ANSI®

B77.2-20??
Revision of
ANSI B77.2-2014

American National Standard
for Funiculars – Safety Requirements

Secretariat
National Ski Areas Association

Approved Date
American National Standards Institute, Inc.

American National Standard

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Published by

American National Standards Institute, Inc.
11 West 42nd Street, New York, NY 10036

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Printed in the United States of America

Contents

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

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

This standard is a revision of B77.2-2014 - *American National Standard for Funiculars – Safety requirements* and was originally based on the *American National Standard for Passenger Ropeways - Aerial tramways, Aerial Lifts, Surface Lifts, Tows and Conveyors - Safety requirements*, ANSI B77.1-1999..

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

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

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

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

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American National Standard for Funiculars – Safety Requirements

Section 1
General requirements

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

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

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

1.1 Scope

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

Funiculars typically have the following characteristics:

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

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

1.2 Purpose

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

a) reflect current state-of-the-art for funicular design, operation, and maintenance;

b) be acceptable for adoption by government agencies and others.

It is recognized that certain dangers and risks are inherent in machines of this type and their operation. It is also recognized that inherent and other risks or dangers exist for those who are in the process of embarking, riding, or disembarking from funiculars. This system is intended to result in funiculars that are designed, constructed, operated, and maintained in a manner that helps reduce danger, exposure to risk to passengers and maintenance and operational personnel, and to encourage improvements in productivity, efficiency, development, and progress consistent with the objectives.

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

1.2.1 Other classifications

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

1.2.2 New materials and methods for funiculars

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

1.2.3 Exceptions

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

1.2.4 Installations

1.2.4.1 Existing installations

Existing installations, and those with design review completed by the authority having jurisdiction prior to the effective date of this standard, need not comply with the new or revised requirements of this edition, except where specifically required by the authority having jurisdiction.

Operation and maintenance shall be in compliance with those requirements specifically listed (not included by reference) in the operation and maintenance subsection 2.3. and normative Annexes A and F 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 any of the following:

a) a change that increases the design speed of the system;

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

c) a change in the path of the rope or guideway;

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

e) a change in the structural arrangements;

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

g) a change of the control system logic.

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

1.2.5 Interpretation of standard

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

1.3 Reference to other codes and standards

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

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

1.4 Definitions

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

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

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

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

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

barrier: A device or object that provides a physical boundary to a hazard.

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

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

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

NOTE – The typical resistances effective in absorbing the energy of a funicular include:
a) the inherent resistance in the system (e.g., friction);
b) incidental resistance (e.g., slope, gravity, wind);
c) applied resistance (e.g., brake, power unit regeneration).

buffer: A device placed at the end of the carrier guideway, or installed on the carrier as an energy absorbing device in the event of overtravel.

bullwheel: A large grooved wheel at a terminal that rotates continuously when the haul rope is moving and deflects the haul rope by an angle of 10 degrees or more.

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

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

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

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

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

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

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

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

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

circuit, electrical: A pathway for electrical current generally to do work or effecting a function and implemented using electrical potential, electrical current, conductors, components, etc.

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 **device** to allow operation of the funicular, under the specific conditions set forth.

combustible liquid: A liquid having a closed cup flash point at or above 100° F (38° C). (Does not include compressed gas or cryogenic fluids). Combustible liquids are subdivided as follows (also see 1.4 – *diesel fuel*):

– Class II Flash point at or above 100° F and below 140° F.

– Class III Flash point at or above 140° F and below 200° F.

control function: Function that evaluates input information or signals and produces output information or activities (also see 1.4 – safety related control function).

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

device: A component, attachment, or mechanism designed to serve a specific purpose or perform a specific function.

Diesel fuel: A Class II combustible liquid fuel (also see 1.4 – *combustible liquid)*.

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.

drive system: A group or combination of interrelated elements which transmits power, or motion to the haul rope.

emergency shutdown: A safety function that initiates a Category 0 Stop (also see 1.4 – *Stop, Category 0)*.

Engine room: A machine room where an internal combustion engine(s) is located.

evacuation power unit: A power unit utilized for the evacuation of a funicular that once engaged, passenger loading ceases and the funicular operation is shutdown once the funicular has been unloaded.

factor of safety (wire rope): The ratio of the minimum breaking force of the rope and the maximum static design tension of the rope.

flammable material: A material capable of being readily ignited from common sources of heat or at a temperature of 600°F (316° C) or less.

flammable liquid: A liquid having a closed cup flash point below 100° F (38° C). (*Does not include compressed gas or cryogenic fluids*). flammable liquids are subdivided as follows (also see 1.4 – *gasoline*):

– Class IA flammable liquids have a flash point below 73°F and a boiling point below 100°F.

– Class IB flammable liquids have a flash point below 73°F and a boiling point greater than or equal to 100°F.

– Class IC flammable liquids have a flash point greater than or equal to 73°F and below 100°F.

flue gas temperatures: The temperatures of the flue products at the point or points of passing close to or through combustible materials, whichever is applicable.

function (electrical): a relationship between cause and effect (inputs and outputs). A function may be logical, mathematical, physical, linear, non-linear, etc. A function may be implemented with algorithms, programmed logic, circuitry (electrical, mechanical), etc. or any combination.

funicular: A system on which passengers or freight 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.

gasoline: A Class IB flammable liquid fuel (also see 1.4 – *flammable liquid)*..

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

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

guard: A barrier that prevents exposure to a hazard.

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

harm: Physical injury or damage to health of people.

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

hazard: A potential source of harm to people or damage to the funicular.

hazard area: (a.k.a. hazard zone) Any space within and/or around a machine in which a person can be exposed to a hazard.

hazardous situation: circumstance in which a person is exposed to a hazard.

loss of control: 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.

NOTE – Loss of control is outlined in Annex J. Table J.8, item 1,"Emergency Shutdown" safety-related control function.

machine room: A room or area where a combustion engine(s), mechanical, hydraulic, or electrical equipment are located.

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

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

NOTE – The term "Minimum Breaking Force" has replaced the term "nominal breaking strength" internationally and in the ASTM A1023 Wire Rope Standard.

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

normal stop: A control function that initiates a Category 0 Stop, Category 1 Stop, or Category 2 Stop (also see 1.4 – *Stop, Category 0, 1, 2*).

obstacle: Any object that may interfere with the funicular operation.

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

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

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

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

passenger: Any person utilizing a funicular for personal transportation.

perimeter guarding: A guard or safeguard designed to limit or detect an individual(s) entering a hazardous area after which the individual(s) is not continuously being detected.

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

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

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

qualified personnel: Individuals who, as a result of training and experience, understand and demonstrate competence with the design, construction, operation or maintenance of a funicular and associated hazards.

risk: The combination of the severity of possible harm and the likelihood of that harm occurring for a given hazard.

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

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

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

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

safeguarding: Protection of personnel from hazards by the use of guards, safeguarding devices, awareness devices or safeguarding methods.

safeguarding method: Safeguarding implemented to protect individuals from hazards by the physical arrangement of distance, holding, openings, or positioning of the machine or machine system to ensure that a hazard cannot be reached.

safe-location safeguarding method: A method of safeguarding by physically locating either the hazard or the individual such that the hazard is not accessible.

safety related control function: (a.k.a. *safety function*) - A control function of a machine whose failure can result in an immediate increase of the risk(s) (also see 1.4 – *control function*).

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

sheave: Pulley or wheel grooved for wire rope.

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

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

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, tension system: A sheave used in the tension reeving system.

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 manually or automatically that decelerates the funicular and brings it to rest using a Category 0, Category 1, or Category 2 stop (also see 1.4 – *brake*).

Stop, Category 0: A stop that when initiated causes one or more brakes (if installed) to be applied and power to be removed from the power unit.

Removing power from the power unit means:

– Electric motor: Full load rated contactor or circuit breaker disconnect devices, or equivalent safety means operate to shut down the motor;

– Internal Combustion engine: Engine shuts down.

NOTE – See 2.1.1.5, Stops and Shutdowns

Stop, Category 1: A stop with power to the power unit available to achieve the stop. Once motion has stopped a brake (if installed) shall be applied and power to the prime mover removed.

Stop, Category 2: A stop with power to the power unit available to achieve the stop. Once motion has stopped a brake (if installed) shall be applied, and power to the prime mover may be maintained.

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 personnel and operations for the funicular (also see 1.4 – *operator*).

tank, atmospheric storage: A storage tank that has been designed to operate at pressures from atmospheric through 1.0 psig (52mm Hg) measured at the top of the tank.

tank, day: A fuel tank, located inside a structure that provides fuel to an engine.

tank, integral: A fuel tank mounted on an engine and is specified or furnished by a qualified engineer, the engine, or the funicular manufacturer.

tank, supply: A separate fuel tank for supplying fuel to the engine or to a day or integral tank.

voltage: Voltage of a circuit is the greatest root-mean-square difference of the potential between any two conductors of the circuit.

voltage, low: A voltage limited to 24 volts nominal.

voltage, high: A voltage of more than 600 volts.

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 criteria for such work.

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

1.5.4 Operation and maintenance

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

Section 2
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 minimum average weight of 170 pounds (77.1 kilograms). It is the owners' responsibility to indicate unusual considerations that might affect the design passenger weight.

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

2.1.1.2 Passenger removal from stranded carriers

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

2.1.1.2.1 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 and 2.3.2.6.4). The guideway shall have access to a service road or walkway which allows passengers to leave the stranded carriers at any place along the guideway, including the passing zone. The service road or walkway 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 slip resistant materials.

Adequate emergency lighting as well as normal lighting shall be provided to accommodate all foreseeable evacuation conditions (see 2.2.11.3).

2.1.1.3 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, zip lines, amusement devices, guywires or other funiculars;

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

n) carrier height above ground or surface;

o) ADA accessibility;

p) fire hazard.

2.1.1.4 Acceleration and speed control

2.1.1.4.1 Maximum sustained acceleration

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

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

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

Table 2-1 includes limits for standing passengers, and a column for seated passengers, showing higher allowable accelerations. The limits in the "Seated" column apply to those vehicles where provisions for standing passengers are not included, resulting in a vehicle interior where all passengers are seated. Where the design allows for standing passengers, the limits in the "Standing" column shall be used.

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

Table 2-1 – Maximum/Minimum allowable sustained 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)

2.1.1.4.2 Carrier speed

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

2.1.1.4.3 Speed provisions

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

a) the guideway shall be protected from unauthorized access;

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

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

c) haul ropes shall have a device or system that detects haul rope departure from its normal zone of operation and initiates a stop of the funicular (see 2.2.3(e));

d) an attendant shall be in each carrier or group of carriers.

2.1.1.4.4 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 2.1.5.

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

2.1.1.5 Stops & Shutdowns

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

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

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

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

2.1.2 Clearances

2.1.2.1 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.

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

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

2.1.2.2 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.

