Guidelines and Principles

for Design of

Rapid Transit Facilities

May 1973

INSTITUTE FOR RAPID TRANSIT

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GUIDELINES AND PRINCIPLES FOR DESIGN OF RAPID TRANSIT FACILITIES

MAY 1973

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SECTION 1

GENERAL

1.1 PURPOSE

In designing structures which are to be used by the public, it is essential that such structures be designed and built to conform to accepted practice, with regard to safety and with regard to adopting the latest technological developments. Similarly, in designing or providing for the supply of equip ment, either fixed or moving, it is equally important that such equipment be designed or specified to conform with the safest and best of accepted practices.

The purpose of these guidelines and principles is to describe in general terms what is considered to be good practice in rapid transit so that those responsible for designing and planning such facilities may have the benefit of this information. A summary of applicable standards presently in use by rapid transit agencies is also attached in the appendix.

Because of the wide divergence in age and character of existing rapid transit systems, it is obviously impossible to set a standard that all must follow. There must be deviations from the guidelines established herein in order to achieve compati bility with existing transit structures and equipment. Individual transit properties are governed by their own authorizing statutes and regulations. These recommendations are endorsed by the Institute and reflect accepted practice for design and construction of new rapid transit systems. The guidelines are not intended to be retroactively applied to existing systems nor are they intended to impose provisions for patron convenience upon new rapid transit systems where the provision of these facilities is at variance with operating policies. The essential purpose of the guidelines is the promotion of public safety and convenience through the use of desirable building standards.

1.2 SCOPE

Rapid transit is a broad subject covering structures, equipment and operations. The scope of these guidelines and principles is limited to structures and fixed equipment applicable to structures. The guidelines place emphasis upon the environ mental features which directly affect the safety and convenience of the transit patron. Recommendations contained in the guidelines respecting patron conveniences are intended to be used only where required by the policies of the operating agency. Many of the features are not included in present acts and standards but are of increasing public interest and concern and are of immediate interest to rapid transit agencies planning new facilities. The reader may also refer to IRT publication "Moving People Safely" for guidelines toward safety in the operation of urban rapid transit systems.

1.3 ABBREVIATIONS

AAR	Association of American Railroads
AREA	American Railway Engineering Association
IES	Illumination Engineering Society
NBCC	National Building Code of Canada
NEC	National Electrical Code
NESC	National Electrical Safety Code
UBC	Uniform Building Code of the International Conference of Building Officials
USASI	USA Standards Institute

1.4 DEFINITIONS

Aerial Structure. Any structure, other than a culvert, which carries transit tracks and spans above an earth or water surface.

Alignment. The horizontal or vertical location of a track as described by curves and tangents.

Ballast. Specified material placed on the track bed to support and restrain the track.

Gauge. The distance between gauge lines, measured at right angles thereto.

Gauge Line. A line 5/8 inch below the top of the center line of head of running rail along that side which is nearer the center of the track.

Guard Rail (Track). A rail or other structure laid parallel with the running rails of a track to control a derailed train, or at turnouts to hold wheels in correct alignment to prevent their flanges from striking the points of turnout or crossing frogs or the points of switches.

Rapid Transit. A mode of urban mass transportation using fixed route on fully grade separated right-of-way

Restraining Rail. A rail placed parallel to the inside running rail on a curve to restrain the wheel flange and reduce wear on the outside running rail.

Running Rail. The rail or surface on which the tread of the wheel bears.

Subway. That portion of a transit line which is constructed beneath the ground surface regardless of its method of construction.

Superelevation. The vertical distance measured at the gauge line of the rails that the outer rail is above the inner rail.

Top of Rail Profile. The profile line representing the elevation of the top of running surface of rails. Where superelevation occurs, the top of rail profile represents the inside or lower running rail.

Trackway. That portion of the rapid transit line included between the outside lines of curbs or shoulders, cut or fill slopes, ditches, channels, waterways and including all appertaining structures.

Trackwork. The rails, switches, frogs, crossings, fastenings, pads, ties and ballast or track support slab over which transit cars are operated.

Tunnel. That portion of a transit line which is constructed beneath the ground surface by a tunneling method.

SECTION 2

PATRON CIRCULATION AND EXITS

2.1 GENERAL

One aspect of transit design that comes more to the forefront in recent years is consideration of the element in the system that affects human comfort.

Many of the criteria involved are common to all environments, such as the control of light, noise, humidity, temperature, wind and odors, or the need for orderliness, through clear and easy circulation and clean appearance. Other criteria that are more specific to the transportation environment are such needs as safety, traffic handling capability, spatial variety, consistently available information and orientation.

An important criteria is the need for safety. This can best be provided by assuring proper orientation. The rider must not only be physically comfortable, he must also know in the fullest sense where he is and where he is going. Since to the layman a public transportation system is to a large extent an invisible skeleton of the city and metropolitan region, the comprehension of that structure generates an awareness and appreciation of the city itself, and an appreciation of travel through it. There are many aspects to achieving this orientation. Circulation at all points must be direct and open.

2.2 CIRCULATION

The major points that must be considered in designing for proper circulation are:

- Clarify circulation by avoidance of unnecessary and disorienting turns.

- Promote circulation by providing adequate space to eliminate bottlenecks.

- Locate fare collection components to avoid cross circulation at constricted decision points and to generally provide right-hand circulation.

- Provide adequate assembly space on platforms preferrably allowing approximately 8 sq. ft. of occupancy space per person for maximum assembly crowds.

- Provide a preferred space of approximately 8 feet between the edge of platform and obstructions such as stairs, escalators, or railings.

- Provide adequate space in mezzanines and entrance lobbies for queuing outside fare collection area without blocking normal traffic channels.

- Clarify circulation by avoiding useless options, dead end corridors and where space is adequate, separate the facilities provided for entering and leaving the station.

- Locate passageways and stairs to encourage balanced train loading and unloading, as passengers will tend to board trains at points where passageways and stairs connect to train platforms.

- Provide escalators whenever the stair height in the up direction exceeds 12 feet and in the down direction exceeds 24 feet.

2.3 WIDTH OF STATION EXITS

To properly size station exits the designer must first determine the volume of patrons being served. It is recommended that the average volume of passengers per minute boarding and leaving trains over the peak 15 minute period under normal operating conditions be estimated and that exits be sized to ensure that passengers from a train are able to exit from the platform before the next train enters. If, for example, trains are operating on a 2-minute headway, it is necessary to size exits to permit clearing of the platform within a period of 2 minutes.

In addition, the designer must consider the possibility of emergency evacuation of a train at any station on the line. The passenger load that is considered should again be the average train load entering the station over the peak 15 minute period under normal operating conditions. Under these conditions it is recommended that the exits be sized to ensure that the loaded train can be evacuated and the platform cleared within a 4-minute period. This criteria will frequently establish the minimum size of exits on line stations.

When determining the required width of exits, the designer may assume a crush capacity of 25 passengers per minute per foot width of passageways; 20 passengers per minute per foot width of stairways; and 100 passengers per minute for each

48-inch escalator. These capacities are only attainable under unidirectional flow conditions and when used for design will result in congested traffic patterns during short peak traffic periods. These crush load conditions may be acceptable for the short durations involved, however if more comfortable conditions are preferred or two-directional traffic is considered the designer may consider lower capacity values for stair and passageway design. Escalators should be equipped with stop devices so that escalators operating the wrong direction can be stopped in an emergency.

2.4 LOCATION OF STATION EXITS

Exits should be located along the platform to provide for uncongested passenger movement and permit safe exiting from trains and platform under emergency conditions.

Each underground platform should be provided with at least two fully separated exits having an aggregate width equal to the requirements of 2.3. The distance from the end of platform to the nearest point of exit should not exceed 200 feet unless provisions are made to safely exit patrons along the invert or walkways within the running tunnel. As a design principle use of the running tunnel or subway as an emergency means of exit from station areas should only be considered where the walking distance to the next station or portal to an open area is a minimum and the travel time will not exceed a safe evacuation period. Under these conditions emergency lighting on duplex feeders from separate sources should be provided in the tunnels. In all cases smoke control facilities as described in sections 4.3 and 6.3 should be provided that will prevent migration of smoke from any source into the path of egress.

To permit grouping of fare collection equipment into a single concourse area, exits from platform may lead to a common concourse.

However, under these conditions adjoining concession areas and service areas used for storage should be separated from the concourse area with a one-hour fire separation designed to effectively control smoke migration.

Illuminated “Exit” signs operated from an emergency power source should be installed to define paths of egress.

2.5 EMERGENCY LINE EXITS

Walkways with a minimum width of 2′-0″ should be provided on one side of all line sections of subways and tunnels and in areas of high speed train operation a grab rail adjacent to the subway wall and 3′-0″ above top of the walkway is recommended. Where practicable, walkways should be located on adjacent sides of the two trackways to permit cross connection between the walkways in each tunnel without crossing over the tracks. These cross passages should be located not more than 1,000 feet apart to provide access between subway lines for main tenance workmen and means of egress from an endangered trackway for evacuating patrons. The traction power rail should be located on the opposite side of the track from the walkway and station platform, unless electrification considerations dictate otherwise.

When under emergency conditions it becomes necessary to evacuate a stalled train within the tunnel, the patrons may be evacuated to the nearest station, portal or exit to an open area using either the 2′-0″ catwalk or the invert. The cross passages may be used to transfer patrons from a smoke-filled or otherwise endangered trackway to safer conditions in the adjacent trackway.

Under emergency evacuation of a rapid transit train within a subway or tunnel under fire conditions, patrons exposed to a long walking distance may be faced with a severe smoke condition before they can reach an exit, unless smoke migration is controlled. This control may be provided through the use of doors in the cross passages joining separate trackways which can be closed after evacuation of the endangered tunnel. Alternatively, fans injecting or exhausting air into the tunnels may be used to control the movement of smoke and prevent its migration towards the path of egress being used by the patrons.

In sections of subways having large station spacing, it may further be necessary to install emergency stairway exits between stations in order to limit the walkway distance during evacuation of a stalled train. Emergency exits may be separate structures, or be incorporated into pumping stations, ventilation or electrical substation structures, but should meet the recommendations of this guideline regarding width and fire protection.

SECTION 3

SECURITY

3.1 GENERAL

The purpose of this section is to establish guidelines for system security which will protect the public and transit system from crime and vandalism during operation.

These guidelines cover the various aspects of transit system design, construction and operations which affect the safety and security of passengers, system personnel and property. They are necessarily closely interrelated with subsequent sections, particularly Fire Protection, Lighting, Telephone and Communications.

3.2 RIGHTS-OF-WAY PROTECTION

The rapid transit rights-of-way must be physically protected to prohibit vehicular or pedestrian encroachment except at designated points of entrance and egress such as stations, surface transit interchange areas and parking lots.

3.3 GRADE SEPARATIONS

Because of close train headways and high speed operation, the entire rapid transit system must be grade-separated to protect passengers and pedestrians. Grade separations for other than underground and aerial sections of the line may be provided by either underpasses or overpasses, depending on vertical transit alignment, aesthetics and the overall economics of each individual situation.

3.4 RIGHTS-OF-WAY BARRIERS

Fencing or other form of barrier must be provided throughout the system to deny unauthorized persons or vehicles access to operating areas.

(a) Acceptable forms of pedestrian barrier include fences, walls and elevation differences of appro priate magnitude and construction. A deterrent in the form of barbed wire or equivalent physical obstruction should be mounted on fences or walls. The total height of the barrier should be a minimum of 7 feet, provided no step occurs which would allow access over the fence, and including a 1 foot high deterrent on top. Fences should bear appropriate signs spaced at not more than 500 foot centers warning of electrical hazard if applicable. Suitable locked gates should be considered for access of maintenance personnel.

(b) Where the transit right-of-way is crossed by a pedestrian walkway, the barrier should effectively prevent objects being dropped on the right-of-way or on passing transit cars.

(c) Acceptable vehicular barriers include highway guard rails, barrier curbs, structural walls and earth embankments.

3.5 PATRON PROTECTION

The design of transit facilities and equipment should be carefully considered to assure the security of transit patrons.

3.5.1 Police Services Protection of the transit patron from crime is an important aspect of design. Persons familiar with security and police protection should be consulted and plans for transit system reviewed during the initial design phases to ensure incorporation of appropriate measures. The cooperation of the transit authority and local government is mandatory for assurance of patron security.

One of the important early decisions to be made by a transit authority is whether to set up a special transit police force or to rely solely on local police protection of patrons on the transit property. Costs and jurisdictional responsibilities should be studied thoroughly as well as crime rate incidences in certain areas and the reaction time required by the authority or local police force under various circumstances.

