



ROMA 1957  
PARIS 1963  
LUZERN 1969  
WIEN 1975  
MÜNCHEN 1981  
GRENOBLE 1987  
BARCELONA 1993  
SAN FRANCISCO 1999  
INNSBRUCK 2005

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INTERNATIONAL ORGANIZATION FOR TRANSPORTATION BY ROPE  
ORGANISACION INTERNACIONAL DES TRANSPORTES POR CABLE

# O. I. T. A. F.

## BOOK 8-1

Edition 2006

replaced by book n 8-1

## RECOMMENDATIONS FOR THE CONSTRUCTION AND OPERATION OF MATERIAL HANDLING UNI-DIRECTIONAL AND REVERSIBLE ROPEWAY INSTALLATIONS, CABLE CRANES AND MATERIAL HANDLING FUNICULARS



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## FOREWORD

Considering the many years that have elapsed since the first publication of the "Recommendations for the Construction and Operation of Material Transport Ropeways and Cable Cranes" in 1980 the International Organisation for Transportation by Rope, O.I.T.A.F., has decided to rewrite the document.

The need to revise and update the document which had been published in 1980 had become impellent O.I.T.A.F. having become aware that it was time to bring recommendations in line with the development of the technology and the introduction of new techniques, as well as to draw the necessary conclusions and teachings from the experience made in the meantime. The working group's proposal to add two additional chapters, one concerned with material handling funiculars, and the other specifying recommendations for temporary material handling ropeways, cable cranes and funiculars has been approved by the Management Committee who had realized the need to specify recommendations for two systems which are having a growing importance and increasingly wide diffusion.

The new version of these recommendations is the result of the cooperative work, discussions and contributions made by delegates appointed by the manufacturers, designers, operators and supervisory authorities of the following European countries: Austria, France, Germany, Italy and Switzerland. The following members have served on the responsible working group:

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*This document is intended as a practical guide and helpful aid for all concerned designers, technicians, managers who design, manufacture, operate, maintain etc. material handling ropeway installations, as well as all other concerned persons, meant to facilitate the exercise of their responsibility and the correct execution of their job in a way which is mindful of all safety requirements and environment friendliness*

*The subject matter covered by this document is being dealt with in the following three chapters*

- I. General Recommendations
- II. Permanent Material Handling Ropeways: Mono-cable and bi-cable uni-directional and reversible ropeway installations, cable cranes, rope cranes, jig back rope cranes, material handling funiculars
- III. Temporary Material Handling Ropeways: mono-cable and bi-cable uni-directional movement and reversible ropeway installations, cable cranes, rope cranes, jig back rope cranes

*These recommendations are not concerned with ropeway installations designed to carry persons nor material handling ropeway installations for pay loads up to 2000 kg, seen that specific recommendations have already been published for either of these two systems.*

## **CHAPTER 1 - GENERAL RECOMMENDATIONS**

### **Introduction**

This new version of the former edition of these recommendations ought to be seen as a complement to national regulations that may exist in different countries.

They are definitely not intended as a replacement of any existing regulation. Notwithstanding that it is hoped that in due course all countries, and in particular countries which do not have specific regulations, standards or specifications, will enforce these recommendations by giving them the status of an official legal instrument. It should be pointed out that these recommendations do not establish strict rules or limits, but should rather be seen as guidelines having the purpose to promote the progress of material handling ropeway systems. Far from us the idea to ban the use or application of new materials, new solutions, new theories, a new approach to design, new types and systems of material handling ropeway installations or new methods of construction simply because they did not exist or were not known when the authors of these recommendations discussed and produced their draft.

For the above reasons all readers and users will be well advised to assess the applicability of all specifications in the light of local conditions, and in particular of specifications which are thought to lack sufficient flexibility or sufficient coverage. Any deviation from the recommended approach shall have to be submitted to the approval of the competent supervisory authority, provided its acceptability can be reasonably motivated and duly justified. To this end and in order to help the competent authority to take a decision applicants shall be well advised to submit the necessary explanatory technical documentation, reports of tests carried out by or verified by officially approved and recognized test houses or laboratories.

## 1.1 Generalities

### 1.1.1 Field of application

These recommendations are applicable to all systems and types of material handling ropeway installations and are equally applicable to old as well as to new ropeway installations.

**Note:** All ropeway systems and types covered by these recommendations are listed in Annex A with the relative specific additional terminology and relative illustrative drawings.

### 1.1.2 Terminology

**1.1.2.1 Material handling ropeway installation.** Ropeway installation designed to transport or haul goods. The carriers of material handling ropeways are either hauled by one or several aerial ropes or hauled along a track which is either embedded in the ground or is supported by fixed structures

#### 1.1.2.2 Uni-directional and reversible aerial material handling ropeways.

Aerial ropeways in which one or several track ropes and one or several haul ropes (bi-cable ropeways) or one or several carrying-hauling ropes (mono-cable ropeways) haul loads from the station situated at one end of the track to the station at the other end. In most instances these aerial ropeways are used to haul relatively small loads (less than 5 t) over rather long distances, the ropes being supported by one or several line support structures. Besides the driving and the return station some ropeways have also one or several intermediary stations along the track. In principle these ropeways are not designed for vertical movements of the load.

There are fixed grip material handling ropeways the carriers of which are fixed permanently to the rope and detachable grip material handling ropeways the rope of which moves at a constant speed and the carriers of which are automatically detached from the rope when they reach the station.

The movement of carriers may be either uni-directional and continuous, or pulsed or reversible.

**1.1.2.2.1 Mono-cable aerial ropeways.** Aerial ropeways in which the carriers are suspended from and hauled by one or several carrying hauling ropes.

**1.1.2.2.2 Double mono-cable aerial ropeways.** Aerial ropeways in which the carriers are suspended from and hauled by two parallel carrying hauling loops or a carrying hauling rope arranged in a double loop.

**1.1.2.2.3 Bi-cable aerial ropeways.** Aerial ropeways in which the carriers are suspended from a rope or group of ropes, the carrying rope or group of carrying ropes, and hauled by another rope or group of ropes, the haul rope or the group of haul ropes.

**1.1.2.3 Cable crane.** Bi-cable ropeway system in which carriers travel along a track rope spanning between two towers, which are either stationary, travelling on a track or swung around by a slewing rope. The crab is fixed to the loop of the haul rope and with it hauled backward and forward, while a hoisting rope moves the bottom running block grip either upwards or downwards. The working range of cable cranes is either a line (stationary runway) or an area in the case of cable cranes with both towers travelling on parallel or radial runways).

**Note:** In France and in Italy cable cranes have been given the name “Blondin” after the family name of a French high wire performer who has crossed the Niagarafalls walking on a high wire.

**1.1.2.4 Rope crane.** Ropeway installation consisting of a tensioned track rope, which is actually the travelling runway of the crab, and a combined haul / lifting rope which has a twofold function i.e. to move the crab forth and back and to hoist or lower the load.

When the combined haul / lifting rope is being operated as a lifting rope the crab is held tight to the track rope by the so called track rope clamping device or by the ballast rope, when the haul / lifting rope is operated as a haul rope which hauls the load back and forth on the track rope the load is held tight to the crab by the load locking clamp.

Loading and unloading of the load may be done anyplace along the track.

**Note:** Rope cranes used in forestry are usually called skyline cranes.

**1.1.2.5 Reversible craneway.** There are mono-cable and bi-cable reversible craneways.

All crabs have a motor powered winch. In most instances both the hoisting and lowering of loads may be done anyplace along the track and the power driven winch is radio controlled.

The track rope of bi-cable reversible craneways which is actually the travelling runway of the crab is a tensioned rope. The crab is hauled to and forth all along the track rope by the haul rope. In the case of craneways built on a slight slope a ballast rope or ballast rope loop hauls the crab to and forth.

Crabs of mono-cable reversible craneways are suspended from and hauled by a combined carrying hauling rope.

**1.1.2.6 Material handling funicular railway.** Ropeway in which carriers are hauled by one or several ropes along a dedicated track which may be fixed to the ground or be supported by fixed structures

**1.1.2.7 Temporary ropeway installations.** Ropeways (mono- and multicable), reversible craneways, rope cranes, cable cranes the foreseen service time of which on the same site usually does not exceed **24 months or 16 000 loading cycles.**

**Note:** In principle most components of temporary installations, such as drives, crabs, hoisting gear, rollers, sheaves, line supports and other accessory components are usually current all purpose standardized, re-usable components.

**1.1.2.8 Carrier.** A component consisting of

- a) a crab and / or a grip
- b) a container, i.e. a bucket, a case, a platform,
- c) a hanger, the structural connection between container and its carrier truck or in the case of cable cranes, the rope connecting the lower hook block to the crab

**Note:** Funicular railways have a wagon consisting of a container mounted to a running gear which travels on the dedicated track; carriers of cable cranes are made up of a crab and running block

**1.1.2.8.1 Hook interlocking clamp.** Mechanical device used to keep the hoisting hook secured to the carrier and thus make sure the combined haul and hoist rope will perform only one of its functions, i.e haul the carrier along the track rope and not hoist or lower the load

**1.1.2.8.2 Track rope clamp.** Mechanical device used to keep the carrier secured to the track rope and thus make sure the combined haul and hoist rope will perform only one of its functions, i.e. lift or lower the load and not haul the carrier along the track rope.

**1.1.2.9 Ropes.** Depending on their type or function ropes are classified as follows:

**1.1.2.9.1 Static rope.** Rope anchored at least at one of its ends and possibly supported by one or more intermediary supports.

**1.1.2.9.2 Track rope.** Static rope arranged to support carriers the carrier truck of which has supporting and running rollers which move along the rope.

**1.1.2.9.3 Tension rope.** Rope connecting the free end of a static rope or the end sheave of a rope loop to the counterweight or tensioning device.

**1.1.2.9.4 Anchor rope.** Rope which transmits forces stemming from the track rope, the towers or any other mechanical component to the anchor.

**1.1.2.9.5 Signal cable.** Static rope having the only function to transmit electric control signals and telephone communications.

**1.1.2.9.6 Air navigation beaconing rope** with coloured globes attached to it having the function to signal to pilots the presence of a ropeway installation.

**1.1.2.10 Moving rope.** Rope arranged in such a way as to allow large longitudinal movements.

**Note:** Usually one or several carriers which are either permanently gripped to moving ropes or can be attached to or detached from the moving rope.

**1.1.2.10.1 Carrying-hauling rope.** Moving rope arranged to transmit its motion to carriers which are attached to it and supported by it.

**1.1.2.10.2 Haulage rope, haul rope.** Moving rope arranged to transmit its motion to carriers which are attached to it but are not supported by it.

**1.1.2.10.3 Counter rope.** In a funicular railway or a bi-cable reversible aerial ropeway the moving rope which is attached to carriers by end fixings without passing over the driving sheave.

**Note:** The term “ballast rope” can be used instead of “counter rope” if the drive station is located on the mountain side.

**1.1.2.10.4 Slewing rope.** Moving rope used to tilt towers sideways.

**1.1.2.10.5 Ballast rope.** Haulage rope attached to the carrier or crab which passes over an additional winch thus permitting to move the carrier or crab in either directions on sites with a small gradient.

**1.1.2.10.6 Combined haul and hoist rope.** Rope which has a twofold function in that it hauls the carrier or depending on the open or closed position of the carrier’s interlocking system (hook interlocking clamp and track rope clamp) lowers or hoists the load.



**1.1.2.10.7 Hoist rope.** Rope which carries out vertical hoisting or vertical lowering movements.

**1.1.2.10.8 Rope loop.** Rope closed into a loop by a splice.

**Note :** The extremities of a rope arranged in an open loop are either fixed to the carrier or the carrier truck.

**1.1.2.11 Sheave.** Rotating support which imparts its own curvature to the rope passing over.

**1.1.2.12 Roller.** Rotating support the radius of which is smaller than the radius of curvature of the rope at its point of contact

**Note:** As a rule the deflection does not exceed 4°

**1.1.2.13 Roller battery.** Set of rollers and their supporting structure with rollers so arranged one after the other as to give the moving rope a new direction

**1.1.2.14 Structures.** Collective term for stations, intermediate line support structures made of steel, timber or reinforced concrete and the track of funicular railways.

**1.1.2.15 Mechanical equipment.** Collective term for drives, tensioning devices, line support equipment (saddles, rollers and their support, roller batteries) sheaves, brakes, acceleration and deceleration ramps, etc.)

**1.1.2.16 Electrotechnical and electronic equipment.** Collective term for motors, controls, remote control systems, safety circuits, telephone cable, illumination, lightning protection equipment etc.)

**1.1.2.17 Auxiliary drive.** Drive other than the main drive which permits operation by replacing the latter, possibly at reduced capacity but with the same level of safety as in normal operation with the main drive

**1.1.2.18 Safety component.** Any component the partial or total failure of which endangers the safety or health of persons.

**Note.** Manufacturers are recommended to put down in writing and regularly update all procedures to be followed so as to bring them in line with the latest technical development so as to ensure

- the perfect identification of safety components and
- the regular registration of the identification.

Manufacturers are also recommended to submit to the competent authority all necessary documents and instructions for the assembly and installation of safety components. Such documents shall include

- a flow chart of the working sequence and a plan of all measures that have to be taken in each specific case
- a check list and plan of all tests which have to be carried during and at the end of each operating step

**1.1.2.19 Operational log book**

Register in which records are kept of all tests and maintenance transactions which have been carried out.

## 1.2 Technical Considerations

### 1.2.1 Basis information

The following fundamental information shall be given to the manufacturer for him to be able to make his offer and to detail his project:

- Purpose of the installation
- Type of the material : grain size distribution, specific weight or size and maximum weight
- Hourly and annual handling capacity
- Estimated service time of the installation
- Longitudinal profile in an appropriate scale, for instance scale 1 : 2000 (\*)
- Topographic survey in an appropriate scale complete of clear indications of crossings with electric lines, telephone lines, roads, railways, rivers etc. transversal slope profile
- Geologic report on the stability of the site, and should it be felt to be necessary, a snow report and information on likely seismic activity
- Climate
- Supply of energy (type and location)
- Information on local conditions: means of transportation, accommodation, road traffic regulations on maximum admissible weights and sizes etc.
- Availability of local labour (specialized, unskilled, hourly wages)
- Enforced specific local legal provisions, standards, regulations.

#### (\*) Note concerning the longitudinal profile survey

- The definitive longitudinal profile shall be plotted by an expert. The expert shall clearly indicate in his survey all points which have a fundamental importance for the quality of the project (elevation data / height data, summits, rocky hillsides, buildings and other obstacles)
- The expert shall also clearly indicate in his map the convenient position of line support structures and towers, and provide information on the nature of the soil, transverse slopes, slopes exposed to the danger of avalanches, crossings with power lines, waterways and sees, pathways, gorges, accessibility of the track and possibility to walk along it
- Durable and indelible flags of the surveyed characteristic points of the longitudinal profile shall be put up along the track.

### 1.1.2 Project engineering, design and documentation

**1.2.2.1** In order to assure the perfect and reliable performance of the ropeway installation the design and execution of all components of the ropeway shall comply with the accepted standards of the latest technical development. Calculation of stresses to which the material is subjected shall be carried out according to specifications laid down in relative standards and regulations. The result of the calculated degree of safety of components shall comply with values specified in the following chapters of this document. All methods of calculation which are being used should be recognized methods of calculation and possibly conform with specifications laid down in the standards for material handling and hoisting equipment.

**1.2.2.2** Design and execution of foundations of stations, line support structures, of the track, anchor blocs, buildings etc. shall be conform with regulations passed by local authorities as well as legal provisions and standards.

- 1.2.2.3** The designers are recommended to apply design criteria for components of ropeway installations which guarantee sufficient resistance to the likely maximum loads of the material to be carried, as well as sufficient resistance to the action of external forces which of course vary from site to site depending on the specific conditions of the site, such as the action of the wind, the load of snow and ice, seismic action etc. The horizontal wind pressure on ropes, carriers, structural members of the installation shall be assumed to be at least equal to  $250 \text{ N/m}^2$ .
- 1.2.2.4** Design values and criteria which are used to design components of ropeway installations shall guarantee sufficient strength and resistance to likely payloads and the effect of external actions so as to guarantee the necessary safety and stability throughout the service life of the installation.
- 1.2.2.5** Selection criteria and the calculation of ropes shall meet minimum requirements which have to be met so as to guarantee the minimum degree of safety.
- 1.2.2.6** The design of stations shall meet all requirements to be met to guarantee the perfect performance of the loading and unloading functions of stations and the safe operation of the installation.
- 1.2.2.7** Foundations and the anchorage of stations shall be calculated with a safety factor against overturning and slipping equal to at least 1.5. This safety factor shall be used to calculate the safety of the two situations to be considered, i.e. the ropeway installations in service and the ropeway installations out of service. The contribution of the surrounding ground may be allowed for in calculations of the degree of safety. The total pressure on the ground of all acting load factors shall not exceed the maximum admissible load specified in the geological / geotechnical report.
- 1.2.2.8** Care shall be taken to allow sufficient clearance for the passage of carriers and establish a clearance gauge limit wide enough to exclude the probability of carriers getting stuck or colliding with other components of the ropeway installations, guides excepted, or obstacles which are not an integral part of the ropeway installation.
- 1.2.2.9** Carriers shall be designed so that they can be perfectly guided and be equipped with appropriate fastening devices to secure goods and materials and thus exclude the probability of carriers or their load becoming the cause of dangerous situations.
- 1.2.2.10** Construction or retrofitting projects shall be submitted complete of all documents which are deemed to be necessary for an assessment of the safety of the ropeway installation or essential for the construction of the installation or execution of the retrofitting projects.  
In principle the documents which have to be submitted are the following ones in particular in the case of projects for bigger ropeway installations and provided there are no contrary decisions of the supervisory authority or the technical manager:

- Technical report and description of the project
- Plan of the site, scale 25000 or 5000, showing the layout of the track
- Longitudinal profile with contour lines, relief variations, rope line configuration, stations, line support structures, the track, crossings with power lines, other ropeway installations, public or private roads, railways, waterways, buildings in the neighbourhood of the ropeway installation
- Geotechnical report, snow report, seismic activity report
- Rope calculation, line calculation, driving force calculations, calculation of the required motive power which the driving sheave must build up in order to transfer the required force to the rope
- Plans of stations, scale 1 : 100, complete of ground plan, section and vertical plan, as well as plans of the station equipment
- Mechanical equipment
- Line support structures and track
- Carriers and grips and graphical verification of the dynamic clearance gauge limit, carrier truck brakes, if any, rail brakes
- Electric equipment including controls, monitoring and safety devices, communication and information equipment, lightning protection and grounding equipment
- Risk analysis (Cf clause 1.2.3)
- Service and maintenance manual

### **1.2.3. Generalities**

- 1.2.3.1** The competent supervisory authority or the operator may request the manufacturer to supply all material testing and conformity certificates for all materials and components which directly affect the safety of the ropeway installation
- 1.2.3.2** The safety of the ropeway is an essential requirement which shall be met in all operating conditions which are likely to arise while the installation is in service. Appropriate measures shall also be taken to prevent any hazardous situation to arise while the installation is out of service.
- 1.2.3.3** All components of the ropeway shall be provided with an adequate protection against corrosion. Care shall be taken to provide an easy access to all components which require frequent maintenance.
- 1.2.3.4** In order to meet all requirements regarding the protection of the staff and third parties the grounding of the mechanical equipment and of components made of metal shall meet the enforced regulations.
- 1.2.3.5** Care shall be taken to guarantee the risk-free, safe performance of all units, devices and of the mechanical and electrical equipment so as to avoid the occurrence of dangerous and harmful situations for persons and materials.
- 1.2.3.6** Care shall be taken to choose an appropriate design and execution of automatic driving systems and relative controls in order to guarantee the safety of the ropeway installation and prevent any hazardous situation to arise during operation.

- 1.2.3.7** Air speed indicators should be provided in the most exposed points of the ropeway installation. Operation of the ropeway shall be discontinued as soon as the indicator records wind speed values which are deemed to be dangerous.
- 1.2.3.8** Crossings with roads, railways, power lines, telephone lines, waterways require the prior approval of the competent supervisory authority. They shall be provided with appropriate guards, for instance bridges or nets. Crossings with second-order roads and branch lines, which normally need not be protected shall be signalled by warning signposts. Ropeway crossings with power lines shall be so arranged that the ropeway passes beneath the aerial power line if the power line cannot be buried. Anyway, either solution requires the prior approval of the competent supervising authority and the more so if it involves a temporary interruption of the power supply or displacement of the line.
- 1.2.3.9** A purposeful, simple and safe maintenance system is a requirement which shall have to be met in order to guarantee a safe and flawless performance of the ropeway installation.

#### **1.2.4 Commissioning of the ropeway installation**

Prior to receiving the authorisation to take up active service any ropeway installation shall have to be tested for acceptance and conformity with the submitted and approved design and specifications having the purpose to assess the compliance with the required degree of safety.

To this end ropeways shall have to be subjected to all specified functional tests under full and partial load having the purpose to assess the most unfavourable load conditions. The testing programme shall include functional tests to be carried out with maximum power output, acceleration, deceleration and braking in the most severe conditions, tests of brakes, tests of automatic devices, emergency stop push buttons, remote control systems tests of safety devices. Tests shall be run for at least two operating hours, which is a period of time deemed to be necessary to assess any warming up of rotating components, excessive oscillations and deformations and the undisturbed free movement of tensioning devices.

#### **1.2.5 Safety analysis**

The designer or the manufacturer are recommended to carry out a complete analysis of all hazards which are likely to arise and to prepare a safety report.

