Dallas Area Rapid Transit
Light Rail Project
Design Criteria Manual

Volume 2

Systems Design

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Design Criteria
Volume 2
System Design

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CHAPTER 1 - GENERAL SECTION

1.1 GENERAL

The Dallas Area Rapid Transit (DART) Transit System Plan includes a light rail system connecting the Central Business District (CBD) with residential and other areas within the City of Dallas and surrounding cities of Addison, Carrollton, Cockrell Hill, Farmers Branch, Garland, Glenn Heights, Highland Park, Irving, Plano, Richardson, Rowlett, and University Park.

1.2 LIGHT RAIL DESCRIPTION

The DART Light Rail System is being constructed in phases. The Starter System was the first phase. It was followed by Buildout Phase 1, and Buildout Phase 2 is under design.

The Starter System consists of approximately 20 miles of main line double track railroad together with a Service and Inspection (S&I) Facility. The Starter System construction includes at-grade, aerial, underground, and street running. It operates south from Park Lane through Downtown to an Oak Cliff trunk with branches to South Oak Cliff and West Oak Cliff.

Buildout Phase 1 consisted of approximately 22 miles of main line double track railroad including at-grade and aerial running. The existing S&I Yard was expanded to include a rail Vehicle Acceptance Facility (VAF) and two additional vehicle shop tracks, 11 storage tracks, and two running tracks. The Phase 1 main line buildout operates north from Park Lane to Parker Road as well as east from Mockingbird Lane to Downtown Garland.

The planned Buildout Phase 2 will add approximately 45 miles to the completed Starter System and Phase 1 Buildout. This Phase will also provide additional S&I Facility storage tracks and expand its maintenance shop. A second service facility, the Northwest Rail Operating Facility (NWROF), will also be designed and constructed. Buildout Phase 2 will operate southward from the east CBD to Buckner and northward from the west CBD to Frankford Road in Carrollton with a branch line operating from Northwest Highway through Irving to DFW Airport North. There will also be an extension from Downtown Garland to Rowlett.

1.3 SYSTEM CHARACTERISTICS

The Starter System and Buildouts are separated into a number of line sections, each section covering a particular portion of the alignment.

1.3.1 Starter System

1.3.1.1 Central Business District (CBD)

The CBD contains a Transit Mall that operates from Houston Street and Pacific Avenue west of CBD to Hawkins and Central Expressway east of the CBD. The alignment is predominantly street running over portions of Pacific Avenue and Bryan Street and includes four passenger stations.

1.3.1.2 Oak Cliff Line (OC)

The OC Line operates from the west CBD. The line continues south to 8th and Corinth Streets where it divides into a west and a south branch. The alignment is a combination of at-grade and aerial construction with a major structure crossing the Trinity River. This line has four passenger stations with a connection to the Trinity Railway Express (TRE) at Union Station. This line section is signalized from Union Station to Oak Ciff Junction and it connects to the S&I Facility via two yard lead tracks.

1.3.1.3 West Oak Cliff Line (WOC)

The WOC Line is a continuation of the Oak Cliff Line. It operates just south of 8th and Corinth Streets to its western termination at Illinois Avenue and Westmoreland Road. The alignment is principally at-grade with a few minor aerial structure portions over creeks and some retained fill. There are four passenger stations, and a terminal interlocking. This line section is line-of-sight operation, i.e., not signaled.

1.3.1.4 South Oak Cliff Line (SOC)

The SOC Line is a continuation of the Oak Cliff Line. It operates just south of 8th and Corinth Streets to its southern termination at Ledbetter Drive. The alignment is totally at-grade with median running. There are five passenger stations. This line section is line-of-sight operation, i.e., not signaled.

1.3.1.5 North Central Line (NC)

The NC Line is a continuation of the CBD. It operates from Hawkins and Central Expressway east of the CBD to its northern termination at Park Lane and Greenville Avenue. The alignment consists of all major construction types including at-grade, cut and cover, bored tunnels, retained cut, "U" walls, and aerial structures. This line section is signalized from Hawkins to Mockingbird and it is line-of-sight operation between Mockingbird and Park Lane.

1.3.1.6 Service and Inspection (S&I) Facility

The S&I Facility is located on Oak Lane south of Downtown, and it is connected to the OC Line via lead tracks. The Starter System Facility consisted of a storage yard, a maintenance building, and a maintenance-of-way building. The Maintenance Building supports Central Rail Operating Division, Fleet Maintenance, Train Control Center, Bus Control Center and Transit Police Dispatch. The Maintenance-Of-Way Building supports Ways, Structures, and The Amenities Maintenance Department.

1.3.2 Buildout Phase 1

1.3.2.1 North Central Line (NC)

The NC Line is a continuation of Starter System. It operates from Park Lane to the Parker Road Transit Center at Park Boulevard and Archerwood Street. The alignment consists of at-grade sections and aerial structures. There are ten passenger stations including four aerial, one pocket track, seven interlockings, two 500 foot long tail tracks, and a NC/NE junction (Katy) located immediately north of Mockingbird Lane. The line section is signalized and the existing section between Mockingbird and Park Lane was upgraded from line-of-sight operation to signalized operation.

1.3.2.2 Northeast Line (NE)

The NE Line is a branch of the NC Line. It operates from just north of Mockingbird Lane to Downtown Garland. The alignment consists of at-grade sections, two tail tracks at Downtown Garland, and aerial structures, four passenger stations, one pocket track, and six interlockings. This line section is signalized.

1.3.2.3 Service and Inspection (S&I) Facility

During the Buildout Phase 1, storage yard track and maintenance shop capacity were increased. The maintenance-of-way building was modified to accommodate a Vehicle Acceptance Facility (VAF).

1.3.3 Buildout Phase 2

1.3.3.1 Southeast Line (SE)

The SE Line will be a new branch that will be connected to a junction at the east end of the CBD. It will operate from Hawkins/Bryan Street over approximately 10 miles of double track railroad to Buckner Boulevard in Dallas. This Line includes street running, at-grade sections, yard lead tracks to the existing S&I, eight passenger stations, and eight interlockings. This line is signalized.

1.3.3.2 Northwest Line (NW)

The NW Line will be a new branch that will be connected to a junction at the west end of the CBD. It will operate from Houston Street over approximately 16.8 miles of double track railroad to the cities of Farmers Branch and Carrollton, in Denton County. This Line includes a mixture of at-grade and aerial structures with a short section below grade at Mockingbird Lane. There are 11 passenger stations including six aerial in this line, a new service and inspection facility (NWROF), and a major interlocking at Northwest Highway. A future connection to Love Field Airport may be included. This line is signalized.

1.3.3.3 DFW/Irving Line (I)

The I Line will be a new branch that connects to the NW Line at Northwest Highway. It will operate from Northwest Highway over approximately 13.2 miles of double track railroad to cities of Irving, Las Colinas, and the DFW Airport. This Line is a mixture of at-grade and aerial structures with eight passenger stations and possible street running in Las Colinas. This line is signalized.

1.3.3.4 Rowlett Extension, Northeast Line (NE)

The R Line will be an extension to the existing NE Line. It will operate from Downtown Garland to the Rowlett Park and Ride over approximately 4.8 miles of double track railroad. This Line is principally at-grade and is a continuation of the existing Northeast Line section. There will be only one passenger station and it will be located at the Rowlett Park and Ride. This line is signalized.

1.3.3.5 Yard Facilities

As part of Phase 2, the existing yard’s storage capacity will be increased to include the addition of six storage tracks. The shop maintenance area will also be expanded. Buildout Phase 2 will provide for the design and construction of a yard known as the Northwest Rail Operating Facility (NWROF).

1.4 SYSTEM REQUIREMENTS

The system shall be designed utilizing the following common characteristics and criteria. These items shall be used by all designers involved in the design of any system element. Reference should be made to each individual chapter of this criteria to ensure that the characteristics listed hereunder are not superseded by more stringent characteristics in the particular chapter.

1.4.1 Service Requirements

The Light Rail System shall be designed using the parameters outlined as follows:

1.4.2 Train Operations

a) Train Headways by Line Section:

Trunk Line:	5 Minutes Peak

Branch Line:	5 Minutes Peak
CBD:	2.5 Minutes Peak

b) Schedule Speed: Average 21 to 25 MPH with a top speed of 65 MPH

c) Station Dwell Time: 20 SEC nominal (varies)

d) For more detail see Operations, Chapter 10.

1.4.3 Environmental Conditions

a) Temperature

Minimum Ambient:	4^{o} F
Maximum Ambient:	115^{o} F
Maximum Daily Range:	50^{o} F

b) Humidity

Minimum:	5 %
Maximum:	100 %

c) Precipitation

Maximum Rainfall Rate:	7 IN per HR
Maximum Snowfall:	8 IN

Maximum Ice: Infrequent measurable quantities

d) Wind

Average wind speed:	10 MPH
Maximum wind gust:	70 MPH

1.4.4 Track Standards

a) Gauge 4 FT 8 1/2 IN

b) Curve

Horizontal:	100 FT radius MIN
Vertical Crest:	1,640 FT radius MIN
Vertical Sag:	1,640 FT radius MIN

c) Grade 6% MAX

d) Superelevation

Actual:	6 IN MAX
Unbalanced:	3 IN MAX

e) Maintenance Tolerances

Ballasted:	FRA Class 5
Fixed:	FRA Class 5

1.4.5 Traction Electrification Standards

a) Voltage

Nominal Line:	750 VDC
Maximum Line:	900 VDC
Minimum Line:	525 VDC

b) Wire

Minimum Height:	14.0 FT
Maximum Height:	22.5 FT
Static Clearance:	5 IN
Passing Clearance:	4 IN

c) Utility Supply 13.2 KV or 24.6 KV

1.4.6 Vehicle Requirements

a) Refer to Design Criteria Manual, Volume 2, Chapter 2, Vehicles

1.5 APPLICATION of DESIGN CRITERIA, VOLUME 2

DART Design Criteria, Volume 2 revision applicability is as follows:

a) Starter System and Buildout Phase 1 Revision 1 and 2

b) Buildout Phase 2 Revision 3 and 4

CHAPTER 2

LIGHT RAIL VEHICLES

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CHAPTER 2 – LIGHT RAIL VEHICLE

2.1 GENERAL

The DART rail vehicle requirements are similar to those of existing vehicles at other properties. The configuration of the light rail vehicles will be a 3 unit, double articulated, 8 axle rail vehicle designated a DART “Super-LRV”. The A and B units at the ends of the LRV will be high floor with step wells. The center unit (C-unit) has a floor height of 16 in above top of rail (TOR) to provide direct level boarding from the platform. Major on board systems are required to be based on service-proven equipment that has been designed for the duty cycle and environmental conditions in the Dallas, Texas area. Refer to Design Criteria Manual, Volume 2, Chapter 1 for environmental details.

The vehicle design shall include the reliability and safety criteria defined in this chapter, Design Criteria Manual, Volume 2, Chapter 2.

Applicable federal, state, and local standards, regulations, and laws shall be observed and incorporated into the vehicle design.

2.1.1 Service Characteristics

The DART Light Rail Transit (LRT) System service characteristics are:

a) Dallas Central Business District

   1) Interim surface running on Pacific Avenue/Bryan Street on a transit mall with street-level boarding from a 15.5 in high curb/platform.

b) Outside Dallas CBD

   1) Parallel existing freeways and on railroad rights-of-way with a combination of boarding from 8 in. high platforms and portions of the platform that are raised to 15.5 in to provide direct, level boarding into the center unit of the LRVs.

c) Track Elevations

1) LRVs will be operating on track ways that are at-grade with grade separations, in tunnels, and on aerial structures.

d) Station Spacing

1) Varies from 0.5 mile to 3 miles.

e) Schedule Speed

1) Approximately 25 MPH to 35 MPH
2) Top speed of 65 MPH.

f) Typical Train Headway

1) Peak periods 5 to 10 minutes
2) Off-peak periods 20 minutes

g) Bus Service Interface

1) To and from all nearby bus stops.

h) Parking Facilities

1) Provided at most outlying stations.

i) Elderly and Handicapped Accessibility

1) Fully accessible, direct, level boarding into the C-unit of the LRVs.

2.2 SYSTEM CONSTRAINTS

This section contains the dimensional and performance requirements for DART’s light rail vehicles.

2.2.1 Vehicle Dimensions and Characteristics

a) Vehicle Length

1) Between 120 ft and 125 ft over coupler pulling faces

b) Vehicle Width

1) Between 8.5 ft and 9.5 ft over side sheets

c) Height Over Roof-Mounted Equipment

1) 12.5 ft, MAX above TOR

d) Height Over Locked-Down Pantograph

   1) 13.0 ft, MAX above TOR

e) Pantograph Width

   1) 6.5 ft ± 1/8 in

f) Pantograph Carbon Width

   1) 4.0 ft, MIN

g) Position of Pantograph

   1) On/near centerline of a truck

h) Pantograph operating range

   1) 13.5 ft to 23.5 ft

i) Level portion of pantograph head

   1) 4.5 ft

j) Horizontal dimension of horn

   1) 12 in

k) Vertical dimension of horn

   1) 9 in to 12 in

l) Pantograph lateral stiffness

   1) 1.0 in per 20 lb MAX (horizontal deflection vs. horizontal force)

m) Pantograph upward pressure

   1) 20-25 lb

n) Height of Floor

   1) High floor section - 40 in, MAX, above TOR
   2) Low Floor Section - 16 in above TOR

o) Height of first step from 8 in platform

   1) 8 in

p) Height of Headlining

1) 7 ft 1 in, MIN, over floor at vehicle centerline

q) Height of Side Door Opening

1) 6.33 ft, MIN, over floor

r) Width of Side Door Opening

1) Cab End 36 in, Articulation End 48 in, C-unit 48 in, clear opening

s) Passenger Seats

1) 102 MIN

t) Truck Center-to-Center Distance

1) 28 ft - 32 ft

u) Truck Wheelbase

1) 7 ft - 8 ft

v) Overhang (truck-center to coupler face)

1) 15 ft - 17 ft

w) Wheel Diameter

1) 28 in new, 26 in worn

x) Fordability

1) Vehicles must be able to operate successfully in water up to 2 in above the top of rail for a distance of 400 ft at speeds up to 10 MPH.

y) Roll

1) Normal Body Roll ± 2.5^{o}
2) Center of rotation 1.25 ft above top of rails
3) Maximum Body Roll ± 4^{o} at suspension stops

2.2.2 Vehicle Weights

a) The weight of each passenger and operator shall be based on an average weight of 155 LBS.

b) AW0 - Empty Car

1) Ready-to-run weight of 140,000 LBS, MAX

c) AW1 - Full Seated Load

1) Full seated passenger load, plus operator, plus AW0 weight

d) AW2 - Full Load

1) Standees at 2.7 sq. ft per passenger (4 pass/sq. m) plus AW1 weight

e) AW3 - Crush Load

1) Standees at 1.8 sq. ft per passenger (6 pass/sq. m) plus AW1 weight

f) AW4 - Design Load

1) Standees at 1.35 sq. ft per passenger (8 pass/sq. m) plus AW1 weight.

2.2.3 Clearances

The following worst-case clearances shall be provided with full suspension travel or failure, structural deflection, wheel wear, track geometry, or any combination of the preceding:

a) Truck Mounted Equipment

1) 2.5 in, MIN (Excluding Track Brakes)

b) Car Body Mounted Equipment

1) 4.0 in, MIN

c) Car Body Static Clearance Outline

1) See attached Tables

d) Car Body Dynamic Clearance Outline

1) See attached Tables

e) Curve Clearance

1) See attached Tables

2.2.4 Track Standards

The following design standards may be assumed for the track:

a) Track Gauge

   1) 4 ft 8.5 in

b) Horizontal Curve Radius

   1) 82 ft (25 m), MIN

c) Vertical Curve Radius

   1) Crest 1,640 ft, MIN
   2) Sag 1,640 ft, MIN

d) Grade

   1) 7 % MAX

e) Super elevation

   1) 6 in MAX

f) Unbalanced Super elevation

   1) 3 in MAX

g) Track Maintenance tolerances

   1) Ballasted, FRA Class 5
   2) Direct Fixation, FRA Class 5
   3) See Design Criteria Manual, Volume 1, Facilities Design for detailed track standards.

2.2.5 Traction Power Standards

The following traction power system design standards may be assumed:

a) Nominal line voltage is 750 VDC

b) Maximum line voltage is 900 VDC

c) Minimum line voltage is 525 VDC

d) Contact wire height range is between 13.5 ft and 22.5 ft

e) Traction power derivation is 12 pulse rectification

2.2.6 Performance Requirements

The following specified dynamic performance standards shall be provided for the light rail vehicles based on dry, level, tangent track. The performance rates shall take into account rotational inertia.

The acceleration performance requirements shall be met with wheels in any condition from new to fully worn at nominal line voltage over the vehicle load range up to AW2. Above AW2, performance may degrade linearly with increasing weight. Acceleration rates shall include train resistance and gear losses.

The braking performance requirements shall be met with wheels in any condition from new to fully worn over the entire vehicle speed and load range, independent of overhead line voltage, and excluding train resistance and gear losses. The braking system is required to maximize the use of the dynamic brake prior to adding supplemental friction braking (blended braking). The friction brake system shall also function as a back up to the dynamic brake systems in the event of dynamic brake failure. Track brakes shall function in emergency braking and as commanded by the operator via a separate switch on the operator's console.

a) Vehicle Speed

1) Maximum Operating Speed is 65 MPH
2) Minimum Balancing Speed is 70 MPH
3) Design Speed is 75 MPH

b) Jerk Limit

1) 3.0 ± 10% MPHPSPS

c) Acceleration Rate

1) Initial Rate is 2.3 MPHPS
2) Base Speed is 20 MPH, MIN
3) Residual Rate at 65 MPH is 0.25 MPHPS, MIN

d) Time/Distance Performance, AW2 weight

1) Speed: 0 MPH to 50 MPH is 30 SEC, MAX
2) Speed: 50 MPH to 65 MPH is 25 SEC, MAX
3) The distance traveled in 20 seconds shall not be less than 600 ft

e) Instantaneous Service Braking Rate

1) 3.0 MPHPS, MIN

f) Instantaneous Emergency Braking Rate

1) Above 30 MPH is 4.0 MPHPS, MIN
2) At or below 30 MPH is 6.0 MPHPS, MIN

g) Control Response Dead Times

1) The control response dead times when transitioning from any mode such as power, brake or coast, to any other mode, shall be 300 milliseconds maximum, excluding jerk limiting influences where applicable.

h) Spin-Slide Protection

1) Acceleration mode spin protection shall be provided and slide protection shall also be provided in the braking mode for both the dynamic and friction braking systems. Spin-slide detection is to be provided on both a per axle basis and per vehicle (synchronous) basis. Tractive effort (propulsion or braking) re-application following spin-slide activity shall be jerk limited. Detection sensitivity is to provide a system with a 70 percent efficiency, minimum. The spin-slide system should take advantage of the speed characteristics of AC induction motors.

i) Duty Cycle

1) Propulsion and braking system duty cycles shall be based on the worst-case line round-trip conditions under the following scenario and assuming a passenger load of AW2 without causing damaging temperatures to equipment:

2) For the propulsion system, 50 percent of the propulsion units are assumed to have failed, and the effective propulsion system tractive effort, in both acceleration and dynamic braking, is to be half the normal value.

3) For the friction braking system, in the event of dynamic brake failure, the system is to be

capable of full braking performance, at the specified rates with an automatically imposed speed restriction of at least 30 MPH, without the need to terminate the run before the end of the line.

2.2.7 Electromagnetic Interference (EMI)

The electrical, electronic, and communications systems shall operate within the DART system and cars without either suffering or causing interferences which may adversely impact the system operation and/or safety because of conducted and/or radiated emissions.

a) Methods and Equipment

1) The Contractor shall employ design techniques, construction methods, and whatever equipment is required to prevent interference caused by internal sources from effecting car systems proper operation. In addition to coordinating frequencies, the Contractor shall provide necessary on-board balancing, filtering, shielding, isolating, and grounding to reduce undesirable interference. Electrostatic and magnetic shielding methods shall be employed to minimize stray signals and transient voltages on interconnecting cables. Interconnecting power and signal cables shall be physically separated. Trainlines shall be located and arranged to minimize voltage induction into train line circuits due to propulsion system, auxiliary power, and catenary current transients.

b) Emission Limits

1) To avoid undesirable effects upon the external environment along the right of way as caused by onboard vehicle subsystems, the electromagnetic emission limits specified here shall not be exceeded.

c) Radiated Emissions

1) Radiated Emissions as measured by the procedures from “Radiated Interference in Rapid Transit Systems, Volume II: Suggested Test Procedures, UMTA-MA-06-0153-85-11 shall conform to the following:

A. From 0.01 MHz to 30 MHz, the maximum permissible interference limit shall not exceed 20 dB above the limit of Figure 22 (RE05) of MIL-STD-461A.
B. From 30 MHz to 88 MHz, the maximum limit shall be 58 dB above one micro volt/meter/Mhz bandwidth.
C. From 88 Mhz to 1,000 Mhz, the maximum limit shall be 68 dB above one micro volt/meter/Mhz bandwidth.

2) These limits shall not be exceeded when measured at a distance of 100 feet from the track centerline.

d) Conductive Emissions

1) The conductive emissions, as measured by the procedures of “Conductive Interference in Rapid Transit Signaling Systems, Volume II: Suggested Test Procedures, UMTA-MA-06-0153-85-6, Method RT/CEO2A, Conductive Emission Test, Vehicle”, shall have a current limit defined by the following curve:
A. 10 A RMS from 1 to 80 Hz
B. 10 A RMS decreasing to 1 A RMS from 80 to 90 Hz
C. 1 A RMS from 90 to 120 Hz
D. 10 A RMS from 120 to 600 Hz
E. 1 A RMS from 600 to 1,500 Hz
F. 0.2 A RMS from 1,500 to 4,000 Hz
G. 0.3 A RMS from 4,000 to 20,000 Hz

2) Each individual piece of power equipment as well as the simultaneous operation of all car power shall meet this condition.

e) Inductive Emissions

1) The inductive emissions, as measured by the procedures of "Inductive Interference in Rapid Transit Signaling Systems, Volume II: Suggested Test Procedures, UMTA-MA-06-0153-85-8, shall be limited to a maximum of 20 milivolts, RMS, rail to rail, at all frequencies between 0 Hz to 1 kHz and a maximum of 10 milivolts from 1 kHz and 20 kHz. Each individual piece of power equipment as well as the simultaneous operation of all equipment shall meet this condition.

f) Meeting the above requirements does not guarantee elimination of interference; it is the first level of defining the interface between the cars and their intended environment. The Contractor shall be responsible to reduce the above limits if necessary to prevent interference with equipment installed on the wayside and the immediate vicinity.

g) Conducted Disturbances

1) The Contractor shall formulate criteria governing generation and toleration of electrical disturbances on conductors between assemblies. The criteria shall identify the basic car circuit types and it shall define a suitable comprehensive disturbances classification that could be present in each circuit type. The criteria shall insure that each connected assembly shall tolerate the disturbances introduced simultaneously by any or all assemblies to which it could be connected. In this regard, special attention shall be directed to the Automatic Trip Stop and other Train Control equipment needs. The criteria shall include any required limit modification as described above, on conducted interference into the catenary and running rails, with levels selected to prevent interference with signal and communications systems which use those circuits for their means of operation and communication. These criteria shall be a part of the EMI control plan and shall be submitted for approval.

h) Inductive Interference

1) The Contractor shall formulate a set of criteria governing generation and toleration of magnetically coupled disturbances on or between assemblies. The criteria shall identify the basic circuits types present on the car and shall define a suitable comprehensive classification of disturbances that could be present in each circuit type. The criteria shall insure that each connected assembly shall be able to tolerate the disturbances introduced simultaneously by any or all other assemblies to which it is magnetically coupled.

i) In this regard, special attention shall be directed to the Automatic Trip Stop apparatus needs. The criteria shall include any required limit modifications, as described above, on the inductive interference into the catenary and running rails, with levels selected to prevent interference with signal and communications systems which use these circuits for their means of operation and communication. These criteria shall be a part of the EMC control plan and shall be submitted for approval.

2.2.8 Noise and Vibration

a) Interior Noise

1) With all auxiliary equipment simultaneously operating normally and the car at rest with windows and doors closed, on open track, the noise level in the car interior shall not exceed 72 dBA. With any one system or unit except ventilation, operating at normal conditions, the interior noise shall not exceed 67 dBa.

2) With all auxiliary equipment including HVAC simultaneously operating at normal conditions with the car traveling on open track at 40 MPH (64 KPH) the noise level in the car interior with windows and doors closed, shall not exceed 75 dBA.

b) Wayside Noise Limits

1) Car or train-produced noise levels shall not exceed the following with all auxiliary equipment operating simultaneously at a distance of 50 ft (15 m) from centerline of track.

2) Car stationary, empty 68 dBA

3) Empty car on tangent track in maximum acceleration from 40 MPH (64 KPH), in maximum dynamic braking from 40 MPH (64 KPH), or maximum friction braking from 40 MPH (64 KPH) (whichever is worse) 76 dBA

4) For this test, the car shall be operated at a location approved by DART, on open tie and ballast track, with welded, ground, and un-corrugated rail.

5) Noise levels produced by traction motors and gear sets of a complete truck, mounted under the car body, with all wheels spinning under no-load conditions at all speeds from zero to the equivalent of 70 MPH (98 KPH) shall not exceed 88 dBA at a distance 16 ft from the center of the truck on the horizontal plane passing through the axles.

6) Noise produced by individual pieces of continuously-operating under car or roof-mounted equipment or systems except traction motors, gears and other equipment which operate only occasionally, such as a circuit breaker or pneumatic venting, HVAC, and air compressor etc., shall not exceed 80 dBA at 16 ft (4.8 m) from the centerline of the equipment while the equipment is operating at normal conditions with the car at rest. The equipment shall be complete, installed, and all components of each system operating during this test for noise levels.

7) Noise levels produced by the individual pieces of under car or roof-mounted equipment which operate occasionally, such as a circuit breaker or a pneumatic pressure relief device, shall not exceed 100 dBA at 16 ft (4.8 m) from the center of the equipment. The level shall be measured using the fast meter response setting. The equipment shall be complete, installed, and all components of each system operating during these tests for noise levels.

c) Vibrations

1) All vehicle equipment shall be designed to operate without damage or degradation of performance when subjected to vibration and shocks encountered during normal service.

2.3 CAR BODY

The car body design is of prime importance to DART. The vehicle appearance must be futuristic with sleek lines and a clean exterior. The vehicles may operate in three car trains with the capability of a three car train to tow another three car train (6 cars total). This section describes the basic parameters for the car body.

2.3.1 General

The car body shall consist of three car body units and two articulation units that semi-permanently connect the three car body units together. The vehicle is to be fabricated predominantly from low-alloy, high-tensile (LAHT) steel and assembled by welding. The exterior skin shall function as part of the load carrying structure. Each end of a vehicle shall be equipped with an anti-climber and collision posts. The vehicle end caps may be fabricated using molded fiberglass. The vehicle exterior shall be painted using polyurethane paint. Feature stripes shall be applied using decals.

2.3.2 Articulation

The articulation section shall be an integral part of the car body. Passenger access to this section when passing from car body to car body shall be provided without the use of train doors and with maximum ease and safety. The close-off panels shall be arranged to prevent injuries to passengers and crew. The articulation section shall be weatherproof and not degrade lighting and HVAC performance in the vehicle interior. The articulation units shall be supported by the center trucks and must allow the vehicle to traverse all horizontal and vertical curves under all vehicle conditions without damage.

2.3.3 Structure

The structure shall be designed to provide a 30-year life without fatigue failure or the need for structural repairs. The strength of the major structural components of the car body shall be capable of sustaining the following loads without causing the materials to yield or reach the critical buckling stresses, except as noted below:

2.3.3.1 Main Body Sections

Under a combined vertical load representative of the crush passenger load and a horizontal load equal to 220,000 lb applied at the end sills, the stress (unrelieved by permanent strain) in the principal framing members shall not be greater than the yield of the materials or the critical buckling stress, whichever is less. The same shall be true without the vertical load present.

2.3.3.2 Articulation Section

With a vertical load, either up or down, of 25,000 LBS, force applied to the principal framing members in combination with a 100,000 lb force applied horizontally and parallel to the longitudinal centerline of the car, there shall be no yielding of the structure.

2.3.3.3 Coupler Pivot

With a 100,000 lb force compression load applied horizontally and parallel to the longitudinal centerline of the car body to the center reaction point of the coupler pivot, the stress in the pivot shall not exceed that at ultimate strength.

2.3.3.4 Anti-Climber

With a vertical load, either up or down, of 40,000 lb force applied at the centerline of the anti-climber, there shall be no yielding of the structure when combined with a 100,000 lb force applied parallel to the vehicle centerline.

2.3.3.5 Collision Posts

The ultimate shear strength of each of the two collision posts at the point of attachment to the under frame shall be 135,000 lb force. When a 45,000 lb force is applied within $\pm 15^{o}$ of the longitudinal vehicle centerline at a height 15 inches above the top of the under frame, there shall be no yielding of the structure.

2.3.4 Configuration

Each vehicle is to be equipped for independent, two-way operation with a complete operator's cab at each end.

The interior of the vehicle shall be designed for ease of cleaning and resistance to vandalism and graffiti.

2.3.4.1 Doors

Each vehicle shall have ten (10) door openings, with five (5) openings per side directly across from each other. The doors nearest the end of the cars shall be on a non-tapered portion of the car body, if a tapered end is required to meet clearances.

2.3.4.2 Passenger Seats

Passenger seats shall be predominantly 2 plus 2 transverse seating, except in the low floor area where flip-up longitudinal seats shall be provided to accommodate wheelchair storage. The seat frames shall be supported at the sidewall and on a pedestal. The shell is to be constructed of stainless steel and be outfitted with an upholstered, padded insert. The seat back shall incorporate a full width handhold to assist standing passengers.

2.3.4.3 Flooring

The floor and step wells shall be covered with rubber sheet goods. The floor covering shall be smooth under the seats for ease of cleaning and have longitudinal grooves in the aisle ways for slip resistance. The step tread covers shall incorporate a contrasting ADA compliant color stripe at the edges of all treads for visibility.

2.3.4.4 Windows

Side passenger windows shall be provided in each car body section. The window shall be made from laminated safety glass. Fixed windows shall be located in the upper portion of the side doors.

2.3.4.5 Destination Sign and Run Number Sign

Roll curtain destination signs shall be provided at both ends of the car and three on each side on the exterior and interior. The signs shall be controlled from signals sent from the active cab via the train lines.

A four-digit run number sign shall be provided in each cab and it shall be clearly visible through the windshield.

2.3.4.6 Stop Request

A mobility impaired passenger stop alert device shall be provided to allow passengers to signal the operator that a passenger with a mobility impairment will be exiting the train. When activated, a sign shall be illuminated to indicate to the other passengers that a stop has been requested.

2.3.4.7 Handicapped Accessibility

ADA compliant accessibility and parking for wheelchairs shall be provided in the low floor area of the C-unit. Space shall be provided with flip-up passenger seats.

2.3.4.8 Signage

A place for display of system information shall be provided inside the vehicle.

2.4 COUPLER

2.4.1 General

Each end of each vehicle is to be outfitted with a slack-free, transit-style, hook-type, automatic mechanical, electrical, and pneumatic coupler. The coupler is to be cantilevered from the draft gear. The electrical heads shall be automatically covered when not coupled. Electric heads shall allow low voltage DC control signals to pass from car to car in a train and shall be either side or top mounted. Electrical isolation shall be provided by either a drum switch or relay configuration. The coupler shall permit the coupling of cars at speeds up to and including 3 MPH without release of the energy absorption element. The coupler is to be configured for both remote (from an adjacent cab) and manual operation.

2.4.2 Energy Absorption

The coupler shall incorporate a self-centering device to hold the coupler head within the gathering range for mechanical coupling. This device is to include provisions for disabling to allow coupling on other than tangent track.

The draft gear shall incorporate a cushioning element that shall allow the coupler to elastically deflect up to 2 in. The coupler drawbar shall incorporate an energy absorption element. After bolts in the drawbar shear at 75,000 lb force, or higher value as may be agreed between DART and the vehicle contractor, the coupler head shall begin to move back and allow the anti-climbers to come together. The energy shall be absorbed in a linear manner by crushing a canister or other acceptable method of deforming metal. A minimum of 75,000 ft LBS of energy is to be absorbed and the coupler is to collapse a minimum of 1 in more than that needed to permit full anti-climber engagement.

2.5 OPERATOR'S CAB

2.5.1 General

Each end of the vehicle is to be provided with a complete operator's cab. The cab is to be separated from the passenger compartment by a divider wall with a door for access. The divider wall and door shall include windows for passenger visibility through the cab. Horizontal sliding sash windows shall be provided on each side of the cab.

2.5.2 Layout and Equipment

The operator’s cab, seat, controls, indicators, etc, shall be designed to accommodate operation of the vehicle from both a seated and standing position. All equipment in the cab shall be ergonomically designed and positioned for ease of operation.

The cab is to include all the controls necessary for operating the vehicle, either as a single car or in a train. The controls shall be located on the console within easy and comfortable reach of the operator in the seated position.

The cab design shall accommodate a U.S. 95th percentile male and U.S. 5th percentile female. The cab shall be provided with the following other features:

- Operator's Seat
- Cab Light
- HVAC Diffuser
- Windshield Wiper
- Coat Hook
- Cab Heater
- Sun Visor
- Bell
- Horn
- Mirror
- Fire Extinguisher
- Defroster
- Windshield Washer
- Equipment Locker
- Waste Receptacle
- Pressure Gauges
- Cab Door Lock
- Annunciator Panel
- Silent Alarm
- Operable Side Window

2.6 PASSENGER DOORS AND CONTROLS

2.6.1 General

Five sets of sliding passenger doors shall be provided on each side of the car. They shall be controlled from the active cab and interlocked to prevent opening when the car is in motion, and to inhibit the application of power and the release of the brakes when the doors are open. An interlock override switch shall be provided to permit returning a car to the maintenance facility with a door that cannot be closed.

2.6.2 Configuration

The four sliding doors at the cab ends of the car and the four doors nearest the articulation section shall be configured with fixed step wells for loading from either a 8 in or 15.5 in platform. The two sliding doors in the low floor area of the C-unit shall be configured for direct level boarding of passengers from a 15.5 in platform.

2.6.3 Control

The doors shall be controlled in groups by side of train from the operator's console via the door control train lines. The doors shall be controlled locally at each doorway by the passengers from both interior and exterior pushbuttons after the operator “enables” the doors. There shall be a door close warning device installed at each doorway.

2.6.4 Operators

The door operators shall be either electrically or pneumatically powered. Acceptable door configuration shall be of a sliding design only. Doors shall be retained in the closed position by a positive locking mechanism that may be incorporated in the design of the door linkages.

2.6.5 Obstacle Detection

The leading edge of each door leaf shall incorporate a detection device that shall cause a door to cycle open if an obstruction is detected and then attempt to re-close. In the event of a defective doorway, provisions shall be included to bypass the affected doorway to permit the train to continue in service. Under these conditions, the door shall be mechanically restrained in the closed position.

2.6.6 Manual Release

A manual release shall be included at each doorway in the interior to allow passengers to open the doors in an emergency and exit the vehicle. When this device is activated, it shall interrupt the interlock circuitry, apply the brakes, and release the doors so that the passengers can manually open them, even if the door was previously bypassed.

A manual release shall also be provided on the vehicle exterior adjacent to one door at each end of the car to allow for entry in the event of a loss of power. Crew switches shall also be provided at these locations to permit powered opening of the adjacent doors.

2.6.7 Indication

A light shall be provided on the vehicle exterior above each doorway and also on the interior of the car (light emitting diode) to indicate when both leaves in a doorway are not closed and locked. Indicator lights on the console shall indicate when all doors in a train are closed and locked.

2.7 HEATING, VENTILATION, AND AIR CONDITIONING

2.7.1 General

Each light rail vehicle shall be equipped with a heating, ventilation and air conditioning system (HVAC) to control interior temperatures based on ambient temperatures. The HVAC system shall consist of three, roof-mounted, unitized air conditioning units that blend in with the car roofline. The HVAC system shall incorporate resistive heaters to warm the fresh air and to provide a re-heat function for humidity control when the air conditioning system is in use. In addition, there shall be strip heaters located along the walls of the car underneath the seats, as well as cab heaters and defrosters.

2.7.2 Operational Description

The roof-mounted units shall draw return air from the passenger compartment and mix it with fresh air drawn in through the fresh air ducts, heat or cool the air as may be appropriate, and force it into the supply ducts in the ceiling. The conditioned air shall be discharged into the passenger compartment through diffusers incorporated as part of the main lighting fixtures and into the cab through the cab HVAC diffuser. Fresh airflow shall be approximately 1,200 cubic feet per minute. Total airflow shall be as determined by the HVAC designer based on evaporator coil selection. The design of the car body and the ventilation system shall provide for positive pressurization inside the vehicle.

The fresh air intakes shall be equipped with a damper to block off the fresh air in hazardous conditions.

2.7.3 Temperature Control

The car interior temperature shall be based on the external ambient temperature. For conditions where heating is required, the internal temperature shall be 68^{0}F (20^{0}C) or 48^{0}F (22^{0}C) above the ambient, whichever is lower. When cooling is required, the internal temperature shall be 73^{0}F (23^{0}C) or 30^{0}F (14^{0}C) below the ambient, whichever is higher, with the relative humidity limited to 50%, maximum. Between 68^{0}F (20^{0}C) and 73^{0}F (23^{0}C), the system shall normally be in the ventilation or reheat mode, except when ambient temperatures are extreme, at which time limited heating or cooling shall be required. Heating and cooling shall be modulated in stages so that capacity can be matched to the loads.

Layover heat shall be provided to maintain the interior car temperature at 45^{0}F (7^{0}C) with an outside ambient of 4^{0}F (-16^{0}C). Cab heat shall be capable of maintaining an interior temperature of 72^{o}F (22^{0}C) with the windows closed and an ambient of 4^{0}F (-16^{0}C).

2.8 LIGHTING

2.8.1 Interior

Passenger compartment interior lighting shall be by fluorescent lights with slot-type diffusers for the air comfort system. One fluorescent fixture above each doorway shall remain powered from the battery when the low voltage power output is interrupted. Lights shall also be provided in the step wells and shall illuminate when the doors are open.

A ceiling mounted fixture shall be located in the cab for use by the operator.

2.8.2 Exterior

On the exterior, there shall be headlights, high-intensity headlights, taillights, stoplights, turn signals, marker lights, run number sign lights, emergency light and strobe light consistent with The State of Texas Vehicle Code. Additionally, there may be other signal (informational) type lights installed on the vehicle exterior to aid operations. The exterior lights shall be housed in a stainless steel enclosure and be re-lamped from the interior.

2.9 AUXILIARY ELECTRICAL SYSTEM

2.9.1 Pantograph

The vehicle shall use a pantograph to collect power for propulsion and auxiliary loads from the catenary system. The pantograph shall be spring raised and electrically or pneumatically lowered. The pantograph shall be mechanically restrained in the lowered position by a lock or other approved positive retention method. The pantograph shall be of a sacrificial, frangible design to minimize damage to the overhead catenary system in the event of an incident. The pantograph shall be designed with two carbon wear strips sized to conduct the maximum propulsion, brake, and auxiliary loads.

2.9.2 Auxiliary Power Supply

The unitized air conditioning system, air compressor and interior fluorescent light shall be powered from the output of the auxiliary power supply. The auxiliary power supply output shall be 120/240 VAC, 60 Hz, 3 phase and 120 VAC, single phase. The auxiliary power supply shall be either a motor alternator or a static inverter. If a static inverter is provided, total harmonic distortion shall be less than 10 percent. The design shall incorporate a method to continue to provide power to the auxiliary power supply to mitigate the loss of output power in the event of a pantograph bounce.

2.9.3 Low Voltage Power Supply

The low voltage power supply and battery charger shall derive its input power directly from the overhead catenary system and shall be transformed and rectified in a controlled manner to power the low voltage DC loads and charge the battery. The low voltage power supply output shall be 37.5 VDC.

In the event of a loss of output power from the low voltage power supply, all essential low voltage DC loads shall continue to be powered for one hour by the nickel-cadmium battery. Cell charging voltage shall be 1.5 volts.

2.9.4 Shop Supply

A knife switch and shop power connector shall be provided. The knife switch shall be able to connect the auxiliary loads to either the pantograph or shop power supply, with the propulsion system being disconnected, for maintenance purposes.

2.10 PROPULSION SYSTEM

2.10.1 General

Tractive effort shall be provided by an AC drive propulsion system with a separate inverter for each motor truck. The configuration shall be of bi-motor design with parallel drive gearboxes. The inverters shall be controlled by signals from the train lines, which are in turn controlled by the master controller and signal equipment. The inverter shall be of the variable voltage, variable frequency type. The method selected for cooling the inverters must take into account the worldwide trend towards moving away from the use of chlorofluorocarbons (CFCs) because of the damage they cause to the environment.

The propulsion system shall provide both positive and negative tractive effort to power and brake the car. Regenerative dynamic braking capability shall be provided. For those occasions when the regenerated power exceeds line receptivity, the power shall be dissipated as heat from a brake resistor grid installed on the vehicle.

2.10.2 Controls

The master controller shall be located to the right of the operator's seat and shall include a dead man feature. The motion of the handle shall be in the forward and aft direction in a vertical plane. The master controller shall include a propulsion zone, a coast position, a braking zone and a maximum brake position. The master controller movement shall be forward for propulsion and back for braking. Maximum brake shall consist of full service brake combined with track brakes, sand, and slide protection and shall be retrievable. Emergency braking shall be effected by a console mounted red mushroom button and shall be the same as maximum brake except that no slide protection shall be available.

2.10.3 Protection

A high speed circuit breaker shall be required to protect the propulsion equipment against damaging electric loads. A filter capacitor bank shall be provided to condition the input power.

2.11 TRUCK

2.11.1 General

The double articulated car shall be supported on four trucks, two of which shall be powered and located under the cab ends of the A and B car body units. The two non-powered trucks shall be located under the articulation sections.

2.11.2 Suspension

The suspension systems shall consist of an elastomeric primary and pneumatic secondary springs. Roll stability shall be provided by torsion bars. Floor height shall be controlled by leveling valves to compensate for differences in passenger load.

2.11.3 Structure

The truck frame and bolster may be a weld-fabricated or cast-weld design. Both inside or outside frame designs may be provided. The truck-to-car body connection shall use a slewing ring, appropriately damped to prevent truck instability over the entire operating speed range.

2.11.4 Wheels and Axles

Axles may be of the solid or hollow design. Ground brushes shall be bolted-on to the end of the axles, or attached to gearboxes or journal bearings. Two brushes per axle shall be provided. The axle ends shall be machined to interface with DART's wheel truing machine. Resilient wheels shall be provided and the wheel profile shall be determined in close cooperation with DART. Splashguards shall be provided to prevent water slung from the wheels from spraying on the under frame. Safety bars shall be provided to prevent objects on the track bed from going under the truck.

The wheels shall be 5.5 in wide. The profile shall be selected in coordination with the track designer and provided at a later date.

2.12 FRICTION BRAKES

2.12.1 General

The friction brake system shall consist of an air compressor, air reservoirs, control valves, pressure gauges, load weigh equipment, pneumatically applied actuators, pneumatically released spring parking brakes, brake discs, pneumatically assisted sanders and articulated track brakes. The friction braking system shall supplement the dynamic brakes when:

a) The dynamic brake system use has been maximized

b) After dynamic brake fade, as a final stopping brake

c) Serve as a backup system to the dynamic brakes in the event of dynamic brake failure

d) Act as a parking brake to hold a AW4 loaded car on a 7% grade

e) The friction brake system shall also provide the emergency brake function

f) The emergency brake shall be designed to be fail-safe

2.12.2 Compressor

The air compressor shall be of the reciprocating type and shall be sized to provide compressed air for all braking needs, including slide controls, sanders and other on-board systems such as the air springs and doors, as appropriate. Additionally, this air shall be train lined through the emergency brake pipe to share air with other cars coupled in a train.

2.12.3 Disc Brakes

The brake discs shall be mounted on the axles inboard of the wheels. The disc shall have a separate hub and ring to permit replacement with a split ring when the original disc reaches the condemning limit.

2.12.4 Control Values

The control valves shall take air from the air reservoirs adjacent to the truck and reduce the pressure proportional to the commanded effort from the master controller as modified by the load weigh system to effect a brake application or release as may be appropriate to the system configuration.

2.13 COMMUNICATIONS

The on-board communications equipment shall consist of a train radio, public address system, cab intercom and passenger emergency intercom. The public address speakers shall be located in the ceiling in the passenger compartment and along both sides of the vehicle on the exterior to broadcast messages to passengers waiting on the platforms.

2.14 AUTOMATIC TRAIN PROTECTION (ATP), TRIP STOP SYSTEM (TSS) AND TRAIN-TO-WAYSIDE COMMUNICATIONS (TWC)

The signal system shall consist of a combination of a wayside cab signal system combined with automatic train protection, magnetic trip stop system and train-to-wayside communications equipment, installed on the vehicle. The vehicle contractor shall supply the on board Automatic Train Protection, train to wayside communications and trip stop systems. Wayside equipment for these three systems is to be supplied by others.

2.15 FLAMMABILITY AND SMOKE EMISSIONS

All of the materials selected for use in the DART light rail vehicle shall meet the current USDOT "Recommended Fire Safety Practices for Rail Passenger Car Materials Selection - January 1989" as contained in 54CFR10, pages 1837-1840. Additionally, the requirements of NFPA 130 shall be observed.

2.16 CLEARANCES

2.16.1 Clearance Assumptions

The clearance tables are based on the largest vehicle that is permitted by DART Policy. The basic dimensions that were used are as follows:

a) Length is 125 ft

b) Width is 9.5 ft

c) Width over side mirrors is 10.8 ft

d) Height to bottom of mirror is 9.8 ft

e) Roll is $\pm 4^0$

f) Truck spacing is selected to meet clearance requirements

2.16.2 Clearance Table Instructions

The Clearance tables combine the effects of car body roll, super elevation and curve displacement into a single "X, Y" coordinate that defines the position of the selected point in space from the Origin, "0,0", of the system which is at Top of Rail on the centerline of the track way.

Directions for the use of the tables are as follows:

a) Select the point on the vehicle or pantograph that is to be checked from Fig 1-1; P2 to P24

b) Go to the table that corresponds to the selected point. Each table provides the information for one point on the car body and is identified with the "Location" of that point, P2 to P24, in the upper left corner of the table.

c) Define the track conditions, curve radius and super elevation, that shall be used to determine the clearance information for the selected point.

d) Find the curve radius in the left column of the table. If there is not an exact match in the table, round the curve radius "down" to the nearest value in the table. For example, a curve radius of 1200 ft should be "rounded down" to the table value of 1000 ft.

e) Read across the table to the super elevation column that corresponds to the defined conditions. If there is not an exact match in the table, round the super elevation value "up" to the nearest table value. For example: a super elevation of 5.25 in should be "rounded up" to 5.5 in.

f) The "X and Y" values that are in the box at the intersection of the "selected curve row" and the "selected super elevation column" define the coordinates of the selected point on the car body, from track centerline.

2.16.3 Reference Drawing and Clearance Tables

Attached are Fig 1-1 showing the 24 different reference points on the car body that are used for the table calculations. Each table represents the displacement for one point on the reference drawing.

2.17 LOAD DISTRIBUTION

Figures 1-2 and 1-3 present typical axle load distribution diagrams for three car trains. Figure 1-2 represents the shortest vehicle allowed by DART Policy and Fig. 1-3 represents the longest vehicle. Truck spacing, axle spacing and end overhang for the two different vehicle lengths reflect typical values for an articulated vehicle. Each drawing has a table showing the expected axle loads, "F1" for motor truck axles and "F2" for articulation truck axles, for the following conditions:

a) Empty Car-Ready to run condition 140,000 LBS

b) Crush Loaded Car-250 passengers at 155 LBS per passenger

c) 20% Load on Articulation Truck-40% Load on Motor Trucks (2)

d) 30% Load on Articulation Truck-35% Load on Motor trucks (2)

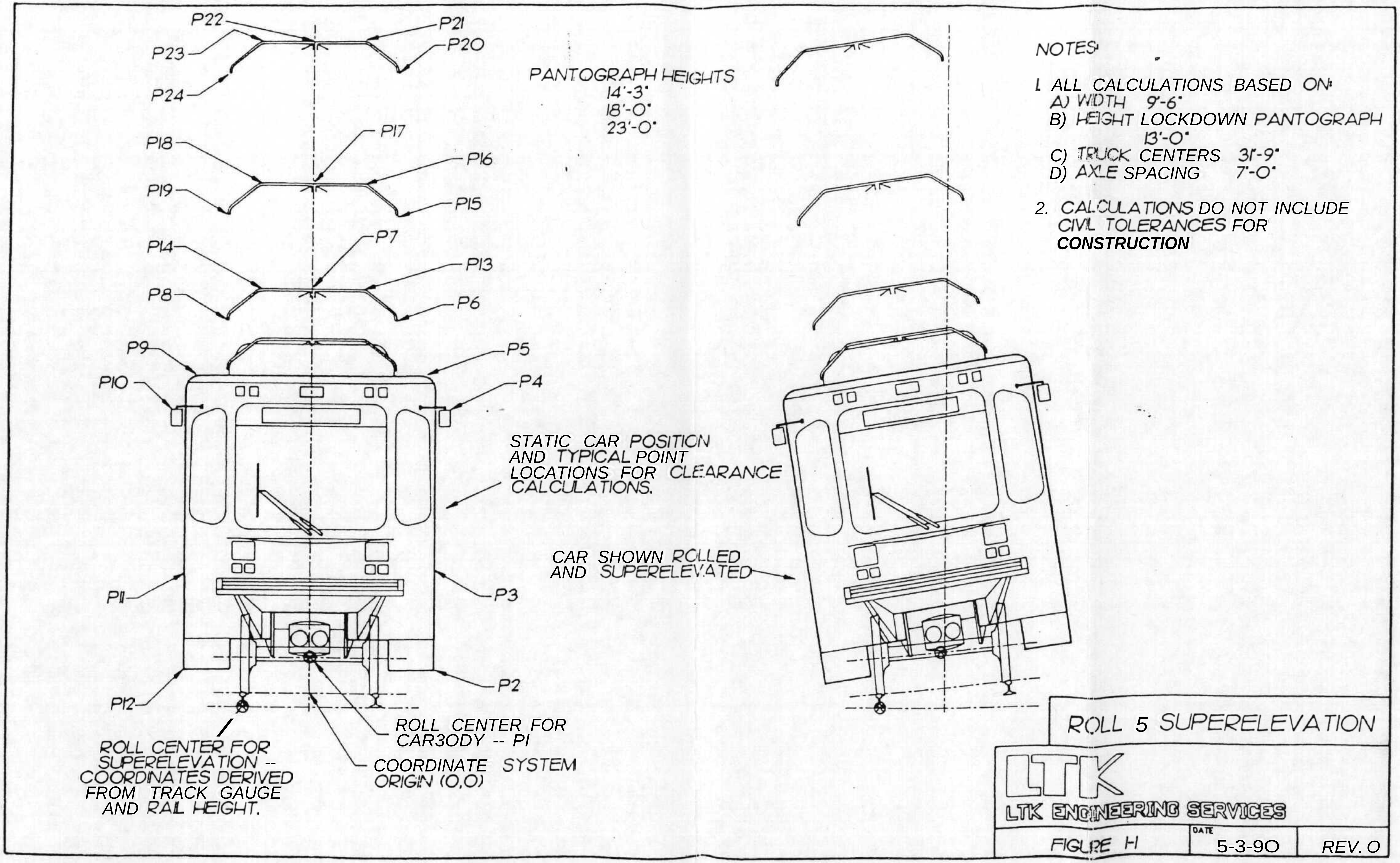
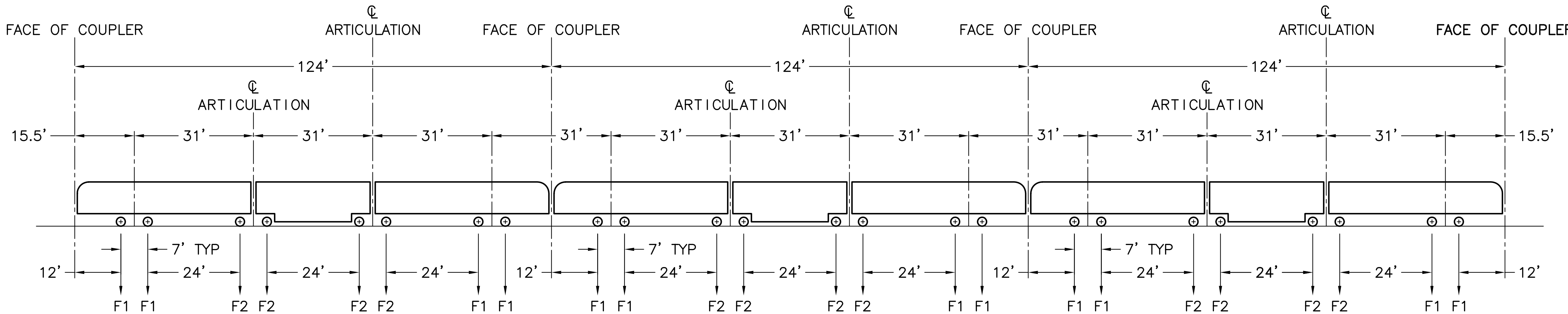


Figure 1-1, Roll and Superelevation, Design Criteria Manual, May 2005, Chapter 2, Page 29



NOTES:

1. CRUSH LOAD ASSUMED 380 PASSENGERS PER CAR, 154 LBS PER PASSENGER.
2. LOAD VARIATION ALLOWED 21% TO 25% OF TOTAL CAR WEIGHT OVER ARTICULATED TRUCKS.
3. (21%) IS DEFINED AS: 29% OF THE TOTAL WEIGHT ON EACH MOTORED TRUCK AND 21% OF THE TOTAL WEIGHT ON THE ARTICULATED TRUCK.
4. (25%) IS DEFINED AS: 25% OF THE TOTAL WEIGHT ON EACH MOTORED TRUCK AND 25% OF THE TOTAL WEIGHT ON THE ARTICULATED TRUCK.
5. TRUCK AXLE SPACING RANGE 7' TO 8'.

