American National Standard for Funiculars – Safety Requirements

Secretariat
National Ski Areas Association

Approved (XXXX xx, 2013)
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Forward (This forward is not part of American National Standard B77.2-2013)

This standard deals with passenger transportation systems that use wire ropes to provide motion to the carriers that ride on rails or are contained by a guideway. Several names are used regionally to identify these systems (i.e., Cable Railways, Inclines, Planes), but are all considered Funiculars. These systems have unique requirements that rely on ropeway technology. The B77.2 will give guidance to these systems that are not classified as elevators or Automated People Movers.

This standard is a revision of B77.2-2004 - American National Standard for Funiculars – Safety requirements and was originally based on the American National Standard for Passenger Ropeways - Aerial tramways, Aerial Lifts, Surface Lifts, Tows and Conveyors - Safety requirements, ANSI B77.1-1999.

Section 1 provides the scope and general definitions for Funiculars covered in this standard. Sections 2 covers mechanical design, electrical design, and operational requirements. Three (3) Normative Annexes and four (4) Informative Annexes are included in the standard. Normative Annexes are considered part of the standard. Informative Annexes are presented for the information provided and are not considered part of this standard.

Because of the diverse nature of the industries that may use this standard, it is recommended that authorities having jurisdiction consider an effective date of one year from the approval date of the standard. The approval date of this standard is a criterion selected by the committee and not by the American National Standards Institute.

Suggestions regarding improvement of this standard are welcome. They should be sent to the ASC B77, c/o National Ski Areas Association, 133 South Van Gordon Street, Suite 300, Lakewood, CO 80228 or e-mailed to ascb77@nsaa.org.

This standard was approved for submittal to ANSI by the Accredited Standards Committee (ASC) B77 on Aerial Passenger Ropeways. Committee approval of the standard does not necessarily imply that all the committee members voted for its approval or the approval of every requirement in the standard. At the time this standard was approved, the ASC B77 Committee had the following members:

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American National Standard

For Funiculars – Safety Requirements

Section 1
General requirements

Funicular systems, especially such a system operated on a steep incline with simultaneous ascending and descending carriers on (usually very nearly parallel) guideways counterbalancing one another, are also known as cable railways or inclines.

Carriers reciprocate between the terminals, propelled and controlled by a wire rope or other flexible element operating through drive and tensioning equipment installed in the terminals.

Provisions of this section envision a system having a reversible operating mode. See Subsection 1.1 for applicable component requirements for systems in a continuous or intermittent circulation with stop-to-load features, such as a fixed attachment individual carrier or grouped carrier, which are not covered by this standard.

1.1 Scope

This document establishes a standard for the design, manufacture, construction, operation, and maintenance of funiculars for passenger transport.

Funiculars typically have the following characteristics:

- carrier capacity over 20 passengers;
- maximum operating speed over 300 feet per minute (1.5 meters per second);
- complex guideway that may contain curves, variable inclinations and a passing zone;
- direct operator supervision.

There are other types of transportation systems that utilize similar characteristics such as Incline Elevators (see ASME A17), Automated People Movers (see ASCE 40193), etc. The authority having jurisdiction, using information from the manufacturer and owner, shall specify any or all provisions of this standard that apply to the funicular.

1.2 Purpose

The purpose of this standard is to develop a system of principles, specifications, and performance criteria that will meet the following objectives:

- a) Reflect current state-of-the-art for funicular design, operation, and maintenance;
- b) Be acceptable for adoption by government agencies and others.

It is recognized that certain dangers and risks are inherent in machines of this type and their operation. It is also recognized that inherent and other risks or dangers exist for those who are in the process of embarking, riding, or disembarking from funiculars.

This system is intended to result in funiculars that are designed, constructed, operated, and maintained in a manner that helps reduce danger, exposure to risk to passengers and maintenance and operational personnel and to encourage improvements in productivity, efficiency, development, and progress consistent with the objectives.

Such a system with these stated objectives constitutes a safety standard.

1.2.1 Other classifications

Funicular configurations that do not fall within the definition specified in 1.4 - funicular, but fall within the general category of funiculars should be evaluated by the authority having jurisdiction based upon the design engineer’s specifications and the applicable provisions of this standard.

1.2.2 New materials and methods for funiculars

Adoption of technological improvements in materials and advances in techniques is essential to enable the industry to keep pace with progress. If a designer or manufacturer proposes to use materials or methods not covered by this standard, those materials, methods, or both, shall be clearly identified. Complete design and test information shall be provided to the purchaser or the owner and the authority having jurisdiction (see 1.4 – authority having jurisdiction).

1.2.3 Exceptions

Strict application of the provisions of this standard may not be appropriate in every instance. Wherever it may be proposed to depart from the provisions of this standard, the authority having jurisdiction may grant exceptions from the literal requirements or permit the use of other devices or methods that provide features comparable to those included in this standard.
1.2.4 Installations

1.2.4.1 Existing installations

Existing installations, and those with design review completed by the authority having jurisdiction prior to 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.

Operation and maintenance shall be in compliance with those requirements specifically listed (not included by reference) in the operation and maintenance subsection 2.3 and normative Annex A for each funicular in the most current edition of this standard.

1.2.4.2 Relocated installations

An existing funicular, when removed and reinstalled, shall be classified as a new installation (see 1.2.4.3).

1.2.4.3 New installations

New installations, and those with a design review completed by the authority having jurisdiction after the effective date of this standard, shall comply with the new or revised requirements of this edition.

1.2.4.4 Modifications

A modification shall be defined as an alteration of the current design of the funicular that results in:

- a) a change in the design speed of the system;
- b) a change in the rated capacity by changing the number of carriers, load capacity of the carriers, or a change in weight or carrier size;
- c) a change in the path of the rope or guideway;
- d) a change in the type of brakes and devices or components thereof;
- e) a change in the structural arrangements;
- f) a change in energy source or type of power unit, evacuation power unit or alternate carrier unloading system (used in evacuations);
- g) a change of the control system logic.

Modified funiculars shall be inspected and/or tested to assure compliance with the modified design. Test procedures and inspection criteria shall be provided by the designer or manufacturer.

1.2.5 Interpretation of standard

In cases where additional explanation or interpretation of this standard is required, such requests should be referred to Accredited Standards Committee (ASC) B77, c/o National Ski Areas Association, 133 South Van Gordon Street, Suite 300, Lakewood, CO 80228-1706 or e-mail ascb77@nsaa.org.

1.3 Reference to other codes and standards

The design, installation, operation, and maintenance of funiculars and their components that are not covered by this standard should conform to applicable standards or codes. To the extent that they are available, applicable codes or standards shall be selected to cover all features, including, but not limited to, ADA, allowable unit stresses and properties of materials. Each code or standard should be of the most recent issue, and the designer shall state which code or standard was followed.

Features not covered by this standard, shall be handled in accordance with sound engineering judgment to the satisfaction of the authority having jurisdiction.

1.4 Definitions

ADA accessible: Describes a site, building, facility, or portion thereof that complies with ADAAG (Americans with Disabilities Act Accessibility Guidelines).

approved: The word “approved” means “approved by the authority having jurisdiction”.

attendant: The individual assigned to particular duties or functions in the operation of a funicular (also see 1.4 – supervisor).

authority having jurisdiction: The phrase “authority having jurisdiction” means any government agency empowered to oversee the design, manufacture, construction, operation, maintenance, and use of funiculars. Where no such agency exists, the owner of the funicular shall be considered the authority having jurisdiction.

auxiliary power unit (APU): Generic term to generally describe a gas or diesel engine generally used as a backup to the prime mover. It can be designated as a prime mover or evacuation power unit depending upon use and configuration.

Basic Life Support (BLS): Medically accepted non-invasive procedures used to sustain life.

brake: A device consisting of one or more friction devices which, if applied, accomplishes braking.

braking: The process of absorbing energy in order to maintain or reduce the speed of the funicular.

NOTE – The typical resistances effective in absorbing the energy of a funicular include:

- a) the inherent resistance in the system (e.g., friction);
- b) incidental resistance (e.g., slope, gravity, wind);
- c) applied resistance (e.g., brake, power unit regeneration).

buffer: A device placed at the end of the carrier guideway, or installed on the carrier as an energy absorbing device in the event of overtravel.
bullwheel: A large grooved wheel at a terminal that rotates continuously when the haul rope is moving and deflects the haul rope by an angle of 10 degrees or more.

bullwheel, deflection: A bullwheel that deflects the haul rope at least 10 degrees.

bullwheel, diameter of: Wherever the term diameter is used in specifying bullwheels, it refers to the diameter at the bottom of bullwheel grooves (tread diameter).

bullwheel, drive: A bullwheel that delivers power to the haul rope.

bullwheel, fixed return: When acting simply as a fixed return for the haul rope.

bullwheel, tension: A bullwheel that maintains tension in the haul rope by changing its position.

cabin, enclosed: A cabin utilized for the transportation of passengers in which no part of the passenger can extend more than 6 inches through any opening, including windows and doors.

cabin, open: A cabin utilized for the transportation of passengers in which passengers can enter or exit through open doors or the sides of the cabin, or when windows are not covered allowing passengers outside access during operation.

carriage: A structural framework for supporting the cabin(s) on the guideway, providing attachment points for the rope(s).

carrier: The structural and mechanical assemblage in or on which the passenger(s) of a funicular system are transported. Unless otherwise specified, the carrier includes the cabin and carriage.

circuit, electrical power: The electrical power circuit is a normally de-energized circuit that, when energized, provides electrical power to the drive motor, other funicular-related electrical power equipment, or both.

circuit(s), bypass: A circuit(s) that partially or entirely circumvents monitoring devices and remote signal inputs of a malfunctioning operating circuit to allow operation of the funicular, under the specific conditions set forth.

Complex electronic element: An electrical device composed of one or more solid state components for which the failure modes are not well defined or detectable, or for which the behavior of the device under fault conditions cannot be completely determined.

EXAMPLE – A photocell operating a relay to implement a stop.
gasoline: A Class I liquid fuel.

Ground-Fault Circuit Interrupter (GFCI): A device intended for the protection of personnel that functions to de-energize a circuit or portion thereof within an established period of time when a current to ground exceeds the values established for a Class A device. Class A ground-fault circuit interrupters trip when the current to ground has a value in the range of 4mA to 6mA.

ground fault protection: A system intended to provide protection of equipment from damaging line-to-ground fault currents by operating to cause a disconnecting means to open ungrounded conductors of the faulted circuit. This protection is provided at current levels less than those required to protect conductors from damage through operation of a supply circuit overcurrent device.

guideway: A surface of concrete, steel or other approved material, that supports the carrier and controls its lateral movement.

haul rope: A wire rope used on a funicular that provides motion to a carrier(s) and is powered by the drive bullwheel.

magnetic rope testing (MRT): Non-destructive magnetic rope testing (MRT) is the use of either electromagnetic or permanent magnetic equipment using magnetic-flux and/or magnetic flux leakage principles capable of detecting discontinuities and/or changes in metallic cross-sectional area in ferromagnetic wire ropes and cables.

minimum breaking force: The specified value that the actual (measured) breaking force must meet or exceed in a test.

NOTE – The term "Minimum Breaking Force" has replaced the term "nominal breaking strength" internationally and in the new ASTM Wire Rope Standard.

nominal voltage: A nominal value assigned to a circuit or system. The actual voltage at which a circuit or system operates can vary from the nominal within a range that permits satisfactory operation of the equipment.

non-complex element: An electrical element in which the failure modes are well defined and the behavior of the element under fault conditions can be determined.

EXAMPLE – A system comprising one or more limit switches operating one or more contactors or relays to de-energize a motor.

normal stop: A stop in which the prime mover or other systems may be involved in braking and in which the funicular comes to rest in a controlled manner. (also see 1.4 – emergency shutdown).

operation circuit: An electrical circuit that provides power to or controls the funicular machinery.

operator: The individual in charge of a funicular (also see 1.4 – attendant).

overhauling: An operating condition in which unbalanced loading exceeds system friction and creates a torque, acting to produce rotation of drive bullwheel in either direction when all brakes and the prime mover are inactive.

owner: A person who owns, manages, or directs the operations and maintenance of a funicular. Owner may apply to a state or any political subdivision or instrumentality thereof.

NOTE – The owner is sometimes referred to as the “operator” or “area operator”. Not to be confused with the individual funicular “operator” as herein used.

passenger: Any person utilizing a funicular for personal transportation.

prime mover: Power unit utilized for the continuous operation of a funicular.

Programmable Logic Controller (PLC): Any solid state automatic device that has programmable memory and is used to process input and output logic functions.

protection circuit: Electrical circuits designed to stop the funicular in the event of a malfunction or failure of the funicular system.

Qualified Engineer: An engineer who is registered as a Professional Engineer in the United States of America.

roller: Rotating cylinder used to guide or support the rope in its proper operating zone.

rope: Unless otherwise specified, the term rope shall mean wire rope, which consists of several strands twisted together. (The terms rope, wire rope, and cable are interchangeable).

ropeway: As used in this standard, this term refers to equipment covered under ANSI B77.1 – Passenger Ropeways.

rotation-resistant rope: Wire rope consisting of inner strands laid in one direction covered by a layer of strands laid in the opposite direction. This has the effect of counteracting torque by reducing the tendency of the finished rope to rotate.

shall: This word is to be used to convey a strict requirement, from which the reader/user may not deviate in order to be considered in conformance with the standard.

sheave: Pulley or wheel grooved for wire rope.

sheave unit: The largest assembly of sheaves that are independently articulated on a common shaft.

sheaves, diameter of: Wherever the term diameter is used in specifying sheaves, it refers to the diameter at the bottom of sheave grooves (tread diameter).
1.5 Quality assurance program

Written Quality Assurance (QA) programs shall be developed and utilized to ensure the integrity of the design, manufacture, construction, operation, and maintenance of funiculars. The objective of these QA programs is to assure that funiculars meet the applicable requirements of this standard.

1.5.1 Design

A Qualified Engineer shall design, or be in responsible charge of the design of new and modified funiculars (see 1.2.4).

The designer’s QA program for new, modified, relocated funiculars shall include verification and documentation of the design criteria. This program shall include calculations, analysis, and checking procedures.

For relocated funiculars, the designer of the relocation shall be responsible for the establishment of the QA program for that installation. The designer shall describe what QA methods were used for the various components of the relocated funicular. These methods may include sampling procedures, nondestructive testing, and prior satisfactory “in use” service.

1.5.2 Manufacture

The manufacturer’s QA program for funiculars shall include verification and documentation that manufactured parts conform to the design criteria. For relocated funiculars, this requirement is for newly manufactured parts only.

1.5.3 Construction

For new or modified funiculars, a qualified engineer shall certify to the owner that the construction and installation has been completed in accordance with the final design criteria for such work.

The installer’s QA program for all new or modified funiculars shall include verification and documentation that the funicular installation conforms to the design criteria.

1.5.4 Operation and maintenance

The owner’s QA programs shall verify and document that the funicular is operated and maintained in accordance with the design criteria, including the performance of in-use periodic testing, and general inspections by qualified personnel.
Section 2
Funicular

2.1 Design and installation

2.1.1 General

The designer shall specify the maximum design capacities and the design loading conditions under which the funicular may be operated. The maximum rope speed shall be that specified by the designer and established as functional by testing and operational performance.

2.1.1.1 Design passenger weight

For purposes of design, a passenger shall be considered as having a minimum average weight of 170 pounds (77.1 kilograms). It is the owners' responsibility to indicate unusual considerations that might affect the design passenger weight.

If a funicular transports freight, the freight shall be weighed and not exceed the design load capacity. The designer shall determine the maximum design live load for transporting freight on the funicular. The operational manual shall document the live load parameters and relevant operational conditions.

2.1.1.2 Location

In selecting the location and alignment of an installation, consideration shall be given to the following items, and to any others that may be particularly pertinent to the funicular type and location:

a) electric power lines and their supports;

b) railways;

c) highways;

d) structures;

e) rock and earth slides, cave-ins, wash-outs, and the like;

f) snow creep, avalanches and snow accumulations along the track;

g) wind action;

h) icing;

i) ski slopes and trails;

j) rivers and gullies;

k) buried installations, including pipelines;

l) crossing or close proximity to other passenger ropeways or other funiculars;

m) control of air space below, above, and adjacent to the installation;

n) carrier height above ground or surface;

o) ADA accessibility;

p) fire hazard

2.1.1.3 Width of guideway

The funicular shall have a dedicated right-of-way with total horizontal separation from any other transport systems.

The guideway clearing shall be wide enough to prevent interference with the funicular system by adjacent vegetation. Such clearings shall be protected, if necessary, to avoid washouts, avalanches, snow creep, or other natural hazards that might endanger the installation.

2.1.1.4 Clearances

Clearances shall take into account the maximum possible lateral and vertical movement of each carrier in the direction of stationary objects, or in case of passing carriers, of each simultaneously towards the other.

In no case shall trees or vegetation extend within 5 feet (1.53 meters) of any portion of the carrier under normal operating conditions.

2.1.1.4.1 Vertical clearances above carriers

In terminals, tunnels, overhead roadways, or other covered areas, a minimum space of 18 inches (460 mm) shall exist between the highest point of the carrier and the tunnel ceiling or any projection. For crossings with passenger aerial ropeways, funiculars shall be considered public transportation and have the clearances required in latest edition of ANSI B77.1.

2.1.1.4.2 Vertical clearance below an elevated guideway

The following minimum vertical clearances shall exist between the lower edge of any funicular component (i.e., guideway, carrier, etc.) of an elevated system and any portion of the terrain or other obstructions, including snow:

a) 16.5 feet (5.03 meters) for vehicle transportation;

b) 10 feet (3.05 meters) for ski under;

c) Where clearance is less than 8 feet (2.44 meters), provisions shall be made to prevent access by unauthorized persons to the area beneath the guideway.
2.1.1.4.3 Horizontal clearances

The following clearances shall be maintained:

a) Clearance to obstructions:
   1. Enclosed carriers shall maintain a minimum horizontal clearance of 18 inches (460 mm).
   2. Open carriers shall maintain a minimum horizontal clearance of 3 feet (915 mm).

b) Clearance to another carrier in a passing zone:
   1. Enclosed carriers shall maintain a minimum horizontal clearance of 4 feet (1.22 meters) between carriers.
   2. Open carriers shall maintain a minimum horizontal clearance of 6 feet (1.83 meters) between carriers.

The loading/unloading platforms in terminals and stations shall be designed to allow for the unobstructed passage of the carrier during all operating conditions.

For approaches and parallel runs with vehicular roadways, a minimum distance of 5 feet (1.53 meters) shall be maintained between the vertical boundary lines of carriers, or guideway elements and the edge of the roadway. Protective devices or barriers shall be used where roadway vehicles could encroach upon the guideway.

2.1.1.4.3.1 Tunnel clearances

In tunnels and overhead roadway crossings, clearances of 2.1.1.4.3(a) shall be met. Additionally, where exit doors are provided on carriers, at least 32 inches (815 mm) of clearance shall be provided on the side of the car with the exit door.

If exit doors open out, the minimum clearance shall be measured from the outermost projection of a fully opened door.

2.1.1.4.3.2 Funiculars crossing roadways

Funiculars shall not cross a roadway at grade level.

For funiculars crossing over roadways, a minimum distance of 5 feet (1.53 meters) horizontal shall be maintained between the guideway vertical supports and the edge of the roadway unless the design considerations for the guideway support include possible vehicle contact.

For funiculars crossing under roadways, clearances stated in 2.1.1.4.1 and 2.1.1.4.3 shall be maintained.

2.1.1.4.3.3 Guideway crossings with pedestrian pathways

Pedestrian pathways crossing a guideway at grade level is not permitted unless specific measures are taken to protect pedestrians from funicular moving components and moving carriers.

2.1.1.5 Carrier speed

The maximum carrier speed shall be that specified by the designer and established as functional by testing and operational performance.