**Note:** An example of a risk analysis of a material handling ropeway installation is given in Annex

2.

### **1.3 Operation**

#### **1.3.1 Ropeway operation management**

- 1.3.1.1** It is recommended to entrust the technical management of ropeway installations to a person having the necessary technical competence and administrative responsibility, referred to in the following with the term “manager”.
- 1.3.1.2** The manager shall put down in writing rules for the operation of the installation. In order to be able to do so he ought to be expected to know perfectly the

technicalities of the installation, the operating conditions as well as service and maintenance instructions of the ropeway manufacturer. A copy of his operating rules shall be handed out to every member of the staff and, if so specified in the regulations, submitted to the competent supervisory authority.

- 1.3.1.3** In order to make sure that all requirements regarding the operational safety and the necessary protection and safety of third parties will be fully met the manager is recommended to employ a sufficient number of staff.
- 1.3.1.4** The manager is recommended to assess the professional ability of all members of the staff, provide the necessary professional training and clearly outline the responsibilities of every professional profile.
- 1.3.1.5** The manager is recommended to put down in writing operating procedures he deems to be necessary to prevent situations that might put at risk the life and health of persons and the integrity of the material and goods.
- 1.3.1.6** The manager shall take all steps he deems to be necessary to make sure the operation of the ropeway installation is perfectly consistent with applicable regulations, that it is submitted to regular controls and meets specifications for its regular maintenance.
- 1.3.1.7** No ropeway installation should ever be started or restarted if the manager, his assistant or designated competent members of the staff have not verified beforehand the perfect state and function of the ropeway installation and in particular the perfect state and function of telephone lines and of the signalling equipment.
- 1.3.1.8** Transportation of persons is not permitted. Yet an exception may be made for
- a) Persons who have to inspect the ropeway installation or carry out maintenance work
  - b) Persons who have to take the ropeway in order to get to their working place
- provided the ropeway has the necessary equipment which needs to be provided whenever persons are to be carried by the ropeway and provided that all the necessary additional requirements which are specified in the operating manual have been met and the manager has authorized the transport of persons. \*)
- If necessary an official request shall be made to the competent supervisory authority to authorize the transport of persons.
- \*) Additional operating instructions are listed in Annex C, Annex C*
- 1.3.1.9** Care shall be taken to maintain perfectly readable and easily discernible warnings and warning sign posts which shall be put up in stations, intermediary stations, along the track or on carriers to indicate the interdiction to carry persons, the maximum permissible pay load, the interdiction for unauthorized persons to enter into stations or approach or climb on line support structures, the interdiction to dwell within the passage areas of carriers in intermediary stations, as well as any other information or interdiction the manager deems to be necessary.

## **1.3.2 Service and maintenance manual**

- 1.3.2.1** The manufacturer is required to put down in writing and hand out the service and maintenance manual.
- 1.3.2.2** The manufacturer shall specify in the service and maintenance manual the following technical data of the supplied ropeway installation.
- Length [m] .....
  - Difference in altitude [m] .....
  - Max. load [t] .....
  - Permissible dimensions of the load  
Length .....[m], width ..... [m], height ..... [m]
  - Max. speed .....
  - List of ropes and their technical characteristics: .....
  - .....
  - Technical data of engines .....
  - Number of line support structures ..... Nr.
  - etc.
- 1.3.2.3** The manufacturer should be free to specify in his operating rules the required number of staff and the required professional qualification of staff members.

### **1.3.3 Operating rules**

The manager is recommended to specify in his operating rules all requirements and conditions that have to be met, measures that need to be taken and rules of behaviour of the staff, as well as information on at least the following features and details of the ropeway installation :

- Ropeway operation management
- Technical data of the ropeway installation
- Notice boards and sign posts indicating interdictions and rules of behaviour
- Additional technical measures which need to be taken in addition to those mentioned in the service and maintenance manual
- Survey of the manufacturer's service and maintenance instructions
- Telecommunication and transmission of signals
- Rules of behaviour in adverse weather conditions
- Fire prevention and control
- Rope maintenance
- Transportation of persons
- Oblique pull
- Etc. etc.

**Note** : For reference see example of operating instructions in annex C

## **CHAPTER II – PERMANENT MATERIAL HANDLING ROPEWAY INSTALLATIONS**

### **2.1 Mono cable and bi-cable uni-directional and reversible aerial ropeways**

#### **2.1.1 Generalities**

In principle most ropeways used to handle goods and materials are uni-directional mono-cable and bi-cable aerial ropeways. Reversible mono-cable and bi-cable aerial ropeways are mainly used in cases in which the required capacity is rather small or whenever it is necessary to handle big sized unit loads.

#### **2.1.2 Degree of safety**

**2.1.2.1** All components of the ropeway shall be designed and manufactured according to the precepts of latest state of the art. The execution of components, as well as the quality of the materials used to make them are expected to comply with this general rule.

**2.1.2.2** The manufacturer is recommended to apply generally recognized standards for design and calculation and material specifications (i.e. either specifications and standards which are applicable in the country of the manufacturer or specifications and standards applicable in the country in which the ropeway is built).

**2.1.2.3** The degree of safety of mechanical components shall be defined with reference to the yield strength of their constituting materials. Structures shall be designed with a safety factor at least equal to 1.7, while moving mechanical components subjected to the tensile stress of ropes (carrier trucks, sheaves etc.) shall be designed with a safety factor at least equal to 2.5. The fatigue safety factor shall be at least equal to 1.8

#### **2.1.2.4 Wind velocity**

Calculations shall be made with the following values for the dynamic pressure

- |                    |                       |                       |
|--------------------|-----------------------|-----------------------|
| 1. out of service: | dynamic wind pressure | 1200 N/m <sup>2</sup> |
| 2. in service:     | Dynamic wind pressure | 250 N/m <sup>2</sup>  |

Calculations for ropeways which are built on sites in extremely windy regions shall be made with higher values.

#### **2.1.3 Clearance above ground**

**2.1.3.1** The following conditions shall be met:

The vertical distance from the lowest point of the rope configuration and lowest point of the travelling component of the ropeway to the ground or other obstacles shall be at least equal to 2.5 m, due allowance being made for the likely height of the layer of snow or likely effect of the dynamic action. A clearance less than 2,5 m is permissible in places where the track is guarded or where there is no



sidewalk along the track. The clearance above areas and sites accessible to or used by motor vehicles or above crossings with roads shall be at least equal to 4, 5 m.

In the case of crossings with power lines or power lines parallel to the ropeway installations the clearance to be complied with is the clearance specified in safety regulations for power lines.

In order to determine the necessary clearance between two parallel ropeways or the clearance to be maintained in the case of a crossing of two ropeways due consideration shall be given to the clearance gauge limit of each ropeway. Due consideration shall also be given to possible upward jerks and vertical oscillations of ropes.

Air traffic regulations, if any, shall also have to be complied with.

- 2.1.3.2** There is no specified maximum height above ground limit for ropeway installations except in the case of ropeways which have received the authorization to carry persons and meet the requirements laid down in clause 1.3.1.8 b).

#### **2.1.4 Track**

The track should in principle be rectilinear. Horizontal deviation from the straight line on line support structures is tolerated if the component of the forces stemming from the deviation of the track rope or carrying-hauling rope, in the case of mono-cable ropeways, does not exceed by more than 5 % the minimum rope pressure. Angular stations shall be foreseen if the layout of the track requires a greater deviation.

#### **2.1.5 Stations**

- 2.1.5.1** The design of stations shall give due consideration to requirements of the loading and unloading procedures that have to be met to ensure the flawless transport of goods. Next to the optimization of the loading and unloading functions it is necessary to meet operational and maintenance requirements and hence adopt a layout which best meets these requirements.
- 2.1.5.2** Service rooms used by the staff shall be at least 2,5 m high.
- 2.1.5.3** Appropriate measures shall be taken to prevent unauthorised persons from entering into the operator's stand, the power room, the tensioning equipment and rooms of the electrical equipment
- 2.1.5.4** An adequate lighting installation shall be foreseen in all rooms of the station.
- 2.1.5.5** Appropriate measures shall be taken to prevent ill-coupled carriers of ropeways with detachable grips from leaving the station.
- 2.1.5.6** Design and construction of stations shall meet the requirements specified in standards and regulations for industrial buildings. To calculate the necessary strength of bearing structures of station rails the string of aligned loaded carriers shall be assumed as design load.
- 2.1.5.7** The mechanical and electrical equipment of stations shall be weather resistant or protected against the effect of adverse weather conditions, yet be easily

accessible for the necessary maintenance and protected against unlawful misuse.

- 2.1.5.8** Wherever necessary sufficient space shall be provided in stations for carrier storage sidings, spare parts stores, the storage of assembly tools, lubricants, as well as a repair shop.
- 2.1.5.9** Suspension hooks for ropes shall be provided for in stations to facilitate the inspection, repair and maintenance and replacement of ropes.
- 2.1.5.10** Lateral clearance of at least 0.5 m shall be provided for between containers (open or closed) of carriers and structural members of the station, other objects and other carriers all along the containers' travel through the station. This value shall be met also by carriers (open or closed) which tend to oscillate up to 20 % in unguided sections of their travel through the station.
- 2.1.5.11.** An appropriate water discharge shall be provided in all rooms liable to be afflicted by water infiltrations.
- 2.1.5.12** Fire prevention and control, as well as lightning protection shall be provided the choice of the measures being made dependant on local conditions and local regulations, if any.

## **2.1.6 Ropes**

- 2.1.6.1** Ropes shall have the best suited structure for their intended use. Track ropes shall be closed coil or half closed coil ropes. Haul ropes and carrying hauling ropes shall be parallel lay stranded ropes. Tension ropes shall be stranded and preferably galvanized ropes.
- 2.1.6.2** Tensile safety factor. The degree of safety is defined by the ratio of the design breaking load of the rope to the maximum axial rope tension which is built up in service. It shall be at least equal to the following value:
- |                                 |     |     |
|---------------------------------|-----|-----|
| - Track rope                    | 2.8 |     |
| - Haul rope in a closed loop    | 4.0 |     |
| - Drum wound haul rope          | 5.0 |     |
| - Carrying-hauling rope         | 4,5 |     |
| - Hoist rope                    | 5.0 |     |
| - Tension rope                  | 4.0 |     |
| - Signalling rope               | 2.5 | (1) |
| - Air navigation beaconing rope | 2.5 | (1) |

(1) 1.2 if ropes are anchored at both ends and assuming the most adverse weather conditions

- 2.1.6.3** Calculation of the maximum rope tension shall be made with the following values.
- 2.1.6.3.1** Track ropes
- a) Nominal tension of the rope (counterweight)

- b) height dependant weight component of the rope
- c) friction on track rope saddles
- d) friction on the deflection sheave which deflects the rope to the counterweight
- e) If ropes are anchored at both ends due consideration shall be given to the increase of the tension due to temperature variations, the extent of which varies with varying local conditions and variations which vary with the position of the carriage on the line.

#### 2.1.6.3.2 Haul ropes and carrying-hauling ropes

- a) nominal tension of the rope
- b) height dependant weight component of the rope
- c) weight component of containers
- d) friction between rope and rollers and friction between containers and rollers
- e) inertial forces which build up when the ropeway is being started or its speed reduced by brakes

#### 2.1.6.3.3 Hoist ropes

- a) height dependent weight component of the rope
- b) load on the concerned branch of the rope
- c) friction between rope and rollers
- d) inertial forces which build up when the ropeway is being started or its speed reduced by brakes

#### 2.1.6.3.4 Tensioning ropes

- a) nominal tension
- b) friction in the tensioning device

#### 2.1.6.3.5 Signal(ling) ropes and air navigation beaconing ropes

With counterweight

- a) nominal tension
- b) height dependent weight component of the rope and globes
- c) friction in the tensioning device and along the line + the additional friction if the rope is anchored at both ends
- d) increase in tension due to variations in temperature the extent of which shall be determined with due regard to local conditions and an assumed dynamic pressure  $q_w = 1200 \text{ N/m}^2$ .

In some instances, i.e. specific conditions of the site, it might prove convenient to make calculations with the following design assumptions:

- temperature : - 5 °C
- twice the load of the ice, i.e.  $q_e = + 0.4 d \text{ (N/m)}$  where  $d$  = nominal diameter of the rope in mm
- dynamic pressure of the wind  $q_w = 250 \text{ N/m}^2$

The action of the wind on spans longer than 400 m may be calculated by assuming a virtual length of the span equal to  $240 + 0.4 L$ , where  $L$  is the length of the inclined straight line of the span in mm. Where the distance between signal ropes and the ropeway installation, its ropes and carriers is rather small care shall be taken to verify that the required minimum distance between the signal rope and ropes and carriers is maintained even in the case of the maximum permissible lateral wandering of the rope due to lateral wind.

- 2.1.6.4** The number of carrier truck rollers shall be chosen so that the ratio of the minimum tension of the track rope to the component of the perpendicular pressure exerted by each roller on the track rope, due allowance being made for the component of haul rope forces transmitted to the carrier truck, is at least equal to 50 and hence the number of carrier truck rollers determined accordingly.
- 2.1.6.5** The ratio of the total weight of the load to the minimum axial tension of the carrying hauling rope of mono-cable ropeways should never be greater than 1:10.
- 2.1.6.6** End fixings of track ropes may be either drum wound rope fixings, poured sockets made with a fitting filler or else clamps, the choice of the best suited fixing being made by the manufacturer of the ropeway. Where ropes are fixed directly to anchor drums or track ropes are deflected in the station directly onto track rope shoes and the track rope cannot wind itself up or unwind itself or be displaced longitudinally the ratio of the diameter of the drum to the diameter of the rope shall at least be equal to 50.  
The method to be used shall be decided by the supplier of the ropeway. Other than the end fixing systems described above are admissible provided a safety analysis of the envisaged system has shown that its level of safety is equivalent.
- 2.1.6.7** Rope end fixings shall be corrosion proof and easily accessible for visual inspection.
- 2.1.7 Towers and their equipment**
- 2.1.7.1** Towers shall have the necessary height and the distance from each other shall be such as to prevent ropes from leaving their seat and lifting off in the most unfavourable load conditions.
- 2.1.7.2** Provisions shall be taken to guarantee the easy access to all towers along the whole length of the track.
- 2.1.7.3** Provisions shall be taken to facilitate the access to towers and their equipment so as to permit to all members of the staff and of the maintenance team to perform their functions in safe conditions of work (for instance ladders, platforms etc).
- 2.1.7.4** Towers shall be complete of appropriate and necessary mounting and fastening devices to help operators lift the rope and facilitate the installation, the displacement and the maintenance of ropes.
- 2.1.7.5** All towers shall be numbered in a progressive order.
- 2.1.7.6** The clearance between a tower and an up to 20 % laterally deflected container shall be at least equal to 0.20 m. In the longitudinal direction the design clearance shall allow for a 20% oscillation of the container.  
Spacer guides may have to be provided, if required.
- 2.1.7.7** Tower foundations shall be calculated with a safety factor 1.5 against overturning, slippage and lifting of in the most unfavourable service and out of service conditions due consideration being given to the contribution of the pressure of the earth backfill. Other design assumptions may be used to calculate tower foundations, provided their validity has been verified.

- 2.1.7.8** Towers shall have the necessary rigidity to preserve in normal service conditions their capacity to guide and support ropes despite stresses due to torsion or lateral wind.
- 2.1.7.9** Bi-cable ropeways with low hauling ropes shall be fitted with a rope re-engagement device for perfect guidance of ropes on supporting rollers.
- 2.1.7.10** Track rope saddles shall be given the best suited shape which ensures the smooth and noiseless passage of the carrier truck.  
The radius of the groove of the track rope saddle should be 10 % greater than the radius of the rope. Appropriate measures shall be taken to facilitate the lubrication of saddles.  
Track rope saddles shall be fixed to the tower by means of a system which facilitates their alignment with the axis of the ropeway. The minimum radius of saddles shall be at least equal to 150 times the diameter of the rope and shall not give rise to a radial acceleration of the carrier truck exceeding  $2.5 \text{ m/s}^2$ .
- 2.1.7.11** Sheave assembly and roller bearings shall be adjustable to permit an easy alignment with the axis of the ropeway.
- 2.1.7.12** Roller batteries of mono-cable ropeway towers shall consist of at least two rollers. Single rollers may only be used to guide ropes which arrive on the drive or return sheave.
- 2.1.7.13** The minimum rope pressure on each supporting roller of mono-cable ropeways shall be at least equal to 500 N. A 40 % increase of the rope tension shall not cause the rope to be lifted and loose contact with the roller of a tower the head of which is lower than the chord connecting the two neighbouring towers.
- 2.1.7.14** No supporting roller shall cause carrying-hauling ropes and hauling ropes to deflect by more than 10 %.
- 2.1.7.15** The maximum angle of deflection of ropes on a line support structure shall not exceed the values specified for rope saddles and roller batteries.
- 2.1.7.16** The diameter "D" [cm] of line rollers shall be calculated with the help of the following formula which establishes its dependency on the angle of deviation " $\varphi$ ", the diameter "d" of the rope and the tension "S" [N]

$$\frac{S * \tan \varphi}{d * D} \approx 50 \text{ to } 80 \text{ N/cm}^2$$

Other values may be used provided satisfactory evidence may be brought that the chosen material is capable of resisting to higher loads.

The diameter "D" shall be at least equal to 8 d.

## **2.1.8 Drives**

- 2.1.8.1** The main drive shall be designed to give a sufficient starting capacity and give a smooth start of the ropeway in the most unfavourable load conditions. In the case of uni-directional ropeways the carriers of which are detached automatically when they reach the station the most unfavourable load condition is the

departure under full load. To this end due consideration shall be given to the adverse effect of the layout of the track and operating regulations.

**2.1.8.2** The present state of the art permits to operate the following ropeway installations with the maximum speed listed hereafter

- bi-cable uni-directional aerial ropeways : 6 m/s
- mono-cable uni-directional aerial ropeways : 6 m/s
- mono-cable reversible aerial ropeways : 8 m/s
- bi-cable reversible aerial ropeways : 12 m/s

**2.1.8.3** The angle of contact between rope and drive sheave shall be determined with due regard to the required transmission of the motive force to the rope in the most unfavourable service conditions. To this end due consideration shall be given to the ratio of the tension of the branch carrying loaded carriers to the tension of the branch carrying empty carriers, as well as to the forces of inertia which build up when the ropeway is being started and run down.

Verification of the frictional adherence between rope and the groove of the sheave shall be made with the following coefficients of friction:

- Steel groove, unlined 0.10
- Rubber lined groove 0.20 – 0.25

Evidence shall have to be presented for the validity of coefficients of friction used for materials other than the materials listed above.

**2.1.8.4** The minimum diameter of drive sheaves and return sheaves shall be at least equal to 60 times the diameter of the rope. The diameter of the winch drum shall be at least equal to 40 times the diameter of the rope.

**2.1.8.5** Each drive shall have two brakes, working independently one from another, one of the brakes being the drive sheave brake which exerts its braking force directly on the drive sheave. The braking force shall be produced by weights or springs, i.e. due to a so-called negative action. Where necessary the drive may also be fitted out with a manually adjustable brake. Self-braking ropeways may do with one brake only which is released either automatically when the ropeway stops or manually.

**2.1.8.6** In the most unfavourable service conditions with loads travelling downwards all braking systems shall be expected to guarantee a mean deceleration of  $0.2 \text{ m/s}^2$  to  $2 \text{ m/s}^2$ , the deceleration being the ratio of the speed to the square to the double of the braking distance. The required deceleration value shall be determined with due regard to the results of the safety analysis.

## **2.1.9 Tensioning devices**

**2.1.9.1.** Ropeways shall have counterweights or other suitable equipment capable of maintaining the required tension of hauling and carrying-hauling ropes.

**2.1.9.2** Where track ropes are anchored at both ends solutions shall have to be found to measure (may be indirectly) and adjust the tension of the rope.

- 2.1.9.3** Counterweight guides shall be installed having the function to prevent rotations of suspended counterweights
- 2.1.9.4** Stops shall be placed at both ends of travel of the counterweight and of the tensioning lorry so as to keep their movements within the required limits of their field of action.
- 2.1.9.5** In order to preserve the free motion of the counterweight within its field of action and have a means to control it it is recommended to install a graduated ruler which permits to read anytime the position of the counterweight. Due consideration ought to be given to the fact that the distance between the counterweight and the bottom of the pit should be at least equal to 0.20 m and hence the extreme permissible position of the counterweight marked accordingly.
- 2.1.9.6** The diameter of the tension sheave shall be at least equal to 40 times the diameter of the rope.
- 2.1.10 Carriers**
- 2.1.10.1** Design and execution of carriers shall satisfy requirements for the safe handling of goods and materials.
- 2.1.10.2** Care shall be taken to distribute uniformly the total load of the transported material over all rollers of the carrier truck of containers of bi-cable ropeways.
- 2.1.10.3** No oscillation, whatever its cause or nature, nor oscillations due to the passage over a line support structure shall exceed the maximum permissible limit beyond which they might cause carrier trucks to lift off.
- 2.1.10.4** Tilting containers shall be provided with a locking catch to prevent their accidental overturning.
- 2.1.10.5** Grips shall be calculated for a non-slip safety at least equal to 1.5, due allowance being made for the action of all forces to which the carrier is likely to be subjected and the likely reduction of the diameter of the rope. Appropriate tests shall be carried out to verify the required resistance to slip. Design and execution of grips are expected to meet clearance requirements for the opening and closing of grips, due consideration being given to the likely service life of grips and the likely reduction of the rope diameter, as well as the likely manufacturing tolerances of the rope. Grips need not be removed as long as their resistance to slip meets requirements specified in the service and maintenance manual.
- 2.1.10.6** Adequate measures shall be taken to facilitate the relocation of grips of fixed grip ropeways (for instance reversible aerial ropeways).
- 2.1.10.7** Measures shall be taken to prevent carriers which have been detached at their entry into the station from leaving the station and taking the line if they have not been attached correctly.
- 2.1.11 Safety devices**
- 2.1.11.1** The electrical equipment of the ropeway shall have a key operated master switch and a differential circuit breaker capable of interrupting the overall power supply.

