American National Standard

for Funiculars -
Safety Requirements

ANSI B77.2-2004



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B77.2-2004

American National Standard

for Funiculars - Safety Requirements

Secretariat

National Ski Areas Association

Approved December 31, 2003

American National Standards Institute, Inc.

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Foreword (This foreword is not part of American National Standard ANSI B77.2-2004.)

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 all are considered Funiculars. These systems have unique requirements that rely on ropeway technology. ANSI B77.2 will give guidance to manufacturers of those systems that are not classified as elevators or Automated People Movers.

This is a new standard 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. Section 2 covers mechanical design, electrical design, and operational requirements. Section 3 addresses wire rope requirements.

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.

This standard contains four informative annexes, which are not formally considered part of this standard.

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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Sid Roslund*, Committee Administrator
(National Ski Areas Association)
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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 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 approaching, loading, unloading, and departing from funiculars. This system is intended to result in funiculars that are designed, constructed, operated, and maintained in a manner that helps reduce danger and 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.

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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 wire rope subsection (3.4) 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 change in:

a) the maximum design speed of the system;

b) the rated capacity by changing the number of carriers, load capacity of the carriers, or a change in weight or carrier size;

c) the path of the rope or guideway;

d) the type of brakes and devices or components thereof;

e) the structural arrangements;

f) energy source or type of power unit, auxiliary power unit or alternate carrier unloading system (used in evacuations);

g) control system logic.

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 – *conductor*).

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.

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

brake: A device that, 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.

bull wheel: A terminal sheave that deflects the rope 150 degrees or more. When under power, the sheave is referred to as a drive sheave (or drive bull wheel); when acting as a movable tensioning device, it is referred to as a tension sheave (or tension bull wheel); and when it is acting simply as a fixed return for the rope, it is referred to as a fixed return sheave (or fixed return bull wheel).

cabin: An enclosed or semi-enclosed compartment for transporting passengers.

carriage: A structural framework for supporting the cabin(s), providing attachment points for the rope(s) and which is equipped with wheels or other methods, to support the cabin(s) on the guideway.

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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.

circuit(s), control power: The control power circuit is a normally de-energized circuit. When energized this circuit provides power to the operating control circuit.

circuit(s), operating control: The operating control circuit is a normally de-energized circuit. When energized, these circuits provide power to all electrical control functions responsible for start, stop, run, and speed control. De-energizing the operating control circuits causes the system to stop or remain at rest.

conductor: An attendant assigned to duties or functions in a cabin (also see 1.4 – *supervisor*).

deropement: The term used when the rope leaves its intended operating zone relative to the groove of a rope support or guidance sheave.

design capacity: The number of passengers per hour (pph) established by the designer as the current ultimate operating capability of the facility in the direction specified.

double reversible: A funicular system wherein two carriers or group(s) of carriers oscillate between the terminals on two parallel guideways, or alternately on a single guideway with a passing zone at the mid-section of the guideway.

electromagnetic wire rope testing: Electromagnetic Wire Rope Testing (EWRT) is any of several nondestructive testing procedures that derive indications of wire rope condition from sensors measuring electromagnetic flux in or adjacent to the rope resulting from imposition of a known flux within the wire rope.

emergency shutdown: A stop that occurs when it is detected that a stop command has failed to function in accordance with design criteria. It takes priority over all other stop commands or devices. When initiated, one or more brakes shall be applied and power shall be removed from the power unit. Removing power from the power unit shall mean:

- *Electric motor*: Full load rated contactor or circuit breaker disconnect devices operate to shut down the motor;
- *Internal combustion engine*: Engine shuts down. (also see 1.4 – *stop*)

funicular: A system in which passengers are transported in/on carrier(s) that are supported and guided by a level or inclined guideway (excluding elevators) and propelled by means of a haul rope or other flexible element that is driven by a power unit remaining essentially at a single location.

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 sheave.

normal stop: A stop in which the prime mover may be involved in braking and in which the funicular comes to rest in a controlled manner.

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 sheave 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: A passenger is any person utilizing 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.

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, wire rope, or haul rope* shall mean rope, which consists of several wire strands twisted together.

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.

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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.

sheaves: Pulleys or wheels grooved for the support or deflection of a rope.

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

sheave, counterweight: A sheave used in the counterweight reeving system that is active during normal operations.

sheave, deflection: A terminal sheave that deflects the rope at least 10 degrees but less than 150 degrees.

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).

sheave, drive: A terminal sheave that is driven by one or more power units.

sheave, guideway: Sheaves that support or hold down any ropes along the guideway or in terminals. (The angle of rope deflection is usually small.)

sheave, terminal: A rope sheave at a terminal that rotates continuously when the rope is moving and deflects the rope by an angle of 10 degrees or more.

should: This word is to be used to convey a recommendation, describe a recommended practice or procedure, or introduce a related standard (or publication).

single reversible: A funicular system wherein a single carrier or group of carriers moves back and forth between the terminals on a single guideway.

stop: A function initiated by an automatic or manual command that decelerates the funicular and brings it to rest (also see 1.4 – *emergency shutdown*).

strand: Unless otherwise specified, the term *strand* shall mean wire strand, consisting of several wires twisted together (as compared with wire rope, which consists of several strands twisted together).

supervisor: An individual in responsible charge of the funicular operations and personnel (also see 1.4 – *operator*).

wire rope: see 1.4 – *rope*

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 plans and specifications for such work.

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 by personnel.

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Section 2
Funiculars

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 weight of 170 pounds (77.1 kg).

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) seismic and other geotechnical considerations.

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. 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 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.

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 funicular

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 minimum horizontal clearance between two passing carriers or any stationary item shall be 18 inches (460 mm), provided that the carriers are enclosed such that a passenger cannot encroach upon the clearance. If such enclosure is not provided, then the minimum horizontal clearance between two passing carriers shall be 4 feet (1.22 meters).

In tunnels and overhead roadway crossings, a minimum clearance of 18 inches (460 mm) is acceptable on one side of an enclosed carrier, provided there are no exits to that side of the car. Where exit doors are provided, at least 32 inches (815 mm) of clearance shall be provided on the side of the car with the exit door.

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

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, guideway elements and the edge of the roadway. Protective devices or barriers shall be used where roadway vehicles could encroach upon the guideway.

2.1.1.4.4 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.

2.1.1.4.5 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 (6.0 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 be supervised by a device or system that detects haul rope departure from its normal zone of operation and initiates a stop of the funicular;

d) a conductor shall be in each carrier or group of carriers and the drive stations shall be staffed with an attendant(s) or operator.

2.1.1.6 Structures and foundations

All structures and foundations shall be designed and constructed in conformance with 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 220-1999 *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.

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

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 220-1999.

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 machinery 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 conductor.

2.1.1.8 Internal combustion engine installation

2.1.1.8.1 Fuel tanks for combustion engines

Fuel tanks shall have adequate capacity to permit uninterrupted operation during the normal operating period. The installation shall comply with *American National Standard for Stationary combustion engines and gas turbines*, ANSI/NFPA 37-2002.

Liquid fuels stored outside of a motor room, either above ground or below ground, shall be in compliance with the appropriate regulatory authority.

For the purposes of interpreting ANSI/NFPA 37-2002, the auxiliary power units utilizing a combustion engine shall be considered, “used for emergency purposes.” Also, “on roof of structure” shall mean “on the drive terminal structure.” Structural members shall not be used for or contain fuel tanks.

