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21–13

Automated People Mover Standards

This document uses both the International System of Units (SI) and customary units

ASCE

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Automated People Mover Standards

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STANDARDS

In 2006, the Board of Direction approved the revision to the ASCE Rules for Standards Committees to govern the writing and maintenance of standards developed by the Society. All such standards are developed by a consensus standards process managed by the Society's Codes and Standards Committee (CSC). The consensus process includes balloting by a balanced standards committee made up of Society members and nonmembers, balloting by the membership of the Society as a whole, and balloting by the public. All standards are updated or reaffirmed by the same process at intervals not exceeding five years.

The following standards have been issued:

ANSI/ASCE 1-82 N-725 Guideline for Design and Analysis of Nuclear Safety Related Earth Structures

ASCE/EWRI 2-06 Measurement of Oxygen Transfer in Clean Water

ANSI/ASCE 3-91 Standard for the Structural Design of Composite Slabs and ANSI/ASCE 9-91 Standard Practice for the Construction and Inspection of Composite Slabs

ASCE 4-98 Seismic Analysis of Safety-Related Nuclear Structures

Building Code Requirements and Specification for Masonry Structures: Containing Building Code Requirements for Masonry Structures (TMS 402-11/ACI 530-11/ASCE 5-11), Specification for Masonry Structures (TMS 402-11/ACI 530-11/ASCE 6-11), and Companion Commentaries

ASCE/SEI 7-10 Minimum Design Loads for Buildings and Other Structures

SEI/ASCE 8-02 Standard Specification for the Design of Cold-Formed Stainless Steel Structural Members

ANSI/ASCE 9-91 listed with ASCE 3-91

ASCE 10-97 Design of Latticed Steel Transmission Structures

SEI/ASCE 11-99 Guideline for Structural Condition Assessment of Existing Buildings

ASCE/EWRI 12-13 Guideline for the Design of Urban Subsurface Drainage

ASCE/EWRI 13-13 Standard Guidelines for Installation of Urban Subsurface Drainage

ASCE/EWRI 14-13 Standard Guidelines for Operation and Maintenance of Urban Subsurface Drainage

ASCE 15-98 Standard Practice for Direct Design of Buried Precast Concrete Pipe Using Standard Installations (SIDD)

AF & PA/ASCE 16-95 Standard for Load Resistance Factor Design (LRFD) of Engineered Wood Construction

ASCE 17-96 Air-Supported Structures

ASCE 18-96 Standard Guidelines for In-Process Oxygen Transfer Testing

ASCE 19-10 Structural Applications of Steel Cables for Buildings

ASCE 20-96 Standard Guidelines for the Design and Installation of Pile Foundations

ANSI/ASCE/T&DI 21-13 Automated People Mover Standards—Part 1

SEI/ASCE 23-97 Specification for Structural Steel Beams with Web Openings

ASCE/SEI 24-05 Flood Resistant Design and Construction

ASCE/SEI 25-06 Earthquake-Actuated Automatic Gas Shutoff Devices

ASCE 26-97 Standard Practice for Design of Buried Precast Concrete Box Sections

ASCE 27-00 Standard Practice for Direct Design of Precast Concrete Pipe for Jacking in Trenchless Construction

ASCE 28-00 Standard Practice for Direct Design of Precast Concrete Box Sections for Jacking in Trenchless Construction

ASCE/SEI/SFPE 29-05 Standard Calculation Methods for Structural Fire Protection

SEI/ASCE 30-00 Guideline for Condition Assessment of the Building Envelope

SEI/ASCE 31-03 Seismic Evaluation of Existing Buildings

SEI/ASCE 32-01 Design and Construction of Frost-Protected Shallow Foundations

EWRI/ASCE 33-09 Comprehensive Transboundary International Water Quality Management Agreement

EWRI/ASCE 34-01 Standard Guidelines for Artificial Recharge of Ground Water

EWRI/ASCE 35-01 Guidelines for Quality Assurance of Installed Fine-Pore Aeration Equipment

CI/ASCE 36-01 Standard Construction Guidelines for Microtunneling
SEI/ASCE 37-02 Design Loads on Structures during Construction
CI/ASCE 38-02 Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data
ASCE/EWRI 39-03 Standard Practice for the Design and Operation of Hail Suppression Projects
ASCE/EWRI 40-03 Regulated Riparian Model Water Code
ASCE/SEI 41-06 Seismic Rehabilitation of Existing Buildings
ASCE/EWRI 42-04 Standard Practice for the Design and Operation of Precipitation Enhancement Projects
ASCE/SEI 43-05 Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities
ASCE/EWRI 44-05 Standard Practice for the Design and Operation of Supercooled Fog Dispersal Projects
ASCE/EWRI 45-05 Standard Guidelines for the Design of Urban Stormwater Systems
ASCE/EWRI 46-05 Standard Guidelines for the Installation of Urban Stormwater Systems
ASCE/EWRI 47-05 Standard Guidelines for the Operation and Maintenance of Urban Stormwater Systems
ASCE/SEI 48-11 Design of Steel Transmission Pole Structures
ASCE/SEI 49-12 Wind Tunnel Testing for Buildings and Other Structures
ASCE/EWRI 50-08 Standard Guideline for Fitting Saturated Hydraulic Conductivity Using Probability Density Functions
ASCE/EWRI 51-08 Standard Guideline for Calculating the Effective Saturated Hydraulic Conductivity
ASCE/SEI 52-10 Design of Fiberglass-Reinforced Plastic (FRP) Stacks
ASCE/G-I 53-10 Compaction Grouting Consensus Guide
ASCE/EWRI 54-10 Standard Guideline for Geostatistical Estimation and Block-Averaging of Homogeneous and Isotropic Saturated Hydraulic Conductivity
ASCE/SEI 55-10 Tensile Membrane Structures
ANSI/ASCE/EWRI 56-10 Guidelines for the Physical Security of Water Utilities
ANSI/ASCE/EWRI 57-10 Guidelines for the Physical Security of Wastewater/Stormwater Utilities
ASCE/T&DI/ICPI 58-10 Structural Design of Interlocking Concrete Pavement for Municipal Streets and Roadways
ASCE/SEI 59-11 Blast Protection of Buildings
ASCE/EWRI 60-12 Guideline for Development of Effective Water Sharing Agreements

FOREWORD

The Board of Direction approved revisions to the ASCE Rules for Standards Committees to govern the writing and maintenance of standards developed by ASCE. All such standards are developed by a consensus standards process managed by the ASCE Codes and Standards Committee (CSC). The consensus process includes balloting by a balanced standards committee and reviewing during a public comment period. All standards are updated or reaffirmed by the same process at intervals of five years.

This standard is a consolidation of the previous four-part *Automated People Mover Standards*. An automated people mover (APM) is defined as a guided transit mode with fully automated operation, featuring vehicles that operate on guideways with exclusive right-of-way.

Chapters 1–11 cover requirements for design of an APM system, and Chapters 12–16 cover requirements for an APM in passenger operation, including chapters on security; emergency preparedness; system verification and demonstration; operations, maintenance, and training; and operational monitoring.

The standard also includes

- one mandatory annex on system safety program plan (SSPP) requirements;
- one nonmandatory reference bibliography of examples and guidance for other SSPPs;
- one nonmandatory informative annex on inspection and test guidelines; and
- two nonmandatory annexes: Recommended Practice for Acceptance of an APM System Application and Recommended Practice for Working Safely near APM Systems.

The provisions of the nonmandatory annexes and recommended practices are written in permissive language and, as such, offer the user a series of options or instructions, but do not prescribe a specific course of action. Significant judgment is left to the user of these annexes and recommended practices.

The development of these standards began in 1991 with a plan of producing partial standards in sequential segments. The first printing of Part 1, Chapters 1–6, was in 1996; followed by Part 2, Chapters 7 and 8, in 1998; Part 3, Chapters 9–11, in 2000; and the final Part 4, Chapters 1–6, in 2008.

During this early development period, Parts 1, 2, and 3 were reaffirmed on their five-year anniversary, as required by ASCE and ANSI rules and amended as needed.

The ultimate goal was to conduct a concurrent reaffirmation of all 16 chapters in one master volume to better serve the APM industry.

This publication now contains all 16 chapters of the completed standard and will be reaffirmed as needed, at least on a five-year cycle.

This standard establishes the minimum set of requirements necessary to achieve an acceptable level of safety and performance for an APM system. As such, it may be used in the safety certification process. The overall goal of this standard is to assist the industry and the public by establishing standards for APM systems.

This standard has no legal authority in its own right but may acquire legal standing in one or more of the following ways:

- Adoption by an authority having jurisdiction,
- Reference to compliance with the standard as a contract requirement, or
- Claim by a manufacturer or manufacturer's agent of compliance with the standard.

This standard will be beneficial to transportation engineers, civil engineers, safety engineers, and contractors of APM systems. Also, anyone who owns, operates, builds or maintains, designs, tests, insures, oversees, or certifies APMs or other innovative technology transit systems, such as magnetic levitation, air cushion, personal rapid transit, and monorail systems, will also benefit.

This standard has been prepared in accordance with recognized engineering principles and should not be used without the user's competent knowledge for a given application. The publication of this standard by ASCE is not intended to warrant that the information contained herein is suitable for any general or specific use, and ASCE takes no position respecting the validity of patent rights. The user is advised that the determination of patent rights or risk of infringement is entirely his or her own responsibility.

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ACKNOWLEDGMENTS

The ASCE APM Standards Committee formed two decades ago as a volunteer group of individuals sharing a common belief that the fledgling APM industry would benefit by the development of a minimum set of requirements necessary to achieve an acceptable level of safety and performance for the public.

Many individuals and organizations from many backgrounds gave their time, resources and expertise in hosting meetings, providing web and email communications, drafting sections, and shepherding complicated technical specifications through the challenging consensus process and finally publication.

One individual stands out during these 22 years and is recognized by all committee members, past and present, as the driving force and catalyst behind the creation of this standard. This special acknowledgment is given to the founder and chairman of this committee for its first 17 years cumulating with the final production of the four volume APM standard.

Tom McGean, Chairman Emeritus, has tirelessly led all aspects of the creation of the standard—from securing the sponsorship of ASCE, assembling a balanced membership from diverse backgrounds, nurturing the collegial spirit necessary to create a consensus standard, producing the standard in four consecutive parts to meet the evolving industry needs, and astutely guiding its acceptance within the competitive APM industry.

The committee dedicates this first publication of the combined standard to Tom McGean and hereby proclaims that this standard would not exist or be as well accepted by the transit and APM industry, without his quiet, persistent persuasion and gentle leadership.

Lawrence Smith, P.E., *Chair;* Paul Didrikson, P.Eng, *Secretary;* Tedd Snyder, P.E., *Vice-Chair;* Thomas McGean, P.E., *Past-Chair*

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Chapter 1
GENERAL

1.1 SCOPE

This standard has been combined from four previous parts identified below, to expedite the approval and release process and to facilitate ease of use.

Previous Parts 1, 2, 3, and 4 of ASCE 21-05 and 21-08 cover a minimum set of requirements for design of an automated people mover (APM) with an acceptable level of safety and performance. The previous numbering system is retained (with additions):

Part 1 of ASCE 21-05 consists of

1. General
2. Operating Environment
3. Safety Requirements
4. System Dependability
5. Automatic Train Control (ATC)
6. Audio and Visual Communications

Part 2 of ASCE 21-08 consists of

7. Vehicles
8. Propulsion and Braking

Part 3 of ASCE 21-08 consists of

9. Electrical Equipment
10. Stations
11. Guideways

Part 4 was a minimum set of requirements for maintaining an acceptable level of safety and performance for an automated people mover in passenger operation.

Part 4 of ASCE 21-08 consists of

12. Security
13. Emergency Preparedness
14. System Verification and Demonstration
15. Operations, Maintenance, and Training
16. Operational Monitoring

Annex A. System Safety Program Requirements
Annex B. Bibliography
Annex C. Recommended Practice for Acceptance of an APM System Application
Annex D. Inspection and Test Guidelines
Annex E. Recommended Practice for Working Safely near APM Systems

1.2 EXISTING APPLICATIONS

Existing installations and projects in progress before the effective date of this standard need not comply with the new or revised requirements of this edition, except where specifically required by the authority having jurisdiction. Existing APMs, when completely removed and reinstalled, shall be classified as new installations.

1.3 NEW APPLICATIONS

New installations begun after the effective date of this standard shall comply with the new or revised requirements of this edition.

1.4 REFERENCE STANDARDS

The following documents or portions thereof are incorporated by reference in this standard:

AASHTO: American Association of State Highway and Transportation Officials, Suite 249, 444 North Capitol Street NW, Washington, D.C. 20001; phone (202) 624-5806.

AASHTO LRFD Bridge Design Specifications, 4th Edition, 2007 (cited in Sections 11.9.1, 11.9.2, and 11.9.3)

AASHTO Standard Specifications for Highway Bridges, 17th Edition, 2002 (cited in Sections 11.9.1, 11.9.2, and 11.9.3)

ACGIH: American Conference of Government Industrial Hygienists, 1330 Kemper Meadow Drive, Cincinnati, OH 45240; phone (513) 742-2020.

ACGIH Publication #7 DOC-648, *Whole Body Vibration: TLV Physical Agents,* 7th Edition, 2001, “Documentation” (cited in Section 7.7.3.2)

NOTE: An equivalent source for the above is ISO 2631-1-1985 (1985), *Evaluation of Human Exposure to Whole-Body Vibration*, which is no longer supported by or available from the ISO but may be purchased from the IHS Standards Store, 15 Inverness Way East, Englewood, Colo. 80112; phone (303) 792-2181 ext. 1950.

ANSI Publications: American National Standards Institute, Attn: Customer Service, 11 West 42nd Street, New York, N.Y. 10036; phone (212) 642-4900.

ANSI S1.4-1983 (1983a), *Specification for Sound Level Meters* (cited in Sections 2.2.1 and 7.7.4)

ANSI S3.29-1983 (1983b), *Guide to the Evaluation of Human Exposure to Vibration in Buildings* (cited in Section 2.2.2)

ANSI/ASME B15.1-2000 (2000), *Safety Standard for Mechanical Power Transmission Apparatus* (cited in Section 8.5)

ANSI B77.1-2006 (2006), *Passenger Ropeways—Aerial Tramways, Aerial Lifts, Surface Lifts, Tows and Conveyors—Safety Requirements* (cited in Sections 8.2.2 and 11.0)

ANSI Z97.1-2004 (2004), *Safety Glazing Materials Used in Buildings—Safety Performance Specifications and Methods of Test* (cited in Sections 10.2.1 and 10.2.2)

ANSI Z26.1-1996 (1996), *American National Standard, Safety Code for Safety Glazing Materials for Glazing Motor Vehicles Operating on Land Highways* (cited in Section 7.9)

ANSI 117.1-2003 (2003), *Guidelines for Accessible and Usable Buildings and Facilities* (cited in Section 11.5)

APTA Publications: American Public Transportation Association, 1666 K Street, NW, Washington, D.C. 20006; phone (202) 496-4800.

APTA SS-E-010-98 (1998), *Standard for the Development of an Electromagnetic Compatibility Plan* (cited in Section 2.1.8)

ASHRAE: American Society of Heating, Refrigeration and Air Conditioning Engineers, 1791 Tullie Circle NE, Atlanta, Ga. 30329; phone (800) 527-4723.

2005 ASHRAE Handbook Fundamentals Volume, Chapter 28, Table 1 (cited in Section 7.7.1)

2009 ASHRAE Handbook—Fundamentals, Chapter 14, Climatic Design Information (cited in Section 2.1)

ASTM: Formerly the American Society for Testing and Materials, 100 Bar Harbor Drive, West Conshohocken, Penn. 19428-2959; phone (610) 832-9585.

ASTM D635-06 (2006a), *Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position* (cited in Section 9.3.6)

ASTM C1036-06 (2006b), *Standard Specification for Flat Glass* (cited in Sections 10.2.1 and 10.2.2)

ASTM C1048-04 (2004), *Standard Specification for Heat Treated Flat Glass* (cited in Sections 10.2.1 and 10.2.2)

Code of Federal Regulations: U.S. Government Printing Office, Superintendent of Documents, 732 North Capitol Street, NW, Washington, D.C. 20401; phone (202) 512-1800.

CFR, Title 47, Chapter I, Part 15, *Radio Frequency Devices* (cited in Section 2.2.3)

CFR, Title 47, Chapter I, Part 90, Subparts S and T, *Private Land Mobile Radio Services* (cited in Section 2.2.3)

16 CFR 1201, *Consumer Products Safety Commission Standard on Architectural Glazing Materials* (cited in Sections 10.2.1 and 10.2.2)

Gale Research Publication: Gale Research Company, P.O. Box 33477, Detroit, Mich. 48232; phone (800) 877-4253, Ext. 5477.

Weather of U.S. Cities, Fifth Edition, Vols. 1 and 2 (1996), by Richard A. Wood (cited in Section 2.1)

IEC Publications: International Electrotechnical Commission (IEC) Central Office, 3, rue de Varembé, CH-1211, Geneva 20, Switzerland; phone +41 22 919 02 11; Website: www.iec.ch.

IEC 62236 Edition 2.0, 2008–12, Parts 1–5, Railway Applications—Electromagnetic Compatibility (cited in Section 2.1.8)

IEEE Publications: Institute of Electrical and Electronic Engineers, 3 Park Avenue, New York, N.Y. 10016-5997; phone (800) 678 4333.

IEEE Standard 1474.1-2004 (2004), *IEEE Standard for Communications-Based Train Control (CBTC) Performance and Functional Requirements* (cited in Sections 3.6 and 5.0)

IEEE Standard 32-1972 (1972, revised 1990), *Standard Requirements, Terminology and Test Procedures for Neutral Grounding Devices* (cited in Section 7.12.5)

IEEE Standard 242-2001 (2001), *Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems*, Section 1.0, First Principles (cited in Section 9.1.3)

IEEE Standard 519-1992 (1992), *IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems* (cited in Section 9.2.3)

IEEE Standard 142-1991 (ANSI C114.1-1991) (1991), *IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems* (cited in Section 9.1.4.1)

ISO: See ACGIH.

Military Standards: Defense Printing Service, Building A, 700 Robbins Avenue, Philadelphia, Penn. 19111; phone (215) 697-2179 or 2667.

MIL-STD-810 F (2000), *Environmental Test Methods and Engineering Guidelines* (cited in Section 2.1.5)

NACE: National Association of Corrosion Engineers, 1440 South Creek Drive, Houston, Tex. 77084; phone (281) 228-6200.

NACE Standard RP0169-2002 (2002), *Control of External Corrosion on Underground or Submerged Metallic Piping Systems* (cited in Section 9.1.2)

NEMA: National Electrical Manufacturers Association, 1300 North 17th Street, Suite 1752, Arlington, Va. 22209; phone (703) 841-3200.

All NEMA standards (cited in Section 7.12.2.2)

NFPA Publications: National Fire Protection Association, Customer Service Department, 1 Batterymarch Park, P.O. Box 9101, Quincy, Mass. 02269-9101; phone (800) 344-3555.

NFPA 72-2002 (2002), *National Fire Alarm Code* (cited in Section 6.1.6)
NFPA 70, 2005 edition, *National Electrical Code* (cited in Sections 7.12.2.2, 9.1.4.2, 9.2.9, and 9.4)
NFPA 101, 2006 edition, *Life Safety Code* (cited in Section 10.4)
NFPA 130, 2003 and 2007 editions, *Fixed Guideway Transit and Passenger Rail Systems* (cited in Sections 6.1.2, 7.10, 7.10.1, 7.11.2, 7.12.2.1, 7.12.3, 9.1.1, 9.2.9, 10.4, 10.5.2, 10.5.3, 11.1, 11.3, 11.3.1, 11.3.2, 11.3.3, 11.4, 11.5, 11.6, and 11.7)

NOAA Publications: National Climatic Data Center, 151 Patton Avenue, Room 120, Ashville, N.C. 28801-0900; phone (828) 271-4800.

Local Climatologic Data, Annual Summary with Comparative Data, National Oceanic and Atmospheric Administration, updated annually (cited in Section 2.1)

SAE: Society of Automotive Engineers International, SAE World Headquarters, 400 Commonwealth Drive, Warrendale, Penn. 15096-0001; phone (877) 606-7323 (U.S. and Canada), 1-724-776-4970 (outside U.S. and Canada).

SAE J673-2005 (2005), *Automotive Safety Glasses* (cited in Section 7.9)

TIA, Telecommunications Industry Association Publications: Telecommunications Industry Association, 2500 Wilson Boulevard, Suite 300, Arlington, Va. 22201; phone (703) 907-7700.

Wireless Communications Systems—Performance in Noise and Interference-Limited Situations—Recommended Methods for Technology-Independent Modeling, Simulation, and Verification, Addendum 1, TIA/EIA Telecommunications Systems Bulletin TSB-88-A-1, January 2002 (cited in Section 6.1.6)

UL Publications: Underwriters Laboratories Publications, 333 Pfingsten Road, Northbrook, Ill. 60062; phone (847) 272-8800.

UL 96A, 11th Edition (2001). *Installation Requirements for Lightning Protection Systems* (cited in Section 2.1.4)
UL 813-1993 (1993), *Commercial Audio Equipment* (cited in Section 6.1.3)

1.5 DEFINITIONS

Automated People Mover (APM): A guided transit mode with fully automated operation, featuring vehicles that operate on guideways with exclusive right-of-way.

Automatic Train Control (ATC): The system for automatically controlling train movement, enforcing train safety, and directing train operations. ATC includes subsystems for automatic train operation (ATO), automatic train protection (ATP), and automatic train supervision (ATS).

Automatic Train Operation (ATO): The subsystem within the automatic train control system that performs any or all of the functions of speed regulation, programmed stopping, door and dwell time control, and other functions otherwise assigned to the train operator.

Automatic Train Protection (ATP): The subsystem within the automatic train control system that provides the primary protection for passengers, personnel, and equipment against the hazards of operations conducted under automatic control.

Automatic Train Supervision (ATS): The subsystem within the automatic train control system that monitors and manages the overall operation of the APM system and provides the interface between the system and the central control operator.

Bogie: The bogie consists of the elements that transmit lateral, longitudinal, and vertical loads between the guideway and the carbody. Bogies are also referred to as trucks.

Braking, Emergency: Irrevocable braking to a complete stop at a rate never less than the minimum guaranteed rate.

Braking, Service: Braking of vehicle motion at a rate that is regarded as comfortable for repeated use in service stopping and/or slowing.

Carbody: The structural body shell, enclosing the passenger compartment(s).

Central Control: That location where automatic train supervision is accomplished for the entire transit system; the train command center.

Central Control Operator: Any person authorized to operate the APM system from Central Control.

Consist: The makeup or composition (number and specific identity) of a train of vehicles.

Cosmetic Damage: Damage that does not impair system function, performance, safety, or structural integrity.

Dwell Time: The total time the train services the station measured as the time from door open command to the time the doors are closed and locked.

Dynamic Sign: A sign on which the messages can be changed.

Fail-Safe: A characteristic of a system or its elements whereby any failure or malfunction affecting safety causes the system to revert to a state that is known to be safe.

Failure: An inability to perform an intended function.

Free Field: An isotropic, homogeneous sound field that is free from all bounding surfaces.

Guideway: A track or other riding surface (including supporting structure) that supports and physically guides transit vehicles specially designed to travel exclusively on it.

Hazard: An existing or potential condition that can result in an accident.

Headway: The time separation between two trains, both traveling in the same direction on the same guideway, measured from the time the head end of the leading train passes a given reference point to the time the head end of the train immediately following passes the same reference point.

Interlock: An arrangement of control elements so interconnected that their operations must succeed each other in proper sequence.

Jerk: The time rate of change of acceleration or deceleration.

MTBHE: Mean time between hazardous events (Table 3-1).

Operating Loads: Definitions of operating loads are presented in Section 7.4.4.1.1 as lateral loads, vertical loads, and longitudinal loads.

Overspeed: Train speed that is in excess of the speed limit as defined for the relevant point on the guideway.

Overtravel: Continued movement of a train beyond a specified stopping point.

Passenger Compartment: If a vehicle is divided into separate areas between which passengers are either unable or not permitted to move, each such area is defined as a passenger compartment. If the vehicle is not so divided, then the entire vehicle is the passenger compartment.

Permissive Decision: Granting permission or authority for the system or a part of the system to enter any state other than the safe state.

Risk: A measure of the severity and likelihood of an accident.

Safe State: System state that is deemed acceptable by the hazard resolution process (see Section 3.1.2).

Safety-Critical: A designation placed on a system, subsystem, element, component, device, or function denoting that satisfactory operation of such is mandatory to mitigation of unacceptable and undesirable hazards as defined in Table 3-1.

Separation: The distance between the adjacent ends of two trains traveling along the same guideway as measured along the guideway centerline.

Shall: In this standard, the word "shall" denotes a mandatory requirement.

Should: In this standard, the word "should" denotes a recommendation.

Slow-Speed People Movers: Site applications in which all vehicles travel no more than 32 km/h (20 mph) at any location on their routes during normal operation.

Subsystem: A major functional subassembly or grouping of items or equipment that is essential to operational completeness of a system.

System: A composite of people, procedures, facilities, and/or equipment that are integrated to perform a specific operational task or function within a specific environment.

System Dependability: The overall set of criteria used to measure the performance of an operating system in terms of reliability, maintainability, and availability.

System Safety: The application of engineering and management principles, criteria, and techniques to optimize all aspects of safety within the constraints of operational effectiveness, time, and cost throughout all phases of the system life cycle.

Tabletop Drill: A simulated or theoretical drill in which personnel carry out their functions by discussion.

Train: A train consist of one or more contiguous vehicles combined into an operating unit.

Vehicle: The smallest unit that can operate alone or that comprises one of the basic building blocks of a train.

Zero Speed: A specified speed below which automatic train control considers a train to be stopped.

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Chapter 2
OPERATING ENVIRONMENT

There are two aspects to operating environment considerations. One deals with the existing environmental conditions in which the system must operate (ambient), and the other deals with the environment resulting from the existence and operation of the system (induced). Both of these aspects are covered herein.

2.1 AMBIENT CONDITIONS

The following sources of historical climatic data shall be considered when specifying design climatic values. Source number 1 is a basic compilation of low, high, and mean values of temperature, humidity, steady and gusting winds, rainfall rates, and other climatic characteristics, as compiled by the National Oceanic and Atmospheric Administration (NOAA). Source number 2 summarizes the NOAA data in convenient form. Source number 3 provides temperature data and methods for calculating 50-year return temperatures specified in Section 2.1.1.

1. *Local Climatologic Data, Annual Summary with Comparative Data,* National Oceanic and Atmospheric Administration, updated annually.
2. *Weather of U.S. Cities*, Fifth Edition, Vols. 1 and 2, by Richard A. Wood, Gale Research Company, Detroit, MI, 1996; ISBN 0-8103-5525-6.
3. *2009 ASHRAE Handbook—Fundamentals,* Chapter 14, Climatic Design Information: ISBN: 978-1-933742-54-0; ISSN 1523-7222.

When the proposed site is located outside of the area of coverage of these documents or within a microclimate, data from these sources shall be augmented with local weather data.

2.1.1 Temperature and Humidity

The system shall be designed to, at a minimum, be capable of continuous operation and serviceability in site temperature conditions that represent the 50-year return highest maximum and lowest minimum extreme annual daily temperatures under naturally occurring combinations of temperature and humidity. Chapter 14, "Climatic Design Information," of ASHRAE (2009) demonstrates the method of calculating the 50-year return temperatures. Also, it is not intended that the automated people mover (APM) system should operate when the service area (e.g., urban area or major activity center) is closed because of any of these extreme conditions.

The temperature and relative humidity limit requirements for equipment shall reflect the operating environment at the location in the system where it is installed. These environmental conditions are not intended for the design and operation of the HVAC systems.

2.1.2 Wind

Maximum wind speeds shall be established for at least the following conditions:

1. Normal system operation,
2. Manual operation, and
3. System survival.

The maximum wind speed for normal system operation shall be used as the design wind speed for safe automated system operation. If this wind speed is exceeded, automated operation shall not be permitted or shall be appropriately degraded.

The maximum wind speed for manual system operation shall be used as the design wind speed for safe manual operation. If this wind speed is exceeded, the system shall not be permitted to operate.

The maximum wind speed for system survival shall be the design wind speed for all structures. This wind speed shall be that used by local building codes.

2.1.3 Precipitation

If the system is intended for operation while subjected to rainfall, snowfall, and icing, it shall be designed for operation at rates consistent with historical data. Historical data are defined as the extreme conditions under which the area to be served (e.g., urban area or major activity center) would remain in operation and not be closed. It is not intended to impose operational requirements more restrictive than the owner intends.

2.1.4 Lightning

Protection shall be provided against lightning incidence in the area for those systems that are susceptible. Such protection should be in compliance with UL 96A, 11th Edition (2001).

2.1.5 Existing Atmospheric Pollution

The system design shall tolerate atmospheric pollutants that exist at the site. Such pollutants may include dust, dirt, salt, ozone, smog, and other matter specific to the site. In the cases of dust and dirt, compliance shall be with Military Standard MIL-STD-810-F (2000), method 510.4.

2.1.6 Solar Heat Load

The design of systems that are subject to solar heating shall be based on a peak, direct solar heat gain appropriate to the site. Material selection shall minimize the deleterious effects of ultraviolet radiation.

2.1.7 Flood Zones

Flood levels shall be specified as the 100-year flood level. The system shall be capable of surviving flooding with minimal damage to structure and equipment. Equipment and facility elements that can be damaged by flooding shall be protected or installed above the flood plain elevation.

2.1.8 Electromagnetic Background

The system and all its components shall be electromagnetically compatible with the site environment at the initiation of system operation. All system electrical and electronic equipment shall function satisfactorily in the presence of electromagnetic emissions generated externally at the site. The environment may include, but is not limited to, communications systems, microwave facilities and transmissions, television and radio transmitters and repeaters, radar systems, computer equipment and accessories, traffic control devices, magnetometers, electric motors, controls, power tools, welders, X-ray equipment, power substations and equipment, automotive vehicles, aircraft, and high-voltage power lines. The electromagnetic environment particular to the site should be determined, and the design should provide for elimination of the influence of these conditions upon the equipment. Compliance shall be in accordance with requirements of the International Electrotechnical Commission (IEC) 62236 series of standards, in particular,

- IEC 62236-1, *Railway Applications—Electromagnetic Compatibility—Part 1: General*
- IEC 62236-2, *Railway Applications—Electromagnetic Compatibility—Part 2: Emission of the Whole Railway System to the Outside World*
- IEC 62236-3-1, *Railway Applications—Electromagnetic Compatibility—Part 3-1: Rolling Stock—Train and Complete Vehicle*
- IEC 62236-3-2, *Railway Applications—Electromagnetic Compatibility—Part 3-2: Rolling Stock—Apparatus*
- IEC 62236-4, *Railway Applications—Electromagnetic Compatibility—Part 4: Emission and Immunity of the Signalling and Telecommunications Apparatus*
- IEC 62236-5, *Railway Applications—Electromagnetic Compatibility—Part 5: Emission and Immunity of Fixed Power Supply Installations and Apparatus*

An electromagnetic compatibility (EMC) control plan and/or EMC management plan shall be developed in accordance with APTA SS-E-010-98 (1998).

2.2 INDUCED ENVIRONMENTAL PARAMETERS

The system shall be operated, stored, and maintained without imposing on the site any condition that exceeds the limitations defined herein.

2.2.1 Exterior Airborne Noise

The following exterior noise levels emanating from the system with all equipment operating normally should not be exceeded under the conditions defined. Exterior noise levels shall be measured using at least a Type II instrument, as defined in ANSI Standard S1.4-1983 (1983a), and shall be set for fast or slow response as indicated.

1. Vehicle stopped on the guideway in a free field with all auxiliary onboard equipment in normal operation at a point outside, 1.5 m (5 ft) from the doorway on a line aligned to the centerline of the doorway and perpendicular to the plane of the doorway and 1.5 m (5 ft) above the doorway threshold: 74 dB (slow response).
2. Under all normal operating conditions in a free field, 15 m (50 ft) from guideway centerline and 1.5 m (5 ft) above ground level to 1.5 m (5 ft) above guideway running surface: 76 dB (fast response).
3. For the purposes of measurement, the “free field” is approximated in tests carried out in an open area away from any major obstructions or noise reflectors.

Noticeable pure tones are not permitted. A pure tone is defined to exist when one 1/3-octave band exceeds the arithmetic average of the two adjacent bands by 4 dBA or more in the range of frequencies between 250 and 8,000 Hz. If an adjacent band contains a pure tone, the next closest band without a pure tone shall be used in its place. A noticeable pure tone shall be considered to exist when the 1/3-octave band containing the pure tone contributes more than 1.0 dBA to the overall dB level.