SEE NOTES 2, 3 & 4

	EMPTY CAR 21%	CRUSH LOADED 21%	EMPTY CAR 25%	CRUSH LOADED 25%
F1 (MOTOR TRUCK)	21,200	28,515	18,250	25,565
F2 (ARTICULATION)	15,300	22,615	18,250	25,565
VEHICLE WEIGHT	146,000	204,520	146,000	204,520

FIGURE 1–2
LRV DESIGN LOAD DISTRIBUTION
124 FOOT CAR

REV. 2
OCT. 2004

LOCATION:

COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

REV: C (25/9/91)

P2 LOWER CORNER OF CARBODY - OUTSIDE OF CURVE

SUPERELEVATION LEFT WITH ROLL LEFT (TOWARD INSIDE)

LENGTH:	95 FT
WIDTH:	9.5 FT
W MIRRORS	10.8 FT

DOORS CLOSED

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	FT

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
82	8.01	0.67	8.04	1.00	8.03	1.07	8.01	1.13	8.00	1.19	7.98	1.25	7.96	1.32	7.95	1.38	7.93	1.44	7.91	1.50	7.89	1.56	7.87	1.62	7.85	1.69	7.83	1.75
100	7.53	0.67	7.56	1.00	7.55	1.07	7.53	1.13	7.52	1.19	7.50	1.25	7.48	1.32	7.47	1.38	7.45	1.44	7.43	1.50	7.41	1.56	7.39	1.62	7.37	1.69	7.35	1.75
150	6.76	0.67	6.79	1.00	6.77	1.07	6.76	1.13	6.74	1.19	6.73	1.25	6.71	1.32	6.69	1.38	6.67	1.44	6.66	1.50	6.64	1.56	6.62	1.62	6.60	1.69	6.58	1.75
200	6.35	0.67	6.38	1.00	6.37	1.07	6.35	1.13	6.34	1.19	6.32	1.25	6.30	1.32	6.29	1.38	6.27	1.44	6.25	1.50	6.23	1.56	6.21	1.62	6.19	1.69	6.17	1.75
250	6.11	0.67	6.13	1.00	6.12	1.07	6.10	1.13	6.09	1.19	6.07	1.25	6.06	1.32	6.04	1.38	6.02	1.44	6.00	1.50	5.98	1.56	5.96	1.62	5.94	1.69	5.92	1.75
300	5.94	0.67	5.97	1.00	5.95	1.07	5.94	1.13	5.92	1.19	5.90	1.25	5.89	1.32	5.87	1.38	5.85	1.44	5.83	1.50	5.81	1.56	5.79	1.62	5.77	1.69	5.75	1.75
350	5.82	0.67	5.84	1.00	5.83	1.07	5.81	1.13	5.80	1.19	5.78	1.25	5.77	1.32	5.75	1.38	5.73	1.44	5.71	1.50	5.69	1.56	5.67	1.62	5.65	1.69	5.63	1.75
400	5.72	0.67	5.75	1.00	5.74	1.07	5.72	1.13	5.71	1.19	5.69	1.25	5.67	1.32	5.66	1.38	5.64	1.44	5.62	1.50	5.60	1.56	5.58	1.62	5.56	1.69	5.54	1.75
450	5.65	0.67	5.68	1.00	5.67	1.07	5.65	1.13	5.64	1.19	5.62	1.25	5.60	1.32	5.58	1.38	5.57	1.44	5.55	1.50	5.53	1.56	5.51	1.62	5.49	1.69	5.47	1.75
500	5.59	0.67	5.62	1.00	5.61	1.07	5.59	1.13	5.58	1.19	5.56	1.25	5.54	1.32	5.53	1.38	5.51	1.44	5.49	1.50	5.47	1.56	5.45	1.62	5.43	1.69	5.41	1.75
550	5.55	0.67	5.58	1.00	5.56	1.07	5.55	1.13	5.53	1.19	5.51	1.25	5.50	1.32	5.48	1.38	5.46	1.44	5.44	1.50	5.42	1.56	5.41	1.62	5.39	1.69	5.36	1.75
600	5.51	0.67	5.54	1.00	5.52	1.07	5.51	1.13	5.49	1.19	5.48	1.25	5.46	1.32	5.44	1.38	5.42	1.44	5.40	1.50	5.38	1.56	5.37	1.62	5.35	1.69	5.32	1.75
650	5.47	0.67	5.50	1.00	5.49	1.07	5.47	1.13	5.46	1.19	5.44	1.25	5.42	1.32	5.41	1.38	5.39	1.44	5.37	1.50	5.35	1.56	5.33	1.62	5.31	1.69	5.29	1.75
700	5.45	0.67	5.47	1.00	5.46	1.07	5.44	1.13	5.43	1.19	5.41	1.25	5.40	1.32	5.38	1.38	5.36	1.44	5.34	1.50	5.32	1.56	5.30	1.62	5.28	1.69	5.26	1.75
750	5.42	0.67	5.45	1.00	5.44	1.07	5.42	1.13	5.40	1.19	5.39	1.25	5.37	1.32	5.35	1.38	5.34	1.44	5.32	1.50	5.30	1.56	5.28	1.62	5.26	1.69	5.24	1.75
800	5.40	0.67	5.43	1.00	5.41	1.07	5.40	1.13	5.38	1.19	5.37	1.25	5.35	1.32	5.33	1.38	5.31	1.44	5.30	1.50	5.28	1.56	5.26	1.62	5.24	1.69	5.22	1.75
850	5.38	0.67	5.41	1.00	5.39	1.07	5.38	1.13	5.36	1.19	5.35	1.25	5.33	1.32	5.31	1.38	5.29	1.44	5.28	1.50	5.26	1.56	5.24	1.62	5.22	1.69	5.20	1.75
900	5.36	0.67	5.39	1.00	5.38	1.07	5.36	1.13	5.35	1.19	5.33	1.25	5.31	1.32	5.29	1.38	5.28	1.44	5.26	1.50	5.24	1.56	5.22	1.62	5.20	1.69	5.18	1.75
950	5.35	0.67	5.38	1.00	5.36	1.07	5.35	1.13	5.33	1.19	5.31	1.25	5.30	1.32	5.28	1.38	5.26	1.44	5.24	1.50	5.22	1.56	5.20	1.62	5.18	1.69	5.16	1.75
1000	5.33	0.67	5.36	1.00	5.35	1.07	5.33	1.13	5.32	1.19	5.30	1.25	5.28	1.32	5.27	1.38	5.25	1.44	5.23	1.50	5.21	1.56	5.19	1.62	5.17	1.69	5.15	1.75
1500	5.25	0.67	5.27	1.00	5.26	1.07	5.24	1.13	5.23	1.19	5.21	1.25	5.20	1.32	5.18	1.38	5.16	1.44	5.14	1.50	5.12	1.56	5.10	1.62	5.08	1.69	5.06	1.75
2000	5.20	0.67	5.23	1.00	5.22	1.07	5.20	1.13	5.18	1.19	5.17	1.25	5.15	1.32	5.13	1.38	5.12	1.44	5.10	1.50	5.08	1.56	5.06	1.62	5.04	1.69	5.02	1.75
5000	5.12	0.67	5.15	1.00	5.14	1.07	5.12	1.13	5.10	1.19	5.09	1.25	5.07	1.32	5.05	1.38	5.04	1.44	5.02	1.50	5.00	1.56	4.98	1.62	4.96	1.69	4.94	1.75
10000	5.09	0.67	5.12	1.00	5.11	1.07	5.09	1.13	5.08	1.19	5.06	1.25	5.04	1.32	5.03	1.38	5.01	1.44	4.99	1.50	4.97	1.56	4.95	1.62	4.93	1.69	4.91	1.75
50000	5.07	0.67	5.10	1.00	5.09	1.07	5.07	1.13	5.06	1.19	5.04	1.25	5.02	1.32	5.01	1.38	4.99	1.44	4.97	1.50	4.95	1.56	4.93	1.62	4.91	1.69	4.89	1.75
100000	5.07	0.67	5.10	1.00	5.08	1.07	5.07	1.13	5.05	1.19	5.04	1.25	5.02	1.32	5.00	1.38	4.99	1.44	4.97	1.50	4.95	1.56	4.93	1.62	4.91	1.69	4.89	1.75

LOCATION:

COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

REV: C (25/9/91)

P3 INTERDIMATE POINT OF CARBODY - OUTSIDE OF CURVE

SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)

LENGTH:	95 FT
WIDTH:	9.5 FT
W MIRRORS	10.8 FT

DOORS CLOSED

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	FT

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
82	8.01	7.00	7.60	7.32	8.34	6.72	8.27	6.79	8.21	6.85	8.14	6.91	8.07	6.98	8.01	7.04	7.94	7.10	7.87	7.17	7.80	7.23	7.73	7.29	7.66	7.35	7.59	7.41
100	7.53	7.00	7.12	7.32	7.86	6.72	7.79	6.79	7.73	6.85	7.66	6.91	7.59	6.98	7.53	7.04	7.46	7.10	7.39	7.17	7.32	7.23	7.25	7.29	7.18	7.35	7.11	7.41
150	6.76	7.00	6.35	7.32	7.08	6.72	7.02	6.79	6.95	6.85	6.89	6.91	6.82	6.98	6.75	7.04	6.69	7.10	6.62	7.17	6.55	7.23	6.48	7.29	6.41	7.35	6.34	7.41
200	6.35	7.00	5.94	7.32	6.68	6.72	6.61	6.79	6.55	6.85	6.48	6.91	6.41	6.98	6.35	7.04	6.28	7.10	6.21	7.17	6.14	7.23	6.07	7.29	6.00	7.35	5.93	7.41
250	6.11	7.00	5.69	7.32	6.43	6.72	6.37	6.79	6.30	6.85	6.23	6.91	6.17	6.98	6.10	7.04	6.03	7.10	5.96	7.17	5.89	7.23	5.82	7.29	5.75	7.35	5.68	7.41
300	5.94	7.00	5.52	7.32	6.26	6.72	6.20	6.79	6.13	6.85	6.07	6.91	6.00	6.98	5.93	7.04	5.86	7.10	5.79	7.17	5.72	7.23	5.66	7.29	5.59	7.35	5.51	7.41
350	5.82	7.00	5.40	7.32	6.14	6.72	6.08	6.79	6.01	6.85	5.94	6.91	5.88	6.98	5.81	7.04	5.74	7.10	5.67	7.17	5.60	7.23	5.53	7.29	5.46	7.35	5.39	7.41
400	5.72	7.00	5.31	7.32	6.05	6.72	5.98	6.79	5.92	6.85	5.85	6.91	5.78	6.98	5.72	7.04	5.65	7.10	5.58	7.17	5.51	7.23	5.44	7.29	5.37	7.35	5.30	7.41
450	5.65	7.00	5.24	7.32	5.98	6.72	5.91	6.79	5.85	6.85	5.78	6.91	5.71	6.98	5.64	7.04	5.58	7.10	5.51	7.17	5.44	7.23	5.37	7.29	5.30	7.35	5.23	7.41
500	5.59	7.00	5.18	7.32	5.92	6.72	5.85	6.79	5.79	6.85	5.72	6.91	5.66	6.98	5.59	7.04	5.52	7.10	5.45	7.17	5.38	7.23	5.31	7.29	5.24	7.35	5.17	7.41
550	5.55	7.00	5.13	7.32	5.87	6.72	5.81	6.79	5.74	6.85	5.68	6.91	5.61	6.98	5.54	7.04	5.47	7.10	5.40	7.17	5.33	7.23	5.27	7.29	5.20	7.35	5.13	7.41
600	5.51	7.00	5.10	7.32	5.83	6.72	5.77	6.79	5.70	6.85	5.64	6.91	5.57	6.98	5.50	7.04	5.43	7.10	5.36	7.17	5.29	7.23	5.23	7.29	5.16	7.35	5.09	7.41
650	5.47	7.00	5.06	7.32	5.80	6.72	5.73	6.79	5.67	6.85	5.60	6.91	5.53	6.98	5.47	7.04	5.40	7.10	5.33	7.17	5.26	7.23	5.19	7.29	5.12	7.35	5.05	7.41
700	5.45	7.00	5.03	7.32	5.77	6.72	5.71	6.79	5.64	6.85	5.57	6.91	5.51	6.98	5.44	7.04	5.37	7.10	5.30	7.17	5.23	7.23	5.16	7.29	5.09	7.35	5.02	7.41
750	5.42	7.00	5.01	7.32	5.75	6.72	5.68	6.79	5.61	6.85	5.55	6.91	5.48	6.98	5.41	7.04	5.35	7.10	5.28	7.17	5.21	7.23	5.14	7.29	5.07	7.35	5.00	7.41
800	5.40	7.00	4.99	7.32	5.72	6.72	5.66	6.79	5.59	6.85	5.53	6.91	5.46	6.98	5.39	7.04	5.32	7.10	5.26	7.17	5.19	7.23	5.12	7.29	5.05	7.35	4.98	7.41
850	5.38	7.00	4.97	7.32	5.70	6.72	5.64	6.79	5.57	6.85	5.51	6.91	5.44	6.98	5.37	7.04	5.31	7.10	5.24	7.17	5.17	7.23	5.10	7.29	5.03	7.35	4.96	7.41
900	5.36	7.00	4.95	7.32	5.69	6.72	5.62	6.79	5.56	6.85	5.49	6.91	5.42	6.98	5.35	7.04	5.29	7.10	5.22	7.17	5.15	7.23	5.08	7.29	5.01	7.35	4.94	7.41
950	5.35	7.00	4.93	7.32	5.67	6.72	5.61	6.79	5.54	6.85	5.48	6.91	5.41	6.98	5.34	7.04	5.27	7.10	5.20	7.17	5.13	7.23	5.07	7.29	5.00	7.35	4.92	7.41
1000	5.35	7.00	4.93	7.32	5.67	6.72	5.61	6.79	5.54	6.85	5.48	6.91	5.41	6.98	5.34	7.04	5.27	7.10	5.20	7.17	5.13	7.23	5.07	7.29	5.00	7.35	4.92	7.41
1500	5.33	7.00	4.92	7.32	5.66	6.72	5.59	6.79	5.53	6.85	5.46	6.91	5.39	6.98	5.33	7.04	5.26	7.10	5.19	7.17	5.12	7.23	5.05	7.29	4.98	7.35	4.91	7.41
2000	5.25	7.00	4.83	7.32	5.57	6.72	5.51	6.79	5.44	6.85	5.37	6.91	5.31	6.98	5.24	7.04	5.17	7.10	5.10	7.17	5.03	7.23	4.96	7.29	4.89	7.35	4.82	7.41
5000	5.20	7.00	4.79	7.32	5.53	6.72	5.46	6.79	5.39	6.85	5.33	6.91	5.26	6.98	5.19	7.04	5.13	7.10	5.06	7.17	4.99	7.23	4.92	7.29	4.85	7.35	4.78	7.41
10000	5.12	7.00	4.71	7.32	5.45	6.72	5.38	6.79	5.31	6.85	5.25	6.91	5.18	6.98	5.11	7.04	5.05	7.10	4.98	7.17	4.91	7.23	4.84	7.29	4.77	7.35	4.70	7.41
50000	5.09	7.00	4.68	7.32	5.42	6.72	5.35	6.79	5.29	6.85	5.22	6.91	5.16	6.98	5.09	7.04	5.02	7.10	4.95	7.17	4.88	7.23	4.81	7.29	4.74	7.35	4.67	7.41
100000	5.07	7.00	4.66	7.32	5.40	6.72	5.33	6.79	5.27	6.85	5.20	6.91	5.13	6.98	5.07	7.04	5.00	7.10	4.93	7.17	4.86	7.23	4.79	7.29	4.72	7.35	4.65	7.41

LOCATION: COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

REV: C (25/9/91)

P4 UPPER CORNER OF MIRROR - OUTSIDE OF CURVE

LENGTH:	95 FT	DOORS CLOSED
WIDTH:	9.5 FT	
W MIRRORS	10.8 FT	

SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	FT

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
82	9.86	9.80	9.25	10.16	10.35	9.47	10.26	9.55	10.17	9.62	10.08	9.69	9.99	9.76	9.90	9.83	9.81	9.90	9.71	9.97	9.62	10.03	9.52	10.10	9.43	10.16	9.33	10.23
100	9.20	9.80	8.59	10.16	9.69	9.47	9.60	9.55	9.51	9.62	9.42	9.69	9.33	9.76	9.24	9.83	9.15	9.90	9.05	9.97	8.96	10.03	8.86	10.10	8.77	10.16	8.67	10.23
150	8.13	9.80	7.52	10.16	8.63	9.47	8.54	9.55	8.44	9.62	8.36	9.69	8.26	9.76	8.17	9.83	8.08	9.90	7.98	9.97	7.89	10.03	7.80	10.10	7.70	10.16	7.61	10.23
200	7.57	9.80	6.96	10.16	8.06	9.47	7.97	9.55	7.88	9.62	7.79	9.69	7.70	9.76	7.61	9.83	7.52	9.90	7.42	9.97	7.33	10.03	7.24	10.10	7.14	10.16	7.04	10.23
250	7.22	9.80	6.61	10.16	7.72	9.47	7.63	9.55	7.54	9.62	7.45	9.69	7.35	9.76	7.26	9.83	7.17	9.90	7.08	9.97	6.98	10.03	6.89	10.10	6.79	10.16	6.70	10.23
300	6.99	9.80	6.38	10.16	7.48	9.47	7.39	9.55	7.30	9.62	7.21	9.69	7.12	9.76	7.03	9.83	6.94	9.90	6.84	9.97	6.75	10.03	6.65	10.10	6.56	10.16	6.46	10.23
350	6.82	9.80	6.21	10.16	7.31	9.47	7.22	9.55	7.13	9.62	7.04	9.69	6.95	9.76	6.86	9.83	6.77	9.90	6.67	9.97	6.58	10.03	6.48	10.10	6.39	10.16	6.29	10.23
400	6.69	9.80	6.08	10.16	7.18	9.47	7.09	9.55	7.00	9.62	6.91	9.69	6.82	9.76	6.73	9.83	6.64	9.90	6.54	9.97	6.45	10.03	6.36	10.10	6.26	10.16	6.17	10.23
450	6.59	9.80	5.98	10.16	7.08	9.47	6.99	9.55	6.90	9.62	6.81	9.69	6.72	9.76	6.63	9.83	6.54	9.90	6.44	9.97	6.35	10.03	6.26	10.10	6.16	10.16	6.07	10.23
500	6.51	9.80	5.90	10.16	7.00	9.47	6.91	9.55	6.82	9.62	6.73	9.69	6.64	9.76	6.55	9.83	6.46	9.90	6.36	9.97	6.27	10.03	6.18	10.10	6.08	10.16	5.99	10.23
550	6.44	9.80	5.83	10.16	6.94	9.47	6.85	9.55	6.76	9.62	6.67	9.69	6.58	9.76	6.48	9.83	6.39	9.90	6.30	9.97	6.20	10.03	6.11	10.10	6.02	10.16	5.92	10.23
600	6.39	9.80	5.78	10.16	6.88	9.47	6.79	9.55	6.70	9.62	6.61	9.69	6.52	9.76	6.43	9.83	6.34	9.90	6.24	9.97	6.15	10.03	6.06	10.10	5.96	10.16	5.86	10.23
650	6.34	9.80	5.73	10.16	6.84	9.47	6.75	9.55	6.66	9.62	6.57	9.69	6.47	9.76	6.38	9.83	6.29	9.90	6.20	9.97	6.10	10.03	6.01	10.10	5.91	10.16	5.82	10.23
700	6.30	9.80	5.69	10.16	6.80	9.47	6.71	9.55	6.62	9.62	6.53	9.69	6.43	9.76	6.34	9.83	6.25	9.90	6.16	9.97	6.06	10.03	5.97	10.10	5.87	10.16	5.78	10.23
750	6.27	9.80	5.66	10.16	6.76	9.47	6.67	9.55	6.58	9.62	6.49	9.69	6.40	9.76	6.31	9.83	6.21	9.90	6.12	9.97	6.03	10.03	5.93	10.10	5.84	10.16	5.74	10.23
800	6.24	9.80	5.63	10.16	6.73	9.47	6.64	9.55	6.55	9.62	6.46	9.69	6.37	9.76	6.28	9.83	6.18	9.90	6.09	9.97	6.00	10.03	5.90	10.10	5.81	10.16	5.71	10.23
850	6.21	9.80	5.60	10.16	6.70	9.47	6.61	9.55	6.52	9.62	6.43	9.69	6.34	9.76	6.25	9.83	6.16	9.90	6.06	9.97	5.97	10.03	5.88	10.10	5.78	10.16	5.69	10.23
900	6.19	9.80	5.58	10.16	6.68	9.47	6.59	9.55	6.50	9.62	6.41	9.69	6.32	9.76	6.22	9.83	6.13	9.90	6.04	9.97	5.94	10.03	5.85	10.10	5.76	10.16	5.66	10.23
950	6.16	9.80	5.55	10.16	6.66	9.47	6.57	9.55	6.48	9.62	6.39	9.69	6.30	9.76	6.20	9.83	6.11	9.90	6.02	9.97	5.92	10.03	5.83	10.10	5.74	10.16	5.64	10.23
1000	6.14	9.80	5.53	10.16	6.64	9.47	6.55	9.55	6.46	9.62	6.37	9.69	6.28	9.76	6.18	9.83	6.09	9.90	6.00	9.97	5.90	10.03	5.81	10.10	5.72	10.16	5.62	10.23
1500	6.02	9.80	5.41	10.16	6.52	9.47	6.43	9.55	6.34	9.62	6.25	9.69	6.15	9.76	6.06	9.83	5.97	9.90	5.88	9.97	5.78	10.03	5.69	10.10	5.59	10.16	5.50	10.23
2000	5.96	9.80	5.35	10.16	6.45	9.47	6.36	9.55	6.27	9.62	6.18	9.69	6.09	9.76	6.00	9.83	5.91	9.90	5.81	9.97	5.72	10.03	5.63	10.10	5.53	10.16	5.44	10.23
5000	5.85	9.80	5.24	10.16	6.34	9.47	6.25	9.55	6.16	9.62	6.07	9.69	5.98	9.76	5.89	9.83	5.80	9.90	5.70	9.97	5.61	10.03	5.51	10.10	5.42	10.16	5.32	10.23
10000	5.81	9.80	5.20	10.16	6.30	9.47	6.22	9.55	6.12	9.62	6.03	9.69	5.94	9.76	5.85	9.83	5.76	9.90	5.66	9.97	5.57	10.03	5.48	10.10	5.38	10.16	5.29	10.23
50000	5.78	9.80	5.17	10.16	6.28	9.47	6.19	9.55	6.09	9.62	6.01	9.69	5.91	9.76	5.82	9.83	5.73	9.90	5.63	9.97	5.54	10.03	5.45	10.10	5.35	10.16	5.26	10.23
100000	5.78	9.80	5.17	10.16	6.27	9.47	6.18	9.55	6.09	9.62	6.00	9.69	5.91	9.76	5.82	9.83	5.72	9.90	5.63	9.97	5.54	10.03	5.44	10.10	5.35	10.16	5.25	10.23

LOCATION: COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

REV: C (25/9/91)

P5 UPPER CORNER OF CARBODY - OUTSIDE OF CURVE

SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)

LENGTH:	95 FT	DOORS CLOSED
WIDTH:	9.5 FT	
W MIRROR!	10.8 FT	

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	FT

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
82	8.01	10.50	7.36	10.81	8.55	10.21	8.46	10.28	8.36	10.35	8.26	10.41	8.16	10.48	8.06	10.54	7.97	10.60	7.87	10.67	7.77	10.73	7.67	10.79	7.57	10.85	7.46	10.90
100	7.53	10.50	6.88	10.81	8.07	10.21	7.98	10.28	7.88	10.35	7.78	10.41	7.68	10.48	7.58	10.54	7.49	10.60	7.39	10.67	7.29	10.73	7.19	10.79	7.09	10.85	6.98	10.90
150	6.76	10.50	6.10	10.81	7.30	10.21	7.20	10.28	7.10	10.35	7.01	10.41	6.91	10.48	6.81	10.54	6.71	10.60	6.61	10.67	6.51	10.73	6.41	10.79	6.31	10.85	6.21	10.90
200	6.35	10.50	5.70	10.81	6.89	10.21	6.80	10.28	6.70	10.35	6.60	10.41	6.50	10.48	6.41	10.54	6.31	10.60	6.21	10.67	6.11	10.73	6.01	10.79	5.91	10.85	5.81	10.90
250	6.11	10.50	5.45	10.81	6.64	10.21	6.55	10.28	6.45	10.35	6.35	10.41	6.26	10.48	6.16	10.54	6.06	10.60	5.96	10.67	5.86	10.73	5.76	10.79	5.66	10.85	5.56	10.90
300	5.94	10.50	5.28	10.81	6.48	10.21	6.38	10.28	6.28	10.35	6.19	10.41	6.09	10.48	5.99	10.54	5.89	10.60	5.79	10.67	5.69	10.73	5.59	10.79	5.49	10.85	5.39	10.90
350	5.82	10.50	5.16	10.81	6.35	10.21	6.26	10.28	6.16	10.35	6.06	10.41	5.97	10.48	5.87	10.54	5.77	10.60	5.67	10.67	5.57	10.73	5.47	10.79	5.37	10.85	5.27	10.90
400	5.72	10.50	5.07	10.81	6.26	10.21	6.17	10.28	6.07	10.35	5.97	10.41	5.87	10.48	5.77	10.54	5.68	10.60	5.58	10.67	5.48	10.73	5.38	10.79	5.28	10.85	5.18	10.90
450	5.65	10.50	5.00	10.81	6.19	10.21	6.09	10.28	6.00	10.35	5.90	10.41	5.80	10.48	5.70	10.54	5.61	10.60	5.51	10.67	5.40	10.73	5.31	10.79	5.21	10.85	5.10	10.90
500	5.59	10.50	4.94	10.81	6.13	10.21	6.04	10.28	5.94	10.35	5.84	10.41	5.74	10.48	5.65	10.54	5.55	10.60	5.45	10.67	5.35	10.73	5.25	10.79	5.15	10.85	5.05	10.90
550	5.55	10.50	4.89	10.81	6.09	10.21	5.99	10.28	5.89	10.35	5.80	10.41	5.70	10.48	5.60	10.54	5.50	10.60	5.40	10.67	5.30	10.73	5.20	10.79	5.10	10.85	5.00	10.90
600	5.51	10.50	4.85	10.81	6.05	10.21	5.95	10.28	5.85	10.35	5.76	10.41	5.66	10.48	5.56	10.54	5.46	10.60	5.36	10.67	5.26	10.73	5.16	10.79	5.06	10.85	4.96	10.90
650	5.47	10.50	4.82	10.81	6.01	10.21	5.92	10.28	5.82	10.35	5.72	10.41	5.62	10.48	5.53	10.54	5.43	10.60	5.33	10.67	5.23	10.73	5.13	10.79	5.03	10.85	4.93	10.90
700	5.45	10.50	4.79	10.81	5.98	10.21	5.89	10.28	5.79	10.35	5.69	10.41	5.60	10.48	5.50	10.54	5.40	10.60	5.30	10.67	5.20	10.73	5.10	10.79	5.00	10.85	4.90	10.90
750	5.42	10.50	4.76	10.81	5.96	10.21	5.86	10.28	5.77	10.35	5.67	10.41	5.57	10.48	5.47	10.54	5.37	10.60	5.27	10.67	5.17	10.73	5.07	10.79	4.97	10.85	4.87	10.90
800	5.40	10.50	4.74	10.81	5.94	10.21	5.84	10.28	5.74	10.35	5.65	10.41	5.55	10.48	5.45	10.54	5.35	10.60	5.25	10.67	5.15	10.73	5.05	10.79	4.95	10.85	4.85	10.90
850	5.38	10.50	4.72	10.81	5.92	10.21	5.82	10.28	5.72	10.35	5.63	10.41	5.53	10.48	5.43	10.54	5.33	10.60	5.23	10.67	5.13	10.73	5.03	10.79	4.93	10.85	4.83	10.90
900	5.36	10.50	4.71	10.81	5.90	10.21	5.80	10.28	5.71	10.35	5.61	10.41	5.51	10.48	5.41	10.54	5.32	10.60	5.22	10.67	5.12	10.73	5.02	10.79	4.92	10.85	4.81	10.90
950	5.35	10.50	4.69	10.81	5.89	10.21	5.79	10.28	5.69	10.35	5.60	10.41	5.50	10.48	5.40	10.54	5.30	10.60	5.20	10.67	5.10	10.73	5.00	10.79	4.90	10.85	4.80	10.90
1000	5.33	10.50	4.68	10.81	5.87	10.21	5.78	10.28	5.68	10.35	5.58	10.41	5.48	10.48	5.38	10.54	5.29	10.60	5.19	10.67	5.09	10.73	4.99	10.79	4.89	10.85	4.78	10.90
1500	5.25	10.50	4.59	10.81	5.78	10.21	5.69	10.28	5.59	10.35	5.49	10.41	5.40	10.48	5.30	10.54	5.20	10.60	5.10	10.67	5.00	10.73	4.90	10.79	4.80	10.85	4.70	10.90
2000	5.20	10.50	4.54	10.81	5.74	10.21	5.64	10.28	5.55	10.35	5.45	10.41	5.35	10.48	5.25	10.54	5.15	10.60	5.05	10.67	4.95	10.73	4.86	10.79	4.75	10.85	4.65	10.90
5000	5.12	10.50	4.46	10.81	5.66	10.21	5.56	10.28	5.47	10.35	5.37	10.41	5.27	10.48	5.17	10.54	5.07	10.60	4.97	10.67	4.87	10.73	4.78	10.79	4.67	10.85	4.57	10.90
10000	5.09	10.50	4.44	10.81	5.63	10.21	5.54	10.28	5.44	10.35	5.34	10.41	5.24	10.48	5.15	10.54	5.05	10.60	4.95	10.67	4.85	10.73	4.75	10.79	4.65	10.85	4.55	10.90
50000	5.07	10.50	4.42	10.81	5.61	10.21	5.52	10.28	5.42	10.35	5.32	10.41	5.22	10.48	5.12	10.54	5.03	10.60	4.93	10.67	4.83	10.73	4.73	10.79	4.63	10.85	4.52	10.90
100000	5.07	10.50	4.41	10.81	5.61	10.21	5.51	10.28	5.42	10.35	5.32	10.41	5.22	10.48	5.12	10.54	5.02	10.60	4.92	10.67	4.82	10.73	4.72	10.79	4.62	10.85	4.52	10.90

LOCATION: COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

P6 END OF PANTOGRAPH - OUTSIDE OF CURVE REV: C (25/9/91)

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)

LENGTH:	95 FT	DOORS CLOSED
WIDTH:	9.5 FT	
W MIRRORS	10.8 FT	

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	ft

INCLUDES .18 FT LATERAL MOTION TO OUTSIDE

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	3.56	13.25	2.71	13.45	4.26	13.05	4.14	13.11	4.02	13.16	3.90	13.21	3.78	13.26	3.65	13.32	3.53	13.37	3.41	13.41	3.28	13.46	3.16	13.51	3.03	13.55	2.91	13.60

LOCATION: COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

P7 CENTER OF PANTOGRAPH REV: C (25/9/91)

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)

SYMETRICAL WITH ROLL LEF

LENGTH:	95 FT	DOORS CLOSED
WIDTH:	9.5 FT	
W MIRRORS	10.8 FT	

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	ft

LATERAL MOTION "+ OR -" 0.18 FT FROM CENTER

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	0.00	14.25	-0.91	14.22	0.78	14.25	0.64	14.27	0.51	14.30	0.38	14.32	0.25	14.35	0.11	14.37	-0.02	14.39	-0.15	14.41	-0.28	14.43	-0.41	14.45	-0.55	14.46	-0.68	14.48

LOCATION: COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

P8 END OF PANTOGRAPH - INSIDE OF CURVE REV: C (25/9/91)

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL LEFT (TOWARD INSIDE)

LENGTH:	95 FT	DOORS CLOSED
WIDTH:	9.5 FT	
W MIRRORS	10.8 FT	

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	ft

INCLUDES .18 FT LATERAL MOTION TO INSIDE

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	-3.56	13.25	-4.38	12.99	-4.50	12.98	-4.62	12.96	-4.75	12.94	-4.86	12.92	-4.98	12.90	-5.10	12.88	-5.22	12.86	-5.34	12.84	-5.46	12.81	-5.58	12.79	-5.70	12.76	-5.81	12.73

LOCATION:

COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

REV: C (25/9/91)

P9 UPPER CORNER OF CARBODY - INSIDE OF CURVE

LENGTH:	95 FT	DOORS CLOSED
WIDTH:	9.5 FT	
W MIRRORS	10.8 FT	

SUPERELEVATION LEFT WITH ROLL LEFT (TOWARD INSIDE)

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	FT

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
82	-6.48	10.50	-7.11	10.15	-7.21	10.12	-7.30	10.09	-7.40	10.06	-7.49	10.03	-7.59	10.00	-7.68	9.97	-7.77	9.94	-7.87	9.90	-7.96	9.87	-8.05	9.84	-8.15	9.80	-8.24	9.76
100	-6.20	10.50	-6.83	10.15	-6.93	10.12	-7.02	10.09	-7.12	10.06	-7.21	10.03	-7.30	10.00	-7.40	9.97	-7.49	9.94	-7.59	9.90	-7.68	9.87	-7.77	9.84	-7.86	9.80	-7.95	9.76
150	-5.77	10.50	-6.41	10.15	-6.50	10.12	-6.60	10.09	-6.69	10.06	-6.78	10.03	-6.88	10.00	-6.97	9.97	-7.07	9.94	-7.16	9.90	-7.25	9.87	-7.34	9.84	-7.44	9.80	-7.53	9.76
200	-5.56	10.50	-6.19	10.15	-6.29	10.12	-6.38	10.09	-6.48	10.06	-6.57	10.03	-6.67	10.00	-6.76	9.97	-6.85	9.94	-6.95	9.90	-7.04	9.87	-7.13	9.84	-7.22	9.80	-7.32	9.76
250	-5.43	10.50	-6.07	10.15	-6.16	10.12	-6.26	10.09	-6.35	10.06	-6.45	10.03	-6.54	10.00	-6.64	9.97	-6.73	9.94	-6.82	9.90	-6.92	9.87	-7.01	9.84	-7.10	9.80	-7.19	9.76
300	-5.35	10.50	-5.98	10.15	-6.08	10.12	-6.17	10.09	-6.27	10.06	-6.36	10.03	-6.46	10.00	-6.55	9.97	-6.64	9.94	-6.74	9.90	-6.83	9.87	-6.92	9.84	-7.01	9.80	-7.11	9.76
350	-5.29	10.50	-5.92	10.15	-6.02	10.12	-6.11	10.09	-6.21	10.06	-6.30	10.03	-6.40	10.00	-6.49	9.97	-6.58	9.94	-6.68	9.90	-6.77	9.87	-6.86	9.84	-6.95	9.80	-7.05	9.76
400	-5.25	10.50	-5.88	10.15	-5.97	10.12	-6.07	10.09	-6.16	10.06	-6.26	10.03	-6.35	10.00	-6.45	9.97	-6.54	9.94	-6.63	9.90	-6.73	9.87	-6.82	9.84	-6.91	9.80	-7.00	9.76
450	-5.21	10.50	-5.84	10.15	-5.94	10.12	-6.03	10.09	-6.13	10.06	-6.22	10.03	-6.32	10.00	-6.41	9.97	-6.50	9.94	-6.60	9.90	-6.69	9.87	-6.78	9.84	-6.87	9.80	-6.97	9.76
500	-5.18	10.50	-5.82	10.15	-5.91	10.12	-6.01	10.09	-6.10	10.06	-6.19	10.03	-6.29	10.00	-6.38	9.97	-6.48	9.94	-6.57	9.90	-6.66	9.87	-6.75	9.84	-6.85	9.80	-6.94	9.76
550	-5.16	10.50	-5.79	10.15	-5.89	10.12	-5.98	10.09	-6.08	10.06	-6.17	10.03	-6.27	10.00	-6.36	9.97	-6.45	9.94	-6.55	9.90	-6.64	9.87	-6.73	9.84	-6.82	9.80	-6.91	9.76
600	-5.14	10.50	-5.77	10.15	-5.87	10.12	-5.96	10.09	-6.06	10.06	-6.15	10.03	-6.25	10.00	-6.34	9.97	-6.43	9.94	-6.53	9.90	-6.62	9.87	-6.71	9.84	-6.80	9.80	-6.90	9.76
650	-5.12	10.50	-5.76	10.15	-5.85	10.12	-5.95	10.09	-6.04	10.06	-6.14	10.03	-6.23	10.00	-6.33	9.97	-6.42	9.94	-6.51	9.90	-6.60	9.87	-6.70	9.84	-6.79	9.80	-6.88	9.76
700	-5.11	10.50	-5.74	10.15	-5.84	10.12	-5.93	10.09	-6.03	10.06	-6.12	10.03	-6.22	10.00	-6.31	9.97	-6.40	9.94	-6.50	9.90	-6.59	9.87	-6.68	9.84	-6.77	9.80	-6.87	9.76
750	-5.10	10.50	-5.73	10.15	-5.83	10.12	-5.92	10.09	-6.02	10.06	-6.11	10.03	-6.20	10.00	-6.30	9.97	-6.39	9.94	-6.49	9.90	-6.58	9.87	-6.67	9.84	-6.76	9.80	-6.85	9.76
800	-5.09	10.50	-5.72	10.15	-5.82	10.12	-5.91	10.09	-6.01	10.06	-6.10	10.03	-6.19	10.00	-6.29	9.97	-6.38	9.94	-6.47	9.90	-6.57	9.87	-6.66	9.84	-6.75	9.80	-6.84	9.76
850	-5.08	10.50	-5.71	10.15	-5.81	10.12	-5.90	10.09	-6.00	10.06	-6.09	10.03	-6.18	10.00	-6.28	9.97	-6.37	9.94	-6.47	9.90	-6.56	9.87	-6.65	9.84	-6.74	9.80	-6.83	9.76
900	-5.07	10.50	-5.70	10.15	-5.80	10.12	-5.89	10.09	-5.99	10.06	-6.08	10.03	-6.18	10.00	-6.27	9.97	-6.36	9.94	-6.46	9.90	-6.55	9.87	-6.64	9.84	-6.73	9.80	-6.83	9.76
950	-5.06	10.50	-5.70	10.15	-5.79	10.12	-5.89	10.09	-5.98	10.06	-6.07	10.03	-6.17	10.00	-6.26	9.97	-6.36	9.94	-6.45	9.90	-6.54	9.87	-6.63	9.84	-6.73	9.80	-6.82	9.76
1000	-5.06	10.50	-5.69	10.15	-5.78	10.12	-5.88	10.09	-5.97	10.06	-6.07	10.03	-6.16	10.00	-6.26	9.97	-6.35	9.94	-6.44	9.90	-6.54	9.87	-6.63	9.84	-6.72	9.80	-6.81	9.76
1500	-5.01	10.50	-5.65	10.15	-5.74	10.12	-5.84	10.09	-5.93	10.06	-6.03	10.03	-6.12	10.00	-6.22	9.97	-6.31	9.94	-6.40	9.90	-6.49	9.87	-6.59	9.84	-6.68	9.80	-6.77	9.76
2000	-4.99	10.50	-5.63	10.15	-5.72	10.12	-5.82	10.09	-5.91	10.06	-6.00	10.03	-6.10	10.00	-6.19	9.97	-6.29	9.94	-6.38	9.90	-6.47	9.87	-6.56	9.84	-6.66	9.80	-6.75	9.76
5000	-5.01	10.50	-5.65	10.15	-5.74	10.12	-5.84	10.09	-5.93	10.06	-6.03	10.03	-6.12	10.00	-6.22	9.97	-6.31	9.94	-6.40	9.90	-6.49	9.87	-6.59	9.84	-6.68	9.80	-6.77	9.76
10000	-5.04	10.50	-5.67	10.15	-5.77	10.12	-5.86	10.09	-5.96	10.06	-6.05	10.03	-6.15	10.00	-6.24	9.97	-6.33	9.94	-6.43	9.90	-6.52	9.87	-6.61	9.84	-6.70	9.80	-6.80	9.76
50000	-5.06	10.50	-5.70	10.15	-5.79	10.12	-5.89	10.09	-5.98	10.06	-6.07	10.03	-6.17	10.00	-6.26	9.97	-6.36	9.94	-6.45	9.90	-6.54	9.87	-6.63	9.84	-6.73	9.80	-6.82	9.76
100000	-5.07	10.50	-5.70	10.15	-5.79	10.12	-5.89	10.09	-5.98	10.06	-6.08	10.03	-6.17	10.00	-6.27	9.97	-6.36	9.94	-6.45	9.90	-6.55	9.87	-6.64	9.84	-6.73	9.80	-6.82	9.76

LOCATION:

COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

REV: C (25/9/91)

P10 UPPER CORNER OF MIRROR - INSIDE OF CURVE

SUPERELEVATION LEFT WITH ROLL LEFT (TOWARD INSIDE)

LENGTH:	95	FT
WIDTH:	9.5	FT
W MIRROR:	10.8	FT

DOORS CLOSED

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	FT

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
82	-6.48	9.80	-7.06	9.40	-7.15	9.37	-7.24	9.34	-7.33	9.30	-7.42	9.27	-7.50	9.23	-7.59	9.19	-7.68	9.16	-7.76	9.12	-7.85	9.08	-7.93	9.04	-8.02	9.00	-8.10	8.96
100	-6.20	9.80	-6.78	9.40	-6.87	9.37	-6.96	9.34	-7.05	9.30	-7.13	9.27	-7.22	9.23	-7.31	9.19	-7.39	9.16	-7.48	9.12	-7.57	9.08	-7.65	9.04	-7.74	9.00	-7.82	8.96
150	-5.77	9.80	-6.36	9.40	-6.44	9.37	-6.53	9.34	-6.62	9.30	-6.71	9.27	-6.80	9.23	-6.88	9.19	-6.97	9.16	-7.05	9.12	-7.14	9.08	-7.23	9.04	-7.31	9.00	-7.40	8.96
200	-5.56	9.80	-6.14	9.40	-6.23	9.37	-6.32	9.34	-6.41	9.30	-6.50	9.27	-6.58	9.23	-6.67	9.19	-6.76	9.16	-6.84	9.12	-6.93	9.08	-7.01	9.04	-7.10	9.00	-7.18	8.96
250	-5.43	9.80	-6.02	9.40	-6.11	9.37	-6.19	9.34	-6.28	9.30	-6.37	9.27	-6.46	9.23	-6.54	9.19	-6.63	9.16	-6.72	9.12	-6.80	9.08	-6.89	9.04	-6.97	9.00	-7.06	8.96
300	-5.35	9.80	-5.93	9.40	-6.02	9.37	-6.11	9.34	-6.20	9.30	-6.28	9.27	-6.37	9.23	-6.46	9.19	-6.55	9.16	-6.63	9.12	-6.72	9.08	-6.80	9.04	-6.89	9.00	-6.97	8.96
350	-5.29	9.80	-5.87	9.40	-5.96	9.37	-6.05	9.34	-6.14	9.30	-6.22	9.27	-6.31	9.23	-6.40	9.19	-6.49	9.16	-6.57	9.12	-6.66	9.08	-6.74	9.04	-6.83	9.00	-6.91	8.96
400	-5.25	9.80	-5.83	9.40	-5.92	9.37	-6.00	9.34	-6.09	9.30	-6.18	9.27	-6.27	9.23	-6.36	9.19	-6.44	9.16	-6.53	9.12	-6.61	9.08	-6.70	9.04	-6.78	9.00	-6.87	8.96
450	-5.21	9.80	-5.79	9.40	-5.88	9.37	-5.97	9.34	-6.06	9.30	-6.14	9.27	-6.23	9.23	-6.32	9.19	-6.41	9.16	-6.49	9.12	-6.58	9.08	-6.66	9.04	-6.75	9.00	-6.83	8.96
500	-5.18	9.80	-5.77	9.40	-5.85	9.37	-5.94	9.34	-6.03	9.30	-6.12	9.27	-6.20	9.23	-6.29	9.19	-6.38	9.16	-6.46	9.12	-6.55	9.08	-6.63	9.04	-6.72	9.00	-6.81	8.96
550	-5.16	9.80	-5.74	9.40	-5.83	9.37	-5.92	9.34	-6.01	9.30	-6.09	9.27	-6.18	9.23	-6.27	9.19	-6.35	9.16	-6.44	9.12	-6.53	9.08	-6.61	9.04	-6.70	9.00	-6.78	8.96
600	-5.14	9.80	-5.73	9.40	-5.81	9.37	-5.90	9.34	-5.99	9.30	-6.08	9.27	-6.17	9.23	-6.25	9.19	-6.34	9.16	-6.43	9.12	-6.51	9.08	-6.60	9.04	-6.68	9.00	-6.77	8.96
650	-5.19	9.80	-5.78	9.40	-5.86	9.37	-5.95	9.34	-6.04	9.30	-6.13	9.27	-6.22	9.23	-6.30	9.19	-6.39	9.16	-6.47	9.12	-6.56	9.08	-6.64	9.04	-6.73	9.00	-6.82	8.96
700	-5.23	9.80	-5.82	9.40	-5.91	9.37	-5.99	9.34	-6.08	9.30	-6.17	9.27	-6.26	9.23	-6.34	9.19	-6.43	9.16	-6.52	9.12	-6.60	9.08	-6.69	9.04	-6.77	9.00	-6.86	8.96
750	-5.27	9.80	-5.85	9.40	-5.94	9.37	-6.03	9.34	-6.12	9.30	-6.21	9.27	-6.29	9.23	-6.38	9.19	-6.47	9.16	-6.55	9.12	-6.64	9.08	-6.72	9.04	-6.81	9.00	-6.89	8.96
800	-5.30	9.80	-5.89	9.40	-5.97	9.37	-6.06	9.34	-6.15	9.30	-6.24	9.27	-6.32	9.23	-6.41	9.19	-6.50	9.16	-6.58	9.12	-6.67	9.08	-6.75	9.04	-6.84	9.00	-6.93	8.96
850	-5.33	9.80	-5.91	9.40	-6.00	9.37	-6.09	9.34	-6.18	9.30	-6.26	9.27	-6.35	9.23	-6.44	9.19	-6.53	9.16	-6.61	9.12	-6.70	9.08	-6.78	9.04	-6.87	9.00	-6.95	8.96
900	-5.35	9.80	-5.94	9.40	-6.03	9.37	-6.11	9.34	-6.20	9.30	-6.29	9.27	-6.38	9.23	-6.47	9.19	-6.55	9.16	-6.64	9.12	-6.72	9.08	-6.81	9.04	-6.89	9.00	-6.98	8.96
950	-5.38	9.80	-5.96	9.40	-6.05	9.37	-6.14	9.34	-6.23	9.30	-6.31	9.27	-6.40	9.23	-6.49	9.19	-6.57	9.16	-6.66	9.12	-6.75	9.08	-6.83	9.04	-6.92	9.00	-7.00	8.96
1000	-5.40	9.80	-5.98	9.40	-6.07	9.37	-6.16	9.34	-6.25	9.30	-6.33	9.27	-6.42	9.23	-6.51	9.19	-6.59	9.16	-6.68	9.12	-6.77	9.08	-6.85	9.04	-6.94	9.00	-7.02	8.96
1500	-5.52	9.80	-6.11	9.40	-6.19	9.37	-6.28	9.34	-6.37	9.30	-6.46	9.27	-6.55	9.23	-6.63	9.19	-6.72	9.16	-6.81	9.12	-6.89	9.08	-6.98	9.04	-7.06	9.00	-7.15	8.96
2000	-5.59	9.80	-6.17	9.40	-6.26	9.37	-6.35	9.34	-6.43	9.30	-6.52	9.27	-6.61	9.23	-6.70	9.19	-6.78	9.16	-6.87	9.12	-6.95	9.08	-7.04	9.04	-7.12	9.00	-7.21	8.96
5000	-5.70	9.80	-6.28	9.40	-6.37	9.37	-6.46	9.34	-6.55	9.30	-6.63	9.27	-6.72	9.23	-6.81	9.19	-6.89	9.16	-6.98	9.12	-7.07	9.08	-7.15	9.04	-7.24	9.00	-7.32	8.96
10000	-5.74	9.80	-6.32	9.40	-6.41	9.37	-6.50	9.34	-6.58	9.30	-6.67	9.27	-6.76	9.23	-6.85	9.19	-6.93	9.16	-7.02	9.12	-7.10	9.08	-7.19	9.04	-7.27	9.00	-7.36	8.96
50000	-5.77	9.80	-6.35	9.40	-6.44	9.37	-6.53	9.34	-6.61	9.30	-6.70	9.27	-6.79	9.23	-6.88	9.19	-6.96	9.16	-7.05	9.12	-7.13	9.08	-7.22	9.04	-7.30	9.00	-7.39	8.96
100000	-5.77	9.80	-6.35	9.40	-6.44	9.37	-6.53	9.34	-6.62	9.30	-6.70	9.27	-6.79	9.23	-6.88	9.19	-6.97	9.16	-7.05	9.12	-7.14	9.08	-7.22	9.04	-7.31	9.00	-7.39	8.96

LOCATION:

COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

REV: C (25/9/91)

P11 INTERMEDIATE POINT OF CARBODY - INSIDE OF CURVE

SUPERELEVATION LEFT WITH ROLL LEFT (TOWARD INSIDE)

LENGTH:	95 FT	DOORS CLOSED
WIDTH:	9.5 FT	
W MIRROR:	10.8 FT	

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	FT

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
82	-6.48	7.00	-6.87	6.65	-6.94	6.63	-7.00	6.60	-7.06	6.58	-7.13	6.55	-7.19	6.52	-7.25	6.50	-7.32	6.47	-7.38	6.44	-7.44	6.41	-7.50	6.38	-7.56	6.35	-7.63	6.32
100	-6.20	7.00	-6.59	6.65	-6.65	6.63	-6.72	6.60	-6.78	6.58	-6.84	6.55	-6.91	6.52	-6.97	6.50	-7.03	6.47	-7.09	6.44	-7.16	6.41	-7.22	6.38	-7.28	6.35	-7.34	6.32
150	-5.77	7.00	-6.16	6.65	-6.23	6.63	-6.29	6.60	-6.35	6.58	-6.42	6.55	-6.48	6.52	-6.54	6.50	-6.61	6.47	-6.67	6.44	-6.73	6.41	-6.79	6.38	-6.85	6.35	-6.92	6.32
200	-5.56	7.00	-5.95	6.65	-6.01	6.63	-6.08	6.60	-6.14	6.58	-6.21	6.55	-6.27	6.52	-6.33	6.50	-6.39	6.47	-6.46	6.44	-6.52	6.41	-6.58	6.38	-6.64	6.35	-6.70	6.32
250	-5.43	7.00	-5.82	6.65	-5.89	6.63	-5.95	6.60	-6.02	6.58	-6.08	6.55	-6.14	6.52	-6.21	6.50	-6.27	6.47	-6.33	6.44	-6.39	6.41	-6.45	6.38	-6.52	6.35	-6.58	6.32
300	-5.35	7.00	-5.74	6.65	-5.80	6.63	-5.87	6.60	-5.93	6.58	-5.99	6.55	-6.06	6.52	-6.12	6.50	-6.18	6.47	-6.25	6.44	-6.31	6.41	-6.37	6.38	-6.43	6.35	-6.49	6.32
350	-5.29	7.00	-5.68	6.65	-5.74	6.63	-5.81	6.60	-5.87	6.58	-5.93	6.55	-6.00	6.52	-6.06	6.50	-6.12	6.47	-6.19	6.44	-6.25	6.41	-6.31	6.38	-6.37	6.35	-6.43	6.32
400	-5.25	7.00	-5.63	6.65	-5.70	6.63	-5.76	6.60	-5.83	6.58	-5.89	6.55	-5.95	6.52	-6.02	6.50	-6.08	6.47	-6.14	6.44	-6.20	6.41	-6.27	6.38	-6.33	6.35	-6.39	6.32
450	-5.21	7.00	-5.60	6.65	-5.66	6.63	-5.73	6.60	-5.79	6.58	-5.85	6.55	-5.92	6.52	-5.98	6.50	-6.04	6.47	-6.11	6.44	-6.17	6.41	-6.23	6.38	-6.29	6.35	-6.35	6.32
500	-5.18	7.00	-5.57	6.65	-5.64	6.63	-5.70	6.60	-5.76	6.58	-5.83	6.55	-5.89	6.52	-5.95	6.50	-6.02	6.47	-6.08	6.44	-6.14	6.41	-6.20	6.38	-6.26	6.35	-6.33	6.32
550	-5.16	7.00	-5.55	6.65	-5.61	6.63	-5.68	6.60	-5.74	6.58	-5.80	6.55	-5.87	6.52	-5.93	6.50	-5.99	6.47	-6.06	6.44	-6.12	6.41	-6.18	6.38	-6.24	6.35	-6.30	6.32
600	-5.14	7.00	-5.53	6.65	-5.59	6.63	-5.66	6.60	-5.72	6.58	-5.78	6.55	-5.85	6.52	-5.91	6.50	-5.97	6.47	-6.04	6.44	-6.10	6.41	-6.16	6.38	-6.22	6.35	-6.28	6.32
650	-5.12	7.00	-5.51	6.65	-5.58	6.63	-5.64	6.60	-5.71	6.58	-5.77	6.55	-5.83	6.52	-5.90	6.50	-5.96	6.47	-6.02	6.44	-6.08	6.41	-6.14	6.38	-6.21	6.35	-6.27	6.32
700	-5.11	7.00	-5.50	6.65	-5.56	6.63	-5.63	6.60	-5.69	6.58	-5.75	6.55	-5.82	6.52	-5.88	6.50	-5.94	6.47	-6.01	6.44	-6.07	6.41	-6.13	6.38	-6.19	6.35	-6.25	6.32
750	-5.10	7.00	-5.49	6.65	-5.55	6.63	-5.62	6.60	-5.68	6.58	-5.74	6.55	-5.81	6.52	-5.87	6.50	-5.93	6.47	-5.99	6.44	-6.06	6.41	-6.12	6.38	-6.18	6.35	-6.24	6.32
800	-5.09	7.00	-5.48	6.65	-5.54	6.63	-5.61	6.60	-5.67	6.58	-5.73	6.55	-5.80	6.52	-5.86	6.50	-5.92	6.47	-5.98	6.44	-6.05	6.41	-6.11	6.38	-6.17	6.35	-6.23	6.32
850	-5.08	7.00	-5.47	6.65	-5.53	6.63	-5.60	6.60	-5.66	6.58	-5.72	6.55	-5.79	6.52	-5.85	6.50	-5.91	6.47	-5.98	6.44	-6.04	6.41	-6.10	6.38	-6.16	6.35	-6.22	6.32
900	-5.07	7.00	-5.46	6.65	-5.52	6.63	-5.59	6.60	-5.65	6.58	-5.71	6.55	-5.78	6.52	-5.84	6.50	-5.90	6.47	-5.97	6.44	-6.03	6.41	-6.09	6.38	-6.15	6.35	-6.21	6.32
950	-5.06	7.00	-5.45	6.65	-5.52	6.63	-5.58	6.60	-5.64	6.58	-5.71	6.55	-5.77	6.52	-5.83	6.50	-5.90	6.47	-5.96	6.44	-6.02	6.41	-6.08	6.38	-6.14	6.35	-6.21	6.32
1000	-5.06	7.00	-5.45	6.65	-5.51	6.63	-5.57	6.60	-5.64	6.58	-5.70	6.55	-5.76	6.52	-5.83	6.50	-5.89	6.47	-5.95	6.44	-6.02	6.41	-6.08	6.38	-6.14	6.35	-6.20	6.32
1500	-5.01	7.00	-5.40	6.65	-5.47	6.63	-5.53	6.60	-5.60	6.58	-5.66	6.55	-5.72	6.52	-5.79	6.50	-5.85	6.47	-5.91	6.44	-5.97	6.41	-6.03	6.38	-6.10	6.35	-6.16	6.32
2000	-4.99	7.00	-5.38	6.65	-5.45	6.63	-5.51	6.60	-5.57	6.58	-5.64	6.55	-5.70	6.52	-5.77	6.50	-5.83	6.47	-5.89	6.44	-5.95	6.41	-6.01	6.38	-6.08	6.35	-6.14	6.32
5000	-5.01	7.00	-5.40	6.65	-5.47	6.63	-5.53	6.60	-5.60	6.58	-5.66	6.55	-5.72	6.52	-5.79	6.50	-5.85	6.47	-5.91	6.44	-5.97	6.41	-6.03	6.38	-6.10	6.35	-6.16	6.32
10000	-5.04	7.00	-5.43	6.65	-5.50	6.63	-5.56	6.60	-5.62	6.58	-5.69	6.55	-5.75	6.52	-5.81	6.50	-5.88	6.47	-5.94	6.44	-6.00	6.41	-6.06	6.38	-6.12	6.35	-6.19	6.32
50000	-5.06	7.00	-5.45	6.65	-5.52	6.63	-5.58	6.60	-5.64	6.58	-5.71	6.55	-5.77	6.52	-5.83	6.50	-5.90	6.47	-5.96	6.44	-6.02	6.41	-6.08	6.38	-6.14	6.35	-6.21	6.32
100000	-5.07	7.00	-5.45	6.65	-5.52	6.63	-5.58	6.60	-5.65	6.58	-5.71	6.55	-5.77	6.52	-5.84	6.50	-5.90	6.47	-5.96	6.44	-6.02	6.41	-6.09	6.38	-6.15	6.35	-6.21	6.32

LOCATION:

COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

REV: C (25/9/91)

P12 LOWER CORNER OF CARBODY - INSIDE OF CURVE

LENGTH:	95	FT
WIDTH:	9.5	FT
W MIRRORS	10.8	FT

DOORS CLOSED

SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	FT

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
82	-6.48	0.67	-6.43	0.72	-6.52	0.98	-6.54	0.96	-6.55	0.94	-6.57	0.92	-6.58	0.89	-6.59	0.87	-6.61	0.85	-6.62	0.83	-6.63	0.80	-6.64	0.78	-6.66	0.76	-6.67	0.74
100	-6.20	0.67	-6.15	0.72	-6.24	0.98	-6.26	0.96	-6.27	0.94	-6.28	0.92	-6.30	0.89	-6.31	0.87	-6.32	0.85	-6.34	0.83	-6.35	0.80	-6.36	0.78	-6.37	0.76	-6.39	0.74
150	-5.77	0.67	-5.72	0.72	-5.82	0.98	-5.83	0.96	-5.84	0.94	-5.86	0.92	-5.87	0.89	-5.88	0.87	-5.90	0.85	-5.91	0.83	-5.92	0.80	-5.94	0.78	-5.95	0.76	-5.96	0.74
200	-5.56	0.67	-5.51	0.72	-5.60	0.98	-5.62	0.96	-5.63	0.94	-5.65	0.92	-5.66	0.89	-5.67	0.87	-5.69	0.85	-5.70	0.83	-5.71	0.80	-5.72	0.78	-5.74	0.76	-5.75	0.74
250	-5.43	0.67	-5.38	0.72	-5.48	0.98	-5.49	0.96	-5.51	0.94	-5.52	0.92	-5.53	0.89	-5.55	0.87	-5.56	0.85	-5.57	0.83	-5.59	0.80	-5.60	0.78	-5.61	0.76	-5.62	0.74
300	-5.35	0.67	-5.30	0.72	-5.39	0.98	-5.41	0.96	-5.42	0.94	-5.44	0.92	-5.45	0.89	-5.46	0.87	-5.48	0.85	-5.49	0.83	-5.50	0.80	-5.51	0.78	-5.53	0.76	-5.54	0.74
350	-5.29	0.67	-5.24	0.72	-5.33	0.98	-5.35	0.96	-5.36	0.94	-5.38	0.92	-5.39	0.89	-5.40	0.87	-5.42	0.85	-5.43	0.83	-5.44	0.80	-5.45	0.78	-5.47	0.76	-5.48	0.74
400	-5.25	0.67	-5.19	0.72	-5.29	0.98	-5.30	0.96	-5.32	0.94	-5.33	0.92	-5.34	0.89	-5.36	0.87	-5.37	0.85	-5.38	0.83	-5.40	0.80	-5.41	0.78	-5.42	0.76	-5.43	0.74
450	-5.21	0.67	-5.16	0.72	-5.25	0.98	-5.27	0.96	-5.28	0.94	-5.29	0.92	-5.31	0.89	-5.32	0.87	-5.33	0.85	-5.35	0.83	-5.36	0.80	-5.37	0.78	-5.39	0.76	-5.40	0.74
500	-5.18	0.67	-5.13	0.72	-5.23	0.98	-5.24	0.96	-5.25	0.94	-5.27	0.92	-5.28	0.89	-5.29	0.87	-5.31	0.85	-5.32	0.83	-5.33	0.80	-5.34	0.78	-5.36	0.76	-5.37	0.74
550	-5.16	0.67	-5.11	0.72	-5.20	0.98	-5.22	0.96	-5.23	0.94	-5.24	0.92	-5.26	0.89	-5.27	0.87	-5.28	0.85	-5.30	0.83	-5.31	0.80	-5.32	0.78	-5.33	0.76	-5.35	0.74
600	-5.14	0.67	-5.09	0.72	-5.18	0.98	-5.20	0.96	-5.21	0.94	-5.22	0.92	-5.24	0.89	-5.25	0.87	-5.26	0.85	-5.28	0.83	-5.29	0.80	-5.30	0.78	-5.32	0.76	-5.33	0.74
650	-5.12	0.67	-5.07	0.72	-5.17	0.98	-5.18	0.96	-5.20	0.94	-5.21	0.92	-5.22	0.89	-5.24	0.87	-5.25	0.85	-5.26	0.83	-5.27	0.80	-5.29	0.78	-5.30	0.76	-5.31	0.74
700	-5.11	0.67	-5.06	0.72	-5.15	0.98	-5.17	0.96	-5.18	0.94	-5.19	0.92	-5.21	0.89	-5.22	0.87	-5.23	0.85	-5.25	0.83	-5.26	0.80	-5.27	0.78	-5.29	0.76	-5.30	0.74
750	-5.10	0.67	-5.05	0.72	-5.14	0.98	-5.16	0.96	-5.17	0.94	-5.18	0.92	-5.20	0.89	-5.21	0.87	-5.22	0.85	-5.24	0.83	-5.25	0.80	-5.26	0.78	-5.27	0.76	-5.29	0.74
800	-5.09	0.67	-5.04	0.72	-5.13	0.98	-5.14	0.96	-5.16	0.94	-5.17	0.92	-5.19	0.89	-5.20	0.87	-5.21	0.85	-5.23	0.83	-5.24	0.80	-5.25	0.78	-5.26	0.76	-5.27	0.74
850	-5.08	0.67	-5.03	0.72	-5.12	0.98	-5.14	0.96	-5.15	0.94	-5.16	0.92	-5.18	0.89	-5.19	0.87	-5.20	0.85	-5.22	0.83	-5.23	0.80	-5.24	0.78	-5.25	0.76	-5.27	0.74
900	-5.07	0.67	-5.02	0.72	-5.11	0.98	-5.13	0.96	-5.14	0.94	-5.15	0.92	-5.17	0.89	-5.18	0.87	-5.19	0.85	-5.21	0.83	-5.22	0.80	-5.23	0.78	-5.25	0.76	-5.26	0.74
950	-5.06	0.67	-5.01	0.72	-5.11	0.98	-5.12	0.96	-5.13	0.94	-5.15	0.92	-5.16	0.89	-5.17	0.87	-5.19	0.85	-5.20	0.83	-5.21	0.80	-5.23	0.78	-5.24	0.76	-5.25	0.74
1000	-5.06	0.67	-5.00	0.72	-5.10	0.98	-5.11	0.96	-5.13	0.94	-5.14	0.92	-5.15	0.89	-5.17	0.87	-5.18	0.85	-5.19	0.83	-5.21	0.80	-5.22	0.78	-5.23	0.76	-5.24	0.74
1500	-5.01	0.67	-4.96	0.72	-5.06	0.98	-5.07	0.96	-5.09	0.94	-5.10	0.92	-5.11	0.89	-5.13	0.87	-5.14	0.85	-5.15	0.83	-5.16	0.80	-5.18	0.78	-5.19	0.76	-5.20	0.74
2000	-4.99	0.67	-4.94	0.72	-5.04	0.98	-5.05	0.96	-5.06	0.94	-5.08	0.92	-5.09	0.89	-5.10	0.87	-5.12	0.85	-5.13	0.83	-5.14	0.80	-5.16	0.78	-5.17	0.76	-5.18	0.74
5000	-5.01	0.67	-4.96	0.72	-5.06	0.98	-5.07	0.96	-5.09	0.94	-5.10	0.92	-5.11	0.89	-5.13	0.87	-5.14	0.85	-5.15	0.83	-5.17	0.80	-5.18	0.78	-5.19	0.76	-5.20	0.74
10000	-5.04	0.67	-4.99	0.72	-5.08	0.98	-5.10	0.96	-5.11	0.94	-5.13	0.92	-5.14	0.89	-5.15	0.87	-5.17	0.85	-5.18	0.83	-5.19	0.80	-5.20	0.78	-5.22	0.76	-5.23	0.74
50000	-5.06	0.67	-5.01	0.72	-5.11	0.98	-5.12	0.96	-5.13	0.94	-5.15	0.92	-5.16	0.89	-5.17	0.87	-5.19	0.85	-5.20	0.83	-5.21	0.80	-5.23	0.78	-5.24	0.76	-5.25	0.74
100000	-5.07	0.67	-5.01	0.72	-5.11	0.98	-5.12	0.96	-5.14	0.94	-5.15	0.92	-5.16	0.89	-5.18	0.87	-5.19	0.85	-5.20	0.83	-5.22	0.80	-5.23	0.78	-5.24	0.76	-5.25	0.74

LOCATION: COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

P13 INTERMEDIATE POINT OF PANTOGRAPH - OUTSIDE OF CURVE

REV: C (25/9/91)

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)

LENGTH:	95 FT
WIDTH:	9.5 FT
W MIRRORS	10.8 FT

DOORS CLOSED

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	ft

INCLUDES .18 FT LATERAL MOTION TO OUTSIDE

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	2.56	14.25	1.64	14.39	3.33	14.09	3.20	14.14	3.06	14.19	2.93	14.24	2.80	14.28	2.67	14.33	2.54	14.37	2.40	14.41	2.27	14.45	2.14	14.49	2.01	14.53	1.87	14.57

LOCATION: COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

P14 INTERMEDIATE POINT OF PANTOGRAPH - INSIDE OF CURVE

REV: C (25/9/91)

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL LEFT (TOWARD INSIDE)

LENGTH:	95 FT
WIDTH:	9.5 FT
W MIRRORS	10.8 FT

DOORS CLOSED

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	ft

INCLUDES .18 FT OF LATERAL MOTION

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	-2.56	14.25	-3.46	14.04	-3.59	14.03	-3.71	14.02	-3.85	14.01	-3.97	14.00	-4.10	13.98	-4.23	13.97	-4.36	13.95	-4.49	13.93	-4.62	13.91	-4.74	13.89	-4.87	13.87	-5.00	13.85

LOCATION: COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

P15 END OF PANTOGRAPH - OUTSIDE OF CURVE

REV: C (25/9/91)

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)

LENGTH:	95 FT
WIDTH:	9.5 FT
W MIRRORS	10.8 FT

DOORS CLOSED

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	ft

INCLUDES .18 FT LATERAL MOTION TO OUTSIDE

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	3.56	17.00	2.45	17.19	4.49	16.79	4.34	16.85	4.18	16.91	4.03	16.96	3.87	17.01	3.71	17.07	3.56	17.12	3.40	17.16	3.24	17.21	3.09	17.26	2.93	17.30	2.77	17.35

LOCATION: COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

P16 INTERMEDIATE POINT OF PANTOGRAPH - OUTSIDE OF CURVE

REV: C (25/9/91)

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)

LENGTH:	95 FT
WIDTH:	9.5 FT
W MIRRORS	10.8 FT

DOORS CLOSED

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	ft

INCLUDES .18 FT LATERAL MOTION TO OUTSIDE

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	2.56	18.00	1.38	18.13	3.55	17.84	3.39	17.89	3.23	17.94	3.06	17.99	2.90	18.03	2.73	18.08	2.57	18.12	2.40	18.16	2.23	18.20	2.07	18.24	1.90	18.28	1.74	18.32

LOCATION: COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

P17 CENTER OF PANTOGRAPH

REV: C (25/9/91)

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)

LENGTH:	95 FT
WIDTH:	9.5 FT
W MIRRORS	10.8 FT

DOORS CLOSED

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	ft

LATERAL MOTION "+ OR -" .18 FT FROM CENTER

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	0.00	18.00	-1.17	17.96	1.00	17.99	0.84	18.02	0.67	18.05	0.51	18.07	0.34	18.10	0.18	18.12	0.01	18.14	-0.15	18.16	-0.32	18.18	-0.48	18.20	-0.65	18.21	-0.82	18.23

LOCATION: COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

P18 INTERMEDIATE POINT OF PANTOGRAPH - INSIDE OF CURVE

REV: C (25/9/91)

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL LEFT (TOWARD INSIDE)

LENGTH:	95 FT
WIDTH:	9.5 FT
W MIRRORS	10.8 FT

DOORS CLOSED

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	ft

INCLUDES .18 FT OF LATERAL MOTION

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	-2.56	18.00	-3.72	17.78	-3.88	17.77	-4.04	17.76	-4.21	17.74	-4.37	17.73	-4.53	17.71	-4.69	17.69	-4.85	17.67	-5.01	17.65	-5.18	17.62	-5.33	17.60	-5.50	17.57	-5.66	17.54

LOCATION: COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

P19 END OF PANTOGRAPH - INSIDE OF CURVE REV: C (25/9/91)

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL LEFT (TOWARD INSIDE)

LENGTH:	95 FT
WIDTH:	9.5 FT
W MIRROR!	10.8 FT

DOORS CLOSED

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	ft

INCLUDES .18 FT OF LATERAL MOTION

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	-3.56	17.00	-4.65	16.73	-4.80	16.72	-4.95	16.70	-5.11	16.68	-5.26	16.65	-5.41	16.63	-5.56	16.60	-5.71	16.58	-5.87	16.55	-6.02	16.52	-6.17	16.49	-6.32	16.46	-6.47	16.43

LOCATION: COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

P20 END OF PANTOGRAPH - OUTSIDE OF CURVE REV: C (25/9/91)

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)

LENGTH:	95 FT
WIDTH:	9.5 FT
W MIRROR!	10.8 FT

DOORS CLOSED

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	ft

INCLUDES .18 FT OF LATERAL MOTION

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	3.56	22.00	2.10	22.18	4.80	21.78	4.60	21.84	4.40	21.90	4.20	21.96	4.00	22.01	3.80	22.07	3.60	22.12	3.40	22.16	3.19	22.21	3.00	22.26	2.79	22.30	2.59	22.34

LOCATION: COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

P21 INTERMEDIATE POINT OF PANTOGRAPH - OUTSIDE OF CURVE REV: C (25/9/91)

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)

LENGTH:	95 FT
WIDTH:	9.5 FT
W MIRROR!	10.8 FT

DOORS CLOSED

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	ft

INCLUDES .18 FT OF LATERAL MOTION

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	2.56	23.00	1.03	23.12	3.86	22.83	3.65	22.88	3.44	22.93	3.24	22.98	3.03	23.03	2.81	23.08	2.61	23.12	2.40	23.16	2.19	23.20	1.98	23.24	1.77	23.28	1.56	23.31

LOCATION: COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

P22 CENTER OF PANTOGRAPH - OUTSIDE OF CURVE REV: C (25/9/91)

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL RIGHT (TOWARD OUTSIDE)

LENGTH:	95	FT
WIDTH:	9.5	FT
W MIRRORS	10.8	FT

DOORS CLOSED

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	ft

LATERAL MOTION "+ OR -" .18 FT FROM CENTER

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	0.00	23.00	-1.52	22.95	1.31	22.98	1.10	23.01	0.89	23.04	0.68	23.07	0.47	23.09	0.26	23.12	0.05	23.14	-0.16	23.16	-0.37	23.18	-0.58	23.20	-0.79	23.21	-1.00	23.22

LOCATION: COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

P23 INTERMEDIATE POINT OF PANTOGRAPH - INSIDE OF CURVE REV: C (25/9/91)

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL LEFT (TOWARD INSIDE)

LENGTH:	95	FT
WIDTH:	9.5	FT
W MIRRORS	10.8	FT

DOORS CLOSED

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	ft

INCLUDES .18 FT OF LATERAL MOTION

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	-2.56	23.00	-4.07	22.77	-4.27	22.76	-4.48	22.74	-4.69	22.72	-4.89	22.70	-5.10	22.68	-5.31	22.65	-5.51	22.63	-5.71	22.60	-5.92	22.57	-6.12	22.54	-6.33	22.50	-6.53	22.47

LOCATION: COORDINATE SYSTEM ORGIN, "0,0" CENTER LINE OF TRACKWAY AT TOP OF RAIL

P24 END OF PANTOGRAPH - INSIDE OF CURVE REV: C (25/9/91)

PANTOGRAPH CENTERED OVER TRUCK

SUPERELEVATION LEFT WITH ROLL LEFT (TOWARD INSIDE)

LENGTH:	95	FT
WIDTH:	9.5	FT
W MIRRORS	10.8	FT

DOORS CLOSED

	X	Y	
P1 - ROLL POINT OF VEHICLE	0	1.25	ft

INCLUDES .18 FT OF LATERAL MOTION

	LEVEL		ROLL LEFT		0.5 INCH		1.0 INCH		1.5 INCH		2.0 INCH		2.5 INCH		3.0 INCH		3.5 INCH		4.0 INCH		4.5 INCH		5.0 INCH		5.5 INCH		6.0 INCH	
RADIUS	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
ALL	-3.56	22.00	-4.99	21.72	-5.19	21.70	-5.39	21.68	-5.59	21.65	-5.78	21.63	-5.98	21.60	-6.18	21.57	-6.37	21.54	-6.57	21.50	-6.76	21.47	-6.96	21.43	-7.15	21.39	-7.34	21.35

CHAPTER 3

TRACTION ELECTRIFICATION

Chapter 3

TRACTION ELECTRIFICATION

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CHAPTER 3 - TRACTION ELECTRIFICATION

3.1 GENERAL

This chapter, together with Chapter 1 - General Section, describes the design requirements for electrical systems to supply traction power to the DART rail vehicles and electrical power to signal and communication bungalows.