The transit authority could also consider establishment of a coordinating security force of its own which would work in harmony with the other local authorities and police agencies along the system. The establishment and maintenance of complete confidence of the traveling public, as well as the flexibility required to properly police a major public facility in various jurisdictions is mandatory.

Whichever method of police protection is selected, the key to maintaining public confidence is to assure patrons of adequate police availability at all times to discourage the incidence of crime. One proven effective method is the actual presence of police in public areas of the transit property, particularly during late evening hours. This is especially important during the early stages of the system after commencing revenue operation.

3.5.2 Closed Circuit Television System A closed circuit television surveillance system (CCTV) can be installed in passenger stations to aid in ensuring the safety and protection of transit patrons. CCTV permits remote surveillance of station platforms, mezzanines and other areas. Video cameras should be strategically located to effectively cover the station platforms and other areas with a minimum of camera positions. The associated video monitors may be located in the station Attendant's kiosk, where this is normally manned, for local surveillance. Consideration should also be given to providing Central Control with the capability of monitoring cameras at each station on a selective basis for additional aid in identifying and rapidly dealing with security problems.

Whereas a CCTV system is not a substitute for adequate police protection, it can be helpful in discouraging various types of crime as well as reducing the reaction time of police, particularly when coupled with effective communication systems.

3.5.3 Communication Systems An effective network of internal communication systems is a key tool in assisting management and operating personnel in providing a safe and efficient rapid transit system. Central control of the transit system communi cations network is necessary to coordinate the various sub-systems of the network. Security functions can be handled efficiently with the following sub-systems.

(a) Internal Telephone System

The telephone system may be part of the main system-wide internal telephone network or Private Automatic Branch Exchange (PABX). The PABX may be owned, operated and maintained by the transit authority or owned and partially maintained by the local commercial telephone system. If the latter is selected, it is usual to have that portion of the system located in hazardous areas, such as the track level in the running tunnels, maintained by transit authority personnel. Access to the common carrier network will be provided through the PABX system.

Telephones should be installed at regular locations along the rights-of-way such as emergency power trip stations, emergency crossovers, substations, tie-breaker stations, signal rooms and other critical points. Provisions should be made to receive emergency calls from each telephone directly at an emergency console located at Central Control. When these telephones are used for other than emergency calls, facilities should be provided for pre-empting other calls during emergencies.

In passenger stations, emergency telephones should be located at least at each end of each train platform and in the station attendant's kiosk. Consideration should be given to the station attendant being able to monitor emergency calls originating in his station.

Consideration should also be given for provision for the automatic monitoring and tape recording of all conversations made during emergencies. The time of each conversation should also be noted automatically.

(b) Passenger Information System

In each passenger station a public address (PA) system should be provided which will allow input from Central Control and locally from the station attendant's kiosk. The PA system should also permit Central Control staff monitoring CCTV to speak to patrons in the station. The system should comply with the provisions of Section 9.

The PA system should also be extended to non-public areas of the station for paging of security and main tenance personnel.

(c) Mobile Radio System

Probably the most effective aid in providing for the security of system patrons is the mobile radio system. This systemwide network can be used by security personnel to facilitate the rapid assignment and movement of personnel throughout the system. A special channel of the radio system should be pro vided for maintaining constant communication between security field personnel and security headquarters. A dedicated common carrier line may also be provided between security headquarters, which will be manned during all hours of system operation, and local fire, ambulance and police dispatch units.

Security personnel at Central Control should be in close proximity or at least be provided with facilities for constant communication with the main Central

Control system supervisor for rapid and coordinated effort in dealing with security problems.

Field security personnel should be provided with light, portable radio units for communication with Central Control from any point in the system.

(d) Carborne Communication Equipment

Carborne communication equipment should provide for two-way communication between Central Control and the train attendant. One-way communication to the passengers from the train attendant and from Central Control should also be provided. Provisions may be made for automatic announcements of station stops and route connections over the train PA system.

3.6 PROPERTY PROTECTION

Protection of transit authority property is another function of the security system.

3.6.1 Intrusion Alarm System A system may be provided for the protection of property and safety of system patrons by the detection of unauthorized entry to areas of the transit property. The system should be divided into specific zones centered on each passenger station. The station attendant may be provided with an alarm board indicating all points of detection within that particular zone. When unauthorized entry into any restricted area is detected, a local alarm can be sounded at the point of entry and a light flashed with an audible signal at the station attendant's kiosk. Simul taneously, an alarm can be sounded at Central Control indicating the station zone in which the local condition has occurred. Specific examples of restricted areas are traction power substations, station train control and communication rooms, kiosks and station security closure facilities.

3.6.2 Vandalism One of the serious and costly problems facing transit properties is that of controlling vandalism within the public areas of the system and on revenue vehicles. This problem should be fully recognized by the system designers all materials and details specified to discourage vandalism and simplify cleaning and maintenance. If vandalism occurs, damage should be corrected quickly to discourage further violations.

3.7 PASSENGER STATION DESIGN

Architectural design concept influences security. This point cannot be overemphasized in the planning of new systems. A few general comments regarding station design as it influences security follow:

(a) An open, spacious design within the limits of economics, provides patrons with a feeling of security. Open stairwells, elimination of or reduction in the number of columns on station platforms, high ceilings, and generally uncluttered design all contribute to a sense of patron safety.

(b) Elimination of dog-leg passages, dark corners and reverse stair landings improve security design.

(c) Station design should provide for maximum direct surveillance by the station attendant or by closed circuit TV.

(d) The maximum use of glass within the bounds of maintainability can often improve surveillance and security.

(e) Good lighting design is mandatory. The concept of "increased lighting/decreased crime" has been proven on the streets of many cities.

3.7.1 Entrance Barriers The selection of suitable entrance barriers is important to system security. Patron convenience and passenger station aesthetics are also directly influenced. Entrance barriers include station security closure facilities, platform barriers, fare collection facilities and related barriers in the mezzanine or fare collection areas.

3.7.2 Station Closure Facilities Station security closure facilities should be provided at all entrances to passenger stations unless the system remains in service continuously. Closures should be sturdy, aesthetically pleasing yet easily closed, locked and maintained. The closure barriers should be located to minimize the amount of transit authority equipment, stairs and passageway exposed to the public during non-operating hours. This will reduce maintenance, vandalism and loitering on system property. A closure barrier near an escalator can be a hazard to patrons if the barrier is closed and space does not exist at the leaving end to allow dispersal of users. When locating closure barriers near escalators, caution should be taken to avoid these hazards.

A barrier system must be designed and used in conjunction with fare collection facilities to divide paid and unpaid areas of the station. These barriers must be sturdily constructed of easily maintained materials in a height suitable to the type of station entrance. Barrier heights are covered in a subsequent section. Each barrier must be provided with a wide pass gate which can easily be opened by the station attendant or others in the event of an emergency requiring rapid evacuation of the station. These gates supplement the turn-stile egress facilities. Gate widths and number of turnstiles should be designed to suit individual station volumes under emergency conditions. One 5 foot wide pass gate per entrance can be considered a minimum. The pass gates at entrances which are manned full time, may be opened by a simple concealed latch or remotely from the station attendant's kiosk. Pass gates and turnstiles at unmanned entrances must be remote controlled.

3.7.3 Unattended Entrances Unattended entrances are often installed to reduce operating costs of the system. Some passenger stations may be designed with two entrances, one on each end of the station, to improve service to the public by providing more direct access to the station. The transit authority might decide to man both entrances only during peak operating hours. In this case the secondary entrance could be closed off entirely by the use of security gates to prevent entry to the mezzanine area both from the street and station platform. When the entrance is closed, the patron should be clearly informed and redirected by the graphics system.

The secondary entrance might also be used during off-peak hours but unmanned. In this case surveillance and patron assistance could be provided by a system of CCTV and a two-way PA system which would allow direct communication between patron and station attendant.

If the transit authority adopts a policy of allowing entirely unmanned stations a CCTV and PA system and direct telephone communication are required for patron assistance with fares and other problems. These communication links would then be installed between station fare collection area and Central Control.

System capital and operating costs should be researched thoroughly to determine the economics of unmanned stations. Additional security costs and revenue loss through non-payment of fares could offset potential savings.

3.7.4 Fare Collection Facilities The selection of fare collection facilities does not involve the security of patrons directly. The degree of sophistication provided by automatic equipment is more a matter of concern to the operating staff who are responsible for revenue collection. However, the style of equipment is influenced by security problems. In areas of potential security risk unattended entrances might be provided with high entrance and exit turnstile equipment. The revenue collection equipment including pay turnstiles, ticket vending equipment, money changers, transfer machines and related revenue collection equipment, should be well secured in place and be designed to discourage robbery attempts.

3.7.5 Barrier Heights There are two types of station entrances which affect fare collection barrier heights:

(a) Attended entrances should be provided with a barrier rail system with a minimum height in the 38 to 42 inch range. This system could also be used where transit authority policy dictates for unmanned entrances having CCTV surveillance or other types of security precautions.

(b) In unattended areas and wherever proper fare collection presents a serious problem, a high barrier should be considered to complement the high entrance and exit turnstile facilities. These barriers should be at least 7 feet in height and provide a positive physical barrier between paid and unpaid areas of the station.

3.8 REVENUE COLLECTION SYSTEM

Initial planning for rapid transit facilities should include adequate consideration of currency collection and distribution of tickets. Currency collection should be frequent to minimize the amount of stored cash. There is a wide divergency in procedures now used by transit authorities. These include collection of revenue:

(a) By outside security agencies using regular armored car, surface vehicle facilities.

(b) By transit authority using surface security vehicles.

(c) By transit authority in specially designed rail cars.

The revenue collection system involves the transport of money from the passenger station fare collection equipment to a central accounting and auditing facility and, ultimately, to the bank.

Security measures to be taken will vary widely with the collection method selected. Collection tasks must be handled without disruption to normal service.

Basically, revenue collection must be divided into well defined and scheduled tasks. All contact with actual money by personnel outside the authorized counting station should be avoided. Controls should be established to preclude collusion and theft of funds from within the organization.

Special equipment might be designed to facilitate revenue collection and storage of tickets and money within the transit system, depending on the collection procedures. This equip ment might include vaults, money handling carts, security containers and similar items. Vaults within transit stations should be guarded by a well conceived intrusion alarm system.

Security arrangements during revenue collection should be co ordinated with the local police departments and insurance companies.

SECTION 4

FIRE PROTECTION

4.1 INTRODUCTION

The severity of the hazards of a fire in a building or structure is affected by:

(a) The amount and type of combustible materials in the area.

(b) The type of construction.

(c) The means of egress provided for the building occupants.

(d) The accessibility of the structure to fire-fighting equipment.

In Rapid transit structures of non-combustible construction, except in occupied areas such as areas containing equipment rooms, storage areas or concession areas, the potential fuel contribution to the fire hazard is normally very low. Smoke is a prime hazard and the use of materials that produce large volumes of dense or toxic smoke when ignited should be limited in usage within the structure, equipment and rolling stock of rapid transit properties. Elimination of combustibles within the structure and the isolation of fire loads of occupied areas from the means of egress through proper compartmentation are major fire safety factors.

4.2 DEFINITIONS

Non-Combustible Construction. Construction minimizing the hazards of fire by the use of non-combustible materials, for structural elements or assemblies, and by limiting the amount of combustible materials that are incorporated into the building construction.

Fire Resistant Non-Combustible Construction. Non-combustible construction which has a fire resistance rating through application of a protective fire resistive membrane such as masonry or concrete to supporting steel.

Fire Resistance Rating. An hourly rating assigned to a tested element or assembly by the Underwriters Laboratories Inc., or other recognized authority.

Fire Load. The average weight of the combustible contents of a room or floor area in pounds per square foot, including the building materials, furnishings, equipment, and transit vehicles.

Fire Separation. A barrier against the spread of fire and the migration of smoke having a fire resistance rating.

4.3 REQUIREMENT TO RESIST FIRE SPREAD AND COLLAPSE IN BELOW GRADE STRUCTURES

Public Areas. The floor and roof assemblies, load bearing walls, columns, beams, and arches should be of non-combustible construction. Public areas forming part of an exit from platform to street level should be separated from service areas used for storage and concession areas by a fire separation in which all glass shall be wired glass. Occupancies adjacent to below grade public areas should have a fire load not exceeding 10 p.s.f.

Service and Concession Areas. The floor and roof assemblies, load bearing walls, columns, beams and arches should be of fire resistant non-combustible construction. Areas below grade used as storage areas or concession areas should be sprinklered. The fire resistance rating of protected supporting steel or fire separations should be determined by the occupancy fire load.

4.4 STANDPIPE AND HOSE SYSTEM REQUIREMENTS

Standpipe and hose stations should be located within the rapid transit structure in accordance with the requirements of local authorities.