More stringent noise requirements may be necessary to satisfy local environmental limitations.

2.2.1.1 Commentary for Interior Noise Levels (Section 7.7.4) and Exterior Airborne Noise (Section 2.2.1) Limits in Tunnels

The following commentary is provided as an explanation of why the standard does not specify noise limits inside buildings and tunnels.

The conditions for measuring vehicle exterior airborne noise are specified in Section 2.2.1 as, "Under all normal operating conditions *in a free field*, 15 m (50 ft) from guideway centerline and 1.5 m (5 ft) above ground level to 1.5 m (5 ft) above guideway running surface."

The conditions for measuring vehicle interior noise is specified in Section 7.7.4 as ". . . with all auxiliary equipment operating. All noise measurements are to be taken *in a free field environment*, with no passengers (up to three test personnel permitted) in the vehicle. Interior noise levels shall be measured 1.5 m (5 ft) above the floor, above the suspension and/or running gear, and at the geometric center of the vehicle floor . . ."

In both cases, the vehicle is specified to be operating in a *free field environment* to determine purely the noise energy that is emitted from the train without any content of reflected noise or other noise generators that otherwise can compromise the measurements.

When a vehicle or train is operated inside a tunnel or building, noise emitted from the vehicle or train can be reflected and can increase the amplitude of the measured noise. Because the geometries, designs, and surface materials of such structures can vary significantly, it is not possible to know the extent that reflected noise may be experienced. Hence, neither consistent conditions nor standard tests exist for specifying noise limits in tunnels and buildings.

The current standard sets a limit on the noise energy that can be emitted by a vehicle or train. Designers of buildings and tunnels are provided with the limit on emitted noise energy that they need as an input on which they can make designs. Because they are in control of the architectural structure (size, shape, materials, and reflective surfaces), they are in control of what the resultant noise is in a tunnel or building. Buyers of APM systems can specify noise limits, taking into account the architectural designs they specify.

2.2.2 Structure-Borne Noise and Vibration

System-induced vibrations shall be imperceptible at or in surrounding buildings. The threshold of perception shall be as defined by ANSI Standard S3.29-1983 (1983b).

2.2.3 Electromagnetic Radiation

The system shall be electromagnetically compatible with its environment. The system shall not produce electromagnetic emissions, whether conducted, radiated, or induced, that interfere with normal operation of electromagnetic devices or equipment used in and around the site at the initiation of system operation.

All system transmitting and receiving equipment, such as for automatic train control (ATC) and audio and visual communications, shall meet the licensing requirements of the Code of Federal Regulations, Title 47, Chapter I, Part 90, Subparts S and T, and the interference requirements defined in Title 47, Chapter I, Part 15.

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Chapter 3
SAFETY REQUIREMENTS

A system safety program, per Section 3.1, shall be instituted during the system planning and design phase and shall continue throughout the system construction and operation. The system safety concept shall emphasize the prevention of accidents by resolving hazards in a systematic manner in accordance with Section 3.1.2, Hazard Resolution Process.

3.1 SYSTEM SAFETY PROGRAM

A system safety program shall be implemented to identify and resolve hazards. The owner shall provide for the development of a system safety program plan (SSPP) to assist in implementing and documenting that program. The SSPP shall identify the responsibilities of all parties for implementing a system safety program.

The system safety program and SSPP shall

1. Have as their objective to provide for the safety of the passengers, employees, the general public, and equipment;
2. Encompass all system elements and organizations within the automated people mover (APM) system;
3. Identify the safety roles and responsibilities of all organizational elements and require accountability;
4. Designate one individual to be responsible for the safety of the system who has a clearly defined role and responsibilities established through a written policy;
5. Contain a hazard resolution process that includes the procedures necessary to identify and resolve hazards throughout the system life cycle; and
6. Provide for and maintain owner and management commitment in the form of an adopted policy and the allocation of resources.

The individual identified to carry out the system safety program shall have clear evidence of the authority to ensure its implementation and shall report directly to top management.

3.1.1 System Safety Program Plan

An SSPP shall be developed during the planning and design phase of the APM project and shall be maintained current throughout the APM system life cycle. The SSPP shall be prepared in general accordance with Annex A, System Safety Program Requirements, A.1 (System Safety Program Plan), or the equivalent. The SSPP shall, at a minimum, identify the scope of the system safety program activities, including those identified in Section 3.1.

3.1.2 Hazard Resolution Process

The hazard resolution process shall be initiated by defining the physical and functional characteristics of the APM system to be analyzed. These characteristics shall be presented in terms of the major elements that make up the system and its environment, including equipment, facilities, procedures, and people.

The hazards shall be identified. The techniques and methods used to identify the hazards shall include the following:

1. Data from previous accidents or operating experience;
2. Expert opinion and hazard scenarios;
3. Checklists of potential hazards;
4. Previous hazard analyses; and
5. Other analysis techniques, as appropriate.

All identified hazards shall be assessed in terms of the severity or consequence of the hazard and the probability of occurrence.

Risk assessment estimates (Table 3-1) based on mean time between hazardous events (MTBHE) shall be used as the basis in the decision-making process to determine whether individual APM system or subsystem hazards shall be eliminated, mitigated, or accepted. Hazards shall be resolved through a design process that emphasizes the elimination of the hazard. Resolution strategies or countermeasures to be used, listed in order of decreasing preference, shall be the following:

1. Design to eliminate hazards;
2. Design to control hazards;
3. Use safety devices;
4. Use warning devices;
5. Implement special procedures;
6. Accept the hazard; and
7. Eliminate the system, subsystem, or equipment.

This process shall include full documentation of the hazard resolution activities. The effectiveness of the countermeasures shall be monitored to determine that no new hazards are introduced. In addition, whenever substantive changes are made to the system, analyses

Table 3-1. Risk Assessment

Frequency of Occurrence	Hazard Severity			
	I Catastrophic	II Critical	III Marginal	IV Negligible
A—Frequent	IA	IIA	IIIA	IVA
B—Probable	IB	IIB	IIIB	IVB
C—Occasional	IC	IIC	IIIC	IVC
D—Remote	ID	IID	IIID	IVD
E—Improbable	IE	IIE	IIIE	IVE

Notes:
IA, IIA, IIIA, IB, IIB, and IC = Unacceptable.
ID, IIC, and IIIB = Undesirable (allowable with agreement from authority having jurisdiction).
IE, IID, IIE, IIIC, IIID, IVA, and IVB = Acceptable with notification to the authority having jurisdiction.
IIIE, IVC, IVD, and IVE = Acceptable.
A—Frequent = MTBHE is less than 1,000 operating hours.
B—Probable = MTBHE is equal to or greater than 1,000 operating hours and less than 100,000 operating hours.
C—Occasional = MTBHE is equal to or greater than 100,000 operating hours and less than 1,000,000 operating hours.
D—Remote = MTBHE is equal to or greater than 1,000,000 operating hours and less than 100,000,000 operating hours.
E—Improbable = MTBHE is equal to or greater than 100,000,000 operating hours.
It is understood that the quantification of the probability or frequency of occurrence of elements within the safety verification process may be required to be subjectively (i.e., qualitatively) determined. All subjectively determined elements shall be identified, and the rationale and justification for the estimation shall be described.
I—Catastrophic = Death, system loss, or severe environmental damage.
II—Critical = Severe injury, severe occupational illness, or major system or environmental damage.
III—Marginal = Minor injury, minor occupational illness, or minor system or environmental damage.
IV—Negligible = Less than minor injury, occupational illness, or less than minor system or environmental damage.

shall be conducted to identify and resolve any new hazards.

3.1.2.1 Hazard Analyses

Hazard analyses shall be used to assist in the evaluation of potential hazards and to document their resolution. As a minimum, a preliminary hazard analysis (PHA) shall be conducted for each new APM system project. Other detailed analyses, including subsystem hazard analysis (SSHA), system hazard analysis (SHA), and operating and support hazard analysis (O&SHA), shall also be conducted if mandated by the SSPP. These analyses shall be conducted in general accordance with Annex A, System Safety Program Requirements, Sections A.2 (PHA), A.3 (SSHA), A.4 (SHA), and A.5 (O&SHA), or the equivalent, respectively.

3.2 SAFETY PRINCIPLES

The following safety principles shall be observed in the APM system (Table 3-1 defines unacceptable and undesirable hazards):

1. When the system is operating normally, there shall be no unacceptable or undesirable hazard conditions.
2. The system design shall require positive actions to be taken in a prescribed manner to either begin system operation or continue system operation.
3. The safety of the system in the normal automatic operating mode shall not depend on the correctness of actions or procedures used by operating personnel.
4. There shall be no single-point failures in the system that can result in an unacceptable or undesirable hazard condition.
5. If one failure combined with a second failure can cause an unacceptable or undesirable hazard condition, the first failure shall be detected before the second failure occurs.
6. Software faults shall not cause an unacceptable or undesirable hazard condition.
7. Unacceptable hazards shall be eliminated by design.
8. Maintenance activities required to preserve risk levels (Table 3-1) shall be prescribed to the individual responsible for the system safety program

(Section 3.1) during the design phase. These maintenance activities shall be minimized in both the frequency and in the complexity of their implementation. The personnel qualifications required to implement these activities adequately shall also be identified.

3.3 ATC SYSTEM FAIL-SAFE DESIGN

All safety-critical elements of the ATC system (see Chapter 5, Automatic Train Control) shall be designed and implemented in accordance with fail-safe principles and shall use one or more of the techniques described as follows, or the equivalent, to detect potentially unsafe failure modes and force the system to a known safe state. Fail-safe principles shall be realized by designing the system to have intrinsically safe failure characteristics or by designing the system with verifiable techniques that detect potentially unsafe failures and ensure that the system reverts to a known safe state. Documentation of the means used and proof that the fail-safe principle has been met shall be required for every safety-critical system or subsystem.

3.3.1 Intrinsic Fail-Safe Design

Intrinsically fail-safe systems shall be designed using verifiable physical, mechanical, and/or electrical component characteristics. For these designs, the effect of every relevant failure mode on the operation of the system shall be considered, analyzed, and documented in a comprehensive failure mode and effects analysis, or the equivalent.

3.3.2 Alternatives to Intrinsic Fail-Safe Design

Many control system designs use integrated circuits, microprocessors, and software to achieve the required functional characteristics. Designs that do not exhibit intrinsically safe failure characteristics shall use one or more of the following techniques (Sections 3.3.2.1 through 3.3.2.4). The effectiveness and completeness of these techniques shall be documented and proven as part of system validation and verification (Section 3.4). The measure of the technique's effectiveness shall be its ability to detect fault conditions and ensure that the technique is installed as designed and is required for the system to operate.

3.3.2.1 Checked Redundancy

The application of the checked-redundant principle shall include at least two parallel systems performing identical functions. A means shall be provided to compare the output of the parallel systems. If the two systems do not agree, then the safety-critical function being performed shall default to a known safe state. The following characteristics shall be incorporated and verified in the checked-redundant design:

1. The checking process shall ensure that agreement shall not be indicated unless the redundant outputs agree. Lack of agreement of the checking process shall result in a known safe state.
2. The checking process shall include the comparison of all safety-critical results with all safety-critical functions.
3. Any failure that could affect system safety in either of the redundant units shall result in a known safe state.
4. The redundant units shall be independent from one another so that no common environmental or power fluctuations, errors, and/or faults can cause unacceptable or undesirable hazards (Table 3-1).
5. The checking process shall be comprehensive in coverage (including functions tested and the rate at which functions are tested) to ensure that the probability of failures or compensating failures producing unacceptable or undesirable hazards is at an acceptable level (Table 3-1).
6. For units using software-programmed elements, the software shall be shown to be free from errors, including any errors introduced during the compilation process, by proven principles and practices of verification and validation (Section 3.4).

3.3.2.2 N-Version Programming

The application of the *N*-version programming principle shall require at least two parallel programmed systems performing identical functions. The software in each system shall be unique and independently written by different persons or teams, using different languages and tools. The hardware may or may not be identical, or it may include both programmed systems within one hardware processing unit. A means shall be provided to compare the output of the parallel programmed systems. If the two systems do not agree, then the safety-critical function being performed shall default to a known safe state. The following characteristics shall be incorporated and verified in the design:

1. The checking process shall be fail-safe. Agreement shall not be indicated unless the redundant outputs agree. Lack of agreement of the checking process shall result in a known safe state.
2. The checking process shall include the comparison of all safety-critical results with all safety-critical functions.

3. Any failure that could affect system safety in either of the units shall result in a known safe state.
4. The parallel programmed systems shall be independent from one another so that no common environmental or power fluctuations, errors, and/or faults can cause unacceptable or undesirable hazards (Table 3-1).
5. The checking process shall be comprehensive in coverage (including functions tested and the rate at which functions are tested) to ensure that the probability of failures or compensating failures producing unacceptable or undesirable hazards is at an acceptable level (Table 3-1).
6. The software processed by the parallel programmed systems shall be proven to be independent.

3.3.2.3 Diversity and Self-Checking

The use of diversity and self-checking concepts shall require that all critical functions be performed in diverse ways, using diverse software operations and/or diverse hardware channels, and that critical system hardware be tested with self-checking routines. Permissive outputs shall be allowed only if the results of the diverse operations correspond and the self-checks reveal no failures. The following characteristics shall be incorporated and verified in the design:

1. The checking of the results of the diverse operations shall be fail-safe. Permissive decisions shall not be allowed unless the diverse results agree. Lack of agreement with the diverse checking process or with self-checks shall result in a known safe state.
2. The diverse operations and the self-checking process shall include the verification of all safety-critical results of all the safety-critical functions.
3. Any failure that could affect system safety shall result in a known safe state.
4. The diversity and self-checking routines shall be comprehensive in coverage (including functions tested and rate at which functions are tested) to ensure that the probability of failures or compensating failures producing unacceptable or undesirable hazards is at an acceptable level (Table 3-1).
5. For units using software-programmed elements, the software shall be shown to be free from errors, including any errors introduced by the compilation process by proven principles or practices of verification and validation (Section 3.4).

3.3.2.4 Numerical Assurance

The numerical assurance principle shall require permissive decisions to be represented by large unique numerical values, calculated by combining numerical values representing each of the critical constituents of a permissive decision. The following characteristics shall be incorporated and verified in the design:

1. The numerical values representing the permissive decisions shall be proven to be unique and to require unique values added by each of the critical constituents.
2. All critical processes that do not add unique values to the permissive results, per the previous characteristic, shall generate unique numerical values that are verified for correctness.
3. The system calculating the numerical results must have no prior knowledge of the correct permissive numerical values.
4. The process used to verify the correctness of the numerical results shall be fail-safe.
5. Any failure that could affect system safety shall result in a known safe state.
6. Lack of correctness of any of the numerical results shall result in a known safe state.
7. The numerical process shall be comprehensive in coverage (including functions protected by numerical values and the frequency at which the numerical values are calculated and verified) to ensure that the probability of failures or compensating failures producing unacceptable or undesirable hazards is at an acceptable level (Table 3-1).

3.4 VERIFICATION AND VALIDATION

The design and implementation of all safety-critical hardware and software elements of the system as identified in the hazard resolution process (Section 3.1.2) shall be subjected to verification and validation. This process includes elements designed and implemented in accordance with safety principles (Section 3.2) and ATC system fail-safe design (Section 3.3). The objective of this verification and validation shall be to verify that all safety-critical elements have been designed and implemented to achieve safe operation and to verify the level of safety achieved.

The verification and validation process shall include

1. The identification of all factors on which the assurance of safety depends. Such factors shall be directly associated with the design concept used, i.e., checked redundancy, *N*-version programming, diversity and self-checking, or numerical assurance.
2. The identification of all safety-critical functions performed by the system.

3. Analyses demonstrating that all dependent factors have been satisfied and that each safety-critical function has been implemented in accordance with safety principles.

3.5 ATC SYSTEM MEAN TIME BETWEEN HAZARDOUS EVENTS

The ATC system (see Chapter 5, Automatic Train Control) shall, in addition to the aforementioned, have a calculated aggregate mean time between hazardous events (MTBHE) (total of all catastrophic and critical hazards) of 10**8 (1 × E 8) system operating hours or greater. System safety documentation shall support this aggregate MTBHE calculation and substantiate the methodology used to arrive at the result.

3.6 COMMENTARY ON CHAPTER 3.0 AND SUBPARTS

Section 3.4 of this standard describes formal procedures for verifying and validating that safety-critical hazards have been identified and resolved. It should be noted that Section 3.4 does not apply just to the ATC system but rather requires verification and validation of *all* safety-critical hardware and software elements of the entire APM system that were identified in the hazard resolution process explained in Section 3.1.2 of the standard.

Unlike Section 3.4, Section 3.5 provides an additional MTBHE requirement that applies *only* to the ATC system.

As noted in Section 3.1.2, all individual APM system or subsystem hazards are to be assessed in terms of both the severity and consequence of the hazard and its likelihood of occurring. The risk assessment table (Table 3-1) provided in the standard is to be used as a basis for deciding whether the hazard needs to be eliminated or mitigated or whether it may be accepted. The table provides guidelines for the level of risk that is completely acceptable, the level allowable provided notice is given to the authority having jurisdiction, and the level that can only be accepted with the specific approval of the authority having jurisdiction. Finally, there is a risk level that is so serious that it cannot be accepted and must be either mitigated or eliminated.

It is important to emphasize that this evaluation is performed on each individually identified system or subsystem hazard for the entire APM system. As noted in Table 3-1, it is understood that quantifiable estimates of probability or frequency of occurrence may not always be available. In that event, it is acceptable to subjectively or qualitatively estimate the risk. If such qualitative estimates are used, all subjectively determined elements are to be identified and the rational justification for the estimate is to be documented.

The results of this process would normally be a set of hazard resolution forms describing each hazard, the consequence of the hazard and its severity, and the steps taken to mitigate or eliminate the hazard if it is not acceptable. The form also documents the residual acceptable risk level after mitigation in the event the hazard has not been completely eliminated.

Section 3.1.2 of the standard lists acceptable approaches to elimination or mitigation of hazards. The preferred solution is to eliminate or control the hazard by a design change. If this solution is not possible, safety or warning devices can be used. If this solution is not practicable, procedures such as periodic inspection are suggested. Finally, the offending equipment responsible for introducing the hazard can simply be eliminated from the design altogether. Acceptance of the hazard is only allowed if it is not in one of the shaded risk categories in Table 3-1. These shaded risk areas represent an unacceptable combination of hazard severity and likelihood of occurrence.

Section 3.5 sets an additional safety criterion for the ATC system over and above the mitigation or elimination of individual hazards required by Section 3.4. This additional safety criterion is an aggregate MTBHE (total of all catastrophic and critical hazards) for just the ATC system. This MTBHE figure is to be supported by safety documentation.

Two different overall MTBHE values are specified. If the system does not use communications-based train control (CBTC), the requirement is a calculated aggregate MTBHE of 10**8 system operating hours or greater for the entire ATC system.

If the ATC system uses CBTC, the MTBHE requirement is to be superseded by that specified in IEEE 1474.1-2004 (2004), Section 5.3.4. This section specifies an MTBHE of a least 10**9 operating hours for all wayside and train-borne CBTC equipment in a contiguous portion of a one-way route that can be traversed by a train traveling at the specified maximum authorized speed for one hour or less. In addition, the maximum number of trains should be in operation on the segment at their peak operating headway.

It should be noted that the 10**8 number in this standard covers the entire ATC system, whereas the 10**9 number covers only car and wayside CBTC equipment on only a portion of the total route, so the two numbers are not directly comparable.

Chapter 4
SYSTEM DEPENDABILITY

System dependability is the overall set of criteria used to measure the performance of an operating system in terms of reliability, maintainability, and availability. It shall be established in accordance with the principles outlined in this chapter.

Throughout this chapter, references to "system" may also be applied to "system subsets" for purposes of determining their individual contribution to overall system dependability.

Partial service or degraded service adjustments may be applied in defining overall system dependability. Factors, ratios, or separate calculations by system subset may be used to provide for such adjustments.

4.1 SERVICE RELIABILITY

Service reliability is defined as the mean time between system or system subset failures ($MTBF_s$).

$$MTBF_s = \frac{\text{Operating Hours}}{\text{Number of Failures}} = OH_s / NF_s$$

where

OH_s = Total number of hours of scheduled operation over which the service reliability is being determined; the period of operating hours, and

NF_s = Number of failures, malfunctions, and operating disruptions classified as service interruptions during the period of operating hours.

4.1.1 Service Interruptions

Service interruptions are those events or failures that prevent passenger use of the system or system subset as intended. Service interruptions shall be defined and weighted in accordance with their relative importance. At a minimum, the following types of service interruptions shall be included:

1. Unscheduled stoppage of one or more trains,
2. Rerouting of trains caused by equipment malfunction so that any stations normally served are not served,
3. Door malfunctions that prevent passengers from entering or exiting trains at stations in automatic operation, and
4. Malfunctions that result in potentially hazardous operations.

The owner will specify if erroneous operator actions that result in service interruptions are to be included.

4.1.2 Exceptions

The following shall not be considered service interruptions:

1. Malfunctions that result in an interruption of normal train operations for an interval of time equal to or less than a specified period of time (grace time);
2. Malfunctions or disruptions caused by vandalism, passenger misuse of the system, or passenger-induced delays;
3. Disruptions caused by unauthorized intrusion of persons, animals, or inanimate objects into the system, except where the intrusion or failure results from the malfunction of any security system or devices designed to protect against such intrusion;
4. Disruptions caused by external causes, including loss of primary power, police or security directives, force majeure, or environmental conditions beyond specified limits;
5. Disruptions for special training, guideway inspections, or extended repair purposes that have been arranged in advance; and
6. Stoppages caused by normal functioning of the automatic train control system where specified operating performance requirements are met.

4.2 SERVICE MAINTAINABILITY

Service maintainability is defined as the mean time to restore service ($MTTR_s$) after a system service interruption.

$$MTTR_s = \frac{\text{Sum Total Time to Restore Service}}{\text{Number of Failures}}$$

$$MTTR_s = (1/NF_s)\sum_{i=1}^{NF_s} TTR_i$$

where

TTR_i = Time to restore service after the ith service interruption (downtime interval), and

NF_s = Number of failures, malfunctions, and operating disruptions classified as service interruptions during the period of operating hours.

In computing the cumulative time to restore and the associated number of failures (NF_s), only service interruptions with downtime intervals greater than grace time (see Section 4.1.2) shall be included. However, once the specified maximum number of grace time allowances has been reached, no further grace time shall be allowed and all subsequent service interruptions shall be included in the calculation of downtime intervals. In addition, the downtime interval for each such event shall be the full time interval of cessation of service according to the following points:

1. The grace time shall not be subtracted from the TTR_i for a countable system service interruption.
2. The downtime interval shall be measured from the time of detection of the service interruption until the time of restoration of service for the specific train or equipment that malfunctioned, whether the restoration is accomplished by automatic means or by repair or replacement of the malfunctioning equipment.

4.3 SERVICE AVAILABILITY

Service availability (A_s) is defined as follows:

$$A_s = \frac{MTBF_s}{MTBF_s + MTTR_s}$$

Service availability shall be calculated over a specified time interval. This calculation of service availability is equivalent to the actual operating hours (scheduled operating hours minus the accumulated downtime) divided by the scheduled operating hours.

Chapter 5
AUTOMATIC TRAIN CONTROL

The ATC subsystem shall provide automatic train protection (ATP), automatic train operation (ATO), and automatic train supervision (ATS) functions. ATP shall provide the primary protection for passengers, personnel, and equipment against the hazards of operations conducted under automatic control. ATP functions shall have precedence over both the ATO and ATS functions. ATO shall control basic operations that would otherwise be performed by an operator and does so within the protection limits imposed by ATP. The ATS shall provide system status information and the means for the central control operator to monitor and override the automatic control for various functions of the system.

For automated people mover (APM) systems that use communications-based train control (CBTC) for ATC, the requirements of IEEE 1474.1-2004 (2004) shall apply in lieu of the requirements provided in Sections 5.1 and 5.2.

5.1 AUTOMATIC TRAIN PROTECTION (ATP) FUNCTIONS

All ATP functions shall be designed and implemented in accordance with Sections 3.2, Safety Principles, and 3.3, ATC System Fail-Safe Design.

5.1.1 Presence Detection

Presence detection shall be an ATP function if it is required to ensure the protection aspects of other ATP functions, such as train separation assurance and/or guideway switch interlocks.

As an ATP function, presence detection shall be continuous in accordance with Section 5.1.7 in any and all automated areas of the guideway. All trains and any other vehicles that operate on the system in the presence of trains running in automatic operation shall be detected, regardless of whether they are being operated in automatic or manual control.

The presence-detection function shall be reinitialized and all trains shall be located and identified by positive detection before the resumption of automatic operation. In no case shall automatic operation be allowed based on manual input of position data.

5.1.2 Separation Assurance

Separation assurance shall be a required ATP function for any APM system configuration that operates trains in following moves around the guideway.

Separation assurance shall provide protection against rear-end collisions for following trains by maintaining a zone at the rear of each train that continuously provides sufficient stopping distance for the following train assuming that the train ahead can stop instantaneously.

Stopping distance shall be calculated analytically using the cumulative worst-case characteristics of relevant elements, where worst case pertains to the characteristic of the element that results in maximum stopping distance. This requirement includes, but is not limited to,

1. Maximum runaway acceleration,
2. Minimum emergency braking condition,
3. Maximum cumulative time delays,
4. Maximum attainable overspeed,
5. Grade,
6. Worst-case load,
7. Minimum adhesion and traction, and
8. Maximum design tailwind.

For stopping distance calculation purposes, minimum emergency braking condition shall be based on the single worst-case failure conditions of the braking system elements as determined by an appropriate analysis conducted in accordance with the requirements of Section 3.1.2.1, Hazard Analyses.

For APM systems that permit the automated operation of trains in opposing directions on the same track, separation assurance using calculated stopping distances for both trains shall apply for the prevention of head-on collisions.

For APM systems that use automatic coupling, the coupling maneuver shall be permitted, provided the entire maneuver is conducted under the protection of ATP and can be verified and validated to be in accordance with Section 3.3, ATC System Fail-Safe Design.

For APM systems where the separation between successive trains is physically maintained, as it is in a cable-propelled system, and where it can be shown by analysis according to Section 3.1.2.1, that slippage and/or detachment from the physical mechanism is possible, then such slippage or detachment shall be detected and emergency braking shall be initiated to stop the slipping or detached train and all other trains connected to that mechanism.

Comparable separation assurance protection shall be required for APM systems that use other means to maintain separation between successive trains.

5.1.3 Unintentional Motion Detection

Detection of unintentional motion shall be a required ATP function for all APM systems.

The ATP shall initiate emergency braking in the event that a train is detected to be moving when it has not been commanded to move. Emergency braking shall also be initiated whenever a train is detected to be moving against the permitted travel direction (rollback).

5.1.4 Overspeed Protection

Overspeed protection shall be a required ATP function for all APM systems.

Guideway alignment, civil constraints, and train traffic conditions as determined by ATP shall define the speed limits that represent the maximum allowable train speed at any point on the guideway.

The overspeed protection function shall provide speed enforcement, ensuring that the speed of a train never exceeds the defined speed limit anywhere along the entire route. The overspeed protection equipment shall include speed-measuring devices that furnish signals that are a measure of the actual speed of the train. If ever the actual speed of the train exceeds the speed limit, the overspeed protection equipment shall immediately command emergency braking.

5.1.5 Overtravel Protection

Overtravel protection shall be a required ATP function for any APM system configuration that permits the automatic operation of trains up to or close to an end-of-guideway terminus.

Overtravel protection shall be incorporated into, or function in conjunction with, overspeed protection to prevent trains from overtraveling the end of the guideway or, if buffers are specified, to prevent trains from exceeding the design limits for impact with an end-of-guideway buffer. Overtravel protection design shall be based on stopping distance calculations using cumulative worst-case characteristics of relevant elements, as in Section 5.1.2.

5.1.6 Parted Consist Protection

Parted consist protection shall be an ATP function for APM systems that use separate vehicles coupled together in a consist of two or more vehicles to form a train. Parted consist protection shall be required regardless of whether the individual vehicles are considered to be permanently coupled or whether they are routinely uncoupled for maintenance or operational purposes.

Parted consist protection shall detect the uncoupling, detachment, and/or separation of vehicles in a consist and shall thereupon immediately cause all vehicles of the previously connected train to brake to a full stop.

Presence detection, if applicable under the requirements of Section 5.1.1, shall detect the individual presence and precise location of each separated entity to the extent possible within the limits of the presence detection segmentation.

5.1.7 Lost Signal Protection

For all APM systems, all signals that are critical to the functions of ATP shall be continuous or be of such a repetitive nature that signal interruption is detected. Detection of signal interruption shall result in emergency braking by ATP in sufficient time so as not to compromise any safety aspect of the ATP functional design.

5.1.8 Zero Speed Detection

On APM systems where the trains are required to stop, zero speed detection shall be a required ATP function.

Zero speed shall not be registered until a speed of 0.30 m/s (0.95 ft/s) or less is attained and braking is commanded.

5.1.9 Unscheduled Door Opening Protection

Unscheduled door opening protection shall be a required ATP function for all APM systems.

If any automatic door or emergency exit door on a train unlocks for any reason while the train is in motion (above zero speed as defined in Section 5.1.8), that train shall be caused to brake to a full stop.

For systems that include train–platform separation walls and automatic station doors, unscheduled door opening protection by ATP shall also apply. If any automatic station door is unlocked for any reason, trains shall be prohibited from entering or leaving that station platform. If any of these doors are unlocked for any reason as a train is entering or leaving the station platform area, the process of braking the train to a full stop shall be immediately initiated.

In the event of any unscheduled door opening (of a train or station), a local manual reset by authorized personnel shall be required before the restoration of automated train operation.

5.1.10 Door Control Protection Interlocks

Door control protection interlocks shall be provided by ATP on all APM systems.

These interlocks shall ensure that the following conditions are satisfied before enabling the automatic unlocking and opening of the train doors and, if provided, the station platform doors:

1. The train is properly aligned at a station platform per the criteria in Section 5.2.2,
2. Zero speed is detected,
3. Propulsion power is removed from the motors, and
4. The train is positively constrained against motion.

For APM systems where trains do not achieve a complete stop for boarding and discharging passengers, the following conditions shall be satisfied for automatic unlocking and opening of train doors and station platform doors (if provided):

1. Speed shall not exceed 0.35 m/s (1.1 ft/s).
2. Acceleration and jerk rates shall be limited to values determined to be acceptable by analysis according to the requirements of Section 3.1.2.1, Hazard Analyses.
3. The entire door opening and door closing sequence shall occur within the designated zones as determined by an analysis conducted in accordance with Section 3.1.2.1.

5.1.11 Departure Interlocks

Departure interlocks shall be provided by ATP on all APM systems.

Any train stopped in a station shall not be permitted to move until all doors (train and station platform, if provided) are properly closed and locked. Only then shall the constraint against motion be removed and the power be applied to the propulsion motors.

For APM systems where trains do not achieve a complete stop for boarding and discharging passengers, departure interlocks shall be provided to stop the train from departing the station if all doors are not closed and locked.

5.1.12 Direction Reversal Interlocks

Travel direction reversal interlocks shall be provided by ATP on all APM systems requiring bidirectional operation on any segment of the automated guideway.

Any reversal of train travel direction shall occur only after zero speed has been registered (see Section 5.1.8). Reversing of train direction shall occur automatically at stations or terminal zones as required by the system configuration for the support of pinched loop, intermediate turnback loop, reverse direction loop, or shuttle modes of operation.

Any reversal of a train shall also be possible by remote manual command from the central control.

5.1.13 Propulsion and Braking Interlocks

Propulsion and braking interlocks shall be provided by ATP on all APM systems.

Emergency braking shall be irrevocable, that is, once it is initiated, it shall remain activated until the train comes to a complete stop. After the train has stopped, the emergency braking shall be required to be reset for normal operation to resume. For situations where the method of reset is not specified by Chapter 5, the method shall be determined by an analysis conducted in accordance with Section 3.1.2.1, Hazard Analyses. If conditions as determined by ATP are not correct for the train to move, the emergency braking shall remain applied regardless of any reset signals or actions, except that it shall be possible to switch to full manual operation, thus disabling the ATP functions of that train. If correct ATP conditions exist after irrevocability has been removed, the train shall be permitted to move, but if a subsequent malfunction occurs, the irrevocable emergency braking shall be applied as before.

The emergency braking controls shall be interlocked with the propulsion controls such that braking commands dominate.

5.1.14 Guideway Switch Interlocks

Guideway switch interlocks shall be provided by ATP for any APM system that operates trains under automatic control over a switch or switches installed along the guideway. For switching mechanisms on board the train, comparable interlocks that meet the intent of this section, as determined by analysis in accordance with the requirements of Section 3.1.2.1, Hazard Analyses, shall be provided.