The Traction Electrification System (TES) includes:

a) The Traction Power Substations (TPSS)

b) The DC Feeder System

c) The Overhead Contact System (OCS)

d) The Signal and Communication Power Supply System

3.2 SYSTEM DESCRIPTION

The DART Light Rail Transit (LRT) System to be electrified consists of underground, at-grade, and elevated sections. The system is double-track operation except in the yard and shop areas where multi-track operation is required.

AC drive electric traction motors, driving steel wheels through the appropriate gearing, propel the transit vehicles. The vehicles collect the electrical traction power from an Overhead Contact System by means of a pantograph. The OCS is energized at nominal 750 volts direct current (VDC) from traction substations located along the system route. Track running rails are used for DC traction current return. The substations are connected to the nominal 15 KV, 60 Hz three-phase local power utility system distribution network, and they include all the equipment required to convert the primary AC supply voltage to the nominal VDC electrification voltage.

3.2.1 Traction Power Substations

The TPSS consists of all equipment between the power utility metering point, and the interface point with the DC feeder system. Each substation includes 15KV AC cables, 15KV AC switchgear, a transformer/thyristor-rectifier unit, DC switchgear, positive and negative busbars, negative drainage panel, substation housing and foundation, grounding system, negative return system, control system metering and protection system, auxiliary power supply system, heating and ventilation inside the substation, batteries and chargers, security system, lightning arresters, alarms, and supervisory control equipment.

3.2.2 DC Feeder System

The DC feeder system includes the multiple positive DC feeders from the TPSS's DC switchgear to the OCS, the negative return cables from the substation negative bus to the rails, and any parallel underground feeders required to locally reinforce the Overhead Contact System's electrical capacity. Also included are positive and negative feeder duct banks and manholes.

3.2.3 Overhead Contact System

The OCS consists of all equipment between the DC feeder system and the vehicle pantograph. This equipment includes the supporting structures, guys, foundations, conductors, overhead feeders, ancillary wires, hangers, insulators, conductor supports, hardware, jumpers, tensioning devices, sectionalization equipment, disconnect switches and operating gear, and lightning arresters.

3.2.4 Signal and Communication Power Supply System

TPSS shall be designed to supply AC power to signal and communication bungalows. The interface point between the TPSS station and the signal and communication system is the termination point of the power supply cable at each TPSS.

3.3 CODES AND STANDARDS

All work relating to the electrification design shall conform to the latest editions of all applicable industry codes and standards, other local and State codes as required. The designer shall consult these publications and provide systems in accordance with the most stringent applicable code or industry practice.

3.4 GENERAL

The traction electrification system shall be designed using the parameters defined below:

3.4.1 DC System Data

a)	Nominal System Voltage	750	VDC
b)	Maximum Vehicle Voltage	900	VDC
c)	Minimum Vehicle Voltage	525	VDC
d)	Maximum Rail to Ground Voltage	72	VDC
e)	Nominal control power battery charger/eliminator	125	VDC

While vehicles are equipped with regenerative braking, the system will be designed without consideration of the effect of regeneration. Regenerated power will not be returned to the utility.

3.4.2 Train Operations

Design Train Headway:	5 MIN on trunk line 10 MIN on branch lines 2.5 MIN in Central Business District (CBD)
Train consist (peak period)	3 SLRV car trains

Note: Traction Power Substations should support five (5) minute train headways on line sections on NW-3 and NW-4.

3.4.3 Utility System Data

Voltage:	Nominal 15 KV, 3-phase
Frequency:	60 Hz
Fault Level:	Determined by the utility delivery point

3.4.4 Operating Criteria

The TES shall be capable of supplying the transit vehicles during the periods of maximum traffic density. The system shall be designed to enable operation of avoirdupois weight AW2 loaded trains with the maximum number of cars at minimum headways. The lowest voltage at any train shall be maintained above the minimum value and substations will be designed to permit overloading within the maximum allowable ANSI C34, heavy duty rating during emergency operations and outage conditions.

The TES design shall consider three light rail operating conditions: 1) Normal, 2) Emergency, and 3) Outage.

Under normal operating conditions, all substations are in service and the TES shall supply sufficient power to enable all trains to achieve the maximum allowable speed and acceleration rates at normal headways.

Under emergency operating conditions, all substations are in service and the TES shall supply sufficient power to enable all trains to achieve the maximum allowable speed and acceleration rates at the emergency headway. The emergency operating condition is employed for train schedule catch-up operations and all transit vehicles will be permitted to operate at maximum performance.

Under an outage operating condition, one or more non-adjacent substations are out of service. This operating condition shall permit reduced train operations in affected TES sections subject to the restriction that adjacent substations inbound and outbound from an out of service substation remain in operation. During an outage operating condition, trains may have to reduce speed and acceleration.

3.4.5 Sectionalization

The DC power distribution will be of the double end-feed type where electrical continuity between adjacent substations is provided by the OCS.

The two mainline tracks will be electrically independent with section insulators installed at all mainline crossovers.

Overlaps or 1/2 tension air breaks in the OCS will allow sectionalization by track zones. Section insulators may be installed in the mainline tracks only with DART’s approval.

Disconnect switches will be installed at Overhead Contact System feeding points and across selected sectioning locations in the mainline to provide flexibility in operations.

The traction power supply to the yard, maintenance shops, and mainline shall be electrically separated. The negative return system in the shop shall be grounded to the shop building and shop grounding system. The return rails for the mainline and yard shall be electrically insulated from earth and meet the minimum resistance-to-earth criteria as defined in the Corrosion Control Criteria for stray current mitigation in Chapter 8. All yard and mainline substations shall be designed to ground the negative buss should the buss reach a predetermined voltage level.

Yard tie switches shall be provided for emergency interconnection of the yard traction power supply to the mainline traction power supply system.

Insulated rail joints shall be installed at the shop facility entrance and a section insulator shall be installed in the OCS to isolate the traction power system for the shops and that for the yard.

3.5 TRACTION POWER SUBSTATIONS

3.5.1 General

All substations shall be self-contained and integrated package units factory pre-wired and pre-tested, and ready for mounting on foundations. All packaged substations shall be identical except as approved by DART. The enclosure, including doors, shall be constructed of not less than No. 14 gauge steel mounted on a structural frame. The steel base frame shall be capable of supporting the substation when installed on pier foundations.

3.5.2 Substation Location

Whenever practical, the TPSS stations shall be located where trains are likely to accelerate, such as near passenger stations and near major interlocking locations. These locations shall be optimized with respect to specified operations, system safety, system efficiency, system availability, stray current control, and minimum life cycle costs.

All TPSS will typically be located at-grade. Substation site selection shall be coordinated with DART to facilitate Real Estate acquisition.

TPSS, where possible, require drive up access for maintenance vehicles and fire department. Require preferred location of TPSS to be within 150 feet of public street where a fire hose could be laid and therefore eliminate/minimize the need for dedicated fire access lanes.

3.5.3 Substation Enclosure

All TPSS shall be designed to meet basic safety and fire protection requirements that may vary depending upon the location of each individual substation. TPSS shall be considered as Group B, Division 4 occupancies when referencing the International Building Code(IBC) for occupancy related requirements.

The basic requirements to be incorporated into the building design shall include the following:

a) Substations located beneath guideways or beneath passenger stations or elevated platforms shall include Class A or non-combustible roof covering.

b) Emergency access to and egress from the substations shall be in accordance with local fire codes and the International Building Code.

c) Emergency lighting and exit signs shall be in accordance with local codes, the International Building Code, and Fixed Guideway Transit Systems (National Fire Protection Association (NFPA) NFPA 130).

d) Substations shall be provided with an automatic fire detection system and portable fire extinguishers. They shall comply with Chapter 38 of the International Building Code and local code. In addition, the automatic fire detection system device status shall be monitored and displayed at the train control center. Requirements for additional fire protection must be coordinated through the local authority having jurisdiction.

e) Substation doors shall be monitored by a security system. Entry by unauthorized persons shall be prevented by means of locks and special keys. Wayside electrical control equipment and switches shall be secured by key locks.

f) Substation shall be provided with emergency trip stations inside all entrances to allow substation de-energization. An additional emergency trip station shall be located outside of the substation main entrance. This external emergency trip station is intended for DART Supervisory personnel and the local authority fire department use and it shall be contained in an approved lock box.

3.5.4 Substation Rating

The basis for transformer/thyristor-rectifier rating will be the heavy traction load cycle as defined in the NEMA RI-9 Standard.

Each substation will have one transformer/thyristor-rectifier unit.

3.5.5 AC Feeders

Each substation will be supplied by one utility feeder. Feeders from the same utility circuit will not be used to supply adjacent substations. Utility feeders circuit information shall be provided by the local utility company.

3.5.6 Equipment

The basic requirements to be incorporated into the equipment design include the following:

a) AC switchgear shall be metal clad as defined by the C37 series of American National Standards Institute (ANSI) specifications.

b) Transformers and thyristor-rectifiers shall be equipped with interlocked door switches which remove power and prevent equipment energization while the door is open.

c) Disconnecting devices which do not have load-break capabilities shall be equipped with interlocks to prevent unsafe operations.

d) Thyristor-rectifiers and DC switchgear shall be isolated from earth ground (high resistance ground) and shall be equipped with monitoring devices which detect and annunciate the breakdown of insulation between the enclosure and ground, and between the enclosure and traction power positive potential. Insulation breakdown detection between enclosure and traction power positive or between the enclosure and ground shall result in the tripping of all AC and DC circuit breakers. Grounded equipment located within 6 feet of the thyristor-rectifier and DC switchgear equipment shall be protected by electrical insulating material sufficient to increase the effective distance to the grounded portion of the equipment to a minimum of 6 feet.

e) DC switchgear shall be metal enclosed draw-out type feeder breakers equipped with load measuring auto re-closing systems. Rate of rise relays, or other sensing elements, which can discriminate between high-resistance faults and train starting currents, shall be provided for all feeder breakers. The rectifier DC breaker shall be equipped with reverse current trip only.

f) High dielectric strength material shall be provided on the floor around the rectifier and DC switchgear for a distance of at least 6 feet if building permits. All grounded surfaces within DC switchgear shall be covered with electrical insulating material. Material provided around the DC switchgear shall be flush with the finished floor.

g) Indicating meters shall be provided to display the following:

- AC line current
- AC bus voltage
- DC positive bus voltage
- DC feeder line current
- DC feeder voltage
- DC negative bus voltage
- Ground fault detection system

h) Facilities for future drainage cable connection and stray current measurement.

i) The designer shall consider industry standards and design practices that ensure fail-safe operation of AC Main, DC Main, and Feeder breaker protective relays is achieved such that protective relay failure or loss of protective relay power shall result in a breaker trip.

3.5.7 Raceways and Cables

Conduits, ducts, manholes, and cableways shall be provided for the AC supply cables from the TPSS to the interface point with the utility. The cableway requirements shall be coordinated with other DART construction contracts and with the utility.

The basic requirements to be incorporated into the raceways and cable design shall include the following:

a) All material manufactured for use as conduits, raceways, ducts, boxes, cabinets, equipment enclosures and their surface finish material shall be suitable to withstand temperatures of 932^{o} F (500^{o} C) for one hour, and shall not support combustion under the same temperature condition.

b) All conductors except those specifically excluded by DART shall be insulated. Minimum thickness of insulation and jacket shall conform to the National Electrical Code (NFPA 70) for the voltage and use intended.

c) All insulation shall conform to Article 310 of the National Electrical Code and be moisture and heat resistant types carrying temperature ratings corresponding to the conditions of application. Only insulation materials designed for temperature ratings higher than 194^{o} F (90^{o} C) will be used.

d) All cables in open raceways shall pass the flammability requirements of Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations (Institute of Electrical and Electronics Engineers, Inc.(IEEE 383) and the smoke emission requirements of Smoke Generation of Solid Materials (NFPA 238).

3.5.8 Substation Foundation

The substation foundation design shall conform to: Design Criteria Manual, Volume 1, Facility Design; established civil and structural engineering practices; American Society for Testing Materials (ASTM); American Concrete Institute (ACI) standards; other applicable standards; and local codes. The substation foundation shall be structurally capable of withstanding the substation equipment live and dead loads occurring during substation installation, operation, and maintenance. Substation foundation materials and construction shall be accordance with appropriate Facility Standard Specifications.

3.5.9 Substation Grounding

The substation grounding system shall be designed to provide safety to personnel and to protect equipment. The substation ground grid shall consist of ground rods and conductors, and shall be designed so that step-and-touch potentials at the maximum available ground fault current are in accordance with IEEE 80. The substation grounding designs shall be coordinated with DART.

3.5.10 Air Conditioning

The substations shall be air conditioned utilizing multiple air conditioning units to provide redundancy. The environmental design shall maintain the maximum substation temperature at a level that permits the traction power transformers, rectifiers, and all other substation equipment to operate at their designed load ratings. The maximum temperature that allows all substation equipment to operate at designed load ratings shall be maintained with the loss of any one air conditioning unit.

3.5.11 Site Improvements

The civil line section designer will provide final design for all site improvements including grading, drainage, access roads, raceways, fencing and landscaping.

In environmentally sensitive areas, the section designer may furnish architectural treatments that blend with their surroundings. At these locations, the substations may be housed inside architectural screens designed by the section designer.

3.5.12 Noise Level

The substation sound level shall be limited to a maximum of 45 dBA as measured by microphones spaced 3 feet apart at a distance of 50 ft. from the housing.

3.5.13 Supervisory Control and Data Acquisition

Essential substation data and condition shall be continuously monitored through a Supervisory Control and Monitoring System. The monitoring system shall also incorporate the remote control of key substation functions.

3.5.14 Miscellaneous

Telephone: A telephone with access to the DART Private Automatic Branch Exchange (PABX) Network will be provided in each substation as a part of the communications system.

Lighting: Adequate lighting shall be provided for normal working conditions inside the substations and in the immediate external area in accordance with the appropriate facility class as defined in the International Building Code (IBC) and local code.

Auxiliary Power: The power for station services (240/120 VAC) in and about the substations shall be provided. These loads include, but are not limited to lighting, battery charger, environment control, and SCADA.

Uninterrupted Power System: Maintenance free batteries and a battery charger shall be used as a backup power source for the SCADA and essential control and protection devices. In the event of a utility power failure, the batteries shall be designed to power essential and protection devices for eight hours.

Public Water and Sewer Service
The substations shall not be connected to the public water and sewer systems.

Safety Details
For further safety information see Chapter 12.

3.6 DC FEEDER SYSTEM

3.6.1 General

The DC Feeder System shall consist of cables and raceways designed to supply power from the substation to the OCS. Feeder conductors shall be insulated, conform to ASTM specifications, and be suitable for both wet and dry locations. The raceway shall be underground and the design for ductwork, embedment depth, and the manhole spacing shall be in accordance with the NEC requirements.

Underground feeders shall be protected against current surge due to lightning strikes where feeders transition from aerial to conduit encased.

3.6.2 Cables

Insulated cables appropriate for the voltage level in standard, readily available sizes will be used throughout the project. In every circuit, cable quantity and size shall be designed to provide adequate capacity and acceptable voltage drop.

All feeder cables shall be continuous from origin to equipment termination without using splices in intermediate pull boxes except as approved by DART.

The exposed positive and negative traction power cables shall be adequately supported on insulated racks or trays to mitigate physical damage possibilities. Flame resistant jacketed cables shall be used in exposed installations.

3.6.3 Raceways

External substation feeder cables shall be installed in polyvinyl chloride (PVC) ducts encased in concrete or similar material. Detail design and raceway routing from the interface manhole(s) just outside the substation to other locations, will be performed by the civil line section designers based on a conceptual layout provided by the electrification designer. Manholes and pull boxes shall be located to facilitate cable installation. Ducts shall be designed to include 50 percent spare capacity or a minimum of two spare ducts unless otherwise approved by DART.

OCS pole risers shall be galvanized rigid steel conduits.

3.7 OVERHEAD CONTACT SYSTEM

3.7.1 General

The Overhead Contact System (OCS) shall permit adequate current collection at the maximum train loads enabling the required service level to be achieved.

The OCS shall allow operation of 1 to 3 SLRV cars with associated train consist pantographs without causing excessive oscillation of the Overhead Contact System or pantograph bouncing. The Overhead Contact System shall be designed according to the American Railway Engineering and Maintenance-of-Way Association (AREMA) Chapter 33, Electrical Energy Utilization recommendations.

The design of the OCS shall be based on technical, economical, operational and maintenance requirements as well as on the local climatic conditions, which are outlined in Chapter 1 of these criteria.

In order to maintain the contact wire on the pantograph head, the design factors to be considered shall include catenary conductor blow-off, contact wire deviation due to movement of hinged cantilevers, mast deflection due to imposed loads, vehicle roll and lateral displacement, sway of pantograph, track maintenance tolerances, equipment erection tolerances, and a pantograph security factor.

3.7.2 OCS Configuration

a) A Simple Catenary Auto-Tensioned System (SCAT) consists of a messenger wire supporting a contact wire by means of hangers. SCAT will be used for LRT mainline at-grade and aerial sections.

b) A Twin Contact Wire System (TCWS) may be used in areas where the vertical clearance does not allow the use of the simple catenary system as may be the case at low clearance overhead bridges or similar structures. The catenary system will be supported by hinged cantilevers attached to wide flange steel poles located between the tracks whenever possible. In certain areas with DART approval, other pole configurations may be used. If necessary, at special locations such as track crossovers, turnouts and junctions, or where insufficient clearance is available poles may be located on the outside of the tracks. A headspan configuration or double track cantilevers may be used in multi-track areas where single poles are not practical.

c) A Single Wire Fixed Termination (SWFT) will be used in the yard and shop areas. The contact wire in the yard will be supported by means of single or back-to-back pole-mounted cantilevers, bracket arms, cross-spans, and headspans. In the shops, the system will be attached to the building structure.

d) Parallel feeders will be utilized where the capacity of the Overhead Contact System cannot satisfy the electrical load requirements. Parallel feeders shall be installed underground wherever they are required.

3.7.3 Contact Wire Height

The nominal contact wire height for various alignment segments shall be in accordance with the NESC as follows:

Wire Height Above Rail

Alignment Type	Minimum (*)
Segregated right-of-way	16'-0"
Mixed-used, pedestrian only	16'-0"
Mixed-use with road vehicles	18'-0"
Mixed-use with railroad	22'-0"

(*) "Minimum" is absolute minimum for the worst combination of tension, sag, temperature, construction and maintenance tolerances, and applicable electrical clearances.

Contact wire height shall be changed gradually to prevent pantograph bounce and arcing. The maximum gradients for contact wire change in elevation relative to the track elevation, shall be as follows:

Speed Limit/Location	Maximum Gradient
Yard	2.3%
0 - 30 mph	1.3%
30 - 45 mph	0.8%
45 - 65 mph	0.6%

The change of grade from one span to the next shall in the yard not exceed 1.15%.

3.7.4 Vehicle Data

See Design Criteria Manual, Volume 2, Systems Design, Light Rail Vehicle, Chapter 2

3.7.5 Climatic Conditions

The OCS design shall be based on the following climatic parameters:

a) Ambient Temperature

	Location At-grade/Aerial
Normal	70^{o} F
Minimum	4^{o} F
Maximum	115^{o} F

Normal temperature is the temperature at which the cantilevers in the auto-tensioned system are set perpendicular to the track.

b) Ice

Dallas is in the "heavy" ice loading area as outlined in the National Electrical Safety Code (NESC) and the ice loading for structural design shall be as follows:

- 0.5 inch radial on all wires

c) Wind

Based on the Basic Wind speed diagram outlined in the NESC, the wind loadings on the OCS equipment shall be as follows:

- With Trains Operating:

  1. 55 MPH with no ice.
  2. 40 MPH with ice on both wires (32F).

- With No Trains Operating

  1. 70 MPH with no ice

3.7.6 Conductor Loading

Conductor loading shall be based on NESC Rule 250-B, combined wind and ice loading, "heavy" loading district:

a) 4 LB/FT ^{2} horizontal wind pressure
b) 1/2 IN radial ice on conductors
c) 0.3 LB/FT constant added to the resultant

d) 0^{o} F temperature

3.7.7 Factors of Safety

The OCS conductors shall be designed in accordance with the factors outlined in the NESC under the loading conditions specified.

The permitted wear of the contact wire shall not be greater than 30 percent of the original cross sectional area.

3.7.8 Poles and Foundations

3.7.8.1 Steel Structures

Poles shall be wide flange galvanized steel with steel base plates. In aesthetic sensitive areas the poles may, with DART approval be designed to accommodate aesthetic requirements. OCS poles locations shall be reviewed with respect to signal pole locations to ensure signal visibility is not impaired. All poles, except those on aerial structures and other selected structures, shall be installed on cast-in-place reinforced concrete foundations, by means of embedded anchor bolts. On the aerial structures the poles shall be supported by means of anchor bolts installed through the deck.

The design of all steel structures, poles and supports shall conform to the AISC ninth edition - Allowable Stress Design "Specification for the Design, Fabrication and Erection of Structural Steel for Buildings." In all cases, these structures shall be designed to carry the OCS loads as outlined in these criteria, without experiencing failure. Provisions shall be made in the designs to accommodate overloading as a result of temporary construction loads imposed during OCS assembly and wire installation. The design shall conform to the following:

a) All steel materials and related processes and manufacturing methods shall be specified in accordance with ASTM standards, wherever applicable and deemed appropriate, including requirements for hot-dipped galvanizing of steelwork and hardware.

b) The design of bolted steelwork connections shall conform to AISC requirements and shall specify materials and methods in accordance with ASTM standards.

c) All welding shall conform to the AWS, Standard D.1, "Structural Welding Code."

d) Any required painting shall be specified to conform to the Steel Structure Painting Council, "Steel Structure Painting Manual."

3.7.8.2 Structure Deflection

OCS structures and foundations shall be designed so that their deflection, under the loads imposed, during normal operating conditions shall not cause a contact wire displacement that will jeopardize acceptable tracking and performance of the pantograph current collector.

The maximum allowable live-load operating deflection of the pole and foundation structure together at the normal design contact wire height shall be limited to 2 inches. For the purpose of structural design, this is considered to be a dynamic operating condition and the structure shall fully recover from its displacement due to this live loading.

For all non-operating loading conditions, the maximum total deflection of the pole and foundation together (measured at the pole top) shall not exceed 2.5 percent of the total pole length due to static (dead) loads and live loads combined. For the purpose of structural design, this condition shall be considered a dynamic operating condition, and the structure shall fully recover from its displacement due to the loading combination.

The foundation and steel pole, or vertical members of the support structure, shall be designed to enable the pole to be raked during construction. This rake shall allow for the static loads that are imposed on the structure by the cantilevers, headspans, equipment, and along track conductors to bring the top of the pole plumb with the base.

Poles shall be grounded by a bonding cable attached between the pole/pole base plate and a ground rod installed in conjunction with the foundation. On aerial structures the pole shall be grounded by means of a grounding cable installed in the anchor bolt pedestal and a ground rod installed at ground level. Poles without traction power feeders or surge arrestors shall have a resistance to ground that does not exceed 25 ohms. Poles with traction power feeders and/or surge arrestors shall have a resistance to ground that does not exceed 5 ohms.

3.7.8.3 Foundations

The design of all OCS foundations shall conform to the requirements and guidelines of the International Building Code (IBC), particularly with respect to the allowable lateral pressure criteria for foundation diameters and embedment depths;

and as generally applicable to non-constrained foundations. All foundation design shall be in accordance with the ACI Code and proven foundation and anchoring engineering methods. Foundation design shall be coordinated with the section designers. The design and construction of the pole and down guy foundations shall conform to established civil and structural engineering practices, ASTM and ACI standards and other applicable codes.

Existing geotechnical conditions shall be established by local field testing, sampling and soils investigations in accordance with the appropriate section of the DART Design Criteria Manual. Information suitable for satisfactory foundation design shall be obtained regarding the soil strata conditions, state, uniformity, water content, weights and densities and these shall be used in the foundation design. Uniform layer descriptions and their unique compositions shall be provided at regular intervals along the LRT right of way. These investigations shall also identify the sand and rock types encountered. The permissible increase in soil resistance values, as defined in the IBC, as being applicable to free standing structures, shall be taken into consideration in the OCS foundation design in accordance with the IBC formula.

3.7.9 Electrical Clearances

The minimum electrical clearance between live equipment and any grounded structure or equipment shall be as follows:

	Normal	Reduced
Static	5 in.	4 in.
Passing	4 in.	3 in.

Reduced clearances shall be used only with DART's approval.

3.7.10 OCS Hardware

OCS hardware for cantilevers, bracket arms, cross-spans, headspans, counterweights, etc. shall be made up of standard components, providing a proven, reliable, easy to install, and adjustable system.

3.7.11 Disconnect Switches

Disconnect switches shall be hand-operated with local control provisions or motor-operated with remote control provisions. Disconnect switches shall be installed as directed by DART. Hand-operated disconnect switches cannot be interlocked to prevent unsafe switch operation when the OCS is energized. Hand operated switches shall be provided with a means to install locks or locking devices.

Disconnect switches shall be mounted on the OCS poles whenever possible.

3.7.12 Catenary Tensioning

Counterweights used for catenary tensioning purposes shall be cast iron or steel, and they shall be mounted on the wide flange poles.

3.8 SIGNAL AND COMMUNICATIONS POWER SUPPLY SYSTEM

When signal and communication power supply feeds originate from the TPSS auxiliary power transformer and panelboard, provisions shall be made in the panelboard design to provide single phase, 480 VAC, circuit breakers. Conduit duct openings shall be provided in the substation flooring and foundation to provide underground service feeds to adjacent signal and communication bungalows. All openings shall be coordinated with other DART civil construction contracts for: routing; and signal and communication ductbank construction.

3.9 INTERFACES

The Traction Electrification design shall be fully coordinated and interfaced with the affected utilities, railroads, agencies, and other designs on this project. The major interface areas include:

a) Track Alignment
b) Trackwork Configuration
c) Utilities
d) Structures
e) Vehicles
f) Operations
g) Electrical and Mechanical Equipment
h) Signaling, Communications, and Train Control Center
i) Yards and Shops
j) Architectural
k) Corrosion Control
l) Passenger Stations
m) Real Estate
n) Noise and Vibration

CHAPTER 4

SIGNAL SYSTEM

Chapter 4

SIGNAL SYSTEM

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CHAPTER 4 – SIGNAL SYSTEM

4.1 GENERAL

This section establishes baseline design criteria for the signaling control system, circuits and equipment required for safe train operation on the Dallas Area Rapid Transit Light Rail System (DART) System.

4.1.1 General System Requirements

The DART Signal System includes four distinct operating modes: Street Running; Wayside Block Signal; Cab Signaling; and Yard Control with switch position indicators.

4.1.2 Street Running/Unsignaled Territory

The street running portion of the system is operated line-of-sight. In some areas, train movement is controlled by LRT bar signals that are controlled by the city’s traffic controllers.

At each end of the Central Business District (CBD), train-to-wayside (TWC) loops are used to initiate routes in the adjacent junctions.

When traffic preemption is required in unsignaled areas, Train detection may be provided by track circuits, TWC loops, or Loop Vehicle Detectors (LVD) to provide signals for traffic signal clearance offsets. As a minimum, detection in approach to the crossing is required to initiate a clearance offset, and detection in advance of the crossing is required to provide a clear signal to the traffic controller.

Where sight distance in an unsignaled section is restricted, Block Indicators are used to allow trains to operate at higher speeds in approach to the visually obstructed area.

Interlockings in unsignaled territory will be provided with switch position indicators to show that a route has been locked through the interlocking. Aspects on the switch position indicators will be as follows:

a) Green

Route aligned and locked for the normal/straight route. Proceed at authorized speed.

b) Yellow

Route aligned and locked for a diverging/converging route. Proceed at authorized speed.

c) Red over Yellow (where provided)

Call-on Stop. Contact Controller. Proceed at restricted speed when authorized.

d) Red

STOP - Remain standing for 30 seconds. Call controller for instructions.

4.1.3 Wayside Block Signal

The wayside block signaling sections use fixed wayside signals at interlockings and Automatic Block Signals (ABS) between interlockings. Signals shall be spaced to provide the required design headway using a double-red signal scheme.

The fixed block wayside signal system shall be equipped with 3-aspect color light automatic block signals and a wayside train stop system. ABS aspects will be consistent with DART Operating Rules and conform to the following:

a) Green

CLEAR - Proceed at authorized speed.

b) Flashing Yellow

APPROACH DIVERGE - Proceed, prepared to diverge at next interlocking.

c) Yellow

CAUTION – Proceed, prepared to stop at the next signal or end of auto block.

d) Yellow over Lunar

CAUTION - TIMED SECTION - Proceed in timed section not to exceed 55 mph.

e) Red

STOP - Remain standing for 30 seconds. Call controller for instructions.

At interlockings, signals shall be equipped with double heads, each with 3-aspects. A single head for a call-on aspect shall be located beneath the double heads.

4.1.4 Cab Signal

The cab signal system shall utilize cab signaling-enforced overspeed protection with wayside interlocking route indicators to ensure safe operation of trains.

Vital wayside and carborne train-control functions shall be generated with vital microprocessors. Vital plug-in relays shall be used for specific applications. All non-vital functions shall be performed using non-vital microprocessors.

The Signal System technology shall ensure safe and reliable control of the operation of trains upon the System. The system design shall be fail-safe and provide safe degraded operating modes.

Within interlocking limits, a positive train detection system shall provide detector locking. Train detection between interlockings shall be continuous and shall be accomplished by track circuits.

The wayside cab signal system shall transmit cab signal speed commands to the train. The carborne Aspect Display Unit (ADU) shall display the maximum enforced speed limit in the operating cab. During an overspeed condition, the carborne Automatic Train Protection (ATP) equipment shall remove propulsion power from the motors and provide both an audio and visual alarm to the train operator. If the overspeed condition exists for longer than a pre-determined length of time, or if the minimum braking rate is not maintained once initiated, the carborne ATP equipment shall command an irrevocable penalty-brake application request.

As a minimum, the system shall recognize and enforce at least 12 codes. A zero code shall be used to command a stop. The cab signal system shall interpret the absence of code in cab signaled territory as a failure.

In addition to the mainline ATP speed commands, a code shall be available to switch the cab signal operation to manual mode. A manual mode command shall be transmitted to trains approaching the end of cab-signaled territory. This command will allow the train operator to drive the train manually in the street-running and wayside block signaled portions of the System at speeds up to 65 mph.

Trains entering cab signaled territory shall be switched automatically from manual mode into the cab signal operating mode.

Prior to leaving a yard or storage track, the onboard ATP equipment shall have passed self-test to establish that both the vital and non-vital portions of the equipment are fully operable.

At Interlockings in cab-signaled territory, the signal system shall be a 4-aspect route indicator and a wayside train stop system. Indicator aspects will be consistent with DART Operating Rules and conform to the following:

a) Green Arrow/Green Aspect

PROCEED, NORMAL - Proceed straight route.

b) Yellow Arrow/Yellow Aspect

PROCEED, DIVERGING - Proceed on diverging route.

c) Red over Yellow

Call-on - Stop. Contact Controller. Proceed at restricted speed when authorized.

d) Red

STOP - Remain standing for 30 seconds. Call controller for instructions.

4.1.5 Operations

In street running and ABS portions of the system, primary responsibility for safe operations is the responsibility of the vehicle operator. The operator will be responsible for operating under the designated maximum speed for the section of track upon which the train is operating in accordance with the last wayside signal aspect and operating rules. Train stops at all wayside signals will enforce braking should a train pass a signal displaying a stop aspect.

In cab signaled sections, ATP will enforce operation to the safe operating speed based on track conditions.

At terminal interlockings, on-board TWC equipment will be used to transmit information to the system indicating that the train is ready to depart. When the terminal Interlocking mode is “Auto”, the TWC signal shall initiate the appropriate route request.

Interlockings will be provided where junctions, crossovers, yard tracks, terminals, or pocket tracks are installed.

Passenger information signs will be provided at terminal stations and at intermediate dispatch stations to indicate from which platform the next train will depart. The ‘next train’ logic shall be derived and provided by the signal system.

The signal system will be designed to meet DART operational requirements as presented in the Operations Criteria Chapter.

The signal system design shall provide a 3 minute design headway on all branches. Design headway calculations shall be made using a dwell time of 20 seconds, with all trains stopping at all stations. Junctions will be designed to support a 90 second design headway on the common branch.

4.1.6 Safe Braking Distance

4.1.6.1 Wayside Block Signal

The braking rate shall be based on fail safe application of the friction brake system instantaneously applied in the emergency mode. Signal spacings shall be based on the friction brake rate adjusted for rail adhesion and safety factors using the following formula.

$$B_D = RD + ((1.467*S_o)^2 - (1.467*S_i)^2) / 2(BR - G*0.33)$$

B_D = Braking distance in feet

BR = Braking rate = -2.45 fpsps

S_i = Initial speed at train stop in mph

S_o = Final or end speed in mph

G = % Grade: positive for up grade, negative for down grade

RT = Reaction time = 3.0 seconds

RD = Reaction distance = 1.467 x RT x S_i

Reaction time is based on a maximum power removal time of 1.5 seconds, a mode change dead time of 0.5 second, and a brake build-up time of 1.0 second. The worst case adhesion rate of 1.67 mphps is also used.

4.1.6.2 Cab Signal

Safe Braking Distance for determination of proper speed codes shall be based on a braking model that simulates the worst case braking effort. The model shall simulate braking as a series of consecutive events, defined as follows:

a) Primary Reaction Distance – The distance traveled by a vehicle at the initial velocity as it crosses a block boundary. The distance is that traveled through the “dead” section where a valid code may be unavailable. The initial velocity to be used is the previous speed code plus the overspeed tolerance of the vehicle cab signal equipment. In the model, acceleration due to downhill slope should be considered.

b) Code Recognition Time – The worst-case period that the vehicle equipment would take to recognize a valid speed code. Assume the vehicle is speed-maintaining through this period. Include acceleration due to downhill slope.

c) Runaway Acceleration – Assumes a propulsion system control failure that sends the vehicle into full acceleration at the maximum available rate adjusted for grade. The runaway acceleration occurs until the system has detected an overspeed condition and initiated power removal.

d) Mode Change Time – The time for the vehicle equipment to remove power and initiate a brake command after an overspeed has been detected. During this period, power is removed and acceleration force of grade is included.

e) Brake Build-up Time – The time from the initiation of braking until full deceleration is achieved. During this period, braking shall be calculated as a linear increase from 0 to full braking.

f) Constant Braking – When the brakes have built up to maximum deceleration, the braking model shall complete the braking at a constant brake rate adjusted for grade. Twice the vehicle overhang distance is added to this value.

4.1.7 Equipment Requirements

Modular design shall be used throughout the systems. Electrical and mechanical components shall be organized in plug-in assemblies wherever practical and be rack mounted.

4.1.7.1 Rack Mounting

All equipment and components mounted on racks shall be accessible for testing or replacement without removal of other components.

Design shall provide for cooling air space around all transformers, rectifiers, reactors, and other heat generating devices.

All relays, equipment, and entrance racks will have reference test points for all voltages associated with the equipment installed on such racks.

4.1.7.2 Environment

Physical:

All equipment housed in CIH's and cases will be designed to function without damage within a temperature range of –40ºC to +71ºC (-40ºF to +160ºF) and relative humidity of 0 percent to 95 percent, noncondensing.

Any equipment housing that will hold microprocessor equipment shall have forced ventilation and air conditioning. Both fan and air conditioning shall be thermostatically controlled. The control shall be interlocked so that at a selected temperature, the fan is switched off and the air conditioner is switched on.

Vibration:

Signal equipment shall be designed to operate safely and reliably while exposed to vibrations of 2-10 Hz, 0.2 inch displacement, peak to peak; and at 10-500 Hz. at 1.0G.

4.2 VITAL FUNCTIONS

A vital function is any circuit or software logic that can affect safety of train operations. All vital functions shall meet the fail safe design principles described herein.

Fail Safe Design Criteria - Vital logic design shall be based on closed loop circuit principals with the operator considered as an active element.

Component or system failures that are not self-detecting shall not cause unsafe conditions, even if added to other failures. Any number of simultaneous component or system failures attributable to the same cause or related causes shall not cause unsafe conditions.

Any component becoming grounded, or any combination of such grounds shall not cause unsafe conditions.

4.2.1 Vital Relay Systems

Vital relay circuits shall meet AREMA Signal Manual requirements.

Except when specified, all circuits which leave a housing shall be double break, using ungrounded DC power supplies. Side-by-side above ground housings interconnected by vandal proof, weather tight enclosures shall be considered one housing. The cable way between adjacent housings shall be limited to a 50 percent fill limit.

Vital functions contained within a CIH or case shall be positive energy, single break equations or circuits.

All vital repeater relay circuits shall be designed on the cascade principle. Paralleling of vital repeater relays shall not be permitted.

Repeater relay contacts shall be so assigned that safety will not be compromised by failure of any repeater relay to energize.

Non-vital contacts used in vital circuits shall only be permitted in the energy feed of a circuit. If non-vital contacts are used in vital circuits it shall be assumed these relays can fail and an armature may stick in any position. None of the above events shall cause an unsafe condition.

4.2.2 Vital Microprocessor Systems

Where used for interlockings, redundant vital processor systems shall be installed in a warm standby configuration with an automatic switch-over when a failure is detected.

4.2.3 Locking Functions

Locking functions shall prevent unsafe switch operation and prevent clearing of signals for opposing or conflicting routes. Types of locking to be provided are as follows:

4.2.3.1 Approach Locking

Approach locking shall lock switches within a route governed by a cleared wayside signal when a train is occupying the approach circuit to such signal. Once initiated, approach locking will remain in effect until the locking time has transpired or until released by the occupancy of the first two track circuits in the locked route. Approach locking shall prevent clearing of wayside signals for opposing or conflicting routes for a predetermined time after a cleared wayside signal has been reset to stop unless the approach to such signal was unoccupied while the signal was cleared. Approach locking shall be provided for all controlled signals. Approach release time shall be calculated in accordance with AREMA Signal Manual Section 2.4.20.

4.2.3.2 Time Locking

Time locking shall be provided for electric locked hand-operated switches within a route governed by a cleared wayside signal. Opposing or conflicting routes shall be locked until released by Train Control Center (TCC) or the local control panel.

4.2.3.3 Route Locking

Route locking shall lock all switches within a route when a signal is cleared and shall maintain the locking after a train has accepted the wayside signal governing such route and completed its travel through the route. Portions of the route behind the train shall be released when it is safe to do so. Route locking shall also lock switches outside the route when set by the route-selection system to provide overrun fouling protection.

4.2.3.4 Sectional Release

Where necessary to meet headway requirements, switch locking circuits shall be designed with sectional release. Such design is required to release each switch after the final axle of a vehicle has vacated the detector locking track circuit, providing that the train no longer fouls the vacated portion of the route.

4.2.3.5 Detector Locking

Detector locking shall lock all switches within the limits of a track circuit when such track circuit is occupied. Detector locking shall not be released by momentary loss of shunt.

4.2.3.6 Switch Locking

Switches at interlockings shall be locked by approach locking, time locking, route locking, and detector locking. Switch locking shall be released when approach locking, time locking, route locking, and detector locking are released.

4.2.3.7 Time Release Locking

Time Release Locking is to provide safe entry into an occupied turnback track, storage track, or terminal track. The vital timer shall be adjustable from 5 to 60 seconds. Time release shall operate upon detection of train occupancy in a turnback track, storage track or terminal track, and thus allow a call-on signal to be requested after completion of time. The length of time adjustment shall ensure the train occupying the interlocking can stop before a call-on route is allowed.

All vital timing functions required to energize a circuit shall use vital timers with adjustable time settings. Mechanical timers shall provide back check logic. Such back check logic in a vital circuitry will assure that time has fully run before reset. Time settings shall be shown on route and locking charts and on circuit drawings next to timer symbols. Each signal shall have a dedicated timer.

4.2.3.8 Traffic Locking

Traffic locking shall prevent clearing opposing signals into a section of track. Individual traffic circuits shall be provided for each section of track between interlockings.

Direction of traffic shall be locked on a section of track over which traffic locking is provided when any track circuit within that track section is occupied, when traffic direction is requested into that track section, or when approach or time locking is effective for a signal which had been cleared into such track section. Traffic direction, once established will remain locked until unlocked and a request is made to enter from the opposite end. Traffic direction shall be locked while the traffic section is occupied, including the exiting interlocking track circuits except where the route is freed by sectional release.

A signal governing movement into a section of track for which Traffic Locking is effective shall not clear until traffic direction has been established and locked in the direction of movement and the individual traffic relays in each ABS case are picked in proper alignment for the direction of traffic.

Clearing of ABS signals will be controlled by the direction of traffic. ABS signals will not clear until traffic relays for the proper direction are energized.

Traffic logic shall initiate a change of direction by a route request from the local train storage system without the aid of the remote train storage subsystem or presence of a person at the adjacent signal CIH.

4.2.4 Signal Clearing

Route check circuits shall be provided to prevent premature locking. The route check shall initiate signal clearing for each signal which governs movement over a track containing a track switch. A route check relay shall be energized to initiate wayside signal clearing only when switch point positions correspond to the positions required for the route between the selected entrance and exit points, an opposing signal has not been called, and an opposing movement is not in progress.

Signal clearing shall be effective for the route selected when the proper route check relay is energized, and approach, time, and traffic locking for an opposing or conflicting route is not in effect.

For signals that do not govern movements over track switches, signal clearing shall be initiated directly from the entrance point if an opposing signal has not been called and no opposing train movement is in progress.

Signal indication circuits shall indicate and distinguish between a signal being called, the same signal being clear, and such signal being in time locking.

4.2.5 Signal Lighting

A signal indicating route alignment shall display aspects as previously described. Each signal aspect shall be energized through vital contacts or driver circuits. Such aspects shall be energized when the route is aligned regardless of presence or absence of a train in approach to the signal. Occupancy of the approach shall energize the signal regardless of traffic direction. Signal lighting circuitry shall prevent undesirable flashes of inappropriate aspects when changing from one aspect to another.

4.2.6 Fleeting Circuit Requirements

Fleeting circuits shall automatically reestablish energy to the signal clearing circuit, after train passage, whenever a fleet control button for a signal has been placed in fleeting position. Fleeting shall be provided for normal and reverse direction of traffic.

When a signal has been fleeted, it shall not re-clear until circuit requirements are met as defined by the control lines.

Canceling a fleet request shall not cancel the route.

4.2.7 Signal Blocking

Signal Blocking Circuits shall be provided for each interlocking signal. Blocking circuits will be initiated from TCC or the local control panel. Signal blocking will prevent an exit at the signal selected. Signal block circuits shall be interfaced with the vital home relay circuits to prevent an exit at the signal selected and interfaced with non-vital logic circuits to prevent a preliminary exit indication at the signal selected.

4.2.8 Line Circuits

Line circuits shall be provided to pass information between locations. Line circuits may be dedicated, traffic reversed, DC coded, or vital serial communications, as necessary to provide complete logic information to control trains.

4.2.9 Approach Circuits

An approach circuit shall be provided for each interlocking signal. The approach section shall include all track circuits in approach of the interlocking signal within braking distance of such signal. Where signals are approach cleared, additional approach circuits used to make a signal request shall include track circuits in approach to the approach signal sufficient to ensure that the home signal can clear (including worst case switch throw time) and that the approach signal is cleared to allow at least three seconds of viewing time for a train traveling at the maximum allowable speed.

4.2.10 Lightning Protection

Lightning protection shall be provided in the design of the Signal System in accordance with AREMA Signal Manual Part 11.2.1. In addition, the design shall provide for lightning protection and surge protection on all track circuits and electronics. Inputs to electronic components from devices external to the case or instrument house where the electronic equipment is located shall be protected.

4.2.11 Track Circuits

4.2.11.1 ABS Areas and Crossovers

Track detection shall be accomplished by two-element vane relay type track circuits, utilizing 100 Hz steady energy. Shunting sensitivity shall be 0.25 ohm under dry weather conditions. Track circuits shall be capable of properly functioning in a direct current traction power system environment, utilizing vehicles with AC traction motors.

Track circuit shall provide broken rail protection for both rails on normal routes and single rail circuits on the crossover portion of turnouts.

Track circuit equipment shall either detect the failure of any insulated joint or protect against it causing an unsafe condition.

Track circuits shall operate correctly with ballast resistance as low as 5 ohms per thousand feet.

Five second loss of shunt protection shall be included within interlockings to prevent switch movement within such time period.

Design of the track circuit system shall take into consideration cross bonding for traction power negative returns as required.

4.2.11.2 Cab Signal

Main line track circuits in cab signaled territory shall be jointless audio frequency type.

Track circuits in crossovers shall be power frequency. Loops through turnouts shall be used to transmit speed codes.

4.2.12 Switch Operating Circuits

Switch operating circuits shall enable power switch machines to operate if locking is not in effect. Switch operating circuits shall be two-wire. Each switch machine motor shall be energized by an individual ungrounded power supply. Power shall be removed when the switch has reached the requested position and is in correspondence.

4.2.12.1 Switch Overload

Switch overload circuits shall protect each switch-and-lock movement by using a switch overload stick circuit. An overload stick circuit shall be provided for each switch machine motor. Overload circuits shall remove energy from a switch machine when the operating current rises above the desired maximum due to stalled points or other causes of overload. Once the overload has occurred, energy shall remain off until the switch is called to the opposite direction. Time for pickup of the overload relay shall be the manufacturer's recommendation, but shall not exceed ten (10) seconds.

4.2.12.2 Switch Repeater

Switch repeater circuits for switch-and-lock movements shall indicate the normal or reverse position of switch points. One normal and one reverse switch repeater relay shall be provided for each crossover or turnout. When the switch repeater relay is controlled by two or more switches that make up a crossover, all switches must be mechanically and electrically locked in a normal or reverse position before switch repeater circuits can be energized.

4.2.12.3 Switch Correspondence

Switch correspondence circuits shall have relays separate from switch repeater relays and check that position of the switch in the field is in agreement with the position requested at TCC or from the local panel. Switch correspondence circuits shall indicate correspondence between switch position and switch request. One normal and one reverse switch correspondence relay will be provided for each crossover. A switch correspondence relay shall be energized when position of switch points as indicated by the switch repeater circuit agrees with the switch request as produced by switch control circuits.

4.2.12.4 Switch Blocking

A switch blocking circuit shall be provided for each switch within an interlocking. The block will be initiated from TCC or the local control panel. This block shall be vitally interfaced with switch and signal circuits to prevent operation of such switch when the block is in effect.

4.2.13 Control Functions

The following conditions are necessary to clear a route:

a) All switches are aligned and locked in the proper position.

b) Traffic is properly aligned and locked in the direction of travel for the track section being entered.

c) Tracks are unoccupied within the interlocking route being cleared and an overrun condition does not exist.

d) An unsafe or conflicting condition does not exist. All special conditions required by the interlocking are satisfied.

When a cleared route is canceled, interlocking logic shall ensure time locking and traffic locking remain in effect for a calculated time. Time shall be calculated based on sufficient time to achieve braking to a full stop and not overrun the signal. Logic shall not run time when the approach block to the specific signal is, and has been unoccupied while the signal was clear.

When a route is canceled there shall be no attempt to provide automatic routing for the next train which occupies the approach or advance approach at the time of canceling.

In ABS territory, the signal system shall allow trains to proceed at rule book speed up to an interlocking signal at stop. A magnetic train stop shall protect overrun by causing an emergency brake application.

At turnback tracks, storage tracks, terminals or other special circumstances, automatic routes shall not be cleared when the destination track is occupied. TCC, local control panel or wayside push button will request a call-on or restricting route. A call-on will be displayed after a predetermined time to ensure an approaching train has stopped.

Train destination routing shall be used at locations where two or more destinations are possible. Train destination shall be decoded from TWC prior to the advance approach track. Route requests shall be initiated at the signal in advance of the distant signal, if conditions permit. If the route cannot be cleared, the destination shall be stored and the route initiated when conditions permit. The system shall use a storage register to store requested routes for all following trains entering an automatic routing zone. The storage register shall advance when the train enters the interlocking. When storage register identities are out of sequence with actual conditions it shall be corrected by a storage register identity clear out circuit

Train ready routing shall be initiated from a train ready indication sent by the TWC subsystem. Operation of the train ready button on a vehicle shall request routes at terminals.

Auxiliary Switch Control circuit shall be initiated by a signal from the TWC to move power operated switches either normal or reverse for designated automatic routes.

At converging junctions or other locations as required, TCC shall have the capability of inhibiting any automatic route from being initiated while in automatic operation.

If the data link to TCC is not functioning, the inhibit shall be removed and the signal will operate automatically. Automatic signal inhibit must be initiated for each train.

4.3 NON-VITAL FUNCTIONS

Non-vital circuits may use vital or non-vital equipment as predicated by design requirements.

Non-vital circuits which leave a CIH or case may be single break.

Logic to perform the following functions shall be provided. These functions shall include, but not be limited to:

4.3.1 Route Clearing

Route clearing shall be entrance/exit logic from local, automatic and Train Control Center.

4.4 SYSTEM CONTROL

In the TCC, an overview display will show status of the entire System. Individual terminals will permit detailed monitoring of smaller sections of the system or individual interlockings. Subsystem failures that could affect the safety or reliability of the System will be shown as alarms. Functions available to dispatchers shall include the ability to control interlockings for special moves or hold trains at stations.

Controls and indications shall be communicated between wayside signal equipment and the TCC via the SCADA system. The signal system shall provide RTU functions to collect required information and communicate it in the necessary format and protocol.

4.4.1 Control Mode Hierarchy

Local control panels shall be provided with two key-operated switches that permit an override of TCC control. The mode-selector switch shall allow switching from Automatic or Local control to TCC control. To switch out of the TCC mode, a signal releasing control must be received from the TCC. An emergency key-operated switch shall allow an override and permit control to be switched without TCC concurrence.

4.4.2 Automatic Routing

Circuitry to automatically align routes shall be as follows:

4.4.2.1 Automatic Clearing - Route

All normal direction routes shall be automatically cleared.

4.4.2.2 Automatic Clearing - Train Destination

Detection of a train on the advance approach shall cause the initiation logic to clear a route depending on train destination.

If the route is not available while the train is on the advance approach and has subsequently moved into the approach circuit, the logic shall wait until the route is available and then clear the signal.

When an automatically cleared route is canceled, it shall not reclear automatically until the advance approach and approach become unoccupied by the train that requested the signal to automatically clear.

4.4.2.3 Automatic Clearing - Approach Only

Interlocking signals with one possible automatic route shall be cleared by train detection only. When more than one train is within the advance approach, the signal will clear for each succeeding train as conditions ahead permit.

4.4.2.4 Automatic Clearing - Train Ready

Operations at turnbacks and terminals may require special automatic clearing methods. Detection of train ready from the TWC system shall be provided as necessary to clear automatic routes.

4.4.2.5 Destination Decoding, Storage and Transmission

ID and destination received from the train via TWC shall permit the clearing of interlocking signals.

4.4.2.6 Unidentified Train

An unidentified train ID or destination shall be entered in the proper message sequence with other normal trains. The unidentified data may be generated by the decoder when an incorrect TWC message is received or by track occupancy when no TWC message is received.

4.4.2.7 Automatic Register Clear

A register clear shall be generated when a code is stored and a train is not on the advance approach or approach (code without a train) or when there is a train on the advance approach or approach and there is no code in the register (train without a code).

4.4.2.8 Route Rotating Priority

Automatic route rotating priority shall be provided to control the flow of trains through interlockings where conflicting automatic and/or wayside push button requests will be vying for routes through interlockings.

4.4.3 Terminal Control

Train operation at terminal interlockings shall be sequenced by mode selection. Dual mode control logic that can be controlled by the local control panel or TCC shall be provided. Mode selection logic shall automatically determine the tail track and/or platform track that each train will take as it arrives at the terminal. Operation shall be as follows:

a) Mode 1 will be set for trains approaching terminal locations to diverge to the left side track station platform and depart from there on a straight route.

b) Mode 2 will be set for trains to alternate platforms when more than one train is to be at the station at one time.

c) Mode 3 will be set for trains to approach terminal locations on the right side track and cross over upon departure.

If both tracks are available, the train will be routed to the normal inbound departure track.

4.4.4 Local Control Panel

The local control panel shall utilize push button operation to control entrance/exit logic operation at all locations. The local control panel shall have a key operated control mode.

Control push buttons and indicators shall be provided to enter route requests, operate switches, enable automatic routes, control terminal mode and indicate status of power, fuses, grounds, and other miscellaneous information.

4.4.4.1 Switch Position Indication

A Switch Position Indication push button shall be provided. When pushed and held in, it shall cause all current switch positions to illuminate. It shall be possible to operate this button without use of the key switch to observe switch positions.

4.4.4.2 Entrance/Exit Operation Control

Interlockings shall be provided with entrance/exit operation for route selection/signal clearing. A push button shall be located on the track diagram at each possible entrance or exit point. Pushing an entrance/exit push button shall establish an entrance request, which will cause the appropriate entrance indicator to illuminate steady white, and cause the indicators at push buttons for all available exits to illuminate flashing white. Pressing one (1) of the available exit push buttons shall establish a route between selected entry and exit points, and shall cause all other flashing exit indicators to go dark.

Routes shall be canceled by pulling the signal indicator push button for the entry point of the specific route.

4.4.4.3 Terminal Mode Selection

Terminal mode selection shall be by means of a rotary selector switch located on a separate panel. The panel may be located within the CIH, adjacent to the local control panel, or in a weatherproof box in the station area. Terminal mode functions shall be made available in the TCC via the SCADA system. The selected mode as described in Section 4.4.3 will be indicated by yellow lamps.

4.4.4.4 Panel Indications

Indicators provided shall include (but not be limited to) the following functions:

a) TCC/Local Indicator.

b) Signal Indicators.

c) Switch Position Indicators.

d) Switch Locked Indicators.

e) Traffic Direction Indicators.

f) Interlocking Track Occupancy Indicators.

g) Non-Interlocking Track Occupancy Indicators.

The following alarm indicators are to be illuminated when the associated alarm condition exists, regardless of TCC/Local switch and Panel Lights switch position. These alarms shall be sent to TCC and also be used to control the CIH alarm light in conjunction with the high temperature alarm:

a) Blown Fuse Indicators.

b) Power Off Indicators.

c) AC Line Indicators.

d) Data Transmission System Failure Indicator.

e) Ground Detector Indicator.

f) Wayside Case Failure Indicators.

g) Intrusion Indicators.

4.4.4.5 Switch Preconditioning

Switch preconditioning is prohibited.

4.5 NON-VITAL ELECTRONIC CIRCUITS

Non-vital electronic circuitry shall be used in conjunction with relay logic circuitry where applicable. Diode based circuits may be used where applicable to provide isolation of energy in non-vital circuits.

TWC circuits and associated equipment for automatic ID routing (destination decoding and shift register) shall be microprocessor based.

4.6 ENERGY DISTRIBUTION CIRCUITS

Source energy for the signal power distribution system shall be obtained from Traction Power Substation auxiliary panelboard breakers. Where required and DART approved, the design may use a TXU power source in lieu of the signal power distribution center source.

Distribution circuits shall distribute AC and DC energy to the racks and equipment with voltage drops of less than five (5) percent maximum. Such drop shall not affect the proper performance of equipment. These tolerances shall be measured between power source and load.

4.6.1 AC Power Distribution

AC power shall be distributed as required to all signal locations. Signal power distribution centers shall be provided as near to the Traction Power Substation as possible. Power distribution centers shall consist of two-480 VAC two pole, thermal magnetic, molded case circuit breakers housed in NEMA 12 enclosures.

Step-down transformers shall be provided at each location as required by the design.

The design shall provide protective devices for each function such that failure in one (1) circuit will not affect more than one (1) function. Function to be individually protected shall include but not be limited to the following:

a) Each power supply,

b) Each wayside signal,

c) Each traffic rectifier,

d) Each switch machine rectifier,

e) AC ground detector,

f) Each AC track circuit,

g) RTU Power Supply,

h) Interface circuits to TCC.

4.6.1.1 ABS Territory

Distribution voltage shall be 480 volts 100 Hz for track circuits and 480 volts 60 Hz for signal power. The source for track circuit power shall be from a solid state frequency converter located at signal power distribution centers. Signal power distribution shall consist of one 480 VAC single-phase two wire 100 Hz track circuit power and 480 VAC single-phase two wire 60 Hz express power cables installed in an underground duct system, cable trough or trench along the right-of-way. Sectionalizing shall be provided in the transmission line by means of double pole, single throw switches at various locations.