In addition, hose stations may be located on the platform so that all portions of a rapid transit vehicle can be reached by the hose stream while the vehicle is stopped within the length of the platform.

Hose stations may be located in a hose cabinet containing hoses, reels, fittings and a portable fire extinguisher. Fire Department connections should be provided for all standpipe systems.

4.5 PORTABLE FIRE EXTINGUISHERS

Portable fire extinguishers should be installed in all machine, electrical rooms and collector’s booths.

4.6 FIRE ALARM AND FIRE DETECTOR SYSTEMS

A fire alarm system connected directly to the Fire Department and to a central supervisory station, should be installed in each station.

To avoid panic conditions, the system should be so designed that the alarm signal is conveyed to employees and the Fire Department, and be supplemented by a public address system for use in sounding a general alarm for evacuation.

A communication system should be installed in all unmanned fare collection or control areas to permit reporting of emergency conditions to the Fire Department or a central supervisory station.

An automatic fire detection system should be installed in all concession areas, storage areas, machine rooms and electrical rooms. Where automatic sprinkler systems are installed and provided with water flow alarm signals which will fulfill the functions of automatic fire detection requirements, (in addition to their primary function of fire extinguishers), such may be used in lieu of automatic fire detection systems. Smoke detectors may be used in lieu of fire detecting devices.

The design of the fire alarm system and fire detection or smoke detection system should be in accordance with the authority having jurisdiction.

SECTION 5

LIGHTING

5.1 PURPOSE

An inviting image of comfort, pleasantness, cleanliness and security must be created for transit facilities. Lighting is one of the means by which such an atmosphere is established. These criteria are intended as a guide to photometric performance, component design and selection of lighting equipment to achieve the desired environment.

5.2 SCOPE

These criteria cover normal and emergency lighting systems for the proper illumination of passenger stations, underground, at-grade and aerial structures, parking and bus loading areas, car storage yards, transit vehicles, and other special structures.

5.3 STANDARDS, CODES AND REFERENCES

The following codes and references should be used to guide design:

National Electrical Code (NEC)

Illuminating Engineering Society Lighting Handbook (IES)

Canadian Standards Association (CSA) in Canada

5.4 ILLUMINATION LEVELS

These criteria are a guide to minimum illumination levels considered acceptable in operating properties for passenger safety and convenience. After thorough evaluation by the designer, a standardized lighting fixture arrangement might be adopted, because of economic or architectural considerations, which would create illumination levels above or below the general range suggested. However, a minimum lighting level must be maintained to promote safety of passengers from tripping hazards, particularly during rapid transfer to and from trains, as well as safety from crime. A brightly lit station with a minimum of dark corners or narrow, circuitous passageways facilitates surveillance and tends to discourage crime.

Particular attention should be paid to passenger station entrance areas. Lighting should provide for a comfortable transition from street to station entry area. Illumination levels should be increased during daylight hours to minimize the otherwise abrupt change from outdoors to indoors. The use of photoelectric cells for the operation of additional lighting fixtures should be considered as a means of achieving this feature.

Standardization of illumination levels for similar areas throughout the system is desirable. The levels suggested are intended to produce a restful background free from dis orderly, irrelevant patterns of overly bright lighting fixtures. They should not preclude, however, delightful and exciting public areas where variations in illumination levels add interest and exhiliration to the environment.

The difference in illumination suggested should be used to create patterns of light and avoid a completely bland appearance. Light patterns and sign illumination, for instance, can be used to aid in passenger orientation and focus attention on fare collection equipment, telephone facilities, advertising and other station features.

5.4.1 Passenger Stations

	Recommended Minimum Maintained Illumination Levels (fc)
Platform, subway	20
Platform, under canopy, surface and aerial	15
Uncovered platform ends, surface	5
Mezzanine	20
Ticketing area - turnstiles	30
Passages	20
Stairs and escalators	25
Fare collection kiosk	100
Concessions and vending machine areas	30
Elevator (interior)	20
Above ground entry to subway (day)	30
(night)	10
Washrooms	30
Service and utility rooms	15
Electrical, mechanical and train control equipment rooms	20
Storage areas	5

5.4.2 Surface Passenger Loading Areas

	Recommended Minimum Maintained Illumination Levels (fc)
Bus loading platforms	5
Streetcar loading platforms	5
Bus and streetcar loops	2
Kiss and ride areas	5

5.4.3 Parking Areas

Self-parking	2
Pedestrian walkways	3
Entrance and exit roadways	2

The illumination on all entrance and exit roadways shall be graduated up or down to the illumination level of the “feeder” street or highway.

5.4.4 Transit Rights-of-Way and Storage

Underground		1.5
Entrances and exits within	(Night)	1.5
300 feet of portal	(Day)	10
On grade and aerial structures		0.5
Underground special trackwork areas		3
Yard and other special trackwork areas		2
Transit vehicle storage areas		1

5.4.5 Operations Central Control Building

Central Control Area

Lighting depends on the type of panels. General lighting should be designed to complement panel lighting and should be capable of being dimmed.

General illumination	100*
Face of Control Panels (vertical)	150*
Rear of Control Panels (vertical)	10
Dispatch Desks (horizontal, desk level)	50
Emergency Lighting	3

*Illumination levels should be variable ± 50 percent of levels indicated.

5.4.6 Passenger Vehicles

	Recommended Minimum Maintained Illumination Levels (fc)
Interiors	30

5.4.7 Calculation of Illumination Levels The normal methods of calculating illumination levels are outlined in the IES Lighting Handbook. The levels suggested in the criteria are intended to be average, maintained, in service values.

The working plane for illumination is assumed at floor or track level except in vehicles where a 33-inch high working plane at 45 degree is used as a reading plane reference at seats.

5.4.8 Maintenance Factors (MF) An average maintenance factor for use in all areas of transit system lighting other than offices should not exceed:

$$MF = 0.65$$

This recommendation is based on station platform environment which is assumed to be maintained on a good, regular basis. Certain system areas remote from train operation will have a cleaner atmosphere which could justify a somewhat higher MF based on the same maintenance program. However, even remote areas of a passenger station are usually subjected to com paratively high air currents which carry dust and dirt to all parts of the system. In other areas, such as tunnels between stations, the atmosphere is dirtier, and maintenance might be more sporadic but the requirement for an exact minimum main tained illumination level is less.

5.5 BRIGHTNESS RATIOS

5.5.1 Typical brightness ratio between stairs, escalators, etc., to general platform or mezzanine areas should be approximately - 2/1

5.5.2 Station interiors should have luminance ratios typically not to exceed:

Wall to floor	- 3/1
Wall to ceiling	- 1/3
Luminous coffers to walls and/or adjacent horizontal surfaces	- 10/1
Luminaires to adjacent surfaces	- 20/1

5.5.3 Elevated Stations (at night) Exterior Areas

Wall to floor	No limit set
Wall to ceiling	No limit set
Luminaires to adjacent surfaces	- 40/1

5.5.4 Substations, switchrooms and control rooms should have luminance ratios not to exceed:

Wall to floor	- 3/1
Wall to ceiling	- 1/3
Luminaires to adjacent surfaces	- 20/1

Luminaires in control rooms in particular should be so positioned that no reflected glare from meter faces or cathode ray tube monitoring screens meets the operator's eyes while at his normal operating position. Non-specular glass should be used on meter faces.

5.5.5 Small areas for accent, design interest, or message purposes, such as for station identification, safety or guidance, will be allowed to have brightness ratios in excess of the preceding criteria.

5.6 GLARE

Rapid transit lighting facilities should be designed to minimize direct glare from lighting sources by the proper choice of location, number, luminance and shielding of luminaires.

5.6.1 Discomfort Glare Rating (DGR) The DGR should not be greater than 90 for indoor lighting. This affords complete visual comfort for 65 percent of the population.

5.6.2 Rights-of-Way Lighting Luminaires between stations should be shielded to prevent direct glare from obstructing vehicle attendants view of the track area.

5.6.3 General Outdoor Lighting Special care must be taken to avoid direct glare from outdoor lighting which will affect adjacent properties. This is particularly important in residential areas.

5.7 REFLECTANCE

The system environment should be designed for visual comfort and free from glare and high contrast ratios.

5.7.1 Recommended Reflectance Value Ranges

Ceilings	60 to 95 percent
Walls	45 to 75 percent
Floors	15 to 55 percent

These values are for the dominant area only.

5.7.2 Specular Surfaces Careful consideration needs to be given to the proper coordination of architectural and lighting designs if specular (glossy) materials are chosen for major surfaces. Reflected glare must be minimized for passenger comfort.

5.8 EMERGENCY LIGHTING

All underground stations, subways and tunnels must have emergency lighting supplied from an independent source, such as batteries or standby generators. In all cases the emergency lighting should conform to the codes and regulations of authorities having jurisdiction over public safety. The emergency system should allow for a minimum of three hours continuous operation and shall have a maximum start up time of three seconds. Emergency lighting may be used as part of the general lighting system.

5.8.1 Illumination Levels

Area	Minimum Illumination Levels (fc)
Passenger station areas including platform, mezzanines, ticketing areas, passageways, and entrances	1
Service and utility rooms, washrooms	0.5
Electrical service rooms	1
Stairs, escalators	2
Fare collection kiosks	5
Underground track areas	0.25

5.8.2 Illuminated Signs Exit lights and essential signs shall be included on the emergency lighting circuits.

SECTION 6

SUBWAY VENTILATION

6.1 GENERAL REQUIREMENTS

The objectives of ventilation in subway structures are to:

- Provide a comfortable environment for patrons and staff.

- Provide, in the event of fire, control of smoke migration; and, an effective means to purge smoke and supply fresh air to patrons and fire department personnel during evacuation and fire fighting operations.

- Provide for the removal of equipment-heat generated through normal operation of system elements including trains, lights, and electrification and train control equipment, so that the normal life expectancy of such equipment will not be reduced.

- Provide positive control of condensate and haze, and removal of objectional or hazardous odors and gases.

6.2 STATION VENTILATION

Two conceptual means of ventilating public spaces within stations are available:

(1) Ventilation through the piston-like action of moving trains through a relatively close-fitting tunnel section, and

(2) Mechanical means.

A discussion of each follows:

Piston-Action Ventilation. Through careful design of station configuration, it is often possible to provide effective ventilation through the use of the piston-action developed when trains are operated in the subway tunnels. The effect of this type of ventilation is dependent upon the type of tunnels and vent shafts provided on the line sections; the stair and passageway configurations of the station; and the type of closures provided at entrances to the station as well as train speeds and frequency of operation.

The effectiveness of this type of ventilation can be predicted using mathematical analysis or scale model tests. Where it is considered that piston-action ventilation will not be effective in providing enough air changes to remove the heat, then mechanical ventilation should be installed to supplement the piston-action to adequately remove the heat and provide a minimum of four air changes per hour.

Mechanical Ventilation. Mechanical ventilation of public spaces is achieved through the incorpora tion of fans situated in the subway at locations selected to ensure a satisfactory ventilation rate, together with auxiliary equipment including air intake and exhaust structures at grade and plenums and other distributive ductwork at the various levels within the structure to exchange station and outside air. Ventilation of special areas of concern, such as electrical or mechanical service rooms, washrooms and the station agents' booth, is usually provided through an independent means supplying or exhausting air at a rate appropriate to the use of the area using filters where necessary to control the quality of the air.

It should be recognized that the patrons in the public subway spaces are in transit between the outdoor conditions and the passenger cars for a relatively short period of time, and, consequently, there may be no necessity for providing an environment within these spaces superior to the existing outdoor conditions if these are satisfactory.

6.3 LINE SECTION VENTILATION

Normal Ventilation. The primary purpose of providing for positive and effective ventilation of trainway spaces under normal (non-emergency) conditions is to ensure that the heat generated from fixed and rolling stock equipment and people is carried off at a rate sufficient to preclude an objectionable temperature rise in such spaces and avoid the presence of offensive odors.

Normal ventilation can be supplied through piston-action developed from trains operating through the subway tunnels. To be effective and to ensure an adequate number of air changes for heat removal, ventilation shafts must be located between stations to facilitate exhaust and supply of air. The vent shafts must be designed to provide a direct route to atmosphere with care taken to avoid unnecessary bends or other restrictions to air flow. Vent shafts should be equipped with dampers to allow variable control of the ventilation.

The subway tunnels must be designed to provide a high blockage ratio of train to structure cross-section so that a large percentage of the air mass will be forced ahead of the operating train rather than allowed to short circuit around it. From a ventilation standpoint, separate tunnels enclosing each trainway are more efficient than a larger tunnel enclosing two or more trainways because of the decrease in piston action due to a low blockage ratio. Through mathematical analysis or scale model tests the most effective size, shape and location of vent shafts can be predicted.