2.1.2.3 Vertical clearance below an elevated guideway

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

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

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

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

2.1.2.4 Horizontal clearances

The following clearances shall be maintained:

a) *Clearance to obstructions*:

1) Enclosed carriers shall maintain a minimum horizontal clearance of 18 inches (460 mm);

2) Open carriers shall maintain a minimum horizontal clearance of 3 feet (0.915 meters).

b) *Clearance to another carrier in a passing zone*:

1) Enclosed carriers shall maintain a minimum horizontal clearance of 18 inches (460 mm) between carriers;

2) Open carriers shall maintain a minimum horizontal clearance of 6 feet (1.83 meters) between carriers.

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

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

2.1.2.5 Tunnel clearances

In tunnels and overhead roadway crossings, clearances of 2.1.2.4(a) shall be met. Additionally, where exit doors are provided on carriers, at least 32 inches (815 mm) of clearance shall be provided on the side of the carrier with the exit door.

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

2.1.2.6 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 2.1.2.2 and 2.1.2.4 shall be maintained.

2.1.2.7 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.

2.1.3 Structures and foundations

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

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

2.1.3.1 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 (152 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.

2.1.3.2 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 220-2018 *Standard on Types of Building Construction,* as determined by an engineering analysis of potential fire exposure hazards to the structure.

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

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

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

Structures such as remote vertical exit shafts and ventilation structures shall be not less than Type I (332) approved noncombustible construction as defined in ANSI/NFPA 220-2018.

2.1.4 Machinery systems

2.1.4.1 General

Mechanical power transmission apparatus shall be safeguarded by a guard, device, or safe-location safeguarding method to prevent inadvertent contact with hazardous machinery motion or thermal hazards. Material used in the construction of guards shall be of such design and strength as to protect individuals from identified hazards. Where breakage of a mechanical power transmission component can result in injury, provision shall be made for appropriate containment of components.

When tasks such as start-up, set-up, repair, adjustment, or maintenance require removing, disabling, bypassing, or suspending one or more safeguards, alternate hazard reduction measures shall be required. Only properly trained and authorized personnel shall be allowed access to a hazard area. The bypass process shall be documented and shall include specific procedures and appropriate training of personnel.

Protection against static electricity shall be provided.

2.1.4.2 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.

2.1.4.3 Machinery housed in a machine room

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

2.1.4.4 Entrance and Egress

Permanent stairs and walkways shall be provided for entrance, egress, and emergency evacuation from all enclosed machinery areas. The angle of inclination for the stairs shall not exceed 70 degrees to the horizontal. Stairs and walkways shall have a minimum clear width of 18 inches (460 mm). Walkway surfaces and stair treads shall be of non-skid construction. Handrails shall be provided on open sides of the stairway. Provisions shall include extraction of incapacitated persons using common emergency response equipment.

2.1.4.5 Automatic fire detection

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

2.1.4.6 Portable fire extinguishers

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

2.1.4.7 Power units

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

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

2.1.4.7.1 Prime Mover

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

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

If changes are made to the drive system components that affect rotational inertia (i.e. removal of electric motor), the resulting stopping distances and deceleration rates shall meet the requirements of 2.1.1.5

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

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

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

connection.

One of the following methods shall be provided:

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

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

2.1.4.7.3 Power Unit Interlock

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

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

2.1.4.7.4 Combustion engine(s) and fuel handling

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

2.1.4.8 Speed reducers and gearing

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

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

2.1.4.9 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 2.1.4.1.

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

2.1.5 Brakes

service brake (see 2.1.5.1);

bullwheel brake (see 2.1.5.2);

carrier brake (see 2.1.5.3).

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) 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 2.1.1.5);

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

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

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

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

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

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

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

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

Such testing shall be accomplished as part of normal maintenance 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.

2.1.5.1 Service brake

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

The service brake shall be an automatic brake to stop and hold the funicular under the most unfavorable design loading condition. The brake force shall be adjusted such that by itself it will stop the funicular from maximum design speed, with the design loading condition most unfavorable to stopping, within the requirements specified in 2.1.1.5.

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

Deceleration rates specified in 2.1.1.5 shall be achieved by the service brake without the aid of other braking devices or drive system regeneration.

2.1.5.2 Bullwheel brake

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

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

The bullwheel brake shall operate on any drive terminal bullwheel assembly that meets the requirements of 2.1.6.2.

Application of the bullwheel brake shall automatically disconnect the power source from the power unit in use. This brake shall act automatically if a carrier travels beyond its normal stopping position in either terminal (see 2.2.3.2).

2.1.5.3 Carrier brake

Each carrier, whether one or more are used in a group shall be equipped with a carrier braking system.

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

The braking system shall be capable of:

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

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

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

d) manual activation by the attendant in the cabin;

e) interlocking so that the brake will not set until the carrier's upward travel has stopped except in an overspeed condition;

f) automatically functioning in specified overspeed conditions.

2.1.6 Bullwheels and sheaves in terminals and stations

2.1.6.1 General

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

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

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

The designer shall consider load increases for drive bullwheels with more than one groove, and deviations in groove diameter.

2.1.6.2 Haul rope terminal bullwheels

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

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

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

EXCEPTION – Multi-groove, through-running bullwheels or bullwheel systems not used for the passage of spliced ropes may have smaller diameters and meet all other design requirements for driving, braking and deceleration. The minimum diameter for these bullwheels shall be loss of con40 times the nominal haul rope diameter. A reduction in bullwheel diameter to between 72 and 40 times the nominal haul rope diameter shall be based on approval of a qualified engineer.

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

If climatic or other conditions tend to cause excessive sheave groove contamination, groove scrapers and/or contamination detection devices shall be mounted on all bullwheels, except winch drum applications.

Table 2-2 Design coefficient of friction for bullwheel liners

Bullwheel liner	Coefficient of friction
Steel or cast iron grooves	0.070
Leather	0.150
Rubber, neoprene, or others	0.205

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

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

NOTE – Guideway sheave requirements under 2.1.7.

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.

2.1.7 Guideway sheaves and mounts

2.1.7.1 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.

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.

2.1.7.2 Sheave and roller mounting

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

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

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

2.1.8 Tension systems

Counterweights, hydraulic and pneumatic cylinders, or other suitable devices may be used to provide the tensioning requirements of the particular installation. All devices used to provide the tension shall have sufficient travel to adjust to all normal operating changes in loading and temperature.

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

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

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

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

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

Rope Type	Sheave diameter		
	Condition A	Condition B	Condition C
6x7	72*d*	42*d*	24*d*
6x19	45*d*	30*d*	20*d*
6x37	27*d*	18*d*	12*d*
NOTE - *d* equals the nominal rope diameter			

2.1.8.1 Tension bullwheel carriages

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

2.1.8.2 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.

2.1.8.3 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.

2.1.8.4 Counterweights

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

2.1.8.4.1 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.

2.1.8.5 Wire ropes in tension systems

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

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

2.1.8.6 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 2.1.6.3 for rope.

2.1.8.7 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.

2.1.9 Terminal provisions for passengers

2.1.9.1 Loading and unloading areas

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

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, slip resistant 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.

2.1.10 Provisions for operating personnel

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

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

a) the communications and controls required of the work position;

b) the operating instructions and emergency procedures;

c) a fire extinguisher(s) (see F.6.1 in Annex F);

d) provisions to be locked to prevent unauthorized entry when unattended.

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

The control room shall contain indicators that will show the

location of the carrier(s) at all times (see 2.1.1.4.3).

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

2.1.10.1 Communications

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

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

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

2.1.11 Guideway design

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

2.1.11.1 Guideway access

Means shall be provided for access to the guideway structure(s). Means such as permanent ladders or portable ladders shall be provided. If portable ladders are used, they shall be readily available in sufficient quantities (see 2.1.1.2.1).

2.1.11.2 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 101-2015, *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 101-2015. 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.

2.1.11.3 Guideway rails

Guideways and terminals shall be arranged so as to keep the rails securely fastened to the guideways and terminal structure under the most adverse operating and non-operating conditions. These provisions shall not interfere with any carrier brake operation. The type of rails chosen depends on the working load, the bearing on the supports, and the functional type of the carrier brake. The attachment of the rails to the supports must be able to transfer all influencing forces, especially those of the carrier brake.

2.1.11.4 Guideway curves

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

$R = A \times V^2$ where:

R = Radius of guideway curve

A = Constant

V = Velocity of the carrier

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

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

2.1.11.5 Guideway inclination

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

See Annex H for Tunnel and Enclosure Ventilation.

2.1.11.6 Guideway loads

Any individual carrier 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

2.1.11.7 Guideway passing zone

Where guideway mid-point passing zones are required for the passage of the carriers, minimum clearances between the carriers in accordance with 2.1.2.4(b) 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 carriers during a haul rope failure from rated speed, such that the carriers do not come into contact while in the passing zone.

2.1.11.8 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 over-travel. These buffers shall be designed to absorb the energy of impact and bring a loaded carrier or line of carriers to a full stop, without damage to the terminal. The minimum velocity for the design of the buffers shall be the lowest normal supervised speed during terminal entry, as determined by the manufacturer.

2.1.12 Guideway equipment

2.1.12.1 Haul rope(s)

See annex A for additional wire rope requirements.

2.1.12.1.1 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.

2.1.12.1.2 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 2.1.5.3(c)).

In the haul rope system, a rope tension-monitoring device shall be installed to stop the drive system if the rope tension is beneath a minimum recommended value specified by the funicular designer (see 2.2.3.4).

2.1.12.2 Rope retention

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

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

Rollers may also be used for rope support. Rollers do not have to meet the minimum diameter as set forth in table 2-3.

2.1.13 Carriers

2.1.13.1 General

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

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

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

A minimum factor of safety of 2 must be maintained against overturning at maximum lateral operational wind speed. Consideration should be given to wind load, centrifugal forces, rail alignment, inclination of guideway, location of center of gravity of carrier, etc. (see 2.1.11.4).

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

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

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

2.1.13.2 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.

2.1.13.3 Carriage attachments

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

2.1.13.4 Cabin

A 60 in. (1525 mm) diameter clear space for wheelchair

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

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

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

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

a) each cabin shall meet the illumination requirements of 2.2.11.1 and 2.2.11.3.2;

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.

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.

Additional carrier requirements are located under 2.3.2.6 for automated funicular operation.

2.1.13.4.1 Enclosed cabins

Passenger cabins shall be adequately ventilated.

All cabins or compartments shall have an emergency exit.

2.1.13.4.2 Open cabins

The manufacturer shall determine the features or devices that support and contain the passenger for the purpose of riding in an open cabin. This may include but not limited to entrances, seats, side walls, walls, hand rails, passenger instructions, etc.

2.1.13.4.3 Cabin entrances and doors

Entrances to cabins shall meet the following:

a) the minimum width shall be 32 inches (815 mm);

b) have doors or be designed to minimize passenger access while carrier is in motion;

c) the horizontal gap between the entrance floor edge and platform edge shall not be greater than 1 inch (25.4 mm);

d) the height of the entrance floor and the platform shall be within ±1/2 inch (±12.7 mm).