4.6.1.2 Cab Signal Territory

480 Volt, 60 Hz power shall be obtained at the SPDC and distributed to signal equipment locations.

At interlockings, inverters shall convert DC battery source to 100 Hz. supply for power frequency track circuits.

At junctions and terminal interlockings, an alternate source for back-up AC power shall be obtained. An automatic transfer switch shall detect when the primary source value drops below a set limit and transfer to the alternate source. The transfer switch shall automatically restore the system to the primary source when the voltage of the primary source rises to a set value after a delay to ensure stability.

Where an alternate source is provided, the load shall be segregated onto “Essential” and “Nonessential” busses. The

Essential buss shall receive power from the automatic transfer switch and the Nonessential buss shall receive power from the primary source only.

4.6.2 DC Power Distribution

DC power shall be produced at each signal equipment control location using transformers and rectifiers appropriate for the application. Backup batteries shall be sealed type with no outgassing or requirements for adding water. Batteries and chargers shall be provided at all CIH's for all vital and non-vital circuits and/or processors.

Positive and negative DC energy shall be distributed on logic racks in the form of energy loops. Wire size of the energy loop shall be capable of carrying full loop current.

A voltage reference wire for each power buss shall be designed to serve racks, wayside equipment, junction boxes, switch machines, and other required components. This reference wire shall provide a means for voltage readings when only one side of the power buss is used in any particular location.

4.6.2.1 ABS Territory

Batteries shall be designed to support operations by preventing signal system stick circuits or similar software logic from canceling after a power failure is restored. Batteries shall be sized to hold stick circuits or processor memory for 8 hours after power failure. The circuits shall be designed such that energy from one fuse does not connect to energy from another fuse.

The design shall provide protective devices for each function such that failures in one circuit will not affect more than one function except on logic racks. Functions to be protected individually shall include but not be limited to the following:

a) Each track circuit,

b) Local Control Panel Lighting,

c) Local Control Panel Controls,

d) Each TWC Unit, route decoder, and storage register.

4.6.2.2 Cab Signal Territory

All equipment necessary to operate normal routes using cab signals and to maintain data communications shall have at least eight hours of battery backup, calculated to include rush hour service levels.

4.6.3 Ground Detection

Ground detection shall be provided on the 110 volt AC used for signal lighting and other signal functions and for ungrounded DC voltage used for line and logic circuits.

4.7 WAYSIDE SIGNAL EQUIPMENT

This section defines the design requirement of wayside signal components including:

a) Switch-and-Lock Movements

b) Impedance Bonds

c) Rail Connections

d) Insulated Joints

e) Conduits and Accessories

f) Cables

g) Overlay Track Circuits

h) Loop Vehicle Detectors

i) Wayside Signals

j) Wayside Train Stops

k) Housings

l) Train-to-Wayside Communications

m) Junction Boxes

n) Carborne Equipment

4.7.1 General

All wayside signal system equipment shall be designed, constructed, and installed to operate in an environment encountered in the Dallas area. The following particular conditions shall be used as design guidelines and shall be considered as operational requirements. Actual localized temperatures and conditions within spaces and enclosures may be more severe than the ambient climatic conditions and shall be evaluated during the design effort to ensure that no damage occurs during manufacture, storage, and shipment as a result of climatic conditions that differ from those below:

Temperature & Solar Load:

Minimum ambient air temperature external to equipment:	4°F
Maximum ambient air temperature external to equipment:	115°F
Maximum solar radiation:	275/BTU/hrft^2
Maximum daily temperature range:	50°F
Average days less than 32°F	38

Precipitation:

Maximum rainfall rate (may occur simultaneously in a worst case wind):	7"/hr.
Maximum snowfall: Measurable quantities	(infrequently)
Ice: Measurable quantities	(infrequently)

Average Relative Humidity:

Morning:	82%
Afternoon:	56%
Max Average:	87%

Wind:

Average speed:	11 mph
Maximum sustained for 1 minute:	70 mph
Maximum gusting:	70 mph

Air Contamination. Equipment shall operate as specified in the atmosphere commonly found in rail vehicle environments and the Dallas Metropolitan region. These include the following:

Particulates:	
Average:	0.175 mg/m^3
Maximum	0.324 mg/m^3
Ozone:	0.200 ppm, max.
NO2:	0.25 ppm, max.
SO2:	262 µg/m^3
CO:	20 ppm, max.
Chloride:	13.9 mg/m^3
Moisture Acidity pH	4.41

4.7.1.1 Clearance

Wayside signal equipment shall be located outside the Light Rail Vehicle dynamic clearance envelope.

4.7.1.2 Installation

Wayside signal equipment shall be installed in a manner to be directly accessible for maintenance and to allow for efficient removal and/or replacement. Signal equipment shall be installed so as to cause a minimum of interference with periodic track maintenance.

4.7.1.3 Wayside Signal Equipment Grounding

A grounding system shall be provided for wayside signal system equipment in accordance with AREMA Signal Manual Section 11.4. It will be the installation contractor's responsibility to develop a grounding system for wayside signal equipment for connection to a ground network provided by others, where applicable. DC resistance to ground shall not exceed 5 ohms.

4.7.2 Main Line Switch-and-Lock Movements

Remote controlled main line switch-and-lock layouts shall include a dual control 120 VDC switch-and-lock movement with a maximum switch throw distance of 4 3/4 inches. Switch-and-lock movements shall be mechanically coupled to the track switch points and securely mounted to ties in ballasted track areas or secured to concrete in direct fixation areas. Switch-and-lock movements shall be insulated from the track and be at ground potential only where the mechanical connection to the tie is in contact with earth.

The signal system contractor shall interface to track switch equipment. The track contractor will supply one operating basket for each switch. The signal system contractor shall supply the basket nuts (cone and lock). Track contractor will supply and dap the headblock ties, and extra length ties, as required.

4.7.3 Impedance Bonds

4.7.3.1 General

Impedance bonds shall be provided at all locations requiring signal system and traction power return interconnection with the running rails. Track windings of the impedance bond shall be capable of carrying maximum current requirements of the Traction Electrification System. Impedance bonds shall function properly with a traction current imbalance within ten (10) percent.

Impedance bonds shall be capable of sustaining a surge of 10,000 amps per rail for one (1) second.

Where provided in cab signal territory, impedance bonds shall include tuning units for track circuit transmitter and receiver frequencies, as well as the cab signal frequency.

4.7.3.2 Installation

In tie and ballast areas, impedance bonds shall be mounted to provide a minimum of one (1) inch clearance below top of rail using lag screws to fasten the layout to the ties. If signal system contractor's impedance bond layout requires a separate field tuning unit both bond and tuning unit shall be mounted together on a steel plate and fastened to the ties. When mounted on concrete ties, stainless steel fasteners shall be used to secure the steel plate.

On direct fixation locations, impedance bond layouts shall be mounted to provide a minimum of one (1) inch clearance below top of rail. There shall be a one-half (1/2) inch minimum space under the impedance bond. If a separate tuning unit is required, tuning units and bond shall be mounted on a steel plate and the plate affixed to the concrete with one-half (1/2) inch space under the plate.

4.7.4 Rail Connections

4.7.4.1 General

The signal system contractor shall provide and test all connections, cable, and connection accessories required on the running rails. Cable size No. 6 AWG and larger shall be connected to rails via exothermic welding.

4.7.4.2 Impedance Bonds

Traction power track leads shall be connected to the center of the rail web by exothermic welding. Crossbonding shall be provided at locations to be determined by block design and traction power requirements. Crossbonding cable shall be connected to the impedance bond center tap. Substation negative return cables shall be installed from impedance bonds to riser terminal cable adapters in accordance with traction power requirements. Substation negative return cables shall be connected to the bond center tap.

4.7.4.3 Mechanical Joint Power Bonding

Rail head bonds shall be provided for mechanical joints (minimum of two (2) 250 KCMIL), frog jumpers (minimum of a single 500 KCMIL), switch point jumpers (minimum of a single 500 KCMIL), and fouling jumpers (minimum of two (2) 500 KCMIL) as required. Size of the jumpers shall be coordinated with the Traction Electrification System and provide maximum broken rail protection. Traction power jumpers shall be connected to the rail by exothermic welding.

4.7.5 Insulated Joints

Insulated joints shall be furnished and installed by the track contractor at locations determined by signal system design. Staggered distance of a pair of insulated joints shall not exceed 4-1/2 feet and the preferred distance will be 2-1/2 feet.

4.7.6 Conduit and Accessories

Typically, all conduits under track will be provided by the civil contractor. The signal system contractor shall provide all conduits and accessories above ground required for the wayside signal system equipment. Conduit used above ground shall be galvanized rigid steel. All open unused entrances in the cable tray shall be closed by the contractor. All ballast or road surface removed or altered during conduit installation shall be restored to original condition by contractor. Location of conduits shall be indicated on the cable plans. Contractor shall leave thirty (30) percent spare space in conduits.

4.7.7 Cables

Cable used for vital signal circuits shall be specified in accordance with standard signal industry practice for vital signal safety circuits. Cables specified shall have a proven history of use on transit and railroad vital signal systems.

4.7.8 Overlay Track Circuits

Where required for short range train detection within a larger detection zone, overlay track circuits shall be used. Overlay track circuits shall operate in the audio frequency range. Frequency of overlay track circuits shall not create interference with any other system or subsystem on the wayside or onboard the vehicle. Pre-shunt and post-shunt of overlay track circuits shall be less than thirty feet.

4.7.9 Loop Vehicle Detectors

Where track circuits are not practicable, vital train detection shall be accomplished using loop vehicle detectors.

4.7.10 Wayside Signals

Interlocking and automatic signal layouts shall include signal heads, brackets, electrical fittings, junction boxes, terminals, and hardware required for installation. Masts and foundations shall also be provided.

Signal heads shall be three aspect color light type. The top lens of each signal head shall be green, middle lens yellow, and bottom lens red. Route indicators shall be masked with an arrow corresponding to the route.

Ladders shall be complete with stays, fasteners, extensions, and other necessary hardware. Ladders shall be as appropriate to each particular location. Ladders shall be provided where the highest aspect is mounted more than six (6) FT above the surface where a maintainer can stand.

Wayside signal layouts mounted in ballasted areas shall be installed on concrete foundations either of monolithic or sectional construction.

Wayside signals mounted in direct fixation track areas shall be mounted to the concrete structure or wall as appropriate. All fastening to concrete shall be with pre-packaged epoxy adhesive. Fasteners shall be stainless steel hardware. Concrete drilling shall be done using approved steel template.

4.7.11 Train Stops

Wayside magnetic train stop layouts shall be installed at all wayside signal locations to activate the carborne magnet to command an emergency brake application. Train stop layouts shall include a wayside magnet, brackets, electrical fittings, junction boxes, terminals and hardware for installation. Wayside magnets shall be mounted between the rails. Train stop layouts shall be designed to be fail safe in that a failure of any component will cause the vehicle to initiate a penalty brake application.

4.7.12 Housings

Contractor shall provide wayside Central Instrument Houses (CIH), Intermediate Instrument Houses (IIH), and wayside cases to house signal equipment. Instrument houses and wayside cases shall be complete with foundations, racks, sideboards, grounding, illumination, fire and intrusion alarms, and environmental control equipment as necessary. Instrument houses shall be walk-in type provided with concrete step(s) as required.

Instrument houses and wayside cases shall be located in such a manner that no part will foul the vehicle clearance envelope. Each instrument house and wayside case shall be installed level and plumb on concrete piers in at-grade trackwork, on steel mounting brackets in direct fixation areas, and on special areas provided on aerial structures.

Instrument houses and wayside cases shall be of sufficient size to house all signal equipment required for a particular location. Instrument houses shall not exceed ten (10) ft. in width. Length shall vary in two (2) ft. lengths from eight (8) ft. to a maximum of forty-eight (48) ft. Any length over forty-eight (48) ft. shall require two (2) instrument houses. Interior head room shall be a minimum of seven (7) ft. Wayside cases shall not exceed seven (7) ft. wide, seven (7) ft. high, and twenty-eight (28) inches deep.

4.7.13 Train-to-Wayside Communications (TWC)

TWC shall be used to transmit train destination from the vehicle to wayside equipment to facilitate automatic routing. TWC shall also permit a signal to be generated manually by the train operator to initiate preemption, crossing starts or signal requests, as may be required at a station.

Where requests are transmitted from the vehicle in a standing position, the circuits shall also provide a cancel for the request.

4.7.14 Junction Boxes

Junction boxes for signal equipment shall meet the requirements of AREMA Signal Manual, Parts 7 and 15.

Junction boxes shall be provided with gaskets to prevent entrance of moisture and dust, in accordance with the AREMA Signal Manual, Part 15.2.10.

Mast-mounted equipment shall be provided with split-base junction boxes.

4.7.15 Carborne ATP Equipment

Carborne ATP equipment shall include:

a) Aspect Display Unit (ADU) for each cab

b) Tachometers on two axles

c) Truck-mounted antennae and body – mounted junction boxes on each lead truck

d) Bypass switches

e) Limited mode pushbuttons

f) Decelerometer

g) Logic units with card cradle, power supply and associated equipment

Carborne ATP shall decode speed codes generated by wayside signal equipment. The speed code carrier frequency shall be overlaid on track circuit frequencies and modulated to correspond to predefined speed limits.

4.7.16 Electric Locks

Electric lock layouts shall be used with hand-operated switch-and-lock movements that interface with mainline tracks, and other locations as required.

4.8 HIGHWAY GRADE CROSSINGS

Signal systems at highway grade crossings will include all signs, signals, and warning devices and their supports located within the rail right-of-way. The function of these systems will permit safe and efficient operation of rail vehicles, highway traffic, and pedestrians over level grade crossings.

Grade crossing warning devices will be designed in conformance with the TXMUTCD, TXDOT, and the recommended AREMA practices.

Grade crossing warning devices and systems are intended for use in both new installations and at locations where existing apparatus is replaced. All grade crossing signal systems shall comply with the TXMUTCD. Signal malfunction signs shall be installed at each crossing. Such signs shall conform to TXMUTCD, Standard Highway Sign Design for Texas and Standard Alphabets for Highway Signs and Pavement Markings. Pavement markings, lighting, other highway signage and adjacent street traffic control systems shall be furnished and installed by others.

The flashing light signal may be supported on the same mast with the gate mechanism or it may be separately mounted.

On multiple-lane highways, cantilever-mounted signals are to be used when deemed necessary to improve motorist preview and roadside warning. These flashing lights will be mounted over the inner traffic lanes to provide the motorist with an unobstructed view of the signals should the standard flashing lights be blocked from view.

Operation of highway crossing warning signals and gates and their interconnection with the wayside rail signal system shall be considered vital.

Where practicable, gates shall be located to cross sidewalks or walkways adjacent to the highway.

4.8.1 Highway Grade Crossing Operation

The minimum design requirements shall be in accordance with AREMA practices and the TXMUTCD. The design gate length parameter shall be twenty-nine (29) feet and the maximum gate length shall be thirty-five (35) feet.

Where highway crossings are located beyond station platforms, the warning device shall not operate while the train is in the stopping profile or stopped at the platform. Prior to leaving the station platform, the train operator will initiate operation of the crossing warning devices via the TWC by operation of the train ready push button on the cab console. Where such distance exceeds 600 feet, a posted speed will be imposed to provide the necessary warning time.

Coordination with the highway traffic system shall be implemented where required. This coordination shall be considered non-vital.

Occupancy of the island track circuit shall result in crossing warning operation regardless of rail traffic direction. When the train has vacated the island track circuit crossing gates shall rise and warning signals turn off. Gate release push buttons shall be provided at all crossings in locked boxes.

Approach extension circuits shall be used to prevent a short gate up movement when one train has just cleared the crossing and another approaching train again lowers the gates before a complete gate up movement can occur. The train detection system should be configured to provide a signal if a train is within ten seconds of initiating the crossing warning equipment.

Where a switch lies in the approach to the crossing or in advance of the crossing such that a diverging route effects the speed of an approaching train, the crossing approach for each route over the switch shall be calculated and detection through each route established to provide the appropriate warning time.

4.9 YARD SIGNAL SYSTEM

4.9.1 Description

The yard signal system shall be designed to meet the functional requirements of yard operations. Switch machines shall be power operated trailable machines designed for use in yard operations. Control of switch machines shall be by TWC or wayside push buttons. Design of switch control shall not preclude the addition of remote control.

4.9.2 Yard Control Subsystem

A train detection subsystem will be utilized in the control of yard switch machines. Control logic will be implemented with non-vital microprocessor controllers. Request for switch operations will be through the vehicle TWC console or by operation of wayside push buttons. Train detection shall be used to ensure the presence of a train before allowing the switch to operate and to prevent operation of a switch while a train is over a switch.

4.9.3 Wayside Push Button Box Layouts

Push-button layouts shall be provided, to permit the light rail vehicle operators to initiate their own route request. Push-button boxes shall be weather proof and adaptable for mounting on concrete walls or pipe masts as required. Push buttons shall be located at least ten (10) FT in approach to the switch with which they are associated. Push buttons shall be accessible from operator's cab of vehicle. Push button pole or box shall not obscure the switch points as viewed from vehicle cab.

4.10 INTERFACES

The Signal System design shall be fully coordinated and interfaced with the affected utilities, railroads, agencies, and other project designs. The major interface areas include:

a) Track Alignment

b) Trackwork Configuration

c) Utilities

d) Structures

e) Vehicles

f) Operations

g) Electrical and Mechanical Equipment

h) Communications, and Train Control Center

i) Yards and Shops
j) Architectural
k) Corrosion Control
l) Passenger Stations
m) Real Estate
n) Noise and Vibration

4.11 ABBREVIATIONS

ABS:	Automatic Block Signal
AC:	Alternating Current
ADU:	Aspect Display Unit
AREMA:	American Railway Engineering and Maintenance-of-Way Association
ATP:	Automatic Train Protection
AWG:	American Wire Gauge
CIH:	Central Instrument House
DART:	Dallas Area Rapid Transit
DC:	Direct Current
HZ:	Hertz
ID:	Train Identification
IIH:	Intermediate Instrument House
KCMIL:	Thousand Circular Mills
LRT:	Light Rail Transit
NEMA:	National Electrical Manufacturers Association
RTU:	Remote Terminal Unit
SCADA:	Supervisory Control and Data Acquisition
TCC:	Train Control Center
TXMUTCD:	Texas Manual on Uniform Traffic Control Devices

TWC: Train to Wayside Communications

TXDOT: Texas Department of Transportation

TXU: Texas Utilities Electric

4.12 DEFINITIONS

Alarm Condition - Any abnormal condition that requires attention of a controller or operator.

Audible Alarm - Sounding of a bell, buzzer, or other acoustic device to draw attention of the control operator to an alarm condition.

Automatic Routing System - A system to automatically establish route selection at an interlocking or control point to permit routing of trains in accordance with a predetermined schedule or other method of automatic route selection.

Auxiliary Switch Operation/Switch Test Key - Part of an entrance/exit control system; a manual control that permits a request for operation of an individual switch or crossover without an associated route request.

Ballast Impedance - The total impedance caused by electrical leakage paths of a given section of electrically isolated unoccupied track.

Ballast Resistance - The total resistance caused by electrical leakage paths of a given section of electrically isolated unoccupied track.

Block - Track of defined limits the use of which is governed by block signals or cab signals.

Block Indicator – A signal that indicates only the occupied status of a block immediately in advance of the signal.

Blocking - Means to prevent operation of a switch or clearing a signal to prevent a train movement to enter a block.

Bootleg - Protection for track wires where wires leave the ground near rail.

Brake Assurance – A function of the Automatic Train Protection subsystem that commands a vehicle to initiate penalty brake application when the actual brake rate is less than the required brake rate.

Brake, Emergency – An irretrievable brake application to fully stop a vehicle at the full service brake rate assisted by track brakes. Emergency brake can only be applied by the Operator.

Brake, Full Service – The normal maximum braking effort achieved through use of dynamic and disc braking systems.

Brake, Penalty – An irretrievable brake application to fully stop a vehicle at the full service brake rate.

Buss - A conductor or a group of conductors that are terminated as a common connection for two or more circuits.

Cab Signal – The transmission, reception and enforcement of the ATP speed limit, as transmitted to the vehicle by vital wayside equipment.

Call-On Signal - A wayside signal aspect authorizing a following train movement into an occupied block, with the route lined and locked.

Central Instrument House - A walk-in type housing used to house signal equipment and terminate cable at an interlocking.

Clearance Offset – A function that modifies the sequence of a traffic signal cycle when an electrical signal is present that indicates a train is approaching a highway crossing where highway traffic through the crossing is affected by the traffic signals.

Continuous Welded Rail - Tracks welded together in the absence of rail joints, except at special track work areas.

Control (Supervisory) - A coded message from a control console to a field location to change the status of signal equipment.

Controlled Signal - A wayside signal located at interlockings and capable of being remote controlled either locally or from the Train Control Center.

Control Point - A wayside location where signals and switches may controlled, either remote or locally.

Cross-Bond - An electrical connection between tracks to distribute traction power negative return currents.

Crossover - Two turnouts, with track between the frogs, arranged to form a continuous passage between two tracks.

Crosstalk - Undesirable interference created by coupling between one system and another system or from one portion of a system to another portion of the same system.

Derail - A device that causes rolling equipment to leave the rails.

Entrance-Exit Type Route Control - Automatic route control implemented by defining an entrance point and an exit point.

Fleet - A method of route control in which an established route is not canceled by the passage of a train.

Frog – A track structure used at the intersection of two rails to provide support for the wheels and passageways for the flanges, permitting wheels to roll on either rail.

Headway – The time interval between the passage of consecutive vehicles traveling in the same direction measured at a given reference point.

Headway, Design – The minimum headway supported by the signal system, using an ideal train model and nominal dwell times.

Impedance Bond - A device that provides a high impedance to an AC signal while providing a low resistance path for DC current. Where required, impedance bonds shall provide a means of coupling track circuit and speed code frequencies to the rails.

Indication (Supervisory) - A coded message from a field location to a control console to report status of signal equipment or train operation.

Insulated Joint - A rail joint in which electrical insulation is provided between adjoining rails.

Interlocking - An arrangement of signals, switch layouts and appliances at special trackwork, so interconnected that their movements must succeed each other in proper sequences, permitting train movements over controlled routes only if safe conditions exists.

Interlocking Limits - The length of track or tracks between opposing wayside signals controlled by an interlocking.

Jerk Rate – The maximum allowed rate of change of acceleration or deceleration.

Joint Electron Device - Cooperative effort of Electronic Industries Association (EIA) and Engineering Council

Locking – The electrical and/or mechanical establishment of a condition for a signal component or function which cannot be altered except by a prescribed and inviolate sequence of unlocking.

Lunar is a white signal aspectas defined in the AREMA. Communications & Signal Manual, Part 7.1.10.

National Electrical Manufacturers Association (NEMA).

Noise, Electrical - Interference caused by undesirable random voltage or currents.

Non-Vital - Any design, circuit, device, software or processor where flaws, operation, misoperation or failure does not directly affect safety.

Precondition - To store information that will be acted on by an anticipated movement to cause a device or devices to function in a predetermined manner.

Reaction Time - Time used by equipment, operator, or both, that elapses between the moment an action is called for and the desired result occurs.

Remote Terminal Unit (RTU) - Equipment that constitutes the field end of a data transmission system.

Right-of-Way Hazard - The existence of an abnormal condition on, or near, the tracks which could impair safe train movement.

Route - A specified succession of contiguous blocks over which trains operate between controlled interlocked signals.

Signal - An appliance that conveys vital information governing train movements responsive to dynamic information based on train position and status of the track ahead.

Signal Aspect - The appearance of a fixed signal conveying an indication as viewed from the direction of an approaching train.

Signal Indication - The information conveyed by the aspect of a signal.

Skate - A sliding device placed on a rail to engage with a car wheel so as to provide continuous braking by sliding friction.

Subsystem - A subsystem comprises elements within a system that are interconnected to perform a specific function.

Switch-and-Lock Movement - A device which performs the sequential functions of unlocking, operating, and locking a track switch.

Switch (Track) - A pair of switch points with their fastenings and operating rods providing means for establishing a route from one track to another.

Switch Circuit Controller - A device for opening, closing, or shunting electrical switch control and indication circuits operated by a rod connected to a switch point.

Switch Test Key/Auxiliary Switch Operation - Part of an entrance and exit control system; a manual control that permits a request for operation of an individual switch or crossover without an associated route request.

Thru-Routing - A method of entrance-exit route selection design whereby intermediate signal requests are automatically initiated between available entrance and intermediate exit points by initiating only initial entrance and final available exit commands.

Track Circuit - An arrangement of electrical and/or electronic equipment, including a length of the running rails, which permits detection of trains within the limits of the running rails.

Track Transformer - A transformer designed to couple electrical energy to and from the rails of a track circuit.

Traction Power System - The substations, feeder cables, overhead contact wires, switchgear, and other equipment and providing the electrical power for the movement of trains and operation of auxiliary systems.

Traffic Circuit - A circuit which controls and maintains the direction in which a signal system will accept and govern train movements.

Train Control Center - The principal control and monitoring point for DART's rail operations.

Traffic Control System - A signal system permitting trains to operate in either direction on the same track governed by indications of block signals.

Train Detection Equipment - Circuits and associated equipment used to detect the presence of trains.

Train Shunt Impedance - Electrical impedance between running rails when spanned by train wheels and axles.

Train Stop - Devices located at wayside signals which initiates a penalty brake application by activating vehicle-borne equipment.

Train-to-Wayside Communications (TWC) - a solid state digital communications between train and wayside to provide a continuous information flow between train, wayside and TCC.

Turnout - An arrangement of a track switch and frog that provides means for rolling stock to be diverted from one track to another.

Unsafe Condition - Any condition that endangers human life or property.

Vital - Any design, circuit, device, software or processor which affects safety of train operations.

Wayside Case - A housing, located along the Right-of-way, used to house signal apparatus and terminate cable.

CHAPTER 5

COMMUNICATIONS

Chapter 5

COMMUNICATIONS

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CHAPTER 5 - COMMUNICATIONS

5.1 GENERAL

This chapter describes the functional requirements and the interface criteria to be designed into all Dallas Area Rapid Transit (DART) Light Rail Communication Systems. Provisions for these subsystems shall meet the requirements of applicable standard and directive drawings and shall be coordinated with DART. Subsystems shall be compliant with federal, state, and local laws such as the Americans with Disabilities Act (ADA) and applicable National Fire Prevention Association (NFPA) codes and standards relating to public transportation and communications systems.

5.2 DESCRIPTION

The Communications System shall consist of the following subsystems: communications transmission; radio; public address; visual message board; telephone; fire detection and/or suppression system as required by the local jurisdiction; and intrusion detection and security. The communications system shall also be designed with provisions for a future closed circuit television (CCTV) subsystem.

Additional supervisory control and control center operational communications subsystems are described in the Design Criteria Manual, Volume 2, Chapter 6.

5.3 COMMUNICATIONS SUBSYSTEMS SCOPE

5.3.1 Communication Transmission Subsystem (CTS)

The Communications Transmission Subsystem provides the medium for point-to-point, shared voice, and data transmission. It consists of transmission, multiplexing and inter-connect equipment and provides interfaces for all terminal equipment requiring connectivity from field communicating sites to the Operations Control Center (OCC).

The CTS backbone network shall be based on the Synchronous Optical Network (SONET) standard and shall comply, at a minimum, with Telcordia Technologies GR-253-CORE, SONET Generic Criteria requirements. High-speed optical interfaces shall operate at a minimum line rate of OC-12 (622.08 Mbps) and shall be capable of being upgraded through intermediate line rates up to and including OC-192 (9953.28 Mbps). Electrically equivalent tributaries shall be available in granularities of DS-1, VT1.5 and framed DS-3. The network topology shall consist of multiple subtended Unidirectional Path Switched (UPSR) rings to allow for diverse path protection and network segmentation generally delineated by line sections. No single node shall terminate a subtended ring entirely. Rather, any new subtended ring shall extend from at least two nodes of an existing ring. Multiple fiber strands from the same cable shall be terminated and patched through (also referred to as a 'collapsed ring') at each communications node to complete the ring topology. Nodes shall be capable of peer-to-peer communication. Equipment shall be functionally compatible with existing field and OCC equipment.

Low speed digital interfaces and tributary multiplexing equipment shall be based on the North American Digital Hierarchy utilizing Pulse Code Modulated (PCM), Digital Service level 0, DS-0, channels in groups of 24 with D4 framing to form 1.544 Mbps DS-1 signals. Twenty-eight (28) DS-1 signals may be multiplexed into a 44.736 Mbps DS-3 signal to be used for higher density transport and grooming through the Digital Cross Connect Switch (DACS) located at the OCC. Higher order multiplexing (M1-2 and M1-3) shall not be based on proprietary framing or synchronization schemes. DSX panels shall be deployed at all locations to distribute DS-1 or DS-3 signals. Time Division Multiplex (TDM) signals shall be terminated, cross connected, and distributed via a local distribution frame.

Physical CTS interfaces within the communications house or facility consist of: two-wire or four-wire audio frequency channels; EIA Standard Interfaces RS-232, RS-422 or RS-485; high speed optical or wireless technologies; and Ethernet 10/100/1000 Base T.

All optical multiplexers shall employ redundant, east-west optical interfaces for high-speed sections. Low speed multiplexer sections shall employ 1:1 or 1:N protection switching on circuits determined operationally critical by DART. CTS common control card equipment such as CPU's, switch matrices, timing reference cards, shelf controllers, power supplies and all other critical system resources shall be deployed with fully redundant active and standby modules.

Fiber optic cabling and associated fiber optic modem and/or media converters shall be used for connectivity between each communication house/facility and Traction Power Substation (TPSS), signal Central and Instrument House (CIH), and Communications Interface Cabinet (CIC) for distributing the local TCP/IP, RS-232, or other data transmissions over fiber. Multi-pair copper communications cabling shall be used for TDM voice, alarm and analog data connectivity between these same facilities.

The head-end CTS node is located at the OCC. CTS communications nodes shall be located along each line section within communications houses or other designated communications facilities to support all field communication requirements. Each communications facility shall have connectivity to the OCC either directly with or through an intermediate CTS node. All field communications shall be distributed from these communications facilities, either directly, or through intermediate cabinets, or enclosures. An element or network management system shall be located at the head-end node that is capable of real-time monitoring and CTS node provisioning.

Operational signals shall share transmission media with fire and security signals such that the following requirements shall be met:

a) The transmission media shall conform to the requirements of Installation, Maintenance and Use of Proprietary Protective Signaling Systems (NFPA 72).

b) Common transmission media shall not impair the fire alarm function.

Fire alarms, security trouble alarm, and supervisory signal transmission from transit facilities to the appropriate central supervising station may be accomplished primarily via the Communications Transmission Subsystem.

5.3.2 Radio Subsystem - Rail

The Radio Subsystem shall consist of three parts, as follows:

a) Two-way communications to support light rail operations, maintenance and public safety shall be carried on a conventional five channel, 800 MHz network that covers all above grade, underpass, tunnel, and depressed Right-of-Way (ROW) sections.

b) Build-Out expanded coverage shall be part of the radio subsystem planning. This includes software-based coverage prediction and simulation tools for RF propagation studies and the performance of field coverage studies that shall give indication of the need for system expansion based on geographic factors.

c) Radio system coverage shall be provided in tunnel, underpasses and depressed sections of ROW, in accordance with NFPA 130 (the city of Dallas currently utilizes a 470MHZ system for the tunnel that DART maintains). Portable radio coverage shall be a design parameter.

The 800 MHz conventional radio network shall utilize existing DART equipment and newly acquired base station or remote receiver equipment. The five radio channels are typically allocated as follows, per DART FCC licensed (Allocation may change based on operational requirement:

a) Train Operations – Primary
b) Train Operations – Secondary
c) Yard Operations
d) Maintenance and Police
e) Police

The implementation of additional channels shall be contingent upon business need, light rail system expansion, budget allocation, and availability of frequency licenses (as a result of any frequency use and allocation changes mandated by the Federal Communications Commission [FCC]). These five (5) channels are the minimum requirement to support the existing system. Future expansions of the system (Phase 2 and beyond) may require additional radio channels, determined by the number of new users needed to support the expansion of the Light Rail Transit System. Any new frequency allocations shall be dictated by the FCC rules in place at the time of the contract, as well as the aforementioned conditions. Under existing FCC rules, and due to the classification of the DART system as a Public Safety agency, a new frequency pair will be justified for every seventy (70) new users added to the system. Special consideration will have to be obtained by DART, as the maximum number of the channel-pairs (5) allocated within a 64-km of a conventional system is already in use.

Each channel shall be an open channel, such that all radios operating on a channel shall hear all communications on that channel. The design shall anticipate that radio equipment will employ a form of Coded Squelch (CS) in the future.

New equipment shall be capable of operating with 12.5 kHz bandwidth capabilities, and, 6.25 kHz if available.

New remote receivers shall be added as needed. New receivers shall be compatible with existing equipment such that new equipment audio may be “voted” with the existing remote receivers’ audio.

New transmitter equipment, shall be capable of supporting transmissions with a 12.5 kHz bandwidth and if available, 6.25 kHz. Equipment that only operates with 25 kHz bandwidth shall not be accepted or considered. A plan for the transition of the existing transmitter equipment, from 25 kHz bandwidth to 12.5 kHz bandwidth, shall be developed and implemented, to comply with pending changes to FCC regulations.

An RF field strength simulation tool shall be employed to assist in determining any required base station placement. New base station transmitter equipment shall be synchronized to existing transmitter equipment. Synchronization methods to be utilized shall be compatible with the existing and operational system in use. These methods include, but are not limited to, smart controllers, semi-automatic and/or manual timing and adjustment processes. In the event that interference zone(s) cannot be avoided, these zone(s) shall be located outside of DART's transit system radio service areas. Duplicate message broadcast (time delayed, multiple zones) is not acceptable.

LRV radios will be supplied by the vehicle supplier. The prime consideration for portable radios shall be performance and stability. The use of solid state radios shall be required. Radios shall be digital-capable and analog compatible, if available and offered as a standard commercial product.

In order to provide coverage for the 800 MHz, 900 Mhz and/or any jurisdictional authority as required, where the over the air signal is inadequate (tunnels, underpasses and depressed ROW sections), a slotted coaxial cable antenna or other repeater or base station equipment shall be used. The slotted coaxial cable shall be jacketed with a fire-retardant, halogen-free material. A distributed amplifier system shall be utilized as appropriate to minimize new base station requirements. FCC rules for intermodulation power and emissions from Tunnel portals shall be utilized. The most current FCC bandwidth rules in effect at contract award shall be followed.

Each rail operations controller and yard operations controller console shall have the capability to transmit and receive on all five 800 MHz channels.

Any expansion shall provide a required coverage of 95% of the service area, 95% of the time, including the areas along the Right-of-Way (ROW). The field signal levels required to meet the coverage requirements, from all locations, shall be 3.0 dB or better, above the receiver's 12 dB SINAD sensitivity threshold, measured at the input to the receiver's RF port (-112 dBm or .56 μV signal).

When radio coverage is extended, CTS channels are the preferred path to connect OCC radio system audio to the base station/repeater, satellite receiver, or voting sites. If CTS channels are not available, an alternate path such as microwave or leased lines shall be employed in the design.

5.3.3 Closed Circuit Television (CCTV) Subsystem

CCTV conduits shall be provided at all passenger stations for future CCTV equipment installation. Conduits shall be sized to allow for camera power and control cabling that includes pan/tilt/zoom (PTZ) functions. Conduits shall connect individual station camera locations to the Communications Interface Cabinet (CIC) serving that station. The design shall adequately accommodate signal, power and control cabling. Camera power shall be provided by a UPS, with a backup time equal to that required by PA, VMB, and other station equipment located within the CIC.

Camera locations are defined in the Design Criteria Manual, Volume 1, Facilities Design, Chapter 22. Cameras shall be mounted to limit access to vandals, but shall be conspicuous to patrons. Aerial and at-grade stations platform level camera locations shall provide a full view of all patron accessible areas. Enclosed stations will have CCTV installed in accordance with NFPA 130.

5.3.4 Public Address and Visual Message Board Subsystem (PA/VMB)

Passenger stations shall be equipped with public address and visual message board equipment to allow communication with patrons or employees, as appropriate during emergency or interruptions of train service equipment shall be designed to comply with ADA accessibility guidelines.

Each station design shall specify a minimum of two zones and each system shall operate as a single zone so that each announcement shall be available throughout the station.

At any station, the system shall be capable of originating announcements from: the Train Control Center (TCC); station fire management panel (if installed); security room; or at least one locally designated area, such as the Communications Interface Cabinet. The local announcement panel shall have line of site station platform and concourse visibility, where practical. Announcements from the fire management panel shall automatically override other announcements. TCC announcements shall have second priority to any local announcement. The station VMB design shall include a local keyboard access feature for ad hoc station messaging. The system shall be capable of storing multiple canned voice and visual messages.

TCC Controllers and supervisors shall have the capability to select any combination of stations to receive PA/VMB announcements utilizing the communications workstation consoles as described in the Design Criteria Manual, Volume 2, Chapter 5, Communications, Section 5.3.8.

PA loudspeakers shall be installed in the vertical axis at passenger stations and shall be arranged in a pattern so that every point at a height of 5 ft above the floor is within the horizontal and vertical 6 dB beam width cone of at least one speaker. Public address amplifiers shall be modularly designed with isolated A and B channel outputs so that a single failure shall not disable the system. Cable runs to speakers shall be daisy chained in a two-zone (A/B) per platform configuration so that adjacent speakers shall not be powered by the same amplifier.

The PA layout at any new station and conduit layouts at other stations shall be designed for a uniformly distributed minimum sound pressure level of 80 A-weighted decibels (dBA) at a height of 5 ft above the floor on passenger station platforms. On station platforms the coverage shall be uniform level over 90% of the open platform area. Station platform minimum levels shall be obtained when trains are not operating and when the ambient noise level is minimal. The sound pressure level shall be automatically adjustable based on ambient noise to a maximum of 105 dBA. At locations with high background noise levels, a speech processor shall be used to enhance the performance and intelligibility. Voice intelligibility shall meet or exceed the minimum standards set forth NFPA 72. Sound trespass to areas adjacent to stations shall be minimized to meet local ordinances or adjustable to levels approved by the authority having jurisdiction.

The Visual Message Boards shall be placed to afford maximum achievable visibility from all parts of the station while complying with ergonomic and ADA guidelines. This includes quantities, height, and distance from platform ends. For equipment placement in accordance with ADA requirements, the PA/VMB system is responsible for coverage over an effective platform use area not to exceed 400 ft end-to-end. DART Operations is the primary user of the Visual Message Boards, if these signs are to be used by any others than operations, their need shall be secondary to Operations.

The specified platform 400 ft end-to-end length is considered to be, for design purposes, a typical platform length. References and design decisions are based on this 400 ft end-to-end requirement. Platforms that exceed the 400 ft end-to-end length shall be considered to be atypical. Atypical design shall impact the design considerations specified herein. Design impacts shall include: Visual Message Board quantities; the distance between boards; the number of speakers; the number of audio amplifiers; cable runs; conduits; and platform/station related equipment.

Conduit runs and junction boxes shall be concealed wherever possible to minimize the station architectural aesthetic impact and shall be furnished by the station Contractor. Speaker enclosures, message board enclosures, and associated mounting hardware shall be vandal-resistant and shall blend with other fixtures and finishes within each station. Speakers shall be double re-entrant weather-proof type.

5.3.5 Telephone Subsystem

The Telephone Subsystem shall provide emergency and administrative voice and dial-up data services to communications devices throughout the communications system. Communications devices are also referred to as instruments or telephones in this section. These devices include administrative telephones, passenger emergency call (PEC) units, elevator emergency telephones, wayside telephones, and digital communications alarm transmitter (DACT) units. The system shall allow communications between and among various DART field facilities and the Operations Control Center and enable communications between DART field facilities and the Public Switched Telephone Network (PSTN).

All telecommunications circuits and switching services shall be provided by a DART owned and operated Private Automatic Branch Exchange (PABX) switched network. The primary electronic switching equipment shall be located at the DART OCC, with tie lines to one or more remote sites with compatible switching equipment. These interconnected switches should provide monolithic or pseudo-monolithic switching operation with respect to call processing, dial plan, and other system features. The PABX network shall be maintained by DART Information Technology. Dial plan and extension requirements shall be coordinated through DART IT.

TCC console operators shall have the ability to uniquely identify, accept, acknowledge, and disconnect each incoming emergency call (from PEC units and elevator emergency telephones), regardless of the order in which it came in, without disconnecting concurrent calls.

Communications system connection to the DART PABX network shall be accomplished through a line side T-1 interface with multiple T-1 trunks necessary to provide an adequate number of extensions. T1 trunks from the PABX shall be groomed and individual analog circuits transported to all field communications device locations over the CTS.

PEC units, elevator emergency telephones, and wayside telephones shall be capable of being remotely programmed and automatically monitored (polled) for fault, health, and traffic statistics. All programming shall be held in non-volatile memory. These devices shall also have operating instructions on or adjacent to the instrument.

All communications devices, with the exception of DACTs, shall be telephone line powered. All communications devices, cables, protected terminals, and other interconnect equipment shall be grounded according to manufacturers standards. Each building distribution frame shall include transient surge protection for all trunks and lines.

5.3.5.1 Administrative Telephone

Administrative telephones shall be provided at signal and communications equipment facilities, substations, crew rooms and other areas as determined by DART. Standard desk or wall mount, 12-digit dial pad telephone equipment shall be compatible with analog PABX extensions delivered from either existing or new DART owned and operated switches.

The following call functions shall be provided over single pair telephone lines run to administrative telephones:

a) Four-digit dialing for all DART extensions at all new DART rail and administrative facilities. Dialing plan shall be uniform for Direct Inward Dialed (DID) calls.

b) Direct Outward Dialing (DOD) with single digit ('8' or '9') access to trunks and capability of dialing a ten-digit local telephone number.

5.3.5.2 Passenger Emergency Call (PEC)

PEC units shall be installed in designated station areas to provide a direct means of emergency communications between patrons and the Public Safety Answering Point (PSAP).

The PEC unit shall be an outdoor-rated, weatherproof, hands-free, ADA compliant emergency telephone instrument. The instrument shall have two push buttons. One pushbutton to initiate an emergency call, a second pushbutton for customer service. The instrument shall have a dial pad.

Each telephone shall be served by a single Telco line with no local parallel or ‘party-line’ wiring between instruments allowed. The instrument shall be capable of storing and auto-dialing at least a primary and secondary telephone extension. The primary telephone extension shall be designated the PSAP. The secondary telephone extension shall be the TCC operator console stations when a patron initiates a call.

Each of these telephones shall be equipped with a blue marker light in a vandal-resistant fixture and shall be distinctive in color with their location and emergency function plainly indicated by appropriate signage.

A minimum of two (2) PEC units shall be installed per center at-grade station platform, or public telephone devices may be substituted such that the travel distance from any point in the public area to a PEC shall not exceed 300 ft (91.4 m) unless otherwise approved by the authority having jurisdiction. At aerial and underground stations, in compliance with NFPA 130, PEC's shall be located on the passenger platform with an additional unit optionally located adjacent to the fare vending area or at some other designated area on the concourse or mezzanine level.

5.3.5.3 Elevator Emergency Telephone

Elevator emergency telephones shall be integrated into each elevator cab installed in stations to provide a direct means of emergency communications from a station patron, located inside the elevator, to the operations control center. The design shall conform to ASME A17.1 latest edition, Safety Code for Elevators and Escalators, and ADA design guidelines.

The instrument shall be hands-free and have only a single push button to initiate an emergency call. The instrument shall not have a dial pad or a corded handset. The instrument shall be flush mounted and integrated into the elevator control panel. Each telephone shall be served by a single PABX with no local parallel or 'party-line' wiring between instruments allowed.

The instrument shall be capable of storing and auto-dialing at least a primary and secondary telephone extension of designated TCC operator console stations when a patron initiates a call.

5.3.5.4 Wayside Telephone

Wayside telephones shall be installed in normally non-public areas such as grade-separated guideway, bridges, tunnels, freight or heavy rail crossings, and at designated fire management panels.

Wayside telephones and enclosures shall be NEMA 4X rated, with a 12-digit dial pad and a non-modular armored cord with handset.

Between any two communications facilities, wayside telephones may be paralleled into line groups with a maximum of four telephones per line. No two adjacent wayside telephones shall be wired to a pair from the same communications facility. Telephones in northbound and southbound tunnels shall be independently wired. Drops for wayside telephones shall be in a parallel-through configuration with the cable enclosed in conduit from the cable trough, through a protected entrance terminal, to the telephone wiring terminal.

The following call functions shall be provided by wayside telephones:

a) Four-digit dialing for all DART extensions at all new DART rail and administrative facilities. Dialing plan shall be uniform for Direct Inward Dialed (DID) calls.

b) Direct Outward Dialing (DOD) with single digit ('8' or '9') access to trunks and capability of dialing a ten-digit local telephone number.

Each of these telephones shall be equipped with a blue marker light in a vandal-resistant fixture and shall be distinctive in color with their location plainly indicated by appropriate signs. Hand-hold bars shall be provided with wayside telephone to support personnel against an oncoming vehicle.

Wayside telephones shall be installed every 800 ft along tunnel portions of the right-of-way. Wayside emergency telephones shall be recessed so as not to interfere with pedestrian movements along walkways, yet, shall be within easy reach of the walkway. Wayside emergency telephones shall also be installed on aerial track structures longer than 2500 ft at the beginning and end of the structure and, at a minimum, every 1000 ft along the structure.

5.3.6 Fire Detection Subsystem

The Communications Contractor shall only provide subsystems that are located in the Communications houses and rooms that they construct. Facility and other Contractors that provide fire detection systems or devices shall supply those components and provide connections to the fire detection system or fire detection systems provided by others. The responsible Contractor shall provide fire detection sensors triggered by both heat and smoke detectors arranged for cross-zone verification with class-A wiring. Communications facilities shall be configured for a minimum of two detection zones. Each zone shall consist of at least one smoke and one rate-of-rise heat detector. If more than one detector zone is activated, a fire alarm shall be annunciated from the fire detection panel and shall be indicated to the local RTU for TCC logging. Fire supervisory indications shall be allocated for future use in the event that a facility requires this monitoring function. Local alarm annunciation shall be accomplished with horn and strobe lights.

The fire detection control panel shall provide a CTS interface via an RTU so that a single alarm for each location can be indicated to the TCC. Alarm processing is described in the Design Criteria Manual, Volume 2, Chapter 6, Train Control Center and Supervisory Control System. Primary reporting shall be accomplished by using an Underwriter's Laboratory (UL) approved Digital Alarm Communication Transmitter (DACT). DACT's are installed at each field location with connection to the local fire detection systems that shall communicate with the existing TCC Digital Alarm Communication Receiver (DACR). This alarm reporting scheme is subject to approval by the fire marshall who represents an authority having jurisdiction.

All fire detection equipment shall conform to the latest requirements of NFPA Codes Section 12A, 72, 72-90 and 130.

5.3.7 Intrusion Detection Subsystem

The Communications Contractor shall provide intrusion detection and alarming equipment in the Communications houses, interface cabinets, facilities and rooms. In addition, intrusion detection equipment monitoring via SCADA indication over the CTS shall be provided for Fare Collection equipment, emergency exits, equipment rooms, and other secure locations. An OCC interface shall be provided via the CTS described in the Design Criteria Manual, Volume 2, Chapter 6, Operations Control Center and Supervisory Control System. Communication house or room intrusion detection circuits shall be supervised by a separate intrusion detection panel or by an intrusion detection module within the fire alarm control panel. The ability at TCC to read/write numeric identification numbers and log ingress and egress shall be provided. Alarm activation shall be time delayed to allow deactivation with a key or control code from inside the house or room. An intrusion alert occurs when the Communications Room door is opened. It shall be annunciated with a low-level buzzer and indicated to the RTU for logging at the TCC. An intrusion alarm occurs if the alert is not deactivated within a selectable time period. Alarms shall be annunciated locally with a 105 dBA bell and indicated to the control center via an RTU interface. CIC intrusion shall be indicated by a log entry and a visual or audio notification to controller via the Supervisory Computer System (SCS). Local annunciation is not required.

5.3.8 Communications Control

A Communications workstation shall be provided at each ROC and Yard Operations Controller console. Communications workstation equipment shall not interact with the supervisory control equipment in the console, although all equipment shall be fully integrated within the console.

The console communications equipment shall include: a touch screen LCD; keyboard; mouse; processor; and audio equipment, i.e., headset, speaker, and footswitch. The processor shall be a commercially available type state-of-the-art unit to allow for ease of upgrades and expansion to the system. Each console processor shall communicate with a central Communications Controller via an industry standard interface. The Communications Controller shall provide all audio switching, line level adjustment and line signaling functions.

The communications workstation LCD display shall provide a menu-based man-machine software interface that can provide notification and pre-assigned priority call selection for the following channel types:

a) Radio
b) Wayside Telephone
c) Elevator Emergency Telephone
d) Administrative Telephone
e) Passenger Emergency Call (PEC)
f) Public Address / Visual Message Boards (VMB)

Utilizing a combination of function keys and menu windows, it shall be possible to select incoming calls or initiate calls and also to make public address and VMB announcements to equipped station(s). The communications channels available at each workstation shall be assigned in pre-programmed groups to allow for flexible peak and off-peak personnel assignments.

5.4 DESIGN REQUIREMENTS

5.4.1 Electromagnetic Compatibility Requirements

Electromagnetic Compatibility (EMC) is the ability of equipment and systems to perform their intended functions within a transit system electromagnetic environment. The primary methods available for achieving electromagnetic compatibility are: shielding; grounding; balancing; filtering; isolation; separation; orientation; circuit impedance; level control; and cable design. The primary objective is to develop equipment and installation parameters that shall assure an electromagnetically compatible system. This objective shall be achieved through: Communications Systems equipment selection coordination; design; and installation.

The designer shall consider designs and practices that mitigate electromagnetic interference (EMI) and radio frequency interference (RFI) from sources commonly associated with a transit environment such as: traction power systems; the AC power distribution system; the vehicle propulsion system; the signaling system; and nearby non-DART electrical utilities. Consideration must be given to: the location; routing; isolation; installation; grounding; and electrical circuit, wire, and cables shielding such that undesirable EMI and RFI generation and undesirable circuit coupling are mitigated. All Communications equipment shall meet FCC Regulatory Standards Part 15 for radiation and conduction. Shielded cabinets and line filters shall be utilized as required to meet these standards. Fiber optic cabling shall be used where practical to eliminate electromagnetic interference.

5.4.2 Communication Houses, Cabinets and other Facilities

Except as stated otherwise in following sections, all Communications System equipment shall be located in equipment rooms at the OCC, yards, shops, and maintenance right-of-way facilities and in pre-wired houses or cabinets at stations and other locations as necessary along the transit system. In the tunnel portions of the system, the houses may be set in niches in the tunnel walls. At remote surface locations, the houses shall be set on pre-cast concrete piers, monolithic slabs, or other methods as determined by local geotechnical testing data and structural engineering calculations. If any of the houses are required in elevated sections, provision shall be made where appropriate for mounting them on the structure or on piers below the structure.

At-grade station communications equipment shall be installed within a single CIC cabinet. The CIC should be sized to accommodate all communications equipment (current planned and future), power supplies, and supporting devices required to provide station services. It shall be located on the station platform or adjacent to it, in nearby proximity to an accessible utility or systems manhole. The CIC pad footprint shall include an extended foundation or sidewalk that allows personnel to safely access every CIC face. The pad footprint shall be no less than three feet in all directions from the CIC base. CIC cabinets shall be installed at a maximum distance of 2 km (1.25 miles) from the communications node. Alternately, station equipment may be installed within a combined communications house / local interface cabinet up to 350 ft from the nearest station platform. In this configuration, the CIC is eliminated and all station communications equipment is absorbed into racks within the communications house.

At aerial stations, communications equipment shall be installed within a communications facility approximately 11 ft by 20 ft, located in a combined, but physically segmented structure on the concourse level that includes the station emergency lighting control and generator equipment facilities.

Communications interface cabinets within Signal Houses and Substations shall be wall mounted enclosures containing protected terminal blocks and other necessary communications equipment. Multi-paired communications cables entering the house or substation shall be terminated and interfaced with communications equipment therein. Power requirements for communications equipment at these locations shall be coordinated carefully, as available power sources may be non-standard or unprotected.
To reduce construction and testing costs, the majority of the communications equipment shall be mounted in equipment facilities, houses, or cabinets, which shall be factory pre-wired and pre-tested. When communications equipment is installed in equipment rooms, the equipment and all cross-connect panels shall be of modular design, which limits on-site wiring and testing. All communications equipment facilities, cabinets, or enclosures shall be environmentally controlled to prevent heat or cold damage to electronic equipment.

5.4.3 Yard Control

To fulfill its responsibilities, the Yard Controller shall be provided with the following capabilities:

5.4.3.1 Service and Inspection Yard

a) Receive, log, printout, and annunciate fire, security, and supervisory alarms generated from field devices.

b) Receive, record and log emergency telephone messages, including designation of the origin of the call within the S&I facilities.

c) Real time communication with passenger vehicle operators and other on-duty transit personnel within the S&I facilities and yard area.

5.4.3.2 Northwest Rail Operating Facility

a) NWROF will have supervisory control and monitoring of all yard TPSS circuit breakers in the NWROF yard office.

The Communications workstation for the Yard Controller shall be integrated within the yard control console. The workstation shall be LCD based and similar in design to the rail operations control console.

5.4.4 Connection to Other Systems

Subsystem interconnection shall be accomplished by cables from the equipment rooms and from the communications facilities to the CICs in stations, substations and Signal houses. Outside plant cables between facilities shall be terminated on protected distribution blocks as described in following sections. Demarcation panels shall be used at each station as an intermediate terminal point to connect to equipment furnished, installed, or wired by the Contractor. Details regarding the application of the demarcation panel at stations can be found in Design Criteria Manual, Volume 2, Chapter 5, Section 5.5.

5.4.5 Communications Cable

Copper communications cables, utilized for transmitting distances longer than 75 ft shall be formed from twisted pairs of individually insulated copper conductors. Cross-connect wiring, connectorized cables and other short communications cables shall also be formed from twisted pairs unless specifically indicated. All multiple pair communications cables shall be color coded per telecommunications industry standards. Adequate slack shall be specified to allow for at least three re-terminations at each cable end.

All multiple pair communications cables to be installed outside of a building, station, or other protected structure shall be gel-filled, shielded, and shall have an outside jacket suitable for direct burial installation. Intra-building communications cables shall have a jacket rated for plenum installation. Cable installed in exposed areas within tunnel sections and enclosed right-of-way (ROW) cut sections shall be jacketed with a low smoke rated material. All outside plant cables shall be shielded.

Backbone optical fiber cables shall be armored single mode cable with dual 1310 nm and 1550 nm wavelength window fibers. Subnet optical fiber cabling for local signal distribution shall be armored multimode or single mode cable with dual wavelength window fibers. Hybrid fiber cables consisting of a combination of multi and single mode fiber strands are acceptable. New fiber connecting CTS backbone nodes via high-speed SONET interfaces shall be deployed with no less than 24 strands of fiber within a single cable. Fiber optic cable ends shall have service loops of not less than 150 ft to be stored in a Fiber Slack Enclosure (FSE). All multiple stranded fibers cables shall be terminated on fiber distribution panels to allow for ad hoc or emergency patching between strands. SC or MTRJ style connectors shall be utilized on all fiber terminations, panels, attenuators and jumpers.

Communications cables shall be enclosed in trough, conduits, raceways, boxes, or cabinets.

Penetrations through floor and fire-rated walls shall utilize galvanized rigid Steel (GRS) conduits and shall be firestopped using an F rated firestop under the rating criteria of ASTM E814.

All outside plant metallic communications cabling requires over voltage protected entrance terminals at each cable end. Entrance terminals shall utilize a fuse link type connection equipped with gas tube, or solid state, line protectors. Modules shall be rated for 230 V or higher surges. Each individual conductor terminated shall be protected.

5.4.6 Power Systems and Grounding

5.4.6.1 Uninterruptible Power Systems

Uninterruptible Power Systems (UPS) shall be provided for Communications Facilities and Communication Interface Cabinets to provide backup power for communications and station equipment. The UPS shall be sized appropriately to provide eight hours of backup in Communications houses or rooms and one hour of backup power in CICs. Battery backup times may be reduced in facilities that are also backed up by station power generation equipment, i.e., at aerial station communications facilities which shall be backed up by natural gas generators and are to support essential communication loads. All UPS units shall include maintenance free batteries enclosed within the UPS housing. The UPS battery charging system shall incorporate overcharge protection to prevent battery damage and to prevent batteries from emitting hazardous levels of combustible gases. UPS load connections shall include a bypass switch to permit connecting the load to local AC power when UPS maintenance or replacement is required.

5.4.6.2 Grounding, Bonding and Lightning Protection

All communications equipment, racks, and electrical equipment shall be properly grounded to prevent equipment damage or personnel injury due to lightning strikes or power surges. Refer to Design Criteria Manual, Volume 2, Chapter 9, System Grounding for grounding criteria.

5.4.6.3 Facility Grounding

Communications Shelters and CICs shall be grounded with a ground mat system. The ground mat shall achieve a maximum allowable resistance to ground of 3 ohms. The ground mat system shall consist of ground rods that are interconnected with bare copper stranded wire. The grid conductor and ground rods shall be connected by permanent bonding methods. If the Communications shelter and/or CIC are located at a station with more than one grounding system, the communications ground grid shall be connected to the site central reference grounding point.

5.4.6.4 Ground Element Bonding

Subsurface electrical ground system elements shall be permanently bonded by exothermic welding methods. Mechanical connections shall not be accepted as a permanent bond.

5.4.6.5 Station Communications Equipment Grounding

Communications station equipment grounding, such as Wayside Telephones and VMB equipment, shall comply with the Design Criteria Manual, Volume 2, Chapter 9, System Grounding provisions.

5.4.6.6 Lightning Protection

A Lightning Surge Arrester shall be connected to all ungrounded AC power conductors entering communications shelters or CIC's as specified in the NEC, Article 280 "Surge Arresters." Utilize revision current at time of design. All metallic outside plant cables entering a Communications shelter or CIC shall be terminated with station protectors for protection of lightning induced voltage spikes or surges.

5.5 INTERFACING REQUIREMENTS

5.5.1 Station Demarcation Panel

Each station shall have a demarcation panel provided and installed by the Contractor. The demarcation panel is a physical interface point between facilities and systems work. It allows the Contractor to independently consolidate, route and wire all copper audio, visual, SCADA and emergency voice circuits from station equipment locations back to a central point. The demarcation panel facilitates the Contractor's work by allowing the Contractor to connect from the CIC to the demarcation panel, where all facilities provided circuits have been landed, and complete all communications circuits or connections. This panel can be located within either the Central Emergency Lighting Power Supply (CELPS) (UPS) room or similar location at aerial stations or in a separate cabinet located near the CIC or station platform at at-grade stations. The Contractor shall include all conduits to communications devices in the station area (PA, VMB, PEC, CCTV, Telephone, Ticket Vending Machines, SCADA, etc.) and copper cable wiring to these devices on the station side of demarcation panel. The Systems design shall include all equipment and wiring on CIC side of demarcation panel. All critical alarms shall be wired in a fail-safe condition.

5.5.2 General Interface Coordination

The Communications System is associated with many other systems and other project activities. It is intended to provide a communications system that is fully interfaced with other project activities and perform all required functions. Any additional required interfaces shall be identified and a recommendation made for the most effective method of their control and alarm monitoring. Interface requirements shall be logged and tracked to help ensure that the requirements are completed. This chapter's interface descriptions are not in complete detail. Rather, they are intended for use in conjunction with Communications Interface Drawings and other Design Criteria Manual criteria. The following list includes potential interface areas that the designer shall take into consideration:

a) Transit Vehicle System

    1) Vehicle mobile radio are supplied by LRV supplier

b) Corrosion Control and Grounding System

    1) Communications system grounds
    2) Communications systems shielding
    3) Electromagnetic compatibility
    4) Electromagnetic interference control
    5) Station, Tunnel, Aerial, Yard, Shop, OCC Ground Grid

c) Trackwork System

1) Track location and length
2) Cable express trough routing and transitions to ductbank
3) Wayside cable and equipment installation

d) Station System

1) Power supply to:

- Public address subsystem amplifiers
- Visual Message Board signs
- CCTV cameras and equipment
- Passenger Emergency Call Equipment
- Transmission Equipment
- "Blue Light" Wayside and Emergency Telephone Stations
- Ticket Vending Machines

2) Facility equipment remote terminal unit (RTU)
3) Equipment controls and indications interface to RTU
4) Location and installation in stations of:

- Public address amplification equipment
- Public address speakers
- Public address microphones and controls
- CCTV cameras
- RTU
- Telephones (Station Emergency)
- Visual Message Board Signs
- Elevator
- Passenger call units (PEC subsystem)
- Communications interface cabinets
- Ticket Vending Machines

5) Fire alarm subsystem interfaces to RTU and external zones

6) Intrusion alarm subsystem interfaces to RTU and external zones

7) Radiating cable routing and installation in tunnel, stations or under passes

8) Conduit runs for all communications subsystems

9) Cable installation for all communication subsystems

10) Telephone Company Interface Location for station payphones

11) Fire Management Panel

e) Tunnel and Right-of-Way System

1) Tunnel emergency telephones
2) Bungalow locations
3) Other wayside equipment locations
4) Cableway (subway and elevated stations)
5) Conduit into stations (subway and elevated)
6) Conduit/cableway to signal bungalows and traction
7) Electrification substations and tie stations
8) Cable route (surface sections)
9) Cable installation
10) Radiating cable supports and installation (subway)
11) Fire Management Panel
12) Ventilation system controls and indications

f) Yard and Shop System

1) Power source
2) Equipment location
3) Radio Subsystem

- Base and control station equipment
- Antenna mounting
- Radiating cable in buildings

4) Conduit runs for all communications systems
5) Cable installation for all communications systems

g) Train Control System

1) CTS Interfaces
2) Telephones within bungalows
3) ROC control console layout
4) Yard Control Tower console layout

h) Traction Power System

1) SCADA Interface to transmission system
2) Sectionalizing switch locations (Emergency telephones)
3) Substation telephone locations

i) Operations Control Center Structure System

1) Heating, ventilating and air conditioning
2) Power source
3) Floor loading
4) Lighting

5) Conduit/cable tray layouts
6) Cable installation
7) Equipment installation
8) Acoustical environment

j) Utility Services

1) Interfaces with power companies

- Temporary power
- Cable interference and/or relocation
- Electromagnetic interference coordination

2) Interfaces with gas companies

- Cable or pipeline interference and/or relocation

3) Interface with water/sewer utilities

- Cable, culvert, or pipeline interference and/or relocation

4) Interface with telephone companies

- Cable or fiber interference and/or relocation
- PBX trunks or Centrex Lines
- Leased circuits for control of radio base stations and satellite receivers not served by the Communications Transmission Subsystem, dial back-up for RTUs

5) EMI coordination
6) Temporary telephones

k) Highway and Street

1) Cable routing details at road crossings

l) Railroad

1) Electromagnetic interference coordination
2) Cable interference

m) Safety

1) Fire department radio in tunnels
2) Level of CCTV surveillance required (active or passive)
3) 911 Telephone Zones

n) Fare Vending

1) Data Channel Requirements
2) Central Fare Collection Location

o) Public Information

1) Information Operators

- Number of Operators
- Anticipated Call Volume

p) Airport Authorities (Love Field and DFW International Airport)

1) Radio Frequency Interference
2) Security Coordination

q) Regional Transportation Authorities

1) Denton County Transportation Authority
2) Trinity Railway Express
3) Other Commuter Rail Systems

5.6 ABBREVIATIONS AND DEFINITIONS

ADA - Americans with Disability Act

Administrative Telephone Subsystem - Used to provide communications between various DART field facilities and Operations Control Center and communications between DART field facilities and the Public Switched Telephone Network (PSTN).