During periods of no train movement when there is no piston-action the ventilation must be provided by mechanical means.

<u>Emergency Ventilation.</u> The primary objective of emergency ventilation is to control smoke migration by supplying fresh air and exhausting smoke at an appropriate rate as an aid in evacuating passengers and in fire fighting. The location of the fan shafts is contingent upon the location of the vent shafts and the volume of air to be handled. The fans could be reversible so that air can be supplied or exhausted depending upon the operating requirements of the circumstances being dealt with.

The fan shafts must be located relative to the vent shafts and stations to ensure that all sections of the subway and stations can be purged under emergency conditions. Dampers installed in the vent shafts may be operated to facilitate the mode of operation required to remove smoke or cope with the particular emergency situation.

The ventilation rate is dependent upon ensuring a satisfactory supply of fresh air to evacuees in the event of fire and the purge rate for entry of maintenance personnel or return to service. It is assumed that a ventilation rate that satisfies the purge rate will ensure an acceptable supply of fresh air to evacuees and fire fighting personnel.

It should be recognized that a fire generating large volumes of smoke requiring operation of the emergency ventilation system has probably caused extensive damage to equipment and facilities within the subway and will involve a major outage of service therefore a high ventilation rate is not warranted. A minimum velocity of flow of 4 feet per second is recommended for sizing of fans and appurtenances. In tunnels where normal ventilation will be provided through mechanical means the fans should be sized to ensure adequate removal of the heat.

Vent and fan shaft openings on the surface should be located in areas which are free as possible from fumes caused by vehicle traffic and other air pollutants so that these pollutants are not drawn into the subway environment. Acoustic treatment of the shafts should be considered to reduce noise levels transmitted from fans and operating equipment in the subway.

Fans for emergency ventilation should be connected to two power feeders from separate sources and should be operable through remote controls located at a central station.

SECTION 7

ACOUSTICS

7.1 GENERAL

Contemporary environmental control can create an artificial environment in buildings that will meet all the physical, psychological and physiological demands of the occupants. It is not necessary to go to this extent in a transit system environment, but it is necessary that the environment be improved over conditions that often exist today. By so doing, the comfort of the passenger will be increased and marginal passengers encouraged to use the system.

In addition to operational acoustical problems to be overcome for the benefit of system passengers, rapid transit operation can have a significant impact on the community. There is a growing awareness of noise pollution and its effect on the environment. Today's transit system designer is confronted with not only technical problems to solve but in many areas overriding social problems relating to the community will dictate design solutions, particularly in this field.

7.2 SCOPE

For the purpose of these guidelines, "acoustics" will be defined to include all noise and vibration control problems relating to rapid transit system operations.

7.3 GOALS

The two basic-goals of the rapid transit industry in its effort to control noise and vibration are:

- To provide system patrons with an acoustically comfortable environment by maintaining noise levels in vehicles and stations within acceptable limits.

- To reduce the impact of system operation on the community by minimizing transmission of noise and vibrations to adjacent properties.

The acoustical performance of a rapid transit system will depend on the consideration that has been given by the designer to noise and vibration problems during the design phase.

General problem areas to be considered during design are:

7.3.1 Improving Acoustical Environment For Patrons This is achieved through control of noise and vibrations in transit vehicles, in underground stations, in tunnels, and in above-ground stations. Particular attention must also be given to patron noise exposure caused by traffic in open stations adjacent to highways.

7.3.2 Reducing Impact on the Community Increased community acceptance requires control of air-borne noise from surface and aerial transit operations, and from transit ancillary areas, such as yard operations, vent and fan shafts of the ventilation system, electrical substations and air conditioning chiller plants. The design must also provide control of ground-borne vibrations and resultant noise from subway operations.

7.4 NOISE AND VIBRATION SOURCES

The designer should identify the various potential sources of noise and vibration within the transit system. Noise generators may be subdivided into three general areas.

7.4.1 Vehicle Running noise including wheel-on-rail noise, such as rolling, side slippage of the wheel across the railhead, wheel slippage on curves, wheel flange bearing on restraining rail and side of running rail, and collector shoe running on third rail.

Under-car equipment noise including noise radiation from car trucks, wheels, drive gears, traction motors, compressors, brake shoe bearing on wheel tread, motor alternators and air conditioning condenser fans and refrigerant compressors.

Car interior noise such as ventilating or air conditioning fan noise.

Noise radiated by rattling components, such as doors, seats, coupling guard rails, air conditioning louvres and windows.

7.4.2 Trackwork Particular noise sources are special trackwork, track curves, rail irregularities, restraining rails, mechanical joints and insulated joints.

7.4.3 Structures and Equipment Noise and vibration radiated by way structures and equipment such as ventilating fans, car noise from vent shafts, escalators, vibrating panels, metal ducts, doors and equipment covers, substation transformers, transit maintenance facilities, air conditioning chiller plant fans and cooling towers.

7.5 EFFECTS OF NOISE AND VIBRATION

An understanding of the effects of noise and vibration is necessary for the establishment of acceptable acoustical criteria. Acousticians have measured and substantiated a broad range of effects; however, other effects are less well known. The effects of noise and vibration include:

- PSYCHOLOGICAL EFFECTS, including annoyance, interference with rest or sleep, interference with work performance and interference with sound communication.

- ECONOMIC EFFECTS, such as decreased property values or interference with commercial activities.

- PHYSIOLOGICAL EFFECTS, including discomfort levels, permanent hearing loss, temporary hearing loss, and other general effects on health.

7.6 CRITERIA FOR NOISE AND VIBRATION IN VEHICLES AND STRUCTURES

Noise and vibration control methods should be developed to ensure compliance with criteria which are based on some measure of human response to noise. There are two basic types of noise criteria:

Criteria Based On Ambient Noise Levels. This type of criterion uses limits based on the difference between the noise in question and the prevailing ambient noise. Criteria based on ambient noise levels are often used to set objectives for remedial design in existing systems. They are generally applicable in problems relating to the system impact on the community.

Ambient noise levels in the community have been rising rapidly in recent years. Criteria based on ambient levels should be reviewed periodically to determine whether or not the ambients will have any significant effect on the public.

Absolute Limit Criteria. These criteria use absolute limits related to measurable physical quantities. They usually deal with hearing damage and protection, speech communication or interference with other tasks and subjective reactions such as annoyance and are used in ensuring an acceptable acoustical environment for passengers and employees of the system.

The use of absolute limit criteria in design problems relating to system impact on the community should be considered carefully. There is a wide variation in public reaction that can occur even at the same noise levels.

Factors which may affect public reaction to noise, besides the fact that a noise is new and higher than existing ambient level, include high socio-economic status, property ownership, duration and frequency of noise, previous community exposure, nature of the community and its previous success with com plaints. However, the primary objective in good transit design should therefore be to reduce annoy ance rather than simply reduce complaints.

The purpose of these criteria is to establish good practice guidelines in modern rapid transit design for those designing and planning new facil ities. Deviations from these guidelines would generally be necessary to achieve compatibility with existing transit equipment. The guideline cri teria are not intended for, nor are they to be confused with, noise abatement controls of the type already enacted or propsed in various communities.

The following bases have been used in establishing criteria herein:

Noise or sound levels are measured with a sound level meter which meets the Type 2 requirements of American National Standard (ANS) S1.4-1971, Specification for Sound Level Meters.

All noise levels are A-weighted sound levels, per (ANS) S1.4-1971, in decibels referenced to 0.0002 microbar.

The “slow” meter response is assumed for all noise level measurements except those involving measure ments of moving and transient sources such as exter ior train noise, train noise from vent shafts and car door operation. The latter sources should be measured using “fast” meter responses.

Table A, Summary of Transit Noise and Vibration Criteria, is a compilation of criteria discussed in subsequent sections of this guideline.

TABLE A

SUMMARY OF TRANSIT NOISE AND VIBRATION CRITERIA

Section	Item	Criteria
7.6.1	TRANSIT VEHICLES, NOISE AND VIBRATIONS	
7.6.2	Vehicle Interior Noise Levels (Empty car)	
	In open (ties and ballast) at maximum speed	68 dBA
	In open (concrete trackbed) at maximum speed	72 dBA
	In tunnels at maximum speed	78 dBA
	All auxiliaries operating, car stationary	65 dBA
	One auxiliary system operating, car stationary	60 dBA
	Door operation	65 dBA
7.6.3	Vehicle Exterior Noise Levels (50 ft. from T & B track)	
	Car stationary, auxiliaries operating	60 dBA
	Two-car train at 80 mph	86 dbA
	Two-car train at 60 mph	82 dBA
7.6.4	Vehicle Equipment Noise Levels (15 ft. from car)	
	Propulsion system at equivalent to 80 mph	90 dBA
	Propulsion system at equivalent to 60 mph	84 dBA
	Car stationary, auxiliaries operating	65 dBA
	Decrease in criteria for presence of pure tones	3 dBA
7.6.5	Vibration Levels	
	Measurements taken on car interior surfaces unless noted. Displacements measured peak-to-peak. Velocity and acceleration are:	

Section	Item	Criteria
	Maximum amplitude	0.10 in.
	Maximum acceleration, up to 10 Hz.	0.01 g.
	Maximum velocity, 10 Hz. and over	0.03 in/sec.
	Maximum amplitude on detached traction motors	0.0015 in.
7.6.6	NOISE IN UNDERGROUND STATIONS	
	Platform level, trains entering and leaving	80 dBA
	Platform level, trains passing through	85 dBA
	Platform level, trains stationary	67 dBA
	Maximum train room reverberation time	1.6 to 2 sec.
	Platform level, only station ventilation system operating	55 dBA
	In station attendants' booths	45 dBA
7.6.7	NOISE IN ABOVE-GROUND STATIONS	
	Platform level, trains entering and leaving	70-75 dBA
7.6.8	NOISE IN SUBWAY TUNNELS	
	Min. design reduction in reverberant noise levels with acoustic treatment	10 dBA

7.6.1 Transit Vehicles, Noise and Vibrations The transit car specifications should include both definitions of the desirable limits for noise and vibration and the procedures and techniques to be used in testing for conformance with the specifications. The tests should include determination of acoustical performance of car components, equipment and complete car assembly.

Experiments have been made to evaluate the various physical measurement scales to determine those scales which most closely correlate with subjective evaluations of noise. For most typical noise such as street traffic, transit vehicles and general community noise, it has been found that the sound level meter "A" weighting scale gives good and adequate correlation with subjective evaluation of response to noises. Thus the "A" weighted sound level, which can be read directly from a sound level meter, is best for evaluating, on an engineering basis, the probable response of people to the noise created by transit car noises.

To the human ear a random noise with audible pure tone is more annoying than the simple random noise even if both noises have the same A-weighted sound level. The specifications should include controls over pure tone noise.

Noise criteria specified assume the following:

> Car interior noise criteria apply to measurements taken in a complete but empty car and made 4 to 6 feet above the car floor at all points 1 foot or more from a wall surface.
>
> Exterior noise criteria are based on measurements taken in essentially a free-field environment away from reflective or shielding surfaces.

7.6.2 Vehicle Interior Noise Levels For ease of communication and passenger comfort the sound level should not exceed 68 dBA. Under normal operating conditions, at maximum speeds, on ties and ballasted track in the open, this noise level represents a realistically attainable goal and a datum upon which other noise criteria can be based. In all vehicles for public conveyance it is desirable to maintain a background sound level which will afford some degree of speech privacy for passengers. Efforts to significantly reduce interior sound levels below this criteria would be undesirable. Standardizing noise measurements, both interior and exterior, with cars operating on ties and ballasted track in the open, reduces the number of variables which arise when the trains are operated through or on the many varieties of structure used in mass transit systems today.

Interior noise levels when operating on concrete trackbed at-grade or on aerial structures should not exceed 72 dBA at maximum speeds.

In underground structures a goal of 78 dBA maximum could be established. This would likely require acoustical tunnel treatment or additional care in the acoustical design of the vehicles if they are to be operated extensively at maximum speeds underground.

A consistent goal for background noise created by the car auxiliary equipment and the air conditioning and ventilating system when the car is stationary, is 65 dBA or less. Similarly, with any one of the auxiliary systems operating, such as the air refrigeration or heating and distribution system, the motor alternator, the air compressor or equivalent, the motor control system and traction power motor cooling blowers or cooling system, the car interior noise level should not exceed 60 dBA.

Noise produced by operation of only the vehicle doors should not exceed 65 dBA measured 1 foot or more from the door.