Cabin doors if installed shall be designed as follows:

e) fill the width of the opening;

f) each compartment door provided with a lock located in such a manner that it can be locked and unlocked by authorized persons or by automatic means;

g) at least one door in each passenger compartment which is manually operable from the interior without vehicle power;

h) if not closed and locked will prevent the start of a trip;

i) if opened during a trip will initiate a stop;

j) a key or release placed under glass, posted to prohibit use except under specified emergency conditions;

k) equipped with a mechanism accessible from the carrier exterior to manually unlock the doors without carrier power;

l) swing type doors open outwards from passenger compartment.

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.

2.1.13.4.4 Structural fire resistance

Portions of the carrier body separating major ignition, energy, or fuel-loading sources such as flammable and combustible liquids and flammable gas mixtures 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 estimated evacuation time of a full load of passengers from the cabin 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 passengers, and the use and right-of-way characteristics that affect evacuation time.

2.1.13.4.5 Interior fire resistance

Materials and finishes in the cabin shall have sufficient fire-resistive rating in the interior of the cabin for a period consistent with the estimated evacuation time of a full load of passengers from the carrier. The aforementioned materials and finishes shall be evaluated under a fire hazard assessment for cabin(s) including material characteristics other than fire 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 carriers are to do a hazard analysis or use appropriate material properties.

NOTE – For examples, see Appendix D or Table 5-2.4 in ANSI/NFPA 130-2020, *Standard for fixed guideway transit and passenger rail systems.*

The aforementioned materials and finishes shall include the carriage structure, interior walls and ceiling linings, floor coverings, ceiling, seats, shades, drapes, curtains,

glazing, transparencies, partitions, elastomer(s), and nonelectrical insulation of carriers.

2.1.14 Acceptance inspection and tests

Prior to the acceptance inspection and the acceptance tests, the funicular shall be continuously operated with empty carriers on the line as follows:

a) 6-hours on each power unit classified as a prime mover;

b) 1-hour on each power unit classified as an evacuation power unit.

Stops shall be minimized to replicate normal operation during the continuous operation.

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

2.1.14.1 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 system components;

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

f) haul rope alignment at entrance to bullwheels;

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 Annex H).

2.1.14.2 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 2.1.1.5). Motive power and all braking devices (see 2.1.5) shall be proved adequate under the most adverse loadings and at design speeds.

2.1.14.3 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 2.1.14.2).

2.1.15 Operational and maintenance manuals

2.1.15.1 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.

2.1.15.2 Maintenance manual

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

a) types of lubricants required and frequency of application;

b) definitions and measurements to determine excessive wear;

c) recommended frequency of service to specific components;

d) carrier testing procedures and acceptance criteria;

e) brake testing and adjustment;

f) dynamic testing procedure.

2.2 Electrical design and installation

2.2.1 General design and installation testing

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

2.2.1.1 Applicable codes

All electrical systems shall comply with *American National Standard National electrical code,* ANSI/NFPA 70-2020, and *American National Standard National electrical safety code*, ANSI/IEEE C2-2017.

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 C2-2017.

2.2.1.3 Protection

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

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

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

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

2.2.1.4 Reserved

2.2.1.5 Wiring

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

2.2.1.5.1 Control wiring classification

All control wiring shall be Class 1 in accordance with Article 725 of ANSI/NFPA 70-2020.

2.2.1.5.2 Communication wiring

All communication wiring and systems are exempt from the requirements in Article 800 of ANSI/NFPA 70-2020.

2.2.1.5.3 Insulation

All control wiring is exempt from the requirements of Article 725.49 Part B of ANSI/NFPA 70-2020. The designer shall specify conductor size, type, and insulation suitable for the electrical and mechanical requirements of the application.

2.2.1.5.4 Exterior non-funicular-related circuits

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

2.2.1.5.5 Ground fault circuit interrupter protection for personnel

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

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

2.2.1.6 Grounding

2.2.1.6.1 Structures

All metallic structures shall be bonded to form a grounding electrode system as defined in Article 250 ANSI/NFPA 70-2020. 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 70-2020. 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 bullwheels or sheaves with conductive liners or equivalent means should be provided at one location for the purpose of grounding ropes, as applicable, for static electrical discharge. For rope systems with an isolated or insulated rope incorporated in the operating circuitry, no means of grounding are required when the operating circuit takes into consideration static electrical discharge.

2.2.1.6.4 Lightning protection

If lightning protection is provided, it shall follow ANSI/NFPA 780-2020, *Standard for the installation of lightning protection systems*.

2.2.2 Electrical system function design and classification

The designer or funicular manufacturer responsible for the design shall identify and classify any function which is not already classified as a safety related control function (see 2.2.3) or control function (see 2.2.4).

2.2.2.1 Function priority

Safety functions shall have priority over all other functions.

2.2.3 Safety related control functions

Safety functions shall be specified relative to the level of corresponding risk being controlled. The performance of each safety function shall meet the requirements established in Annex J.

NOTE – Safety functions that have already been assigned a Risk Reduction Level (RRL) do not need to be reevaluated. See criteria for RRLnominal and RRLminimum in Table J.8.

The designer or manufacturer shall develop procedures and frequency for testing safety functions. As a minimum, all safety functions shall be calibrated and tested annually.

Safety functions include, but are not limited to:

a) emergency shutdown (see 2.2.3.1);

b) carriage overtravel detection device (see 2.2.3.2);

c) tension system monitoring (see 2.2.3.3);

d) rope tension-monitoring (see 2.2.3.4);

e) guideway haul rope monitoring (2.1.1.4.3.(c));

g) overspeed monitoring (see 2.2.3.5);

h) acceleration/deceleration monitoring (see 2.2.3.6);

i) speed regulation check points (see 2.2.3.7);

j) cabin door fault detection (see 2.1.13.4.3);

2.2.3.1 Emergency shutdown

All funicular systems shall include at least one category 0 stop function (see 1.4 – *stop, category 0*). This safety function shall be labeled as “Emergency Shutdown” (see 1.4 – *emergency shutdown* and 2.1.1.5). The emergency shutdown shall have priority over all other safety and control functions.

2.2.3.2 Carrier overtravel detection device

An overtravel sensing device shall be installed that will stop the system if a carrier travels beyond its normal stopping location.

2.2.3.3 Tension system monitoring

Active tension systems, (i.e., counterweight, hydraulic, etc.) shall have a safety function that initiates a stop when a tension system exceeds its range of normal travel.

When pneumatic or hydraulic tension systems are used, pressure or load-sensing devices shall also be incorporated that will stop the funicular system in case the monitoring device signal goes above or below the design range. Such sensing devices shall be located with respect to the actual tensioning device, in a manner that will provide the required monitoring. It shall not be possible to isolate the sensing devices from the actual tensioning device.

EXCEPTION – The sensing device may be isolated by a high-velocity check valve (see 2.1.8.3).

2.2.3.4 Rope tension-monitoring

A rope tension-monitoring device shall be installed to stop the drive system if the rope tension is beneath a minimum recommended value specified by the funicular designer (see 2.1.12.1.2).

2.2.3.5 Overspeed monitoring

A safety function shall be provided that will stop the funicular when the rope speed at the drive terminal exceeds the design speed by 10%.

2.2.3.6 Acceleration/deceleration monitoring

The rate of acceleration and deceleration of the funicular shall be monitored. In the event that acceleration or deceleration exceeds the provisions of 2.1.1.4, the funicular shall stop and annunciate the error.

2.2.3.7 Speed regulation check points

A redundant device or system shall initiate a stop in the event manual or automatic speed regulation fails to reduce funicular speeds to the designated values in the station and any other designated zones.

2.2.4 Control functions

The designer or manufacturer shall identify the control functions that require periodic testing and develop procedures and frequency for testing.

Control functions may include, but are not limited to:

a) information display units;

b) braking system monitoring (see 2.1.5(a) through 2.1.5(c);

c) normal stop (see 1.4 – *normal stop* and 2.1.1.5);

d) speed command circuits (i.e., fast, slow, etc.);

e) prime mover speed control;

f) power unit interlock (see 2.1.4.7.3);

g) combustion engine protective devices (see F.3 in Annex F);

h) gearbox oil pressure, oil flow and temperature;

i) telephone and sound powered systems (see 2.1.10.1);

j) audible warning devices (see 2.2.9);

k) wind speed and direction systems;

l) contamination detection for bullwheel grooves if installed (see 2.1.6.2).

m) carrier brake application detection (see 2.1.5.3)

2.2.5 Bypass circuits

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

2.2.6 Electrical prime mover

All funicular systems equipped with electrical prime movers (electrical motors) shall have the following when speed regulation can be adversely affected by such voltage variations.

a) phase loss protection on all power phases;

b) under voltage protection or over voltage protection or both.

2.2.7 Electronic speed-regulated drive monitoring

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

a) field loss (dc motors);

b) overspeed;

c) speed feedback loss as applicable;

d) overcurrent.

2.2.8 Manual control devices

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

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

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

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

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

2.2.9 Safety of operating and maintenance personnel

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

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

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

2.2.10 Software security

The "as built" drawings shall include a procedure, developed by the funicular manufacturer or Qualified Engineer, to ensure 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.

2.2.11 Illumination

2.2.11.1 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.

2.2.11.2 Cabin illumination

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

floor. Lighting shall be of a consistent level.

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

2.2.11.3 Emergency lighting

Emergency lighting shall also 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.

2.2.11.3.1 Emergency station/guideway lighting

Emergency lighting systems shall be installed and maintained in accordance with ANSI/NFPA 70-2020.

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

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.

2.2.11.3.2 Emergency carrier lighting

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

2.3 Operation and maintenance

This subsection covers the requirements for operation and maintenance of funiculars. Many requirements are listed elsewhere in Section 2 and referenced Annexes, since they also regulate installation and design. It is imperative that operating and maintenance personnel be familiar with applicable provisions of this section and the funicular operational and maintenance manuals (see 2.1.15).

2.3.1 General and personnel safety

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 approximate number of adult passengers shall be posted prior to the loading platform and in each cabin;

c) instructions for procedures in emergencies shall be prominently posted inside each carrier;

d) to exclude the entry of unauthorized persons posted at entrances to machine rooms, operators', and attendants' rooms.

The sign – "Personnel Working on Funicular - Do Not Start" or a similar warning sign applicable to "Lock-Out Tag-Out" procedures shall be hung on the main disconnect switch and at control points for starting the prime mover or evacuation power unit when persons are working on the funicular (see 2.2.9).

See F.1.6 in Annex F for signage requirements for flammable and combustible liquid cabinets.

2.3.2 Operation

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

2.3.2.1 Personnel and supervision

Funiculars shall be operated by trained personnel, and the owner shall be responsible for their supervision and the training to perform the duties listed in 2.3.2.3. Procedures for monitoring the operation and use of the funicular and for advising and assisting passengers, including passengers with common adaptive equipment, shall be included in the training. One or more persons familiar with emergency procedures shall be on the site at all times when the funicular is in operation. All personnel shall practice good housekeeping. Personnel shall comply with the

operational procedures and regulations for the funicular. Persons performing the duties of the funicular personnel may exchange assignments as directed by the supervisor; provided they are trained for each assignment undertaken.