An integral tank is a fuel tank furnished by the engine or funicular manufacturer. It shall be securely mounted to the engine assembly and protected against vibration, physical damage, engine heat, and the heat of exhaust piping.

> EXCEPTION – The funicular manufacturer may supply, or a Qualified Engineer may specify, an integral or day fuel tank for mounting on a combined drive-tension carriage or an overhead fixed drive terminal. The tank shall be sized 25 gallons (94.6 liters) maximum, constructed, and installed in accordance with applicable provisions of ANSI/NFPA 37-2002.

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

2.1.1.8.2 Exhaust systems

Exhaust systems shall be designed and installed to discharge to the atmosphere in a manner that does not allow precipitation to enter the exhaust system. Exhaust stacks 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), and shall be insulated where they pass through combustible building materials.

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 section 1.3.

The loading and unloading areas shall be provided with approximately level platforms at each cabin entryway and the necessary handrails, steps or ramps to provide access, guidance, and passenger control. Load gates, artificial surfaces, and other loading aids shall be designed and installed with consideration to all passengers including those using adaptive equipment. Platforms shall be provided with sufficient space to accommodate passengers waiting to embark and passengers disembarking the carriers. Provisions for separation of incoming and outgoing passengers shall be made to guide passengers to and from the carriers and the routes shall be designated.

2.1.1.10 Passenger removal from stranded carriers

Funiculars shall be provided with means to evacuate passengers from stranded carriers.

2.1.1.10.1 Carrier evacuation

Provisions shall be made in the design of the funicular for emergency evacuation of all passenger types (see 2.3.2.5.7). The guideway shall contain a service road or path at least on one side. A service road or path shall be provided which allows passengers to leave the stranded vehicles at any place along the guideway, including the passing zone. The service road or pathway shall be a minimum horizontal width of 32 inches (815 mm).

In tunnels, walking surfaces designed for evacuation of passengers shall be constructed of non-combustible materials.

Adequate emergency lighting as well as normal lighting shall be provided to accommodate all foreseeable evacuation conditions.

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2.1.1.11 Acceptance inspection and tests

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:

a) tightness of all structural connections;

b) lubrication of all moving parts;

c) alignment and clearances of all open gearing;

d) installation and alignment of all drive components;

e) position and freedom of movement of counterweights or other tension systems and carriages;

f) haul rope alignment at entrance to bull wheels;

g) operation of all electrical components, including circuit protection and grounding;

h) brake torque testing;

i) minimum carrier clearances;

j) proper alignment of haul rope and sheave units;

k) actual testing of evacuation equipment and procedures at the most difficult location;

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;

m) ventilation system (see 2.1.2.12.7).

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 all required and appropriate tests 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 2.1.2.4). Motive power and all braking devices (see 2.1.2.5) shall be proved adequate under the most adverse loadings and at design speeds.

Prior to the acceptance inspection and the above acceptance tests, the funicular shall be operated, with empty carriers on the guideway at least 16 hours, at least 6 of which is continuous to check for overheating of moving parts, excessive vibration or deflection of mechanical or structural components, free movement of tension systems, and other related conditions.

All terminal and guideway equipment shall be thoroughly checked both before and during the continuous run test.

2.1.1.12 Safety of operating and maintenance personnel

Provision shall be incorporated in the funicular design to render the system inoperable when necessary for the protection of personnel working on the funicular. See 2.3.1.1 for placement of applicable warning signs.

The funicular shall incorporate an audible warning device that signals of 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 begins to move. The audible device shall be heard inside and outside all terminals, carriers and machine rooms above the ambient noise level.

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.

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

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

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2.1.2.1.1 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) Auxiliary power unit or other mechanical system, when provided, shall not depend upon the mechanical integrity of any other power unit to drive the funicular and shall be electrically wired to meet the requirements of 2.2.1.7.2 so it can be stopped by the Emergency Shutdown Circuit.

b) An alternate carrier unloading system utilizing a nonmotorized drive system to move the carriers at a controlled speed.

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.

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 2.1.2.6.1

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 equipment 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.

Table 2-1 – Maximum/Minimum allowable accelerations

DESCRIPTION	STANDING	SEATED
Maximum Average Acceleration	3 ft/s^2 (0.91 m/s^2)	3 ft/s^2 (0.91 m/s^2)
Stop – Maximum Horizontal Deceleration	5 ft/s^2 (1.52 m/s^2)	11 ft/s^2 (3.34 m/s^2)
Emergency Shutdown - Maximum Horizontal Deceleration	10 ft/s^2 (3.05 m/s^2)	19 ft/s^2 (5.76 m/s^2)
Stop and Emergency Shutdown - Minimum Horizontal Deceleration	1 ft/s^2 (0.30 m/s^2)	1 ft/s^2 (0.30 m/s^2)
Vertical Accelerations	±8 ft/s^2 (±2.44 m/s^2)	±8 ft/s^2 (±2.44 m/s^2)
Lateral Accelerations	3 ft/s^2 (0.91 m/s^2)	8 ft/s^2 (2.44 m/s^2)

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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 2.1.2.5.1 and 2.1.5.1.2.

The drive 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 auxiliary power unit.

2.1.2.5 Brakes

The funicular shall have the following friction-type brakes:

- service brake (see 2.1.2.5.1);
- drive sheave brake (see 2.1.2.5.2);
- carrier brake (see 2.1.2.5.3).

They shall be designed and monitored to ensure that:

a) once the funicular begins movement in the intended direction, the brakes are maintained in the open position;

b) the failure of one braking system shall not impair the function of the other systems;

c) 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 2.1.2.4);

d) the failure of one braking system to properly decelerate the funicular shall automatically initiate a second braking system.

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 drive sheave 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.

2.1.2.5.1 Service brake

The service brake can be located at any point in the drive train such that there is no belt, friction clutch, or similar friction-type device between the brake and the drive sheave.

The service brake shall be an automatic brake to stop and hold the funicular under the most unfavorable design loading condition. The rate of application of this brake shall be adjustable. 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 2.1.2.4.

The brake shall be in a normally applied position and shall not open prior to the drive system developing torque. 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 2.1.2.4 shall be achieved by the service brake without the aid of other braking devices or drive regeneration.

2.1.2.5.2 Drive sheave brake

Drive sheave 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 drive sheave brake shall operate on the drive sheave assembly.

Application of the drive sheave brake shall automatically disconnect the power source from the power unit in use. This brake shall act automatically if the carriers travel beyond their normal stopping position in either terminal.

The drive sheave brake shall be an automatic brake to stop and hold the funicular under the most unfavorable design loading condition. The rate and force of application of this brake shall be adjustable.

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2.1.2.5.3 Carrier brakes

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 force shall be applied by springs or other approved forms of stored energy. 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 conductor in the cabin;

e) interlock so that brake will not set until the carrier's upward travel has stopped;

f) automatically functioning in specified overspeed conditions (see 2.1.2.11.2(k)).

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 braking system shall automatically effect an emergency shutdown.

2.1.2.6 Location of machinery

2.1.2.6.1 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/ASME B15.1-2000.

Protection against static electricity shall be provided.

Machinery areas shall be protected by a minimum of two 10-lb. Dry Chemical ABC fire extinguishers or equivalent (or a 20-lb. Dry Chemical ABC fire extinguisher).

2.1.2.6.2 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.

2.1.2.6.3 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 machinery is rated for operation in an unheated room.