CCTV - Closed Circuit Television

CELPS - Central Emergency Lighting Power Supply

CIC - Communications Interface Cabinet

CTS - Communications Transmission Subsystem - A bi-directional fiber optic based digital communications carrier system providing analog and data connections between the OCC and the field.

CRT - Cathode Ray Tube

DACS - Digital Cross Connect Switch - Software based, microprocessor-controlled digital access and cross-connect system that provides for channel swapping of DS-0 slots between different DS-1 (T1) channels.

DACT - Digital Alarm Communication Transmitters

DACR - Digital Alarm Communication Receiver

dBA - Decibels A filter weighted

Demarcation Panel - The physical interface point between facilities and systems work, which allows the Contractor to independently consolidate, route and wire copper audio, visual, SCADA and emergency voice circuits from station equipment locations back to a central point.

DFW - Dallas-Fort Worth

DID - Direct Inward Dial

DOD - Direct Outward Dial

DTMF - Dual Tune Multi-Frequency

EIA - Electronic Industry Association

E&M - Telephone circuit signaling control lines

EMC - Electromagnetic Compatibility - The ability of a device, equipment, or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment or being affected by the environment in an undesirable way.

EMI - Electromagnetic Interference

FCC - Federal Communications Commission

LCD - Liquid Crystal Display

GRC - Galvanized Rigid Conduit

IMC - Intermediate Metallic Conduit

KHz - Kilohertz

Km - Kilometer

m - meter

Mbs - Megabits

MHz - Megahertz

NEC - National Electric Code

NFPA - National Fire Protection Association

NM - Nanometer

OCC - Operations Control Center - The OCC includes the Train Control Center (TCC), the Yard Control Center (YCC), the Security Control Center (SCC), the Bus Control Center (BCC), and the OCC Equipment Room.

OCU - Office Channel Unit

PA - Public Address

PABX - Private Automatic Branch Exchange

PBX - Private Branch Exchange

PCM - Pulse Code Modulated
PEC - Passenger Emergency Call - A communication system used to allow a passenger in an emergency situation to signal an alarm to the TCC, open and latch a voice channel and allow TCC personnel

to establish two-way communications with the passenger via the CTS.

PTZ - Pan/Tilt/Zoom

PSTN - Public Switched Telephone Network

RTU - Remote Terminal Unit - The equipment that constitutes the field end of a Data Transmission.

ROC - Rail Operations Controller

ROW - Right-of-Way

S&I - Service and Inspection

SCADA - Supervisory Control And Data Acquisition

SCS - Supervisory Control System

SINAD - Signal Noise and Distortion

SONET OC-3 - Synchronous Optical Network (SONET) - rate of 155.52 Mb/s consisting of three (3) multiplexed OC-1 rate channels as defined by CCITT. The optical signal that corresponds to the STS-3c electrical signal.

SONET OC-12 - Synchronous Optical Network (SONET) - rate of 622.08 Mb/s consisting of twelve multiplexed OC-1 rate channels as defined by CCITT. The optical signal that corresponds to the STS-12c electrical signal.

Subsystem - A subsystem comprises elements within a system that are interconnected to perform a specific function.

TDM - Time Division Multiplex

TPSS - Traction Power Substation

TCC - Train Control Center - Facility located within the OCC that is staffed and dedicated to the operation, monitoring, and control of the LRT system.

UL - Underwriters Laboratory

UPS - Uninterruptible Power Supply - An auxiliary power system that provides an uninterrupted power source during a normal power source failure.

UPSR - Unidirectional Path Switch Ring

VMB - Visual Message Board

CHAPTER 6

TRAIN CONTROL CENTER
AND
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CHAPTER 6 - TRAIN CONTROL CENTER AND SUPERVISORY CONTROL SYSTEM

6.1 GENERAL

6.1.1 Purpose

The Operations Control Center (OCC) is located at DART's S&I Facility, 3021 Oak Lane, Dallas, Texas, and is also used for dispatch supervision of bus, coach and Transit Police operations. The Train Control Center (TCC) is the principal site for the supervision of DART rail operations, and is located within the OCC.

The TCC includes radio, public address/visual message board, telephone, and supervisory control system equipment to allow rail operations staff to monitor and control wayside and station equipment. The TCC equipment includes: a system of Large Screen displays; Rail Operations Controllers' (ROC) and Yard Operations Controller consoles, with voice communications equipment and supervisory control LCDs; The Yard Operations Controller's console is adjacent to the TCC and is located overlooking the yard area; a DACR to receive all reporting fire alarms, alerts, and system trouble indications communicated through field DACTs (via dialup).

The Equipment Room (ER) is located within the OCC and is separated from the TCC by the Communications maintenance support area. The Equipment room houses the centralized equipment to support TCC operational activities. The Equipment Room also houses a System’s manager console with voice communications equipment.

Data communications facilities and remote supervisory control system equipment are located at stations, traction electrification substations, and in communications and signal bungalows.

This chapter:

a) Provides an overview of TCC Light Rail staff operating functions.

b) Provides a description of the TCC area designated for Light Rail operations, and describes architectural requirements of the facility.

c) Defines requirements for the Light Rail supervisory control system and equipment.

6.1.2 Scope

The existing TCC space is currently designed to support supervision of the Starter System, North East and North Central Expansion corridors, and the Yard. The TCC will be modified to support the increased operational requirements as a result of additional expansion corridors. Operational territory will be expanded by the North West (NW), South East (SE), Irving (IR), and Rowlett (RW) Corridors. The existing Yard will be modified, and a North West Rail Operating Facility (NWROF) will be added. NWROF supervision shall be in accordance with Design Criteria Manual, Volume 2, Chapter 5, Communications, Paragraph 5.4.3.2.

Radio and telephone communications systems and coverage will be expanded between the TCC and all new revenue operations line segments.

The supervisory control system shall monitor and control, from TCC, the following field subsystems in the North West, South East, Irving, and Rowlett line segments:

a) The signal system and associated alarms,

b) The traction electrification system and associated alarms,

c) Station and tunnel facilities,

d) Communications equipment and associated alarms,

e) Intrusion alarm conditions for station fare collection equipment.

The supervisory control system shall continue to support all alarm, indication and controls implemented in the Starter System, North Central, and North East Expansion Corridors. Furthermore; additional power requirement, current OCC UPS load and available load will be analyzed to ensure it can support the future upgrade and modification at TCC and Equipment room.

6.2 TCC Staff Operating Functions

TCC currently includes equipment for radio communications between TCC and the Light Rail service area, emergency telephone system communications, alarm and state display from and command input to wayside and station equipment via the supervisory control system, public address/visual message board capability, fire subsystem monitoring and alarming, and administrative telephone connections to other DART staff and outside public safety agencies. The current operating functions will be available in the Light Rail service area to be expanded, i.e., the North West, South East, Irving, and Rowlett Line Sections.

TCC Light Rail operations staff will utilize the equipment to perform operating functions in the following areas:

a) Mainline Train Supervision (Signaling System)

b) Traction Electrification Supervision

c) Communications Equipment Supervision

d) Yard Supervision

e) Coordination with Bus and Coach operations

f) Emergency Support

g) Security Monitoring

h) General Coordination

6.2.1 Mainline Train Supervision

TCC facilities and equipment will be modified as needed to ensure the following mainline train supervision functions continue to perform per required response times for both the existing system and Phase II expansion corridors:

a) Supervise single track operation

b) Authorize and monitor special moves such as reverse operations and early turnback

c) Supervise train operation to schedule

d) Authorize train entry onto mainline

e) Support scheduled and unscheduled mainline maintenance activities

f) Designate track as closed or slow/reduced speed

g) Supervise unscheduled mainline coupling and uncoupling

h) Help train operators to troubleshoot vehicle problems on the mainline

i) Record incidents, signal violations, and voice radio and telephone conversations

j) Notify Yard or Maintenance of cars needing maintenance

6.2.2 Traction Electrification Supervision

TCC facilities and equipment will be modified as needed to ensure the following Traction Electrification Supervision functions continue to perform per required response times for both the existing system and expansion corridors:

a) Control overhead catenary power to support wayside maintenance and emergency response activities

b) Provide proper power status information in wayside and station emergencies situations

c) Maintain information on power outages and the times of outage and restoration

d) Monitor emergency traction power cutout

6.2.3 Communications Equipment Supervision

TCC facilities and equipment will be modified as needed to ensure the following Communications Equipment Supervision functions continue to perform per required response times for both the existing system and expansion corridors:

a) Monitor Major and Minor Alarms associated with critical communications equipment used to support DART light rail operations.

6.2.4 Yard Supervision

TCC facilities and equipment will be modified as needed to ensure the following Communications Equipment Supervision functions continue to perform per required response times for both the existing system and Phase II expansion corridors:

a) Support pre-dispatch exceptions

b) Supervise car storage and movement

c) Issue Run assignments to train operators

d) Distribute schedule to train operators

e) Distribute bulletins

f) Coordinate car movement to/from Maintenance Area

g) Record voice radio conversations

6.2.5 Coordination with Bus and Coach Operations

TCC facilities and equipment will be modified as needed to ensure rail operations staff can continue to perform the following functions:

a) Reports on major schedule deviations affecting feeder operation and major transfer points

b) Requests for bus, coach and van bridge service

6.2.6 Emergency Support

TCC facilities and equipment will be modified as needed to ensure the following Emergency Support functions continue to perform per required response times for both the existing system and Phase II expansion corridors:

a) Monitor Fire Alarms occurring at:

- Traction electrification substations (TPSS)
- Signal bungalows and Communications bungalows
- Tunnel areas, City Place station, and Aerial Stations
- OCC and Maintenance facilities
- Other areas as required

b) In the event of a tunnel fire, control tunnel ventilation equipment, and execute Emergency Ventilation Scenarios.

c) Access and follow pre-defined emergency procedures and information.

d) Coordinate emergency response activities with the Fire Department and other public emergency services using 911, Radio, and Emergency Telephones

e) Generate Public Address and Visual Messages to the Patrons located within the usable limits of Station Platforms and Underpasses.

f) Communicate with Emergency and Wayside Telephones.

g) Monitor fire suppression equipment failures

h) Monitor tunnel and station sump pumps

i) Monitor Fire Management Panel usage

j) Support testing of fire alarms

k) Support testing of fans and dampers

l) Monitor status of primary power and UPS for station, tunnel ECS, and Communications equipment

6.2.7 Security Monitoring

TCC facilities and equipment will be modified as needed to ensure the following security related functions continue to perform per required response times for both the existing system and expansion corridors:

a) Monitor intrusion alarms from station fare collection equipment, signals and TPSSs bungalows, communications equipment rooms and bungalows, station facilities including Knox-boxes, and other required wayside areas

b) Monitor intrusion gate alarms at tunnel station entrances

c) Support testing of intrusion alarms

6.2.8 General Coordination

TCC facilities and equipment will be modified as needed to ensure the following functions are available for both the existing system and Phase II expansion corridors:

a) Provide voice communications patches as appropriate

b) Monitor status of Light Rail subsystems equipment and report abnormal conditions to Maintenance

c) Monitor status of Light Rail facilities and report abnormal conditions to Maintenance

d) Maintain a log of:

- Systems-related events
- Facilities-related events

6.3 TCC PHYSICAL DESCRIPTION

The Train Control Center (TCC) at the S&I facility is used for supervision of mainline and yard Light Rail operations and includes a Light Rail overview display system and individual consoles for the rail operations staff. The Equipment Room at the S&I facility houses supporting systems equipment including: voice and data communications controllers, field interface equipment, and supervisory control computers and peripheral devices.

6.3.1 Train Control Center

The TCC will house any new communications and supervisory control consoles used by Rail Operations Controllers (ROCs) and the Chief. It will also include any expansion to the existing Wall format Overview Displays.

A future Commuter Rail Controller may also be located in the TCC. Future security staff, responsible for monitoring CCTV and responding to patron emergency calls, will be located elsewhere in the S&I facility.

Additional consoles and supporting equipment shall be added to support the operational requirements of the system expansion. The TCC shall be modified as needed to contain up to six ROC consoles.

The consoles for operational staff shall be located to facilitate communications among the staff. The following additional conditions shall be met:

a) The ROC consoles shall be arranged for effective operation with up to six manned.

b) All ROC consoles shall be located to have a good view of an Overview Display. Staff manning the consoles shall be able to see the Overview Display while seated normally at the console, with horizontal angular range not exceeding 70 degrees and vertical angle not exceeding 30 degrees. Each shall be close enough to easily discern the Overview Display legends and symbols.

c) Access to the TCC shall be located to minimize the disturbance to staff communications or their view of the Overview Display.

6.3.2 ROC Consoles

All new ROC consoles shall be similar in Aesthetic Appearance to the existing Consoles. Performance Requirements shall meet or exceed that of the existing consoles. Consoles shall have the following design requirements:

a) Console dimensions shall be selected consistent with ergonomic limits

b) Frequently used equipment shall be located most accessibly. Most-frequently used procedures shall require the fewest actions possible. Equipment location shall relate to the normal flow of staff activities.

c) Single purpose function buttons and switches shall be used for, but limited to, functions which are frequently used or require rapid activation.

d) Voice communications interfaces shall be integrated such that staff need not switch between more than two devices to interact with the several parties with whom they may need to maintain contact.

e) Choice of command entry devices shall consider the impact upon staff and of other activities (e.g., voice actuation vs. other verbal activities, frequency and duration of arm extension for touch panel or cursor device, motion accuracy requirements).

f) LCD's shall be sized consistently with information requirements and density to minimize emission exposure. LCD's shall be high resolution, low flicker. Color capabilities shall be consistent with information requirements.

g) Audio outputs shall have volume controls. LCD's shall have easily accessible intensity and color controls.

h) Horizontal surfaces, which are touched by operators, shall be non-metallic (low thermal conductivity). Edges shall be rounded.

i) Assemblies and wiring shall be modular to allow replacement of a failed unit within thirty minutes, and replacement shall not require shutdown of the functioning portion of the console. Interface devices shall utilize plug connectors or equivalent for convenient device replacement.

6.3.3 Overview Displays

The existing Overview Displays will be used for the Starter System, North Central, and North East Corridors. Additional Overview Display Equipment will be specified to support operational requirements associated with the expansion corridors. The Overview Display equipment shall display an overview of system status sufficient for Rail Operations Controllers to integrate information regarding: blocks of signaled track where trains are located, traction electrification system status, and critical alarm conditions. The following specific physical features shall be provided:

a) Display of multiple simultaneously displayed colors and object display attributes (including flashing).

b) Display legends shall be easily read from ROC consoles. Abbreviations shall be permitted in legends.

c) The display equipment shall be maintainable with minimal disruption to operations.

d) Display intensity and room lighting levels shall be consistent with easy visibility over long periods.

6.3.4 Equipment Room

The Equipment Room (ER) is located within the OCC and is separated from the TCC by the Communications maintenance support area. The Equipment room houses the centralized equipment to support TCC operational activities. The Equipment Room also houses a System’s manager console with voice communications equipment. The following Equipment is currently housed within the Equipment Room:

a) A Redundant Optical Add/Drop SONET Multiplexer

b) TCC Local Area Network Equipment

c) A Digital Cross Connect System

d) Channel banks

e) Fiber optic cable termination equipment

f) Main Distribution Frame (MDF)

g) A Communications Controller and associated equipment to support Voice, Radio, and PA/VMB communications by the operators

h) Radio voting equipment

i) Audio recorders

j) Supervisory Control System Equipment

k) Test equipment storage

l) Documentation storage for equipment and software

m) Work area for technicians

The Existing Equipment Room layout shall be modified as needed to support additional equipment requirements as a result of the Phase II expansion.

6.3.5 Environmental Features

The following environmental features shall be considered when modifying the TCC and Equipment Room with additional equipment:

a) Controls and air conditioning equipment capacity shall be sufficient to maintain room temperatures within the range of 65 to 75 degrees Fahrenheit (within .5 degrees) and within a relative humidity of 60 to 80 percent.

b) All work areas shall be illuminated. The TCC shall have general lighting that can be dimmed and controlled from a central location. In addition, spot lighting shall be provided for all consoles. All general lighting shall be connected to Essential Power.

6.3.6 Intrusion and Emergency Services Features

Modifications to the TCC and Equipment Room shall not diminish existing Emergency services. The following emergency service features shall continue to be supported:

a) TCC and Equipment Room access control provided with locked doors.

b) A fire alarm system and/or clean agent fire suppression system for the Equipment Room and the TCC, with overriding shutoff.

c) Emergency egress systems. These include flashing lights, unlocking power doors, etc., sufficient to ensure occupants will have clear exit routes.

6.4 LIGHT RAIL SUPERVISORY CONTROL SYSTEM

The existing Light Rail Supervisory Control System (SCS) automates and/or augments some of the functions for LRT operations. The SCS is computer-based and includes equipment at the TCC, Equipment Room, communication and signal houses, Traction Power Substations, Light Rail stations, and other field locations.

The major elements of the SCS are:

a) Remote terminal units (RTUs) located along the wayside to acquire devices and alarm states and to implement ROC device control commands.

b) Computer equipment located at the TCC, the Overview Display, and ROC console-based display and input devices. Display devices provide up-to-date wayside, station, and alarm information.

6.4.1 Data Communications between RTUs and the TCC

A fiber optic communications system is currently in place between TCC and the following line segments of the system:

a) Oak Cliff not including SOC and WOC

b) North Central

c) North East

A fiber optic communications system shall be provided between TCC and the following line segments of the system:

a) North West

b) South East

c) Irving

d) Rowlett

Fiber optic-based communications is also provided between TCC and the traction electrification substations in the CBD and OC line sections, not including WOC and SOC.

The RTUs in the expansion line segments and the TCC computer equipment shall communicate over the fiber optic communications system utilizing industry-standard physical level and link level data communications protocols.

6.4.2 Automated Features

The SCS shall continue to provide the following automated features for the expansion:

a) Monitor and report to the ROCs change-of-state for:

   - Signal system devices and alarms
   - Traction electrification system devices and alarms
   - Station Fare Collection equipment intrusion alarms
   - Fire alarms, station facility alarms, station alarms, and tunnel ventilation system devices and alarms
   - Security/intrusion detection device alarms
   - Communications equipment alarms

b) Keep current all displayed information on the Overview Display and console LCD displays.

c) Initiate control actions to station and wayside devices in response to ROC commands entered at the ROC consoles. Control actions shall include those to:

d) Control traction electrification system breakers and motorized disconnect switches

e) Control emergency traction power disconnect

f) Control ventilation system fans and dampers in response to tunnel fires

g) Control signal equipment

h) Request routes of signal system vital interlockings

i) Operators can place track blocks on segments of tracks for indication only, but there will be no impact in the field.

j) Recall and display emergency operating procedures and recommended ventilation scheme for response to tunnel fires

k) Log system events, alarms, and operator-entered commands

6.4.3 Rail Operations Controllers and Other Users

Rail operations staff shall continue to utilize ROC consoles to supervise Light Rail system activities. All new ROC consoles shall be similar to existing consoles, and shall meet or exceed the performance characteristics of the existing consoles.

6.4.4 General Graphical Requirements

The new Overview Display and console graphics for the expansions shall provide a semi-geographic representation of the Light Rail system and its major subsystems. All displayed information, symbols, and associated graphics shall be consistent with the current implementation.

6.4.5 System Response Time Requirements

The elapsed time from:

a) First possible detection by an RTU of an alarm or device change of state until display at TCC shall not exceed four (4) seconds.

b) When an ROC enters a command for any individual device control until the RTU generates the associated output signal shall be no more than four (4) seconds.

6.4.6 System Availability

The Supervisory Control System is intended to operate 24 hours per day seven days a week. Modifications to the SCS architecture shall not compromise system availability.

6.4.7 Remote Terminal Units (RTUs)

RTU equipment is located within communications and signal bungalows along the wayside, and in traction electrification system (TES) bungalows. Additional RTUs shall be provided to support expansion corridors. RTUs:

a) Provide device signal state acquisition, change of state detection, and corresponding reporting to central computer equipment

b) Initiate device control actions based on commands from central computer equipment

c) Provide alarm signal acquisition and corresponding reporting to central computer equipment

d) New RTUs shall be solid-state microprocessor-based units with logic elements and auxiliary components configured as easily replaceable plug-in modules. All communications RTUs shall be from the same manufacturer; common function subsystem modules shall be interchangeable between the RTUs.

e) RTU configuration shall be modular to provide expansion of performance and capacity by adding subsystem modules. This shall include the ability to add I/O subsystem modules.

f) RTUs shall be capable of unattended operation. RTUs shall automatically begin operation upon power on.

g) Each RTU shall be capable of continued operation with the loss of communication to TCC as a result of either communication equipment failures or central equipment failures. Each RTU shall, in the event of loss of power, perform auto-restart after resumption of power.

h) RTUs shall support local initialization and troubleshooting with either local control panel or portable test equipment.

6.4.7.1 RTU I/O

RTUs shall support digital inputs and outputs via contact closure and relays (or optically isolated solid state equivalents such as silicon controlled rectifiers). I/O shall be electrically isolated to protect against power surges.

Input and output circuit wiring shall be terminated at terminal blocks, where they will be connected to device indication or control circuit wiring provided by others.

For inputs:

a) The RTU shall provide DC voltage to an input circuit to sense contact closure

b) Each input circuit shall be scanned such that all events lasting at least 500 milliseconds are acquired

c) Abnormal or inaccurate sensing conditions due to signal bounce and power transients shall be accommodated

For outputs:

a) The RTU shall provide and drive a relay and dry contact

b) Each digital output shall be controlled by software to close for a specific time length; the length of time shall be pre-defined (and configurable) for each point to be between 100 milliseconds and 2 seconds.

c) The RTU shall prevent unintended energizing of output circuits upon power up and power restoration.

LED indicators shall be provided on the front of each I/O card indicating the current status i.e., input contact closed, output relay energized.

RTU I/O subsystems (including cables) shall be equipped with extra capacity for both input and outputs.

6.4.7.2 Data Communications between RTUs and the Central Equipment

RTUs shall utilize an Ethernet connection to the fiber optic communications system to communicate with the TCC. Speed shall be at least 10 Mbps and as much as 100 Mbps. Signal System RTUs shall be interfaced serially to the Communication Systems RTU. Error correction and detection shall utilize an industry standard scheme (such as CCITT CRC-16) and at a minimum shall: detect all errors of up to 16 contiguous bits; and detect at least 99% of all error bursts greater than or equal to 16 bits.

For RTU locations where the fiber optic communications system is not present, the RTU shall communicate with the TCC using a dial-up telephone line.

6.4.7.3 Maintainability

RTUs shall:

a) Perform self-tests upon power up and on command from local test equipment and from central. I/O subsystems and I/O cards shall also perform self-tests.

b) Detect and report I/O subsystem card failures and indicate via card LEDs

c) Detect and indicate (via local LED) lack of communication link

d) Provide for safe maintenance and testing of I/O circuits and safe replacement of I/O cards while power is applied to the RTU and I/O subsystem.

e) Include and support use of portable test units which can:

- Emulate RTU to the TCC
- Emulate the TCC to the RTU

6.4.7.4 Environmental Requirements

RTUs shall be capable of continued operation between -10C and +60C with up to 95% humidity (non-condensing)

RTUs shall be capable of continued operation in the electromagnetic environment where they will be located, such as TES, signal, and communications bungalows. RTU electromagnetic emissions shall meet FCC requirements.

6.4.7.5 Enclosures

RTUs shall be located in racks or cabinets. Racks, Cabinets, and equipment shall be properly grounded.

I/O cables shall be labeled and shall have keyed plug connectors for connection to I/O cards.

6.5 REQUIREMENTS FOR INTERFACE TO OTHER SYSTEMS

6.5.1 Service and Inspection Building Systems Interfaces

The S&I building shall provide the following support interfaces:

a) Building Power

- The building facilities provide Essential Power and House Power for the current loads.
- Additional power loads will be calculated to account for any added equipment. Requirements shall be communicated to building facilities for possible expansion.

b) Grounding Interface

- The building facilities have provided existing grounding systems. The TCC system equipment utilizes two independent grounding systems. The grounding systems shall have connection points in the Equipment Room and the TCC.

- The current grounding system shall be evaluated and modified to support any additional connections required.

6.5.2 Signal System Interface

The signal system shall continue to provide portions of indication and control circuitry to enable the RTUs to:

a) All signal system Local Control Panel control, alarm, and Terminal Mode functions shall be available on the shall be available at the TCC and OCS

b) Monitor and report signal system power alarm conditions, e.g.: conditions caused by events such as blown fuse, ground detection, AC and DC power failures

c) Monitor and report state for signal system devices such as: track circuits/blocks, switches, signals and platform limits.

d) Monitor and report fire alarms at signal bungalows

e) Request track inhibit (to prevent train entry into closed track), and request track inhibit reset

f) Request switch inhibit (to prevent realignment of a switch), and request switch inhibit reset

g) Request routes of interlockings, including routes in support of reverse train movement

h) Support testing of signal bungalow fire alarms

The Signal System shall provide one or more terminal blocks to which RTU I/O wiring can be connected, and shall provide and wire circuitry between the terminal block and its devices.

The signal bungalows shall contain sufficient space for an RTU/Communications cabinet, and shall provide sufficient power for the RTU and supporting devices.

6.5.3 Traction Electrification System Interface

The Traction Electrification System shall provide portions of indication and control circuitry to enable the RTUs to:

a) Monitor and report TES alarm conditions, e.g. caused by events such as: high substation temperature; high transformer temperature; uninterrupted power system fault

b) Monitor and report change-of-state for traction electrification system:

- AC feeder breaker
- AC over/under voltage and over current
- DC over/under voltage and over current
- DC rate of rise

c) Monitor and report change-of-state (energized/de-energized status) of OCS sections

d) Monitor and report if a circuit breaker has been placed in local control mode

e) Monitor and report Blue Light station local lockout state, and support testing of emergency traction power disconnect from Blue Light stations

f) Monitor and report fire alarms at TESs

g) Command open and/or close of DC and AC circuit breakers

h) Command disconnect/restoration of DC power to a catenary section

i) Support testing of TES bungalow fire alarms

j) Monitor presence of voltage indication on station Buss and catenary sections

The TES shall provide one or more terminal blocks to which RTU I/O wiring can be connected, and shall provide and wire circuitry between the terminal block and its devices.

The TES substation bungalows shall contain sufficient space for an RTU/Communications cabinet, and shall provide sufficient power for the RTU and supporting devices.

6.5.4 Station Facilities and Ventilation System Interfaces

Station facilities and ventilation system shall provide portions of indication and control circuitry to enable the RTUs to:

a) Monitor and report fire/smoke alarms in:

   - Tunnel areas and underground station(s)
   - Aerial Stations

b) Monitor and report activation of local Fire Management Panels at tunnel areas and underground station(s)

c) Monitor and report change-of-state for ventilation equipment (fans and dampers) in tunnel areas and underground station(s)

d) Monitor and report station high temperature alarms, e.g., in equipment rooms, bungalows, interface cabinets

e) Monitor and report alarm conditions for station environmental control equipment:

   - Fire water pump (low water level)
   - Sprinkler system
   - Air conditioning system

f) Monitor and report high water alarm state from tunnel sump pumps

g) Monitor and report station power-related alarms:

   - Primary AC feed and circuit breaker
   - Station UPS (transfer to/failure)

h) Monitor and report fare vending equipment intrusion alarms

i) Monitor and report intrusion alarms at selected areas

j) Issue "test" control to fire alarms in:

- Tunnel areas
- Non-tunnel areas

k) Control ventilation fans and dampers in tunnel and underground station areas

The station facilities, station environmental control system, and ventilation system shall provide one or more terminal blocks in each communications equipment room to which RTU I/O wiring can be connected, and shall provide and wire circuitry between the terminal block and its devices.

The station communications equipment rooms shall contain sufficient space for and RTU/Communications cabinet, and shall provide sufficient power for the RTU.

CHAPTER 7

FARE COLLECTION

Chapter 7

FARE COLLECTION

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CHAPTER 7 - FARE COLLECTION

7.1 GENERAL

The DART Light Rail (LRT) Fare Collection System consists of fare collection equipment and a related Centralized Data Collection System (CDCS).

The fare collection equipment for the Light Rail Buildout Phase 2 System shall use the barrier-free, self-service method. The fare collection equipment shall have been proven in transit revenue service.

Each station shall have fare collection equipment consisting of one or more ticket vending machines (TVM), and one or more Stand Alone Validators (Validators). Each TVM shall have the capability to vend single-ride and day pass tickets, of various pricing levels. The TVM shall issue tickets already validated or not validated. Validators shall validate pre-purchased tickets by stamping an inserted ticket with current date, issue time, and a validator code.

Transit patrons shall purchase tickets, validate them if necessary, and retain the validated tickets as evidence of payment for passage throughout the system.

The fare collection equipment shall be designed to meet applicable standards such as the National Electrical Code (NEC), National Electrical Safety Code (NESC), and Underwriters' Laboratories, Inc. (UL), and the local codes of authorities having jurisdiction.

The fare collection equipment shall be designed to meet the rules in Title 49, Code of Federal Regulations, Part 37 resulting from the Americans with Disabilities Act. In particular, rules related to Automated Teller Machines (49CFR37, Appendix A, Section 4.34) and appended guidelines for Controls and Operating Mechanisms (Appendix Section A4.27) must be addressed in the fare collection equipment design.

7.2 TICKET VENDING MACHINES

TVMs shall:

a) Dispense tickets according to fare policy

b) Accept U.S. coins for payment

c) Accept U.S. bills for payment

d) Have a display to provide information to patrons that is fully visible in direct sunlight

e) Meet all applicable requirements of ADA

f) Have buttons that allow Patrons to make choices regarding language, zones, type and quantity of tickets

g) Recirculate coins

h) Have supplemental change units

i) Accept overpayments and issue overpayment tickets

j) Have cancel button

k) Allow purchase of multiple tickets in a single transaction

l) Meet the temperature requirements of the local environment

7.2.1 Coin and Bank Notes

The TVM shall accept, validate and retain only United States coins.

a) Coins accepted and validated shall only include:
   - Dollar coins
   - Fifty-cent coins
   - Quarters
   - Dimes
   - Nickels

b) The coin validator shall be configurable to accept an Authority defined token.

c) The TVM shall return change.

d) The coin system shall consist of:

   - Coin re-circulation unit capable of handling all above coin denominations with the exception of Fifty-cent coins.
     1) Receptacle capacity of 70 coins per unit

   - Coin escrow units that return the exact same coins deposited during that transaction.
     1) Minimum size based upon the re-circulation unit

   - Supplemental change units
     1) Minimum capacity of 700 coins

   - Coin Vaults
     1) Minimum size of 366 cubic inches
     2) Weight not to exceed 10 pounds empty

e) Any component of the coin system shall be removable and, when removed, the TVM shall remain in service for bank note transactions.

The TVM shall accept, validate, and retain only United States bank notes.

Bank Note capability shall include the following:

a) One dollar
b) Five dollar
c) Ten dollar
d) Twenty dollar

Accepted bank notes shall be stacked and stored separate and apart from the coinage in a locked vault.

a) Minimum capacity of 1,000 bills
b) Weight not to exceed 10 pounds empty

Bank notes shall be accepted in all four orientations.

The bill validator shall reject foreign objects and all bank notes not in acceptable condition.

The bill system shall be removable and, when removed, the TVM shall remain in service for coin transactions.

The TVM shall contain a bill escrow unit that holds up to 15 bills.

7.2.2 Ticket Stock

The TVM shall dispense ticket stock as follows:

a) Minimum of four (4) unique ticket stocks.

7.2.3 User Information

Each TVM shall facilitate ticket purchase by:

a) Logically arranged step-by-step ticket purchase information

b) Presenting information in the following forms:
- American English
- Spanish
- Information that complies with Title 49, Code of Federal Regulations Part 37

7.2.4 Display

The TVM shall contain a patron user display device and the display device shall provide information necessary to purchase ticket(s).

7.2.5 Additional TVM Features

The additional following TVM features shall be provided:

a) Cancel Button - To immediately cancel the transaction and return any coins or bills that are held in escrow.

b) Automatic Time-Out - If a transaction is not completed within a preset time, the TVM shall cancel the current transaction and prepare for the next transaction.

c) Recording of Transactions - The TVM shall record each and every transaction. As a minimum the following data shall be recorded:

- Date
- Time
- Event code
- Employee code
- Totals for each ticket type selected
- Total transaction value
- Overpayments
- All Maintenance and Revenue access and the actions taken.
- Count by bill and coin type received for all vaults and hoppers.

d) Programming Capabilities - The TVM shall have the capability to be programmed by authorized service personnel to modify the ticket printed and to update the fares associated with each button.

e) Authorized service personnel shall have the capability to modify (through the CDCS) the maximum change returned.

f) Authorized service personnel shall have the capability to modify (through the CDCS) the bank notes denominations accepted.

g) An audit register ticket showing vaulted money shall be created for counting room audit purposes.

h) Environmental - The TVM must be suitable for outdoor operation in exposed locations under the full range of climatic conditions as detailed in the <u>Design</u> Criteria Manual. Volume 2, Systems, Chapter 1.

i) Ergonomic Factors - Design for:

- Optimized human factors performance
- Patron information and instructions
- Ticket purchasing methods and operations
- Revenue and ticket stock servicing
- TVM maintenance servicing

7.2.6 TVM Dimensions

Overall TVM dimensions above mounting base:

Width: 3ft - 0in
Depth: 2ft - 0in

Range of operable control:	In accordance with ADA requirements
Cabinet overhang:	Not lower than 80in
Access:	Wheel chair front and side

7.3 TICKET VENDING MACHINE HARDWARE REQUIREMENTS

The TVMs shall be constructed of modular components that provide for ease of maintenance and servicing, including:

a) Modular hardware design

b) Lowest level replaceable unit modules

c) Provide module exchange method for machine servicing from the front

d) A coin slot with verifier and escrow unit to validate the coins used as payment.

e) Coin re-circulating unit:
- Allows current use of inserted coins for making of change.
- Requires the change to come from the re-circulating unit until it is empty.
- Whenever the re-circulating unit cannot dispense change, then change shall be dispensed from the supplemental change units.

f) Coin vaults for:
- Receiving coins
- Securing coins

g) Integrated bill acceptance system:
- Bank note acceptor and verifier
- Escrow unit

h) Bill vaults with stackers for:
- Receiving bank notes
- Securing bank notes

i) The coin and bill vaults shall be uniquely keyed and:
- Be protected so that they can only be opened by authorized personnel in the counting room.
- Have an exclusive, secured chamber in the TVM assembly or pedestal.

j) A ticket tray for:
- Ticket dispensing
- Returning change

k) Microprocessor logic for:
- Controlling the machine
- Monitoring its condition

1) Data shall exit the machine by way of fiber optic cable stubbed up into the TVM base.

m) Power Backup to:
- Complete the last ticket transaction if money has already been inserted.
- Ensure that the data is keep intact so that events may be tracked.
- Maintain the local alarm for at least four hours.

n) Provide for a local shut-off for the local alarm.

o) A security system as described in Paragraph 7.5, Security

p) Sufficient memory capacity to electronically retain all transactional data for replacement of hard drive or subsequent transmittal to data storage facility:
- ASCII data format
- Removable memory device (i.e. PCMCIA card or floppy)

q) Remote monitoring and reporting over the communications network.

r) The TVM may include:
- Bank credit/debit card reader/validator
- Credit card reader/validator

7.3.1 Equipment Enclosure

The TVM cabinet characteristics shall include the following:

a) Constructed from stainless or cold-rolled, commercial-quality steel.

b) Provide front access

c) Be free of sharp edges and burrs on all exterior surfaces including all controls and appurtenances.

d) Built to resist damage to exterior cabinet and components due to abuse and vandalism and shall further protect all accessible components of the machine from unauthorized entry.

e) No screws or hinges shall be accessible from the exterior

f) All metal parts that can be contacted by patrons shall be electrically grounded.

7.3.2 Lighting

a) TVM shall be equipped with a fluorescent lighting fixture to illuminate the front and back areas when the ambient light conditions are low.

b) Fluorescent lighting shall be controlled by a photoelectric sensor.

c) There shall be an interior cabinet light to aid maintenance and service personnel, which shall automatically illuminate each time the cabinet door is opened.

7.3.3 Utility Connections

a) The TVMs shall take power from a branch of the station service at 120 volts AC, 60 Hz, single phase.

b) Power shall enter the machine by way of conduit stubbed up into the base area.

7.4 RELIABILITY AND MAINTAINABILITY

a) The TVM shall be required to meet minimum reliability standards. The equipment shall have a design life of a minimum of 15 years.

b) The software logic shall include a diagnostic capability that shall identify defective modules.

c) Faults shall be self-diagnosing and reported by event with detailed error codes.

d) Maintenance information shall be retained at the TVM and also sent to the CDCS.

7.5 SECURITY

a) Each TVM shall be designed and mounted to minimize the effects of tampering and vandalism.

b) Vault access shall use controlled keying and high security locks that are mounted to prevent tampering.

c) All exterior doors shall be locked with at least a three-point latching device with a bascule bolt and a hook locking bar, or DART approved equivalent.

d) Access to the TVM for maintenance functions shall not provide access to the money vaults.

e) The TVM shall detect intrusions and shall signal the Train Control Center (TCC) via the LRT System communications network.

f) In the event the door on the TVM should be opened without proper authorization, an audible alarm shall annunciate this condition locally at the machine and immediately send the alarm message to the CDCS and to the TCC.

g) The communications link integrity shall be automatically checked on a periodic basis to confirm that it is functional.

7.6 CENTRALIZED DATA COLLECTION SYSTEM

a) The TVMs shall be networked together for information transfer between the CDCS and each TVM installed.

b) The CDCS provides:
- Transaction record integrity when moving data from the TVM to the Data Storage Computer.
- Daily TVM polling to ensure transmittal of data from the TVM to the CDCS.
- Data repository for all event and transactional data.
- Control of various TVM operating parameters from a remote location to allow new system files to be sent to the TVMs.
- A vehicle to generate required system reports.

c) The CDCS shall receive status indication from the TVM via the communications network.

d) At a minimum, the following TVM originated information shall be transmitted to the CDCS:

- Intrusion Alarm Data
  1) Machine identification number
  2) Event code triggered
  3) Date and time
- Transaction Data
  1) Machine identification number
  2) Date and time
  3) Overpayment amount
  4) Escrow amount

5) Card number
6) Ticket information
   i. Type
   ii. Value
   iii. Quantities

e) Event Data
- Machine identification number
- Date and time
- Event code
- Access information

f) Revenue Container Insertion and Removal
- Data Machine identification number
- Date and time
- Revenue container identification
- Employee ID

7.7 VALIDATORS

a) Validators shall:
- Be stand-alone devices
- Imprint an inserted ticket with:
  1) Date
  2) Ticket expiration time
  3) Station
  4) Validator identification code

b) Imprint marks shall be clearly visible on the ticket.

c) Approximate validator dimensions excluding its mounting post or ventilating hood shall be:

Height:	27in
Width:	14in
Depth:	14in

d) Range of operable control:
- In compliance with ADA requirements

CHAPTER 8

CORROSION CONTROL

Chapter 8

CORROSION CONTROL

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CHAPTER 8 - CORROSION CONTROL

8.1 GENERAL

8.1.1 Purpose

This chapter describes design requirements necessary to provide corrosion control for DART LRT System. Corrosion control systems shall: prevent premature corrosion failures; minimize stray current effects on DART owned and other underground structures; and be economical to install, operate, and maintain.

8.1.2 Transit System Description

Traction power for transit vehicles is supplied by a nominal 750-volt DC overhead catenary system. The catenary system is energized by Traction Power Substations located along system route. The running rails of each track are used as negative conductors for the return of traction power to substations. The system operates on fixed facilities, such as aerial and at-grade trackway facilities. Negative return rails are crossbonded at approximately 2000 ft. intervals to maintain electrical continuity and equal potential levels for all rails.

8.1.3 Scope

Corrosion control design criteria encompass all engineering disciplines applied to the project. The criteria is separated into three areas: Soil Corrosion, Stray Current Corrosion and Atmospheric Corrosion Controls. The criteria for each are described below:

a) Soil Corrosion Control. Criteria shall apply to systems or measures installed to mitigate corrosion caused by soils and ground waters. Designs shall be based on the corrosive characteristics of soils as documented in the predesign investigations report or from actual on-site measurement, if necessary. The report shall be used by the designer to aid with the design and preparation of construction contract documents.

b) Stray Current Corrosion Control. Criteria shall apply to systems or measures installed with the traction power system and trackwork to assure that stray earth currents are maintained within acceptable ranges based on system characteristics and the characteristics of other underground facilities.

c) Atmospheric Corrosion Control. Criteria shall apply to systems or measures installed to mitigate corrosion caused by local climatological conditions and air pollutants. Design shall be based on the corrosive characteristics of the atmosphere as documented in the predesign investigations report. The report shall be used to aid with the design and preparation of construction contract documents.

8.1.4 Interfaces

Corrosion control engineering shall be interfaced and coordinated with other designs, including the utility, mechanical, civil, structural, electrical, trackwork, traction electrification, environmental, geotechnical, architectural, safety requirement system grounding, bonding design for lightning protection, and signals and communications system designs. The DART system shall be designed and constructed in segments, corrosion control shall be coordinated throughout the design, installation, and start-up process of each segment.

8.1.5 Expansion Capability

The design criteria contained in this chapter applies to each construction segment. However, the corrosion control criteria shall be applicable to the entire system without major reconfiguration, reconstruction, redundancy and duplication of equipment. Unique prototypes and experimental systems of a research nature are discouraged. Any such systems or prototypes must be reviewed and approved by DART prior to their implementation and prior to incurring any costs for billing to the Authority.

8.2 SOIL CORROSION CONTROL (BURIED STRUCTURES)

8.2.1 Purpose

The purpose of this section is to provide criteria for designs to prevent corrosion of DART structures due to soil and water conditions. The designs shall be based on achieving a 75-year life for buried structures. Where failure would affect safety or interrupt continuity of operations, corrosion control provisions shall be required for all facilities regardless of location and material for construction.

Materials of Construction. All piping (pressure and non-pressure) and conduit shall be non-metallic unless metallic materials are required for specific engineering purposes. Use of metallics must be supported by engineering calculations when used in lieu of non-metallics. Aluminum and its alloys shall not be used for direct burial purposes.

8.2.2 Scope

The structures which may be affected by soil and water corrosion shall be identified. Typically, these include, but are not limited to:

a) Ferrous or concrete tunnel liners
b) Buried and on-grade reinforced concrete structures
c) Pier and piling structures
d) Ferrous pressurized piping (water, fire water, sewage ejectors, and so forth)
e) Hydraulic elevator and lift cylinders
f) Chilled water systems
g) Underground storage tanks
h) Other underground structures

Designs shall be provided for DART structures to permit a safe and reliable operation for the 75-year life span specified above. Corrosion control measures for structures owned by others shall be coordinated with the interested owner(s). This coordination shall be required to resolve design conflicts and to minimize the impact of other designs, such as interference of cathodic protection. All contacts with owners of other structures shall be coordinated through DART.

8.2.3 Design of Soil Corrosion Prevention Systems

Protection of metal structures shall include corrosion control techniques such as coating, electrical isolation, electrical continuity, and cathodic protection. The corrosion control designer shall coordinate the designs to identify concrete structures subject to attack, and shall specify cement types in accordance with ASTM C-150. For severe environments, supplemental coatings shall be specified.

a) Coatings. Coatings specified for corrosion control of buried metallic or concrete facilities shall meet the following minimum criteria:

- Minimum volume resistivity of 10^{10} ohmcentimeters

- Thickness as recommended for the specific system but not less than 15 mils

- Provide a chemical or mechanical bond to metal or concrete surface. Pressure sensitive or nonbonding systems are not acceptable.

- A minimum five year performance record for intended service.

- Mill application wherever possible, with compatible tape systems for field application.

- Mechanical characteristics capable of withstanding reasonable abuse during handling and earth stresses after installation for the design life of the system.

- Design shall specify surface preparation, application procedure, primer, number of coats, dry film thickness, testing and repair procedures for the specific system used. Suitable generic coating systems include but are not limited to the following:

  1) Extruded Polyethylene/Butyl Based System

  2) Coal Tar Epoxies (Two Component Systems)

  3) Polyethylene Backed Butyl Mastic Tapes (Cold Applied)

  4) Bituminous Mastics (Airless Spray)

b) Electrical Isolation. Devices used for electrical insulators for corrosion control shall include non-metallic inserts, insulating flanges, couplings, unions, and concentric support spacers. Devices shall meet the following minimum criteria:

- Devices shall have a minimum of 10 megohms prior to installation and shall have mechanical and temperature ratings equivalent to the structure in which it is installed.

- Devices shall have sufficient electrical resistance after insertion into the operating piping system such that no more than 2% of a test current applied across the device flows through the insulator, including flow through conductive fluids if present.

- Devices (except non-metallic units) buried in soils shall be encapsulated in a non-conductive heat shrink sleeve in accordance with manufacturers recommendations.

- Devices installed in chambers or otherwise exposed to partial immersion or high humidity shall have a protective coating applied over all components.

- Design shall specify the need for, and location of, insulating devices. All devices shall be equipped with permanent test facilities when they are not accessible or when specialized equipment is necessary for access.

- Wherever possible, a minimum clearance of six inches shall be provided between new and existing structures. When field conditions prohibit a six-inch clearance, the design shall include special provisions to prevent electrical contact with the existing structure(s).

c) Electrical Continuity. Electrical continuity shall be provided for all non-welded pipe joints and shall meet the following minimum criteria:

- Use direct burial insulated, stranded copper wires with the minimum length necessary to span the device being bonded.

- Wire size shall be based on the electrical characteristics of the structure and resulting network to minimize attenuation and allow for cathodic protection.

- A Minimum of two wires shall be used per joint for redundancy.

- Exothermic welds and adjacent bared piping shall be coated.

d) Cathodic Protection. Cathodic protection systems shall be provided for buried metallic structures consistent with the structure life objectives. Wherever feasible, cathodic protection shall be accomplished by sacrificial galvanic anodes to minimize corrosion interaction with other underground utilities. Impressed current systems shall be used only when use of sacrificial systems is not technically and economically feasible. DART shall approve use of these systems at the conceptual stage prior to detailed design. Cathodic protection schemes using forced drainage of transit induced stray DC currents that require connections to the negative system shall not be used.

- The cathodic protection design shall consider the following:

  1) Presence of anaerobic bacteria

  2) Need for mutual protection schemes

  3) Limitation of cathodic potential

  4) Inaccessibility after construction is completed

  5) Need for monitoring facilities

- Cathodic protection system design shall be based on theoretical calculations for each system including the following minimum parameters:

  1) Cathodic current density (minimum 1.0/ma/ft^2 of bare area)

  2) Current requirements

  3) Anticipated current output/anode

  4) Assumed percentage bare surface area (minimum 1%)

  5) Indicated total number of anodes, size, spacing

  6) Anticipated anode bed resistance

  7) The sum of the anticipated anode life and time to failure based on corrosion rates anticipated at 90% cumulative probability level, shall not be less than 75 years.

e) <u>Impressed Current Systems</u>. Impressed current rectifier systems shall be completely designed using variable voltage and current output rectifiers. Rectifiers shall be rated a minimum of 50% above calculated operating levels to overcome a higher than anticipated ground bed resistance, lower than anticipated coating resistance, or presence of interference bonds. Other conditions which may result in increased voltage and current requirements shall be considered.

f) Water Treatment. Chemical treatment of chiller, condenser and boiler supply and return systems shall be designed to minimize internal corrosion and to prevent component fouling. Water treatment systems shall be designed to prevent corrosion rates in excess of 2.0 mils per year for steel and 0.1 mil per year for copper. Provisions for corrosion rate measurements shall be made in the return lines. All chemical treatment systems shall comply with environmental protection requirements. The corrosion control design shall include appropriate measures and provide space requirements for treatment equipment.

g) Test Facilities/Testing. Test stations consisting of two structure cables, one reference electrode, conduits, and termination boxes shall be designed to permit initial and periodic tests of cathodic protection levels, interference currents, and system components (anodes, insulated fittings, and continuity bonds). The corrosion control design shall specify the locations and types of test facilities for each cathodic protection system.

8.2.4 Materials and Structures

a) Ferrous Pressure Piping. All DART owned buried cast iron, ductile iron and steel pressure piping shall be cathodically protected. Designs shall be provided by the DART and will include the following:

- Application of a protective coating to the external surfaces of the pipe (See Coatings 8.2.3.b).

- Electrical insulation from interconnecting piping, other structures, and segregation into electrically insulated discrete sections depending upon the total length of the piping (See Electrical Insulation 8.2.3.c).

- Electrical continuity through installation of insulated copper wires across all mechanical joints other than intended insulators (See Electrical Continuity 8.2.3.d).

- Permanent test/access facilities installed at all insulated connections and at intervals of not greater than 200 feet, to allow for the verification of continuity, the effectiveness of insulators and coating, and the evaluation of protective level.

- Impressed current anodes and rectifier units or sacrificial anodes; the number of anodes and the size of rectifiers shall be determined on an individual structure basis.

b) Copper Piping. Buried copper pipe shall have an exposed and accessible insulating union installed at all locations where the piping enters through a building wall or floor. A non-metallic, insulating, and watertight seal shall be installed at each pipe penetration point to separate the piping from building structural elements.

c) Reinforced/Prestressed Concrete Pressure Pipe. The design and fabrication of reinforced concrete pipe and steel cylinder pre-stressed concrete pipe shall include the following:

- A low permeability concrete by controlling the water/cement ratio (ratios of 0.3 for core concrete and 0.25 for mortar are preferred, but industry practices may result in changes to these levels).

- Maximum of 200 ppm chloride concentration in mixing water for concrete.

- General use of Type I Portland Cement.

d) Concrete/Reinforced Concrete. For concrete in contact with soils, design shall be based on the following:

- Use of Type I Portland Cement.

- Maximum water/cement ratio of 0.45 by weight.

- Maximum 200 ppm chloride concentration in mixing water and admixtures combined.

- Minimum 2 in. of concrete cover on the soil side of all steel reinforcement when the concrete is poured within a form or a minimum 3 in. of cover when the concrete is poured directly against soils.

e) Gravity Flow Piping (Non-Pressured)

- Corrugated steel piping shall meet the following minimum:

  1) Application of a sacrificial metallic coating and an outer organic barrier coating to interior and exterior surfaces.

- Cast or ductile iron piping shall be designed and fabricated to meet the following minimums:

  1) Use an internal mortar lining with a bituminous steel coating on ductile iron only (not required for cast iron soil pipe).

  2) Use a bonded protective coating or unbonded dielectric encasement on the external surfaces in contact with soils.

  3) Use a bituminous mastic coating on the external surfaces of pipe 6 in. from each side of a concrete/soil interface.

- Design, fabrication and installation of reinforced concrete non-pressure piping shall include the following minimums:

  1) Water/Cement ratios meeting minimum provisions of American Water Works Association (AWWA).

  2) Maximum 200 ppm chloride concentration in mixing water.

f) Electrical Conduits. Buried metallic conduits shall include the following minimum:

- Galvanized steel with a PVC top coat or other coating acceptable for direct burial, including couplings and fittings.

- Galvanized steel with a minimum of 3 in. concrete cover on soil sides within duct banks.

- Electrical continuity through use of standard threaded joints or bond wires installed across non-threaded joints.

g) Hydraulic Elevator and Lift Cylinders. Steel hydraulic elevator and lift cylinders shall be designed, fabricated and installed to meet the following minimums:

- Application of an external protective coal tar epoxy or coal tar tape coating resistant to deterioration by petroleum products (hydraulic fluid).

- An outer concentric fiberglass reinforced plastic (FRP) casing. Casing thickness diameter and resistivity shall be designed to prevent moisture intrusion (including the bottom), and to maximize electrical isolation between the cylinder and earth.

- Silica sand fill between the cylinder and FRP casing with a minimum resistivity of 25,000 ohm-centimeters, a pH of between 7.0 and 7.5 and a maximum chloride concentration of 200 ppm.

- Cathodic protection through the use of a PVC Sleeve to isolate the cylinder.

- A removable moisture-proof sealing lid shall be installed on the top of the casing prior to installation of the cylinder. The top of the casing shall be permanently sealed against moisture intrusion after installation of the cylinder.

h) Support Pilings. Designs based on using a steel shell filled with reinforced concrete with the concrete as the load-bearing member will not require further corrosion control measures. Designs based on the use of metallic supports exposed to the soil, such as piles, shall use protective coatings and cathodic protection. The need for any special measures shall be based on the type of structures, analysis of soil borings for the corrosive characteristics of soils, and the degree of anticipated structural deterioration caused by corrosion.

i) Subway Structures

- Cut and Cover Construction. Cast-in-place concrete shall include the following provisions:

- Type V Cement, or a fly ash modified Type II Cement, capable of resisting groundwater sulfate concentrations in excess of 1,500 ppm.

- Maximum water/cement ratio of 0.45 by weight and use of an air entrainment, admixture to establish a dense, low permeability concrete in accordance with American Concrete Institute (ACI) standard specifications.

- Maximum chloride concentrations of 200 ppm in the cement, mixing water, aggregate, and admixture combined.

- Concrete cover over reinforcing steel in accordance with ACI codes, but not less than 2 inches for those surfaces exposed to soils.

j) Bored Construction. Corrosion control for concrete or ferrous tunnels shall be determined pending the result of soil boring analysis. Alternatives will include coatings, bonding, cathodic protection and test electrodes.

k) Non-Metallic Materials. Plastics, fiberglass, and other non-metallic materials for pressurized piping may be appropriate to aid in corrosion control. The corrosion control design shall consider the following:

- Manufacturer's recommendations
- Mechanical strength and internal pressure limitations
- Elasticity/expansion characteristics
- Comparative costs
- Expected life
- Failure modes
- Local codes
- Prior experiences with the proposed non-metallic material in similar applications.

8.3 STRAY CURRENT CORROSION CONTROL

8.3.1 General

This section provides criteria for designs to minimize the corrosive effect of stray currents from the DART system on DART structures and adjacent structures owned by others.

Stray current control shall reduce or limit the level of stray earth currents at the source, under normal operating conditions, rather than trying to mitigate the corresponding effects (possibly detrimental) which may otherwise occur on DART facilities and other underground structures being impacted by

DART Light Rail Operations. The basic requirements for stray current control, which have been established, are as follows:

Operate the DART mainline system with no direct, or indirect, electrical connections between either the positive or negative traction power distribution circuits and ground.

The system structures which may be affected by stray current shall be identified and designs to minimize the impact of stray currents from the DART system shall be provided.

8.3.2 Scope

Structures and systems that are used to control stray current levels or may be affected by stray currents shall be identified. Typically they include, but are not limited to:

a) Components of traction power electrification system
b) Trackwork components
c) Reinforced concrete structures
d) Metallic pipes
e) Metallic or concrete tunnel liners
f) Metallic Piles

Designs shall be provided to permit safe and reliable operation of the underground structures and to maintain their expected life span. Designs shall be coordinated with the outside agencies through DART.

8.3.3 Traction Power System

The traction power distribution system shall be separated into three electrically isolated sections: the mainline, yards, and shops.

a) Traction Power Substations

   - Substations shall be spaced at intervals such that track-to-earth potentials along the main line will be within the range of normal operating voltage during normal revenue operations.

   - Substations shall be provided with access to the negative bus for stray current monitoring. Access shall be provided either inside through use of dedicated wall space, if available, or outside through use of a weather tight enclosure with an open conduit between the enclosure and the negative bus.

- Provisions to monitor track-to-earth potentials continuously using permanent installed recorders shall be included.

b) Positive Distribution System

- Resistance-to-Earth Criteria

  1) The positive distribution circuit, consisting primarily of the overhead distribution and contact system, shall have a minimum effective in-service resistance to earth of at least one million ohms per 1,000 FT of double catenary system. This resistance shall be reasonably maintainable during the anticipated life of the overhead system (approximately 30 years).

- Electrical Ground Connections, OCS Support Poles

  1) For locations other than at aerial structures, electrical ground facilities for adjacent OCS support poles shall not be interconnected. This will eliminate the possible transference of stray earth currents, from one portion of the transit system to another, because of an electrically continuous ground system.

  2) Where OCS poles shall be located on aerial structures, provisions shall be made to interconnect these electrically and connect them to a ground electrode.

- The positive distribution system shall be operated as an electrically continuous bus with no breaks, except during emergency or fault conditions, and with intentional electrical segregation of yard, shop and mainline traction power distribution systems.

c) Negative Distribution System

- Resistance-to-Earth Criteria for mainline running rails, including special trackwork and all ancillary system connections shall be designed to have the following minimum in-service resistance per 1,000 ft. of track (2 rails):

1) Aerial - 625 Ohms/1,000 ft.-2 Rails

2) At Grade - 625 Ohms/1,000 ft.-2 Rails

3) Grade Crossings - 300 Ohms after installation

4) Embedded Track - 150 Ohms/1,000 ft.-2 Rails

5) Tunnel - 625 Ohms/1,000 ft.-2 Rails

- Rail to ground resistance shall be continuously monitored during construction to detect variations or decreases in the resistance. Investigations shall be initiated as soon as a low resistance reading is detected and the adverse condition(s) repaired immediately by the Contractor at no additional expense. Delay of repair(s) could impact additional construction elements and result in higher repair costs.

- These criteria shall be met through use of appropriately designed insulating track fastening devices such as insulated tie plates, rail clips, direct fixation fasteners, or other approved methods. Test facilities shall be included, to the extent necessary, to determine resistance-to-earth levels during construction and operations.

d) Track Crossbonds

- Crossbonding shall be provided, as required, to meet criteria for traction power, signaling, and other considerations. Track crossbonds shall be provided between mainline inbound and outbound tracks at the following locations for stray current control:

1) At each traction power substation.

2) Within 500 ft. of passenger station platforms if not covered by above or other criteria for crossbonds.

e) Auxiliary

- Switch machines, train control devices, train communication systems and other devices or systems which may contact the rails shall be electrically isolated from earth. The criteria shall be met through the use of dielectric materials electrically separating the devices/systems from earth such that the minimum resistance-to-earth criteria are maintained.

f) Yards

– The yard/mainline traction power segregation point shall be located such that all track on the mainline side of the segregation point is electrically insulated from earth and meets the minimum resistance-to-earth criteria.

1) The yard traction power substation shall include provisions for emergency interconnection to the mainline traction power system.

2) Substations shall be provided with access to the negative bus for stray current monitoring. Access shall be provided either inside through use of a dedicated wall space, if available, or outside through use of a weather tight enclosure with an open conduit between the enclosure and the negative bus.

3) Yard/Mainline track shall include the following minimum provisions at end of track, or prior to rail insulated joints where bumper posts are installed:

- Use of high-resistivity, well drained ballast material.

- A minimum of 1 in. clearance between the ballast material and all metallic surfaces of the rail and of metallic track components in electrical contact with the rail.

- All dead-ended tracks shall have insulated joints installed to isolate bumping posts or similar devices that are electrically grounded.

- All dead-ended track shall have the negative power rail crossbonded to other negative power rails within ten ft. of the end of the track.

- Cross-bonding negative feeder cables shall utilize a main cable run (possibly several cables) with taps to negative power rail(s) as opposed to long runs of individual cables connected to single negative power rails.

- Yard - Minimum in-service track to earth resistance of 20 Ohms/1000 ft.-2 Rails.

g) Maintenance Shops

- Rail insulators shall be installed immediately off the apron to avoid breaking of the apron concrete if a shorting condition occurs in the insulator.