2.3.2.1.1 Supervisor

An individual shall be designated to oversee the funiculars operating practices and operating personnel for the purpose of public use. The designated supervisor may delegate some authority to others, but shall oversee the operations and operations personnel of the funicular as called for by the owner as part of the operations and maintenance quality assurance plan (see 2.3).

2.3.2.1.2 Operator

An individual(s) shall be designated the operator and shall be in charge of the funicular. The operator(s) shall be trained and experienced in normal operational and emergency procedures (see 2.3.2.1.2), and such training shall be documented.

2.3.2.1.3 Attendants

Attendant(s) shall be assigned to particular duties under direction of the operator. The attendant shall be trained in operations and emergency procedures pertaining to their assignments (see 2.3.2.1.3); and such training shall be documented.

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

2.3.2.1.4 First aid

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

2.3.2.2 Minimum operating personnel

The following personnel are the minimum that shall be required:

a) a supervisor shall be in charge of the funicular operation and personnel. The individual may serve concurrently as an operator if the additional role doesn't interfere with the duties of the supervisor;

b) an operator shall be in charge of the funicular during the trip cycle. The individual may serve concurrently as an attendant if the additional role doesn't interfere with the duties of the operator and is approved by the supervisor;

c) an attendant shall be on duty at each loading/unloading platform or station. Personnel assigned to a cabin may also act as a platform or station attendant;

d) an attendant shall be in each carrier or group of carriers for speeds over 1200 feet per minute (6.0 meters per second);

e) one or more trained and competent persons shall be available, consistent with the operational procedures, to evaluate and address abnormal operational conditions.

In addition, the staffing requirements (if any) specified by the funicular manufacturer shall be observed.

2.3.2.3 Duties of operating personnel

All personnel shall use reasonable care while performing their duties.

2.3.2.3.1 Supervisor

The duties of the individual designated as the supervisor include:

a) to oversee practices that will determine that the funicular is operational and that all operating personnel are trained, equipped, and capable of performing their duties prior to public operation;

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

c) to oversee operational procedures and adherence to applicable regulations pertaining to the funicular.

2.3.2.3.2 Operator

The duties of the individual designated as the operator include:

a) to be knowledgeable of operational and emergency procedures (see 1.4 – *loss of control*) and the related equipment needed to perform the assigned duties;

b) to assume responsible charge of the funicular;

c) to be knowledgeable of the attendant duties and to assign and supervise all attendants on the funicular;

d) to verify that the preoperational inspection (see 2.3.2.4.2) is completed and documented before public operation;

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

f) to start the funicular while operating for the public (see 2.3.2.5.2 and 2.3.2.5.4);

g) to deny access to the funicular to individuals, using provided practices;

h) to advise the supervisor of observed abnormal or unusual conditions that may adversely affect the

safety of the operation;

i) to terminate passenger operations (see 2.3.2.5.8);

j) to assist in evacuation of the funicular, as assigned (see 2.3.2.5.7);

k) to be knowledgeable of the procedures for reporting incidents and obtaining appropriate first aid personnel.

2.3.2.3.3 Attendant

The duties of an attendant include:

a) to be knowledgeable of operational, emergency and loss of control (see 1.4 *loss of control and 2.2.3.1 – Emergency shutdown*) procedures and the related equipment needed to perform the assigned duties;

b) to monitor the passengers' use of the funicular, including observing, advising and assisting them while they are in the attendant's work area as they embark on or disembark from the funicular; and to respond to unusual occurrences or conditions, as noted. The attendant should respond by choosing an appropriate action, which may include any of the following:

1) assisting the passenger;

2) slowing the funicular (if applicable);

3) stopping the funicular;

4) continuing operation and observation.

c) to deny access to the funicular to individuals, using provided practices;

d) to advise the operator of observed abnormal or unusual conditions that may adversely affect the safety of the operation;

e) to reasonably maintain loading and unloading platforms;

f) to assist in evacuation of the funicular, as assigned (see 2.3.2.5.7);

g) to advise and assist passengers with adaptive equipment, as assigned;

h) to be knowledgeable of the procedures for reporting incidents and obtaining appropriate first aid personnel.

2.3.2.4 Operational procedures

Operational procedures may supplement the designer's operational manual (see 2.1.15.1) and the owner's quality program (see 1.5.4).

2.3.2.4.1 Control of passengers

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

2.3.2.4.2 Daily pre-operational inspection

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

a) a visual inspection of each terminal, station, and the entire length of the guideway;

b) assurance that the tension system, if applicable, is functional and that tension system devices (counterweights, cylinders, carriages, and the like) have adequate travel with appropriate clearances at both ends;

c) operation of all manual and automatic switches in terminals, stations, carriers, and loading and unloading areas per the manufacturer's instructions;

d) operation of all drive system brakes;

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

e) operation of all communication systems;

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

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

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

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

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

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

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

2.3.2.4.3 Periodic operation of drive units

During the normal operating period(s), funiculars having internal combustion engines shall have the engine(s) checked and started at least once each week. The funicular shall also be operated using each internal combustion engine designated as a prime mover for at least 30 continuous minutes per month.

The funicular manufacturer or qualified engineer shall designate the parameters, methods, and minimum operating interval for additional drive systems that are not designated as a prime mover that move the haul rope for the evacuation of passengers.

The starting and operation of internal combustion engines and additional drive systems shall be documented.

2.3.2.4.4 Access to facilities

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

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

2.3.2.4.5 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.

The owner/supervisor shall review the clearances below, above and adjacent to the funicular and maintain compliance with 2.1.2.

2.3.2.5.2 Starting

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

2.3.2.5.3 Loading and unloading areas

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

2.3.2.5.4 Stops

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

2.3.2.5.5 Damage to carriers

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

2.3.2.5.6 Hazardous conditions

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

2.3.2.5.7 Evacuation

Provisions shall be made for the emergency evacuation of the funicular carriers and stations (see 2.1.1.2.1 and 2.3.2.6.4).

The owner shall be responsible for the development, training, implementation, documentation and annual review of a plan for evacuation of passengers and personnel from the funicular. At a minimum, the plan shall include:

a) the definition of the line of authority in the event of an evacuation. This line of authority shall list:

1) the individuals or positions responsible for determining the need for and ordering an evacuation by use of the evacuation power unit or evacuation from individual carriers;

2) the individuals or positions responsible for performing the evacuation, for first aid, and for ground care of individual carrier evacuated passengers.

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

c) training shall be performed throughout the year in the steps and functions required for the evacuation of the funicular. An evacuation simulation drill shall be performed at a minimum of once per year. Training and drills shall be recorded in the funicular evacuation log (see 2.3.5.4);

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 non-ambulatory 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) provision for emergency lighting for evacuations that occur in or may extend into the hours of darkness (see 2.2.11.3(b));

m) provisions for a post-evacuation report.

All nonmetallic rope used for evacuation shall be rated for Life Safety applications. Breaking strength, when new, shall be at least 15 times the maximum expected operating load but in no case less than 4000 lbs (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 self-closing, self-locking type and rated for rescue/life safety use.

2.3.2.5.8 Termination of daily operations

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

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

2.3.2.5.9 Bypass requirements

The use of temporary circuits that have been installed for the purpose of bypassing failed electrical circuit(s) (see 2.2.5) shall meet these requirements in the following order:

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

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

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

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

e) the operator control panel(s) shall indicate that a bypass is in use.

2.3.2.6 Automatic operation

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

2.3.2.6.1 Operation monitoring

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

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

2.3.2.6.2 Fencing off the guideway

Those parts of the guideway which are accessible by unauthorized personnel shall be fenced off.

The fencing shall be at least 5 feet (1.5 m) high.

2.3.2.6.3 Access to the guideway

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

The doors shall not open in the direction of the track if the horizontal clearances in section 2.1.1.4 are not maintained.

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

2.3.2.6.4 Evacuation

In addition to 2.3.2.5.7, it shall be possible for the passengers to evacuate from the carriers by complying with instructions displayed in the carrier or communicated by the monitoring station. An evacuation path conforming to 2.1.1.2.1 shall be provided. It shall be possible to open the doors and emergency exits from the inside.

2.3.2.6.5 Special safety devices at platforms

The station platforms shall be equipped with solid sliding doors. The horizontal clearance between the carrier door and the closed sliding door on the platform shall not exceed 5 in. (127 mm) up to a height of 5.75 feet (1.8 meters) above the floor, unless additional monitoring of this area is provided.

2.3.2.6.6 Special safety devices on carriers

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

2.3.2.6.7 Carrier voice communications

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

2.3.3 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 2.1.15.2) of the designer or Qualified Engineer shall be followed. Maintenance records shall be kept (see 2.3.5).

2.3.3.1.1 Maintenance

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

a) all wire rope and end connections;

b) guideway sheave units, sheaves, bearings, and liners;

c) bullwheels, bearings, and liners;

d) tension systems;

e) drive system, including bearings and couplings;

f) braking systems;

g) electrical control systems;

h) communication systems;

i) carriers;

j) structures;

k) guideway structures;

l) ventilation system (if any).

2.3.3.2 Maintenance personnel

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

2.3.4 Inspections and testing

2.3.4.1 General inspection

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

2.3.4.2 Dynamic testing

Dynamic testing shall be performed at intervals not exceeding seven (7) years.

A written schedule for systematic dynamic testing shall be developed and followed. The owner shall provide experienced personnel to develop and conduct the dynamic test. The schedule shall establish specific frequencies and conditions for dynamic testing. The testing shall simulate or duplicate inertial loadings. The test load shall be equivalent to the design live load. The results of the testing shall be documented in the maintenance log.

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

a) braking systems;

b) evacuation systems;

c) tension system;

d) electrical systems.

2.3.4.3 Wire rope, and end connection inspection

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

2.3.4.4 Carrier testing

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

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

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

the test results.

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

2.3.5 Records

2.3.5.1 Operational log

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

a) date;

b) names and work positions of operating personnel;

c) operating hours and purpose of operations;

d) temperature, wind, and weather conditions;

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

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

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

h) signature of operator;

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

2.3.5.2 Maintenance log

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

2.3.5.3 Wire rope and end connection log

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

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

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

c) date installed;

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

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

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

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

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

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

2.3.5.4 Evacuation log

An evacuation log shall be maintained including records of:

a) evacuation training conducted for each funicular (see 2.3.2.5.7(c));

b) the post-evacuation report for each evacuation of the funicular (see 2.3.2.5.7(m));

c) maintenance and inspection of evacuation equipment.

2.3.6 Passenger conduct and responsibilities

2.3.6.1 Passenger responsibilities

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

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

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

b) obeying all written and oral instructions and warnings;

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

d) properly use the funicular and equipment provided.

2.3.6.2 Passenger dexterity and ability

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

2.3.6.3 Passenger embarkation and disembarkation

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

2.3.6.4 Passenger riding

Passengers, while riding a funicular, shall not throw or expel therefrom any object, nor shall any passenger do any act or thing that shall interfere with the operation of

the funicular. Passengers shall not willfully engage in any type of conduct that may contribute to or cause injury to any other person.