2.1.2.6.4 Automatic fire detection

Heat and smoke detectors shall be installed in all machinery areas and shall be connected to the operators' station. Signals received from such devices shall be readily identifiable as to the origin of signals.

2.1.2.6.5 Portable fire extinguishers

Portable fire extinguishers shall be provided in such numbers, sizes, and types and at locations in tunnels as determined by the authority having jurisdiction.

2.1.2.7 Sheaves in terminals and stations

2.1.2.7.1 General

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

When lined sheave grooves are used, the allowable bearing pressures of the liner material shall not be exceeded.

2.1.2.7.2 Haul rope terminal sheaves (bull wheels and deflection sheaves)

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

The sheave assembly shall be designed to retain the haul rope and prevent deropement. 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.

Drive sheaves and terminal rope deflection sheaves shall be fabricated of steel or cast steel. The design safety factor for drive and counter sheaves shall not be less than 2.0 to the yield strength if residual rope tensions are considered and welded steel or cast steel is used for the sheaves.

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The minimum diameter of haul rope terminal sheaves that act as driving, braking or deceleration sheaves shall be 72 times the nominal diameter of the haul rope.

Haul rope terminal sheaves that act as driving, braking, or holding sheaves shall be so designed that the haul rope does not slip in the groove. The design coefficient of friction for a particular sheave liner shall not exceed the accepted standard values or the manufacturers recommended value.

Groove scrapers shall be mounted on all haul rope terminal sheaves, except winch drum applications.

2.1.2.7.3 Sheaves in tension systems and sheaves not specifically covered elsewhere in this standard

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

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 – Minimum diameters for sheaves in tension systems and sheaves not specifically covered elsewhere in this standard

Rope Type	Sheave diameter		
	Condition A	Condition B	Condition C
6x7 6x19 6x37	72*d* 45*d* 27*d*	42*d* 30*d* 18*d*	24*d* 20*d* 12*d*
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 2.1.2.11.2(c)).

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 sheaves 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.

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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 3.1.3.1). 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 sheave 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 sheave carriages

The available travel of the tension sheave and tension sheave 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 2.1.2.7.3 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 Manual and automatic control devices

All stop circuits and switches shall conform to the requirements of 2.2.1.7.

2.1.2.11.1 Manual stop devices

The following manual stop devices shall be installed and be conspicuously and permanently marked:

a) a stop device at each terminal platform;

b) a stop device on the conductor's control console in each carrier when a conductor is required in the carrier (see 2.1.1.5.1(d));

c) a stop device at the operator's station;

d) emergency shutdown device at each station and in the machine rooms (see 2.2.1.7.2).

2.1.2.11.2 Provisions for automatic stop devices.

The following automatic stop devices or systems shall be installed:

a) a device(s) that will be actuated in the event manual or automatic controls fail to reduce funicular speeds to design values at critical control points along the guideway;

b) a device(s) that will stop the funicular before the carrier reaches its limit of travel. A buffer system shall also be installed in accordance with 2.1.3.7;

c) a device(s) that will not allow the funicular to start when the tensioning system exceeds its range of normal operating travel. When pneumatic or hydraulic tensioning systems are used, pressure-sensing devices shall also be incorporated that will stop the funicular system in case the operating pressure falls below or exceeds the design pressure range. Such pressure-sensing devices shall be located close to the actual tensioning device;

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d) a device that will be actuated by the application of the carrier brake. These devices shall effect an emergency shutdown;

e) a device that will stop the funicular in the event a cabin door is not closed;

f) guideway obstruction sensors (mounted on front of carriers in the direction of travel, for automated unattended carriers only);

g) a mechanical overspeed device mounted on or directly connected to the drive sheave or drum shall apply the drive sheave brake in the event the funicular speed exceeds the rated speed by more than 15% in either direction;

h) a device shall be installed which will initiate a stop in the event the funicular speed exceeds the rated speed by more than 10% in either direction;

i) a device that will be actuated in the event of inadvertent actuation of the drive brake system;

j) a device that will stop the funicular in the event that the haul rope comes in contact with the guideway or other grounded equipment, when required by 2.1.1.5.1(c);

k) an overspeed device mounted on the carrier that shall actuate a carrier brake (see 2.1.2.5.3) in the event the carrier exceeds the rated speed by more than 25%;

l) a device that will stop the funicular in the event of a haul rope failure or when the minimum rope tension specified by the designer is not met.

2.1.2.12 Venting for tunnels and enclosures

2.1.2.12.1 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 2.1.1.10.1).

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

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.

2.1.2.12.2 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 in enclosed funiculars;

b) Produce airflow rates sufficient to prevent backlayering of smoke in the path of egress within enclosed funiculars;

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.

2.1.2.12.3 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).

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

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 airflows 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 91-1998, *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.

2.1.2.12.4 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 re-circulation 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.

2.1.2.12.5 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.

2.1.2.12.6 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 110-2002, *Standards for emergency and standby power systems*

All wiring materials and installations shall conform to the requirements of ANSI/NFPA 70-2001, *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 70-2001;

c) All insulation shall conform to Article 310 of ANSI/NFPA 70-2001 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-

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propagating criteria of IEEE Std 383-1974 (R1992), *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.

2.1.2.12.7 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 light, portable ladders shall be provided. The latter, if used, shall be in at least sufficient quantity to be available at each point where attendants are stationed (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 nonoperating 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, which ever 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 wheel load shall not be less than

$20\% \times 1/n \times L \times \cos \propto$

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
$\propto$ = Inclination of guideway
n = Number of wheels per carrier

2.1.3.6 Guideway passing zone

Where guideway passing zones are required for the passage of the carriers at mid-point, minimum clearances between the carriers in accordance with 2.1.1.4.3 shall be maintained for a length equal to or greater than the length of a carrier or line of carriers.

Passing zone lengths shall take into consideration the stopping distance of the carrier haul rope failure from rated speed, such that the carriers do not come into contact while in the passing zone.

2.1.3.7 End of guideway buffers (bumpers)

At the end of each guideway of the funicular, energy-absorbing buffers shall be provided to prevent carriers from impacting the terminal structures in the event of an overtravel. These buffers shall be designed to absorb the energy of impact and bring to a full stop, without damage to the terminal, a loaded carrier or line of carriers. The minimum velocity for the design of the buffers shall be the lowest normal supervised

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speed during terminal entry, as determined by the manufacturer.

2.1.3.8 Emergency exit detail

Emergency exits shall be provided from tunnels and enclosed guideways to a point of safety.

Emergency exit stairways shall be provided throughout the tunnels and spaced so that the distance to an emergency exit shall not be greater than 1250 feet (381 meters) unless otherwise approved by the authority having jurisdiction. The stairway shall be designed in accordance with ANSI/NFPA 101-2003, *Code for safety to life from fire in buildings and structures*, Class A designation. The stairway shall be enclosed and shall lead directly to the outdoors or to a safe refuge area.

Doors to the exit access shall open in the direction of exit travel and shall be equipped with hardware in accordance with ANSI/NFPA 101-2003. The force required to open the doors fully when applied to the latch side shall be as low as possible, not exceeding 50 lb (222 N). In addition, doors and hardware shall be adequate to withstand positive and negative pressures created by passing carriers.

Emergency exit facilities shall be suitably identified and maintained to allow for their intended use.

2.1.4 Guideway equipment

2.1.4.1 Haul rope(s)

See Section 3 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.