2.1.1.5.1 Speed provisions

Funicular(s) with a carrier operating speed up to 1200 feet per minute (6 meters per second) shall meet the following requirements:

a) the guideway shall be protected from unauthorized access;
   b) the control room shall contain indicators that will show the location of the carrier(s) at all times.

Funicular(s) with a carrier operating speed over 1200 feet per minute (6.0 meters per second) shall meet the above requirement plus the following:

   c) haul ropes shall have a device or system that detects haul rope departure from its normal zone of operation and initiates a stop of the funicular (see 2.2.3.4);
   d) an attendant shall be in each carrier or group of carriers.

2.1.1.6 Structures and foundations

All structures and foundations shall be designed and constructed in conformance with subsection 1.3 and shall be appropriate for the site. Applied design loads shall include dead, live, snow, wind, and dynamic loads due to normal conditions and for foreseeable abnormal conditions.

Structures and foundations located in snow creep areas shall be designed for such conditions and loads, or protective structures shall be provided as required by the conditions.

2.1.1.6.1 Reserved

2.1.1.6.2 Foundations

In determining the resistance of the soil to motion of the foundation, the subsoil conditions at the site shall be considered, including any buoyancy due to groundwater that may be present. If the resistance of the soil is not practically determinable, the foundation or anchorage should be designed as a gravity anchor, using a coefficient of friction appropriate to the general character of the soil. Foundations on rock shall be firmly anchored to solid rock unless designed as gravity foundations. The design of foundations shall consider the freezing and thawing of the soil.

The top of concrete foundations shall not be less than 6 inches (150 mm) above finished grade unless specific directions for the protection of the foundation and structural steel below grade is specified by the designer.
The design shall have a minimum factor of safety of 2 in resisting overturning and, concurrently, 2 against sliding, under dead load and live load conditions. The minimum factors shall be 1.5 under these loadings plus wind or seismic activity acting simultaneously.

2.1.1.6.3 Underground construction materials

Where guideway sections are to be constructed by the cut-and-cover method, perimeter walls and related construction shall not be less than Type I or Type II or combinations of Type I and Type II approved noncombustible construction as defined in ANSI/NFPA 220-2009 Standard on Types of Building Construction, as determined by an engineering analysis of potential fire exposure hazards to the structure.

Where guideway sections are to be constructed by a tunneling method through earth, unprotected steel liners, reinforced concrete, shotcrete, or equivalent shall be used.

EXCEPTION – Rock tunnels shall be permitted to utilize steel bents with concrete liner if lining is required.

Noncombustible rail ties shall be used in underground locations. Fire-retardant, pressure-treated ties are permitted at switch or passing zone locations.

Structures such as remote vertical exit shafts and ventilation structures shall be not less than Type I (332) approved noncombustible construction as defined in ANSI/NFPA 220-2009.

2.1.1.7 Communications

A permanently installed two-way voice communication system shall be provided between the prime mover and alternate carrier unloading control point, drive system building, loading and unloading platforms. The power for this system shall be independent of the primary power and the communication system shall be functional and audible during a power failure.

Audio indicators shall be audible over all ambient noise levels, and visual indicators (e.g., Light Emitting Diodes), if provided, shall be visible even in bright sunlight.

An additional system of two-way voice communication from operating station to all carriers and to opposite terminal platform shall be provided where carriers are attended by a cabin attendant.

2.1.1.8 Combustion engine(s) and fuel handling

Internal combustion engine installation and fuel handling requirements are located in normative Annex F.

2.1.1.9 Loading and unloading areas

Platforms, ramps, and related units comprising the loading and unloading areas of the funicular are integrally related to its operation. They shall be designed and installed in conformance with subsection 1.3.
2.1.1.11.1 Acceptance inspection

Before a funicular that is new, relocated, modified (see 1.2.4) or that has not been operated for routine maintenance within the previous 2 years is opened to the public, it shall be given a thorough inspection by a Qualified Engineer to verify compliance with the plans and specifications of the designer.

It shall be the responsibility of the owner to ascertain or verify that the following conditions have been met:

1. **a)** tightness of all structural connections;
2. **b)** lubrication of all moving parts;
3. **c)** alignment and clearances of all open gearing;
4. **d)** installation and alignment of all drive system components;
5. **e)** position and freedom of movement of counterweights or other tension systems and carriages;
6. **f)** haul rope alignment at entrance to bullwheels;
7. **g)** operation of all electrical components, including circuit protection and grounding;
8. **h)** brake torque testing;
9. **i)** minimum carrier clearances;
10. **j)** proper alignment of haul rope and sheave units;
11. **k)** actual testing of evacuation equipment and procedures at the most difficult location;
12. **l)** proper location of terminals and guideway elevations in accordance with the plans and specifications. Terminals, guideway working points, funicular working points and carrier-loading areas shall be documented by an “as built” survey. Any variations shall be noted and approved by the qualified engineer responsible for design. All designations of guideway elevation are to indicate the top edge of the guideways that support the carriers;
13. **m)** ventilation system (see 2.1.2.11.7).

2.1.1.11.2 Acceptance tests

Before a funicular that is new, relocated, modified (see 1.2.4), or that has not been operated for routine maintenance within the previous 2 years is opened to the public, it shall be given a thorough inspection by a Qualified Engineer to verify compliance with the plans and specifications of the designer. The designer, manufacturer, or Qualified Engineer shall propose and submit an acceptance test procedure. Thorough load and operating tests shall be performed under full loading and any partial loadings that may provide the most adverse operating conditions. Test load per carrier shall be 110% of the design live load. The functioning of all push-button stops, automatic stops, limit switches, deropement switches, and communications shall be checked. Acceleration and deceleration rates shall be satisfactory under all loadings (see 2.1.2.5). Motive power and all braking devices (see 2.1.2.6) shall be proved adequate under the most adverse loadings and at design speeds.

2.1.2 Terminals and stations

2.1.2.1 Power units

All power units or combinations thereof shall have the capacity to operate the funicular at the most unfavorable design loading conditions, including the starting of the funicular loaded to 110% of capacity in weight.

The prime mover or evacuation power unit for the funicular shall be designed to prevent accidental changing of directions whenever the funicular is in motion.

2.1.2.1.1 Prime Mover

Power units engaged as a prime mover shall have the systems required in subsections 2.1 and 2.2 functional during operation (see 1.4 – Prime Mover).

The prime mover shall be disconnectable in the event of a mechanical lockup.

If changes are made to the drive system components that affect rotational inertia (i.e. removal of electric motor), the resulting stopping distances and deceleration rates shall meet the requirements of 2.1.2.5.

2.1.2.1.2 Evacuation power unit or alternate carrier unloading (docking) system

If the primary power unit(s) is not operational, an alternate method shall be provided to return stranded carriers and passengers to a terminal station or an approved unloading area. It shall be capable of starting and moving the carriers at a controlled speed under full loading (110% of capacity in weight) and any partial loading that may provide the most adverse operating conditions.

The unloading method shall be designed to become operational and move the carriers to a terminal station or unloading area within 30 minutes of initiating its connection.

One of the following methods shall be provided:

a) Evacuation power unit or other mechanical system, when provided, shall be electrically wired to meet the requirements of 2.2.3.1 so that it can be stopped by the Emergency Shutdown Circuit. The evacuation power unit shall not depend upon the mechanical integrity of the prime mover to drive the unit;

b) An alternate carrier unloading system utilizing a non-motorized drive system to move the carriers at a controlled speed.
2.1.2.1.3 Power Unit Interlock

System(s) or device(s) shall be installed that allow only one power unit to be actively connected to the mechanical drive system while operating. Electrical interlock systems shall comply with 2.2.4.

EXCEPTION – Multiple drive power units that are designed to operate together.

2.1.2.2 Speed reducers and gearing

All speed reducers and gearing shall have the capacity for starting the funicular under the most unfavorable design loading conditions without exceeding design rating. They shall have a service factor appropriate for the application.

Where manual multispeed transmissions are used on either the prime mover or evacuation power unit, gears shall not be shifted when the funicular is in motion.

2.1.2.3 Bearings, clutches, couplings, and shafting

Bearings, clutches, couplings, shafting and universal joint shafts (cardan shafts) shall be selected on the basis of the manufacturer’s published data for the particular use. All shafting shall be designed in accordance with accepted standard practices. Guarding and containment shall be in accordance with the provisions of 2.1.2.7.1.

Provisions shall be made for adjustment and lubrication of all bearings, clutches, and couplings, when required.

2.1.2.4 Acceleration and speed control

2.1.2.4.1 Maximum sustained acceleration

The drive system shall be designed to accelerate the funicular smoothly and to avoid severe oscillations or undulation under any operating condition.

The funicular shall be started at its lowest point of speed range after any type of stop. After any type of stop is initiated, the stop cannot be canceled and the funicular may not be started until it has come to a complete stop. The funicular shall accelerate smoothly from a stop to the intended speed.

The accelerations introduced by guideway geometry and vehicle speed changes shall not exceed the limits stated in Table 2-1. “Sustained” refers to the nominal values excluding random vibration effects above ½ Hz.

Table 2-1 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.

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

2.1.2.4.2 Speed control

The following requirements shall be incorporated in the design:

a) Carrier(s) shall be brought to a stop for loading and unloading, and provisions shall be made to keep the carrier(s) in its approximate position during the loading and unloading process;

b) provision shall be made for overhauling loads. The system shall always operate at a controlled speed not exceeding design speed by more than 6%. The energy developed by the overhauling load shall be dissipated in a satisfactory manner without using the brakes specified under 2.1.2.6.

The drive system shall be capable of moving the unloaded system at reduced speed for rope inspection and equipment maintenance. This reduced-speed operation may be obtained by the use of the evacuation power unit.

2.1.2.5 Stops & Shutdowns

For all stops, the acceleration rates shall not exceed the limits stated in Table 2-1. These measurements shall be measured over any one second interval under any operating condition and referenced to the rope speed at the drive system terminal.

Normal stop: (see 1.4 – normal stop). The service brake shall have been applied by the time the funicular comes to a stop.

Emergency shutdown: (see 1.4 – emergency shutdown) The bullwheel brake shall be applied. The service brake shall have been applied by the time the funicular comes to a stop. The designer shall designate which control functions of the funicular system shall initiate an emergency shutdown.

The designer may define other stopping modes in addition to normal stop and emergency shutdown. For other stopping modes, the designer shall specify the method of stopping, including the type and timing of brake(s) that may be applied, and the stopping criteria.
### 2.1.2.6 Brakes

The funicular shall have the following friction-type brakes:

- service brake (see 2.1.2.6.1);
- bullwheel brake (see 2.1.2.6.2);
- carrier brake (see 2.1.2.6.3).

They shall be designed and monitored to ensure that:

- Once the funicular begins movement in the intended direction, the brakes are maintained in the open position;
- Multiple brakes or brake systems shall not be simultaneously applied such that excessive deceleration is applied to the funicular under any condition of loading (see 2.1.2.5);
- The failure of one braking system to properly decelerate the funicular shall automatically initiate a second braking system.

The service brake and bullwheel brake shall be designed such that failure of one braking system shall not impair the function of the other systems.

Brakes shall have the braking force applied by springs, weights, or other approved forms of stored energy.

Hydraulic systems shall be designed to reduce the possibility of oil contaminating the braking surfaces in the event of a failure of a hose, cylinder or fitting.

Each braking system shall be capable of operation to comply with daily inspections and periodic testing.

The manufacturer or a Qualified Engineer shall furnish a written procedure to be followed and specify the auxiliary equipment necessary for periodic testing and adjustment of the holding force of each brake.

The procedure shall specify the minimum and maximum holding force for the service brake and bullwheel brake.

This procedure shall be performed at the completion of the acceptance test, and then at the frequency specified in the procedure above, to demonstrate the ability of each brake to produce the required torque.

Such testing shall be accomplished as part of normal maintenance during the operating season and shall be performed when the funicular is not open to the public.

As a minimum, this testing shall be performed monthly while in operation.

If a device is permanently installed to cause a brake to be disabled for testing, it shall be electronically monitored so that the funicular cannot be operated in its normal mode when the brake is so disabled.

### 2.1.2.6.1 Service brake

The service brake can be located at any point in the drive system such that there is no belt, friction clutch, or similar friction-type device between the brake and the drive bullwheel. The service brake shall not act on the same braking surface as the bullwheel brake.

The service brake shall be an automatic brake to stop and hold the funicular under the most unfavorable design loading condition. The brake force shall be adjusted such that by itself it will stop the funicular from maximum design speed, with the design loading condition most unfavorable to stopping, within the conditions specified in 2.1.2.5.

The brake shall be in a normally applied position and shall not open prior to the prime mover providing control to the funicular. It shall be held open for operation of the funicular and shall be applied when power is removed or the funicular is stopped.

Deceleration rates specified in 2.1.2.5 shall be achieved by the service brake without the aid of other braking devices or drive system regeneration.

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**Table 2-1 – Maximum/Minimum allowable accelerations**

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>STANDING</th>
<th>SEATED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Average Acceleration</td>
<td>3 ft/s² (0.91 m/s²)</td>
<td>3 ft/s² (0.91 m/s²)</td>
</tr>
<tr>
<td>Stop – Maximum Horizontal Deceleration</td>
<td>5 ft/s² (1.52 m/s²)</td>
<td>11 ft/s² (3.34 m/s²)</td>
</tr>
<tr>
<td>Emergency Shutdown - Maximum Horizontal Deceleration</td>
<td>10 ft/s² (3.05 m/s²)</td>
<td>19 ft/s² (5.76 m/s²)</td>
</tr>
<tr>
<td>Stop and Emergency Shutdown – Minimum Horizontal Deceleration</td>
<td>1 ft/s² (0.30 m/s²)</td>
<td>1 ft/s² (0.30 m/s²)</td>
</tr>
<tr>
<td>Vertical Accelerations</td>
<td>±8 ft/s² (±2.44 m/s²)</td>
<td>±8 ft/s² (±2.44 m/s²)</td>
</tr>
<tr>
<td>Lateral Accelerations</td>
<td>3 ft/s² (0.91 m/s²)</td>
<td>8 ft/s² (2.44 m/s²)</td>
</tr>
</tbody>
</table>
2.1.2.6.2 Bullwheel brake

The bullwheel brake shall be an automatic brake to stop and hold the funicular under the most unfavorable design loading condition.

Bullwheel brake controls shall be located and the brake activated in a manner that deceleration will begin within 3 seconds after the operator or attendant reacts to the stimulus to apply the brake.

The bullwheel brake shall operate on any drive terminal bullwheel assembly that meets the requirements of 2.1.2.8.2.

Application of the bullwheel brake shall automatically disconnect the power source from the power unit in use. This brake shall act automatically if a carrier travels beyond their normal stopping position in either terminal.

2.1.2.6.3 Carrier brake

Each carrier, whether one or more are used in a line, on the funicular shall be equipped with a carrier braking system.

The braking system shall be designed to stop the funicular while considering the risk of injury to passengers and damage to the guideways or rails, carriers, or structures under all design conditions.

Application of the carrier braking system shall remove power from the power unit.

The braking system shall be capable of:

a) holding a fully loaded carrier in case of a haul rope or counter rope failure;

b) holding a fully loaded carrier at the point of maximum gradient of the guideway with a safety factor of 1.35 with new brake liners;

c) automatically functioning in case of a haul rope failure or when the minimum rope tension specified by the designer is not met;

d) manual activation by the attendant in the cabin;

e) interlock so that brake will not set until the carrier’s upward travel has stopped except in an overspeeding condition;

f) automatically functioning in specified overspeed conditions.

2.1.2.7 Location of machinery

2.1.2.7.1 General

Moving machine parts that normally may be in reach of personnel shall be fitted with guards. Where breakage of a power transmission component can result in injury, provisions shall be made for appropriate containment of said components. Guards and containment shall be done in conformance with American National Standard Safety standard for mechanical power transmission apparatus, ANSI B15.1-2000 (R-2008).

Protection against static electricity shall be provided.

Fire-fighting device(s) shall be available (see F.6 in Annex F).

2.1.2.7.2 Machinery not housed in a machine room

Provisions shall be made to keep the public away from the machinery. All machinery and controls shall be rated for use in their intended environment.

2.1.2.7.3 Machinery housed in a machine room

The machine room shall be adequately ventilated. It shall have a permanently installed lighting system, including an emergency lighting system to provide adequate illumination in case of a power outage, adequate for required machinery maintenance and safety of operating personnel. The arrangement of the machinery shall permit required maintenance. A door with a suitable lock shall be provided, and the design shall keep the public away from the machinery. When a passageway is provided between machines or machinery and walls, a minimum passageway width of 18 inches (460 mm) shall be maintained. Means shall be provided to heat the machine room unless the designer or manufacturer certifies that the drive system machinery is rated for operation in an unheated room.

2.1.2.7.4 Automatic fire detection

Heat and smoke detectors shall be installed in all machinery areas (see F.6.5 in Annex F).

2.1.2.7.5 Portable fire extinguishers

Fire extinguishers shall be provided (see F.6 in Annex F).

2.1.2.8 Bullwheels and sheaves in terminals and stations

2.1.2.8.1 General

All bullwheels and sheaves, including their mountings and frames, shall be designed to withstand static and dynamic loads. Bullwheel and sheave bearings and mountings shall be selected, designed, and installed in accordance with the recommendations of the manufacturers of the bearings.

When unlined grooves are used for wire rope, they should be V-shaped and shall have rounded bottoms with a radius equal to approximately 55% of the rope diameter.

When lined bullwheel or sheave grooves are used, the allowable bearing pressures of the liner material shall not be exceeded.
2.1.2.8.2 Haul rope terminal bullwheels

Provisions shall be incorporated in the terminal design to retain the terminal bullwheels in their approximate normal operating position in the event of failure of the bearings, shaft, or hub.

Means shall be provided to prevent any haul rope deropement on bullwheels. A flange extension of 1-1/2 times the rope diameter (measured radially from the bottom of the rope groove) shall be deemed adequate for retention.

The minimum diameter of bullwheels that act as driving, braking or deceleration bullwheels shall be 72 times the nominal diameter of the haul rope. The design safety factor for bullwheels shall not be less than 2.0 to the yield strength if residual rope tensions are considered.

Driving, braking, or holding bullwheels shall be so designed that the haul rope does not slip in the groove. The design coefficient of friction for a particular bullwheel liner shall not exceed the values shown in Table 2-2 or the manufacturers recommended value.

Groove scrapers shall be mounted on all bullwheels, except winch drum applications.

2.1.2.8.3 Sheaves in tension systems and sheaves not specifically covered elsewhere in this section

The minimum diameters for these sheaves shall be as indicated in Table 2-3.

Condition A is applicable where rope bending around sheaves is of major importance.

Condition B is applicable where rope bending around sheaves is important, but some sacrifice in rope life is acceptable to achieve reduction in weight, economy in design, etc.

Condition C is applicable to sheaves that should not rotate due to any tension system movement but should rotate only due to tension system adjustment.

Provisions shall be made to assure that all tension system sheaves rotate freely.

Table 2-2 Design coefficient of friction for bullwheel liners

<table>
<thead>
<tr>
<th>Bullwheel liner</th>
<th>Coefficient of friction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel or cast iron grooves</td>
<td>0.070</td>
</tr>
<tr>
<td>Leather</td>
<td>0.150</td>
</tr>
<tr>
<td>Rubber, neoprene, or others</td>
<td>0.205</td>
</tr>
</tbody>
</table>

Table 2-3 Minimum diameters for sheaves in tension systems and sheaves not specifically covered elsewhere in this section.