ATP shall prevent a train from entering a switch that is not properly aligned and locked and shall prevent a switch from becoming unlocked and/or moved once a train is committed to traversing it.

Control circuits shall be arranged so that an aligned and locked switch cannot be signaled for a route until each portion of the switch is verified to be in the correct position. When switch conditions are not correct (whether the switch has been activated automatically or manually), the control signals normally transmitted to approaching trains shall ensure that any approaching train in automatic mode shall stop before reaching the entrance point of the switch.

Whenever a train is in the protected zone associated with a switch or a series of switches, route locking shall prevent the automatic or remote manual movement of any of the switches in the protected zone and shall prevent any conflicting train movements from occurring.

Presence detection locking shall be used to prevent a switch from being moved if there is a train occupying it, regardless of whether the switch is being operated under automatic or remote manual control.

Time locking (with approach release of that time locking optional) shall be used in the switching circuits so that, if the section of guideway approaching a switch has been cleared for movement over that switch, the switch cannot be moved until a definite time has elapsed after the speed limit for the approaching section has been placed in a zero speed condition and the switch is not occupied. The time allowance shall be at least 10 percent greater than the time required for the train to traverse the stopping distance, as calculated in accordance with Section 5.1.2. If the option of approach release of the time locking is used, then the time can be zero if there is no part of a train occupying the approach section. The length of the approach section for the switch shall be greater than the worst-case stopping distance computed for that specific guideway section.

ATP shall prevent the automatic or remote manual unlocking of a switch after a train has committed to traversing it until the train has cleared the switch. Protection against inadvertent release of locking caused by momentary loss of power or train detection shall be provided.

5.1.15 Off-Line Sections Operation—Special Conditions

Off-line sections are defined as guideway sections featuring automatic operation at restricted speed, such as off-line stations or vehicle storage areas (lanes). For off-line sections operation, three different zones are considered:

1. Transition zone to and from the main line,
2. Circulation zone, and
3. Docking zone.

Transition zone: When entering or leaving the main line to or from the off-line section, the vehicle shall be detected by the ATP system of the off-line section, and speed shall be adjusted accordingly. Vehicle movement between main-line and off-line lanes shall be accomplished in accordance with the principles of Section 5.1.14.

Circulation zone: Contact between two moving vehicles may be acceptable at low speed, only under failure conditions, if the contact speed is low enough as determined by an analysis conducted in accordance with Section 3.1.2.1, Hazards Analyses, to

1. protect against damage to vehicles (reversible shock absorbers may be used) and
2. protect against passenger injuries (collision impact shall meet all criteria of Section 7.4.4.9.2).

The permissible contact speed shall be enforced by ATP.

Docking zone: Contact between a moving vehicle and a vehicle stopped at a docking position (with doors open and brakes applied as per Section 5.1.8) may be acceptable at low speed, only under failure conditions, if the contact speed is low enough, as determined by an analysis conducted in accordance with Section 3.1.2.1, Hazards Analyses, to

1. protect against damage to vehicles (reversible shock absorbers may be used);
2. protect against passenger injuries (collision impact shall meet all criteria of Section 7.4.4.9.2); and
3. prevent any movement of the stopped vehicle. Passenger on platform and passenger embarking and disembarking safety shall be in accordance with Section 10.2, Platform Edge Protection. Door control protection and departure interlocks shall be in accordance with Sections 5.1.10 and 5.1.11, respectively.

5.2 AUTOMATIC TRAIN OPERATION (ATO) FUNCTIONS

The ATO shall function to automatically operate trains around the system in accordance with prescribed operating criteria but within the safety constraints imposed by ATP.

5.2.1 Motion Control

The starting, stopping, and regulation of the train speed as it travels along the guideway shall be controlled by ATO so that the acceleration, deceleration, and jerk rates are within acceptable passenger comfort limits and the speed is maintained below the overspeed limits imposed by ATP.

5.2.2 Programmed Station Stop

Programmed station stops shall be made within acceptable passenger comfort limits. When boarding and discharging passengers, the train shall provide at all doors at least an 82-cm (32.5-in.) clear opening within the designated boarding zone. This opening shall allow egress only onto the platform.

If the train and station doors are misaligned by more than the distance permitted in the preceding paragraph, the doors shall not open automatically. An alarm shall be sent to central control.

5.2.3 Door and Dwell Time Control

Train doors shall be automatically controlled by ATO during passenger boarding and discharging. If automatic station doors are provided, they shall be controlled as a set with matching train doors. Train and matching station doors, if provided, shall open and close together.

It shall be possible to manually disable the operation of any door set (on the train or at the station) without affecting the automatic operation of other unaffected sets. When automatic station doors are provided and a door set (of the train or station) is disabled, then the matching set shall also be disabled with respect to automatic operations but without the need for manual intervention.

If any doors fail to open or fail to close within 10 seconds of being commanded to do so, an alarm shall be sent to central control.

The amount of time the train remains in the station with doors open shall be established by the designer and automatically controlled by ATS as a function of fully automated operation. Once door open time has expired and any “hold door open” commands initiated by ATS or the central control operator have been removed, all doors shall be commanded to close.

When a train under manual control is properly berthed in a station and the train operator commands the train doors to open or close, the corresponding station doors, if provided, shall also open or close.

5.3 AUTOMATIC TRAIN SUPERVISION (ATS) FUNCTIONS

Automatic train supervision (ATS) shall monitor and manage the overall operation of the system. ATS shall provide the interface between the system and the central control operator. Through audio and visual displays, information shall be presented describing the status of the system on a real-time basis. This information shall allow the central control operator to assess conditions throughout the system and to take appropriate actions. The central control operator shall be able to issue commands to initiate and terminate system operations, override selected automatic commands and operations, and perform other system management functions.

For APM systems where there is no operator physically located in a central control office, alarms and malfunction information must be transmitted to a responsible individual authorized to respond to the situation in a timely manner.

5.3.1 Constraints on ATS

Should ATS become completely inoperative for any reason, ATP and ATO shall remain operable unless a system shutdown is commanded by the central control operator. Emergency controls on the central control console shall, independent of the ATS equipment, provide at least the following system emergency shutdown functions:

1. All trains stop, and
2. All propulsion power shuts off.

5.3.2 Status and Performance Monitoring

System status and performance information shall be presented to the central control operator by way of functionally separate displays: the system operations display and the power schematic display.

5.3.2.1 System Operations Display

The system operations display shall provide a visual representation of real-time operating conditions throughout the system. The display design shall

1. Be of sufficient size and/or quantity and display resolution to be viewed with ease from the normal seating area at the central control operator consoles;
2. Show approximate geographical representations of the guideway and the locations of relevant physical features, such as passenger stations, switches, and/or maintenance and storage facilities;
3. Dynamically depict any of the following system operating conditions that are pertinent to the system configuration:
   a. The location and identification of all trains in all parts of the system designed for automatic operation,
   b. The direction of travel of all active trains,
   c. The number of cars comprising each train (if train consist is variable),
   d. The train identification number used to interact with the train (if train identification is not obvious from the system configuration),
   e. The status of any switches in the system,

   f. The operating mode and status of selected system equipment, and
   g. The status of each station, including the current active dwell for each station; and
4. Incorporate such other visual aids as may be necessary to permit the central control operator(s) to manage the system efficiently.

5.3.2.2 Power Schematic Display

The power schematic display (PSD) shall provide a visual indication of the power distribution system status throughout the system. The PSD shall be of sufficient size and/or quantity and display resolution to be viewed with ease from the normal seating area at the central control operator console(s).

The PSD shall clearly display the following conditions as a minimum:

1. The presence or absence of electrical power in each propulsion power circuit that may be individually energized or deenergized;
2. The presence or absence of any power distributed along the guideway by guideway segment for each power segment that may be individually energized or deenergized;
3. The status of all circuit breakers and/or switches in the power supply system (any tripped condition shall be alarmed);
4. The presence or absence of backup power; and
5. The presence of any alarm condition.

Indication of power status shall be by both voltage monitoring and device position indication. PSD indication and control functions shall not be affected by any single-point failure.

5.3.3 Performance Control and Override

Management and operation of the system shall be accomplished by the control and override functions. There shall be both automatically controlled and manually initiated control and override functions, as described in this section.

5.3.3.1 Automatic Control Functions

To the extent warranted, the ATS system shall perform the control and coordination functions necessary to achieve fully supervised automatic operation of the system.

5.3.3.1.1 Mode Management The ATS shall manage all specified modes of operation. Available modes shall depend on system technology, guideway configuration, operating plan, and failure mode recovery plan.

5.3.3.1.2 Train Tracking The ATS shall systematically track each train around the system to the extent warranted by the system configuration and in a manner that is consistent with the requirements for management of the specified modes of operation.

5.3.3.1.3 Headway Management Consistent with the selected mode of operation and the specified degree of interactive train regulation, the ATS shall act to maintain the required time (as measured at a fixed point on the guideway) and/or distance spacing between trains in automatic operation on the system.

5.3.3.1.4 Train Routing The ATS shall automatically accomplish all routing functions required by the selected mode of operation. This set of functions shall include initiating route, switch position, and travel direction reversal requests, as required.

5.3.3.2 Manual Control and Override Functions

The capabilities and functions described in this section shall be incorporated in the central control console. Controls and displays associated with ATC shall be integrated with the controls and displays of the communications (see Chapter 6, Audio and Visual Communications) and electrical (see Section 5.3.2.2, Power Schematic Display) subsystems to facilitate the efficient and effective supervision of all subsystems by one operator at the console.

Manual controls shall be provided that enable the central control operator to perform the following functions:

1. *Train dispatching*—The central control operator shall be able to dispatch trains into service from any designated off-line launch point.
2. *Train routing*—Depending on the system configuration, the ATS shall be designed so that each train can be assigned to a specific operating mode, lane, or route, via an instruction from the central control operator.
3. *Initiation of service*—The central control operator shall be able to initiate system service.
4. *Termination of service*—The central control operator shall be able to terminate system service.
5. *Modify train operations*—The central control operator shall be able to issue commands that modify normal train operation.
6. *Remove trains*—For systems that provide off-line storage, the central control operator shall be able to direct a train to proceed out of service.
7. *Initiate failure mode operations*—The central control operator shall be able to convert the

system from its normal operating mode to any available alternative operating mode for failure management purposes.

8. *Hold trains*—The central control operator shall be able to command trains to hold in the stations.
9. *Command switches*—When switches are provided, the central control operator shall be able to individually command switches to move.
10. *Stop all trains*—The central control operator with one command shall be able to stop all trains on the guideway.
11. *Command power off or on*—The central control operator shall be able to command propulsion power off or on to the entire system or to individual power circuits, depending on the segmentation provided.
12. *Acknowledge and process alarms*—The central control operator shall be able to receive from several subsystems, acknowledge, store, and recall alarm message displays and acknowledge accompanying audible alarms.

Except for a single-event command, once a command is imposed by the central control operator and accepted by ATS, the action shall remain operative until it is subsequently removed by the operator.

5.3.3.3 Alarms and Malfunction Reporting

Major system components shall be automatically monitored and alarms shall be annunciated for malfunctions and failures thereof. Also, system-related facilities shall be monitored and alarms annunciated for fire and life safety problems and/or security intrusions. The central control console shall incorporate both an incident (message) display and audible alarms for the benefit of the central control operator. Within 2 seconds of detection, the occurrence of an incident or condition shall be reported on a display, indicating the time of the incident, the nature and classification of the incident or condition, the identification of the vehicle and train, and/or the specific guideway or station location involved. Each alarm shall be indexed and time-tagged as to when the fault was detected. Alarms shall be stored and have the capability to be recalled and/or redisplayed by an index number or by hardware type with which it is associated (e.g., train, substation, passenger station, or switch). Acknowledgment of the alarm by the central control operator shall cause the audible alarm to cease; however, the associated alarm indication shall persist until the condition is cleared. All alarm reports and clearing shall be recorded in memory and printed on a line printer.

Data communications between central control and trains shall be maintained and confirmed. Failure of any train to respond shall be alarmed and annunciated at central control.

5.3.3.3.1 System Alarms System operation malfunctions, alarms, and reporting shall be primarily for security, safety, and unscheduled stoppage problems.

As a minimum, system operations malfunctions shall be reported in one of two priority classifications, described as follows. The level of classification and reporting of faults shall be sufficiently detailed to allow operating and maintenance personnel to make rational decisions in reacting to the reports, consistent with the functions required of them in the operation and maintenance plans, procedures, and manuals.

Priority I malfunctions pose an immediate threat to passenger safety and/or the threat of damage to system equipment.

Priority II malfunctions do not pose an immediate threat but could cause a potential threat to passengers or equipment if not corrected quickly.

5.3.3.3.2 Facility Fire and Intrusion Alarms Facility fire and/or smoke and intrusion alarms, if provided, shall be annunciated separately and redundantly (audibly and visually) on the central control console. The location of the alarm point shall be indicated.

5.3.3.4 Data Recording and Reporting

The ATS subsystem shall include the recording of selected data transactions between central control and other portions of the system. Such data shall be recorded in a format that includes the date and exact time of each data transmission. Data shall be recorded and stored on appropriate media in a format suitable for both a permanent file and random access retrieval and for use with system data processing software to produce reports, if provided.

If specified, an appropriate subset of this recorded data shall be able to be printed in real time on a printer at central control. This printout shall constitute the daily operations log.

5.4 MANUAL OPERATION LIMITATIONS

This standard is intended for fully automatic operation and does not apply to extended passenger service in manual mode. Manual mode operation may be used for testing, recovery, maintenance and system failures and failure management, or other abnormal conditions. The hazard resolution process of Section 3.1.2 shall address the hazards introduced by manual operation.

For limited manual operation, the design shall enable the operator(s) to observe guideway conditions; communicate with central control and passengers; observe vehicle status indications; and control vehicle propulsion, braking, and doors. When not in use, the controls and status indicators shall be protected from access by passengers.

Chapter 6
AUDIO AND VISUAL COMMUNICATIONS

All audio and visual communications equipment shall operate independently of guideway power and shall function fully under the ambient conditions to which it may be exposed. All audio and visual communications equipment required by this standard shall be powered by uninterruptible power for a time period as determined by an analysis in accordance with Section 3.1.2.1, Hazard Analyses.

6.1 AUDIO COMMUNICATION

Facilities and equipment shall be provided to permit voice communications between the central control operator and (1) passengers and (2) operations and maintenance personnel located throughout the system.

All audio communication systems and public address systems required herein shall meet the requirements of Section 6.1.6.

6.1.1 Station Public Address

A station public address system shall enable live announcements to be made from central control to all public areas of all station platforms.

Live messages shall override any prerecorded messages, if provided. All speakers in a given station zone shall deliver announcements simultaneously when that station or zone is selected. The public address system zoning shall provide full coverage to all public areas of each station.

6.1.2 Emergency Station and Wayside Communications

There shall be two-way emergency audio communications linking central control with all passenger stations and any blue light stations (as specified by Section 11.4.1 of NFPA 130 [2003]). Each emergency communication device (ECD) shall automatically call central control when activated. A display at central control shall identify the communicating ECD and indicate whether there are any additional activated ECDs.

All ECD equipment shall be of heavy-duty, vandal-resistant design, including a tamper- and weather-resistant enclosure. These emergency audio communications shall be independent of any other communication system. The person operating the ECD shall receive an audible indication that the unit is calling. Instructions for use shall be provided in vandal-resistant signs integral with or adjacent to the ECDs.

6.1.3 Train Voice Communication and Public Address

A full-duplex communication system shall be provided to permit two-way voice communication between the central control operator and passengers or personnel within each passenger compartment of each train. Full coverage of all trains throughout the system shall be provided. Activation of two-way voice communication between central control and the trains shall be possible only from central control. Passenger-initiated communication requests from a train, including the passenger compartment identification number, shall automatically be displayed at central control for the central control operator to activate the communication link. The display shall also show any queue of such communication requests. The central control operator shall be able to activate this link on receiving an indication of a passenger-initiated communication request or at any other time to receive communications. A passenger-initiated communication request shall include an audio and visual on-board indication that the call has been requested.

A train public address function shall be provided for the central control operator in two modes: (1) to make audible announcements in all passenger compartments of any one train and (2) to make audible announcements in all passenger compartments of all trains in the system. Live messages shall override any prerecorded messages, if provided. Speaker fire resistance shall meet the requirements of UL 813-1993 (1993). Full coverage of all trains throughout the system shall be provided. For trains that can be operated in manual mode, a means shall be provided to enable the train operator to make announcements throughout the train.

6.1.4 Operations and Maintenance (O&M) Personnel Communications

The APM system shall include an internal telephone or intercom system connecting central control, all administrative offices and maintenance areas, and selected storage and equipment rooms. Telephones or intercoms not otherwise protected shall be of heavy-duty, vandal-resistant design, including a tamper- and weather-resistant enclosure.

An O&M radio system shall be provided for communications between the central control operator and O&M personnel. Each O&M person on duty not having direct access to the internal telephone or intercom system shall have a portable radio at all times.

6.1.5 Recording of Audio Transmissions

An audio recording device shall be provided to record all communications over train voice communications, ECDs, and public address systems with the central control operator. This device shall be capable of individually recording at least 24 hours of continuous audio for each audio communication system of Sections 6.1.1 through 6.1.3 with indication of date and time. Recording media shall be provided so that each day's recording can be stored.

6.1.6 Intelligibility of Audio Communications

The required audio communications systems shall meet the following requirements:

1. Station public address systems, emergency station and wayside communications systems, and the internal O&M telephone or intercom system shall meet the intelligibility requirements of NFPA 72-2002 (2002). In meeting the intelligibility requirements, measurement conditions shall represent the entire passenger space of the station or the position of the telephone or intercom and shall provide the average result of all reflected signals and reverberations, and all auxiliary systems shall be in normal operation, such that the ambient noise will be at typical maximum levels. The tests of telephones and intercoms shall be repeated for a representative number of locations throughout the system.
2. All wireless voice communications between the wayside and the trains, including central control, shall meet DAQ 3 of Table 1, Annex A of TIA/EIA TSB88 January 2002 (2002), for 97 percent of the trainway. In areas of the trainway where DAQ 3 is met, the intelligibility shall meet the intelligibility requirements of NFPA 72-2002 (2002). The vehicle interior noise shall be at least at the maximum interior level as measured in accordance with Part 2, Section 7.7.4. This test shall be repeated for a representative number of locations throughout the system.
3. All voice communications exclusively within a train shall meet the intelligibility requirements of NFPA 72-2002 (2002). The vehicle interior noise shall be at least at the maximum interior level as measured in accordance with Section 7.7.4.
4. The O&M radio system shall provide signal coverage greater than or equal to DAQ 3, as referenced previously, for 97 percent area coverage reliability within the system where O&M personnel may work.

6.2 VIDEO SURVEILLANCE

A closed-circuit television (CCTV) subsystem shall be provided and installed to permit central control to monitor passenger activities on all station platforms in the system, particularly the boarding areas and along the entire edge of any open platforms. Video surveillance is not required for attended station platforms.

6.2.1 Central Control Equipment

Central control shall be equipped with monitors for displaying camera outputs, organized in a logical order with identifications displayed on each screen to orient the central control operator and facilitate identification of the image location.

CCTV monitors shall provide a clear picture in the ambient light level of the central control room.

6.2.2 Passenger Station Equipment

Cameras shall have a usable picture with scene illumination from 0.3 lux (0.03 foot-candle) up to bright sunlight, using automatic light compensation. Cameras shall be tamper proof and vandal resistant. Cameras shall automatically adjust to the environmental and the ambient light conditions of each station throughout the operating day.

Camera position for platform viewing, particularly the boarding areas and along the entire edge of any open platforms, shall be fixed and shall not be remotely controlled. Camera mounts and any housings shall be tamper proof and vandal resistant for all applications and weather resistant for outdoor applications.

6.2.3 Recording of Video Transmissions

A system shall be provided to record the image of each camera in the system, but not necessarily all cameras simultaneously, to include identification of the camera, time, and date.

6.3 PASSENGER INFORMATION DEVICES

The following audio announcements and dynamic signs are required for APM systems.

6.3.1 Vehicle

Each passenger compartment shall have automatic onboard audible announcements that signal each station as it is approached to inform passengers of the impending stop. For APM systems that have trains operating over more than one route from the same platform, audio announcements shall indicate the name of the station.

For APM systems that have trains operating over more than one route from the same platform, dynamic signs shall be provided for each passenger compartment that indicate train route and/or destination and the name of the station at which the train is approaching or has stopped. These dynamic signs shall be positioned for maximum visibility by passengers.

6.3.2 Stations

Each station platform shall be provided with automatic audible and visual warnings that signal the arrival and departure of trains. The arrival warning shall be made before the train enters the station. The departure warning indicating that the doors are about to be closed shall be communicated to passengers both in the trains and on the platform. APM systems where trains do not achieve a complete stop for boarding and discharging passengers shall provide warnings that meet an equivalent facilitation, in accordance with Section 3.1.2.1, Hazard Analyses. APM systems that have trains operating over more than one route from the same platform shall also audibly announce train route and/or destination.

For APM systems that have trains operating over more than one route from the same platform, dynamic station signs shall be provided on each station platform to inform passengers of the train route and/or destination. The vehicle dynamic sign may satisfy this requirement, provided that the message is also posted on the exterior of the vehicle and can be read by passengers on the station platform.

Chapter 7
VEHICLES

This section provides standards for automated people mover (APM) vehicles. These APM standards have been developed for vehicle cruise speeds up to 100 km/h (60 mi/h). They may be applied to higher speed systems at the discretion of the user; however, professional engineering judgment is needed with regard to suitability for such higher speed applications.

7.1 VEHICLE CAPACITY AND LOAD

Vehicle passenger *design capacity* shall be defined in number of persons, by the owner, based on the owner's preferred comfort standards. Total passenger area shall be all of the area available to seated and standing passengers. The definition of *standee floor area* is the total passenger area less 0.42 m^2 (4.5 ft^2) for each nonremovable or nonstowable seat position. For calculating the loads imposed by passengers seated on benches, 0.45 m (18 in.) of width shall be allocated for each seated passenger unless otherwise established by the seat design.

The following loadings are established for APM vehicles:

AW0: Weight of an empty vehicle, ready to be operated, but without passengers.

AW1: Design load shall be AW0 plus a force of 712 N (160 lb) per passenger, multiplied by the design capacity.

AW2: Maximum operating load shall be AW0 plus 712 N (160 lb) multiplied by the maximum number of passengers that the vehicle is permitted to transport, if limited by load weigh systems designed in accordance with Section 3.3, ATC System Fail-Safe Design. Otherwise, AW2 shall be equal to AW3 for the brake system design; for the propulsion system design, AW2 shall equal AW3 or, alternatively, AW2 for propulsion shall be determined by simulation of the worst-case anticipated load profile along the alignment.

NOTE: This definition of AW2 is intended to define AW2 as the maximum load that can be encountered by a moving vehicle. AW3 is the maximum load that can be encountered by a stationary vehicle. In the absence of a load weigh system designed in accordance with the fail-safe design principles of Section 3.3, AW2 and AW3 are the same.

AW3: The crush load shall be AW0 plus 5,120 N/m^2 (107 lb/ft^2) multiplied by the standee floor area, plus 712 N (160 lb) per seat multiplied by the number of nonremovable or nonstowable seats.

If luggage racks are provided, a luggage load of 2,870 N/m^2 (60 lb/ft^2) shall be considered for both AW2 and AW3.

All operating vehicle subsystem design requirements that are not safety related shall meet loading requirements from AW0 to AW1. All conditions affecting safety, including automatic train protection, emergency braking, propulsion duty cycle, and clearances, shall meet loading requirements from AW0 to AW2. Structural design shall be in accordance with Section 7.4.

7.2 VEHICLE DYNAMIC ENVELOPE

The vehicle dynamic envelope is defined as the space occupied by the dynamic outline of the transit vehicle under normal operating conditions and probable combinations of vehicle failures. The dynamic envelope shall also consider the effect of manufacturing, construction, installation, and maintenance tolerances and the effects of normal wear of wheels or tires and other components.

The dynamic envelope shall include, but not be limited to, the overhang on curves, effects of chording, vehicle speed, suspension characteristics and failures, and applicable external forces, such as wind, acting on the vehicle or other system equipment. The dynamic envelope shall also include a margin of 90 cm (36 in.) for passenger limbs for those vehicles that permit passenger limbs to extend through windows or other openings.

The risk of any part of the vehicle extending outside its dynamic envelope under failure conditions shall be assessed in accordance with Table 3-1, and the risk classification shall be assessed to be neither "unacceptable" nor "undesirable."

7.3 CLEARANCE IN STATIONS

Slow-speed people movers are defined as those particular site applications where all vehicles travel no more than 32 km/h (20 mi/h) at any location on their route during normal operation.

For slow-speed people movers, when the vehicle is stopped in a station with the doors open for boarding, the horizontal gap between the station platform and the vehicle door threshold shall be no greater than 25 mm (1.0 in.), and the height of the vehicle floor shall be within 12 mm (0.5 in.) of the platform height under all normal static load conditions from AW0 to AW1.

For all other people movers (such as those not covered by the slow-speed definition), the horizontal gap as defined shall be no greater than 50 mm (2.0 in.), and the height of the vehicle floor shall be within 15.5 mm (0.625 in.) of the platform height under all normal static load conditions from AW0 to AW1.

7.4 VEHICLE STRUCTURAL DESIGN

The vehicle supplier shall perform a complete structural analysis of the body structure, suspension and guidance elements, and equipment mounts.

7.4.1 Structural Analysis

The structural analysis shall identify the design loads and include evaluation of the following:

1. Strength of primary structural members of the body structure and suspension and guidance elements;
2. Strength of load-bearing joints, connections, and equipment mounts;
3. Flexural and torsional deformation of the vehicle structure;
4. Tipping stability; and
5. Crashworthiness.

7.4.2 Previous Structural Analysis

A previous structural analysis may be used, provided that it is updated as needed to account for the following:

1. Pertinent changes in environmental or operating conditions that affect design loading;
2. Pertinent engineering changes in the vehicle dimensions, materials, or manufacturing processes; and
3. Experience from prior installation.

7.4.3 Structural Design Life

The vehicle structure shall be designed to operate in passenger service, with recommended maintenance, for at least 20 years while meeting the specified system operating criteria, unless explicitly specified otherwise by the owner.

7.4.4 Structural Design Criteria

Structural design criteria are as follows.

7.4.4.1 Design Loads

Design loads for the vehicle structural elements shall be defined in terms of operating loads and worst-case loads.

7.4.4.1.1 Operating Loads Operating loads (those loads that occur repeatedly during normal system operation) are defined as follows:

1. *Lateral load*: A reversing force under normal speed operation over the alignment equal to the centrifugal force to be experienced by a vehicle loaded to AW1, plus the load resulting from an additional reversing acceleration of no less than 0.1*g* for a vehicle loaded to AW1.
2. *Vertical load*: The vertical load from an AW1 loaded vehicle, plus the load resulting from a reversing acceleration of no less than 0.2*g* for a vehicle loaded to AW1.
3. *Longitudinal load*: A reversing longitudinal load caused by normal acceleration or braking operation but no less than the load resulting from a reversing acceleration of 0.1*g* applied to an AW1 loaded vehicle.

All of the aforementioned loads shall be assumed to be distributed as they would be applied in passenger service. Loads attributed to the unsprung mass shall be considered based on vehicle and suspension dynamics. Grade and superelevation shall be considered where appropriate.

Actual loads, measured over a route duplicating all site geometry and operating speeds, shall be permitted in place of these operating loads.

The vehicle operating stress ranges resulting from these loads shall not exceed 0.75 of the material allowable fatigue stress range from an accepted industry standard considering a 97.5 percent lifetime survival probability for the structural design life, per Section 7.4.3.

7.4.4.1.2 Worst-Case Loads Worst-case loads are defined as follows:

1. *Lateral load*: A lateral load equal to the greater of the following:
   a. A maximum force under either maximum normal or manual speed operation over the proposed alignment equal to the maximum centrifugal force to be experienced by a vehicle

loaded to AW2, under worst-case overspeed conditions subject to automatic train protection, plus the force resulting from an additional acceleration of $0.1g$, plus a lateral wind load normal to the side of the vehicle body, per Section 2.1.2, Wind, or
   b. A survival wind load, as specified in Section 2.1.2, Wind, normal to the side of the stationary vehicle body, plus the lateral load component from the worst-case combinations of guideway superelevation and vehicle load from AW0 to AW3.
2. *Vertical load*: A vertical load equal to the greater of the following:
   a. An AW3 loaded vehicle, or
   b. An AW2 loaded vehicle; the force resulting from a reversing acceleration of $0.2g$.
3. *Longitudinal load*: The largest longitudinal load resulting from dragging of brakes caused by any single-point failure on an AW2 loaded train, plus applicable wind loads as specified in Section 2.1.2.
4. Any other applicable worst-case loads, including (but not limited to) tire scrubbing (cornering) and wheel locking.

All of the aforementioned loads shall be assumed to be distributed as they would be applied in passenger service. Loads attributed to the unsprung mass shall be considered based on vehicle and suspension dynamics. Grade and superelevation shall be considered where appropriate.

Stresses resulting from all worst-case possible combinations of these loads applied to a train, including a load factor of 1.5, shall not exceed the material yield strength of any structural element or connection.

Under a combined maximum vertical load and an end load applied horizontally to the end structure of the vehicle equivalent to AW0, stresses in the principal framing members shall not be greater than the yield strength of the associated structure.

Any roof area intended to be traversed by personnel shall be capable of supporting a point load of 1,110 N (250 lb) over a 15 cm × 10 cm (6 in. × 4 in.) area, without permanent deformation. The portions of the roof intended to support personnel shall also support a uniform load of 1,440 N/m^2 (30 lb/ft^2) without permanent deformation.

The floor load shall be based upon an AW3 loading condition. The floor shall be capable of withstanding a point load of 712 N (160 lb) over a 13-mm (0.5-in.) diameter circle.

Each seat pan, seat structure, and attachment to the structure shall support, without permanent deformation, a 2,160 N (485 lb) vertical load applied uniformly at each seating position.

Wheelchair areas shall be considered as 76 cm × 122 cm (30 in. × 48 in.), with a weight of 2,670 N (600 lb).

Stanchions shall be rigidly attached at their ends, be rattle free, and withstand a horizontal load, in any direction, of 890 N (200 lb) applied at the vertical midpoint.

Doors, supporting tracks, and linkages shall withstand a force of 980 N (220 lb) applied at right angles to and approximately at the center of a panel and shall be distributed over an area of approximately 10 cm × 10 cm (4 in. × 4 in.), without permanent deformation or binding of the door mechanism.

7.4.4.2 Jacking and Lifting

Jacking and lifting loads shall be considered in the design of the vehicle structure.

Adequate attachment points shall be provided as required for handling the vehicle. Jacking pads shall be provided if jacking is required. The vehicle structure design shall consider jacking and handling loads, using vehicle weight as AW0, per Section 7.1. Expected jacking and lifting loads shall not exceed material yield strength of any structural members, including a load factor of 1.5.

7.4.4.3 Material Properties

Documentation showing the as-delivered properties of the materials used in the vehicle structure, including fasteners and welds, shall be available. This documentation shall include at least the guaranteed minimum yield and ultimate strengths, elongation, and Young's modulus data for each material, in the form of test reports certified by the manufacturer, along with allowable fatigue stress assumptions for each material.

7.4.4.4 Paints, Coatings, and Protection of Metals

The structure shall be protected by finish coating systems so that it does not sustain corrosion damage during its structural design life, per Section 7.4.3, when maintained as specified.

7.4.4.5 Allowable Stress

Reduction in allowable stresses shall be made because of stress concentrations and the effects of welded or bolted connections and castings or if the failure of a component could result in unacceptable and/or undesirable hazard conditions per Table 3-1.

7.4.4.6 Deformation

Elastic deformations occurring under any loading conditions per Section 7.4.4.1 shall not interfere with normal and/or safe operation of the vehicle or any of its subsystems, including door operation.

7.4.4.7 Structural Joints and Connections

Joining with welds and fasteners shall be performed in accordance with an applicable standard. Bonding, including chemical and thermal adhesion, shall be performed in accordance with proven, documented manufacturer's or industry procedures or standards.

7.4.4.8 Tipping Stability

The vehicle shall be stable under the worst-case combination of loads, per Section 7.4.4.1.2. No vehicle guideway friction effects shall be included in computing vehicle stability.

7.4.4.9 Crashworthiness

As applicable, the vehicle or train shall be capable of withstanding collisions with other vehicles or trains and/or end-of-track overtravel protection devices as specified here.

As applicable, the vehicle and overtravel protection device shall have anticlimbing capability in a collision to prevent one vehicle in a train from climbing another, or an overtravel protection device. This protection may be provided by capture to the guideway or by vehicle design in a manner that limits vertical movement.

