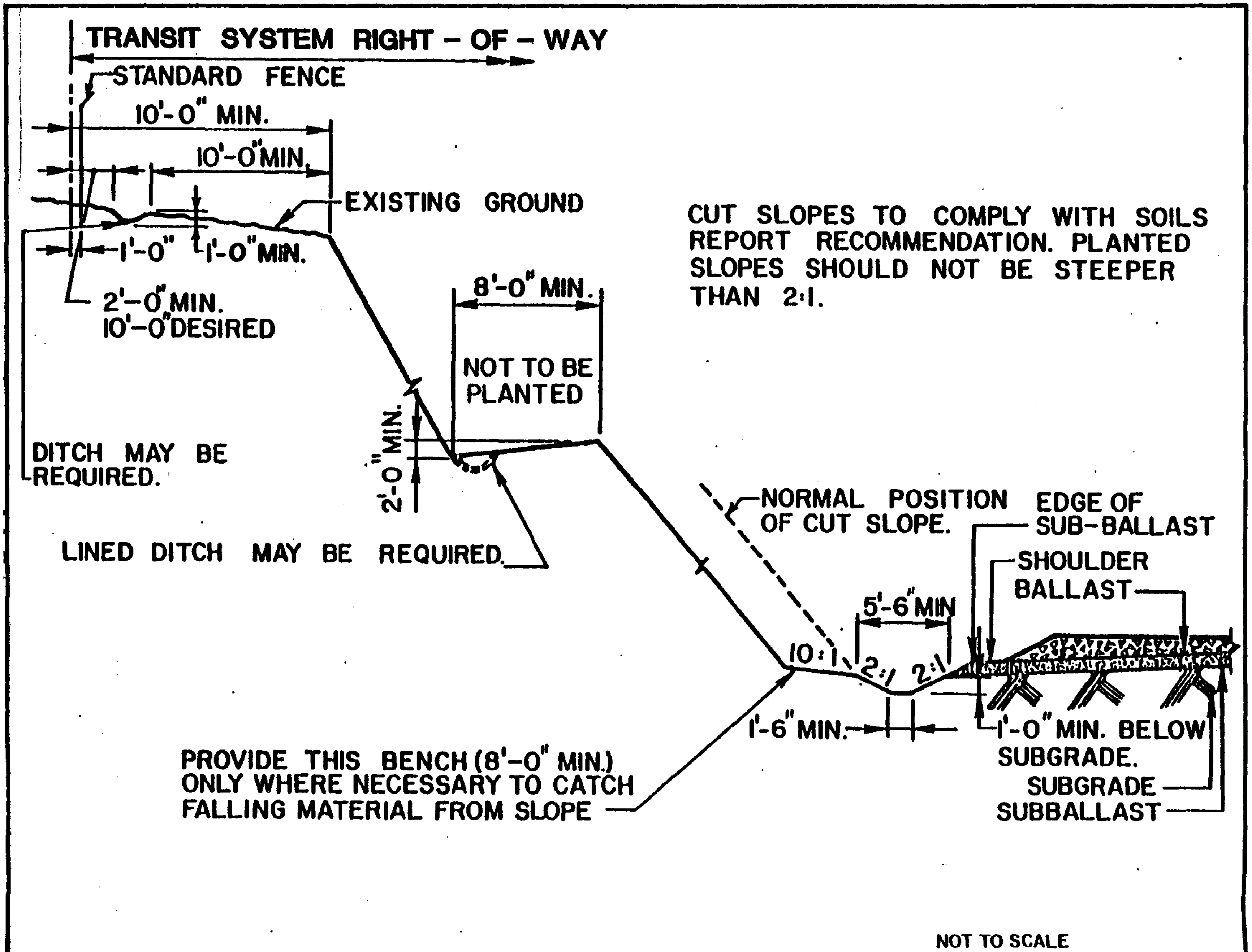


NOTES:

1. FOR A AND T DIMENSIONS REFER TO VOLUME II, SECTION 1.6.2 CLEARANCES.
2. REFER TO FIGURE II-1-39, FOR CLEARANCE ENVELOPE DIMENSIONS.
3. WHERE GREATER THAN 26'-0" TREAT AS 2 SINGLE TRACKS.
4. WALKWAY MAY BE EITHER BETWEEN THE TRACKS OR ON THE OUTSIDE OF EACH TRACK.

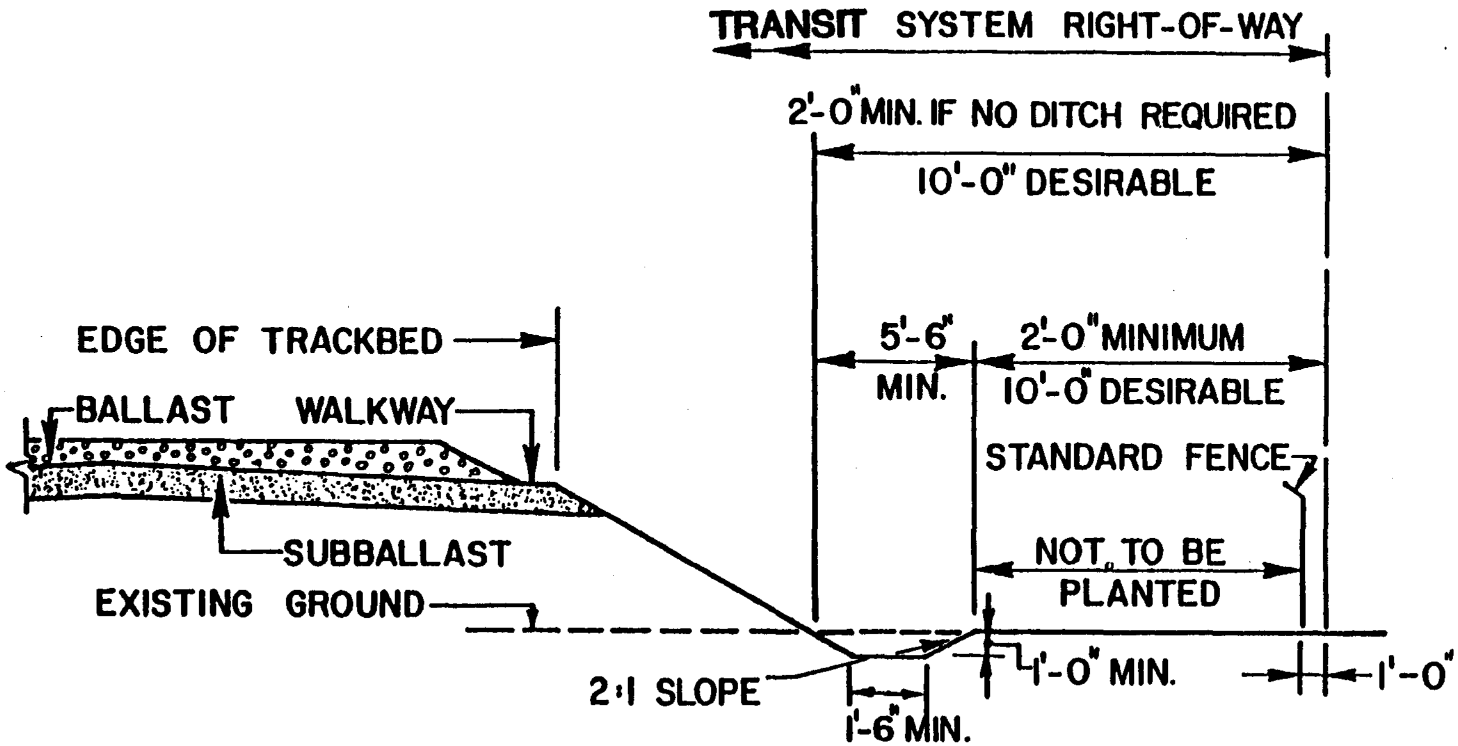
NOT TO SCALE

TYPICAL AT-GRADE RETAINED TRACK
FIGURE II-1-36



HALF TRACKWAY SECTION IN CUT

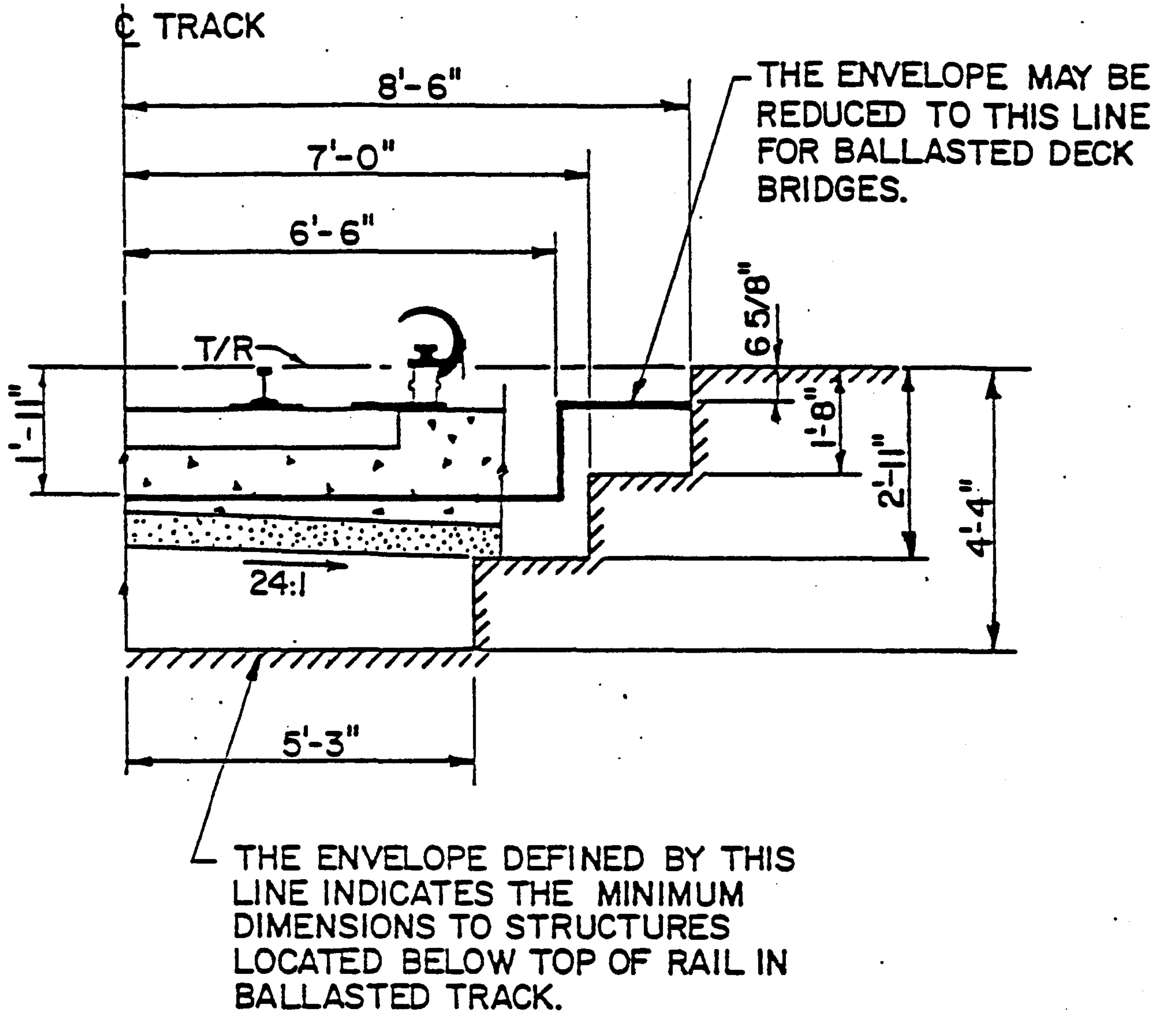
FIGURE II-1-37



FILL SLOPES TO COMPLY WITH SOILS REPORT RECOMMENDATION. PLANTED SLOPES SHOULD NOT BE STEEPER THAN 2:1

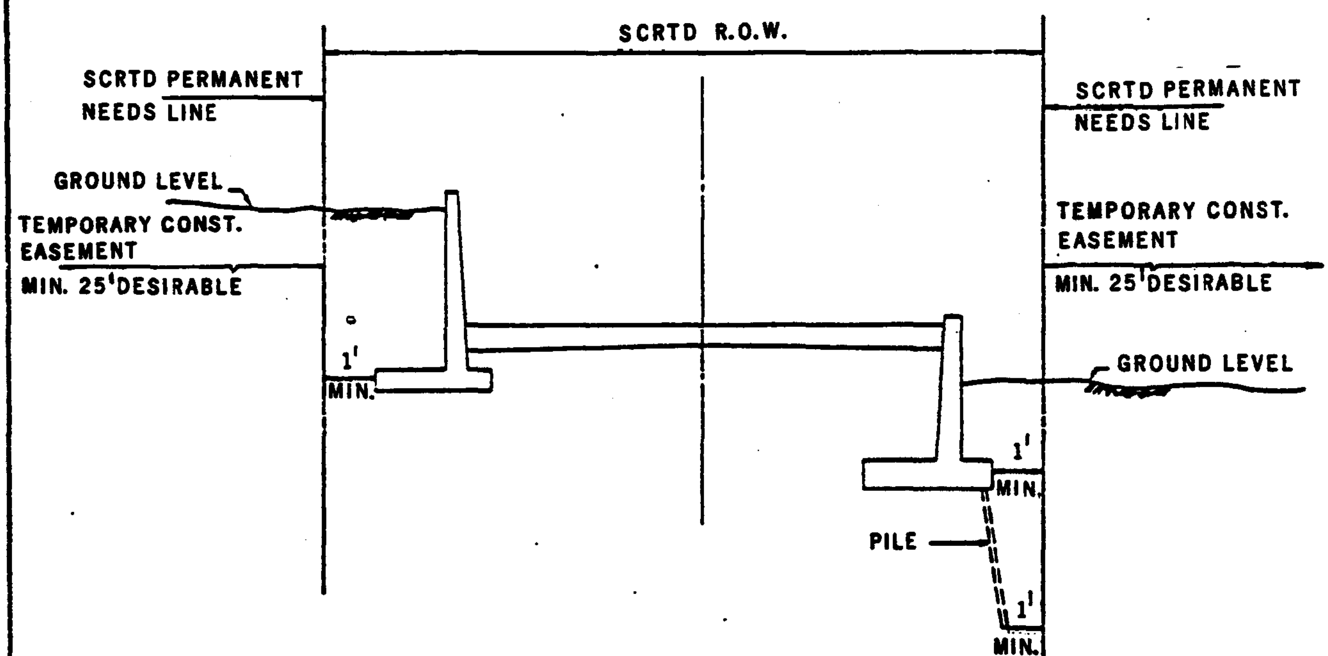
NOT TO SCALE

HALF TRACKWAY SECTION IN FILL
FIGURE II-1-38



CLEARANCE ENVELOPE FOR STRUCTURES BELOW T/R IN BALLASTED TRACK

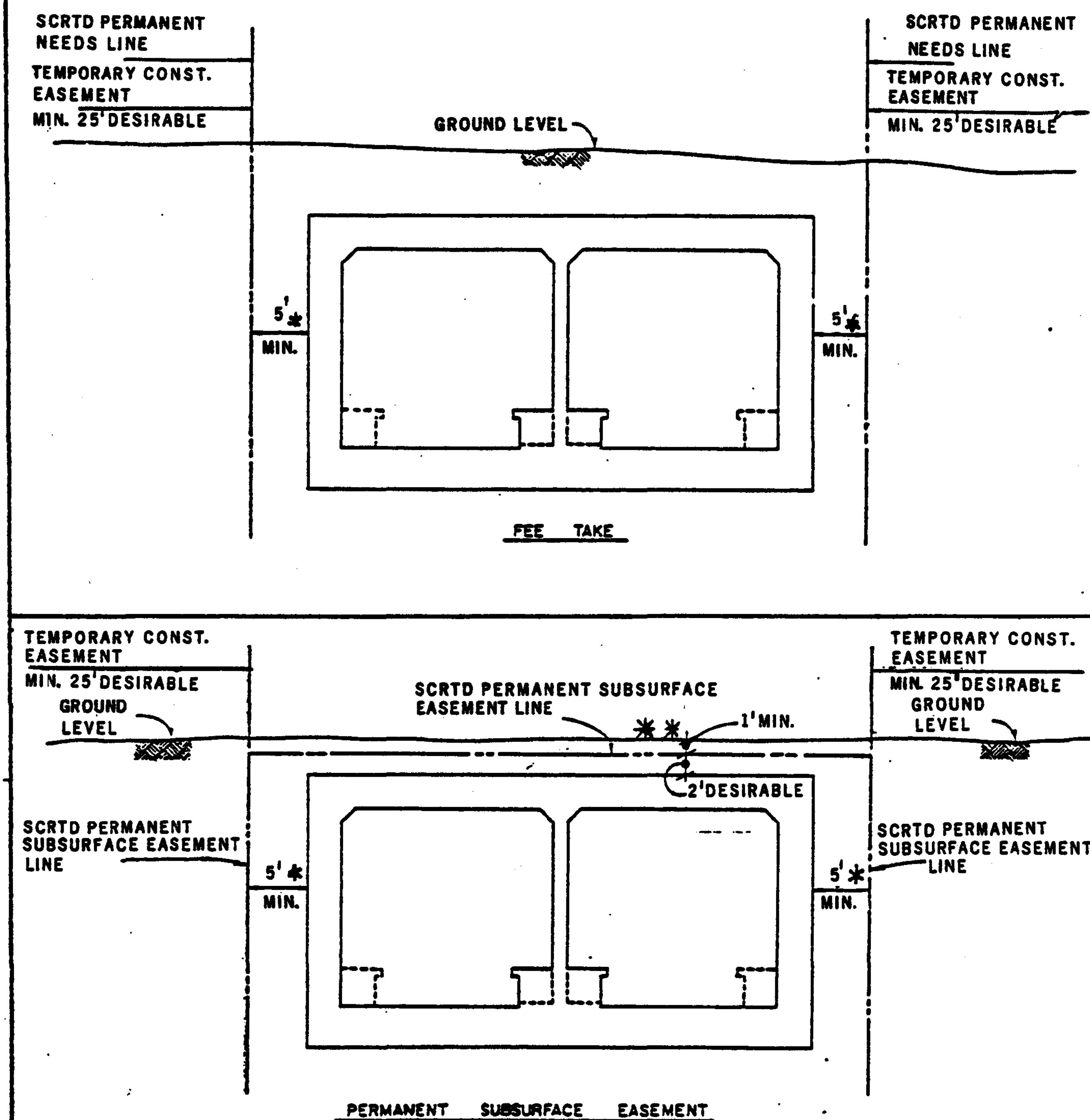
FIGURE II-1-39



NOTES:

1. THIS SECTION IS PROVIDED AS A GUIDELINE FOR ESTABLISHING RIGHT-OF-WAY LIMITS ONLY.
2. DIMENSIONS GIVEN ARE FOR GENERAL CONDITIONS AND ARE TO BE MODIFIED WHERE ENGINEERING OR REAL ESTATE REQUIREMENTS DICTATE.

RIGHT - OF - WAY TYPICAL SECTION
RETAINED AT - GRADE SECTION
THROUGH PRIVATE PROPERTY
FIGURE II - 1 - 40

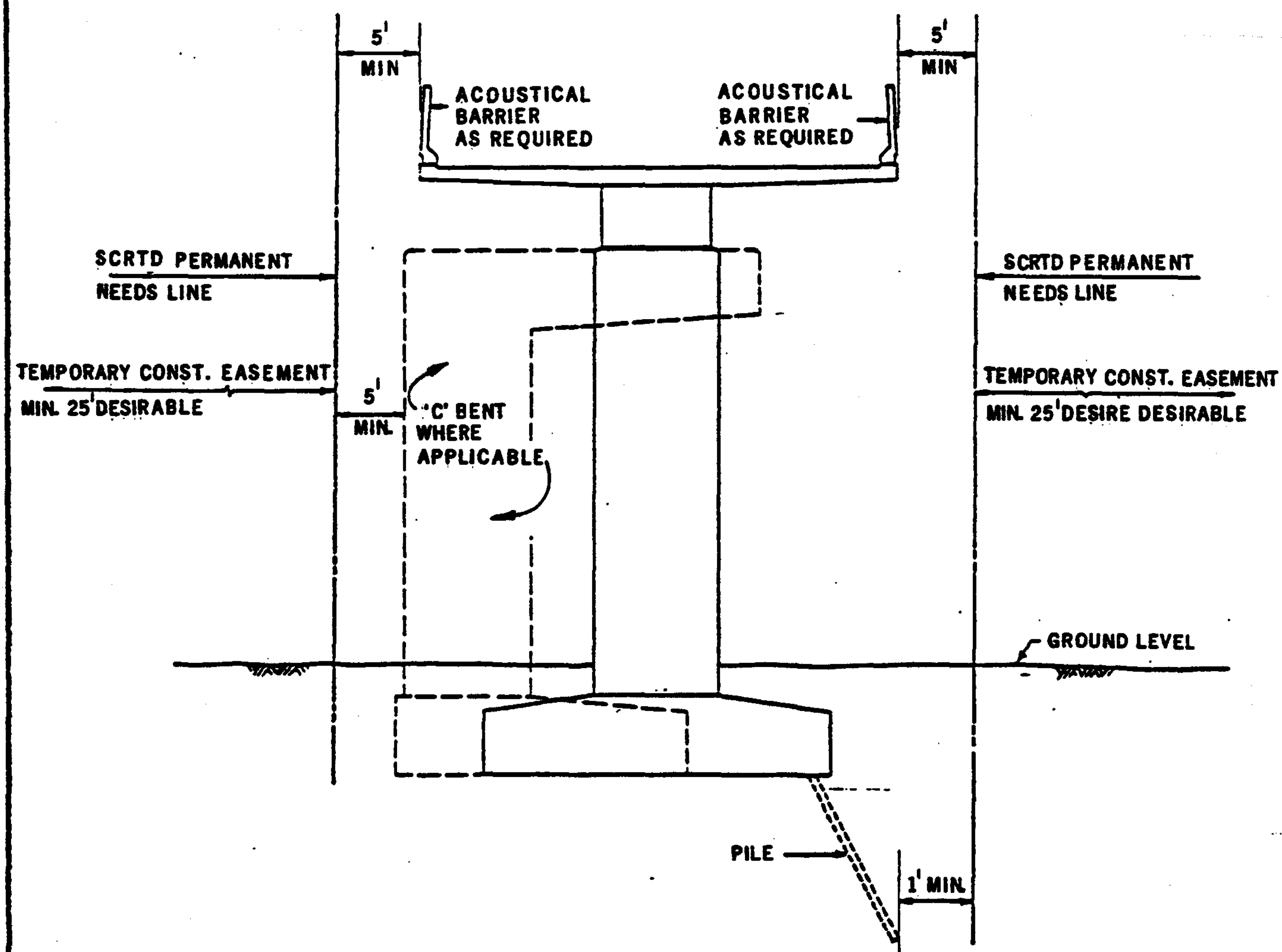


NOTE: THESE SECTIONS ARE PROVIDED ONLY AS GUIDELINES FOR ESTABLISHING RIGHT-OF-WAY LIMITS. DIMENSIONS MAY BE MODIFIED WHERE ENGINEERING OR REAL ESTATE REQUIREMENTS DICTATE.

* DESIRABLE MINIMUM
ABSOLUTE MINIMUM = 1' WHERE EXCAVATION SUPPORT SYSTEMS ARE NOT USED.
ABSOLUTE MINIMUM = 3' WHERE EXCAVATION SUPPORT SYSTEMS ARE USED.

* * WHERE UTILITIES ARE NOT A CONSIDERATION; WHERE UTILITIES MUST BE CONSIDERED, ABSOLUTE MINIMUM COVER = 8' – 0"

RIGHT - OF - WAY TYPICAL SECTION
SUBWAY
FIGURE II - 1 - 41



NOTES

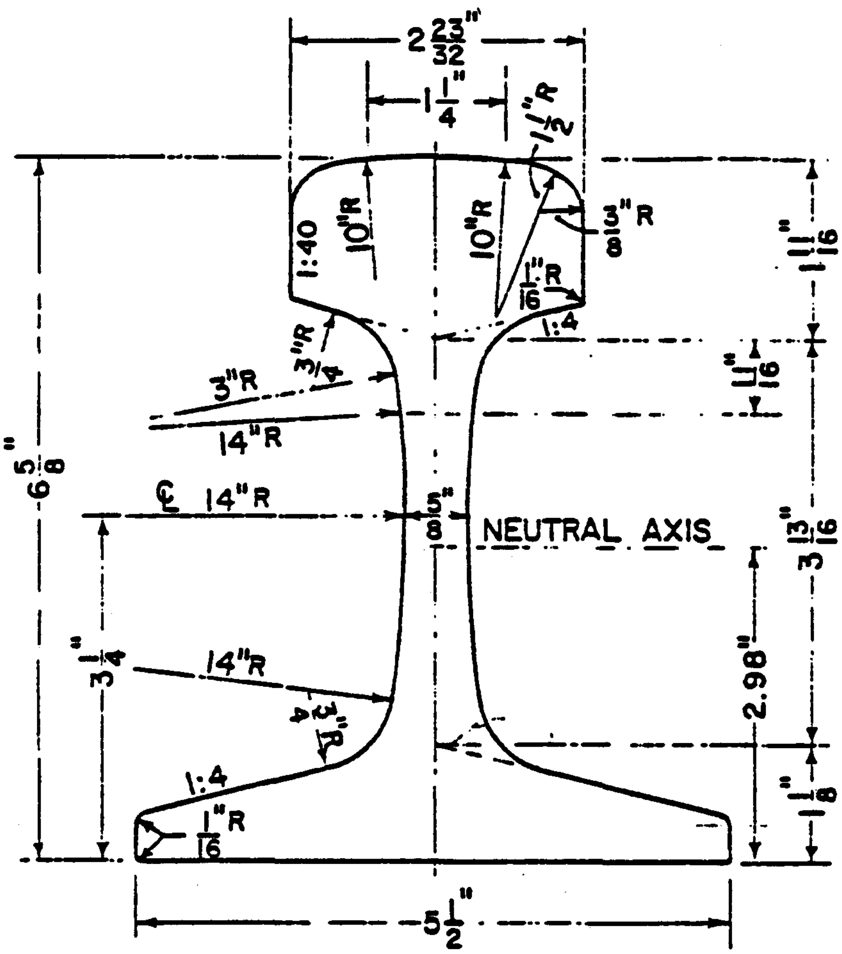
1. THIS SECTION IS PROVIDED AS A GUIDELINE FOR ESTABLISHING RIGHT-OF-WAY LIMITS ONLY.
2. DIMENSIONS GIVEN ARE FOR GENERAL CONDITIONS AND ARE TO BE MODIFIED WHERE ENGINEERING OR REAL ESTATE REQUIREMENTS DICTATE.

RIGHT - OF - WAY TYPICAL SECTION

AERIAL SECTION THROUGH PRIVATE PROPERTY

04/30/85 Revision 1

FIGURE II-1-42



	Area, Sq In	Percent
Head	3.91	34.8
Web	3.05	27.1
Base	4.29	38.1
Total	11.25	100.0

Moment of inertia, in.[4]	65.6
Section modulus, head, in.[3]	18.0
Section modulus, base, in.[3]	22.0
Ratio m.i. to area, in.[2]	5.83
Ratio s.m. head to area, in.	1.60
Ratio height to base	1.20
Calculated weight, lb per yd.	114.7

115 RE RAIL SECTION

FIGURE II - 1 - 43

NO. OF TURNOUT	SWITCH RAIL LENGTH	TYPE OF SWITCH	SPEED THROUGH TURNOUT M.P.H.	
			NORMAL OPERATING SPEEDS	MAXIMUM OPERATING SPEEDS
NO. 6	**11'-0"**	**STRAIGHT**	**10**	13
NO. 8-Y	16'-6"	STRAIGHT	25	25
NO. 8	16'-6"	STRAIGHT	15	18
NO.10	19'-6"	CURVED	25	25
NO.15	26'-0"	CURVED	35	37
NO.20	39'-0"	CURVED	50	50

NOTES:

1. NORMAL OPERATING SPEED IS THE NEAREST ~~ATC~~ SPEED COMMAND BELOW MAXIMUM OPERATING SPEED.

2. MAXIMUM OPERATING SPEED IS BASED ON U*=3" AND IS DETERMINED USING THE LEAD RADIUS AND THE SWITCH RADIUS (FOR CURVED SWITCHES) OR THEORETICAL SWITCH (FOR STRAIGHT SWITCHES) WITH THE MOST RESTRICTIVE SPEED GOVERNING.

U*= UNBALANCED SUPERELEVATION

SPEED THROUGH TURNOUTS

FIGURE II-1-44

TURNOUT NO.	TYPE OF TRACK CONSTRUCTION	MINIMUM DISTANCE FROM POINT OF SWITCH THRU TURNOUT TO:	
		T.S.or T.C.	P.V.C.
6	BALLASTED	57'	71'
8	DIRECT FIXATION	81'	81'
8	BALLASTED	98'	98'
8-Y	DIRECT FIXATION	85'	85'
8-Y	BALLASTED	100'	100'
10	DIRECT FIXATION	97'	97'
10	BALLASTED	116'	116'
15	DIRECT FIXATION	140'	140'
15	BALLASTED	165'	165'
20	DIRECT FIXATION	184'	184'
20	BALLASTED	222'	222'

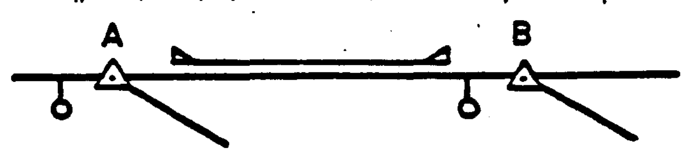
LIMITING DIMENSIONS FOR SPECIAL TRACKWORK

FIGURE II-1-45

BACK-TO-POINT TURNOUTS OF SAME HAND

TURNOUT & HAND		A-B DISTANCE (MIN.)	
A	B	8'-0" END APPROACH	4'-0" END APPROACH
6R	6R	84.58	84.58
6L	6L	84.58	84.58
8R	8R	112.44	112.44
8L	8L	"	"
8R	10R	"	"
8L	10L	"	"
8R	15R	"	"
8L	15L	"	"
10R	10R	140.35	140.35
10L	10L	"	"
10R	15R	"	"
10L	15L	"	"
10L	20L	"	"
10R	20R	"	"
15R	15R	210.23	210.23
15L	15L	"	"
15R	20R	"	"
15L	20L	"	"

NOTE: THESE ARE TENTATIVE DISTANCES TO BE REVISED.



NOTE: CONTACT RAIL IS REQUIRED IN ALL OF THE ABOVE CASES

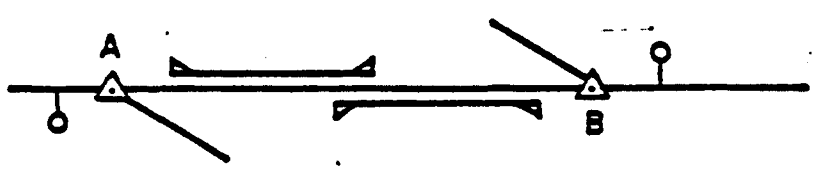
REQUIRED DISTANCES BETWEEN P.I.s OF TURNOUTS

FIGURE II-1-46

BACK-TO-BACK TURNOUTS OF SAME HAND

TURNOUT & HAND		A-B DISTANCE (MIN.)	
A	B	8'-0" END APPROACH	4'-0" END APPROACH
8R	8R	134.417'	134.417'
8L	8L	•	•
8R	10R	151.605'	151.605'
8L	10L	•	•
8R	15R	189.021'	189.021'
8L	15L	•	•
10R	10R	168.792'	168.792'
10L	10L	•	•
10R	15R	206.209'	206.209'
10L	15L	•	•
10R	20R	244.730'	244.730'
10L	20L	•	•
15R	15R	243.625'	243.625'
15L	15L	•	•

NOTE: THESE ARE TENTATIVE DISTANCES TO BE REVISED.



NOTE: CONTACT RAIL IS REQUIRED IN ALL OF THE ABOVE CASES.

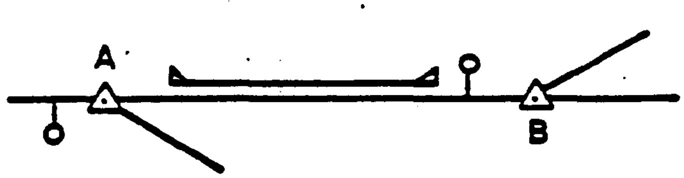
REQUIRED DISTANCES BETWEEN P.I.s OF TURNOUTS

FIGURE II-1-47

BACK-TO-POINT TURNOUTS OF OPPOSITE HAND
(LARGER FROG ANGLE LEADING)

TURNOUT & HAND		A-B DISTANCE (MIN.)	
A	B	8'-0" END APPROACH	4'-0" END APPROACH
8R	8L	105.042'	105.042'
8L	8R	"	"
8R	10L	106.458'	106.458'
8L	10R	"	"
8R	15L	115.021'	115.021'
8L	15R	"	"
10R	10L	123.604'	123.604'
10L	10R	"	"
10R	15L	132.167'	132.167'
10L	15R	"	"
10R	20L	151.730'	151.730'
10L	20R	"	"
15R	15L	169.625'	169.625'
15L	15R	"	"
15R	20L	189.188'	189.188'
15L	20R	"	"

NOTE: THESE ARE TENTATIVE DISTANCES TO BE REVISED.



NOTE: CONTACT RAIL IS REQUIRED IN ALL OF THE ABOVE CASES.

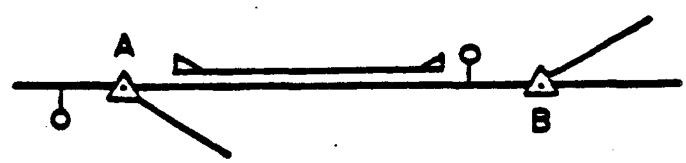
REQUIRED DISTANCES BETWEEN P.I.s OF TURNOUTS

FIGURE II-1-48

BACK-TO-POINT TURNOUTS OF OPPOSITE HAND (SMALLER FROG ANGLE LEADING)

TURNOUT & HAND		A-B DISTANCE (MIN.)	
A	B	8'-0" END APPROACH	4'-0" END APPROACH
8R	8L	105.042'	105.042'
8L	8R	"	"
10R	8L	122.188'	122.188'
10L	8R	"	"
10R	10L	123.604'	123.604'
10L	10R	"	"
15R	8L	159.646'	159.646'
15L	8R	"	"
15R	10L	161.062'	161.062'
15L	10R	"	"
15R	15L	169.625'	169.625'
15L	15R	"	"
20R	10L	201.083'	201.083'
20L	10R	"	"

NOTE: THESE ARE TENTATIVE DISTANCES TO BE REVISED.