<table>
<thead>
<tr>
<th>Rope Type</th>
<th>Condition A</th>
<th>Condition B</th>
<th>Condition C</th>
</tr>
</thead>
<tbody>
<tr>
<td>6x7</td>
<td>72d</td>
<td>42d</td>
<td>24d</td>
</tr>
<tr>
<td>6x19</td>
<td>45d</td>
<td>30d</td>
<td>20d</td>
</tr>
<tr>
<td>6x37</td>
<td>27d</td>
<td>18d</td>
<td>12d</td>
</tr>
</tbody>
</table>

NOTE - d equals the nominal rope diameter

2.1.2.9 Tension systems

Counterweights, hydraulic and pneumatic cylinders, or other suitable devices may be used to provide the tensioning requirements of the particular installation.

All devices used to provide the tension shall have sufficient travel to adjust to all normal operating changes in loading and temperature.

The tension for haul/counter ropes for all modes of operation shall be determined by the design engineer. Tension systems may be automatic or manual; however, all systems shall have monitoring equipment that will automatically prevent operation outside of design limits (see 2.2.3.3).

Tension systems may be adjustable to provide proper tensions for different modes of funicular operation.

The tension system design shall consider changes, for each mode of operation, in tensions due to rope elongation, friction, and other forces affecting traction on driving, braking, or holding bullwheels to assure that tensions remain within design limits.

Friction and other forces developed in the tension system composed of the movable carriage, counterweight sheaves, reeving, and guide system shall be included in calculated haul rope tension for all conditions of loading.

2.1.2.9.1 Hydraulic and pneumatic systems

Hydraulic and pneumatic cylinders, when used, shall have sufficient ram travel to accommodate all normal operating changes in loading and temperature. Provisions shall be made to keep the cylinder free from climatic-induced conditions and contaminants that may interfere with free movement.

If the system fails to provide the design operating pressure, the funicular shall be able to be operated to unload passengers. Cylinders and their attachments shall each have a minimum factor of safety of 5. The factor of safety is equal to the ultimate tensile strength of the cylinder divided by the maximum steady state design tension.
The systems providing operating pressure for the cylinder shall have a minimum factor of safety of 5 unless a high-velocity check-valve or flow-control device is used where the pressure line is connected to the cylinder. The check-valve shall be rated to hold, at a minimum, twice the normal operating pressure. The remainder of the system shall not exceed the manufacturer’s published working pressure.

Provisions shall be made to restrict the movement of pressure lines or hoses should they become severed under pressure. When pneumatic storage cylinders, accumulators, or other similar devices are used, they shall be located so that they cannot be knocked over or damaged.

2.1.2.9.2 Counterweights

Counterweights, when used, shall be arranged to move freely up and down. Enclosures for counterweights shall be provided where necessary to prevent snow, ice, water, and other materials from accumulating under and around the counterweights and interfering with their free movement. Visual access shall be provided to areas beneath and above all counterweights contained in enclosures or pits. When a counterweight is contained in a structural frame, guides shall be provided to protect the frame and to ensure free movement of the counterweight. Where snow enclosures are not required, guardrails or enclosures shall be provided to prevent unauthorized persons from coming in contact with or passing under counterweights.

2.1.2.9.2.1 Counterweight buffers (bumpers)

If counterweight buffers (bumpers) are used, they must be designed to absorb the energy calculated from carrier brake actuation at the most unfavorable load and carrier position.

2.1.2.9.3 Wire ropes in tension systems

Wire ropes in tension systems shall have a minimum factor of safety of 6 when new (see A.1.3.1 in Annex A). On arrangements involving rope reeving, the maximum design static tension with sheave friction taken into account shall be the basis for determining the factor of safety. No rotation-resistant ropes shall be used in tension systems (see 1.4 - rotation-resistant rope).

Wire ropes in tension systems shall be adjusted so that the counterweight will reach the end of its travel before the attached tension bullwheel carriage comes within 6 inches (150 mm) of the end of its travel. When wire ropes are used with pneumatic or hydraulic cylinders, they shall be adjusted so that connecting devices will not contact the reeving devices before the ram reaches the travel limits of the cylinder.

2.1.2.9.4 Tension bullwheel carriages

The available travel of the tension bullwheel and tension bullwheel carriage shall be adequate for the maximum limits of motion produced by the most unfavorable design loading and operating conditions.

2.1.2.9.5 Rigid-mounted carriages

For carriage arrangements with vertical motion, guides shall be provided. For all carriage arrangements other than those whose motion is vertical, the mounting that travels under the action of the tension system shall be supported on rigid straight rails by means of wheels or other low friction devices. All loads, including torsional loads, due to driving torque and braking shall be considered, and the structure and carriage shall adequately transmit these loads to the foundation.

2.1.2.9.6 Cable winch adjusting devices

Winches or other mechanical devices that are used for take-up and remain part of the system shall have a minimum factor of safety of 6 against their ultimate capacity. They shall have a positive lock against release. Where this factor cannot be established by manufacturer's endorsement, a device shall be installed on the tension system rope ahead of the winch/device that will keep the tension system intact in the event of a release or failure of the device.

The diameter of the winding drum shall not be less than the specified minimum sheave diameters referenced as Condition C in 2.1.2.8.3 for rope.

2.1.2.10 Anchoring devices

All anchoring end connections shall be above finished grade.

Wire ropes or strands, and their connections, used to anchor, tension, or otherwise secure terminal structures, shall be designed with a minimum factor of safety of 6. Where adjusting devices are used in the arrangement, the devices shall be capable of being securely locked or removed during operation.

All connections between ropes or cables used and anchoring devices shall be in accordance with the requirements of the designer.
2.1.2.11 Venting for tunnels and enclosures

2.1.2.11.1 Emergency ventilation system

The following environmental conditions and the mechanical ventilation system requirements shall be used for a fire emergency within a funicular tunnel or any associated passageway(s) (see 2.1.3.8).

NOTE – Annex D provides information on types of mechanical systems for normal ventilation of funicular systems for determining a tenable environment.

2.1.2.11 Venting for tunnels and enclosures

The following ventilation requirements are based on the length of the underground or enclosed guideway:

- a) greater than 1000 feet (304.8 meters) shall require a mechanical emergency ventilation system;
- b) less than or equal to 1000 feet (304.8 meters) and greater than 200 feet (61.0 meters) shall comply with one of the following:
  - 1) a mechanical emergency ventilation system shall be provided;
  - 2) an engineering analysis to determine the need for a mechanical emergency ventilation system shall be done.
- c) less than or equal to 200 feet (61 meters), a mechanical emergency ventilation system shall not be required.

The mechanical emergency ventilation system shall make provisions for the protection of passengers, employees, and emergency personnel from fire and smoke during a fire emergency. It shall be designed to maintain the required airflow rates for a minimum of 1-hour but not less than the anticipated evacuation time.

3.2.1.2.11.2 Design

The emergency ventilation system shall be designed to do the following:

- a) Provide a tenable environment along the path of egress from a fire incident;
- b) Produce airflow rates sufficient to prevent back-layering of smoke in the path of egress;
- c) Be capable of reaching full operational mode within 120 seconds.

The design shall encompass the following:

- d) The heat release rate produced by the combustible load of a vehicle and any combustible materials that could contribute to the fire load at the incident site;
- e) The fire growth rate;
- f) Tunnel and enclosure geometries;
- g) A system of fans, shafts, and devices for directing airflow in tunnels and enclosures;
- h) A program of predetermined emergency response procedures capable of initiating prompt response from the operator in the event of a fire emergency.

2.1.2.11.3 Emergency ventilation fans

The ventilation system fans that are designated for use in fire emergencies shall be capable of satisfying the emergency ventilation requirements in either the supply or exhaust mode. Individual emergency ventilation fan motors shall be designed to achieve their full operating speed in no more than 30 seconds from a stopped position when started across the line and in no more than 60 seconds for variable speeds motors.

Emergency ventilation fans, their motors, and all related components exposed to the exhaust airflow shall be designed to operate in an ambient atmosphere of 482°F (250°C) for a minimum of one hour with actual values to be determined by analysis. In no case shall the operating temperatures be less than 300°F (149°C).

NOTE – Examples of fan rating systems are given in Annex D.

Local fan motor starters and related operating control devices shall be located away from the direct airstream of the fans to the greatest extent practical. Thermal overload protection devices on motor controls of fans used for emergency ventilation shall not be permitted.

Fans associated only with passenger or personnel comfort and that are not designed to function as a part of the emergency ventilation system shall shut down automatically on identification and initiation of a fire emergency ventilation program so as not to jeopardize or conflict with emergency airflows. Non-emergency ventilation airflows that do not impact the emergency ventilation system shall be permitted to operate where identified in the engineering analysis.

Critical fans required in battery rooms or similar spaces where hydrogen gasses or other hazardous gasses might be released shall be designed to meet the ventilation requirements of ANSI/NFPA 91-2010, Standard for exhaust systems for air conveying of vapors, gasses, mists, and noncombustible particulate solids. These fans and other critical fans in automatic funicular control rooms, communications rooms, and other related enclosures/spaces shall be identified in the engineering analysis and shall remain operational as required during the fire emergency.

2.1.2.11.4 Ventilation Components

Components that are interrelated with the emergency ventilation fans and that are required to meet the emergency ventilation system airflows shall be structurally capable of withstanding both maximum repetitive and additive piston pressures of moving funiculars and emergency airflow velocities.
Components shall be constructed of noncombustible, fire-resistant materials capable of functioning at anticipated operating temperatures.

**EXCEPTION – Finishes applied to noncombustible devices.**

Component controls shall be protected against fire in the immediate area to the greatest extent practical.

Shafts that penetrate the surface and that are used for intake and discharge in fire or smoke emergencies shall be positioned or protected to prevent recirculation of smoke into the system through surface openings. If this is not possible, surface openings shall be protected by other means to prevent smoke from re-entering the system. Adjacent structures and property uses also shall be considered.

2.1.2.11.5 Emergency ventilation system control/operation

Operation of the emergency ventilation system components shall be initiated from the supervisor’s control station. The supervising station shall receive verification of proper emergency ventilation fan(s) and interrelated device(s) response. Local controls shall be permitted to override the central supervising station in all modes in the event where the central supervising station becomes inoperative or where the operation of the emergency ventilation system components is specifically redirected to another site.

Operation of the emergency ventilation system shall not be discontinued until directed by the supervisor.

2.1.2.11.6 Power and wiring

The power for the emergency ventilation fan plants shall originate from two separate and distinct utility sources. The feeders from those two sources to the individual components shall be isolated from one another to the greatest degree possible. If a second feeder is not available, an emergency backup system shall be permitted to provide the second power source if designed to meet the demands of the emergency modes. Where an emergency backup system is utilized, it shall comply with the provisions of ANSI/NFPA 110-2010, Standards for emergency and standby power systems.

All wiring materials and installations shall conform to the requirements of ANSI/NFPA 70-2008, National Electrical Code, and in addition, shall satisfy the following requirements:

- a) Materials manufactured for use as conduits, raceways, ducts, boxes, cabinets, equipment enclosures, and their surface finish shall be capable of being subjected to temperatures up to 932°F (500°C) for 1 hour and shall not support combustion under the same temperature condition. Other materials, when encased in concrete, shall be acceptable;
- b) All conductors shall be insulated. Ground wires shall be permitted to be bare. All thicknesses of jackets shall conform to ANSI/NFPA 70-2011;
- c) All insulation shall conform to Article 310 of ANSI/NFPA 70-2011 and be moisture- and heat-resistant types carrying temperature ratings corresponding to the conditions of application and in no case lower than 194°F (90°C);
- d) Wire and cable constructions intended for use in control circuits and power circuits to related emergency devices shall pass the flame-propagating criteria of IEEE Std 383-2003, Standard for type tests of Class 1E electrical cables, field splices, and connections for nuclear power generating stations;
- e) All conductors for emergency ventilation fans and related emergency devices shall be protected from physical damage by funicular vehicles or other normal funicular system operations and from fires in the funicular system by suitable embedment, encasement, or location. Encased conductors shall be enclosed in their entirety in armor sheaths, conduits, or enclosed raceway boxes and cabinets, except in ancillary areas or other nonpublic areas. Conductors in conduits or raceways shall be permitted to be embedded in concrete or to run in concrete electrical duct banks but shall not be installed exposed or surface-mounted in air plenums that might carry elevated temperatures accompanying fire emergency conditions;
- f) Overcurrent elements that are designed to protect conductors serving motors for both emergency fans and related emergency devices that are located in spaces other than the main electrical distribution system equipment rooms shall not depend on the thermal properties for operation.

2.1.2.11.7 Emergency ventilation system testing

The Manufacturer or a Qualified Engineer shall furnish a written procedure to be followed for testing the ventilation system. This procedure shall be performed during the acceptance test and then at the frequency specified not to exceed one year.

2.1.3 Guideway design

The design of the guideway or rail bed and guideway support structures shall conform to 1.3.

2.1.3.1 Guideway access

Means shall be provided for ready access from the ground to the guideway structure(s). Means such as permanent ladders or portable ladders shall be provided. If portable ladders are used, they shall be readily available in sufficient quantities.(see 2.1.1.10.1)
2.1.3.2 Guideway rails
Guideways and terminals shall be arranged so as to keep the rails securely fastened to the guideways and terminal structure under the most adverse operating and non-operating conditions. These provisions shall not interfere with any carrier brake operation. The type of rails chosen depends on the working load, the bearing on the supports, and the functional type of the carrier brake. The attachment of the rails to the supports must be able to transfer all influencing forces, especially those of the carrier brake.

2.1.3.3 Guideway curves
The minimum radius of a horizontal curve of the guideway shall be a minimum of 328 feet (100 meters) or the value generated by the following formula, whichever is greater:

\[ R = A \times V^2 \]

where:
- \( R \) = Radius of guideway curve
- \( A \) = Constant
- \( V \) = Velocity of the carrier

If \( R \) is measured in feet, \( V \) is measured in feet per second, constant \( A = 0.7625 \); if \( R \) is measured in meters, \( V \) is measured in meters per second, constant \( A = 2.5 \).

Vertical curves of the guideway are permissible provided the manufacturer’s recommended values for minimum/maximum sheave loading limits are satisfied.

2.1.3.4 Guideway inclination
Inclinations in excess of 100% shall be subject to approval by the authority having jurisdiction.

2.1.3.5 Guideway loads
Any individual carrier wheel load shall not be less than

\[ 20\% \times \frac{1}{n} \times L \times \cos \alpha \]

under the most unfavorable loading conditions (wind, winding curves, centrifugal force) for conventional double reversible funiculars with a passing zone, where

- \( L \) = Weight of one carrier
- \( \alpha \) = Inclination of guideway
- \( n \) = Number of wheels per carrier

2.1.3.6 Guideway passing zone
Where guideway mid-point passing zones are required for the passage of the carriers, minimum clearances between the carriers in accordance with 2.1.4.3(b) shall be maintained for a length equal to or greater than the length of a carrier or line of carriers.

2.1.4 Guideway equipment
2.1.4.1 Haul rope(s)
See Annex A for additional wire rope requirements.

2.1.4.1.1 Factor of safety
Static factor of safety is equal to the nominal breaking force divided by the computed maximum tension caused by design loads, including the effects of friction, but excluding dynamic loads, in the section of rope that is most highly stressed. All ropes shall have a minimum static factor of safety of 6, when new. During the use of the carrier brakes, the counter or counterweight rope safety factor may be reduced to a minimum of 3.
For funiculars, which, due to their location or alignment, may be subject to adverse conditions relating to the potential life of the haul rope, such as high corrosion, rockslide potential or numerous horizontal curves, the factor of safety shall be 8. This determination shall be provided by the design engineer.

2.1.4.2.1 Rope sheaves

The tread diameter of a haul rope sheave shall be not less than 10 times the nominal rope diameter for metallic sheaves or 8 times for sheaves with elastomer liners.

The tread diameter of a counter rope sheave(s) shall be not less than 8 times the nominal diameter of the rope.

Rollers may also be used for rope support. Rollers do not have to meet the minimum diameter as set forth in Table 2-2.

The funicular designer shall determine the maximum allowable load per sheave.

Sheave flanges shall be as deep as possible, considering other features of the system. At the same time, the attachments on the carriers shall be designed in relation to the sheave groove so as not to contact sheave flanges during normal operation, taking into consideration the anticipated amount of wear of the sheave liner groove.

2.1.4.2.2 Sheave and roller mounting

Sheaves and rollers shall be installed for proper guidance of the rope along the guideway. They shall be located and spaced to prevent the rope(s) from contacting their mountings or structural members of the guideway.

In the event of a deropement from a sheave, provision shall be made for the rope to be returned to the sheave groove as a carrier passes over the sheave or support, as well as ensuring that the rope does not become entangled in the guideway equipment.

Sheave and roller mountings design shall consider the requirement for carrier brake actuation.

2.1.4.2.3 Rope retention

Provisions shall be made to retain all rope(s) in the guideway sheave groove under all anticipated conditions of loading, including concave guideway profiles, and under all design normal operating conditions including acceleration and braking, except as required for carrier passage.

Near intermediate terminals or close access to the adjacent guideway by the public at the inside of horizontal curves, protective structures shall be provided to protect passengers and public from a deropement.

2.1.5 Carriers

2.1.5.1 General

The carrier and all carrier components shall be designed by qualified engineers in accordance with accepted practices of design. The maximum capacity of each carrier shall be specified by the funicular designer. The maximum operating load for the carrier shall be the number of passengers multiplied by the design passenger weight and/or any material handling capabilities.

If the carrier design has not had prior successful use for passenger transportation, its adequacy shall be verified by test loading, trial operations, and test under repetitive loadings.

Structural parts shall be designed so that application of worst-case loads involving cabin weight, live load, seismic and wind loads multiplied by a safety factor of 3 does not exceed the material yield strength at any point.

A minimum factor of safety of 2 must be maintained against overturning at maximum lateral operational wind speed. Consideration should be given to wind load, centrifugal forces, rail alignment, inclination of guideway, location of center of gravity of carrier, etc. (see 2.1.3.3).

For a funicular using 3 rails, double track or single track, overturning shall be positively prevented by applying respective mechanical stops within the rails.

For operations utilizing a group of carriers, the carriers shall be coupled by a means of rigid drawbars and a secondary connection designed to withstand all normal and emergency forces imposed on the carrier undercarriages. Carrier connections shall have a safety factor of 6. A group of carriers shall be electrically connected and bonded.

For funiculars operating in tunnels or other enclosed areas, the carriers shall use fire resistant materials wherever possible. Fluids carried on the carriers for brake systems, etc. in amounts exceeding 1 gallon U.S. (3.8 liters) shall be nonflammable.
2.1.5.2 Undercarriage

The undercarriage shall be equipped with devices that will, as far as is possible, prevent a derailment of the carrier. Where icing conditions may exist, the undercarriage shall be equipped with ice-scraping devices that will not contact the rail under normal anticipated operating conditions.

2.1.5.3 Carriage attachments

Haul rope attachments to carriages shall comply with the requirements of A.3.2 in Annex A. Use of a type of attachment other than those listed in A.3.2 in Annex A shall require approval by the authority having jurisdiction. The Qualified Engineer shall establish the criteria and frequency for periodic inspection of the haul rope attachment.

2.1.5.4 Cabin

A minimum clear floor space for wheelchairs of 48 inches by 30 inches (1220 mm x 760 mm) shall be provided. Floor surfaces shall be slip resistant.

All carrier glazing and windows shall be of tempered glass or shatterproof material.

The maximum capacity of each cabin, both in pounds and kilograms and approximate number of adult passengers, shall be posted in a conspicuous place in each cabin.

For nighttime, underground, and enclosed guideways longer than 50 feet (15.25 meters) or 1 car length whichever is greater:

a) each cabin shall meet the illumination requirements of 2.2.13.2 and 2.2.13.3.2;
b) carriers shall be equipped with exterior headlights in each direction of travel.

Cabin doors shall be design as follows:

a) A door not closed and locked will prevent the start of a trip;
b) a door opened during a trip will initiate a stop;
c) a cabin door key or release shall be placed under glass, posted to prohibit use except under specified emergency conditions.