7.4.4.9.1 Vehicle–Vehicle Collision The collision at any speed up to 5 km/h (3 mi/h) of either end of a moving train with another AW2 loaded train of any length, parked on a level guideway with its brakes released (not applied), shall not cause damage to the vehicles of either train. This requirement shall be met for any condition of the moving train between the shortest length train at AW0 and a maximum length train at AW2.

7.4.4.9.2 Vehicle–Overtravel Protection Device Collision The vehicle under any possible loading conditions or train configuration, except pushing or pulling with another vehicle or train, shall be capable of withstanding a collision with the end-of-track overtravel protection device at the maximum impact speed attainable under automatic control at that specific location (see Section 5.1.5, Overtravel Protection) and a maximum deceleration rate of 1.2g with only cosmetic damage to the train.

The vehicle or train, under any possible loading condition or train configuration, including pushing or pulling with another vehicle or train, shall not leave the guideway during a collision with the overtravel protection device for speeds at which the train can be driven under manual control not subject to automatic train protection (ATP) as defined in Section 1.5. In this collision event, the integrity of the passenger compartment shall be maintained.

7.4.4.10 Mounted Equipment and Attachments

Bogie- and carbody-mounted equipment and attachments shall be designed to withstand the worst-case and operating loads associated with that equipment.

7.5 COUPLING

If coupling between vehicles is used, it shall meet the following requirements.

7.5.1 Mechanical Design

Couplers shall be slack free and shall allow coupling and uncoupling of trains anywhere in the system, including within any maintenance facilities or storage yards. A positive lock shall ensure that the coupler, once engaged, cannot release without prior release of this lock.

Coupling shall be accomplished by moving vehicles under manual control or using an automatic process and shall not require the placement of an individual in the area between vehicles while either vehicle is in motion.

7.5.2 Electrical and Control Requirements

Automatic coupling shall meet all requirements of Chapter 3, Safety Requirements, and Section 5.1, Automatic Train Protection (ATP) Functions. Mechanical couplers shall not be used as an electrical ground or a means to transmit current between vehicles.

7.5.3 Coupler Interfaces

For manually coupled vehicles, all required electrical, pneumatic, and hydraulic coupling connections shall be made automatically during a mechanical coupling event or made manually after such an event. These connections may be disconnected automatically or manually before a mechanical uncoupling event. Fully automatic coupling shall not require manual intervention to accomplish electrical, pneumatic, or hydraulic connections.

Electrical connections between coupled vehicles shall include circuit and shield grounds as appropriate. Electrical coupling shall prevent incorrect alignment of electrical connections and shall have weather- and moisture-resistant protection for contacts when not in use.

High-voltage circuits shall not be trainlined between vehicles that may be coupled or uncoupled.

Hydraulic and pneumatic trainlines between vehicles shall have valves to shut off the lines when not coupled to another vehicle. If more than one hydraulic or pneumatic trainline is required, they shall be configured so that misconnection is not possible.

7.6 SUSPENSION AND GUIDANCE

Where pneumatic tires are used, failure of a tire to maintain proper pressure shall not result in a condition that allows damage to the vehicles, electrical system, or guideway, or that presents a hazard to passengers, per Section 3.1.2.1, Hazard Analyses. Similarly, loss of levitation elements shall also not result in such conditions.

7.7 PASSENGER COMFORT

This section describes the vehicle design areas that affect passenger comfort.

7.7.1 Heating and Air Conditioning

Heating and air conditioning are optional, but when provided shall meet the following requirements. Design capacity, per Section 7.1, shall be used as the basis for vehicle cooling load calculation.

Local meteorological conditions are to be used in the heating and air conditioning system analysis as defined in ASHRAE (2005) 1% day (summer) and 99% day (winter), per Chapter 28, Table 1.

Cooling capacity shall be calculated to include the following heat loads:

1. Carbody conduction;
2. Duct gains;
3. Forced fresh air, per Section 7.7.2;
4. Lighting;
5. Passengers;
6. Solar radiation; and
7. Miscellaneous interior.

NOTE: Miscellaneous interior loads shall include heat gains from control equipment, communications equipment, and other onboard equipment.

With doors closed, the heating and air conditioning system shall maintain the vehicle interior temperature at an owner-specified set temperature and with a relative humidity not exceeding 60%.

The heating and air conditioning control system shall be fully automatic, allowing automatic control in cooling, ventilation, or heating modes without manual intervention. All heating and air conditioning system controls shall be inaccessible to passengers. The system shall maintain temperature uniformity (maximum temperature deviation) within the passenger space with doors closed, at steady state, of 2 °C (4 °F). Also, the air discharged from vents shall have minimum and maximum air temperatures of 5 °C and 50 °C (40 °F and 120 °F), respectively.

Solar loading shall be based on local summer conditions and shall be calculated for typical solar exposure on the vehicle.

Filtration shall be provided at the evaporator supply duct or interface.

7.7.2 Ventilation

Proper ventilation shall be provided on all vehicles. Fresh air shall be provided for passengers at a rate of no less than 15 m^3/h (9 ft^3/min) per passenger at design capacity and shall continue to operate at a rate of no less than 9 m^3/h (5.3 ft^3/min) per passenger under emergency conditions, including loss of guideway power, for a time period as determined by the hazard analyses performed in accordance with Section 3.1.2.1. Fresh air ventilation shall also be filtered. Provision shall be made to allow for the controlled deactivation of emergency ventilation to prevent the infusion of smoke or fumes from under the cars.

7.7.3 Ride Quality

The vehicle shall produce a ride within the passenger comfort limits detailed in this section. Testing for verification of ride quality is to be done with vehicles at AW0 with not more than three test or observation personnel onboard with necessary test equipment.

Measurements shall be taken at the vehicle floor above the trucks and at the geometric center of the vehicle floor.

7.7.3.1 Acceleration and Jerk Limits

Acceleration of the vehicle depends on system design parameters, including civil design. As such, guideway geometric design shall be limited to the following sustained acceleration and jerk criteria. For both acceleration and jerk, values are given for vehicles with standing passengers and also for vehicles where only seated passengers are permitted.

7.7.3.1.1 Maximum Sustained Acceleration The accelerations introduced by guideway geometry and vehicle speed changes shall not exceed the limits stated in Table 7-1. "Sustained" refers to the nominal values, excluding random vibration effects above 0.5 Hz.

Table 7-1 includes limits for standing passengers and a column for seated passengers, showing higher allowable accelerations. The limits in the Seated column apply to those vehicles where provisions for standing passengers are not included, resulting in a vehicle interior where all passengers are seated. Where the design allows for standing passengers, the limits in the Standing column shall be used.

Lateral, vertical, and longitudinal accelerations are as measured by an inertial accelerometer mounted on the vehicle floor. The vertical axis shall be perpendicular to the floor, and the lateral axis shall be perpendicular to the direction of vehicle travel.

When grade effects are excluded from the sustained standing acceleration, it shall be limited to 0.13*g* for normal longitudinal effects and 0.25*g* for emergency longitudinal effects.

7.7.3.1.2 Maximum Jerk Rate Jerk is defined as the rate of change of sustained acceleration. The jerk limits in Table 7-2 must not be exceeded for speed changes and vertical and horizontal curves. Jerk during onset of emergency braking may exceed these limits.

7.7.3.2 Human Response Testing

Ride quality, if testing is required, shall be measured on an empty vehicle, with not more than three test or observation personnel and necessary equipment, using a Bruel & Kjaer Type 2512 (or 2522) human response vibration meter (or equal) with a 4322 triaxial accelerometer (or equal). For any single station-to-station run (not including dwells), root mean square (RMS) accelerations between 1 and 80 Hz shall fall below the levels outlined in ACGIH Publication #7 DOC-648 (2001) using the 1-hour threshold limit values tabulated in Tables 1 and 2, with all acceleration values divided by 3.15.

NOTE: This testing produces the same values as in ISO 2631-1 (1985; revised 1997) for 1-hour exposure to reduced comfort, and either reference may be used.

7.7.4 Interior Noise Levels

The interior noise levels in Table 7-3 shall not be exceeded under the conditions defined with all auxiliary equipment operating. All noise measurements are to be taken in a free field environment, with no passengers (up to three test personnel permitted) in the vehicle. Interior noise levels shall be measured 1.5 m (5 ft) above the floor, above the suspension and/or running gear, and at the geometric center of the vehicle floor, using at least a Type II instrument, as defined in ANSI (1983a) Standard S1.4-1983 (revised 2006), and shall be set for fast or slow response as indicated.

Slow response shall be used for the vehicle stopped in the station, and fast response shall be used for noise testing with the vehicle in motion.

Noticeable pure tones are not permitted. A pure tone is defined to exist when one 1/3-octave band exceeds the arithmetic average of the two adjacent bands by 4 dBA or more in the range of frequencies between 250 and 8,000 Hz. If an adjacent band contains a pure tone, the next closest band without a pure tone shall be used in its place. A noticeable pure tone shall be considered to exist when the 1/3 octave band containing the pure tone contributes more than 1 dBA to the overall dBA level. Exterior noise level limits are presented in Section 2.2.1, Exterior Airborne Noise.

Table 7-1. Maximum Sustained Acceleration

Direction	Standing	Seated
Lateral	±0.10*g*	±0.25*g*
Vertical[a]	±0.05*g*	±0.25*g*
Longitudinal normal[b]	±0.16*g*	±0.35*g*
Longitudinal emergency[b]	±0.32*g*	±0.60*g*

[a]This is with respect to a 1*g* datum.
[b]Including effect of grade.

Table 7-2. Maximum Jerk Rate

Direction	Standing	Seated
Lateral	00.0.06*g*/s	0.25*g*/s
Vertical	0.04*g*/s	0.25*g*/s
Longitudinal	0.0.10*g*/s	0.25*g*/s

Table 7-3. Interior Noise Levels

Vehicle Condition	Noise Level
Vehicle stationary, doors shut	74 dBA
Vehicle moving up to 48 km/h (30 mi/h)	76 dBA
Vehicle moving above 48 km/h (30 mi/h)	79 dBA

7.7.4.1 Commentary for Interior Noise Levels (Section 7.7.4) and Exterior Airborne Noise (Section 2.2.1) Noise Limits in Tunnels

The following commentary is provided as an explanation of why the standard does not specify noise limits inside buildings and tunnels.

The conditions for measuring vehicle exterior airborne noise are specified in Section 2.2.1 as, "Under all normal operating conditions *in a free field*, 15 m (50 ft) from guideway centerline and 1.5 m (5 ft) above ground level to 1.5 m (5 ft) above guideway running surface."

The conditions for measuring vehicle interior noise is specified in Section 7.7.4 as ". . . with all auxiliary equipment operating. All noise measurements are to be taken *in a free field environment*, with no passengers (up to three test personnel permitted) in the vehicle. Interior noise levels shall be measured 1.5 m (5 ft) above the floor, above the suspension and/or running gear, and at the geometric center of the vehicle floor . . ."

In both cases, the vehicle is specified to be operating in a *free field environment* to determine purely the noise energy that is emitted from the train without any content of reflected noise or other noise generators that otherwise can compromise the measurements.

When a vehicle or train is operated inside a tunnel or building, noise emitted from the vehicle or train can be reflected and can increase the amplitude of the measured noise. Because the geometries, designs, and surface materials of such structures can vary significantly, it is not possible to know the extent that reflected noise may be experienced. Hence, neither consistent conditions nor standard tests exist for specifying noise limits in tunnels and buildings.

The current standard sets a limit on the noise energy that can be emitted by a vehicle or train. Designers of buildings and tunnels are provided with the limit on emitted noise energy that they need as an input on which they can make designs. Because they are in control of the architectural structure (size, shape, materials, and reflective surfaces), they are in control of what the resultant noise is in a tunnel or building. Buyers of APM systems can specify noise limits, taking into account the architectural designs they specify.

7.7.5 Vibration

The interior of the vehicle shall be designed to avoid resonance of panels and other vehicle components. Equipment mounts shall be designed to minimize the transmission of vibration.

7.7.6 Passenger Compartment Provisions

The following sections describe general passenger compartment provisions.

7.7.6.1 Priority Seating Signs

Each vehicle shall contain sign(s) that indicate that certain seats are priority seats for persons with disabilities and that other passengers should make such seats available to those who wish to use them.

Characters on required signs shall have a width-to-height ratio between 3:5 and 1:1, with a minimum character height (using an uppercase X) of 16 mm (0.625 in.), and with wide spacing (generally, the space between letters shall be 1/16 the height of uppercase letters), and shall contrast with the background, either light on dark, or dark on light.

7.7.6.2 Interior Circulation, Handrails, and Stanchions

Handrails and/or stanchions shall be provided to assist safe boarding, onboard circulation, seating and standing, and alighting by persons with disabilities.

Handrails, stanchions, and seats shall allow a route at least 82 cm (32 in.) wide so that at least two wheelchair or mobility-aid users can enter the vehicle and position the wheelchairs or mobility aids in the appropriate areas. Each handrail, stanchion, and seat shall have a minimum clear space of 76 cm × 122 cm (30 in. × 48 in.) so as not to unduly restrict movement of other passengers. Passenger compartments 6.7 m (22 ft) in overall outside length or less need provide only one wheelchair or mobility-aid space. Space to accommodate wheelchairs and mobility aids may be provided within the normal area used by standees, and designation of specific spaces is not required. Particular attention shall be given to ensuring maximum maneuverability immediately inside doors. Ample vertical stanchions from ceiling to seat back rails shall be provided. Vertical stanchions from ceiling to floor shall not interfere with wheelchair or mobility-aid user circulation and shall be kept to a minimum in the vicinity of doors. Stanchions and handrails immediately in the entrances and exits of the vehicle should be a visibly contrasting color to aid the visually impaired.

The diameter or width of the gripping surface of handrails and stanchions shall be 32 mm to 38 mm (1.25 in. to 1.5 in.) and shall provide a minimum 76 mm (3 in.) knuckle clearance from the nearest adjacent surface.

7.7.6.3 Floor Surfaces

Floor surfaces on aisles, places for standees, and areas where wheelchair and mobility-aid users are to be accommodated shall be slip resistant.

7.7.6.4 Materials and Fasteners

Materials used for the vehicle shall be vandal resistant. Fasteners exposed to passenger access shall be tamper resistant.

7.8 DOORS, ACCESS, AND EGRESS

Vehicles shall be equipped with automatically controlled, horizontally sliding doors for passenger entry and exit. Door openings shall be a minimum of 193 cm (76 in.) in height. The door width shall provide a minimum clear opening per Section 5.2.2, Programmed Station Stop. If doorways connecting adjoining cars in a multicar train are provided, such doorways shall have a minimum clear opening of 76 cm (30 in.).

Vehicle doors shall be considered to be in the closed position when the door opening is less than 9.5 mm (0.375 in.) wide. A locking mechanism shall hold the door in the closed position.

Upon final closing, vehicle door control shall detect an obstruction of 25 mm (1 in.) or greater located at any point along the leading edges. When such obstruction is contacted, the door shall not lock and the interlocking requirements of Section 5.1.11, Departure Interlocks, shall be met.

Door closing forces shall not exceed 133 N (30 lb) for the full range of door motion, including the force exerted on contact or detection. Door closing shall be annunciated by audio and visual warning signals, as specified in Section 6.3.2, Stations.

Each side of the passenger compartment that has doors shall have at least one door that is manually operable from the exterior of the vehicle without powered assistance.

Provision shall be made for emergency vehicle evacuation, either using the regular doors or special emergency exits. It shall be possible to manually open the emergency exits from inside the vehicle without powered assistance with a force not to exceed 156 N (35 lb).

The emergency exit operating mechanism on the inside of the vehicle shall be conspicuously marked and designed to discourage unintentional operation.

Simple operating instructions shall be posted. In some cases, there will be conditions when operation of an emergency exit could present a hazard. In such cases, a proper hazard resolution process, per Section 3.1.2, shall be undertaken.

7.9 WINDOWS

All vehicle glazing shall meet the requirements of SAE J673-2005 (2005) and ANSI Z26.1-1996 (1996).

All windows shall meet ANSI Z26.1-1996 (1996) item 3 tests for glass and glass laminates or item 4 tests for rigid plastics.

7.10 FIRE PROTECTION AND FLAMMABILITY

Incidence of fire shall be considered a Category I (catastrophic) hazard, as defined in Table 3-1. Fire protection design shall meet all requirements of Chapter 8 of NFPA 130 (2007).

7.10.1 Material Selection

The materials used for vehicle construction shall comply with the requirements contained in Chapter 8 of NFPA 130 (2007). Oils and hydraulic fluids shall be flame retardant, except as required for normal lubrication. Up to 0.02% of the empty vehicle weight (AW0) shall be exempted from these requirements.

7.10.2 Thermal Protection

Thermal protection shall be provided for electric motors either by thermal sensors or overcurrent sensors installed in the circuit.

7.10.3 Fire Extinguishers

Each passenger compartment shall be fitted with at least one 5-lb (11-kg) Class ABC fire extinguisher per 75 AW1 passengers. Units shall be mounted in a visible and readily accessible location.

7.10.4 Smoke Detectors

Each passenger compartment shall have smoke detectors that, when activated, will annunciate an alarm in central control. There shall be a means to test the smoke detectors.

7.11 LIGHTING

Each vehicle shall be provided with interior and exterior lighting as described below.

7.11.1 Interior Lighting

Vehicle interiors shall be designed with lighting fixtures that are secure, rattle free, and vandal resistant. Fluorescent tubes or other powered fixtures shall be inaccessible to passengers. Diffusers of a material that is shatterproof shall be provided.

Under nonemergency operating conditions, interior lighting levels shall be a minimum of −54 lux (5 foot-candle) measured at the vehicle floor, including all doorways, when the vehicle is stopped in the station, with the exception of areas within 15 cm (6 in.) of a seat, and −215 lux (20 foot-candle) when measured 76 cm (30 in.) above the vehicle floor.

Lighting shall be of a consistent level.

7.11.2 Emergency Lighting

Emergency lighting power is to be provided by vehicle-borne batteries capable of sustaining required levels of lighting for a time period as determined by the hazard analysis performed as specified in Section 3.1.2.1.

The emergency lighting system shall provide minimum lighting levels per NFPA 130 (2007), Section 8.8.3, Emergency Lighting, measured in the immediate area of the doors.

7.11.3 Directional Identification and Headlights

The front and rear of a vehicle or train shall be readily identifiable as such and shall be visible at all times.

Vehicles that can be operated manually onboard shall include headlights that shall provide sufficient illumination for forward visibility of at least 5 lux at 10 m (0.5 foot-candle at 33 ft).

7.12 ELECTRICAL SYSTEMS

Electrical wiring and equipment shall be inaccessible to passengers.

7.12.1 Propulsion Subsystem

Propulsion requirements are specified in Chapter 8.

7.12.2 Auxiliary Subsystem

The auxiliary subsystem shall provide for the distribution and conversion, as required, of collected power for purposes other than propelling the vehicle.

7.12.2.1 Low-Voltage Power

A low-voltage direct current (DC) source shall be provided for powering all onboard control circuits. It shall operate in conjunction with and may serve as the charger for a storage battery that has sufficient capacity to provide emergency power, per Section 7.12.2.3. Storage batteries shall be mounted in a ventilated enclosure (if appropriate) isolated from the passenger compartment and shall meet NFPA 130 (2007), Section 8.6.10, Battery Installation.

7.12.2.2 Protection Devices

All onboard circuits and devices of the auxiliary subsystems shall be protected from overload by circuit breakers, fuses, or other interrupt devices. All such devices shall be manufactured in accordance with NEMA standards or have demonstrated proven operation in same or similar service. The protection system shall be in accordance with practices of NFPA 70 (2005).

7.12.2.3 Emergency Power

Emergency power to critical subsystems shall be maintained when primary power is lost, for a time period as determined by a hazard analysis performed in accordance with Section 3.1.2.1. Critical subsystems shall include communications, fresh air ventilation, emergency lighting (interior and exterior), and automatic train protection.

7.12.3 Wiring

Vehicle wiring shall be unalloyed copper. Wiring shall be clearly marked in accordance with the vehicle electrical schematic for ease of identification in maintenance and troubleshooting. Minimum wire size shall be in accordance with NFPA 130 (2007), Section 8.6.8.2; cable and wire sizes in accordance with Section 8.6.8.3; and wiring methods in accordance with Section 8.6.8.4.

Control wiring shall be physically isolated from power wiring to prevent conducted electromagnetic interference from interfering with system performance.

7.12.4 Power Collectors

If electrically powered from the wayside, each vehicle shall be provided with power collectors that are compatible with the characteristics of the power rail.

The power collector shall function under all permissible vehicle dynamic and operating conditions as per Section 7.2, and the vehicle environmental operating conditions per Section 2.1, Ambient Conditions. Fully redundant power collector assemblies shall be provided to ensure continuous power collection. Each of the redundant collector assemblies shall be sized to carry the entire vehicle root mean square (RMS) electrical load for an indefinite period of time when operating in a normal duty cycle at an AW2 load. It shall not be possible to apply shop power to the vehicle without electrically disconnecting the power collectors. The shop power connector, if provided, shall be protected from the environment and shall be intrinsically safe to prevent inadvertent touching of the stinger probe.

7.12.5 Grounding

Where the maximum voltage onboard the vehicle exceeds 48 V RMS, the vehicle electrical system and body shall be positively grounded under all operating conditions, except as explicitly noted otherwise herein.

The carbody shall not be used to carry current for either the negative return of primary power or the negative return of low-voltage power.

Electrical subsystem equipment enclosures are to be grounded with the grounding system in contact with the system ground rail at all times.

Grounding of equipment shall use direct bonding of the equipment enclosure to a carbody frame member by metal-to-metal contact between the two surfaces. Where direct bonding is not feasible, grounding conductors of sufficient cross-sectional area shall be used to limit the resistance across the bond to 0.0025 ohm and to carry lightning discharge current or fault current of the equipment. Bogie-mounted components shall be bonded to the bogie frame.

Negative return circuits shall be routed to a common negative bus, which shall be isolated from the carbody and pass the isolation resistance test of IEEE 32-1972 (1972, revised 1990). A grounding cable with ample capacity for the service intended shall bond the negative bus to the negative return power collectors. If the non-current-carrying ground rail is not provided as permitted by Section 9.1.4.1, fourth paragraph, then the negative return power collectors and the negative return plate may either be the same or separate from the ground plate and vehicle ground collectors. For alternating current (AC) systems, AC primary powered equipment shall have a separate non-current-carrying connection to a system ground plate connected to the system ground through grounding collectors compatible with the non-current-carrying ground rail required by Section 9.1.4, Grounding.

The maximum direct current (DC) contact impedance in bolted connections in the vehicle traction circuit returns and other intentional circuit grounds shall not exceed 0.0025 ohm.

All load circuits connected to the low-voltage DC (LVDC) bus shall be two-wire with separate ground conductors connected to a common ground or shall be equipped with a ground fault detection system if a floating (ungrounded) LVDC system is used. The LVDC bus system enclosure shall be grounded to the carbody frame by means of a single removable ground strap, through which no intentional current shall flow. The LVDC common ground, when isolated from the carbody, shall pass the isolation resistance test (IEEE 32-1972, revised 1990). Individual branch circuit ground connections to the LVDC common ground shall permit circuit isolation to check circuit integrity. The LVDC common ground terminal shall be connected to the system ground rail at all times through collectors compatible with the ground rail requirements of Section 9.1.4, Grounding.

Chapter 8
PROPULSION AND BRAKING

The propulsion and braking system (PBS) shall consist of all those elements associated with train propulsion that respond to signals from the automatic train control (ATC) system and/or manual controller to produce and adjust tractive effort and braking necessary for train acceleration, cruising, coasting, deceleration, and stopping. The PBS may be of the wayside or onboard type.

The PBS shall provide minimum required traction effort and required stopping distances based on the operating requirements and the hazard analysis and safety principles defined in Chapter 3, Safety Requirements, and Section 5.1.2, Separation Assurance.

8.1 PROPULSION AND BRAKING SYSTEM RATING

The PBS shall be rated to provide traction and all train movement along the guideway, under specified loading per Section 7.1, and environmental conditions per Chapter 2, Operating Environment, and to ensure motion control up to the maximum speed specified so that the acceleration, deceleration, and jerk rates are within acceptable passenger comfort limits per Section 7.7.3.

The PBS shall be thermally rated at AW2 load for the highest temperature per Section 2.1.1, without degradation to equipment. The system shall also be rated for intermittent operating conditions, including (if provided) towing, pushing, motor failures, and other specified conditions. Limits of stopping distance per Section 5.1.2, Separation Assurance, shall be met. Multiple brakes or combinations of dynamic and/or regenerative braking with mechanical friction braking when used simultaneously, shall be applied in such a fashion as to not exceed the limits for deceleration and jerk constraints specified in Section 7.7.3, Ride Quality.

8.2 PROPULSION AND BRAKING METHODS

Vehicle or train propulsion and braking units of the onboard or wayside type may use any methods of propulsion and braking, including the following:

1. Adhesion propulsion,
2. Tension member propulsion,
3. Air flow propulsion, and
4. Electromagnetic drives.

These propulsion and braking methods imply specific requirements that are described in the following subsections.

Other methods of propulsion, if provided, shall also adhere to the applicable functional requirements herein. Overheating of propulsion or braking elements shall be addressed in the hazard resolution process per Section 3.1.2.

8.2.1 Adhesion Propulsion

Measures shall be taken, where necessary, to provide proper guideway running surface adhesion.

8.2.2 Tension Member Propulsion

Rope drives shall comply with ANSI B77.1-2006 (2006), Chapter 2, Sections 2.1.2.8, 2.1.2.9, 2.1.2.10, 2.1.2.11, and 2.1.4.1. For systems that use onboard emergency braking, have no rope splices, and operate on maximum slopes less than 15 percent, the requirements for minimum diameter of terminal sheaves (Section 2.1.2.8.2 of ANSI B77.1-2006 [2006]) shall be not less than 40 times the nominal diameter of the haul rope.

8.2.3 Air Flow Propulsion

Suitable devices must be incorporated to protect the public and the environment from any stray air emerging from the system along the guideway, the vehicles or train, and along the station platform areas.

8.3 BRAKING FUNCTIONS

The PBS shall provide the functions of service braking, emergency braking, and parking braking. Internal friction can serve as one or all of the braking methods if the minimum internal friction of the system under all conditions is redundant, including unacceptable or undesirable energy source for emergency brakes using electrical, pneumatic, or hydraulic power for actuation. The failure of any one energy source shall be detected according to the requirements of Sections 3.2, Safety Principles, and 3.3, ATC System Fail-Safe Design. Hazards, as defined in Table 3-1, are sufficient to meet the braking requirements of this section and of Section 5.1.2, Separation Assurance.

8.3.1 Service Braking

Service braking shall be applied to accomplish the requirements of Section 5.2.1, Motion Control. Braking performance and braking capacity shall be sufficient to accommodate specified loading conditions without overheating under continuous operation.

8.3.2 Emergency Braking

It shall be possible to use the emergency brake, with friction-type braking only, using stored energy. Emergency braking shall be designed in accordance with Section 3.2, Safety Principles, and shall have priority over any other method of braking.

The emergency braking system shall be capable of decelerating and stopping a vehicle or train under the worst-case conditions of Section 5.1.2, Separation Assurance; AW2 loading; and worst-case environmental conditions, per Section 2.1 for a minimum of three repeated stops at the minimum cycle time for the system while meeting all of the requirements of Chapter 5, Automatic Train Control.

If the emergency braking system has any elements in common with the service braking system, then the emergency braking system shall comply with the aforementioned stopping requirements after meeting all requirements for the service brake duty cycle. Braking performance must meet acceptable passenger comfort limits, conforming to the deceleration rates in Section 7.7.3, Ride Quality, and the speed limits imposed by Section 5.1.4, Overspeed Protection.

Emergency braking shall be irrevocable (i.e., once the command is issued by the automatic train protection for this braking to be applied, braking shall be continuous until the vehicles or train has come to a complete stop). The emergency braking system shall operate properly without wayside, vehicle, or propulsion power. The energy source for emergency brakes using electrical, pneumatic, or hydraulic power for actuation shall be redundant. The failure of any one energy source shall be detected according to the requirements of Sections 3.2, Safety Principles, and 3.3, ATC System Fail-Safe Design, and shall not result in a braking capability less than that required by Section 5.1.2, Separation Assurance. Energy storage devices may be used to meet this redundancy requirement. In the event that failure of an energy source has been detected, a Priority 1 system alarm shall be transmitted to central control (Section 5.3.3.3.1, System Alarms), and the train shall be removed from service.

Onboard emergency braking shall be provided for all automated people mover (APM) systems, except for systems with wayside emergency brakes. For these wayside-braked systems, in lieu of this requirement, a satisfactory hazard resolution process may be provided, per Section 3.1.2, showing that no hazard will result and the vehicle or train can be stopped by other means within the required limits. If such braking is applied directly on the guideway or guideway-mounted rails, it shall provide gradual stopping of the vehicle or train without damaging the guideway, guideway rails, vehicles, or train when applied.

8.3.3 Parking Braking

The parking braking function shall be activated whenever the vehicle is parked and not in operation. The parking braking function shall be capable of holding an AW3-loaded train on the maximum grade, considering all environmental conditions, without application of guideway or vehicle-borne power for the maximum period of time required to evacuate passengers during a total system power failure. It shall be capable of holding an AW0-loaded train on the maximum grade for at least 24 h and for an indefinite period thereafter with manual intervention permitted. AW0 and AW3 loads shall be as defined in Section 7.1.

The parking braking function may be provided by elements of the service and/or emergency brake equipment, provided that the requirements of Chapter 3, Safety Requirements, are satisfied.

8.4 PROPULSION AND BRAKING SYSTEM COMPONENT DESIGN

The components of the PBS shall be designed for the service and application as defined in these sections.

8.4.1 Design Requirements

PBS components shall be designed to meet all relevant requirements of Chapter 7, Vehicles, and Section 3.2, Safety Principles. In performing the safety evaluation process outlined in Chapter 3, Safety Requirements, the APM manufacturer shall include the following:

1. Description of the PBS method, explaining the philosophy and principal components used;
2. Results and data of analytical computations and detailed hazard analysis considering worst-case operating conditions; and
3. Results of relevant tests conducted.

Wayside-type propulsion and braking unit equipment locations shall be considered as part of the guideway for purposes of measuring exterior airborne noise per Section 2.2.1, item 3.

8.4.2 Service Requirements

Propulsion and braking components shall have service factors appropriate for the duty cycle, per Section 8.1. For APM systems that require bidirectional operation, all components shall be rated for bidirectional use.

Friction brakes, excluding self-braking, shall incorporate a manual release mechanism. The tractive effort performance of the propulsion unit and the braking performance shall not degrade below the required values because of deterioration anticipated, according to Section 3.1.2.1, Hazard Analyses, within the specified service life.

8.5 INSTALLATION AND PROTECTION

All rotating power transmission components shall be guarded in accordance with ANSI/ASME B15.1-2000 (2000). Equipment mounting shall permit access for proper maintenance and inspection.

Onboard-type propulsion and braking machinery shall be housed in a compartment separate from the passenger compartment.

Propulsion and braking machinery placed along the guideway or in stations shall be determined to be acceptable by analysis, according to Section 3.1.2.1, Hazard Analyses.

Building rooms housing machinery shall be protected to prevent unauthorized access. Such facilities shall have a permanently installed lighting system adequate to perform routine maintenance and inspection.

8.6 CONTROLS AND INTERLOCKS

Propulsion and braking interlocking shall be according to Section 5.1.13.

When emergency braking is applied, the propulsion power shall automatically be disconnected such that simultaneous propulsion and emergency braking cannot occur.

8.7 BRAKE TESTING

Periodic testing of emergency braking and any other braking system, as required, shall be performed at a frequency sufficient to verify compliance with Section 3.1.2.1, Hazard Analyses.

Testing provisions shall be included by the system supplier as part of the operating and maintenance procedures.

As a minimum, the testing provisions shall specify the testing interval, testing equipment, connection procedures, pass/fail criteria, and modes of operation.

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Chapter 9
ELECTRICAL EQUIPMENT

9.1 GENERAL

The following requirements shall apply to all automated people mover (APM) electrical equipment.

9.1.1 Safety

Passengers, operations and maintenance personnel, and emergency response personnel shall be protected from contact with voltages that could result in injury or death.

Blue light stations shall be provided as defined in Section 6.2.7 of NFPA 130 (2007).

9.1.2 Corrosion Control

To avoid deterioration of buried metallic structures, stray current protective measures shall maintain stray earth currents within acceptable ranges by maintaining a minimum negative return rail to ground isolation resistance per Section 9.3.8 and per the requirements of NACE Standard RP0169-2002 (2002). For direct current (DC) traction systems, a means for testing shall be provided on all electrically bonded system structures to measure and monitor stray currents.