- 2.1.11.3** The ropeway installation shall have a built-in emergency shutdown circuit which may be opened by readily identifiable emergency shutdown push buttons placed in all critical points of the ropeway. The emergency shutdown circuit shall bring the ropeway to a rest within the shortest possible and for passengers and loads acceptable reaction time (shortest possible distance). Restart shall not be possible unless activated by the conductor's direct manually operated restart command. This emergency shutdown circuit shall also be automatically actuated by a power outage.
- 2.1.11.4** All safety circuits (including the emergency shutdown circuit) shall be closed circuits. Outside the drive station only low tension power supply of circuits shall be permitted. The shutdown array of switches shall be capable of bringing the ropeway safely to a rest, for instance by means of forced commutation contacts or special circuit techniques, such as for instance circuit duplication and functional tests. Emergency shutdown push buttons shall have to be reset manually.
- 2.1.11.5** Every disorder responsible for the stoppage of the ropeway installation shall be displayed on the monitor and the signal shall not be cancelled until the ropeway's perfect operability has been restored.
- 2.1.11.6** The ropeway shall be duly protected by a built-in lightning protection and grounding system, and shall be complete of an over-voltage protection of all electrical lines leaving the drive station.
- 2.1.11.7** All metallic components of the ropeway installation (drive station, track ropes, line support structures, return station etc.) shall be electrically interconnected by means of electrical conductors having an adequately dimensioned cross-section.
- 2.1.11.8** Ropeway installations shall feature all necessary indicators, such as for instance a power consumption meter, speed meter, indicator of the hydraulic pressure, counter of operating hours, counter of travels etc.
- 2.1.11.9** The ropeway should feature a fail safe stored programme control, SPC, having the function to monitor, keep record and documented evidence of all arising events and disorders. Installation of a remote inquiry system is desirable.
- 2.1.11.10** All concerned persons shall be duly warned in advance against likely risks that might arise when the ropeway installation is being started.
- 2.1.11.11** The ropeway shall feature a built-in over-speed monitor which actuates the release of the safety brake of the drive and opens the emergency shutdown circuit as soon as the speed of the ropeway exceeds the maximum permissible speed.
- 2.1.11.12** All ropeway installations shall have built in overload monitoring devices to stop the drive if the load is excessive.
- 2.1.11.13** The release of the different braking systems, and in particular braking systems actuated by a power outage or emergency stop shall not give rise to an excessive deceleration of the ropeway.



- 2.1.11.14** A reliable telephone based communication system shall be installed to ensure perfect communication between terminals.
- 2.1.11.15** The entry into stations of reversible ropeways shall be monitored by means of a monitoring device which actuates the power-down cycle if the speed at the entry into the station exceeds the maximum permissible speed. A buffer system having the required dimensions and strength may also be adopted as an alternative solution in lieu of the monitor based system.
- 2.1.11.16** An automatic service stop shall be placed at the end of the track of ropeways operated in the reversible mode. In addition reversible ropeways shall have a built-in emergency shutdown system which is actuated by a failure of the service stop and has the function to trigger the release of the emergency brake.

## **2.1.12 Transportation of persons (Cf. clause 1.3.1.8 b)**

- 2.1.12.1** Adequate additional measures shall be taken to guarantee the safety of persons who have to take the ropeway to perform their duties (Cf clause 12, annex C).
- 2.1.12.2** The carrier shall meet all requirements of a vehicle deemed to be suited for the transport of persons and should it be so required, its use submitted to the prior authorization of the competent authority.
- 2.1.12.3** Carriers used to transport persons shall be identified by means of a plate fixed on the carrier with written on it the number of persons who may be carried in one carrier, the useful load of the carrier and the interdiction to carry persons and goods in one and the same carrier.

## **2.2 CABLE CRANES, ROPE CRANES, REVERSIBLE CRANEWAYS**

### **2.2.1 Generalities**

- 2.2.1.1** The following recommendations specify guidelines for the construction of cable cranes designed to handle, lift, haul and deposit materials along an axis or within a rectangular or circular area. The crab of cable cranes travels on a track consisting of one or several track ropes. The crab hauling rope hauls the crab while the hoisting rope hoists or lowers vertically the material to be handled. Sometimes, as in the case of a rope cranes, all movements of the crab, i.e. hauling, hoisting and lowering of the load are carried out by a combined hoist and haul rope. The rope equipment of these cranes may comprise additional ropes for additional functions.

**Note:** In the following chapter the term cable crane stands for the above mentioned three types of cranes and crane ways.

- 2.2.1.2** Cable cranes are classified as follows:
- Stationary cable cranes. crane ways. jig back rope cranes
  - Luffing cable cranes,
  - Radial cable cranes
  - Cable cranes with both towers travelling on parallel tracks
- 2.2.1.3** Both the axis and the specific execution of cable cranes for the construction of bridges and viaducts are predetermined by the design of bridges and viaducts and the site conditions (in principle stationary cable cranes and cable cranes with

towers). This is also true for stockyard cranes (in principle cable cranes with both towers travelling on parallel tracks or cable cranes with slewing towers)

**2.2.1.4** The choice of the cable crane system best suited for the construction of a dam varies from case to case and has to be made by giving due consideration to the local conditions and main features of the project and site, i.e. the dimensions of the dam, the topography of the building site, the position of the concrete mixing plant, power supply and access roads. This is why the choice of the cable crane system is a choice to be made in the early stages of the project.

The number of cable cranes to be foreseen, their position on the building site and required specific technical data are the specific and determinant factors of a cable crane system.

The manufacturer of cable cranes shall be required to make the necessary calculations to make sure that the concrete bin with its full load travelling on the track rope will travel at a safe distance above the working area and in the final working stage at a safe distance above the crown of the dam.

## **2.2.2 Degree of safety**

**2.2.2.1** Design and execution of all components of cable cranes and the quality of materials used to make them shall meet the requirements of the latest state of the art.

**2.2.2.2** The manufacturer is required to apply the generally applicable standards for the design and published standards for the used materials (standards of the country of the manufacturer or standards of the country in which the cable crane will be erected).

**2.2.2.3** The safety factor of mechanical components shall be defined with reference to the yield strength of the material. Structural members shall be calculated with a safety factor at least equal to 1.7, while moving mechanical components subjected to the direct tension of the rope (for instance carrier trucks, sheaves) shall have to be calculated with a safety factor of at least equal to 2.5. The calculated safety factor against fatigue shall be at least equal to 1.8.

### **2.2.2.4** Wind velocities

Calculations of the velocity of wind shall be made with the following values for the dynamic pressure:

1. Out of service with crabs in the parking position (usually the loading point of concrete bins):                      Dynamic pressure 1200 N/m<sup>2</sup>
2. in service:    Dynamic pressure 250 N/m<sup>2</sup>

Higher values shall be taken for very windy areas

## **2.2.3 Range of action and clearance**

**2.2.3.1** The range of action of the cable crane is the space between the ground and the track rope. Its limits are determined by the maximum sag of the track rope under full load and the required minimum clearance of the bottom of the bin (in its highest working position) above the dam, the ground, the building site and its equipment.

- 2.2.3.2** It is deemed to be acceptable to reduce the height of towers and to assume a reduction of loads and of the load induced sag in the final stages of the project.
- 2.2.3.3** For the same reason it may be deemed to be permissible to increase the tension of the track rope in the final stages of the work provided the higher tension does not exceed the maximum permissible tension of the track rope and provided that the maximum permissible load remains within the limits of the assumed load reduction.
- 2.2.4 Driver's cab and engine room**
- 2.2.4.1** Any room which is used by the staff or other persons shall be at least 2.5 m high.
- 2.2.4.2** Adequate provisions shall be taken to prevent unauthorized persons from entering into the operator's station, engine rooms, room or pit of the tensioning device, electrical equipment room and service rooms.
- 2.2.4.3** Care shall be taken to provide adequate illumination in all rooms.
- 2.2.4.4** Care shall be taken to provide an adequate water discharge system in rooms subject to likely penetration of water.
- 2.2.4.5** Adequate fire control and lightning protection shall be provided for. To this end due consideration shall be given to local regulations, if any.
- 2.2.4.6** The position of the driver's cab should preferably be as close as possible to the loading station of the cable crane for the driver to have the best possible view of the overall range of action of the cable crane. Care shall be taken to avoid positions in which the driver could easily be blinded by the sun and to reduce as far as possible the viewing angle of the range of action between the loading and the unloading stations.
- 2.2.4.7** It is standard practice to have usually all drives operated from the driver's cab. Radio operated remote control of drives is permissible.
- 2.2.4.8** In order to facilitate servicing and maintenance it is advisable to arrange several operating stands close to the hoisting rope winch, the crab travel winch, carrier trucks, and winches of travelling towers. All cable crane controls shall be electrically interlocked.
- 2.2.5 Ropes**
- 2.2.5.1 Track ropes**
- 2.2.5.1.1** The track rope shall preferably be a closed coil rope. Other rope types may be used, provided they have a steel core.
- 2.2.5.1.2** In principle it is not permissible to have track rope joints in points which are within the range of action of crabs. If however for various reasons, such as transport requirements or assembly work, it is not possible to avoid joints of the track rope in this area, the passage over the track rope joints shall be permitted only at reduced speed and with reduced loads.

- 2.2.5.1.3** Track ropes may have a fixed anchorage at both ends. Manufacturers will however be well advised to install a tension take-up device at one end of the rope offering the possibility to compensate likely variations of the modulus of elasticity, tolerances of the cut length of the track rope or the permanent elongation of the rope.
- 2.2.5.1.4** It is permissible to assume that the hoist rope and the tensile rope contribute to the load bearing capacity of the track rope and hence to calculate the load bearing capacity accordingly.
- 2.2.5.1.5** Where saddles happen to be in the proximity of the anchorage the effective rope pressure shall suffice to maintain the firm contact of rope and saddle in the most unfavourable service conditions.
- 2.2.5.1.6** The design breaking load of the track rope shall be at least equal to 2.7 times the maximum track rope tension in normal operating conditions.  
A greater safety factor shall be used for spans less than 1 000 m long, i.e. a factor resulting from the following equation

$$v = 3.2 - 0.0005 \times l$$

where  $l$  is the length of the track rope span.

If neither of the end bearings of the track rope is a hinged bearing due consideration shall be given to the additional bending stresses and hence calculations made with a higher safety factor.

- 2.2.5.1.7** The maximum tension of the track rope shall be calculated from the following values:
- the maximum nominal load in the middle of the span
  - Where the distance between track rope anchoring points is a variable, such as for instance in the case of radial cable cranes with a single runway or cable cranes with slewing towers, the maximum distance of the track rope anchoring points
  - the maximum hoisting height, (the weight of the hoisting rope)
  - the lowest ambient temperature

The following values may be neglected:

- Dynamic forces generated by an acceleration and the resulting oscillations of ropes
- A difference between the measured sag and the nominal design sag not exceeding 4%.

- 2.2.5.1.8** The maximum track rope bending due to the passage of carrier truck rollers varies with the ratio of the minimum track rope tension to the maximum load of the roller.

In principle the ratio should be greater than 50 and hence the necessary number of rollers shall be determined accordingly.

For a limited number of working cycles of the carrier truck and provided that a shorter service life of the track rope is deemed to be acceptable a ratio of the rope tension to the pressure of rollers of less than 50 but not smaller than 30 is deemed to be acceptable.

- 2.2.5.1.9** The minimum tension of the track rope shall be calculated from the following values
- The maximum nominal load on the span corresponding to the smallest distance from the field of action to the anchoring point of the track rope.
  - The minimum distance of non stationary anchoring points, such as for instance anchoring points of radial cable cranes with a single runway or cable cranes with slewing towers.
  - The maximum hoisting height in the span corresponding to the smallest distance from the range of action to the anchoring point of the track rope, Cf point a), (weight of the hoisting rope).
  - The highest ambient temperature.

The following values may be neglected:

- Dynamic forces generated by an acceleration and resulting rope oscillations
- A difference between the measured sag and the design sag not exceeding 4%.

- 2.2.5.1.10** The ratio of the track rope span to the maximum sag shall preferably be usually equal to 17 and not greater than 22.

- 2.2.5.1.11** In order to reduce wearing stresses to which track ropes are subjected it is recommended to change from time to time the point in which the crab is being loaded, for instance by adopting an appropriate layout of the loading station.

- 2.2.5.1.12** The track rope anchorage and hoist rope and crab travel rope guides of radial and slewing cable cranes shall be adjustable to every inversion of the rope direction. Care shall also be taken to avoid excessive bending of ropes.

## **2.2.5.2 Crab travel ropes**

- 2.2.5.2.1** Crab travel ropes shall usually be lang lay ropes.

- 2.2.5.2.2** Cable cranes the crab travel rope of which is not tensioned by a counterweight shall be equipped with a tension take-up device having the function to build up the tension which is necessary to guarantee the adherence of the crab travel rope to the drive sheave, as well as to guarantee the required degree of safety of the cable crane.

- 2.2.5.2.3** The design breaking load of the crab travel rope shall be at least equal to 4 times the maximum crab travel rope tension in normal operating conditions of sheave driven cable cranes and at least equal to 4.5 times the maximum crab travel rope tension in normal operating conditions of winch driven cable cranes, due allowance being made in both cases for the additional acceleration and deceleration forces which build up in normal operating conditions. Oscillations of the load and tensions generated by an emergency stop can be neglected.

- 2.2.5.2.4** The diameter of crab travel rope sheaves as referred to the axis of the rope shall be at least equal to 40 times the diameter of the crab travel rope. In order to have the certainty to achieve a reasonable service life of the rope it is recommended to use sheaves and drums having a greater diameter.

### 2.2.5.3 Hoist ropes

2.2.5.3.1 Hoist ropes should preferably be cross lay stranded ropes, but at any rate anti-rotation ropes.

2.2.5.3.2 One end of the hoist rope shall be attached to the hoist rope drum and the other end to the opposite track rope anchorage.

2.2.5.3.3 The design breaking load of the hoist rope shall be at least equal to 5 times the maximum hoist rope tension in normal operating conditions due consideration being given to additional acceleration and deceleration forces which build up in normal operation. An alternative method of calculation consists in taking the overall useful load increased by 15 %. Another element which shall be entered into calculations is the tension produced by the dead weight of the hoist rope, i.e. the weight corresponding to the maximum hoisting height of the rope.

2.2.5.3.4 The diameter of the hoist rope sheave and hoist rope winches shall be at least equal to 40 times the diameter of the hoist rope as referred to the axis of the rope. In order to have the certainty to achieve a reasonable service life of the rope it is recommended to use sheaves and drums having a greater diameter.

### 2.2.5.4 Tower slewing ropes and guy ropes

2.2.5.4.1 The design breaking load of slewing ropes shall be at least equal to 5 times the slewing rope tension in normal operation allowance being made for the wind force in operation.

As for the verification of the compliance with the specified degree of safety of cable cranes out of operation towers shall be assumed to be standing in their vertical position (it is recommended to specify this rule in the operating instructions and in the maintenance and servicing manual). The slewing system shall be designed to resist in its deflected position to the action of the wind to which it is subjected when the cable crane is out of operation, i.e. the calculations of the slewing rope shall be made with a safety factor at least equal to 3.5.

2.2.5.4.2 The diameter of the slewing rope sheave, as referred to the axis of the rope shall be at least equal to 20 times the diameter of the slewing rope. The lateral deflection shall not exceed 3°.

2.2.5.4.3 The diameter of the anchoring drum of the slewing rope, as referred to the axis of the rope, shall be at least equal to 30 times the diameter of the rope.

### 2.2.5.5 Guy ropes and anchoring ropes

2.2.5.5.1 Lateral and backside guy ropes are used to secure towers used as a mounting support for track ropes.

2.2.5.5.2 Manufacturers are recommended to choose an anchoring system for guy ropes and anchoring ropes which does not cause excessive bending of the rope and hence no wire breakage.

2.2.5.5.3 The safety factor of guy and anchoring ropes shall **be at least equal to 1.2 times the degree of safety of the track rope**, due allowance being made for all

static forces, the action of the wind, the different positions of towers, the slope of the rope as well as for all other factors which contribute to the maximum rope tension.

- 2.2.5.5.4** Care shall be taken to choose an appropriate anti-rotation anchoring rope fixing system so as to prevent rotational movements of the tower.
- 2.2.5.5.5** Anchoring ropes can also be anchored in the ground and secured to a drum-like reinforced concrete block with a timber stave lining by making at least three windings around the drum. Free rope ends shall be secured by clamps which have been calculated with a safety factor 3 against slippage. An additional clamp shall be added for the sake of a visual monitoring of the slippage.
- 2.2.5.5.6** Anchoring blocks shall be calculated with a safety factor against slippage, overturning and up-lift at least equal to 1.5. The passive lateral pressure of the soil may be neglected. It shall be permitted to secure stationary towers and masts with rock anchors.
- 2.2.5.5.7** The diameter of the drum, as referred to the axis of the rope, shall be equal to 30 times the diameter of stranded ropes, equal to 40 times the diameter of open spiral ropes and equal to 50 times the diameter of closed spiral ropes.
- 2.2.5.5.8** Hinged poured metal socket end fixings may be used to fasten anchoring ropes.

## **2.2.6 Towers and masts**

- 2.2.6.1** The following values shall be used to calculate towers:  
the dead weight of towers, stresses transmitted to towers by ropes or generated by the action of wind and stresses due to seismic phenomena, if any..
- 2.2.6.2** Cable crane towers shall be complete of the necessary assembly and maintenance facilities. Provisions shall be taken to facilitate the access to towers and their equipment and guarantee the safety of the staff.
- 2.2.6.3 Travelling towers and masts**
  - 2.2.6.3.1** The design and execution of counterweights shall meet all requirements of the latest state of the art and perfect performance capability in all operating conditions that may arise.
  - 2.2.6.3.2** Travelling and stationary towers which are not secured by anchoring ropes are required to resist to overturning in the most unfavourable load conditions (maximum nominal static load and dynamic pressure in operation) and shall hence be calculated with the safety factor against overturning 1.5.
  - 2.2.6.3.3** The required number of running and guiding rollers which shall be assembled in the rocker to give a uniform distribution of the load to which running rails are subjected and the appropriate arrangement of rockers shall be determined with due regard to the fact that acting forces vary with every variation of the cable crane position. An admitted solution are power driven running rollers.
  - 2.2.6.3.4** Towers shall be calculated with a safety factor 1.2 against wind induced lateral wandering. In operating conditions the effect of the brakes of travelling tower

drives normally builds up a sufficient resistance and hence safety against wind induced drift off.

Automatically or manually released track brakes or made to purpose locking systems develop additional resistance and hence safety against wind induced drift off of cable cranes out of operation. Safety devices shall prevent the cable crane from being started again while the brake is still engaged or the locking system activated.

**2.2.6.3.5** Care shall be taken to install a limit switch having the function to prevent towers from colliding with limit stops.

**2.2.6.3.6** Buffers shall be installed at the end of the runway and fixed to towers to prevent collisions and attenuate the impact of the collision in the case of a failure of the limit switch.

**2.2.6.3.7** Most towers travel at a speed of 9 to 18 m/min.

**2.2.6.3.8** All necessary measures shall be taken to guarantee the travel synchronism of all towers (cable cranes with both towers travelling on parallel runways and cable cranes with slewing towers).

#### **2.2.6.4 Stationary towers and masts**

**2.2.6.4.1** Stationary towers are expected to resist to slippage, overturning and up-lift in the most unfavourable load conditions and shall therefore be calculated with a safety factor against slippage, overturning and up-lift at least equal to 1.5. The lateral passive pressure of the soil may be neglected. It shall be permitted to secure stationary towers and masts with rock anchors.

**2.2.6.4.2** Stationary towers shall normally be supported by a hinged bearing (globe and socket joint) so as to minimize the action of different stresses and have the towers prevalently subjected to compressive stresses. This is why due consideration shall be given to the likely action of other stresses (mainly flexural stresses) if another bearing solution is being used.

#### **2.2.7 Drives (crab travel winch, hoisting winch, slewing winch)**

**2.2.7.1** The maximum crab travel speed shall be adjusted to conditions that have to be met for suspended rope carriers to be able to fulfil efficiently their function. Progressive adjustment of speed and acceleration shall be provided. Simultaneous crab travel and hoisting of the load or crab travel and lowering is possible.

**2.2.7.2** It is recommended to provide cable cranes with electrical controls having the function to govern the progressive adjustment of the starting acceleration and the progressive running down of the cable crane so as to avoid excessive oscillations of the load and permit to operate the crane with the low speed which is needed for the visual inspection of ropes.

**2.2.7.3** All necessary measures shall be taken to make sure drives will be fully operative even in the most adverse service conditions. Motors shall be designed to provide adequate deceleration.



**2.2.7.4** The braking force shall be produced by weights or compression springs. The release of brakes which are kept open by compressed air or compressed liquids shall be triggered by the loss of pressure.