All doors shall be equipped with a mechanism accessible from the carrier exterior to manually unlock the doors without carrier power. Each passenger compartment shall have at least one door, which is manually operable from the interior without vehicle power. Swing type doors may only be opened to the outside.

Unless some other means is provided by the operator, the horizontal gap between the cabin door opening floor edge and platform edge shall not be greater than 1 inch (25.4 mm). The height of the cabin floor and the platform shall be within ±1/2 inch (±12.7 mm).

2.1.5.4.4 Structural fire resistivity

Portions of the carrier body separating major ignition, energy, or fuel-loading sources from the passenger compartment including equipment-carrying portions of carrier roofs shall have sufficient resistance to external fire penetration to the interior of the cabin for a period consistent with the safe evacuation of a full load of passengers from the carrier in the worst-case situation.

Design of floor systems shall take into account the potential fire hazard associated with under-floor operating components, items carried onto a cabin by riders, and the use and right-of-way characteristics that affect evacuation time.

2.1.5.4.5 Interior fire propagation resistance

Materials and finishes in the cabin shall have sufficient resistance to fire propagation in the interior of the vehicle by an internal fire for a period consistent with the safe evacuation of a full load of passengers from the carrier. The aforementioned materials and finishes shall be evaluated under a fire hazard assessment for
vehicles including material characteristics other than fire propagation resistance: such as smoke emission, ease of ignition, rate of heat, and smoke release.

Two methods for assessing the fire hazard for materials and finishes used in a cabin interior are to do a hazard load analysis or use appropriate material properties.

NOTE – For examples, see Appendix D or Table 5-2.4 in ANSI/NFPA 130-2010, Standard for fixed guideway transit and passenger rail systems.

The aforementioned materials and finishes shall include interior walls and ceiling linings, floor coverings, ceiling, seats, shades, drapes, curtains, glazing, transparencies, partitions, elastomer(s), and nonelectrical insulation.

2.1.6 Provisions for operating personnel

Operator and attendant work positions shall be located to provide visual surveillance of the station and the guideway in the vicinity of the work position. The operator controls and communicating devices shall be within reach without leaving their position.

Station work positions, when enclosed, shall be heated, ventilated, and lighted as required to perform the function of the work position. When enclosed, work positions shall include:

a) the communications and controls required of the work position;
b) the operating instructions and emergency procedures;
c) a fire extinguisher(s) (see F.6.1 in Annex F);
d) provisions to be locked to prevent unauthorized entry when unattended.

This does not preclude additional communications and controls to be located at other areas of the funicular.

The control room shall contain indicators that will show the location of the carrier(s) at all times.

The use of Closed Circuit Television (CCTV) surveillance shall be subject to approval by the authority having jurisdiction.

2.1.7 Operational and maintenance manuals

2.1.7.1 Operational manual

The designer of each new or reinstalled funicular shall prepare an operational manual in English for use with each installation. The manual shall describe the function and operation of the components and provide instructions for the correct usage of the installation.

2.1.7.2 Maintenance manual

The designer of each new or reinstalled funicular shall provide with delivery of the funicular, a maintenance manual in English for each installation. The manual shall describe recommended maintenance procedures, including but not limited to:

a) types of lubricants required and frequency of application;
b) definitions and measurements to determine excessive wear;
c) recommended frequency of service to specific components;
d) carrier testing procedures and acceptance criteria;
e) brake testing and adjustment;
f) dynamic testing procedure.

2.2 Electrical design and installation

2.2.1 General design and installation testing

Prior to operation of a newly installed funicular, or after any modification thereafter of the electrical system, the electrical system shall be tested and shown to meet the requirements of this standard and the test results shall be recorded. Design of all electronic controls and drives shall consider minimum sensitivity to electrical noise and electrical emissions, such as noise spikes from power lines and lightning, radio transmitters, thyristors (SCR), or solenoid or relay noise at levels and frequencies that could initiate loss of control.

2.2.1.1 Applicable codes


2.2.1.2 Location

All electrical power transmission wiring located near or proposed to cross over the funicular shall comply with the applicable requirements of ANSI/IEEE C2-2007.

2.2.1.3 Protection

All electrical equipment with operating voltages above 24 volts nominal shall be marked conspicuously with letters/numbers that are no smaller than ¼ inch (6 mm) in height designating the greatest voltage that may be in the equipment, the number of phases and whether the voltage is alternating or direct current. All electrical equipment rated over 600 volts shall be marked with conspicuous warning signs stating “Danger High Voltage”.

EXCEPTION – 120 volt single phase lighting circuits and convenience outlets.

All power equipment shall be protected against overloads by circuit breakers or fuses.

In locations where electrical equipment, including batteries, is likely to be exposed to physical damage, enclosures or guards shall be so arranged and of such strength as to prevent such damage.
2.2.1.4 Reserved

2.2.1.5 Wiring

All wiring shall be in accordance with the designer's specifications and applicable codes.

2.2.1.5.1 Control wiring classification

All control wiring shall be Class 1 in accordance with Article 725 of ANSI/NFPA 70-2011.

2.2.1.5.2 Communication wiring

All communication wiring and systems are exempt from the requirements in Article 800 of ANSI/NFPA 70-2011.

2.2.1.5.3 Insulation

All control wiring is excepted from the requirements of Article 725.49 Part B of ANSI/NFPA 70-2011. The designer shall specify conductor size, type, and insulation suitable for the electrical and mechanical requirements of the application.

2.2.1.5.4 Exterior non-funicular related circuits

All ungrounded non-funicular-related circuits, mounted on or within 60 feet (18.3 meters) of the funicular centerline, shall be ground fault protected. (see 1.4 – ground fault protection).

2.2.1.5.5 Ground fault circuit interrupter protection for personnel

All 120-volt single phase, 15 and 20 ampere receptacles in areas where electrical diagnostic equipment, electrical hand tools, or portable lighting equipment may be used shall have ground fault circuit interrupter protection for personnel (see 1.4 – ground-fault circuit interrupter).

EXCEPTION – Receptacles dedicated to permanently mounted devices need not comply with this requirement.

2.2.1.6 Grounding

2.2.1.6.1 Structures

All metallic structures shall be bonded to form a grounding electrode system as defined in Article 250 ANSI/NFPA 70-2011. Electrical continuity of all metal parts of the structures shall be assured by mechanical connection and shall be electrically bonded to the common bonding conductor.

2.2.1.6.2 Drive terminal structure

The drive terminal structure shall have one point referred to as a ground point, as defined in ANSI/NFPA 70-2011. All DC and AC electrical systems shall be referred to this point. If an electrical prime mover is used, the electric service-grounding conductor shall terminate at this point, as well as the structure's ground referenced in 2.2.1.6.1. Under the worst-case conditions, the resistance from the ground point to any grounded point within the funicular system shall not exceed 50 ohms, for the purpose of grounding the control circuit. The grounding system for the funicular shall not be used as a grounding system for any other system not related to the funicular system.

To ensure that the 50-ohm grounding requirement is met under all conditions of soil, moisture, temperature, and circulating ground and air currents, all terminal and guideway structures shall be bonded together with a bonding conductor.

2.2.1.6.3 Rope grounding

Grounding bullwheels or sheaves with conductive liners or equivalent means should be provided at one location for the purpose of grounding ropes, as applicable, for static electrical discharge. For rope systems with an isolated or insulated rope incorporated in the operating circuitry, no means of grounding are required when the operating circuit takes into consideration static electrical discharge.

2.2.1.6.4 Lightning protection

If lightning protection is provided, it shall follow ANSI/NFPA 780-2008 Standard for the installation of lightning protection systems.

2.2.2 Electrical system circuit design and classification

The designer or funicular manufacturer responsible for the design shall identify and classify any new electrical circuits not already classified as protection circuits, operations circuits, or supervision circuits.

2.2.2.1 Circuit priority

Protection circuits shall have priority over all other circuits. Operations circuits shall have priority over supervision circuits. If any circuit's function is connected to circuits of a higher level of protection, it shall be classified at the higher level.

2.2.3 Protection circuits

Electrical circuits designed to stop the funicular in the event of a malfunction or failure of the funicular system shall be classified protection circuits. All funicular systems shall contain two or more protection circuit(s) at least one of which shall be designated the emergency shutdown circuit (see 2.2.3.1). Protection circuits shall be energized to permit system operation and when de-energized shall initiate a stop, or shall be through continuous diagnostic coverage (see 1.4 – continuous diagnostic coverage) that the failure of a complex electronic element will cause the funicular to stop unless another element in the protection circuit is performing the same function (redundancy). If functional redundancy is implemented, the failure of the first element must be annunciated, at a minimum,
1 at the beginning of operations on a daily basis.
2 The designer or manufacturer shall develop
3 procedures and frequency for testing protection
4 circuits. As a minimum, all protection circuits shall be
5 calibrated and tested annually.
6 Protection circuits include, but are not limited to:
7 a) Emergency shutdown (see 2.2.3.1);
8 b) carriage overtravel detection device (see
9 2.2.3.2);
10 c) tension system fault (see 2.2.3.3);
11 d) rope tension-monitoring (see 2.2.3.4);
12 e) guideway haul rope monitoring (2.1.5.1.(c));
13 f) brake system (see 2.2.3.5);
14 g) overspeed (see 2.2.3.6);
15 h) acceleration/deceleration error (see 2.2.3.7);
16 i) speed regulation check points (see 2.2.3.8);
17 j) cabin door fault (see 2.1.5.4.3);
18 k) carrier brake application detection (see
19 2.1.2.6.3).

2.2.3.1 Emergency shutdown circuit
20 All funicular systems shall include at least one
21 protection circuit labeled emergency shutdown circuit
22 (see 1.4 – emergency shutdown). The shutdown shall
23 have priority over all other control stops or commands.
24 If, for any reason, the operator has lost control of the
25 funicular while using the operating control circuitry, the
26 controls shall include an emergency shutdown circuit
27 allowing the operator/attendant to stop the funicular.
28 Any one of the following conditions is considered a loss
29 of control of a funicular:
30 a) Funicular will not SLOW DOWN when given the
31 command to do so;
32 b) Funicular will not STOP when given the
33 command to do so;
34 c) Funicular OVERSPEEDS beyond control
35 settings and/or maximum design speed;
36 d) Funicular ACCELERATES faster than normal
37 design acceleration;
38 e) Funicular SELF-STARTS or SELF-
39 ACCELERATES without the command to do so;
40 f) Funicular REVERSES direction unintentionally
41 and without the command to do so.

2.2.3.2 Carrier overtravel
42 An overtravel sensing device shall be installed that
43 applies the bullwheel brake if a carrier travels beyond
44 its normal stopping location in either terminal (see
45 2.1.2.6.2).

2.2.3.3 Tension system
46 Active tension systems, (i.e. counterweight, hydraulic,
47 etc.) shall have a protection device(s) that initiates a
48 stop when the haul rope tension carriage exceeds its
49 range of normal operations.

2.2.3.4 Rope tension-monitoring
50 In the drive terminal, a rope tension-monitoring device
51 shall be installed to stop the drive system if the rope
52 tension is beneath a minimum recommended value
53 specified by the designer.

2.2.3.5 Braking system
54 All braking systems shall be designed and monitored to
55 ensure that they meet the requirements of 2.1.2.6 (a)
56 through 2.1.2.6 (d).

2.2.3.6 Overspeed
57 If the line speed exceeds the design speed by 10%,
58 the service brake, if installed, shall slow and stop the
59 funicular automatically.
60 A system or device shall be installed that automatically
61 applies the bullwheel brake when the speed of the haul
62 rope exceeds the design value by 15% in either
63 direction.

2.2.3.7 Acceleration/deceleration monitoring
64 The rate of acceleration and deceleration of the
65 funicular shall be monitored and cause the system to
66 shut down in the event that acceleration or
67 deceleration exceeds the provisions of 2.1.2.4.

2.2.3.8 Speed regulation check points
68 A redundant device or system shall initiate a stop in the
69 event manual or automatic speed regulation fails to
70 reduce funicular speeds to the designated values in the
71 station and any other designated zones.

2.2.4 Operation Circuits
72 An operation circuit is a circuit that provides power to
73 or controls the funicular machinery.
74 The designer or manufacturer shall identify the
75 operation circuits that require periodic testing and
76 develop procedures and frequency for testing. As a
77 minimum, all operation circuits shall be tested and
78 calibrated annually.
79 Operation circuits include, but are not limited to:
80 a) Power circuits;
81 b) drive fault circuits;
82
2.2.5 Supervision circuits

Supervision circuits include all communications systems. In addition, supervision circuits may be provided to monitor or supervise the performance of various funicular systems or provide the funicular operator with system information.

The designer or manufacturer shall identify supervision circuits that require periodic testing and develop procedures and frequency for testing supervision circuits. As a minimum, all supervision circuits shall be calibrated and tested annually.

Supervision circuits may include, but are not limited to:

- a) Telephone and sound powered systems (see 2.1.1.7);
- b) information display circuits;
- c) audible warning devices (see 2.2.10);
- d) wind speed and direction sensors and display units;
- e) gearbox oil pressure, oil flow and temperature;
- f) pneumatic and hydraulic tension system pressure (see 2.2.5.1);
- g) unauthorized passenger detection.

2.2.5.1 Pneumatic and hydraulic tension systems

When pneumatic or hydraulic tension systems are used, pressure-sensing devices shall also be incorporated that will stop the funicular system in case the operating pressure goes above or below the design pressure range. Such pressure-sensing devices shall be located close to the actual tensioning device. It shall not be possible to isolate the pressure sensor from the actual tensioning device.

2.2.6 Bypass circuits

A temporary circuit may be installed for the purpose of bypassing failed electrical circuits. The use of these bypass circuits shall meet the requirements of 2.3.2.5.9.

2.2.7 Phase-loss protection

All funicular systems equipped with electrical prime movers (electrical motors) shall have phase-loss protection on all power phases and under-voltage protection or over-voltage protection, or both, when speed regulation can be adversely affected by such voltage variations.

2.2.8 Electronic speed-regulated drive monitoring

All electronic speed-regulated drives and electric motors shall shut down in the event of:

- a) field loss (dc motors);
- b) overspeed (protection circuit see 2.2.3(g));
- c) speed feedback loss as applicable;
- d) overcurrent.

2.2.9 Manual control devices

All automatic and manual stop and shutdown devices shall be of the manually reset type. An exception to this requirement is allowed for magnetic or optically operated automatic stop devices, if the operating circuit is such that it indicates that such devices initiated the stop and the circuit is of the manually reset type.

Manual stop switches (push button) shall be positively opened mechanically and their opening shall not be dependent upon springs.

Manual control devices shall be installed at all attendants' and operators' work positions, in machine rooms, and out-of-doors in proximity to all loading and unloading areas.

As a minimum, each of these control locations shall include an Emergency Shutdown device and a Normal Stop device. All manual control devices located in or on a control cabinet shall be mounted so that they are in the same plane or face of the cabinet.

The devices listed in Annex E shall be conspicuously and permanently marked with the proper function and color code.

2.2.10 Safety of operating and maintenance personnel

Provision shall be incorporated in the funicular design to render the system inoperable when necessary for Lock-out Tag-out protection of personnel working on the funicular.

The sign "Personnel Working on Funicular - Do Not Start" or a similar warning sign shall be hung on the main disconnect switch or at control points for starting the prime mover or evacuation power unit when persons are working on the funicular (see 2.3.1.1.).

The funicular shall incorporate an audible warning device that signals an impending start of the funicular. After the start button is pressed, the device shall sound an audible alarm for a minimum of 2 seconds and shall continue until the funicular drive system begins to move. The audible device shall be heard inside and outside all terminals and machine rooms above the ambient noise level.
1.2.2.11 Electrical system acceptance tests

2. Upon completion of the acceptance test and before public operation of the funicular, the design and function of software and/or relay logic shall be certified by the Qualified Engineer of record and the certification shall be included in the acceptance test report. Any modifications made to the electrical design shall be clearly marked on the on-site documentation and signed by a Qualified Engineer (see 2.1.1.11.2).

2.2.12 Software security

11. The “as built” drawings shall include a procedure, developed by the funicular manufacturer or Qualified Engineer, to insure the security of the software logic and operating parameters that will control the funicular. Upon completion of the acceptance testing, this procedure shall be implemented in a manner that will prevent unauthorized personnel from making changes to the software logic or operating parameters. All programmable logic software and parameters shall be documented.

21.2.13 Illumination

22.2.13.1 Station illumination

23. Lights shall be located in a manner to provide generally uniform illumination. Minimum illumination levels measured at floor level should be 20 ft-candles (215 lux).

27. Lights shall be mounted on substantial poles or standards. Terminal structures may be used for supporting lights, subject to the following requirements:

30. a) Approval shall be obtained from a Qualified Engineer;

32. b) The service conductors to each funicular terminal structure shall be underground or in rigid raceways;

35. c) A separate enclosed disconnect or circuit breaker shall be required for each terminal structure;

38. d) All metallic raceways on a guideway or terminal structure shall be grounded;

40. e) The lighting installation shall not conflict with other requirements of this standard and shall not interfere with operations of the funicular in any manner.

44.2.13.2 Cabin illumination

45. Under non-emergency operating conditions, interior lighting levels shall be a minimum of 2 ft-candles (21 lux) measured at the vehicle floor, including all doorways. When the carrier is stopped in the station, interior lighting levels shall be 20 ft-candles (215 lux) when measured 30 inches (760 mm) above the cabin floor. Lighting shall be of a consistent level.

53. If required, cabin 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.

58.2.13.3 Emergency lighting

59. Emergency lighting shall also be provided in the event of electric power failure to permit:

61. a) regular unloading of funicular facilities;

62. b) emergency evacuation of carriers;

63. c) operation of the alternate carrier unloading (docking) system.

65.2.13.3.1 Emergency station/guideway lighting

66. Emergency lighting systems shall be installed and maintained in accordance with ANSI/INFPA 70-2011.

68. Exit lights, essential signs, and emergency lights shall be included in the emergency lighting system and shall be powered by a standby power supply or a supply independent of the funicular’s main drive system. Emergency fixtures, exit lights, and signs shall be wired separately from the emergency distribution panels.

75. The illumination levels of underground or enclosed area walkways and walking surfaces shall be a minimum of 0.25 ft-candles (2.6 lux) at the walking surface.

79.2.13.3.2 Emergency carrier lighting

80. Emergency lighting power is to be provided by vehicle-borne batteries, capable of sustaining required levels of lighting for a minimum of 1 hour but not less than the anticipated evacuation time. The emergency lighting system shall provide minimum lighting levels of 5 ft-candles (54 lux) in the immediate area of the doors.

86.2.3 Operation and maintenance

88. This subsection covers the requirements for operation and maintenance of funiculars. Many requirements are listed elsewhere in Section 2 and referenced Annexes, since they also regulate installation and design. It is imperative that operating and maintenance personnel be familiar with applicable provisions of this section and the funicular operational and maintenance manuals (see 2.1.7).

95.2.3.1 General and personnel safety

96. Operation and maintenance of funicular equipment can be dangerous to personnel performing these tasks. Procedures for performing these functions shall require precautionary measures necessary to reduce the risks for the personnel involved. Implementation of the procedures intended for the protection of the public and operating and maintenance personnel shall be the responsibility of the owner, supervisor, and the individual worker.
Passengers and operating personnel shall be cautioned or prevented, as required, from transporting objects or materials that may encroach upon limitations of carrier clearances or design live loads.

### 2.3.1 Signs

All signs for instruction of the public shall be bold in design with wording short, simple, and to the point. All such signs shall be prominently placed, and those pertaining to the funicular operations shall be adequately lighted for night operation. Additional signs, deemed necessary by the owner, may be posted but should not detract attention from any required sign.

The signs, as described below, shall be posted where they may be easily seen by all passengers using the funicular.