2.1.4.1.2 Minimum haul rope tension

The minimum operating haul rope tension under any condition of loading and/or deceleration shall be greater than the minimum rope tension value set for the automatic triggering of the guideway carrier brake (see 2.1.2.5.3(c)).

In the drive station, a rope tension-monitoring device shall be installed to stop the drive if the rope tension is beneath a minimum standard recommended value specified by the funicular designer (see 2.1.2.11.2(l)).

2.1.4.2 Guideway sheaves and mounts

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 structural members of the guideway.

Construction of the sheave mounting or of a sheave unit shall be such that the rope cannot become entangled in the mounting or sheave unit at such time as the rope leaves the sheaves(s).

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.

If required, sheave and sheave mount 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

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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 3.0 does not exceed the material yield strength at any point.

A minimum factor of safety of 2.0 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 funiculars 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 1.0 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 3.3.2 Use of a type of attachment other than those listed in 3.3.2 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

Fully enclosed passenger cabins shall be adequately ventilated.

Each compartment door shall be provided with a lock located in such a manner that it can be locked and unlocked only by authorized persons or by automatic means. The minimum opening width shall be 32 inches (815 mm). Automatic doors must not exert a closing force in excess of 30 pounds (133 N) at any point in its travel. All automatic doors shall be equipped with “safety edges” or sensors that extend the full height of the doorway and will stop and reopen the door in the event that it is obstructed while closing.

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.

All enclosed carriers or compartments shall have an emergency exit (see 2.1.1.4.3 and 2.1.1.10.1).

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.

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).

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 number of 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 be equipped with interior lighting and emergency lighting (see 2.2.2);

b) carriers shall be equipped with exterior headlights in each direction of travel.

Cabins with a capacity of under 35 persons shall be equipped with a 10-lb. Dry Chemical ABC fire extinguisher, clearly visible, with instructions concerning its use.

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Cabins with a capacity of over 35 persons shall be equipped with a minimum of two 10-lb. Dry Chemical ABC fire extinguishers, clearly visible, with instructions concerning their use.

2.1.5.4.1 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.

2.1.5.4.2 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 of ANSI/NFPA 130-2003*, 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 stations shall be located to provide visual surveillance of the incoming carriers and loading and unloading platforms. When operator and attendant work stations are enclosed they shall be heated, ventilated, shielded from noise, and lighted as required to perform the assigned duties. When the work station is enclosed, it shall contain:

a) the communications and controls required of the station;

b) the operating instructions and emergency procedures;

c) a fire extinguisher(s);

d) controls for the operation of auxiliary drive or alternate carrier unloading system.

This does not preclude additional communications and controls located outside the work station. All enclosed work stations shall be locked to prevent unauthorized entry. The operator shall be located where he/she can observe the loading and unloading platforms. The operator's controls and communicating devices shall be within reach of the operator's position.

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.

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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

All electrical systems shall comply with *American National Standard National electrical code,* ANSI/NFPA 70-2001, and *American National Standard National electrical safety code*, ANSI/IEEE C2-2002.

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 C2-2002.

2.2.1.3 Protection

All transformer stations and other high voltage electrical equipment shall be marked with conspicuous warning signs and shall be protected so as to prevent unauthorized persons from entering the area or coming in contact with any portion of the equipment or wiring. All power equipment shall be protected against overloads by circuit breakers or fuses.

2.2.1.4 Voltage limitations for overhead circuits

Signal, communication, and control circuits may be supported above grade. Voltage on overhead or exposed circuits shall be limited to 50 volts with the exception of the intermittent ring-down circuits for telephone systems.

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 Parts A and B of ANSI/NFPA 70-2001.

2.2.1.5.2 Communication wiring

All communication wiring and systems are exempt from the requirements in Article 800 of ANSI/NFPA 70-2001.

2.2.1.5.3 Insulation

All control wiring is excepted from the requirements of Article 800 of ANSI/NFPA 70-2001. 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.

2.2.1.6 Grounding

2.2.1.6.1 Structures

All metallic structures shall be connected to a common bonding conductor (see 2.2.1.6.2) for the purpose of grounding the control circuit in such a manner that an inadvertent ground, anywhere in the control circuit, would stop the funicular as required in 2.2.1.7.1. 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 70-2001. All DC and AC electrical systems shall be referenced 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 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.

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2.2.1.6.4 Lightning protection

If lightning protection is provided, it shall follow *Standard for the installation of lightning protection systems*, ANSI/NFPA 780-1997.

2.2.1.7 Circuits

2.2.1.7.1 Operating control circuits

All funicular systems shall contain one or more normally de-energized circuit(s) that, when energized, allow(s) the system to start, accelerate to and run at designated speeds, and when interrupted or de-energized by manual stop switches, automatic stop devices, inadvertent ground or a power failure, cause(s) the system to stop.

Operating circuits shall not have anything across or parallel with the contacts of switches, relays, or automatic stopping devices (including solid state devices monitoring the circuits or devices), unless it can be shown that any failure mode of the device placed across the contacts does not defeat the purpose of the operating circuit devices.

All start/run/stop and speed control switches shall be conspicuously and permanently marked with its intended function.

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.

2.2.1.7.2 Emergency shutdown circuit

All funicular systems shall include a normally de-energized circuit that, when energized, allows the system to run and when interrupted, effects an emergency shutdown (see section 1.4 – *emergency shutdown*). The emergency shutdown shall have priority over all other control stops or commands. Any one of the following conditions is considered a loss of control of a funicular:

a) funicular will not SLOW DOWN when given the command to do so;

b) funicular will not STOP when given the command to do so;

c) funicular OVERSPEEDS beyond control settings and/or maximum design speed;

d) funicular ACCELERATES faster than normal design acceleration;

e) funicular SELF-STARTS or SELF-ACCELERATES without the command to do so;

f) funicular REVERSES direction unintentionally and without the command to do so.

The shutdown circuit shall not have anything across or parallel with the contacts of switches, relays, or other devices in this circuit, but can have such devices as solid state monitoring devices and microprocessors in series with the manual shutdown device and main control contacts (main control disconnect coil).

This circuit shall include a manual shutdown device at each station and in the machine room. The shutdown device shall be conspicuously and permanently marked and shall be red in color.

2.2.1.7.3 Bypass circuits

A temporary bypass circuit may be installed for malfunctions in operating control circuitry (see 2.3.2.5.9).

Prewired controls bypassing any portion of the operating control circuitry shall be located such that it may be operated only by the supervisor of the funicular or his/her designated representative.

The operator panel shall indicate that a bypass circuit is in use. The function bypassed shall be under constant, close visual observation

2.2.1.8 Electrical prime mover and power circuits

2.2.1.8.1 Electrical prime mover

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.

2.2.1.8.2 Electronic speed-regulated drives

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

a) field loss (dc motors);

b) speed feedback loss;

c) overspeed;

d) overcurrent;

e) overacceleration.

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2.2.1.9 Electrical system acceptance tests

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).

2.2.1.10 Software security

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.

2.2.2 Illumination

2.2.2.1 Station illumination

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).

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

a) Approval shall be obtained from a Qualified Engineer;

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

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

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

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.

2.2.2.2 Carrier illumination

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

Under nonemergency operating conditions, interior lighting levels shall be a minimum of 5 ft-candles (54 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.