Section 3
Normative references

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

ANSI/IEEE C2-2017, *National electrical safety code*

ANSI/NFPA 10-2018, *Standard for portable fire extinguishers*

ANSI/NFPA 58-2020, *Liquefied petroleum gas code*

ANSI/NFPA 70-2020, *National electrical code*

ANSI/NFPA 72-2019, *National fire alarm and signaling code*

ANSI/NFPA 91-2020, *Standard for exhaust systems for air conveying of vapors, gasses, mists, and noncombustible particulate solids*

ANSI/NFPA 130-2020, *Standard for fixed guideway transit and passenger rail systems*

ANSI/NFPA 780-2020, *Lightning protection code*

American Petroleum Institute Standard No. 2000, *Venting atmospheric and low-pressure storage tanks*

For Underground Installations only:

ANSI/NFPA 101-2021, *Life safety code*

ANSI/NFPA 110-2019 *Standards for emergency and standby power systems*

ANSI/NFPA 220-2018, *Standard on types of building construction*

Annex A
(normative)

Wire rope and end connections requirements

A.1 Physical properties

A.1.1 Specifications

Wire rope used as tension members shall be specified by the funicular designer.

This specification shall state that the wire rope complies with the rope provisions of A.1.

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

The funicular designer or wire rope manufacturer shall prescribe the frequency and methods for any additional maintenance or inspections of wire rope or strand not covered in this annex.

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

A.1.1.1 Wire rope specification

The specification for wire rope shall include the following:

a) nominal diameter;

b) diameter tolerance;

c) number and arrangement of wires;

d) strength grade;

e) type of core;

f) lay of wire rope;

g) minimum breaking force;

h) type of lubrication.

A.1.1.2 Relocated Wire Rope

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

A.1.2 Diameter tolerance

A.1.2.1 Wire rope

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

A.1.3 Minimum breaking force

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

A.1.3.1 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 minimum breaking force (see 1.4 – *minimum breaking force*) listed in the manufacturer's published catalog or table A-1 for the diameter, classification, and strength grade selected by the designer.

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

A.1.4 Torsion requirements

A.1.4.1 Wire torsion values for wire rope

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

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

A.2 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.

A.2.1 Testing procedures – wire rope

A.2.1.1 Sampling – wire rope

A sample long enough to provide 9 feet (2.75

meters) of free length shall be cut from each manufactured length to be used for the actual rope ultimate strength test and diameter measurement.

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

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.

A.2.1.2 Examination of diameter – wire rope

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

A.2.1.3 Breaking force test

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

A.2.1.4 Wire torsion tests

Wire torsion value shall be determined by either of the two following methods:

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

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

A.2.1.4.1 Test procedure

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

A.2.1.4.2 Alternate test procedure

Because the number of revolutions in the torsional test is proportional to the free length, a free length before the test may be 4 inches + 1/16 inch (101.6 mm + 1.6 mm) for wires up to 0.040 inch (1.02 mm) in diameter or 6 inches + 1/16 inch (150 mm + 1.6 mm) for wires not more than 0.060 inch (1.52 mm) in diameter. The wire specimens with a free length of 4 inches (101.6 mm) shall not break when twisted one-half the number of revolutions shown in table A-2. The wire specimens with a free length of 6 inches (152.4 mm) shall not break when twisted three-fourths the number of revolutions shown in table A-2. Testing shall be done in the same manner as described in A.2.1.4.

A.2.3 Test reports

A.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 cross-sectional metallic area; grade; type of core; minimum breaking force of the rope. The number, diameter, arrangement, and cross-sectional metallic area of wires;

b) actual rope diameter;

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

d) results of torsion testing including the size of wires tested (see A.2.1.4).

A.2.4 Rejects and retests

A.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.

A.2.4.2 Retests

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

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

considering it a retest.

In torsion tests of wires, one wire may fall below the requirement, but by not more than 20% below. In such a case, six additional wires of the same size will be tested, all of which shall pass.

Table A.1 Wire Rope Minimum Breaking Force *(Nominal Breaking Strength)*

		6 x 7 FC		6X19 AND 6X36 FC						6X19 AND 6X36 IWRC						DIAMETER RANGE	
DIAMETER		IPS	1770	IPS	1770	EIP	1960	EEIP	2160	IPS	1770	EIP	1960	EEIP	2160	(see A.1.2.1)	
in.	mm	tons	kN	tons	kN	tons	kN	tons	kN	tons	kN	tons	kN	tons	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 lbs
1770, 1960, 2160 = Grade in SI unites

1

Table A-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 0.080-0.159	 (2.36/d) - 2 (2.36/d) - 2	 (2.20/d) - 2 (1.92/d) - 2	 (2.20/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

2

Table A-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	A.0
0.020	0.029	2.0	4.0
0.030	0.039	A.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	A.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

A.3 End connections for wire rope

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

End connection installation shall be performed by or under the supervision of a competent facility or person and in accordance with instructions approved by the funicular designer, fitting manufacturer or Qualified Engineer.

Documentation shall be provided by the facility or person performing any splice or end connection stating that it has been accomplished in accordance with the provisions of this standard. This document shall become part of the wire rope log.

A.3.1 Splices

A.3.1.1 Haul ropes

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

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

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

A.3.1.2 Ropes used in tension systems

No splices shall be permitted in tension system ropes.

A.3.2 End connections

A.3.2.1 Wire ropes used in tension systems

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

A.3.2.2 Anchoring devices

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

A.3.2.3 Types and methods

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

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

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

A.3.2.3.1 Poured sockets

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

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

A.3.2.3.2 Mechanical and Clamping sockets

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

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

A.3.2.3.3 Swaged sockets

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

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

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

c) critical dimensions are as follows: Outside diameter before swaging; outside diameter after swaging; inside diameter; depth of hole;

d) swaged sockets shall be applied only to wire rope having a steel center in the section of rope inserted to the bottom of the hole. Fiber core rope shall have the core removed from this section and a strand of IWRC of the proper diameter installed before swaging.

A.3.2.3.4 Wire rope clips and thimbles

Wire rope clips and thimbles shall be used as follows:

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

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

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

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

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

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

A.3.2.3.5 Mechanical thimble splices

Two types of mechanical thimble splices shall be permitted:

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

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

A.3.2.3.6 Bollards

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

A.4 Maintenance, inspections, and replacement

A.4.1 Wire rope

A.4.1.1 Lubrication

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

A.4.1.2 Inspection

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

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

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

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

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

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

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

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

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

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

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

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

The inspector shall verify that the rope(s) have not met the replacement criteria in A.4.1.3. A written and signed report stating that the rope is satisfactory for continued use shall be filed with the

owner. The report shall be included in the wire rope log (see 2.3.5.3) and be available to the general inspector (see 2.3.4.1).

A.4.1.3 Repair/replacement of wire rope

The following shall be applied to the entire length of the wire rope excluding any sections in end connections or splices. For areas in end connections or splices, see A.4.2.1

Table A-4 Loss of cross-sectional metallic area

Maximum permissible loss of metallic area	Reference length
7.5%	6d
10%	30d
25% (one strand)	6d

NOTES – d = nominal wire rope diameter

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 C for examples of how to calculate the number of broken wires allowed.

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

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

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

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

A.4.1.3.1 Criteria

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

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

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

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

d) evidence of rope deterioration from corrosion;

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

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

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

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

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

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

A.4.1.3.2 Accidental damage

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

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

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

c) details of the cause are apparent and identifiable;

d) the cause is corrected;

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

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

A.4.1.4 Repairs of wire rope

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

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

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

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

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

d) the repaired area shall be inspected at the completion of the repair and once weekly for a period of 6 weeks of operation. Thereafter, it shall be subject to routine wire rope inspection. The wire rope shall be removed from operation immediately if core collapse, pulling, high stranding, or other significant distortions occur;

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

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

A.4.2 Connections

A.4.2.1 Splices

Damage within splices can often be corrected by proper repair.

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

a) the cross-sectional metallic area of broken wires at a tuck exceeds the values given in table
A-4. Leading and trailing tuck strands shall be considered independent of one another when making this evaluation;

b) any sign of slippage;

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

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

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

A.4.2.2 End connections

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

a) more than one broken wire at the connection;

b) connection is installed improperly;

c) slippage of attachment fitting outside of design parameters;

d) evidence of deterioration from corrosion;

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

Sections of rope permanently deformed or damaged by the application of wire rope clips or bent around thimbles, sheaves, or other anchoring devices not meeting the minimum diameters specified in Condition C of 2.1.2.8.3 shall not be relocated and reused as part of the section under load.

Annex B
(normative)

Measuring the diameter of wire rope

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

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

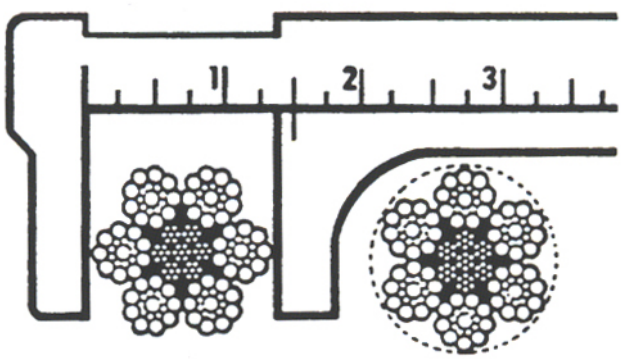


Figure B-1 – Correct method for measuring

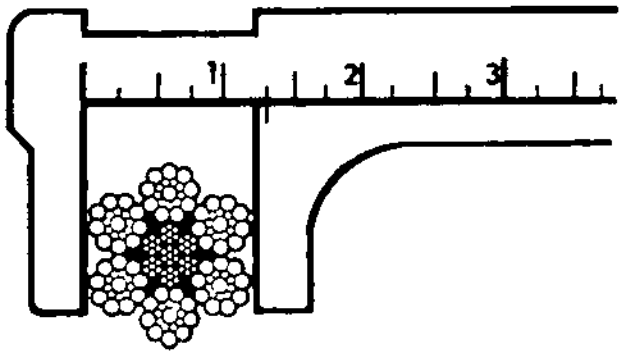


Figure B-2 – Incorrect method of measuring

Annex C
(informative)

Wire rope –
Formulas for calculating allowable broken wires

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

Each rope must have the calculations done based on the data from the wire rope specifications and test reports due to variations between manufacturers. (See A.2.3 in annex A.)