- **a)** Instructions and warnings for use of the funicular may include the duties and obligations of the passenger and shall be posted in a location prior to the loading platform;
- **b)** Maximum capacity of each cabin in pounds and kilograms and approximate number of adult passengers shall be posted prior to the loading platform and in each cabin;
- **c)** Instructions for procedures in emergencies shall be prominently posted inside each carrier;
- **d)** To exclude the entry of unauthorized persons posted at entrances to machine rooms, operators, and attendants rooms.

The sign – “Personnel Working on Funicular - Do Not Start” or a similar warning sign applicable to “Lock-Out Tag-Out” procedures shall be hung on the main disconnect switch and at control points for starting the prime mover or evacuation power unit when persons are working on the funicular (see 2.2.10).

### 2.3.2 Operation

The requirements of this subsection are a basis for operations of a funicular. The number of personnel at each level may be increased and the required duties of the operating personnel can be redistributed to meet the requirements of the manufacturer and unique specifics of the funicular operations requirements. These revisions shall be specified in the documented funicular operating procedures.

#### 2.3.2.1 Personnel and supervision

Funiculars shall be operated by trained personnel, and the owner shall be responsible for their supervision and the training to perform the duties listed in 2.3.2.3. Procedures for monitoring the operation and use of the funicular and for advising and assisting passengers, including passengers with common adaptive equipment, shall be included in the training. One or more persons familiar with emergency procedures shall be on the site at all times when the funicular is in operation. All personnel shall practice good housekeeping. Personnel shall comply with the operational procedures and regulations for the funicular. Persons performing the duties of the funicular personnel may exchange assignments as directed by the supervisor; provided they are trained for each assignment undertaken.

#### 2.3.2.1.1 Supervisor

An individual shall be designated to oversee the funiculars operating practices and operating personnel for the purpose of public use. The designated supervisor may delegate some authority to others, but shall oversee the operations and operations personnel of the funicular for which the individual is designated; unless modified by the owner as part of the operations and maintenance quality assurance plan (see 1.5.4).

#### 2.3.2.1.2 Operator

An individual(s) shall be designated the operator and shall be in charge of the funicular. The operator(s) shall be trained and experienced in normal operational and emergency procedures, and such training shall be documented.

#### 2.3.2.1.3 Attendants

Attendant(s) shall be assigned to particular duties under direction of the operator. The attendant shall be trained in operations and emergency procedures pertaining to their assignments; and such training shall be documented.

If a cabin attendant is provided, they shall be trained for duty in connection with enclosed cabins, including loading and unloading procedures, communications, and the use of door locks and keys. The cabin attendant shall be familiar with load limits and applicable safety regulations, well versed in the use of any manual control device under their control, and trained in the use of emergency evacuation equipment and procedures, and such training shall be documented.

#### 2.3.2.1.4 First aid

One or more persons trained to provide first aid/emergency care at the Basic Life Support (BLS) level, including CPR, shall be available at all times when a funicular is operating and transporting passengers. There shall be ready access to first aid/emergency care supplies and equipment, including provisions for transporting an injured person to an enclosed and, if required, heated shelter.

#### 2.3.2.2 Minimum operating personnel

The following personnel are the minimum that shall be required:

- **a)** A supervisor shall be in charge of the funicular operation and personnel. The individual may serve concurrently as an operator if the additional role doesn’t interfere with the duties of the supervisor;
b) an operator shall be in charge of the funicular during the trip cycle. The individual may serve concurrently as an attendant if the additional role doesn’t interfere with the duties of the operator and is approved by the supervisor;
c) an attendant shall be on duty at each loading/unloading platform or station.
d) an attendant shall be in each carrier or group of carriers for speeds over 1200 feet per minute (6.0 meters per second)
e) one or more trained and competent persons shall be available, consistent with the operational procedures, to evaluate and address abnormal operational conditions.

2.3.2.3 Duties of operating personnel
All personnel shall use reasonable care while performing their duties.

2.3.2.3.1 Supervisor
The duties of the individual designated as the supervisor include:

a) to oversee practices that will determine that the funicular is operational and that all operating personnel are trained, equipped, and capable of performing their duties prior to public operation;
b) to discontinue operations on the funicular due to physical, weather, personnel, or other reasons;
c) to oversee operational procedures and adherence to applicable regulations pertaining to the funicular.

2.3.2.3.2 Operator
The duties of the individual designated as the supervisor include:

a) to be knowledgeable of operational and emergency procedures and the related equipment needed to perform the assigned duties;
b) to assume responsible charge of the funicular;
c) to assign and supervise all attendants on their funicular;
d) to verify that the preoperational inspection (see 2.3.2.4.2) is completed before public operation;
e) to maintain an operational logbook as required in 2.3.5.1;
f) to start the funicular while operating for the public (see 2.3.2.5.2);
g) to deny access to the funicular to any person using procedures and criteria provided;
h) to advise the supervisor of observed abnormal or unusual conditions that may adversely affect the safety of the operation;
i) to terminate passenger operations (see 2.3.2.5.8).

2.3.2.3.3 Attendant
The duties of an attendant include:

a) to be knowledgeable of operational and emergency procedures and the related equipment needed to perform the assigned duties;
b) to monitor the passengers’ use of the funicular, including observing, advising and assisting them while they are in the attendant’s work area as they embark on or disembark from the funicular; and to respond to unusual occurrences or conditions, as noted. The attendant should respond by choosing an appropriate action, which may include any of the following.

1) assisting the passenger;
2) slowing the funicular (if applicable);
3) stopping the funicular;
4) continuing operation and observation.
c) to deny access to the funicular to any person; using procedures and criteria provided;
d) to advise the operator of observed abnormal or unusual conditions that may adversely affect the safety of the operation.

2.3.2.4 Operational procedures
Operational procedures may supplement the designer’s operational manual (see 2.1.7.1) and the owner’s quality program (see 1.5.4).

2.3.2.4.1 Control of passengers
Each funicular shall have a definite method for marshalling different passenger types for loading and unloading. Fences, gates, and alternate access and/or loading methods may be required to implement the system for individuals/groups.

2.3.2.4.2 Daily pre-operational inspection
Prior to public operations, or at least once per day during continuous operation, a daily preoperational inspection shall be performed and documented. As a minimum, the inspection shall consist of the following:

a) a visual inspection of each terminal, station, and the entire length of the guideway;
b) assurance that the tension system, if applicable, is functional and that tension system devices (counterweights, cylinders, carriages, and the like) have adequate travel with appropriate clearances at both ends;
c) operation of all manual and automatic switches in terminals, stations, carriers, and loading and unloading areas per the manufacturer’s instructions;
d) operation of all drive system brakes

NOTE – The designer of the funicular system may specify that this inspection is to take place while the funicular is not moving.

e) operation of all communication systems;

f) operation of the funicular, including a visual inspection of all ropes and carriers;

g) checking each control circuit for circuit continuity and integrity at its most remote terminal on a daily basis;

h) for a funicular having a primary power internal combustion engine, determining that the fuel quantity is sufficient to conduct the anticipated period of operation without refueling. For those installations having internal combustion engines, the fuel supply shall be adequate to unload the funicular. During refueling, power units shall be shut down.

Funiculars having evacuation power units or alternate carrier unloading (docking) system shall have the engine(s) or system(s) checked during this inspection and operated at least once each week. The evacuation power unit shall be operated for at least 30 minutes per month or two complete round trips of the carrier(s). Alternate unloading systems shall be tested and run at the recommendations of the manufacturer;

i) inspecting the loading and unloading facilities and, if necessary, clearing them of ice and snow to permit the ingress and egress of passengers;

j) inspecting and checking the mechanical features of the carriers for correct operation;

k) where applicable, checking of ventilation system controls and power sources as required by the manufacturer.

2.3.2.4.3 Access to facilities

While in operation, entrances to all machinery, operators’ and attendants’ rooms shall be restricted to authorized personnel only. All entrances shall have the signs required in 2.3.1.1.

While not in operation, entrances to all machinery, operators’, and attendants’ rooms shall be locked. To provide shelter and emergency telephone access for public safety, specified entrances may remain unlocked provided the funicular equipment cannot be operated by unauthorized personnel.

2.3.2.4.4 Transport of flammable materials

Transport of flammable materials shall not be simultaneous with the transport of passengers in any car of a system.

2.3.2.5 Operational requirements

2.3.2.5.1 General

The owner and supervisor of each funicular shall review the requirements of this standard to ascertain that original design and installation conditions have not been altered in a manner such as to violate the requirements of the standard.

2.3.2.5.2 Starting

Following procedural clearances, the funicular shall be started by the Operator or by direction of the Operator.

2.3.2.5.3 Loading and unloading areas

The maze or corral and platform surfaces shall be reasonably maintained according to the prevailing weather conditions and established procedures.

2.3.2.5.4 Stops

After any stop of a funicular, the operator shall determine the cause of the stop, and not restart until clearance has been obtained from all attended positions.

2.3.2.5.5 Damage to carriers

Should any carrier or compartment become damaged or otherwise rendered unfit for passenger transportation during normal operation, it shall be clearly and distinctively marked and not used for passengers until repaired or replaced.

2.3.2.5.6 Hazardous conditions

When wind or icing conditions are such that operation is hazardous to passengers or equipment, in accordance with predetermined criteria based upon the area’s operational experience and the designer’s design considerations, the funicular shall be unloaded and the operation discontinued. If necessary under the predetermined criteria, device(s) shall be installed at appropriate location(s) to ascertain wind velocity and direction when funiculars are operated. No funicular shall operate when there is an electrical storm in the immediate vicinity that may affect operations. Should such conditions develop while the funicular is in operation, loading of passengers shall be terminated, and operation shall be continued only as long as necessary to unload all passengers. When such shutdown has been caused by an electrical storm, grounding of control circuits and haul ropes that are used as conductors in communication systems is permissible. Such grounding shall be removed prior to resumption of passenger operations.
2.3.2.5.7 Evacuation

Provisions shall be made for the emergency evacuation of the funicular carriers and stations (see 2.1.1.10.1 and 2.3.2.6.4).

A plan for evacuation of passengers from each funicular shall be developed and documented. The plan shall include:

a) the definition of the line of authority in the event of an evacuation. This line of authority shall list:
   1) the individuals or positions responsible for determining the need for and ordering an evacuation by use of the evacuation power unit or evacuation from individual carriers;
   2) the individuals or positions responsible for performing the evacuation, for first aid, and for ground care of individual carrier evacuated passengers.

b) a description of the equipment necessary for evacuation and where it will be stored;

c) training shall be performed throughout the year in the steps and functions required for the evacuation of the funicular. An evacuation simulation drill shall be performed at a minimum of once per year. Training and drills shall be recorded in the funicular operational log (see 2.3.5.1);

d) an estimate of the time necessary for the total evacuation of each funicular;

e) a description of unusual terrain conditions and how each of these conditions will be dealt with during an evacuation;

f) an estimate of when the evacuation should begin in the event the funicular becomes inoperable;

g) provisions for communications with passengers of an inoperable funicular, the frequency of such communication, how soon after the funicular becomes inoperable such communication to the passengers will start, and the frequency of communications thereafter;

h) the methods of evacuation to be used for the typical passenger and the methods to be used for incapacitated passengers and nonambulatory passengers;

i) provisions for communication with the evacuation teams;

j) provisions for suspending the evacuation in the event that the funicular is made operable during the evacuation;

k) provisions for control and assistance of evacuated persons until released;

l) provisions for a post-evacuation report.

All nonmetallic rope used for evacuation shall be of nylon or polyester (Dacron) fiber of either laid or braided construction. Laid rope of nylon shall be of a hard lay. These ropes shall be either of a static rescue type or a dynamic mountaineering type. Breaking strength, when new, shall be at least 15 times the maximum expected operating load but in no case less than 4000 lbf (17.8 kN). No natural fiber or polypropylene ropes shall be used.

These ropes shall be carefully stored when not in use and shall be examined after each completed funicular evacuation and prior to each season of operation, both summer and winter, to ascertain that they are in satisfactory condition.

Carabiners, if used, shall be of the locking type.

2.3.2.5.8 Termination of daily operations

Procedures shall be established for terminating daily operations in such a manner that passengers will not be left on the funicular after it has been shut down. Loading ramps, as required, shall be closed and so marked.

When either loading or unloading portions of an intermediate station is not in operation, it shall be so signed and the loading station shall be closed to public access.

2.3.2.5.9 Bypass requirements

The use of temporary circuits that have been installed for the purpose of bypassing failed electrical circuit(s) (see 2.2.6) shall meet these requirements in the following order:

a) The condition that the circuit indicated is in default shall be thoroughly inspected to ensure an electrical operating circuit malfunction, rather than the indicated condition, actually exists;

b) The bypass shall be authorized only by the funicular supervisor or his/her designated representative;

c) When a bypass is in operation, the function bypassed shall be under constant, close visual observation;

d) The use of a bypass circuit shall be logged and shall indicate when, who authorized, and for what duration a bypass was used;

e) The operator control panel(s) shall indicate that a bypass is in use.
2.3.2.6 Automatic operation

The automatic operation of a funicular without the immediate presence of personnel at the installation is permissible subject to approval by the Authority Having Jurisdiction and the following conditions:

2.3.2.6.1 Operation Monitoring

In the event of a shutdown, assistance shall arrive at the funicular within 30 minutes to take appropriate actions (see 2.3.2.2(e)). Communications with the carriers should occur as soon as possible after the shutdown.

Closed Circuit TV monitoring of all platforms shall be provided with monitoring at a manned location such as a security or monitoring station.

2.3.2.6.2 Fencing off the guideway

Those parts of the guideway which are accessible by unauthorized personnel shall be fenced off. The fencing shall be at least 5 feet (1.5 m) high.

2.3.2.6.3 Access to the guideway

Any doors in the fencing required by 2.3.2.6.2 shall be fitted with safety devices. If doors are opened, the installation shall automatically be brought to a stop and further operation shall not be possible.

The doors shall not open in the direction of the track if the horizontal clearances in section 2.1.1.4.3 are not maintained.

When a door is also specified for use for the evacuation of passengers, it shall be possible to open it from the inside without a key, even if it is locked.

2.3.2.6.4 Evacuation

In addition to 2.3.2.5.7, it shall be possible for the passengers to evacuate from the carriers by complying with instructions displayed in the carrier or communicated by the monitoring station. An evacuation path conforming to 2.1.1.10.1 shall be provided. It shall be possible to open the doors and emergency exits from the inside.

2.3.2.6.5 Access to carriers

The horizontal clearance between the carrier door and the closed sliding door on the platform shall not exceed 4 in. (100 mm) up to a height of 5 feet 9 inches (1.8 m) above the floor, unless additional monitoring of this area is provided.

2.3.2.6.6 Special safety devices on carriers

The carriers shall be equipped with devices which automatically stop the installation in the event of any impact with an obstruction on the track.

2.3.2.6.7 Carrier Voice Communications

A full-duplex communications system shall be provided to permit two-way voice communications between the monitoring station and passengers or personnel within each passenger compartment of each carrier.

Activation of two-way voice communications between the monitoring station and the carriers shall be possible only from the monitoring station. Passenger-initiated communications requests from a carrier shall be automatically annunciated at the monitoring station. The monitoring station shall be able to activate this link upon receiving an indication of a passenger-initiated communication request or at any other time to receive communications. A passenger-initiated communications request shall include an audio and visual on-board indication that the call has been requested.

2.3.2.6.8 Special safety devices at platforms

The station platforms shall be equipped with solid sliding doors conforming to the specifications for cabin doors in 2.1.5.4.3.

2.3.3 Maintenance

2.3.3.1 General

Foundations and all structural, mechanical, and electrical components shall be inspected regularly and kept in a state of good repair. The maintenance and testing requirements (see 2.1.7.2) of the designer or Qualified Engineer shall be followed. Maintenance records shall be kept (see 2.3.5.3).

2.3.3.1.1 Maintenance

A written schedule for systematic maintenance shall be developed and followed. The schedule shall establish specific frequencies for periodic lubrication, inspection, and adjustment. The schedule shall include, but not be limited to, the following:

a) all wire rope and end connections;
b) guideway sheave units, sheaves, bearings, and liners;
c) bullwheels, bearings, and liners;
d) tension systems;
e) drive system, including bearings and couplings;
f) braking systems;
g) electrical control systems;
h) communication systems;
i) carriers;
j) structures;
k) guideway structures;
l) ventilation system (if any).
2.3.3.2 Maintenance personnel

Funiculars shall be maintained by trained and competent personnel. The owner shall be responsible for their supervision and training, and such training shall be documented. All personnel shall practice good housekeeping, with particular emphasis on avoiding the development of any condition that might contribute to personal injury. Personnel shall comply with the operational rules and regulations of the specific funicular.

2.3.4 Inspections and testing

2.3.4.1 General inspection

Each funicular shall be inspected annually by a funicular specialist independent of the owner. Inspection(s) shall verify preservation of original design integrity and cover the requirements of this standard for maintenance, operation, inspections, and record keeping. Items found either deficient or in noncompliance shall be noted. A report signed by the funicular specialist shall be filed with the owner.

2.3.4.2 Dynamic testing

Dynamic testing shall be performed at intervals not exceeding seven (7) years. A written schedule for systematic dynamic testing shall be developed and followed. The owner shall provide experienced personnel to develop and conduct the dynamic test. The schedule shall establish specific frequencies and conditions for dynamic testing. The testing shall simulate or duplicate inertial loadings. The test load shall be equivalent to the design live load. The results of the testing shall be documented in the maintenance log.

The testing shall include, but not be limited to the following as applicable:

a) braking systems;

b) evacuation systems;

c) tension system;

d) electrical systems.

2.3.4.3 Wire rope, and end connection inspection

Inspection of wire rope and end connections shall comply with A.4 in Annex A.

2.3.4.4 Carrier testing

All carriers shall be tested against acceptance criteria, established by the designer or manufacturer; or in cases in which the designer or manufacturer is no longer in business and the original criteria are no longer applicable, by a Qualified Engineer.

Each carriage and cabin shall be uniquely identified by the manufacturer or the owner. If any defects are found, the designer/manufacturer/Qualified Engineer shall be consulted. Units failing to meet the acceptance criteria shall not be placed back into service until their defects are corrected.

If the carriages and cabins are tested by an agency other than the original equipment manufacturer, then the original funicular manufacturer shall receive a copy of the test procedure and results. In all cases, the owner shall receive a copy of the test procedure and the test results.

Testing personnel shall be qualified in accordance with the designer/manufacturer/Qualified Engineer's requirements. The testing agency shall provide certification of qualification of personnel performing the test and to certify to the owner that testing has been in accordance with criteria prescribed by the designer/manufacturer/Qualified Engineer.

2.3.5 Records

2.3.5.1 Operational log

A logbook shall be maintained for each funicular. Daily entries shall be made giving the following minimum information:

a) date;

b) names and work positions of operating personnel;

c) operating hours and purpose of operations;

d) temperature, wind, and weather conditions;

e) record of compliance with daily pre-operational inspection including loading and unloading platforms, signs, and ramps;

f) position and condition of the tension carriage, counterweights, or other tension system devices;

g) accidents, malfunctions, or abnormal occurrences during operation;

h) signature of operator;

i) record of funicular evacuations and evacuation drills (see 2.3.2.5.7(c)) and 2.3.2.6.4.

2.3.5.2 Maintenance log

A signed complete log shall be maintained wherein the actual execution of maintenance work shall be recorded daily or at the time maintenance is performed. The log shall state components serviced and the condition of the components. A record shall be kept of replacement of components.
2.3.5.3 Wire rope and end connection log

A logbook shall be maintained for each funicular, giving the following information on each wire rope and end connection:

a) specification (see A.1.1 in Annex A);

b) copy of wire rope(s) certified test report;

c) date installed;

d) splicing certificate for each splice or laid-in strand;

e) record of lubrication, including type of lubricant and date applied;

f) record of maintenance inspections (see A.4.1 in Annex A);

g) report of wire rope inspections (see A.4.1 in Annex A);

h) report of accidents or injury to wire rope or strand;

i) documentation of end attachment (see A.4.2 in Annex A).