7.6.3 Vehicle Exterior Noise Levels With the vehicle stopped and all systems operating simultaneously under normal conditions, the noise level measured 50 feet horizontally from the track centre line 4 feet above grade or at the axle centre line elevation, whichever is higher, should not exceed 60 dBA at any point along the length of the car on either side.

Similarly, when a two-car train is moving on tangent, at-grade, ties and ballasted track with smooth ground rail at 80 mph with all vehicle systems operating simultaneously, the noise level should not exceed 86 dBA measured 50 feet from the car centre line. Similarly at 60 mph noise levels should not exceed 82 dBA.

7.6.4 Vehicle Equipment Noise Levels When traveling at high speed the principal noise sources are the propulsion system, motors and gearing, and the wheel/rail system. At medium speeds the wheel/rail noise usually predominates while at higher speeds propulsion system noise predominates. Care must be exercised then in the design and maintenance of both systems.

Propulsion system noise level criterion should be 90 dBA maximum with propulsion motors and wheels operating at rpm equivalent to 80 mph. Similarly, 84dBA should be the criterion for operation at 60 mph. This criterion should be checked at 15 feet from the car centre line by placing the car on jacks and allowing free-wheeling. Measurements to be taken at the level of the truck axles.

A limit of 65 dBA, at 15 feet from the car centerline, should be established as appropriate for noise levels from auxiliary equipment when the car is stationary. The criterion includes air brake noises such as the rapid release of “dumping” of air at terminals.

These criteria should be reduced 3 dBA if significant pure tones in the range from 300 Hz. to 4000 Hz. are present. Pure tones are significant if any 1/3 octave band sound pressure level is 4 dB, or more, higher than the average of the two adjacent 1/3 octaves containing no pure tones.

7.6.5 Vibration Levels The primary purpose for limiting vibration levels caused by equipment and auxiliaries mounted anywhere on the car is to prevent the car door and seals from vibrating at levels which would be annoying to passengers. In general, the response of people is approximately proportional to vibration ACCELERATION at frequencies below 10 Hz. and to vibration VELOCITY for frequencies above 10 Hz. Human sensitivity to horizontal vibrations is 30 percent to 70 percent of sensitivity to vertical vibrations.

It is appropriate to limit the maximum amplitude, at very low frequencies in particular, to prevent visual perception of vibration. The maximum amplitude should therefore be limited to 0.10 inch, peak-to-peak, at any frequency. Similarly, vibration criteria should limit car vibrations to within the "barely perceptible" to "distinctly perceptible" ranges. Up to a frequency of 10 Hz. vibration acceleration levels should be limited to 0.01 peak (3.84 in./sec./sec.) and above 10 Hz. velocity levels should not exceed 0.03 in./sec. peak. These criteria pertain to measurements of vibration from car equipment made anywhere on the car floor, walls, and seat frames.

The vibration of any traction motor, detached and supported on resilient mountings having at least 0.25 in. static deflection with equivalent horizontal and vertical stiffnesses, should not exceed a displacement of 0.0015 in. peak-to-peak measured anywhere on the motor running at speeds corresponding to maximum and half-maximum running speeds.

7.6.6 Noise In Underground Stations Trains operating at top speeds of 80 mph and using maximum acceleration and braking levels could enter or leave stations at about 50 mph depending on platform length, approaching and leaving grades, station spacing and other factors. Noise levels should be limited to a maximum of 80 dBA by an appropriate acoustical design. In the case of express trains operating through the stations, noise levels should be limited to 85 dBA. Absorption materials to control noise must be applied and for adequate noise reduction about 30 percent coverage of walls and ceilings will likely be necessary depending on the size and shape of the train room.

Stationary car noise should be limited to 65 dBA at 15 feet from the train. Station noise levels should therefore be limited to about 67 dBA maximum anywhere on the train platform.

A limit of about 1.6 to 2.0 sec. maximum should also be placed on the reverberation time in the station to reduce speech interference. Low reverberation times are desirable but depend on station size and design as well as acoustic treatment. This should allow intelligibility of public address system announcements and patron voice communication.

Ventilating system noise is probably the simplest to control by selection of the fan locations and acoustical design of the fans. Since this noise may be regarded as steady state during lengthy periods of operation, an appropriate design criterion for station platforms would be 55 dBA.

In station attendants' booths the noise level should be limited to 45 dBA.

7.6.7 Noise In Above-Ground Stations In above-ground stations noise levels will be governed by train operations. A maximum noise level criterion of 70-75 dBA as measured on the train platforms should be established.

Station location is a potential problem, particularly when train platforms are located in a highway median. An appropriate acoustical design can relieve an otherwise serious noise problem created by traffic noises for platform patrons.

In some instances, where open station platforms are in close proximity to busy airports, it may be impractical and uneconomical to apply the above criteria to noise from aircraft operations. Some measure of protection should be afforded the passenger, however, such as appropriately designed acoustical shelters to minimize directional noise. The upper noise level criteria for train operations in underground stations of 85 dBA is suggested for uniformity.

7.6.8 Noise in Subway Tunnels Appropriate noise abatement techniques should be used to reduce extreme noise levels from high speed train operation in tunnels to an acceptable level. A criterion of 78 dBA for interior car noise at maximum tunnel operating speeds is recommended. An acoustical absorption system may be provided in the tunnels or additional sound insulation may be provided on the cars to meet this criterion. Tunnel sound absorption treatments can, for instance, provide 5 dB or more reduction in noise levels inside the car. Reducing tunnel noise by a sound absorption system improves the acoustical environment for system employees and aids in complying with the hearing conservation requirements of the Occupational Safety and Health Act.

7.7 CRITERIA FOR NOISE AND VIBRATION IN COMMUNITY

The purpose of this subsection is to consider the effect of noise and vibration on the community because of its importance in influencing public acceptance of the system. Sources of wayside intrusions or annoyance due to noise and vibration created by a rail transit facility include:

Airborne noise from surface and aerial train operation.

it is possible for persons sitting and listening to detect an intruding transient sound when it is about 5 dB less than the background noise, particularly where pure tones are present.

There are two basic types of airborne noise from ancillary facilities, transient and steady-state. Transient noise occurs during passages of trains, for example. Usually night time headways are relatively infrequent when noise problems are critical. Steady-state noise may be characterized by fan noises or noises from electrical substations and chiller plants. The criteria for acceptable levels of the two noises can differ. Transient noises are acceptable at higher levels than steady-state noises, particularly steady-state noises containing pure tones.

In defining noise levels from ancillary systems, the four general categories of urban or suburban area defined in Table B will be used. Table D suggests noise levels in each of these categories which, if not exceeded by the transit operation noises, should result in general community acceptance.

TABLE D

CRITERIA FOR NOISE FROM ANCILLARY TRANSIT FACILITIES

		Noise Level Criteria	
	Area Category	Transient	Steady-State
1.	Quiet residential	45 dBA	40 dBA
2.	Average residential	50 dBA	45 dBA
3.	Busy residential, semi-commercial	55 dBA	50 dBA
4.	Commercial/open	60 dBA	55 dBA

7.7.3 Groundborne Noise And Vibration

Vibration levels from modern transit cars and track are below the threshold of perception in most circumstances. However, these levels are still sufficient to generate a low frequency rumbling noise which can signal the passage of a train. This noise level is frequently of sufficient loudness to create a significant intrusion or annoyance.

By utilizing recent experience in track and vehicle design vibration levels from normal transit operations can be reduced sufficiently to prevent significant intrusions of noise in buildings at distances of 50 to 100 feet or more, depending on building construction type and quality, occupancy, type of subway structure, train speed, etc. However, where there is special trackwork, such as turnouts and crossovers, and at points where buildings are less than 50 feet from the tunnel centre line, there might be need of additional vibration reduction measures within the subway such as isolated invert or floating slab construction. There are also some special cases where buildings, such as hospitals and medical labora tories next to tunnels contain equipment sensitive to mech anical vibration. These cases will require further investigation and the possible use of further vibration reduction measures such as isolation within the building itself.

The principal noise sources in modern buildings are the air conditioning and ventilating systems and background noises transmitted into the building from street traffic. Noise and vibration from these sources will often exceed those generated by transit operations.

The most critical locations where noise could create intrusion are sleeping rooms and auditoriums or concert halls. Since sleeping rooms are most common and found in various classes of residences, interior noise criteria relating to these areas should be considered in the same area categories as airborne noise from transit ancillary equipment.

For the three categories of residential area the background noise in sleeping spaces is generally different and the allowable noise level can be greater in the noisier areas. Table E indicates the range of levels for transient noise generated by mechanical vibration of the building structures, which should be acceptable to the community if not exceeded. It would be unreasonable in most cases to design for a noise level that is undetectable by occupants. The low level transient noises generated by groundborne vibrations from passing trains must be made unobtrusive but not necessarily undetectable.

TABLE E

NOISE CRITERIA FOR INTERIOR SLEEPING AREAS

	Area Category	Building Type And Sleeping Space Description	Groundborne Noise Level Criteria
1.	Quiet residential	Private residences	25 to 30 dBA
		Apartments	30 to 35 dBA

Area Category	Building Type And Sleeping Space Description	Groundborne Noise Level Criteria
2. Average residential	Private residences	30 to 35 dBA
	Apartments	35 to 40 dBA
	Hotels	40 to 45 dBA
3. Busy residential	Private residences	35 to 40 dBA
	Apartments	40 to 45 dBA
	Hotels	40 to 45 dBA

Similarly, Table F presents generally acceptable noise levels in occupied spaces of various types of buildings. This Table is not intended to be all inclusive but may be a convenient general guide to the designer.

TABLE F

MISCELLANEOUS ROOM NOISE CRITERIA

Type of Building or Room	Groundborne Noise Level Criteria
Auditoriums and Concert Halls	25-30 dBA
Churches and Theaters	30-35 dBA
Music Rooms and TV Studios	30-35 dBA
Hospital Sleeping Rooms	35-40 dBA
Courtrooms	35-40 dBA
Schools	35-40 dBA
University Buildings	35-40 dBA
Offices	40-45 dBA
Commercial Buildings	45-50 dBA

Noise caused by the vibrations which meets the design criteria listed above will not be inaudible in all cases, however, the level will be sufficiently low that no significant intrusion or annoyance should occur. In most cases, there will be noise from street traffic, other occupants of a building, or other sources, which will create intrusion that is greater in level than the noise from transit trains passing by in adjacent tunnels.

SECTION 8

GRAPHICS

8.1 GENERAL

The most important single criterion in graphics is orientation. The need for orientation places great emphasis on maps and a consistent system and style of identification and directional signing. Graphics then emerges as a major factor in the design of each element of the system, a factor that must be given high priority in the early design phases of each project. A graphics standards manual should be prepared by the operating authority to coordinate the efforts of designers working on various parts of the system and serve as a guide for up-dating the system. Signing and graphics policies must be controlled to ensure continuity of the graphics system.

8.2 GUIDELINES

Graphics requires the "systems approach". Arriving and departing passengers have distinctly different needs. The designer must work out a continuous path of graphics from the street to the train and from the train back out to the street.

The principal guidelines promoting good graphics design in station design are:

- Use one style of lettering for all graphics in stations, on cars and on surface vehicles, including all station name signs.

- Segregate advertising from information graphics.

- Avoid advertising at critical decision-making points.

- Provide illuminated signs at station entrances.

- Locate information signs at decision points for maximum visibility.

- Provide map space immediately adjacent to fare collection equipment and at other decision points such as platform areas and interior of vehicles.

- Locate station name signs so they may be easily seen by passengers in transit cars.

- Signs directing motorists to, or within, station areas must be coordinated with appropriate Federal and State highway standards.

The supplemental guidelines promoting good graphics design in station design are:

- Locating advertising opposite departing and waiting passengers, in linear clusters and with accent lighting.

- Relate advertising in groups to special conditions of structure, where possible.

- Walls at ends of passageways, opposite major entrances, or leading to exits, or opposite turnstiles, should be kept free of miscellaneous doors and advertisements so that they may be used for information graphics.

- Consideration may be given to color coding of lines and stations.

- Consider relating outbound passengers to surrounding community with appropriate signage.

- Design map mounting system to allow easy replacement and up-dating of maps.

- Consider use of automatic destination signs for lines with a number of branches or terminals.

SECTION 9

PUBLIC TELEPHONES AND COMMUNICATIONS

9.1 GENERAL

Rapid transit facilities require many and different forms of communication equipment. Each transit system has its own communication support needs, such as local and remote control public address facilities for cars, stations and platforms; television monitors of specific public areas; telephone between central control and agents or attendants, or patrons in trouble with automatic fare control; plus intricate electronic control devices to operate and control trains.

It is the intent of this Section to set guidelines for public communications facilities only, which will normally be required at passenger stations.