- Shop traction power shall be provided by a separate dedicated DC power supply electrically segregated in both the positive and negative circuits from the yard traction power system.

- Shop track shall be electrically grounded to the shop building and shop grounding system.

- Shop track shall be electrically insulated from yard track by the use of rail insulating joints. Actual locations of insulators shall ensure that parked vehicles will not electrically short the shop to the yard for periods of time longer than that required to move a vehicle in or out of the shop.

8.3.4 Water Drainage and Infiltration

a) Tunnels and other below grade structures shall be designed to prevent water from dropping or running onto the negative rails and rail appurtenances and shall be designed to prevent the accumulation of free standing water.

b) Mainline water drainage systems shall be designed to prevent water accumulation from contacting the rails and rail appurtenances.

c) Yard water drainage systems shall be designed to prevent water accumulation around ties and rail appurtenances.

d) Shop water drainage systems shall be designed to prevent water accumulation around the rail insulating joints immediately off the shop apron.

8.3.5 DART Fixed Facilities

a) Tunnels and Stations

- Reinforcing steel in the tunnel and underground passenger station inverts shall have electrical continuity. Minimum requirements shall include the following:

  1) Welding of all or a portion of the longitudinal lap splices.

  2) Welding of all longitudinal members to transverse members at intervals not exceeding 500 ft and at electrical breaks in the longitudinal members, such as expansion and contraction joints.

- Test stations shall be installed as follows:

  1) Install test station approximately every 200 ft maximum within tunnels. The test station will be used to monitor stray current effects and to provide a controlled shunt of stray current from reinforcing steel to earth, if necessary.

b) Aerial Structures

- Non-ballasted aerial structures shall be designed to include the following minimum provisions:

  1) The top layer of reinforcement in the slab beneath the trackway shall be made electrically continuous by tack welding the longitudinal bars at the splices. Alternatively, top and bottom mat epoxy coated rebar can be used which eliminates this requirement.

- Collector bars shall be tack welded to the longitudinal reinforcement at each end of the structure and at electrical breaks in the structure such as contraction/expansion joints. The size of the collector can be the same as the transverse reinforcement. Collector bars on each side of an electrical break shall be connected with a minimum of two bonding cables.

- A ground electrode system shall be provided at each end of the structure and at intermediate points depending on the length of the structure. The number and location of rods and resistance-to-earth of the ground electrode system shall be determined for each structure.

- Test facilities shall be provided at each end of the structure to house wires from collector bars and the ground electrode system to monitor stray current effects and to provide a controlled shunting of stray currents from reinforcing steel to earth, if necessary.

- Metallic structural deck members (reinforcing and girders) shall be electrically insulated from support piers.

c) Existing and new, ballasted aerial structures that are designed to permit the electrical separation of deck reinforcing steel from support pier reinforcing steel shall include the provisions of aerial structures. Where this is not possible, these structures shall include the following minimum provisions:

- The structural surface supporting the ballast shall be well drained.

- A waterproof insulating membrane shall be provided over the entire surface on which the ballast contacts the structure.

- An electrically continuous collector grid shall be placed between the membrane and the ballast. The width should be at least equal to that of the trackway.

- A ground electrode system shall be provided at each end of the structure and at intermediate points depending on the length of the structure. The number and location of rods and resistance-to-earth of the ground electrode system shall be determined for each structure.

- Test facilities shall be provided at each end of the structure to house wires from collector bars and the ground electrode system to monitor stray current effects and to provide a controlled shunting of stray currents from reinforcing steel to earth, if necessary.

8.3.6 Utility Structures

a) All piping and conduit shall be non-metallic unless metallic facilities are required for specific engineering purposes. There are no special provisions required if non-metallic materials are used.

b) Metallic Facilities (Main line)

- Pressure or non-pressure piping exposed within the tunnel structure or embedded in the invert shall not require special provisions.

- Pressure piping that penetrates the tunnel or station walls shall be electrically insulated from the outside piping to which it connects and from watertight wall sleeves. Electrical insulation of interior piping from outside piping shall be made on the interior of the tunnel or station.

- All buried pressure piping outside of the tunnel and station structures shall meet criteria of Section 8.2.3

c) Metallic Facilities (Shops)

- All reinforcing, structural steel and rails within the shop building shall be electrically connected to a common grounding grid.

- All pressure piping within the shop building or perimeter of the shop steel reinforcing grid shall have the following minimum provisions:

  1) Electrical insulation from interconnecting pressure piping located outside the shop building or perimeter of reinforcing grid.

  2) Electrical insulation from watertight wall/floor sleeves.

  3) Electrical connection to the common ground grid at sufficient locations such that there will be only negligible potential differences between the piping and grounding network during fault or normal operating conditions.

d) Metallic Facilities (Yards)

- All buried pressure piping shall meet the criteria of Section 8.2.3.

- All metallic fencing surrounding the yard perimeter shall be made electrically continuous.

8.3.7 Facilities Owned by Others

a) Replacement/Relocation Facilities

- Corrosion control requirements for underground facilities which are owned and/or operated by others, and will be either relocated or replaced as part of the project, shall be limited to the minimum requirements necessary for stray current control. The scope of these requirements relates to buried, metallic pressure piping only. Specifically, the following minimum criteria shall be met for steel, cast iron, and ductile iron pressure piping:

  1) Electrical continuity through the installation of insulated copper wires across all mechanical joints for which electrical continuity cannot be assured.

  2) Electrical access to the piping through test stations at 200 ft. intervals maximum.

- The need for additional measures, such as electrical isolation through the use of insulated connections and application of a protective coating system, and/or installation of a cathodic protection system shall be the responsibility of the individual utility operator with DART providing engineering guidance. The need for these, and/or other measures, shall be based on the stray current/corrosion control requirements of the specific utility, and the established performance record of the various structures within the given environment.

b) Existing Utility Structures

- Five or three wire test stations shall be installed at select points along existing metallic utility structures that are exposed as part of transit system construction for the purpose of evaluating stray earth current effects during startup and revenue operations. The specific locations shall be determined by the individual utility operation, with guidelines for this work as follows:

1) At all utility crossings with the system and on structures which are in close proximity to and parallel the system right-of-way.

2) At locations on specific utility structures which are in close proximity to the system traction power substations.

8.4 ATMOSPHERIC CORROSION PREVENTION

8.4.1 Purpose

The purpose of this section is to provide criteria for atmospheric corrosion control for the reduction of maintenance costs and preservation of appearance. Systemwide criteria include the following:

a) Materials Selection: Materials shall have established performance records for the service application.

b) Sealants: Sealants shall be used in crevices to prevent the accumulation of moisture.

c) Protective Coatings: Barrier or sacrificial coatings shall be used on carbon steel.

d) Design: The use of dissimilar metals and recesses that trap moisture shall be avoided.

8.4.2 Scope

Structures which may be affected by atmospheric corrosion shall be identified. Typically, these include:

a) Catenary structures and hardware
b) Vehicles
c) Exposed metal surfaces on aerial stations, aerial main line structures, at-grade stations and surface main line structures
d) Right-of-way fences
e) Exposed metal surfaces at shop and yard areas, and mechanical, electrical, signal and communications devices, and structures in equipment rooms, vents, fan, and exit shafts

8.4.3 Design of Atmospheric Corrosion Prevention Systems

a) Materials. Metals exposed to area atmospheric environments shall be selected and protected as follows:

- Steel and Ferrous Alloys. Carbon steel and cast iron exposed to the atmosphere either outside or inside the tunnel area shall have a coating applied to all external surfaces. Rail and certain rail fasteners, i.e., spring clips, spikes, rail plates, etc. will not require coatings.

- High strength, low alloy steels shall be similarly protected except where used as weathering steel exposed to the outside environment. The design shall incorporate complete drainage of all surfaces, the coating of metal-to-metal contact surfaces, and the sealing of crevices. The potential staining of adjacent structures shall be considered.

- Series 200 and 300 stainless steels are suitable for use in any exposed situation without further protection, but Type 316 is preferred for superior corrosion resistance. Series 400 stainless steels can also be used but may exhibit staining.

- Stainless steel surfaces shall be cleaned and passivated after fabrication.

- Aluminum Alloys. An anodized finish shall be used to provide the best weather resistant surface.

- Copper Alloys. Copper and its alloys can be used where exposed to the weather without additional protection.

- Magnesium Alloys. When long term appearance is critical, magnesium alloys shall have a barrier coating applied. Bi-metallic couples shall be avoided.

- Zinc Alloys. Zinc alloys can be used without additional protection. Bi-metallic couples shall be avoided.

b) Coatings. Coatings shall have an established performance record for the intended service and be compatible with the base metal to which applied. Coatings shall demonstrate satisfactory gloss retention, color retention, and resistance to chalking over the life of the coating. The minimum life expectancy of coatings (the time to major maintenance or recoating) shall be twelve years.

c) Metallic Coatings (for carbon and alloy steels). Acceptance metallic coatings for use both in tunnels or above grade are: zinc (hot dip galvanizing), aluminum, or a combination of aluminum and zinc.

d) Organic Coatings. Organic coating systems shall consist of a wash primer (if the condition of the substrate requires it), a primer, intermediate coat(s), and a finish coat. Minimum volume resistivity for coating per ASTM D257. Minimum thickness of coating shall be 15 mils. Acceptable organic coatings for use in tunnels or above grade are as follows:

- Aliphatic polyurethanes
- Vinyl copolymers
- Epoxy (as a primer where exposed in the atmosphere or as the complete system where sheltered from sunlight)
- Acrylics (where not exposed to direct sunlight)
- Alkyds (where not exposed to direct sunlight)

CHAPTER 9

SYSTEM GROUNDING
AND
RACEWAYS

Chapter 9

SYSTEM GROUNDING AND RACEWAYS

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CHAPTER 9 - SYSTEM GROUNDING AND RACEWAYS

9.1 PURPOSE

This chapter describes the design requirements for safety grounding so that grounding and corrosion control requirements do not conflict. The design key is to provide proper location of insulation points and timely operation of grounding mechanisms to prevent electrical shock hazards to the public and to operating personnel and protect equipment from damaging voltages and currents. The grounding resistance shall be a maximum of 2 ohms, unless otherwise noted.

Non current-carrying metal enclosures or parts of all primary voltage, alternating current equipment, including A.C. switchgear shall be firmly grounded to the ground buss. Structural metalwork where exposed within the substation, supervisory control cabinets, ventilation equipment or ductwork, and exposed metallic conduits, or raceways enclosing or supporting alternating current carrying cables, shall be grounded to the ground buss.

Grounding protection systems shall be designed to accomplish the following:

a) Protect passengers and DART operating and maintenance personnel against hazardous system voltages

b) Provide a ground path for lightning surges and fault currents

c) Assure integrity of corrosion control systems

d) Meet the most stringent grounding code requirements applicable to the system

9.2 GENERAL

Grounding protection shall be provided for traction power substations, signal and communications housings, passenger stations, shops and yards, aerial and catenary structures, and other wayside locations. Due to the difference between safety grounding and corrosion control requirements, all grounding design shall be submitted for review by the corrosion control engineer, so that corrosion control designs are not compromised and a safe system is provided.

9.3 CODES AND STANDARDS

All work relating to the grounding design shall conform to the latest editions of industry codes and standards including: National Electrical Code, IEEE Standards 1100-1999(IEEE Recommended Practice for Powering and Grounding Electronic Equipment, The Emerald Book), IEEE Standards 142-1991(IEEE Recommended Practice for Grounding of Industrial and Commercial

Power Systems, The Green Book), IEEE Standards 80-2000 (IEEE Guide for Safety in AC Substation Grounding), and IEEE 1050,(Guide for Instrumentation and Control Equipment Grounding in Generating Stations).

Other local and State codes may also apply. The designer shall consult these publications and provide systems in accordance with the most stringent code or industry practice.

9.4 DESIGN CONSIDERATIONS

9.4.1 Traction Power Substations

Please refer to Chapter 3 for the description of the Traction Power System.

Grounding for traction power substations shall consist of a ground buss connected to ground rods and bare-copper conductors interconnected to form a low-resistance grid mat. The mat shall meet IEEE Standard 80 to provide safe touch-and-step potentials. All risers to the buss shall be capable of carrying the anticipated range of short circuit currents without damage.

b) Negative Grounding Device

Each substation shall be provided with a negative grounding device capable of bonding the substation negative buss to the substation ground grid. This device shall be in the open position under normal operation. In the event that an unsafe voltage or an excessive current occurs on the negative return system, the device shall ground the negative return system to the ground grid.

The device shall consist of a bi-directional solid-state switch with associated sensors, relaying, and control circuits to solidly bond the substation ground grid to the negative return system. The device shall have settings between 50V and 100V in 10-volt steps for field adjustments. The device shall also provide separate alarm contacts for the local anunciator panel and the SCADA system. The device shall be mounted inside each rectifier unit.

9.4.2 Signal and Communications Housing/Equipment

Please refer to Chapters 4 and 5 for descriptions of the Signal and Communications systems.

Grounding shall be designed to minimize the noise voltage generated by currents from two or more circuits flowing through a common ground impedance and to avoid creating ground loops which are susceptible to magnetic fields and differences in ground potential.

The design shall provide a single point signal grounding system for all equipment enclosures, cabinets, drawers, assemblies, and subassemblies (chassis/cabinet). The communications signal ground conductors shall be isolated from the equipment ground and from all enclosures, trays, conduits, and structures.

Safety considerations also require the chassis or enclosure for electrical equipment to be grounded. Potentials appearing at equipment neutrals shall be minimized. The equipment single point grounding system shall be connected to the facility grounding grid where available.

Ground detectors shall be provided for each housing to detect AC and DC circuits grounding conditions.

9.4.3 Passenger Stations and Facilities

Refer to Facilities Design Criteria for detailed descriptions of the passenger stations and facilities.

All metal parts of electrical boxes and machines that are susceptible to contact by patrons and operating and maintenance personnel shall be electrically grounded.

Grounding for passenger stations shall consist of a ground mat under each facility comprised of a buried grid-and-rod system. Interconnection with steel piling and steel reinforcement to reduce touch potentials shall be specified where necessary. To guard against contact by passengers, grounded equipment, metal enclosures, motors, and so forth shall not be located closer than 6 FT from the edge of the platform.

Grounding connections shall not be made on mechanical and utility pipes (including water) outside the dielectric coupling used to provide an electrical termination point for corrosion control systems. Additionally, underground interconnections shall not be made between ground mats and water piping or other utility structures.

9.4.4 Aerial Structures

Grounding for aerial structures shall consist of a ground electrode with rods and conductors at each end of the structure. An intermediate grounding point for structures in excess of 2,500 FT in length may be required. Ground electrode resistance to earth shall not exceed 2 ohms unless otherwise noted.

Structures on the aerial structure such as catenary poles, handrails, cable trough components, and other metal components shall be made electrically continuous with the top layer of reinforcing steel in the deck. At each end of the structure, insulated cables shall be installed between the reinforcing steel and the ground electrode via an appropriately sized and conveniently located weatherproof junction box or manhole. Support piers shall be insulated from the structural deck members.

9.5 INTERFACES

In order to provide compatible grounding design for the various elements, close coordination must include the following designs:

a) Architectural
b) Structures
c) Utilities
d) Operations
e) Electrical and mechanical equipment
f) Traction Electrification
g) Signal and Communications
h) Passenger Stations
i) Yard and Shop
j) Corrosion Control

9.6 DUCT BANKS

9.6.1 Purpose

This criteria describes the requirements for the planning and design of system wide duct banks for DART. The duct banks are groups of ducts joined together to accommodate AC/DC wires and cables for the transmission of communication signals and power.

9.6.2 Scope

Duct banks as referenced under this application shall include all duct banks to be installed outside the tunnel and aerial sections of the project, where concrete troughs will be installed. Drawings will be issued depicting cable transition details for transition from at-grade to aerial structures and from at-grade to tunnel sections. In mainline raceways, where possible, transitions shall be designed to include removable covers exposing trough raceway interior that shall enable cable laying directly into the trough/raceway without removing cable from the reel. Locations immediately adjacent to unavoidable direct cable layment impediment in the mainline raceway may be exempted from this requirement as required to avoid unnecessary costs. To enable splicing and cable pulling of conductors, duct bank manholes shall be incorporated into the duct bank design.

9.6.3 Codes and Standards

All work relating to the duct bank design shall conform to the latest editions of industry codes and standards such as NEC, NEMA, NFPA 130, ASTM and IEEE recommendations. Other local and state codes may also apply. The designer shall consult these publications and provide systems in accordance with the most stringent code or industry practice.

9.6.4 Signals and Communications System Duct Bank

This duct bank will be utilized to carry signal and communication cables along the entire system. The duct bank will be buried underground as directed by the appropriate codes and standards. The duct bank shall be designed to accommodate all necessary signal and communication cables together with appropriate spare conduits. The specific number of spare conduits shall be determined in accordance with good industry practice and coordinated with DART.

9.6.5 Traction Power Duct Bank

Duct banks for traction power purposes shall be as follows:

a) Incoming Utility Service
b) Positive Feeders
c) Negative Return Feeder

They shall be designed in accordance with all design requirements outlined in Chapter 3 (Traction Electrification) of this design criteria. The design must be carefully coordinated with underground utilities to assure safe access within the right-of-way.

9.6.6 Design Considerations

All duct banks shall be designed to slope downwards toward the manholes with a pitch of not less than 0.60 percent. Conduits in systems duct banks shall be designed at a depth of not less than 48″ below top of rail where crossing under LRT rail except where designed in or below a track slab in which case no depth requirement shall apply. Elsewhere conduits in systems duct banks shall be designed at a depth of not less than 36″ below finish grade. The duct banks will normally consist of schedule 40 polyvinyl chloride (PVC) ducts, however, if rigid steel conduit is required it shall be galvanized in accordance with the appropriate standard. Conduits constructed of high density polyethylene (HDPE), fiberglass reinforced epoxy (FRE), and multiple-conduit preformed plastic duct systems, are also acceptable where application suitability can be demonstrated.

The duct bank shall run as directly as possible but shall be located so as to avoid existing utilities, foundations and footings. Conduits of dissimilar materials shall be joined with the use of anti-oxidant compounds and insulating couplings to prevent galvanic corrosion in accordance with the corrosion control/grounding chapter of these criteria.

Bends in the duct bank should be kept to a minimum both vertically and horizontally and shall have a minimum radius as recommended in the appropriate codes and standards. If bends are required which exceed these codes, the direction change shall be accomplished by means of manholes. All such transit system duct banks shall be installed only within the DART right-of-way. If it appears prudent to transgress other than DART territory, a formal request must be forwarded to DART for consideration and review, to determine if the purchase of additional right-of-way is warranted.

A standard colored marker tape shall be specified for installation in the trench directly above the duct bank approximately 12 IN above the duct bank.

Any request by Texas Utilities Company to route feeder circuits within the right-of-way shall be presented to DART for approval and coordination with the system duct bank. Wherever possible, the designer shall use express cable trough with removable covers to interconnect manholes in the mainline manhole raceway system. Express cable trough and removable covers shall be manufactured of polymer concrete with sand and/or stone aggregate and shall be designed and manufactured to withstand AASHTO HS-20 loading under occasional use. However, express cable trough need not be designed for continuous highway loading. Express cable trough shall have removable polymer concrete covers secured by at least one tamper proof security bolt as described herein. Interlocking covers may be employed where practical to reduce the required security bolt quantity without affecting security. Express cable trough shall be located between the northbound and southbound tracks or between either track and a retaining wall or ballast wall where appropriate. Security bolts for all systems manholes, handholes, pullboxes and express trough shall be stainless steel and shall employ a pentahead pattern conforming to the standard used by the maintenance department. Joints in express cable trough shall be wrapped in geo-textile fabric to minimize the infiltration of dirt and debris.

9.6.7 Manholes

Manholes shall be of the pre-cast concrete type and constructed of as many sections as necessary to provide adequate room for pull irons, terminators, cable racks and a ladder, while providing the worker with sufficient space to pull and terminate cables. Cast in place manholes may be specified for design requirements where no readily available pre-cast manholes will satisfy the project demands. The manhole shall have a grounding means suitable for connection to a ground rod.

A drain and gravel sump shall be provided at the lowest point in the manhole and properly installed to assure drainage. The manholes shall be supplied with a cast iron lid and ring marked appropriately. Manholes will be spaced approximately every 400 FT or closer as required by final design except at center platform stations where architectural considerations prohibit manhole placements closer than 550 feet on centers and where pulling tensions are demonstrated to be less than that allowed for the specific cables to be installed for the duct bank configuration designed.

Manholes, handholes, and pullboxes located in the guideway shall be designed to withstand AASHTO HS-20 loading under occasional use. However, they need not be designed for continuous highway traffic loading. Systems manholes shall not be installed with the manhole cover located in a public street traffic area.

Manholes shall be designed to a depth as necessary to: connect duct banks that are required to be routed under obstructions; maintain a minimum duct bank depth required below top of sub grade to effectively eliminate interference with sub grade construction operations; and to drain the conduits to the manhole.

Manholes located along the guideway shall be designed to mitigate potential fall exposures on a site specified basis. Manhole lids shall also be designed so that the lids, when opened, do not intrude into the vehicle dynamic envelope.

FRP channel inserts shall be of pultruded, glass-reinforced polyester or vinyl ester resin.

CHAPTER 10

OPERATIONS

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OPERATIONS

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CHAPTER 10 – OPERATIONS

10.1 GENERAL

10.1.1 Purpose

This section provides a functional overview of the Dallas Area Rapid Transit (DART) Light Rail Transit (LRT) System. Operations criteria are achieved based on implementation of systems and facilities design standards. Additional system operation details are contained in the Operations and Maintenance Plan and the DART Rail Operations Manual.

10.1.2 System Description

Trains shall operate over a double tracked corridor that consists of exclusive right-of-way including tunnel and aerial sections, partially separated right-of-way, street median alignment, and operation through an urban transit mall.

All line sections shall be double tracked. Under normal conditions, trains shall operate in the forward direction on the right hand track of the double tracked route. Trains shall reverse direction at scheduled terminal stations located at the ends of the operating route and/or at designated intermediate points.

Crossovers shall be provided at various locations along the route to permit reverse running operations for emergencies and/or maintenance-of-way activities. Storage tracks shall be strategically located to provide emergency storage for disabled vehicles.

Regulation and supervision of train operations and the supervisory control of associated electrical, mechanical and communications subsystems shall be performed by designated DART Train Control Center (TCC) personnel. Train operations relating to station stopping, door operation, selected route requests, acceleration, deceleration, and speed maintenance shall be manually controlled by the Train Operator.

10.2 OPERATIONS

10.2.1 Period of Operation/Headways

LRT scheduled operations shall span the hours of 3:30 a.m. to 1:00 a.m. (21-1/2 hours), seven days per week. Adjustments may be made based on ridership characteristics and changes to DART policy.

LRT System Headways are based on system ridership projections and DART policy.

Trains operate at optimal headways during the morning and evening peak periods. The morning peak period begins at approximately 6:00 a.m. and ends at 9:00 a.m. The evening peak period begins at approximately at 3:00 p.m. and ends at 6:00 p.m. Branch line peak headway is 5-10 minutes. Trunk Line headways e.g., Oak Cliff Junction to Katy Junction including CBD Mall, shall be based on negotiations between the City of Dallas and DART Policy. Train consists shall be determined based on ridership demand; consists shall be a mixture of 1, 2 or 3 car consists.

Mid-day service headways shall generally be 2.5 minutes on the CBD, 5 minutes on the trunk sections and 10 minutes on the branch lines. Late night operation shall normally be with single car consists.

Weekend service headways shall generally be 5 minutes on the CBD, 10 minutes on the trunk sections and 20 minutes on the branch lines. Weekend consists shall normally be a single car unless ridership dictates.

Detailed headway plans are contained in the Operations and Maintenance Plan. Design headways are described in the Dart Design Criteria Manual, Volume 2, Chapter 4, Signal System. Design headways shall take into consideration abnormal operation recovery times. Operating headways shall be adjusted based on ridership demand and DART policy.

10.2.2 Operating Speeds

Maximum Operating speeds are determined by civil and alignment characteristics, the Signal System, and vehicle performance parameters. The maximum system operating speed shall be 65 mph.

The Signal System is described in the DART Design Criteria Manual, Volume 2, Chapter 4, Signal System. On line sections where train control systems are in effect, train speeds up to 65 mph shall be permitted subject to civil speed restrictions.

In areas where train movements are not protected by automatic train control systems, speeds shall be limited to a maximum speed of 45 mph. Street or median alignment speeds shall be governed by the civil and progression speed for the parallel street. LRT speeds may be up to 10 mph above the local street traffic speed limit. Speeds shall be coordinated with local authorities.

10.2.3 Terminal Operations

Turnback operations shall be facilitated by interlockings that shall be located immediately in advance of each terminal station. Interlocking equipment shall provide automatic routing of inbound and outbound trains, controllable from the TCC and at the local control panel in the wayside Central Instrument House (C.I.H.).

Terminal stations shall be equipped with crew rooms and provide (at a minimum) one telephone, one fax, and restroom facilities for DART personnel.

Terminal stations shall be equipped with tail tracks to facilitate midday and overnight storage; or cutting and adding of cars. Tail tracks shall be a minimum of 500 feet long, and signaled to provide sufficient stopping distance between platform and tail track signals to allow permissive aspects at terminal interlockings with the tail tracks occupied.

Ideally, terminal stations shall have a center platform design where space, available right-of-way and cost considerations permit. Terminal station design shall also take into consideration future extensions, after which, the station may become a run through and/or intermediate turnback station.

10.2.4 Station Operations

Passenger stations function as the patron entrance and exit points for the LRT system. They also serve as transfer points between automobile, bus and pedestrian modes of travel and the LRT system. Stations shall provide the facilities for automated, self-service fare collection, and information on system use.

Stations shall be designed as barrier-free, unmanned stations. Fare collection equipment shall, therefore, be designed to be used by patrons without the need for assistance from station attendants. Fare collection at stations will be accomplished as stated in the DART Design Criteria Manual, Volume 2, Chapter 7.

Escalators and/or elevators shall provide primary patron access at all underground or aerial stations. Stairways between levels at each underground and aerial station shall also be installed. Elevators shall be provided to accommodate mobility-impaired passengers at any station not at surface level. Elevator operation shall be automatic and not require any actions by DART personnel.

DART is implementing a level boarding initiative. This includes modification of the current LRV fleet by addition of a C-car that allows level boarding. The C-car unit train shall incorporate 3 sections and is designated as a SLRV. In addition existing high-level special use platforms will be phased out through modifications of station platforms to a 15-1/2 inch height above top-of-rail or installation of discrete level boarding areas.

In order for TCC personnel to monitor platform occupancy, the Train Control System design shall ensure that station platform limits are specifically defined by detector circuits.

Stations on a curve must include mirrors installed on the platform. The location of the mirrors must be such that the train operator is able to see all doors while berthing at noted berthing markers.

Escalator, stairway, and passageway capacities shall be based on local codes and NFPA 130. Egress calculations shall be developed for each station by the designer.

The number of fare vending machines for each station shall also be related to expected station passenger volumes.

Station maintenance and cleaning shall generally be performed by personnel traveling between stations in highway vehicles. Hose bibs shall be installed to facilitate station maintenance and cleaning. In addition, secured electrical outlets and connections shall be installed for use by maintenance personnel.

10.2.5 Yard Operations

Yard operations are those functions that are necessary to provide trains for revenue service and receive trains for maintenance, cleaning, or for storage in accordance with established operating schedules. Yard control and supervision functions and work locations shall be closely coordinated with the DART Train Control Center.

Yard operations shall include train movement between yard storage tracks and mainline tracks, the changing of train consists, and vehicle movement between the car wash and maintenance shop facilities. Train Operators shall have the capability to perform any train movement within the yard or on the mainline. A bypass track around the main servicing and storage areas shall be incorporated.

Key yard crossovers and turnouts shall be powered, but shall not be fully interlocked and shall be locally controlled by the Train Operator based on a yard operating assignment or yard control supervisor’s direction. TCC permission shall be required before leaving or entering the yard. Refer to the DART Design Criteria Manual, Volume 2, Chapter 4, Signal System for yard turnout operation details.

Yard operating speed shall not exceed 10 mph except for test activities on specified yard tracks.

10.2.6 CBD Mall Operations

The DART LRT system shall operate at-grade through the Dallas Central Business District (CBD) transit mall.

The line is double track through the CBD Mall. Emergency crossovers shall be installed at each end of the mall to permit single-track operation or scheduled turnbacks.

Operation through the mall shall be by line-of-sight. Trains shall be controlled by the traffic signal system that incorporates train progression. Traffic signal cycle time and timing sequence shall permit trains to move on consecutive cycles where only one train of the same direction per cycle is permitted. The CBD traffic system interface is being modified to implement Full Traffic Signal Preemption design in order to enhance operating efficiency.

10.2.7 Median/Street Operations

Operation in the median of a street or highway or in mixed street traffic shall be by “line-of-sight.” Trains shall be controlled by the same traffic signal system that controls the movement of parallel vehicular traffic. Speeds shall be the civil speed for traffic on that roadway with LRT provisions for speeds up to ten mph above the vehicular speed limit, subject to the 45 mph maximum permitted train speed.

Traffic signal requirements, roadway signage, and traffic interfaces for median and mall operation are described in the DART Design Criteria Manual, Volume 1, Chapter 5, Traffic Control. Traffic signal cycle times and signal phasing shall take into account the LRT operating requirements described in Chapter 5.

10.2.8 Operations in Signalized Territory

Train operations in signalized territory shall conform to signal aspects, indications and procedures defined in the Rail Operations Manual. The Signal System shall be designed using fail-safe principals as described in the DART Design Criteria Manual, Volume 2, Chapter 4. Wayside signal aspects shall be based on a red, yellow, green, and lunar color light system. The cab Signal System Operations shall be based on carborne cab signal aspects.

Train operation past a signal indicating STOP shall force an immediate brake application. A counter shall be installed on the vehicle to register that such an incident has occurred. Signal indications shall provide information regarding diverging moves.

10.2.9 Line-of-Sight Operations

DART currently operates by line-of-sight outside of signalized territory. Safe train separation shall be assured through visual observation of operating conditions, rules, and procedures. Block indicator signals may be necessary on specified segments where sight distance is limited due to sharp curvature or other wayside conditions. Speed limits in line-of-sight territory shall not exceed 45 mph.

10.2.10 Emergency/Unscheduled Operations

The train control system and operating procedures shall permit trains to move in the reverse direction against the normal flow of traffic between crossovers under the supervision of the TCC. Train movements against the normal flow of traffic may be utilized in the event of emergency or unscheduled operating conditions.

Operating procedures and permissible headways shall be developed for conducting unscheduled operations during emergencies, scheduled maintenance and abnormal operations. The Operations and Maintenance Plan and Standard Operating Procedures shall describe operating procedures during abnormal conditions.

10.3 FACILITIES

10.3.1 Special Trackwork

Special trackwork shall be located along the routes to allow merging and diverging moves at junctions, access to either track at terminals, and single-track operation to sustain off peak headways of fifteen minutes or less for disrupted conditions or scheduled maintenance. Crossovers on mainline tracks should ideally permit a speed of at least 20 mph and not less than 15 mph.

Crossovers shall be one of two types as follows:

a) Powered, interlocked, and remotely controlled by the rail operations controller in the TCC. All crossovers in signalized territory shall be of this type.

b) Power protected with powered operation but not fully interlocked.

Additionally, each transit corridor shall have (at a minimum) one pocket track strategically located to facilitate train operations. Pocket tracks shall be a minimum of 500 feet in length. The exact location and length of the pocket track shall be determined by an operational analysis.

Signal logic at major junctions and terminal stations shall be developed to permit normal merging and diverging moves without requiring trains to stop and have the Train Operator activate wayside pushbuttons. Pushbuttons or other control devices may be installed for abnormal conditions. For interlockings in signalized territory, the TCC shall have the option of remotely controlling train routing.

Double (scissors) crossovers may be used in space-constrained locations. Turnouts and crossovers in signalized territory shall allow both TCC and local operation.

Switch and crossover risk analysis must be made when determining their location in order to evaluate hazards associated with their proximity to bridge/overpass, and other supporting structures. Refer to the DART Design Criteria Manual, Volume 2, Chapter 12, System Safety.

10.3.2 Grade Crossings

Where required, highway and street grade crossing warning devices shall be installed. Crossing device shall provide safe and efficient rail and highway traffic operations at grade crossings.

The device shall be automatically activated by the approaching train and shall consist of flashing lights, bells, and gates.

Train speeds through grade crossings shall be determined on a site-specific basis and shall be consistent with safe operating practices, track speed, and maintenance of required trip times.

Integrity of freight railroad grade crossings must be maintained along shared corridors throughout LRT construction and installation phases.

10.3.3 Wayside Signs

Wayside signs are installed along the right-of-way or in station areas to provide additional information on track speed, berthing marker, and application of audible warning devices.

Additional signs which do not directly impact train movement are located at stations and along the right-of-way, these include passenger directional signs at stations, no trespassing signs, etc.

10.4 SUPERVISORY CONTROL

10.4.1 Train Supervision

Train supervision shall be accomplished by both field personnel and Train Control Center (TCC) personnel.

Field supervisors shall be assigned to specific locations where train congestion is likely to occur and shall also rove in assigned territories around the system.

Systemwide train operations shall be under the supervision of the DART Rail Operations Controllers located at the TCC, as described in the DART Design Criteria Manual, Volume 2, Chapter 6. Train operations in signalized territory shall be continually monitored from the information received automatically from the field via the communication system and from information provided by Train Operators and Supervisors. Controllers shall also be able to communicate with train operators via the Radio Subsystem described in the DART Design Criteria Manual, Volume 2, Chapter 5, Communications.

10.4.2 Train Control Center (TCC)

The Train Control Center (TCC) shall be the principal monitoring and control point for all LRT System Operations.

The major TCC subsystems are described in the DART Design Criteria Manual, Volume 2, Chapter 6, Train Control Center and Supervisory Control System. TCC subsystems shall monitor and control the following:

a) Signal systems;

b) Communications systems;

c) Communicating territory traction electrification system;

d) Yard operations;

e) Tunnel ventilation fans;

f) Fire alarms and fire protection systems;

g) Intrusion alarms.

TCC design philosophy is intervention by exception. Normal functions such as train routing at junctions and terminals shall be performed automatically.

The signal system shall be capable of continuously monitoring train operation and performance in signalized territory. By continuously monitoring train performance, the need for correcting performance irregularities and detecting emergency situations can be readily determined.

TCC equipment shall incorporate a mimic board with an overall display of the system and monitors at individual workstations. Sizing and space requirements at the TCC shall account for future line extensions.

10.5 SYSTEM SECURITY

10.5.1 Field Operations Security

Field operations security shall be accomplished by uniformed and plain-clothes police officers who shall be positioned at significant stations and also ride trains.

Contract security personnel may supplement the police officers and fare inspectors shall be used to enforce DART fare policy.

10.5.2 Security

Field security shall be augmented by a Security Controller who shall have radio contact with field personnel. There shall be a space available for a Security Control Center as part of the Operations Control Center.

Stations equipped with CCTV cameras shall be monitored by the Security Controller. The Security Controller may be located in a space at the station or at the security control center.

10.6 SYSTEM SAFETY

10.6.1 System Safety Elements

Major system safety elements are covered in detail in the DART Design Criteria Manual, Volume 2, Chapter 12, System Safety. The following system safety elements may affect train operations:

a) Safety Signage at Stations;

b) Adjacent Freight Operations, the DART Design Criteria Manual, Volume 2, Chapter 12, System Safety;

c) Operation Interfaces, the DART Design Criteria Manual, Volume 2, Chapter 12, System Safety;

d) Code of Federal Regulations-Roadway Worker Safety, 49 CFR 214;

e) Rail Safety Indoctrination Training.

CHAPTER 11

RELIABILITY AND MAINTAINABILITY

CHAPTER 11

RELIABILITY AND MAINTAINABILITY

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CHAPTER 11 – RELIABILITY AND MAINTAINABILITY

11.1 INTRODUCTION

High levels of reliability and maintainability relate directly to the availability and thus the overall performance and success of a transit system. Basic principles of reliability and maintainability shall, therefore, be applied in the design of all systems equipment, including, but not limited to: LRVs, TPSS, signals, communications, fare collection, and other system elements (stations / bridges / structures / track, etc.)

These principles establish the basis for a comprehensive effort to ensure DART's mission goals are met and life cycle ownership costs are reduced. This chapter defines the principles of reliability and maintainability, outlines the potential for their use, and serves to show how those involved in the design process of the various DART systems should use them. This chapter should be viewed as a helpful design guide to achieving a reliable and maintainable transit system, rather than as an all inclusive blueprint.

Reliability is defined as the probability that a system will perform a required function under stated conditions for a specified period of time.

The maintenance criteria provides the major maintenance issues to be addressed in the design. Mean-Time-To-Repair (MTTR) and Mean-Time-Between-Failures (MTBF) shall provide the measurements to verify the various systems meet the minimum goals of availability.

11.1.1 Operating and Maintenance Safety

Operating and maintenance safety shall be the most important consideration in the design, installation, and construction of the System's equipment.

11.1.2 Principles

A reliable system is one that operates without material error, fault or failure during a specified time in a specified environment. The four essential principles underlying such a system are:

a) Availability. The system is available for operation and use at times set forth in service agreements.

b) Security. The system is protected against unauthorized physical and logical access. (Logical access is the ability to read or manipulate data through remote access.)

c) Integrity. System processing is complete, accurate, timely and in accordance with the entity’s transaction approval and output distribution policy.

d) Maintainability. The system can be updated in a manner that provides near continuous availability, security and integrity.

The determination of the reliability of a system uses criteria from each of the above four underlying principles, organized into the following three distinct categories:

a) Communications: The entity has defined and communicated performance objectives in accordance with established policies and standards.

b) Procedures: The entity uses procedures, people, software, data, and infrastructure to achieve system availability, security, integrity and maintainability objectives in accordance with established policies and standards.

c) Monitoring: The entity monitors the system and takes action to achieve compliance with system availability, security, integrity, and maintainability objectives, policies and standards.

A system must satisfy all of the above three criteria to be deemed reliable.

11.1.3 Availability and Dependability

Availability is defined as *“The ability of an item to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval, assuming that the required external resources are provided.”*

Inherent Availability (A_i) as used by DART is the ideal state for analyzing availability. It is a function only of the Mean-Time-Between-Failures (MTBF), and the Mean-Time-To-Repair (MTTR);

preventive maintenance is not considered. Inherent availability is defined as:-

$$A_i = \frac{MTBF}{MTBF + MTTR}$$

Other elements to be considered are repairability and serviceability. Repairability is the probability that a failed system can be made operational in a specified interval of repair time, while serviceability addresses the ease with which the system can be repaired.

The specifications shall establish the standards for all of the above elements and shall reflect minimum performance goals.

Dependability is the capability of the Light Rail Transit (LRT) System to perform its function continuously and consistently during revenue hours. For example, dependability of the vehicle is measured by the percentage of trips completed, number and percentage of late trains, passenger delays, and vehicle and systems availability.

11.1.4 Reliability

Reliability is defined as the ability of a component, item, or system to perform a required function under stated conditions for a specified period of time.

Reliability can be expressed as a function of the Mean-Time-Between-Failures (MTBF) or the Mean-Distance-Between-Failures (MDBF). Reliability directly affects the availability of a component, item, or system as described in Section 11.1.2. The measure of a component’s or item’s reliability by time (MTBF), or distance (MDBF), depends on that system’s operating functions, uses, and characteristics.

Subcomponents of reliability are the Mean-Time-Between-Service-Failure (MTBSF) that measures failure rates in revenue service conditions and Mean-Time-Between-Maintenance (MTBM) that measure the maintenance requirements of the system or component.

Systems reliability can be analyzed in two ways. First, using “service-proven” equipment consistent with successful past performance, and adjusted for subsequent improved reliability designs and up-to-date enhancements. The second approach is to apply predictive reliability models and techniques to each subcomponent and to its total system.

To maximize reliability, the systems design shall use service-proven equipment and standardized components available and in general use in the rail transit industry. This approach promotes component availability and standardization over the life cycle of the system.

Requirements shall be established for conducting formal reliability programs including program monitoring, configuration and systems control, reporting, and documentation. Quantitative reliability factors provided shall be verifiable and consistent with DART's transit industry experience. All quantitative requirements specified in the Contract Documents for developing a reliability analysis shall be reasonable and practical.

11.1.5 Reliability Program Plan

A plan shall be established and maintained for a Reliability Program throughout the design, manufacturing, installation, and testing of the Light Rail System.

The plan shall describe a program that integrates the reliability engineering function with other program elements throughout the design, parts selection, manufacturing, installation, and testing. See Section 11.1.14 - Reliability and Maintainability Program Plan.

11.1.6 Reliability Requirements

DART reserves the right to have any failed or defective item disassembled, photographed, and documented by any means necessary to permit examination and analysis of the discrepancy. The cause of the discrepancy shall be categorized to determine if corrective action should be in the area of design, quality, or materials selection. When the appropriate corrective action has been implemented, a monitoring period shall be instituted to assure the corrective action has been effective. If the monitoring period does not produce favorable results in a reasonable time frame, the analysis portion of the program shall be restarted.

11.1.7 Reliability Demonstration Testing

DART reserves the right to witness a Reliability Demonstration Test of all systems/equipment. All testing on the program shall be considered reliability testing for the purpose of incident monitoring.

At the completion of system acceptance and integrated testing, a Reliability Demonstration Test shall be conducted for a period of one (1) year.

Each system's equipment shall be included in the demonstration test.

A schedule, plan and procedure shall be prepared for the Reliability Demonstration Test. The plan and procedure shall address the following:

a) Operational monitoring and incident reporting responsibilities;

b) Maintenance performance and responsibility including completion of incident report forms;

c) Incident Evaluation Committee procedures;

d) Test reports;

e) Pass/fail criteria;

f) Identification of procedures, requirements, and areas needed for impounding and securing all failed hardware in bonded (fenced in, secured, and locked) areas on DART premises.

During the Reliability Demonstration Test, performance results shall be evaluated for compliance of equipment performance with the approved requirements. If test experience indicates that approved requirements are not being met, corrective action shall be taken and the test demonstration shall be restarted from the beginning.

11.1.8 Maintainability

Maintainability is most frequently identified by Mean-Time-To-Repair (MTTR).

Primarily, MTTR is the time to restore a defective system or equipment to an operating condition.

Typically, MTTR is calculated as:

$$\text{MTTR} = \frac{\text{Cumulative Repair Time in Hours}}{\text{Total Number of Repair Actions}}$$

A repair, as defined in the calculation, is a corrective action resulting from an equipment failure or breakdown. The repair may also be the result of preventive maintenance inspections or scheduled maintenance.

The repair or servicing time is the active working time to effect the maintenance action. The time element excludes transportation time to the site or waiting for a repair person, and/or parts. It includes fault detection and isolation, access, testing, replacement or adjustment, and time to restore the system or equipment to a state of operational readiness. To control exceptional cases, the 90^{th} percentile is used to indicate that the repair time is not exceeded 90% of the time.

Modular design principles shall be maximized to facilitate maintainability goals. The modular concepts shall range from plug-in units to easy replacement or subsystem components and assemblies. Fault isolation, or check areas, and components subject to a high frequency of replacement or wear failures shall be readily accessible.

Implementation of a maintainability program shall be an iterative process, beginning with the design phase and continuing through demonstration testing into operations.

11.1.9 Maintainability Concept

The maintainability concept shall employ the maximum use of modular Lowest Level Replaceable Unit (LLRU) items to minimize the time taken for implementing corrective action and returning the defective equipment to revenue service.

Preventive maintenance and inspection for equipment shall be per accepted industry practices for equipment of the type specified. The requirements for preventive maintenance and inspection shall be determined during the design phase and schedules for preventive maintenance shall be developed as part of the Maintainability Program Plan and incorporated into the applicable maintenance manuals.

11.1.10 Maintainability Program Plan

A Maintainability Program Plan shall be prepared and integrated with the Reliability Program Plan. The plan shall be updated throughout the design, installation, testing, and initial operating period to verify maintainability goals.

The Maintainability Program Plan shall outline all schedules and activities for corrective and preventative maintenance. The Plan shall include data reporting, tasks performed, and the total active maintenance time to effect repairs. The Plan shall outline each maintenance task, time schedules, recommended tools, personnel, and skill levels required. These recommendations shall be based upon those of the Contractor and of the equipment suppliers. This data shall be used for logistics planning, life cycle maintenance costs, and design recommendations. See Section 11.1.14 - Reliability and Maintainability Program Plan.

11.1.11 Maintainability Review

Maintainability design guidelines shall be developed and submitted for evaluation during design reviews of equipment and components proposed for incorporation into the DART Transit System. For each equipment type, the maintainability features shall be specifically identified in the design review data. As a minimum, this identification shall include the following items, as applicable:

a) LLRU identification and Mean-Time-To-Repair (MTTR) predictions at the primary and secondary level;

b) Fault annunciation or troubleshooting analysis;

c) Equipment adjustments (minor and major) and calibration requirements;

d) Expendable or limited life items included in the design;

e) Major overhaul and restoration recommendations, including preventive maintenance schedules for equipment and parts requirements;

f) Recommended maintenance skill levels and training to be applied;

g) Listing of required test and support equipment required for performing both preventive and corrective maintenance;

h) Procedure requirements by reference to maintenance and operating manuals;

i) Quantities of parts in the component(s) and system(s).

11.1.12 Fault Isolation and Troubleshooting Plan

Within the Maintainability Program Plan, a Fault Isolation and Troubleshooting Plan shall be developed. This plan shall be a working document used during design to ensure that fault isolation and troubleshooting features are incorporated in the equipment design. The Fault Isolation and Troubleshooting Plan shall also become one of the source documents in assessing the adequacy of maintenance manuals and maintenance training.

11.1.13 Maintainability Demonstration Test Plan

As part of the training program for DART maintenance personnel, a Maintainability Demonstration Test Plan shall be developed. The Test Plan shall address where special emphasis, instruction, or proficiency are required. The Plan shall also address selected servicing, preventive maintenance, troubleshooting, change-out of components, corrective maintenance, and the use of special tools.

11.1.14 Reliability and Maintainability Program Plan

A Reliability and Maintainability Program Plan shall be developed for all applicable systems.

The Plan shall, at a minimum, include the following items and/or requirements as applicable:

a) Reliability program objectives;

b) Identification of key personnel responsible for managing the Contractor’s Reliability and Maintainability Programs;

c) Reliability program schedule, which identifies specific tasks, with start and completion dates, and explains how these task will be coordinated and integrated with major program milestones for design, manufacturing, and testing;

d) Details of design and component selection and screening processes to be used to meet reliability requirements;

e) Details of methodology and procedures to be used to calculate Mean-Time-Between-Failures (MTBF) and Mean-Time-To-Repair (MTRR) predictions;

f) Identification of sources proposed to be used for component reliability data;

g) Proposed serialized type forms and reports, including preventive maintenance and discrepancy reports specifically for joint use of the Contractor and the Authority during the field reliability assessment testing program;

h) Controls and procedures for ensuring that the activities of subcontractors and suppliers comply with the methods and objectives of the Reliability and Maintainability Program Plan;

i) Procedures to evaluate design changes for possible effects on system reliability and maintainability;

j) Provisions for furnishing predicted design reliabilities;

k) Procedures for field reliability testing;

l) Provisions for continual comparisons of field reliability testing results with accept-reject criteria;

m) Provisions for early fault detection and rapid fault isolation;

n) Demonstration testing plans for verification of compliance with specified reliability requirements when calculations and analyses are inconclusive, or when past performance records are incomplete or unavailable;

o) Provisions for furnishing a time log showing the actual factory time spent in repairing each piece of defective equipment removed during the course of the Maintainability Testing Program;

p) Provisions for field report time analysis;

q) Corrective measures to obtain satisfactory performance;

r) The predicted availability of the equipment stated as a percentage of a 21.5-hour operating day, with 7 day-per-week operations.

11.1.15 Maintenance Concept

The maintenance concept shall rely upon the maximum practical use of modular Lowest-Level-Replaceable-Units (LLRU) to restore service in the shortest practical elapsed time, i.e. Mean-Time-To-Repair (MMTR).

11.1.16 Preventive Maintenance

Preventive Maintenance is defined as a systematic arrangement of inspection, cleaning, lubricating, servicing, and minor repairs (adjusting and tightening) carried out at predetermined intervals or according to prescribed criteria, to reduce the probability of failure or the degradation of the functioning of an item, to optimize equipment life, minimize disruptive operational failures, and initiate repairs before breakdowns occur.

11.1.17 Preventive Maintenance Plan

A Preventive Maintenance Plan shall be developed which identifies all scheduled maintenance required on DART equipment and facilities. The Plan shall indicate when to perform maintenance tasks, detail all of the tasks needed to perform a particular maintenance function, outline all tasks in their proper sequence as required to perform tests and inspections, and describe all tasks required for each periodic inspection and the projected time needed for each task. All of these requirements shall be identified and clearly documented in the Plan. Preventive maintenance activities shall include:

a) Servicing and Inspection. All systems will be given a periodic servicing and inspection. The level and frequency of servicing and inspection shall be consistent with industry practices.

b) Cleaning. All facilities, parking lots, roads, storage areas, and vehicles (revenue and non-revenue) shall be periodically swept and cleaned.

c) Overhaul. This is a special maintenance activity concerned with the planned rehabilitation, retrofit, or modification of vehicle equipment. The activity shall generally improve equipment performance and minimize future failures.

11.1.18 Corrective Maintenance

Corrective maintenance shall be directed at repairing failed or malfunctioning parts, components, or subsystems. The intent is to restore the equipment to a operational and safe condition within the shortest reasonable time. Corrective maintenance shall be performed on both an unscheduled and scheduled basis.

Unscheduled corrective maintenance shall apply to a failed item or component that is repaired in a short time period, requiring a minimum amount of effort. It shall also apply to emergency repairs.

Tables shall be prepared to show all potential equipment failures at any level--from the highest-level assembly to the lowest-level replacement component. The tables shall be organized by symptom for observable equipment failures. Symptoms shall be identified in terms of observable indicators only. The tables shall list all possible causes for each symptom and shall indicate the lowest level of maintenance for each fault isolation step and corrective action that can be performed.

DART’s maintenance philosophy is to be prepared to react to unscheduled maintenance as a matter of course and to provide reasonable turnaround to keep the required equipment available at an optimum cost.

Scheduled corrective maintenance shall be carried out when the repair action cannot be completed in a short time period because:

a) The action is considered a major repair activity requiring a significant amount of time or resources.

b) Required materials, equipment, tools, or resources are not immediately available.

c) The repair can be safely deferred and performed more efficiently at a later time in conjunction with some other repair action.

11.1.19 Work Control

All maintenance activities shall be conducted within the framework of a comprehensive work control and management system. The system shall consist of documented maintenance policies, administrative and repair procedures, automated information systems, and management reports for control and follow-up on all DART maintenance activities. The process will enable DART rail management to achieve maintenance program objectives and monitor the various phases of the startup, pre-revenue testing, and equipment warranty provisions.

11.1.20 Warranty Work

All maintenance activities performed during the warranty of systems and components shall be reported on a work control system based on DART's Management Information System (MIS) for tracking reliability and maintainability goals and objectives. The definitions and classifications for specification compliance shall be defined by DART.

11.1.21 Warranty Goals

Maintenance failure criteria shall be developed to define a system or component design action that is required by the vendor during the warranty periods for the system and components. Should the respective failures attain or exceed the thresholds, the system shall be automatically declared a design fault, and the supplier shall institute a corrective action plan.

When the corrective action has to be installed on the vehicle or other systems, the warranty period shall be re-initialized. The “Fix” shall be the responsibility of the supplier.

11.1.22 Materials Management

An integral element of system maintainability and availability is the availability of parts and materials to repair or service the system so that downtime is minimized. Designers shall incorporate parts requirements and materials into the contract documents.

DART’s rail materials management group shall have three fundamental objectives:

a) Provide effective support to maintenance functions by ensuring that parts are available when and where they are needed.

b) Manage the investment in inventory at a level consistent with demand and associated carrying costs.

c) Track inventory and minimize the loss of material from theft or other causes.

To avoid maintaining a large inventory, such factors as failure rates, inventory draw down rates, and lead times for replenishment shall be analyzed to determine spare parts requirements. As inventory usage depends on conditions that are unique to DART (vehicle mileage, failure rates, etc.), a work control system shall be used to collect and analyze failure and repair data. This information shall be used to assist in predicting inventory requirements. The initial warranty period on new equipment shall provide sufficient data to allow starting this analysis and prediction process. This work control system shall be based on DART’s automated MIS program.

11.1.23 Training and Technical Manuals

Technical manuals and training materials shall be made available to DART for any transfer of work from the supplier. The manuals may initially be in draft form, but must be sufficiently current for DART personnel to effectively and efficiently perform the activity. The manuals shall cover all operating, maintenance and special procedures required by DART to successfully operate and support the new equipment. The goal of manual design and development shall be completeness and accuracy of coverage in the most concise manner possible. The manuals and training materials shall be made available sufficiently in advance of any transfer of work to DART to permit training and on-the-job experience to minimize the learning curve’s influence on operating costs.

11.2 Reliability and Maintainability Program Plan

A Reliability and Maintainability Program Plan shall be developed for each system.

Items to be addressed shall include:

a) Availability—interpreted as a function of the MTBF and MTTR measures discussed previously in this chapter, appropriately related to the system being designed;

b) Reliability—reliability for system shall be defined, accompanied by reliability requirements, failure analysis plans, and a reliability demonstration plan—with associated procedures;

c) Warranty work—outline of warranty terms and conditions, penalties for non-compliance with warranty conditions, warranty issue resolution, and warranty work plans;

d) Preventative maintenance—policies and procedures shall be outlined for all levels of progressively periodic inspection and any daily inspection. Courses of action for preventative maintenance activities shall evolve as designs and maintenance policies are finalized;

e) Corrective maintenance—methods of corrective repair to out-of-service components (for both scheduled and unscheduled outages).

11.3 GLOSSARY OF TERMS

Terms and definitions on which emphasis shall be applied for reliability and maintainability are contained within this section of the criteria. In the event of conflict between definitions contained in reference documents and those contained herein, the definitions of this is criteria shall govern.

Accept Criteria - The limits for Reliability and Maintainability (R&M) parameters which will lead to an acceptance of tested items if the values measured during an R&M demonstration are within prescribed limits.

Acceptance Tests - Test conducted for the purpose of accepting or approving products and performance of the Contractor.

Accessibility - A measure of the relative ease of admission to the various areas of an item for the purpose of operation or **maintenance.**

Adjustment - Changing (by electronic, electrical or physical means) a variable in an item to cause a change in its output characteristics.

Administrative Delay Time - Administrative Delay: The accumulated time during which an action of corrective **maintenance** on a faulty item is not performed due to administrative reasons.

Alert Time - That element of **up-time** during which an item is assumed to be in its specified operating conditions, and is awaiting a command to perform its intended mission.

Assembly – Two or more components semi-permanently joined to satisfy a particular function.

A grouping of components or piece parts that may be permanently or semi-permanently connected and that performs a definable function.

Availability - The ability of an item to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval, assuming that the required external resources are provided.

The measure of a system or equipment's availability for its designed purpose, i.e., revenue or shop operating inherent availability is related to the Mean-Time-Between-Failures (MTBF) and the Mean-Time-To-Repair (MTTR) through the following equation:

$$A_i = \frac{MTBF}{MTBF + MTTR}$$

Availability Goal – A system or component objective established in consideration of operational performance, cost, capability, and capacity of a system and includes reliability and maintainability goals. The goal is a desired result and can either be a minimum or maximum expected performance level.

Basic Reliability - The ability of an item to perform its required functions without **failure** or **defect** for the duration of its **life profile**.

Note: Reliability is deemed to include **Durability** (defined below).

Built-In-Test (BIT) - An integral capability of the equipment which provides an on-board test capability to detect, diagnose, or isolate system **failures**. The **fault** detection and, possibly, isolation capability is used for periodic or continuous monitoring of a system’s operational health, and for observation and, possibly, diagnosis as a prelude to **maintenance** action.

Built-in Test Equipment (BITE) - Any device permanently mounted in the equipment and used for the express purpose of testing the equipment, either independently or in association with external test equipment.

Burn-In - The operation of an item to stabilize its characteristics. Basically, a **reliability** conditioning procedure which is a method of ageing an item by operating it under specified environmental and test conditions in accordance with an established procedure in order to eliminate early **failures** and age or stabilize the item prior to final test and shipment.

Calibration - The comparison of Measuring and Test Equipment or a measurement standard of unknown accuracy to a measurement standard of known accuracy which is traceable to the National Bureau of Standards, in order to detect, correlate, report, or eliminate by adjustment any variation in the accuracy of the instrument being compared.

CALS - An acronym for Continuous Acquisition and Life Cycle Support, previously the acronym stood for Computer-aided Acquisition and Logistic Support. It is an effort to document and utilize technical information, in a digitized format.

Certificate of Compliance or Conformance - A written statement, signed by a qualified party, attesting that the items or services are in accordance with specified requirements and accompanied by additional information to substantiate the statement.

Certified Inspection Reports - Reports signed by the Contractor’s Quality Control Representative (CQCR) attesting that the items inspected meet the specification requirements other than any exceptions included in the report.

Certified Test Reports - Reports of tests signed by a qualified professional attesting that tests were performed in accordance with the test method specified, that the test results reported are accurate, and that items tested meet or fail to meet the stated minimum requirements. Include calibration certificates, if required.

Common (Critical) Failure Mode - Failures of distinct components caused by an initiating event.

Comprehensive Maintenance – A maintenance program that includes all elements of routine and non-routine maintenance. Routine maintenance is the entire scheduled system of preventive and planned maintenance activities through the useful life cycle of the vehicle.

Concurrent Engineering - A systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including **quality**, cost, schedule and user requirements.

Confidence Level - That probability that a given statement is true. The statement in question normally refers to whether a given parameter lies between two limits, is above a lower limit, or is below an upper limit.

Configuration Control - The establishment of an agreed build standard for an item and the procedure for controlling change to that standard, in order that it may be defined at any time.

Consensus Standard - An artifact or process that is a de-facto standard by written agreement between the Contractor and the Authority where the de-facto standard’s content and applicability are established prior to application and is applied in place of a recognized U.S. national standard.

Consumer’s Risk - The probability of accepting equipment with a true **Mean Time Between Failure** (MTBF) equal to the lower test MTBF. The probability of accepting equipment with a true MTBF less than the lower test MTBF will be less than the **consumer’s risk**.

Contractor Data Requirements List (CDRL) - A contractual term which refers to all the written documents (i.e. reports, drawings, procedures, data) which a contractor is obligated, under the contract, to provide to the procuring activity. This is over and above any hardware or services which the contractor may be also obligated to provide.

Contractor Quality Control (CQC) Plan (System) - A written description of proposed actions to control and assure quality.

The CQC Plan defines applicable quality policy for the project and applicable quality procedures. The CQC Plan shall be established and maintained by the Contractor to ensure compliance with the Contract requirements. No portion of the Plan may be delegated to subcontractors or suppliers without the prior approval of the Authority.

Corrective Action - Corrective action identifies action to be taken to correct immediate defects and correct the root cause to prevent recurring defects. Corrective action addresses systemic or chronic problems. Corrective action includes procedures for investigating the cause of nonconforming work and procedures for analysis to detect and eliminate potential causes of nonconforming work.

Corrective Maintenance (See **Corrective Maintenance Time** – Activities performed to restore a defective part of a vehicle or component to a satisfactory condition by correcting the malfunction that caused the vehicle or component to be below the specified performance.

Corrective Maintenance Time (See **Corrective Maintenance**) - That part of the **maintenance** time including that due to **logistic delays**, during which corrective **maintenance** is performed on an item.

Critical Failure - A **failure** that could result in injury to persons or that prevents an item from performing an essential mission.

Critical Function – A function which, if degraded or lost, has a major impact on system performance, such as loss of vehicle movement and control.

Critical Item - An item whose **failure** could result in a **critical failure** or that requires special effort during development/production.

Note: Examples, that might be tailored for each System Element, are listed below:

1. The failure of which would critically affect system safety, cause the system to become unavailable or unable to achieve stated objectives, or cause extensive/expensive maintenance and repair.

2. The **failure** of which would prevent the acquisition of data to evaluate system **safety, availability**, or need for **maintenance**/repair.

3. An item which has stringent performance requirement(s) in its intended application relative to state-of-the-art techniques for the item.

4. A **single point failure** which causes system **failure**.

5. An item which is stressed in excess of specified **derating** criteria.

6. An item which has a limitation which warrants controlled surveillance under specified conditions.

7. An item which is known to require special handling, transportation, storage, or test precautions.

8. An item which is difficult to produce or manufacture relative to state-of-the-art techniques.

9. An item which has exhibited an unsatisfactory operating history or which does not have sufficient history of its own to provide confidence in its **reliability**.

10. An item which has past history, nature, function or processing with a deficiency warranting a total traceability.

11. An item that can be produced by only one company, i.e. (sole supplier).

12. Long lead time items.

Defect - A fault or imperfection.

Dependability – The capability of the Light Rail Transit (LRT) System to perform its function continuously and consistently during revenue hours.

Derating - Using an item in such a way that applied stresses are below rated values.

Derating Factor - Complement-to-1 of the quotient of actual stress to the rated stress value.

Design Life – The stated operating life of a component before replacement or renewal.

Diagnostics - The detection, isolation and analysis of **faults** and **failures.**

Discrimination Ratio - It is one of the standard test plan parameters. It is the ratio of the upper test Mean-Time-Between-Failures (MTBF) to the lower test.

Down-Time - That period of time during which an item is not in a condition to perform a required function.

Duty Cycle – The actual portion of the operating time during which the equipment or hardware is subject to stress resulting from executing the design function.