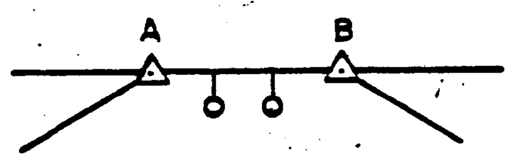
NOTE: CONTACT RAIL IS REQUIRED IN ALL OF THE ABOVE CASES.

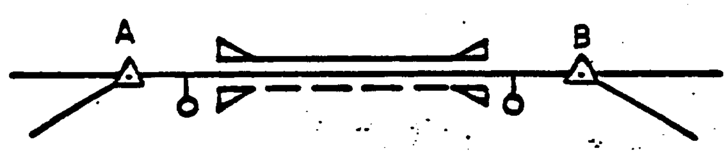
REQUIRED DISTANCES BETWEEN P.I.s OF TURNOUTS

FIGURE II-1-49

POINT-TO-POINT TURNOUTS OF **OPPOSITE HAND**

TURNOUT		REQ'D DIST. W/O CONTACT RAIL	A-B DISTANCE (MIN.) *	
A	B		8'-0" APPROACH	4'-0" APPROACH
6 R/L	6 R/L	48.792'		
6 R/L	8 R/L	59.792'		
8 R/L	8 R/L	76.031'	122.500'	117.500'
8 R/L	10 R/L	77.448'	123.916'	118.916'
10 R/L	10 R/L	78.864'	125.333'	120.333'
10 R/L	15 R/L	83.177'	133.896'	128.896'
15 R/L	15 R/L	90.656'	142.458'	137.458'
10 R/L	20 R/L	106.990'	153.458'	148.458'





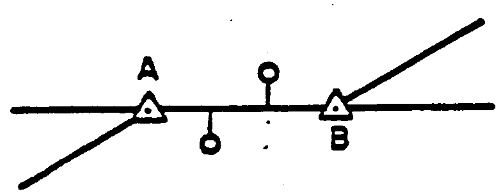
* THESE ARE TENTATIVE DISTANCES TO BE REVISED.

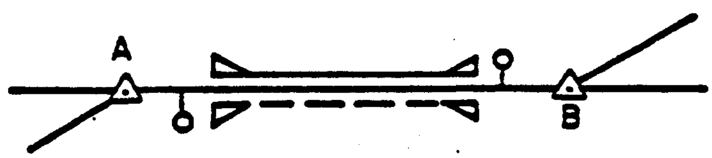
REQUIRED DISTANCES BETWEEN P.I.s OF TURNOUTS

FIGURE II-1-50

POINT - TO - POINT TURNOUTS OF SAME HAND

TURNOUT		REQ'D DIST. W/O CONTACT RAIL	A-B DISTANCE (MIN.) *	
A	B		8'-0" APPROACH	4'-0" APPROACH
6^{R}_{L}	6^{R}_{L}	48.792'		
6^{R}_{L}	8^{R}_{L}	59.792'		
8^{R}_{L}	8^{R}_{L}	76.031'	122.500'	117.500'
8^{R}_{L}	10^{R}_{L}	77.448'	123.916'	118.916'
10^{R}_{L}	10^{R}_{L}	78.864'	125.333'	120.333'
10^{R}_{L}	15^{R}_{L}	83.177'	133.896'	128.896'
15^{R}_{L}	15^{R}_{L}	90.656'	142.458'	137.458'
10^{R}_{L}	20^{R}_{L}	106.990'	153.458'	148.458'

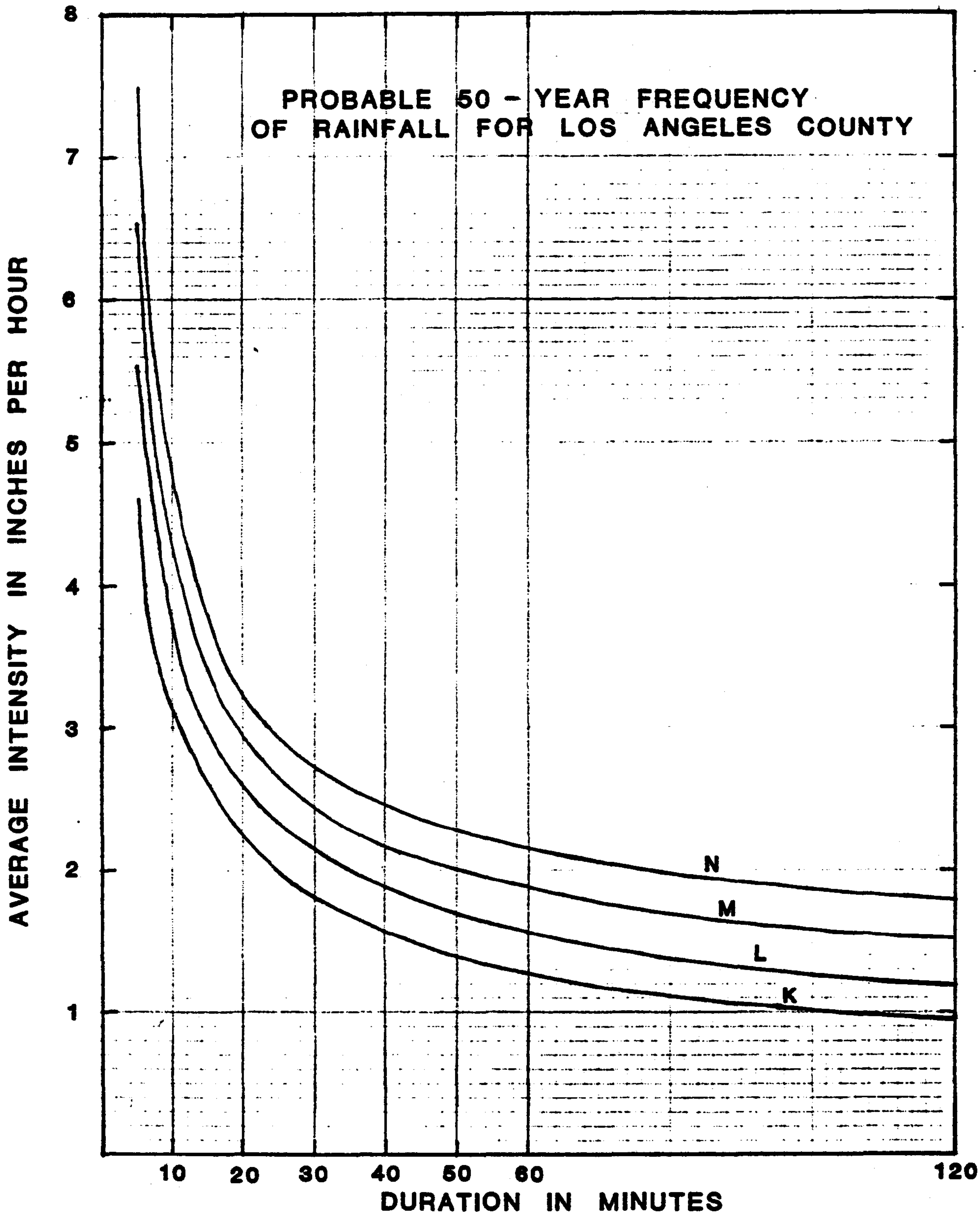




* THESE ARE TENTATIVE DISTANCES TO BE REVISED.