7.5% of rope in 6d

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

10% of rope in 30d

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

25% of one strand in 6d

$$\frac{\text{Cross-Sectional Metallic Area of Rope} \times 0.25}{\text{Cross-Sectional Area of Outer Wire X 6}} = \text{Broken Wires}$$

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

Figure C-1 – Wire rope log sample chart for calculated broken wires allowances

Diameter / rope construction	Cross-sectional metallic area of rope	Outside wire diameter	Cross-sectional metallic area of outside wire	Number of broken wires		
				7.5% of rope in 6d	10% of rope in 30d	25% of one strand in 6d

Annex D
(informative)

Ventilation

D.1 General

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

D.1.1 Tenable environments

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

a) 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;

b) 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);

c) 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;

d) 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);

e) 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;

f) 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);

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

D.1.2 Rating fans

Fans can be rated in accordance with ANSI/ASHRAE 51/AMCA 210-1999 (and ANSI/ASHRAE 51-2007, ANSI/AMCA 210-2007, Addendum 1), *Laboratory methods of testing fans for rating*, AMCA 300-96, *Reverberant room method for sound testing fans*, or the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE), *Handbook Fundamentals.*

Annex E
(normative)

Operator control devices

Table E-1 – Device function and characteristics

FUNCTION	COLOR	LABEL	FEATURES	EXCEPTIONS
Normal Stop	RED	STOP	Mushroom operator with a minimum diameter of 1-3/8 inches (38 mm)	If a designer defines an additional stop function and the button for that function meets the size and color requirements of normal stop, then the normal stop button does not need to meet the same requirements
Emergency Shutdown	RED	EMERGENCY SHUTDOWN	Actuator must be visible but shielded to prevent inadvertent operation.	Shield is not required if the circuit is the only stop circuit on the ropeway

Annex F
(normative)

Combustion engine(s), fuel supply handling, and fire hazard reduction

F.1 Combustion engines

Engines shall be situated so that they are accessible for maintenance, repair and firefighting (see 2.1.4.3).

F.1.1 Machine and engine rooms

Machine and engine rooms must be of noncombustible or fire-resistive construction and fire resistive rating shall be in accordance with type of construction and classification.

F.1.2 Engine rooms located within buildings and structures

When engine rooms are located within occupied buildings or structures, the engine room enclosure (interior walls, floors, and ceilings) shall not have less than a 1-hour fire-resistive rating or in accordance with a fire hazard analysis.

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

Doors or other openings in the engine room that open into other mixed occupancy sections of attached, building, structure or tunnel shall be provided with automatic or self-closing fire doors or dampers in accordance with NFPA 80 and be labeled with manufacturer and fire-resistive rating to contain a fire to the engine room.

F.1.3 Hazard Reduction

F.1.3.1 Drive and Return Terminals and Intermediate Stations

Drive and return terminals and intermediate stations shall use appropriate material properties and have sufficient fire-resistive rating for a period of time consistent with estimated time for evacuation of cabin(s). Drive and return terminals or intermediate stations containing flammable and combustive liquids or flammable gases shall be in accordance with structural fire resistance requirements. (See 2.1.13.4.4 and 2.1.13.4.5).

F.1.3.2 Cabins

Cabin construction and materials shall meet requirements identified by fire hazard assessment. (See 2.1.13.4.5).

Fire detection and firefighting devices (fire extinguishers, etc.) shall be provided on each cabin as required by type of use. (See F.6.1 and F.6.5.1)

Smoking or any open flame shall not be allowed on any open or closed cabin(s) or in adjacent terminals, intermediate stations or platforms.

Flammable materials such as paper, cardboard, wood, and cleaning cloths shall only be stored in appropriate containers and in designated locations.

F.1.3.3 Fire Response

Maintenance and operating personnel response training and inspections of evacuation routes, fire detection, firefighting equipment and extinguishers shall be conducted at least annually.

When fire is detected, the following alert-save-extinguish measures shall be taken as far as possible and be implemented appropriately.

Inform personnel in all stations and on carriers and stop loading;

Alert internal/external emergency firefighting personnel;

Evacuate carriers and stations; and

Begin firefighting activity.

F.1.4 Air supply and ventilation

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

There shall be provisions for adequate ventilation within the engine room to prevent a hazardous accumulation of flammable vapors in order to reduce risk of fires and explosions both when the engine is operating or shut down.

F.1.5 Flammable and combustible liquids, flammable materials, and battery use and storage

In engine or machine rooms, incidental storage of flammable and combustive liquids and flammable materials is permissible as long as storage meets the requirements below. Only flammable and combustible liquids and flammable materials specified by manufacturer/designer/Qualified Engineer for the operation and maintenance of funicular equipment may be stored within an engine or machinery room. Quantities shall be consistent with specified usage.

Class I flammable liquids shall be contained in UL listed or original container and shall be limited to 2 gallons. Any Class I flammable liquids in excess of 2 gallons shall be contained in an OSHA approved or UL listed flammable liquid storage cabinet.

Any Class II or III combustible liquids shall be contained in UL listed or in original container. Any Class II or III combustible liquids in excess of 10 gallons shall be stored in an OSHA approved or UL listed combustible fluid storage cabinet.

No flammable materials may be stored in an engine or machine room unless used for the maintenance and operation of funicular. Stored flammable material shall be protected from any source of heat to reduce fire hazard.

In engine and machinery rooms, or in other areas where batteries are used or stored, batteries shall be enclosed to reduce risk of damage to equipment or injury to personnel from corrosion or explosion from shorting or arcing or release of flammable gas mixtures. Batteries shall be situated and maintained to reduce fire hazard from flammable, combustive and hydraulic fluids.

F.1.6 Signage

Flammable and combustible liquid storage cabinets shall be conspicuously labeled, “FLAMMABLE or COMBUSTIBLE, KEEP FIRE AWAY”. Smoking shall not be permitted adjacent to areas where flammable and combustible liquids are stored or other designated locations such as cabins, stations or platforms. “NO SMOKING” signs shall be conspicuously posted.

A sign shall be posted stating that “Passengers are prohibited from concealing and/or carrying flammable liquids or gases onto the cabin.”

When a fire extinguisher is partially or totally hidden from view within a cabin, a sign stating “Fire Extinguisher” shall be posted to identify the location of the fire extinguisher.

F.1.7 Open flames

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

F.1.8 Engine support

Engines shall be securely mounted on substantial noncombustible supports.

F.2 Electrical installations

F.2.1 Hazardous locations

Engine rooms or other locations shall not be classified as hazardous locations as defined in Article 500 of the NFPA 70-2020, solely by reason of the engine fuel.

F.2.2 Combustion engine wiring

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

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

F.3 Combustion engine protective devices

F.3.1 Evacuation power unit

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

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

EXCEPTION – All combustion engines of 50 HP and under.

b) all engines must be wired into the emergency shutdown safety function;

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

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

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

F.3.2 Prime mover

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

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

b) an automatic engine shutdown device for high coolant temperature.

F.4 Fuel supply and location

F.4.1 Structural members used as fuel tanks

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

F.4.2 Outside aboveground fuel supply tanks

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

F.4.3 Underground tanks and piping

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

F.4.4 Provisions for internal corrosion

Tanks shall be designed to protect against internal corrosion in accordance with the American Petroleum Institute, American Society of Mechanical Engineers, or the Underwriters Laboratories Inc. Standards.

F.4.5 Fuel Tanks

F.4.5.1 Fuel Tank Capacity

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

F.4.5.2 Integral or day tanks

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

F.4.5.3 Integral tanks

Class IB liquids: The storage capacity of an “integral

tank" shall not exceed 25 gallons (95 liters).

Class II liquids: The storage capacity of an "integral or day tank" shall not exceed 660 gallons (2500 liters) per tank.

F.4.5.4 Day or supply tanks

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

F.4.5.5 Supply Tanks

Aboveground Class IB and Class II tanks at ground level shall be located a minimum of 10 feet (3 meters) horizontally from a vertical plane created by the path of the haul rope.

Underground supply tanks shall comply with all federal, state and local regulations.

F.4.5.6 Supply tanks located aboveground

Fuel tanks greater than 25 gallons (95 liters) capacity located above grade shall have secondary containment. Alternately, a wall, curb or dike having a capacity at least equal to that of the largest surrounded tank, or a wall, curb, or dike of lesser capacity equipped with an overflow or drainage system that shall be adequate in size and location to convey any spillage of fuel to a tank or other containment.

F.4.5.7 Marking fuel tanks

When a fuel tank is partially or totally hidden from view within a machine room, any surfaces blocking the tank from view shall be conspicuously marked to inform personnel of the presence of the fuel tank. Markings shall define the limits and contents of the fuel tank.

F.4.6 Fuel flow control

F.4.6.1 Liquid fuel supply systems

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

If a supply tank is located higher than the engine room floor, an anti-siphon device is required.

F.4.6.2 Pumps

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

F.4.6.3 Engine air intake

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

F.4.7 Filling

F.4.7.1 Fill pipes

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

F.4.7.2 Gasoline and diesel fuel tanks

Fuel tanks shall be filled by a closed piping system.

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

F.4.7.3 Fuel quality

A procedure or program shall be established to ensure a liquid fuel's quality is suitable for use in the intended combustion engine.

F.4.8 Fuel piping, valves, venting, piping and fittings

F.4.8.1 Atmospheric storage tanks

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

EXCEPTION – Integral tanks of 25 gallons or less do not require vent piping.

F.4.8.2 Normal vents

Normal vents and piping shall be sized in accordance with either:

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

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

F.4.8.3 Fill or withdrawal connection

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

F.4.8.4 Vent pipe outlets

Vent pipe outlets for tanks storing Class IB, or Class II liquids shall be located so that vapors are released at a safe point outside of terminal enclosure or other buildings and not less than 12 feet (3.66 meters) above the adjacent ground or normal snow level. Vapors shall be discharged upwards or horizontally away from adjacent walls to assist in vapor dispersion. Vent outlets shall be located so that flammable vapor will not be trapped by eaves or other obstructions and shall be at least 5 feet (1.53 meters) from building openings.

F.4.8.5 Location and arrangement of vents for Class II liquids

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

F.4.8.6 Vent piping for storage

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

F.4.8.7 Vent manifolding

Vent piping for storage tanks storing Class IB liquids shall not be manifolded with vent piping for tanks with Class II liquids unless positive means are provided to prevent the vapors from Class IB liquids from entering tanks storing Class II liquids to prevent contamination and possible change in classification of the less volatile fuel.

F.4.8.8 Emergency relief venting

Every aboveground storage tank shall be equipped with additional venting that will relieve excessive internal pressure caused by exposure to fires.

F.4.8.9 Piping systems

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

F.4.8.10 Valves

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

F.4.8.11 Openings for gauging

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

F.4.8.12 Fill pipes and discharge lines

For top-loaded tanks other than day or integral tanks, a metallic fill pipe shall be designed and installed to minimize the generation of static electricity by terminating the pipe within 6 inches (152 mm) of the bottom of the tank, and it shall be installed in a manner that it is resistant to damage from vibration.

F.4.9 Transfer of liquid fuel to engines

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

F.5 Exhaust piping

F.5.1 Design and construction

F.5.1.1 Engine exhaust

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

F.5.1.2 Exhaust pipes

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

F.5.1.3 Low points

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

F.5.2 Installation

F.5.2.1 Exhaust pipes

Exhaust pipes shall terminate outside the terminal, building or engine room. Hot gases or sparks shall not be discharged against combustible material, other adjacent buildings, into atmospheres containing flammable gases or vapors or combustible dusts. Exhaust pipes shall not terminate under loading platforms or structures, or near ventilation air inlets. Additionally, exhaust pipes shall be adequately supported and shall be connected to the engine or muffler so that emission of sparks, flame or gas within the structure is prevented.