When required, cathodic protection shall be considered for use in the presence of anaerobic bacteria, in the need for mutual protection schemes, in regard to limitations of cathodic potential inaccessibility after construction is completed, and as a means for testing.

9.1.3 Electrical System Protection

Automatic protection of fault, overcurrent, reverse current, overvoltage, undervoltage, lockout, ground fault, and phase sequence, as applicable to alternating current (AC) or direct current (DC) power distribution systems, shall be provided. The protection system shall be selective, i.e., all protective devices shall be coordinated so that any fault or overcurrent condition results in tripping of the smallest isolatable portion of the system and as per the recommendations of Section 1.0, First Principles, of IEEE Standard 242-2001 (2001).

Phase imbalance and other relays susceptible to harmonics shall include harmonic filters to permit application of the most sensitive recommended settings. All equipment and circuits shall be surge- and ground-fault protected.

The system shall incorporate a ground-fault circuit interrupter or other device intended for the protection of personnel. The ground-fault device shall functionally deenergize a circuit or portion thereof within an established period of time when a current to ground exceeds some predetermined value. This activation current value shall be less than that required to operate the overcurrent protective device of the supply circuit. Automatic tripping of any circuit breaker shall have an indication and trigger an alarm at central control. Lightning protection shall be provided in accordance with Section 2.1.4.

9.1.4 Grounding

This section provides requirements for grounding of the APM system. Additional grounding requirements associated with equipment operations are contained in Section 7.12.5.

Grounding systems shall protect equipment from damaging voltages and currents and shall be designed to prevent electrical shock hazards. The focus of the requirements contained herein is safety, and additional grounding requirements for protection of microprocessor devices or other equipment shall be considered as required. Electrical hazards shall be assessed through a hazard analysis performed in accordance with Section 3.1.2.

9.1.4.1 Traction Power Grounding

A non-current-carrying ground rail shall be provided to afford proper continuous grounding of the vehicle. This ground resistance to earth shall not exceed 5 ohm when measured in accordance with IEEE Standard 142-1991 (1991), Section 4.4.

For DC traction power distribution systems, the current-carrying return shall have no more than one single-point ground on the APM system. Cathodic protection shall be provided at this single-point ground to protect other structures and utilities in the regions of the ground.

Under conditions of worst-case operating current and/or vehicle fault current, the traction power grounding system shall not permit a voltage (touch potential) greater than 60 V to appear anywhere on the vehicle when measured between earth ground and the vehicle or any adjacent station platform, metallic enclosure, or metallic guideway structure. Also, under conditions of worst-case fault current, the system shall not permit a voltage of greater than 60 V to appear on any enclosure when measured between the enclosure and its connection to the grounding electrodes in the substation.

For DC traction power distribution systems, deletion of the non-current-carrying ground rail may be considered if an alternative approach provides equivalent protection from leakage currents and electrical system faults. In this case, substations shall be provided with access to the negative bus for stray current monitoring, and the voltage, referenced to ground, in the main line negative return rails shall not exceed 60 V. The voltage, referenced to ground, in the yard negative return rails shall not exceed 10 V.

Maintenance shop tracks shall be electrically grounded to the shop building and shop grounding system. Shop tracks shall be electrically insulated from storage yard tracks. For DC single-point ground systems, the shop building ground shall be separated from the yard and mainline ground systems.

Temporary paralleling is allowed during train transition between shop tracks and yard or storage tracks.

9.1.4.2 Facilities and Structure Grounding

Grounding shall be provided for fixed facilities and structures in accordance with NFPA 70 (2005), Article 90-2, Subsection B. Grounding shall consist of a ground mat under the station or facility and shall be composed of a buried grid-and-rod system. Interconnection with steel piling and steel reinforcement shall be provided. A hazard analysis shall address the safety of electrical grounds during emergency evacuation situations, per Section 3.1.2.1.

9.1.5 Redundancy

Sufficient redundancy shall be designed into the power distribution system so that no single-point electric power failure will preclude operations of the APM system. Degraded modes of operation are permitted. Failure of critical elements of the power distribution system shall be annunciated as specified in Section 5.3.2.2.

NOTE: The service availability requirements in Section 4.3 assume fully available primary power.

9.1.6 Design Life

Transformers, rectifiers, and all wiring and cables shall have a design life of 30 years unless explicitly specified by the owner. Power rails and all other nonconsumable equipment shall have a design life of 15 years unless explicitly specified by the owner.

9.1.7 Voltage Regulation

The power distribution system shall be designed to maintain, under normal operating conditions, voltage regulation at a level such that specified system performance is met. Voltage regulation shall also ensure that the service life of the various motors onboard the vehicles is not degraded.

9.1.8 Capacity

The equipment, including feeder cables and power rails, shall be sized to withstand the peak loads encountered during startup, normal, degraded, and recovery modes of operation of the ultimate fleet of vehicles planned for the system. The traction power substation equipment and associated power distribution wiring and equipment shall have a design duty cycle rating based on these operating conditions for vehicles loaded to an AW2 capacity, as defined in Section 7.1.

If the APM system is expected to grow in phases, not all equipment need be provided initially. However, the design should accommodate the future addition of equipment as the system is expanded.

9.2 TRACTION POWER SUBSTATION EQUIPMENT

Substation equipment shall be designed with the following interfaces and performance criteria.

9.2.1 Interfaces with the Local Utility Company

All electrical connections and equipment shall properly interface with the local utility company.

9.2.2 Power Factor

The system power factor, when averaged over any two-hour period, shall be at least 0.8 in lagging power factor conditions and shall not permit leading power factor conditions. This value may be achieved by the use of power factor correction equipment where necessary. The power factor shall be measured at the point of interface between the electric utility and the APM system. Coordination with the local utility company shall occur during system design.

9.2.3 Harmonics

The power conversion equipment and load elements within the system shall be designed so that the voltage distortion limits, at the point of common coupling between the electrical utility and the APM system, conform to the guidelines set forth in Table 11.1 of IEEE Standard 519-1992 (1992).

Electromagnetic background and radiation shall be in conformance with Sections 2.1.8 and 2.2.3 of this standard.

9.2.4 System Monitoring and Alarms

Indicating instruments shall be installed within each substation to display voltage, current, and power demands. Abnormal conditions shall be transmitted as an alarm to central control per Sections 5.3.2.2 and 5.3.3.3. As a minimum, the following conditions shall result in an alarm:

Overvoltage	Switchgear local mode (see Section 9.2.7)
Undervoltage	Overtemperature
Overcurrent	Loss of phase
Ground fault	Fire or smoke

All transformers and rectifiers shall be provided with overtemperature sensors that activate alarms at central control and cause automatic shutdown of the affected equipment at the preset temperature. Alarms shall be transmitted first at impending overtemperature, then with critical overtemperature accompanied by equipment shutdown.

9.2.5 Power Regeneration Equipment

Traction power regeneration may be specified. If specified, the system shall make efficient use of train regeneration capability. The system shall be designed to accommodate the worst-case overvoltage conditions associated with power regeneration at maximum vehicle speeds, loading, and train length. Provisions for regeneration shall prevent excessive voltage from being returned to the utility power source. If power regeneration is specified, the hazard of regenerating power into the deenergized power rail shall be analyzed in accordance with Section 3.1.2.1.

9.2.6 Remote Monitoring and Control

The traction power substation shall be remotely monitored and controlled through the automatic train supervision system (see Sections 5.3.2.2 and 5.3.3.2, item 11). Monitoring shall include data logging (see Section 5.3.3.4). All commands for power application and removal shall be logged, with a time stamp.

9.2.7 Local Control

The power distribution equipment shall include provisions for local control (open and close) of the switchgear in addition to the remote control provisions cited. Each separate switchgear element shall have a lockout switch allowing local control of the switchgear, locking out remote control when in local mode. Local mode shall be annunciated at central control.

9.2.8 Restoring Power

The power distribution equipment shall allow the main switchgear at the power substation to be closed, both from central control and locally at the traction power substation, to reenergize the substation. Restoration of power shall be done in accordance with operational procedures.

Automatic reclosing of power distribution equipment shall be permitted only after thorough hazard analysis in accordance with Section 3.1.2.1. If implemented, the design shall provide for reclosing only when line testing verifies that the short-circuit condition does not exist.

9.2.9 Substation Facilities

Substation facilities and the structure housing the power distribution equipment shall be provided in accordance with NFPA 70 (2005). Traction power substation equipment shall provide its own auxiliary and control power.

A fire protection system shall be provided to detect the presence of and contain fire. Traction power substation design may be considered in combination with station design to provide fire-rating compliance, as approved by local fire authorities. Traction power substations shall comply with the requirements of Section 5.2.3.2 of NFPA 130-2007 (2007), and of Section 5.3.3.3.2, Facility Fire and Intrusion Alarms of this standard.

9.3 WAYSIDE POWER COLLECTION

As the interface to onboard power collection equipment, wayside power collection equipment shall be provided in accordance with the following sections.

9.3.1 Guideway-Mounted Power Distribution

The system providing power to the vehicle shall use rigid power rails or other means. The power rail system consists of the power rails, fastening means, expansion joints, protective covers, and other hardware. Power rails shall be electrically insulated from each other and from adjacent structures, as determined by the operating voltage. The location and method of mounting the power rails shall include consideration of the operating dynamic envelope of the vehicles.

The power rail system shall be sized for its current and voltage drop requirements and to provide structural strength for appropriate support spacing.

The power rail system shall not be damaged by the electromagnetic forces developed during short-circuit conditions.

9.3.2 Power Zones

Where the power distribution system is sectionalized, the power feeding arrangements shall include sufficient flexibility to allow each section of the guideway to be powered even if power is removed from adjacent sections, so that degraded-mode operation can continue under failure conditions or maintenance outages. Power zones shall be coordinated with the blue light station design (see Section 9.1.1).

A single vehicle shall be able to bridge power gaps between zones to provide a continuous electrical supply at all times that the APM system is operational. An exception shall be made when two adjacent zones are electrically incompatible, in which case a nonbridgeable isolating gap shall be provided. A means shall be provided to prevent the accidental energizing of an unpowered section of guideway (e.g., during maintenance), which could be caused by bridging a power gap with a vehicle.

9.3.3 Splice Joint Requirements

The power rails and splice plates shall provide positive and rigid splice joints. The length, cross-sectional area, and profile of the splice plate or plates shall be designed to provide adequate heat dissipation surfaces to limit heat rise increases to no greater than 2 °C (3.5 °F) above the power rail temperature at its operating capacity.

9.3.4 Expansion Joints and Sections

Expansion joints and sections shall be provided to accommodate the thermal expansion and contraction of the power rails caused by changes in ambient temperature and heat rise of the conductor caused by electrical load, solar radiation effect, and guideway movement.

The expansion joint or section slider assembly shall be able to withstand electromagnetic forces encountered during short-circuit conditions. All jumpers providing electrical continuity shall have capacity equal to or greater than the power rail capacity.

9.3.5 Power Rail Transitions

If there are breaks in the guideway power rail, means shall be provided to facilitate smooth engagement and disengagement of current collector shoes at the train's rated speed.

9.3.6 Insulators

The surface of the insulating material shall be smooth, hard, UV-resistant, and rated either self-extinguishing or nonburning per ASTM D635-06 (2006a).

Power conductor rails shall be protected from inadvertent contact.

9.3.7 Mounting

Power rails, if used, shall be solidly supported to prevent lateral or vertical motion, while allowing longitudinal movement necessary for thermal expansion.

9.3.8 Power Rail to Earth Resistance

Each conducting power rail of the guideway power distribution system shall have a minimum in-service effective resistance to earth of 1 megohm per 300 m (1 megohm per 1,000 ft) under all conditions.

For DC supply systems, negative return elements shall be designed to have a minimum in-service effective rail resistance to earth of 500 ohm per 300 m (1,000 ft) for a single track.

9.3.9 Power and Ground Rail Heating

Power and ground rail heating, if required, shall be provided with sufficient heat for local anticipated icing conditions. The heating system shall be segmented, with each segment independently controlled.

9.4 PASSENGER STATION ELECTRICAL EQUIPMENT

Station equipment shall be designed so that housekeeping power and lighting distribution are provided from one location. Station communications and alarms, emergency lighting, and signage shall have backup power. Typical loads to be supplied by the facilities electrical substation include automatic train control (ATC), uninterruptible power supply (UPS), communications, and other station equipment. The facilities electrical substation shall be designed in accordance with NFPA 70 (2005).

9.5 UNINTERRUPTIBLE POWER SUPPLY

In the event that primary power is unavailable, equipment requiring power shall be supported by UPS devices. Uninterruptible power shall be provided for at least the following functions:

- ATC (per Chapter 5),
- Communications (all audio and visual, per Chapter 6),
- Fire and other appropriate safety and security equipment, and
- Power distribution system control power at the substation.

UPS equipment shall be sized to provide for all of the aforementioned functions for a period determined in accordance with Section 3.1.2.1, Hazard Analyses.

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Chapter 10
STATIONS

The areas of the station addressed by this chapter include automated people mover (APM) equipment spaces and passenger boarding and alighting platforms.

10.1 DISABLED PERSONS ACCESS REQUIREMENTS

This section presents disabled access requirements for the APM interface between the vehicle floor edge and the station platform edge. The specific requirements presented in this section focus on those areas applicable to the vehicle–platform gap and detectable warnings and do not address those considered architectural concerns.

NOTE: Disabled access in the United States is subject to the Americans with Disabilities Act of 1990, and applicable federal regulations should be consulted.

10.1.1 Vehicle–Platform Gap

The vertical and horizontal vehicle–platform gap requirements are presented in Section 7.3.

10.1.2 Detectable Warning Strip

The platform edge between the guideway and station, if not protected by platform edge barriers, shall have a detectable warning. Such detectable warnings shall be 0.6 m (2 ft) wide and run the full length of the unprotected platform.

NOTE: In accord with the aforementioned requirement, platform edges protected per items 1 or 2 of Section 10.2 do not require detectable warning strips. For item 3 of Section 10.2, detectable warning strips are required only at openings in the platform. For item 4 of Section 10.2, detectable warning strips are required to run the full length of the platform edge.

Detectable warning strips shall consist of raised truncated domes with a nominal diameter of 23 mm (0.9 in.), a nominal height of 5 mm (0.2 in.), and a nominal center-to-center spacing of 60 mm (2.35 in.) and shall contrast visually with adjoining surfaces, either light on dark or dark on light.

The material used to provide contrast shall be an integral part of the walking surface. Detectable warnings used on interior surfaces shall differ from adjoining walking surfaces in resiliency or sound-on-cane contact.

10.2 PLATFORM EDGE PROTECTION

A means of platform edge protection shall be provided to protect people from the potential hazard of being struck by a moving train or moving elements within the guideway, falling from the platform, shock, or electrocution.

Acceptable means of platform edge protection include the following:

1. *Intrusion prevention* through full-height solid barriers and automatic horizontal sliding doors (see Section 10.2.1).
2. *Intrusion control* through barriers with a minimum height of 1.1 m (42 in.) and automatic horizontal sliding doors or gates (see Section 10.2.2).
3. *Intrusion detection* in association with platform edge barriers (minimum height 1.1 m [42 in.]), with openings located at the doors of stopped vehicles. The openings shall be provided with an intrusion detection device that monitors the opening in the railings (see Section 10.2.3).
4. *Intrusion detection* using a system located in the guideway or along the platform edge for the entire station length of the platform (see Section 10.2.3).
5. Any other method that provides acceptable protection as approved by the authority having jurisdiction over the system and as demonstrated by a hazard analysis per Section 3.1.2.1.

For conditions in which a fall of more than 1.5 m (5 ft) from the station platform is possible, either intrusion prevention per item 1 or intrusion control per item 2 shall be required (see also Sections 10.2.1 and 10.2.2).

For conditions in which passengers can extend limbs from vehicles through windows or other openings (see Section 7.2), the means of platform edge protection shall be analyzed for these risks by a hazard analysis per Section 3.1.2.1.

10.2.1 Intrusion Prevention System

An intrusion prevention system consisting of station platform edge barriers and their associated doors, when provided, shall meet the following requirements:

1. Platform edge doors shall be compatible with the requirements of Section 5.2.2, with height equal to or greater than that of the vehicle door opening.

2. The platform edge barriers, door assembly, supporting tracks, and linkages shall withstand a force of 1,110 N (250 lb) applied at right angles to and approximately at the center of a panel, distributed over an area of approximately 10 cm × 10 cm (4 in. × 4 in.) without permanent deformation or binding of the door mechanism. Platform edge barriers and their associated doors shall also be designed to withstand wind loads and buffeting forces when applicable.
3. If glass is used in station platform edge barriers or platform doors, the glass shall comply with the requirements of ASTM C1048-04 (2004) and ASTM C1036-06 (2006b); ANSI Z97.1-2004 (2004); and 16 CFR 1201. Markings as specified in ANSI Z97.1-2004 (2004) shall be on each separate piece of glass and shall remain visible after installation.
4. Platform edge doors shall comply with Sections 5.1.10 and 5.1.11 and all applicable requirements of Section 7.8 regarding locking, closing forces, obstruction detection, and emergency egress. A keyed platform side-lock release shall be provided to allow authorized access to the guideway for maintenance and evacuation purposes. Moreover, to avoid any injury, the kinetic energy of the moving parts (door leaf and all pieces of equipment mechanically coupled to it) shall be limited to 10 J (88.5 in. lb), computed for the average door speed. The average door closing speed shall be calculated by measuring the time required for the leading edge of the door to travel from a point 25 mm (1 in.) away from the open jamb to a point 25 mm (1 in.) away from the point of closure of the doors. Demonstration of compliance by test in lieu of calculation may be provided.
5. Initiation of platform edge door closing shall be annunciated by audio and visual warning signals, as specified in Section 6.3.2.
6. The space between the platform doors and the vehicle doors shall be designed to prevent door closure when passengers are in the space between the vehicle doors and the platform doors, unless the gap is less than 130 mm (5 in.) from the platform level up to 1.1 m (42 in.) above the platform level.
7. Vehicle and station platform door opening and closure shall be coordinated per Section 5.2.3.

10.2.2 Intrusion Control System

An intrusion control system, when provided, shall include barriers with a minimum height of 1.1 m (42 in.) and automatic horizontal sliding doors or gates and shall meet the following requirements:

1. Doors or gates shall be compatible with the requirements of Section 5.2.2, with height at least equal to that of the associated barriers.
2. The platform edge barriers, door or gate assembly, supporting tracks, and linkages shall withstand a force of 1,110 N (250 lb) applied at right angles to the panel and 1 m (3.3 ft) above floor level, distributed over an area of approximately 10 cm × 10 cm (4 in. × 4 in.), without permanent deformation or binding of the door or gate mechanism.
3. Where glass is used in barriers, doors, or gates, the glass shall comply with the requirements of ASTM C1048-04 (2004) and ASTM C1036-06 (2006b); ANSI Z97.1-2004 (2004); and 16 CFR 1201. Markings as specified in ANSI Z97.1-2004 (2004) shall be on each separate piece of glass and shall remain visible after installation.
4. Doors or gates shall comply with Sections 5.1.10 and 5.1.11 and all applicable requirements of Section 7.8 regarding locking, closing forces, obstruction detection, and emergency egress. A keyed platform side-lock release shall be provided to allow authorized access to the guideway for maintenance and evacuation purposes. Moreover, to avoid any injury, the kinetic energy of the moving parts (door leaf and all pieces of equipment mechanically coupled to it) shall be limited to 10 J (88.5 in. lb), computed for the average door speed. The average door closing speed shall be calculated by measuring the time required for the leading edge of the door to travel from a point 25 mm (1 in.) away from the open jamb to a point 25 mm (1 in.) away from the point of closure of the doors. Demonstration of compliance by test in lieu of calculation may be provided.
5. Door or gate closing shall be annunciated by audio and visual warning signals, as specified in Section 6.3.2.
6. The space between the doors or gates and the vehicle doors shall be designed to prevent closure when passengers are in the space between the vehicle doors and the doors or gates, unless the gap is less than 130 mm (5 in.).
7. Vehicle and station platform door opening and closing shall be coordinated per Section 5.2.3.
8. Openings or spaces between elements of the door, gate, or barrier shall be designed such that a 100-mm- (4-in.-) diameter sphere will not pass

through. Fences and gates shall be constructed to inhibit contact with the vehicle per Section 7.2.

10.2.3 Intrusion Detection System

If provided, an intrusion detection system shall be capable of detecting the intrusion of a sphere 0.3 m (1 ft) in diameter or larger weighing 9 kg (20 lb) or more, falling or otherwise passing from the platform to the guideway at any open location, at a height between platform level and 1.1 m (42 in.) above the platform surface.

When activated, the detection system shall initiate the following:

1. Command for appropriate braking for trains entering or approaching the station, as determined by a hazard analysis per Section 3.1.2.1;
2. Command to stop any moving apparatus on the guideway exposed to potential contact by the intruder (for example, drive ropes) in the vicinity of the detected intrusion; and
3. An alarm to central control.

The procedures used to reset the detection system and to restore traffic after an intrusion detection shall be analyzed through a hazard analysis per Section 3.1.2.1.

10.3 EVACUATION OF MISALIGNED TRAINS

A means shall be provided to allow egress from a misaligned train onto the station platform. Such means shall meet the requirements of Section 11.3. Where auxiliary egress doors or gates are used, a latching mechanism shall be provided on the guideway side to allow passengers to exit onto the platform. Permissible misalignment shall be per Section 5.2.2.

Access shall be provided for authorized personnel to the interior of each car of a train at any location along the guideway, including any location within the station. If auxiliary egress doors or gates are used for access through station barrier walls, then a keyed platform side-lock release shall be provided in these auxiliary egress doors or gates to allow authorized access to the cars. The opening of any such auxiliary egress door or gate shall result in the facility door detection and response requirements specified in Section 5.1.9.

10.4 EMERGENCY LIGHTING AND VENTILATION

For APM station platforms located within airport terminals or office, retail, entertainment, or other such buildings, the station lighting and ventilation shall be in accordance with local building codes, as applicable, and NFPA 101 (2006), Sections 7.9 and 9.2. For interpretation of such building codes, the APM platforms shall be treated, for lighting and ventilation issues only, as elevator lobbies. (Refer also to Section 10.5.1, Fire Detection.)

For freestanding stations dedicated to the APM system, the station emergency ventilation and emergency lighting provisions shall comply with NFPA 130 (2007), Sections 5.3 and 5.6, respectively. Lighting fixtures shall be designed as vandal resistant.

10.5 FIRE PROTECTION

A fire protection system shall be provided. Station design may be considered in combination with platform doors to provide fire-rating compliance, as approved by local fire authorities.

10.5.1 Fire Detection

All stations and associated equipment rooms shall be provided with smoke and/or heat detection and alarm devices that shall be annunciated on a fire monitoring display in central control. Upon activation of a smoke or fire alarm, appropriate automatic or operational procedures shall be implemented to address the hazards associated with fire or smoke as required by a hazard analysis per Section 3.1.2.1.

10.5.2 Fire Containment

Station platform barriers and doors, if intended to serve as fire barriers, shall comply with the requirements of NFPA 130 (2007), Sections 5.2.3.2 and 5.2.3.3. The fire separation of all stations shall be based on an engineering analysis of potential fire exposure hazards conducted in accordance with Section 3.1.2.1, Hazard Analyses.

10.5.3 Fire Suppression

A fire suppression system, if specified by the authority having jurisdiction, shall comply with local building codes and/or NFPA 130 (2007).

Chapter 11
GUIDEWAYS

The requirements given in this section apply to all rigid guideways: elevated, at-grade, and underground.

Systems suspended by wire rope or cable are addressed by the requirements given in ANSI B77.1-2006 (2006).

The guideway shall be designed and constructed in such a way that the ride quality criteria and the vehicle clearance restrictions are met along the entire alignment. The guideway shall be designed to support all loads and forces associated with vehicles, vehicle interfaces, the environment, and any other facilities affixed to the guideway.

11.1 BLUE LIGHT STATIONS

Blue light stations shall be provided as defined in Sections 6.1.2 and 9.1.1 of this standard and in NFPA 130 (2007), in Section 6.2.7 and Section 10.4.1 in its entirety.

11.2 INTRUSION PROTECTION AND DETECTION

The system shall be designed to protect against unauthorized persons or foreign objects entering the vehicle dynamic envelope. This protection shall be in the form of fencing or other suitable barriers, as determined by a hazard analysis per Section 3.1.2.1.

Where deemed appropriate from the hazard analysis per Section 3.1.2.1, intrusion detection devices shall be provided to alert the system to unauthorized access.

11.3 EMERGENCY EVACUATION AND ACCESS

The automated people mover (APM) guideway emergency evacuation and access shall be designed in accordance with the requirements of NFPA 130 (2007), Sections 6.2.1, 6.2.2, and 6.2.3. In addition, the APM guideway shall meet the following two stipulations:

1. Under NFPA 130 (2007), Section 6.2.1 regarding evacuation of passengers from a disabled train, guidance and control by authorized personnel shall involve voice communication by the central control operator, and such involvement shall be sufficient to meet the intent of Section 6.2.1.
2. If any passenger activates the door release within any vehicle, creating a condition allowing passengers to exit the vehicle onto the guideway or its associated emergency walks, or other suitable means of evacuation, passengers shall be protected, as determined by a hazard analysis per Section 3.1.2.1. Hazards shall include making contact with an energized power rail or any other device of dangerous electrical potential and entering any portion of the guideway where other vehicles are still moving.

All station or guideway doors that do not provide emergency egress shall be so identified and clearly labeled “Not an Exit.” Emergency egress doors shall not be locked on the inside at any time. Emergency exits shall have the capability of being readily opened from the outside by the fire department or other rescue personnel.

11.3.1 Tunnel Guideway

Emergency exits shall comply with the requirements of NFPA 130 (2007), Sections 6.2.1 and 6.2.2. This requirement includes doors, exit hatches, and emergency lighting. When interpreting NFPA 130 (2007) requirements, a “point of safety” shall be defined as an enclosed fire exit that leads to a public way or safe location outside the structure, or an at-grade point beyond any enclosing structure, or another area that affords adequate protection for passengers.

11.3.2 Surface Guideway

For an at-grade or any unroofed structure other than elevated structures, the emergency access and egress should comply with NFPA 130 (2007), Sections 6.2.1 and 6.2.3.1.

11.3.3 Elevated Guideway

Elevated structures are all structures not defined in this standard as surface or underground structures. For elevated structures, the emergency access and egress should comply with NFPA 130 (2007), Sections 6.2.1 and 6.2.3.2.

Passenger egress from elevated guideways shall comply with NFPA 130 (2007), Sections 6.2.1 and

6.2.3.2. An acceptable "other suitable means" to using an elevated emergency walkway shall be a means that evacuates the maximum number of passengers who can be in a maximum-length train to a point of safety within no more than 15 min from the time the evacuation is initiated. The means and duration shall be subject to a hazard analysis per Section 3.1.2.1.

11.4 FIRE PROTECTION

For tunnels, the fire protection provisions of NFPA 130 (2007), Section 6.5, shall apply. Tunnel construction materials shall comply with Sections 6.3.1.1.1, 6.3.1.1.2, and 6.3.1.1.3 of NFPA 130 (2007).

A fire suppression system, if specified by the authority having jurisdiction, shall comply with local building codes and/or NFPA 130 (2007).

11.5 SIGNAGE

Signage shall be provided along the guideway and in the adjacent right-of-way to inform passengers, operating personnel, and emergency services personnel of features that may be critical for safe evacuation or to minimize the severity of a life-threatening incident and to enhance system operation.

The types and location of signs shall comply with the requirements of NFPA 130 (2007), including Sections 6.2.6, 6.2.8, and 6.2.9. Where not otherwise specified, ANSI 117.1-2003 (2003) should be consulted for signage lettering size, color, and contrast. In addition, the following types of signage shall be provided:

Emergency Exit—The emergency evacuation route to the point of safety shall be provided with the following signage: (a) direction to nearest exit (signs spaced no more than 30 m [100 ft] apart); (b) designation of exit; (c) instructions for using the exit; and (d) warning sign of potential hazards in the exit area. Emergency exit signage shall be visible at all times.

Power Section—The boundaries of each power section shall be clearly marked.

Location Information—Location information shall be provided on, and visible from, the guideway at intervals of no more than 100 m (325 ft).

Exposed Power-Delivery Device—Clearly visible signs shall be provided to warn of hazard greater than 50 V presented by exposed power rails or other exposed power-delivery devices, in accordance with NFPA 130 (2007), Section 6.2.6.2. Signs shall be provided on the guideway at station locations and at intervals of no more than 30 m (100 ft) along the guideway.

11.6 EMERGENCY LIGHTING AND VENTILATION

For underground systems, lighting provisions shall be in accordance with NFPA 130 (2007), Section 6.2.5. Underground systems shall comply with the ventilation requirements of NFPA 130 (2007), Section 6.3.3.2.9.

For elevated and at-grade systems, the egress route shall have a level of illumination of no less than 2.7 lux (0.25 ft-candles).

11.7 EMERGENCY POWER SUPPLY

For underground systems, the power supply for emergency ventilation provisions of NFPA 130 (2007), Section 6.3.3.2.9, shall apply.

11.8 GUIDEWAY ALIGNMENT

The guideway shall be designed and constructed in accordance with vehicle ride quality criteria per Section 7.7.3.

Horizontal alignment may consist of any combination of straight (tangent) sections, spiral transitions, and curved sections.

The effects of centrifugal forces, superelevation, ride comfort criteria, and the related limitation of operating speed shall be considered in establishing the guideway horizontal alignment. Vehicle turning restrictions shall also be considered.

Vertical alignments may also consist of any combination of straight sections, spiral transitions, and curved sections. The effects of centrifugal forces, ride comfort criteria, and vehicle geometric limitations to vertical curve radius (crest and trough) shall be considered in establishing guideway vertical alignment.

When the vehicle is stopped at a station, the guideway shall be designed so that the vehicle floor shall not be inclined by more than 1% in any direction with respect to a horizontal plane.

When the vehicle is stopped at any other location along the guideway, (a) the angle at which the vehicle floor is inclined laterally shall not exceed 12% with respect to a horizontal plane, and (b) the angle at which the vehicle floor is inclined longitudinally shall be limited by the normal longitudinal limits for maximum sustained acceleration, including the effects of grade, per Section 7.7.3.1.1.

11.8.1 Clearances

The vehicle dynamic envelope per Section 7.2 shall be separated from any other vehicle dynamic envelope on an adjacent trackway by at least 100 mm (4 in.).

Nonstructural system components that provide less clearance shall be permissible subject to a hazard analysis per Section 3.1.2.1.

The vehicle dynamic envelope shall be separated from any fixed structure by at least 100 mm (4 in.). Station platform edges and APM system equipment that are designed to physically interface with the vehicles are excluded from this requirement.

The maximum allowable clearance between the vehicle threshold and the station platform edge shall be per Section 7.3.

If the vehicle is designed to come in contact with the platform edge under normal operating conditions, the platform edge shall be designed so that the vehicle ride quality criteria given in Section 7.7.3 are met, except that the jerk limit in all directions shall be 0.1*g*/s for standing passengers.

If the vehicle dynamic envelope is such that the vehicle may come in contact with the platform edge under failure conditions, the platform edge and/or vehicle shall be designed to allow no more than cosmetic damage to the vehicle when the vehicle impacts the platform edge while operating at design speed.

11.8.2 Operating Equipment Interfaces

The guideway shall provide support and guidance to passenger vehicles and service vehicles throughout the APM system. The design of the guideway shall accommodate all elements of the APM system that are to be installed on the guideway.

11.8.3 Drainage

If the guideway design is such that water may accumulate on the surfaces, provisions shall be made in the design for draining the water. The drainage system shall route the water to a location acceptable to all local, state, and national codes and regulations and shall not cause drainage water or hazardous accumulations of snow or ice to fall onto pedestrian or vehicular paths.

In cases in which a drainage system is included in the design of the guideway, surfaces shall be sloped toward the drains with a minimum 1% slope (excluding the running surface as long as provisions are made for minimizing water accumulation on the running surface).

The drainage system shall be designed to operate in all environmental conditions per Section 2.1.

11.9 STRUCTURAL CRITERIA

The guideway for an APM shall comply with the following structural design requirements and the applicable requirements in local codes.

11.9.1 Loads and Forces

The guideway shall be designed for the following loads and forces, with appropriate consideration of point loads, distributed loads, and interrelated loads that occur for a specific technology's suspension, propulsion, and entrainment characteristics.

Dead Load—The dead load shall consist of the maximum weight of all permanent structures, including the weight of permanently fastened material and equipment.