#### **2.2.7.5 Crab travel drive**

**2.2.7.5.1** As a rule the crab travel drive shall have a grooved drive sheave. The material of the lining shall be chosen with due regard to the material's capacity to prevent slippage of the rope on the drive sheave in all service conditions and normal acceleration and deceleration. It is recommended to line grooves of the drive sheave with an elastic material having a coefficient of friction at least equal to 0.20.

Steps shall be taken to avoid slippage of the rope in the grooves of the drive sheave in all likely service conditions and in conditions of normal acceleration and normal deceleration.

**2.2.7.5.2** Crab travel drives shall be complete of a service brake which is automatically triggered by a power outage and is released when the crab has reached the limit stop.

Where the track has a steep upward gradient the drive shall be equipped with a safety brake which is automatically released in the case of a failure of the service brake and acts directly upon the drive sheave. Either brake shall cut the power supply of the drive as soon as they have been actuated. Manual opening of either brake shall be possible.

**2.2.7.5.3** In some specific situations the cab driver shall have the possibility to take the crab beyond the normal field of action of the cable crane.

#### **2.2.7.6 Hoisting winch**

**2.2.7.6.1** In order to achieve a longer service life of the hoist rope it is recommended to install hoisting winches which have a grooved drum and to fix the end of the hoisting rope on the drum.

**2.2.7.6.2** The hoisting winch shall have a service brake which is automatically released by a power outage or as soon as the crab has reached the limit stop.

The hoisting winch shall in addition have a safety brake which is automatically released in case of a failure of the service brake and acts directly on the rope drum. Either brake shall cut the power supply of the drive as soon as they have been released. It is recommended to choose a brake design which permits to open brakes manually if concrete is the material to be handled by the cable crane.

**2.2.7.6.3** Hoist winches with long drums shall have in addition rope winding guides if the rope deflection exceeds  $2.5^\circ$ .

**2.2.7.6.4** The hoist winch drive shall have a redundant mechanical over-speed monitor which is directly connected with the hoist winch drum and actuates the safety brake as soon as the speed exceeds by 20 % the nominal operating speed.

#### **2.2.7.7 Drives for travelling and slewing towers**

The brakes of the running lorries of travelling and slewing towers shall be actuated by power outages.

## **2.2.8 Suspended rope carriers**

- 2.2.8.1** In principle crab travel ropes and hoist ropes shall be supported by regularly spaced suspended rope carriers having the function to prevent extreme sagging of ropes, rope cross-over and severe speed variations due to very frequent sag variations which are likely to arise in adverse operating conditions.
- 2.2.8.2** There are two different suspended rope carrier systems: immovable suspended rope carriers which are fixed to the track rope and travelling suspended rope carriers. Care shall be taken to choose a suspended rope carrier design and execution which do not impede the smooth and safe operation of the cable crane.
- 2.2.8.3** In all operating conditions suspended rope carriers are required to guide perfectly the crab travel rope and the hoist rope. Appropriate steps shall be taken to prevent collisions of crabs and suspended rope carriers.

## **2.2.9 The runway**

- 2.2.9.1** The outlay of radial runways shall be chosen with due regard to the requirement to minimize variations of the distance between the two anchoring points of the track rope (length of the cord of the track rope).  
The horizontal runway draws the arc of a circle. Sloping runways develop along a spherical surface the centre of the sphere being coincident with the fixed anchoring point of the track rope.  
Where more than one cable crane travel on a single runway, variations of the distance between the two anchoring points of the track rope are unavoidable seen that the anchoring points of the cable cranes are not coincident with the centre of the sphere or the centre of the circle. Rope tensions and anchoring forces shall be calculated for every single cable crane as well as for all important specific situations along the runway. Due consideration shall also be given to variations of the track rope cord due to variations of the swing or traversing movement of slewing towers of cable cranes with one stationary tower and one tower travelling on a radial runway.
- 2.2.9.2** The execution of the runway and laying of runway rails require special attention and care. It is most important to position running rails and supporting rails most accurately, the accuracy of execution being a requirement which has to be met to avoid the lateral drift off of running wheels.
- 2.2.9.3** Due consideration shall be given to the requirement to maintain a correct relationship between the pressure which rails exert on foundations and the compressive strength of the concrete grade used to make foundations. Steel plates may be embedded into foundations for improved distribution of the pressure. The maximum permissible compressive stress to which the concrete may be subjected shall be verified according to the specification of recognized standards.
- 2.2.9.4** In order to assess the wheel pressure to which rails are subjected due consideration shall be given to the physical properties of the steel used to make the wheels and of the steel used to make rails, as well as to the expected service intensity and expected service life of the cable crane. It is recommended to use

for rails a steel which has a lower degree of hardness than the steel used to make wheels.

The permissible pressure, the safety factor, as well as the ratio of the specific rail to wheel contact pressure shall be calculated according to specifications laid down in recognized standards.

## **2.2.10 Crabs**

**2.2.10.1** It is recommended to attach particular importance to measures which need to be taken in order to reduce the wear of the track rope throughout the likely service life of the cable crane and hence to decisions regarding the number and diameter of running rollers and the appropriate hardness of the roller lining.

**2.2.10.2** Crabs shall feature an anti derailment device.

**2.2.10.3** All running rollers shall have a rubber lining or else have a lining made of a resilient material and shall be lodged in rockers to permit a uniform distribution of the load.

**2.2.10.4** The same is true for the return sheave and rollers all of which shall be lined with rubber or a resilient material.

**2.2.10.5** The crab travel rope shall be fixed to the travelling gear by means of a poured metal socket, a wedge socket or a drum wound fixing.

**2.2.10.6** Crabs shall feature a catwalk for inspection and maintenance teams.

## **2.2.11 Safety devices**

**2.2.11.1** The overall power supply of cable cranes shall be interrupted by two safety devices i.e. a key operated master switch and a differential relay circuit breaker.

**2.2.11.2** Circuit diagrams of the electrical, hydraulic and pneumatic equipment shall be kept in the drive station ready to be handed out to the maintenance technicians. All diagrams shall be complete of accurate reference indications of all components. All components shall have indelibly marked on them their identification.

**2.2.11.3** An emergency shut down circuit shall be provided which can be opened by means of easily identifiable emergency shutdown push buttons placed in all critical points of the cable crane installation. The emergency shutdown circuit shall bring the cable crane to a rest in the shortest possible yet for persons and loads reasonably acceptable reaction time (after the shortest possible yet reasonably acceptable distance). Resumption of the operation shall not be possible unless activated by means of a manually operated restart command of the conductor. This emergency shut down circuit shall also be automatically actuated by a power outage.

**2.2.11.4** All safety circuits (including the emergency shut down circuit) shall be normally closed circuits. Outside the drive station circuits shall be fed only with a low tension power supply. The shutdown array of switches shall be capable of bringing the cable crane safely to a rest, for instance by means of forced commutation contacts or special circuit techniques, such as for instance circuit

duplication and functional tests. Resetting of shut down push buttons shall be manual.

**Note:** A closed circuit is a circuit in which there is normally in the idle condition a permanent flow of the current. Interruption of the flow of current initiates the desired function.

- 2.2.11.5** Every disorder responsible for the stoppage of the cable crane shall be displayed on the monitor and signals shall not be cancelled until the perfect operability of the cable crane has been restored.
- 2.2.11.6** The cable crane shall be duly protected against lightning and perfectly grounded. All metallic components of the cable crane (drive station, track rope, line support structures, return station etc) shall be electrically interconnected by means of electrical conductors having an adequate cross-section. All electrical lines leading out of the drive stations shall be protected against over-voltage.
- 2.2.11.7** Care shall be taken to provide the cable crane with all necessary indicators such as for instance indicators of power consumption or torque meter, speed, hydraulic pressure, operating hours, number of trips.
- 2.2.11.8** Cable cranes shall be equipped with a fail safe stored programme control, SPC, having the function to monitor, keep record and documented evidence of all events and disorders. Installation of a remote inquiry system is desirable.
- 2.2.11.9** No person shall ever be put in danger when the ropeway is being started. All likely involved persons shall be duly warned in advance against likely risks.
- 2.2.11.10** Cable cranes shall be equipped with speed monitors having the function to actuate the drive sheave safety brake and to open the emergency shutdown circuit without delay if the speed exceeds the permissible operating speed.
- 2.2.11.11** An overload monitor shall actuate the power down cycle of the drive as soon as the load exceeds the allowed useful load.
- 2.2.11.12** The release of the different braking systems, and in particular braking systems actuated by a power outage or an emergency shutdown, shall not produce an excessive deceleration.
- 2.2.11.13** A reliable communication system shall ensure perfect communication between the cable crane driver's cab and the loading and unloading areas, as well as with the engine room.
- 2.2.11.14** Indicators of the distance travelled by the crab and of the distance covered by the hoisting or lowering movement shall be provided in the driver's cab of the cable crane.
- 2.2.11.15** A monitor shall be placed at the entry into stations of jig back cable cranes which actuates the power down cycle as soon as the speed at the entry into the station exceed the allowed speed. Jig back cable cranes having no entry monitors shall have buffers having the necessary dimensions placed at the entry into stations.
- 2.2.11.16** An automatically operated service stop shall be placed at the track end of jig back cable cranes. Jig back cable cranes shall also have an emergency shutdown system which is actuated in case of a failure of the service stop and triggers the release of the emergency brake.

## **2.2.12 Transportation of persons (Cf 1.2.1.8 b)**

- 2.2.12.1** Adequate additional measures shall be taken to guarantee the safety of persons who for various reasons have to take the cable crane (Cf Annex C, clause 12).
- 2.2.12.2** The carrier shall meet all requirements of a vehicle deemed to be suited for the transportation of persons and should it be so required, submitted to the prior authorization of the competent authority.
- 2.2.12.3** Carriers used to transport persons shall be identified by a plate fixed on the carrier with written on it the number of persons that may be carried in one carrier, the useful load of the carrier and the interdiction to carry persons and goods in one and the same carrier.

## **2.3 MATERIAL HANDLING FUNICULARS**

### **2.3.1 Generalities**

Material handling funiculars are rope driven means of transportation the carriers of which have steel or rubber lined wheels which run on rails or a concrete track. Material handling funiculars have either one single vehicles hauled by a hauling rope which is either driven by the drum of a winch around which it forms several windings or driven by a drive sheave, case in which the haul rope is tensioned by a travelling counterweight, or reversible funiculars with two vehicles running on two rails or a single rail with a central turnout section. Most material handling funiculars have only one haul rope. There are no limits to the maximum permissible load besides the restrictions imposed by the state of the art or building standards.

### **2.3.2 Degree of safety**

- 2.3.2.1** All funicular components shall be designed and manufactured to the specifications of the latest state of the art, which means that both the material execution of components as well as the quality of the materials used to make them shall meet the requirements imposed by the latest progress of the art.
- 2.3.2.2** The manufacturer shall apply all general standards for design and as well as standards for building materials (standards applicable in the manufacturer's own country or standards applicable in the country of destination of the funicular).
- 2.3.2.3** The degree of safety of mechanical components shall be calculated with reference to the yield strength of materials. Calculations of the minimum degree of safety of mechanical structural members shall be made with a safety factor 1.7 and shall be made with a safety factor 2.5 in the case of mobile mechanical components subjected to the direct action of the rope tension (for instance carrier truck, sheaves). The fatigue safety factor used to calculate components shall be at least equal to 1.8.
- 2.3.2.4** Wind velocities:  
Calculations shall be made with the following values for the dynamic pressure:

1. out of operation      dynamic pressure: 1200 N/m<sup>2</sup>
2. in operation          dynamic pressure: 250 N/m<sup>2</sup>

Calculations for sites exposed to strong winds shall be made with higher values.

### **2.3.3 Clearance and crossings**

With a view to ensuring an adequate protection of all involved persons the clearance in respect of fixed structures or obstacles and the distance between two carriers on the turnout section shall be at least equal to 0.50 m. A smaller distance from obstacles and level crossings shall be tolerated provided adequate measures are taken to ensure an adequate level of safety.

### **2.3.4. The Track**

- 2.3.4.1** Wherever possible the track shall have a uniform upward slope. Curves in the vertical as well as in the horizontal plane may be tolerated.
- 2.3.4.2** Conspicuous variations of the gradient shall be avoided and to this end earth works done or bridges built to minimize variations, where possible. If no such remedy is possible rope guiding rollers shall be arranged along the track.
- 2.3.4.3** A purposeful arrangement of rollers along the track is recommended so as to avoid an excessive uplift of ropes.
- 2.3.4.4** Warning signs shall be placed along the track to warn unauthorized persons that the access to the track is not permitted.
- 2.3.4.5** Appropriate steps shall be taken to protect the track against falling trees or falling objects.

### **2.3.5 Stations**

- 2.3.5.1** In the early stage of design due consideration shall be given to the loading and unloading function of the station and relative requirements to be met. Besides solutions that are adopted to optimize these functions it is necessary to adopt a layout which facilitates the maintenance of the station and ensures the safety of the staff and of the maintenance teams.
- 2.3.5.2** All rooms used by the staff or other persons shall be at least 2.5 m high.
- 2.3.5.3** Appropriate measures shall be taken to prevent unauthorized persons from entering into operator's stands, counterweight pits, if any, service rooms of the electrical equipment.
- 2.3.5.4** Illumination of all rooms shall be adequate and sufficient.
- 2.3.5.5** Design and execution of stations shall meet all requirements applicable to industrial buildings.

- 2.3.5.4** The mechanical and electric equipment shall be weatherproof or shall be adequately protected against the action of adverse weather conditions, yet remain easily accessible for maintenance.
- 2.3.5.7** Wherever necessary the layout of the station shall allow sufficient space for an inspection pit, parking rails for carriers, store rooms for spare parts, assembly tools, lubricants, as well as a machine shop.
- 2.3.5.8** In order to facilitate the inspection, maintenance and repair of ropes it is recommended to arrange a sufficient number of anchoring points for the rope lifting gear.
- 2.3.5.9** An adequate water discharge system shall be provided in rooms in which water penetration is likely.
- 2.3.5.10** Steps taken to provide an adequate fire prevention and control and an adequate lightning protection system shall meet local specifications for fire and lightning protection.

## **2.3.6 Ropes**

- 2.3.6.1** Ropes shall have the best suited structure for their intended use. The use of possibly galvanized stranded Lang lay ropes is recommended.
- 2.3.6.2** The safety factor for rope tension is defined by the ratio of the ultimate breaking load to the maximum rope tension. The safety factor shall be at least equal to the following values:
- |                              |     |
|------------------------------|-----|
| - Haul rope and ballast rope | 4.0 |
| - Winch driven haul rope     | 5.0 |
| - Tensioning rope            | 4.0 |
- 2.3.6.3** The rope safety factor shall be determined from the following values:
- 2.3.6.3.1** Haul rope and winch driven haul rope
- Nominal tension of the tensioning system, if any.
  - Weight component of the carrier in the most unfavourable position.
  - Weight component of the rope (inclusive of the weight of the ballast rope if any).
  - Friction of the carrier including the additional friction in curves.
  - Friction of line rollers and guiding rollers and friction of return sheaves.
  - Starting and braking inertia in normal operating conditions (mean acceleration and mean deceleration).

Considering all the above no further additional dynamic strain needs to be taken into account.

**2.3.6.3.2 Ballast rope**

- a) Nominal tension of the tensioning system,
- b) Resistance of the tensioning system,
- c) Maximum weight component of the rope,
- d) Resistance of line rollers,
- e) Inertia calculated as for haul rope.

If the maximum tension is calculated in this way the additional dynamic stresses can be neglected.

**2.3.6.3.3 Tensioning ropes**

- a) Nominal tension
- b) Friction in the tensioning system

**2.3.7 Rails, track and track equipment**

**2.3.7.1** Rails and their anchorage in the ground shall have a sufficient stability to resist to all likely stresses produced in normal operating conditions.

**2.3.7.2** The maximum line roller deflection of ropes shall not exceed 5.7°.

**2.3.7.3** The diameter of line rollers “D” [cm] is a function of and varies with the angle of deflection “φ”, the diameter of the rope “d” [cm] and the rope tension “S” [N] and shall be chosen accordingly by entering the relative values into the following equation:

$$\frac{S * \tan \varphi}{d * D} \approx 50 \text{ to } 80 \text{ N/cm}^2$$

Other values shall be tolerated provided that evidence can be brought that the material which is used resists to heavier loads.

The diameter of the roller “D” shall be at least equal to 8 d.

**2.3.8 Drives**

**2.3.8.1** Design and execution of drives shall ensure a soft start even in the most unfavourable conditions of the specific track routing or resulting from the specific operating rules.

**2.3.8.2** The present state of the art permits to operate funiculars with the following operating speed:

- Funiculars driven by a drive sheave 14 m/s
- Winch driven funiculars 8 m/s

In addition operation at a speed ranging from 0.3 to 0.5 m/s, i.e. the low speed used to inspect the funicular shall always be possible.



- 2.3.8.3** The winding angle on the drive sheave shall have the appropriate aperture to be able to resist to the peripheral force and transmit the motive force to the rope. In order to determine the necessary aperture of the angle due consideration shall be given to the most unfavourable ratio of the rope tension of the two rope branches, as well as to the starting and braking inertia.

Verification of the adherence of the rope to the sheave groove shall be based on the following assumptions:

- Steel groove without lining, coefficient of friction 0.10
- Rubber lined groove, coefficient of friction 0.20 – 0.25
- Evidence shall have to be brought for the validity of the coefficient of friction entered into calculations for materials other than the material listed above.

- 2.3.8.4** The diameter of the drive sheave and return sheave shall be at least equal to 60 times the diameter of the rope, the diameter of the winch drum at least equal to 40 times the diameter of the rope.

- 2.3.8.5** All drives shall have at least two brakes which are independent one from the other. One of the two brakes shall apply its braking force directly to the drive sheave. The braking force shall be produced by weights or compression springs. Should it be deemed to be necessary a manually operated brake shall be added.

- 2.3.8.6** Each braking system shall be capable of producing a mean deceleration ranging from 0.2 to 2 m/s<sup>2</sup> in the most unfavourable conditions with the load hauled downwards, the deceleration being defined by the ratio of the speed to the square to the double of the braking distance. The most appropriate deceleration shall be determined with reference to the results of the safety analysis.

### **2.3.9 Tensioning devices**

- 2.3.9.1** The ballast rope, if any, shall be tensioned by counterweights or another appropriate tensioning system.

- 2.3.9.2** A guiding system shall be provided to contrast likely rotations of suspended counterweights

- 2.3.9.3** Movements of the counterweight and of the tensioning lorry shall be limited by stops placed at far ends of their working range.

- 2.3.9.4** Appropriate steps shall be taken to ensure the free movement of counterweights and their positions shall be monitored with the help of a graduated scale with marked on it the permissible extreme positions of the counterweight and the required minimum distance from the bottom of the counterweight pit which shall be at least equal to 0.20 m.

- 2.3.9.5** The diameter of the tension sheave shall be at least equal to 40 times the diameter of the rope.

## **2.3.10 Carriers**

- 2.3.10.1** Design and execution of carriers shall guarantee the safe haulage of materials. Tipping containers shall be equipped with a safety lock to contrast accidental tipping over.
- 2.3.10.2** All necessary calculations shall be made to verify and provide evidence that neither acceleration nor lateral wind or passing over curves at a speed equal to 1.5 the nominal operating speed shall cause running rollers to uplift. If need be the carrier truck shall be equipped with devices having the function to contrast derailment and uplift of running rollers.
- 2.3.10.3** Running rollers shall be either flanged steel wheels or steel, rubber, Vulkolan rollers or else rollers made of another equivalent material.
- 2.3.10.4** Different types of end fixing systems may be used to fix the haul rope to carriers. i.e. clamps, wedge sockets, a drum wound end fixing or poured socket. Other types of end fixings shall be tolerated provided evidence can be brought that their safety is equivalent to the safety of the above mentioned types of end fixings.
- 2.3.10.5** The requirements laid down in clause 1.3.1.8 b) shall have to be complied with if carriers are used to transport persons, i.e. the maximum permissible operating speed shall not exceed 50 % of the nominal operating speed and never exceed 2.0 m/s. Adequate measures shall be taken to protect persons against the risk of falling out of the carrier. Gripping brakes, if any, shall be within the reach of passengers for them to release the brake anytime. Communication via telephone or radio shall be provided for technicians who take a carrier in order to inspect the line to have the possibility to communicate directly with the engine operator.
- 2.3.10.6** Gripping brakes shall be provided for if the safety analysis reveals the need to provide gripping brakes as a means to eliminate or minimize identified danger scenarios.
- 2.3.10.6.1** Measures shall be taken to provide certainty that the failure of the haul rope or ballast rope will trigger the release of the gripping brake and that the release of the gripping brake will not give rise to the risk of derailment or uplift of the carrier truck.
- 2.3.10.6.2** Depending on the solutions which has been adopted the gripping brake shall either exert its action on the track rail, a dedicated braking rail or on a brake rope. The required safety shall have to be verified in all cases in which there is a potential risk that the action of the brake may give rise to a unilateral force affecting the stability of the carrier.
- 2.3.10.6.3** Where the release of the gripping brake has been triggered by the failure of the rope the built up braking force shall bring the carrier to a rest on the steepest section of the track with a deceleration at least equal to 0.5 m/s due allowance being made for the consequences of a possible wear of the brake shoes or dirt on the rail.
- 2.3.10.6.4** The release of the gripping brake shall automatically cause the drives to be powered down (slack rope switch).