Early Life Failures - **Failures** which occur in the early life of an item. The early life of an item is normally characterized as a period in which the **failure** rate of the item is considerably higher than that of the subsequent period. Such **failures** are usually amenable to removal by **burn-in** or **environmental stress screening**.

Environmental Stress Screening (ESS) - A series of tests conducted, at an early stage, under environmental stresses to disclose weak parts and workmanship **defects** for correction.

Factory Tests - Tests made on various products and component parts prior to shipment to the job site.

Failure – Any malfunction whereby a system, subsystem, component, or human ceases to properly perform its required function within previously specified limits. This includes the cases where different components or parts of a subsystem may be failing, causing the subsystem to fail in a cumulative manner.

NOTE: **Failures** may be classified as to such aspects as cause, degree, relevancy, chargeability, dependency and responsibility.

Failure Analysis - The logical, systematic examination of a failed item to identify and analyze the **failure** mechanism, the **failure** cause, and the consequences of the **failure**.

Failure Mode - The consequences of the mechanism through which the **failure** occurs, i.e. short, open, fracture, excessive wear.

Failure Modes and Effects Analysis (FMEA) - A procedure by which each potential **failure mode** of a component, equipment or subsystem in a system is analyzed to determine the results or effects thereof on the overall system and to classify each potential **failure mode** according to its severity.

Failure Modes, Effects & Criticality Analysis (FMECA) - A qualitative method of **reliability** analysis which involves a **fault** modes and effects analysis together with a consideration of the probability of their occurrence and of the ranking of the seriousness of the **faults**.

Failure Rate - The number of **failures** of an item per unit of measure of life, expressed in hours, cycles, miles, events as applicable to the item.

Fail Safe - In the presence of equipment failure, the system shall continue to be in a condition of safety. An equipment failure shall result in the imposition of a restrictive condition if necessary to avoid a safety problem.

Fault - The state of an item characterized by its inability to perform a required function, excluding the inability during preventive **maintenance** or other planned actions, or due to lack of external resources.

NOTE: A fault if often the result of a **failure** of the item itself, but may exist without prior **failure**.

Fault Tolerant - Fault Tolerance: The attribute of an item that makes it able to perform a required function in the presence of certain given sub-item **faults**.

Fault Tree Analysis (FTA) - An **FTA** provides a diagrammatic means of showing the logical relationship between a particular system **failure mode** and the basic **failure** causes.

Field Replaceable Unit (FRU) - A replaceable unit able to be, in a safe and timely manner, removed and replaced by the Authority at the location where that unit operates or is maintained.

Human Engineering - The area of human factors, which applies scientific knowledge to the design of items to achieve effective man-machine integration and utilization including operations, **maintenance**, support and disposal of the system.

Human Error - A human action that produces an unintended and unwanted result.

Inactive Time - That time during which an item is in an inactive or non-operational inventory, i.e. it is being held in reserve for potential future assignment to the inventory of an operational unit.

NOTE: The distinction between **inactive time** and down time is that down time implies that the item is both on the inventory of an operational unit and dysfunctional, whereas **inactive time** would only mean that the item in not in an operational unit’s inventory.

Incident – Any unexpected event observed during the equipment operating time where a deviation from the required function is demonstrated. Usually provides an initial indication of a possible **defect** or **failure**.

Independent Failure – A failure is independent when it is not caused by the malfunction of other equipment or hardware, component abuse, or an incorrect maintenance procedure.

Infant Mortality (See **Early Life Failures**)

Inherent Maintainability - The **maintainability** potential present in a design, i.e. the **maintainability** which is dependent solely on the **quality** of the design and assumes perfect **quality** of manufacture and correct use in the field.

Inherent Reliability - The **reliability** potential present in a design, i.e. the **reliability** which is dependent solely on the **quality** of the design and assumes perfect **quality** of manufacture and correct use in the field.

In-Service R&M Demonstration - A procedure to demonstrate the **reliability** and **maintainability** achieved by an equipment against the requirements specified in the contract using production standard equipment under agreed in-service conditions.

Interchangeability - A condition which exists when two or more items possess such functional and physical characteristics as to be equivalent in performance and **durability**, and are capable of being exchanged one for the other without alteration of the items themselves, or of adjoining items, except for adjustment, and without selection for fit and performance.

Intrinsic Availability - The probability that the system/equipment is operating satisfactorily at any point in time when used under stated conditions, where the time considered is **operating time** and repair time (active).

Thus, **intrinsic availability** excludes from consideration all free time, storage time, **administrative delay time** and **logistic delay** time.

Intrinsic R&M (See **Inherent Reliability and Inherent Maintainability**)

Life Cycle Cost (LCC) - The sum total of the direct, indirect, recurring, non-recurring and other related costs incurred, or estimated to be incurred, in the design, development, production, operations, **maintenance**, support and disposal of a major system over its anticipated useful life span.

Life Limited Item - An item that has a limited and predictable useful life and could be considered for replacement on a pre-planned basis for **reliability, safety**, or economic reasons.

Life Profile - A time-based description of the events and environments an item experiences from manufacture to final expenditures or removal from the operational inventory, to include one or more **mission profiles**.

Line of Maintenance - An echelon in an organization where specified levels of **maintenance** are to be carried out on an item.

NOTES:

1. Examples of **maintenance** echelons are: field, repair shop, and manufacturer.

2. The **maintenance** echelon is characterized by the skill of the personnel, the facilities available, the location etc.

Line Replaceable Unit (LRU) - A unit designated to be removed upon **failure** from a larger entity (equipment, system) in the operational environment.

Logistics - The science of planning and carrying out the movement and **maintenance** of equipment. In its most comprehensive sense, those aspects of operations which deal with:

a. Design and development, acquisition, storage, movement, distribution, **maintenance**, evacuation and disposition of materiel;

b. Acquisition or construction, **maintenance**, operation and disposition of facilities; and

c. Acquisition of furnishing of services.

Logistic Delay Time - Logistic Delay: That accumulated time during which a **maintenance** action cannot be performed due to the necessity to acquire **maintenance** resources, excluding any administrative delay.

NOTE: Logistic delays can be due to, for example, traveling to unattended installations, pending arrival of spare parts, specialists, test equipment, information and suitable environmental conditions.

Logistic Support (See **Logistic Support Analysis**)

Logistic Support Analysis (LSA) - The selective application of scientific and engineering efforts undertaken during the acquisition process, as part of the system engineering process, to assist in:

a. Causing support considerations to influence design;
b. Defining support requirements that are related optimally to design and to each other;
c. Acquiring the required support;
d. Providing the required support during the operational phase at minimum cost.

During the later production and in-service phase LSA is conducted on a repetitive basis in order to meet life cycle costs, readiness, and **supportability** objectives.

Lowest Level Replaceable Unit (LLRU) – A replaceable unit able to be removed and replaced by the Authority, which itself does not include any constituent replaceable units.

Maintainability - The probability that a given **maintenance** action, for an item under given conditions of use, can be carried out within a stated time interval, when the **maintenance** is performed under stated conditions and using stated procedures and resources.

NOTE: The term **"maintainability"** is also used to denote the **maintainability** performance quantified by this probability.

Maintainability Demonstration (See also **Maintainability Verification**) - A **maintainability verification** performed as a compliance test.

Maintainability Model - A mathematical model used for prediction or estimation of **maintainability** performance measures of an item.

Maintainability Prediction - An activity performed with the intention of forecasting the numerical values of a **maintainability** performance measure of an item, taking into account the **maintainability** performance and **reliability** performance measures of its sub-items, under given operational and **maintenance** conditions.

Maintainability Qualification Test (MQT) - A compliance test carried out prior to the production phase to ensure that the design can accommodate the **maintainability** requirements.

Maintainability Verification - A procedure applied for the purpose of determining whether the requirements for **maintainability** performance measures for an item have or have not been achieved.

NOTE: The procedure may range from analysis of appropriate data to a **maintainability demonstration.**

Maintenance

1. All action taken to retain materiel in or to restore it to a specified condition. It includes inspection, testing, servicing, classification as to serviceability, repair, rebuilding and reclamation.

2. The routine recurring work required to keep a system element or a facility (plant, building, structure, ground facility, utility system or other real property) in such condition that it may be continuously utilized, at its original or designed capacity and efficiency for its intended purpose.

Maintenance Concept - A description of the planned general scheme for **maintenance** and support of an item in the operational environment. The **maintenance concept** provides the practical basis for design, layout and packaging of the system and its test equipment and establishes the scope of **maintenance** responsibility for each level (echelon) of **maintenance** and the personnel resources (**maintenance** manning and skill levels) required to maintain the system.

Maintenance Down Time - The interval between the time a system/equipment is made available for preventive or corrective **maintenance** until that **maintenance** action is successfully completed.

Maintenance Plan – A schedule of maintenance activities that is performed periodically without interrupting the satisfactory operation of the System’s Elements.

Maintenance Procedures – Methods for periodically checking and servicing items to prevent failure(s) or to effect a repair, renewal, or overhaul.

Malfunction (See **Fault**)

Man-Machine Systems - A system comprising of persons and equipment interacting together to perform a function.

Markov Chain - A stochastic process on a discrete time basis that has finite or a denumerable number of infinite states and in which the probabilities of occurrence of future states depend only on the present state and not on the history of prior states. A stochastic process is one which can be modeled by a family of random variables $(R_{(t)})$.

Maximum Mean Time to Repair (A_{max}x (0.90) – The time expressed in hours required to perform 90% of all corrective maintenance actions.

Mean Distance Between Failures (MDBF) – The mean distance between failures of an item is the ratio of the total operating distance, d, accumulated by the total population of identical items to the total number of relevant failures, F, occurring within the population of identical items during the time, t. It is expressed by the following equation:

$$MDBF = \frac{d}{F}$$

Mean Time Between Critical Failures (See **Mean Time Between Failures and Critical Failures**) - Similar to **Mean Time Between Failures (MTBF)** except that only **critical failures** are counted. It is a measure of expected time between **critical failures**.

Mean Time Between Failure (MTBF) - A measure of the expected (average) time during which a system will continuously perform within its specified limits under stated conditions without a chargeable failure. It can be estimated by dividing life units (hours, miles, etc) accrued during a stated period under stated conditions by the number of **failures** during the period and is a basic measure of **reliability** for repairable items. It is expressed by the following equation:

$$\mathrm{MTBF} = \frac{t}{F}$$

Note: Acceptable sources of MTBF data shall include the following:

1. Manufacturer's generally available published MTBF information.

2. Manufacturer's published data (signed and dated by a manager in the manufacturer's organization) determined from laboratory tests of identical or substantially equivalent equipment.

3. Manufacturer's data (signed and dated by a manager in the manufacturer's organization) determined from calculations based on the current revision of Military Standard MIL-HDBK-217 - *Reliability of Electronic Equipment*.

4. Manufacturer's data, signed and dated by a manager in the manufacturer's organization), determined, using a documented data acquisition and analysis procedure, from recorded experience with installed equipment (identical to or substantially equivalent to the make and model for which the MTBF data is to be submitted) in similar operating environments, provided the data acquisition and analysis procedure and reliability records substantiating the MTBF information are provided.

5. Existing third-party analyses or third-party data which are fully documented, signed, dated, and verifiable may be proposed for equipment and applications, which are identical or manifestly similar. The third party shall be

a reputable testing laboratory or similar organization regularly involved in assessing and documenting the reliability of equipment similar to the subject equipment. In any case, the source of all data and/or results used shall be clearly identified and the rationale used in extrapolating data for application to the Authority's environment shall be explicitly stated.

Mean Time Between Maintenance Actions (MTBMA) - A measure of the expected (or average) time between all **maintenance** (preventive and corrective) actions. It can be estimated by dividing the total number of system life units (hours, miles, etc) by the total number of **maintenance** actions (both preventive and corrective) during a stated period of time. It provides information related to the demand for **maintenance** manpower.

Mean Time Between Service Failure (MTBSF) – Mean Time Between Service Failure is the average equipment operating time per independent equipment service failure. MTBSF is the reciprocal of the service failure rate and is expressed mathematically as:

$$\text{MTBSF} = \frac{\text{Equipment Operating Time}}{\text{Independent Service Failures}}$$

Mean Time to Failure (MTTF) (See **Mean Time Between Failure**) - This is similar to **Mean Time Between Failure (MTBF)** but applies to non-repairable systems. It is a measure of the expected life until **failure**. It can be estimated by dividing the total number of **failures** within a population into the total number of life units of the population during a stated period under stated conditions.

Mean Time to Repair (MTTR) – The combined average time required to: (1) Troubleshoot, and (2) Repair equipment for operation after report of a failure. This time is measured from the time troubleshooting and repair work begins until restoration is completed. MTTR is a measure of maintainability of the design and equipment. Time required to locate and repair dependent (non-chargeable) failures shall be included in the total repair time. The MTTR shall be estimated by the total elapsed **corrective maintenance time** divided by the total number of **corrective maintenance** actions during a given period of time.

Typically, MTTR is calculated as:

$$\text{MTTR} = \frac{\text{Cumulative Repair Time in Hours}}{\text{Total Number of Repair Actions}}$$

Measurement Standard - A metrology reference standard device used to calibrate measuring and test equipment (M&TE) or other measurement standards where a measurement standard has a National Institute of Standards and Technology (NIST) traceability property such that comparative measurement or value of a measurement standard is related to stated references through an unbroken chain of comparisons all having stated uncertainties.

Minimum Design Life – The inherent durability of the equipment/system. Typically specified in the system/equipment design and normally stated in years.

Mission Profile - A time-phased description of the events and environments an item experiences from initiation to completion. It identifies the task, events, durations, operating conditions and environments for each phase.

Mission Reliability - The probability that an item will perform its required functions for the duration of a specified **mission profile** (See **Mission Profile**)

Mission Time - That element of **up-time** required to perform a stated **mission profile.**

Modular Design – The logical assemblage of electrical and mechanical components together in replaceable sub-assemblies according to the function they perform.

Monte Carlo Computer Simulation Techniques - A method utilizing random sampling to obtain inputs for computer **simulation** trials and obtaining approximate solutions in terms of a range of values each of which has a calculated probability of being the solution to the problem.

Nonconformance - A discrepancy in characteristic, documentation, or procedure which affects form, fit, or function and renders the quality of an item unacceptable or indeterminate in regard to meeting relevant project requirements. Examples of nonconformance include physical defects, test failures, incorrect or inadequate documentation, or deviation from prescribed processing, inspection, or test procedures.

Non-Operating Time - The amount of time that a system/equipment is not operating but assumed to be operable. **Non-Operating Time** refers only to systems not committed to a specific mission.

Non-Scheduled Non-Routine Maintenance – Necessary actions to restore a system or equipment to a serviceable condition. (See also **Corrective Maintenance**)

Operating Time - The time during which the system or equipment is turned on and actively performing at least one of its functions.

Operational Availability (See also **Intrinsic Availability**) - The probability that an equipment/system at any instant in the required **operating time** will operate satisfactorily under stated conditions where the time considered includes operating, corrective and **preventive maintenance, administrative delay time,** and **logistic delay time.**

Overhaul - The effort, usually performed at workshop level, when a complete disassembly inspection, rework and reassembly, of an item is required to restore the item to a 'like new' condition.

Part – One (1) or more pieces semi-permanently joined to satisfy a particular function.

Parts Control Program - A documented policy and procedure intended to control the method for selecting and using parts to enhance system/equipment performance and **reliability.**

Parts Count Analysis - A method of predicting item **reliability** utilizing models which need part types and quantity, part quality levels and equipment environment. This prediction method is normally utilized during early design phases and assumes the time to **failure** of the parts is exponentially distributed, i.e. a constant **failure rate.**

Parts Stress Analysis (See also **Parts Count Analysis**) - A method of predicting item **reliability** utilizing models which require additional information to that in **Parts Count Analysis**, particularly stresses on parts (e.g. temperature, power or current rating, complexity etc). It is normally applied at later design phases for trade-offs between **reliability** versus part selection. The **parts stress analysis** method assumes the time to **failure** of the parts is exponentially distributed (i.e. a constant **failure rate**).

Preconditioning (See also **Burn In, Early Life Failures** and **Environmental Stress Screening (ESS)**) - A method of ageing an item by operating it under specified environmental (normally high temperature or vibration) in order to eliminate **early life failures** prior to final test or shipment.

Prediction - The **reliability** computed from the observed, assessed or extrapolated **reliability** of its parts for the stated conditions of use, and taking into account the design of a product.

Predictive Maintenance – A systematic methodology of system/component failure analysis to identify the probability of damaged equipment and cost/benefit analysis of preventive maintenance actions to minimize costs and maximize performance.

Premature Failure (See **Early Life Failure**)

Preventive Maintenance – A systematic arrangement of inspection, cleaning, lubricating, servicing and minor repairs (adjusting and tightening) carried out at predetermined intervals or according to prescribed criteria, to reduce the probability of **failure** or the degradation of the functioning of an item, to optimize equipment life, minimize disruptive operational failures, and initiate repairs before breakdowns occur.

Procedure - Procedure as used in regard to maintainability shall be understood to mean written instructions identifying what is to be done, who will do it, and how, where, and when it shall be scheduled to be done.

Producer’s Risk - The probability of rejecting equipment which has a true Mean-Time-Between-Failures (MTBF) equal to the upper test MTBF. The probability of rejecting equipment which has a true MTBF greater than the upper test MTBF will be less than the **producer’s risk**.

Product - A type or a category of manufactured goods, constructions, installations, and natural and processed materials or those associated services whose characterization, classification, or functional performance determination is specified by standards.

Production Reliability Acceptance Test (PRAT) - A test conducted under specified conditions, by, or on behalf of, the Authority, using delivered or deliverable production items, to determine the producer's compliance with specified **reliability** requirements.

Projects – Maintenance action undertaken on a pre-established number of items of equipment to correct a material or design defect. Projects may last more than a year and may be made part of the capital program.

Provisioning - The process of determining and acquiring the quantity and type of support items, spares, repair parts, tools and test equipment necessary to operate and maintain an item for an initially stated period of time.

Quality - The totality of characteristics of an item that bear on its ability to satisfy stated and implied needs.

Quality Assurance – QA is a system of coordinated activities that attempts to prevent maintenance performance from deviating from what is expected within the maintenance department's cost and performance objectives. Activities can include incoming inspection of materials, component performance testing, component vendor surveys, and component defect analysis to predict the probability of occurrences of defects of components, control production, and to design inspection **sampling plans**.

Quality Control Inspection - Examining, testing, analysis, or sampling products or workmanship, including when appropriate, raw materials, components, and intermediate assemblies, to determine conformance to stated requirements.

Quality Control Tests - Tests conducted and performed by the Contractor for the purpose of monitoring the quality of products and performance of the Contractor.

Random Failure - A **failure** whose time of occurrence is predictable only in a probabilistic sense (i.e. not deterministic).

Reaction (or Reponse) Time - The time used by equipment, operator, or both, that elapses between the moment an action is called for and when the desired result occurs.

Reject Criteria - The limits for Reliability and Maintainability (R&M) parameters which will cause a rejection of tested items when the limits are reached or exceeded during an R&M demonstration.

NOTE: Possible parameters for **reject criteria** are the number of chargeable **failures** (for **reliability**) or repair times (for **maintainability**).

Relevant Failure - A relevant failure of an item is an independent failure which results in a loss of function of that item caused by either of the following:

1. A fault in the item while operating within its design and environmental specification limits, or

2. Improper operation, maintenance or testing of the item as a result of Contractor-supplied documentation.

Reliability - The ability of a component, item, or system to perform a required function under stated conditions for a specified period of time.

NOTE: The term **reliability** is also used as a **reliability** characteristic denoting a probability of success, or a success ratio.

Reliability Analysis – A quantitative analysis of equipment or operation that determines whether the function under study will comply with the specified reliability or availability goals.

Reliability Block Diagram (RBD) - A **reliability** model that provides a pictorial representation of system **reliability** performance and shows the logical connection of (functioning) components needed for system success.

NOTE: In the symbolic representation, no distinction is made between open circuit, short circuit, or other **fault** modes. However in the numerical evaluation this is possible.

Reliability Center Maintenance (RCM) - A method for establishing a scheduled (preventive) **maintenance** program which will efficiently and effectively achieve the **inherent reliability** and **safety** levels of equipment. It is methodology which can be applied to the development of a preventive **maintenance** program and results in improved component **reliability** and minimized overall program costs. The intended end result is improved overall equipment **safety, availability,** and economic operation.

Reliability Demonstration - A demonstration using a statistical evaluation of tests or operating data to show that system/equipment **reliability** complies with the specified quantitative requirements.

Reliability Growth - The improvement in a **reliability** parameter caused by the successful correction of deficiencies in item design or manufacture.

Reliability Growth Model - A mathematical model to monitor/control the improvement of a **reliability** parameter generated by the successful correction of deficiencies in system/equipment design or manufacture.

NOTE: Usually a distinction is made between parametric and non-parametric **reliability growth models**. Parametric models allow users to plan, monitor/control, and predict the **reliability growth**.

Reliability Growth Test - A series of tests conducted to disclose deficiencies in item design and manufacturing and to verify that corrective **actions** will prevent recurrence. It measures the degree of improvement in item **reliability** as a result of **corrective actions** in the design and manufacturing processes.

Reliability and Maintainability (R&M) Allocation and Apportionment - The allotment of **reliability** and **maintainability** requirements to sub-systems such that, if these sub-system requirements are met, the allotment will result in satisfactory system level **reliability** and **maintainability**.

Reliability and Maintainability (R&M) Assessment - The determination of the R&M values of an item within stated confidence limits, from test or field data, on nominally identical items. The source of the data must be stated.

NOTE: Alternatively, point estimates may be used, the basis of which must be defined.

Reliability and Maintainability (R&M) Assurance - The implementation of adequate planned and systematic actions necessary to provide confidence that an item will satisfy given **reliability** and **maintainability** requirements.

Reliability and Maintainability (R&M) Model - A mathematical model used for prediction or estimation of R&M performance measures of a product.

Reliability and Maintainability (R&M) Program Plan - A plan that defines the management and technical tasks to be undertaken and the organizations responsible for them.

Reliability Maintenance – Reliability maintenance is the process of modifications that increases the probability that a system or component will continue to efficiently operate.

Reliability Qualification Test - A test conducted under specified conditions, by, or on behalf of, the Authority, using items representative of the approved production configuration, to determine compliance with specified **reliability** requirements as a basis for production approval.

Reliability Stress Analysis - The study of the **reliability** effects of stresses (electrical, mechanical, thermal, etc.) on a product and their distributions taking into account the operational requirements.

Repair - A corrective action resulting from an equipment failure or breakdown. A repair may also be the result of preventive maintenance inspections or scheduled maintenance. In either case, repair is an activity that restores a malfunctioning item to an operable state.

Repair Time - The active working time to effect the maintenance action. The time element excludes transportation time to the site or waiting for a repair person, and parts. It includes fault detection and isolation, access, testing, replacement or adjustment, and time to restore the system or component to a state of operational readiness. To control exceptional cases, the 90^{th} percentile is used to indicate that the repair time is not exceeded 90% of the time.

Repairability - The probability that a failed system can be operational in a specified interval of repair time.

Replaceable Unit - Any physical unit (e.g. component, printed circuit board, sub-assembly, etc.) which can be removed and replaced, and whose removal and replacement does not require removing soldering, re-soldering or re-wiring (other than disconnecting from/connecting to a wiring terminal) of that unit, nor of any other unit in order to access the replaceable unit. If a unit is not a replaceable unit and is not within a replaceable unit as defined in the preceding sentence, the entire shelf/chassis/rack/cabinet within which the unit is situated shall be considered a replaceable unit.

Replacement Schedule – The specified period(s) when components of operating equipment and systems are to be replaced. Replacement is the removal of components which are approaching the end of their useful lives or the time interval specified for component overhaul or rework and installation with a serviceable component.

Sampling Plan - A sampling plan is the process of measuring a few items and assuming information about the group from the same measurements.

Safety - The likelihood of a product to maintain throughout its life cycle an acceptable level of risk that may cause an injury to personnel or major damage to the product or its environment.

Scheduled or Routine Maintenance (See **Preventive Maintenance**) - Maintenance activities to be performed on an established frequency or periodicity.

Screening - A process for inspecting items to remove those that are unsatisfactory or those likely to exhibit **early life failure**. Inspection includes visual examination, physical dimension measurement and functional performance measurement under specified environmental conditions.

Secondary Failure - A **failure** of an item, caused either directly or indirectly by a **failure** or a **fault** of another item.

Selection Time - Time necessary to select requisite test equipment/programs.

Serviceability - The ease with which the system can be repaired.

Servicing Time (See **Repair Time**)

Shelf Life - The length of time an item can be stored under specified conditions and still comply with specified requirements.

Simulation - The representation of selected behavioral characteristics of one physical or abstract system by another system.

Single Point Failure - The **failure** of an item which would result in **failure** of the system and is not compensated for by redundancy or an alternative operational procedure.

Sneak Analysis - **Sneak Circuit Analysis**: A procedure conducted to identify latent paths which cause occurrence of unwanted functions or inhibit desired functions assuming all components are properly functioning.

Software Quality - A software product’s totality of features and characteristics that determine its ability to satisfy stated needs and conformity to specified and referenced standards. The degree to which a software system meets the specified and referenced standards.

Software Quality Assurance (SQA) - SQA is the planned and systematic set of activities that ensure that software process including all activities involved in design, coding, testing, and maintaining products including software, associated data, documentation and all supporting and reporting paperwork conform to requirements, specified standards, and procedures.

Software System Test - The activity of testing integrated hardware and software systems to verify whether the system meets the Authority’s specified reliability, and technical requirements.

Software Validation and Verification - Two complementary aspects of testing a product’s fitness for purpose. Formal process to confirm software meets Agency’s specifications and fulfills its intended purpose.

Spare Parts Scaling - The determination of how many spares of each type should be held to support an equipment by the unit in which it is fitted, having considered the numbers of equipment fitted, likely **failure rate,** and proximity of the alternative sources.

Standby Mode - That mode of an item during which it is not fully operating but assumed to be completely operable.

Standby Operation - A sequence of elementary activities carried out during a quasi-operational state.

Supportability - A measure of the degree to which all resources required to operate and maintain the system/equipment can be provided in sufficient quantity and time.

System Life Cycle - The period divided into phases, ranging from the first considerations on the need for a system/equipment through the development and in-service stages down to phasing-out and disposal.

Tailoring - The process by which the individual requirements (paragraphs, sub-paragraphs or sentences) of the selected documents are evaluated to determine the extent to which each requirement is most suitable for a specific system or equipment acquisition and the modification of these requirements, where necessary, to ensure that each achieves an optimal balance between operational needs and cost. This process must take care not to exclude those R&M requirements which are determined as essential to meeting operational needs.

Testing Process - A series of tests conducted to disclose deficiencies or to verify that **corrective actions** will prevent recurrence and to determine compliance with specified R&M requirements.

Unsafe Condition - Any condition that endangers human life or property.

Up-Time - That period of time during which an item is in a condition to perform a required function.

Wear Out Failure - A **failure** whose probability of occurrence increases with the passage of time, as a result of processes inherent in the item.

Work Center – A group of production shops which are considered a unit for organizational or performance control or cost accounting purposes.

Work Measurement- A system for determining the time to perform a specific task and comparing planned work performance to actual.

Work Standards – The time required to perform a specific task by a craft-person with average working skills working at a pace that can be maintained under normal working conditions.

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CHAPTER 12 – SYSTEM SAFETY

12.1 INTRODUCTION

12.1.1 Purpose

The purpose of the DART SYSTEM SAFETY DESIGN CRITERIA is to provide engineers, architects, planners and other project participants with sufficient detailed information to permit a uniform and comprehensive approach to design development.

Designing the system to incorporate system safety, by itself, will not assure a safe operating system after operations have begun. A safe design is only the first element in a comprehensive system safety program. The complete program shall include assurance that: design criteria are incorporated in the final system design, the system components and construction are provided as designed, staff is trained to safely operate and maintain the system, and adequate management controls are in place to assure adherence with the safety plan throughout the operations cycle.

12.1.2 Goals

Safety criteria shall provide performance values, procedures and specifications for measuring design attainment of the following safety goals:

a) All elements of system layout, design and operation shall have safety performance equal to or greater than currently demonstrated in the existing DART light rail transit system.

b) No equipment failure within the system shall result in a catastrophic or critical accident.

12.1.3 Objective

The system safety design criteria shall, at a minimum, meet the following objective:

Identified unacceptable and undesirable hazards shall be eliminated or controlled using the following hierarchy of hazard resolution:

Design for Minimum Risk. Design, redesign or retrofit to eliminate (i.e., design out) the hazards through design selection. If an identified hazard cannot be eliminated, reduce the severity and/or probability of occurrence to an acceptable level. This may be accomplished, for example, through use of fail-safe devices and principles in design, the incorporation of high reliability systems and components, and the use of redundancy in hardware and software design.

Safety Device. Hazards that cannot be eliminated through design or controlled through design selection will be controlled to an acceptable level through the use of fixed, automatic, or other protective safety design features or devices. Examples of safety devices include interlock switches, protective enclosures, and safety pins. Care must be taken to ascertain that the operation of the safety device reduces the loss or risk and does not introduce an additional hazard. Safety devices will also permit the system to continue to operate in a limited manner. Provisions will be made for periodic functional checks of safety devices.

Warning Devices. When neither design nor safety devices can effectively eliminate or control an identified hazard, devices will be used to detect the condition and to generate an adequate warning signal to correct the hazard or provide for personnel remedial action. Warning signals and their application will be designed to minimize the probability of incorrect personnel reaction to the signals and will be standardized within like types of systems.

Procedures and Training. Where it is not possible to eliminate or adequately control a hazard through design selection, or use of safety and warning devices, procedures and training will be used to control the hazard. Special equipment operating procedures can be implemented to reduce the probability of a hazardous event and a training program can be conducted. The level of training required will be based on the complexity of the task and the minimum trainee qualifications contained in the training requirements specified for the subject system element and element subsystem. Procedures may include the use of personal protective equipment. Precautionary notations in manuals will be standardized. Safety critical tasks, duties, and activities related to the system element/subsystem will require certification of personnel proficiency. However, without specific written approval, no warning, caution or other form of written advisory will be used as the only risk reduction method for Category I and II hazards. Hazard categories are covered in the DART Operations SSPP, Section 5.

12.1.4 Analysis Methods

There are several hazard analysis techniques that should be considered to assist in the evaluation of potential hazards and to document their resolution including a Preliminary Hazard Analysis (PHA), Failure Modes and Effects Analysis (FMEA), and Operating Hazard Analysis (OHA). These analyses should be conducted in accordance with the latest version of MIL-STD-882. This standard provides uniform requirements for developing and implementing a system safety program of sufficient comprehensiveness to identify the hazards of a system and to impose design requirements and management controls to prevent mishaps. The system safety program addresses hazards from many potential sources, including system design, hazardous materials, advancing technologies, and new techniques. Detailed guidelines on utilizing these techniques can be found in the FTA publication *Hazard Analysis Guidelines for Transit Projects January 2000*. The hazard analysis shall include the following information:

a) Component identification and function;

b) Next higher assembly identification;

c) Effects of failure on system performance;

d) Means by which failure is detected;

e) Hazard severity categories are defined to provide a qualitative measure of the worst credible mishap resulting from personnel error, environmental condition, design inadequacies, procedural deficiencies, system, subsystem or component failure or malfunction as follows:

  1) Category I: Catastrophic: Death, system loss or severe environmental damage.

  2) Category II: Critical: Severe injury, severe occupational illness, major system, or environmental damage.

  3) Category III: Marginal: Minor injury, minor

occupational illness, minor system, or environmental damage.

4) Category IV: Negligible: Less than minor injury, occupational illness, or less than system or environmental damage.

e) Hazard likelihood is the probability that a hazard will be experienced during the planned life expectancy of the system. It can be estimated in potential occurrence per unit of time, events, population, or activity. However, qualitative hazard likelihood may be derived from research, analysis, and evaluation of historical safety data from similar systems. Supporting rationale for assigning a hazard probability shall be documented in hazard analysis reports. When hazard probability assessments are determined to be necessary for classification of critical hazards, the following qualitative hazard likelihood ranking shall be used (see page 12-5):

Descriptive Word	Level	Within Specific Individual Item	Within a Fleet or Inventory
Frequent	A	Likely to occur frequently. MTBE* is less than 1000 operating hours	Continuously experienced
Probable	B	Will occur several times in life of an item. MTBE is equal to or greater than 1000 operating hours and less than 100,000 operating hours	Will occur frequently
Occasional	C	Likely to occur sometime in life of an item. MTBE is equal to or greater than 100,000 operating hours and less than 1,000,000 operating hours	Will occur several times
Remote	D	Unlikely but possible to occur in life of an item. MTBE is greater than 1,000,000 operating hours and less than 100,000,000 operating hours	Unlikely but can reasonably be expected to occur
Improbable	E	So unlikely, it can be assumed occurrence may not be experienced. MTBE is greater than 100,000,000 hours	Unlikely to occur, but possible

*MTBE = Mean time between events

12.1.5 Design Characteristics for Safety

Specific characteristics shall be incorporated into equipment designs to accomplish the safety objectives. Examples of some of these characteristics are:

a) Redundancy / Fail-Safe Philosophy: Where redundancy is employed to satisfy a safety critical function, the methods employed shall be totally independent to preclude both elements failing from a common cause. In addition, a failure of either element shall be readily detectable, such that the need for remedial action is indicated before a critical hazard can arise. Redundancy shall be employed where fail-safe philosophy cannot be satisfied. Fail-safe means the item shall achieve a mode of operation known to be “safe” after experiencing its first failure.

b) Hazard Isolation: The design shall incorporate hazard isolation features so that the effect of any hazardous event shall be contained as close to the source as possible and shall not impact any other system.

c) System Status Verification: The design shall include all necessary means to verify safe system performance and operation.

d) Component Interlocks: The design includes component interlocks whenever out of sequence operation could cause a critical hazard.

12.1.6 Design Safety Optimization

System safety techniques for optimizing design include:

a) Establishing safety goals/criteria and checking;

b) Safety evaluations;

c) Qualitative hazard analysis.

12.1.7 System Safety Protection Policy

The level of system safety protection included in the design criteria is based on the following general policies.

12.1.7.1 General Public

The DART light rail system provides the highest standards of safety and security for its property, passengers, and members of the public when revenue service commences. This shall include provisions to meet the special needs of those members of the general public with physical disabilities including sight impairments, hearing impairments, lack of coordination, disabilities due to age, and semi-ambulatory or non-ambulatory disabilities.

12.1.7.2 Transit System Employees

Any employee of DART shall be provided the same level of protection as the general public.

12.1.7.3 Environment

Design of the DART light rail system shall include protection of the environment and protection of the facility from nearby accidents.

Crime Prevention through Environmental Design (CPTED) methodologies shall be used to evaluate station and facility locations.

12.1.7.4 Equipment and Structures

All equipment and structures necessary to prevent or mitigate the consequences of various accidents or events shall be protected from identified potential hazards.

12.1.8 Postulated Safety Hazards

Safety design criteria are intended to provide controls for those hazards commonly found in a transit system. The postulated hazards that the DART System Safety Design Criteria are intended to provide protection against include the following:

a) Fire/Explosion - in vehicles, tunnels, stations, right-of-ways, yards, and shops;

b) Collision - vehicle with another vehicle, structure, automobile, or person, either on the track or in the right-of-way;

c) Electrocution - on vehicles in tunnels, stations, right-of-ways, in yards, and in shops;

d) Flood – in right-of-way, tunnel, subway station, guideway, yards, shops, and systems equipment;

e) Entrapment/Crushing - in vehicle doors, between cars, under cars, between cars and platforms, on right-of-ways, in yards and shops, in station gates, elevators, and escalators;

f) Falls/Contusions - in rail vehicles, elevators, on escalators, stairs, ramps, platforms, right-of-ways, crossings, yards, and shops;

g) Environmental Pollution - release of a hazardous material into the air, ground, or water, or the creation of any adverse effect on the environment;

h) Security concerns – terrorist threats, vandalism, assaults, and thefts.

12.1.9 System Safety Performance Criteria

The following sections provide general criteria for system performance to protect against the hazards identified in Section 12.1.4. Later sections will provide more specific design criteria for subsystems.

12.1.9.1 Fire/Explosion Accident Control

General

Vehicles, circuits, structures, furnishings, equipment and operating procedures shall be designed, arranged, and implemented in accordance with the following criteria:

a) Combustible and potential ignition sources shall be separated by distance and/or barriers.

b) Material in passenger/public areas shall be selected and arranged to contain fires typical for these areas safely without further general propagation. This includes fires from public carelessness and minor vandalism such as from burning cigarettes, matches on seats and trash fires.

c) Materials shall be selected to conform to flammability standards and be specifically designed for applications in any areas where they may be exposed to a high-energy electrical arc, and minimize the production of toxic smoke or particles.

d) Critical areas shall be protected by supervised fire and intrusion detection systems monitored at the Train Control Center (TCC).

e) Heat generating equipment (transformers, resistors, motors, generators, rectifiers, etc.) shall be ventilated as required.

f) Standardized informational graphics shall be provided throughout the system to indicate the location of regular and emergency exits and exit paths, emergency telephones, fire extinguishers and other safety critical items.

g) Fire detection and suppression equipment shall be provided in accordance with the particular requirements of each area. This will include sprinkler protection, Halon or clean agent fire extinguishing systems in TCC and electronic equipment areas, portable fire extinguishers in the subway, stations, and on board cars, and a standpipe system in underground stations, tunnels and aerial stations.

h) Protection shall be provided that prevents the intrusion of flammable and combustible liquids and vapors.

i) Access shall be provided for emergency response personnel, through passenger stations, or from crossing of parallel streets or on special access roads along the right-of-way.

Evacuation

Evacuation from rail vehicles, trainways, and station areas shall be an integral part of system safety design for all such areas. Systems shall be designed to provide for complete evacuation of a fully loaded train from any point in the subway tunnel within 30 minutes, from an underground station platform in 4 minutes or less, and from the most remote point on the platform to a point of safety in 6 minutes or less. Design of several subsystems will impact these criteria.

The criteria for these subsystems include the following:

a) Vehicle

1) Emergency door controls shall permit opening of all doors from inside and selected doors from outside the vehicle to permit evacuating the vehicle within one minute.

2) Vehicle fire containment and materials fire resistance shall meet the requirements of the latest edition of NFPA 130, Standard for Fixed Guideway Transit and Passenger Rail Systems, Applicable Chapter. Portions of the vehicle body separating major ignition or energy sources from the passenger compartment shall have sufficient resistance to fire penetration to the interior of the vehicle by an external fire for a period consistent with the safe evacuation of a full load of passengers from the vehicle in the worst-case situation.

3) Vehicle emergency lighting and communication systems shall remain operative for a period of not less than one hour following loss of traction power.

b) Tunnel

1) The emergency telephone system in the tunnel shall remain operative for at least 30 minutes following any interruption of the normal power supply.

2) Tunnel wiring and cabling for communications, lighting, and power distribution shall be selected and installed to minimize smoke and fume emission for a period of at least 30 minutes following initiation of a tunnel fire.

3) The number and location of entrances and exits shall be adequate for evacuation under emergency conditions. The number, location, and lighting of emergency exits shall be in accordance with

the provisions of the latest edition of NFPA 130. Emergency access points shall be provided such that no point in the tunnel is more than 1,250 feet from an emergency exit. Cross tunnel passages shall be provided at intervals of no more than 800 feet with fire rated doors.

4) Capability shall be provided for emergency deactivation of traction power within the tunnel. Emergency trip station shall remain operative for at least 30 minutes following loss of power to the control circuits.

5) Emergency lighting shall be provided and shall remain operative for at least 90 minutes following any interruption of the normal power supply. The minimum level of illumination shall be 1 foot candle on the surface of the walkway.

6) The tunnel ventilation system shall be reversible and shall be capable of removing the combined heat, smoke, and toxic fumes from a fire event away from the direction of passenger evacuation.

7) The emergency ventilation fans, their motors, and related components exposed to ventilation airflow shall remain operative in an ambient atmosphere of 482 degrees Fahrenheit for at least one hour. Per NFPA 130, a design analysis shall be permitted to be used to reduce this temperature; however, it shall not be less than 302 degrees Fahrenheit.

8) Continuous walkways with a clear envelope at least 24 inches wide shall be provided to an egress point of at least 36 inches wide, except in the crossover sections where a minimum of 24 inches shall be provided. Handrails shall be provided along the walkway. The walkway envelope may be 22 inches wide in selected locations adjacent to obstructions.

9) Egress path shall not be obstructed.

10) Markers shall be regularly placed along walkways indicating the direction and distance to the closest exit.

11) A standpipe system and outlets to supply water for fire fighting activities will be provided throughout the tunnel sections at an interval satisfactory to the Authority Having Jurisdiction (AHJ).

c) Aerial Structures

1) Access points for emergency vehicles shall be provided such that access to the aerial structure shall be spaced at a maximum interval of 2,500 feet unless a change is approved or requested by the AHJ.

2) A continuous walkway with a clear envelope of at least 24 inches wide shall be provided to egress points. The walkway envelope may be 24 inches wide in selected locations adjacent to obstructions. Guardrails shall be provided along the outside of aerial structures.

d) Subway Station

1) The number and location of exits, lighting and methods of securement shall all be in compliance with the provisions of the latest editions of NFPA 130, NFPA 101 – Life Safety Code and local Building Codes.

2) Public access areas shall be equipped with automatic fire detection and fire protection systems in accordance with the provisions of the latest edition of NFPA 130, and the AHJ.

3) The ventilation system shall be reversible and of sufficient capacity to remove heat, smoke, and toxic fumes at the projected volumes to provide a tenable environment. Remote control of fans and dampers shall be located at TCC and the local fire management panel. The ventilation system shall meet the criteria of the latest edition, NFPA 130.

e) Fenced Trainway

1) Access gates shall be provided in fences such that access to the trainway shall be spaced at a maximum interval of 2500 feet unless approved by the AHJ. Highway-rail grade crossings, systems access gates, and station access points can be used to satisfy the 2500 foot requirement. System access gates, when installed, shall be identified for the AHJ and Operations personnel through the use of signage containing the location and unique gate identification.

2) Security of gates shall allow operational and emergency access. A Knox Padlock linked to an authority lock and chain shall used to secure the access gate.

3) An “Area of Refuge” within a fenced trainway may be considered on a case-by-case basis as a means to satisfy emergency egress requirements. If selected the Area of Refuge shall:

A. Have clearly defined limits;
B. Meet the definition of a point of safety;
C. Be demarked with appropriate signage;
D. Not create an additional unacceptable hazard.

12.1.9.2 Collision Accident Control

Operators will manually control trains. An Automatic Train Protection (ATP) system shall prevent vehicles from penetrating occupied blocks in high speed signalized sections. On surface sections with line-of-sight operation the maximum allowable speed will not be more than 45 mph.

Train progress in signalized territory shall be monitored by the TCC. Traction power, brake, and train protection subsystems and their controls shall be designed to be fail-safe, both as independent subsystems, and when interacting as permitted by the integrated system design.

Surface operation in streets, along transit malls and along median alignments will generally conform to that of other street vehicular traffic and in accordance with the provisions of the DART Design Criteria Manual, Volume 2, Chapter 10, Section 10.2.2- Operating Speeds. Operation in these segments and other non-signalized territory shall be by line-of-sight where safe separation of trains is maintained through visual observation of conditions and operating rules and procedures. Collisions resulting in injuries shall be minimized through providing an adequate field of vision, an exterior surface contoured to guide objects away from the track, an exterior surface free from projections that could cause injury, and energy absorption structures at both ends of the car.

In station areas (except the Central Business District), pedestrian crosswalks and station elements shall be arranged to provide transit vehicle and patron visibility for at least 600 feet in both directions. The sight triangle should be measured at least 12 feet-0 inches from the centerline of the near track.

Signage shall be provided near station area crosswalks to encourage patrons to look both ways prior to crossing the track. Station area signage shall also be provided to discourage trespass, discourage crossing at locations other than crosswalks, and to remind patrons to stand behind the tactile warning strip.

Right-of-way warning signs shall be erected at locations including highway-rail grade crossings, bridges, and the ends of station platforms and along the guideway at approximately 400 foot intervals to warn of the high voltage hazard and discourage trespass. The signs shall be pole, fence, or wall mounted. Additional signs shall be installed on a case-by-case basis as deemed appropriate for the environment.

Train collisions with other vehicles shall be minimized through the effective design of crossings. This shall include the use of grade separations in areas of high hazard, use of medians or traffic barriers to inhibit gate violations and fully gated crossings in all other areas except the CBD and the median running sections where traffic signal controls will be used.

Crash safety design shall include standards for the integrity of the car body and its furnishings, progressive structural crushing and deformation of structure to absorb crash impact loads, vertical strength of end of car, and strength for shear mechanism. Passenger seats and stanchions shall be designed to accommodate crash loadings. Interior cabinets and attachments shall not open or release their contents under expected crash loading conditions.

Right-of-Way (ROW) fencing and/or barriers shall be provided when civil design/operational train speeds are anticipated to be greater that 45 mph. Additional or supplemental fencing and / or barriers shall be evaluated on a case-by-case basis for special circumstances. The following conditions warrant an evaluation:

a) Adjacent public or private schools;
b) Adjacent parks and recreational areas;
c) Special event locations where fences/barriers may be needed for channelization;
d) Areas with anticipated security concerns;
e) Parking areas next to at-grade stations.

In corridors shared with freight railroads, fencing shall be installed between the LRT and railroad track to provide a clear operational separation. Crossing of the railroad for fire/life safety access and egress is discouraged. In the event this access or egress is required, sliding gates shall be used to prevent encroaching into clearance envelopes.

If clearances are not available for the standard fence, barriers shall be installed between the LRT and railroad in areas where personnel will need to be on the ROW. Barrier installations will be evaluated on a case-by-case basis. Areas to install the barriers are:

a) Special trackwork;
b) Switching yards;
c) Pocket tracks;
d) Maintenance facilities.

A standard 6 foot high chain link fence is the minimum recommended for ROW or railroad separation fencing. Fencing installations shall follow clearance, grounding, taper and flare and other requirements found throughout the DART Design Criteria Manual, Volumes 1 and 2, in addition to the above requirements.

Fencing, landscaping, and other structures near the highway-rail crossing shall be located, arranged, or placed to maximize visibility at the crossing. Examples of placement considerations include:

a) Crossing warning device controls placed for normal operating direction;

b) Within 200 feet of the edge of the roadway, fencing and landscaping shall quickly taper (in 20 feet) to a maximum height of 4 feet and flare to at least 40 feet from the centerline of the near track, or to the edge of the Right-of-Way if less than 40 feet;

c) Vertical elements within 200 feet of a crossing shall be held to a maximum of 4 feet in height.

Rail Safety Indoctrination shall be required of all contractors/employees whose duties include work around rail operations. The indoctrination shall be coordinated with the Manager Rail System Safety.

Track alignments which place supporting columns of an overhead structure (bridge, overpass) within 50 feet of the track shall be minimized. In the event that the alignment is closer than 50 feet from a support column, the approach shall be kept clear of switch points. Control methods to minimize potential damage to the columns shall be evaluated on a case-by-case basis.

12.1.9.3 Electrocution Accident Control

Electrical equipment will be enclosed in rooms or vaults, or shall be guarded by barriers to prevent unauthorized access. Critical areas shall be protected by intrusion alarm systems.

A means for locally removing power from specific sections of the system shall be provided. TCC shall have the capability to fully monitor the provision of power to each section, as well as the ability to remove and reapply power.

Vehicle, propulsion power and auxiliary electrical circuits design shall minimize stray or leakage currents. Installation design shall be in accordance with the National Electrical Code and the National Electric Safety Code.

Employees shall be protected from live high voltage circuits and components by cabinet designs that incorporate circuit-interrupting interlocks in access doors where appropriate.

Propulsion power wires shall be so located that they adequately clear all normal or emergency traffic and cannot be reached without the aid of ladders or lifts. The nominal contact wire height for various alignments is covered in the DART Design Criteria Manual, Volume 2, Section 3.

Due to the potential of electric shock on the boarding areas of station platforms, grounded equipment (metal enclosures, metal handrails, metal racks, etc.) shall not be located closer than 6 feet from the platform edge.

Propulsion power circuits shall be interrupted in the event of a ground fault.

12.1.9.4 Flooding

Tunnels and other below grade structures shall be designed to prevent water from dripping or running onto the rails and rail appurtenances shall be designed to prevent the accumulation of standing water.

Pumping stations shall be provided at low points in the system. A high water alarm shall be provided at TCC.

Drainage pumps shall be of sufficient size to handle intrusions from weather, water leaks, and fire fighting operations. The use of internal combustion powered pumps shall not be permitted below grade.

Where pumps operate automatically, pumps shall also be provided with local controls to manually override the system.

Primary drainage shall be achieved through the use of proper roadbed design and construction. Excessive water shall drain into grates to be carried in culverts to a pump pit.

Vehicles shall be designed to operate through specified flood levels safely, e.g., water 2 inches above top of rail for 400 feet at up to 10 mph.

12.1.9.5 Entrapment/Crushing Accident Control

Vehicle doors, elevator doors, escalators, tunnel refuge areas, platform ends, special use platforms, and yard and shop work areas shall be designed and operated to guard passengers and employees from exposure to entrapment and crushing hazards.

Doors on moving vehicles (rail cars and elevators) shall be interlocked with the vehicle propulsion and braking systems so that the vehicles cannot be moved until the doors are closed and locked in rail vehicles, or positioned as permitted in elevators by ANSI A17.1.

Dimensions and forces exerted by door closure seals shall be controlled such that either, a) the door cannot be closed on any portion of a person's body to the position which closes the propulsion interlock circuit; or b) the force required for extraction of a portion of the body on which the door can lock is not more than 20 lbs. An interlock with vehicle control system shall prevent opening when the vehicle is in motion (greater than 2 mph).

Escalator and elevator installations shall conform to ANSI A17.1.

Door status indicators shall be provided at the train operator's console shall indicate when any vehicle door is open and when all doors are closed.

Mirrors shall permit, and operating rules shall require, a visual check by the operator that no person is entrapped along a train, before the train is moved from the station.

Vehicles shall have no projections which can ensnare objects or people on exterior surfaces.

Underground and other selected stations shall be monitored on Closed-Circuit Television (CCTV) by local agents or by the Controller at TCC. Emergency telephones shall be located in these areas.

Horizontal spacing between platform and train body shall be a design 3.0 inches for stations on tangent track based on the edge of the platform being 4 feet 8 inches from the centerline of the track. Vertical spacing of the platform shall be designed to be 15 1/2 inches above top of rail. The LRV threshold interface with the platform edge shall meet applicable ADA and TAS requirements.

Level boarding of the SLRV shall be accomplished by phasing out existing high-level special use platforms through modifications of station platforms or installation of discrete level boarding areas. Interim special use platforms or discrete level boarding areas shall not discharge in the direction of the trackway or to other hazardous areas.

Yard and shops will be protected in accordance with applicable sections of OSHA 29 CFR 1910 and ANSI A117.1.

The Authority will establish operating rules guarding against entrapment and crushing.

Emergency exits from all areas of the guideway, tunnel, and facilities shall be provided with adequate signage and lighting.

Emergency exit hatches shall be designed to withstand the anticipated loads of the location, and shall require no more than 29 lbs. of pressure to open from the exit direction. They shall conform to the requirements of the latest edition NFPA 130, and NFPA 101.

12.1.9.6 Falls/Contusions Accident Controls

General

Walking areas shall be designed to minimize tripping/falling hazards through the design of walking surfaces, travel paths, handrails, and lighting levels.

Stairs

Stairs shall have uniform closed risers at a height designed to minimize tripping hazards. Riser nosing shall be rounded with a maximum extension ½ inch. Treads shall be covered in abrasion resistant, non-slip materials and be designed to minimize slipping hazards. Exterior stairs shall have a wash slope down of 1:100. Handrails shall be of graspable design with no protrusions or design elements that could be impacted in a fall.

Handrails and landings shall be in conformance with OSHA and Local Building Codes.

Ramps

The use and location of ramps shall be in accordance with local Building Codes and Texas Accessibility Standards (TAS). Ramps in buildings shall be sufficiently wide to accommodate turning movements of wheelchairs. All ramps shall have handrails on both sides. Surface shall be non-skid. Ramps at station platform areas shall give sufficient space at the top and bottom of the ramp for a wheelchair turnaround.

Escalators

Step treads shall have a non-slip surface. Level runs of three steps shall be provided at entrances and exits. Lighting shall be a minimum of 5 horizontal foot candles diffused, positioned to avoid shadow and glare effects.

Emergency stop buttons shall be provided at the top and the bottom of each escalator run. Escalator speeds shall be set at no more than 120 fpm.

Elevators

Elevators shall have a non-slip floor surface. A grab-bar shall be provided on back and sidewalls. Elevator controls shall be as specified in Texas Accessibility Standards to accommodate the disabled. Door closing shall have a detector to provide for door recycling when an obstruction is encountered.

Elevators shall be equipped with a temperature sensing device which will prohibit stopping on the fire floor, but with capability for override by emergency response personnel (Phase II fire recall).

Elevators shall be equipped with an emergency communication device that rings to the TCC.

Escalators and elevators shall be designed consistent with the requirements specified in the DART Design Criteria Manual, Volume 1, and Chapter 31.

12.1.9.7 Environmental Protection Control

Environmental protection controls shall include:

a) Protection of users of the system from release of hazardous materials in the vicinity of the stations and guideway.

b) Protection of groundwater contamination through the design of underground storage tanks and drainage system.

12.1.10 Codes and Standards

Detailed codes and standards references are included for each of the system sub-components in the respective chapters of the DART Design Criteria Manual. General references to safety specific criteria shall be made in the respective sub-component section of these System Safety Design Criteria. It is intended that the design of the entire system meet the most stringent requirements of all of the applicable codes and standards. This includes and shall not be limited to:

a) National Fire Protection Association;

b) National Fire Protection Association 130, *Standard for Fixed Guideway Transit and Passenger Rail Systems;*

c) Uniform Building Code;

d) International Building Code (BOCA);

e) Building Codes of the DART Member Cities;

f) Uniform Fire Code;

g) International Fire Code (BOCA);

h) Fire Codes of the DART Member Cities;

i) Texas Accessibility Standards;

j) Occupational Safety and Health Act. 29CFR 1910 & 1926;

k) Texas Manual on Uniform Traffic Control Devices;

l) NTSB-RSS-71-1 Special Study of Rail Rapid Transit Systems;

m) NTSB-RSS-73-1 Safety Methodology in Rail Rapid Transit System Development;

n) APTA, Moving People Safely;

o) MIL-STD-882, System Safety Program Requirements;

p) NESC - National Electric Safety Code;

q) North Central Texas Council of Governments - Standard Specification, for Public Works Construction.

12.1.11 Compliance

DART and its contractors (including consultants) shall be responsible for establishing and monitoring a document control system to ensure incorporation of these criteria into the design of the DART rail transit system.

12.2 LIGHT RAIL VEHICLES

12.2.1 General

12.2.1.1 Anti-Climb

Adequate anti-climb devices shall be provided on each transit vehicle end.

12.2.1.2 Windows

All transit vehicle windows and windshields shall be of impact and fire resistant material and shall comply with the latest edition NFPA 130 and 49 CFR 223. Windows shall be constructed to meet FRA Type II impact and ballistic requirements.

12.2.1.3 Hand-holds

Handholds and grab rails shall be provided for all passengers. This may include seat backs, horizontally below the ceiling, and within each side doorframe. Grab-rails shall meet OSHA standards for diameter and wall distance.

12.2.1.4 Finishes

Interior and exterior finish shall be devoid of sharp edges and dangerous protrusions.

12.2.1.5 Electromagnetic Radiation

Wherever practical, the design shall locate equipment producing electromagnetic radiation outside of the passenger compartment.

12.2.1.6 Under-floor Fire and Roof Protection

The vehicle end caps shall be designed to prevent propagation of an under floor fire to the vehicle interior. Fire-stops shall be provided at floor and roof penetrations. Consideration shall be given to prevention of arc penetration and susceptibility to ignition of materials used in the roof assembly of the vehicle. Floors shall have a minimum fire resistance rating of 30 minutes.

12.2.2 Combustible Content

12.2.2.1 Combustibility Limit

The design of the passenger vehicle shall place major emphasis upon limiting the total combustible content of the vehicle. Each combustible material above a minimum weight specified shall be specifically identified by suppliers name and type, use in the vehicle, total weight, and heating value in BTU/lb.

Total combustible content of each passenger vehicle shall not exceed a heating value that would lead to an unsafe condition.

12.2.3 Flammability of Vehicle Materials

12.2.3.1 Testing

Materials used in passenger vehicles shall be tested for compliance with requirements as specified in the latest edition NFPA 130.

12.2.3.2 Other Material Characteristics

Materials and finishes shall be evaluated under a fire risk assessment for transit vehicles including material characteristics other than fire propagation such as smoke emission, ease of ignition, rate of heat rise, and smoke release rate.

12.2.4 Toxicity

Those materials and products generally recognized to have high toxic products of combustion shall not be used (e.g. polyvinyl chloride, hypolon, asbestos, lead, and urethane foam).

12.2.5 Fire Extinguishers

At least two approved multipurpose portable fire extinguishers of the 10-lb class rated 4-A: 30-B:C minimum shall be provided in each vehicle with one extinguisher at the end of each passenger compartment.

12.2.6 Electrical Requirements

12.2.6.1 Lighting

Passenger compartment interior lighting shall be provided by fluorescent lights. One fluorescent fixture above each doorway shall remain powered from the battery when the low voltage power output is interrupted. Lights shall also be provided in the step wells and shall illuminate when the doors are open. A ceiling mounted fixture shall be located in the cab for use by the operator. Emergency interior lighting shall be provided in the vehicle. Minimum illumination shall be one foot-candle measured at the floor of the vehicle.

On the exterior, there shall be headlights, high-intensity headlights, taillights, stoplights, turn signals, marker lights, run number sign lights, emergency light and strobe light consistent with The State of Texas Vehicle Code. Additionally, there may be other signal (informational) type lights installed on the vehicle exterior to aid operations. Exterior indicator lights placed above the center side doors shall indicate whether the doors are open or unlocked.

12.2.6.2 Motors, Wiring and Circuitry

All motors, motor controls, current collectors, and auxiliaries shall be of a type and construction suitable for use on fixed guideway transit vehicles. Low smoke flame retardant wiring shall be used where possible.

Self-ventilated resistors shall be mounted with adequate air space between resistor elements and combustible materials. Heat-resistant barriers shall ensure protection from overheated resistors.

Wires connected to different sources of energy shall not be cabled together or run in the same conduit, raceway, tubing, junction box, or cable unless all such wires are insulated for the highest rated voltage in such locations.

All wire and cable shall have insulation suitable for the intended operating environment and shall be supported and protected so as to offer the least possible chance of mechanical damage. Motor leads where entering the frame shall be securely clamped and fit to prevent moisture from entering the motor case.

Electrical circuits and associated cabling shall be designed with gap and creepage distance between voltage potentials and car body ground, in accordance with the environmental conditions to which the circuits and cabling will be subjected. Creepage distances shall be in accordance with the provisions of the latest edition of NFPA 130.

Non-combustible protection shall be considered for use between any part of the current collector assembly that is at line voltage and any other portion that is at ground potential.

The battery installation and circuitry shall be designed to minimize combustion hazards and exposure to toxic materials. Fire stops shall be provided in raceways to control spread of fire.

Metal enclosures that surround arcing devices shall be lined with insulating material. Adequate shields or separators shall be provided to prevent arcing to adjacent equipment and wiring.

Propulsion and braking resistors shall be designed to minimize combustibility

Power resistor circuits should incorporate protection devices.

Resistor elements shall be electrically insulated from resistor frames, and frames shall be electrically insulated from supports. When forced ventilation is provided the resistor leads shall be separated, secured, and cleated for protection in the event of loss of air circulation of the ventilating system. Leads shall be so routed or otherwise protected from resistor heat.

12.2.7 Communications

12.2.7.1 Public Address

A Public Address System (PA) shall be provided so that train operators can communicate emergency information to passengers including the passengers on a platform. There shall be provisions in each vehicle so that passengers may contact the train operator.

12.2.7.2 Two Way Radio

Direct radio voice communication shall be provided between the train operator and TCC.

12.2.8 Doors and Emergency Exiting

The number, width, and location of doors shall be designed to provide for evacuation of a fully loaded car within one minute. Doors shall be interlocked to prevent train movement while doors are open. Doors shall be of sufficient dimensions to provide emergency egress by handicapped persons with the assistance of other persons.

Operator control switches for transit vehicle doors shall be located on the same side of the cab as the passenger doors which are being activated.

A door sensing circuit shall be provided to recycle doors open when an obstruction is met. Door closing force shall not exceed 30 lbs.

Doors shall allow for withdrawal of trapped clothing when doors are closed.

Provisions for normal and emergency door opening shall include normal operation from the cab or, after release from the cab, by push-buttons at the interior and exterior of each door. Emergency opening shall be provided through manual controls inside and outside for selected doors, including after the loss of power.

A positive door control device shall be provided to prevent side doors from accidental opening.

An audible warning shall sound inside the transit vehicle when doors are closing. Safety signs shall be developed for side doors.

Doors shall be designed to be opened by patrons under emergency conditions with the train stopped, even with the loss of electrical power to those doors.

12.2.9 Couplers

Couplers shall be designed to allow safe manual coupling and shall be designed for proper energy absorption. Coupling shall automatically assure proper electrical connections to train line control functions.

12.2.10 Heating, Ventilation and Air Conditioning

Ventilation equipment throughout the train shall be controllable from the controlling operator’s cab.

Heater elements shall incorporate protective devices.

The operator shall have the capability, from the controlling cab, of closing all outside air openings and shutting down all air ventilation fans on the train.