F.5.2.2 Flexible connections

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

F.5.2.3 Exhaust system guards

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

F.5.3 Clearance from combustible materials

F.5.3.1 Exhaust pipes

Exhaust pipes shall be installed with clearances of at least 9 inches (230 mm) to combustible material, except as provided in F.5.3.2 and F.5.3.3.

F.5.3.2 Exhaust pipes through roofs

Exhaust pipes passing directly through combustible roofs shall be guarded at the point of passage by ventilated metal thimbles that extend not less than 9 inches (230 mm) above and below roof construction

and are at least 6 inches (150 mm) in diameter larger than the exhaust pipe.

F.5.3.3 Exhaust pipes through walls

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

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

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

F.6 Fire protection

F.6.1 Fire extinguishers, classification

F.6.1.1 Low hazard

Operator and attendant building (enclosed work positions) used for the operation and maintenance of a funicular which are not designated as a Moderate Hazard shall be classified as Light (Low) Hazard, as defined by NFPA 10-2018.

Carriers shall be classified as Light (Low) Hazard as defined by NFPA 10-2018.

Light (Low) Hazard areas shall be protected by a minimum of a 10-lb. (or two 5-lb.) Dry Chemical ABC fire extinguisher or equivalent.

F.6.1.2 Moderate hazard

Terminals and intermediate stations or other buildings with engine rooms or machine rooms shall be classified as Ordinary (Moderate) Hazard, as defined by NFPA 10-2018.

Ordinary (Moderate) Hazard areas shall be protected by a minimum of a 20 lb. (or two 10-lb. or four 5-lb.) Dry Chemical ABC fire extinguisher or equivalent.

F.6.2 Fire extinguishers, location

Extinguishers shall be conspicuously located where they will be readily accessible and immediately available in the event of fire. Preferably, they shall be located along normal paths of travel, including exits from areas. Both attended and unattended carriers shall have extinguishers located in passenger cabins. Attended carriers shall have an extinguisher located in carrier operator's immediate vicinity. (See F.1.6 Signage)

F.6.2.1 Obstructions

Extinguishers shall not be obstructed or obscured from view.

F.6.2.2 Mounting

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

F.6.2.3 Travel distances

Travel distances within an engine room or machine room for portable extinguishers shall not exceed 30 feet (9.1 meters). Extinguishers should be placed at regular intervals within an engine room or machine room so that the maximum walking distance from any point to the nearest extinguisher does not exceed the maximum travel distance.

EXCEPTION – The travel distance between fire extinguishers can be increased to 50 feet (15.25 meters) maximum, if the area is protected with a 20 lb. Dry Chemical ABC fire extinguisher or equivalent.

F.6.3 Inspection and maintenance of fire extinguishers

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

a) monthly inspections (see F.6.3.1);

b) annual Maintenance (see F.6.3.2);

c) recharging (see F.6.3.3).

F.6.3.1 Inspection

F.6.3.1.1 Frequency

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

F.6.3.1.2 Procedures

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

a) located in designated place;

b) no obstructions to access or visibility;

c) operating instructions on nameplate legible and facing outward;

d) seals and tamper indicators not broken or missing;

e) determine fullness by weighing or "hefting" (CO_2);

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

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

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

F.6.3.2 Maintenance of fire extinguishers

F.6.3.2.1 Frequency

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

F.6.3.2.2 Maintenance

Maintenance procedures shall include a thorough examination of the three basic elements of an extinguisher:

a) mechanical parts;

b) extinguishing agent, and;

c) expelling means.

EXCEPTION – During annual maintenance, it is not necessary to internally examine non-rechargeable extinguishers, carbon dioxide extinguishers, or stored pressure extinguishers except for those types specified in NFPA 10-2018, 4-4.1.1. However, such extinguishers shall be thoroughly examined externally in accordance with the applicable item (a) stated above.

Every six years, stored rechargeable pressure extinguishers shall be emptied and subjected to the applicable maintenance procedures. When the applicable maintenance procedures are performed during periodic recharging and hydrostatic testing, the six-year requirement shall begin from that date.

EXCEPTION – Non-rechargeable extinguishers shall not be hydrostatically tested but shall be removed from service at a maximum interval of 12 years from the date of manufacture.

F.6.3.3 Recharging of fire extinguishers

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

F.6.4 Operating instructions of fire extinguishers

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

EXCEPTION – In addition to manufacturers' labels, other labels that specifically relate to operation, classification, or warning information shall be permitted on the front.

F.6.5 Automatic fire detection and alarms

All engine rooms located beneath the path of the haul rope (vaulted) shall have an automatic fire detection system conforming to ANSI/NFPA 72-2016. Actuation of a single smoke detector or other automatic fire detection device shall immediately activate an audible and visual alarm at an operator station from which emergency action can be initiated.

F.6.5.1 Cabin Fire Detection

Fire detection devices are required on cabins that travel in tunnels longer than 1000 feet (305 meters). Devices shall transmit an alarm to the cabin operator or to the drive terminal control station if cabin is unattended.

If there is risk that fire will damage a fire detection device on board a cabin, and risk can cause operation failure, there shall be:

(a) For an attended cabin;

1) A dedicated bidirectional audible communication system between the cabin and terminal control station (i.e. "push to talk" full duplex phone systems);

2) Cabin operator and passengers communicate with each other either orally or via a specific device

(b) For an unattended cabin;

1) A dedicated bidirectional, audible communication system shall remain operational during the cabin evacuation period.

F.7 <u>Liquefied petroleum gas</u>

F.7.1 Fuel handling <u>and location</u>

LP-gas shall be handled in accordance with the latest edition of the Liquefied Petroleum Gas Code, ANSI/NFPA 58.

The minimum horizontal separation between a liquefied petroleum gas (LP-gas) container and a Class I, II, or III liquid storage tank shall be in accordance with ANSI/NFPA 30.

Any aboveground or underground ASME LP-gas containers shall be located a minimum horizontal distance from a funicular terminal enclosure or operator/attendant station or work position as listed in ANSI/NFPA 58, Appendix I.

ASME container offset distances:

- 125 to 500 Gallons Water Capacity 10 feet (3.05 meters) minimum.
- Up to 2000 Gallons Water Capacity (Underground) 10 feet. (3.05 meters) minimum.
- Up to 2000 Gallons Water Capacity

  (Aboveground) 25 feet (7.6 meters) minimum.

NOTE- Regardless of its size, any ASME container filled on-site must be located so that the filling connection and fixed liquid level gauge are at least 10 feet from external source of ignition.

Annex G
(informative)

International system of units (SI) metric conversion factors

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

To convert from	To	Multiply by
Acceleration		
feet per second2	meter per second2 (m/s2)	3.048 000 E–01
inches per second2	meter per second2 (m/s2)	2.540 000 E–02
feet per minute2	meter per minute2 (m/m2)	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		
feet2	meter2 (m2)	9.290 304 E–02
inch2	meter2 (m2)	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
mile (statute)	meter (m)	1.609 3E+03
inch	meter (m)	2.540 000 E–02

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)	4.882 428 E+00
pound/inch^2	kilogram per meter^2 (kg/m^2)	7.031 000 E+02
Mass per Unit Length		
pound-foot • inch	kilogram per meter (kg/m)	1.448 164 E+00
pound-foot • foot	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 (C)	t°C = (t°F – 32)/1.8
degree Fahrenheit	degree 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

Annex H
(Normative)

Tunnels and Enclosure Ventilation

H.1 Emergency ventilation system

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

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

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

a) greater than 1000 feet (305 meters) shall require a mechanical emergency ventilation system;

b) less than or equal to 1000 feet (305 meters) and greater than 200 feet (61 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.

H.2 Design

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

a) provide a tenable environment along the path of egress from a fire incident;

b) produce airflow rates sufficient to prevent back-layering of smoke in the path of egress;

c) be capable of reaching full operational mode within 120 seconds.

The design shall encompass the following:

d) the heat release rate produced by the combustible load of a vehicle and any combustible materials that could contribute to the fire load at the incident site;

e) the fire growth rate;

f) tunnel and enclosure geometries;

g) a system of fans, shafts, and devices for directing airflow in tunnels and enclosures;

h) a program of predetermined emergency response procedures capable of initiating prompt response from the operator in the event of a fire emergency.

H.3 Emergency ventilation fans

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

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

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

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

Fans associated only with passenger or personnel comfort and that are not designed to function as a part of the emergency ventilation system shall shut down automatically on identification and initiation of a fire emergency ventilation program so as not to jeopardize or conflict with emergency airflows. Non-emergency ventilation airflows that do not impact the emergency ventilation 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 91-2020, *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.

H.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.

H.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.

H.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 110-2019, *Standards for emergency and standby power systems.*

All wiring materials and installations shall conform to the requirements of ANSI/NFPA 70-2020, *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 70-2020;

c) all insulation shall conform to Article 310 of ANSI/NFPA 70-2020 and be moisture- and heat-resistant types carrying temperature ratings corresponding to the conditions of application and in no case lower than 194°F (90°C);

d) wire and cable constructions intended for use in control circuits and power circuits to related emergency devices shall pass the flame- propagating criteria of IEEE Std 383-2003, *Standard for type tests of Class 1E electrical cables, field splices, and connections for nuclear power generating stations;*

e) all conductors for emergency ventilation fans and related emergency devices shall be protected from physical damage by funicular vehicles or other normal funicular system operations and from fires in the funicular system by suitable embedment, encasement, or location. Encased conductors shall be enclosed in their entirety in armor sheaths, conduits, or enclosed raceway boxes and cabinets, except in ancillary areas or other nonpublic areas. Conductors in conduits or raceways shall be permitted to be embedded in concrete or to run in concrete electrical duct banks but shall not be installed exposed or surface-mounted in air plenums that might carry elevated temperatures accompanying fire emergency conditions;

f) overcurrent elements that are designed to protect conductors serving motors for both emergency fans and related emergency devices that are located in spaces other than the main electrical distribution system equipment rooms shall not depend on the thermal properties for operation.

H.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.