**2.3.10.6.5** The release (may be accidental) of the braking device, in particular release while the carrier is travelling uphill, shall never give rise to a dangerous situation, for instance failure of a rope, derailment, loss of the load. To obviate the occurrence of such a risk it is possible to carry out the uphill travel with a reduced braking force or install a brake release retarder.

**2.3.10.6.6** Measures shall be taken to ensure a safe access to the carrier, for instance by providing an inspection platform, an inspection vehicle, a ladder, etc.

### **2.3.11 Safety devices**

**2.3.11.1** The electrical equipment of funiculars shall include a key operated master switch and a differential relay circuit breaker capable of interrupting the overall power supply.

**2.3.11.2** Circuit diagrams of the electrical, hydraulic and pneumatic equipment shall be kept in the drive station ready to be handed out to the maintenance technicians. Diagrams shall be complete of accurate reference indications of all components and of their identification. All components shall have indelibly marked on them their identification.

**2.3.11.3** The funicular shall have a built-in emergency shutdown circuit which can be opened by readily identifiable emergency shutdown push buttons placed in all critical points of the funicular. The emergency shutdown circuit shall bring the funicular to a rest within the shortest possible, yet for persons and loads reasonably acceptable reaction time (shortest possible, yet reasonably acceptable distance). Restart shall not be possible unless actuated by the conductor's manually operated restart command. The power outage shall also cause the emergency shutdown circuit to become active.

**2.3.11.4** All safety circuits (including the emergency shutdown circuit) shall be normally closed circuits. Outside the drive station only low voltage power supply of circuits shall be permitted. The array of shutdown devices shall bring the funicular safely to a rest, for instance by means of forced commutation contacts or special circuit techniques, such as for instance circuit duplication and functional tests. Emergency shutdown push buttons shall have to be reset manually.

**2.3.11.5** Every disorder responsible for a stoppage of the funicular shall be displayed on the monitor and the signal shall not be cancelled until the ropeway's perfect operability has been restored.

**2.3.11.6** All funiculars shall have an in-built lightning protection and grounding system. All metallic components (drive station, track rope, line support structures, return station etc) shall be electrically interconnected by means of electrical conductors having an adequate cross-section. All electrical lines entering the station shall be protected against over-voltage.

**2.3.11.7** Funiculars shall feature all the necessary indicators, such as for instance indicators of power consumption, speed meters, indicators of the hydraulic pressure, counters of hours of operation, counters of trips etc.

**2.3.11.8** The funicular should preferably feature a fail-safe stored programme control, SPC, having the function to monitor, keep records and documented evidence of

all arising events and disorders. Provision of a remote enquiry system is desirable.

- 2.3.11.9** No person shall ever be put in danger when the funicular is being started. All concerned persons shall be duly warned in advance against likely risks.
- 2.3.11.10** The ropeway shall feature a built-in over-speed monitor which triggers the release of the safety brake of the drive and opens the emergency shutdown circuit as soon as the speed of the ropeway exceeds the maximum permissible speed.
- 2.3.11.11** Funiculars shall feature built-in overload monitoring devices which stop the drive if the load exceeds the permissible payload.
- 2.3.22.12** The release of the different braking systems, and in particular of the braking systems which have been actuated by a power outage or emergency stop, shall not lead to an excessive deceleration of the funicular.
- 2.3.11.13** A reliable telephone based communication system shall ensure perfect communication between stations.
- 2.3.11.14** The entry into stations of funiculars operating in the reversible mode shall be monitored by means of a monitoring device which actuates the power-down cycle if the speed at the entry into stations exceeds the maximum permissible speed or else, as an alternative have a buffer system which has the necessary strength and dimensions installed at the entry into stations.
- 2.3.11.15** An automatic service stop, as well as an emergency shutdown system actuated by a failure of the service stop having the function to actuate the release of the emergency brake shall be placed at the end of the track of funiculars operating in the reversible mode.
- 2.3.12 Transportation of persons (Cf clause 1.3.1.8.b)**
- 2.3.12.1** Adequate additional measures shall be taken to guarantee the safety of persons who have to take the funicular to perform their duties. (Cf Annex C, clause 12)
- 2.3.12.2** The carrier shall meet all the requirements of a vehicle deemed to be suited for the transportation of persons.
- 2.3.12.3** Carriers used to transport persons shall be identified by means of a plate fixed to the carrier with written on it the number of persons that may be transported in one vehicle, the useful load of the carrier and the interdiction to transport persons and goods in one an the same carrier.

## CHAPTER III

### TEMPORARY MATERIAL HANDLING ROPEWAYS

#### 3.1 Definitions and generalities

Temporary material handling ropeway installations is a technical term which stands for ropeways, cable cranes, rope cranes and jig-back rope cranes the service life of which principally does not exceed **24 months or 16 000 operating cycles**.

In principle all the above mentioned ropeway installations, whatever their type and system, are specially designed and executed to suit the requirements of a limited service time. Actually the requirements to be met are essentially the same as the requirements specified in chapter II for permanent material handling ropeways and this is the reason why this chapter specifies only recommendations which differ from recommendations for permanent installations.

**Note :**

- Recommendations specified in this chapter are not concerned with material handling funiculars.
- All material handling ropeway installations may also be used as temporary material handling ropeways and seen that their likely usage is limited in time designers and planers try to find solutions to reduce to a minimum the necessary earth works, assembly and dismantling operations.
- Wherever possible use is made of standard components, adjusted, if necessary to the specific requirements of the site and destination. Components of temporary material handling ropeways, i.e. drives, carrier trucks, hoisting gear, rollers, sheaves, line support structures and other accessories are in most cases reusable standard general purpose components. As for the design, dimensioning and execution of made to purpose components due consideration is given in most instances to the fact that their service life is limited in time.

#### 3.2 Curves in the track

The perfect running performance of a track which is not rectilinear shall be verified. Tracks can be given a bend without the need to erect an angle station. Indeed it is sufficient to use rope saddles having an adequate curvature and adequate shape of the groove to guarantee the perfect guidance of the track rope. The haulage of carriers in curves requires special attention and frequently recurring checks.

#### 3.3 Stations

As a rule temporary material handling ropeways have no stations. Where necessary shelters shall be provided to protect the conductor and drives against bad weather. Special loading and unloading areas shall be arranged along the track, as well as easily accessible areas to facilitate the work of and ensure the safety of the inspection and maintenance teams.

#### 3.4 Ropes

Track ropes are often ropes which have been already used and removed from another ropeway installation. Where ropes are delivered without the necessary documents and data sheets of their characteristics, tests shall be carried out to asses the breaking load of the ropes. Prior to the commissioning the temporary

ropeway shall be submitted to a visual inspection. To this end it is recommended to carry out a magnetographic inspection of the working length of the rope.

**Note:** In most cases haul ropes of temporary installations have a rather short service life.

### **3.5 Line support structures**

Steel and timber line support structures shall have the necessary strength to meet the specific requirements. Line support structures shall have a hinged bearing and shall be guyed. To calculate the required strength of the different anchoring systems (concrete foundation, dead man's anchorage, trees, earth pegs, rock anchorage) due consideration shall be given to stresses which are transmitted to the anchoring system. Line support structures shall have a sufficient number of hooks to secure the personal protection equipment of inspection and maintenance technicians who have to climb on these structures.

**Note:** The so-called dead man's anchorage is a system of anchor logs placed in the earth and stabilized by the back-fill placed above it.

### **3.6 Drives and safety devices.**

All components shall satisfy relevant safety prescriptions.

Drives of temporary material handling ropeways are usually compact general purpose units.

Seen that usually the range of action of temporary ropeways is situated within eyesight, the operation of temporary ropeways is entrusted to an attending conductor who is present on the site or is controlled by a remote control system similar to the one used to operate building cranes. This is also the reason why, departing from specifications for permanent installations, it is tolerated to operate temporary installations without some of the safety devices which automatically actuate the power down system of ropeways, such as for instance the over-speed monitor, the limit switch placed at both ends of the track which actuate the emergency shutdown circuit.

It shall also be tolerated, departing again from specifications for permanent ropeways, to equip the hoist rope winch with one service brake only instead of two service brakes. It is recommended, but not compulsory, to provide the conductor with adequate indicators, such as for example, position indicators, speed indicators, power consumption indicator etc.

### **3.7 TRANSPORTATION OF PERSONS (Cf clause 1.3.1.8 b)**

**3.7.1** Transportation of persons shall be regarded as a secondary function of a temporary ropeway installation, i.e. a function which is performed only in a number of rides equal to no more than 10 % of the total number of rides made by the ropeway.

**3.7.2** Transportation of persons shall be permitted only if all requirements specified in Annex C, clause 1.2.5 and clause 12 have been met and provided that a safety analysis which contemplates also the safety of passengers has been carried out.

**3.7.3** No loads shall be transported in carriers transporting persons. Passengers may take with them duly secured tools and spare parts they may need.

- 3.7.4** The useful load of carriers which transport persons and their tools (assumed weight of one person: 80 kg) shall not exceed 30% of the admissible overall useful load of carriers transporting only materials.
- 3.7.5** Safe, closed carriers or cabins shall be made available for the transportation of persons.
- 3.7.6** Passengers shall be given a perfectly performing radio or telephone based means of communication for them to establish a contact with the conductor if the latter cannot see the whole length of the track from his control stand. The system of communication shall be checked before each departure. With the provided system of communication the conductor shall be given timely information about the carriers passage over a line support structure and its arrival at the loading or the unloading area.
- 3.7.7** Adequate measures shall be taken to prevent an accidental opening of the carrier hook or the cabin fastening hook.
- 3.7.8** Carriers and cabins used to transport persons shall be identified by a plate fixed on the carrier or cabin with written on it the number of persons that may be carried in one carrier or cabin, the useful load of the carrier and the interdiction to carry persons and goods in one and the same carrier or cabin.
- 3.7.9** Clear and accurate readings of the speed and the position of carriers shall be supplied by speed and position indicators placed on the driver's operating stand.
- 3.7.10** The effective length of the track shall be limited by appropriate stops. An appropriate additional distance of the track shall be provided for between the point in which the stopping command is given and the stop marking the end of the track. Bumpers placed at the track end of funiculars without monitors supervising the entry into the station shall have the necessary dimensions and strength to absorb or attenuate the kinetic energy. At their arrival at the terminal end of the track oscillations of the carrier shall not be greater than oscillations which have been assumed to determine the oscillation clearance limits.

### **3.8 Design criteria and safety levels**

Considering that the service life of temporary ropeway installations is limited in time and that they have a specific application, it shall be admitted to multiply design values specified for permanent ropeway installations in chapter II with a reduction factor.

The order of magnitude of reductions and the application of less stringent design criteria and safety levels shall be determined with due regard to their correlation with and dependency of factors which are fundamental for the safety of the ropeway installation.

The design value  $W_1$  is the design value to be entered into design calculations for permanent ropeway installations and shall hence be used in design calculations of temporary ropeway installations as reference basis value for the calculation of the reduced value to be entered into calculations of components of temporary ropeway installations.

The value W2 shown in the table is the absolute minimum which shall be entered into calculations of components of temporary ropeways even if the application of the reduction formula results in a lower value.

### 3.8.1 Table of Design Criteria

		Design criterion																					
		Min. haul rope safety factor in endless rope loop		Min. haul rope safety factor for winch driven ropeway		Min. safety factor of carrying hauling rope		Min hoist rope safety factor		Min. slewing rope safety factor		Min. ratio of roller Ø to haul or hoist rope Ø		Min. ratio of sheave Ø to hoist or haul rope Ø		Min. track rope safety factor		Min. ratio of the track rope saddle radius to the track rope Ø		Min. ratio of the tension of the carrying hauling rope to the max. lifeload		Min. ratio of the track rope pressure to the max. bearing pressure of carrier truck rollers	
		Sich. Zse		Sich. ZSw		Sich. FS		Sich. HS		Sich. SS		Fak. R/S		Fak. S/Z		Sich. TS		Fak. TR/TS		Fak. TS/Q		Fak. TS/LR	
		MSB	KK	MSB	KK	MSB	MSB	KK	KK	MSB	KK	MSB	KK	MSB	KK	MSB	KK	MSB	MSB	MSB	MSB	MSB	KK
Maximum value = permanent ropeways = basis		4.0	4.0	5.0	4.5	4.5	5.0	5.0	5.0	8.0	8.0	60	40	2.7	2.7	150	10	50	50				
Minimum value for limited service life		3.0	3.0	3.5	3.5	3.0	3.5	3.5	3.5	5.0	5.0	15	15	2.7	2.7	50	7	15	15				
Factors of influence	Number of cycles	ΣLS								ΣLS		ΣLS		No reduction		ΣLS		ΣLS		ΣLS			
	Load spectrum	LK		LK	LK	LK	LK	LK	LK	LK		LK				LK		LK		LK		LK	
	Track rope structure	MT														MT							
	Rope structure	MA		MA	MA	MA	MA	MA	MA	MA		MA						MA		MA			
	Running time	Σt		Σt	Σt	Σt	Σt	Σt	Σt	Σt		Σt											
	Smallest sheave Ø	SRD		SRD	SRD	SRD	SRD	SRD	SRD	SRD		SRD											
	Single strand hoist Direct hoist	ES						ES															
Number of factors of influence		4		4		4		5		4		3		3		0		3		3		3	

#### Legend

- Sich = safety factor
- Fak = ratio
- MSB = Uni-directional and reversible material handling ropeway
- KK = Cable cranes, including rope cranes and jig-back rope cranes



## 3.8.2 Factors of influence

Factors of influence	<b>1</b>	<b>Number of cycles</b>	2000	4000	8000	16000	=>16000	
		$\Sigma LS$	0.85	0.9	0.94	0.975	1	
	<b>2</b>	<b>Load spectrum</b>	Light duty	Medium duty		Heavy duty		
			Low frequency of heaviest loads	Almost equal frequency of light weight, medium weight and heavy loads		By and large only heaviest loads		
		LK	0.85	0.925		1		
	<b>3</b>	<b>Track rope structure</b>	Closed coil	Spiral strand rope		Strand rope		
		MT	1	0.95		0.85		
	<b>4</b>	<b>Structure of haul, hoist, slewing and carrying hauling ropes</b>						
		Wire strength	1570	1770	1960	2160		
		MA	0.85	0.925	0.975	1		
	<b>5</b>	<b>Operating hours</b>	500	1000	2000	4000	=>8000	
		$\Sigma t$	0.85	0.905	0.945	0.975	1	
	<b>6</b>	<b>Smallest ratio of return sheave <math>\varnothing</math> to rope <math>\varnothing</math></b>						
		<b>Ratio</b>	60	50	40	=>30		
		SRD	0.8	0.9	0.95	1		
	<b>7</b>	<b>Hoist rope arrangement</b>	Direct tension (1 rope)			Several ropes		
		ES	1.5			1		

**Legend**

$\Sigma LS$  = Number of working cycles (max. 24 months on the same site and max. 16 000 working cycles)

LK = Load spectrum (Type of duty)

MT = Track rope structure (wear characteristics of the track rope structure)

$\Sigma t$  = Operating hours (service time)

SRD = Ratio of return sheave diameter to rope diameter (bending stress of moving ropes)

ES = Hoist rope arrangement (degree of freedom of the rotatory motion)

## 3.8.3 Table of calculation formulae

				Minimum value
Design parameter	Minimum haul rope safety factor in endless rope loop	MSB	$Sich. = 4.0 \times LK^2 \times MA \times \Sigma t$ $Zse \quad \quad \quad \times SRD^2$	min. = 3.0
		KK	$Sich. = 4.0 \times LK \times MA \times \Sigma t$ $Zse \quad \quad \quad \times SRD$	min. = 3.0
	Minimum haul rope safety factor for winch driven ropeways	MSB	$Sich. = 5.0 \times LK^2 \times MA \times \Sigma t \times SRD$ $ZSw$	min. = 3.5
		KK	$Sich. = 4.5 \times LK^2 \times MA \times \Sigma t$ $ZSw \quad \quad \quad \times SRD$	min. = 3.5
	Minimum safety factor of carrying hauling ropes	MSB	$Sich. = 4.5 \times LK^2 \times MA \times \Sigma t$ $FS \quad \quad \quad \times SRD^2$	min. = 3.0
	Minimum hoist rope safety factor	MSB	$Sich. = 5.0 \times LK^2 \times MA \times \Sigma t$ $HS \quad \quad \quad \times SRD^2 \times ES$	min. = 3.5
		KK	$Sich. = 5.0 \times LK^2 \times MA \times \Sigma t$ $HS \quad \quad \quad \times SRD^2 \times ES$	min. = 3.5
	Minimum slewing rope safety factor	KK	$Sich. SS = 5.0 \times LK^2 \times MA \times \Sigma t$ $\quad \quad \quad \times SRD$	min. = 3.5
	Minimum ratio of roller Ø diameter to the haul rope or hoist rope Ø	MSB	$Fak. = 8.0 \times \Sigma LS^2 \times LK^2 \times MA$ $R/S$	min. = 5.0
	Minimum ratio of the sheave Ø to the haul rope or hoist rope Ø	MSB	$Fak. = 60 \times \Sigma LS^4 \times LK^4 \times MA^2$ $S/Z$	min. = 15
		KK	$Fak. = 40 \times \Sigma LS^2 \times LK^2 \times MA$ $S/Z$	min. = 15
	Minimum track rope safety factor	MSB	$Sich. = 2.7 - 3.2$ $TS$	No reduction
		KK	$Sich. = 2.7 - 3.2$ $TS$	No reduction
	Minimum ratio of the radius of the track rope saddle to the track rope Ø	MSB	$Fak. = 150 \times \Sigma LS^2 \times LK^2 \times MT^2$ $TR/TS$	min. = 50
	Minimum ratio of the tension of the carrying hauling rope to the maximum life load	MSB	$Fak. = 10 \times \Sigma LS^2 \times LK \times MA$ $TS/Q$	min. = 7
	Minimum ratio of the track rope tension to the max. bearing load of the carrier truck roller	MSB	$Fak. = 50 \times \Sigma LS^3 \times LK^3 \times MT^3$ $TS/LR$	min. = 15
KK		$Fak. = 50 \times \Sigma LS^3 \times LK^3 \times MT^3$ $TS/LR$	min. = 15	

Values entered into calculations shall never be inferior to the listed minimum values, even if the value resulting from the application of the calculation formulae is inferior to that value.

# **ANNEX A**

## **TERMINOLOGY AND DRAWINGS**

### **1 Reversible aerial ropeway**

- 1.1.1 Fixed grip reversible mono-cable aerial ropeway
- 1.2.1 Bi-cable reversible aerial ropeway

### **2 Jig back rope crane**

- 2.1.1 Fixed grip jig back rope crane, drive sheave driven
- 2.2.1 Bi-cable jig back rope crane, runway on one track rope, with drive sheave
- 2.2.2 Bi-cable jig back rope crane, runway on one track rope, winch driven
- 2.2.3 Bi-cable jig back rope crane, runway on one track rope, winch driven with counter rope

### **3 Uni-directional aerial ropeway**

- 3.1.1 Fixed grip mono-cable uni-directional aerial ropeway
- 3.1.2 Detachable grip mono-cable uni-directional aerial ropeway
- 3.2.1 Detachable grip bi-cable uni-directional aerial ropeway

### **4 Cable crane**

- 4.1.1 Fixed runway between two fixed anchorages
- 4.1.2 Fixed runway between two stationary towers and fixed anchorages
- 4.1.3 Fixed runway between two stationary guyed towers
- 4.2.1 Runway between two swaying towers
- 4.3.1 Cable crane car travelling on a radial runway
- 4.3.2 Cable crane with towers travelling on a radial runway
- 4.4.1 Cable crane with towers or crabs travelling on parallel tracks

### **5 Rope crane**

- 5.1.1 Rope crane with haul and hoist rope and sloping track
- 5.2.1 Rope crane with combined haul and hoist rope, counter rope, horizontal or sloping track

### **6 Funicular**

- 6.1.1 Single rail funicular with one carrier, winch driven
- 6.1.2 Single rail funicular with one carrier, uni-directional continuous operating mode
- 6.2.1 Funicular with two carriers, a central Abt turnout section, no ballast rope
- 6.2.2 Funicular with two carriers, a central turnout section and ballast rope
- 6.2.3 Funicular with two carriers, parallel rail tracks, no ballast rope
- 6.2.4 Funicular with two carriers, parallel rail tracks and ballast rope