Live Load—The live load shall consist of the weight of the applied load of one or more maximum-length, crush-loaded trains under normal and failure conditions, including any specified push or pull retrieval capability, plus any additional service and emergency equipment included in the system that might be brought out on the guideway for maintenance or during failures. Multiple trains shall be considered if the guideway supports multiple lanes. The weight of the applied load of passengers on the emergency walkway(s), if provided, also shall be considered. Crush load shall consider both a static AW3 load and a dynamic AW2 load.

NOTE: Load imbalance and the potential for future increases in AW2/AW3 should be considered in the design.

Walkway Load—Live load on service or emergency walkways shall be at least 4.0 kPa (85 lb/ft^2). The total live load transferred from the walkway to the guideway need not exceed the total weight of evacuated passengers.

Dynamic, Vibratory, and Impact Forces—The ratio of vehicle crossing frequency (*VCF*) to span fundamental frequency (*SF*) shall be computed for each span, where:

VCF is defined as the number of spans crossed per second by a vehicle, computed as vehicle speed in meters per second (feet per second) divided by span length in meters (feet).

SF is defined as the lowest guideway natural frequency excited by vertical train loading on the span, computed based on guideway dead load mass and guideway structural stiffness properties.

Vehicle frequency *(VF)* is defined as the lowest natural frequency of a vehicle excited by vertical loading.

For values of *VCF/SF* less than 0.2, the minimum dynamic load allowance (*I*) applied to the vertical live load shall be 0.1.

For values of *VCF/SF* greater than or equal to 0.2 but less than or equal to 0.3, the minimum dynamic load allowance (*I*) applied to the vertical live load shall be calculated as follows:

$$I = VCF/SF - 0.1$$

For values of *VCF/SF* greater than 0.3, a dynamic analysis shall be performed considering the dynamic properties of the guideway and the vehicles (*VCF, SF,* and *VF*). The dynamic analysis shall be used to determine guideway deflections, dynamic load allowances, and vehicle vertical accelerations. However, the dynamic load allowance (*I*) shall not be less than 0.2.

Centrifugal Force—The centrifugal force (*CF*) acting radially through the center of gravity of the vehicle on curved track shall be calculated as follows:

$CF = V^2LL/R$ (SI units) or $CF = V^2LL/32.2R$ (English units), where *V* is the design speed for the particular curve in meters per second (feet per second); *LL* is the vehicle live load in Newtons (pounds force); and *R* is the radius of the curve in meters (feet). The effects of superelevation on vertical and lateral loads shall be taken into account.

Longitudinal Force—The guideway shall be designed for maximum longitudinal forces caused by acceleration, service deceleration, and emergency deceleration, including grade effects, applied to the live loads. In addition, the guideway shall be designed for severe loads caused by suspension or propulsion system failure as determined from a hazard analysis in accordance with Section 3.1.2.1.

Steering Force—Forces from vehicle steering shall be applied to the guidance and running surfaces. The magnitude of these forces shall be based on the steering characteristics of a maximum-size AW2-size train, with consideration for abnormal steering. Steering force shall include forces caused by steering misalignment, hunting, and the difference between the direction of vehicle motion and the steering angle.

Buffeting Force—The effect of buffeting forces when a maximum-length train enters a narrow, closed passage shall be investigated, and these pressures shall be treated as a special condition of wind load for load combinations.

Thermal Force—Provisions shall be made in the structural design for stresses and deformations occurring from ambient temperature changes, radiant and solar heating, and radiation cooling in accordance with AASHTO LRFD Bridge Design Specifications 4th edition 2007, Section 3.12. Where applicable, stresses induced by heating provisions for ice and snow conditions and by differential movement of guideway elements shall be included. Special consideration shall be given to systems operating in a controlled environment.

Wind Loads—Wind loads on the elevated guideway only shall be computed and applied in accordance with AASHTO LRFD Bridge Design Specifications 4th edition 2007, Section 3.8. The maximum wind speed for survival as defined in Section 2.1.2 of this standard shall be used. Both horizontal and vertical wind effects shall be considered.

Wind loads on the exposed areas of the vehicle in combination with the wind loads on the elevated structure shall be computed using the same method as used for the wind load on the structure. These loads shall be based on the maximum wind speed for manual operation as defined in Section 2.1.2 of this standard. Only horizontal wind effects on the vehicle need to be considered.

For systems in which empty vehicles are stored on the elevated guideway or parked on the elevated structure when the system is shut down, maximum wind speed for survival as defined in Section 2.1.2 of this standard shall be used to calculate the wind effects on both the elevated structure and the vehicles.

Snow and Ice Loads—Loads resulting from freezing rain and from consolidation of snow on the guideway superstructure shall be included as appropriate, considering the environmental conditions per Section 2.1.3 of this standard and the potential for buildup based on the configuration of the guideway.

Loads on the guideway caused by ice pressure or floating ice shall be computed and applied in accordance with Section 3.18 of AASHTO Standard Specifications for Highway Bridges, 17th edition 2002 or Section 3.11 of AASHTO LRFD Bridge Design Specifications 4th edition 2007.

Earth Pressure—Earth pressure shall be computed and applied in accordance with Section 3.20 of AASHTO Standard Specifications for Highway Bridges, 17th edition 2002 or Section 3.7 of AASHTO LRFD Bridge Design Specifications 4th edition 2007.

Seismic Force—Seismic forces on elevated guideways shall be computed and applied in accordance with Section 3.10 of AASHTO LRFD Bridge Design Specifications 4th edition 2007 or Division 1-A of AASHTO Standard Specifications for Highway Bridges, 17th edition 2002.

Seismic forces for underground structures must consider a site-specific analysis for ground shaking, fault rupture, regional tectonic movements, landslides, liquefaction, and differential consolidation of sediments. In areas where these design parameters are not available to the geotechnical or underground designer, a seismic hazard evaluation shall be conducted to assess the above risk and provide ground motions, site responses, and racking parameters for design of structures. For structural analysis, the earthquake loading may be applied as a distortion or racking, superimposed on the static loading conditions.

NOTE: For areas with high seismic activity, local codes and governing authorities should be consulted.

Stream Flow—Loads resulting from flowing water shall be computed and applied in accordance with Section 3.18 of AASHTO Standard Specifications for Highway Bridges, 17th edition 2002 or Section 3.7 of AASHTO LRFD Bridge Design Specifications 4th edition 2007.

Highway Vehicle Collision—Columns located within a distance of 10 m (30 ft) from the edge of a roadway shall be protected with a structural traffic barrier or designed in accordance with Section 3.6.5 of AASHTO LRFD Bridge Design Specifications 4th edition 2007.

The possibility of overheight vehicles colliding with a guideway beam shall be considered for guideways with less than 5 m (16.5 ft) clearance over existing roadways.

Expansion—A continuously welded guide rail directly fastened to the guideway induces an axial force in the structure through the fastener restraint when the structure expands or contracts because of variations in temperature. The axial stress in the guide rail shall be considered because of movement of the structure. Correspondingly, where rail motion occurs, the relaxation of the rail stress must be analyzed to determine its effect on the structure. Rail motion may occur when

1. Guide rail expansion joints are present,
2. Radial or tangential movements of the guide rail and guideway occur at curves,
3. A guide rail break occurs at low temperature, or
4. Continuous guide rails cross structure joints.

Construction Loads—Loads caused by construction equipment and materials that may be imposed on the guideway structure during construction should be considered. Additionally, transient load effects during construction caused by wind, ice, stream flow, and seismic events should be considered commensurate with the expected duration of the particular construction stages.

Other Guideway Equipment Forces—The guideway loads and forces caused by attached wayside equipment, such as propulsion cables, sheaves, linear induction motors, and guideway switches, as applicable, shall be considered.

11.9.2 Load Combinations

Loads and forces shall be investigated in combination as specified in Section 3.22 of the AASHTO Standard Specifications for Highway Bridges, 17th edition 2002 or in Section 3.4 of AASHTO LRFD Bridge Design Specifications 4th edition 2007, with the single exception that the live load factor in load combination "Group I" of AASHTO Standard Specifications for Highway Bridges, 17th edition 2002 shall be changed from 1.67 to 1.35.

NOTE: This live load factor has been reduced because the APM empty vehicle and passenger loads are known. The load magnitude uncertainty is therefore reduced relative to that of live loads on highway bridges. Therefore, the live load factor in the first load combination only of AASHTO Standard Specifications for Highway Bridges, 17th edition 2002 has been reduced.

11.9.3 Design and Analysis

Deflections and Tolerances—Guideway design and construction tolerances shall be coordinated with the system designer to achieve the ride quality requirements and clearance requirements of Section 7.7.3.

Fatigue—Fatigue design shall be in accordance with AASHTO Standard Specification for Highway Bridges, 17th edition, 2002, or AASHTO LRFD Bridge Design Specifications, 4th edition, 2007. The number of cycles of maximum stress range caused by AW1 operating loads to be considered in the design of the guideway (except for running and guidance elements) shall correspond to an infinite fatigue life. If a design life shorter than 50 years is explicitly specified by the owner, then the fatigue life may be reduced appropriately. Depending on the span lengths and the maximum train size, there may be multiple stress cycles associated with the passing of each train.

The running and guidance elements shall be designed, with recommended maintenance, for at least a 20-year life while meeting the specified system operating criteria, unless explicitly specified otherwise by the owner.

Structural Deformation and Settlement—All structural deformations, including differential foundation settlement, shall be considered in the structural behavior of the guideway and vehicle guidance provisions. The control of deformation to maintain acceptable ride comfort requirements per Section 7.7.3 shall be considered in the structural design of the guideway.

Chapter 12
SECURITY

A system security program, per Section 12.1, shall be instituted during the system planning and design phase and shall continue throughout the system construction, testing, and operation. The system security program shall emphasize the prevention of incidents by identifying and resolving threats and vulnerabilities in a systematic manner. A written plan shall be developed in accordance with Section 12.2 to assist in implementing and documenting that program. The system security program and emergency preparedness program, per Chapter 13, shall be coordinated to avoid conflicts.

12.1 SYSTEM SECURITY PROGRAM

A system security program shall meet the following requirements.

12.1.1 Management and Accountability

The system security program and emergency preparedness program shall be established and documented in plans per Sections 12.2 and 13.1, respectively.

1. These plans shall be updated to reflect antiterrorist measures and any current threat conditions.
2. These plans shall be part of an integrated system program, including regional coordination with other agencies, security design criteria in procurements, and organizational charts for incident command and management systems.
3. These plans shall be signed, endorsed, and approved by senior management.
4. Management of these plans shall be assigned to a senior-level manager.
5. Security responsibilities shall be defined and delegated throughout the entire organization.
6. All operations and maintenance supervisors, forepersons, and managers shall be held accountable for security issues under their control.

12.1.2 Security Problem Identification

A threat and vulnerability assessment resolution process shall be established and used. Security-sensitive intelligence information shall be shared among appropriate security-related authorities. (For guidance concerning definition of security-critical systems and facilities, see the System Security Program Plan bibliography in Annex B.)

12.1.3 Employee Selection

Background investigations shall be established. Criteria shall be established for these background investigations.

12.1.4 Training

Security orientation and awareness materials shall be provided to all employees. Ongoing training programs on security required by Section 15.8 shall be provided by work area. Public awareness materials shall be developed and distributed on a systemwide basis.

12.1.5 Audits and Drills

Periodic audits of security policies and procedures shall be conducted at the following intervals:

1. Tabletop and functional security drills shall be conducted at least once every six months.
2. Full-scale exercises, coordinated with appropriate emergency response providers, shall be performed at least annually.

12.1.6 Document Control

Access to documentation of security-critical systems and facilities shall be controlled.

12.1.7 Access Control

Requirements for access control shall be established.

12.2 SYSTEM SECURITY PROGRAM PLAN

A written system security program plan shall be developed to document the system security program and assist in the implementation and monitoring of the program. The plan shall be approved and signed by the owner and management.

Guidance to assist in the development of a system security program plan is set forth in Annex B, System Security Plan Bibliography.

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Chapter 13
EMERGENCY PREPAREDNESS

This section presents requirements for an emergency preparedness program.

13.1 EMERGENCY PREPAREDNESS PROGRAM PLAN

The emergency preparedness program shall be documented in an emergency preparedness program plan. The emergency preparedness program plan shall be developed during the system planning and design phase and shall be implemented during the system testing and operation phases.

13.1.1 Objective of Plan

The objective of the program plan shall be to document how the system, system employees, other support groups, and other supporting agencies will respond to an emergency.

13.1.2 Contents of Plan

The program plan shall, as a minimum, include the following contents:

13.1.2.1 Introduction

This section shall identify the purpose and scope of the program plan.

13.1.2.2 Policy

This section shall state the commitment of the owner or operator to emergency preparedness.

13.1.2.3 Scope of Program

This section shall include a summary description of the automated people mover (APM) system and identify the responsibilities and functions covered by the program plan.

13.1.2.4 Participating Agencies and Agreements

This section shall identify the other agencies that may be involved, provide contact information, identify their capabilities and responsibilities, and reference applicable interagency agreements.

13.1.2.5 Emergency Management Process

This section shall identify the process the system operator will follow once an emergency has been identified. The process shall include, as a minimum, the following:

1. Notification,
2. Response,
3. Resolution,
4. Restoration of operations, and
5. Reporting.

13.1.2.6 Central Control Responsibilities

This section shall identify and describe the responsibilities of central control personnel in an emergency. This section of the emergency preparedness program plan shall be coordinated with Section 15.1 of this standard, System Operations Plan.

13.1.2.7 Duties and Responsibilities

This section shall assign duties and responsibilities to personnel. These duties include, at a minimum, the following:

1. Management and administration personnel,
2. Emergency commander,
3. Dispatcher,
4. Operations personnel,
5. Maintenance personnel,
6. Safety personnel,
7. Security and law enforcement personnel,
8. Fire fighting personnel,
9. Medical personnel,
10. Environmental personnel, and
11. Public information officer.

13.1.2.8 Emergency Preparedness Response Policies and Procedures

This section shall identify emergency response policies and procedures that have been developed. These policies and procedures shall be coordinated with the requirements of Chapters 12, Security, and 15, Operations, Maintenance, and Training. Specifically, the results of the threat assessment carried out under Chapter 12 shall be used as input into the emergency preparedness program plan. The following are examples of emergencies that shall be addressed:

1. Fire;
2. Vehicle collision or derailment;
3. Bomb threat;

4. Hazardous material or other environmental hazard;
5. Terrorist act;
6. Structural failure;
7. Regionally occurring natural disaster, such as floods, tornadoes, hurricanes, or earthquakes;
8. Medical emergency; and
9. Power and communication infrastructure failure.

13.1.2.9 Emergency Preparedness Training and Drills

This section shall identify and describe the training, including drills, that will be required of APM system personnel, other support groups within the APM or owner's organization, and outside responding agencies. (See Section 13.2.)

13.1.2.10 Plan Management

This section shall identify who is responsible for the plan, its revisions, and its dissemination.

Topics to be addressed include but are not limited to

1. Frequency of review and updates,
2. Changes in emergency preparedness in response to changes in system configuration,
3. Documentation control with regard to revisions and distribution of the plan, and
4. Debriefings after emergencies to aid in improving training and updating the plan. (See Section 13.3.)

13.1.2.11 Appendices to Plan

Supporting documents or portions thereof required for effective implementation of the emergency preparedness plan shall be included in appendices unless they are covered elsewhere in the plan.

13.1.3 Guidance

Guidance to assist in the development of the emergency preparedness program plan is set forth in Annex B, System Security Plan Bibliography.

13.2 TRAINING AND DRILLS

The training program required by Section 15.8 shall incorporate means to maintain proficiency in understanding and implementing the emergency preparedness program and its procedures. In addition, a means to periodically update the training program in these areas shall be provided.

Refresher training shall be conducted at least annually to review procedures with response personnel.

Drills of emergency scenarios shall be conducted as part of the training requirement, shall be conducted at least annually, and shall include outside agencies when applicable.

13.3 POSTEMERGENCY INCIDENT AND DRILL COORDINATION

The owner or operator shall conduct formal debriefings attended by representatives of the involved personnel after drills and emergency incidents to critique and improve the emergency preparedness program.

Chapter 14
SYSTEM VERIFICATION AND DEMONSTRATION

Included in this chapter are the specifications of the minimum standards by which an automated people mover (APM) system application shall be verified to meet the ASCE APM standards. Verification that an APM system application meets ASCE APM standards may be carried out separately or integrated with acceptance and demonstration activities.

14.1 APPLICABILITY OF PRIOR VERIFICATION

Where a feature of the APM system application is site specific, it shall be verified to meet applicable requirements for that application and shall not be verified by any previous similar verification.

Where a feature of the APM system application is not site specific, previous verification of the feature may be used, provided that it is updated as needed to account for the following:

1. Pertinent changes in environmental or operating conditions that affect the feature;
2. Pertinent engineering changes in the feature design, materials, manufacturing processes, and/or interfaces;
3. Experience with the same feature from a prior application; and
4. Current verification requirements and conditions as specified in these standards.

14.2 METHODS OF VERIFICATION

Compliance with ASCE APM standards shall be verified by the following:

1. Design review,
2. Analysis,
3. Qualification tests,
4. Acceptance tests,
5. Inspection,
6. Demonstration, and/or
7. Previous experience.

14.3 SYSTEM VERIFICATION PLAN

Compliance of an APM system application with the ASCE APM standards shall be verified in accordance with a system verification plan. The following sections define the minimum requirements for the system verification plan.

14.3.1 Plan Requirements

The plan shall set forth the specific verification activities, their sequence, and dependencies. Verification activities shall be grouped into categories. Verification activities shall be conducted by category, with no activity performed unless all of the activities in the prerequisite categories have been successfully completed and the results documented. Any modification that invalidates a previous verification activity shall be cause for reverification. Activities that are closely related may be conducted together, but documentation must be kept separated. All documentation required by the standard shall be verified for compliance.

14.3.2 Verification Sequence

The logical sequence for verification is as follows:

1. Reviews of designs and analyses;
2. Manufacturer (or contractor, or entity building the system) verification; and
3. Major subsystem and integrated system verification.

On-site major subsystem and integrated system verification shall be conducted in accordance with the sequence illustrated in Fig. 14-1.

14.3.3 Inspection and Test Procedure Documentation

Each verification activity shall be documented and include pass/fail criteria. Verification inspection or test procedures shall include the following:

1. Title: Title of inspection or test.
2. Reference Section of Standard: The section number(s) and title(s) of the specific ASCE APM standards that are addressed by the inspection or test.
3. Prerequisite Activities: The verification activity categories that must be successfully completed before conducting the inspection or test.
4. Objectives: The specific requirement(s) to be verified.

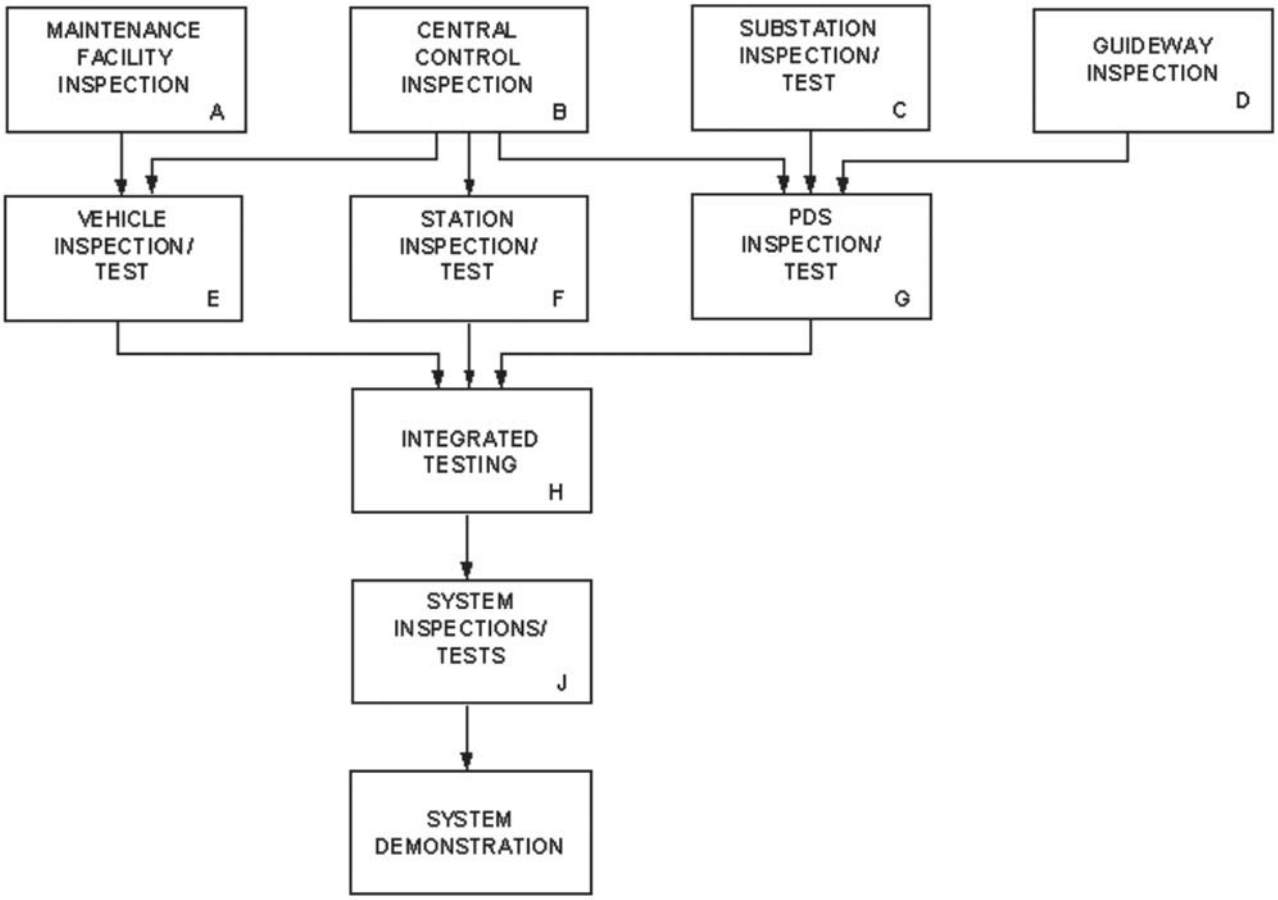

FIGURE 14-1. Major subsystem and integrated system verification sequence; PDS is power distribution system

5. Sample Size: The number of units (e.g., vehicles) required to be used in the inspection or test or the specific area involved (e.g., guideway section).
6. Environmental Requirements: Any specific environmental conditions required for the inspection or test to demonstrate conformance with the referenced standard requirement(s).
7. Equipment and/or Facility Requirements: Any test equipment or special facility needs.
8. Personnel and Skill Requirements: The personnel and skills required.
9. Data to Be Recorded: The specific data that are necessary to show compliance and the means by which they are to be obtained. The specific method of documentation shall be identified.
10. Pass/Fail Criteria: The specific limits within which the data identified in item 9 must fall for the verification activity to be acceptable.
11. Procedures: The detailed, step-by-step description of the inspection or test.
12. Comments: Narrative description of any occurrences or events that may have an effect on personnel safety, equipment integrity, or the validity of the data.
13. Conclusions: The results of the inspection(s) or test, including documentation.

14.4 MINIMUM VERIFICATION REQUIREMENTS

Table 14-1 references each of the requirements to be verified according to section or subsection number of this standard. For each referenced standard, the verification requirements cite what specifically is to be verified and how it is to be verified. Items identified in the hazard analyses required by Section 3.1.2.1 as affecting safety shall be verified by an individual who is qualified in the safety of APM systems, in accordance with Section 16.3.1.

Where this standard contains specific means of verification, such requirements shall be verified as specified.

14.5 APPLICATION-SPECIFIC ACCEPTANCE REQUIREMENTS

Beyond the acceptance requirements specified for demonstrating compliance with this standard, most APM installations should satisfy additional application-specific acceptance requirements. Annex C provides a recommended practice for acceptance of an APM system application, including typical requirements beyond those that demonstrate compliance with this standard.

Table 14-1. Minimum Verification Requirements

Section	Specific Requirement	Verification Type
2 Operating Environment	Verify system designed per Chapter 2	DR
2.1.4 Lightning	Lightning protection	I
2.1.5 Existing Atmospheric Pollution	Dust and dirt	QT, E
2.1.8 Electromagnetic Background	Electromagnetic interference (EMI) susceptibility	D
2.2.1 Exterior Airborne Noise	Exterior noise level	AT1
2.2.2 Structure-Borne Noise and Vibration	Noise and vibration level	D
2.2.3 Electromagnetic Radiation	EMI emissions	D
3 Safety Requirements	As specified	A, DR
3.4 Verification and Validation	Automatic train control (ATC) system mean time between hazardous events (MTBHE)	A, DR
4 System Dependability	Service availability	D
5 Automatic Train Control (ATC)	Verify ATC designed per Chapter 5 [Note: For APM systems that use communications-based train control for ATC, verify requirements per corresponding sections of IEEE 1474.1-2004 (2004) as correlated below.]	DR
5.1.1[IEEE 1474.1-2004 (2004), section 6.1.1] Presence Detection 5.1.2 [IEEE 1474.1-2004 (2004), section 6.1.2] Separation Assurance 5.1.3 [IEEE 1474.1-2004 (2004), section 6.1.4] Unintentional Motion Detection 5.1.4 [IEEE 1474.1-2004 (2004), section 6.1.3] Overspeed Protection 5.1.5 [IEEE 1474.1-2004 (2004), section 6.1.5] Overtravel Protection 5.1.6 [IEEE 1474.1-2004 (2004), section 6.1.6] Parted Consist Protection 5.1.7 [IEEE 1474.1-2004 (2004), section 6/Paragraph 2]	Operation confirmed by test	ATall

Table 14-1. (*Continued*)

Section	Specific Requirement	Verification Type
Lost Signal Protection		
5.1.8 [IEEE 1474.1-2004 (2004), section 6.1.7]		
Zero Speed Detection		
5.1.9		
Unscheduled Door Opening Protection		
5.1.10 [IEEE 1474.1-2004 (2004), section 6.1.8]		
Door Control Protection Interlocks		
5.1.11[IEEE 1474.1-2004 (2004), section 6.1.9]		
Departure Interlocks		
5.1.12 [IEEE 1474.1-2004 (2004), section 6.1.12]		
Direction Reversal Interlocks		
5.1.13 [IEEE 1474.1-2004 (2004), section 6.1.10]		
Propulsion and Braking Interlocks		
5.1.14 [IEEE 1474.1-2004 (2004), section 6.1.11]		
Guideway Switch Interlocks		
5.2.1 [IEEE 1474.1-2004 (2004), section 6.2.1]	Operation confirmed by test	ATall
Motion Control		
5.2.2 [IEEE 1474.1-2004 (2004), section 6.2.2]		
Programmed Station Stop		
5.2.3 [IEEE 1474.1-2004 (2004), section 6.2.3]		
Door and Dwell Time Control		
5.3.1	Functions confirmed by demonstration	D
Constraints on ATS		
5.3.2		
Status and Performance Monitoring		
5.3.3		
Performance Control and Override		
6.1	Confirm meets NFPA 130 (2003)	DR, I
Audio Communication		
6.1.1	Live messages override recorded messages	D
Station Public Address	Announcements delivered simultaneously	
6.1.2	Heavy-duty, tamper- and weather-resistant enclosure	DR, I
Emergency Station and Wayside Communications	Automatic activation	D
	Identification of emergency communication device (ECD) at central control	
	ECD user information	
6.1.3	Two-way voice communication activation and display	D
Train Voice Communication and Public Address	Train public address operating modes	
	Live messages override recorded messages	
	Speaker fire resistance	DR, I
6.1.4	Heavy-duty, tamper- and weather-resistant enclosure	DR, I
Operations and Maintenance (O&M) Personnel Communications	Sufficient quantity of radios	
6.1.5	Recording capacity	D
Recording of Audio Transmissions		
6.1.6	Coverage and clarity of communication	AT1
Intelligibility of Audio Communications		
6.2.1	Surveillance coverage and monitors layout	I
Central Control Equipment		
6.2.2	Camera sensitivity and tamper-proof design and locations	DR, I
Passenger Station Equipment		
6.2.3	Recording capacity	D
Recording of Video Transmissions	Identification of camera, time, and date	

Table 14-1. (*Continued*)

Section	Specific Requirement	Verification Type
6.3.1 Vehicle	Automatic audio and visual station information	D
6.3.2 Stations	Automatic audio and visual warnings and information	D
7.1 Vehicle Capacity and Load	Passenger load density	DR
7.2 Vehicle Dynamic Envelope	Dynamic envelope	DR, QT
7.3 Clearance in Stations	Vertical and horizontal gaps	ATall
7.4 Vehicle Structural Design	Verify vehicle structural design per Section 7.4	A, DR
7.4.4.1.2 Worst-Case Loads	Seat loading Wheelchair loading Stanchion horizontal load Door load	QT
7.4.4.2 Jacking and Lifting	Frame rigidity	QT
7.4.4.6 Deformation	Deformation interfering with normal and/or safe operation	D
7.5.1 Mechanical Design	Coupling operation and lock	D
7.5.2 Electrical and Control Requirements		
7.5.3 Coupler Interfaces	Electrical and pneumatic coupling connection Grounding	D
7.6 Suspension and Guidance	Tire or levitation failure	DR
7.7.1 Heating and Air Conditioning	Heating and cooling capacity and temperature control	QT
7.7.2 Ventilation	Fresh air flow	QT
7.7.3.1.1 Maximum Sustained Acceleration	Acceleration limits	QT
7.7.3.1.2 Maximum Jerk Rate	Jerk limits	QT
7.7.3.2 Human Response Testing	Ride quality	QT
7.7.4 Interior Noise Levels	Interior noise	QT
7.7.6.1 Priority Seating Signs	Signage requirements	I
7.7.6.2 Interior Circulation, Handrails, and Stanchions	Passenger accommodation	DR, I
7.7.6.3 Floor Surfaces	Slip resistance	DR, I
7.7.6.4 Materials and Fasteners	Vandal resistance	DR, I
7.8 Doors, Access, and Egress	Dimensions Locking Obstruction detection and operation Closing force Manual operation Emergency evacuation	ATall, D

Table 14-1. (*Continued*)

Section	Specific Requirement	Verification Type
7.9 Windows	Glazing	DR
7.10 Fire Protection and Flammability	Chapter 8 of NFPA 130 (2003)	DR
7.10.1 Material Selection	Chapter 8 of NFPA 130 (2003)	DR
7.10.2 Thermal Protection	Thermal protection	QT
7.10.3 Fire Extinguishers	Location and type	I
7.10.4 Smoke Detectors	Activation and annunciation	ATall
7.11.1 Interior Lighting	Design and illumination	DR, D
7.11.2 Emergency Lighting	Illumination and duration	QT
7.11.3 Directional Identification and Headlights	Directional identification Illumination	ATall
7.12.2.1 Low-Voltage Power	Ventilated, isolated enclosure	I
7.12.2.2 Protection Devices	Circuit breakers and fuses	DR, D
7.12.2.3 Emergency Power	Power level and duration	QT
7.12.3 Wiring	Size and marking	DR, I
7.12.4 Power Collectors	Electrical capacity Shop power	DR, D
7.12.5 Grounding	Carbody grounding Equipment grounds	DR, ATall
8.1 Propulsion and Braking System Rating	Duty cycle	DR
8.2.2 Tension Member Propulsion	Rope, rope drives, and sheaves	DR
8.2.3 Air Flow Propulsion	Protection of environment	I
8.3.1 Service Braking	Function and duty cycle	DR, ATall
8.3.2 Emergency Braking	Function, duty cycle, fail safety, stopping distance	DR, ATall
8.3.3 Parking Braking	Function	DR, ATall
8.4.1 Design Requirements	Special hazard analysis	DR
8.4.2 Service Requirements	Duty cycle Manual release Deterioration over time	DR, QT, D
8.5 Installation and Protection	Protection from rotating equipment	DR, I
8.6 Controls and Interlocks	Propulsion and brake interlocks	DR, D
9.1.1 Safety	All blue light stations	D

Table 14-1. (*Continued*)

Section	Specific Requirement	Verification Type
9.1.2 Corrosion Control	Galvanic protection and stray currents	DR
9.1.3 Electrical System Protection	Fault, overload, overvoltage, undervoltage, ground fault, and phase imbalance Provision of harmonic filters Surge and ground fault protection Circuit breaker trip annunciation	DR, ATall
9.1.4.1 Traction Power Grounding	Voltage under worst-case fault current	DR, A, QT
9.1.4.2 Facilities and Structure Grounding	Compliance with NFPA 70 (2005)	DR, I
9.1.5 Redundancy	No single-point failure to preclude operation	DR, D
9.1.6 Design Life	Design life	DR
9.1.7 Voltage Regulation	Minimum worst-case voltage	DR
9.1.8 Capacity	Duty cycle	DR, D
9.2.2 Power Factor	Power factor	AT1
9.2.3 Harmonics	Voltage distortion limits	D
9.2.4 System Monitoring and Alarms	Substation monitors and alarms	D
9.2.5 Power Regeneration Equipment	Acceptance by system and utility of regenerated power	D
9.2.6 Remote Monitoring and Control	Logging over power application and removal	D
9.2.7 Local Control	Control and lockout	DR, D
9.2.8 Restoring Power	Power restoration	D
9.2.9 Substation Facilities	Compliance with NFPA 70 (2005) Provision of fire protection Compliance with NFPA 130 (2003)	DR, I
9.3.1 Guideway-Mounted Power Distribution	Electrical insulation Expansion joints Protective covers Power rail sizing and mounting	DR, I
9.3.2 Power Zones	Zone isolation and bridging	DR, D
9.3.3 Splice Joint Requirements	Power rail splices	DR
9.3.4 Expansion Joints and Sections	Thermal expansion Short circuit electromechanical loads Current carrying capacity	DR
9.3.5 Power Rail Transitions	Engagement and disengagement of collectors with power rail	D
9.3.6 Insulators	Insulation properties, including flammability Protection from inadvertent contact by persons	DR, E, QT
9.3.8 Power Rail to Earth Resistance	Electrical resistance to ground	QT

Table 14-1. (*Continued*)

Section	Specific Requirement	Verification Type
9.3.9 Power and Ground Rail Heating	Heating for de-icing	DR, QT
9.4 Passenger Station Electrical Equipment	Compliance with NFPA 70 (2005)	DR, I
9.5 Uninterruptible Power Supply	Electrical capacity and duration	DR, QT
10.1.2 Detectable Warning Strip	Tactile platform edge strip	DR, I
10.2.1 Intrusion Prevention System	Door requirements Door structural load Glass safety	QT
10.2.2 Intrusion Control System	Door locking, closing forces, closing energy, obstruction detection Emergency egress and manual operation Door closing audio and visual warning signals Space between platform doors and vehicle doors Vehicle and platform door coordination	DR, ATall
10.2.3 Intrusion Detection System	Size of object Initiation of braking Stopping of moving apparatus on guideway Alarm to central control Restoration of service	DR, D, ATall
10.3 Evacuation of Misaligned Trains	Design features	D
10.4 Emergency Lighting and Ventilation	Performance with applicable codes	DR, I
10.5.1 Fire Detection	Provision of smoke alarms and annunciation at central control	D
10.5.2 Fire Containment	Provision of fire barriers	DR, I
10.5.3 Fire Suppression	Compliance with codes	DR, I
11.2 Intrusion Protection and Detection	Fencing of right of way Intrusion alarms	DR, I, D
11.3 Emergency Evacuation and Access	Voice communication Protection after manual door opening Labeling and locking of station and guideway doors	DR, D
11.3.1 Tunnel Guideway 11.3.2 Surface Guideway	Compliance with NFPA 130 (2003)	DR, I
11.3.3 Elevated Guideway	Definition of other suitable means	DR, AT1
11.4 Fire Protection	Compliance with NFPA 130 (2003)	DR, I
11.5 Signage	Requirements for life safety signage	I
11.6 Emergency Lighting and Ventilation	Compliance with NFPA 130 (2003) Egress route illumination level	DR ATall
11.7 Emergency Power Supply	Compliance with NFPA 130 (2003)	DR, I

Table 14-1. (*Continued*)

Section	Specific Requirement	Verification Type
11.8	Vehicle floor inclination when stopped	DR, AT1
Guideway Alignment		
11.8.1	Vehicle and fixed facilities clearances	ATall
Clearances		DR, D
11.8.3	Contact with platform edge	DR, I
Drainage	Drainage routes and slopes	
11.9.1	Guideway design loads and forces	DR, A
Loads and Forces		
11.9.2		
Load Combinations		
11.9.3		
Design and Analysis		

CODES:
A: Analysis. An analysis must be submitted to demonstrate compliance with the standard.
AT1: Acceptance test conducted on only one item of the subject equipment within the total population of such equipment.
ATall: Acceptance test conducted on the total population of such equipment within the system.
D: Demonstration. Demonstration by actual operation that the installed system performs per the standard.
DR: Design review. Compliance with the standard is determined by means of the design review activity.
E: Previous experience confirmed by documentation of experience equivalent to a qualification test.
I: Inspection. Inspection of the installed item for compliance with the standard.
QT: Qualification test. A test must be conducted to confirm that the design meets the standard. Alternatively, documentation from a prior test of the same item may be submitted.