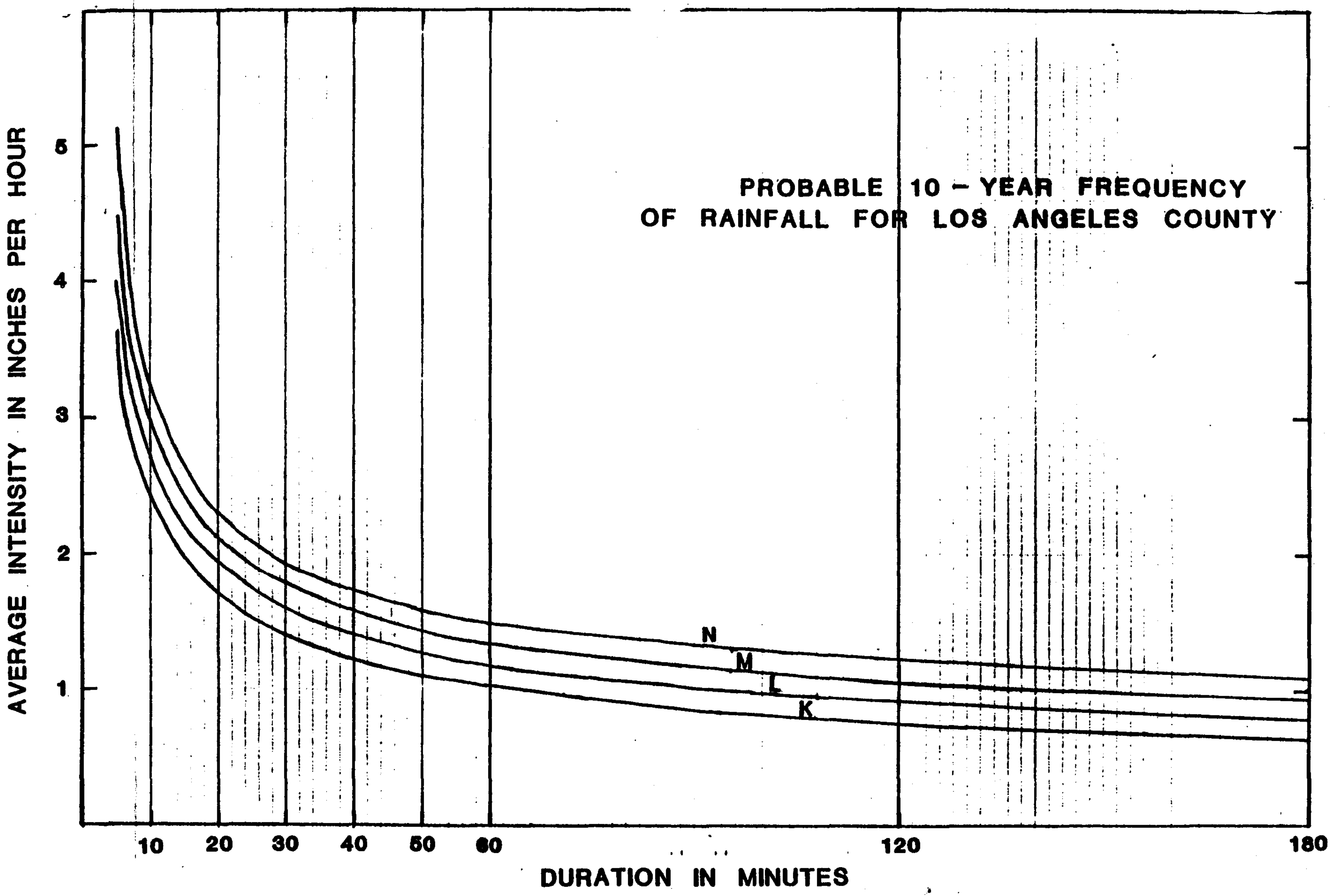
REQUIRED DISTANCES BETWEEN P.I.s OF TURNOUTS

FIGURE II - 1 - 51



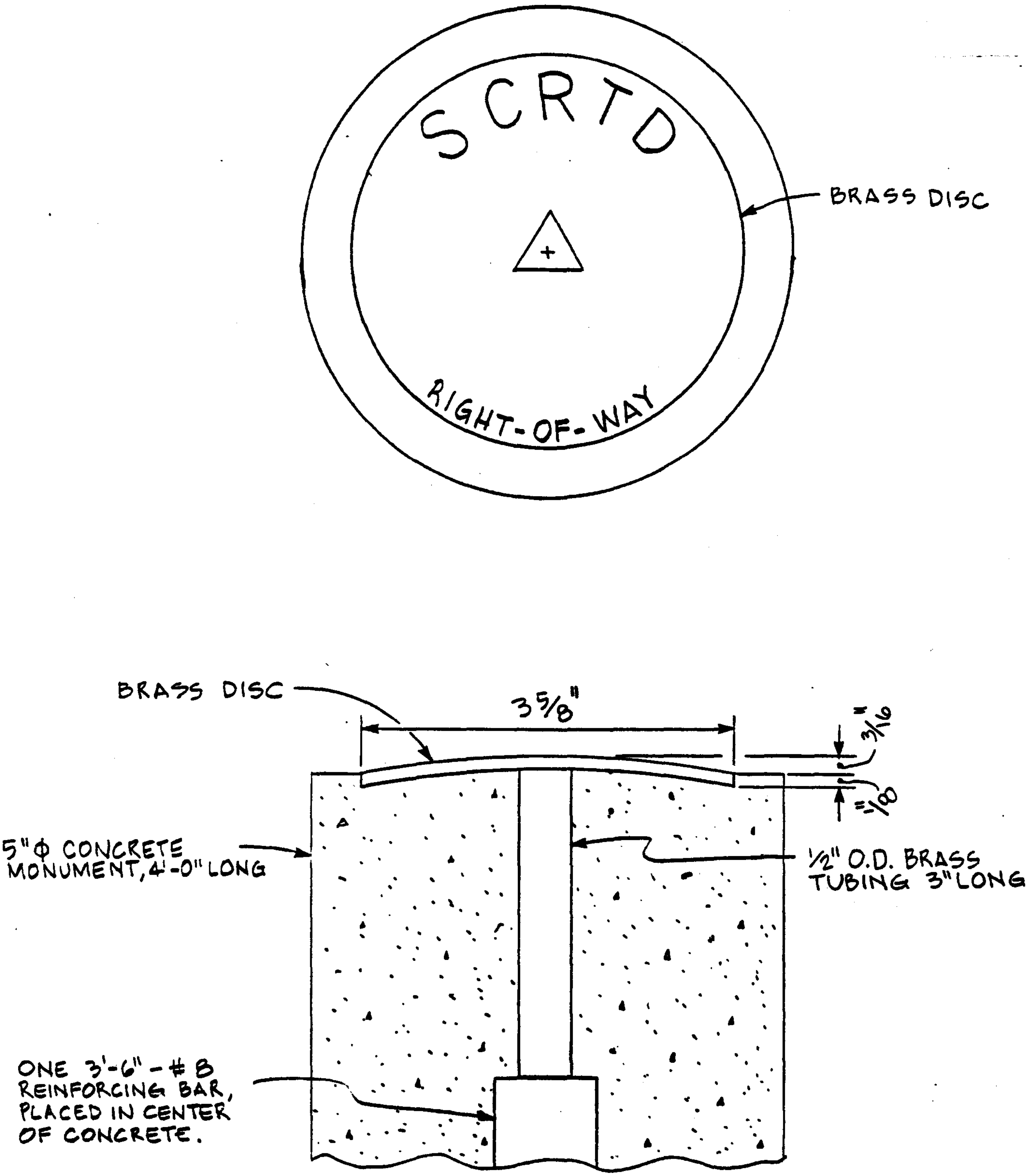
AVERAGE INTENSITY DURATION CURVES

FIGURE II-1-52



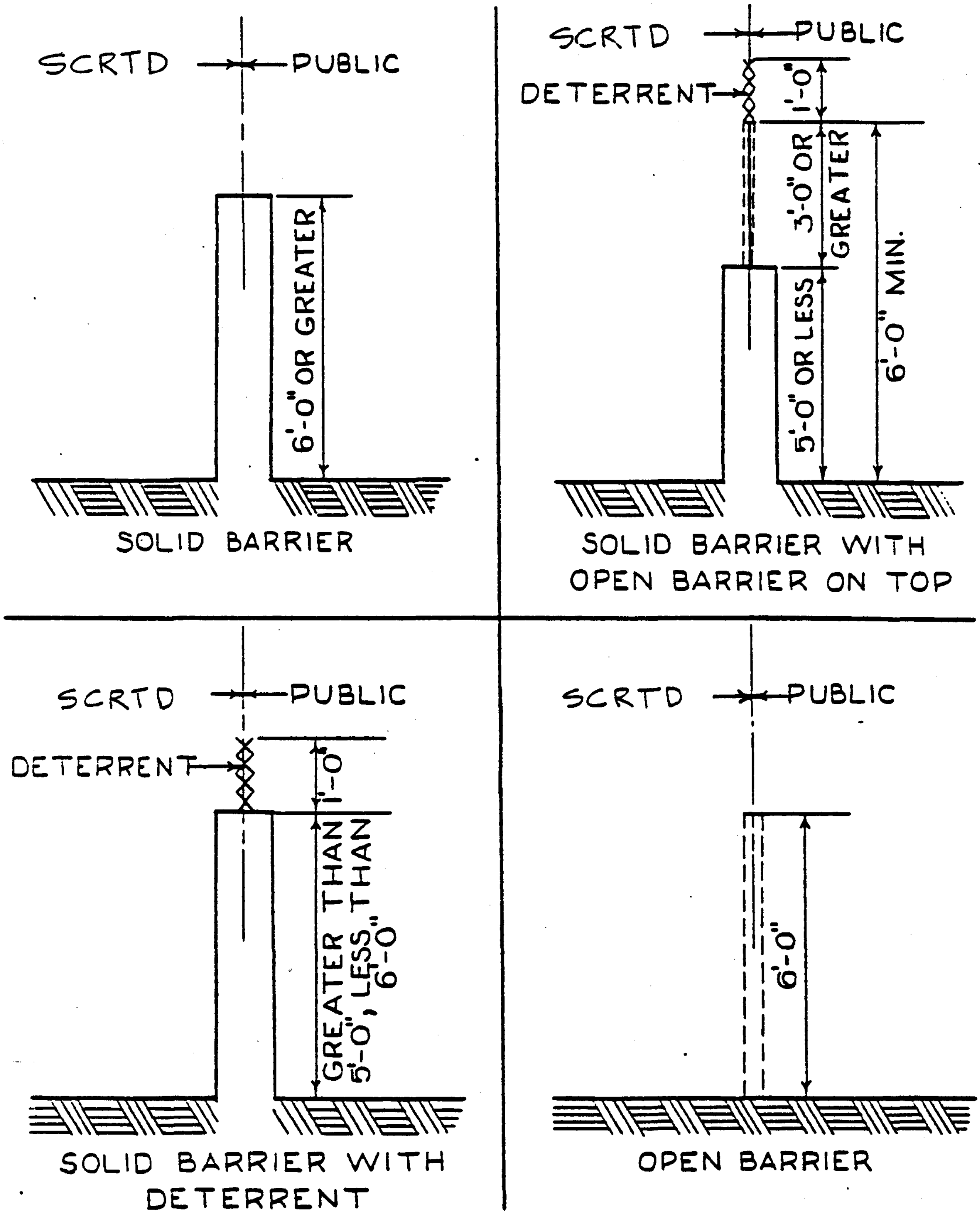
AVERAGE INTENSITY DURATION CURVES

FIGURE II-1-53



SCRTD RIGHT - OF - WAY MONUMENT

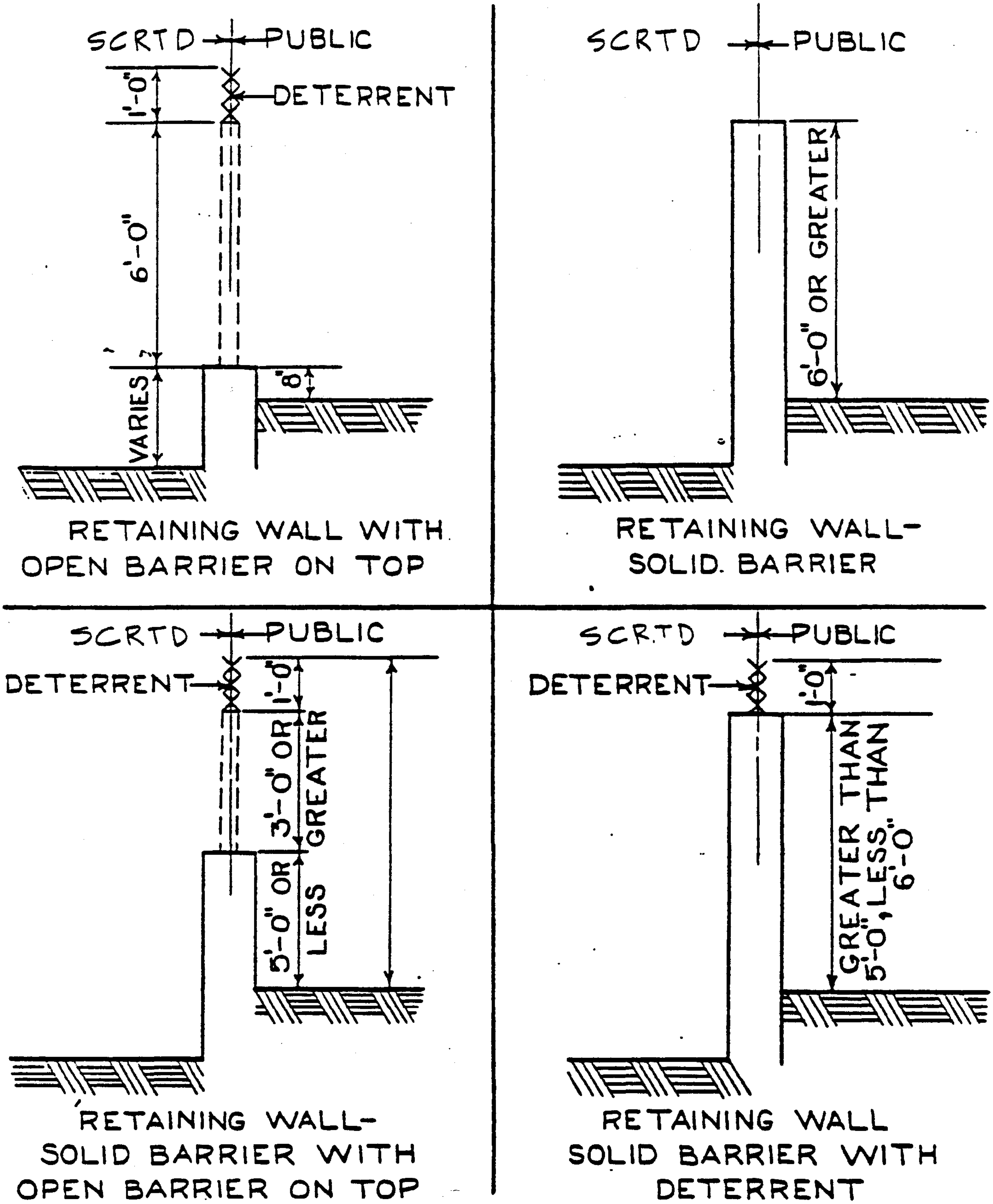
FIGURE II-1-54



NOTE: SOLID BARRIER TO HAVE NO FOOT HOLDS ON PUBLIC SIDE

CONTROL OF ACCESS AT -GRADE CONDITION

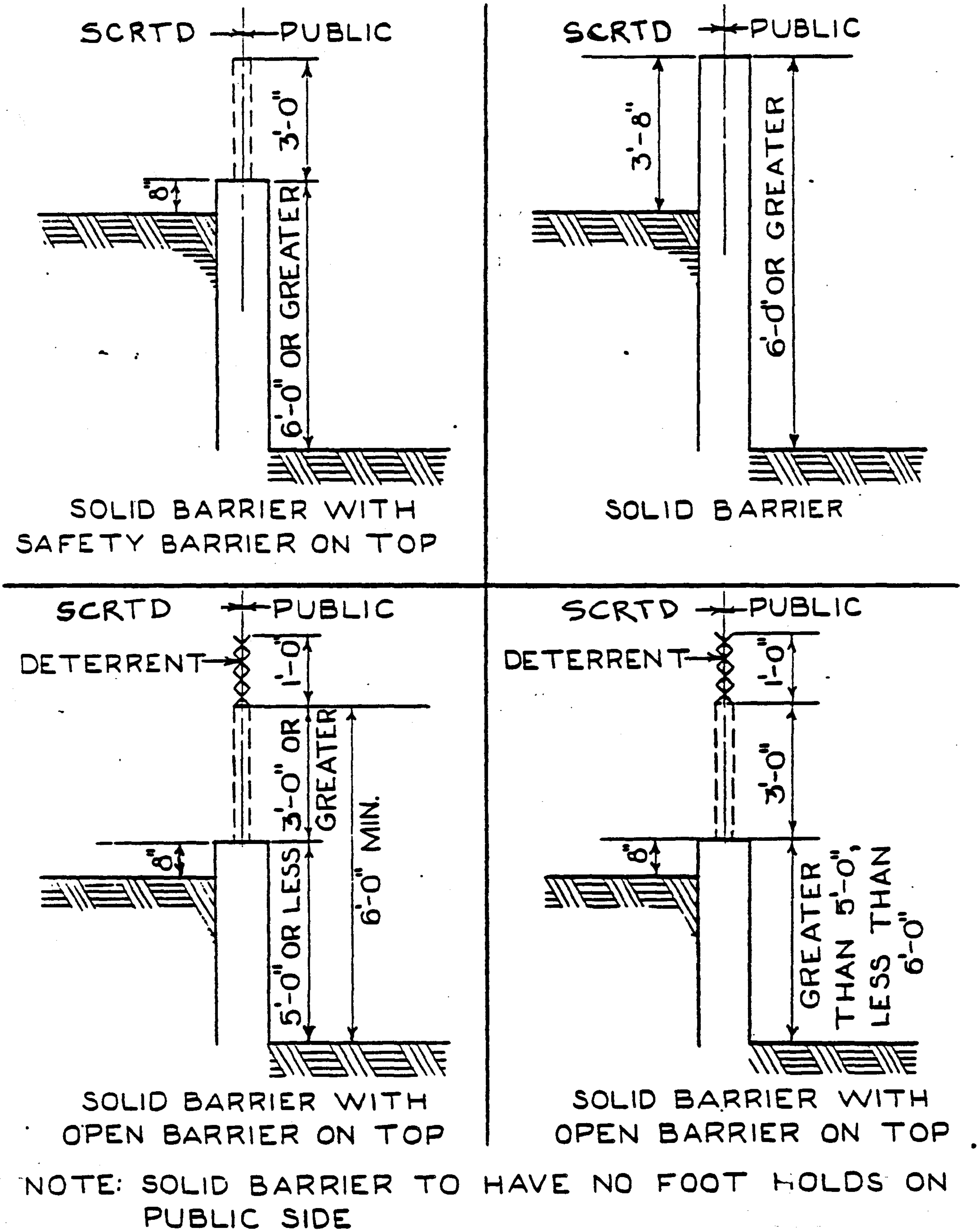
FIGURE II-1-55



NOTE: SOLID BARRIER TO HAVE NO FOOT HOLDS ON PUBLIC SIDE

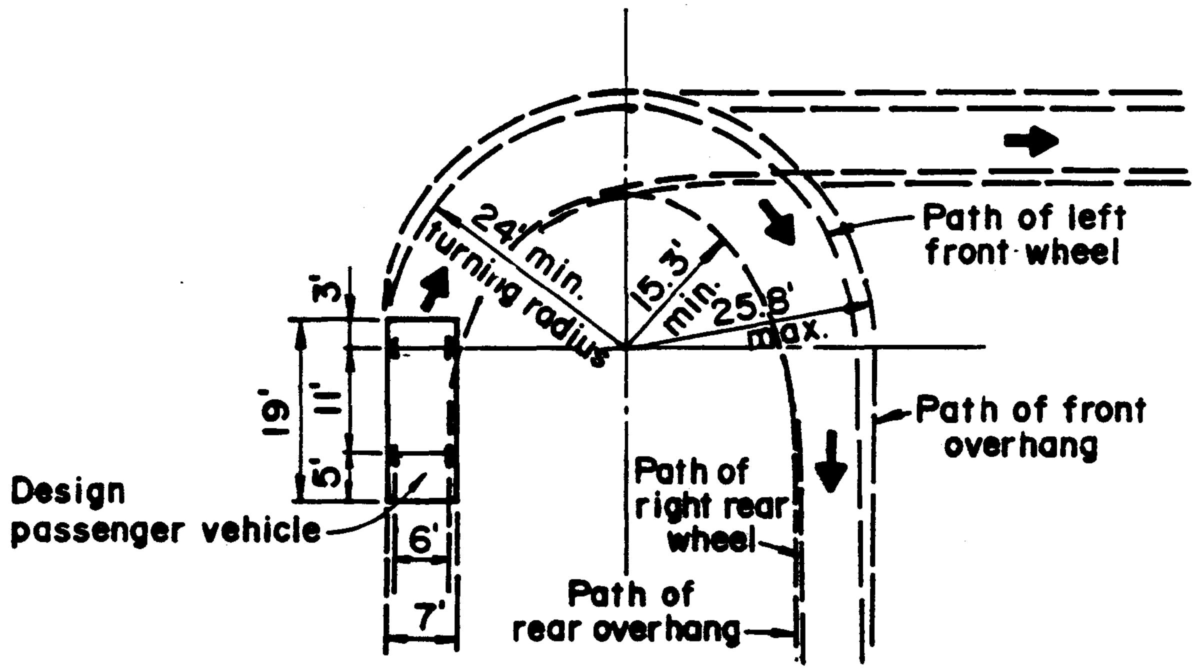
CONTROL OF ACCESS PUBLIC AREA RETAINED

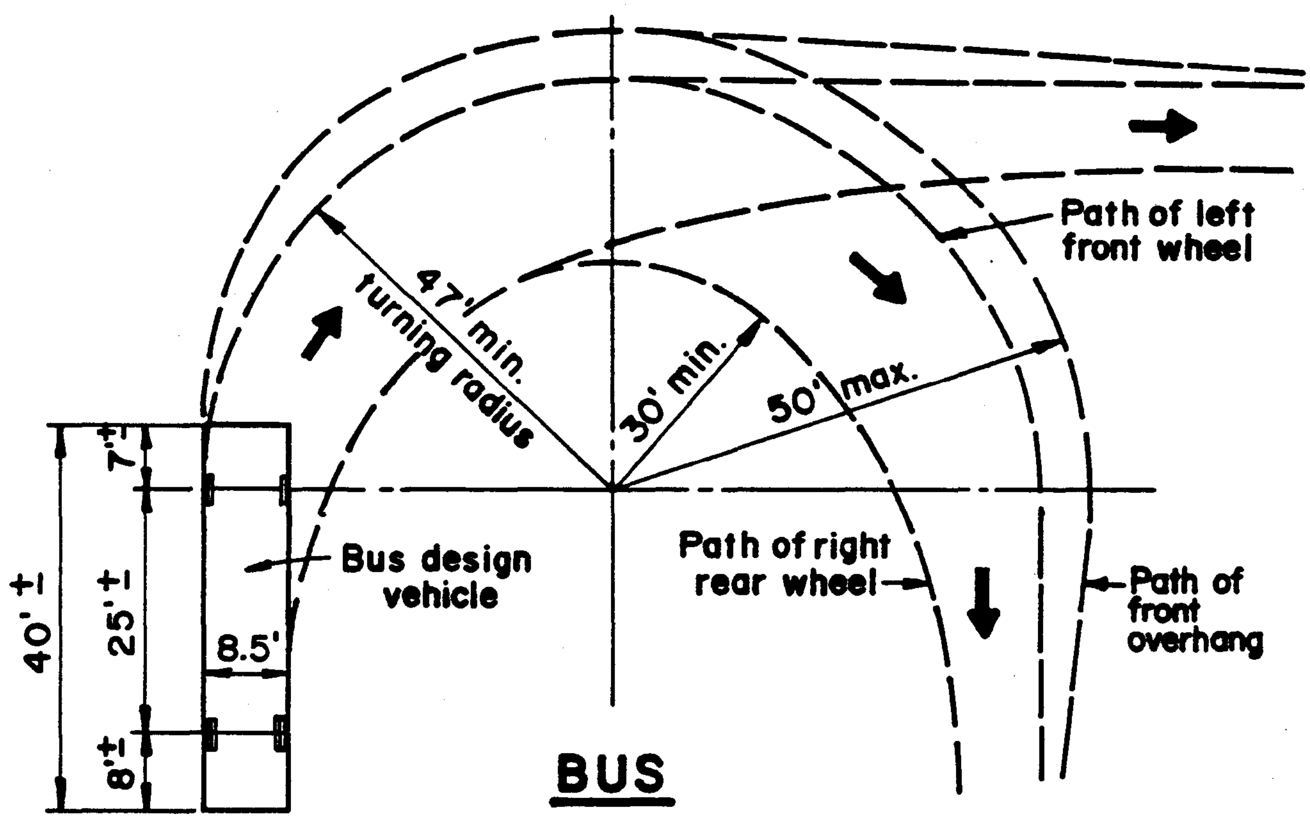
FIGURE II-1 - 56



CONTROL OF ACCESS TRANSIT R.O.W. RETAINED

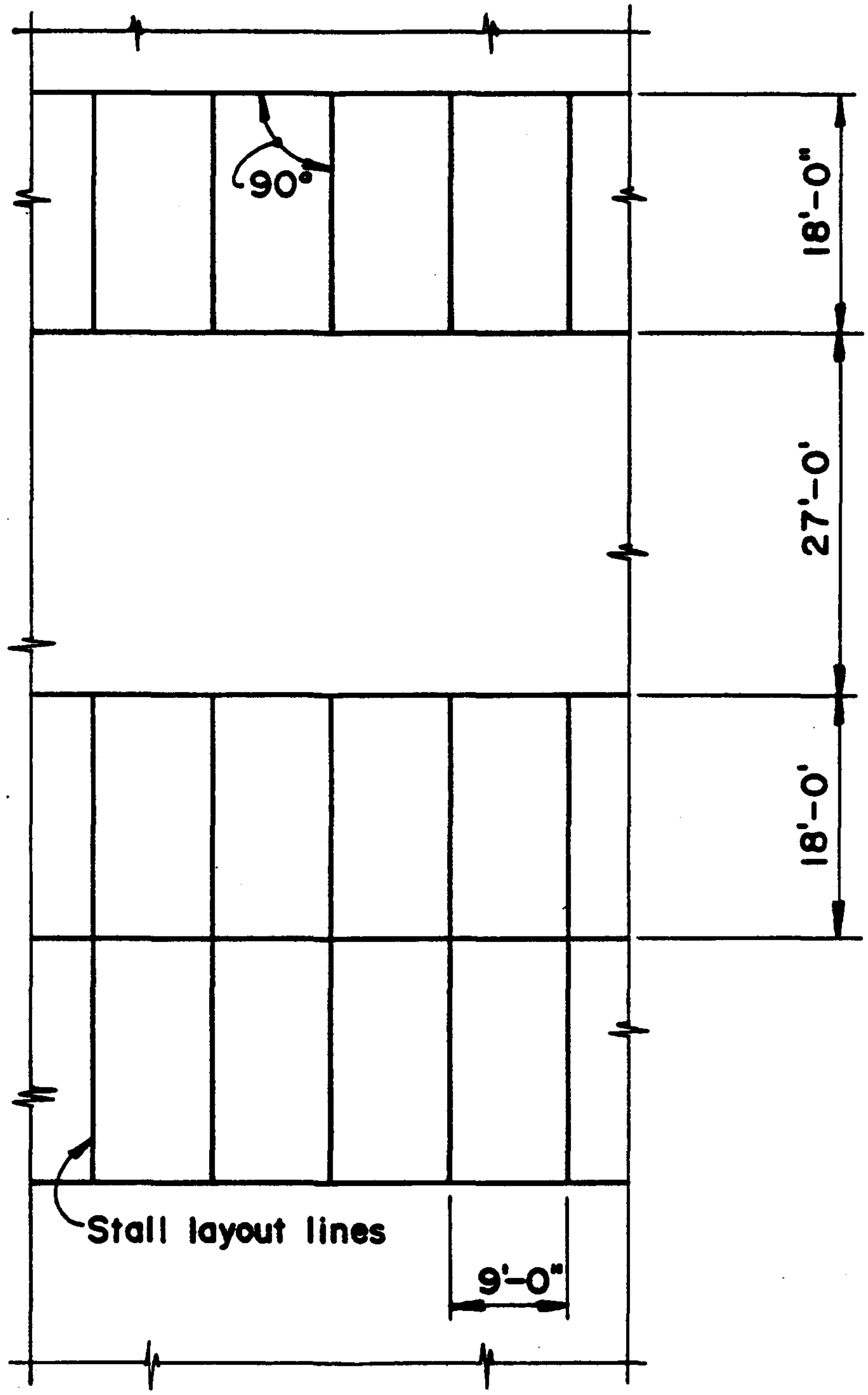
FIGURE II-1-57





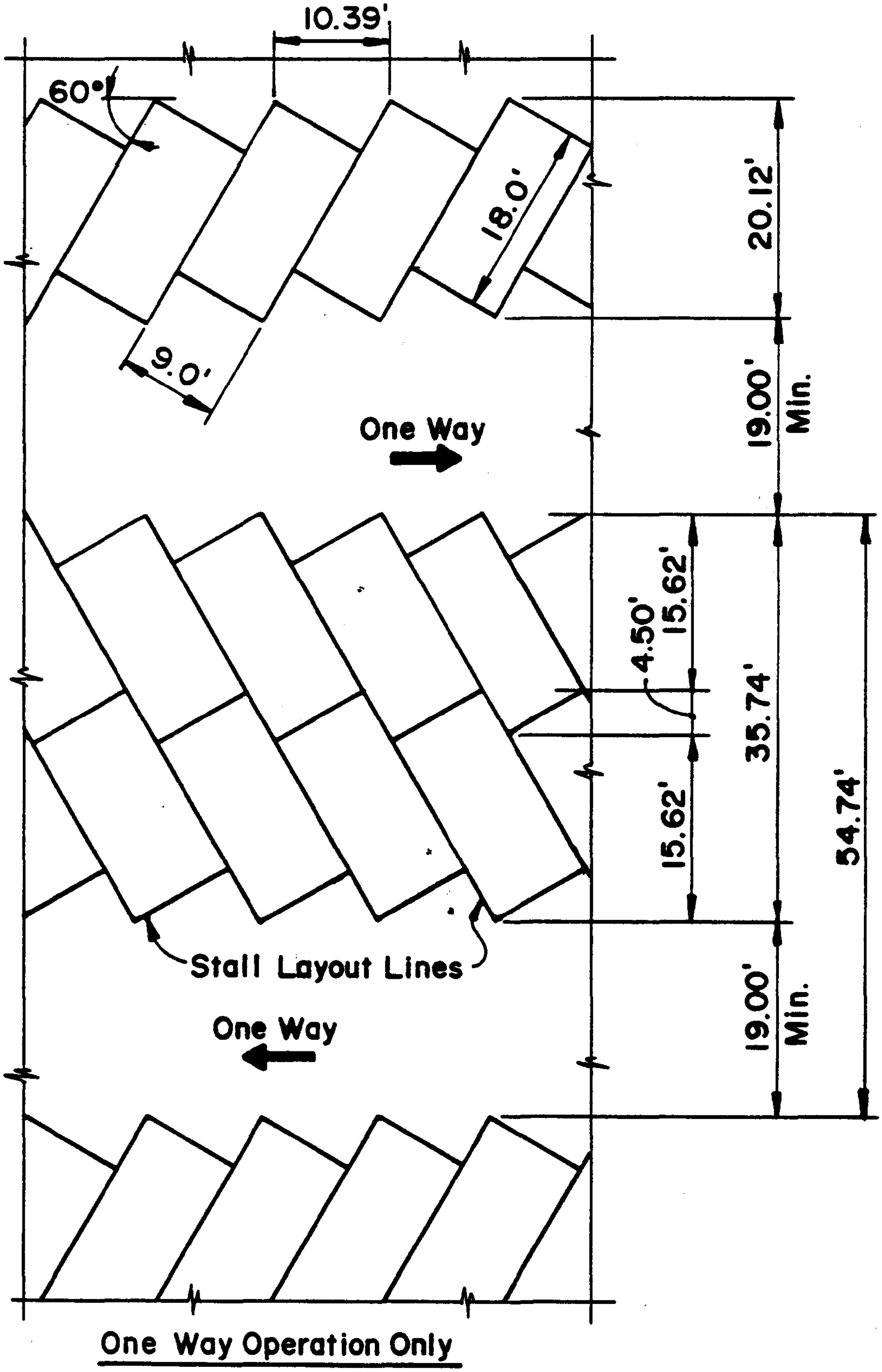
DESIGN VEHICLES AND MINIMUM TURNING PATHS

FIGURE II-1-58



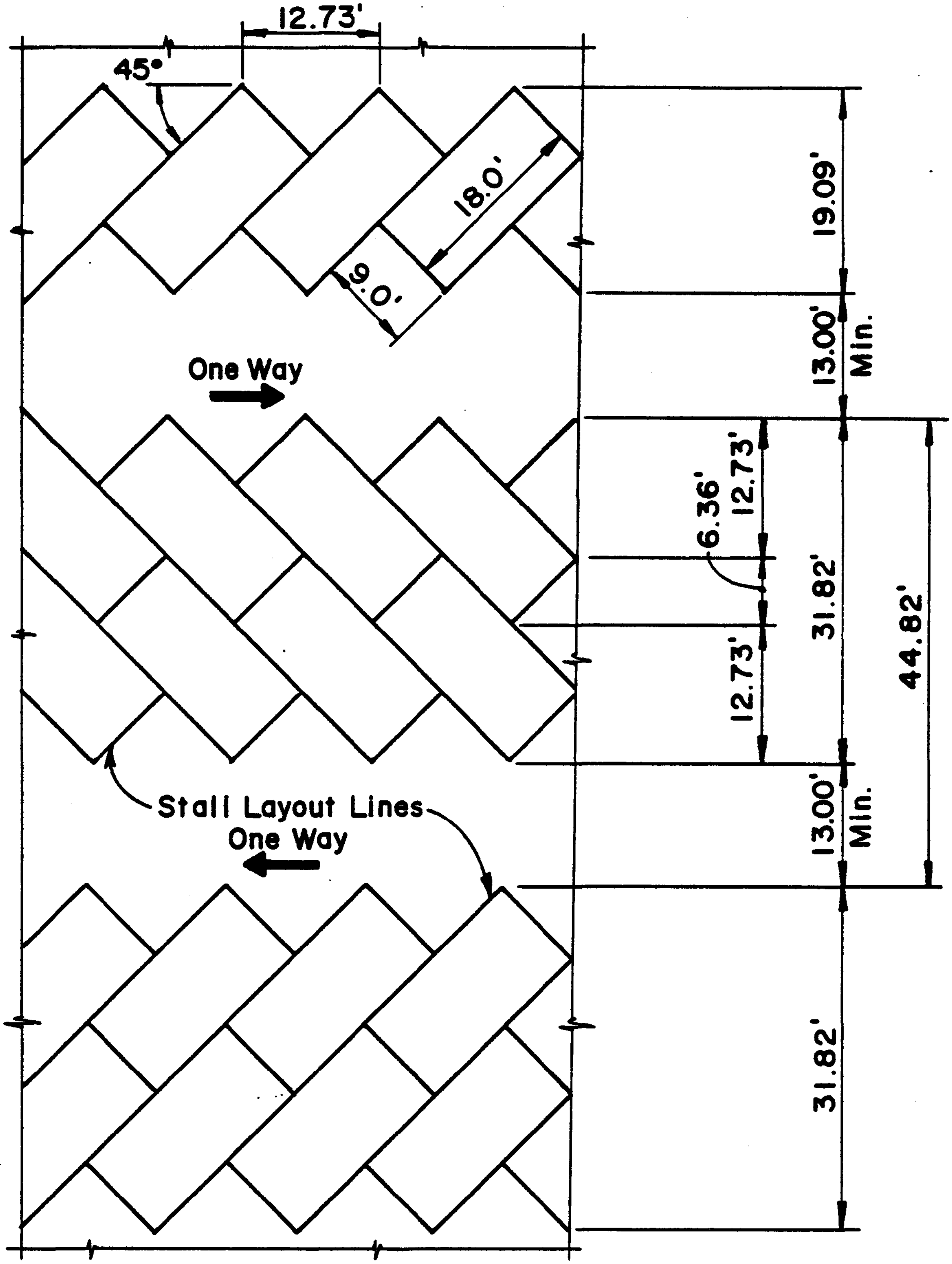
PARKING LOT LAYOUT – 90° 9'-0" STALLS

FIGURE II-1-59



PARKING LOT LAYOUT–60° 9'–0" STALLS

FIGURE II-1-60

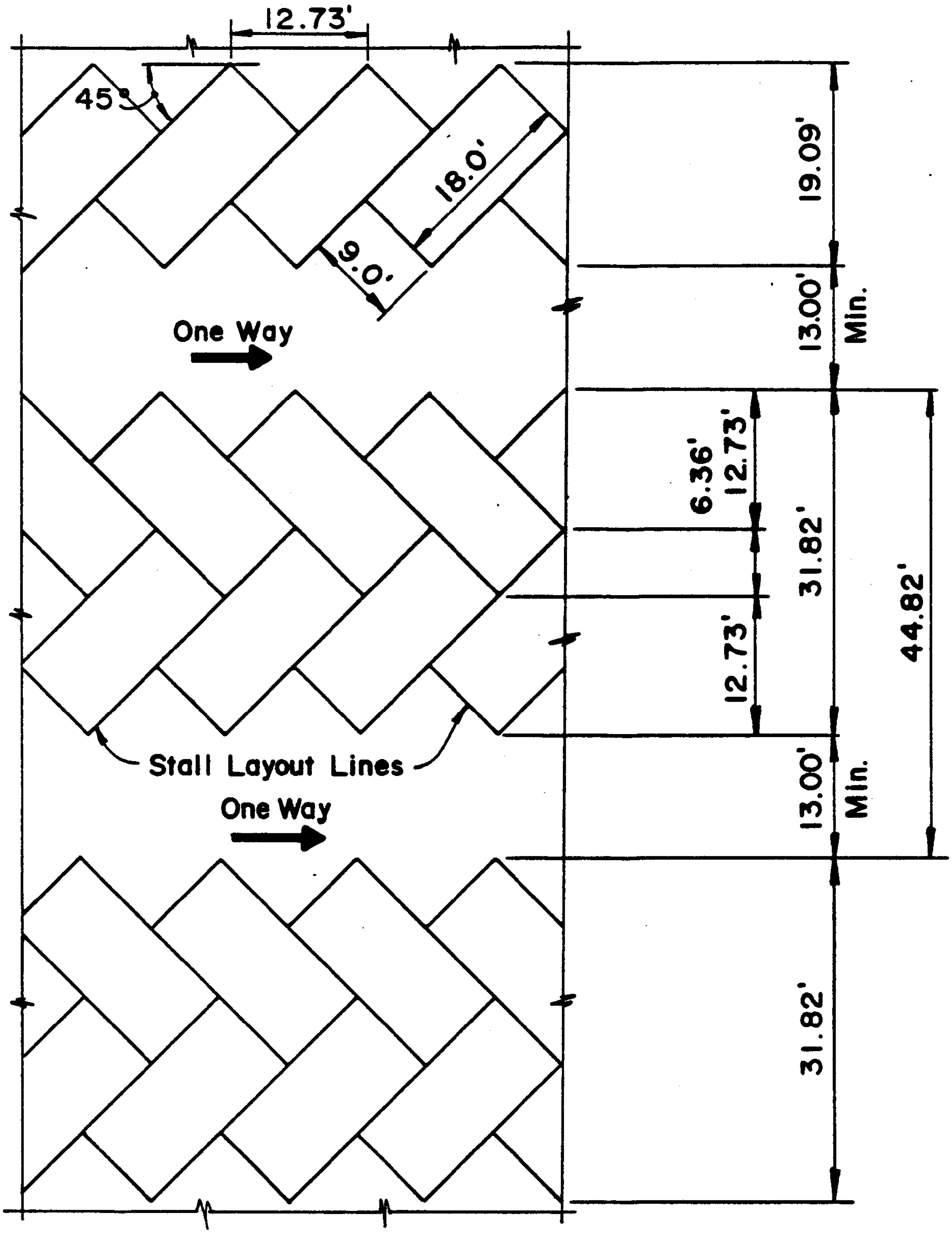


TYPE A PATTERN

One Way Operation Only

PARKING LOT LAYOUT–45° 9'–0" STALLS

FIGURE II-1-61



TYPE B PATTERN

One Way Operation Only

PARKING LOT LAYOUT—45° 9'–0" STALLS

FIGURE II-1-62

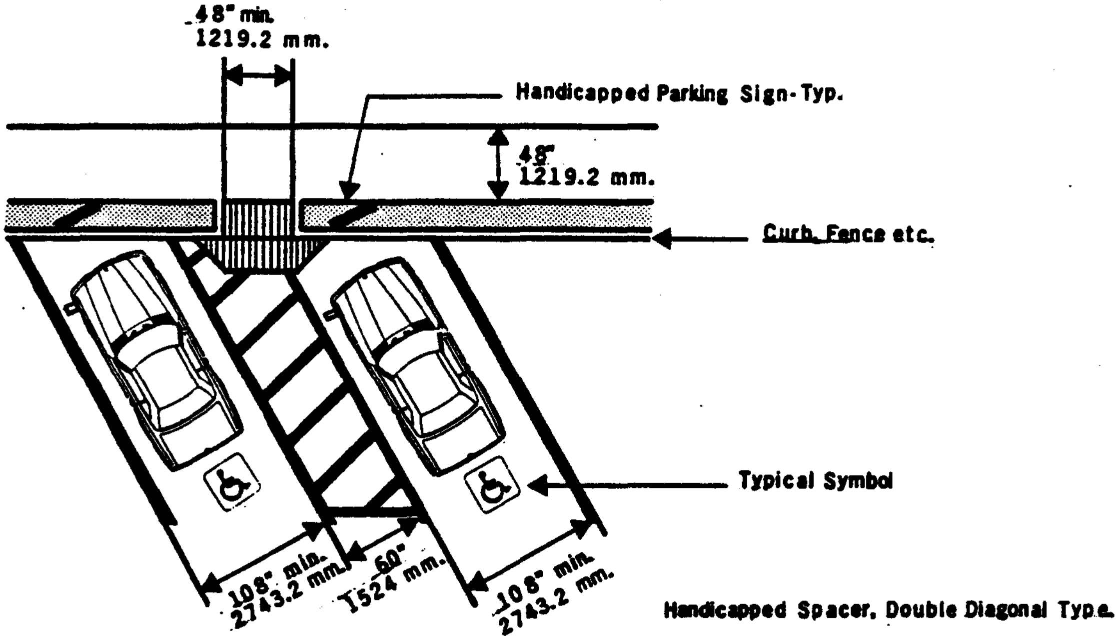
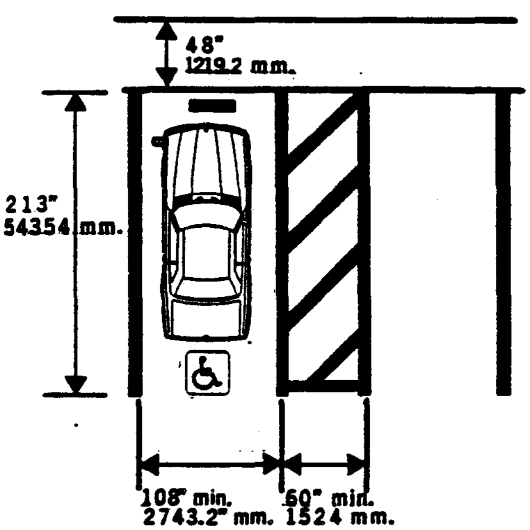


Figure 1 (Title 24, Figure 71-1B)

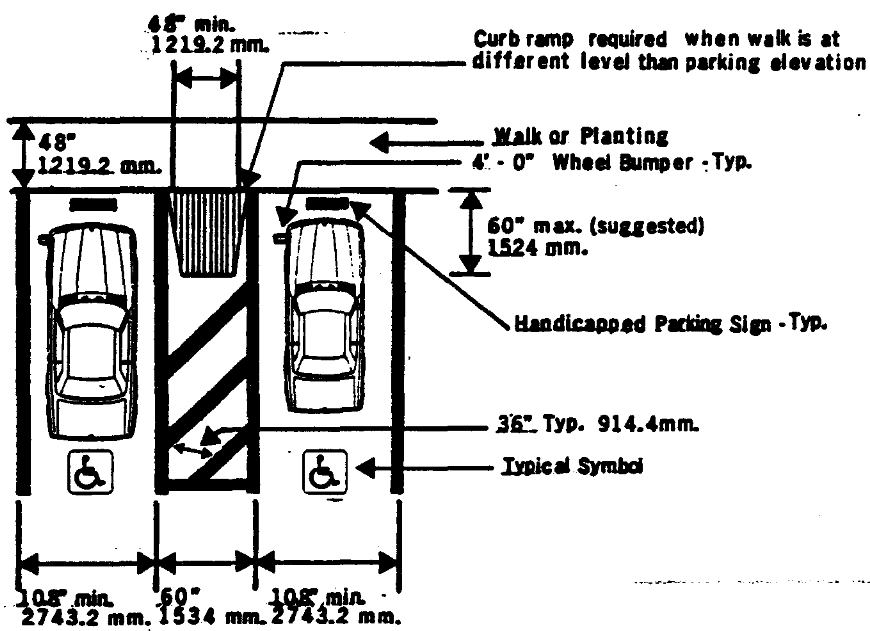
NOTES:

1. Handicapped space must permit use of either driver doors.
2. Bumper required when no curb or barrier is provided which will prevent encroachment of cars over sidewalks.
3. Wheelchair users must not be forced to go behind parked cars other than their own.



Handicapped Space, Single Type

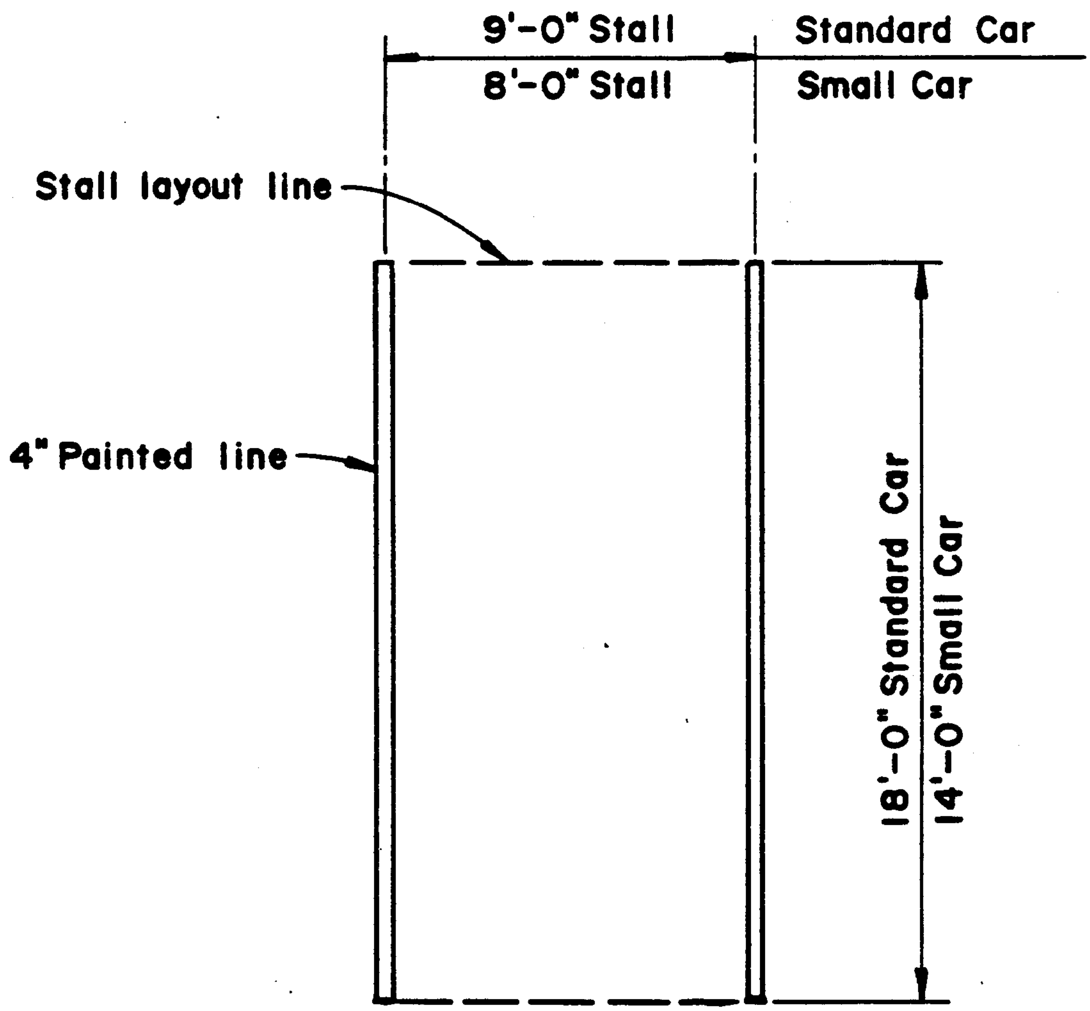
Figure 2



Handicapped Spaces, Double Type

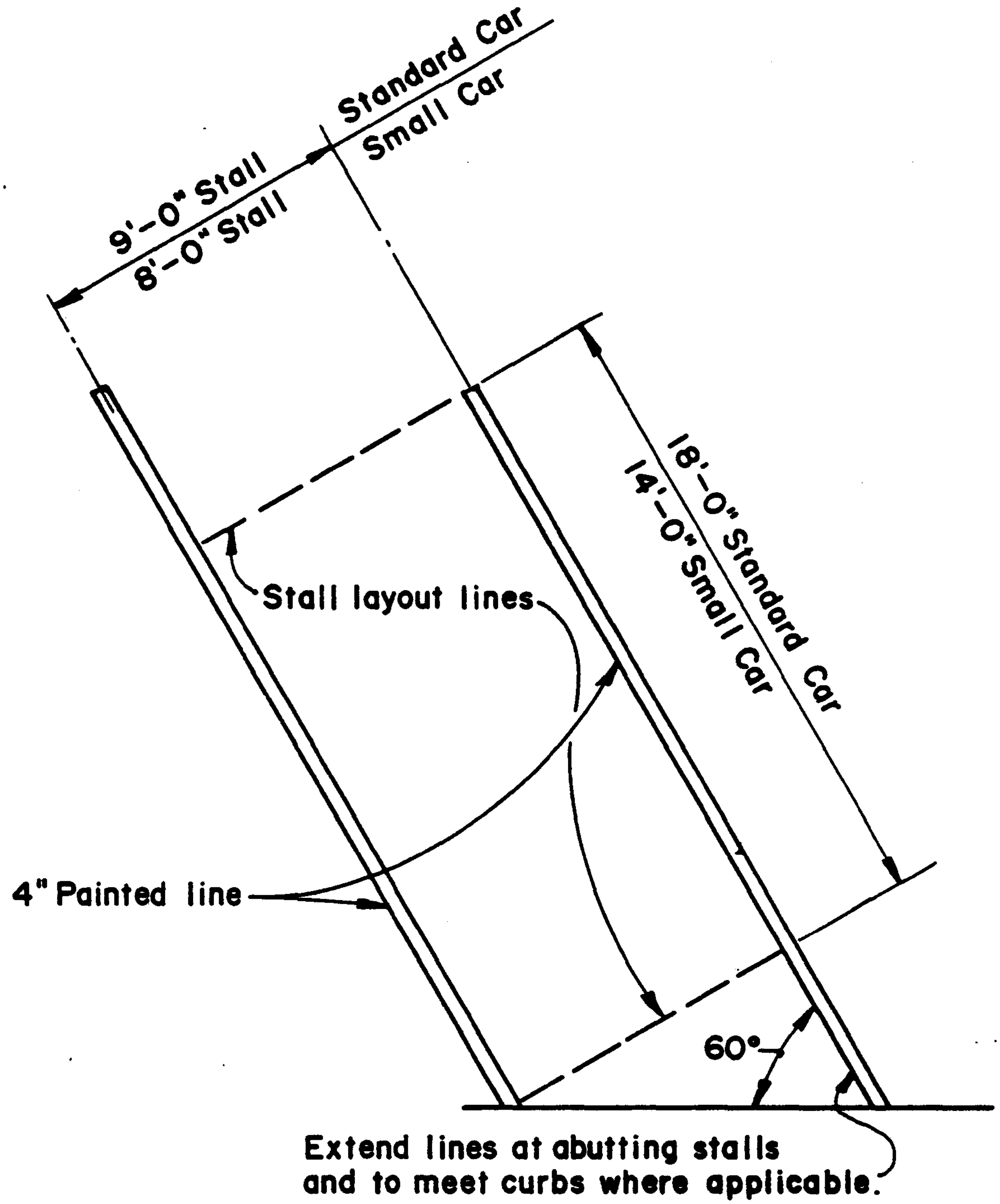
Figure 3 (Title 24, Figure 71-1A)

These diagrams illustrate the specific requirements of these regulations and are intended only as an aid in building design and construction.



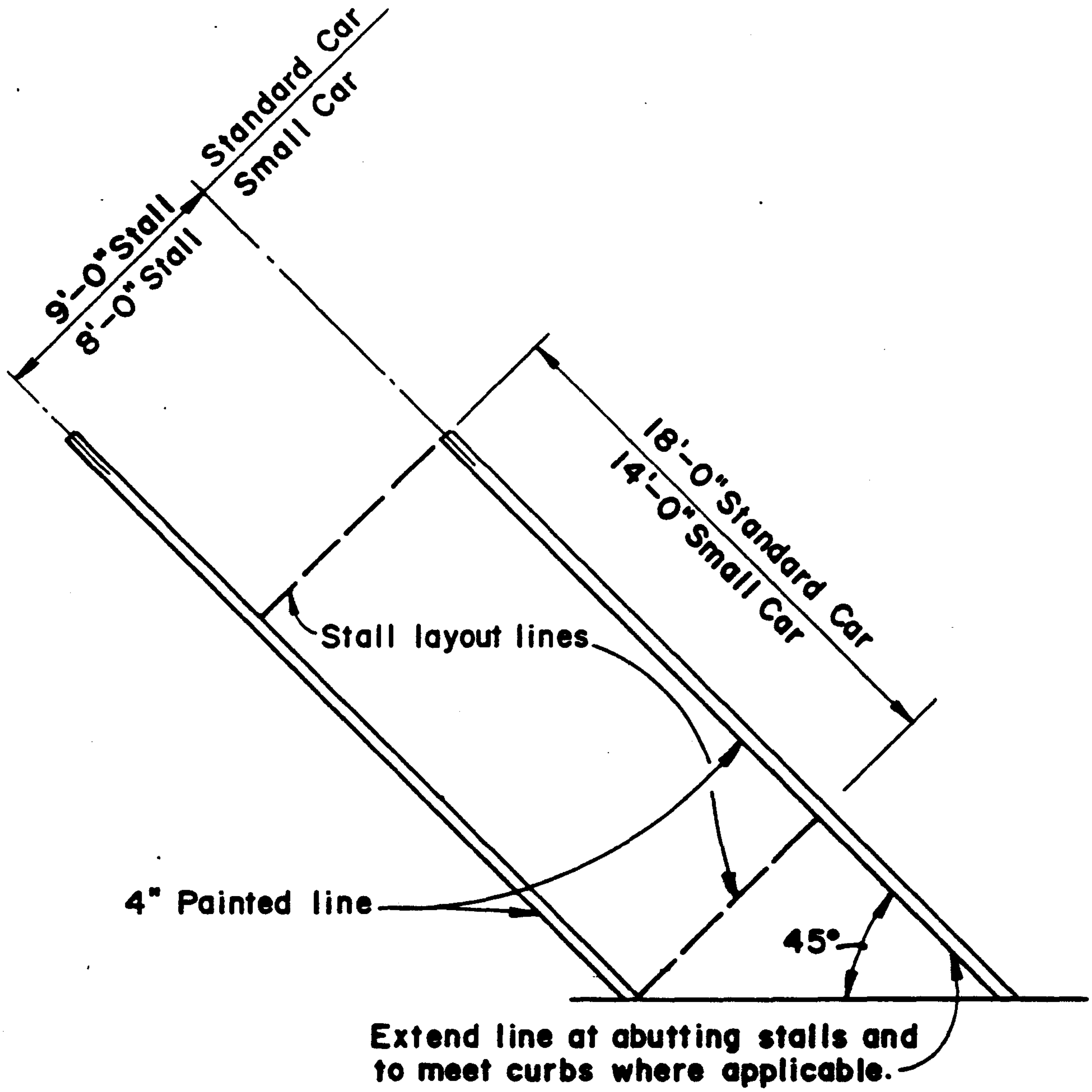
PARKING LOT STALL LINES—90°

FIGURE II-1-64



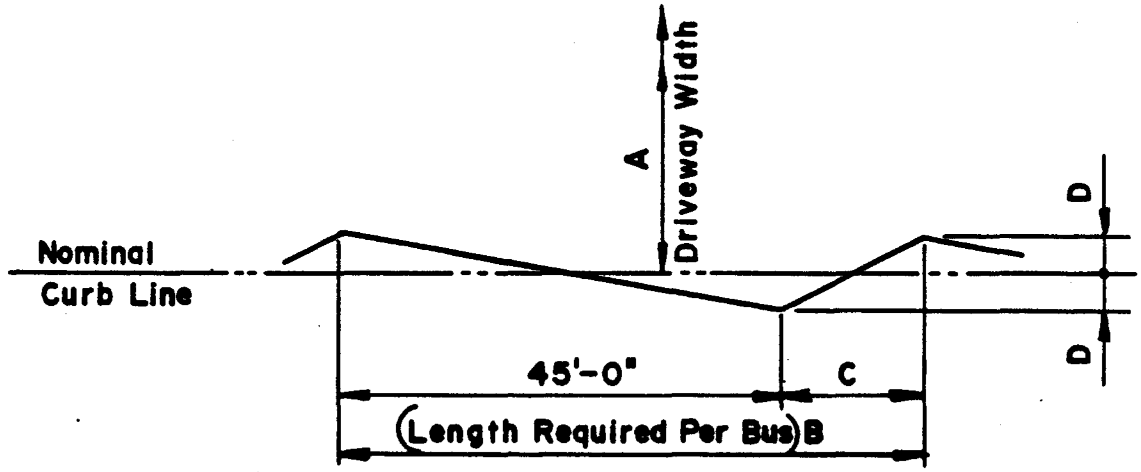
PARKING LOT STALL LINES—60°

FIGURE II-1-65



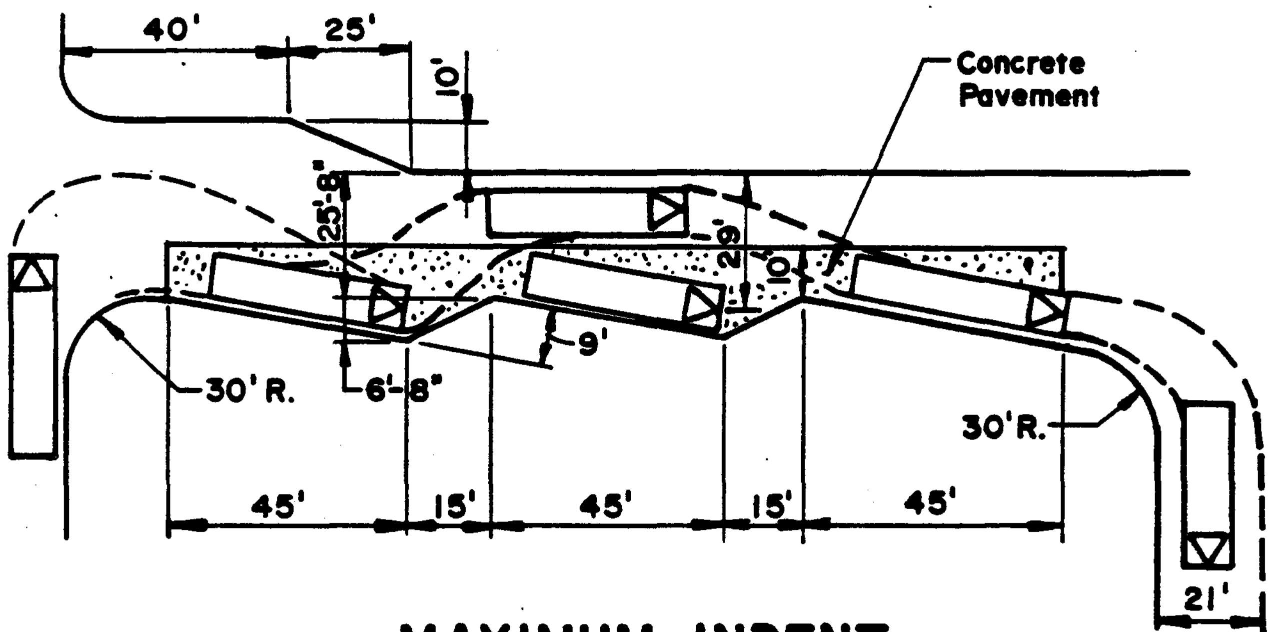
PARKING LOT STALL LINES-45°

FIGURE II 1-66



A	24	25	26	27	28	29
B	80	76	72	68	64	60
C	35	31	27	23	19	15
D	0	0'-8"	1'-4"	2'-0"	2'-8"	3'-4"