2.3.6 Passenger conduct and responsibilities

2.3.6.1 Passenger responsibilities

It is recognized that certain dangers and risks are inherent in machines of this type, and their operation. It is also recognized that inherent and other risks or dangers exist for those who are in the process of embarking, riding or disembarking from funiculars (see 1.2). Passengers accept the risks inherent in such participation of which the ordinary prudent person is or should be aware.

Passengers shall use good judgment and act in a responsible manner while using the funicular including:

a) participate in the embarkation, riding and disembarkation processes in such a manner as to reduce risks for themselves and others;

b) obeying all written and oral instructions and warnings;

c) refraining from using the funicular while under the influence of drugs or alcohol;

d) properly use the funicular and equipment provided.

2.3.6.2 Passenger dexterity and ability

All passengers who use a funicular shall be responsible for their own embarkation, riding and disembarkation. They shall be presumed to have sufficient ability, physical dexterity, and/or personal assistance to negotiate and to be evacuated from the funicular safely.

2.3.6.3 Passenger embarkation and disembarkation

A passenger shall get on and get off a funicular at designated areas. No passenger shall embark without first understanding and observing the proper loading, riding, and unloading procedures (see 2.3.1.1).

2.3.6.4 Passenger riding

Passengers, while riding a funicular, shall not throw or expel therefrom any object, nor shall any passenger do any act or thing that shall interfere with the operation of the funicular. Passengers shall not willfully engage in any type of conduct that may contribute to or cause injury to any other person.
Section 3
Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this American National Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this American National Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

ANSI/IEEE C2-2007, National electrical safety code
ANSI/NFPA 10-2007, Standard for Portable Fire Extinguishers
ANSI/ASME B15.1-2000 (R 2008), Safety standard for mechanical power transmission apparatus
ANSI/NFPA 30-2008, Flammable and combustible liquids code
ANSI/NFPA 37-2010, Stationary combustion engines and gas turbines
ANSI/NFPA 70-2011, National electrical code
ANSI/NFPA 780-2008, Lightning protection code

For Underground Installations only:
ANSI/NFPA 220–2009, Standard on Types of Building Construction
ANSI/IEEE 383–1992; Standard for Type Tests if Class IE electrical Cables, Field Splices, and Connections for Nuclear Power Generating Stations
ANNEX A
(Normative)
Wire rope and end connections requirements

A.1 Physical properties
A.1.1 Specifications
Wire rope used as tension members shall be specified by the funicular designer.
This specification shall state that the wire rope complies with the rope provisions of A.1.

A.1.2 Diameter tolerance
A.1.2.1 Wire rope
Wire rope shall have a diameter tolerance of +5% oversize, 0% undersize. Measurements shall be made on new wire rope when the rope is tensioned between 10% and 20% of its minimum breaking force.

A.1.3 Minimum breaking force
In a test, an acceptable wire rope shall not break under a tension less than its minimum breaking force (see A.2.1.3).

A.1.4 Torsion requirements
A.1.4.1 Wire torsion values for wire rope
Wires shall meet the applicable torsional values shown in table A-2.

A.2 Testing
Before operation, a certified test report in English covering the test required herein shall be provided from an experienced, qualified testing laboratory. Unless otherwise specified, the manufacturer of the wire rope is responsible for all testing requirements in this standard.
Copies of the test reports shall be furnished to the owner, funicular manufacturer, and the authority having jurisdiction.

The funicular designer or wire rope manufacturer shall prescribe the frequency and methods for any additional maintenance or inspections of wire rope or strand not covered in this annex.
Copies of the specification shall be furnished to the funicular manufacturer, owner, and authority having jurisdiction.

A.1.1.1 Wire rope specification
The specification for wire rope shall include the following:

a) nominal diameter;
b) diameter tolerance;
c) number and arrangement of wires;
d) strength grade;
e) type of core;
f) lay of wire rope;
g) minimum breaking force;
h) type of lubrication.

A.1.1.2 Relocated Wire Rope
For relocated wire rope, the wire rope inspector shall be supplied the service history, perform a visual wire rope inspection, and perform an internal inspection of the rope at several random locations to determine its condition. An MRT examination shall be performed in conjunction with the visual inspections on wire ropes to be used on funiculars. A Qualified Engineer shall determine whether the rope meets the requirements of this standard and the funicular specifications. Copies of the test and the inspections shall be furnished to the owner and authority having jurisdiction.

A.2.1 Wire rope
The strength of the wire rope on which the designer shall base the funicular calculations including design factor of safety shall not be more than the minimum breaking force (see 1.4 – minimum breaking force) listed in the manufacturer’s published catalog or table A-1 for the diameter, classification, and strength grade selected by the designer.
The factor of safety is equal to the minimum breaking force of the rope divided by the maximum steady state tension.

A.1.4 Torsion requirements
Wires shall meet the applicable torsional values shown in table A-2.

Wire torsion tests are not required for wire ropes in tension systems.
A.2.1 Testing procedures - wire rope

A.2.1.1 Sampling - wire rope
A sample long enough to provide 9 feet (2.75 meters) of free length shall be cut from each manufactured length to be used for the actual rope ultimate strength test and diameter measurement.

If torsion tests are to be performed on wires removed from the finished rope, a second sample, 36 inches (915 mm) long, shall be cut.

A.2.1.2 Examination of diameter - wire rope
The diameter shall be measured on the long sample, 9 feet (2.75 meters), at the center of its length, and 36 inches (915 mm) on each side of center (see A.1.2.1). The average of these three measurements shall be the diameter of the wire rope being inspected.

A.2.1.3 Breaking force test
An actual (measured) breaking force test shall be made on a complete rope. The tests shall be made on the long sample (see A.2.1.1). The actual (measured) breaking force shall meet or exceed the minimum breaking force specified for the wire rope.

A.2.1.4 Wire torsion tests
Wire torsion value shall be determined by either of the two following methods:

a) Wires shall be tested prior to fabrication into rope;

b) Wires shall be removed from a rope after fabrication and tested.

A.2.1.4.1 Test procedure
Wires for the torsional test shall be hand straightened. The free length of wires in the testing machine, before the test, shall be 8 inches + 1/16 inch (203.2 mm + 1.6 mm). One clamp in the testing machine shall be movable parallel to the axis of the tested wire, and an axial tensile force in accordance with table A-3 shall be applied to keep the tested wire straight during the test. The tested wire shall be twisted by either of two methods: Both clamps may be rotated in opposite directions or one clamp may be rotated while the other is held stationary at a uniform rate of not more than 60 revolutions per minute. In either case, the total rotations shall be counted and reported.

A.2.1.4.2 Alternate test procedure
Because the number of revolutions in the torsional test is proportional to the free length, a free length before the test may be 4 inches + 1/16 inch (101.6 mm + 1.6 mm) for wires up to 0.040 inch (1.02 mm) in diameter or 6 inches + 1/16 inch (150 mm + 01.6 mm) for wires not more than 0.060 inch (1.52 mm) in diameter. The wire specimens with a free length of 4 inches (101.6 m) shall not break when twisted one-half the number of revolutions shown in table A-2. The wire specimens with a free length of 6 inches (152.4) shall not break when twisted three-fourths the number of revolutions shown in table A-2. Testing shall be done in the same manner as described in A.2.1.4.1.

A.2.2 Test reports
A.2.2.1 Wire rope
The test reports for wire rope shall include the following:

a) complete description of wire rope furnished for the test, including cross sectional metallic area; grade; type of core; minimum breaking force of the rope. The number, diameter, arrangement, and cross sectional metallic area of wires.

b) actual rope diameter;

c) actual (measured) breaking force (see A.2.1.3);

d) results of torsion testing including the size of wires tested (see A.2.1.5).

A.2.3 Rejects and retests
A.2.3.1 Wire rope
If only one test sample is supplied from a manufactured length, and any test specimens taken from this sample fail to pass any specified tests, all reels or coils of rope from that manufactured length shall be rejected.

If a separate test sample is furnished from each piece of rope that is reeled or coiled for shipment, failure of any test specimens to pass any specified tests shall be cause for rejection of only the particular reel or coil from which the faulty specimens have been taken.

A.2.4 Retests
A.2.4.1 Rejects
In the ultimate-strength test of the wire rope, if the measured breaking force falls below the requirement, one retest shall be made on a sample from the same reel or coil. If the measured breaking force meets or exceeds the requirement, this shall pass for acceptance.

Where the test specimen breaks in the jaws of the machine or at a termination, the results may be discarded and another specimen tested without considering it a retest.

In torsion tests of wires, one wire may fall below the requirement, but by not more than 20% below. In such a case, six additional wires of the same size will be tested, all of which shall pass.
<table>
<thead>
<tr>
<th>DIAMETER</th>
<th>6 x 7 FC</th>
<th>6X19 AND 6X36 FC</th>
<th>6X19 AND 6X36 IWRC</th>
<th>DIAMETER RANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>in. mm</td>
<td>tons kN</td>
<td>tons kN</td>
<td>tons kN</td>
<td>tons kN</td>
</tr>
<tr>
<td>6</td>
<td>21.2</td>
<td>21</td>
<td>23.3</td>
<td>25.7</td>
</tr>
<tr>
<td>1/4</td>
<td>2.64</td>
<td>2.74</td>
<td>3.01</td>
<td>3.49</td>
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<td>7</td>
<td>28.8</td>
<td>28.6</td>
<td>31.7</td>
<td>34.9</td>
</tr>
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<td>8</td>
<td>37.6</td>
<td>37.4</td>
<td>41.4</td>
<td>45.6</td>
</tr>
<tr>
<td>9</td>
<td>47.6</td>
<td>47.3</td>
<td>52.4</td>
<td>57.7</td>
</tr>
<tr>
<td>3/8</td>
<td>5.86</td>
<td>6.1</td>
<td>6.71</td>
<td>7.38</td>
</tr>
<tr>
<td>10</td>
<td>58.8</td>
<td>58.4</td>
<td>64.7</td>
<td>71.3</td>
</tr>
<tr>
<td>11</td>
<td>71.1</td>
<td>70.7</td>
<td>78.3</td>
<td>86.2</td>
</tr>
<tr>
<td>7/16</td>
<td>7.93</td>
<td>8.27</td>
<td>9.1</td>
<td>10</td>
</tr>
<tr>
<td>12</td>
<td>10.3</td>
<td>10.7</td>
<td>11.8</td>
<td>12.9</td>
</tr>
<tr>
<td>13</td>
<td>99.3</td>
<td>98.7</td>
<td>109</td>
<td>120</td>
</tr>
<tr>
<td>14</td>
<td>115</td>
<td>114</td>
<td>127</td>
<td>140</td>
</tr>
<tr>
<td>9/16</td>
<td>13</td>
<td>13.5</td>
<td>14.9</td>
<td>16.3</td>
</tr>
<tr>
<td>5/8</td>
<td>15.9</td>
<td>16.7</td>
<td>18.4</td>
<td>20.2</td>
</tr>
<tr>
<td>16</td>
<td>150</td>
<td>150</td>
<td>166</td>
<td>182</td>
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<td>18</td>
<td>190</td>
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<td>210</td>
<td>231</td>
</tr>
<tr>
<td>19</td>
<td>212</td>
<td>211</td>
<td>233</td>
<td>257</td>
</tr>
<tr>
<td>3/4</td>
<td>22.7</td>
<td>23.8</td>
<td>26.2</td>
<td>28.8</td>
</tr>
<tr>
<td>20</td>
<td>235</td>
<td>234</td>
<td>259</td>
<td>285</td>
</tr>
<tr>
<td>22</td>
<td>284</td>
<td>283</td>
<td>313</td>
<td>345</td>
</tr>
<tr>
<td>7/8</td>
<td>30.7</td>
<td>32.2</td>
<td>35.4</td>
<td>39.0</td>
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<tr>
<td>24</td>
<td>338</td>
<td>336</td>
<td>373</td>
<td>411</td>
</tr>
<tr>
<td>1</td>
<td>39.7</td>
<td>41.8</td>
<td>46</td>
<td>50.6</td>
</tr>
<tr>
<td>26</td>
<td>397</td>
<td>395</td>
<td>437</td>
<td>482</td>
</tr>
<tr>
<td>28</td>
<td>461</td>
<td>458</td>
<td>507</td>
<td>559</td>
</tr>
<tr>
<td>1 1/8</td>
<td>49.8</td>
<td>52.6</td>
<td>57.9</td>
<td>63.6</td>
</tr>
<tr>
<td>1 1/4</td>
<td>61</td>
<td>64.6</td>
<td>71.1</td>
<td>78.2</td>
</tr>
<tr>
<td>32</td>
<td>602</td>
<td>598</td>
<td>662</td>
<td>730</td>
</tr>
<tr>
<td>1 3/8</td>
<td>73.1</td>
<td>77.7</td>
<td>85.5</td>
<td>94.0</td>
</tr>
<tr>
<td>1 1/2</td>
<td>86.2</td>
<td>92</td>
<td>101</td>
<td>111</td>
</tr>
<tr>
<td>40</td>
<td>935</td>
<td>1035</td>
<td>1140</td>
<td>1140</td>
</tr>
<tr>
<td>1 5/8</td>
<td>107</td>
<td>118</td>
<td>129</td>
<td>140</td>
</tr>
<tr>
<td>44</td>
<td>1131</td>
<td>1252</td>
<td>1380</td>
<td>1380</td>
</tr>
<tr>
<td>1 3/4</td>
<td>124</td>
<td>136</td>
<td>150</td>
<td>153</td>
</tr>
<tr>
<td>1 7/8</td>
<td>141</td>
<td>155</td>
<td>171</td>
<td>174</td>
</tr>
<tr>
<td>48</td>
<td>1346</td>
<td>1490</td>
<td>1642</td>
<td>1642</td>
</tr>
<tr>
<td>2</td>
<td>160</td>
<td>176</td>
<td>194</td>
<td>198</td>
</tr>
<tr>
<td>52</td>
<td>1579</td>
<td>1749</td>
<td>1927</td>
<td>1927</td>
</tr>
<tr>
<td>2 1/8</td>
<td>179</td>
<td>197</td>
<td>217</td>
<td>221</td>
</tr>
<tr>
<td>56</td>
<td>1832</td>
<td>2028</td>
<td>2235</td>
<td>2235</td>
</tr>
<tr>
<td>2 1/4</td>
<td>200</td>
<td>220</td>
<td>242</td>
<td>247</td>
</tr>
<tr>
<td>60</td>
<td>2103</td>
<td>2328</td>
<td>2566</td>
<td>2566</td>
</tr>
<tr>
<td>2 3/8</td>
<td>222</td>
<td>2344</td>
<td>269</td>
<td>274</td>
</tr>
</tbody>
</table>

NOTES –
Tons = 2000 lbs
1770, 1960, 2160 = Grade in SI units.
### Table A-2  Torsion values for main rope wires

<table>
<thead>
<tr>
<th>Wire Diameter (inch)</th>
<th>Revolutions in a gage length of 8 inches*</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Improved plow steel</td>
<td>Extra-improved plow steel</td>
<td>Extra-extra improved plow steel</td>
</tr>
<tr>
<td><strong>Wires tested prior to fabrication of rope</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.000-0.079</td>
<td>(2.36/d) - 2</td>
<td>(2.20/d) - 2</td>
<td>(2.20/d) - 2</td>
</tr>
<tr>
<td>0.080-0.159</td>
<td>(2.36/d) - 2</td>
<td>(1.92/d) - 2</td>
<td>(1.92/d) - 2</td>
</tr>
<tr>
<td><strong>Wires removed from rope after fabrication</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Diameters</td>
<td>(2.24/d) - 2</td>
<td>(2.16/d) - 8</td>
<td>(2.16/d) - 8</td>
</tr>
</tbody>
</table>

**NOTE:** d equals diameter of wire in inches  
* To convert to torsions (revolutions) in 100d, multiply values by 12.5d

### Table A-3  Tensile force on wires during torsional test

<table>
<thead>
<tr>
<th>Wire Diameter</th>
<th>Tensile Force</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>From (in)</td>
<td>To (in)</td>
<td>Minimum (lb)</td>
</tr>
<tr>
<td>0.000</td>
<td>0.009</td>
<td>0.5</td>
</tr>
<tr>
<td>0.010</td>
<td>0.014</td>
<td>1.0</td>
</tr>
<tr>
<td>0.015</td>
<td>0.019</td>
<td>1.5</td>
</tr>
<tr>
<td>0.020</td>
<td>0.029</td>
<td>2.0</td>
</tr>
<tr>
<td>0.030</td>
<td>0.039</td>
<td>A.0</td>
</tr>
<tr>
<td>0.040</td>
<td>0.049</td>
<td>4.0</td>
</tr>
<tr>
<td>0.050</td>
<td>0.059</td>
<td>5.0</td>
</tr>
<tr>
<td>0.060</td>
<td>0.069</td>
<td>6.0</td>
</tr>
<tr>
<td>0.070</td>
<td>0.079</td>
<td>A.0</td>
</tr>
<tr>
<td>0.080</td>
<td>0.089</td>
<td>8.0</td>
</tr>
<tr>
<td>0.090</td>
<td>0.099</td>
<td>9.0</td>
</tr>
<tr>
<td>0.100</td>
<td>0.109</td>
<td>10.0</td>
</tr>
<tr>
<td>0.110</td>
<td>0.119</td>
<td>11.0</td>
</tr>
<tr>
<td>0.120</td>
<td>0.129</td>
<td>12.0</td>
</tr>
<tr>
<td>0.130</td>
<td>0.139</td>
<td>13.0</td>
</tr>
<tr>
<td>0.140</td>
<td>0.149</td>
<td>14.0</td>
</tr>
<tr>
<td>0.150</td>
<td>0.159</td>
<td>15.0</td>
</tr>
<tr>
<td>0.160</td>
<td>and up</td>
<td>16.0</td>
</tr>
</tbody>
</table>
A.3 End connections for wire rope

The funicular designer, wire rope manufacturer, fitting manufacturer, or a Qualified Engineer shall specify the parameters for installation, inspections, and intervals for replacement of end connections. End connection installation shall be performed by or under the supervision of a competent facility or person and in accordance with instructions approved by the funicular designer, fitting manufacturer or Qualified Engineer. Documentation shall be provided by the facility or person performing any splice or end connection stating that it has been accomplished in accordance with the provisions of this standard. This document shall become part of the wire rope log.

A.3.1 Splices

A.3.1.1 Haul ropes

Splicing shall be performed by an experienced splicer. The minimum length of the splice shall be 1200 times the nominal rope diameter. The tails, or lengths of the rope strands tucked into the core of the rope on splicing, shall be a minimum of 30 times the nominal rope diameter in length.

When two or more contiguous long splices occur in a rope, they shall be separated by an undisturbed length of rope that is a minimum of 2400 times the nominal rope diameter.

No type of connection other than the conventional “long” splice shall be used in a haul rope.

A.3.1.2 Ropes used in tension systems

No splices shall be permitted in tension system ropes.

A.3.2 End connections

A.3.2.1 Wire ropes used in tension systems

End connections shall be designed to not fail or slip under a tension equal to 80% of the minimum breaking force of the rope and shall be in accordance with A.3.2.3.

A.3.2.2 Anchoring devices

When rope or strands are used as guys or anchors to structures, the rope or strand and its end connections shall have a factor of safety of 6.

A.3.2.3 Types and methods

Rope and cable sockets (poured or swaged) shall be designed so that they shall not be stressed beyond the yield point of the material used when the ropes or cables they anchor are under tensions equal to the design working load of the funicular multiplied by the applicable design factor of safety.

NOTE – An acceptable method of establishing the competence of a facility or person to make poured or swaged socket end connections is to perform a breaking force test of a length of wire rope or strand similar to and prepared in the manner that will be used in the working assembly. The test specimen shall not fail below the minimum breaking force. The purpose of this test is to establish the ability of the facility or person to make a proper connection.