It is generally desirable that public telephone service be provided for transit patrons. Such service may be located in both paid and free areas with enough telephones provided to eliminate waiting time in all but extreme conditions.

9.2 PUBLIC TELEPHONES

Many factors determine the number of telephones to be furnished for transit patrons. Some factors to be considered in making this determination are:

- Number of patrons on and off at the transit station.
- Patrons' mode of arrival at and departure from station.
- The station environment.
- Terminal, on route or interchange station.

The telephone company can furnish guidelines for the number of phones required, but it is considered advisable to install a minimum number and make provisions for additional units as experience dictates.

9.3 PUBLIC ADDRESS SYSTEM

A public address system should be provided for use by the station agent and the central operations supervisor for making announcements. It should be used only in special circumstances as the station design should provide visual announcements that will suffice for all routine communications to passengers.

The public address system may also be used in conjunction with the station intercommunication system to call the station agent to his telephone when he is away from his booth. This may be accomplished by a coded chime. Other coded chimes may be used for fire alarm.

9.3.1 Design Characteristics There are two general types of public address systems; one a high level type using large high powered speakers located at relatively high elevations. This system is generally best utilized in outdoor locations and for addressing concentrations of people in small areas, but should be used with discretion in residential areas. The preferred type of system is a moderate or low level sound system where relatively low powered speakers are located at frequent intervals to provide wide area, uniform sound coverage.

The public address system should be designed for moderate sound levels throughout, with speakers spaced at frequent intervals and arranged to give good coverage of all public areas, with no objectionably high close-range spots. The variation in sound level from position to position in a given area should not exceed six decibels. The objective of the public address system is to provide high fidelity speech reproduction at ear level throughout the station. The public address system should be on emergency power circuits.

9.3.2 Volume Control Automatic volume control, based on the ambient sound level of each area, may be required to regulate the speaker volume of that area. Microphones should be mounted in the ceiling or on columns in heavy traffic spots to sense the ambient noise.

Speakers' volume level should exceed the average background noise by 15 to 20 db. The background noise may be as much as 80 db therefore, the system should have the capacity to provide a sound level up to at least 95 db at ear level.

9.3.3 Switching Switching may be provided so that messages may be directed to appropriate areas of the system.

SECTION 10

CONCESSIONS

10.1 GENERAL

A well defined policy for concessions should be established by the transit agency before commencing station design. In determining this policy, anticipated concession revenues and patron convenience should be weighed against all of the costs involved. Such costs include provision of space, maintenance, refuse removal, and the control of vandalism and loitering.

10.2 CONCESSION AREA

Concessions may be located in either the paid or free area. The free area is preferred because of the elimination of problems associated with non-transit employee access. It is not recommended that concessions be located in platform areas.

Concessions should be so located that they do not interfere with transit patron movements and concession signs located so that there is no interference with station graphics. Specifically, care should be exercised to assure that concessions do not impede movement on stairways and escalators, in corridors and in fare collection areas. Allowance should be made for the delivery of concession materials without obstructing patron flow through the station.

10.3 TYPE OF VENDING

Vending over a counter is preferred. This system offers full time supervision of concession operations, and the presence of an attendant provides additional station surveillance. A prime duty of the attendant should be that of keeping the concession area clean and free from debris. Otherwise, the transit agency must provide these services.

Automatic vending has become accepted for a wide range of articles, but such a system requires surveillance and may present maintenance problems.

10.4 CONCESSION FACILITIES

Station lighting arrangement should provide for the concession area. Depending upon the type of concession, electrical outlets and water and waste facilities may be necessary. Considera tion should be given to the separate metering of electrical facilities.

Concession facilities should be so designed that they can be isolated from the rest of the station when not in use and made secure.

SECTION 11

SANITARY SERVICES

11.1 GENERAL

Building codes often specify details of type, number and location of toilets that must be provided in public buildings. Structures such as rapid transit stations may not be covered by the local building code, and if such is the case, a policy should be developed by the transit agency in regard to its obligation to furnish toilet facilities. If a policy of freely providing for all patrons is adopted, the facilities should conform to applicable local codes or to the require ments of Uniform Building Code (UBC) of the International Conference of Building Officials.

It is essential to provide sanitary facilities at each station for transit employees. These may consist of single water closets and wash bowls for men and for women. At terminals and principal stations, emergency public facilities should be considered. Where public facilities are available, it is appropriate to keep them attended or locked with access upon request.

11.2 VENTILATION

Adequate ventilation as specified in local codes or UBC should be provided. Special attention must be given to exhaust locations, being cognizant of air currents generated by transit vehicles.

SECTION 12

FACILITIES FOR THE PHYSICALLY HANDICAPPED

12.1 INTRODUCTION

In establishing a policy relating to provisions for handi capped patrons the operating authority must give consideration to the safety of all its patrons and the cost of providing the facilities. Through appropriate design it is possible to accommodate many persons with physical disabilities such as loss of sight, loss of hearing, incoordination, disabilities due to age, and semi-ambulatory or non-ambulatory disabilities. The specific problems that must be considered in design are orientation, horizontal travel, vertical travel, passage through fare collection equipment, transfer from the train platform to the transit vehicle, and egress under emergency conditions within the stations or tunnels. Facilities for the handicapped are described in USA Standards Institute A 117.1-1961 "Making Buildings and Facilities Accessible to and Useful by the Physically Handicapped". On those properties which are required by policy or law to provide facilities for the physically handicapped, definitions and detail requirements may be obtained by reference to this Standard. Modifications to this standard may be adopted where for safety or economic reasons it is considered appro priate to encourage the patronage of specific segments of the handicapped. At the same time consideration may be given to providing a separate transportation service designed for and dedicated to the use of special groups of the handi capped such as the non-ambulatory.

12.2 PURPOSE

The purpose of this section is to establish design guidelines to make transit facilities used by the public, accessible to, and functional for the physically handicapped, without loss of operating capability where the general public is concerned.

12.3 SITE DEVELOPMENT

Public walks should be at least 48 inches wide and should have a gradient of not greater than 5 percent. Such walks should be of a continuing common surface, not interrupted by steps or abrupt changes in level. When walks cross other walks, driveways or parking lots, they should blend to a common level.

Parking lots should have spaces that are accessible and approximate to the transit facility and set aside and identified for use by individuals with physical disabilities.

A parking space open on one side, allowing room for individuals on wheel chairs or individuals on braces and crutches to get in and out of an automobile onto a level surface, suitable for wheeling and walking, is adequate. Parking spaces for individuals with physical disabilities when placed between two conventional diagonal or head-on parking spaces should be 12 feet wide. Care in planning must be exercised so that individuals in wheel chairs and individuals using braces and crutches are not compelled to wheel or walk behind parked cars. Consideration should be given the distribution of spaces for use by the disabled in accordance with the frequency and persistency of parking needs.

12.4 STATIONS OR BUILDINGS

12.4.1 Ramps with Gradients Where ramps with gradients are necessary, the ramp should have a slope no greater than one foot rise in 12 feet or 8.33 percent. A ramp should have handrails on at least one side and preferably two sides that are 32 inches in height, measured from the surface of the ramp, that are smooth and extend one foot beyond the top and bottom of the ramp. This requirement may be at variance with local building codes in which case two sets of handrails should be installed to serve all people. The ramp should have a surface that is non-slip and should have a level platform at the top of the ramp if a door occurs at that location. Each ramp should have at least 6 feet of straight clearance at the bottom and should have level platforms at 30-foot intervals or where turns occur in the ramp.

12.4.2 Entrances and Exits At least one entrance and exit to each station should be usable by individuals in wheel chairs.

12.4.3 Doors and Doorways Doors should have a clear opening of not less than 32 inches when opened and shall be operable by a single effort. It is recommended that all doors have kick plates extending from the bottom of the door to at least 16 inches from the floor. The floor on the inside and outside of each doorway should be level for a distance of 5 feet from the door in the direction of the door swings and should extend one foot beyond each side of the door. Where possible thresholds should be flush with the floor.

12.4.4 Stairs Stairs should have handrails 32 inches high as measured from the tread at the face of the riser. Stairs should have at least one handrail that extends at least 18 inches beyond the top step and beyond the bottom step. Handrails should have no stub ends; they should either return to the adjacent wall or bend down 180 degrees. Steps should, wherever possible and in conformance with the existing step formulas, have risers that do not exceed seven inches.

12.4.5 Floors Floors should have a non-slip surface and should be of a common level throughout and be connected by a ramp or elevator. Floors adjacent to unprotected areas of danger, such as platform edges, should have surfaces with a different finish to the general finish to aid those with sight disabilities in identifying the danger.

12.4.6 Controls Switches and controls for use by the general public such as fire alarms, elevator controls, and similar controls of frequent or essential use should be placed within the reach of individuals in wheel chairs.

12.4.7 Identification Appropriate identification of specific facilities within the transit facility used by the public is particularly essential to the blind.

Essential facilities should be indicated by raised letters or numbers.

Doors that are not intended for normal use and not kept locked, but might prove dangerous if entered by the blind, should be made quickly identifiable to the touch by knurling the door handle or knob.

12.4.8 Warning Signals Audible signals should be accompanied by visual signals and visual signals by audible signals, for the benefit of those with hearing or sight disabilities.

12.4.9 Elevators In a multiple-story building, or station, elevators are essential to the successful functioning of non-ambulatory physically disabled individuals. They should conform to the following requirements:

(a) elevators should be accessible to, and usable by, the physically disabled on the level that they use to enter the building, and at all levels normally used by the general public;

(b) elevators should allow for traffic by wheel chairs.

12.4.10 Fare Collection Gates A service gate at least 3 feet wide should be accessible to the physically handicapped. Operation of the gate may be controlled either by the attendant or by fare collection equipment. If the gate is controlled by equipment, the equipment should be designed for use by the blind.

SECTION 13

STATION FINISH MATERIALS

13.1 GENERAL

The selection of materials and the choice of finishing details are important considerations in assuring a satis factory operating transit system, years after the architect and engineer have completed their tasks of constructing the system.

The interior aesthetics of the station is an important factor in determining the public acceptance of a rapid transit system. Functional efficiency will not assure ridership if the design does not assure a pleasant inviting station environment. Colour and texture may be used to aid in passenger orientation. Where colour coding is used care must be taken in selecting materials to ensure colours compatible with the coding requirements.

A pleasant environment is achieved through the selection of materials and details that not only have aesthetic value at the time of opening the station, but will continue to do so through years of public use. The materials must be able to endure and resist accidental and intentional abuse by the patrons of the system, therefore, must be resistant to breakage, markings, dirt and many other attacks upon it. The air within a subway usually consists of outside air, further contaminated with dirt produced from the wear of brakes, wheels, rails and moving parts of equipment within the subway.

During the selection of station finish materials, it is important that a cleaning program be considered and possibly developed as the materials are being selected. The cleaning and maintenance program is directly related to the selection of finish materials and has a considerable effect on the total cost of the operating transit system. Maintenance problems are usually simplified through the use of as few different materials as possible.

13.2 FLOORS

Floors in heavy wear areas should have a wear surface separate from the structural slabs to facilitate replacement.

Floors should have a dense, low absorption and soil resistant surface that provides good traction for pedestrians.

Non-slip materials at platform edges and on stair nosings should be used to improve safety.

Flood drains should be installed adjacent to outside walls in below grade structures to prevent seepage water from spilling over large floor areas, causing a slipping hazard.

13.3 WALLS

Walls should be of a dense dirt resistant, polished, enamelled or glazed surface to reduce cleaning and maintenance costs.

Exterior walls in below grade structures should have a cavity between the structural wall and the finish wall to avoid moisture damage to the station finish in the event of groundwater infiltration. Drainage holes should be provided at the bottom of the cavity.

Walls should be started on a floor base to facilitate floor cleaning.

13.4 CEILINGS

Ceilings must be designed to be resistant to damage or soiling and be easily cleaned. Where suspended ceilings are used of the tile or pan type construction, the minimum floor to ceiling height should be 9’-0” to discourage damage by vandals. This type of construction must also include a suspension system sufficiently rigid to resist air flows and pressures resulting from train operations within the rapid transit tunnels. Ceilings offer an effective means of controlling noise levels within the subway station areas, and the designer should therefore give serious consideration to the use of ceiling materials designed for the attenuation of sound.

13.5 DOORS

Doors should be faced with plastic or other damage resistant material to reduce maintenance costs.

13.6 MISCELLANEOUS METALS

Handrails and metal trim should be of stainless steel, anodized a1uminum, or other low maintenance material.