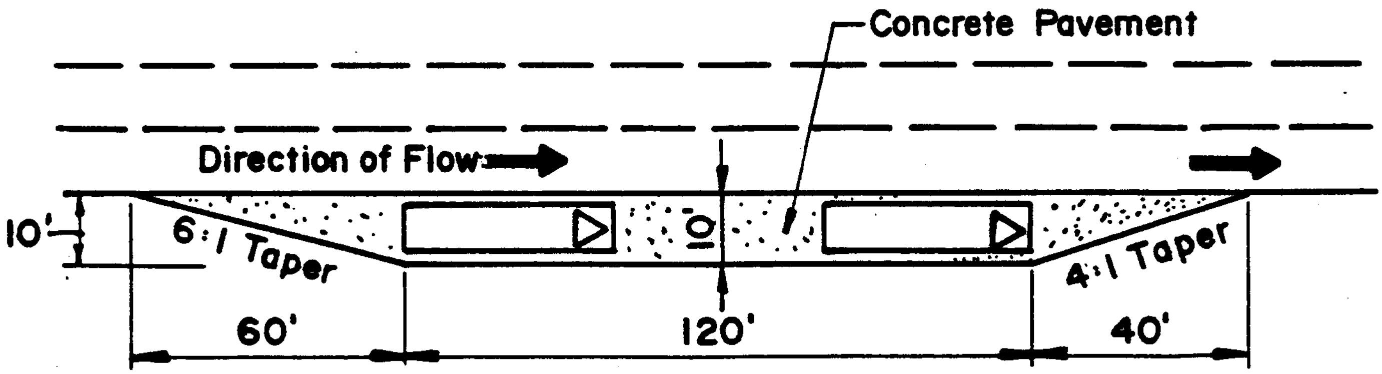
BAY DETAILS



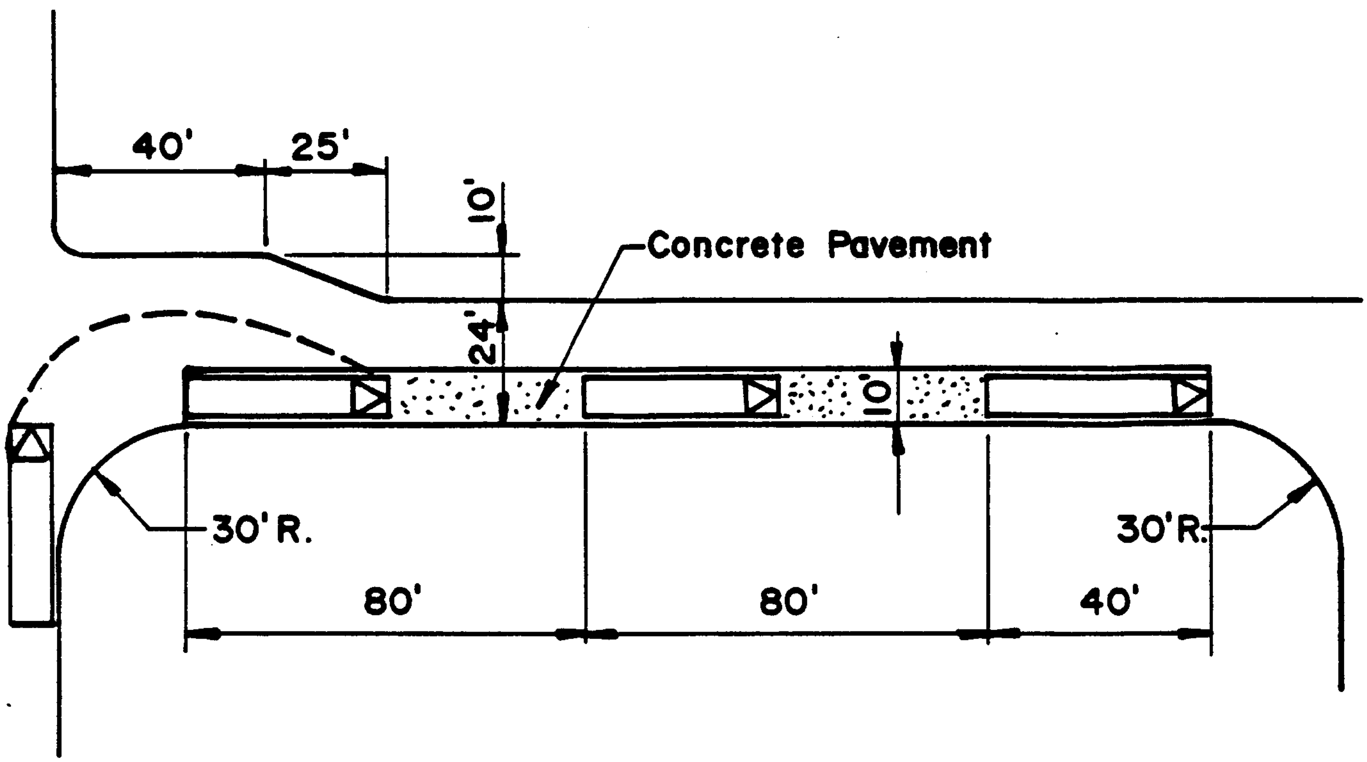
MAXIMUM INDENT

SAWTOOTH BUS BAYS

FIGURE II-1-67



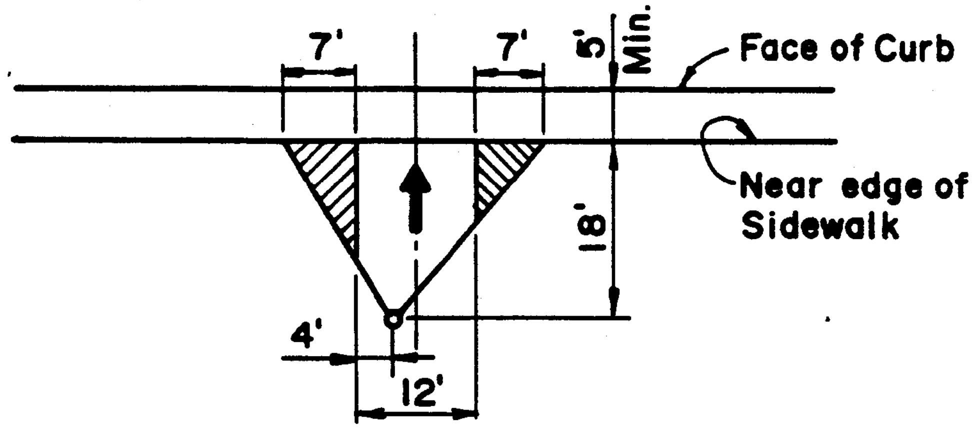
RECESSED BUS BAY



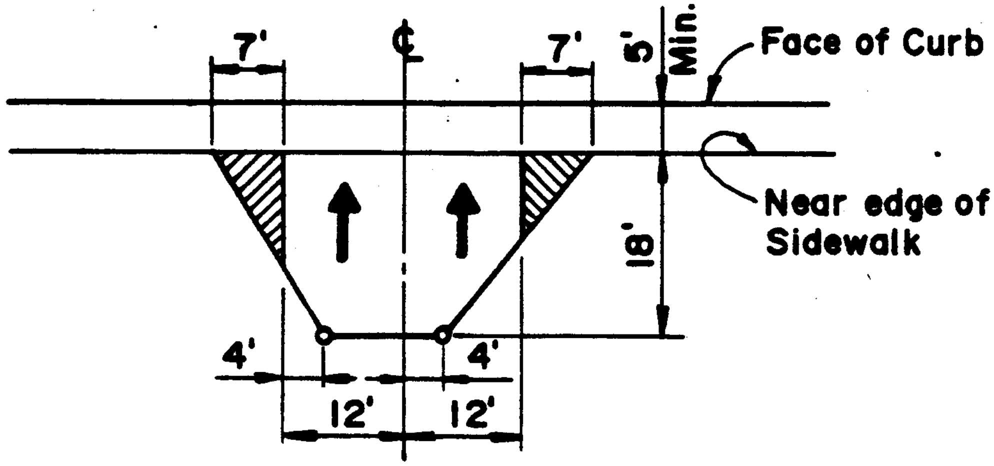
PARALLEL TO CURB BUS BAY

PARALLEL BUS BAYS

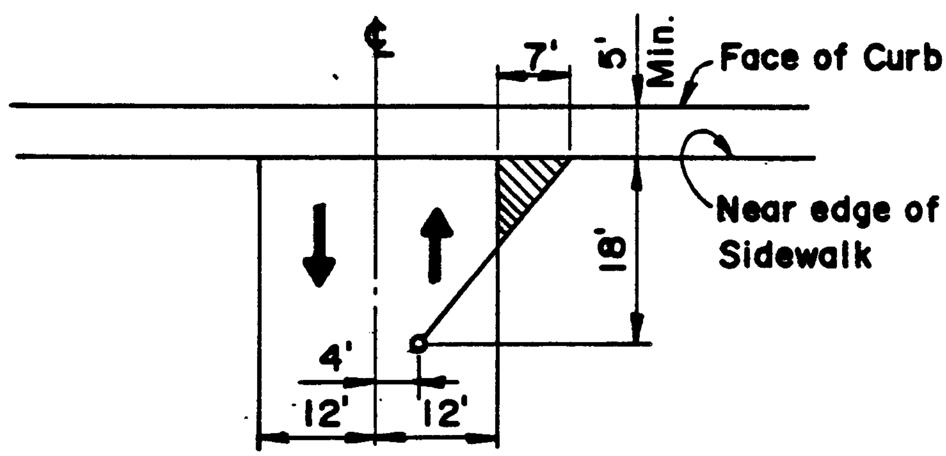
FIGURE II-1-68



ONE-LANE EXIT



TWO-LANE EXIT

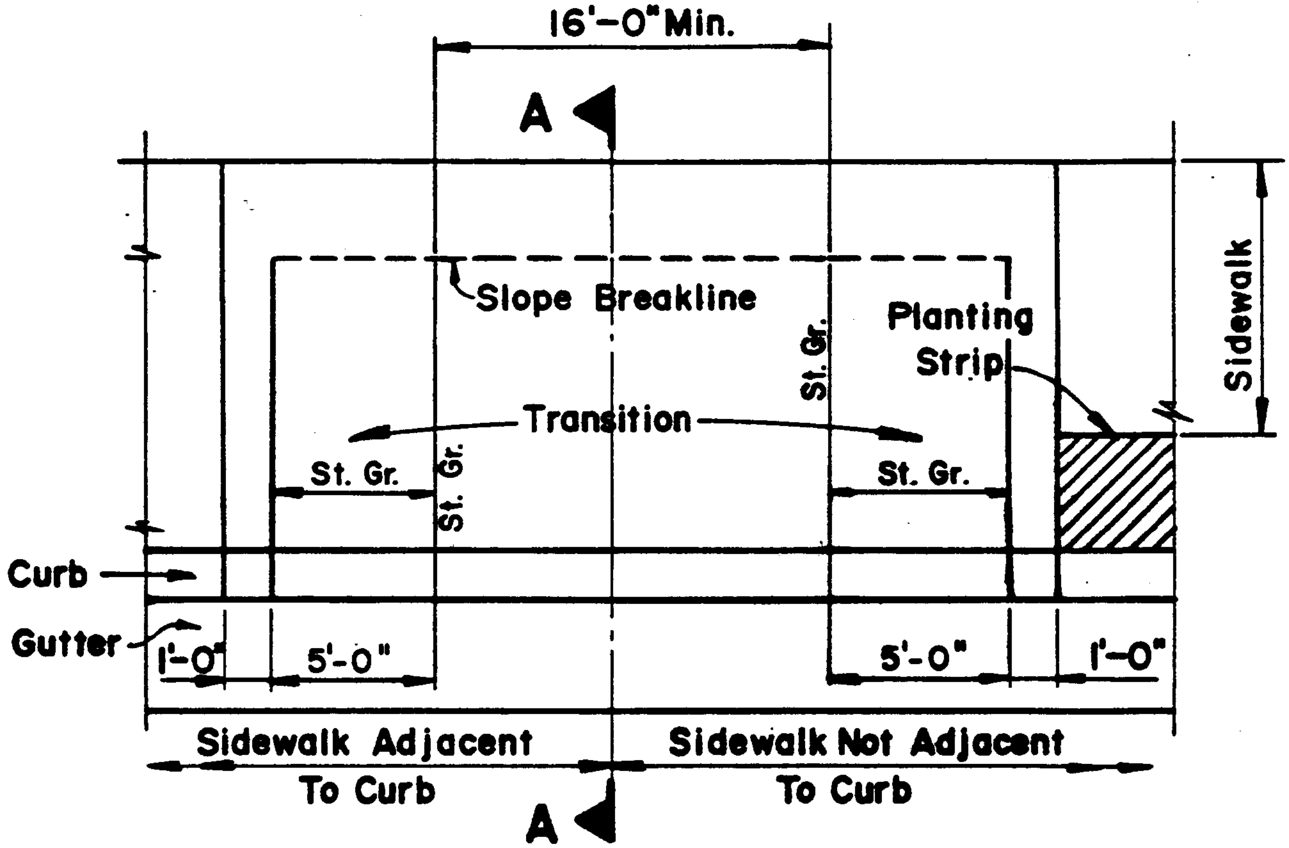


ENTRANCE-EXIT

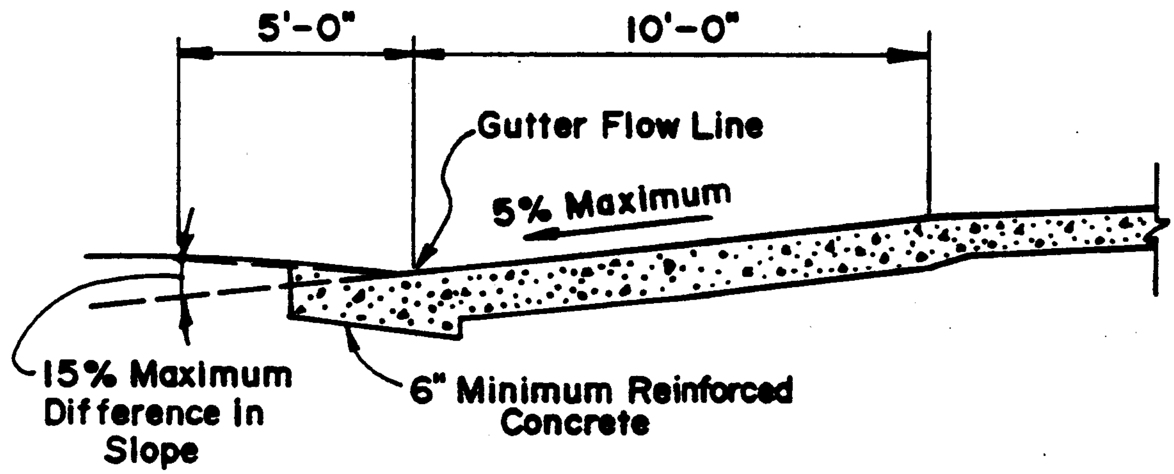
Note: Exclude Objects more than 3'–9" high from Shaded Area.

PARKING STRUCTURE ENTRANCES AND EXITS
SIGHT DISTANCE REQUIREMENTS

FIGURE II-1-69



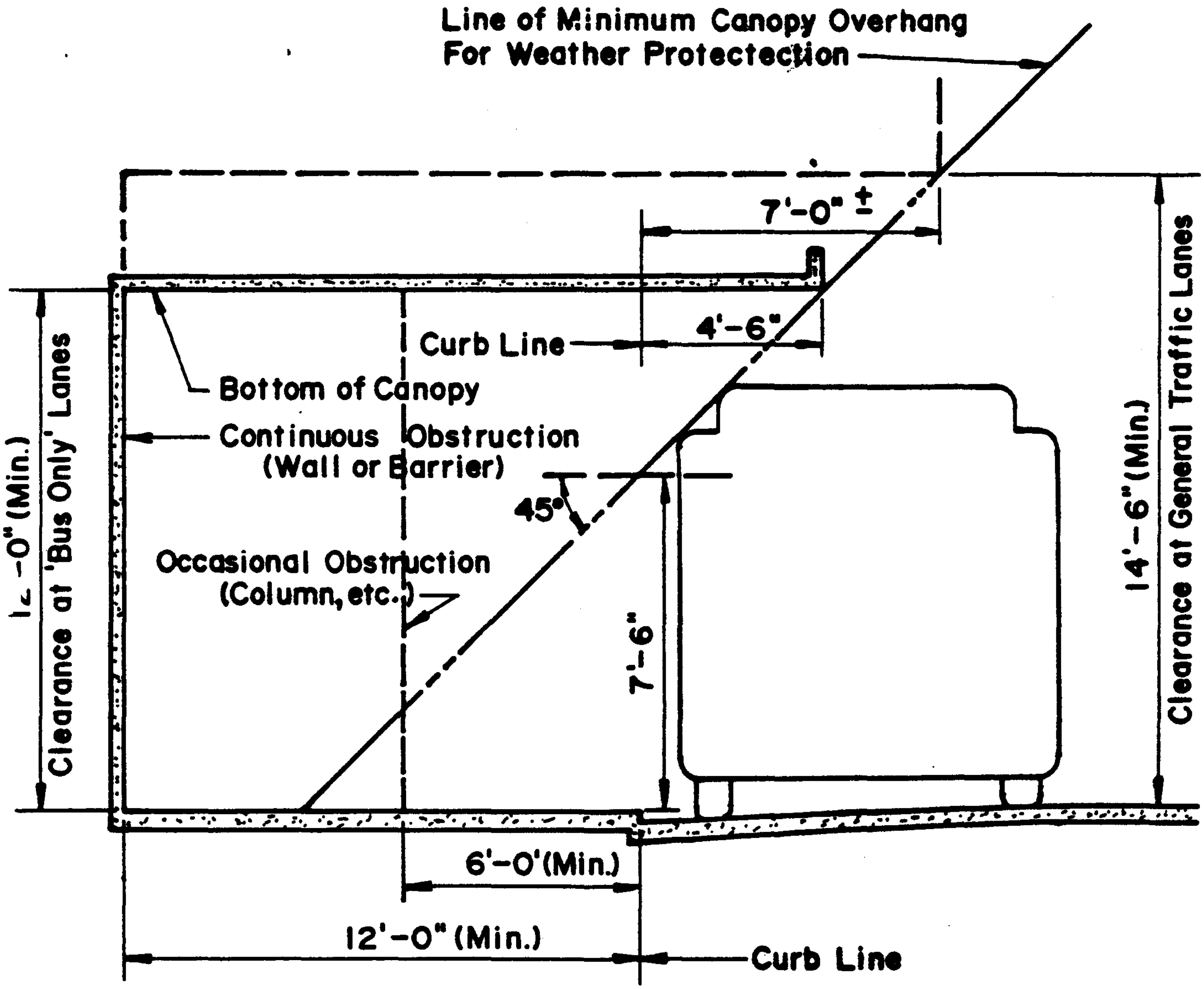
PLAN



SECTION A

DRIVEWAYS FOR PARKING STRUCTURES

FIGURE II-1-70



TRANSVERSE SECTION

CLEARANCES FOR BUS SHELTERS AT STATIONS

FIGURE II-1-71

2. STRUCTURAL

SYSTEM DESIGN CRITERIA AND STANDARDS

VOLUME: II SECTION: 2

STRUCTURAL

REVISION RECORD

NOTICE NUMBER	CR NO/REV	DATE APPROVED	AFFECTED	COMMENTS
1	4-078/	10/12/84	2.3.3 C	
2	6-035/ 6-016/1	11/18/86 10/28/86	Figure II-2-1 2.12.5	p. II-2-9 p. II-2-56 Also update format

SCRTD METRO RAIL SYSTEM DESIGN CRITERIA

Volume 2, Section 2

STRUCTURAL

JUN 30 1983

SCRTD METRO RAIL SYSTEM DESIGN CRITERIA

Volume 2, Section 2

STRUCTURAL

SCRTD METRO RAIL SYSTEM DESIGN CRITERIA

Volume 2, Section 2, Structural

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VOLUME 2, SECTION 2

STRUCTURAL

2.1 SCOPE

A. This Section establishes the basic design criteria for District owned structures, including bridges, cut-and-cover structures, tunnels, stations, retaining walls, buildings, construction structures, and miscellaneous structures for the Southern California Rapid Transit District System. All applicable structural criteria are contained herein and identified for usage. Where special design cases are encountered that are not specifically covered in these criteria, the District shall determine the applicable technical sources for the design criteria to be used.

B. The design of a structure, owned and maintained by an agency other than the District, shall be in accordance with the standards utilized by that agency.

2.2 DESIGN CODES, MANUALS, AND SPECIFICATIONS

The Structural design shall be governed by all applicable portions of the State of California general laws and regulations and the current editions of the following codes, manuals, or specifications, as set forth in this Section.

2.2.1 Building Codes

A. In the County of Los Angeles, "The Los Angeles County Building Laws," 1981 Edition, with appropriate amendments to be developed for the construction of rail rapid transit building facilities.

B. In the City of Los Angeles, "The City of Los Angeles Building Code," 1980 Edition, with appropriate amendments to be developed for the construction of rail rapid transit building facilities, except for concrete use ACI 318-77 and for structural steel use AISC Specifications dated 1978.

C. Other incorporated areas, not governed by any of the above regulations shall be in accordance with local municipal law, or, in the absence of such law, shall be in accordance with "The Uniform Building Code" of the International Conference of Building Officials, 1979 Edition, hereafter referred to as U.B.C., for the construction of rail rapid transit building facilities.

2.2.2 Other Codes, Manuals, and Specifications

A. For bridges, District or other, which support railroad loadings, the design requirements of the applicable railroad. In the absence of such requirements, the current edition of the "Manual for Railway Engineering" of the American Railway Engineering Association, hereinafter referred to as the AREA Manual.

B. For bridges, District or other, which support highway loading, the design requirements of the applicable jurisdiction. In the absence of such requirements, the Twelfth Edition, 1977, of the "Standard Specifications for Highway Bridges" of the American Association of State Highway and Transportation Officials, hereinafter referred to as AASHTO Specifications.

C. For reinforced concrete retaining walls the AREA Manual.

D. For concrete, reinforced concrete, precast concrete, and prestressed concrete structures other than bridges subjected to railroad or highway loading, the 1977 edition of the "American Concrete Institute Standard Building Code Requirements for Reinforced Concrete," hereinafter referred to as the ACI-318.

E. For structural steel structures, other than bridges subjected to railroad or highway loading, the 1978 Edition of the "Specifications of the Design, Fabrication and Erection of Structural Steel for Buildings" of the American Institute of Steel Construction, hereinafter referred to as the AISC Specifications.

F. For timber structures, other than buildings within the jurisdiction of the County of Los Angeles or the City of Los Angeles and bridges subjected to railroad or highway loading, the current edition of the "National Design Specification for Stress-Grade Lumber and Its Fastenings," recommended by National Forest Products Association.

G. For cast iron structures, the current edition of "The Gray Iron Castings Handbook" of the Gray Iron Founders' Society.

2.3 LOADS AND FORCES

All rapid transit structures shall be designed to sustain the maximum dead and live loads to which they may be subjected, including erection loads occurring during construction, and all other loads and forces listed as follows:

A. Dead Loads (DL)

B. Live Loads (LL)

C. Earthquake Forces (EQ)

D. Impact or dynamic effect of the live load (I)

E. Centrifugal Force (CF)

F. Rolling Force (RF)

G. Longitudinal Braking and Tractive Force (LF)

H. Earth Pressure (E)

I. Buoyancy (B)

J. Flooding (FL)

K. Stream Flow (SF)

L. Wind Load on Structure (W)

M. Wind Load on Live Load (WL)

N. Shrinkage Force (S)

O. Thermal Force (T)

The loading criteria to which the structures are designed shall appear on the structural drawings. When required by design conditions, concrete placing sequence shall be indicated on the plans or in the specifications.

2.3.1 Dead Loads (DL)

The dead loads consist of the actual weight of the structure and include permanently installed trackwork, partitions, electrification, service walks, pipes, conduits, cables, utilities, services, and all other permanent construction and fixtures. Since dead load stresses are always present, the structure should be so designed as to sustain them at all times without reduction. The dead load should be computed from the weights of the materials composing the structure and its permanent fixtures. The approximate unit weights of materials normally used in construction are shown in Table II-2-1. A specific check should be made as to the actual weight where a variation might affect the adequacy of the design or where the construction may vary from the normal practice.

A. Structures Constructed by Cut-and-Cover Methods

1. The dead load for structures constructed by cut-and-cover methods shall consist of the weight of the basic structure, the weight of secondary elements permanently supported by the structure, and the weight of the earth cover supported by the top of the structure and acting as a simple gravity load.

2. The dead load shall be applied in stages to realistically represent the life history of the design structure. For example, removal of the earth cover from a prestressed concrete span at some future date may create a serious upward deflection problem and therefore should be analyzed as a separate loading case.

3. The design unit weight of earth, both above and below the groundwater table, shall not be less than 130 pcf for the analysis of the structural frame. In making calculations with regard to dead weight resisting flotation of the structure, the actual unit weight of backfill placed over the structure shall be used, but in no case shall be taken as greater than 120 pcf. Where full hydrostatic pressure below the groundwater table is used as a design load, a submerged design unit weight of not more than 68 pcf shall be used for earth below the groundwater table.

B. Earth and Mixed Face Tunneled Structures

The long term dead load for earth and mixed face tunneled structures shall be the same as for cut-and-cover structures. The construction and short term loading shall depend on the particular location under consideration.

C. Rock Tunneled Structures

Construction and long term loading cases depend on the particular location under consideration.

D. Minimum Earth Cover for Design

All underground structures shall be designed for actual cover depth, or for an assumed minimum cover depth of 8'-0" when the actual cover depth is less than 8'-0".

E. Loads from Adjacent Building Foundations or Other Structures

1. The Designer shall determine the need for all permanent underpinning of buildings or structures. The underground structures shall be designed for loading from existing adjacent buildings or structures. Considerations shall be given to the maximum and minimum loads which can be transferred to the design structure, and design loads shall be assumed to be as those for which the adjacent structure was designed; but, in the absence of this information, provisions in the applicable building code or the actual weights and the heaviest occupancy for which the building is suitable shall be used.

2. Horizontal and vertical distribution of loads from foundations of existing buildings shall be determined by the Designer in consultation with the Geotechnical Consultant.

VOLUME 2, SECTION 2 STRUCTURAL (Cont'd)

TABLE II-2-1

WEIGHTS OF MATERIALS

Aluminum alloys	175	pcf
Asphalt mastic, bituminous macadam	150	pcf
Ballast, crushed stone, compacted earth	120	pcf
Compacted gravel	140	pcf
Ceilings, plaster board, unplastered	3	pcf
gypsum ceiling tile, 2 inch unplastered	9	pcf
pressed steel	2	pcf
Ceramic glazed structural facing tile, 4 inch	33	pcf
Concrete-plain or reinforced; Gravel Aggregates	150	pcf
Special & Light Weight Concretes	By Test	
Electrification, including third rail & fastenings	60	plf
Floors, gypsum floor slab, per inch of depth	5	psf
asphalt mastic	5	psf
ceramic tile, on 1 inch mortar bed	23	psf
terrazzo, 1 inch on 1/2 inch mortar bed	18	psf
marble, 1 inch on 1/2 inch mortar bed	20	psf
linoleum, 1/4 inch	2	psf
maple, 7/8 inch on sheathing, 2 inch cinder fill, no ceiling	18	psf
oak, 7/8 inch on sheathing, wood joists at 16 inch centers, no ceiling	11	psf
Glass	160	pcf
Gravel, Sand	120	pcf
Iron, cast	450	pcf
Partitions, plaster, 2" channel stud, metal lath	20	psf
plaster, 4" channel stud, metal lath	32	psf
hollow plaster, 4 inch metal lath	22	psf
gypsum block, solid, 3") both sides	19	psf
gypsum block, hollow, 5") plastered	22	psf
marble wainscoating, 1"	15	psf
steel partitions	4	psf
ceramic glazed structural tile, 4"	33	psf
Rails and fastenings, per track (2 rails)	200	plf
Roofs, roofing felt, 3 ply, and gravel	5-1/2	psf
5 ply,	6-1/2	psf
Sheathing, 3/4 inch thick	3-1/2	psf
Steel	490	pcf
Timber, untreated	48	pcf
treated	60	pcf
Walls, brick solid, per inch	10	psf
terra cotta tile 4") - plastering - add	25	psf
8") 5 psf per side	33	psf
12")	45	psf
glass, structural, per inch	15	psf
windows, frame, glass, sash	8	psf
stone, 4 inch	55	psf
steel sheeting, 14 gauge	3	psf

F. Aboveground Structures

The dead load for aboveground structures shall consist of the weight of the basic structure and the weight of secondary elements permanently supported by the structure.

G. Miscellaneous Loads

1. Consideration shall be given to any system or facility which will apply a permanent load or force to the design structure.

2. Provisions of agreements with property owners, railroads, and other agencies regarding special loading 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. Attention shall be paid to proposed future constructions.

2.3.2 <u>Live Loads (LL)</u>

Live loads shall consist of any non-permanent loads including the weight of machinery, equipment, stored materials, persons, transit vehicles, elevators, escalators or other moving objects, construction loads, and loads due to maintenance operations.

A. Rapid Transit Vehicle - See Figure II-2-1 for car dimensions and weights. Any combination of train lengths and loadings which produces the critical design loading shall be used for structural design.

B. Crane Car - See Figure II-2-2 for car dimensions and weights.

C. Roadway

1. Roadway live loads on underground rapid transit structures shall be based on the HS 20-44 loading according to the AASHTO Specifications. Superimposed wheel load from this loading shall be distributed in accordance with the AASHTO Specifications, Article 1.3.3, to a maximum depth of four feet. At depths between four feet and eight feet, a graduated uniform live load of 440 psf to

300 psf shall be used. Below a depth of eight feet, a uniform live load of 300 psf shall be used. The depth used in LL calculations shall be measured to the top of the underground structure's roof slab.

2. All underground structures having less than eight feet of earth cover shall be designed for two conditions:

   a. The actual depth of cover plus superimposed HS 20-44 wheel load distributed in accordance with the above requirements.

   b. An assumed future cover of eight feet plus a uniform live load of 300 psf.

   c. The more severe of these two conditions shall govern.

D. Pedestrian Areas

1. Station platforms, pedestrian ramps, mezzanines, and other pedestrian areas shall be designed for a uniform load of 100 psf.

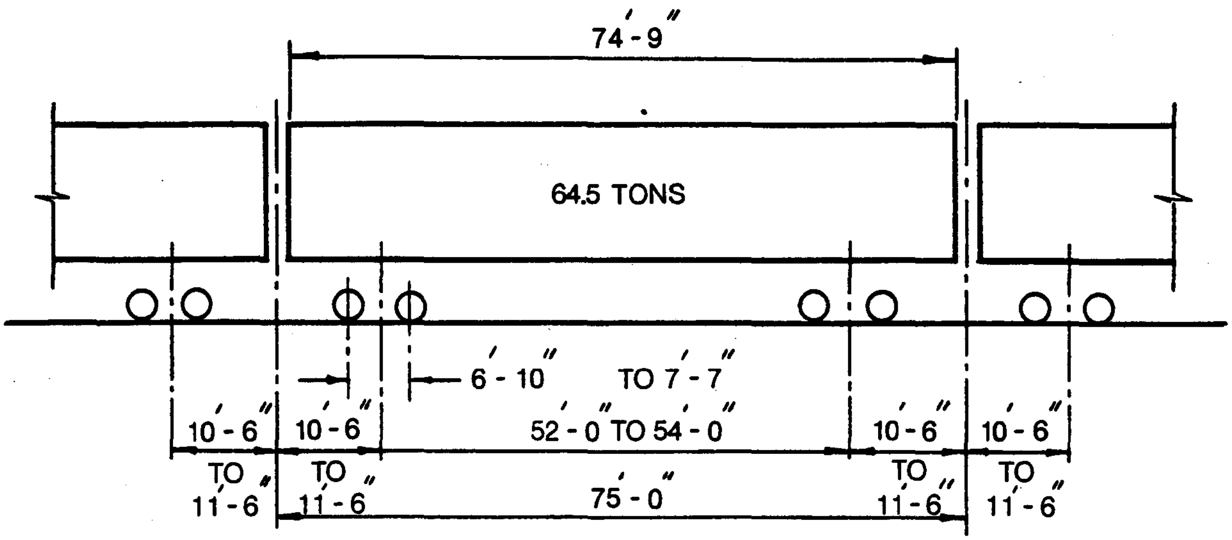
2. Stairways shall be designed for a uniform load of 100 psf or a concentrated load of 300 pounds on the center of stair treads, whichever is critical.

E. Storage Space and Machinery Rooms

Electrical equipment rooms, pump rooms, service rooms, storage space, and machinery rooms shall be designed for uniform loads of 250 psf, to be increased if storage or machinery loads so dictate.

F. Escalators and Passenger Conveyors

Structures supporting escalators or passenger conveyors shall be designed for the maximum reactions from any of the manufactured units considered for use in the Rapid Transit Systems.



1. DESIGN LOADS ---------------- VEHICLE ______ 82,000 LB.
   -------------- PASSENGERS ______ 47,000 LB.
   TOTAL RAPID TRANSIT LOADING (LL) ______ 129,000 LB.