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Chapter 15
OPERATIONS, MAINTENANCE, AND TRAINING

This chapter presents planning and documentation requirements for system operations, maintenance, and training.

15.1 SYSTEM OPERATIONS PLAN

A system operations plan shall be prepared before the beginning of passenger service. The plan shall include a comprehensive description of operating strategies, procedures, and staffing for the system and shall be coordinated with the instructions provided in the system operating manuals. It shall specifically cover all requirements for operation of the system defined by the owner.

The system operations plan shall, as a minimum, contain the following sections, which are detailed in Sections 15.1.1, 15.1.2, and 15.1.3:

1. System operational strategies,
2. Manual of operating procedures, and
3. Staffing plan.

15.1.1 System Operational Strategies

The first section of the system operations plan shall provide a description of system operational strategies, including hours of system operation during weekdays, weekends, holidays, and special events; modes and levels of service for each period; methods for selecting and changing modes; and consist complement on each route for each period.

15.1.2 Manual of Operating Procedures

The second section of the system operations plan, the manual of operating procedures, shall provide detailed operating instructions for the system, each component, and/or subsystem. The manual shall, as a minimum, provide operating procedures for the following:

1. Startup,
2. Shutdown,
3. Modes of operation,
4. Vehicle dispatching,
5. Vehicle operation and function,
6. Mode changing,
7. Failure management,
8. Emergency responses,
9. Passenger communications and management,
10. Service restoration,
11. Power distribution system management, and
12. General rules for staff.

The manual of operating procedures shall contain a detailed description of control console(s) and their functional role in system operations, with a listing of procedures for dealing with all anticipated normal and abnormal conditions.

15.1.3 Staffing Plan

The third section of the system operations plan shall be the staffing plan. This plan shall include an organizational chart, job descriptions, qualifications, and staffing levels required for operation, maintenance, and administration of the system.

15.2 MANAGEMENT PLAN

The management plan shall include the description, policies, rules, and procedures for managing the organization. Details of the management plan are beyond the scope of this standard.

15.3 PLANNED SYSTEM STARTUP AND SHUTDOWN

System startup and shutdown shall be done in accordance with documented procedures.

15.3.1 Planned System Startup

Procedures for startup shall state that before commencing service, the following processes shall be followed:

1. It shall be verified that the guideway is clear of persons, tools, equipment, and hazards.
2. It shall be confirmed that system elements are ready for operation.
3. Announcements that system operation will commence shall be made in stations and on the vehicles.
4. Appropriate graphics and/or communications shall be activated at each station.

15.3.2 Planned System Shutdown

Procedures for shutdown shall state that before discontinuing service, the following processes shall be followed:

1. Announcements that system operation will cease shall be made in stations and on the vehicles.
2. Appropriate graphics and/or communications shall be activated at each station.
3. Adequate procedures shall prevent passengers from being stranded within the system.
4. Vehicle operations shall then be terminated, and the system shall be secured.

15.3.3 Unscheduled System Shutdown and Startup

Unscheduled system shutdown and startup shall address the processes listed in Sections 15.3.1 and 15.3.2 as applicable. In addition, the cause and duration of the shutdown shall be investigated and logged, and a system announcement shall inform passengers and personnel of the system condition.

15.4 SERVICE RESTORATION ANALYSIS

A service restoration analysis shall be prepared, detailing failure conditions that can take place throughout the entire system and the appropriate response to each. Based on this analysis, criteria and methodology shall be established to restore normal operations with minimal downtime. These criteria and methodology shall include the following:

1. Criteria for determining when, where, and how maintenance personnel are dispatched and whether guideway power should be deenergized;
2. Criteria for determining if the disruption results from a wayside fault and, if so, that personnel are provided with guidance needed to initiate the necessary repair or replacement and check-out operations;
3. Criteria for determining if the disruption results from a vehicle fault and, if so, that personnel are provided with guidance for choosing between manual operation and other retrieval responses;
4. Criteria for determining if the disruption results from conditions external to the system;
5. Criteria to confirm that all system personnel, equipment, and other persons or systems are prepared for the restart of service;
6. Timely options for reacting to short-term disruptions caused by disabled vehicles, including criteria for choosing the appropriate option;
7. Conditions required to provide a clear path for the removal of disabled vehicles, reentry of vehicles used to recover another vehicle, and introduction of spare vehicles onto the system; and
8. Conditions required to enable passenger egress from disabled vehicles in an orderly fashion.

This document shall serve as a primary input to the system operations plan and operation and maintenance manuals.

15.5 ALARMS AND MALFUNCTIONS REPORTING

Operational system components shall be automatically monitored for malfunction per Section 5.3.3.3.

15.6 RECORDKEEPING AND MANAGEMENT REPORTS

Procedures and methodology for evaluating reports of system alarms and acknowledgments of all central control operator (CCO) commands and other CCO-initiated activities shall be developed in accordance with Section 5.3.3.4. Voice communications between the CCO and passengers shall provide for recording of all conversations (see Section 6.1.5). Recorded media shall be retained for a prescribed period of time, to be agreed on with the authority having jurisdiction. In the event of an incident, accident, or hazardous condition, relevant information shall be retained pending investigation. Procedures shall be provided such that system data associated with failures and/or alarms are maintained and stored as required for system maintenance, troubleshooting, and recovery.

15.7 MAINTENANCE

The maintenance program shall be comprehensive and shall be incorporated into all aspects of system design. The maintenance program shall include the development of system maintainability data for the full system and subsystems, planning and procedures for preventive maintenance, procedures for corrective maintenance, and the documentation of all processes and parts in maintenance manuals.

15.7.1 System Maintainability

A maintainability program shall be developed and implemented during the design and manufacturing period to promote ease of maintenance, diagnotics, repair, checkout, and test. The maintainability program shall include the involvement of qualified personnel. (A maintainability program shall not be required if the system is already in operation when this standard is applied.) Maintainability requirements shall be consistent with overall system and equipment requirements.

15.7.2 Maintenance Plan

A comprehensive maintenance plan for the system shall be developed consistent with the system dependability requirements. For all subsystems and equipment, the maintenance plan shall prescribe preventive maintenance schedules and delineate each task necessary to accomplish inspection and calibration of equipment, servicing, preventive maintenance, corrective maintenance, and overhaul. The plan shall include procedures to prevent equipment that has not fulfilled check-out requirements from being placed into revenue service.

The maintenance plan shall include lists of spare equipment, parts, and consumable supplies. It shall also include procedures for maintaining an adequate inventory of spare parts and consumables and shall estimate necessary storage requirements for these items. The plan shall prescribe the facilities and equipment necessary for each maintenance task and specialized tools required, together with realistic estimates of the required manpower, skill levels, and task duration.

15.7.3 Maintenance Manuals

Maintenance manuals shall be provided for all elements of the system. These manuals shall detail procedures and reference data for performing all required maintenance tasks. The text and detail of these manuals shall be consistent with the required maintenance personnel skill levels, facilities, and equipment. The manuals shall include instructions for assembly and disassembly and expanded assembly diagrams as required. The maintenance manuals shall, as a minimum, contain the following items:

1. Preventive maintenance and overhaul schedules for all system components;
2. Descriptions of maintenance procedures for all system components;
3. Description of system operations, including interactions among major subsystems elements;
4. Detailed technical descriptions of individual subsystems, assemblies, and circuits, including clearances, tolerances, circuit operations, test point voltages, and waveforms as required for maintenance; these descriptions shall refer to system drawings as needed;
5. Descriptions of components, including drawings and other information as necessary for maintenance;
6. Detailed descriptions of system-specific test equipment operation and procedures for its correct use in equipment maintenance;
7. Troubleshooting guides at the system, subsystem, and subassembly level to aid in diagnosis of common failure modes;
8. Safety warnings as appropriate for equipment and procedures;
9. An illustrated parts breakdown, including a description of replacement parts and associated part numbers; and
10. Special requirements and qualifications for maintenance personnel.

15.8 TRAINING

Training shall be provided for operation and maintenance personnel before the start of passenger service and as needed thereafter to maintain competency. The training program shall include formal instruction and on-the-job training and shall lead to qualification of employees for their respective tasks.

Training shall include instructional literature and equipment necessary to train personnel. Training on the actual system equipment and/or spare equipment is permitted.

15.8.1 Training Plan

A training plan shall be developed that identifies the following elements as a minimum:

1. Training program goals and objectives;
2. A schedule illustrating sequence and duration for training;
3. Methods and materials for conducting classroom and hands-on training;
4. Requirements and methods for determining and documenting training and qualification for each individual;
5. Qualifications for training personnel;
6. A process for updating the training and qualification program to keep it current;
7. Levels of competency associated with job descriptions (from the staffing plan per Section 15.1.3);
8. Tasks associated with each job description;
9. Statement of training objectives for each task; and
10. Pass/fail criteria.

15.8.2 Training Instructors

Instructors shall be proficient in oral and written communication and qualified and knowledgeable in their areas of instruction.

15.8.3 Training Materials

Courses shall be defined and developed for training of all personnel identified in Section 15.1.3. The following training materials shall be provided for each course:

1. Lesson plan and instructor guide;
2. Trainee workbook;
3. Training aids, such as visual aids, exercises, or other interactive tools; and
4. Reference materials.

15.8.4 Ongoing Training

The training program for the owner or operator shall be continued throughout the life of the system.

15.8.5 Training Manuals

Manuals for equipment and subsystems shall be provided for use in training. The manuals shall be updated as required throughout the life of the system to conform to equipment configuration. Manuals shall provide sufficient information and detail to enable personnel to gain a full understanding of the design parameters and criteria; the operation and functioning; and the means of corrective, preventive, and overhaul maintenance for all equipment and subsystems. The following types of manuals shall be provided:

1. Equipment operating manuals;
2. Spare parts list, per Section 15.7.2;
3. Maintenance manuals, per Section 15.7.3;
4. Software manuals;
5. Equipment room plans;
6. Special equipment manual; and
7. Any other manuals necessary to effectively operate and maintain the system.

Software manuals shall be provided for each user-programmable device or subsystem and shall include a user's guide, operating instructions, and description of the software and associated hardware. Commercial "off the shelf" software shall be provided with the software manufacturer's documentation and licenses.

Plans for equipment room(s) shall be provided for each station location and shall include all wiring diagrams and circuits, equipment layout, terminal and cable listings, and related information for externally connected equipment, such as guideway-mounted equipment.

The special equipment manual shall provide application, operation, usage, adjustment, inspection, maintenance, troubleshooting, repair, and storage instructions and parts information for all special equipment required to operate the automated people mover.

Chapter 16
OPERATIONAL MONITORING

A program shall be developed and implemented to monitor the system operation. This program shall consist of the items in the following sections.

16.1 SYSTEM OPERATIONAL MONITORING PLAN

An operational monitoring plan shall be provided to document the system operational monitoring program and identify the activities required to implement the program. This plan shall identify the system elements to be monitored, the organizations responsible for monitoring, and a schedule for the monitoring effort.

16.2 ANNUAL INTERNAL AUDIT RESPONSIBILITIES

A thorough annual internal audit process shall be developed and implemented to provide management with a mechanism for documenting that key safety-related activities are being performing in accordance with the system safety program plan (SSPP). The process shall identify the facilities, equipment, procedures, functions, and safety responsibilities subject to audit. This section details the organizational elements that shall be included and how the auditing process relates to each.

16.2.1 Audit Responsibility

The individual designated to be responsible for the safety of the system, as identified in Section 3.1, System Safety Program, shall be responsible for implementation and oversight of the annual internal audit process. To ensure the integrity and independence of the audit process, the individual(s) or department conducting the audit must not be the individual(s) or department in charge of implementing the activities being audited. Auditors shall be knowledgeable about the activities being audited and able to report their findings and recommendations succinctly.

16.2.2 Audit Reporting

The audit report is an official document that is provided to all appropriate levels of management. Each department being audited shall be provided with the audit report for its respective department or with the report in full. A summary of recommended corrective actions, if any, shall be included in the audit report. Corrective actions approved by the owner or operator shall then be formally tracked for compliance.

16.2.3 Audit Procedures

All departments involved shall be notified when audits are conducted and how the audit examines departmental documents. Whereas ongoing inspections may be conducted on an unannounced basis, actual audits shall be done on a coordinated basis, with full management support.

Audited departments shall know when to expect audits. Audits shall be scheduled so that they are as unobtrusive as possible. Unannounced inspections or spot audits shall be approved as part of the overall audit process with concurrence of the owner or operator. The cycle for audits shall be developed and approved in advance. Spot checking of maintenance documents and records shall be performed on a random basis.

A list of items to be audited shall be prepared in advance. When necessary, audited departments shall be given time to produce necessary documentation. This requirement does not preclude spot checks of individual records, such as maintenance or personnel qualification records.

16.2.4 Audit Elements

The following audit elements, as a minimum, shall be included as a part of the documented audit process. The audit process shall verify documentation that inspections and tests as required by Section 16.4 have been conducted. Audits shall verify

1. That all elements of the configuration management program specified in Section 16.5 are in place and functioning;
2. That a process for the interdepartmental and interagency coordination and exchange of safety-related information specified in Section 16.6 is in place;
3. That an employee safety program incorporating applicable local, state, and federal requirements is in place as specified in Section 16.7;
4. That a hazardous materials program incorporating applicable local, state, and federal requirements is in place per Section 16.8;

5. That a drug and alcohol abuse program per Section 16.9 is in place and documented, per local, state, and federal requirements;
6. That documentation is maintained showing that all contractor personnel are instructed in, understand, acknowledge, and comply with the safety procedures as required by Section 16.10; and
7. That procedures are in place and enforced to preclude the introduction into the automated people mover (APM) system of unauthorized hazardous materials and supplies, as well as defective or deficient equipment, as required by Section 16.11.

In addition, the audit process shall also confirm that the following other elements of this standard are being properly conducted and documented:

1. Audits shall verify that safety data acquisition and analysis are performed as specified in Section 3.1.2, Hazard Resolution Process.
2. The annual internal audit process shall verify the implementation of operating rules and procedures as specified in Section 15.1.2, Manual of Operating Procedures.
3. The audit process shall contain a mechanism for determining if proper documentation is being kept on all maintenance activities specified in Section 15.7. A review of the maintenance records shall be conducted, including document controls over equipment manuals, shop- and site-specific procedures, and tracking and resolution of problems identified during inspections. The audit process shall verify that record keeping coincides with actual maintenance and that required maintenance is being performed.
4. The audit process shall record that all necessary training is being conducted and documented as specified in Section 15.8, Training. Certification records of operating (including maintenance) personnel shall be reviewed for completeness and accuracy. The audit shall verify that the procedures for updating the training materials are being followed.
5. Audits shall confirm that a proactive, prevention-oriented approach to security is in place and operating as required by Chapter 12.
6. The audit process shall record that all security-sensitive procedures and documentation are maintained in accordance with Section 12.1.6.
7. The audit shall assess compliance with emergency response preparedness activities per Chapter 13.
8. The audit shall verify that a management plan to address changes and modification is in place for the implementation of new procedures.

16.3 INDEPENDENT AUDIT ASSESSMENT

An independent evaluation or audit of all key elements with identified system safety responsibilities shall be performed, as a minimum, once every three years (triennially).

16.3.1 Independent Auditor Requirements

The independent auditor shall be sufficiently independent of the system owner or operator to permit its assessment or audit to be objective. This arrangement does not rule out the independent auditor being a related company to the system owner or operator, provided that adequate arrangements are in place to insulate the independent auditor's operation from the commercial operations of the system operator. The term "independent auditor" as described throughout this document is defined to be a person with the necessary education, experience, and capabilities to evaluate and approve the results of inspections and tests performed on the APM system. Upon request from the APM system owner or operator, the independent auditor shall provide verification of meeting these qualifications.

16.3.2 Education and Experience Requirements

An independent auditor shall meet one or more of the requirements listed below:

1. He or she shall be a licensed professional engineer.
2. He or she shall have an accredited equivalent to a bachelor's degree in a technical discipline, technical training in system safety and/or APM system elements, and at least three years' experience participating in APM system audits or inspections. (Refer to Chapter 14.)
3. He or she shall have at least eight years of system safety experience with an operational fixed guideway transit system(s), including APMs, of which three years, minimum, were in a responsible position involving the safety of the following system elements: automatic train control; communications; traction power; guideway and guideway switches; transit vehicles; central control, maintenance, and passenger station facilities; and the safety-related aspects of operations and maintenance rules, procedures, and training.

16.3.2.1 Capabilities, Education, and Experience

The independent auditor shall have a working knowledge of hazard analyses, risk assessments, hazard resolution, system safety program plans, and safety requirements for all system elements. Verifiable evidence of training and experience shall be documented. The independent auditor shall also have the following qualifications:

1. Knowledge and understanding of this standard, all parts;
2. Knowledge of automatic train control, central control, headway, switching, train separation, maintenance, and passenger station facilities;
3. Knowledge of the purpose and function of APM safety devices in the cars, on the guideways, and in power distribution systems, in the stations and in the maintenance areas;
4. General APM system knowledge of mechanical, electrical, and civil principles as applied to machines, mechanisms, pumps, compressors, relays, contactors, buffers, communications, traction power, and track and guideway structures;
5. Familiarity with APM industry terminology, including terms, codes, and standards referenced and used in this standard;
6. Working knowledge of APM operations and maintenance rules, procedures, and training;
7. Knowledge of inspection and test procedures as described in this standard;
8. Ability to interpret architectural and installation drawings, including guideway, power distribution system, central control, and maintenance area layouts;
9. Working knowledge of applicable building, fire, electrical, and accessibility codes;
10. Demonstrated ability to perform duties specified in Section 16.2; and
11. Knowledge of personnel safety practices.

16.3.2.2 Maintenance of Qualifications

To maintain the qualifications as an APM independent auditor, an independent auditor shall

1. Remain familiar with the applications of new technology, including the electronic and materials fields;
2. Maintain knowledge of current administrative or operating procedures necessary to discharge duties;
3. Maintain knowledge of this standard and the applicable codes for buildings, fire safety, electrical systems, and accessibility;
4. Participate in meetings, seminars, and educational programs related to duties; and
5. Upon request from the APM system owner or operator, the independent auditor shall provide verification of meeting these qualifications.

16.3.3 Independent Audit Reporting

An independent auditor shall report the results of the inspection, testing, or document review in accordance with the appropriate administrative procedures, industry standard practice, and the following:

1. Independent audit findings shall be documented in written reports that include an evaluation of the adequacy and effectiveness of the system safety program plan (SSPP) and its implementing procedures and, as applicable, any required corrective action or recommendations and implementation schedule for completion of correction and status reporting.
2. The independent auditor's report shall include a clear description of the scope of the work performed, including the type of inspection and whether or not the inspection was performed in accordance with the applicable requirements of this standard.
3. All deficiencies noted in the report shall include a reference to the applicable code, standard, or rule number.

16.4 INSPECTIONS AND TESTS

A program of periodic inspections and testing shall be developed for safety-related facilities and equipment.

NOTE: Such items as fire protection equipment, emergency communications equipment, and employee safety devices would be included in the category of safety-related facilities and equipment. However, it is not practical to develop a complete list in this document, especially because a custom list for each APM system needs to be developed. See Annex D, Inspection and Test Guidelines, for a sample list of safety-related inspection items.

16.4.1 Manufacturer Tests

The manufacturer of the APM system shall develop specific operational and safety-related tests and/or inspections, along with minimum intervals for these tests and/or inspections to be performed. These tests allow the owner or operator of the APM system to determine whether a given APM system is operating within prescribed operational limits. The manufacturer shall recommend components to be tested and/or inspected, along with appropriate acceptance criteria. The owner or operator is responsible for implementing the test procedures. Any changes or additions to these recommendations shall be communicated to all known owners and operators for the APM system and to independent auditors via manufacturers' bulletins.

16.4.2 Test Acceptance Criteria

The APM system test acceptance criteria should be reasonably obtainable during the expected design life, assuming recommended maintenance and operation procedures have been followed.

16.4.3 Test Procedures

The level of difficulty associated with conducting all test procedures shall not require skills or abilities beyond that which trained owner or operator personnel can reasonably be expected to possess.

16.4.4 Operational Testing Limits

Operational testing of the APM system shall be accomplished within the rated limits of the equipment as provided by the manufacturer. Any operational test, including load testing, performed on an APM system shall be nondestructive.

16.5 CONFIGURATION MANAGEMENT

For safety-critical items, manufacturers shall not make design changes without advising the owner or operator, nor shall the owner or operator make design changes without advising the manufacturer, so that the effect of the change can be suitably assessed. The following should be developed and in place:

1. A description of the configuration management control process, including the identification of who shall have the authority to make configuration changes, render approvals, and formally notify all involved parties;
2. A point of responsibility to identify that modifications are included in the hazard resolution process;
3. A review process for new equipment and modifications to existing equipment that includes description of impact on affected personnel, including safety and training; and
4. An operational readiness process, including sign-off, certification, and reporting for new equipment and modifications before entering service.

After the system has been accepted by the owner or operator, and throughout the operational life of the APM system, the owner or operator shall be responsible for maintaining an effective configuration management program.

16.6 INTERDEPARTMENTAL AND INTERAGENCY COORDINATION

A process for the interdepartmental and interagency coordination and exchange of safety-related information should be in place.

16.7 EMPLOYEE SAFETY PROGRAM

An employee safety program that incorporates applicable local, state, and federal requirements shall be established. The employee safety program shall include a hazard and injury reporting process and provide for the development of corrective actions.

16.8 HAZARDOUS MATERIALS PROGRAM

A hazardous materials program that incorporates applicable local, state, and federal requirements shall be implemented.

16.9 DRUG AND ALCOHOL ABUSE PROGRAM

A drug and alcohol abuse program should be in place and documented, per local, state, and federal requirements.

16.10 CONTRACTOR SAFETY COORDINATION

Contractors working on or near the owner's or operator's property shall follow all safety requirements and procedures. Documentation should be maintained showing that all contractor personnel are instructed in, understand, acknowledge, and comply with the safety procedures.

16.11 PROCUREMENT

Procedures should be in place and enforced to preclude the introduction into the APM system of unauthorized hazardous materials and supplies and defective or deficient equipment. The system owner or operator shall have an appropriate quality management system for spares, components, services, and tools defining what is required and verifying that what is delivered meets this requirement.

Annex A
SYSTEM SAFETY PROGRAM REQUIREMENTS

THIS ANNEX IS A MANDATORY PART OF THE STANDARD.

(As indicated in Chapter 3, Safety Requirements, equivalent techniques may be used in place of the techniques outlined in this annex).

A.1 SYSTEM SAFETY PROGRAM PLAN

A.1.1 Purpose

The system safety program plan (SSPP) shall describe in detail tasks and activities of system safety management and system safety engineering required to identify, evaluate, and eliminate or control hazards, or reduce the associated risk to a level acceptable to the authority having jurisdiction throughout the system life cycle.

A.1.2 Description

The SSPP shall be developed to provide a basis of understanding as to how the system safety program is accomplished to meet safety requirements. The approved plan shall, on an item-by-item basis, account for all required tasks and responsibilities. The SSPP shall include the following:

A.1.2.1 Program Scope and Objectives

Each SSPP shall describe, as a minimum, the four elements of an effective system safety program: a planned approach for task accomplishment, qualified people to accomplish tasks, authority to implement tasks through all levels of management, and appropriate commitment of resources (both staffing and funding) to ensure that tasks are completed. The SSPP shall define a program to satisfy the system safety requirements. This section shall

1. Describe the scope of the overall program and the related system safety program.
2. List the tasks and activities of system safety management and engineering. Describe the interrelationships between system safety and other functional elements of the program. List the other program requirements and tasks applicable to system safety. Identify where they are specified or described.
3. Account for all required safety tasks and responsibilities. A matrix shall be provided to correlate the requirements to the location in the SSPP where the requirement is addressed.

A.1.2.2 System Safety Organization

The SSPP shall describe the following:

1. The system safety organization or function within the organization of the total program, using charts to show the organizational and functional relationships and lines of communication. The organizational relationship between other functional elements that have responsibility for tasks with system safety impacts and the system safety management and engineering organization shall also be shown. Review and approval authority of applicable tasks by system safety shall be described.
2. The responsibility and authority of system safety personnel, other organizational elements involved in the system safety effort, and system safety groups. The methods by which safety personnel may raise issues of concern directly to the program manager or the program manager's supervisor within the corporation shall be described. The organizational unit responsible for executing each task shall be identified, as shall the authority in regard to resolution of all identified hazards.
3. The staffing of the system safety organization for the duration of the contract, including manpower loading, control of resources, and a summary of the qualifications of key system safety personnel assigned to the effort, including those who possess coordination and/or approval authority for prepared documentation.
4. The procedures for the integration and coordination of system safety efforts, including assignment of the system safety requirements to action organizations, coordination of system safety programs, integration of hazard analyses, program and design reviews, program status reporting, and system safety groups.
5. The process through which management decisions shall be made, including timely notification of unacceptable risks, necessary action, incidents or malfunctions, waivers to safety requirements, and program deviations.
6. Details of how resolution and action relative to system safety will be effected at the program management level possessing resolution authority.

A.1.2.3 System Safety Program Milestones

The SSPP shall

1. Define system safety program milestones and relate these to major program milestones, program element responsibility, and required inputs and outputs;
2. Provide a program schedule of safety tasks, including start and completion dates, reports, and reviews;
3. Identify subsystem, component, and software safety activities, as well as integrated system level activities (i.e., design analyses, tests, and demonstrations) applicable to the system safety program but specified in other engineering studies and development efforts to preclude duplication; and
4. Provide the estimated manpower loading required to complete each task.

A.1.2.4 General System Safety Requirements and Criteria

The SSPP shall

1. Describe general engineering requirements and design criteria for safety. Describe safety requirements for support equipment and operational safety requirements for all appropriate phases of the life cycle up to and including disposal. List the safety standards and system specifications containing safety requirements with which the system shall comply. Include titles, dates, and, where applicable, paragraph numbers.
2. Describe the risk assessment procedures and the hazard severity categories, hazard probability levels, and system safety precedence that shall be followed to satisfy the safety requirements of the program. State any qualitative or quantitative measures of safety to be used for risk assessment, including a description of the acceptable or unacceptable risk levels. Include system safety definitions that modify, deviate from, or are in addition to those in this standard.
3. Describe closed-loop procedures for taking action to resolve identified unacceptable risk, including those involving nondevelopmental items.

A.1.2.5 Hazard Analysis

The SSPP shall describe the following:

1. The analysis techniques and formats to be used in qualitative or quantitative analysis to identify hazards, their causes and effects, hazard elimination, or risk reduction requirements and how those requirements are met.
2. The depth within the system to which each technique is used, including hazard identification associated with the system, subsystem, components, software, hazardous materials, personnel, ground support equipment, nondevelopmental items, facilities, and their interrelationship in the logistic support, training, maintenance, operational, and disposal (including render safe procedure and emergency disposal) environments.
3. The integration of hazard analyses performed by others with overall system hazard analyses.
4. Efforts to identify and control hazards associated with materials used during the system's life cycle.

A.1.2.6 System Safety Data

The SSPP shall

1. Describe the approach for collecting and processing pertinent data about historical hazard, mishap, and safety lessons learned;
2. Identify deliverable data by title, number, and means of delivery (e.g., hard copy or electronic); and
3. Identify nondeliverable system safety data and describe the procedures for accessibility by the authority having jurisdiction and retention of data of historical value.

A.1.2.7 Safety Verification

The SSPP shall describe the following:

1. The verification (e.g., test, analysis, or inspection) requirements for making sure that safety is adequately demonstrated. Identify any certification requirements for software, safety devices, or other special safety features (e.g., render safe and emergency disposal procedures);
2. Procedures for making sure safety-related verification information is transmitted to the authority having jurisdiction for review and analysis; and
3. Procedure for ensuring the safe conduct of all tests.

A.1.2.8 Audit Program

The SSPP shall describe the techniques and procedures to be used to make sure the objectives and requirements of the system safety program are being accomplished.

A.1.2.9 Training

The SSPP shall describe the safety training for engineering, technician, operating, and maintenance personnel.

A.1.2.10 Incident Reporting

The SSPP shall describe the mishap or incident alerting notification, investigation, and reporting process, including notification of the authority having jurisdiction.

A.1.2.11 System Safety Interfaces

The SSPP shall identify, in detail, the following:

1. The interface between system safety, systems engineering, and all other support disciplines, such as maintainability, quality control, reliability, software development, human factors engineering, medical support (health hazard assessments), and any others; and
2. The interface between system safety and all system integration and test disciplines.