2.2.2.3 Emergency lighting

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

a) regular unloading of funicular facilities;

b) emergency evacuation of carriers;

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

2.2.2.3.1 Emergency station/guideway lighting

Emergency lighting systems shall be installed and maintained in accordance with ANSI/NFPA 70-2002.

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. Emergency fixtures, exit lights, and signs shall be wired separately from the emergency distribution panels.

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.

2.2.2.3.2 Emergency carrier lighting

Emergency lighting power is to be provided by vehicle-born 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.

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2.3 Operation and maintenance

2.3.1 General and personnel safety

This subsection covers the requirements for operation and maintenance of a funicular. Many requirements are listed elsewhere in Section 2, 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).

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.

2.3.1.1 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 the number of 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.

Additionally, 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 auxiliary or prime mover when persons are working on the funicular (see 2.1.1.12).

2.3.2 Operation

2.3.2.1 Personnel

Funiculars shall be operated by trained and competent personnel, and the owner shall be responsible for their supervision and training. Procedures for assisting passengers loading and unloading, 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 passenger operation. 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 safety regulations of the specific funicular.

2.3.2.1.1 Supervisors

One individual shall be in responsible charge of all operating personnel and attendants. This individual shall be responsible for the operation, and shall have the authority to deny access to the funicular to any person who, in the supervisor’s opinion, is not fit or competent to use the funicular without danger to that person, to others, or to the equipment. The supervisor shall also have the authority to prohibit operation of the funicular under adverse weather or operational conditions. Although he/she may delegate authority to others, the supervisor has the final responsibility.

2.3.2.1.2 Operators

An operator shall be in charge of each funicular. This operator shall be trained and experienced in normal operational and emergency procedures, and such training shall be documented.

2.3.2.1.3 Attendants

An attendant will be assigned to particular duties under direction of the operator. The attendant shall be familiar with operational and emergency procedures, pertaining to their assignment. This training shall include instruction for observation of any potentially dangerous operational or mechanical developments within their view, and such training shall be documented.

2.3.2.1.4 Conductors

Conductors, if required or utilized, 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 conductor shall be familiar with load limits and applicable safety regulations, well versed in the use of any manual switches under their control, and thoroughly trained in the use of emergency evacuation equipment and procedures, and such training shall be documented.

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2.3.2.1.5 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) the supervisor and/or an operator who shall be in charge of the funicular;

b) one attendant who shall be on duty at each loading/unloading platform or station;

c) a conductor shall be in each carrier, if required (see 2.1.1.5.1). A conductor may also act as a platform or station attendant and an operator.

2.3.2.3 Duties of operating personnel

2.3.2.3.1 Supervisor

The duties of the supervisor shall be as follows:

a) to determine that the funicular is operational and that all operating personnel are trained, equipped, and fit to perform their duties;

b) to discontinue operations on any funicular due to physical, weather, personnel, or other reasons;

c) to enforce operational, maintenance, and safety rules.

2.3.2.3.2 Operator

The duties of the operator shall be as follows:

a) to assume responsible charge of the funicular;

b) to assign and supervise all attendants on his/her funicular;

c) to maintain an operational logbook as required in 2.3.5.1;

d) to advise the supervisor of any condition or occurrence that may adversely affect the safety of the operation.

2.3.2.3.3 Attendant and conductor

The duties of the attendant and conductor shall be as follows:

a) to maintain orderly passenger traffic conditions within his/her area of jurisdiction;

b) to advise and assist passengers, as required;

c) to maintain surveillance of his/her area of jurisdiction.

The operator shall be advised of any unusual or improper occurrences. Should a condition develop in which continued operation might endanger a passenger, the attendant/conductor shall stop the funicular immediately and advise the operator The operator shall also be advised of changes in weather, or unusual conditions.

2.3.2.4 Operational procedures

The required operational procedures as set forth in 2.3.2.4 through 2.3.2.5 shall be supplemented by specific requirements as specified in the designer's operational manual (see 2.1.7.1).

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 transporting passengers, or at least once per day during operation, an inspection shall be conducted. 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, and loading and unloading areas per the manufacturer's recommendations;

d) operation of all drive braking systems;

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 auxiliary internal combustion engines, the fuel supply shall be adequate to unload the funicular. During refueling, power units shall be shut down.

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Funiculars having auxiliary power units (APU) or alternate carrier unloading (docking) system shall have the auxiliary engine(s) or system(s) checked during this inspection and operated at least once each week. The funicular auxiliary or alternate unloading systems (if containing an APU) shall be operated with the APU for at least 30 minutes per month;

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

Entrances to all machinery, operators', and attendants' rooms shall be locked when not in use. Unattended entrances accessible to the public, which may be left open, shall be equipped with barriers to entry.

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

No funicular shall be started except at the direction of, or following clearance by, the operator. Funiculars, while operating for the public, shall be started at the operator's station only. Capability for starting from other stations may be provided for maintenance or emergency operation.

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 stations.

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. 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 (see 2.1.1.10.1).

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 positions or names of individuals responsible for determining the need for an evacuation;

2) the positions or names of individuals responsible for ordering an evacuation;

3) the positions or names of individuals responsible for performing the evacuation, for first aid, and for ground care of evacuated passengers.

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

c) provisions for adequate training in the functions performed in the evacuation process at least once each operating season. Such drills are to be recorded in the operational log of each funicular (see 2.3.5.1);

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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

Prior to and during the use of a bypass circuit that has been installed for the purpose of bypassing normal operating control circuits, the conditions listed in this subsection shall be met 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.

2.3.3 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) bull wheels, 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).

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2.3.3.2 Maintenance personnel

Funiculars shall be maintained by trained and competent personnel, and 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:

a) braking systems;

b) auxiliary power units;

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 3.4.

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 duty stations of operating personnel;

c) operating hours and purpose of operations;

d) temperature, wind, and weather conditions;

e) record of compliance with daily 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)).

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2.3.5.2 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 3.1.1);

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 3.4.1);

g) report of wire rope inspections (see 3.4.1);

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

i) documentation of end attachment (see 3.4.2).

2.3.5.3 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.

2.3.6 Passenger conduct

2.3.6.1 Dexterity and ability

Any passenger who uses a funicular shall be presumed to have sufficient physical dexterity or personal assistance, and compatible equipment to negotiate and evacuate the funicular safely.

2.3.6.2 Embarkation and disembarkation

A passenger shall embark and disembark a funicular at designated areas. No passenger shall embark without first understanding the proper loading, riding, and unloading procedures of the funicular.

2.3.6.3 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.

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Section 3
Wire rope and end connections requirements

3.1 Physical properties

3.1.1 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 3.1.

Copies of the specification shall be furnished to the funicular manufacturer, owner, and authority having jurisdiction.

3.1.1.1 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) nominal breaking strength;

h) type of lubrication.

Only wire rope that is the subject of, and in compliance with, the specification shall be installed on a funicular.

3.1.1.2 Relocated Wire Rope

Before a wire rope can be relocated, the following shall be preformed:

a) A visual wire rope inspection, and an internal inspection of the rope at several random locations shall be preformed to determine its condition. A copy of the original test certificates and service history shall be supplied to the wire rope inspector before the inspection.

b) An EWRT examination shall be performed in conjunction with the visual inspections.

c) A Qualified Engineer shall certify that the rope meets the requirements of the funicular specifications and this standard, based on the above visual wire rope inspections and EWRT report, before the used rope is installed.

Copies of the original test certificates, inspections, and EWRT test shall be furnished to the owner and authority having jurisdiction.