2. AXLE LOAD ---------------------------- 35,300 LB.

3. IMPACT ---------------------------- AS SPECIFIED

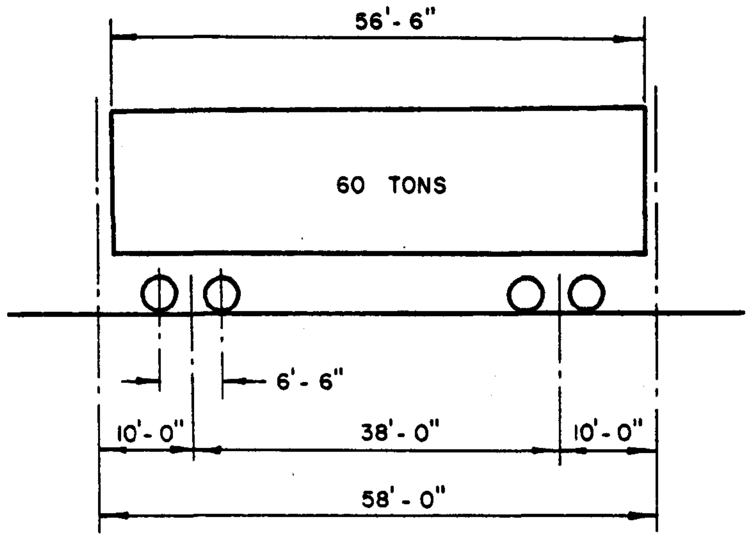
4. CENTRIFUGAL FORCE ------------ (6.7 x SPEED^2 (MPH) ÷ RADIUS OF CURVE (FT.)) % LL

5. ROLLING FORCE -------------------------- 10% LL

6. LONGITUDINAL BRAKING AND TRACTIVE FORCE ------ 20% LL

RAPID TRANSIT VEHICLE DESIGN LOADING

FIGURE II-2-1



1. DESIGN LOADS . . . . CAR — 80,000 LB.
   . . . . PAYLOAD — 40,000 LB.
   TOTAL CRANE CAR LOADING (LL) — 120,000 LB.
2. AXLE LOAD . . . . 30,000 LB.
3. IMPACT . . . . AS SPECIFIED
4. CENTRIFUGAL FORCE . . . . [6.88 x SPEED^2 (MPH) x RADIUS OF CURVE (FT.)] %LL
5. ROLLING FORCE . . . . 10 %LL
6. LONGITUDINAL BRAKING AND TRACTIVE FORCE . . . . . . 15 %LL

CRANE CAR DESIGN LOADING

FIGURE II-2-2

G. Railings

Railings in station platforms and mezzanines shall be designed for a horizontal force of 50 plf and a vertical force of 50 plf at their top. Railings in other places of public assembly shall be designed in accordance with local codes. Railings in equipment rooms and working areas shall be designed for a force of 200 pounds applied in any direction at any point.

H. Gratings

Ventilation shaft gratings in street or in sidewalk shall be designed to carry HS 20-44 loading in accordance with the AASHTO Specifications. Gratings protected from vehicular traffic shall be designed for a uniform load of 250 psf. Gratings which might be subjected to loading from out-of-control vehicles shall be designed for HS 20-44 loading.

I. Curbs

Curbs shall be designed to resist a lateral force of not less than 500 pounds per linear foot of curb, applied at the top of the curb, or at an elevation of ten inches. Where sidewalk, curb, and traffic railing form an integral system, the traffic railing loading shall apply, and stresses in curbs shall be computed accordingly.

J. Service Walks

Service walks shall be designed for a uniform load of 85 psf of walkway area. Except the aerial structures and pedestrian bridges, all member supporting 50 square feet of walkway or more shall be designed for a live load of 60 pounds per square foot of walkway area.

K. Access Doors at Street Level

Access doors shall be designed for a uniform live load of 350 psf.

2.3.3 Earthquake Forces (EQ)

A. All bridges, or aerial structures, shall be designed to resist earthquake motions in accordance with AASHTO Specifications Article 1.2.20 and with consideration of the following:

1. To assist the Designer in obtaining the value of Response Coefficient "C," the figures in AASHTO have been reproduced as Figures II-2-3 through II-2-6 in these criteria.

2. The Seismic Consultant shall determine the depth to rock-like material or, for unusual conditions, furnish a special "C" curve to the Designer.

3. The Seismic Consultant shall furnish the maximum expected acceleration of the bedrocks at the site in question.

4. Earthquake response coefficients furnished by the Seismic Consultant shall take precedence over general information furnished in AASHTO.

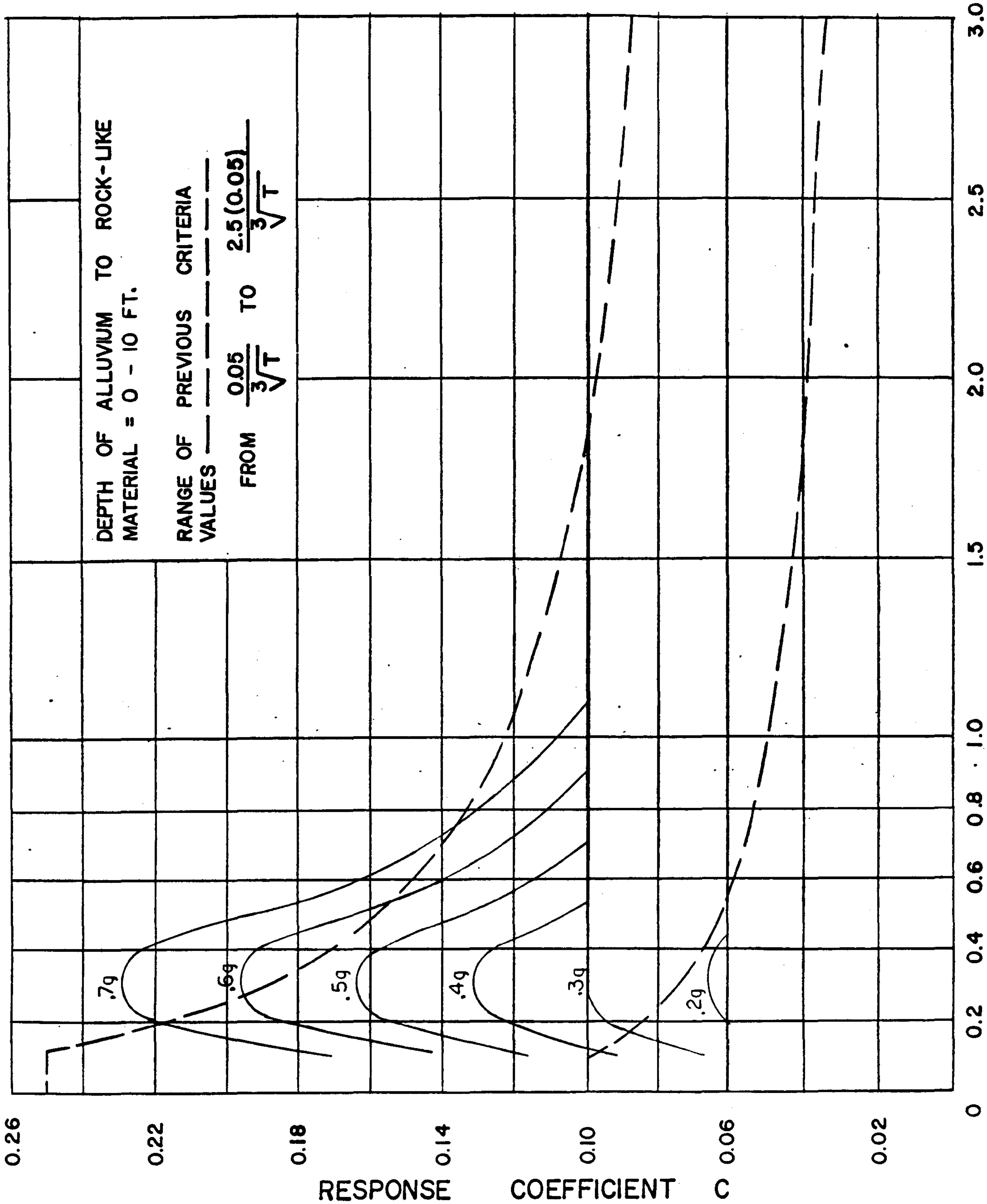
B. All buildings shall be designed to resist earthquake motions in accordance with the applicable building code.

C. The portions of underground structures subject to earthquake motions shall be designed in accordance with "Supplemental Criteria for Seismic Design of Underground Structures" dated June 1984.

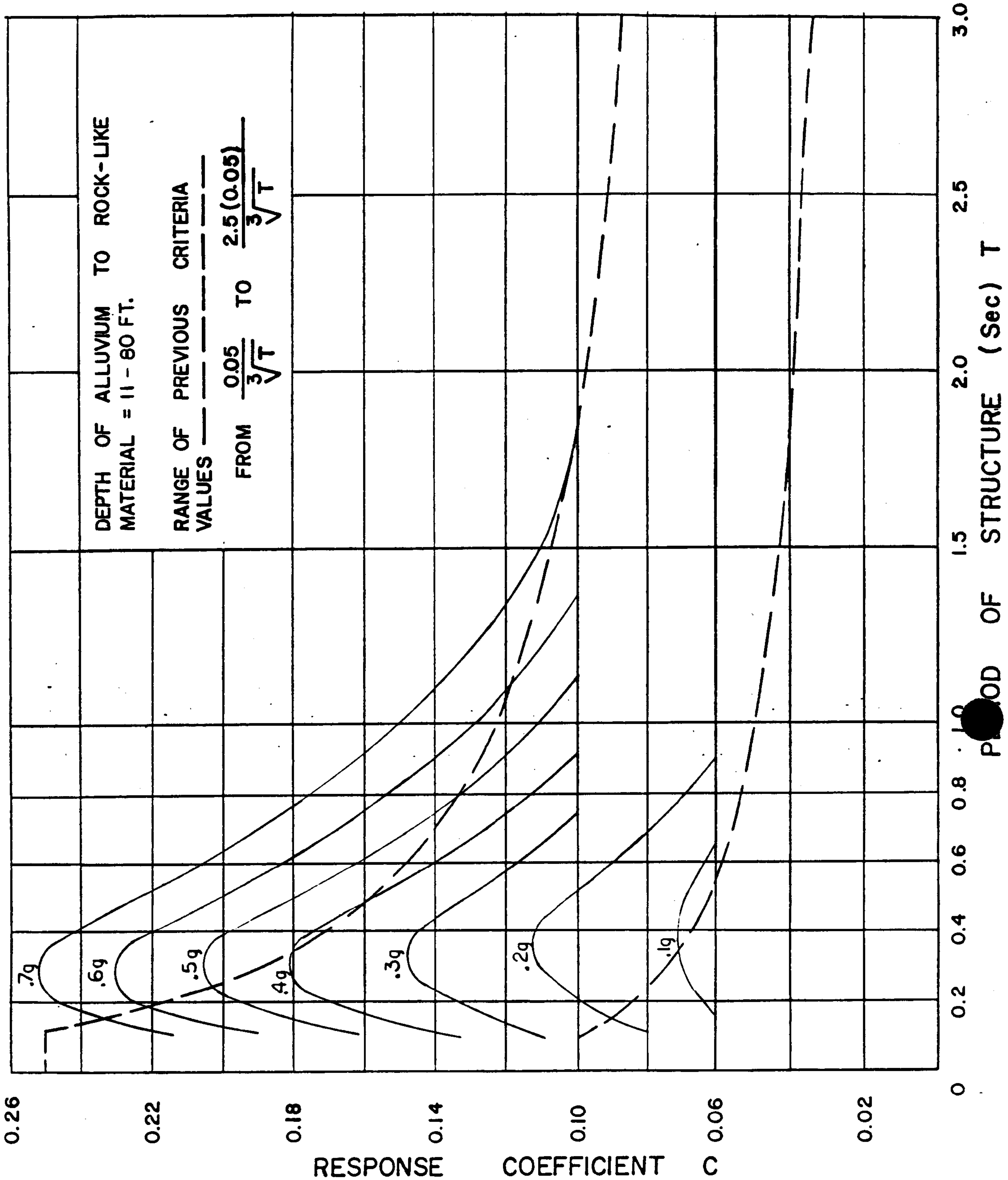
D. Commentary on Earthquake Design Criteria

1. Recent techniques in analyzing a structure for earthquake forces, require consideration of factors such as: 1) location of the site relative to active faults (to obtain anticipated peak rock acceleration), 2) the effect of the overlying soil on the earthquake motion, and 3) the dynamic response of the structure to the ground motion.

2. This new design criteria is structured to consider these factors in determining a seismic coefficient. The first factor to be considered is peak rock acceleration. To obtain the appropriate rock acceleration at a particular site, a map of the state superimposed contours of anticipated peak rock acceleration was developed by the Division of Mines and Geology. This map was constructed by plotting the active faults and assigning probable earthquake magnitudes to them.



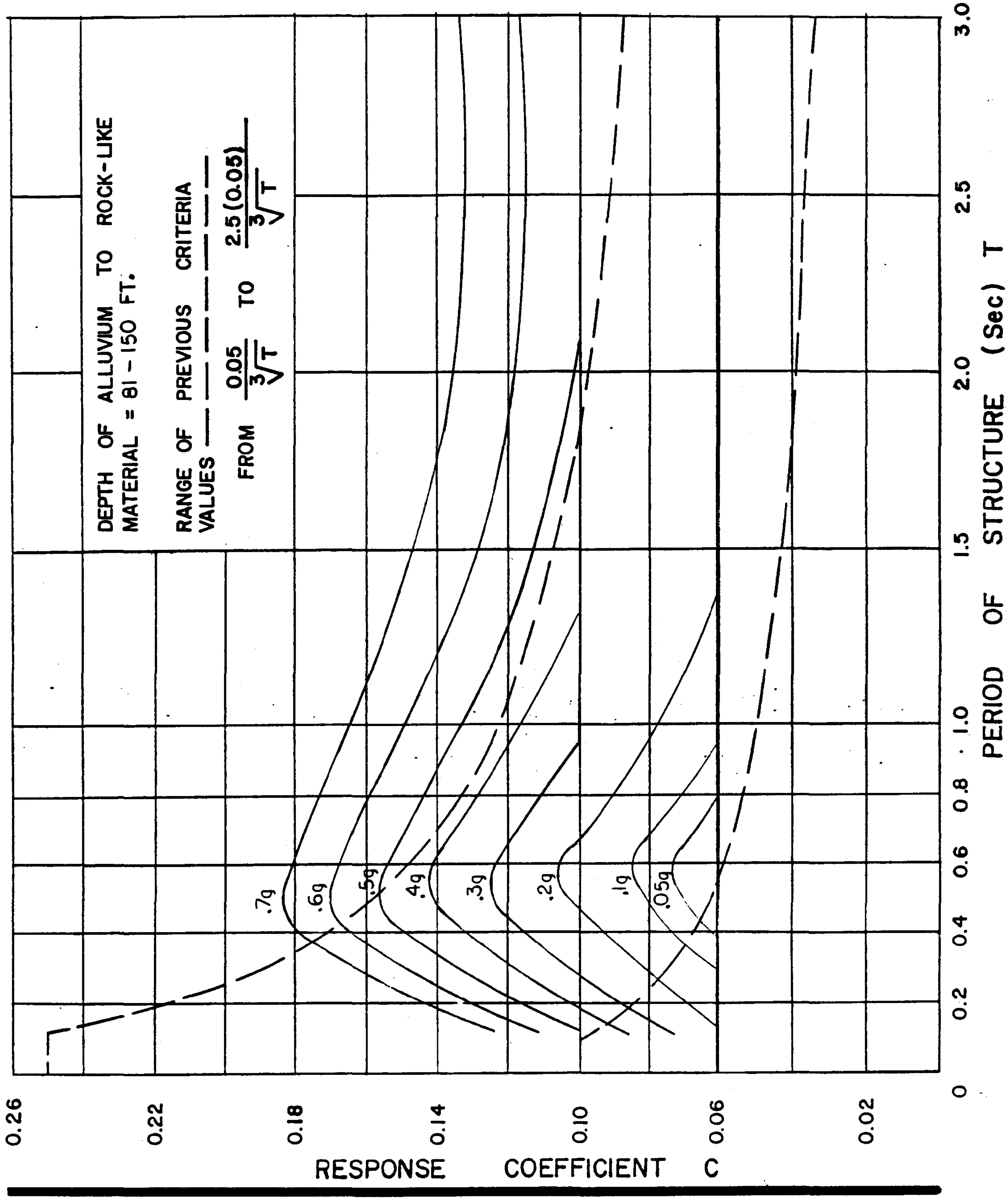
RESPONSE COEFFICIENT 'C' FOR VARIOUS VALUES OF PEAK ROCK ACCELERATION 'A'
(DEPTH OF ALLUVIUM TO ROCK-LIKE MATERIAL 0-10 FT.)
FIGURE II-2-3



RESPONSE COEFFICIENT 'C' FOR VARIOUS VALUES OF PEAK ROCK ACCELERATION 'A'

(DEPTH OF ALLUVIUM TO ROCK - LIKE MATERIAL 11 - 80 FT.)

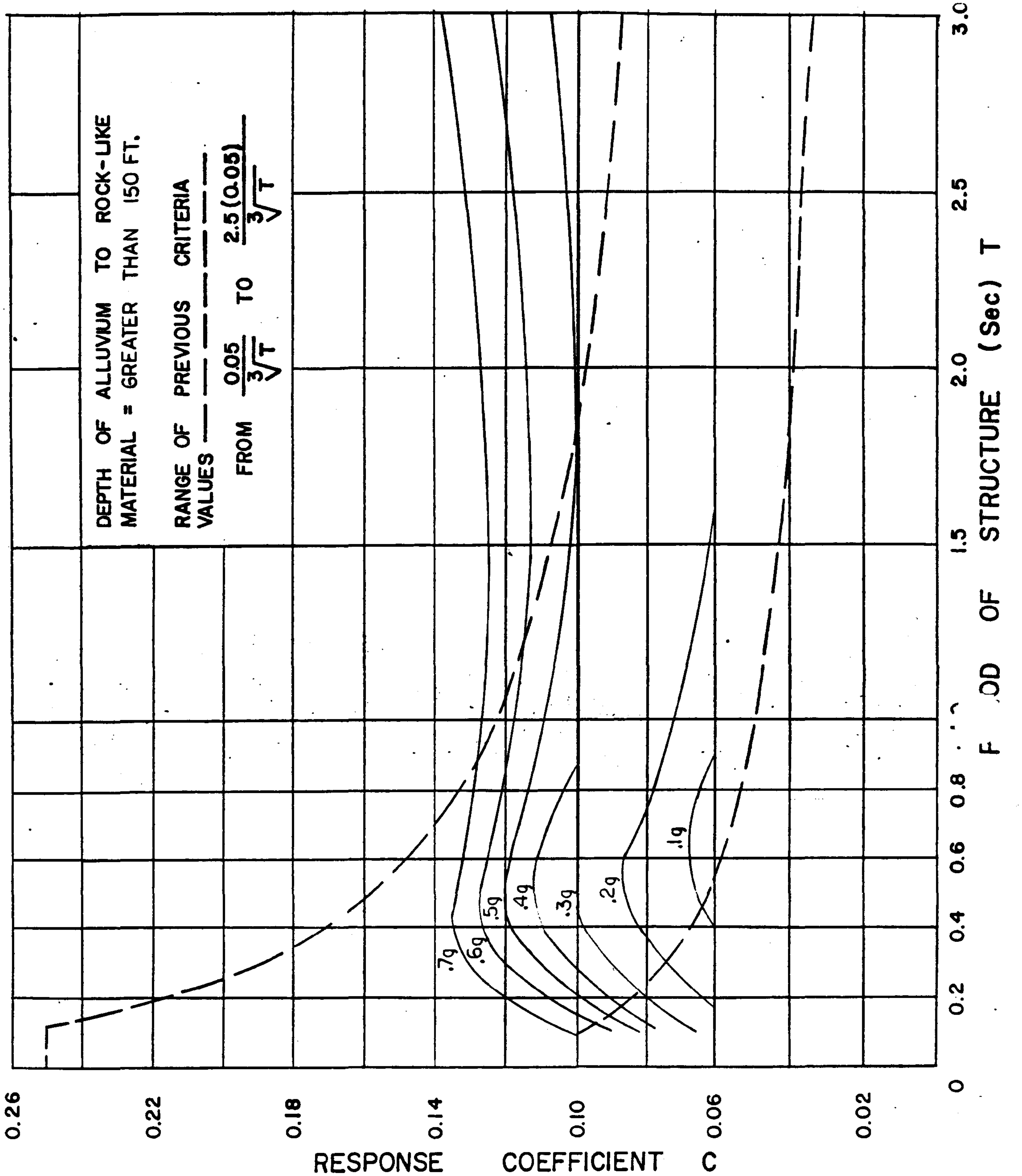
FIGURE II-2-4



RESPONSE COEFFICIENT 'C' FOR VARIOUS VALUES OF PEAK ROCK ACCELERATION 'A'

(DEPTH OF ALLUVIUM TO ROCK - LIKE MATERIAL 81 - 150 FT.)

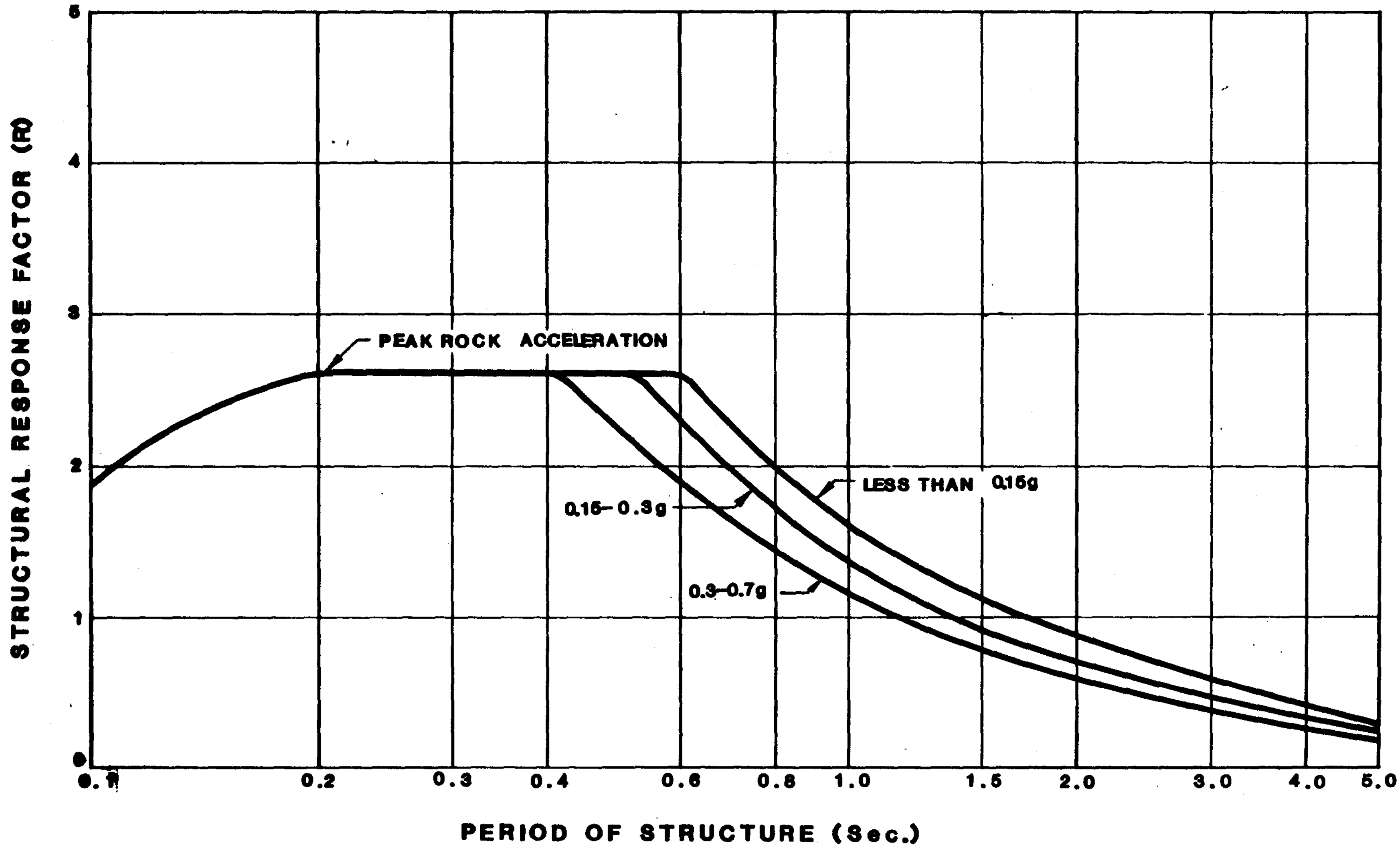
FIGURE II– 2–5



RESPONSE COEFFICIENT 'C' FOR VARIOUS VALUES OF PEAK ROCK ACCELERATION 'A'

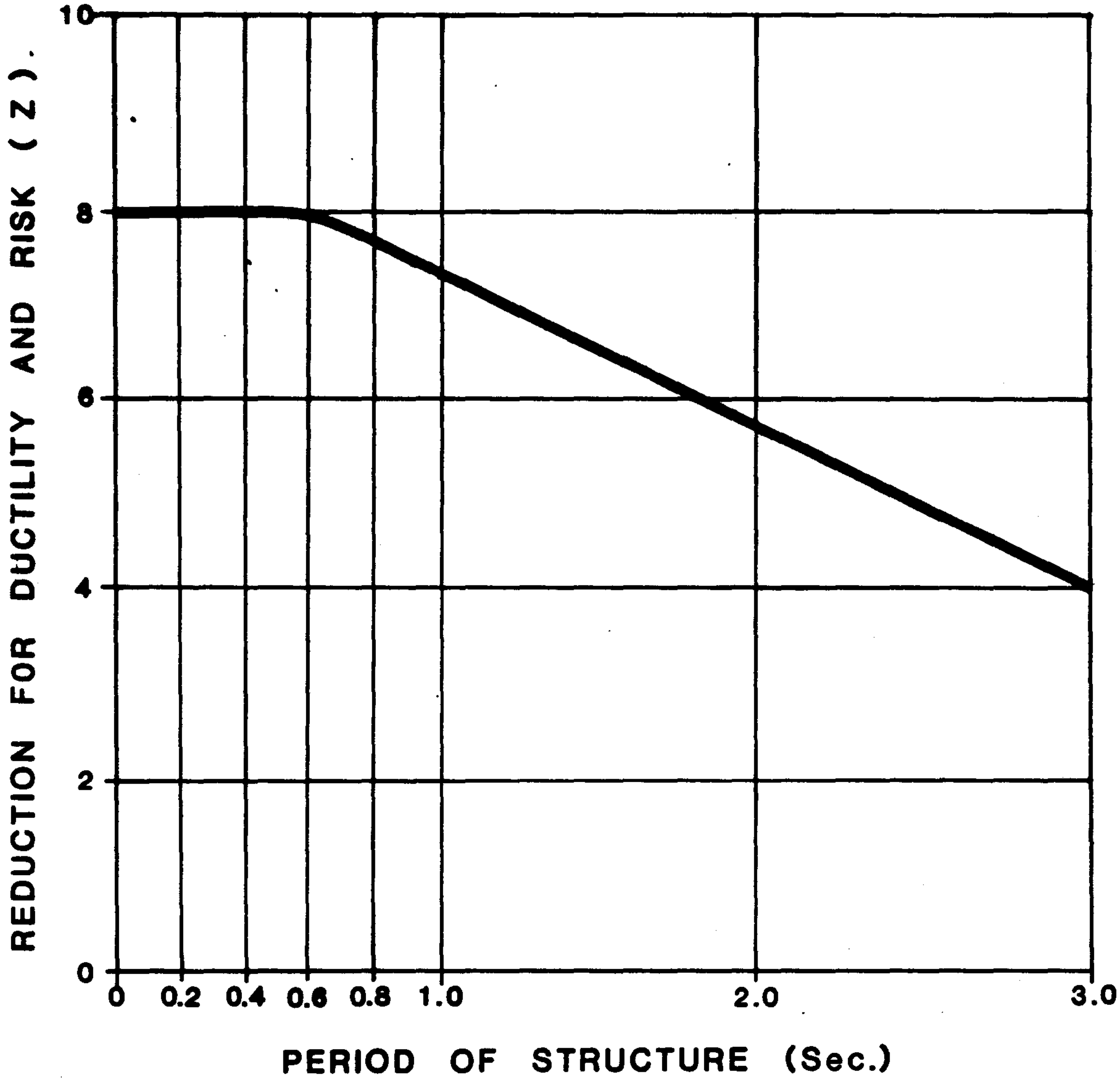
(DEPTH OF ALLUVIUM TO ROCK - LIKE MATERIAL GREATER THAN 150)

FIGURE II– 2 –6



NORMALIZED ROCK SPECTRUM

FIGURE II-2-7



Z ---REDUCTION CURVE FOR DUCTILITY AND RISK ASSESSMENT

FIGURE II- 2-8

These magnitudes were then related to acceleration levels; as the distance from a fault increases, the rock acceleration decreases. To determine the rock acceleration at points away from the fault, attenuation curves developed by Schnabel and Seed of the University of California were used. Map Sheet 23 entitled, "Maximum Credible Rock Acceleration from Earthquakes in California" and a report on its development is available from the State of California, Division of Mines and Geology.

This map is based on past earthquake history and available geologic information and will be updated and refined on a continuing basis as new information is obtained. The latest edition, dated August, 1974, suggest that a rock acceleration value of 0.5 g is appropriate for the Los Angeles Metro Rail Project site.

3. A response spectrum is used to assess the response of structures of different natural periods to an earthquake motion. It has been found that all earthquakes do not produce the same type of motions and therefore structures respond differently to different earthquakes. Some earthquakes do not contain motion with predominant periods corresponding to the natural periods of certain structures.

4. The overcome this deficiency, five percent damped response spectra were drawn from acceleragraphs recorded on rock or rock-like site from five different earthquakes. These earthquakes were: 1) Castaic, 2) Lake Hughes, 3) Pacoima (modified), 4) Parkfield, and 5) Golden Gate. The spectra from these earthquakes were normalized and an average curve was drawn from the five resulting curves. Normalizing the curves provides an expedient means of combining spectra of different maximum values. It also makes it possible to apply the combined spectra to zones of different rock acceleration values. The average curve represents the response at rock level (Figure II-2-7).

5. It is generally recognized that site conditions can significantly modify the rock motion. The

overlying soil can amplify or attenuate the motions. To determine the effect of the soil, a series of soil columns of different depths and stiffnesses were analyzed using a computer program called SHAKE 3, developed at the University of California at Berkeley. These soil columns were subjected to various representative earthquakes. The results from these analyses were used to develop soil amplification curves. It was found that for alluvial soils, depth was the variable that had the greatest effect on response. Other factors such as stiffness, water table, etc., did not have a significant effect. Amplification curves for various depths of alluvium were developed. Although curves are for alluvial sites only, they represent the majority of the bridge sites in California. Other sites will require special analysis as determined by the Geotechnical Consultant.

6. The amplification factors were applied to the rock motion curves. Five percent damped elastic surface response spectra were constructed for four soil depth ranges by multiplying values from the rock motion spectra by amplification factor for each corresponding period. The resulting curves were smoothed by assigning less weight to extreme values, especially in low period regions.

7. The next and most difficult step is to develop design spectra from theoretical elastic spectra. As a result of past experience, it can be concluded that structures can withstand forces far in excess of the theoretical seismic forces for which they were designed. Inelastic response, increase in damping, and ductility of members enable the structure to resist considerably higher forces than indicated by elastic analysis. The state of the art has not progressed to a point where all these parameters can be adequately considered in the analysis. Considerable engineering judgement and knowledge of the performance of structures during an earthquake must be applied in reducing the elastic force levels to design levels. It was decided to use a reduction value of four.

VOLUME 2, SECTION 2 STRUCTURAL (Cont'd)

8. Another factor to be considered is risk. Some bridges such as the common two-span over-crossing are relatively stable and not vulnerable to collapse. Even if columns are severely damaged, the stability provided at the abutments prevents the bridge from overturning. With the increase in column ties and the greater use of spirals, collapse from a lack of concrete confinement should not occur. These lower structures can be readily shored up, repaired, and restored to traffic use. The probability of collapse and the resulting loss of life is minimal for this type of structure. These structures can thus be designed for lower force values than the high single column bent structures which are more vulnerable to collapse and difficult to restore.

9. A risk reduction factor of 2.0 was assigned to the stiff structures with periods up to 0.6 seconds. The factor was decreased linearly to 1.0 for structures with a period of three seconds. The ductility and risk factors were combined to produce a reduction curve. This curve was then used to reduce the elastic response spectra to design coefficient curves (Figure II-2-8). The resulting reduction values ranged from eight to 0.6 seconds, to four at three seconds. In developing the curves, it was decided to limit the maximum force level of 0.25 g. A minimum force level of 0.10 g was established for structures in areas of expected peak rock acceleration of 0.3 g or greater. For areas with a peak less than 0.3 g, a minimum force value of 0.06 g was selected. For the larger more flexible structures with periods over three seconds, it was decided to require that a dynamic analysis be performed.

10. A frame factor needs to be applied to arrive at the final design coefficient. It is proposed that the framing factor for single column bents and piers be 1.0, and for frames, 0.8. It was decided to raise the frame factor from 0.67 previously used to 0.8 because in bridges the multiplicity of joint is not as great as in buildings. Therefore, the reduction should not be as great.

11. The reduction of the pier wall coefficient from 1.33 to 1.0 was made by reasoning that these wide

walls are more stable and a lower coefficient is justified. The lowering of the coefficient is compatible with the philosophy of accepting damage but preventing collapse.

12. The determine the value of the coefficient "C," the designer must first know which soil depth curve to use. Information in the Seismic Investigation Report prepared by the Seismic Consultant will enable the Designer to determine which curve to use and the peak rock acceleration expected at the site. If the report is not available when the Designer needs his seismic coefficient, the Designer is to obtain the necessary information from the Seismic Consultant.

13. For site on soft ground or with material other than granular alluvial material, special soil response studies will be made and a design spectrum for the site will be furnished.

2.3.4 Impact (I)

Impact loads are statically equivalent dynamic loads resulting from vertical acceleration of the live loads.

A. Impact considerations for aerial structures supporting rapid transit loading are covered under Section 2.6, "AERIAL STRUCTURES."

B. Design of the top slab of underground rapid transit structures supporting roadway loading shall conform to the following:

0' -0" to 1' -0" earth cover	I = 30% LL
1' -1" to 2' -0" earth cover	I = 20% LL
2' -1" to 3' -0" earth cover	I = 10% LL
Greater than 3' -0" earth cover	I = 0% LL

The depth of cover shall be measured from the top of ground or paving to the top of the underground structure.

C. Structures supporting special vehicles, such as aircraft, moving equipment, or other dynamic loadings which cause significant impact shall conform to the Building Code of the locality or, if not covered by

Code, shall be considered individually using the best technical information available.