A.2 PRELIMINARY HAZARD ANALYSIS

A.2.1 Purpose

The preliminary hazard analysis (PHA) shall identify safety-critical areas, provide an initial assessment of hazards, and identify requisite hazard controls and follow-on actions.

A.2.2 Description

A preliminary hazard analysis shall be performed and documented to obtain an initial risk assessment of a concept or system. Based on the best available data, including mishap data (if assessable) from similar systems and other lessons learned, hazards associated with the proposed design or function shall be evaluated for hazard severity, hazard probability, and operational constraint. Safety provisions and alternatives needed to eliminate hazards or reduce their associated risk to a level acceptable to the authority having jurisdiction shall be included. The PHA shall consider the following for identification and evaluation of hazards as a minimum:

1. Hazardous components (e.g., fuels, propellants, lasers, toxic substances, hazardous construction materials, pressure systems, and other energy sources).
2. Safety-related interface considerations among various elements of the system (e.g., material compatibilities, electromagnetic interference, inadvertent activation, fire or explosive initiation and propagation, and hardware and software controls). This list shall include consideration of the potential contribution by software (including software developed by other sources) to subsystem or system mishaps. Safety design criteria to control safety-critical software commands and responses (e.g., inadvertent command, failure to command, untimely command or responses, inappropriate magnitude, or other designated undesired events) shall be identified and appropriate action shall be taken to incorporate them in the software (and related hardware) specifications.
3. Environmental constraints, including the operating environments (e.g., drop, shock, vibration, extreme temperatures, noise, exposure to toxic substances, health hazards, fire, electrostatic discharge, lightning, and electromagnetic environmental effects).
4. Operating, test, maintenance, built-in-test, diagnostic, and emergency procedures (e.g., human factors engineering; human error analysis of operator functions, tasks, and requirements; effects of factors such as equipment layout, lighting requirements, potential exposures to toxic materials, and effects of noise or radiation on human performance). Those procedures test unique hazards, which will be a direct result of the test and evaluation of the article or vehicle.
5. Facilities, real property, installed equipment, support equipment (e.g., provisions for storage, assembly, checkout, proof, or testing of hazardous systems and assemblies, which may involve toxic, flammable, explosive, corrosive, or cryogenic materials or wastes; radiation or noise emitters; or electrical power sources), and training (e.g., training and certification pertaining to safety operations and maintenance).
6. Safety related equipment, safeguards, and possible alternate approaches (e.g., interlocks; system redundancy; fail-safe design considerations using hardware or software controls; subsystem protection; fire detection and suppression systems; personal protective equipment; heating, ventilation, and air-conditioning; and noise or radiation barriers).
7. Malfunctions to the system, subsystems, or software. Each malfunction shall be specified, the causing and resulting sequence of events determined, the degree of hazard determined, and appropriate specification and/or design changes developed.

A.3 SUBSYSTEM HAZARD ANALYSIS

A.3.1 Purpose

The subsystem hazard analysis (SSHA) shall

1. Verify subsystem compliance with safety requirements contained in subsystem specifications and other applicable documents;

2. Identify previously unidentified hazards associated with the design of subsystems, including component failure modes, critical human error inputs, and hazards resulting from functional relationships between components and equipment comprising each subsystem; and
3. Recommend actions necessary to eliminate identified hazards or control their associated risk to acceptable levels.

A.3.2 Description

An SSHA shall be performed and documented to identify all components and equipment that could result in a hazard or whose design does not satisfy contractual safety requirements. Areas to consider are performance, performance degradation, functional failures, timing errors, design errors or defects, or inadvertent functioning. The human shall be considered a component within a subsystem, both receiving inputs and initiating outputs, during the conduct of this analysis.

The analysis shall include a determination

1. Of the modes of failure, including reasonable human errors and single-point and common mode failures, and the effects on safety when failures occur in subsystem components;
2. Of potential contribution of hardware and software (including that which is developed by other sources) events, faults, and occurrences (such as improper timing) on the safety of the subsystem;
3. That the safety design criteria in the hardware, software, and facilities specification(s) have been satisfied;
4. That the method of implementation of hardware, software, and facilities design requirements and corrective actions has not impaired or decreased the safety of the subsystem nor has it introduced any new hazards or risks;
5. Of the implementation of safety design requirements from top-level specifications to detailed design specifications for the subsystem; the implementation of safety design requirements, developed as part of the PHA, shall be analyzed to ensure that it satisfies the intent of the requirements;
6. Of test plan and procedure recommendations to integrated safety testing into the hardware and software test programs; and
7. That system-level hazards attributed to the subsystem are analyzed and that adequate control of the potential hazard is implemented in the design.

When software to be used in conjunction with the subsystem is being developed, the individual(s) performing the SSHA shall monitor, obtain, and use the output of each phase of the formal software development process in evaluating the software contribution to the SSHA.

The SSHA shall be updated as a result of any system design changes, including software design changes, that affect system safety.

A.4 SYSTEM HAZARD ANALYSIS

A.4.1 Purpose

The system hazard analysis (SHA) shall

1. Verify system compliance with safety requirements contained in system specifications and other applicable documents;
2. Identify previously unidentified hazards associated with the subsystem interfaces and system functional faults;
3. Assess the risk associated with the total system design, including software, and specifically of the subsystem interfaces; and
4. Recommend actions necessary to eliminate identified hazards and/or control their associated risk to acceptable levels.

A.4.2 Description

An SHA shall be performed and documented to identify hazards and assess the risk of the total system design, including software, and specifically of the subsystem interfaces.

This analysis shall include a review of subsystem interrelationships for the following:

1. Compliance with specified safety design criteria;
2. Possible independent, dependent, and simultaneous hazardous events, including systems failures, failures of safety devices, common cause failures and events, and system interactions that could create a hazard or result in an increase in mishap risk;
3. Degradation in the safety of a subsystem or the total system from normal operation of another subsystem;
4. Design changes that affect subsystems;
5. Effects of reasonable human errors; and
6. Determination
    a. Of potential contribution of hardware and software (including that which is developed by other sources, or commercial off-the-shelf hardware or software) events, faults, and occurrences (such as improper timing) on safety of the system;

b. That the safety design criteria in the hardware, software, and facilities specification(s) have been satisfied; and
c. That the methods of implementation of the hardware, software, and facilities design requirements and corrective actions have not impaired or degraded the safety of the system nor introduced any new hazards.

The SHA may be combined with and/or performed using similar techniques to those used for the SSHA.

When software to be used in conjunction with the system is being developed, the individual(s) performing the SHA shall monitor, obtain, and use the output of each phase of the formal software development process in evaluating the software contribution to the SHA.

The SHA shall be updated as a result of any system design changes, including software design changes, that affect system safety.

A.5 OPERATING AND SUPPORT HAZARD ANALYSIS

A.5.1 Purpose

The operating and support hazard analysis (O&SHA) shall evaluate activities for hazards or risks introduced into the system by operational and support procedures to evaluate adequacy of operational and support procedures used to eliminate, control, or abate identified hazards or risks.

A.5.2 Description

An O&SHA shall be performed to examine procedurally controlled activities. The O&SHA identifies and evaluates hazards resulting from the implementation of operations or tasks performed by persons, considering

1. the planned system configuration or state at each phase of activity;
2. the facility interfaces;
3. the planned environments (or ranges thereof);
4. the supporting tools or other equipment, including software-controlled automatic test equipment, specified for use; the operational or task sequence; concurrent task effects and limitations; and
5. the potential for unplanned events, including hazards introduced by human errors.

The human shall be considered an element of the total system, both receiving inputs and initiating outputs during the conduct of this analysis. The O&SHA must identify the safety requirements (or alternatives) needed to eliminate or control identified hazards or to reduce the associated risk to a level that is acceptable under either regulatory or contractually specified criteria.

The analysis shall identify the following:

1. Activities that occur under hazardous conditions, their time periods, and the actions required to minimize risk during these activities and time periods;
2. Changes needed in functional or design requirements for system hardware and software, facilities, tooling, or support and test equipment to eliminate or control hazards or reduce associated risks;
3. Requirements for safety devices and equipment, including personnel safety and life support equipment;
4. Warnings, cautions, and special emergency procedures (e.g., egress, rescue, and escape), including those necessitated by failure of a computer software-controlled operation to produce the expected and required safe result or indication;
5. Requirements for packaging, handling, storage, transportation, maintenance, and disposal of hazardous materials;
6. Requirements for safety training and personnel certification;
7. Effects of nondevelopmental hardware and software across the interface with other system components or subsystems; and
8. Potentially hazardous system states under operator control.

The O&SHA shall document system safety assessment of procedures involved in system production, deployment, installation, assembly, test, operation, maintenance, servicing, transportation, storage, modification, demilitarization, and disposal.

The O&SHA shall be updated as a result of any system design or operational changes.

Commentary, Annex A, System Safety Program Plan

Requirements for the SSPP identified in other sections of this standard are listed below:

3.1: System Safety Program
3.1.2: Hazard Resolution Process
13.1: Emergency Preparedness Program Plan
14.1: Applicability of Prior Verification
15.4: Service Restoration Analysis
15.7: Maintenance
16.2: Annual Internal Audit Responsibilities
16.5: Configuration Management
16.8: Hazardous Materials Program
16.9: Drug and Alcohol Abuse Program
16.11: Procurement

Annex B
BIBLIOGRAPHY

THIS ANNEX IS INFORMATIVE AND NOT A MANDATORY PART OF THE STANDARD.

Refer to the following for examples and guidance in the conduct of associated activities of the system safety programs:

1. American Public Transportation Association, *Manual for the development of rail transit system safety program plans*, 1999.
2. American Railway Engineering and Maintenance-of-Way Association (AREMA), *Communications and signal manual of recommended practice*, Part 17.
3. EN 50126/IEC 62278: *Railway applications—The specification and demonstration of reliability, availability, maintainability and safety (RAMS)*, September 1999, CENELEC, Central Secretariat: rue de Stassart 35, B-1050, Brussels.
4. EN 50128/IEC 62279: *Railway applications—Communications, signaling and processing systems—Software for railway control and protection systems*, March 2001, CENELEC, Central Secretariat: rue de Stassart 35, B-1050, Brussels.
5. EN 50129: *Railway applications—Communications, signaling and processing systems—Safety related electronic systems for signaling*, February 2003, CENELEC, Central Secretariat: rue de Stassart 35, B-1050, Brussels.
6. *Fault tree handbook*, U.S. Nuclear Regulatory Commission, January 1981, Report No. NUREG-0492.
7. *Handbook for transit safety and security certification*, DOT-FTA-MA-90-5006-02-01, DOT-VNTSC-FTA-02-12.
8. IEC 61508-1: 1998-12, *Functional safety of electrical/electro/programmable electronic safety-related systems, part 1: general requirements*.
9. IEC CDIS 61508-2, Edition 1, *Functional safety of electrical/electro/programmable electronic safety-related systems, part 2: requirements for electrical/electro/programmable electronic safety-related systems*.
10. IEC 61508-3: 1998, *Functional safety of electrical/electro/programmable electronic safety-related systems, part 3: software requirements*.
11. IEC 61508-4: 1998, *Functional safety of electrical/electro/programmable electronic safety-related systems, part 4: definitions and abbreviations*.
12. IEC 61508-5: 1998, *Functional safety of electrical/electro/programmable electronic safety-related systems, part 5: examples of methods for the determination of safety integrity levels*.
13. IEC 61508-6, Edition 1, *Functional safety of electrical/electro/programmable electronic safety-related systems, part 6: guidelines on the application of parts 2 and 3*.
14. IEC 61508-7: 1998, *Functional safety of electrical/electro/programmable electronic safety-related systems, Part 7: Overview of techniques and measures*.
15. IEEE Std 1012-1986, *IEEE standard for software verification and validation plans*.
16. IEEE Std 1059-1993, *IEEE guide for software verification and validation plans*.
17. IEEE Std 1483-2000, *IEEE Standard for verification of vital functions in processor-based systems used in rail transit control*.
18. *System safety analysis handbook*, 2nd Edition, System Safety Society, Sterling, Va., 1997.

Guidance to assist in the development of a system security program plan pursuant to Chapter 12 is provided in the following documents:

1. *FTA's transit system security program planning guide* (FTA-MA-90-7001-94-1).
2. *Transit security procedures guide* (FTA-MA-907001-94-2).
3. *The public transportation system security and emergency preparedness planning guide* (DOT-FTA-MA-26-5019-03-01).

Guidance to assist in the development of the emergency preparedness program plan per Chapter 13 is provided in the following documents:

1. *Recommended emergency preparedness guidelines for rail transit systems* (UMTAMA-06-0152-85-1).
2. *Recommended emergency preparedness guidelines for elderly and disabled rail transit passengers* (UMTA-MA-06-0186-89-1).
3. *Recommended emergency preparedness guidelines for urban, rural, and specialized transit systems* (UMTA-MA-06-0196-91-1).

4. *Critical incident management guidelines* (FTA-MA-26-7009-98-1).
5. *Public transportation system security and emergency preparedness guide* (DOT-FTA-MA26-5019-03-01).
6. *Standard protocols for managing security incidents involving surface transportation vehicles* (DOT-FTA).
7. *NFPA 130 standard for fixed guideway transit and passenger rail systems*.

Annex C
RECOMMENDED PRACTICE FOR ACCEPTANCE OF AN APM SYSTEM APPLICATION

THIS ANNEX IS INFORMATIVE AND IS NOT A MANDATORY PART OF THE STANDARD.

C.1 INTRODUCTION

The following are recommended practices for acceptance of an automated people mover (APM) system that fulfills technical requirements for a specific application, including requirements for safety certification and demonstration of compliance with contractual requirements. The practices cited in this annex are in addition to the demonstration of compliance with the requirements of this standard, as specified in Chapter 14. Acceptance typically consists of two major increments: certification of readiness to enter into unrestricted passenger service (passenger-ready status) and final acceptance.

C.2 PREREQUISITES FOR ACHIEVING PASSENGER-READY STATUS

Passenger-ready status can be achieved on completion of all activities prerequisite to unrestricted passenger service, including as a minimum the following items, plus any additional requirements imposed by the authority having jurisdiction and/or the owner. Section references are noted with respect to this standard.

1. Construction and installation work substantially complete;
2. Applicable testing demonstrating compliance with the requirements of this standard, as required by Chapter 14;
3. System performance aspects not covered in this standard demonstrated to comply with contractual requirements, as described in Section C.5 of this annex;
4. Safety certification activities complete, including documentation of concurrence by the authority having jurisdiction and the owner;
5. Security and emergency preparedness programs in place per Chapters 12 and 13;
6. Operations and maintenance (O&M) documentation submitted and formal training of O&M staff completed as required per Chapter 15;
7. Necessary spare parts and maintenance tools available to support service;
8. Successful completion of system demonstration testing, as described in Section C.6; and
9. Development of an agreed list of items remaining to be resolved after commencement of unrestricted passenger service.

C.3 PREREQUISITES FOR ACHIEVING FINAL ACCEPTANCE

Final acceptance can be achieved on completion of the following items as a minimum, plus any additional requirements imposed by the authority having jurisdiction and/or the owner:

1. Achievement of passenger-ready status;
2. Completion of all remaining construction activities, including any punchlist items;
3. Acceptance of all remaining documentation, including as-built design documents and any required updates to other deliverable documents; and
4. Completion of any unsatisfied contract requirements.

C.4 SYSTEM VERIFICATION, ACCEPTANCE, AND DEMONSTRATION PLAN

Verification of the system's compliance with all contract safety and performance requirements as a prerequisite to entering passenger service should be performed in accordance with a system verification, acceptance, and demonstration plan. The minimum requirements for a system verification, acceptance, and demonstration plan include a means of verifying compliance with the requirements of this standard, as detailed in Chapter 14; demonstration of compliance with system performance requirements not covered in this standard, as discussed in Section C.5 herein; and the definition of a system demonstration test designed to confirm the system's operating modes, reliability, availability, and the readiness of the operations and maintenance (O&M) staff to successfully operate the system, as described in Section C.6 herein. This plan is subject to approval by the owner and the authority having jurisdiction and should provide for oversight of test activities and review and/or approval of test report documentation by the authority having jurisdiction and the owner.

The plan should follow the verification sequence of Section 14.3.2. Verification, acceptance, and demonstration activities should be documented and should include pass/fail criteria. Test procedures should include all elements as specified in Section 14.3.3.

C.5 VERIFICATION OF REQUIREMENTS NOT SPECIFIED IN THIS STANDARD

Verification of requirements in addition to those imposed by this standard should be included in the system verification acceptance and demonstration plan and should consider all requirements of the contract documents and applicable codes and regulations.

Here is a list of typical contractual requirements for system acceptance that are in addition to the requirements of this standard:

1. System performance and passenger capacity under normal and failure conditions;
2. Travel times;
3. Degraded-mode operations;
4. Failure recovery provisions;
5. System configuration;
6. System equipment quality;
7. System equipment quantities;
8. System equipment aesthetics;
9. System operating features;
10. System security features and equipment;
11. System safety features, equipment, and performance not specified in this standard;
12. Vehicle capacity and passenger accommodations;
13. Vehicle performance under normal and failure conditions;
14. Alternative train configurations and vehicle coupling;
15. Station platform passenger accommodation and passenger loading and unloading performance;
16. Passenger information provisions;
17. Communication systems (CCTV, PA, telephones, and maintenance radios);
18. Functionality, equipment, tools, spare parts, and supplies of the maintenance and storage facility; and
19. Outfitting of offices and auxiliary facilities.

C.6 SYSTEM DEMONSTRATION

Requirements for performance of the system demonstration should be included in the system verification, acceptance, and demonstration plan.

The system demonstration should involve day-to-day operation of the APM system in accordance with the system operations plan of Section 15.1 and the maintenance plan per Section 15.7.2. During the system demonstration, the system should be operated as if in passenger service (typically without passengers) in strict accordance with all operations and maintenance policies and procedures. The system demonstration should not be deemed complete until the specified system service availability has been achieved over a specified operating period (e.g., 7 days to 30 days dependent on system complexity). During the system demonstration, the owner may elect to require that some or all trains in operation be loaded to simulate passengers.

The number and skills of personnel involved in the operations and maintenance of the system during the system demonstration should not exceed the number and skills identified in the staffing plan prepared in accordance with Section 15.1.3. Training and qualification of operations and maintenance personnel required per Section 15.8 shall be completed. This is exclusive of personnel required for performing demonstration administration and data collection.

The manual of operating procedures required per Section 15.1.2 and maintenance manuals required per Section 15.7.3 shall be used during the system demonstration, and any deficiencies shall be noted for subsequent revision.

Data should be collected, analyzed, and presented to demonstrate that the required system performance has been met.

Annex D
INSPECTION AND TEST GUIDELINES

THIS ANNEX IS INFORMATIVE AND IS NOT A MANDATORY PART OF THE STANDARD.

This guideline suggests items that should be considered in compiling an inspection and test checklist. It is provided as a sample to assist owners and operators in developing their own checklists. This guideline is not all-inclusive and may contain items not common to every system. The objective of the annex is to provide examples for *internal* inspection and testing by knowledgeable technicians and *not* audit checklist items.

D.1 VEHICLE

The vehicle is typically inspected to the following criteria:

1. Check the condition of the cabin unit for body damage or deterioration.
2. Visually inspect the cabin unit for loose or missing fasteners.
3. Visually inspect all individual seat units for damage and deterioration.
4. Visually inspect for sharp or protruding objects in the passenger areas.
5. Check the condition of the floor surface.
6. Inspect the entry doors and operating mechanisms for proper function or damage.
7. Visually inspect the cabin chassis for cracks or damage.
8. Check the road wheels, steel wheels, and guide wheels for abnormal wear or damage.
9. Check the HVAC for leaks and proper operation.
10. Visually inspect the batteries and storage trays.
11. Check the emergency exit doors for proper operation.
12. Check the communications equipment for proper operation.
13. Check the interior safety signage.
14. Visually inspect the brake linkages and safety switches.
15. Check elastomeric body mounts for deterioration.
16. Check low tire pressure detector sensors.
17. Check that grab bars, handholds, and access panels are properly secured.
18. Check the cabin interior lighting.
19. Check the onboard pneumatic or hydraulic system and reservoirs.
20. Inspect fire extinguishers and other applicable safety equipment for scheduled maintenance, operational condition, and accessibility.
21. Test emergency electric power and charging systems.
22. Check car level sensing system.
23. Check compliance of vehicle with clearance envelope.
24. Visually inspect the suspension components.
25. Check bearings for abnormal wear or damage.
26. Visually inspect the sanding system.
27. Visually check windows for damage and proper fit.
28. Visually inspect coupler(s).

D.2 GUIDEWAY, TRACK, AND SUPPORT STRUCTURE

The guideway, track, and support structure are typically inspected to the following criteria:

1. Visually inspect the guideway for cracks, damage, foreign objects, debris, or deterioration.
2. Check the guideway and track fasteners for looseness or deterioration.
3. Check the vertical and horizontal guide sheave bearings for adequate lubrication.
4. Check for loose or missing fasteners on the guideway and track.
5. Visually inspect the footings and anchor points.
6. Check for abnormal wear or contact between the cabin and the guideway.
7. Visually inspect the track rail and pedestal mounts for cracks.
8. Check the guideway drain trough access ports and covers.
9. Check the power feed and electrical service to the guideway and track.
10. Inspect the vertical and horizontal guide sheaves and mounts.
11. Check the access platforms, walkways, catwalks, and railings.
12. Visually inspect the track expansion and seismic joints.
13. Visually inspect the track running surface.
14. Check the overall condition of the guideway.
15. Visually inspect the condition of the isolator bushings.

16. Visually inspect the guideway safety rail.
17. Check all switches for damage.
18. Visually inspect the conductor rail.
19. Visually inspect the track end buffer.
20. Visually inspect the grounding rail.
21. Visually inspect all signals and signs.
22. Check the tunnel ventilation systems.

D.3 QUEUE AND HOLDING AREAS

The queue and holding areas are typically inspected to the following criteria:

1. Visually inspect the queue walls and fencing for security and damage.
2. Visually inspect the holding areas for hazards to passengers.
3. Check for proper queuing techniques, i.e., signage, graphics, or other.
4. Check for adequate lighting in the passenger traffic areas.
5. Visually inspect for slip, trip, and fall hazards in the queue area.
6. Check for sharp or protruding objects in the queue area.
7. Check the condition, content, and location of all warning and informational signs.
8. Function-test all of the station door systems.
9. Check the communication equipment for proper operation and condition.
10. Check the station areas for adequate staffing or monitoring.
11. Visually inspect emergency exits and egress paths for obstructions.

D.4 PROPULSION AND BRAKING

The propulsion and braking system is typically inspected to the following criteria:

1. Visually inspect the drive equipment (e.g., wiring and power supply) for obvious hazards.
2. Test the emergency drive system unit for proper operation, maintenance, and adequate fuel.
3. Check the fire suppression equipment, if provided.
4. Check the gear reducers for proper oil level and leakage.
5. Visually inspect the tachometric generators and gears.
6. Visually inspect the drive motor.
7. Visually inspect the service brake.
8. Visually inspect the emergency brake.
9. Check the condition of all hydraulic or pneumatic hoses.
10. Check for the proper installation and application of drive guards.
11. Check the brake hydraulic or pneumatic system and manual release systems.
12. Check the tension rope for abnormal wear and damage.

D.5 ELECTRICAL EQUIPMENT

The electrical equipment is typically inspected to the following criteria:

1. Check the transportation device-related distribution equipment.
2. Check for the proper use of ground fault circuit interrupters and grounding, including metal vehicle parts.
3. Visually inspect the lighting for proper operation.
4. Visually inspect the condition of conduit, wiring, connections, and grounding.
5. Check for the proper condition, operation, and labeling of control stations.
6. Check the accessibility for authorized personnel and guarding against passenger access.
7. Check the high voltage distribution panels for appropriate signage.
8. Check all control station indicator lights and displays for proper function.
9. Test all of the internal telephones located at the operator positions.
10. Check the rope supervision output signal, including the derailment function.
11. Visually inspect the batteries and their charging systems.
12. Record the operating hours and the trip cycle count.
13. Perform an automatic train control and automatic train protection diagnostic, if provided.
14. Check passenger vehicle sound and visual annunciation systems.
15. Visually inspect lightning protection.

D.6 OPERATIONAL TESTS

The operational tests are typically performed to the following criteria:

1. Test the service stop and emergency stop buttons at all stations and on all vehicles.

2. Test the operator console controls for proper operation.
3. Cycle the automated people mover in automatic mode through at least three complete cycles (six trips), record the running test cycle times, and check the average running speed.
4. Test the programmer(s) in the test mode.
5. Test the overspeed governing system.
6. Test the acceleration and deceleration supervision in both directions.
7. Check the approach supervision in both directions.
8. Test the zero speed system.
9. Test the vehicle communication devices.
10. Test the overtravel protection system in the stations.
11. Test the vehicle door open sensors and force limit for proper operation.
12. Test the vehicle emergency door system for proper operation.
13. Test the flat tire detection system.
14. Test the service brake.
15. Test the emergency brake and verify proper stopping capability.
16. Check the closed-circuit television for proper operation.
17. Test the station vehicle leveling systems.
18. Test the fail-safe function of the brake system(s).
19. Check the coupler(s) for proper function.
20. Check the sanding system for proper operation.

D.7 OPERATIONAL EMERGENCY TESTS

The operational emergency tests are typically performed to the following criteria:

1. Check emergency equipment and signage on vehicles and at stations.
2. Review emergency situation procedures.
3. Review evacuation procedures.
4. Review operating personnel procedures.
5. Review fire protocols.
6. Perform a tunnel ventilation system test.

D.8 RECORDS AND MISCELLANEOUS

Records and miscellaneous items are typically inspected to the following criteria:

1. Verify that operations and maintenance preopening inspection forms were completed.
2. Check the lockout and tagout points and procedure.
3. Check for proper maintenance and testing of the fire suppression equipment.
4. Check the building fire alarm system for activation devices and audible alarms.
5. Check the drawings, manuals, and calculations for on-site availability.
6. Check that the applicable nondestructive testing has been performed within the required time period and appropriately documented.
7. Check the evacuation routes for proper clearances and accessibility.
8. Check for improper storage of hazardous materials.
9. Check each station for the proper rescue equipment (e.g., ladders).
10. Check the station eyewash unit for proper function.
11. Check safety records.
12. Check maintenance records for safety-critical systems.

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Annex E
RECOMMENDED PRACTICE FOR WORKING SAFELY NEAR APM SYSTEMS

THIS RECOMMENDED PRACTICE IS INFORMATIVE AND IS NOT A MANDATORY PART OF THE STANDARD.

E.1 FOREWORD

The provisions of this document are written in permissive language and, as such, offer to the user a series of options or instructions but do not prescribe a specific course of action. Significant judgment is left to the user of this document.

E.2 INTRODUCTION

The following is a recommended practice developed as a guideline to assist automated people mover (APM) owners and operators with the creation of a site-specific protocol for workers performing work in close proximity to or within the dynamic envelope of an automated people mover system.

E.3 PROTOCOL DOCUMENT CONTENT

The protocol document should be developed with the following content:

1. Users of the document,
2. Overview of the APM system,
3. Zones of concern for safety,
4. Procedure and protocol to follow when planning to work within the APM zones,
5. System lockout procedure,
6. Initiating work,
7. Concluding work,
8. Immediate unscheduled requests,
9. Incident reporting, and
10. Other relevant documentation.

E.4 USERS OF THE DOCUMENT

Identify individuals who may require access to the protocol document, such as the following:

1. Maintenance personnel,
2. Emergency response providers,
3. Custodial services personnel,
4. APM contractors,
5. Contractors and subcontractors,
6. Municipal workers, and
7. An authority having jurisdiction.

Some examples of work that may need to take place near the APM system are as follows:

1. Maintenance work on or near APM equipment, including maintenance bays, equipment rooms, fire alarm systems, sprinkler systems, electrical equipment, lighting, and bird netting;
2. Snow removal processes around, near, or directly beneath the APM guideways;
3. Pavement and grounds work involving overheight vehicles or equipment that may come in contact with the APM vehicles or guideways;
4. Maintenance or installation of signs located around the APM vehicles and guideways;
5. Testing, commissioning, trials, and inspections; and
6. Use of crane, scaffolding, and other equipment.

E.5 OVERVIEW OF THE AUTOMATED PEOPLE MOVER SYSTEM

1. Provide a brief overview of how the APM system operates and technical specifications.
2. Identify what makes it particularly dangerous (e.g., elevated, live rail, high speeds, or quiet operation).
3. Identify any nonapparent areas of danger, in particular stored energy in the system, (i.e., pneumatic, hydraulic, or electrical stored energy) that must be managed or contained before work can begin.
4. Identify preferred hours of shutdown.

E.6 ZONES OF CONCERN FOR SAFETY

1. Identify zones of concern for safety, which should include the dynamic envelope plus additional safe space around specific dangerous machinery or nearby structures.

2. Develop a naming convention to distinguish zones.
3. Identify where permanent barriers permit work near the APM without system shutdown. Here are examples of zones:
   Four (4) m (13 ft) laterally from the outside edges of the guideway structure for the entire length of the guideway, and stretching from potentially below ground to sky;
   Areas between guideways; and
   Areas near adjacent buildings or structures (e.g., overpass roadways, lampposts, trees, spaces for window cleaning on adjacent buildings).
4. Identify who maintains the zone areas (e.g., APM operator or system owner).
5. Identify rules for access to certain areas (e.g., escort, coordination, or system shutdown).
6. Develop and identify warning signage at critical locations.
7. Identify any nonapparent areas of danger, in particular stored energy in the system, (i.e., pneumatic, hydraulic, or electrical stored energy) that must be managed or contained before work can begin.

E.7 PROCEDURE FOR WORKING NEAR AN APM

1. Clearly state that failure to follow the appropriate procedures identified in the protocol document may result in property damage, severe injury, or death, and that anyone found in noncompliance with these procedures must immediately cease work.
2. Those who perform work requiring a system shutdown should attend a formal safety briefing or instructional session that communicates all potential hazards that exist while they are in the work area. Those who perform repeat work, such as custodial work or routine maintenance, should receive an initial training session followed by periodic refresher training.
3. Operations and maintenance staff should be stationed in the vicinity of the work area to provide immediate support to workers during the shutdown if necessary.
4. The shutdown request process should mirror any current shutdown request procedures already present in the organization. If no procedures exist, it is recommended that all individuals with the requirement to enter, or to potentially enter, an APM zone should submit a shutdown request stating the type of work, location of the work, equipment used, elevated work platforms, and duration of the work, as a minimum.
5. Identify how many days before commencement of work the form must be submitted and the process to approve the shutdown.
6. Clearly identify who is responsible for granting the approval, with backup should this person be unavailable.
7. Ensure that all stakeholders are advised of any change in schedule (e.g., APM operator, staff monitoring passenger flow, or municipality).
8. Identify areas directly below the guideway if there is any concern of falling objects caused by construction or maintenance.
9. Establish a contingency plan in case of shutdown of trains (e.g., busing).
10. Clearly identify all roles and responsibilities of individuals involved in the shutdown.
11. Define any specific system access safeguards or interlocks, such as door lock responses within the system (e.g., trapped keys, davit arms, and interlocked access doors) and specific access key signout and use procedures.

E.8 SYSTEM LOCKOUT

Develop a system lockout process that ensures continued shutdown of the system during work operations. The lockout procedures should include method of system lockout, verification of work completion, and system readiness before returning the system to service.

E.9 INITIATING WORK

List all requirements before workers may begin work within a zone (e.g., waiver, approved request number from a shutdown request form process, clear knowledge of lockout procedures, equipment ready to initiate work, lock and tag, or advising a responsible party, such as the APM operator).

E.10 CONCLUDING WORK

List all requirements for workers when concluding work on or near the APM system (e.g., ensure that all personnel have left the area and that no equipment or supplies have been left behind, complete lockout and closeout procedures, remove the lock, and advise responsible party of completion of work). The person responsible for initiating the lockout is the only one who can restore the system.

E.11 IMMEDIATE UNSCHEDULED REQUESTS

Identify a procedure for unscheduled requests, specifically, who has the authority to approve this work and who needs to know about it to keep the area safe.

E.12 ACCIDENT, INCIDENT, HAZARD, AND NEAR-MISS REPORTING

All work-related incidents should be reported, investigated, and recorded. Accident, incident, hazard, and near-miss reporting and investigation are vital in the process of prevention. Wherever possible, hazards should be identified before they result in injury; investigations of near-miss accidents can help to achieve this goal.

E.13 OTHER RELEVANT DOCUMENTATION

List all related documents, including shutdown procedures, the shutdown request form, operation and maintenance manuals for the APM system, system access plans, lockout and tagout plans, the system safety program plan, and contingency plans.

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