Annex J
(Normative)

Safety-Related Control Function Performance

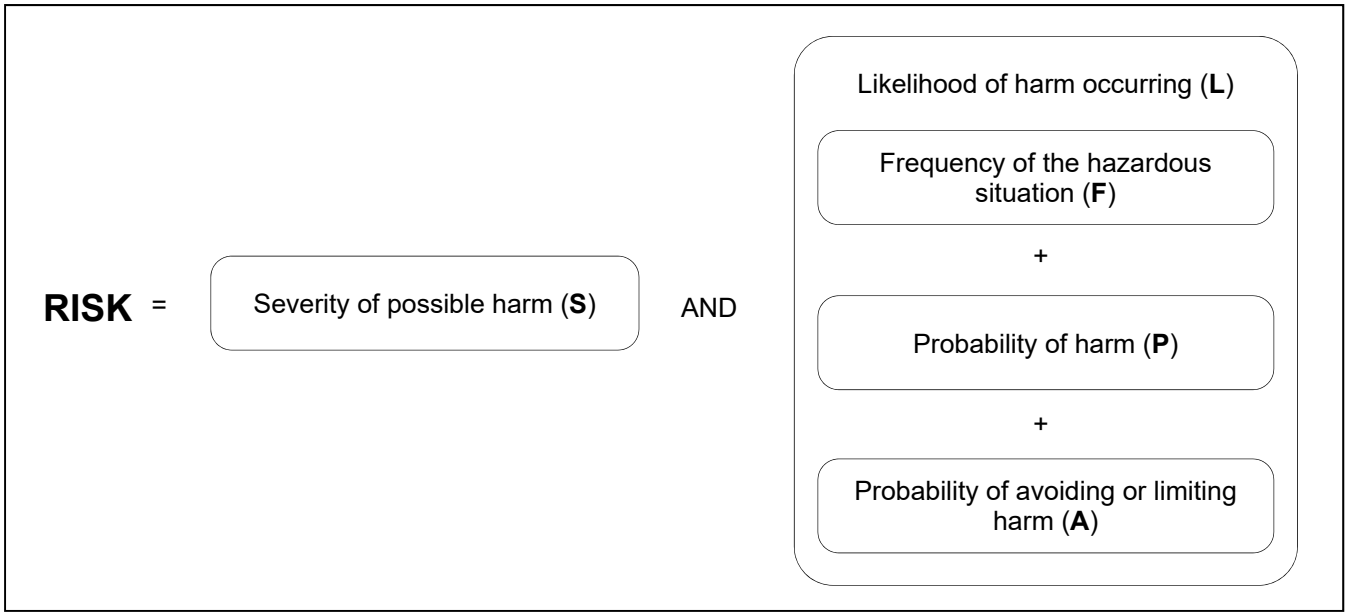
Annex J relates to product design and more specifically to the design of safety-related control functions only. Annex J should not be used outside of this intended purpose.

The performance of safety-related control functions shall be specified relative to the level of corresponding risk being controlled. The process defined herein shall be utilized for estimating risk and defining a suitable level of performance for each applicable safety-related control function identified in this standard, and when defining additional safety-related control functions not currently specified.

Tables with criteria for selecting risk parameters and estimating risk, including an example 5-step process are included in the pages following. Risk shall be estimated without the effect of the applied safety-related control function in place.

Table J.8 Provides a benchmark and identifies both nominal and minimum risk reduction levels for each safety-related control function specified in this standard.

The designer shall specify, design and validate each safety-related control function in accordance with ISO 13849-1:2015 & ISO 13849-2:2012, or IEC 62061:2015 (See Table J.6)



1 **Risk Parameter Selection Tables**

Table J.1 - Severity (S)

Severity of harm that might occur as a result of the hazardous situation	(S)
Major irreversible injury such as losing an eye or limb, or fatality	4
Irreversible injury such as a major broken limb(s) or losing finger(s)	3
Major reversible injury requiring attention from a medical practitioner, such as minor broken bones	2
Reversible injury requiring general first aid	1
The estimation of severity should be conservative, yet reasonable. For example, a fatality is certainly possible when someone trips and falls while walking along a sidewalk, but this is not very likely. It is more reasonable to assume that a person will catch and brace them self during the fall, suffering bruising and lacerations possibly a sprained wrist or minor fracture. For this example, a reasonably conservative selection might be (S) = 2.	

2

Table J.2 - Hazard Exposure Frequency (F)

Frequency of the hazardous situation	(F)
once per hour or more	5
several times per day but less than once per hour	4
several times every two weeks but less than once per day	3
several times per year but less than once every two weeks	2
less than once per year	1
Note – Exposure frequency is the frequency of the hazardous situation and should not be misconstrued with the frequency for which the hazard situation is monitored. For example, a system might continuously monitor for an overspeed condition, while an overspeed condition in a well-tried and proven drive control system might only occur only once or twice per year due to an unforeseen system dynamic. For this example, a reasonably conservative selection might be (F) = 2.	

1

Table J.3 - Probability of Harm (P)

Probability of harm occurring during the hazardous situation	(P)
Very high	5
Likely	4
Possible	3
Rarely	2
Negligible	1
Depending on the application and the conditions, not every hazardous situation will result in harm. For example, if a carrier travels between stations with an open door, the possibility of a passenger falling out of the carrier through the open door is feasible but very rare, and a reasonable selection might be (P) = 2 to maybe 3. Another situation, however, might be a carrier arriving at a terminal at a speed for which it cannot decelerate and stop safely, the probability of passengers being injured as a result would be likely to very high, and a reasonably conservative selection might be (P) = 5.	

2

Table J.4 Probability of Avoidance (A)

Probability of avoiding or limiting harm	(A)
Impossible	5
Possible in some, but not all foreseen circumstances	3
Possible in all foreseen circumstances	1
Many factors can influence a person's ability to avoid a hazard or limit harm. For instance, the speed of which the hazard arises, the person's awareness of the hazardous situation and their reaction time, their ability to escape or brace themselves, etc. For example, if a carrier door were to open, in most cases it would be possible for passengers to back away from the door or secure themselves from falling out, but in the rare situation the door may open unexpectedly and it might not be possible to avoid falling out. In this example, a reasonably conservative selection would be (A) = 3. Another situation, however, might be a carrier arriving at a terminal at a speed for which it cannot decelerate and stop safely, where the probability of being able to grab a handle or brace themselves well enough to reduce or limit harm might be impossible, where a conservative selection might be (A) = 5.	

3

Risk Reduction Level Assignment and Circuit Performance

Table J.5 – RRL Assignment Matrix

Severity (S)	Likelihood of harm occurring (L) = F + P + A				
	(3-4)	(5-7)	(8-10)	(11-13)	(14-15)
4	RRL2	RRL2	RRL2	RRL3	RRL3
3	RRL-LOW	RRL0	RRL1	RRL2	RRL3
2	RRL-LOW	RRL-LOW	RRL0	RRL1	RRL2
1	RRL-LOW	RRL-LOW	RRL-LOW	RRL0	RRL1

Table J.6 RRL correlation to performance and safety integrity levels

Risk Reduction Level (RRL) ANSI B77.2	Safety Integrity Level (SIL) IEC 62061	Performance Level (PL) ISO 13849-1
RRL3	3	e
RRL2	2	d
RRL1	1	c
RRL0	1	b
RRL-LOW	N/A	a
Note: All safety-related control functions shall be specified, designed, and validated in accordance with ISO 13849-1:2015 & ISO 13849-2:2012, or IEC 62061:2015		

Table J.7 Reserved for future use.

Example RRL selection process

Step 1: Create a tabular worksheet like the one below. All notes and assumptions utilized in the selection of each parameters shall also be documented, either in additional columns or another document.

Hazardous Situation	Severity (S)	Frequency (F)	Probability (P)	Avoidance (A)	Likelihood (L) = (F + P + A)	RRL

Step 2: Estimate the risk parameters **S**, **F**, **P**, and **A** utilizing Tables J.1 thru J.4 and enter these parameters into their respective columns.

Hazardous Situation	Severity (S)	Frequency (F)	Probability (P)	Avoidance (A)	Likelihood (L) = (F + P + A)	RRL
Example Hazardous Event	3	2	4	5		

Step 3: Calculate the likelihood (L) by adding parameters F, P, and A, and enter this value into the likelihood column.

Hazardous Situation	Severity (S)	Frequency (F)	Probability (P)	Avoidance (A)	Likelihood (L) = (F + P + A)	RRL
Example Hazardous Event	3	2	4	5	11	

Step 4: With (S) and (L) derived above, use Table J.5 to derive the RRL value.

Severity **(S)**	Likelihood of hazardous event **(L)** = F + P + A				
	(3-4)	(5-7)	(8-10)	**(11-13)**	(14-15)
4	RRL2	RRL2	RRL2	RRL3	RRL3
3	RRL-LOW	RRL0	RRL1	**RRL2**	RRL3
2	RRL-LOW	RRL-LOW	RRL0	RRL1	RRL2
1	RRL-LOW	RRL-LOW	RRL-LOW	RRL0	RRL1

Hazardous Event	Severity (S)	Frequency (F)	Probability (P)	Avoidance (A)	Likelihood (L) = (F + P + A)	RRL
Example Hazardous Situation	3	2	4	5	11	**RRL2**

Step 5: Use table J.6 to find the required PL or SIL value relative to the derived RRL. For this example, RRL2 = PLd (ISO 13849) or SIL2 (IEC 62061).

Table J.8 – Risk Reduction Level (RRL)

The purpose of Table J.8 is to serve as a benchmark for safety-related control function design. The values for $RRL_{Nominal}$ were derived through Ad Hoc committee assessment activities. The values for $RRL_{Minimal}$ are a simple reduction of 1 from the nominal RRL to accommodate various applications whilst maintaining a minimum benchmark.

$RRL_{Nominal}$ is the recommended risk reduction level to be applied to the defined safety-related control function. When this value is applied, it is not necessary to perform a risk estimation process unless the ropeway is of a novel or atypical ropeway design. Applying a risk reduction level higher than $RRL_{Nominal}$ to a safety-related control function is acceptable.

$RRL_{Minimum}$ is the lowest recommended risk reduction level that may be applied to the defined safety-related control function. It may only be applied when a risk estimation process has been performed and documented in accordance with Annex J and can be justified. Applying a risk reduction level lower than $RRL_{Minimum}$ may also be justified in certain applications where conditions are warranted (See section 1.2.3 Exceptions.)

Item	Hazardous Situation	Safety-Related Control Function	Section	$RRL_{Minimum}$	$RRL_{Nominal}$
1	Passengers exposed to severe oscillations in carrier speed during operation	Over Acceleration	2.1.1.4	RRL-Low	RRL0
2	Passengers exposed to high (forward) forces created by excessive carrier deceleration during operation, such as when slowing or stopping	Over Deceleration	2.1.1.5	RRL-Low	RRL0
3	A carrier traveling between terminals with a door not closed and locked, where the doors could potentially be open when departing a terminal, or open on their own or by a passenger during travel between terminals.	Door Closed and Locked Monitor	2.1.13.4.3	RRL1	RRL2
4	Unforeseen event or condition, or the operator perceives a loss of normal funicular control or undetected hazardous situation;	Emergency Shutdown	2.2.3.1	RRL1	RRL2
5	Carrier travels beyond its normal stopping location in either terminal (docking position)	Carrier Overtravel	2.2.3.2	RRL-Low	RRL-Low
6	Haul rope carriage tension exceeds its range of normal operation (tension too low or too high). Note: Scenarios involving too much tension on the haul rope will not likely result in a hazardous event as the specified design parameters for the haul rope would first have to be exceeded.	Tension System Monitoring	2.2.3.3	RRL1	RRL2
7	Carrier travels beyond maximum design speed setpoint by 10%	Carrier Overspeed	2.2.3.5	RRL2	RRL3
8	The speed of the carrier arrives at a terminal entry checkpoint at a speed above the design target entry speed	Speed Regulation Checkpoint Monitoring	2.2.3.7	RRL2	RRL3

Index

(Numbers refer to subclause in this standard.)

This index is intended as a supplement to the table of contents to aid the reader in finding particular subjects or requirements described in this standard. It is not all-inclusive, but rather is directed to the most commonly encountered topics.