D. Impact shall not be considered for stairways, mezzanines, station platforms, or other pedestrian areas.

2.3.5 Centrifugal force (CF)

A. Structures on curves shall be designed for a horizontal radial force equal to the following percentage of the live load, without impact, in all trackways:

$$C = 0.00117S^2D = \frac{6.68S^2}{R}$$

Where

C = the centrifugal force in percent of the live load, without impact

S = the design speed, in miles per hour

D = the degree of curve

R = the radius of the curve, in feet.

B. The centrifugal force shall be applied five feet above the top of low rail, on all tracks.

2.3.6 Rolling Force (RF)

A force equal to ten percent of the rapid transit loading per track shall be applied downwards on one rail and upwards on the other, on all tracks. The rolling force shall be considered in a similar fashion as longitudinal force is considered in the loading combinations of AASHTO Specifications Article 1.2.22.

2.3.7 Longitudinal Braking and Tractive Force (LF)

A. A force equal to 15 percent of the rapid transit loading, without impact, per track, shall be applied five feet above the top of low rail on all tracks. Consideration is to be given to combinations of acceleration and deceleration forces when more than one track occurs. The force shall be considered as a uniformly distributed load over the length of the train in a horizontal plane.

B. For double track structures, three longitudinal loading cases shall be considered:

1. Single Track Loaded - Longitudinal force acting, applicable forces on supporting structure.

2. Both Tracks Loaded - One train accelerating; one decelerating. Maximum longitudinal forces acting, applicable forces on supporting structure.

3. Both Tracks Loaded - Both trains accelerating or decelerating. Longitudinal forces acting in opposite directions, applicable forces on supporting structure.

2.3.8 Horizontal Earth Pressure (E)

A. The Designer shall be responsible for obtaining all soils information from the soils boring program formulated by the Geotechnical Consultant and accepted by the District. In the event of changes in design or construction concepts, between preliminary and final design phases, the District will keep the Geotechnical Consultant informed and his recommendations shall be obtained.

B. Structures which retain earth shall be designed for side pressure due to earth abutting against the structure and load surcharges resting on abutting earth. Allowances shall be made for both dry and submerged earth pressures and for hydrostatic pressure. Consideration shall be given to multi-layered effects where substantial differences in soil properties occur over the depth of subway structures. The effects of specified construction procedures (e.g., "inverted" construction, rigid bulkheads, or cut-off walls) on the development of lateral pressures shall be considered.

1. Rapid transit loading may be assumed as a uniform surcharge equal to three additional feet of earth.

2. Live and dead loads from adjacent foundations of structures, shall be considered in computing horizontal pressures.

3. Where railroad loading occurs, the surcharge shall be determined as specified in the AREA Manual, Chapter 8, Part 5, Paragraph C-1.

4. The rock-earth pressures to be used in design shall be established by the District in consultation with Geotechnical Consultant.

2.3.9 Hydrostatic Pressures and Buoyancy (B)

The effects of hydrostatic pressure and buoyancy shall be considered whenever the presence of ground water is indicated. The possibility of future major changes in ground water elevation shall be considered. During construction and backfill operations, the elevation of ground water shall be observed and controlled so that the calculated total weight of structure and backfill shall always exceed the calculated uplift due to buoyancy by at least ten percent. 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.

2.3.10 Flooding (FL)

Local flooding may add load to subaqueous structures or structures in the flood plain. Design of the structures should make allowance for this loading as required by the particular type of structure and the conditions affecting each location. Assume loading combinations similar to those for stream flow.

2.3.11 Other Loads and Forces

Other loads and forces to be considered, including stream flow, wind loads, shrinkage and thermal forces are covered under Section 2.6, "AERIAL STRUCTURES."

2.4 UNDERGROUND STRUCTURES

All underground structures shall be classified in one of the categories listed below. For each of these structures, the following assumptions shall be made:

2.4.1 Reinforced Concrete Box Line and Station Section

A. These structures retain earth but are not free to yield significantly. As a minimum, four basic loading cases shall be investigated. Values of loading shall be developed in consultation with the Geotechnical Consultant. Additional permanent, temporary, and construction loading cases shall be investigated as required by the particular circumstances.

Case I: Full vertical and long-term horizontal load.

Case II: Full vertical load, long-term horizontal load on side and short-term horizontal load on the other side.

In underground concrete box structures which could be subjected to unequal lateral pressures, the structural analysis shall consider the top slab as both restrained and unrestrained against horizontal translation in arriving at maximum shears, thrusts, and moments.

Case III: Full vertical load with short-term horizontal load neglecting groundwater pressure on both sides.

Case IV: Only dead vertical load with long-term horizontal load including hydrostatic pressures.

B. For stress analysis, variations in the elastic support of the subgrade shall be considered for the different loading cases as appropriate.

C. For design, the horizontal earth pressure distribution diagram shall be the trapezoidal pressure diagram. Compression forces shall not be considered in shear design of the top and bottom slabs in box sections.

D. In evaluating the design for temporary loadings produced by construction conditions such as the removal of horizontal struts, consideration shall be given to:

1. Allowable increase in stresses due to the temporary nature of the loading

2. Creep in the concrete

3. Effect of soil arching

4. Walls and slabs flexibility.

E. Where it is anticipated that restrutting will be proposed by the Contractor due to the limitations inherent in the design of the permanent structure, the construction specifications are to stipulate that the working drawings, supporting computations, and order of procedure submitted for approval by the Contractor must reflect proper consideration of such aspects as magnitude of preload in replacement struts, crushing of packing, and thermally induced stress and deflection of the permanent structure. The Contractor's proposal shall also detail the proposed instrumentation and monitoring thereof so as to ensure that the permanent structure will not be overstressed or otherwise damaged.

F. In all cases, the specifications for support of excavation must reflect any limitations inherent in the design of the permanent structure.

2.4.2 <u>Reinforced Concrete Retaining Walls</u>

These are structures which are free to yield to earth pressure. In retaining walls up to 20'-0" in height, the design earth pressure shall be computed by the AREA empirical method. Refer to Chapter 8, Part 5, Appendix C of the AREA Manual. Retaining walls above 20'-0" in height shall be designed on the basis of specific soils information relating to the backfill material and in accordance with the procedures outlined in the AREA Manual, Chapter 8, Part 5, Appendix B.

2.4.3 Flexible Earth-Tunnel Sections

A. General Requirements

1. These design criteria apply to flexible and semi-flexible precast concrete segmental tunnel liners.

2. The liners may be bolted or unbolted on their longitudinal and circumferential joints.

3. In appropriate circumstances, the liners may be expanded against the ground. More generally, the annulus between the liner and the ground will be completely filled with cement grout.

4. Tapered liner rings shall be used to negotiate curves and correct vertical and horizontal alignment.

5. In tunnneled sections below the watertable, the liners must be capable of being made watertight by means of rubber sealing gaskets and/or caulking and bolt grommets.

B. Design of the Liners

1. The liners shall be designed to sustain all the loads to which they will be subjected with adequate factors of safety. Such loads will include:

   a. handling loads
   b. shield thrust ram loads
   c. erection loads including grouting loads
   d. earth pressure
   e. hydrostatic pressure
   f. self-weight of the tunnel structure
   g. loads due to imperfect liner erection
   h. additional loads due to the driving of adjacent tunnels
   i. effects of tunnels breakouts at cross-passages, portals, and shafts
   j. live loads of vehicles moving in the tunnel or on the surface above it
   k. surcharge loads due to adjacent buildings
   l. seismic loads as indicated in the Seismic Design Criteria.

2. Provisions shall be made in the liner segments for corrosion requirements connected with the elimination of stray currents in the surrounding ground.

2.4.4 Rock Tunnel Liners

A. General Requirements

1. These design criteria apply to cast-in-place concrete liners and flexible or semi-flexible precast concrete segmental liners erected directly behind the tunneling machine.

2. For the cast-in-place concrete liners, temporary support may be required during the excavation phase of the tunneling process. This temporary support, in general, will be provided by steel arch ribs at centers to suit rock conditions. When and if rock conditions permit, these may be replaced by resin-anchored rock bolts at centers to suit rock conditions.

3. The precast concrete segmental liners may be bolted or unbolted on their longitudinal and circumferential joints.

4. In appropriate circumstances the segmental liners may be expanded against the ground. More generally, the annulus between the liner and the ground will be completely filled with cement grout.

5. Tapered segmental liner rings shall be used to negotiate curves and correct vertical and horizontal alignment.

6. In tunneled sections below the watertable, the liners must be capable of being made watertight by means of sealing gaskets, duct sealants, caulking or rock grouting <u>or</u> designed to incorporate a drainage system to relieve hydrostatic pressures behind the liner to drain to an invert drain in the tunnels.

B. Design of the Liners

1. The temporary support systems shall be designed to sustain all the loads to which they will be subjected with adequate factors of safety for temporary conditions. Such loads will include:

   a. rock load determined by rock condition
   b. self-weight
   c. additional loads due to the driving of adjacent tunnels.

2. The cast-in-place liners shall be designed to sustain all the loads to which they will be subjected with adequate factors of safety. Such loads will include:

   a. rock loads based on considerations of rock condition
   b. hydrostatic pressure either total or residual
   c. additional loads due to the driving of adjacent tunnels (if applicable)
   d. live loads of vehicles moving in the tunnel
   e. seismic loads as indicated in the Seismic Design Criteria.

3. The precast segmental liners shall be designed to sustain all the loads to which they will be subjected with adequate factors of safety. Such loads will include:

   a. handling loads
   b. shield thrust ram loads if applicable
   c. erection loads including grouting loads
   d. rock loads based considerations or rock condition
   e. hydrostatic pressure either total or residual
   f. self-weight of the tunnel structure
   g. loads due to imperfect liner erection
   h. additional loads due to the driving of adjacent tunnels
   i. live loads of vehicles moving in the tunnel
   j. seismic loads as indicated in the Seismic Design Criteria.

VOLUME 2, SECTION 2 STRUCTURAL (Cont'd)

2.4.5 Ventilation Shafts

The permanent shaft wall shall be in either precast segmental liner rings, reinforced concrete, or plain concrete. Loadings imposed on the shaft by the surrounding ground shall be determined by the Designer in accordance with the subsurface investigations and consistent with the shaft configuration. Shafts inclined more than 45 degrees from the vertical may be designed for tunnel design pressures.

2.4.6 Tunnel Break-Outs

Permanent walls for tunnel break-outs in shafts, cross-passages, or any other location shall be in reinforced or plain concrete. For tunnels lined with pre-cast segmental tunnel liners, requirements of specially segmented rings to suit break-out configurations shall be determined by the Designer. Crosspassages may be combined with other on-line structures such as pump and ventilation structures.

2.5 PORTALS

Tunnels and box section entrance portals shall be designed in a manner to minimize the rate-of-change of pressure on a train passing through the portal.

The pressure rise is a function of both the cross-sectional area of the portal entrance and the entrance speed of the train (see Figure II-2-9).

2.5.1 Acceptable Design Methods

A. Provide the entrance with a flared transition so that the increase in cross-sectional area approximates the cross-section of six degree conical flare starting at the constant area section of the tunnel or box and extending to the portal opening. This flared transition can be formed using any combination of tapers on the top and sides, provided no plane or surface of the transition section is at an angle in excess of six degrees relative to the center line of the tunnel and provided the side tapers are symmetrical with the center line. For the required length of the flared transition, see Figure II-2-10 and for the required cross-sectional area at the portal, see Figure II-2-11.

B. Design both the top and vertical sides of the entrance without a flare and provide a tapering slot in the top. From a one-foot minimum width at the constant area section the slot should increase to a maximum at the portal at a taper rate of 12 feet per 100 feet of length. The slot opening should, therefore, be 13 feet wide at the portal for 100 foot long transition, or seven feet wide at portal for 50 foot long transition. For the required length of transition, see Figure II-2-10.

2.5.2 Exceptions

Exceptions that do not require special transition portal are:

A. Tunnels of a length less than 200 feet

B. Single track horseshoe tunnels with design train speed of 45 mph or lower

C. Box sections and single track circular tunnels with design train speed of 40 mph or lower

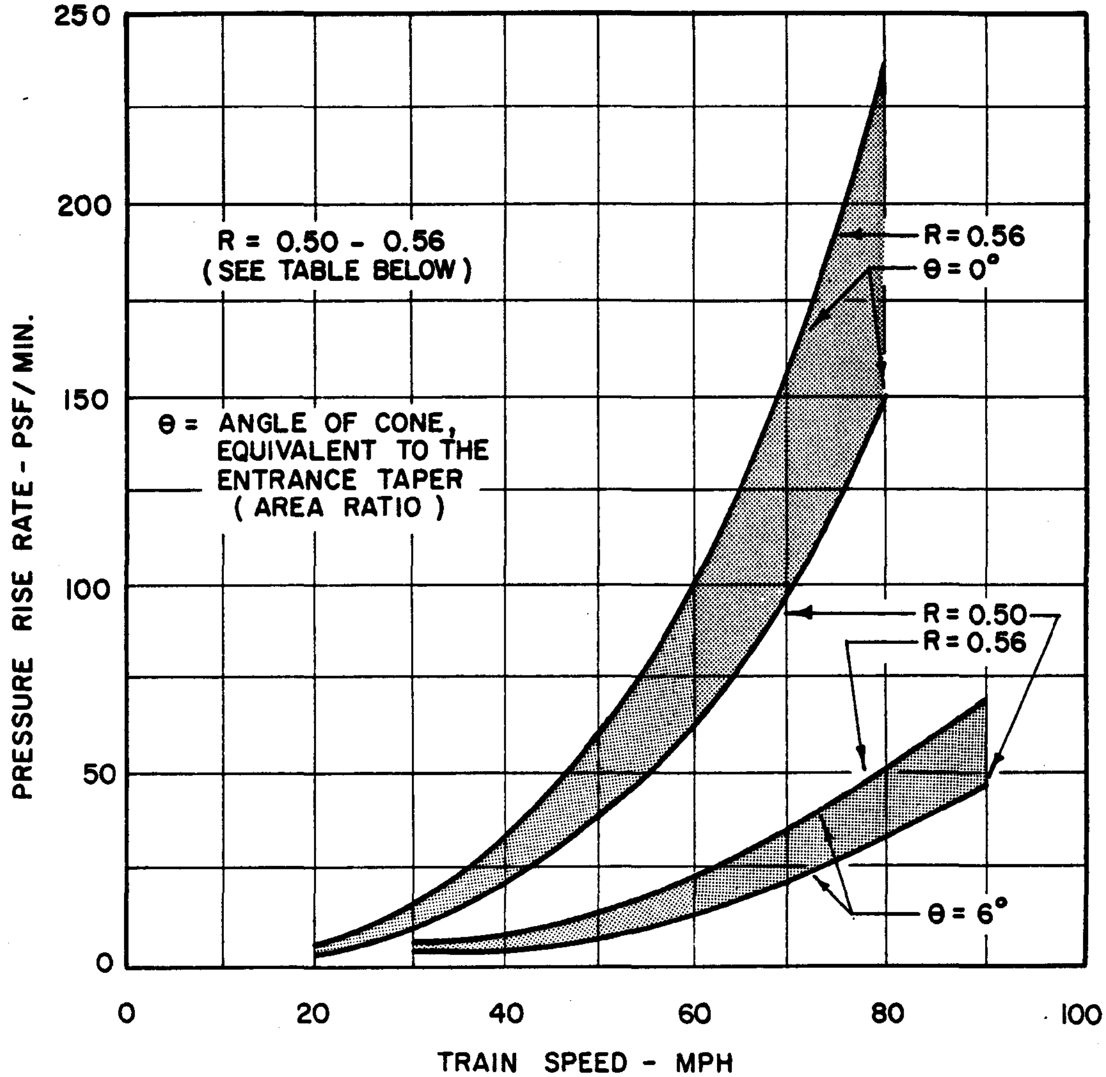
D. Portals at underground stations.

2.5.3 U-Sections

A. In locating portals and determining the ends of U-sections and walls, consideration shall be given to providing protection against flooding resulting from highwater levels near bodies of water and tributary watercourses, or from local storm runoff.

B. Adequate provision shall be made for resistance to hydrostatic uplift. Adequate provision shall be made for immediate and effective removal of water from rainfall, drainage, groundwater seepage, or any other source.

C. U-sections, with both walls continuous with a full width base slab, shall be used for open cut sections where the top of rail is less than four feet above the maximum groundwater table. Above that level independent reinforced concrete cantilever retaining



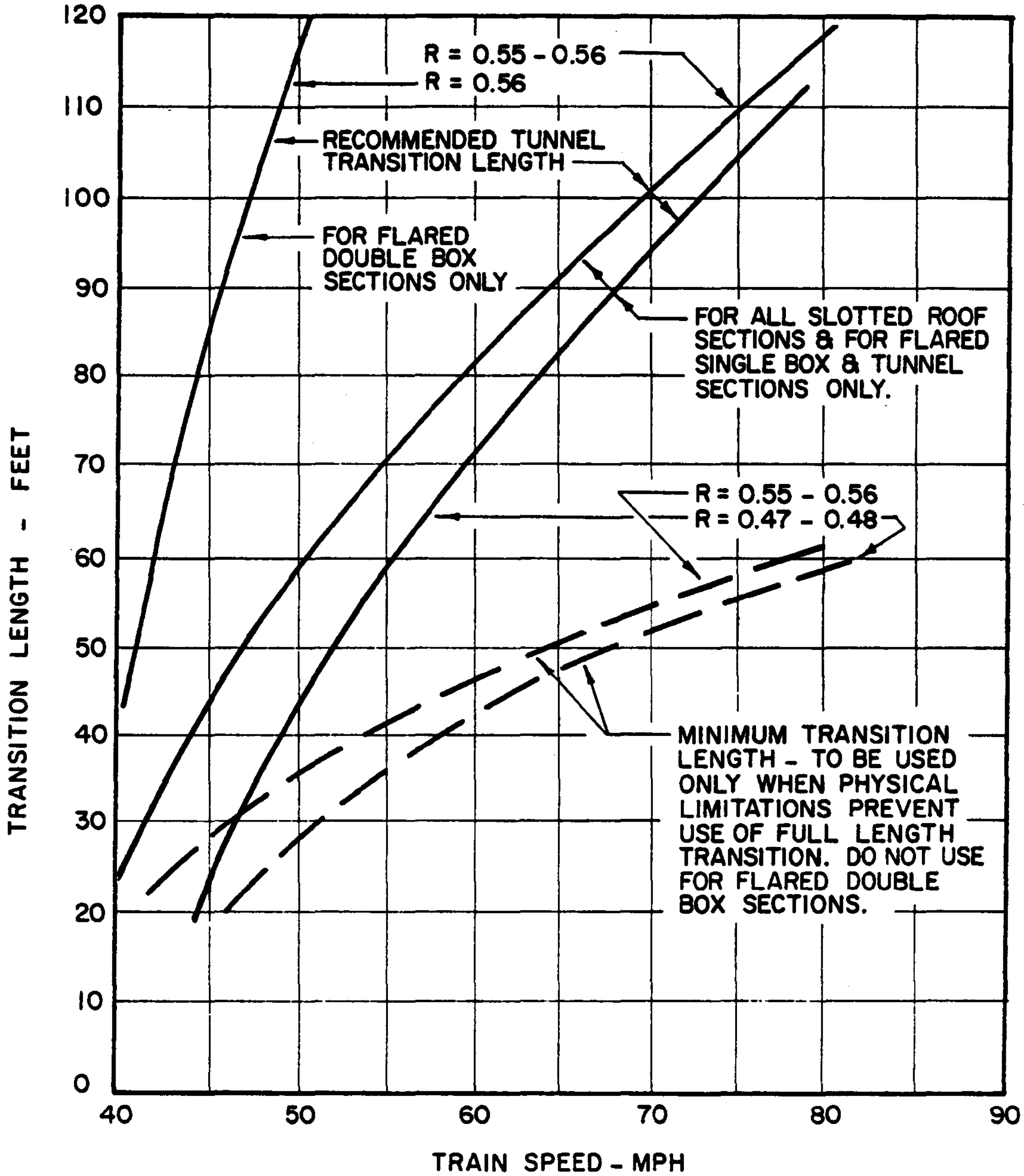
ESTIMATED PRESSURE RISE RATE VS. TRAIN SPEED FOR TUNNEL ENTRANCES WITH NO TAPER [θ = 0°] AND WITH 6° CONICAL TAPER [θ = 6°], OR EQUIVALENT.

TYPE OF TUNNEL	CROSS-SECTIONAL AREA	R
SINGLE BOX, CUT AND COVER	174 sq. ft.	.55
DOUBLE BOX, CUT AND COVER	171	.56
CIRCULAR EARTH TUNNEL	203	.47
HORSESHOE ROCK TUNNEL	180	.53

$$R = \frac{\text{CAR CROSS - SECTIONAL AREA}}{\text{TUNNEL CROSS - SECTIONAL AREA}}$$

PRESSURE RISE RATE VS. TRAIN SPEED

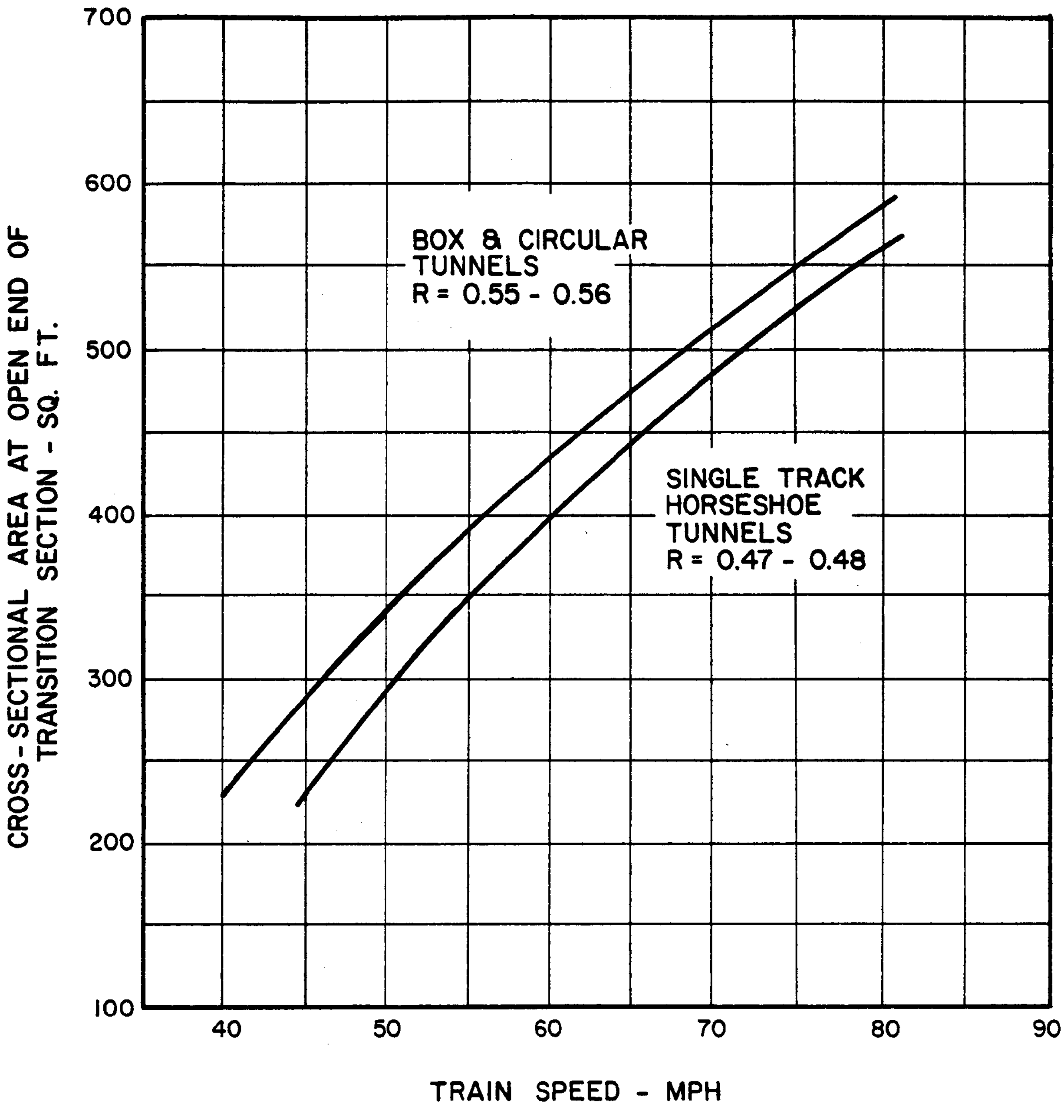
FIGURE II-2-9



RECOMMENDED LENGTH OF TUNNEL PORTAL TRANSITION AS A FUNCTION OF TRAIN VELOCITY FOR SINGLE TRACK TUNNELS.

TUNNEL TRANSITION LENGTH VS. TRAIN SPEED

FIGURE II- 2-10



RECOMMENDED AREA AT PORTAL OF TUNNEL OR BOX SECTION WITH FLARED TRANSITION

FIGURE II- 2-11

walls shall be designed in accordance with the provisions of Section 2.4.2 of these criteria.

D. U-sections may be analyzed as continuous structures on elastic foundations. If at any station the two walls are unequal heights, the factor of safety against sliding shall be a minimum of:

1. 1.50 with no passive resistance of the soil

2. 2.00 with passive resistance of the soil.

E. Wall thickness is to be designed by using:

1. Geotechnical Soil report recommendations for coefficient of lateral earth pressure, at-rest case

2. Hydrostatic pressure

3. Surcharge effects.

F. Grade slab design thickness is to be six inches greater than the wall thickness with a minimum of 24 inches. If the weight of the grade slab (in pounds per square foot) is less than 40 percent of the hydrostatic head (in pounds per square foot) as measured from the bottom of the grade slab, the grade slab shall be designed for uplift pressure.

G. If, at the last U-section segment away from the portals, the abutting at-grade trackway does not consist of a track slab, a depressed approach slab shall be provided to permit the construction of tie-and-ballast trackbed up to the end of the typical base slab without a sharp break in support at that point.

2.6 AERIAL STRUCTURES

The criteria set forth in this section shall pertain specifically to the design of aerial structures carrying rapid transit loadings and aerial stations.

2.6.1 Design Specifications

A. The AASHTO Specifications and Interim Specifications shall govern the design and construction of aerial structures supporting rapid transit loadings.

B. Strength design method (load factor design method as per AASHTO) shall be used for the design of all structural components and connections. To ensure serviceability and durability, permanent deformations under loverloads, live load deflections and fatigue characteristics under service loadings shall be investigated.

2.6.2 Loads and Forces

Where applicable, loads and forces listed in Section 2.3 shall be used for the design of rapid transit aerial structures. Other loads and forces to be considered include:

A. Dead Load (DL)

Trackwork and appurtenances and secondary elements supported by the structure and added after construction of the basic structure shall be considered as superimposed dead load. In areas of tie and ballast construction, the weight of the ties and ballast shall also be considered as superimposed dead load.

B. Live Load (LL)

Refer to Section 2.3 for live load magnitudes. Transit and crane car wheel loads shall be distributed as follows:

1. Where a wheel load is transmitted to a slab through rail mountings placed directly on the slab, the wheel load shall be assumed to be uniformly distributed on the slab over a 3'-0" length of rail and a 1'-2" width normal to the rail and centered at the rail. In addition, the slab shall be designed to support an accidental concentrated load of 23,000 pounds, impact included, located anywhere on the slab surface inside the curb lines. The effective distribution width (E) of this concentrated load shall be as outlined below:

a. For deck between supports

E = 0.58 S but not greater than 3' -0"
where S is the span length between center-lines of supports

b. For cantilever

Moment : E = 2.5 Feet + .2x

Diagonal Tension: E = 4t

Where:

x is the distance from load to point of support

t is the thickness of deck.

C. Impact (I)

1. Impact shall be applied to the superstructure, and generally to those members of the structure which extend down to the main footings. The portion above the ground line of concrete or steel piles rigidly connected to the superstructure as in rigid frame or continuous design is included. Impact shall not be considered for abutments, retaining walls, wall-type piers, piles, footings, and service walks, except for the portion of piles rigidly connected to the superstructure.

2. Vertical impact for aerial structures shall be considered in the design as follows:

a. Impact force for the design of simply supported longitudinal girders less than 150 feet long:

I = 30 percent of the total rapid transit vehicle or crane car loading.

b. For structures with longitudinal girders continuous over supports, including cantilever systems:

I = 40 percent of the total rapid transit vehicle or crane car loading for the girders in regions of negative bending and for the supports where the girders are continuous.

I = 30 percent of the above loading for continuous girders in regions of positive bending and for the supports where the girders are discontinuous.

c. These constant vertical impact factors apply where the unloaded natural frequency of first mode of vibration in not less than 2.5 cycles per second.

D. Stream Flow Pressure (SF)

Anticipated flood elevations shall be determined by a study of official flood records. Stream flow pressures shall be included in the design of aerial structures where applicable. All piers and other portions of structures which are subject to flood forces shall be designed in accordance with sound engineering practice. The requirements outlined in the AASHTO Specification shall be used as a guide.

E. Shrinkage and Creep Forces (S)

These forces are described under Section 2.8, "REINFORCED AND PRESTRESSED CONCRETE DESIGN."

F. Thermal Forces (T)

1. Provision shall be made for stresses and deformations resulting from temperature changes as follows:

a. Concrete

Temperature Rise 40° F
Temperature Fall 40° F
Coefficient of Expansion .0000060 inch/inch/degree F.

b. Steel

Temperature Rise 60° F
Temperature Fall 60° F
Coefficient of Expansion .0000065 inch/inch/degree F.

2. Provision shall be made for transverse and longitudinal forces due to temperature variations in the rail. These forces shall be applied in a horizontal plane at the top of the low rail as follows:

   a. Transverse Force. The transverse force per linear foot of structure per rail shall be determined by the following formula:

   $$T = \frac{191 \text{ Kips}}{R}$$

   Where R = Radius of curvature, in feet.

   b. Longitudinal Force. The longitudinal force per structure per rail shall be determined by the following formula:

   $$T = 0.65 \times P \times L$$

   Where P = Clamping force of rail fastener per linear foot.

   L = Average span length of two adjacent spans.

G. Wind Load on Structure (W)

The forces and loads given herein are based on a wind velocity of 90 mph, as recommended in the final report (1961) of the ASCE Task Committee on Wind Forces.

1. Wind Load on Superstructure

   A horizontal uniform wind load shall be applied simultaneously at the centroid of all exposed areas. For girders and beams: 40 psf in the transverse direction and 10 psf in the longitudinal direction, with a minimum of 240 plf in the transverse direction and 60 plf in the longitudinal direction. 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. This vertical load shall be 20 psf on the plan area of the deck and service walk.

2. Wind Load on Substructure

The substructure shall be designed to withstand the preceding loads applied to the superstructure as they are transmitted to the substructure. In addition, a horizontal wind load of 35 psf in any direction shall be applied simultaneously at the centroid of the exposed substructure area.

H. Wind Load on Live Load (WL)

Design shall include a transverse horizontal wind load of 320 plf of train and a longitudinal horizontal wind load of 80 plf of train for the entire length of track supported by the element being designed. The transverse load shall be applied to the train as concentrated loads at the axle locations in a plane seven feet above the top of the low rail and normal to the track. The longitudinal load 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. The transverse and horizontal wind loads shall be applied simultaneously.

2.6.3 Special Design Considerations

A. Vibration Limitations

1. To limit potential dynamic interaction between aerial structure girders and rapid transit vehicle, the aerial structure shall be designed so the the unloaded natural frequency of the first mode of vibration of the longitudinal girders is not less than 2.5 cycles per second. Further, no more than one span in a series of three consecutive spans shall have first mode frequency less than 3.0 cycles per second.

B. Trackwork

Consideration shall be given to the thermal force interaction between the structural components and the trackwork system. The Designer shall coordinate these aspects of the design with the District.

C. Fatigue

Consideration shall be given to the effect of change of stress levels caused by passage of rapid transit trains over structures. Over the life of the structure, three million cycles of maximum stress shall be used in estimating the number of repetitive maximum stress cycles.

D. Uplift

Provision shall be made for adequate attachment of the superstructure to the substructure should any combination of loading produce uplift at any support. Where DL, E, or any of other loadings tend to reduce the uplift effect, the corresponding load factors shall be taken as 0.9 for DL, 0.75 for E, and zero for other loadings.

E. Friction

Where applicable, friction shall be considered in the design.

2.6.4 <u>Reinforced and Prestressed Concrete Design</u>

Reinforced and prestressed concrete members for rapid transit aerial structures shall conform to the requirements of Section 2.8, except as modified below.

A. Camber and Deflections

As a guide in design, the total long term predicted camber growth shall be limited to 1/2000 of the span length for unballasted, prestressed concrete aerial structures.

The short term camber growth prior to trackwork construction shall be limited to 1/4000 of the span length. A minimum two-month period between structure construction and trackwork installation is assumed.

B. Live Load Deflections

1. Girders of simple or continuous spans shall be designed so that the deflections due to live load plus impact shall 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.

2. For deflection calculations only, normal loading of the rapid transit vehicle may be considered. Live load shall be assumed at 90,000 pounds, distributed equally to four axles.

C. Longitudinal Tension Stresses in Prestressed Members

Longitudinal tension stresses shall not be permitted under any combination of loads, except in the bottom fibers where tension will be permitted for impact loading only. Reinforcing bars shall be added to resist the tension stresses resulting from impact loads.

D. Shrinkage and Creep

Stresses and movements resulting from concrete shrinkage and creep shall be considered in the design and included in all load combinations. The shrinkage coefficient shall be assumed to be 0.0002 inch per inch for both prestressed and reinforced concrete. To minimize creep problems it is suggested that the average prestressing compression stress after losses should not exceed 1000 psi.

E. Structure Deformations and Settlements

All structure deformations, including foundation settlement, shall be considered, not only for their effect on structural behavior, but also for their effect on trackwork. The control of deformations through proper structural design is of paramount importance in obtaining acceptable riding quality for the rapid transit trains.

2.6.5 Structural Steel Design

A. Structural steel and composite steel-concrete flexural members for rapid transit aerial structures shall conform to the requirements of Section 2.9.

B. The requirements governing live load deflections and structure deformations and settlements as outlined for Reinforced and Prestressed Concrete Design shall also apply to Structural Steel Design.

2.6.6 Foundations

Foundations for girder spans up to 150 feet in length shall not have total settlements greater than one inch nor differential settlements greater than 1/4 inch. For spans over 150 feet in length, the Designer shall develop settlement values which meet the approval of the District.