SECTION 14
WATERPROOFING

14.1 GENERAL

In the design of transit systems, particular attention must be given to the maintenance of a safe and satisfactory environment for the patrons, the finish materials and the installed equipment. This is especially true underground, where exposure to high humidity and uncontrolled penetration of groundwater can create an undesirable and in some cases unsafe atmosphere. The only practical means of controlling the effect of groundwater on the system's environment is the provision of waterproofing. This Section of the guidelines discusses the types of structures found in transit systems and waterproofing techniques found suitable for these structures. Waterproofing materials are also reviewed.

14.2 STRUCTURES

For the purposes of this guideline, structures have been classified into open cut cast-in-place concrete structures, including cut-and-cover line and station structures, and tunnel structures. In general, the relationship of the groundwater to the structure falls into one of two categories. In the first, the level of groundwater or other water source is above the crown of the structure. In this condition large water volumes and high hydrostatic pressures may be present, and extreme care must be used in designing and installing waterproofing. In the second, the elevation of groundwater is low relative to the crown. However, in this case the roof of the structure may be subjected to periodic water flows and localized pressures.

In both cases the designer must consider the relationship of the structure to the water elevation, the nature of the water source, the importance of the structure being protected, and the construction type. In any case, the importance of workmanship on the watertightness of the structure cannot be overemphasized.

14.2.1 Open Cut Cast-in-Place Structures These structures, commonly termed cut-and-cover structures, have external elements which are normally designed to meet or exceed a minimum thickness usually 18 inches or 24 inches. Specifi cations will require the concrete to have a low water-cement ratio, with compressive strength normally in the 3000+ range.

Joint spacing of structural units should be controlled to avoid undue shrinkage cracking. Quality workmanship is of utmost importance and proper construction inspection is necessary to minimize honeycombing and other imperfections which provide water paths. It has been found that shrinkage cracking and accompanying water penetration through shrinkage cracks is satisfactorily controlled using careful workmanship and joint spacing in the range of 40 to 65 feet.

Joints other than bonded construction joints should be protected by a waterstop. Selection of the waterstop should consider the adverse construction conditions in which the waterstop is installed. Ease of correct installation is paramount, particularly at splices and bends, as is proper field inspection of the waterstop installation. Contraction joints below groundwater elevation may be further protected using bentonite panels or bentonite gel applied to the exterior surface of the joint.

In all cases, the extent of waterproofing beyond these considerations will depend on the function of the structure, the groundwater level relative to the structure, and the experience of the property. In all cases positive drainage channels should be provided in the invert, and exterior surfaces should be sloped to minimize ponding.

Cut-and-Cover Line Structures. Line structure unit lengths and contraction joints should follow the criteria above. Since the structures are massive structures not exposed to public occupancy, some leakage may be tolerated. Competent workmanship, consideration of minimum structure thickness, and provision of easily installed waterstop at contraction joints should be sufficient to result in an acceptably watertight structure.

Cut-and-Cover Stations. Since the appearance and atmosphere of the station establishes to a great extent the environment for the patron, careful consideration should be given to thorough waterproofing of station areas. In addition to waterstop and joint spacing criteria, consideration should be given to construction joint waterstops and exterior roof and wall waterproofing, either membrane type or bentonite panels applied to the structure exterior.

It positive drainage is provided behind station finish materials, it may be possible to control leakage without exterior wall waterproofing other than at joints by intercepting the water and directing it to the drainage system.

Consideration should be given to designing joints to accommodate drip pans at critical joint locations such as expansion joints, joints between existing and new work and where there is an abrupt change in areas where leaks are likely to occur.

<u>14.2.2 Tunnel Structures</u> Tunnel structures in soft ground consist of metallic or precast concrete segmental linings, or cast-in-place concrete. In rock, tunnel lining may be cast in place or shotcrete. In all tunnels waterproofing becomes a problem wherever the tunnel lies below the groundwater table.

<u>14.2.3 Soft Ground Tunnels</u> With cast-in-place concrete lining in wet ground, waterproofing is generally limited to waterstops at construction joints and seals at interfaces with other structures.

Segmental tunnel linings composed of flanged segments, either bolted metal or precast concrete bolted or unbolted, are generally manufactured to close tolerances; however, leakage will occur between the flange faces unless a positive waterproofing system is provided. This should be sufficiently flexible to remain competent as the lining distorts with the ground movement and the segment joints tend to open over the course of time.

Where segmental linings are used, normally waterproofing difficulties have led to the use of metallic liners either cast iron or steel.

Segmentally lined tunnels in wet ground require waterproofing which can comprise of several systems including: Shield tail space grouting, gaskets and caulking in the segment interfaces, and gaskets at the interfaces with other structures. While external coatings are sometimes applied directly to the segments, it is usually to prevent corrosion rather than to provide waterproofing.

It should be noted that it is customary in shield driven tunnels to fill the void space between the tunnel shield and the liner, thus minimizing settlement as well as distributing load to the liner. Two generally acceptable methods of filling the space which is left between the earth and the outside of the segmental lining as the shield advances are:

(a) Pea gravel, followed at a later stage with a cement grout injection.

(b) A one shot injection of cement/sand (plus sometimes pea gravel). This method provides some waterproofing of the lining. With the addition of chemical compounds, bentonite or fly ash and with a controlled injection technique, one shot grout can be an effective water barrier, though it must usually be supplemented with joint caulking.

14.2.4 Rock Tunnels Cast-in-place concrete or shotcrete lined tunnels in rock are generally drained using weep holes, chases, pans or pipes to control and direct water inflow to the tunnel drainage system. Where external water-proofing is required, an attempt is normally made to close off the paths of water in the rock using injection grouting.

14.3 WATERPROOFING MATERIALS

Waterproofing materials can be classified into two broad categories: The first category includes those materials which by their nature are installed as barriers. Waterstops, membranes, caulking, grommets and gaskets fall into this category.

The second category consists of those materials which by their nature flow, thus sealing openings through which water can penetrate the structure. Sand-cement or epoxy grout and bentonite fall into this category.

14.3.1 Barrier-Type Waterproofing

Membranes. Membrane waterproofing applied to the exterior surface of the structure has been used for years by various operating properties with varying success. Many properties continue to specify membrane waterproofing; others have found that it has not been worthwhile.

Membrane waterproofing consists of an exterior application of either built-up asphalt or other fiberous material with 3 to 5 layers of fabric, according to the magnitude of the water pressure, or an envelope butyl or neoprene sheets bonded together and bonded to the concrete. Membranes must be securely sealed into continuous reglets at discontinuous edges and sealed through to the waterstops at joints. Membrane waterproofing applied to the shoring before concrete is placed or to the structure roof before backfilling is susceptible to tearing or other disruption, thus seriously affecting its effectiveness. After application, the membranes should be protected with at least 2 inches of concrete on horizontal surfaces and with plywood, hardboard or insulation board of suitable thickness on vertical surfaces.

Waterstops. Waterstops are flexible members installed imbedded at joints of cast-in-place concrete structures to bridge the joint, flex with structure movements, and block the passage of water. Waterstop types should be selected on the basis of ease of proper installation, particularly where turning and bonding of waterstop is required. In addition, the waterstop should be flexible and resilient when stressed and rigid during construction. The performance of the several types of waterstops available is largely a matter of workmanship during installation, and the necessity of proper workmanship and inspection cannot be overemphasized.

Caulking, Gaskets and Grommets. Caulking, gaskets and grommets are waterproofing installations used in segmental tunnel liners.

Caulking. Caulking consists of inserting a packing material between segments after erection. Grooves typically 1-inch to 1-1/2 inch by 1/8 inch wide are provided in the outside face of the inner flange full perimeter of the segment. When the segments are erected, a 1/4 inch wide groove is formed. Caulking proceeds as follows:

(a) Lead. Lead in strip form is inserted in the groove and caulked tightly with air actuated tools. For best results, the groove should be well cleaned immediately prior to the caulking operation and the lead should fill the groove. Disadvantages of lead, apart from cost, is the fact that it will loosen if movement occurs in the segment joint. However, where it is accessible it can be tightened effectively by recaulking. Due to the caulking pressures created, it has not been practical to use lead with concrete segments.

(b) Asbestos Cement Yarn. This is often used in the grooves of concrete segments and the requirements and methods of installation are essentially the same as lead. Asbestos cement yarn appears to have some elasticity under small movements. Asbestos cement has the disadvantage of being difficult to install in wet conditions.

(c) Expansive Yarn with Epoxy Back-Up. Two layers of a treated jute core magnesium sulphate filled braded yarn are caulked into the flange perimeter grooves. The remaining groove space is then filled with an epoxy, which provides positive retention of the yarn under the water pressure.

(d) Neoprene "O" Ring. This system also has proved satis factory in development tests. A neoprene strip is forced into the flange toe grooves. Either the neoprene or the groove is pre-coated with an amine epoxy.

Gaskets. Gaskets are preformed fillers which are placed between the liners as they are erected.

(a) Grooves are provided between the bolts and the earth face of the segment on the four external flange faces. A continuous neoprene seal convex on the outside face and of greater depth and lesser width than the groove is cemented in the groove with an epoxy compound. When the segments are bolted together the gasket is compressed, sealing the structure.

(b) Grooves are formed in one side and one end flange face of the segment, and a polysulphide rectangular cross section strip of greater depth and lesser width than the groove is bonded in the groove. When the segments are bolted together, the gasket is compressed and the structure is sealed.

Grommets. Segment bolts require grommeting between the washers and the flanges to provide watertightness. Grommet material is often specified as polyethelene; butyl rubber by test would appear to be satisfactory.

Chamfers should be provided around the bolt hole to facilitate the flow of the grommet into the bolt tolerance space when the bolts are being tightened.

14.3.2 Sealant-Type Waterproofing

Bentonite. Bentonite is a highly expansive clay which when wetted is subject to extreme changes in volume. Bentonite can be applied to the exterior of the structure in several different manners, either locally at joints in conjunction with waterstops or over larger areas such as station walls and roofs. The bentonite is supplied in free form, in a gel, as a paste, or in granular form in cardboard panels. Applied to the structure exterior, the wetted bentonite flows with the water, enters the water path and expands, thus sealing the structure.

Bentonite panels can be secured to the structure or to the excavation shoring. The panels should be protected from exposure to moisture prior to concrete placement or to backfilling.

Grouting. Grouting is a traditional method of sealing water-paths in rock tunnels. Usually accomplished from inside the tunnel, grouting is performed using injection devices pumping pressurized grout through drilled holes. Grouting is difficult to control and expensive to perform.

Grouting is also used to pack the annular space left by the tunnel shield skin when constructing shield driven earth tunnels. While providing a measure of waterproofing this grouting is basically for structural purposes.

CHICAGO TRANSIT AUTHORITY

Engineering Department
Merchandise Mart Plaza
Chicago, Illinois 60654

STANDARDS

PART I   GENERAL INFORMATION

PART II   DESIGN CRITERIA

A. CLEARANCE
- Clearance standard – section with gauge dimensions
- Horizontal clearance alternatives at stations
- Horizontal clearance alternatives between stations
- Horizontal clearance alternatives at crossovers
- Overhang on curves
- Horizontal clearance at contact rail transposition

B. TRACK
- Alignment
  - Speed
  - Gauge
  - Track centers
  - Curves
    - Radius
    - Superelevation
    - Speeds on curves
    - Spirals
    - Reverse curves
    - Runoffs
  - Turnouts (special track work)
  - Construction
    - Single track construction on open deck structure
    - Single track construction on ballast
  - Alignment members for ties
  - Guarding
    - Curves
    - Open deck structures
    - Ballasted deck bridges
    - Joint type curve guard rail plate and brace
    - Intermediate type curve guard rail plate and brace

B. TRACK (Cont'd)

Profile
- Gradients
- Horizontal curves on gradients
- Drainage

Protection of right-of-way at grade

C. STATIONS

General

Fare Collection (passenger controls)

Passenger Control Equipment
- Agent's booth
- Turnstile
- Transfer machines

Platforms
- Deck
- Canopy
- Windbreaks
- Ladders to track
- Fool catcher
- Railings

Stairways, Ramps, Horizontal Passageways, Escalators
- Stairways
- Ramps
- Horizontal passageways
- Escalators

Miscellany
- Concessions
- Public telephones
- Anti-climbing
- Drip pans
- Supervisor's booth
- Lighting
- Electric signs
- Convenience outlets
- Paging
- Master keying schedule

D. GRAPHICS

Signing shall conform to the specified operating require ments and shall harmonize with the architectural treatment of the area where installed. Advertising signs shall be installed only in approved frames and only in locations approved by the Authority.