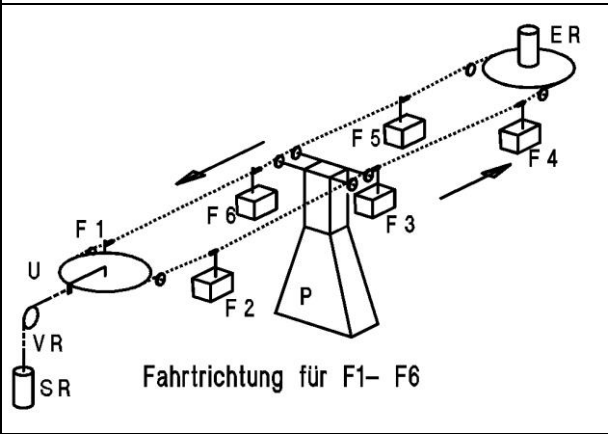
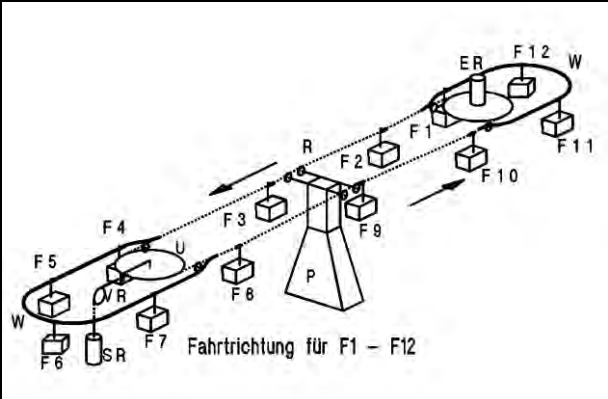
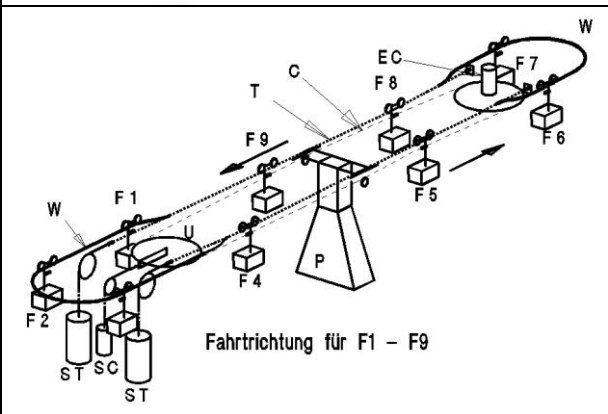
# 1 Reversible aerial ropeway

Nr.	Designation	System Type of carrier or track	Legend	Schematic diagram
1.1.1	Reversible ropeway (1) Mono-cable ropeway (1.1)	With detachable grips	<p>A Drive sheave                      ER Carrying hauling rope drive                      F1 Carrier Nr. 1                      F2 Carrier Nr. 2                      P Tower                      R Carrying hauling rope                      SR Carrying hauling rope counterweight                      U Return sheave                      VR Carrying hauling rope tensioning rope</p>	
1.2.1	Reversible ropeway (1) Bi-cable reversible ropeway (1.2)	Runway on a single track rope	<p>A Drive sheave                      C Haul rope                      T Track rope                      EC Haul rope drive                      F1 Carrier Nr. 1                      F2 Carrier Nr. 2                      P Tower                      U Return sheave                      VT Track rope tensioning rope                      VC Haul rope tensioning rope                      ST Track rope counterweight                      SC Haul rope counterweight</p>	

## 2 Jig-back rope crane

Nr.	Designation	System	Type of carrier or track	Legend	Schematic diagram
2.1.1	Jig back rope crane(2)	Mono-cable jig back crane (2.1)	With fixed grips	<p>A Drive sheave                      B Hoist rope                      F Carrier                      EB Hoist rope drive                      ER Carrying hauling rope drive                      P Tower                      R Carrying hauling rope                      SR Carrying hauling rope counterweight                      U Return sheave                      VR Carrying hauling rope tensioning rope</p>	
2.2.1	Jig -back rope crane (2)	Bi-cable jig -back rope crane (2.2)	Single track rope runway	<p>A Drive sheave                      B Hoist rope                      C Haul rope                      EC Haul rope drive                      EB Hoist rope drive                      F Carrier                      T Track rope                      P Tower                      U Return sheave</p>	
2.2.2	Jig back rope crane (2)	Bi-cable jig back rope crane (2.2)	Single track rope runway and winch drive	<p>AW Winch drive                      B Hoist rope                      C haul rope                      EB hoist rope drive                      F carrier                      T Track rope</p>	
2.2.3	Jig back rope crane (2)	Bi-cable reversible (2.2)	Single track rope runway with winch drive and counter rope	<p>AW Winch                      B Hoist rope                      C Haul rope                      EB Hoist rope drive                      F Carrier                      T Track rope                      RC Counter rope                      RW Counter rope winch (for counter rope)</p>	

### 3 Uni-directional aerial ropeway

Nr.	Designation	System	Type of carrier or track	Legend	Schematic diagram
3.1.1	Uni-directional ropeway (3)	Mono-cable uni-directional ropeway (3.1)	With fixed grip	<p>ER Carrying hauling rope drive                      F1-6 Carriers                      P Tower                      R Carrying hauling rope                      U Return sheave                      SR Carrying hauling rope counterweight                      VR Carrying hauling rope tensioning rope</p>	
3.1.2	Uni-directional ropeway (3)	Mono-cable uni-directional ropeway (3.1)	With detachable grips	<p>ER Carrying hauling rope drive                      F1-12 Carriers                      P Tower                      R Carrying hauling rope                      SR Carrying hauling rope counterweight                      U Return sheave                      W Station rails                      VR Carrying hauling rope tensioning rope</p>	
3.2.1	Uni-directional ropeway (3)	Bi-cable uni-directional ropeway (3.2)	With detachable grips	<p>EC Hoist rope drive                      C Hoist rope                      F1-9 Carriers                      P Tower                      SC Haul rope counterweight                      ST Track rope counterweight                      T Track rope                      U Return sheave                      W Station rail</p>	

4 Cable crane

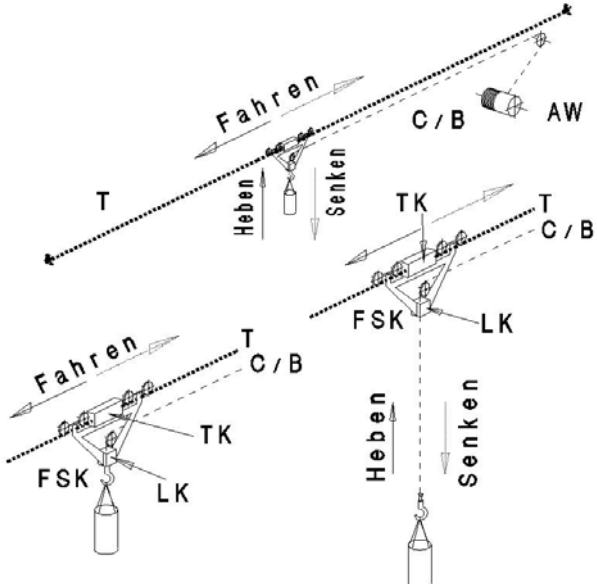
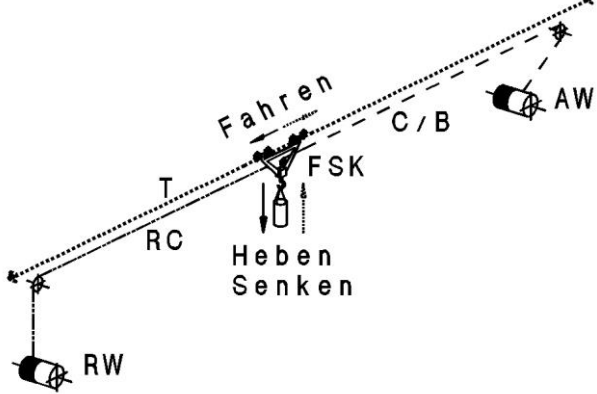
Nr.	Designation	System	Type of carrier or track	Legend	Schematic diagram
4.1.1	Cable crane (4)	Fixed runway(4.1)	Track rope between two fixed anchorages	<p>A4 Fixed anchorage drive                      B Hoist rope                      C Haul rope or crab travel rope                      EC Haul rope drive or crabe travel drive                      EB Hoist rope drive                      F Carrier or crab                      G5 Fixed tail anchorage                      T Track rope</p>	
4.1.2	Cable crane (4)	Fixed runway (4.1)	Track rope between two stationary towers	<p>A1 Head tower                      G1 Tail tower                      B Hoist rope                      C Haul rope or crab travel rope                      EC Haul rope or crab travel drive                      EB Hoist rope drive                      F Carrier or crab                      T Track rope</p>	
4.1.3	Cable crane (4)	Fixed runway (4.1)	Track rope between two stationary guyed towers	<p>A2 Head tower                      B Hoist rope                      C Haul rope or crab travel rope                      EC Haul rope or crab travel drive                      EB Hoist rope drive                      F Carrier or crab                      G2 Tail tower                      H2 Backside guy rope                      K2 Lateral guy rope                      T Track rope</p>	
4.2.1	Cable crane (4)	Swaying towers (4.2)	Track rope between two tilting towers	<p>A3 Swaying head tower                      B Hoist rope                      C Haul or crab travel rope                      EC Haul rope or crab travel drive                      EB Hoist rope drive                      EL Swaying rope drive                      F Carrier or crab                      G3 Swaying tail tower                      L3 Swaying rope                      T Track rope</p>	

4 Cable crane

Nr.	Designation	System	Type of carrier or track	Legend	Schematic diagram
4.3.1	Cable crane (4)	Carrier travelling on a radial runway (4.3)	Track rope between a fixed and a mobile anchorage	<p>A4 Fixed anchorage drive                      A5 Head-end lorry                      B Hoist rope                      C Haul rope or crab travel rope                      EB Hoist rope drive                      EC Hoist rope or crab travel drive                      F Carrier or crab                      G4 Return lorry                      G5 Fixed tail anchorage                      M Radial runway                      T Track rope</p>	
4.3.2	Cable crane (4)	Tower travelling on a radial runway (4.3)	Track rope between a fixed and a mobile anchorage	<p>A4 Fixed anchorage drive                      A8 Travelling head tower                      B Hoist rope                      C Haul rope or crab travel rope                      EB Hoist rope drive                      EC haul rope or crab travel drive                      F Carrier or crab                      G7 Travelling tail tower                      G5 Fixed tail anchorage                      T Track rope</p>	
4.4.1	Cable crane (4)	Parallel travelling (4.4)	Track rope between two mobile anchorages	<p>A5 Head-end lorry                      A8 Travelling head tower                      B Hoist rope                      C Haul rope or crab travel rope                      EB Hoist rope drive                      EC Haul rope or crab travel drive                      F Carrier or crab                      G4 Return carrier                      G7 Tail tower                      N Parallel track                      T Track rope</p>	



5 Rope crane

Nr.	Designation	System	Type of carrier or carrier	Legend	Schematic diagram
5.1.1	Rope crane (5)	Without counter rope (5.1)	Sloping track rope runway Rope crane with combined haul and hoist rope	<p>T Track rope FSK Rope crane crab AW Driving drum C/B Haul and hoist rope TK Track rope clamp LK Load catch</p> <p><u>Function</u> : crab travel TK is open, FSK can travel on T, the load is secured by LK.</p> <p><u>Function</u> : hoisting or lowering FSK is blocked firmly in its position on T by TK, LK is open</p>	
5.2.1	Rope crane (5)	With counter rope (5.2)	Horizontal and sloping runway with combined haul and hoist rope	<p>T Track rope FSK Rope crane crab AW Driving drum C/B Haul and hoist rope TK Track rope clamp LK Load catch RC Counter rope RW Driving drum (for counter rope)</p>	

6 Material handling funicular

Nr.	designation	System	TYpe of carrier or track	Legend	Schematic diagram
6.1.1	Funicular (6)	Reversible mode of operation with 1 carrier (6.1)	Sloping track with counterrope	<p>AW Drum drive                      C Hoist rope                      FS Rail borne carrier                      SCH Track                      U Return sheave</p>	
6.1.2	Funicular (6)	1 reversible mode of operation with 1 carrier (6.1)	Horizontal or sloping track, haul rope loop	<p>A Drive sheave                      C Haul rope                      EC Haul rope drive                      FS Rail born carrier                      SCH Track                      U Return sheave                      SC Haul rope counterweight                      VC Haul rope tensioning rope</p>	
6.2.1	Funicular(6)	Reversible mode of operation with 2 carriers(6.2)	Sloping track with turnout, without ballast rope	<p>A Drive sheave                      C Haul rope                      EC Haul rope drive                      FS1 Carrier                      FS2 Carrier                      SCH Track                      SW Turnout section                      U Return sheave</p>	

**6 Material handling funicular**

Nr.	Designation	System	Type of carrier or track	Legend	Schematic diagram
6.2.2	Funicular (6)	Reversible mode of operation with 2 carriers (6.2)	Horizontal or sloping track with turnout section and ballast rope	<p>A Drive sheave                      CO Upper haul rope                      CU Bottom side haul rope                      EC Haul rope drive                      FS1 Carrier                      FS2 Carrier                      SCH Track                      SW Turnout section                      U Return sheave                      SC Haul rope counterweight</p>	
6.2.3	Funicular (6)	Reversible mode of operation with 2 carriers (6.2)	Sloping parallel tracks No ballast rope	<p>A Drive sheave                      C Haul rope                      EC Haul rope drive                      FS1 Carrier                      FS2 Carrier                      SCH Track</p>	
6.2.4	Funicular (6)	Reversible mode of operation with 2 carriers (6.2)	Horizontal or sloping parallel tracks with ballast rope	<p>A Drive sheave                      EC Haul rope drive                      FS1 Carrier                      FS2 Carrier                      SCH Track                      U Return sheave                      CO Upper haul rope                      CU Valley haul rope                      SC Haul rope counterweight                      VC Haul rope tensioning rope</p>	



## Terminology

<b>Ropeway System</b>		
<b>Aerial Ropeway</b>		(US : aerial tramway; Switzerland: Luftseilbahn; Germany and Austria : Seilschwebbahn): Ropeway, the track or runway of which is a track rope ( T ) or carrying–hauling rope ( R ) (in the case of a mono-cable ropeway)
<b>1</b>	<b>Reversible aerial ropeway</b>	Ropeway with one carrier ( F ) or group of carriers ( F1-Fx) travelling forward and backward on each track between two end stations
Classification of reversible ropeways		Primarily system based on, as a second alternative, based on the function of ropes
1.1	Mono-cable reversible aerial ropeway	Ropeway the carriers ( F ) of which are hauled backward and forward between its two end stations by a carrying-hauling rope ( R ).
1.2	Bi-cable reversible aerial ropeway	Reversible ropeway the carriers ( F ) of which are suspended from and hauled by two separate ropes or groups of ropes.
<b>2</b>	<b>Jig back rope crane</b>	Reversible ropeway the carriers ( F ) of which are equipped each with an own hoist rope drive ( EB ) offering thus the possibility to hoist and lower the load anyplace along the whole length of the track between its two terminals. If loads are picked up or delivered only in the terminals at the end of the track jig back rope cranes are classified as reversible aerial ropeways. The hoisting device is radio controlled.
2.1	Mono-cable jig back rope crane	Jig back rope crane the carriers ( F ) of which are carried and hauled forward and backward by a carrying hauling rope (R).
2.2.1	Bi-cable jig back rope crane	Jig back rope crane the carriers ( F ) of which run along a track rope (T) hauled forward and backward by a hauling rope (C).
2.2.2	Winch driven jig back bi-cable rope crane	Jig back rope crane the carriers ( F ) of which run on a track rope ( T ) hauled forward and backward by a winch ( AW ) driven hauling rope. The downhill trip of the carrier is by gravity.
2.2.3	Winch driven jig back bi-cable rope crane with counter rope	Jig back rope the carriers ( F ) of which run on a track rope ( T ) hauled forward and backward by a winch ( AW ) driven hauling rope. A second driving unit ( RW ) working in synchrony with the hoisting rope winch ( AW ) takes the carrier downhill.

<b>3</b>	<b>Uni-directional aerial ropeway</b>	Uni-directional continuous movement aerial ropeway with carriers mainly used to carry bulk material from one to the other terminal station. There are two different systems of uni-directional ropeways, ropeways with detachable grips the carriers of which are detached from the rope at their arrival in the station and the fixed grip ropeways the carriers of which are permanently attached to the rope.
Classification of uni-directional aerial ropeways		Primarily based on the type of the attachment of the carrier the second possible classification being the one based on the number of ropes.
3.1.1	Fixed grip uni-directional aerial ropeway	Mono-cable uni-directional aerial ropeway the carriers of which ( F1-Fx ) are firmly fixed to a carrying hauling rope ( R ) and remain fixed to it during their travel through the station.
3.1.2	Uni-directional aerial ropeway with detachable grips	Mono-cable uni-directional aerial ropeway the carriers of which ( F1-Fx ) are detached from the carrying hauling rope ( R ) in the terminal stations to permit loading and unloading of the material.
3.2.1	Bi-cable uni-directional aerial ropeway	Uni-directional aerial ropeway the carriers of which ( F1-Fx ) travel on a track rope ( T ) (having the supporting function) and are hauled by the hauling rope ( C ) (having the hauling function) to which they are attached.
<b>4</b>	<b>Cable crane</b>	Crane consisting of two towers and a heavy steel track rope. Towers are either stationary, travelling, guyed or swaying. The material is handled and carried in crabs travelling on the track rope.
4.1	Fixed track	Track consisting of one or several track ropes, the extremities do not move or cannot be displaced.
4.2	Luffing towers	Towers which can be swung in a direction which is perpendicular to the axis of the track rope thus permitting a parallel horizontal displacement of the track rope attached to the towers.
4.3	Radial cable crane	Cable crane with one end of the track rope fastened to a fixed anchorage and the other end fastened to a tower or carrier travelling on a radial track.
4.4	Parallel travelling cable crane	Cable crane featuring a synchronous displacement systems permitting to move the two extremities of the track rope at equal speed.
<b>5</b>	<b>Rope crane</b>	Cable crane the rope of which performs both the function of a hoisting rope as well as that of a haul rope. When the rope is used to hoist a load the carrier is blocked on the track rope by a mechanical track rope catch or a counter rope. When the rope is used to haul the crab the load is secured in the carrier by a mechanical load catch.
5.1	Without counter rope	Sloping track, downhill travel by gravity.
5.2	With counter rope	The crab of the rope crane is hauled either by the crab travel rope or the counter rope thus offering the advantage of handling the material along a horizontal track either in one or the other direction.

6	<b>Material handling funicular railway</b>	A ropeway the carriers ( FS ) of which are rail borne, rails ( SCH ) having the function to support carriers which are hauled by a haul rope ( C ). The track bed is sloping or horizontal. The single carrier or in the case of funiculars with two carriers ( FS ) both carriers travel forward and backward between the two terminal stations. A unidirectional mode of operation is also possible with carriers equipped with automatically detachable couplings.
Classification of funicular railways		Classification based on the number of carriers
6	Rail track with an Abt turnout section	Funicular railway with two carriers which travel forward and backward between the two terminal stations on one and the same track and cross each other on a turnout section consisting of two parallel rails and an Abt rack point.
6	Track consisting of two parallel rail tracks	Funicular railway with two carriers which travel forward and backward between the two terminal stations on two parallel rails.
6	With ballast rope	Horizontal or slightly sloping funicular railways have a ballast rope or counterrope ( ZU ) having the purpose to contribute to the haulage of carriers.

### Terminology of components

Figure	Components and sub-systems	
<b>A</b>	Drive sheave	Motor powered wheel with a grooved rim which transmits its driving force to the rope.
<b>A1</b>	Head tower	Unguyed stationary structure the purpose of which is to serve as a fastening support permitting to secure the head-end of the track rope at the desired height above ground.
<b>A2</b>	Head mast	Guyed rod-shaped structure the purpose of which is to serve as a fastening support permitting to secure the tail-end of the track rope at the desired height above ground. Head masts are anchored to the ground by means of a hinged joint bearing.
<b>A3</b>	Luffing head mast	Mast at the driving end which is swung around its anchorage in the ground by power driven slewing ropes thus permitting to shift the track rope horizontally.
<b>A4</b>	Fixed head-end anchorage	Ground level fixed structure permitting to secure the head-end of the track rope.
<b>A5</b>	Head lorry	Ground level rail travelling structure serving as a fastening, securing and shifting support for the head-end of the track rope
<b>A8</b>	Travelling head mast	Rail born mobile head tower permitting to shift the track rope horizontally
<b>AW</b>	Winch	Power driven rope winding cylinder
<b>B</b>	Hoist rope	Rope of jig back rope cranes (2.2), cable cranes ( 5 ) and rope cranes serving the purpose of hoisting the material. Hoist ropes are wound up on and unrolled from a winding drum.
<b>C</b>	Haul rope	Rope of ropeway installations, cranes and cable cranes performing the haulage function. Haul ropes are wound up on and unrolled from a winding drum.
<b>CU</b>	Valley haul rope	Rope fastened to the carrier at the lower end of the installation.
<b>C/B</b>	Combined haul and hoist rope	Rope of skyline cranes performing a twofold function, i.e. the haulage and hoisting of the material.
<b>EB</b>	Hoist rope drive	Motor powered rope driving hoisting device, in most instances a hoisting winch.
<b>EC</b>	Haul rope drive	Motor powered device ensuring the transmission of mechanical forces to the haul rope. The system most used is one based on the motive power produced by the adherence of the haul rope to the groove of the drive sheave.
<b>EL</b>	Slewing rope drive	Motor powered slewing rope driving device
<b>ER</b>	Carrying hauling rope drive	Motor powered device ensuring the transmission of mechanical forces to the carrying hauling rope. The system most used is one based on the motive power produced by the adherence of the carrying hauling rope to the groove of the drive sheave.
<b>F</b>	Carrier	Load carrying component or container of ropeway installations
<b>F1</b>	Carriers	One or several load carrying components or containers of ropeway installations.