A. Spread Footings

The design shall keep the maximum soil pressure for the various loading combinations within the allowable bearing value and soil pressures as nearly uniform as practicable.

B. Pile Footings

1. Pile footings shall be designed so that the load on any pile does not exceed its allowable load, which shall conform with allowable percentage of basic unit stress for various loading combinations given in AASHTO Specifications. Design should allow for an accidental misplacement of the center of gravity of the substructure, six inches in any direction.

2. For Group I loading, the uplift force on any friction pile shall not exceed five percent of its design load. For other group loadings, the uplift on any pile shall not exceed 25 percent of its design load.

3. Uplift shall not be permitted for bearing piles or combination bearing and friction piles.

C. Drilled in Caissons

The design shall keep the maximum soil pressure at base of caisson within the allowable soil bearing value. Design should allow for an accidental misplacement of the center of gravity of the substructure, six inches in any direction. The design of drilled piers or drilled caissons shall be in accordance with ACI-336, "Suggested Design and Construction Procedures for Pier Foundations."

D. Lateral Resistance

1. Consideration shall be given to the ability of piles or drilled caissons to 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 shall be use in a pile foundation. Battered piles shall have a slope not greater than one horizontal to three vertical. Where battered piles are to be used, consideration shall be given to the possibility of such battered piles encroaching on property outside the right-of-way lines.

2. The axial loads on piles and caissons shall be determined by static analysis of the moment-resistant group, by the method of elastic center, or by any other satisfactory method. Each member, vertical or battered, in a pile or drilled caisson group may be assumed to have lateral resistance capacity, in addition to the horizontal component of the axial load on the battered members, equal to the least of the following values:

    a. Capacity recommended by the Geotechnical Consultant

    b. Capacity of the pile or caisson as a structural member

    c. Ten percent of the member's design compressive capacity perpendicular to the strong axis only, or

    d. 6,000 pounds for piles, perpendicular to strong axis only and 10,000 pounds for caissons.

3. Because an unreinforced concrete pile has essentially no moment resisting capacity, it shall be assumed to have no lateral capacity as a structural member in bending.

4. Unless a pile or caisson is installed to a sufficient depth in competent material to develop fixity, it shall be assumed to have no capacity to resist lateral loads in bending.

VOLUME 2, SECTION 2 STRUCTURAL (Cont'd)

2.7 SOILS AND GEOLOGIC DATA

A. The District has engaged a Geotechnical Consultant to investigate the subsurface conditions, to perform laboratory testing, to describe the geologic features of the area, and to make recommendations relative to geotechnical behavior to be considered for design and construction. These findings are given in the Geotechnical Investigation Report prepared by the Geotechnical Consultant.

B. Earth, rock, and water pressures on the underground structures may vary considerably with geographic location. These pressures and other geotechnical parameters shall be determined by the Designer by reference to the Geotechnical Investigation Report and by consultation with the Geotechnical Consultant and the District.

C. Likewise, allowable bearing and frictional values for foundations shall be determined by the Designer by reference to the Geotechnical Reports and by consultation with the Geotechnical Consultant and the District.

D. If, in the opinion of the Designer, additional subsurface information is required, the Designer shall request the District for additional data stating the type of data required and the purposes they are intended to serve.

E. For structures subject to the jurisdiction of local authorities the allowable bearing and frictional values for foundations shall not exceed the limits given by the local building code, except for deviations as provided for in the code.

2.8 REINFORCED AND PRESTRESSED CONCRETE DESIGN

2.8.1 <u>Cements</u>

A. Type I or Type II Portland Cement ordinarily shall be specified for concrete mix design to be used at the Contractor's option.

B. Type II Portland Cement shall be specified for concrete construction in soils requiring moderate sulphate resistance or moderate heat of hydration.

C. Type III Portland Cement may be specified for concrete mix design requiring a high early strength, except where soil conditions make the use of Type II necessary.

D. Shrinkage Compensation Cement may be used if approved by the District.

2.8.2 Concrete Design Strengths

A. For all underground reinforced concrete cast-in-place structures, including; box lines and stations, abutments, retaining walls, rigid earth tunnels, Type II rock tunnel linings, shafts, cross-passageways, portals, U-sections, spread footings, piles, drilled in caissons and basement walls ----f'_c = 4,000 psi.

B. For all aboveground reinforced concrete cast-in-place structures, including columns, cap beams and superstructure for aerial structures and bridges; columns, beams, slabs and walls for buildings ----f'_c = 4,000 psi.

C. For prestressed concrete ----f'_c = 4,000 psi.

D. For precast prestressed member ----f'_c = 5,000 psi.

E. For precast concrete tunnel liners ----f'_c = 5,000 psi.

F. In certain cases, other strengths of concrete than those specified above might be required. These cases will be as directed by the District in writing.

2.8.3 Reinforcing and Prestressing Steel

A. Reinforcing steel shall meet the requirements of ASTM A615, Grade 60. Spirals, ties, and stirrups may be either Grade 40 or 60.

B. Prestressing steel shall conform to the requirements of AASHTO Specifications Article 2.4.33 (J). The grade of steel shall be as required by the design.

Unbonded and ungrouted prestressing steel shall not be used.

C. To the extent possible, main reinforcing bars shall be spaced at 6", 9", or 12" o.c. in elements of tunnels, cut-and-cover subway, retaining walls, bridge structures, and stations. Exceptions to this rule include beams, columns, stairways, and thin slabs.

D. Standardization of spacing is intended to simplify design details, checking of bar placement, and field inspection. Spacing should also consider ease of concrete placement, room for embedded items, decrease in concrete coverage due to lapped splices and the blockages that might occur by crossings of closely spaced reinforcement. Bar sizes should be selected to avoid crowding, particularly where larger size rebars are used.

2.8.4 Methods of Design

A. For all underground rapid transit cast-in-place reinforced concrete structures, including box lines and stations, rigid earth tunnels, Type II rock tunnel linings, shafts, cross-passageways, portals and U-sections, the design shall be by the Strength Design Method, of ACI-318, or Service Load Design Method of AASHTO Specifications, as applicable.

B. For all above ground and aerial structures, the design shall be by Strength Design Method, or Load Factor Design Method.

C. Prestressed Concrete Design shall be checked by Allowable Stress Design in accordance with AASHTO Specifications Article 1.6.3.

2.8.5 Joints in Cut-and-Cover Structures

A. To promote water-tightness and structural integrity and in view of relatively uniform internal temperatures in the massive main members of subway structures, no permanent expansion or contraction joints shall be provided within the subway line or station structures, but construction joints shall be provided in accordance with provisions stipulated below. At locations of major change in structure section, e.g., from cut-and-cover line to station or from cut-and-cover structure to open cut structure, construction joints shall be provided. Where a tunneled section meets a cut-and-cover section, the connection shall be designed either to absorb any differential movements or to transmit the forces that may occur under any design conditions. In all cases, thorough consideration shall be given to water-tightness.

B. To control shrinkage stresses in monolithically poured concrete slabs and walls and to minimize cracking, construction joints shall be provided at spacing not exceeding 50 feet, and closer if appropriate to the framing involved or to facilitate construction. All construction joints shall have continuous reinforcing steel, keys or other positive means of shear transfer, and in all exterior elements in contact with soil or rock, joints shall have non-metallic waterstops.

C. Under no circumstances should expansion or contraction joints be used in cut-and-cover structures. Temperature and shrinkage reinforcement, as provided by by applicable specifications and codes, shall be installed continuous in all walls and slabs of these underground structures.

2.8.6 Waterproofing

A. Stations

1. Membrane waterproofing shall be provided over the roofs of all cut-and-cover station structures. Boundary conditions details, such as reglets, flashing, laps, etc., shall be shown on the contract drawings.

2. External waterproofing may be omitted from exterior walls in public areas of subway stations if provision is made to permit furring out interior finishes and collecting seepage behind the finishes or if a positive interior waterproofing application is specified.

3. External waterproofing shall not be provided on exterior walls in non-public areas of cut-and-cover subway stations, except as required for equipment rooms, nor under foundation slabs. In

these cases, provisions shall be made for draining seepage to floor drains.

B. Equipment Rooms

1. Train control rooms and auxiliary equipment spaces shall have those roofs and walls in contact with earth waterproofed by an external membrane or by an interior waterproofing applied to these members. Where the base floor is subjected to hydrostatic pressure, it shall be sloped to drain and the equipment shall be installed on raised pads. The equipment should be so located as to permit repair of leaks while the equipment is in operation. Interior waterproofing may be either cement plaster waterproofing or ferrous coating.

2. Substations, switchgear, and similar rooms shall have roof surfaces waterproofed with membrane waterproofing, as previously described.

3. Line ventilation and sump pump rooms shall not be specially waterproofed, but precautions shall be taken to prevent water dripping on the equipment.

4. Conduits leading from walls or roofs of any of the above spaces shall be so installed as to prevent water running along the conduit to the equipment.

C. Line Section

1. External waterproofing need not be applied to reinforced concrete cut-and-cover line sections above or below the water table provided the individual external elements - roof, walls, base slab - are 18 inches or more thick.

D. Repairs

1. Provisions for injection sealing of leaks in walls and slabs shall be made for all underground reinforced concrete rapid transit structures.

2. Special considerations shall be given to design details and construction sequences for reduction of cracking. Also, specifications shall have

provisions that promote high concrete density and impermeability.

2.8.7 Architectural Considerations

In order to assure uniformity of structural concrete color in public areas of the stations, it will be necessary to standardize concrete mix and strength, and the brand of cement to be used in any given area. This will apply to all concrete exposed to public view within the stations or to the concrete exposed to view from outside the station.

2.9 STRUCTURAL STEEL

Consideration shall be limited to the following types of structural steel. Other types may be used only with the approval of the District.

2.9.1 Structural Steel

For normal use. ASTM A36.

2.9.2 High Strength Structural Steel

For uses requiring higher strength steels or where economically justifiable: ASTM A242, A440, A441, A514, A588, and A572.

2.9.3 Connections

A. Shop connections as detailed by the Designer shall be welded unless otherwise approved by the District. All welding shall be in accordance with the current Code or Specifications of the American Welding Society, D1.0 or D2.0, as applicable.

B. Field connections shall be designed for high strength bolts unless otherwise approved by the District. High strength bolts shall be ASTM A325 or A490 bolts.

2.10 SUPPORT AND UNDERPINNING OF EXISTING STRUCTURES

2.10.1 General

A. The Designer, in consultation with the District and the Geotechnical Consultant shall investigate all structures to remain over, or adjacent to, the work, and shall prepare all necessary designs for their protection or permanent support and underpinning.

B. All buildings or structures which require designs shall include, but will not be limited to, the following:

   1. Buildings or structures which extend over the transit structures to such an extent that they must be temporarily supported during construction and permanently underpinned.

   2. Buildings or structures immediately adjacent to the transit structures, which must be carried on underpinning, braced to act as retaining elements supporting the sides of the excavation.

   3. Buildings or structures which may be affected by groundwater lowering. In certain areas, uncontrolled lowering of the groundwater for rapid transit construction may cause settlements of buildings either adjacent to or some distance from the cut-and-cover or tunneled excavation.

   4. Any other buildings or structures for which the District and the Geotechnical Consultant agree that it is appropriate for the Designer to prepare designs.

C. Underpinning walls or piers supporting buildings or structures and forming a portion of the excavation support system shall be extended to a minimum depth of 4'-0" below subgrade elevation of the underground rapid transit structure.

2.10.2 Methods

Methods used to underpin or protect these buildings or structures shall depend on local soil conditions and may include the following:

A. Pier, Pile, or Caisson Method of Underpinning

If soil conditions, structures size, and proximity to the underground rapid transit structure dictate underpinning piers, piles, or caissons, they shall, in general, extend below a sloped line drawing from the side of the excavation at a point 2'-0" below subgrade elevation to the intersection with the vertical projection of the underpinned building foundation. The slope of this line shall be established by the Designer in consultation with the Geotechnical Consultant.

B. Protection Wall Method of Structure Protection

Under some soil conditions, the supporting system for the excavation will be sufficient to protect light structures. Under heavier loading conditions a reinforced concrete cutoff wall, constructed in short clay slurry filled trenches or bored pile sections braced with preloaded struts, could be considered as an alternate to underpinning or to avoid settlement due to dewatering.

C. Stabilization of Soil

In general, techniques such as freezing and chemical injections for the stabilization soil under buildings in lieu of underpinning shall not be specified in the design phase. However, after consultations with the District and the Geotechnical Consultant, these techniques may be considered as alternatives to solve localized soils problems.

D. Temporary Bracing Systems

A tight bracing system is important for the effectiveness of underpinning and for the protection wall support. In addition to the general requirements for support of excavation that are provided in the specifications, the Designer shall indicate special requirements for the installation and removal of the temporary bracing systems that relate to the designs of underpinning and protection walls, such as the levels of bracing tiers, the maximum distances of excavation below an installed brace, and the amount of preloading. However, the detail design of the temporary bracing system shall be the responsibility of the Contractor based on the overall criteria given in the contract documents.

2.11 SUPPORT OF EXCAVATION STRUCTURES

A. Contract Drawings and Specifications shall cover traffic diversions, mandatory restrictions, and necessary construction staging which have been approved by public authorities and utility companies as applicable. Acceptable locations for construction access ramps, or any other construction facility which affect the work, shall also be indicated.

B. Detailed design of the temporary decking, sheeting, and bracing shall be prepared by the Contractor and reviewed by the Designer, based upon criteria and design standards included in the Contract Drawings and Specifications.

C. The Designer shall perform a conceptual/preliminary design of decking, sheeting, and bracing utilizing the criteria that will appear in the contract documents. The design shall be for the purposes of evaluating the support of excavation problems associated with the underground construction, of determining the need for supplementing or revising the criteria, and of arriving at an estimate of cost for the decking, sheeting, and bracing. The designs shall not be shown in the contract drawings except to the extent necessary to clarify unique situations not adequately addressed by the written criteria. In any event, detail design of decking, sheeting, and bracing shall not be shown.

D. It shall be a requirement in the contract documents that the design of support of excavation structures be prepared and certified by a Civil Engineer registered in the State of California. The review and acceptance of the designs submitted by the Contractor shall be made by a Civil Engineer registered in the State of California.

2.12 MISCELLANEOUS STRUCTURES

2.12.1 Gratings

The following grating types shall be adopted as standards for use in this project:

VOLUME 2, SECTION 2 STRUCTURAL (Cont'd)

A. For Light Loading	-	For general use inside subway
Bearing Bars	-	1-1/4" x 1/8" on 1-3/16" centers
Cross Bars	-	4" centers
Maximum Allowable Deflection	-	1/200 span
Grating Type	-	Rectangular-serrated
Material	-	Steel, hot dip galvanized
B. For Heavy Loading	-	Gratings subject to vehicle wheel loads
Bearing Bars	-	4" x 1/4" on 1-3/16" centers
Cross Bars	-	4" centers
Design Loading	-	AASHTO HS 20-44
Maximum Allowable Deflection	-	1/300 span
Grating Type	-	Rectangular - plain
Material	-	Steel, hot dip galvanized

2.12.2 Emergency Access Shafts

A. Access shall be provided to the subway at each vent and fan shaft location, and at other points as directed by the District. No point in the subway system shall be over 1,320 feet from a point of access or egress. To be considered as an emergency exit, the stairway or passageway shall be completely enclosed with walls having two-hour fire resistant rating. Stairs may be of concrete or steel. Stair widths, risers, landings, hand rails, and lighting shall conform to the local codes. Surface exiting configuration must be designed in conjunction with the architects and the District.

B. Hatches on access shafts shall be readily unlatched from the inside of the subway and opened by means of a key from outside at the surface level. Continuous handrails shall be provided in access shaft passageways as well as on stairways.

C. Where doors are required, they shall open in the exit direction at the subway level and at the surface level. Clear width and height for the doors shall conform to the local codes. Where locks are required, doors shall be provided with panic hardware. The doors shall also meet the fire rating specified in the local codes.

2.12.3 Structures Supporting Pedestrian Traffic Only

To avoid the possibility of resonant vibrations induced by pedestrian traffic, the natural frequency of the unloaded structure shall be not less than 2.0 cycles per second. To avoid vibrations that might be objectionable to patrons, the calculated live load deflection, in inches, shall be limited to the span length, in feet, divided by 67, or one inch maximum.

2.12.4 Parapets

Where parapets are used, they shall be designed to withstand dead load, wind, load, force due to thermal expansion and contraction, shrinkage force, and earthquake forces equal to the full dead load of the parapet acting at the center of mass of the component parts.

2.12.5 Miscellaneous Items in Underground Structures Subject to Air Pressure Caused by Running Trains

A. Fans, vent shaft dampers, ancillary walls and doors exposed to the trainway shall be designed to withstand a pressure of 70 psf, reversible in its direction.

B. Doors located at the cross-passages separating two tunnels shall be designed to withstand a pressure of 70 psf, reversible in its direction. Doors shall be equipped with door closures and passage latch sets to allow opening from both sides. All doors and hardware sytems shall be designed to withstand an air pressure of 70 psf applied on either side of the entire door areas.

C. Station ceilings and fixtures shall be designed to withstand a pressure of 30 psf, reversible in its direction.

D. Items located in train control rooms and ancillary rooms shall be designed for pressure of 20 psf, reversible in its direction.

2.12.6 Elevators

The surface structure shall be designed for the loads described below. All loads shall be applied simultaneously with allowable stresses increased in accordance with applicable codes.

A. Dead load of structure

B. Live load of 100 pounds per linear foot applied at the free edges of the canopy frame

C. Wind load of 40 psf on windward side

D. For traction type elevators, the surface structure shall be designed to support elevator beams. The end reaction of elevator beams shall be 18,000 pounds, minimum. The locations of elevator beams vary with the type of elevator and its relative machine room location. Designer shall coordinate with elevator manufacturers for the elevator beam locations.

2.13 PLUMBING

For pertinent criteria, see System Design Criteria and Standards, Volume IV, Section 2.

2.14 DRAINAGE

2.14.1 General

The criteria of this chapter pertains to the design of drainage facilities for SCRTD subway line structures.

2.14.2 General Requirements

A. Invert elevations and the location of drainage facilities at the interface between contract units shall be coordinated with related Designers.

B. The extent practical, drainage shall be by gravity flow. Where collection points are below the elevation of gravity outfalls, pumping station shall be installed.

C. Surface drainage, except from decks, entrances, ventilation shafts, fan shafts, and similar openings, shall not be collected in the subway drainage systems.

D. No sanitary sewage shall be permitted to enter the track drainage system.

2.14.3 Location of Drains

A. Drainage pumps shall be provided at all low points not drained by gravity.

B. In subway line sections, manholes or drainage slot inlets shall be provided at a maximum interval of 350 feet.

C. Clean-outs shall be provided at maximum intervals of 120 feet along all drainage lines. A clean-out is required for each 90 degree bend and for each two 45 degree bends.

2.14.4 Drainage Fittings

The following fittings shall be provided:

A. Manhole Frame and Cover - A manhole frame and cover shall be provided at each access to the main track and at each drainage inlet connected directly to the main track drain.

B. Drain Inlet - A drain inlet shall be provided at each drainage inlet, with a connection to the main track drain.

C. Scupper Drain - A scupper drain shall be provided at the drain inlet from fan shafts, vent shafts, and escalator pits.

D. Clean-Out - Clean-outs shall be provided where access to the drainage piping is required for clean-out purposes only.

2.14.5 Drainage Piping

A drainage piping for subway sections shall be selected from the following:

Diameter (Inches)	Material	Use
4	Extra heavy weight cast iron soil pipe	Drain connections in structural walls and floors
6	Extra heavy weight cast iron soil pipe	Drain connection in structural walls and floors
6	Asbestos cement	Branch connections in structures and underground
8	Asbestos cement	Main track drain

2.14.6 Drainage Volumes

A. The volumes of water to be handled by each drainage system shall be calculated as follows:

1. Open areas draining into the subway drainage system

a. Drainage volumes from decks, entrances, ventilation shafts, fan shafts, and similar openings draining into the subway drainage system shall be calculated by means of the formula:

$$Q = Aci$$

where

Q = Volume, in cubic feet per second

A = Drainage area, in acres

C = Coefficient of runoff

i = Rainfall intensity for 50-year frequency

2. Subway Section in Earth

a. Drainage volume in subway structures in earth, designed to exclude groundwater, shall be based on the formula:

$$q = \frac{a}{30} + \frac{L}{500}$$

where

q = Volume, in gallons per minute

a = Horizontal projected area of all subway openings, in square feet, e.g., station entrances, fan shafts, etc.

L = Linear feet of subway structure in the drainage system

3. Subway Section in Rock

a. Drainage volumes in subway structures in rock, designed to collect groundwater in order to relieve hydrostatic pressure, shall be based on the formula:

$$q = \frac{a}{30} + \frac{L}{50}$$

where g, a, and L are as defined above

2.14.7 Flow Formula

A. Flow and velocity in drainage piping shall be calculated using Manning's formula.

In the use of this formula, the following factors for "n" shall be used:

n = 0.015 for concrete pipe 24 inch diameter and less

n = 0.013 for concrete pipe over 24 inch in diameter

n = 0.013 for asbestos cement and cast iron soil pipe

2.14.8 Grades

A. Drainage piping shall have the following minimum grades:

Pipe Diameter (Inches)	Minimum Grade
4	2.0% or 1/4" per foot
6	1.0% or 1/8" per foot
8	0.65%

B. 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 T/R profile.

C. 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.

2.14.9 Pumping Stations

A. Sump pumps shall be fully sealed to exclude moisture, abrasive materials, corrosive gases, and all other matter hazardous to wear.

B. The pumping stations shall be designed on the following basis:

1. Number of Pumps

   Each pumping station shall have two pumps.

2. Pump Capacity

   Each pump shall have a capacity equal to 100 percent of the calculated drainage volume; the minimum capacity of each pump at the low point shall be 500 gpm; the minimum capacity of each pump above the low point (interceptor pump) in the drainage system shall be 150 gpm.

3. Pump Head

   The pump head shall suit the static and friction heads of each installation; the friction head shall be calculated with two pumps operating.

4. Pump Type

   Pumps shall be of the non-clog, duplex submersible sewage type.

5. Level Control

   Level control shall be of the mechanical type.

6. Pump Clearances

   Pump clearance shall be adequate to pass two-inch solids.

7. Pump Speed

   The pump speed shall not exceed 1750 rpm.

8. Motor Selection

   Motors shall be of the non-overloading type.

C. 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.

2.15 FIRE PROTECTION

For pertinent criteria, see System Design Criteria and Standards, Volume 1, Section 2.

3. YARDS AND SHOPS

SYSTEM DESIGN CRITERIA AND STANDARDS

VOLUME: 2 SECTION: 3

YARD AND SHOPS FACILITIES

REVISION RECORD

NOTICE NUMBER	CR NO/REV	DATE APPROVED	AFFECTED	COMMENTS
1	4-015/	4/18/84	3.1	
2	5-060/1	8/1/86	ENTIRE SECTION	REPLACES PRESENT BASELINE VERSION

SCRTD METRO RAIL SYSTEM DESIGN CRITERIA

Volume 2, Section 3

YARD AND SHOPS FACILITIES

JUN 30 1983

SCRTD METRO RAIL SYSTEM DESIGN CRITERIA

Volume 2, Section 3

YARD AND SHOPS FACILITIES

VOLUME II, SECTION 3, YARD AND SHOPS

CONTENTS

VOLUME II, SECTION 3

YARD AND SHOPS FACILITIES

3.1 INTRODUCTION

The criteria presented herein establish parameters for Yard and Shops layout, sizes, functions, personnel, equipment, activities, and work flow.

3.2. GENERAL

3.2.1 Purpose

The purpose of the Yard and Shops complex will be to serve as the focal point for certain operations and maintenance functions of the system including:

A. Storage for revenue and non-revenue vehicles, maintenance equipment and materials required for maintaining and operating the system.

B. Minor inspection, interior cleaning, and minor servicing of vehicles, exterior car washing.

C. Servicing, overhaul, and major repair of vehicles and other related equipment.

D. Control of yard operations, including track switches and signals.

E. Support of wayside maintenance activities and response to wayside emergencies.

F. Reporting location for transportation and maintenance personnel.

G. Monitoring, supervision, and maintenance of main line train and station operations.

3.2.2 Design Objectives

Design of the Yard and Shops complex shall achieve the following objectives:

A. Safety and security of personnel, equipment, and facilities.

B. Efficient operation, with economy of motion minimizing: distances traveled by personnel and equipment; reverse movements by rail vehicles, number of moves by personnel and equipment; handling of material, equipment, and tools.

C. Flexibility in allowing simultaneous switching in the storage yard, intra-yard moves, and movement to and from the main line.

D. Efficient life-cycle operating costs.

E. Efficient and economical space utilization.

3.3 YARD AND SHOPS SITE SELECTION

Site selection criteria include the following:

3.3.1 Site Size

The Yard and Shops site shall be of sufficient size to permit construction of the facilities necessary to support revenue service and maintenance functions for the Metro Rail system. These facilities shall include those for rail vehicle storage, main line and yard control, heavy repair, inspection and cleaning of rail vehicles, Maintenance-of-Way (MOW) functions, and train and crew dispatching.

3.3.2 Future Expansion

The Yard and Shops complex shall be sized to provide for rail vehicle storage and maintenance of the ultimate fleet size projected for the Metro Rail starter line. Fleet sizing information should be based on Design Directive 002, titled "Accommodation of Patronage Growth," a Metro Rail baselined document.

3.3.3 Site Location

The selected site shall be located to provide convenient access to the Metro Rail main line with a minimum of deadhead mileage. The site selection process shall include consideration of land acquisition, clearing, and construction costs.

3.3.4 Environmental Impact

The selected site shall comply with all environmental requirements minimizing the negative impact on adjoining land. Considerations shall include air and noise pollution, traffic, aesthetics, social, economic, and safety, among others.

3.3.5 Site Configuration

Configuration of the Yard and Shops complex shall permit a functionally efficient layout to provide vehicle storage and work flow that minimizes train and personnel movement required.

3.4 YARD FUNCTIONAL REQUIREMENTS

The yard shall be designed to:

A. Provide an arrangement of tracks which facilitates train makeup and consist change, cleaning, washing, storage of cars, and movement to the shop facilities and main line.

B. Provide storage areas for non-revenue vehicles, materials, and equipment.

C. Support the shop operation as required.

D. Support the main line operation.

3.4.1 Operating Parameters

Operating parameters that shall be used in the design of the yard are:

A. Cars and trains will be operated manually within the yard operating limits at restricted speed.

B. No automatic train control systems will be provided in the yard. Signaling in the yard will consist of conventional signals indicating switch-point positions and where deemed necessary to govern train movements.

C. Supervision of the yard track system will be under the jurisdiction of the yard dispatcher located in the Yard Control Tower. The dispatcher will initiate, control, and monitor all yard movements. The Yard Control Tower will have the capability of remote operation of yard turnouts, route selection and interlocking and two-way communications with employees working in the yard.

D. Shop leads will be under the jurisdiction of the shop supervisor. Points of transition from yard to shop control shall be designated in the System Operating Plan. The shop supervisor will control movements within the Main Shop but will need to request permission from the yard dispatcher for train movements to and from the shop.

E. The initial system will utilize one yard containing storage tracks and major rail maintenance repair facilities. (District maintenance facilities not located in the Yard/Shops complex shall support rail maintenance activity.)

3.4.2 Activities and Areas of Responsibility

Activities and areas of responsibility to be considered in the development of a yard layout include the interrelated requirements, relationships, and responsibilities for system operations between the Rail Control Center, operations management, and yard management. Such areas of joint interest include:

A. Yard

1. Storage of cars
2. Dispatch and reception of trains
3. Interior vehicle cleaning
4. Consist changes and makeup
5. Minor maintenance and servicing
6. Safety inspections and departure testing
7. Exterior vehicle washing.

B. Shops

1. Vehicle availability
2. Vehicle preventive maintenance
3. Failure determination and correction
4. Modification programs
5. On-line troubleshooting
6. Maintenance-of-Way activities, equipment, and access to main lines
7. Vehicle and equipment receiving
8. Other subsystems equipment as required.

C. Transportation Activities

1. Employee reporting and timekeeping
2. Employee supervision and utilization
3. Equipment problem reporting.

3.4.3 General Considerations

In planning the Yard and Shops, specific consideration will be given to the following:

A. Yard and Shops facilities shall be laid out to provide a convenient and efficient facility wherein cars or trains can be put into and removed from revenue service by direct movement between storage tracks and main line via the transfer point.

B. Cars normally removed from service shall be able to move directly through the wash track located between the transfer point and storage tracks without blocking access to the storage yard. Likewise, trains in storage shall have ready access to the car wash track without hindrance to normal yard operations. Alternate routes shall be available between the transfer point and storage yard.

C. The Main Shop building shall be accessible by rail from both ends.

3.5 YARD OPERATIONAL REQUIREMENTS

To perform the various activities, the yard must provide for certain functions and capabilities. The functions are:

3.5.1 Operating Flexibility

A. Within the geographical constraints imposed by the location, maximum operating flexibility shall be ensured. The yard storage tracks shall be double-ended, to provide rail vehicle access to each storage track from either end.

B. No intra-yard movements shall require occupation of the track beyond the yard/main line transfer point. Lead tracks to the main line should be clear to the extent that at least one route is always available.

C. The yard shall be designed to minimize the number of switching movements and reverse movements to and from storage, shops, car wash, etc.

D. A run-around (bypass) track shall be provided to permit double-ended access to the storage tracks. Lead tracks to the Main Shop shall be long enough to provide temporary storage of trains at least two-cars long without blocking adjacent tracks or crossings.

3.5.2 Support of Main Line Operations

The Rail Control Center will be located within the Main Shop building and be responsible for monitoring and controlling main line operation of both revenue and non-revenue vehicles.

3.6 YARD FACILITIES

In addition to the Vehicle Maintenance Shops, the yard shall provide the following:

3.6.1 Storage Tracks

Storage tracks shall be provided for transit vehicles and for rail-mounted maintenance-of-way (non-revenue) vehicles. Electrified storage tracks shall be provided for a minimum of 170 revenue passenger vehicles and shall be stored in six-car consists. No more than three six-car consists shall be stored on a single storage track. A minimum of one non-electrified storage track at least 500 feet long shall be provided for non-revenue vehicles.

3.6.2 Transportation Facilities

The yard will provide transportation facilities to support main line and yard operations and personnel. The facility shall be designed to accommodate the following:

A. Crew reporting area
B. Crew dispatch room
C. Lunch room
D. Manager's office
E. Asst. Manager's office
F. Storage room
G. Meeting/Training room
H. Secretary's area
I. Copier/Supply room
J. Supervisor's office (3 line Supv., 1 Safety Supv.)
K. Conference room
L. Men's/Women's lockers, restrooms, and showers.

3.6.3 Rail Control Center

The yard shall contain the Rail Control Center (RCC) which will monitor and control operations and environmental control and status alarms at stations and in the main line. The Rail Control Center will house the following:

A. Rail Operations Control Room

B. Metro Rail CCTV Room

C. Equipment and Data Processing Rooms.

3.6.4 Communication Facilities

Communications shall be provided in the yard and will include portable (hand held) and vehicle (in-vehicle) radios. Telephones for both internal and external use with direct lines to RCC or the Yard Tower, and a public address or paging system will be provided for both Yard and Shops personnel.

3.6.5 Departure Test Facilities

No special provisions for performing departure tests on trains shall be required as these tests will use only on-board test equipment. The departure test will be performed prior to each dispatch to verify that vehicle subsystems are in operating order.

3.6.6 Yard Control Tower

The Yard Control Tower shall be located with a view of the yard storage tracks and storage track switches. The tower shall have equipment for the control of all switches within the yard, and communication with Yard and Shops personnel, and with the RCC.

3.6.7 Car Wash Facility

A. This facility shall be situated in a location that provides a direct route for washing and layup of trains returning from revenue service without requiring reversing moves. The facility shall permit operating the cars at a slow speed under their own power, through a series of water and acid or detergent sprays. The wash track shall be constructed at grade level with traction power provided by a contact rail throughout the length of the wash. A gap in the contact rail shall be provided to facilitate brush replacement without having to shut off traction power to the track. It shall also meet all environmental control standards that apply, including recycling of wash water.

B. The following criteria shall apply to the car washer:

1. All exposed areas of window jambs and door jambs shall be cleaned.

2. Reliability and maintainability shall be considered in the selection of the type of drive mechanism for the wash components.

3. Acid and/or detergent washing systems shall be accommodated in the car wash facility.

4. The washer shall be capable of automatically adjusting the acid concentration, to obtain

maximum cleaning action under various weather conditions.

5. A paved apron area downstream from the final rinse shall be provided to permit inspection and final hand washing of areas not adequately cleaned.

6. Adequate steps shall be taken to minimize water consumption. Effluent discharged into city sewers must meet local applicable codes.

7. Where toxic materials are used, eye wash and shower facilities will be provided. Enclosed occupied areas shall be suitably ventilated.

8. The washer shall be self-operating and activated by push button operable by the train operator from the cab window or by the train approach.

3.6.8 Interior Car Cleaning Facilities

A. Light Interior Cleaning

1. Routine light interior cleaning of transit vehicles shall be performed regularly in the yard storage tracks area. Refuse shall be removed. Maintenance or repairs requiring greater effort shall be handled during heavy interior cleaning activity.

2. The following are required equipment and facilities for light interior cleaning:

   a. Paved service aisles between yard storage tracks for access of car cleaning personnel and equipment to the cars.

   b. Space provided for storage of the following materials, supplies, and equipment:

      1) Self-propelled cleaning vehicles (battery charging required for electric vehicles)

      2) Trash compactor

3) Janitorial-type tools and supplies in yard area

4) Illumination

5) Portable stairs (or other device for transit car entry)

6 Other equipment as required.

B. Heavy Interior Cleaning

1. Heavy interior cleaning of transit cars shall be performed on a scheduled basis. Included in this activity will be manual cleaning of transit car exterior ends.

2. The following are required equipment and facilities for heavy interior cleaning:

a. A cleaning platform at rail car floor level height on both sides of a yard track, equipped with stair and ramp access.

b. Piped water, drainage, electrical outlets, compressed air, and storage facilities for janitorial tools and supplies.

c. Vacuum capability, janitorial tools and supplies, and other equipment and facilities as required.

Common equipment and/or facilities required for both light and heavy interior cleaning may be shared with other disciplines in the yard and shops complex (e.g., lunchroom to be shared with vehicle maintenance staff).