Some common end attachments and information concerning their attachment are listed in the following subsections.

A.3.2.3.1 Poured sockets

Zinc sockets shall have documentation of all pertinent data including chemical composition of the material used in the socket, temperature of pouring material and preheated socket body.

Resin sockets shall have documentation of all pertinent data including the cleaning process and the material used in the socket.

A.3.2.3.2 Mechanical and Clamping sockets

The funicular designer, wire rope manufacturer, fitting manufacturer, or a Qualified Engineer shall specify the parameters for installation, inspections, and intervals for replacement of mechanical sockets.

Mechanical and clamping sockets shall have documentation of all of the pertinent data including the baseline measurements of rope and socket positions after tension is applied (seating in the housing); subsequent measurements and/or inspections required during initial running.

A.3.2.3.3 Swaged sockets

Swaged sockets shall be attached by a competent person or facility (see note in A.3.2.3) using fittings of a design in general acceptance and in common use by wire rope manufacturers and with attention to the following minimum particulars:

a) Rope shall be inserted to the bottom of the hole;

b) The bottom of the hole shall be one rope diameter beyond the swaged section;

c) Critical dimensions are as follows: Outside diameter before swaging; outside diameter after swaging; inside diameter; depth of hole;
d) Swaged sockets shall be applied only to wire rope having a steel center in the section of rope inserted to the bottom of the hole. Fiber core rope shall have the core removed from this section and a strand of IWRC of the proper diameter installed before swaging.

A.3.2.3.4 Wire rope clips and thimbles

Wire rope clips and thimbles shall be used as follows:

a) Wire rope clips and thimbles shall be limited to ropes used in tension systems, anchors, and guys;

b) Wire rope clips shall be of forged steel. Malleable wire rope clips shall not be used;

c) Wire rope clips and thimbles shall be used in the number and the spacing stipulated by the wire rope clip manufacturer;

d) Wire rope clips of the single saddle type shall be installed with the U-bolt against the “dead end” and the saddle against the “live end”;

e) Torque values and retightening procedures shall conform to the wire rope clip manufacturer’s instructions;

f) The radius of curvature of the rope in combination with the correct clip application shall be designed to achieve a minimum attachment efficiency of 80%.

A.3.2.3.5 Mechanical thimble splices

Two types of mechanical thimble splices shall be permitted:

a) Flemish thimble splices with swaged metal sleeve(s);

b) fold-back, or return loop, with thimble and swaged metal sleeve(s).

A.3.2.3.6 Bollards

The funicular manufacturer shall state the number of wraps required on the bollard. At least one securing clamp plus one gage clamp shall also be required. The diameter of the bollard shall not be less than 18 times the wire rope diameter.

A.4 Maintenance, inspections, and replacement

A.4.1 Wire rope

A.4.1.1 Lubrication

The type of lubricant and frequency as recommended by the rope manufacturer or designer shall be used. Ropes that have little or no motion, such as wire ropes in tension systems, anchors, and guys, require special consideration for protection against corrosion.

A.4.1.2 Inspection

All ropes shall be subject to detailed visual inspections at regularly established intervals, not to exceed 1 year, or immediately after any accident possibly affecting the integrity of the wire rope.

The visual and MRT inspections shall be made by a qualified wire rope inspector. A qualified wire rope inspector is a person who by his/her knowledge, experience, and training in the field of wire rope application is capable of judging the current condition of the wire rope.

Inspection of the entire rope, end connections, and splices including measurements of diameter, lay, and rope length (as determined by counterweight or tension carriage position with reference to temperature and loading) is required as a minimum.

During visual inspection, the inspector shall be positioned sufficiently close to the rope to observe and physically examine it. In the case of moving haul ropes, the inspection shall be made by slowly moving the rope past a fixed inspection station. Frequent stops shall be made to permit detailed inspection and make necessary measurements.

Splices shall be given close attention in haul ropes. The haul rope shall be stopped to examine each splice in detail. End connections require close attention.

MRT inspections of haul ropes shall be required for any of these conditions:

a) when the ratio of the bull wheel diameter to the haul rope diameter of a funicular is less than 80;

b) when the design factor of safety of the haul rope for a funicular is less than 5;

c) funiculars operating over 600 fpm (3 meters/second).

When MRT inspections are required, a base line inspection shall be performed during the first year of operation. Additional MRT inspections shall be performed at 3-year intervals.

The wire rope inspector may require more frequent visual or MRT inspections due to the condition of the wire rope.

Records shall be retained by the owner including the name of the inspector, method of inspection, date, measurements (including location taken), anomalies, condition of the rope, and condition of the splice and/or end connections.

The inspector shall verify that the rope(s) have not met the replacement criteria in A.4.1.3. A written and signed report stating that the rope is satisfactory for continued use shall be filed with the owner. The report shall be included in the wire rope log (see 2.3.5.2) and be available to the general inspector (see 2.3.4.1).
A.4.1.3 Repair/replacement of wire rope

The following shall be applied to the entire length of the wire rope excluding any sections in end connections or splices. For areas in end connections or splices, see A.4.3.

No rope is allowed to remain in service when, in the opinion of a qualified wire rope inspector, the rope has been reduced to less than 80% of its minimum breaking force or nominal cross sectional metallic area as a result of broken wires, wear, and corrosion.

The cross sectional metallic area repair/discard criteria of the wire rope due to broken wires shall be in accordance with the values given in Table A-4.

Table A-4 Loss of cross section metallic area

d = nominal wire rope diameter

<table>
<thead>
<tr>
<th>Maximum permissible loss of metallic area</th>
<th>Reference Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.5%</td>
<td>6d</td>
</tr>
<tr>
<td>10%</td>
<td>30d</td>
</tr>
<tr>
<td>25% (one strand)</td>
<td>6d</td>
</tr>
</tbody>
</table>

NOTE: When calculating the number of broken wires from the metallic cross sectional area, the results will be rounded down to the next whole rope. See Annex B for examples of how to calculate the number of broken wires allowed.

The wire rope inspector shall consider the items listed in A.4.1.3.1 in addition to Table A-4 to determine the repair or replacement of a wire rope. As a result of the visual inspection of the wire rope, the inspector may require that, “opening of the rope”, or more frequent inspections including MRT be performed.

If an inspection indicates that a rope is damaged so as to make it unusable, the rope shall be repaired or replaced. Repair of wire rope shall conform to the requirements of A.4.1.4.

A.4.1.3.1 Criteria

The following items should be considered by the wire rope inspector in determination of the continued use of the wire rope. Observed anomalies should be included in the wire rope inspection report:

a) general condition, lubrication, and history of the wire rope;

b) more than one valley break in one rope lay may indicate some abnormal condition, possibly fatigue and breakage of other wires not readily visible;

c) abrasion, scrubbing, or peening causing loss of the original diameter of the outside wires reducing the cross sectional metallic area of the rope;

d) evidence of rope deterioration from corrosion;

e) severe kinking, severe crushing, or other damage resulting in distortion of the rope structure;

f) evidence of any heat damage. (Sources could be a burn from a torch, or an arc caused by contact with electrical wires, natural electrical charges or fires of any nature);

g) reduction of rope diameter under tension system tension to a diameter less than 94% of the original nominal rope diameter. This procedure includes wear of the outer wires;

h) significant localized increase in the lay length after the rope has broken in;

i) significant increase in the rate of rope stretch after original constructional stretch has been removed. This is determined from records showing the movement of the counterweights or tension carriage. This final stretching indicates deterioration of the wire rope and is accompanied by a further reduction in wire rope diameter and a further increase in lay length;

j) increase of uniform wire breakage rate due to fatigue for anomalous conditions approaching 25% in 500d not including localized mechanical damage.

A.4.1.3.2 Accidental damage

When damage to a rope is accidental and is a non-repetitive event, wire breaks in excess of those stated in Table A-4 may exist provided that:

a) the area is inspected by a qualified wire rope inspector;

b) the damaged area has not been reduced to less than 80% of the minimum breaking force or nominal cross sectional metallic area of the wire rope;

c) details of the cause are apparent and identifiable;

d) the cause is corrected.

e) the area is appropriately marked and observed at intervals required by the wire rope inspector;

f) written documentation shall be entered into the wire rope log.

A.4.1.4 Repairs of wire rope

If the haul rope damage is local, it is permissible to splice in a section of rope of the same size, grade, and construction. Repairs shall conform to requirements of A.3.1.1.

In the event that damage occurs to the haul rope and such damage is confined only to one or two strands of the rope, replacement of the damaged strand or strands will be permitted and the rope may be continued in service under the following conditions:

a) A competent wire rope splicer shall advise the owner, prior to the rope’s being placed back in operation, that a suitable replacement strand was available and that all other conditions were such that he/she was able to make a proper repair to the rope.
by use of this method;

b) The minimum length of the new piece of strand shall be at least 360 times the nominal rope diameter between end tucks, and the length of the tail tucked into the core at each end shall be at least 30 times the nominal rope diameter;

c) The repaired area shall be outside of an existing splice, and the closest tuck shall be at least 96 times the nominal rope diameter from the nearest tuck in an existing splice. When the repair involves laying-in two strands, the tuck position for one strand shall be at least 96 times the nominal rope diameter from the tuck position of the second strand. If the calculated distance from the closest tuck of a laid-in strand, or strands, is less than 96 times the nominal rope diameter distance from the closest tuck in an existing splice, the laid-in strand, or strands, shall be run into the splice.

d) The repaired area shall be inspected at the completion of the repair and once weekly for a period of 6 weeks of operation to ensure that there is no interference with the grips and the newly laid-in strand, or strands, during grip migration. Thereafter, it shall be subject to routine wire rope inspection. The wire rope shall be removed from operation immediately if core collapse, pulling, high stranding, or other significant distortions occur;

e) Documents showing splice diagrams and diagrams of laid-in strand, or strands, shall be prepared by the splicer, dated, and signed for the owner. A copy shall be placed in the wire rope log for that rope;

f) If operating equipment contacting the rope is the cause of the damage, it should be corrected immediately and proper repairs made.

A.4.2 Connections

A.4.2.1 Splices

Damage within splices can often be corrected by proper repair.

Splices shall be retired or repaired if any of the following conditions exist:

a) The cross sectional metallic area of broken wires at a tuck exceeds the values given in A.4.1.1.1(j). Leading and trailing tuck strands shall be considered independent of one another when making this evaluation;

b) any sign of slippage;

c) significant distortion of the rope at the tucks has occurred.

d) the rope diameter measures less than 90% of the original nominal rope diameter.

EXCEPTION - Measurements in the tuck area will not be considered.

A.4.2.2 End connections

Cracked, deformed or excessively worn attachments shall be replaced. End connections shall be reterminated or replaced if any of the following conditions exist:

a) more than one broken wire at the connection;

b) connection is installed improperly;

c) slippage of attachment fitting outside of design parameters;

d) evidence of deterioration from corrosion;

e) does not meet the parameters specified in A.3.2.

Sections of rope permanently deformed or damaged by the application of wire rope clips or bent around thimbles, sheaves, or other anchoring devices not meeting the minimum diameters specified in Condition C of 2.1.2.7.3 shall not be relocated and reused as part of the section under load.
Annex B
(Informative)

Measuring the diameter of wire rope

It is easy and not uncommon to mismeasure the diameter of a wire rope. Figure B-1 shows the correct method to measure the diameter of a wire rope. Figure B-2 shows the incorrect method.

An average diameter for a 6-strand wire rope at a single location is obtained by taking three (3) measurements between the three sets of opposite strands using the method shown in figure B-1. The three measurements are added together and divided by 3 to obtain an average value for the diameter. Four (4) measurements would be taken at one location for an 8-strand rope and the total of the measurements divided by 4.

Figure B-1 – Correct method for measuring

Figure B-2 – Incorrect method of measuring
Annex C

(Informative)

Wire rope –
Formulas for calculating allowable broken wires

The size and actual number of outside wires has a great influence on the number of allowable broken wires when using a percentage based on different rope constructions and sizes.

Each rope must have the calculations done based on the data from the wire rope specifications and test reports due to variations between manufacturers. (See A.2.2 in Annex A.)

7.5% of rope in 6d

\[
\frac{\text{Cross Sectional Metallic Area of Rope} \times 0.075}{\text{Cross Sectional Area of Outer Wire}} = \text{Broken Wires}
\]

10% of rope in 30d

\[
\frac{\text{Cross Sectional Metallic Area of Rope} \times 0.1}{\text{Cross Sectional Area of Outer Wire}} = \text{Broken Wires}
\]

25% of one strand in 6d

\[
\frac{\text{Cross Sectional Metallic Area of Rope} \times 0.25}{\text{Cross Sectional Area of Outer Wire} \times 6} = \text{Broken Wires}
\]

NOTE:
1. All calculated values for broken wires are rounded down to the next whole wire.
2. An “outside” broken wire should be measured to verify the diameter (and cross sectional metallic area) as listed in the wire rope specifications and/or wire rope test report.
3. For specialty ropes such as 8-stand, refer to the formulas provide by the wire rope manufacturer.

Figure C.3 – Wire Rope log sample chart for calculated broken wires allowances

<table>
<thead>
<tr>
<th>Diameter / Rope Construction</th>
<th>Cross Sectional Metallic Area of rope</th>
<th>Outside wire diameter</th>
<th>Cross Sectional Metallic Area of outside wire</th>
<th>Number of Broken Wires</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7.5% of rope in 6d</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10% of rope in 30d</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25% of one strand in 6d</td>
</tr>
</tbody>
</table>
Annex D

(Informative)

Ventilation

D.1 General

The purpose of this annex is to provide guidelines for the potential compatibility of the emergency ventilation system with the normal ventilation of funiculars and their stations. This annex does not present all factors to be considered in the normal ventilation criteria. For normal ventilation, refer to the ASHRAE Handbook Series, (Fundamentals, Applications, Systems and Equipment). Current technology is capable of analyzing and evaluating all unique conditions of each property to provide proper ventilation for normal operating conditions. The same ventilating devices might or might not serve both normal operating conditions and pre-identified emergency requirements. The goals of the funicular ventilation system, in addition to addressing fire and smoke emergencies, are to assist in the containment and purging of hazardous gasses and aerosols such as those that could result from a chemical/biological release.

D.1.1 Tenable environments

Some factors that should be considered in maintaining a tenable environment for periods of short duration can be defined as follows:

1) Air temperatures as follows: maximum of 140°F (60°C) for a few seconds, averaging 120°F (49°C) or less for the first 6 minutes of the exposure and decreasing thereafter.

2) Air carbon monoxide (CO) contents as follows: maximum of 2000 ppm for a few seconds, averaging 1500 ppm or less for the first 6 minutes of the exposure, averaging 800 ppm or less for the first 15 minutes of the exposure, averaging 50 ppm or less for the remainder of the exposure. These values should be adjusted for altitudes above 3000 feet (914 meters).

3) CO generated during smoke conditions that does not exceed 800 ppm based on a 30-minute evacuation period. CO concentrations should decrease as the evacuation period increases.

4) Smoke obscuration levels that are continuously maintained below the point at which a sign illuminated at 7.5 ft-candles (80 lux) is discernable at 100 feet (30.5 meters), doors and walls are discernable at 33 feet (10 meters).

5) Radiation heat flux as follows: maximum of 2000 Btu/ft²/hr (6305 W/m²) for a few seconds, averaging 500 Btu/ft²/hr (1576 W/m²) or less for the first 6 minutes of exposure, averaging 300 Btu/ft²/hr (946 W/m²) for the remainder of the exposure.

6) Air velocities in the exposed funicular tunnel should be greater than or equal to 150 feet per minute (0.76 meters per second) and less than or equal to 2200 feet per minute (11.2 meters per second).

7) Noise levels as follows: maximum of 115 dBA for a few seconds, maximum of 92 dBA for the remainder of the exposure.

D.1.2 Rating fans

Fans can be rated in accordance with ANSI/ASHRAE 51/AMCA 210-1999 (and ANSI/ASHRAE 51-2001, ANSI/AMCA 210-2001, Addendum 1), Laboratory methods of testing fans for rating, AMCA 300-96, Reverberant room method for sound testing fans, or the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE), Handbook Fundamentals.
## Annex E

(Normative)

### Operator control devices

Table E-1 – Device function and characteristics

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>COLOR</th>
<th>LABEL</th>
<th>FEATURES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Stop</td>
<td>RED</td>
<td>STOP</td>
<td>Mushroom operator with a minimum diameter of 1-3/8 inches (38 mm)</td>
</tr>
<tr>
<td>Emergency Shutdown</td>
<td>RED</td>
<td>EMERGENCY SHUTDOWN</td>
<td>Actuator must be visible but shielded to prevent inadvertent operation.</td>
</tr>
</tbody>
</table>
Annex F
(Normative)

Combustion engine(s) and fuel handling

F.1 Combustion engines

Engines shall be situated so that they are accessible for maintenance, repair and fire fighting.

F.1.1 Engine room

Engine rooms must be of noncombustible or fire-resistive construction. If a combustion engine is enclosed within a structure, provisions shall be made for adequate ventilation to prevent a hazardous accumulation of flammable vapors or gasses, both when the engine is operating or shut down.

F.1.2 Engine rooms located within structures

Engine rooms located within structures shall have interior walls, floors, and ceilings of at least 1-hour fire-resistant rating.

EXAMPLE – One layer on walls and two layers on ceiling of properly installed 5/8" Type X gypsum wallboard, or its equivalent, covering all combustible wall and ceiling members would meet this requirement.

Openings in the engine room that open into other mixed occupancy sections of the structure shall be provided with automatic or self-closing fire doors or dampers to contain a fire to the engine room.

F.1.3 Air supply

Provisions shall be made to supply sufficient air for combustion, proper cooling, and adequate ventilation. The air supply requirements will vary with the types and sizes of engines, the driven equipment and other air-consuming equipment within the engine room.

F.1.4 Flammable materials

No flammable liquids may be stored in the building outside of a UL listed container or storage cabinet, unless such flammable liquids are in the original containers and intended for daily usage. Quantities must be consistent with normal daily usage. Class I or II flammable storage materials shall be limited to 2 gallons in a UL listed container and must be stored either in an outside storage area or in a UL listed cabinet.

F.1.5 Open flames

Gasoline, natural gas or liquid phase LP-gas fueled engines shall not be installed in rooms or locations containing fired equipment or open flames.

F.1.6 Engine support

Engines shall be supported on firm foundations or suitable steel framework and properly secured.

F.2 Electrical installations

F.2.1 Hazardous locations

Engine rooms or other locations shall not be classified as hazardous locations as defined in Article 500 of the NFPA 70-2008, solely by reason of the engine fuel.

F.2.2 Combustion engine wiring

Wire and insulation materials shall remain flexible over typical engine operating temperature ranges and have the minimum possible absorption of oils, fuels, and other fluids commonly found on or near the engine.

Wiring shall be protected by either fuses or circuit breakers in accordance with its ampacity. Batteries, wiring and electrical protective devices shall be protected against arcing and accidental shorting.

F.3 Combustion engine protective devices

F.3.1 Evacuation power unit

Engines used only for evacuation purposes shall be equipped with the following devices:

a) An automatic engine shutdown device for low lubricating oil pressure or, in the case of a splash lubricated engine, for low oil level;

b) All engines must be wired into the emergency shutdown circuit;

c) If the engine can drive the rope to exceed 100% of design rope speed under the most unfavorable loading conditions, one of the following devices shall be required:

1) Engine Governor The governor shall limit the engine speed to a maximum of 100% of the design rope speed;

2) Overspeed Device The overspeed device shall initiate an engine shutdown if the line speed exceeds the design speed by more than 10%.