3.1.2 Diameter tolerance

3.1.2.1 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 nominal breaking strength.

3.1.3 Nominal breaking strength

In a test, an acceptable wire rope shall not break under a tension less than of its nominal breaking strength (see 3.2.1.3).

NOTE – The term “Minimum Breaking Force” is replacing the term “Nominal Breaking Strength” internationally and in the new ASTM Wire Rope Standard. This new terminology change will be used in new wire rope catalogs. Until the new Wire Rope Standard is formally accepted and published, the term “Nominal Breaking Strength” will be used in this standard.

3.1.3.1 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 nominal breaking strength listed in the manufacturer’s published catalog or table 3-1 for the diameter, classification, and strength grade selected by the designer.

The factor of safety is equal to the nominal breaking strength of the rope divided by the maximum steady state tension.

For ropes not listed by grade or classification in table 3-1, the designer shall base the funicular calculations including design factor of safety on the rope manufacturer’s nominal breaking strength. The suitability and application of the rope shall be agreed upon by the designer and rope manufacturer with the knowledge of the owner. Consideration shall be given as to the parameters and intervals of inspection and retirement criteria for these ropes and they shall be listed in the specification.

Certain types of funiculars may require wire rope diameters other than the fractional sizes shown in table 3-1 in order to be compatible with the equipment design. Nominal breaking strengths for ropes having nominal diameters between those listed in table 3-1 shall be determined by the following formula:

$$NBS = \frac{nbs \times D^2}{d^2}$$

NBS = Nominal breaking strength of size required
nbs = Nominal breaking strength of closest nominal size in table 3-1
D = Nominal diameter of size required
d = Nominal diameter of closest nominal size listed in table 3-1

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3.1.4 Torsion requirements

3.1.4.1 Wire torsion values for wire rope

Wires shall meet the applicable torsional values shown in table 3-2.

Wire torsion tests are not required for wire ropes in tension systems.

3.2 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.

3.2.1 Testing procedures - wire rope

3.2.1.1 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.

From each short sample, a minimum of one specimen of each size of main wires from each strand shall be taken. The total number of specimens shall not be less than 15% of the total number of main wires.

When wires are tested prior to fabrication, the same density of sampling shall be employed. Records shall be kept by the manufacturer to enable identification of such wires with the actual rope produced.

3.2.1.2 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 3.1.2.1). The average of these three measurements shall be the diameter of the wire rope being inspected.

3.2.1.3 Ultimate-strength test

An ultimate strength test shall be made on a complete rope. The tests shall be made on the long sample (see 3.2.1.1). The actual (measured) breaking force shall meet or exceed the nominal breaking strength (minimum breaking force) specified for the wire rope.

3.2.1.4 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.

3.2.1.4.1 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 3-3 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.

3.2.1.4.2 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 (100 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 (100 mm) shall not break when twisted one-half the number of revolutions shown in table 3-2. The wire specimens with a free length of 6 inches (150 mm) shall not break when twisted three-fourths the number of revolutions shown in table 3-2. Testing shall be done in the same manner as described in 3.2.1.4.1.

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Table 3-1 – Wire Rope Minimum Breaking Force (Nominal Breaking Strength)

DIAMETER		6x7 FC		6X19 AND 6X36 FC						6X19 AND 6X36 IWRC						DIAMETER RANGE See 3.1.2.1	
in.	mm	IPS tons	1770 kN	IPS tons	1770 kN	EIP tons	1960 kN	EEIP tons	2160 kN	IPS tons	1770 kN	EIP tons	1960 kN	EEIP tons	2160 kN	Min.-in.	Max.-in.
	6		21.2		21		23.3		25.7		22.7		25.1		27.7	0.236	0.250
1/4		2.64		2.74		3.01				2.94		3.40				0.250	0.265
	7		28.8		28.6		31.7		34.9		30.9		34.2		37.7	0.276	0.292
5/16		4.1		4.26		4.69				4.58		5.27				0.313	0.331
	8		37.6		37.4		41.4		45.6		40.3		44.7		49.2	0.315	0.331
	9		47.6		47.3		52.4		57.7		51.0		56.5		62.3	0.354	0.372
3/8		5.86		6.1		6.71		7.38		6.56		7.55		8.30		0.375	0.394
	10		58.8		58.4		64.7		71.3		63.0		69.8		76.9	0.394	0.413
	11		71.1		70.7		78.3		86.2		76.2		84.4		93.0	0.433	0.455
7/16		7.93		8.27		9.1		10		8.89		10.2		11.2		0.438	0.459
	12		84.6		84.1		93.1		103		90.7		100		110.7	0.472	0.496
1/2		10.3		10.7		11.8		12.9		11.5		13.3		14.6		0.500	0.525
	13		99.3		98.7		109		120		106		118		130	0.512	0.537
	14		115		114		127		140		124		137		151	0.551	0.579
9/16		13		13.5		14.9		16.3		14.5		16.8		18.5		0.563	0.591
5/8		15.9		16.7		18.4		20.2		17.7		20.6		22.7		0.625	0.656
	16		150		150		166		182		161		179		197	0.630	0.661
	18		190		189		210		231		204		226		249	0.709	0.744
	19		212		211		233		257		227		252		278	0.748	0.785
3/4		22.7		23.8		26.2		28.8		25.6		29.4		32.4		0.750	0.788
	20		235		234		259		285		252		279		308	0.787	0.827
	22		284		283		313		345		305		338		372	0.866	0.909
7/8		30.7		32.2		35.4		39.0		34.6		39.8		43.8		0.875	0.919
	24		338		336		373		411		363		402		443	0.945	0.922
1		39.7		41.8		46		50.6		44.9		51.7		56.9		1.000	1.050
	26		397		395		437		482		426		472		520	1.024	1.075
	28		461		458		507		559		494		547		603	1.102	1.157
1 1/8		49.8		52.6		57.9		63.6		56.5		65.0		71.5		1.125	1.181
1 1/4		61		64.6		71.1		78.2		69.4		79.9		87.9		1.250	1.313
	32		602		598		662		730		645		715		787	1.260	1.323
1 3/8		73.1		77.7		85.5		94.0		83.5		96.0		106		1.375	1.444
	36		762		757		838		924		817		904		997	1.417	1.488
1 1/2		86.2		92		101		111		98.9		114		125		1.500	1.575
	40				935		1035		1140		1008		1116		1230	1.575	1.654
1 5/8				107		118		129		115		132		146		1.625	1.706
	44				1131		1252		1380		1220		1351		1489	1.732	1.819
1 3/4				124		136		150		133		153		169		1.750	1.838
1 7/8				141		155		171		152		174		192		1.875	1.969
	48				1346		1490		1642		1452		1608		1772	1.890	1.984
2				160		176		194		172		198		217		2.000	2.100
	52				1579		1749		1927		1704		1887		2079	2.047	2.150
2 1/8				179		197		217		192		221		243		2.125	2.231
	56				1832		2028		2235		1976		2188		2411	2.205	2.315
2 1/4				200		220		242		215		247		272		2.250	2.363
	60				2103		2328		2566		2268		2512		2768	2.362	2.480
2 3/8				222		2344		269		239		274		301		2.375	2.494