3.6.9 <u>Service Roads and Aisles</u>

A. Interior Service Roads

A network of paved interior service roads shall permit access for personnel and emergency response agencies. A perimeter road shall be provided throughout the yard adjacent to the yard fencing for security patrolling. Only fire service access roads shall cross the body of the storage yard. Service roads shall be provided to all buildings within the Yard and Shops complex to provide access by fire equipment, freight-delivery trucks, and maintenance trucks. No grade crossing shall be located within the area of a track turnout. The minimum width of fire access roads shall be 20 feet with a minimum of 28 feet at turnouts where pumping apparatus is expected to operate. The desired minimum for all other access roads shall be 15 feet and a minimum shoulder width of three feet. If the service road is located adjacent to the third rail, a curb or barrier rail shall be provided.

B. Exterior Service Road

An exterior service road shall be provided to connect the Yard and Shops facilities to the nearest public thoroughfare. Ingress to the yard shall be provided at a yard entrance gatehouse. Exterior service road design and signage shall conform to the local county and/or city codes.

C. Service Aisles

Paved service aisles are required between the storage tracks to facilitate the ingress and egress of personnel and equipment for routine interior cleaning and for emergencies. The minimum aisle width required for circulation between alternate pairs of tracks, shall be six feet curb to curb. This shall be achieved by configuring the storage tracks with alternative track spacing of 14 feet and 19 feet.

3.6.10 <u>Traction Power</u>

Traction power to all yard tracks shall be delivered through substation circuits devoted to that purpose. Power received from a commercial source shall be delivered to one point within the yard area for metering. Power from this point shall then be distributed to the yard, shops, offices, and the adjacent main lines as required. Each track or group of tracks shall be circuited so that power can be removed in emergencies or as required without affecting other tracks in the yard.

3.6.11 Drainage and Sewer Systems

A. Storm Drainage System

1. A complete storm drainage system shall be provided at the yard. The system shall consist of a combination of graded subgrade areas and perforated self-cleaning subdrains located between alternate pairs of tracks and connected to the necessary laterals, collectors and outfall structures. A system of ditches, catch basins, and storm drain pipes shall be designed to direct surface runoff away from all track areas and flow from the subdrain and roof drain systems. The storm drain shall not flow into a subdrain. Measures shall be taken to protect the subdrain system against cathodic deterioration. The yard trackwork areas shall be underlain by a six-inch minimum layer of semi-impervious subballast properly compacted and graded at a minimum slope of four percent to the subdrains. Open areas and material storage areas shall also be covered with a six-inch layer of semi-impervious compactible material and graded to area drains at a minimum slope of two percent. Appropriate steps shall be undertaken to ensure compliance with applicable regulations concerning effluent discharge.

2. The drainage system shall contain the following minimum slopes:

   a. Subdrains - 0.5%

   b. Laterals - 0.3%

   c. Main Collectors - 0.25%

   d. Ditches - 0.25%

3. Cleanouts shall be provided at the terminus of each subdrain. Manholes shall be provided at maximum intervals of 300 feet on the laterals and main collectors in order to facilitate the maintenance of the yard drainage system. The individual subdrain runs shall not be longer than 300 feet.

B. Sewer Systems

1. The sanitary sewer serving the yard shall be connected to the local sanitary sewer system and carry effluent in accordance with local standards.

2. All lines carrying industrial waste from both interior and exterior pits and surface drains shall lead to separators, where grease, oil, and undesirable materials are removed and disposed properly before discharging into the local sewer.

3.6.12 Security

A. Due to the nature of electrification, the entire yard complex shall be fenced off from the general public, except through one "main" gate. A guardhouse designed to be attended shall be provided adjacent to the gate for security. Access beyond employee/visitor parking areas in the yard shall be further secured for safety and theft prevention by additional gates.

B. Outside material storage, parking areas, and the entrance area shall be sufficiently illuminated for safety and to discourage potential theft, trespassing, and vandalism.

3.6.13 Yard Lighting

The yard shall be sufficiently illuminated to permit operations and maintenance activities to be performed safely on a 24-hour basis. A minimum illumination of one foot-candle measured at ground level shall be provided. Yard lights, tower, poles, or stanchions should be so designed and located for maintenance accessibility minimizing shadows and avoiding interference with operations. The mounting of lights on existing non-transit structures shall be permitted.

3.6.14 Fire Protection

Fire protection equipment (hose connections, sprinklers, hydrants, fire hose cabinets, extinguishers, etc.), shall be provided.

3.6.15 Power, Signal, and Communication Ducts

Conduits within the yard which are required to supply power, operate signals, and communication systems, shall be encased in concrete or steel ductbanks to minimize the impact of stray current, to reduce inductive influence on train control systems and to increase strength at track and road crossings. Manholes, pull boxes, and junction boxes are required along the conduit runs to accommodate cable pulling equipment for ease of installation and maintenance. The horizontal and vertical layout of the conduit runs and boxes shall be carefully planned to avoid conflict with drainage pipes, track hardware, and lighting towers. Ductwork shall be provided to locations containing badge readers, transmis terminals, and SCADA (Supervisory Control and Data Acquisition) equipment, and other areas as required.

3.7 SYSTEM MAINTENANCE

3.7.1 System Maintenance Philosophy

The objectives of system maintenance are to provide for:

A. Safety of passengers and employees

B. Minimization of system life-cycle costs

C. Maximization of equipment availability and system dependability.

3.7.2 Maintenance Parameters

The following maintenance parameters shall be considered in design of the shops:

A. Preventive maintenance programs will be stressed where appropriate to:

1. Reduce service failures and unscheduled work

2. Extend equipment life without excessive cost

3. Ensure operational safety

4. Minimize system maintenance costs through work efficiency and productivity

5. Optimize ability to schedule shop activity.

B. Component exchange will be stressed so that repairs and overhauls can be accomplished as follows:

1. Removal and replacement of lowest level replacement parts

2. Repair or overhaul in a component repair shop under conditions of efficient shop layout, maintenance facilities, cleanliness, supervision, and quality control.

C. Using the major repair shop as the overall system equipment repair center, the District will maximize responsible use of existing SCRTD facilities and personnel, including tasks that may be performed at other District facilities such as the Central Maintenance Facility for repair of electronic components, automotive vehicles, seat upholstery, and glazing. Factors to be considered are:

1. Cost of shop equipment and space

2. Liability implications

3. Equipment procurement contractual warranty and reliability verification implications

4. Relative costs to perform the work

5. Maximum use of existing District skills and identification and provision of special skills requirements

6. Availability of non-District shops to perform work on a contract basis.

D. Shop testing will be required for testing equipment received as initial issue, spares, warranty replacement, and from reconditioning. The equipment shall be tested for serviceability and conformance to specifications. Some of these activities can take place at the Central Maintenance Facility (CMF).

E. Troubleshooting electrical and electronic equipment, transit car equipment, train control, communications, and if applicable, fare collection equipment will be performed with portable test equipment having the following characteristics:

1. Light weight and compact size
2. Convenient to use and easy to read
3. Capable of identifying failed components
4. Capable of performing tests under dynamic conditions to the extent practical
5. Easily read and understood maintenance test manuals for troubleshooting.

3.8 SHOPS

Most maintenance activities shall be in the Main Shop and Maintenance-of-Way building. The Main Shop shall be the primary location for repair of all rail rolling stock and related components. The Maintenance-of-Way shop shall be the focal point for maintenance of fixed facilities and equipment. Most component repairs of electronic equipment shall be performed at the SCRTD Central Maintenance Facility.

3.8.1 Heavy Repair Shop

The heavy repair shop shall be the location for the overhaul and major repair of transit vehicles.

A. The heavy repair shop shall be designed to provide for the following activity:

1. Scheduled vehicle preventive maintenance and overhaul including body and equipment repairs
2. Accommodating unscheduled maintenance resulting from equipment failure or accidents
3. Exchange of trucks and other major equipment items

4. Testing and exchange of components and sub-assemblies

5. On-vehicle wheel truing

6. Major modification to vehicles

7. Spare parts storage

8. Warranty maintenance during warranty period(s).

B. Sizing of Heavy Repair Shop

The heavy repair shop shall be designed to service individual units and dependent pairs. Accommodation for servicing is based on a percentage of the system's fleet size. The heavy repair shop shall have accommodations to service eight vehicles or four dependent pairs. These capacity requirements have been based on the following considerations:

1. Amount of revenue service to be provided (car-hours, car-miles)

2. Railcar characteristics and proposed major overhaul frequency

3. Time in the shop, per railcar, for complete overhaul

4. Assignment of railcar work positions to major overhaul versus other major repair tasks

5. Number of work shifts to be used for design year

6. Mean time between failure (MTBF), and mean time to repair (MTTR) for the various major mechanical, electrical, electronic, collision, modification, and body repair tasks which will be performed in the major repair facility.

The experience of other rail transit systems shall be examined when estimating frequency of major repair and overhaul, and the time required to effect these maintenance actions.

The number of work stations shall be determined by examining the MTBF, MTTR, and required shop hours to repair expected number of failures in an eight-hour period.

3.8.2 Service and Inspection Shop

The Service and Inspection (S&I) Shop shall provide the capability for transit vehicle preventive and corrective maintenance (generally of a light and routine nature).

A. The S&I Shop shall be designed to provide for the following activity:

1. Scheduled and unscheduled inspection and preventive maintenance tasks such as lubrication and filter changing
2. Corrective maintenance
3. Testing
4. Exchange of minor components
5. Interior cleaning, spot removal, seat and trim replacement, and repair of damage by vandalism
6. Minor modification projects.

B. This shop shall accommodate individual units, dependent pairs, or coupled trains with a maximum length of six cars.

C. The S&I Shop shall be designed to operate 24 hours per day, seven days per week. The following assumptions shall be used in the design of the service and inspection area:

First Shift	Work to be Performed
7:00 a.m. - 3:00 p.m.	Service and inspection, unscheduled corrective maintenance, modifications
Second Shift	**Work to be Performed**
3:00 p.m. - 11:00 p.m.	Unscheduled corrective and preventive maintenance, pre-inspection cleaning (blowdown)

Third Shift	Work to be Performed
11:00 p.m. - 7:00 a.m.	Unscheduled corrective and preventive maintenance

D. Based on the current operations plan, projected fleet size, and anticipated scheduled and unscheduled maintenance, accommodations for a total of 18 cars shall be provided.

3.8.3 Blowdown Pit

A. A separate air blowing facility shall be provided for undercar cleaning. It shall consist of a pit with a suitable compressed air and exhaust system. The pit shall be at least 10 feet wide and five feet deep and shall be able to accommodate two cars. Separation can be accomplished by partitioning off an area from the rest of the shop or, even better, a completely separated facility isolated from the shop and in a location that is a logical part of the work flow. A single track and pit will be provided.

B. Within the pit, air nozzle connectors shall be properly located to allow men to use lances to blow compressed air against all parts of the car underbody. The dust collection system should be designed for easy removal by railcars or trucks. In addition, a removable nonskid grid floor, walk platform access stairs, filter cleaning equipment, drainage and waste water disposal facilities shall be provided. Utilities to be included are water, compressed air, sewer and auxiliary electrical power.

3.8.4 Steam Degreasing Area

Vehicle trucks, assemblies, and related parts shall be degreased by means of steam. An area outside the shop and with track access to the truck repair shop shall be provided. It shall be outfitted to clean assemblies with steam from beneath or at truck level. The utility services shall include steam, water, air, sewer and auxiliary electrical power. Grease traps shall be provided to meet the local requirements and codes.

3.8.5 Wheel Truing Facilities

Wheel truing facilities shall be provided to remove flat spots and to restore the treads and flanges to the correct wheel profile. This shall be accomplished by use of a wheel truing machine.

A. A wheel truing machine shall be installed in a pit under a track in the heavy repair shop so that the wheels do not need to be removed from the car. The car will be placed over the machine for the truing operation so that the two wheels on any particular axle can be trued simultaneously.

B. The need for wheel truing will be determined by periodic gauging (usually during a car inspection).

C. The wheel truing machine shall include operator protective devices, chip removal devices, and protection against open rail sections.

3.8.6 Truck Shop

The truck shop shall be incorporated into the shop design adjacent to the heavy repair area to provide the capability for complete teardown, repair, and rebuilding of car-truck assemblies. Typical activity will be:

A. Traction motor, gearbox, wheel and axle sets, and truck-component replacement

B. Repair or modification of truck functional or structural elements.

3.8.7 Wheel Shop

A wheel shop shall be included in the Main Shop building adjacent to the heavy repair area and shall provide for:

A. Pressing wheels, gears, and journal bearings onto and from axles

B. Boring individual wheels

C. Non-destructive testing of components.

3.8.8 Metals Shop

A metals shop shall be included in the design to provide for:

A. Fabrication of needed items not readily available

B. Fabrication of prototype articles for test or use

C. Repair of structurally damaged articles

D. Miscellaneous sawing, drilling, or milling operations

E. Fabrication of hatches, brackets, covers, and other metal items

F. Repair of sheet-metal assemblies such as transit car doors

G. Facilities and equipment for car body sheathing and structural repair

H. Frames for various signs, displays, advertising, and other graphics

I. Minor repairs to fixed plant

J. Machining of axles.

3.8.9 Battery Shop

A battery shop shall be provided in the Main Shop building for testing, charging, servicing, storage, and minor repair of batteries.

3.8.10 Welding Shop

A welding shop and equipment shall be provided and be equipped for cutting or welding various similar and dissimilar ferrous metals and aluminum. Portable welding equipment may be housed in this shop.

3.8.11 Component Repair Shops

A. Repair of a failed piece of equipment (such as a passenger vehicle component or fare gate) will typically be accomplished by replacing the lowest-level replaceable unit that has failed with a good unit and then repairing the failed unit in the appropriate component repair shop. Typical component repair shop activities are:

1. Scheduled servicing or overhaul
2. Failure correction or repair
3. Repair of accident or vandalism damage
4. Modification programs
5. Failure analysis
6. Modification or retrofit development and prototyping
7. Testing.

B. The following component repair shops shall be housed in the Main Shop building:

1. Electrical Room - The primary location for electronic component repair will be at other District facilities. However, a room for first line repairs, diagnosis, and storage shall be provided in the Main Shop. This room will accommodate minor repairs of such items as: cradles and cabinets; radios and other communications gear; and train destination signs and other displays, etc.

2. Electrical Repair Shop - An electrical equipment repair shop shall be provided for repair of electrical gear. Typical items to be worked in the electrical repair shop will include:

   a. Major equipment -- electrical coupler heads, current collector assemblies, knife switches, reversers, cam controllers, brake grids, and other large resistors

   b. Small equipment -- various relays, switches, power contractors, and circuit breakers

   c. Various motors -- traction motors, blower motors, switch machine motors, and other high and low voltage drive motors (Note: Specialized activities requiring high-cost capital equipment, such as rewinding and vacuum impregnation, will be contracted.)

d. Lighting fixtures

e. Wiring, cabling, and harnesses.

3. Air Brake Shop - An air brake shop shall be equipped to permit the testing, repair, modification, and certification of:

   a. Truck-mounted friction brake assemblies

   b. Air compressors

   c. Valves and distribution devices

   d. Reservoirs, lines, and fittings

   e. Air suspension components

   f. Pneumatic maintenance equipment.

4. Air Conditioning Shop - Air-conditioning shop activities shall include maintenance and repair of rail vehicle air-conditioning and heating equipment. Air conditioning work may also be performed at the CMF. Items to be repaired include:

   a. Refrigerant compressors

   b. Refrigerant lines and hoses

   c. Condensers, evaporators, and dryers

   d. Temperature and humidity sensors. (Note: These may be assigned to electronics or electrical shop.)

3.8.12 Maintenance-of-Way Shop

The Maintenance-of-Way (MOW) Shop shall be housed in a separate building and will serve as the focal point for the maintenance of wayside equipment and certain facility-related work. The following functions will be performed at the MOW shop:

A. Repair of trackwork and switch equipment

B. Repair of traction power equipment

C. Repair of wayside train control, signals, and communications equipment

D. Repair of certain facility items from station, tunnel, vent structures, and shop buildings

E. Repair of tunnel sump pumps

F. Staging area and point-of-dispatch of MOW personnel performing in-field maintenance

G. Storage of equipment for track and wayside repair and emergency response (e.g., portable sump pumps and rerailing equipment).

The following work areas shall be provided in the MOW building:

A. Laydown/storage area

B. Secured general storage area

C. Building equipment repair

D. Tool room

E. Secured tool room (separate from tool room)

F. Electrical room

G. Warehouse.

The Maintenance-of-Way Shop building shall have both railcar and rubber tired vehicular access. The building floor shall be level at railcar height to facilitate easy transport of equipment and supplies into and out of the shop from a railcar. In addition, the Maintenance-of-Way building shall have a loading dock accessible to both railcars and rubber tired vehicles. An outdoor storage area adjacent to the shop building shall be provided.

3.8.13 Maintenance Administration Offices

The Main Shop building shall house vehicle maintenance offices and the MOW building shall house rail facilities maintenance facilities offices. The following personnel facilities shall be provided within each building:

A. Supervisory office space

B. Crew reporting area

C. Lunch/training room

D. Provisions for handicapped employees

E. Manager's office

F. General office space

G. Telecommunications room

H. Men's and women's lockers, restrooms, and showers

I. Supplies/Copier room

J. Reception area

K. Men's and women's restrooms

3.8.14 Stores

A. Stores facilities shall be included in the maintenance shop buildings to accommodate:

1. Storing, handling, and issuing of tools, spare parts, assemblies, and repairable components, as well as consumable materials

2. Receiving, testing, and acceptance of various new and rebuilt items

3. Disposition of surplus, obsolete, or scrap material

4. Inventory control.

B. Stores facilities shall be located within the shop buildings so as to be convenient to the repair areas for shop employees who will need to withdraw tools, parts, and materials to accomplish their maintenance assignments. The stores area shall include the following:

1. Storage area for inventory of parts and material

2. Tool room for the storage of shop tools

3. Secure storage room for the storage of valuable and/or security sensitive parts, material, and tools

4. Shipping and receiving area for receipt, testing, and acceptance of new parts and material and for shipping of surplus or rejected material

5. Loading dock for truck delivery to the shipping and receiving area

6. Office.

C. In addition to the enclosed stores facility, areas shall be provided for storage of items and materials out-of-doors. These may include:

1. Rail, crossties, ballast, and accessories

2. Transit vehicle wheels, spare trucks and components, and car body structural components

3. Various items of materials used in building and other fixed plant maintenance

4. Flammable, toxic, or otherwise hazardous materials in an area remote from shop building.

3.8.15 Shop Equipment and Facilities

Shop equipment, facilities, and space requirements are identified as follows:

A. Heavy Repair Shop

1. Built-in Equipment

This area shall consist of three through tracks, each containing two married-pair positions. Two tracks shall be equipped with underfloor car and truck lifts, in-track turntables required for exchanging trucks as well as all items of undercar equipment. The other track will house the underfloor wheel truing machine. The shop floor will be free of obstructions and of sufficient capability to permit entry and unloading of materials, including rail transit vehicles from railway flat cars or other type freight cars, as well as materials in highway trucks and trailers. The shop shall be equipped with compressed air, lubrication, and electrical power supply devices, and a stinger for movement of cars within the shop. A ten-ton bridge crane shall be provided overhead.

2. Portable Equipment

The following equipment shall be supplied:

a. Stairs and scaffolds for access to car and locomotive bodies and interiors

b. Roll-about tool chests

c. Stand-up type desks with forms storage

d. Lift truck with various appurtenances for handling undercar equipment

e. Various items of special test equipment and an air-conditioning service cart

f. Reusable containers, glazing transport carts.

The heavy repair shall provide adequate space to accommodate the above items.

B. Service and Inspection Shop

1. Built-in Equipment

This area shall consist of three through tracks, each containing three married-pair positions. One track shall be located over a six-car long pit, while two adjacent tracks shall have two-car long double track pits on the outer ends, with a two-car long floor level track in the center. The S&I tracks shall be equipped with lighting and compressed air, lubrication, and low voltage electrical power supply devices. The pits will be protected by removable railings. Approved overhead stingers, for movement of cars within the shop, will be provided. Pit tracks capable of supporting a locomotive shall be provided.

2. Portable Equipment

The shop shall make provisions for the following:

a. Stairs and scaffolds

b. Roll-about tool chests

c. Stand-up type desks with forms storage

d. Various items of special test equipment.

C. Blowdown Pit

Compressed air outlets shall be properly located to allow hand held lanes to blow compressed air against all parts of the car underbody. A dust collection system should be designed for easy removal of the loosened dust.

D. Wheel Truing Facilities

Equipment provided shall consist of underfloor wheel truing machine, capable of truing wheels on transit vehicles. This equipment shall have accessories for measuring, recording and controlling relative diameters of wheels, and collection and disposal of chips, turnings, shavings, or other debris.

E. Truck Shop

1. The equipment to be provided in the truck shop will include truck repair hoists, various stands and holding fixtures, and an overhead crane system capable of handling complete truck assemblies. This system shall be controlled by a floor operator. Single-hook cranes with a 10-ton capacity shall be provided.

2. Space for storage of various truck components and complete trucks shall be provided.

F. Wheel Shop

1. The major machinery in the wheel shop shall consist of a boring mill and a single-end press.

2. This area shall contain various racks and other fixtures for storing wheels, axles, drive gears, and journal bearings in addition to appropriate materials handling equipment.

G. Metals Shop

1. This area shall be configured to accommodate the following:

   a. Drill Presses
   b. Lathe(s)
   c. Milling Machine
   d. Surface Grinder
   e. Band Saw
   f. Hydraulic Press
   g. Power Hacksaw
   h. Press Brake
   i. Squaring Shears
   j. Rolling/Bending Machine
   k. Bench/Grinder Buffer
   l. Pipe & Tube Bender
   m. Bending Machine
   n. Grinder
   o. Punch Press
   p. Horizontal Band Saw
   q. Buffer

2. This area shall be equipped with work benches and tables, clamps, and holding fixtures, racks for storing routinely worked items such as transit vehicle doors and materials such as steel or aluminum sheet, and storage cabinets for supplies and materials, and a two-ton jib crane.

H. Battery Shop

This area shall be power-ventilated, and provide a floor drain for possible acid spills and cleanup. Racks for storing various batteries will be supplied. Electrolyte storage facilities conforming to applicable safety standards will be provided. Battery charging equipment and load tester, and appropriate cables shall be included. Fresh water must also be supplied. An emergency water eye wash and shower/flush system shall be provided.

I. Welding Shop

1. This area shall be equipped with steel-faced workbenches, various clamps and holding fixtures, and secure material storage areas. Materials handling equipment, (two-ton crane) shall be included. Ventilation equipment and various shields and barriers conforming to applicable safety standards shall be supplied.

2. Various built-in and portable welding, brazing, grinding, heliarc, and other welding systems will be provided commensurate with the materials anticipated to be utilized in the system.

J. Component Repair Shops

1. The shops listed are identified as unique entities, however, some may be combined, or grouped in such a manner as to provide for common administration and supervision. All will require workbenches, tools and materials storage, and in various combinations, compressed air and power supply. Each will require access to technical manuals, time clock areas, and bulletin board areas.

2. The following are known unique requirements for these functions:

   a. Electrical Equipment Shop

   This shop shall require materials-handling equipment for large and bulky items, stands and holding fixtures for the motors and other equipment to be worked. Electrical power at various values for testing equipment will be required. Test equipment such as continuity testers, meggers, and high-potential testers will be utilized. A drill press, grinder, and hydraulic press for pinion removal will be supplied.

b. Air Brake Shop

This shop shall require various air-brake component test racks, drill press, grinder, surface grinder, compressor rebuild and test equipment, and high-pressure testing apparatus for pneumatic reservoirs. Special production equipment shall be provided for mounting brake pads on disc brakes if disc brakes are specified. A clean environment is mandatory.

c. Air-Conditioning Shop

This shop shall be provided with a grinder, drill press, band saw, hydraulic press, in a clean working environment. Facilities for repair of mechanically driven compressors are required. Facilities for soldering and other repairs of evaporators, condensers, and refrigerant lines as required. Pressure testing and compressor functional testing are required. If air-conditioning equipment to be serviced is to be worked as integral units, refrigerant charging apparatus and refrigerant storage will be required. Ventilation must be in accordance with applicable safety standards.

K. Maintenance-of-Way Shop

The MOW Shop shall contain air and electric tools, hydraulic tool set, hand tools and boxes, test equipment (voltmeters and ammeters), and track inspection tools. A drill press, band saw, and radial saw shall also be provided for various MOW functions. The following shall be provided in the MOW shop:

1. Backshops

a. Laydown area with grinders, cutters, welding equipment, and necessary jigs, clamps, and fixtures for cutting and drilling rail and repair of special trackwork components, such as switch-points and frogs.

b. Shop for fabrication and repair of various minor building and shop items. This shop will support forces engaged in building repair, including glazing, signs, and other graphics. This function will be combined with related ones in the facilities maintenance support shop.

c. Mobile maintenance and emergency equipment requirements for equipment needed to handle maintenance and emergencies on the right-of-way shall be developed. Space shall be provided in the MOW building to store and service this equipment. Such equipment shall include but not be limited to:

   1) Rerailing equipment to rerail a passenger or auxiliary vehicle within tunnel, station, or yard areas. This apparatus shall be capable of rerailing the vehicle without the use of traction power provided by the third rail.

   2) Transportable pumps to be used in tunnel, at stations, in the Yard/Shops complex wherever pumping activity is required which cannot be accommodated by the fixed-location sump pumps.

d. Facilities for maintenance of traction power, elevator, escalator, and tunnel pump and ventilation equipment.

3.9 YARD AND SHOPS PERSONNEL WORK ENVIRONMENT

3.9.1 Personnel Needs

The main areas which shall be required for the needs of personnel include, but are not limited, to: lunch room, locker room, wash facilities, toilets, training room, and lounge.

Separate areas, where required, shall be provided for male and female personnel.

3.9.2 Work Environment

The design shall conform to applicable industrial safety, health, and hygienic standards, local building codes, and anti-air pollution regulations. Some of the factors which shall be considered include the following:

A. Provide appropriate shelter as necessary for outdoor functions.

B. Provide sufficient levels of lighting at all work locations including pit areas. Consideration shall be given to the maximum practical use of natural light.

C. Provide heating and ventilation at all work locations and areas for personnel use, where practical and justified.

D. Special systems shall be provided to assure adequate environmental control, including: 1) dust control and collection system in the blowdown pit, and 2) air supply and exhaust systems where required.

E. Adequate communication systems shall be provided.

F. Architectural consideration of floor, wall, and ceiling finishes and colors that best tend to contribute towards accepted human engineering practices shall be encouraged.

G. Adequate soundproofing of office space shall be provided.

3.10 TEST TRACK

(No provisions for a dedicated test track have been made.)

3.11 APPENDIX - DEFINITIONS

Many rapid transit shop terms and words peculiar to, and used within, the industry may be foreign to new suppliers, consultants, and operators. The following list defines the most common terms related to this Section which are not contained in the Metro Rail Project Glossary of Abbreviations and Definitions.

Ancillary Facilities - Subsidiary locations for housing personnel engaged in the organization's activities. These are usually located at strategic stations. They may be permanent or temporary.

Blowdown Pit - A pit located underneath the rails or guideways and equipped with suitable equipment and utilities to clean undercar structures and assemblies. It is generally located in a yard area protected from the elements.

Body Hoist - Electro-mechanical apparatus, generally used in conjunction with truck hoists, for raising and maintaining a vehicle car body in an elevated position. Often called body supports. Installation is part of shop track system.

Capital Inventory - That class of inventory which, by rebuilding, can be returned to specified operating condition rather than consumed.

Car Body - That portion of a car that carries people and all equipment except the truck assemblies.

Cleaning Platform - A platform elevated to car floor height to provide for easy access to car interiors by personnel and equipment for cleaning vehicles.

Car Spot - A single location within a shop or yard of sufficient length and width to hold one car.

Component Repair Shop - A facility specifically designed for repair, overhaul, and/or testing of electrical, electronic, mechanical, hydraulic, or pneumatic parts, modules, assemblies, or subsystems. It may be compared to a manufacturer's service repair shop. It may be a separate building or part of another shop.

Consist Change - The adding to or removal of cars from a train.

Contract Maintenance - The repair, overhaul, and testing of parts, modules, and assemblies under contract to other than an operator's own personnel. The work many be done on or off the operating property. This also can apply to tasks such as facilities janitorial work, landscaping, etc. It is often used for specific items such as elevators, escalators, motors, bearings, etc., generally impacted by labor agreements.

Consumable Inventory - That class of inventory that, once used completely or for some predetermined unit of time or distance, is replaced and discarded, i.e., lubricants, filters, brake shoes, etc.

Departure Test - Preprogrammed confidence checks of train integrity run prior to departure of automatic mode trains.

Diagnostic Test Equipment - Preprogrammed automatic-test sets used to check car circuitry and subsystems usually for use in shops but may refer to portable sets capable of being carried on cars or trains.

Effective Daily Shop Capacity - A measure of the number of transit cars a shop could handle over a three-shift day if every car spot were utilized on a specified average time/car/spot.

Facility - A self-contained physical location housing a yard, shop(s), operations center(s), or some combination thereof, with all necessary equipment and machinery.

In-House Maintenance - The repair, overhaul, and testing services provided to an operating property by its own employees in its own facilities.

Locomotive - A prime mover for towing work cars or moving transit vehicles, generally in the 50-ton and less than 1000-horsepower class.

Lubrication - The application of lubricants, generally on a scheduled basis, to equipment and machinery.

Main Shop - A transit facility specifically designed for heavy maintenance, overhaul, and testing vehicles and equipment. Sometimes called Main Repair Shop.

Maintenance - The upkeep of vehicles, plant, machinery, and equipment. It may be scheduled, planned, progressive, or periodic, based on preestablished intervals of time or mileage, and employing preprinted checklists, or it may be unscheduled or corrective, generally not interval based.

Maintenance Planning System - A system of cost, work, and manpower planning, scheduling and control, either manual or automated, and generally part of a total management information system.

Maintenance-of-Way Shop - A transit facility expressly designed for maintenance of the plant and equipment within the jurisdiction of a Maintenance-of-Way Department.

Manual Operation - The system of train operation that requires a the train operator to control the movement of trains or cars.

Operations Shop - An all-purpose facility performing the different levels of maintenance of transit vehicles, generally split between Service and Inspection Shops and Main Shops; can include Maintenance-of-Way tasks.

Overhaul - The heavy repair or rebuilding of components and complete vehicles or equipment and machinery to restore to "like new."

Pit - A depressed area below floor level mainly between running rails or guideway for undercar lubrication, inspection and maintenance, equipped with all necessary utilities.

Portable Car Jacks - Specially designed jacks (usually in a set of 4) for raising a single car. May be used anywhere at floor level where built-in jacks or hoists are not warranted or cannot be installed.

Records Center - An office of an operating department responsible for operations and maintenance data collection and dissemination of such activities as maintenance scheduling, vehicle and equipment histories, failure reports, warranty reports, standards, etc.

Relay Zone - A grouping of tracks and switches used for temporarily shunting cars during consist change.

Service Aisles - Paved aisles in yards between storage tracks for movement of service vehicles and their personnel and equipment. Such vehicles may include electric carts, forklifts, specially designed cleaning vehicles, etc.

Service and Inspection - The activities of lubrication, inspection and minor maintenance associated with the servicing of transit vehicles. Such activities are generally done in a Service and Inspection Shop or an Operations Shop.

Shielded Room - Special enclosed area, usually within an electronics shop, for radio repair and test.

Shop - Any facility designed for some area of maintenance activities.

Shop Storage - A group of tracks, adjacent to a shop, assigned to the storage of transit vehicles awaiting shop entrance.

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.

Stinger - An electrical device, usually suspended from an overhead trolley, used for applying traction power to vehicles in a shop for testing or moving these vehicles in the absence of a contact rail. Some shops use external means of moving vehicles such as locomotives, track mobiles, or hi-rail vehicles.

Storage Yard

(1) A facility containing a rail or guideway network for receiving, dispatching and storing transit vehicles or trains and work equipment.

A portion of a yard is usually also set aside for large or bulk material storage.

(2) A facility associated solely with a Maintenance-of-Way location.

Support Services - That portion of a shop facility that houses offices, personnel accommodations, subshops, records centers, staff organization, etc.

Test Track - A length of track, usually separated from a main line, of sufficient length to safely operate a car or train through a performance cycle (start, accelerate, run at maximum speed, decelerate, stop). The track is equipped with all the system safety features and, in addition, with automatic train control if the operation is automatic.

Throat - That portion of a yard that connects the storage areas to the main line lead tracks or, in an automatic system, to the transfer tracks.

Train Washer (Car Washer) - An apparatus made up of brushes, spray arches, solution tanks, water reclamation system and controls to wash cars or trains passing through the apparatus. The washer is usually fully automatic and should be located in the best possible work flow position. It is generally placed in a protective building in cold climates.

Transfer Point (Zone) - A location on one or more tracks used in an automatic train control operation, it is located between a yard and main line leads and is the area that separates a manual yard operation from an automatic main line operation.

Transportation Building - A facility specifically designed within a yard as a control location for yardmasters, hostlers, train operators, etc.

Truck - A major transit vehicle assembly of structural members, wheels and axles, motors, gearboxes, brakes, collectors, cable, piping, etc.

Truck Hoist - Apparatus, either electromechanical or hydraulic, generally used in conjunction with body hoists, for raising transit vehicles for inspection and maintenance. Installation is part of shop track system.

Truck Lift - Similar to garage auto lifts, usually hydraulic. Used to position separated car trucks at various elevations for maintenance.

Turntable - A device built into the track system for turning separated or disconnected trucks in a shop for removal from, or installation on, a transit vehicle; or, a larger version for turning complete transit cars in a yard. The devices may be mechanical, electromechanical, or air cushion.

Wheel - May be all steel flanged, aluminum center with steel tire, with or without resilient material, or rubber-tired, with or without steel guide wheels.

Wheel Press - A machine used to press wheels, discs, or gearboxes on and off axles. The machine is generally equipped with a permanent recording device. It is usually located near the truck repair area.

Wheel Truing Machine - A machine for returning steel wheel profile to original contour; it is built into the shop track system; it may be a tracer lathe type or a milling machine type. It should be equipped with chip collection and removal equipment.

Work Cars - Generally specially-built, special-purpose, freight type cars, such as ballast cars, flat cars, rail-cars, wheel cars, grinding cars.

Work Train - A train composed of work cars pulled by a prime mover, generally a locomotive.

Wye (Y) - A track or guideway arrangement allowing a car or train to be turned by a series of moves; it requires much yard space.