F.3.2 Prime mover

Engines intended for continuous operation shall have the devices specified in F.3.1 and the following additional protection shall be provided:

a) An automatic engine shutdown device for engine over speed which shall initiate an engine shutdown when the lift speed exceeds the design speed by 10%;

b) An automatic engine shutdown device for high coolant temperature.
F.4 Fuel supply

F.4.1 Structural members used as fuel tanks

Structural members shall not be used as fuel tanks or contain fuel tanks.

F.4.2 Fuel tanks for combustion engines

Fuel tanks shall have adequate capacity to permit uninterrupted operation during the normal operation period.

F.4.3 Integral or day tanks

Integral or day tanks shall be of steel or aluminum with welded or brazed joints.

F.4.4 Outside aboveground or underground fuel supply tanks

Outside aboveground or underground fuel supply tanks, including those incorporating secondary containment, shall be built in accordance with recognized standards of design or approved equivalents. Tanks shall be built, installed, and used within the scopes of their approvals.

F.4.5 Underground tanks and piping

Underground tanks and piping containing flammable liquids shall comply with all federal, state and local regulations.

F.4.6 Provisions for internal corrosion

When tanks are not designed in accordance with the American Petroleum Institute, American Society of Mechanical Engineers, or the Underwriters Laboratories Inc. Standards, or if corrosion is anticipated beyond that provided for in the design formulas used, additional metal thickness or suitable protective coatings or linings shall be provided to compensate for the corrosive loss expected during the design life of the tank.

F.4.7 Fuel tanks inside structures

F.4.7.1 Integral tanks

Class I fuels Only “integral tanks” of 25 gallons capacity or less are allowed within a structure. Other supply tanks may be located underground or outside of structures.

Class II fuels The fuel storage capacity of an “integral or day tank” shall not exceed 660 gallons per tank.

F.4.7.2 Day or supply tanks

Day or supply tanks within structures shall be securely mounted on substantial noncombustible supports.

F.4.7.3 Supply tanks

Fuel tanks greater than 25 gallons capacity located above grade shall have either a wall, curb or dike having a capacity at least equal to that of the largest surrounded tank, or a wall, curb or dike of lesser capacity equipped with an overflow or drainage system that shall be adequate in size and location to convey any spillage of fuel to a tank (inside or outside the structure) or to a safe area outside the structure.

F.4.7.4 Enclosed fuel tanks

When a structural system is partially or totally enclosing a fuel tank, the structural systems’ exterior surfaces shall be suitably marked to warn personnel of the hazard hidden from view. Markings shall define the limits and contents of the hidden fuel tank.

F.4.8 Fuel flow control

F.4.8.1 Liquid fuel supply systems

Liquid fuel supply systems, including drains from carburetors, shall be designed and installed to minimize as far as practicable the accidental discharge of fuel into the engine room or structure. Adequate alarms, float- controlled valves, and mechanical or remote reading level gauges or protected sight gauges shall be installed to aid personnel in properly operating the fuel system. Stationary powered fuel pumps supplying integral or day tanks shall have “stop” controls sensitive to a tank’s high liquid level.

F.4.8.2 Pumps

Where supplied by pumps, day tanks or integral tanks shall be provided with an overflow return line, a high level alarm, and a high level automatic shutoff. The overflow line shall be continuous piping to the supply tank without valves or traps. Its capacity shall exceed the delivery capacity of the supply lines it serves.

F.4.8.3 Engine air intake

Overflows, vents, and fuel piping of fuel tanks shall not be located at or near engine air intake, exhaust piping, mufflers or filters.

F.4.9 Filling

F.4.9.1 Fill pipes

Fill pipes located beyond the sides of a building or engine room shall have a locked fuel cap. Fill pipes shall be located to avoid toxic fumes and fire hazard during refueling.

F.4.9.2 Gasoline and diesel fuel tanks

Fuel tanks shall be filled by a closed piping system. EXCEPTION – Fuel tanks may be filled by other than closed piping systems when engine is shut down and with no passengers on the funicular. If containers are utilized for filling, they must be UL listed.

F.4.9.3 Fuel quality

A procedure or program shall be established to ensure a liquid fuel’s quality is suitable for use in the intended combustion engine.
F.4.10 Fuel piping, valves, venting, piping and fittings

F.4.10.1 Atmospheric storage tanks

Atmospheric storage tanks shall be adequately vented to prevent the development of vacuum or as a result of filling or emptying and atmospheric temperature changes.

**EXCEPTION** – Integral tanks do not require venting.

F.4.10.2 Normal vents

Normal vents shall be sized in accordance with either:

a) the American Petroleum Institute Standard No. 2000, *Venting Atmospheric and Low-Pressure Storage Tanks*, or;

b) another accepted standard, or shall be at least as large as the filling or withdrawal connection, whichever is larger, but in no case less than 1-1/4 inches (32 mm) nominal inside diameter.

F.4.10.3 Fill or withdrawal connection

If any tank or pressure vessel has more than one fill or withdrawal connection and simultaneous filling or withdrawal can be made, the vent size shall be based on the maximum anticipated simultaneous flow.

F.4.10.4 Pipe outlets

Wherever pipe outlets for tanks storing Class I liquids are adjacent to buildings or public ways, they shall be located so that vapors are released at a safe point outside of buildings and not less than 12 feet above the adjacent ground or normal snow level. In order to aid their dispersion, vapors shall be discharged upwards or horizontally away from closely adjacent walls. Vent outlets shall be located so that flammable vapor will not be trapped by eaves or other obstructions and shall be at least 5 feet (1.53 meters) from building openings.

F.4.10.5 Location and arrangement of vents for class II liquids

Vent pipes from tanks storing Class II liquids shall terminate outside of the building and higher than the fill pipe opening. Vent outlets shall be above normal snow level. They may be fitted with return bends, coarse screens, or other devices to minimize ingress of foreign material.

F.4.10.6 Vent piping for storage

Tank vent pipes and vapor return piping shall be installed without sags or traps in which liquid can collect. Condensate tanks, if utilized, shall be installed and maintained so as to preclude the blocking of the vapor return piping liquid. The vent pipes and condensate tanks shall be located so that they will be protected from physical damage. The tank end of the vent pipe shall enter the tank through the top.

F.4.10.7 Emergency relief venting

Every aboveground storage tank shall have some form of construction or device that will relieve excessive internal pressure caused by exposure to fires.

F.4.10.8 Piping systems

Piping systems shall be substantially supported and protected against physical damage and excessive stresses. The use of approved metallic or nonmetallic flexible connectors for protection against damage caused by settlement, vibration, expansion, contraction or corrosion is acceptable.

F.4.10.9 Valves

Sufficient valves shall be provided to control flow of liquid fuel in the normal operation and to shut off the flow of fuel in the event of a pipe break. These valves shall be adequately labeled at the valve.

F.4.10.10 Openings for gauging

Openings for gauging on tanks storing Class I liquids shall be provided with a vapor tight cap or cover. The cap or cover shall be closed when not gauging.

F.4.10.11 Fill pipes

Fill pipes that enter the top of a tank other than day or integral tanks shall terminate within 6 inches of the bottom of the tank. Fill pipes shall be installed or arranged so that vibration is minimized.

F.4.11 Transfer of liquid fuel to engines

Liquid fuel shall feed to engines by pumps only. If the fuel tank(s) are located above the engine fuel intake, the fuel tank shall be equipped with an anti-siphon device.

F.5 Exhaust piping

F.5.1 Design and construction

F.5.1.1 Engine exhaust

Engine exhaust discharge systems shall be designed on the basis of flue gas temperatures (see 1.4 – flue gas temperature).

F.5.1.2 Exhaust pipes

Exhaust pipes shall be of wrought iron or steel and of sufficient strength to withstand the service. Fittings of cast iron shall be acceptable.

F.5.1.3 Low points

Low points in the exhaust system shall be provided with suitable means for draining of condensate.
F.5.2 Installation

F.5.2.1 Exhaust pipes

Exhaust pipes shall terminate outside the structure at a point where the hot gases or sparks will be discharged harmlessly and not be directed against combustible material or structures, or into atmospheres containing flammable gases or vapors or combustible dusts. Exhaust pipes shall not terminate under loading platforms or structures, or near ventilation air inlets. Additionally, exhaust pipes shall be adequately supported and shall be connected to the engine or muffler so that emission of sparks, flame or gas within the structure is prevented.

F.5.2.2 Flexible connections

Where necessary, a flexible connector shall be provided in an exhaust pipe from the engine to minimize the possibility of a break in the engine exhaust system because of engine vibration or heat expansion. This connection shall not permit the release of dangerous quantities of gas into the engine room.

F.5.2.3 Exhaust system guards

Exhaust stacks, manifolds and turbochargers within reach of personnel shall be equipped with guards or heat shields for a distance of 8 feet (2.44 meters) above the floor or other walking or working surface, or to the ceiling if less than 8 feet (2.44 meters).

F.5.3 Clearance from combustible materials

F.5.3.1 Exhaust pipes

Exhaust pipes shall be installed with clearances of at least 9 inches (to combustible material), except as provided in F.5.3.2 and F.5.3.3.

F.5.3.2 Exhaust pipes through roofs

Exhaust pipes passing directly through combustible roofs shall be guarded at the point of passage by ventilated metal thimbles that extend not less than 9 inches (230 mm) above and below roof construction and are at least 6 inches (150 mm) in diameter larger than the exhaust pipe.

F.5.3.3 Exhaust pipes through walls

Exhaust pipes passing directly through combustible walls or partitions shall be guarded at the point of passage by one of the following methods:

a) Metal ventilated thimbles not less than 12 inches (305 mm) larger in diameter than the exhaust pipe, or;

b) Metal or burned fire clay thimbles built in brickwork or other approved fireproofing materials providing not less than 8 inches (200 mm) of insulation between the thimble and combustible material.

F.6 Fire protection

F.6.1 Fire extinguishers, classification

F.6.1.1 Low hazard

Structures used for the operation and maintenance of a funicular which are not designated as a Moderate Hazard shall be classified as Light (Low) Hazard, as defined by NFPA 10-2007. Light (Low) Hazard areas shall be protected by a minimum of a 10-lb. (or two 5-lb.) Dry Chemical ABC fire extinguisher or equivalent.

F.6.1.2 Moderate hazard

Structures containing a funicular combustion engine shall be classified as Ordinary (Moderate) Hazard, as defined by NFPA 10-2007. Ordinary (Moderate) Hazard areas shall be protected by a minimum of a 20 lb. (or two 10-lb. or four 5-lb.) Dry Chemical ABC fire extinguisher or equivalent.

F.6.2 Fire extinguishers, location

Extinguishers shall be conspicuously located where they will be readily accessible and immediately available in the event of fire. Preferably, they shall be located along normal paths of travel, including exits from areas.

F.6.2.1 Obstructions

Extinguishers shall not be obstructed or obscured from view.

F.6.2.2 Mounting

Extinguishers shall be installed in a bracket and protected from dislodgment and physical damage.

F.6.2.3 Travel distances

Travel distances within an engine room for portable extinguishers shall not exceed 30 feet (9.1 meters). Extinguishers should be placed at regular intervals within a engine room so that the maximum walking distance from any point to the nearest extinguisher does not exceed the maximum travel distance. EXCEPT – The travel distance between fire extinguishers can be increased to 50 feet (15.25 meters) maximum, if the area is protected with a 20 lb. Dry Chemical ABC fire extinguisher or equivalent.
F.6.3 Inspection and maintenance of fire extinguishers

Each extinguisher shall have a tag or label securely attached that indicates the month and year of inspections, maintenance, recharging and identifies the person performing the following services.

a) Monthly inspections (see F.6.3.1);

b) Annual Maintenance (see F.6.3.2);

c) Recharging (see F.6.3.3).

F.6.3.1 Inspection

F.6.3.1.1 Frequency

Extinguishers shall be inspected when initially placed in service and thereafter at approximately 30-day intervals during funicular operation and the inspection recorded in the maintenance log.

F.6.3.1.2 Procedures

Periodic inspections shall include a check of at least the following items:

a) Located in designated place;

b) No obstructions to access or visibility;

c) Operating instructions on nameplate legible and facing outward;

d) Seals and tamper indicators not broken or missing;

e) Determine fullness by weighing or “hefting” (CO2);

f) Examine for obvious physical damage, corrosion, leakage, or clogged nozzle;

g) Pressure gauge reading or indicator in the operable range or position.

When an inspection of any rechargeable extinguisher reveals a deficiency in any of the conditions listed in (c), (d), (e), (f), and (g) stated above, it shall be subjected to applicable maintenance procedures. When an inspection of any non-rechargeable dry chemical extinguisher reveals a deficiency in any of the conditions listed in (c), (d), (e), (f), and (g) stated above, it shall be discharged, marked “used” and removed from service.

F.6.3.2 Maintenance

F.6.2.2 Maintenance of fire extinguishers

Extinguishers shall be subjected to maintenance not more than one year apart or when specifically indicated by an inspection.

F.6.3.3 Recharging of fire extinguishers

All rechargeable extinguishers shall be recharged after any use or as indicated by an inspection or when performing maintenance. When performing the recharging, the recommendation of the manufacturer shall be followed. Only those agents specified on the nameplate, or agents proven to have equal chemical composition and physical characteristics shall be used.

F.6.4 Operating instructions of fire extinguishers

Operating instructions shall be located on the front of the extinguisher. Other labels and markings shall not be placed on the front.

F.6.5 Fire alarms

All machine rooms shall have a fire detection system conforming to NFPA 72-2007. This system shall initiate a visual and audible indication at the operators position.

F.7 Fuel handling

F.7.1 Liquefied petroleum gases

Gas fuels shall be handled in accordance with the latest edition of, ANSI/NFPA 58 - Liquefied Petroleum Gas.
Annex G
(Informative)

International system of units (SI) metric conversion factors

The ropeway industry is an international industry. Manufacturers and authorities having jurisdiction may be involved in using a variety of dimensional factors in describing their equipment. The following is offered as assistance.

<table>
<thead>
<tr>
<th>To convert from</th>
<th>To</th>
<th>Multiply by</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acceleration</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>feet per second²</td>
<td>meter per second² (m/s²)</td>
<td>3.048 000 E–01</td>
</tr>
<tr>
<td>inches per second²</td>
<td>meter per second² (m/s²)</td>
<td>2.540 000 E–02</td>
</tr>
<tr>
<td>feet per minute²</td>
<td>meter per minute² (m/m²)</td>
<td>1.828 800 E+00</td>
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<td><strong>Angle</strong></td>
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<td></td>
</tr>
<tr>
<td>degree (angle)</td>
<td>radian (rad)</td>
<td>1.745 329 E–02</td>
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<td>minute (angle)</td>
<td>radian (rad)</td>
<td>2.908 882 E–04</td>
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<tr>
<td>second (angle)</td>
<td>radian (rad)</td>
<td>4.848 137 E–06</td>
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<tr>
<td><strong>Area</strong></td>
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</tr>
<tr>
<td>feet²</td>
<td>meter² (m²)</td>
<td>9.290 304 E–02</td>
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<tr>
<td>inch²</td>
<td>meter² (m²)</td>
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<td><strong>Bending Moment of Torque</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pound-foot • inch</td>
<td>newton meter (N•m)</td>
<td>1.129 848 E–01</td>
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<tr>
<td>pound-foot • foot</td>
<td>newton meter (N•m)</td>
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<td><strong>Bending Moment or Torque per Unit Length</strong></td>
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<td></td>
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<tr>
<td>pound-foot • foot/inch</td>
<td>newton meter per meter (N•m/m)</td>
<td>5.337 866 E+01</td>
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<tr>
<td>pound-foot • foot/inch</td>
<td>newton meter per meter (N•m/m)</td>
<td>4.448 222 E+00</td>
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<td><strong>Force</strong></td>
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<td>kip (1000 lbf)</td>
<td>newton (N)</td>
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<tr>
<td>pound-force (lbf avoirdupois)</td>
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<td><strong>Force per Unit Length</strong></td>
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</tr>
<tr>
<td>pound-foot/foot</td>
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<td>mile (statute)</td>
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<td>1.609 3E+03</td>
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<td>inch</td>
<td>meter (m)</td>
<td>2.540 000 E–02</td>
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### Mass

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<tr>
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<th>To</th>
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<td>pound (lb avoirdupois)</td>
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<td>4.535 924 E–01</td>
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<td>ton (short, 2000 lb)</td>
<td>kilogram (kg)</td>
<td>9.071 847 E+02</td>
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### Mass per Unit Area

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<tr>
<td>pound/inch²</td>
<td>kilogram per meter² (kg/m²)</td>
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### Mass per Unit Length

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<th>Multiply by</th>
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</thead>
<tbody>
<tr>
<td>pound-foot • inch</td>
<td>kilogram per meter (kg/m)</td>
</tr>
<tr>
<td>pound-foot • foot</td>
<td>kilogram per meter (kg/m)</td>
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</table>

### Mass per Unit Volume

<table>
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<tr>
<th>To</th>
<th>Multiply by</th>
</tr>
</thead>
<tbody>
<tr>
<td>pound/foot³</td>
<td>kilogram per meter³ (kg/m³)</td>
</tr>
<tr>
<td>pound/inch³</td>
<td>kilogram per meter³ (kg/m³)</td>
</tr>
</tbody>
</table>

### Temperature

<table>
<thead>
<tr>
<th>To</th>
<th>Multiply by</th>
</tr>
</thead>
<tbody>
<tr>
<td>degree Fahrenheit</td>
<td>degree Celsius (C)</td>
</tr>
<tr>
<td></td>
<td>t°C = (t°F – 32)/1.8</td>
</tr>
<tr>
<td>degree Fahrenheit</td>
<td>degree Kelvin (K)</td>
</tr>
<tr>
<td></td>
<td>tK = (t°F + 459.67)/1.8</td>
</tr>
</tbody>
</table>

### Velocity

<table>
<thead>
<tr>
<th>To</th>
<th>Multiply by</th>
</tr>
</thead>
<tbody>
<tr>
<td>feet/hour</td>
<td>meter per second (m/s)</td>
</tr>
<tr>
<td>feet/minute</td>
<td>meter per second (m/s)</td>
</tr>
<tr>
<td>feet/second</td>
<td>meter per second (m/s)</td>
</tr>
<tr>
<td>inch/second</td>
<td>meter per second (m/s)</td>
</tr>
</tbody>
</table>

### Volume

<table>
<thead>
<tr>
<th>To</th>
<th>Multiply by</th>
</tr>
</thead>
<tbody>
<tr>
<td>feet³</td>
<td>meter³ (m³)</td>
</tr>
<tr>
<td>gallon (us dry)</td>
<td>meter³ (m³)</td>
</tr>
<tr>
<td>inch³</td>
<td>meter³ (m³)</td>
</tr>
<tr>
<td>yard³</td>
<td>meter³ (m³)</td>
</tr>
</tbody>
</table>

### Volume per Unit Time

<table>
<thead>
<tr>
<th>To</th>
<th>Multiply by</th>
</tr>
</thead>
<tbody>
<tr>
<td>feet³/minute</td>
<td>meter³ per second (m³/s)</td>
</tr>
<tr>
<td>feet³/second</td>
<td>meter³ per second (m³/s)</td>
</tr>
<tr>
<td>inch³/minute</td>
<td>meter³ per second (m³/s)</td>
</tr>
</tbody>
</table>

### Multiplication Factor

<table>
<thead>
<tr>
<th>Multiplication Factor</th>
<th>Prefix</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000 = 10³</td>
<td>kilo</td>
<td>k</td>
</tr>
<tr>
<td>100 = 10²</td>
<td>hecto</td>
<td>h</td>
</tr>
<tr>
<td>10 = 10¹</td>
<td>deka</td>
<td>da</td>
</tr>
<tr>
<td>0.1 = 10⁻¹</td>
<td>deci</td>
<td>d</td>
</tr>
<tr>
<td>0.01 = 10⁻²</td>
<td>centi</td>
<td>c</td>
</tr>
<tr>
<td>0.001 = 10⁻³</td>
<td>milli</td>
<td>m</td>
</tr>
</tbody>
</table>