NOTES – Tons = 2000 pounds. 1770, 1960, 2160 = Rope Grade in SI units

Table 3-2 Torsion values for main rope wires

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

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

Table 3-3 Tensile force on wires during torsional test

Wire Diameter		**Tensile Force**	
From (in)	**To** (in)	**Minimum** (lb)	**Maximum** (lb)
0.000	0.009	0.5	1.0
0.010	0.014	1.0	2.0
0.015	0.019	1.5	3.0
0.020	0.029	2.0	4.0
0.030	0.039	3.0	6.0
0.040	0.049	4.0	8.0
0.050	0.059	5.0	10.0
0.060	0.069	6.0	12.0
0.070	0.079	3.0	14.0
0.080	0.089	8.0	16.0
0.090	0.099	9.0	18.0
0.100	0.109	10.0	20.0
0.110	0.119	11.0	22.0
0.120	0.129	12.0	24.0
0.130	0.139	13.0	26.0
0.140	0.149	14.0	28.0
0.150	0.159	15.0	30.0
0.160	and up	16.0	32.0

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3.2.3 Test reports

3.2.3.1 Wire rope

The test reports for wire rope shall include the following:

a) complete description of wire rope furnished for the test, including number and arrangement of wires, grade, type of core, and nominal breaking strength;

b) actual rope diameter;

c) actual (measured) breaking force (see 3.2.1.3);

d) actual breaking strength and size of wires tested;

e) actual torsion of wires tested.

3.2.4 Rejects and retests

3.2.4.1 Rejects

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.

3.2.4.2 Retests

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.

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.

3.3 Connections for wire rope

3.3.1 Splices

3.3.1.1 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.

3.3.1.2 Ropes used in tension systems

No splices shall be permitted in tension system ropes.

3.3.2 End connections

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.

3.3.2.1 Wire ropes used in tension systems

End connections shall be designed to not fail or slip under a tension equal to 80% of the nominal breaking strength of the rope and shall be in accordance with 3.3.2.3.

3.3.2.2 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.

3.3.2.3 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.

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3.3.2.3.1 Poured sockets

a) Zinc sockets shall have documentation of all pertinent data including chemical composition of the material used, temperature of pouring material and preheated socket body; and name and signature of person preparing and pouring the socket.

b) Resin sockets shall have documentation of all pertinent data including the cleaning process, material used in the socket; and name and signature of the person preparing the socket.

3.3.2.3.2 Swaged sockets

Swaged sockets shall be attached by a competent person or facility (see note in 3.3.2.3) 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.

3.3.2.3.3 Wire rope clips and thimbles

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%.

3.3.2.3.4 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).

3.3.2.3.5 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.

3.3.2.3.6 Mechanical 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.

3.4 Maintenance and replacement

3.4.1 Wire rope

Wire rope maintenance shall include the following:

a) *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;

b) *Inspection*: All ropes shall be subject to detailed inspections at regularly established intervals, not to exceed 1 year, or immediately after any accident possibly affecting the integrity of the wire rope. When either the ratio of the bull wheel to the haul rope diameter of an funicular is less than 96 or when the design factor of safety of the haul rope for any funicular is less than 5, the visual inspection interval shall not exceed 1000 hours of operation;

c) *EWRT Inspection*: An EWRT shall be performed within the first 500 hours of operation when a new or relocated rope is installed and every 6000 hours of operation thereafter.

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

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the rope past a fixed inspection station. Frequent stops shall be made to permit detailed inspection and make necessary measurements.

Splices and fixed grip locations 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.

These inspections shall be made by a competent wire rope inspector who may be an employee of the owner. A competent 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.

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 3.4.1.1. 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).

3.4.1.1 Repair/replacement of wire rope

No rope is allowed to remain in service when, in the opinion of a qualified wire rope inspector, the strength of the rope has been reduced to less than 80% of the maximum steady state tension of the funicular multiplied by the applicable design factor of safety.

Repair or replacement of a wire rope shall be determined by the inspector utilizing the criteria from 3.4.1.1.1.

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 3.4.1.2.

3.4.1.1.1 Criteria

The general conditions, history, and following criteria shall be used by the inspector in deciding upon repair or replacement of the wire rope:

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

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

c) evidence of rope deterioration from corrosion;

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

e) 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;

f) 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;

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

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

i) broken wires in one lay length in excess of 7.5% of the cross sectional metallic area of the rope or 25% of the metallic cross sectional area of one strand (localized damage), or broken wires in five lay lengths in excess of 10% of the metallic cross sectional area of the rope (uniformly distributed damage). Broken filler wires are not counted.

NOTE – When calculating the number of broken wires from the metallic cross sectional area, the results will be rounded down to the next whole wire. See Annex D for examples of wires allowed for calculated metallic cross sectional areas of different wire rope constructions.

3.4.1.1.2 Accidental damage

When damage to a rope is accidental and is a non-repetitive event, wire breaks in excess of those stated in 3.4.1.1.1(i) may exist, provided that:

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

b) details of the cause are apparent and identifiable;

c) the area is appropriately marked and observed at intervals required by the wire rope inspector. Written documentation shall be maintained;

d) the cause is corrected.

3.4.1.2 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 and construction. Damaged splices can often be corrected by proper repair.

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:

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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. The tuck, or tucks, shall be at the normal point, or points of tuck, in the existing 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.

3.4.2 Connections

3.4.2.1 Splices

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

a) the number of broken wires at a tuck exceeds the values given in 3.4.1.1.1(i). Leading and trailing tuck strands shall be considered independent of one another when making this evaluation. Broken filler wires are not counted;

b) any sign of slippage;

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

d) the rope diameter measures less than 94% of the original nominal rope diameter.

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

3.4.2.2 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) any slippage of attachment fitting;

d) evidence of deterioration from corrosion;

e) does not meet the parameters specified in 3.3.2.

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.

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Section 4
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 B77.1-1999, *Passenger ropeways – Aerial tramways, aerial lifts, surface lifts, tows, and conveyors – Safety requirements*

ANSI/IEEE C2-2002, *National electrical safety code*

ANSI/ASME B15.1-2000, *Safety standard for mechanical power transmission apparatus*

ANSI/NFPA 30-2003, *Flammable and combustible liquids code*

ANSI/NFPA 37-2002, *Stationary combustion engines and gas turbines*

ANSI/NFPA 70-2001, *National electrical code*

ANSI/NFPA 91-1998, *Standard for exhaust systems for air conveying of vapors, gasses, mists, and noncombustible particulate solids*

ANSI/NFPA 130-2003, *Standard for fixed guideway transit and passenger rail systems*

ANSI/NFPA 780-1997, *Standard for the installation of lightning protection systems*

For underground installations only:

ANSI/NFPA 101-2003, *Code for safety to life from fire in buildings and structures*

ANSI/NFPA 110-2002, *Standards for emergency and standby power systems*

ANSI/NFPA 220-1999, *Standard on types of building construction*

IEEE Std 383-1974 (R1992); *Standard for type tests of Class IE electrical cables, field splices, and connections for nuclear power generating stations*

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Annexes

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Annex A
(informative)

Ventilation

A.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.

A.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/ft^2/hr (6305 W/m^2) for a few seconds, averaging 500 Btu/ft^2/hr (1576 W/m^2) or less for the first 6 minutes of exposure, averaging 300 Btu/ft^2/hr (946 W/m^2) 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.

A.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.*

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Annex B
(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.