General
- Sign blank details

Passenger Information Signs
- Field of vision
- Station name signs
- Turnstile signs
- Electric signs
- Miscellaneous signs

Advertising Signs
- Sign frames

Trackside Signs
- Installation
- Berth and station signs
- Speed and clear signs
- Clearance signs

E. STRUCTURES

Design procedure
- Standard specifications
- Definition of terms used in AREA specifications
- Clearances
- Open deck construction
- Ballast deck construction

Design loads
- Dead load
- Live load
  - Bridges and elevated structures
  - Deflections
  - Passenger areas
  - CTA rapid transit car axle loads

PART II E. STRUCTURES (Cont'd)

- Distribution of live load
- Impact
- Centrifugal force
- Wind on loaded and unloaded bridges
- Stability of span and towers
- Nosing of locomotives

Design details

- Flange section
- High-strength steel bolts
- Welding

Tables of maximum reactions and moments

PART III) Reserved for future use
PART IV)
PART V)
PART VI)

PART VIII <u>EQUIPMENT</u>

PART IV <u>TRAFFIC DATA</u>

PART X <u>MAPS</u>

DELAWARE RIVER PORT AUTHORITY
Southern New Jersey Rapid Transit System
Administration Building
Benjamin Franklin Bridge Plaza
Camden, New Jersey 08102

Master Standards for Design

April 1964

Section VI Roadway Design

A. General
B. Subbase
C. Pavement Design
D. Intersecting Streets and Roads
E. Curbs and Sidewalks
F. Maintenance of Highway Traffic during Construction

Section VII Drainage

A. General
B. Track Right-of-Way Drainage
C. Station and Parking Areas and Yard Area
D. Roadways
E. Municipal Drainage

Section VIII Public Utilities

A. General
B. Utility Relocations along and within Track Right-of-Way

Section IX Bridge Structure Design

A. General Design Specifications
B. Structure Clearances
C. Basic Design Data
D. Specific Design Criteria
E. Preliminary Studies
F. Final Drawings

Section X Building Structure Design

A. General
B. Standardization
C. Passenger Stations and Platforms
D. Transit Car Maintenance Shop
E. Electrical Substations

Section XI Parking Areas

A. General
B. Curbs and Sidewalks
C. Coin Operated Gates
D. Traffic Control
E. Passenger Shelters and Canopies
F. Landscaping
G. Fencing

Section XII Required Right-of-Way

A. General

Section XIII Construction Items, Quantities & Design Statement

A. Construction Items
B. Quantities
C. Design Statement

Section XIV Completion of Plans

A. General
B. Title Sheet
C. General Plan
D. Estimate of Quantities
E. Geometry Plan
F. Typical and Special Sections
G. Plan-Profile Sheets and Grade Sheets
H. Utility Relocation Plans
I. Structure Sheets and Stage Construction Plans
J. Construction Details and Special Appurtenances
K. Cross Sections
L. Supplementary Drawings – Test Borings

Section XV Specifications

A. General
B. Standard Specifications
C. Design Specifications
D. Departure from Specifications
E. Supplementary Specifications

Section XVI Proposal Estimate

A. General

Section XVII Contract Time Analysis

A. General

Appendices Attached

Appendix A: List of Contracts
Appendix B: New Construction

Bridge Widths – Streets and Roads over Rapid Transit System

Widths – Streets and Roads Under Rapid Transit System

Appendix C: Drainage – Design Curves

Rainfall – Camden, N.J. Area
Inlet Time of Concentration
Area of Grates

Appendix D: Allowable Unit Stresses for ASTM A-441 Steel for Use in Rapid Transit Structures

Appendix E: Allowable Unit Stresses for ASTM A-36 Steel for Use in Highway Structures

Appendix F: List of Contract Items

Appendix G: List of Symbols and Abbreviations

Uniform Building Code of the State of New Jersey available from:

Bureau of Housing Inspection
P. O. Box 2768
Trenton
New Jersey 08625

NEW YORK CITY TRANSIT AUTHORITY
370 Jay Street
Brooklyn, New York 11201

Design Standards Manual

Standards LS

Loads and Stresses

1 Dead Load
2. Live Load
3. Building Load
4. Lateral Forces on Elevated Structures
5. Side Pressure on Subways
6. Eccentric Loading on Sidewall Columns
7. Stresses
8. Combined Stresses

Standards DD

Details of Design for Structural Steel

1. Determinate Design
2. Spans for Calculation
3. Plate Girders
4. Built-up Sections Other Than Plate Girders
5. Net Sections
6. Dimensions and Placing of Rivets
7. Bearing Area of Pins, Bolts and Rivets
8. Welding
9. Bearing at Supports
10. Stiffeners on Beams
11. Stiffeners on Plate Girders
12. Subway Column Details
13. Miscellaneous

Standards AC

Track Alignment and Clearances

1. Alignment
2. Grades
3. Types of Subway Tracks
4. Superelevation
5. Lateral Clearance
6. Permissible Encroachments on Lateral Clearance
7. Vertical Clearance
8. Clearance Tables
9. Formulas for Turnouts and Crossovers
10. Tracks of Reversed Curvature
11. Radial Distance between Circular Curves
12. Crandall's Transition Curve
13. Vertical Curves

Standards WP

General Rules and Details for Waterproofing

1. Waterproofing of Subways
   (a) Roof
   (b) Side Wall
   (c) Invert
   (d) Floors of Side Platforms, Passageways & Entrances
2. Waterproofing at Ventilators at Stations
3. Waterproofing at Ventilators and Drip Pans - at Stations
4. Waterproofing at Ventilators between Stations
5. Sections in Earth - at Stations
   (a) Side Platforms
   (b) Island Platforms
6. Sections in Earth - between Stations
7. Sections in Rock - at Stations
   (a) Side Platforms
   (b) Island Platforms
8. Sections in Rock - between Stations

Standards RC

General Rules for Concrete Design

1. Design Criteria
2. Maximum Allowable Stresses
3. Columns and Struts
4. Details of Construction
5. Anchorage
6. Footings
7. Bearing for Steel Beams
8. Lateral Ties in Walls

Special Standards

Lighting

1. Subway Station Lighting
2. Outdoor Platform Lighting
3. Tunnel Lighting
4. Emergency Lighting

Wire and Cable

Spec.	Group	Index
TGN		General Provisions and Definitions.
TR	0-25	Synthetic Rubber Insulated Wire and Cable.
TP	26-29	Solid Type Impregnated Paper Insulated Lead Covered Cable.
TF	30-38	Asbestos and Asbestos-Varnished Cloth Insulated Wire and Cable.
TC	39-42	Communication Wire and Cable.
TS-1	43-50	Natural Rubber Insulated Signal Wire and Cable.
TS-2	43-50	Kerite Insulated Signal Wire and Cable.
TT	51-54	Fluorocarbon Insulated Wire and Cable.
TU	55-60	National Electric Code Type Wire and Cable.
TH	61-85	Thermoplastic Insulated Wire and Cable.
MISC.		MISCELLANEOUS WIRE AND CABLE
	94	Table 1 Bare Wire and Cable
	96	Table 2 Magnet Wire
	98	Table 3 Varnished Cloth Insulated Cable
	99	Table 4 Old BMT and IRT Passenger Car Wire and Cable (Not to be Re-ordered)

Track Standards

Section Page

SAN FRANCISCO BAY AREA RAPID TRANSIT DISTRICT
800 Madison Street
Oakland, California 94607

Applicable Legislative Acts

California Public Utilities Commission General Orders
California Administrative Code, Title 19, Public Safety
California Electrical Safety Orders
California Industrial Safety Orders

Available from: California Office of State Printing
Sacramento, California

Civil and Structural Design Criteria - 1968

Volume I

1. General
2. Basic Design Policies
3. Geometrics
4. Trackwork
5. Trackway
6. Streets and Parking Lots
7. Utilities
8. Drainage
9. Miscellaneous Standards
10. Unassigned

Volume II

11. Transit and General Loads
12. Reinforced Concrete
13. Prestressed Concrete Design
14. Structural Steel
15. Composite Steel-Concrete
16. Pile Foundations
17. Retaining Walls
18. Aerial Structures
19. Cut and Cover Subway Structures
20. Tunneled Subway Structures
21. System Appurtenances

Electrical Design Criteria - January 1968

Section

1. General

Section (Cont'd.)

2. Electrification
3. Train Control
4. Communications
5. Auxiliary Electrical Systems
6. Lighting
7. Fare Collection
8. Reference Drawings

Manual of Architectural Standards - June 1965

Station Program
Codes
Vehicle Data and Clearances
Aerial Structure
Above Ground Platform Shelter
Acoustics
Advertising
Color
Concessions
Electrical
Fare Collection
Fire Prevention
Heating and Ventilating
Parking and Site Work
Sanitation and Maintenance
Signing
Station Control
Toilets
Train Screen
Vertical Circulation
Materials and Finishes
Door and Access Schedule

TORONTO TRANSIT COMMISSION
1900 Yonge Street
Toronto 7, Ontario

Design Standards Manual

DIVISION 1

OFFICE PROCEDURES

DIVISION 2

DRAWING SCHEDULES & STANDARDS

Part	2.1	Contract Book Schedules
	2.2	Drawing Procedures
	2.3	Drawing Contents
	2.4	Standards
	2.5	Abbreviations

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GENERAL REQUIREMENTS

Part	3.1	Standard Design Vehicle
	3.2	Control of Access
	3.3	Clearance
	3.4	Standard Subway Sections
	3.5	Standard Station Sections
	3.6	Bus Loading Platforms & Turning Movements

DIVISION 4

DESIGN REQUIREMENTS

Part	4.1	Horizontal & Vertical Control
	4.2	Utilities & Paving
	4.3	Structural
	4.4	Architectural
	4.5	Mechanical
	4.6	Electrical

INSTITUTE FOR RAPID TRANSIT

APPENDIX

STANDARDS

OF

TRANSIT AGENCIES

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
Rapid Transit Systems
950 L'Enfant Plaza South, S.W.
Washington, D.C. 20024

Manual of Design Criteria
September 24, 1968

BOOK 1

Section I General

A. Purpose
B. Scope
C. Procedures
D. Glossary

Section II Design Policies

A. General
B. Design Vehicle
C. Cut and Cover Rectangular Sections
D. Double-Track Rock Tunnel Sections
E. Single-Track Rock Tunnel Sections
F. Circular Tunnel Sections
G. Horseshoe Tunnel Sections
H. Surface Track Sections
I. Retaining Wall Sections
J. Turnouts
K. Double Track Aerial Structure
L. Single Track Aerial Structure
M. Acoustical Treatment Allowance
N. Control of Access

Section III Civil

A. Scope
B. Basis of Criteria
C. Control
D. Horizontal Alignment
E. Vertical Alignment
F. Trackwork
G. Clearances

Section IV Utilities

A. General
B. Sewers and Drainage
C. Water
D. Gas
E. Electric
F. Telephone

Section IV Utilities (Cont’d.)

G. Telegraph
H. Paving
I. Fire and Police Alarm Systems
J. Parks
K. U.S. Capitol Grounds
L. Street and Traffic Lights
M. Parking Meters
N. Vaults
O. U.S. Steam Tunnels and Pipes

Section V Structural

A. General
B. Design Codes, Manuals and Specifications
C. Loads and Forces
D. Design Procedures - Earth Retaining Structures
E. Design of Rapid Transit Aerial Structures
F. Soils and Geological Criteria
G. Support of Existing Structures
H. Structural Steel Design
I. Reinforced and Prestressed Concrete Design
J. Design of Circular Segmental Tunnel Liners
K. Temporary Street Decking Systems
L. Ancillary Rooms at Stations
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BOOK 2

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C. Primary Ventilation System
D. Secondary Ventilation Systems
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F. Air Conditioning of Underground Stations
G. Air Conditioning of Ancillary Spaces
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I. Gratings and Miscellaneous Metals
J. Emergency Access Shafts
K. Escalators
L. Vibration Isolation

Section VII Electrical

A. General
B. Scope
C. Glossary
D. Standards and Codes

E. Traction Power

Section VII Electrical (Cont'd.)

F. Substations
G. Auxiliary Electrical Systems
H. Lighting Systems
I. Supervisory Control of Electrical Systems

Section VIII Train Control and Communications

A. General
B. Scope
C. Glossary
D. Standards
E. Rapid Transit System
F. Principle of Automatic Train Control Operation
G. Operating Criteria
H. Automatic Train Protection
I. Automatic Train Operation
J. Automatic Train Supervision
K. Yard Dispatching and Reception
L. Train Control Maintenance Telephone System
M. Communications

Section IX Contract Drawing Standards

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B. Structural Contracts
C. Information to be Supplied by the General Consultants

Section X Yards and Shops

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B. Basic Philosophy - Shops
C. Service and Inspection Shops
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Section XI Rolling Stock

A. General
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C. Car Exterior
D. Car Interior