<b>FS</b>	Carriers of a material handling funicular ropeway	Load carrying carriers of a material handling funicular ropeway.
<b>FSK</b>	Rope crane carrier	Carrier travelling on a skyline crane rope featuring several devices which permit to use one and the same rope for two different functions, the haulage and the hoisting of materials.
<b>G1</b>	Tail tower	Unguyed stationary structure the purpose of which is to serve as a fastening support permitting to secure the tail-end of the track rope at the desired height above ground.
<b>G2</b>	Tail mast	Guyed rod-shaped structure the purpose of which is to serve as a fastening support permitting to secure the tail-end of the track rope at the desired height above ground. Tail masts are anchored to the ground by means of a hinged joint bearing.
<b>G3</b>	Luffing tail mast	Mast at the tail-end which is swung around its anchorage which is fixed in the ground by powered slewing ropes thus permitting to shift the track rope horizontally.
<b>G4</b>	Tail lorry	Ground level rail borne travelling structure serving as a fastening, securing and shifting support for the tail-end of the track rope.
<b>G5</b>	Fixed tail anchorage	Ground level fixed structure serving as a fastening and securing support for the tail-end of the track rope.
<b>G7</b>	Travelling tail-end tower	Rail borne travelling tail-end tower permitting to shift the track rope horizontally.
<b>H2</b>	Guy rope, back side	Rope which takes up the action of the track rope tension to which is subjected a stationary or slewing mast in a direction which is parallel to the direction of the line.
<b>K2</b>	Guy rope, lateral	Rope which takes up the action of the track rope tension and that of the wind to which is subjected the mast in a direction which is normal to the axis of the track rope.
<b>L3</b>	Slewing rope	Rope use to swing the mast around.
<b>LK</b>	Load catch	Mechanical device of the skyline crane carrier permitting to secure the load carried in the carrier during its trip along the runway.
<b>M</b>	Radial runway	Runway with incorporated rails for travelling towers of carriers of radial cable cranes.
<b>N1</b>	Head-end runway	Runway with incorporated rails for the travelling structure serving as a fastening and securing support for the head-end of the track rope.
<b>N2</b>	Tail-end runway	Runway with incorporated rails for the mobile structure serving as a fastening and securing support for the tail-end of the track rope.
<b>P</b>	Tower	Structure supporting ropes at the desired height above ground.
<b>R</b>	Carrying hauling rope	Rope of mono-cable ropeways which transmits the motion to carriers attached to it and are supported by it.
<b>RC</b>	Ballast rope, counter rope	Moving rope attached to the carrier or crab without going through the drive sheave.
<b>RW</b>	Ballast rope drive, counter rope drive	Motor powered ballast rope driving device arranged to work in synchrony with the drive of the combined haul and hoist rope. In many instances the driving device is a winch.
<b>S</b>	Counterweight	Mass attached to the rope end having the function to maintain the desired tension of the rope.
<b>SC</b>	Haul rope counterweight	Mass attached to the rope end having the function to maintain the desired tension of the haul rope.

<b>SCH</b>	Track	Runway consisting of a pair of parallel rails and sleepers.
<b>SR</b>	Carrying hauling rope counterweight	Mass attached to other components in order to maintain the desired tension of the carrying hauling rope.
<b>ST</b>	Track rope counterweight	Mass attached to the track rope or to other components in order to maintain the desired tension of the track rope.
<b>SW</b>	Turnout section	Section of the track consisting of a double pair of rails. The external rail is a through leading uninterrupted carrier guiding rail.
<b>T</b>	Track rope	Rope of reversible ropeway installations, skyline cranes and cable cranes arranged to support carriers.
<b>TK</b>	Track rope catch	Mechanical device arranged in carriers of skyline cranes having the purpose to secure the carrier and keep it firmly fastened to the track rope during the hoisting or lowering operation of the load.
<b>U</b>	Return sheave	Rotating support arranged in a bearing having the function to reverse the direction of the rope.
<b>VC</b>	Haul rope tensioning rope	Rope leading from the counterweight to the sheave having the purpose to transmit the force which is necessary to maintain constant the tension of the haul rope.
<b>VR</b>	Carrying hauling rope tensioning rope	Rope leading from the counterweight to the sheave having the purpose to transmit the force which is necessary to maintain constant the tension of the carrying hauling rope.
<b>VT</b>	Track rope tensioning rope	Rope leading from the counterweight to the track rope. The connection of the track rope end and the tensioning rope end is secured by means of a clamp or socket.
<b>W</b>	Station rail track	Section of the track arranged within stations leading from the point in which carriers are detached from the rope at their arrival in the station to the loading or unloading stations having the function to permit the regular progress of carriers within the station and the execution of the loading and unloading operations.

## **ANNEX B**

### **Risk analyses for aerial cableways**

#### **1 Introduction**

The development of aerial cableways is subject to continuous change. Aerial cableways must meet a wide range of demands. There are often no specific regulations regarding safety. It is therefore necessary to subject each individual aerial cableway to a risk analysis in order to find suitable solutions.

Aerial cableways must satisfy basic safety and health requirements and be constructed in accordance with state-of-the-art technology. It goes without saying that, when used as intended and with care, aerial cableways must not endanger the lives and health of users and third parties.

The following explanations describe how a risk analysis can be carried out systematically to ensure that both the risks for the aerial cableway itself as well as for those for its operating personnel can be covered. They are based on standard EN 1050 "Safety of machinery - Principles for risk assessment". The method described enables cable cranes, temporary cableways for transporting materials and cableways for transporting materials to be analysed.

The quality of a risk assessment is entirely dependent on its completeness. A result that is as all-encompassing as possible can only be achieved as a result of cooperation between a wide range of specialists who are familiar with the product. Collaboration between people from the fields of design, installation, erection, purchasing, control systems and safety is therefore desirable. If possible, future users should also be included.

When using one of the EDP programmes available on the market for risk analyses, it is essential to have a basic knowledge of the connections between hazards, causes and events. The programmes are usually based on EN 1050, the standard mentioned above. While they are a valuable tool, the actual work - such as the formulation of safety targets, the assigning of hazards to the risk matrix and considerations regarding acceptance - is reserved for those people who analyse aerial cableways.

## 2 Procedure

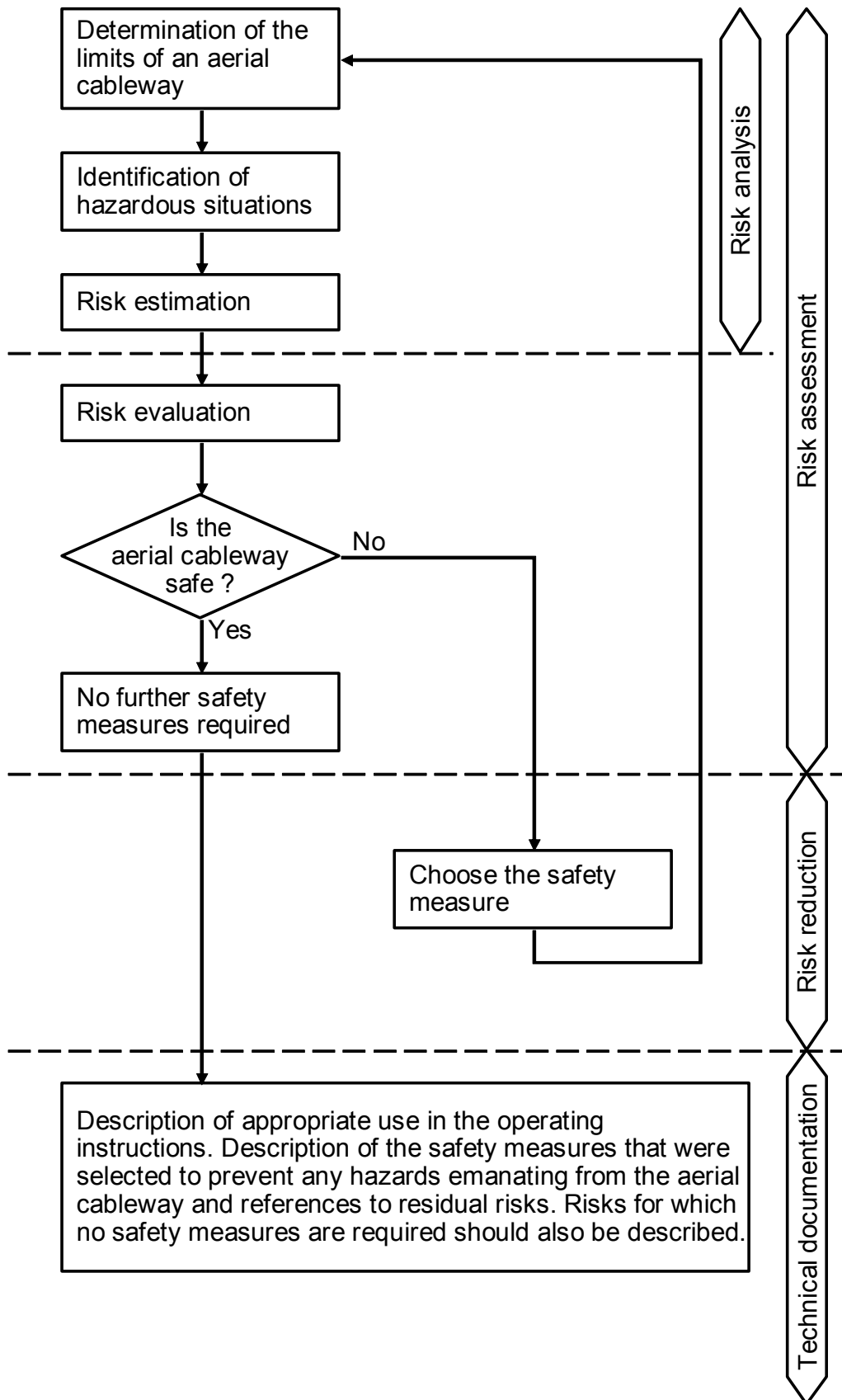


Fig. 1: Overview of the risk assessment procedure.

### 3 How does an event begin?

A prerequisite for the creation of an event, for example of an accident, is the coincidence of a harmful effect (a hazard) and of a component of the aerial cableway or of a person.

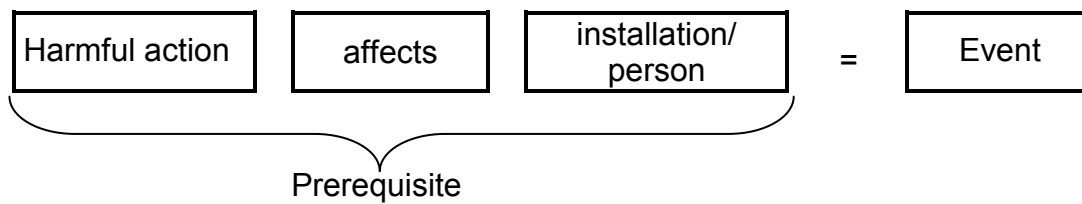


Fig. 2: Prerequisite for an event

### 4 Causes

Hazardous situations can result from the construction of an aerial cableway. The designer must take into account the hazards inherent in an aerial cableway in such a way that the likelihood of an event occurring is minimised to the full. Any residual likely events must be prevented by training those persons that might find themselves in a hazardous situation. All causes that may lead to an event are thus dependent on the ability, knowledge and intentions of a human being. Dependent on the approach adopted by the analysis, all of the hazards and their effects associated with the aerial cableway or with the personnel must be investigated.

### 5 System

If a risk assessment is to be conducted meaningfully, all foreseeable hazardous situations associated with an aerial cableway must be identified.

#### 5.1 Type of installation

##### **Aerial cableway**

The aerial cableway must be described in such a way that it is easy to identify which type of installation is meant, i.e. whether materials or persons are to be transported or both together.

#### 5.2 Area of use

The area of use must be defined in such a way that it is easy to identify what types of goods are transported and with what frequency. The predetermined life expectancy for the planning of the installation must be stated. Any transportation of maintenance personnel must be described in detail. Based on this information, it is possible to determine the loading group for the following categories: transmission, cables and load-bearing structures.

#### 5.3 Scope of the system and the interaction of the individual modules

The spatial limits of the aerial cableway can be derived from the scope of the system. For example, information must be given as to whether the upper station, the lower station, any loading or unloading equipment, the number of supports, any intermediate stations, the cable, etc. must be allocated to the system. The interaction of the individual modules must be shown in a suitable form.

## 6 Identifying the persons concerned

For the implementation of a risk analysis, it is important to know which persons move about or are present in the area of the aerial cableway. On the one hand, they can be persons who are occupied with duties in the area of the installation during normal operation, which means during the intended use of the aerial cableway; on the other hand, they may also be persons who are present during special operations (inspection, erection, servicing, cleaning and maintenance). In particular, a risk analysis must also include third parties, for example hikers and spectators as well as animals.

## 7 Identifying hazardous situations

It is essential to identify and document all the hazards associated with the aerial cableway within the individual part-systems and the interfaces between the systems.

### 7.1 Possible hazards associated with aerial cableways can include:

Surrounding area	Operation	Persons	Load
Rain	Mechanical forces	Loading gauge	Loss of material
Water	Hydraulic forces		Weight of load
Snow	Speed	Faulty operation	Load dimension
Ice/frost	Electricity		
Wind	Static electricity		
Temperature	Vibrations		
Lightning			
Rockfall			
Avalanches			
Fire			
Mudrock			
Earthquake			
Radiation			
Noise			

### 7.2 Possible hazards associated with people can include:

- Mechanical elements
- Thermal energy
- Vibrations
- Materials and other substances
- Unexpected starting
- Power supply failure
- Faulty erection
- Electricity
- Noise
- Radiation
- Change in speed
- Control system power supply failure
- Type of load
- Slipping, stumbling, falling

## 8 Listing hazardous situations

Hazardous situations are identified by investigating whether an existing hazard may have a negative effect on the aerial cableway or on people. All operating conditions must be taken into account, i.e. normal operation and special operation to which maintenance, servicing and overhauls also belong.

## 9 Establish causes and events

Causes that can lead to an event (accident) are identified by investigating what must happen for an aerial cableway or a person to face a hazard. Events can be described based on the causes found.

These investigations must be conducted for all systems, part-systems and their interfaces in all operating modes. With the help of this procedure, it is possible to cover events that affect the aerial cableway, the load or the operating personnel.

Some examples of causes are given below:

Causes that are decisive for a possible event can have their origins at the planning stage, at the design stage, during manufacture or while the aerial cableway is being operated. They can be subdivided into the following categories:

<b>Not being able</b>	<b>Not knowing</b>	<b>Not wanting</b>
Physical size	Inadequate training	Convenience
Disablement	Lack of experience	Lack of deeper insight
Design error	Incomplete instructions	Parsimony
Shortage of time		Being complacent
Overestimation of ability		
Unfavourable ergonomics		
Lack of understanding		

## 10 What does risk mean?

An event can occur as a result of a specific hazardous situation with a certain degree of probability.

The

**risk of a hazardous situation**

is dependent on the

**scope of the possible harm of the event**

and on the

**likelihood of its occurrence**

**The likelihood of its occurrence is determined by the following factors:**  
**The frequency and duration of the hazardous situation that precedes the event.**  
**The likelihood of the event occurring when the hazardous situation is present.**  
**The possibility of avoiding or limiting any harm.**

Fig. 3: Risk elements

**11 Risk estimation**

The maximum harm or damage possible and the likelihood of its occurrence are estimated for each hazardous situation. The extent of harm or damage can be graded in categories based on the impairment of the aerial cableway or on the injury or harm to the health suffered by the persons concerned.

**Damage to the aerial cableway**

1. Damage without any stoppage of operation
2. Time to repair: max. 1 day
3. Time to repair: several days
4. Total loss

**Injuries to persons**

1. Injury without loss of work
2. Minor injury
3. Severe injury
4. Fatality

Fig. 4: Categories for the extent of harm or damage

**Likelihood of occurrence**

The likelihood of occurrence depends on the specific hazardous situation. In the planning phase of an aerial cableway, the likelihood of its occurrence is generally unclear. Entering a fairly high likelihood of occurrence is recommended. The following classification can be used both for damage to the aerial cableway as well as for personal injuries:

- A. Unlikely (1 event during the installation's entire service life)
- B. Rare (1 event per 1/10 of the installation's service life)
- C. Occasional (1 event per 1/50 of the installation's service life)
- D. Frequent (>1 event per 1/250 of the installation's service life)

Fig. 5: Categories for the likelihood of occurrence

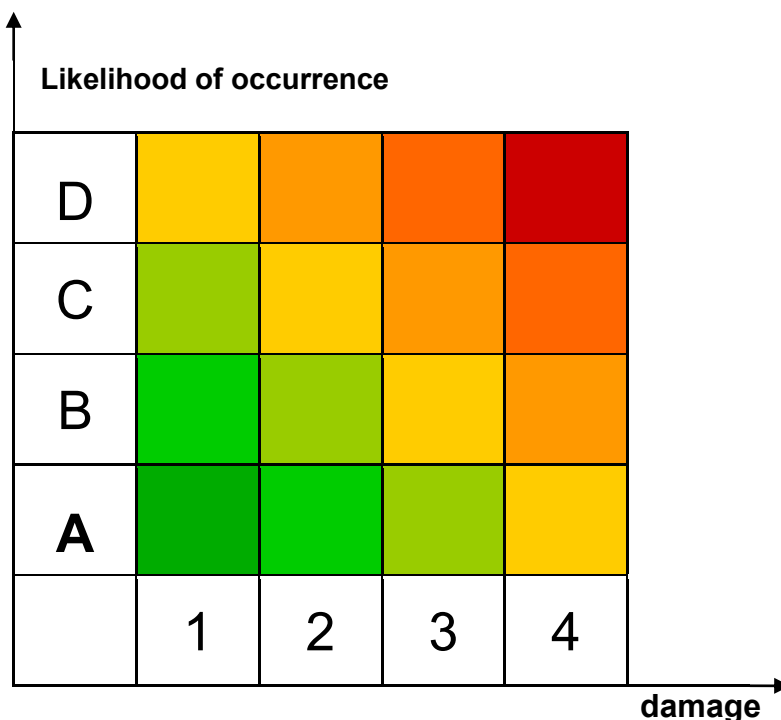




Fig. 6: Depicting risks using a matrix

## 12. Formulating safety targets

A safety target must be formulated for each event. It contains a description of the conditions that the solutions must fulfil if the possible events are not to occur. It is recommended that the safety targets are formulated neutrally to the maximum degree. This permits a wider choice of solutions (measures).

## 13. Determining accepted risk

After taking the currently optimum solutions into account, each aerial cableway will also contain a certain risk, a residual risk. It is the job of the designer to reduce residual risk to an acceptable level. Accepted risk is influenced by the factors of voluntariness and cause. In terms of acceptance, risks entered into voluntarily, for example in a person's free time, are put on a much higher level than risks that arise in an occupational environment. In situations involving a major degree of self-determination, such as, for example, driving motor vehicles, the risks accepted are also higher than is the case with minor self-determination such as flying or riding on an aerial cableway, in which human beings are at the mercy of technical systems.

## 14. Protective measures

When choosing protective measures (solutions), a manufacturer must comply with the following principles in the order stated:

### 1. Eliminating or minimising hazards

Integration of the safety concept into the development and construction of the aerial cableway.

### 2. Implementing the necessary protective measures

Provide for protective measures against hazards that cannot be eliminated.

### 3. Teaching users about residual risks

Based on the incomplete efficacy of the protective measures, reference must be made to a compulsory course of special training or to personal protection equipment.

## 15 Assessing protective measures

Each scheduled protective measure must be assessed for its efficacy according to the procedure described. It must guarantee that the target is met by the use of the protective measure. Only then is there any guarantee that the protective measure will fulfil its purpose and not create any new hazardous situations.

### Example

The following example shows the risk analysis of a single-cable material cableway. The analysis is limited to one support and normal operation. The interactions are shown in the table "Factors that influence components". The table "Risk assessment" shows causes, hazards and events as well as risk before and after the measure.