Heater fanned air distribution ducts and plenums shall incorporate high temperature sensors, fusible link, airflow devices, or other means to detect over temperature or lack of airflow.

12.2.11 Braking Systems

The transit vehicle system shall provide for full service braking through the friction brakes upon the fading of the dynamic system.

There shall be backup operation of the brake system upon the failure of any major brake control subsystem.

Emergency brakes shall be automatically applied and non-retrievable when the emergency brake train line is de-energized or open-circuited. Sand shall be automatically applied and the wheel slip system shall be disabled.

The design of the emergency brake subsystems shall be such that no single failure (single-point failure) can cause an unsafe condition.

The service braking system shall be designed to achieve smooth deceleration at all speeds.

Parking brake shall be capable of holding a design (AW4) loaded car on a 7% grade indefinitely.

A magnetic track brake shall be provided for use in emergency brake application. The emergency brake application shall be by means of a clearly visible control on the console.

12.2.12 Car Body

Car body structure shall be adequate at the front, rear, and side of the vehicle so that interior acceleration/deceleration rates are contained within safe acceptable limits.

The steps, floor, and articulated sections shall be designed to minimize the tripping and slipping hazard.

Stanchions shall be securely fastened so as not to detach under passenger loads and forces typical of collisions. All stanchions and handrails shall be designed to spread impact loads on the human body to reduce injury severity.

Passenger seats shall be designed to preserve their structural integrity under full passenger loads and the most severe collision situations that are possible for the system design. Seat areas shall be designed to prevent passengers from being projected into adjacent seats under collision conditions.

12.2.13 Wheelchair Access

Accessibility for wheelchair users and handicapped patrons shall be provided on each car. Each end door per vehicle shall be configured to provide for wheelchair access. These doorways shall include clearance standards to accommodate wheelchair turning movements, grab bars at seated reach height, and all criteria included within American Public Transportation Association (APTA) guidelines for rapid transit.

Special design features shall be included to provide for the interface between the light rail vehicle and wayside platform or lifting devices. Audible warning devices on board the car shall be used to provide notice of doorway changes. Interlocks and fail-safe design will be used to assure a safe travel path for the wheelchair user.

Provisions shall be made for access to passenger communications system in the wheelchair area.

Level boarding shall be accomplished by phasing out existing high-level special use platforms through modifications of station platforms or installation of discrete level boarding areas. The LRV threshold interface with the platform edge shall meet applicable ADA and TAS requirements.

12.2.14 Steps and Entrances

Steps shall conform to local Building Codes and shall be covered with a non-slip material. Step risers shall ideally all be of the same height designed to minimize tripping hazards. Step tread width shall be uniform on all steps from a minimum of 8 to a maximum of 11 in. Step wells shall be lighted.

Handrail supports shall be capable of withstanding the forces of both normal patterns of use and of those in a fall.

Grab rails shall be provided in the step wells.

Vestibules shall be designed to support safe entrance and exit by providing grab rails, minimizing obstructions, appropriate, and adequate lighting.

12.2.15 Lightning Arrestor

Each vehicle shall be provided with a suitable and effective lightning arrestor for the protection of all electrical circuits.

12.2.16 Propulsion System

Propulsion controls shall be located and designed for ease of operation. High acceleration, deceleration, and jerk shall be controlled to acceptable levels by onboard limiting subsystems.

12.2.17 Clearances

Platform car clearances shall be designed consistent with the criteria in Section 12.1.9.5 and ADA and TAS requirements.

Exterior side protuberances shall be minimized. Car mirrors shall be included in clearance calculations.

12.2.18 Slip/Slide Protection

Slip protection in the acceleration mode and slide protection in the braking mode shall be provided consistent with the requirements defined in Chapter 2. Re-action of tractive effort after slip/slide activity is to be jerk limited.

12.2.19 Train Separation Malfunction

Upon sensing train separation, the rear section of the car shall go into emergency braking while the front section shall go into full service braking after a time delay.

12.2.20 Mirrors

Each car end shall have exterior side mirrors. Mirrors shall be positioned to minimize any collision hazard with pedestrians. Mirrors shall be of such size and location for operator visibility of all train car door openings with doors open or shut.

12.2.21 Audible Warning Devices

Each car shall include a gong (minimum output of 75 dBA 50 feet), whistle, and horn (minimum output of 96 dBA 100 feet).

A silent alarm system shall be provided on the vehicle including an exterior marker light.

12.3 COMMUNICATIONS

12.3.1 General

The communications system will be consistent with the requirements of the DART Design Criteria Manual, Volume 2, Chapter 5, and Communications.

12.3.2 Transit Radio Subsystem

The transit radio subsystem network shall be comprised of base transmitters and receivers, antennas, satellite receivers, portable transceivers, and ancillary equipment. Sufficient base transmitters, receivers, microphone, antennas, and necessary ancillary equipment shall be provided to ensure a high degree of system reliability.

The transit radio subsystem shall provide at least one dedicated 2-way radio voice communication channel for use in emergency situations. The emergency channel shall have the capability of communicating with transit system personnel on trains, in motor vehicles, and at locations within the system.

Either a direct communication link or 911 system shall be provided between TCC and the most appropriate public emergency agency. Two-way radio voice communication capability for non-transit system emergency response personnel shall be provided by their own equipment, except in underground facilities, where facilities for underground communications shall be provided.

12.3.3 Emergency Telephone Subsystem

An emergency telephone subsystem shall be provided for use by employees, and emergency response personnel consistent with the requirements defined in the DART Design Criteria Manual, Volume 2, Chapter 5, Communications. Telephones shall be located along bridges and elevated trainways in excess of 2500 feet, aerial station platforms, subway station platforms, subway tunnels, tunnel entrances, and other strategic locations as needed. Telephones shall be located at the end of the elevated platforms and spaced at intervals not to exceed 1000 feet.

The emergency telephone subsystem shall be designed to fulfill the manual fire alarm and request for emergency response functions and shall conform to the guidelines for all 911 type systems in NFPA 1221. Phones shall be of distinctive color and be demarcated with a blue light as indicated in the latest edition of NFPA 130.

In areas with Fire Management Panels these telephones shall be located adjacent to or integrated with the Fire Management Panel.

12.3.3.1 TCC Emergency Telephone

An emergency telephone line or 911 system shall be provided in the TCC for direct communication between TCC and emergency response agencies. Emergency communications should go directly to member cities Public Service Answering Point (PSAP).

12.3.3.2 Passenger Emergency Call

A Passenger Emergency Call System shall be provided for the use of passengers consistent with the requirements of the DART Design Criteria Manual, Volume 2, Chapter 5. They shall be located in all grade separated stations. Distinctive color and/or a blue light shall identify these units. Public pay phones with 911 capabilities may be used in at-grade, open air stations.

12.3.3.3 Freight System Emergency Call

A telephone line shall be provided between TCC and the designated location of any freight railroad operating on joint right-of-way. Wayside phones shall also be provided at any LRT-freight at-grade crossing and any connection to the general railroad system.

12.3.4 Public Address/Visual Message Board (PA/VMB) Subsystem

All passenger stations shall have PA/VMB subsystems to allow communications with patrons or employees, as appropriate. During emergencies or interruptions to train service, the PA/VMB subsystem shall be used to communicate with patrons, employees, and emergency response personnel. The public address subsystem shall conform with the requirements of NFPA and applicable ADA Requirements, including supervision of circuits for integrity.

TCC shall have the capability of using the PA/VMB subsystem to make announcements. Override access to the passenger station or maintenance facilities PA/VMB subsystems shall be provided at fire management panels associated with the specific facility.

12.3.5 Command Posts

Provisions shall be made for establishing temporary command posts to serve as the focal point for controlling, supervising, and coordinating all activities during emergency operations. Such command posts shall meet the requirements of the latest edition of NFPA 130. The location of the command posts shall be carefully chosen to provide an easily identifiable sites that are convenient for responding personnel and that are suitable for communication with supervision, and coordinating the activities of the emergency response organizations involved. Fire Management Panels (see Section 12.3.6) shall serve as the command posts at underground passenger stations.

12.3.6 Fire Management Panels

Fire Management Panels shall be provided to serve as command posts at all underground stations, maintenance facilities, the car assembly facility, and at other locations as provided. Fire management panels shall have provisions for the following functions:

a) Access to the emergency telephone subsystem with direct access to TCC;

b) Limited access for removal of traction power via TCC requests;

c) Fire/security subsystem status indicators;

d) Distinctive signage and/or lighting for identification;

e) A graphic display of the area within the control of the panel and emergency evacuation routes.

The following provisions shall be incorporated in to the Fire Management Panels, on a site-specific basis:

a) Escalator and elevator controls;

b) Overriding access to the public address system at stations or maintenance facilities;

c) Status of ventilation systems.

12.3.7 Fire/Security Subsystem

The fire/security subsystem shall perform the following functions, in accordance with NFPA 72:

a) Automatic fire detection, alarm, and supervision;

b) Automatic fire suppression equipment activation and supervision;

c) Emergency voice communications subsystems status supervision and control;

d) Control and supervision of the status of various mechanical and electrical systems and equipment, as necessary for proper response to emergencies;

e) Intrusion detection, alarm, and supervision, as required by the DART Design Criteria Manual, Volume 1, Chapter 27, Fire Intrusion Alarm Systems.

Control and supervision of the fire/security subsystems shall occur at TCC. Equipment shall be provided and located as needed to perform in accordance with system safety design criteria.

Manual fire alarm pull stations shall be located in maintenance facilities, the car assembly facility, TCC, and subway station entrances.

12.3.8 Train Control Center

A Train Control Center (TCC) shall be arranged and equipped to function as the central supervising station for the entire rail transit system, in accordance with the latest editions NFPA 72, NFPA 130, and the DART Design Criteria Manual, Volumes 1 and 2. The TCC is located adjacent to the DART Bus Control Center and Security Control Center. The entire complex is referred to as the Operations Control Center (OCC).

During normal operations, TCC shall provide the primary control of the system. During emergency operations, the assigned command post shall be responsible for the local control, supervision and coordination of all activities required to correct or alleviate the emergency. TCC shall retain responsibility for operation of the system except for the immediate emergency area.

12.3.9 Yard Control

A Yard Control function and position shall be arranged and equipped to function as the central supervision station for the yard and maintenance facilities site in accordance with NFPA 72 and Chapter 6 of the DART Design Criteria Manual. In addition, the Yard Control position shall be arranged and equipped to function as a satellite station facility during periods when this position and control station are not manned. The function of the Yard Control shall be closely integrated with the TCC.

12.3.10 Communication Transmission

Transmission of fire and security trouble alarm and supervisory signals from transit facilities to the appropriate central supervising station shall conform to the requirements of NFPA 72.

Common use of electronic transmission media shall not impair, in any way, the fire alarm function.

12.3.11 Closed Circuit Television

Cameras locations shall be consistent with that defined in the DART Design Criteria Manual, Volume 1, Chapter 22, Station Operational Requirements.

Illumination in areas protected by cameras shall be adequate for the particular type of camera being used.

Cameras shall be monitored at the security workstation at OCC. Provisions for video recording shall be provided.

Cameras shall be mounted so as to limit access to vandals, but be conspicuous to patrons.

12.4 TRACTION ELECTRIFICATION

The key elements of the Traction Electrification System (TES) that impact system safety include the protection of the public and employees from electrocution, protection from the fire hazard of high current distribution facilities, and provision of a reliable power supply to assure safe control of train operations

12.4.1 Traction Power Substations

Traction Power Substations (TPSS) shall be considered as Group B, Division 4 occupancies, when referencing the Building Code of the DART Member City for occupancy related requirements.

Traction Power Emergency Trip stations (ETS) shall be provided at strategic locations in the maintenance facility and inside a dual keyed Knox Box located on the exterior of each substation. The limited access emergency trip stations shall provide the capability of isolation of traction power in the traction power zone.

Remote control of the maintenance yard traction power substation shall be provided at the Yard Control position in addition to the controls at the TCC.

Electrical grounding and lightning arrestors shall be provided for all TPSS.

Locks shall be provided on all manual AC/DC breaker control cabinets.

TCC shall have the capability of operating and controlling essential AC/DC switchgear functions. These shall include alarms and visual indication of status changes (i.e. positive voltage protection, open/closed breaker positions, faults, or other abnormal conditions associated with traction power substations.)

Disconnect switches to isolate substations from an Overhead Catenary System (OCS) back-feed shall be provided.

Rate-of-rise or other sensing elements which can discriminate between high-resistance faults and train starting currents shall be provided on feeder breakers.

All draw out switchgear shall provide protection to personnel from accidental contact with live power circuits when the circuit breaker is removed.

Circuit interrupting devices which do not have load-break capability shall be equipped with interlocks to prevent unsafe operation. High-voltage terminations shall be protected to prevent accidental contact by personnel.

Substation direct current equipment enclosed in metal housing shall have monitoring devices that detect and annunciate enclosure insulation breakdown to ground and/or high voltage on the switchgear enclosure.

Rubber matting of high dielectric strength, tar base concrete, or other means of insulation shall be provided on the floor around the perimeter of direct-current conversion equipment and switchgear. This shall be flush with the finished floor.

Clearance around this equipment shall be such that personnel cannot bridge to grounded surfaces. If such clearance cannot be obtained, grounded surfaces shall be adequately insulated.

Substation doors shall be controlled by a security system monitored by intrusion alarms at TCC. Entry by unauthorized persons shall be prevented by means of locks with special keying. The use of keys shall not be required for egress.

Construction

TPSS and enclosures shall be a minimum of Type II-N construction, in accordance with the Building Code of the DART Member City and Applicable Sections of the DART Manual, Volume

2. Designs will minimize the construction of underground substations.

Occupancy Separations

If other facilities, such as train control equipment, communications equipment, or battery power supplies, (unless maintenance free batteries are used) are incorporated into a traction power substation structures, occupancy separations shall be provided.

Access and Egress

Access to and emergency exiting from TPSS shall be per the local fire codes and the Building Code of the DART Member City. Access roads and turnarounds will be provided for fire department equipment as required by the AHJ.

Emergency Lighting and Exit Signs

Emergency lighting and exit signs shall be in accordance with the Building Code of the DART Member City and local codes.

Communications

An emergency telephone shall be provided at each TPSS.

Fire Protection

Substations shall be equipped with fire extinguishers of suitable type and size and fire alarms.

Fire hydrants in accordance with the AHJ shall be provided within 300 feet of TPSS. Clean agent extinguishing systems may be used to increase this distance with AHJ approval.

If automatic fire detection systems are used in traction power substations, then they shall comply with NFPA 72 and local code. The status of any such devices shall be monitored and displayed at TCC thru Supervisory Control and Data Acquisition (SCADA) and the Digital Alarm Communication Receiver (DACR).

Substation Ventilation Systems

Traction power substations shall be independently ventilated as defined in the DART Design Criteria Manual. Ventilation is tied into the fire alarm system. The TPSS will shut down as a result of fire alarm activation.

Electrical Requirements

Traction power circuitry, as well as traction power control circuitry and equipment, shall conform to the requirements of the National Electrical Code, NFPA 70.

Grounding

The substation ground grid shall be designed as defined in the DART Design Criteria Manual, Volume 2, Chapter 3 so that step-and-touch potentials at the maximum available ground fault current do not exceed safe limits.

12.4.2 DC Power Supply

Substations shall be located throughout the system in order to provide operation at design headways.

Substations shall be designed to assure adequate back-up in the event of the loss of a single sub-station.

Wayside electrical control equipment and switches shall be secured by locks.

Equipment shall be properly clad to prevent the accidental contact of live parts by maintenance personnel.

Transformers and rectifiers shall be equipped with interlocked door switches which remove power and prevent energization of the equipment while the door is open.

Rectifiers and DC switchgear shall be isolated from earth ground and shall be equipped with monitoring devices which detect and annunciate the breakdown of insulation between the enclosures and earth, and between the enclosure and traction power positive potential. Breakdown to traction power positive, negative or ground, shall cause DC power to be removed from the substation. Grounded equipment located within six feet of the rectifier and switchgear equipment shall be protected by electrical insulating material to increase the effective distance to the grounded portion of the equipment to six feet.

All materials manufactured for use as conduits, raceways, ducts, boxes, cabinets, equipment enclosures and their surface finish material shall be capable of being subjected to temperatures of 932 degrees F for one hour, and shall not support combustion under the same temperature condition. Other materials when encased in concrete may be acceptable.

All conductors except those specifically excluded by DART shall be insulated. Minimum thickness of insulation and jacket shall meet the requirements of the National Electrical Code, NFPA 70, for the voltage and use intended.

All insulation shall conform to the National Electric Code and be moisture and heat resistant types carrying temperature ratings corresponding to the conditions of application.

All cables in open raceways and in subway trainway areas shall pass the flammability requirements of Type Test of Class 1E Electric Cables, and Field Splices, Nuclear Power Generating Stations (Institute of Electrical and Electronics Engineers, Inc. IEEE 383) and the smoke emission requirements of Smoke Generation of Solid Materials (NFPA 258).

12.4.3 Catenary

The catenary system will conform to the requirements of the DART Design Criteria Manual, Volume 2, Chapter 3.

Foundations shall be steel reinforced and shall be structurally capable of withstanding the catenary equipment loads imposed during installation, operation, and maintenance.

The contact wire clearances shall be as defined in the DART Design Criteria Manual and shall have minimum clearances as defined in the National Electric Safety Code.

All catenary shall be sectionalized to provide for removal of power in zones. Overlaps or air gaps shall be selected for use over insulations where practical.

All catenary support structures shall be grounded and have effective lightning protection.

Protection for patrons, the public, and employees shall be provided between any walkways or bridges over or adjacent to the catenary. The need for protection shall be evaluated when catenary is within 12 feet of a walkway.

12.4.4 Sectionalization (Emergency Trip Stations)

Traction power emergency trip stations shall be provided at each substation. Emergency trip stations shall incorporate a device for tripping traction power feeder breakers and removing traction power from the overhead conductors in the specific power zone. Local lockout capability shall be provided. Emergency trip stations shall be locked so as to prevent access by the public.

Activation of the local mechanical lockout shall preclude restoration of any traction power in the power zone controlled by the emergency trip station until the local mechanical lockout is released.

12.5 SIGNAL SYSTEM

The Signal System shall be designed to provide fail-safe protection to maintain safe separation between trains and to facilitate headway and performance requirements. A Signal System will be used on any segment where the maximum allowable speed exceeds 45 mph. Detailed requirements of the Signal System are defined in the DART Design Criteria Manual, Volume 2, Chapter 4.

12.5.1 General Provisions

The generic techniques used to increase system safety may include:

a) Providing subsystems, such as train detection circuits, to prevent dangerous modes of operation;

b) Using fail-safe design so that a signal is required to indicate a safe condition before operation continues, and no failure of a single component can cause a false indication of safety;

c) Feedback systems so that transmitted commands can be verified;

d) Interlocking to prevent a dangerous change from being made in the system;

e) Monitoring to provide information on the state of essential system elements through a combination of automatic means, human operators, or both;

f) High reliability to minimize incidents or failures;

g) Use of accepted transit industry practices and proven standards of the transit industry and applicable regulatory codes;

h) All visual wayside signal placements shall maximize sight distance for the train operator and shall be at a standard location adjacent to the right-of-way;

i) The design of all wayside and transit vehicle train control equipment shall incorporate electromagnetic compatibility concepts to minimize potential interference from within the train control system and nearby electrical systems;

j) Signals shall be located to allow for the minimum safe braking distance required to stop short of an obstruction, switches not properly aligned, or a conflicting route;

k) Adequate training of personnel in safe operation and maintenance procedures for signals.

12.5.2 Automatic Train Protection

The Automatic Train Protection (ATP) system shall consist of fixed signal blocks with wayside signals at block boundaries. Future use of cab signaling systems shall not be precluded.

The length of signal blocks shall vary depending upon the operating characteristics of the line segment. Block spacing shall be designed to provide for safe stopping distance, visibility, maximum operational performance and headway, location with respect to turnouts, and need for emergency access.

Block locations in the tunnel shall be coordinated with the design of the ventilation system so that a train’s location can be determined with respect to the ventilation fans.

In some segments, such as the CBD Mall, line-of-sight and operating procedures (see the DART Design Criteria Manual, Volume 2, Chapter 10, Sections 10.2.8 and 10.2.9) may be used.

Trip stops shall be used at all signals so that an emergency brake application is automatically initiated if a train goes past a stop signal. A monitoring system shall be provided to indicate to TCC that a violation of a stop signal has occurred.

Special wayside signal protection may be provided in critical locations such as approaching junctions, on severe curves or grades, or where a grade crossing is adjacent to a station. This could include the use of “timed section” signals, repeater signals, or Train-To-Wayside Communications(TWC).

12.5.3 Shared Freight Operation

Any sections operating on the same tracks shared with freight trains shall conform to Federal Railroad Administration regulations, Title 49, Parts 200-299.

In common corridors where mainline freight trains and revenue segments of the LRT system have tracks adjacent to each other, the need for intrusion warning devices on the separation fence shall be evaluated during the design phase. If installed, the top of intrusion warning fence shall be at least six feet above the maximum height of the highest rail and shall set off an intrusion alarm in TCC after any intrusion. The intrusion warning shall be connected to the train control system to force a stop signal on that section of LRT track when activated. Factors to be considered in the evaluation should include freight railroad operating speeds, location of switch points and curves, maintenance and condition of the freight trackage.

Hot box detectors shall be considered along mainline railroad rights-of-way in approach to the common corridor. These detectors shall provide an audible and visual alarm to the TCC when activated.

An appropriate means of communication shall be provided between TCC and appropriate railroad control/dispatching centers.

The need for Derailment/Dragging Equipment Detectors shall be evaluated during design. If installed on the railroad right-of-way approaching and adjacent to the common corridor with mainline railroad freight trains, an alarm shall be provided to TCC and railroad control center when activated.

Highway/Rail Grade Crossings in shared/adjacent track locations shall conform to applicable FRA regulations for installation and maintenance.

12.5.4 Signals

Safe braking distances shall be maintained by wayside signals, or automatic cab signal systems.

The safe stopping distance criterion shall be consistent with the requirements of the DART Design Criteria Manual, Volume 2, Chapter 4, Signal Systems. The safe braking criterion will be adjusted for operation on a grade.

Speed signs shall be located along the right-of-way in advance of permanent and temporary speed restrictions.

The signal aspect displays shall be of uniform design throughout the system. Each defined operating condition shall have a unique signal aspect, with unambiguous indication. Height, size, and illumination levels shall be designed for optimum visibility.

12.5.5 Grade Crossings

At exclusive or joint railroad right-of-way, crossing signals and signage shall be consistent with that defined in the DART Design Criteria Manual, Volume 2, Chapter 5 and Design Criteria Manual, Volume 2, Chapter 4, Signal Systems and the Texas Manual on Uniform Traffic Control Devices (TXMUTCD).

Local traffic signaling, phasing, and location shall take into account the need to protect the rail right-of-way first and foremost.

Pedestrian crossing warning devices shall be used in areas with identified high pedestrian traffic across the right-of-way. Examples include crossings near schools, parks, or special event locations and crossings with adjacent freight railroad operations/tracks. Such protection could include the installation of pedestrian warning gates, pedestrian bridges, channelization, bedstead barriers, “Z” crossings, or tunnels.

12.5.6 Event Recorders

Event recorders shall be considered for installation at signals, railroad crossings, interlockings, crossing gates or protective devices. Recorders shall include indication of date, time, and operating status of the signal, and any crossing gate or protective device.

12.6 FIRE/SECURITY SUBSYSTEMS

12.6.1 Fire Alarms

The Fire Alarm system shall include fire detection/alarms, and manual alarms provided through the emergency telephone system. This section shall describe the automatic alarm system which will be designed in accordance with the provisions of the latest edition NFPA 130, and NFPA 72.

The fire detection and alarm systems shall be electrically supervised, closed circuit, selectively coded, and continuously self-monitoring.

The system shall provide for automatic activation of local alarm devices, shutdown of air conditioning and ventilation system, and closing of fire doors.

The Train Control Center (TCC) shall be the supervisory signal location for all areas except the maintenance facility and yard. The maintenance facility and any yard signals shall be monitored by a yard control monitor which is integrated with the TCC.

12.6.2 Fire Management Panels

Fire Management Panels shall be provided as described in communications section.

12.6.3 Fire Detectors

Detectors will be located throughout protected areas to provide for optimum coverage, eliminated unprotected areas, and assure timely detection.

The type of detector installed shall be designed to meet the specific requirement of each area to be protected. This shall include a combination of fixed temperature, combination fixed temperature and rate of rise, ionization, duct, and smoke detectors.

All detectors shall be UL listed and shall meet the requirements of the AHJ.

Security locks shall be provided on bases of detectors in those areas subject to tampering.

12.6.4 Manual Fire Alarm Stations

Manual fire pull station alarms shall be provided at maintenance facilities, at the car assembly facility, TCC, and the platform areas of underground stations.

Fire alarm stations shall be of type and location approved by the AHJ.

12.6.5 Auxiliary Power

Each Fire Management Panel and fire alarm control panel shall be provided with an auxiliary power supply capable of operating the units for 24 hours.

Output modules of the proper rating shall be provided to provide the required outputs for all subsystem components specified within the Fire Management Panel or fire alarm control panel.

12.6.6 Intrusion Detection and Alarm

Intrusion Detection and Alarm Systems shall be designed to provide protection of the general public and employees from dangerous equipment or operations, from unauthorized entry by persons intent on vandalism or sabotage, and for protection of life safety systems.

Intrusion Detection and Alarms shall be electrically supervised, closed circuit, selectively coded and continuously self monitoring.

The Communications Transmission Subsystem shall be used to transmit intrusion alarms to TCC.

Activation of local alarms shall be indicated by an audible and/or visual signal at each station or facility.

Alarms shall be provided for all enclosed spaces or stations, any rolling grilles at passenger stations, maintenance repair facilities, tunnel cross passage doors, ventilation system access doors, and substations.

The system shall be designed to allow for activation delay at the security console or office to allow time to exit a facility prior to the activation of the alarm.

Intrusion detection equipment and materials shall be designed for the specific requirements of the area to be protected.

An intrusion alarm indicator panel shall be provided for each major facility.

Knox Boxes with tamper switches shall be monitored as part of the fire alarm system as required by the AHJ.

12.6.7 Fire Protection Systems

Fire Protection Systems shall be designed to meet the performance standards of these criteria. This includes subsystem components that suppress and/or extinguish fire or smoke when they occur. Systems shall be designed to respond to the requirements of the area to be protected. This shall take into account the occupancy of the space, access by staff and fire emergency personnel, and fire hazard.

12.6.7.1 Automatic Sprinklers

The design and installation of Automatic Sprinkler Systems shall comply with the provisions of NFPA 13 Standard for the Installation of Sprinkler Systems, latest edition NFPA 130, and the local Building Code.

Automatic sprinklers shall be provided in office areas, locker rooms, lounges, concession stands, restaurant service areas, storage areas, workshops, trash rooms, mechanical rooms, non-public areas of stations, escalator pits, elevator shafts, and all areas of maintenance buildings. Automatic sprinklers or Halon systems shall be installed in electrical rooms with proper shielding or protection of equipment. Typically sprinkler protection will not be required in areas of open stations but shall be evaluated on a case by case as needed per NFPA 130.

Sprinkler flow rates shall be designed to meet occupancy and use requirements. Standards shall be specified for each type of protected area.

Sprinklers shall be located to minimize potential for mechanical damage.

The sprinkler system shall include water flow alarm and supervisory signal service to TCC or the Yard Control Tower.

12.6.7.2 Standpipe Systems

Wet and dry standpipe systems shall be provided to assure adequate water supply for fire fighting activities in all protected facilities. Standpipe systems shall meet the requirements of latest edition NFPA 130.

Standpipe systems shall comply with the requirements of the NFPA 14, Installation of Standpipes and Hose Systems and the AHJ. The AHJ shall approve location, spacing, number and type of standpipe hose valves, and the need for and provision of type of hose.

Wet Standpipe Systems shall not be combined with sprinkler systems unless approved by the AHJ.

Fire department connections for fire department use in supplying the standpipes shall be located within 50 feet of a public road or designated fire lane and within operating distance of fire hydrants as determined by the fire department having jurisdiction for that facility.

All areas of passenger stations shall be within 300 feet of a fire hydrant as the fire hose would be laid.

All areas of passenger stations shall be reachable within 150 feet of fire line from an apparatus or 130 feet of fire line from a standpipe riser.

Subway stations shall be protected by a Class III standpipe system throughout the station entranceways and platforms. Outlets shall be located so that all points in the station are within reach of 100 feet of hose and 30 feet of water stream.

A Wet Standpipe System shall be provided for TCC in conformance with the DART Design Criteria Manual, Volume 1, Chapter 29, Section 29.3.4.

A Dry Standpipe System shall be provided to protect the subway tunnel. This shall include hose outlet connections at a minimum of 200 feet intervals. The system shall be sized to provide a minimum of 250 gallons per minute at the hydraulically most remote point.

Fire Department connections to the standpipe system at TCC, aerial, and at-grade guideway shall be within 150 feet of a street hydrant and within 50 feet of vehicular access.

Standpipe systems may be installed to satisfy the AHJ requirements for suppression in remote areas or stations (G-2 Bridge, Mockingbird Station). Installation requirements shall be determined on a case by case basis with concurrence of the AHJ.

Standpipe systems shall be plainly marked with signage approved by the AHJ.

12.6.7.3 Fire Hose Valve Cabinets

Fire Hose Valve Cabinets shall be provided to support water supply in those areas with a high risk which are not readily accessible because of limitations in the availability and location of regular fire hose and hydrants connections.

Fire Hose Valve Cabinets shall be located in the following areas: all station concessions, subway station mezzanine and platform, throughout the TCC, and throughout the maintenance facilities.

Each fire hose cabinet will be equipped with hose, racks, valves, and adapters as specified by the AHJ.

12.6.8 Fire Hydrants

Fire hydrants in accordance with the provisions of the AHJ shall be provided at each of the following locations:

a) Within 300 feet of each location where the DART guideway crosses over a traveled way or access road. (Highway-rail grade crossing);

b) Within 100 feet of each Fire Department connection to a standpipe or as required by the AHJ;

c) Within 150 feet of each subway station or subway tunnel access point or as required by the AHJ;

d) Along the access road to the TCC, and maintenance facilities at a maximum spacing of 300 feet;

e) Within 300 feet of an at-grade or aerial station;

f) Within 300 feet of a nonpublic structure (Traction Power Substation, Signal Power Distribution Center, Communications house, etc) unless prior approval of the AHJ is obtained;

g) Not closer than 40 feet to the above locations.

Hydrants shall be marked and located in accordance with the provisions of NFPA 291, Recommended Practice for Fire Flow Testing and Marking of Fire Hydrants.

12.6.9 Water Supply

System indicator signals support early fire detection and suppression activities. Water supply requirements of the AHJ shall be coordinated with the local utility having jurisdiction and will conform to North Central Texas of Council Governments, Standard Specifications for Public Works Construction.

The adequacy of water supply shall be determined by flow tests or other suitable means. The computations for fire flow requirements shall be based on “Fire Suppression Rating Schedule”, (ISO 1980) or such other method as is approved by DART.

Street mains shall be sized to carry the required flow, but in no case shall they be less than 8 inches in diameter.

A backflow preventor with detector check shall be installed on connections to the public water supply to prevent any contamination.

Special provisions shall be added in those cases where an automatically controlled fire pump is approved as a single source of water supply by the fire department having jurisdiction.

If water flow requirements indicate a need for a separate water storage tank, such tank shall be designed in accordance with the provisions of NFPA 22, Standard for Water Tanks for Private Fire Protection and ANSI Code of Pressure Piping.

Underground pipe and fittings for fire protection shall be suitable for the working pressures and the conditions under which the pipe is to be installed in accordance with the AWWA (American Water Works Association).

Valves are required at strategic locations to allow segments of the system to be shut off for repairs, or under emergency conditions, without reducing protection over a wide area.

12.6.10 Fire Department Connections

Connections from public water systems for fire protection are for the purpose of providing water supply to the following:

a) Automatic sprinkler systems.

b) Standpipes for hand hose or fire department use.

c) Open sprinklers.

d) Yard systems with private hydrants.

e) Fire pumps.

f) Private storage reservoirs or tanks for fire protection.

Connections shall be provided at the access road side of buildings and shall be located and arranged so that hose lines can be readily connected without obstruction.

Fire Department Connections shall be designated by a sign having raised letters at least 1 inch in height and cast on a plate with the appropriate label. Connections for the station shall also identify the connection as part of the transit station system to distinguish it from any other nearby connections.

Protective coatings shall be provided based on environmental conditions in area of installation.

Fire department connections shall be located within 50 feet of an approved fire lane or public road and within 100 feet of a fire hydrant.

12.6.11 Portable Fire Extinguishers

At least two approved multipurpose portable fire extinguishers of the 10-lb class rated 4-A: 30-B:C minimum shall be provided in each vehicle at the end of each passenger compartment.

Fire extinguisher cabinets or mountings shall be marked to indicate extinguisher location. Marking shall be uniform throughout the system, fire engine red paint shall be used on the cabinet and signage shall placed for optimum visibility.

All portable fire extinguishers shall be UL approved, have a minimum 10 lb capacity, and be of the type as approved by the AHJ for the hazard type.

Portable fire extinguishers shall be generally located in accordance with the provisions of NFPA 10, the AHJ and the latest edition NFPA 130.

a) Underground Guideways: on both sides of entrance at cross passages and at Fire Management Panel on each end of tunnel.

b) Aerial and at-grade stations: in all enclosed ancillary spaces and crew rooms.

c) Underground stations: on station platforms, at each fire hose location, in ancillary areas, adjacent to Fire Management Panel, and as needed to provide a maximum travel distance of 75 feet.

d) TCC: Installed throughout with special consideration for the requirements of Halon 1301 system.

e) Maintenance Facilities: Installed throughout, at each emergency telephone location. Special consideration to areas protected by Halon 1301, paint booth, storage areas, welding area, and others areas of high hazard.

12.6.12 Halon Systems

Halon based protection systems shall be used in designated computer and electronic equipment areas where fast response is critical and regular sprinkler and extinguishment systems would damage sensitive equipment. Safeguards shall be provided for occupied areas. These systems shall not be used in any areas accessible by the public.

Clean agent extinguishing systems equivalent to Halon 1301 may be substituted as approved by the AHJ.

Halon systems shall be designed to conform with the requirements of NFPA 12A, Halon 1301 Fire Extinguishing Systems.

Separate supervisory controls and alarms shall be provided for each Halon 1301 system. Alarms shall be activated by smoke detectors located in each area. The detectors shall be cross zoned so that detection in two zones is necessary for activation of the system. Operation of a single detector shall provide activation of auxiliary devices such as release of door hold-open devices, ventilation system control, and a pre-discharge warning.

There shall be provision for manual activation of the system from each protected area. Manual activation shall cause the same sequence of operation as an automatic operation.

Discharge of the system shall be preceded by a warning followed by a 20 second delay for activation of the system.

Power disconnect to designated electrical equipment shall be located by the exit door of each Halon protected room.

System shall provide a minimum concentration of 7% by volume within 10 seconds and a maximum of 10% in occupied areas or 15% in normally unoccupied areas.

All openings into areas protected by Halon 1301 systems shall be provided with devices to close them automatically during Halon discharge, or shall be protected with Halon 1301 jet screens.

Ventilation system in Halon protected areas shall provide for prompt extraction of decomposition products and venting to the outdoors without recycling of makeup air.

Combustible load shall be specified for Halon protected rooms.

Portable extinguishers shall be of a type designed for use with Halon.

TCC protection shall include the consoles and under floor space.

12.6.13 Air Supply

The elements of the Air Supply System that are essential for system safety are those related to the removal of heat, smoke, and toxic fumes. This is especially critical in underground guideway and station areas. HVAC systems shall be designed to conform with the requirements of the latest edition NFPA 130 to provide a tenable environment along the path of egress from a fire incident.

12.7 TRAIN CONTROL CENTER (TCC)

12.7.1 General

The Train Control Center (TCC) shall be a controlled space for housing electronic equipment, personnel, and supporting facilities to be used for operation and supervision of the transit system through signaling, communication, and fire and security management. The facility shall be used for data processing, status reporting, and transit system supervision. The facility shall be equipped to permit 24-hour operation. Requirements of the TCC are defined in the DART Design Criteria Manual, Volume 2, Chapter 6.

12.7.2 Siting

The TCC structure shall be located in accordance with the UBC and local building codes and to maximize operational, maintenance, safety and cost-effectiveness considerations.

12.7.3 Construction

The TCC facilities shall comply with Type II-N construction requirements, including height and area limitations, of the UBC and local building codes for Group B, Division 2 occupancy. All structural assemblies and building appurtenances in TCC shall be of noncombustible material.

12.7.4 Occupancy Separations

The TCC shall provide and maintain occupancy separations as required by the UBC and local building codes and this section.

TCC, including ancillary rooms, shall be separated from uncontrolled public access areas and other occupancies by a partition with a minimum fire rating of 2 hours.

The TCC data processing and control areas shall be separated from all ancillary rooms by minimum 1-hour fire rated separations.

Cabling from TCC to system operating areas, and to all other services essential to the operation of TCC, shall be routed separately from other building services.

Fire-rated assemblies protecting openings in fire-rated separations shall be automatic or self-closing and shall be installed in accordance with the AHJ. Activation of assemblies shall be by smoke detectors at the opening and by means of a fixed temperature or rate-of-rise device or combination, there of. Assemblies may be released by fixed temperature device alone when a separate smoke barrier is provided.

Egress routes serving TCC and other occupancies shall be 2-hour fire rated enclosures.

All other protection of vertical openings shall be in accordance with local codes and the AHJ for Group B, Division 2 occupancies of Type II-B construction.

12.7.5 Interior Finishes

Interior finishes shall meet NFPA 101 requirements for Class A and Class B interior finishes and the AHJ, Class I and Class II.

12.7.6 Access and Egress

Access to the TCC building shall meet the requirements of the AHJ. Means of egress shall comply with the requirements of the AHJ.

12.7.7 Emergency Lighting

Emergency lighting shall be provided for all egress routes from and throughout the entire TCC area. Emergency lighting shall be installed in accordance with NFPA 101.

12.7.8 Communications

TCC shall have the capability of communicating with operating trains and other system facilities, with any emergency telephone in the operating system, and with the appropriate public emergency response organization(s).

12.7.9 Fire Protection

Site fire flows (water supplies) and hydrants for TCC shall conform to the NFPA 24 and the AHJ.

Standpipe and automatic sprinkler water supplies shall meet the requirements of the NFPA 13 and 14 as well as the AHJ.

If TCC is within a building having occupancies not directly related to transit system operations, the TCC standpipes and automatic sprinkler systems shall be supplied from an independent connection to the municipal system.

Standpipe Systems

Standpipes, as required by the AHJ, shall be installed in TCC.

Automatic Sprinkler System

Automatic sprinkler protection shall be provided throughout TCC, excluding areas protected by Halon 1301 systems. Automatic sprinkler systems shall be hydraulically calculated, designed, and installed in accordance with NFPA 13.

Portable Fire Extinguisher

Portable fire extinguishers, with a minimum rating of 4A:60B:C 10 lb. capacity and UL approval, conforming to NFPA and local codes, shall be installed throughout the TCC facility.

Halon 1211 or equivalent clean agent fire extinguishers shall be installed in the operations room, train control room, computer room, and the areas protected by Halon 1301 systems.

Protective Signaling System

An automatic fire detection, alarm, and control systems, complying with the requirements of NFPA 72 and approved by the AHJ shall be provided throughout the TCC building.

Smoke detectors shall be installed throughout all areas of TCC that are protected by Halon 1301 or equivalent systems, normally unoccupied areas (electrical rooms, elevator machine rooms, mechanical rooms), and return air plenums of HVAC systems serving more than one area.

Automatic sprinkler systems shall be provided with water flow alarm and control valve supervision, for annunciation at TCC.

Manual fire alarm capability shall be provided throughout TCC. This capability may be provided as a part of the emergency telephone system. Fire alarm capability shall generally be located along the normal path of exit.

Fire alarms, trouble alarms, and supervisory signals shall be transmitted by zone, for annunciation at TCC, in accordance with NFPA 72.

If located within a building having other occupancy, TCC shall be provided with at least one summary alarm for fire or evacuation notification, initiated from any part of the building.

The TCC fire alarm system shall be separate from the fire alarm system of any non-transit occupancy, except that remote alarm annunciation form this system may be provided at locations outside TCC, as approved by the local fire authority.

12.7.10 Mechanical Systems

The TCC critical heating, ventilation and air conditioning (HVAC) systems shall be physically and operationally separate from HVAC systems serving any other occupancy. Redundant fan and/or air conditioning units shall be provided, sized, and arranged so that either unit is capable of serving the TCC facilities.

Emergency smoke removal capability shall be provided for TCC with redundant full-capacity outside air intakes.

Battery storage or similar ancillary rooms, in which hydrogen gas or other hazardous gases may be released, shall be ventilated in the manner specified in the DART Design Criteria Manual, Volume 1, Chapter 25.

12.7.11 Electrical Requirements

Light and Power

Electrical equipment and wiring materials and installation shall conform to the requirements of NFPA 70, and local codes.

Emergency Power

A separate onsite emergency power system shall be provided for TCC so that the loss of utility electrical power shall not impair any TCC function. The emergency power system shall meet the requirements of NFPA 110 and shall be capable of providing for a maximum normal load of 24 hours.

12.7.12 Mimic Board

A visual display of the revenue system, stations, and supervisory control locations shall be provided at TCC.

12.7.13 Automated Emergency Response System

The system monitoring functions at TCC shall consider incorporation of an automated emergency response system. This system shall include a graphic display of the system showing all relevant emergency related functions.

12.8 YARD CONTROL

All yard movements at the maintenance facilities shall be monitored by the Yard Control position and control station. Yard Control shall also include supervisory monitoring of the fire alarm system and be the central communication point for emergency communications at the maintenance facility. The functions and location of Yard Control shall be integrated with the TCC.

Yard Control shall be located to provide optimal visual surveillance of the yard throat and storage tracks.

The communication system in Yard Control shall include:

a) Two-way radio communications

b) Emergency telephone system

12.9 ENVIRONMENTAL PROTECTION

12.9.1 Flammable Liquids

Flammable or hazardous liquid or gas lines crossing the track way except when located on public roadways shall have a valve at each end for shut-off in emergencies.

Above ground atmospheric storage tanks for Class I flammable liquids or Class II or Class III combustible liquids and related piping shall not be permitted directly over a sub-surface structure or within 25 linear feet measured horizontally from the outside wall of the substructure unless provided with an approved leak detection monitoring system.

Service stations dispensing Class I flammable liquids and Class II and Class III combustible liquids and located in the area within 100 feet (measured horizontally) from the edge of the at-grade right-of-way not located within public roadways shall be required to comply with the following:

a) The surface around pump islands shall be graded or drained in a manner to divert possible spills away from the right-of-way.

b) Continuous drains and/or curbs at least 6 inches height shall separate service station properties from the right-of-way.

c) No connection shall be permitted of any storage tanks and related piping to an at-grade structure.

d) Dispensing pumps shall be located not less than 25 feet from the face of the pumps to the nearest edge of the at-grade right-of-way.

12.9.2 Air Pollution

The system shall be designed to minimize generation of air pollution in station areas by minimizing movement of motor vehicles through the design of proper access and parking.

The system design shall also include methods to protect for the intrusion of smoke or toxic fumes from surface conditions into the subway tunnel.

12.9.3 Noise and Vibration

Special criteria for sound levels shall be established for the emergency communications systems taking into consideration the areas in which the system is located and levels of background sound.

12.9.4 Drainage Systems

Drainage systems shall be consistent with the Facilities Drainage Design Criteria.

Systems shall be designed to control any release of hazardous materials into ground water.

12.9.5 Hazardous Materials

The system shall be designed to minimize the use of any hazardous materials and to prevent the release of hazardous materials into the atmosphere, surface areas, or surface/subsurface waters or ground areas.

System design shall include provisions for the safe delivery, handling, storage, and disposal of any hazardous materials.

12.10 DEFINITIONS

Alignment - the horizontal and vertical location of a rail system described by curves and tangents.

Approved - design, type, material, procedure, or method given approval by DART.

Aspect - the appearance of a fixed signal conveying an indication as viewed from the direction of an approaching train.

Assembly - a collection of subassemblies and components typically performing a variety of functions within the context of a larger system. Examples of assemblies are trucks, electronic control units, air compressors, etc.

AW0 - weight of empty vehicle.

AW1 - weight of vehicle with full seated load.

AW2 - weight of vehicle with design load – full seated load plus standees at 4 passengers/m^2.

AW3 - weight of vehicle with full load – full seated load plus standees at 6 passengers/m^2.

AW4 - weight of vehicle with crush load – full seated load plus standees at 8 passengers/m^2. (Typically not achievable in normal service, but used as a design parameter.)

Blending - a simultaneous dynamic and mechanical brake application with the effort of each subsystem continuously proportioned to achieve the required total braking effort.

Block - a length of track of defined limits on which the movement of trains is governed by the signal system.

Block, Interlocking - a length of track within a track switching section, entrance to which is governed by interlocked signals and the use of which is governed by rules for automatic or manual train operation. The interlocking block may contain one or more track switches.

Braking, Closed Loop - braking under continuous direction of the train control system.

Braking, Emergency - emergency braking is irretrievable open-loop braking with the spin/slide modulation bypassed.

Braking, Open-Loop - braking at the maximum effort permitted by the traction system without continuous direction from the train control system.

Braking, Service - modulatable braking from 0 to 3 mph/second in normal operation.

Catenary System - an overhead contact traction power system in which the contact wire is supported from one or more longitudinal messengers, either directly by hangers or by hangers in combination with auxiliary conductors and clamps. Attachment of the contact wire to the messenger is made at frequent and uniform intervals so as to produce a contact surface nearly parallel to the top of the track rails.

Coast - the mode of operation in which no propulsion (positive traction) or braking effort is in effect for normal drive train losses.

Component - portions of equipment which are typically repaired or disassembled, such as nuts, bolts, resistors, fittings, single-piece castings. Used interchangeably with “parts”.

Conceptual Design - a generalized plan describing design requirements and used as a guide to preliminary design.

Consist - a consist is the specific makeup or composition of a train of vehicles including their number and identity.

Contact Wire - The lower overhead wire of a catenary system from which a transit vehicle collects power via the pantograph for both propulsion and auxiliary power.

Contract Documents - types of contract documents are Tender, Proposal, the Request for Price Proposals, Contract Forms, General Terms and Conditions. Special/Supplemental Terms and Conditions, Technical Specification, listed drawings and supplemental drawings; all as issued or finally amended and approved.

Contracting Officer’s Representative (COR) - The representative designated by DART’s contracting officer as having contractual authority for a specific contract.

Contractor - the person or persons, firm, partnership, corporation, or combination thereof, which has/have entered into a contract with the authority to provide the materials and/or the services specified.

Contractor’s Drawings - items such as detail drawings, calculations, and catalog cuts which are prepared by the Contractor to supplement or detail contract drawings or specifications, and which are contractual requirements or are prepared at the Contractor’s option to detail his work.

Critical Velocity - the minimum steady-state velocity of the ventilation airflow moving toward the fire within a tunnel or passageway that is required to prevent backlayering at the fire site.

Emergency Procedures Plan - a plan that is developed by the Authority with the cooperation of all participating agencies and which details specific actions required by all those who will respond during an emergency.

Electric Traction - a means for propulsion of railroad vehicles whereby power is provided by electrical energy transmitted from a remote source through a catenary system.

Electrical Isolation - the condition of being electrically separated from other metallic structures of the environment.

Electrical Magnetic Interference (EMI) - transmission of deleterious electrical or magnetic waves which, when acting upon other equipment, can cause unintended operation or malfunction.

Fail-Safe - a characteristic of a system, or hardware configuration, which ensures that the occurrence of any failure, or combination of failures, shall cause the system to revert to a state that is known to be safe.

Failure - a system or equipment is said to have experienced a failure if it can no longer provide the required performance output in a satisfactory manner. Specific definition of failure and satisfactory performance must be provided in any analysis in which these terms are used.

Failure Mode and Effect Analysis (FMEA) - an analysis which determines the effects of all types of subsystem unit failures separately and in combination on the performance output of the system.

Failure Rate - the frequency of failure, expressed as failures per hour, failures per mile, etc. Failure rate is the calculated mathematical reciprocal of MTBF.

Failures, Mean Time Between (MTBF) - a ratio of the number of hours equipment, functions and systems operate in a regular manner to the number of independent failures observed is the mean time between failures.

Fault - a component state that contributes to a possible occurrence of an undesired event.

Fault Tree Analysis - a technical management tool for safety and reliability programs. It first assumes a specific overall system fault (such as collision) and identifies potential subsystem faults that could produce it. Each subsystem is broken down into smaller subsystems, and finally may be detailed down to the individual wire, connector pin, transistor, integrated circuit, etc. Each of these is then examined to determine if and how such failure could occur, the probability it would occur, and what design techniques will eliminate the possibility of occurrence.

Final Design - a design stage during which final specifications, contract drawings, schedules, and cost estimates are prepared for construction.

Fire Emergency - the existence of, or threat of, fire and/or the development of smoke or fumes that calls for immediate action to correct or alleviate the condition or situation.

Fire Growth Rate - rate of change of the head release rate. Some factors that affect the fire growth rate are exposure, geometry, flame spread, and fire barriers.

Gauge (of Track) - the distance between the gauge lines, measured at right angles. (The standard gauge is 4 feet 8-1/2 inches)

Gauge Line - the gauge line can be determined in two ways: (1) A line 5/8 inches below the top of the center of the running rail head; or (2) the corresponding location of tread portion of other trackwork along the side nearer the track center.

Grounded Equipment - equipment connected to the conducting mass of the earth via ground rods, a grounding grid, or both, to ensure an immediate discharge of electrical potential without danger.

Grounded - the state of being connected to earth or to some extensive conducting body that serves instead of the earth, whether the connection is intentional or accidental.

Hazard - Any real or potential condition that can cause injury, illness, or death to personnel, damage to, or loss of equipment or property, or damage to the environment.

Headway - the time interval, measured from front to front, between successive vehicles or trains moving along the same lane or track in the same direction.

Impedance Bond - an iron-core coil of low resistance and relatively high reactance used to confine signaling current to its own track circuit while providing a continuous path for the traction return current around insulated joints to the substation.

Incident Commander - the person who is responsible for managing and coordinating all facets of the fire and emergency responses during a fire incident. The incident commander can be a responsible fire or police representative at the scene.

Indication, Signal - the information conveyed by the aspect of the signal.

Insulation - a device or material that prevents the flow of electric current.

Interface - the points where two or more physical subsystems or systems meet to transfer energy, information, or control. Also a point of coordination and exchange.

Interlocking - an interlocking is an arrangement of gates, control apparatus, and/or track switches interconnected so that functions must succeed each other in proper sequence, permitting train movements over controlled routes only if safe conditions on those routes exist.

Joint, Insulated - a rail joint designed to arrest the flow of electric current from rail to rail by means of insulation, placed so as to separate the rail ends and any other metal parts connecting them.

Light Rail Vehicle (LRV) - a completely assembled, self-contained, read to run electrically powered rail unit to transport passengers along a mixed, fixed guideway.

Load Weighing - the measurement of passenger load for the purpose of adjusting the vehicle's tractive effort to produce a constant acceleration rate in power or braking, regardless of load.

Locking - the electrical or mechanical establishment of a condition for a switch, interlocked route, speed limit or automatic function, which cannot be altered except by a prescribed and inviolate sequence of unlocking.

Maintenance and Recovery Vehicle (MRV) - any vehicle capable of being trackway-mounted, designed to maintain the trackway, carry system equipment along the track for use in subsystem maintenance and repair, and retrieve failed passenger vehicles/trains from the track. The trackway design shall include consideration of the weights associated with the recovery vehicle operation.

Manual - the state of vehicle operations in which control is in the hands of an operator who guides and regulates speed. The operator may depend on visual contact with other vehicles or with signals which indicate the condition of the track ahead.

Mean Cycles Between Failures (MCBF) - the mean number of cycles between failures (MCBF) of a system subunit is the arithmetic mean of the number of cycles between failures requiring corrective maintenance when the system subunit is operated and maintained under stated conditions.

Mean Distance Between Component Failures (MDBCF) - the mean operating mileage between independent failures of a component.

Mean Distance Between Failures (MDBF) - the mean operating mileage between independent failures.

Mean Distance Between Train Delays (MDBTD) - the mean operating mileage between train delays caused by equipment or system failures.

Mean Time Between Failures (MTBF) - the mean time between failures (MTBF) of a system or system subunit is the arithmetic mean of the operating time between failures requiring corrective maintenance when the system is operated and maintained under stated conditions.

Mean Time to Repair (MTTR) - the mean time to repair a failed system (MTTR) is the arithmetic mean of the time between the occurrence of failure and the restoration of the equipment to an operable state when maintenance is performed under stated conditions. In any specific case, whether maintenance is merely replacement with a spare, not counting actual repair, or whether it does reflect repair must be defined. It is also necessary to specify whether repair time refers to active repair time only or whether it also includes other down time.

Messenger Wire - the current-carrying longitudinal wire or cable of a traction power catenary system from which the contact wire is suspended.

Milepost - an identifier for a given location along a railroad line. Mileposts may or may not be located exactly one mile apart and may not be sequentially numbered.

Modem - a modulator and demodulator housed in a common assembly, e.g. phone line to computer.

Multiple-Fed System - electrification system in which substations feed sections of catenary at multiple points.

Multiplexer - any of several types of electrical/electronic equipment that uses a common channel to carry two or more channels.

No Motion - the vehicle speed at or below the lowest speed detectable by the vehicle control systems.

Noncombustible - a material that, in the form in which it is used and under the conditions anticipated, shall not aid combustion or add appreciable heat to an ambient fire.

Materials, where tested in accordance with ASTEM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, and conforming to the criteria contained in Section 7 of the referenced standard shall be considered as noncombustible.

Non-vital Circuit - any circuit the function of which does not affect the safety of the train operation.

Normal - as in, “normal operating conditions” or “operating normally” – a condition in which relevant vehicle equipment is not in a failure mode and the environment is as specified.

Point of Safety - an enclosed fire exit that leads to a public way or safe location outside the structure, or to an at-grade point beyond any enclosing structure, or another area that affords adequate protection for passengers and personnel in the event of an emergency.

Power Demand Analysis and Load-Flow Study - a computer-aided study using specially written computer program to calculate the combined performance of the traction power supply and traction power distribution systems with operating trains. The study results include catenary system voltages, catenary system currents, and substation power demand requirements, optimize spacings between substations, outage consequences to operations, and substation energy consumption.

Preliminary Design - a design stage at which specifications and drawings clearly show all major design elements and define requirements for final design. Design calculations are substantially complete, cost estimates are detailed to an extent compatible with the level of design, and a preliminary construction sequence schedule is prepared.

Proof (used as a suffix) - apparatus is designated as splashproof, dustproof, etc., when so constructed, protected, or treated that its successful operation is not interfered with when subjected to the specified material or condition.

Propulsion Systems - the system of wheels, motors, gears, brakes, controls and appurtenances that propels or retards the vehicle in response to control signals.

Redundancy - the existence in a system of more than one means of accomplishing a given function. Some safety systems rely on redundancy.

Relay, Non-Vital - a relay, the function of which does not affect the safety of train operations is called a non-vital relay.

Relay, Vital - a relay, the function of which affects the safety of train operations is called a vital relay.

Reliability - the probability of performing a specified function, without failure and within design parameters, for the period of time intended under actual operating conditions.

Remote Terminal (RTU) - a digital encoding and decoding terminal, the purpose of which is to receive and consolidate status indications from its local area and transmit these indications to the Train Control Center; and conversely to receive commands from the Train Control Center and transmit these commands to the designated locations.

Repair - repair refers to the restoration of failed equipment to an operable state. It is necessary to specify whether repair is merely unit replacement with a spare or whether it includes actual repair of the failed unit with an accompanying direct return to service.

Revenue Service - all transit service on main line routes established for service to the public.

Route Request - the registration at an interlocking of a desired interlocked route.

Run - one transit vehicle trip in one direction from beginning of a route to the end of it is called a run. When a vehicle completes a round trip on one route, it has completed two runs.

Running, Normal - a train is said to be running normally if the train movement is via the right-hand track, which is in the assigned direction of traffic.

Running, Reverse - a train is in reverse running if the train movement is via the left-hand track, which is opposed to the normal direction of traffic.

Safe - the condition in which passengers, crew, or repairmen are secure from threat or danger, harm, or loss arising from improper design, manufacture, assembly, malfunction, or failure of the signal system or any of its components or subsystems.

Safety - freedom from those conditions that can cause death, injury, occupational illness, or damage to or loss of equipment.

Service, as in Service Use, Service Braking - the operation of the cars under normal conditions with regular passengers.

Service Braking - modulatable braking operation of cars under normal conditions with regular passengers.

Serviceability Design - the performance design of trackway and other structures under service loads. Serviceability requirements to be considered include control of stress, fatigue, vibration, deformation, and cracking.

Skip Stop Operation - skip stop operation is a transit operational mode in which the train stops at every other stop, producing a faster passenger trip time.

Slide, Wheel - a wheel slide is an extreme slip condition wherein the wheel has zero rotational speed and slip speed equals train speed. This could result in flat spots on the wheel tread necessitating wheel re-turning. Also, metal may be built-up on the rail necessitating grinding.

Slip, Wheel - the wheel slip is the difference between the surface speed of wheel thread and rail, usually transient and sporadic.

Specific Optical Density (D_S) - means, as defined in ASTEM E 662, *Standard Test Method for Specific Optical Density of Smoke Generated by Sold Materials*, the optical density measured over unit path length within a chamber of unit volume, produced from a specimen of unit surface area, that is irradiated by a heat flux of 2.5 W/cm^2 for a specified period of time.

Speed, Balancing - the steady-state speed attained by the vehicle or train when resisting exactly equal tractive forces on level tangent track, such as wind resistance.

Speed, Base - the speed to which the maximum constant acceleration can be maintained at the nominal line voltage.

Speed Limit, Civil - the maximum safe speed allowed in a specified zone as determined by the physical limitations of the track structure.

Speed Limit, Operating - the maximum safe speed allowed in a specific area as determined by operating conditions.

Special Instruction - Train Orders that are in effect at the cessation of the day’s service are reissued as Special Instructions the next morning.

Spin, Wheel - during acceleration in power, the condition when the rotational speed of the wheel is greater than that for pure rolling contact between tread and rail. This usually results in build-up of metal on the wheel tread and a depression on the rail, which may necessitate grinding.

Spin/Slide Control - an automatic controlled release of propulsion or braking effort to avoid wheel and rail damage.

Standard Drawings - drawings that specifically define configurations and are repetitiously or commonly used on a project.

Station - a place designated for the purpose of loading and unloading passengers, including patron service areas and ancillary spaces associated with the same structure.

Split Center Platform - staggered and separate NB and SB platforms located between the NB track and the SB track. NB station on northern platform and SB station on southern platform except for MacGregor Station.

Station, Enclosed - a station or portion thereof that does not meet the definition of an *Open station*.

Station, Open - a station that is constructed in such a manner that it is open to the atmosphere, and smoke and heat are allowed to disperse directly into the atmosphere.

Station Master, Yard Control - an authorized individual whose function is to supervise yard operations, including the routing of cars within the yard limits.

Stop, Emergency - the open-loop stopping of a vehicle or train by emergency brake application. Once initiated, the brake application cannot be released until the train has stopped. Spin/Slide Control is negated.

Stop, Service - the stopping of a vehicle or train by application of service braking. Brake application can be released, reapplied, and modulated.

Stop, Train (Track Trip) - an electro-mechanical device, located in the trackway, that enforces the stop aspect of a signal by activation of the car brake system.

Stray Current - current flowing through paths other than the intended circuit.

Stray Current Corrosion - corrosion resulting from current flowing through paths other than the intended circuit.

Substation - traction power supply facility. Typical traction power substation includes power utility interface equipment, disconnects switches, circuit breakers, traction power transformers, switchgear, control equipment, signal power supply equipment, and auxiliary system. Special equipment, such as harmonic filtering and power factor control equipment, may be installed in substations as required.

Supervisor, Yard Control - the yard control supervisor is an authorized individual whose function is to supervise yard operations, including the routing of cars within yard limits.

Switch - a track structure used to divert rolling stock from one track to another.

Systems - Systems include Traction Electrification, Signals, Communications, Train Control Center, Fare Collection and Vehicle.

Tangent - any straight portion of a railway alignment.

Ticket Vending Machine - vending machine where public may purchase fares.

Tight (used as a suffix) - apparatus is designated as watertight, dusttight, etc., when so constructed that the enclosing case will exclude the specified material.

Traction Electrification System - traction power supply and traction power distribution systems.

Traction Power Distribution System - traction power substations located at predetermined spacings along the route.

Tractive Effort, Negative - the retarding force developed by the train braking system.

Tractive Effort, Positive - propelling force developed by the train propulsion system.

Train - consist of one or more LRV’s combined into an operating unit.

Train Control Center (TCC) - the room where the train controllers and their consoles and displays are located.

Train Performance Simulator (TPS) - a computer program representing operation of trains based upon tractive effort of the power units, resistance of the train to motion, and alignment characteristics. TPS can calculate time, distance, speed, acceleration, power demand, energy consumption and loss relationships of a train for all station-to-station runs and for the whole route.

Train, Revenue - any train in transit service on main tracks, which may be used by the public, is a revenue train.

Turnout - an arrangement of a switch and a frog with closure rails, by means on which rolling stock may be diverted from one track to another.

Vehicle - a complete light rail vehicle.

Vital - a term applied to a device or circuit that has known failure modes that should occur with extreme rarity.