To convert from	To	Multiply by
Acceleration		
feet per second^2	meter per second^2 (m/s^2)	3.048 000 E–01
inches per second^2	meter per second^2 (m/s^2)	2.540 000 E–02
feet per minute^2	meter per minute^2 (m/m^2)	1.828 800 E+00
Angle		
degree (angle)	radian (rad)	1.745 329 E–02
minute (angle)	radian (rad)	2.908 882 E–04
second (angle)	radian (rad)	4.848 137 E–06
Area		
feet^2	meter^2 (m^2)	9.290 304 E–02
inch^2	meter^2 (m^2)	6.451 600 E–04
Bending Moment of Torque		
pound-foot • inch	newton meter (N•m)	1.129 848 E–01
pound-foot • foot	newton meter (N•m)	1.355 818 E+00
Bending Moment or Torque per Unit Length		
pound-foot • foot/inch	newton meter per meter (N•m/m)	5.337 866 E+01
pound-foot • foot/inch	newton meter per meter (N•m/m)	4.448 222 E+00
Force		
kip (1000 lbf)	newton (N)	4.448 222 E+03
pound-force (lbf avoirdupois)	newton (N)	4.448 222 E+00
Force per Unit Length		
pound-foot/foot	newton per meter (N/m)	1.459 390 E+01
pound-foot/inch	newton per meter (N/m)	1.751 268 E+02
Length		
foot	meter (m)	3.048 000 E–01
inch	meter (m)	2.540 000 E–02
mile (statute)	meter (m)	1.609 3 E+03

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To convert from	To	Multiply by
Mass		
pound (lb avoirdupois)	kilogram (kg)	4.535 924 E–01
ton (short, 2000 lb)	kilogram (kg)	9.071 847 E+02
Mass per Unit Area		
pound/foot^2	kilogram per meter^2 (kg/m^2)	4.882 4.28 E+00
pound/inch^2	kilogram per meter^2 (kg/m^2)	7.031 000 E+02
Mass per Unit Length		
pound/foot	kilogram per meter (kg/m)	1.448 164 E+00
pound/inch	kilogram per meter (kg/m)	1.785 797 E+01
Mass per Unit volume		
pound/foot^3	kilogram per meter^3 (kg/m^3)	1.601 846 E+01
pound/inch^3	kilogram per meter^3 (kg/m^3)	2.767 990 E+04
Temperature		
degree Fahrenheit	degree Celsius	$t°_C = (t°_F - 32)/1.8$
degree Fahrenheit	kelvin (K)	$t_K = (t°_F + 459.67)/1.8$
Velocity		
feet/hour	meter per second (m/s)	8.466 667 E–05
feet/minute	meter per second (m/s)	5.080 000 E–03
feet/second	meter per second (m/s)	3.048 000 E–01
inch/second	meter per second (m/s)	2.540 000 E–02
Volume		
feet^3	meter^3 (m^3)	2.831 685 E–02
gallon (US dry)	meter^3 (m^3)	4.404 884 E–03
inch^3	meter^3 (m^3)	1.638 706 E–05
yard^3	meter^3 (m^3)	7.645 549 E–01
Volume per Unit Time		
feet^3/minute	meter^3 per second (m^3/s)	4.719 474 E–04
feet^3/second	meter^3 per second (m^3/s)	2.831 685 E–02
inch^3/minute	meter^3 per second (m^3/s)	2.731 177 E–07

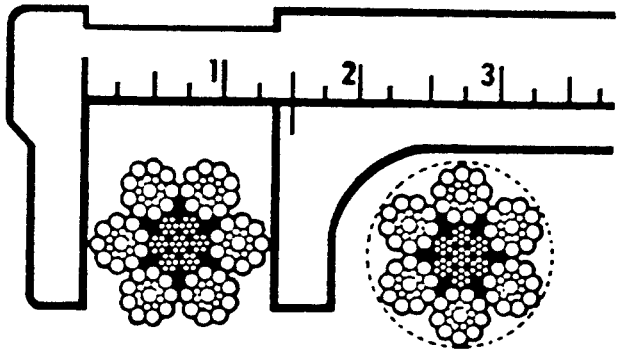
Multiplication factor	Prefix	Symbol
$1000 = 10^3$	kilo	k
$100 = 10^2$	hecto	h
$10 = 10^1$	deka	da
$0.1 = 10^{-1}$	deci	d
$0.01 = 10^{-2}$	centi	c
$0.001 = 10^{-3}$	milli	m

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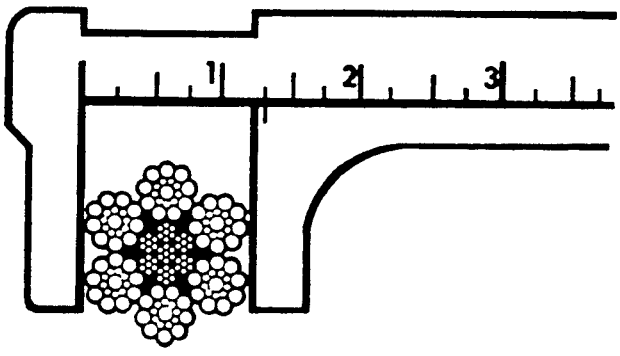
Annex C
(informative)

Measuring the diameter of wire rope

It is quite easy and not uncommon to mismeasure the diameter of a wire rope. Figure C.1 provides the two possible ways of measuring the rope.



CORRECT WAY
(This position gives correct diameter)
(a)



INCORRECT WAY
(This position does not give correct diameter)
(b)

Figure C.1 – Measuring the diameter of wire rope

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Annex D
(informative)

Examples of allowable broken wires in different wire rope constructions

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.

Table D-1 shows examples of the variation in numbers of allowable broken wires for several rope diameters and construction. These values are examples only. Each rope must have calculations done based on the data from the wire rope test reports due to variations between manufacturers. (See 3.2 - Testing.)

Table D-1 - Calculated broken wires allowed based on cross sectional metallic area of specific wire rope

Diameter / Rope Construction	Cross Sectional Metallic Area of rope	Outside wire diameter	Cross Sectional Metallic Area of wire	Number of Broken Wires		
				7.5% of rope in 1 lay	10% of rope in 5 lays	25% of strand in 1 lay
1/2 in 6x7 FC	0.0983 in^2	0.054 in	0.0023 in^2	3	4	1
1-3/8 in 6x19 Seale FC	0.7829 in^2	0.112 in	0.0099 in^2	5	7	3
32 mm 6x19 Seale FC	405 mm^2	2.55 mm	5.107 mm^2	5	7	3
1-1/2 in 6x25 Filler Wire FC	0.9572 in^2	0.098 in	0.0075 in^2	9	12	5
32 mm 6x25 Filler Wire FC	415 mm^2	2.05 mm	3.300 mm^2	9	12	5
1-1/4 in 6x31 Warrington Seale FC	0.7464 in^2	0.080 in	0.0050 in^2	11	14	6
1-5/8 in 6x36 Warrington Seale FC	1.2792 in^2	0.092 in	0.0066 in^2	14	19	8

$$\text{Broken Wires (7.5\% and 10\%)} = \frac{\text{Cross Sectional Metallic Area of Rope} \times \text{Percentage}}{\text{Cross Sectional Area of Wire}}$$

$$\text{Broken Wires (25\% in one Strand)} = \frac{\text{Cross Sectional Metallic Area of Rope} \times \text{Percentage}}{\text{Cross Sectional Area of Wire} \times 6}$$

NOTE: All calculated values for broken wires are rounded down to the next whole wire.

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(Numbers refer to subclause in this standard.)

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