<b>Installation</b>		Single-cable, aerial cableway for bulk materials (gravel, 5,000 kg)																									
<b>Use</b>		12 hours/day, 6 days/week; uphill always with a full load; downhill empty; service life: 20 years, max. wind speed: 100 kph																									
<b>Authoring team</b>		Fritz Meyer, technology; Ruedi Neumach, design; Hans Kerbholz, manufacture; Kari Pfiffig, erection; 7 April 2002																									
<b>Component</b>		<b>Influences</b>	<b>Surrounding area</b>														<b>Operation</b>					<b>People</b>		<b>Type of load</b>			
		<b>Type</b>	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y
		<b>Function</b>	Rain	Water	Snow	Ice/Frost	Wind	Temperature	Lightning	Rockfall	Avalanches	Fire	Mudrock	Earthquake	Radiation	Noise	Mechanical forces	Hydraulic forces	Speed	Electricity	Static electricity	Vibrations	Loading gauge	Faulty operation	Loss of material	Weight of load	Load dimensions
<b>Upper station</b>	1																										
<b>Lower station</b>	2																										
<b>Support</b>	3 1	Foundation				X			X	X			X														
	3 2	Design					X		X														X				
	3 3	Head					X																				X
	3 4	Rollers			X															X	X						
	3 5	Ascent				X																		X			
	3 6	Platform			X	X															X						

"Factors that influence components" table

Safety objectives (Excel-Tabel)

Installation		Single-cable aerial cableway for bulk materials (gravel, 5,000 kg)																
Use		12 hours/day, 6 days/week; uphill always with a full load; downhill empty; service life: 20 years, max. wind speed: 100 kph																
Authoring team		Fritz Meyer, technology; Ruedi Neumach, design; Hans Kerbholz, manufacture; Kari Pfiffig, erection; 7 April 2002																
Damage to the aerial cableway		Injuries to persons			Likelihood of occurrence													
1. Damage without any stoppage of operation		1. Injury without loss of work			A. Unlikely (1 event during the installation's entire service life or every 20 years)													
2. Time to repair: max. 1 day		2. Minor injury			B. Rare (1 event per 1/10 of the installation's service life or every 2 years)													
3. Time to repair: several days		3. Severe injury			C. Occasional (1 event per 1/50 of the installation's service life or every 6 months)													
4. Total loss		4. Fatality			D. Frequent (1 > event per 1/250 of the installation's service life or once a month)													
Interaction	Comp	Function	Influence	Hazard	Cause	Events	Risk				Safety target	Measures	Pointers	Risk				Processed by: on:
							1	2	3	4				1	2	3	4	
3.1.d	Support	Foundation	Ice/frost	Lifting of the foundations	Foundations not deep enough	Foundation is displaced	D	C	B	A	The influence of frost must not affect the integrity of the foundation	The bottom of the foundation must extend below frost levels	Ascertain frost levels	D	C	B	A	
3.1.h	Support	Foundation	Rockfall	Rockfall; stones rolling down	Animals in the area of the supports cause rockfall	Carrying capacity of the foundation is affected	D	C	B	A	The foundation must not be damaged by falling rocks	Install a barrier wall	Consider the possibility of another location	D	C	B	A	
3.1.i	Support	Foundation	Avalanches	Snow pressure	Supports in exposed terrain	Foundation is displaced by snow masses	D	C	B	A	The foundation must not be displaced by the pressure of snow	Install a barrier wall	Consider the possibility of another location	D	C	B	A	
3.1.l	Support	Foundation	Earthquake	Earth vibrations	Gas pressure from inside the earth	Foundation is displaced; Support breaks	D	C	B	A	The foundation must not be damaged by earthquakes up to a magnitude of 4 on the Richter scale	The foundation must be appropriately dimensioned	Clarify risk of earthquakes	D	C	B	A	
3.2.e	Support	Design	Wind	Dynamic pressure of the wind	Wind greater than the assumed figure of 100 km/hr.	Support breaks; topples	D	C	B	A	The support must not be damaged by excessive wind speeds	Windspeed measuring devices on the supports with cutoff facility	Carry out periodic checks for correct operation	D	C	B	A	
3.2.h	Support	Design	Rockfall	Rockfall; stones rolling down	Animals in the area of the supports cause rockfall	Deformation of the supports; cable comes off	D	C	B	A	The supports must not be damaged by falling rocks	Fit the supports with rockfall netting as far as the protective barrier	It must be possible to remove the fitted rockfall netting	D	C	B	A	
3.2.u	Support	Design	Loading gauge	Vehicle or load gets caught on the supports	Poor design or incorrect load	Deformation of the supports; cable comes off	D	C	B	A	The supports must not be damaged by the vehicle or the load	Install guides and deflectors		D	C	B	A	
3.3.e	Support	Head	Wind	Dynamic pressure of the wind	Wind greater than the assumed figure of 100 kph.	Top of the support is deformed; cable comes off	D	C	B	A	The support must not be damaged by excessive wind speeds	Windspeed measuring devices on the supports with cutoff facility	Carry out periodic checks for correct operation	D	C	B	A	
3.3.y	Support	Head	Load dimensions	Load gets caught on the head	Incorrect load	Deformation of the head; cable comes off	D	C	B	A	The supports must not be damaged by the load	Repeat workforce training periodically	Periodic workforce training	D	C	B	A	
3.4.c	Support	Rollers	Snow	Snow in the area of the rollers	Rollers clogged by snow	Roller jammed; cable comes off	D	C	B	A	Snow must not affect the operation of either the rollers or the groove	Install snow scrapers		D	C	B	A	
3.4.s	Support	Rollers	Static electricity	Overvoltage	Electrostatic charge caused by matching unsuitable materials or by friction (wind)	Faults in the control system	D	C	B	A	Static charge must not affect the control system	Install roller linings that are electrically conductive; earth (ground) all components		D	C	B	A	
3.4.s	Support	Rollers	Static electricity	Overvoltage	Electrostatic charge caused by unsuitable matching of materials or by friction (wind)	Workforce suffer electric shocks	D	C	B	A	Persons must not be exposed to static charges	Install roller linings that are electrically conductive; earth (ground) all components		D	C	B	A	
3.4.t	Support	Rollers	Vibrations	Resonance vibrations in the rollers	Inadequate design, not robust enough; cable vibrations	Roller breakage; cable comes off	D	C	B	A	Persons must not be harmed by falling parts of the installation	Fit vibration-absorbers to the roller bearings		D	C	B	A	
3.5.d	Support	Ascent	Ice	Slipping on ice	Ice hanging in the access area	Persons falling; injuries caused by falling ice	D	C	B	A	Persons must not be exposed to the risk of injury caused by hanging ice	The supports must not be climbed if covered with hanging ice; training	Periodic workforce training	D	C	B	A	
3.5.v	Support	Ascent	Faulty operation	Putting oneself at risk	Lack of concentration; mental stress, fatigue	Persons falling	D	C	B	A	Persons must not be exposed to the risk of injury caused by the faulty operation of equipment	Fit PSE; training		D	C	B	A	
3.6.c	Support	Platform	Snow	Slipping on snow	Snow build-up	Persons falling	D	C	B	A	Persons must not be exposed to the risk of injury caused by snow	Use coarse-mesh gratings		D	C	B	A	
3.6.d	Support	Platform	Ice/frost	Slipping on ice	Ice hanging on the platform	Persons falling	D	C	B	A	Persons must not be exposed to the risk of injury caused by hanging ice	Provide for an adequate number of railings and attachment eyelets		D	C	B	A	
3.6.t	Support	Platform	Vibrations	Resonance vibrations of the platform	Inadequate design, not robust enough; cable vibrations	Platform breakage; persons falling	D	C	B	A	Persons must not be exposed to the risk of injury caused by vibrations	Fit vibration-absorbers to the ladder mountings		D	C	B	A	

"Risk assessment" table

## ANNEX C

### OPERATING INSTRUCTIONS

*(this document ought to be regarded as an example and used as reference document which of course has to be adapted to the specific conditions and features of the installation under consideration)*

#### 1 Ropeway operation management

- 1.1 Technical management:      Manager                      NN .....
- Assistant manager      NN .....
- 1.2 Other members of the staff: Engine operator      NN .....
- Station attendants      NN .....

1.3 Operating conditions of the ropeway shall not give rise to dangerous situations which impair the health of passengers or put their life at risk nor cause damage to the material.

1.4 The manager is required to take what measures are deemed to be necessary to guarantee the conformity with operating instructions and specifications of the manufacturer, as well as execution of regular inspections and maintenance.

1.5 The perfect state of the ropeway installation, and in particular the perfect function of the telephone and signaling systems shall be verified prior to every resumption of service.

1.6 Transportation of persons is not permitted. However two exceptions are admitted i.e.

- a) It may be permitted to give a lift to technicians or members of the staff who have to inspect the installation o maintenance work
  - b) persons who have to be carried to their working place, provided the ropeway has been duly equipped for the transportation of persons and all additional requirements relating to the transportation of persons have been met and the manager has given his consent.
- Additional operating instructions are listed in clause 12.

If required a request for authorization shall be submitted to the competent supervisory authority.

#### 2 Technical data

Length \_\_\_\_\_ m

Difference in altitude \_\_\_\_\_ m

Maximum permissible load \_\_\_\_\_ m

Maximum permissible geometric dimensions of the material to be handled

Length \_\_\_\_\_ m, width \_\_\_\_\_ m, height \_\_\_\_\_ m

Maximum travelling speed \_\_\_\_\_ m/s

List and technical data of ropes:

\_\_\_\_\_

\_\_\_\_\_

etc.

### **3 Directions, warning and prohibiting signs**

Perfectly readable signs shall be placed in the terminal and intermediate stations, as well as fixed on carriers to inform all unauthorized persons that the transport of persons and entry into stations, climbing on line support structures, walking along the track and standing in the passage way of carriers in intermediate stations is prohibited, as well as to give them precise information on the permissible maximum pay load and recall the manager's instructions and interdictions. They shall not only be placed within the eye sight of all concerned persons but shall also be perfectly maintained to preserve their readability. The same rule applies to signs indicating the maximum permissible height limits to be complied with at crossings with traffic roads.

### **4 Stations**

- 4.1** No object which is not essential for the regular functioning of the ropeway shall ever be stored in the station, or in the driver's stand or cabin. Easy access shall be provided to all components requiring regular inspection and maintenance and obstacle free access provided to the loading area and the passage way of carriers
- 4.2** The quantity of combustible materials kept in stocks shall be reduced to the minimum which is necessary for the normal operation of the ropeway and the storage system shall be conform with enforced regulations.
- 4.3** No obstacle shall be permitted to hinder the free movement of the counterweight or the tensioning sheave and shall be eliminated. Care shall be taken to keep in perfect order and operating state counterweight pit covers, protections and railings.
- 4.4** Care shall be taken to shorten ropes in time in order to compensate the effect of loads and temperature variations and thus safeguard the free movement of counterweights.
- 4.5** Adequate measures shall be taken to prevent unauthorized persons from entering into stations or acceding to the installation once the operation of the ropeway and the service have been stopped.
- 4.6** Care shall be taken to have anytime at hand perfectly performing fire extinguishers and the necessary first aid material ready.

### **5 Driving and return units**

- 5.1** Care shall be taken to choose a sheave design which offers the certainty of perfect guidance and maintenance of the rope's regular central position at entry on and when leaving the sheave.
- 5.2** Care shall be taken to replace the brake lining and brake pads in time in order to prevent brake drums and brake disks from being damaged.
- 5.3** Care shall be taken to preserve the perfect operability of protections against likely dangerous contacts.
- 5.4** Care shall be taken to maintain the required tension of all ropes.
- 5.5** Haul ropes of winch driven ropeways shall have a sufficient length permitting to make three windings around the drum of the winch.
- 5.6** Appropriate provisions shall be taken to guarantee the correct and regular winding up of ropes on the drum of the winch.

## **6 The track**

**6.1** No external action (for instance falling stones and rock, plants, falling trees, stone and rock slide, avalanches, newly built constructions and roads) shall impair the safety of the ropeway installation and encroach upon its clearance gauge limit.

It shall be prohibited a) to lit fires in the proximity of the track of the ropeway (or at any rate not to lit fires at a distance in which line support structures, the track and ropes might suffer heat damage).

b) to store objects which are not essential for the faultless operation of the ropeway in the immediate vicinity of line support structures and or the track.

**6.2** Adequate provisions shall be taken to ensure anytime the free access to components which require regular inspection and maintenance.

## **7 Operation**

**7.1** A precisely defined signalling and radio based communication system shall be provided for to ensure the operational safety of the ropeway.

**7.2** The warning that the ropeway is about to start shall be announced by means of a radio or signal based communication system.

**7.3** The type of signals and their sequence shall have to be determined tailored to measure for each ropeway installation.

**7.4** The operating staff shall always have the necessary means and possibility to control the operation and take the necessary measures.

**7.5** The ropeway manufacturer's speed, pay load and dimensional specifications shall always be complied with.

**7.6** All exceptional transports, the speed, the pay load or the dimensions of which are superior to the speed, load or dimensional values specified by the manufacturer of the ropeway require a prior authorization to be granted by the manufacturer or if so specified, by the competent supervisory authority.

## **8 Stoppage and resumption of operation**

**8.1** Any disorder which might impair the safety of the ropeway which is detected while the ropeway is being operated shall trigger the stoppage of the installation.

**8.2** It is prohibited to continue to operate the ropeway during a tempest or in other inadmissible conditions representing a menace for the safety of the operation.

**8.3** It is necessary to assess the safety of the ropeway installation before resuming the service after a long standstill of the ropeway or interruption of the operation due to the circumstances mentioned in clause 8.2. Components which ought to be tested are for example the following ones

- Anchorages of ropes,
- End fixing of the haul rope to the carrier truck,
- Condition of the rope in the vicinity of the grip,
- Regular position of the rope along the whole line,
- Clearance gauge limit of the whole track (branches, trees, fences),
- Signalling and telephone communication systems,
- Differential relay circuit breaker,
- Lightning protection fuses.

## **9 Maintenance**

- 9.1** Requirements laid down in the service and maintenance manual handed out by the manufacturer of the ropeway shall be met.
- 9.2** Appropriate solutions shall be adopted in all cases in which the accidental start of the ropeway while maintenance work is being carried out may represent a dangerous situation, for instance a possible solution may be to cut the power supply.
- 9.3** Records of all maintenance operations shall be kept on record in the operational log book and the work which has been carried out shall be properly documented.
- 9.4** All members of the inspection and maintenance team shall always wear and use their personal protection equipment. Where inspection or maintenance has to be carried out in a place high above the ground all involved persons shall use their personal fall and crash protection equipment.
- 9.5** In principle the perfect state of the ropeway installation and in particular the perfect state of the carrying hauling rope end fixing to the carrier shall be verified prior to each inspection and each maintenance run.
- 9.6** As for the inspections and maintenance schedule due consideration shall be given to the specific importance and frequency of each inspection and maintenance to be carried out, whereby due consideration shall be given in particular to the manufacturer's inspection and maintenance instructions.
- 9.7** All ropeway installations shall be submitted at least once every year to an accurate overhaul and all necessary measures shall be taken to repair and eliminate all defects. The general inspection should include for instance the following checks ;
- assessment of the structural soundness of stations, line support structures, tracks and foundations.
  - assessment of the correct alignment and level of foundations.
  - assessment of the longitudinal and transverse gradient, of the torsion and the correct alignment of line support structures and of the track.
  - assessment of the soundness of track rope saddle suspensions, of the correct position of track and haul ropes, the rotational freedom and correct alignment of rollers.
  - assessment of the soundness of the telephone cable fixings In stations and of their attachment to line support structures.
  - assessment of incipient cracks and subsidence of foundations and counterweight pits.
  - assessment of the soundness of the mechanical equipment and of safety devices, tightness of screws and of their safety retentions, soundness of welds, correct gearing of spur and bevel gears, state of brakes, brake linings and operating levers, as well as of the disengaging device of the belt drive, assessment of the required tension of V-belts and flat belts, assessment of the good state of the tensioning devices and of anchorages of track rope and haul rope anchorages, assessment of the good state of brakes, assessment of the soundness of the haul rope attachment to the carrier truck.
  - Assessment of the undamaged state of protections against direct contact with moving components and of railings.
  - Assessment of the good state of catwalks and ladders.
  - Assessment of all components which are subject to strong wear (haul rope rollers, lining rings, brake linings, sheave linings).

- Assessment of the proper lubrication of all moving components.
- Assessment of the presence within eyesight and perfect readability of all required instructions, labels and plates, as well as of warning and prohibiting signs.
- Verification of the satisfactory state of the first aid equipment and material, as well as of the fire extinguishing equipment.
- Inspection of all ropes (Cf clause 10).
- Inspection of the electrical equipment.

Elimination and repair of revealed defects shall be carried out only by an authorized person.

- 9.8** The lightning protection shall be checked at least every three years and submitted to additional checks immediately after a lightning stroke or refurbishment of the ropeway installation. Any revealed defect shall be repaired immediately and a test report drawn up listing precisely defects, the work which has been done and the tests which have been made.
- 9.9** The differential relay circuit breakers shall be actuated once monthly to assess the regular performance of the circuit breaker.
- 9.10** It is prohibited to use fuses which are not identical with the original fuse and hence necessary to keep an adequate number of original fuses in store.
- 9.11** Frequent and regular maintenance of exhaust pipes, if any, is fundamental to ensure faultless elimination of waste gases in the atmosphere and prevent dangerous situations from occurring.
- 9.12** Adequate provisions shall be taken to ensure regular and frequent maintenance of flight warning beaconing systems in accordance with aeronautical regulations.

## **10 Ropes**

### **10.1 Generalities**

Conditions of rope inspections and their frequency shall be comply with manufacturer's instructions.

Inspections of steel ropes shall anyway meet the following requirements and carried out according to the frequency schedules specified hereafter.

### **10.2 Track ropes and anchoring ropes**

- 10.2.1** Visual inspection of ropes shall be carried out at least once every year with a view to assessing the presence of broken wires. If necessary, ropes shall be cleaned prior to each inspection.
- 10.2.2** **Spiral ropes:** Spiral ropes or spiral rope sections shall be replaced if the inspection has shown that in a rope section having a length equal to 200 d (nominal diameter of the rope) more than 10 % of wires are broken or has revealed safety impairing phenomena such as excessive wear, internal corrosion or anomalous rope structure.
- 10.2.3** **Stranded ropes:** Ropes or rope sections shall be replaced if the inspection has shown that in a rope section having a length equal to 200 d more than 15 % of wire are broken or has revealed safety impairing phenomena such as excessive wear, internal corrosion or anomalous rope structure.



**10.2.4 Track ropes** shall be greased with an appropriate lubricant at least once every year, care being taken to lubricate the rope in warm and dry environmental weather conditions. Particular attention shall be given to the perfect lubrication of rope sections supported by rope saddles and track rope connections with the tensioning system.

Broken wires shall be immediately bound together with a ligature and as soon as possible covered by a blind coupling.

### **10.3 Haul ropes, carrying hauling ropes, hoist ropes, combined hauling hoist ropes, sewing ropes**

**10.3.1** An accurate visual inspection of the haul rope shall be made at least once every six months having the purpose to assess the presence of broken wires. It shall be tolerated to reduce the frequency of inspection to one inspection every year if the ropeway is not being operated all the year round. If necessary, ropes shall be cleaned prior to each inspection.

**10.3.2** Besides the above mentioned assessment of broken wires this inspection includes also an assessment of the state of the haul rope fixing to the carrier. If the assessment has revealed any damage or defect, fixings shall be opened, the damaged rope section cut out and the fixing remade in an other point of the rope.

**10.3.3** Rope and rope sections shall be replaced if the inspection has revealed in a rope length equal to 40 d a reduction of the metallic rope cross section exceeding 15% or other damages impairing the safety, such as excessive wear, internal corrosion or anomalous structure of the rope.

**10.3.4** Ropes shall be treated with an appropriate lubricant at least once every year care being taken to lubricate the rope in warm and dry weather conditions.

**10.3.5** Care shall be taken to avoid to clean or lubricate the track rope in points corresponding to their incidence on the sheave or on the drum.

### **10.4 Tensioning ropes**

**10.4.1** Tensioning ropes shall be visually inspected at least once every year. Ropes and rope sections shall be replaced if the inspection has revealed a reduction of the metallic rope cross section exceeding 15 % or other damages impairing the safety, such as excessive wear, internal corrosion or anomalous rope structure in a rope length equal to 40 d.

### **10.5 Signal rope, control rope, air navigation beaconing rope**

**10.5.1** Rope end fixings, rope bearing surfaces, sag of the rope and corrosion of the rope shall be inspected at least once every year.

**10.5.1.1** The visibility and warning effect of signalling globes shall be checked at least once every year.

### **10.6 Rope end fixings**

**10.6.1** Ropes showing broken wires in the proximity of the end fixing shall be shortened in order to eliminate the damaged bit of the rope.

**10.6.2** End fixing slippage shall be checked according to the manufacturer's instructions, but at any rate at least every six months.

## **11 General provisions**

- 11.1** Operators of ropeway installations are required to permit representatives of the competent supervisory authority to visit all constituent parts of the ropeway and to supply all necessary information, to examine with them all documents, operating log books and records, to assist them during their visit and upon their request start the ropeway going and permit them to check it in operation.
- 11.2** The above inspections do not release the ropeway owner, operator and managers from their duty to direct and oversee the permanent supervision of the ropeway installation.
- 11.3** The competent supervisory authority shall be given Immediate notification of all accidents and incidents caused by the ropeway installation.
- 11.4** No modification or refurbishment of the ropeway installation may be carried out without prior authorization of the competent supervisory authority.
- 11.5** Appropriate measures shall be taken to protect all members of the staff against the nuisance of adverse weather conditions, noise and escape gases.

## **12 Transportation of persons (Cf clause 1.3.1.8 b)**

- 12.1** The manager is required to provide the engine operator with all necessary information regarding the specific requirements to be met when persons are permitted to take the ropeway.
- 12.2** Only persons who have received all necessary information regarding the specific requirements to be met and the rules of behaviour to be observed during the trip with the ropeway shall be permitted to take the ropeway.
- 12.3** No transport of materials shall be permitted in carriers transporting persons.
- 12.4** A test run with the empty carrier shall be made before taking persons on board
- 12.5** Passengers shall have the possibility to communicate with the engine operator by means of a radio based communication system if the engine operator cannot see the whole track from his operating stand. A communication test shall be made prior to every run with passengers on board. Passengers are required to use the provided system of communication to inform the engine operator sufficiently in time that their carrier is passing over a line support structure and that their carrier is approaching the disembarking or embarking area.
- 12.6** Embarking and disembarking of passengers shall be permitted only in the areas specially identified by the manager as suited embarking or disembarking area.
- 12.7** Only specially equipped and for the transport of persons suited carriers shall be used to transport persons.
- 12.8** Carriers for the transport of persons shall be equipped with an appropriate rescue apparatus (for instance) descending line
- 12.9 Complementary operating instructions for cable cranes**  
The travel and hoisting speed shall not exceed 50% of the nominal operating speed and never exceed the speed of 1.5 m/s.
- 12.10 Complementary instructions for material handling funiculars**  
The maximum travel speed shall never exceed 50% of the nominal operating speed and never exceed the speed of 2 m/s.

**12.11 Complementary operating instruction for temporary material handling ropeway installations**

The useful load of carriers transporting persons (1 Person = 80 kg) shall not exceed 30% of the maximum rated pay load of materials.

The maximum travel speed of temporary ropeways shall not exceed the speed of 1.5 m/s and the maximum hoisting speed not exceed the speed of 0.5 m/s.