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Hydrometric determinations — Cableway systems for stream gauging

Déterminations hydrométriques — Systèmes de suspension par câbles aériens pour le jaugeage en rivière

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 4375 was prepared by Technical Committee ISO/TC 113, *Hydrometric determinations*, Subcommittee SC 5, *Instruments, equipment and data management*.

This second edition cancels and replaces the first edition (ISO 4375:1979), which has been technically revised.

This corrected version of ISO 4375:2000 incorporates the following corrections.

In Annex A, clause A.1, the equations used for calculating F_{ht} and F_{at} have been corrected.

Hydrometric determinations — Cableway systems for stream gauging

1 Scope

This International Standard defines the requirements for equipment, anchorage, supports and accessories for cableway systems for use in stream gauging. Systems which are operated either entirely from the river bank or from a suspended personnel carriage (also called a "cable car") are discussed. This International Standard does not concern methods for making a discharge measurement which are described in ISO 748.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 31-3:1992, *Quantities and units — Part 3: Mechanics*.

ISO 748:1997, *Measurement of liquid flow in open channels — Velocity-area methods*.

ISO 772:1996, *Hydrometric determinations — Vocabulary and symbols*.

ISO 772:1996 Amd 1[1)], *Hydrometric determinations — Vocabulary and symbols*.

3 Terms and definitions

For the purposes of this International Standard, the terms and definitions given in ISO 772, its amendment 1 and ISO 31-3 as well as the following apply.

3.1
cable
wire rope of simple or complex structure or wire cord, fixed or moving in a cableway system

1) To be published.

4 General description of a cableway system

4.1 Elements of a cableway system

A cableway system can be designed to be operated from the river bank (see Figures 1 and 2) or be designed to be operated from a suspended personnel carriage (Figure 3). The general arrangement of the following elements are common to both systems:

a) towers or cableway supports;

b) track or main cable;

c) anchorage;

d) backstays;

e) suspension cable.

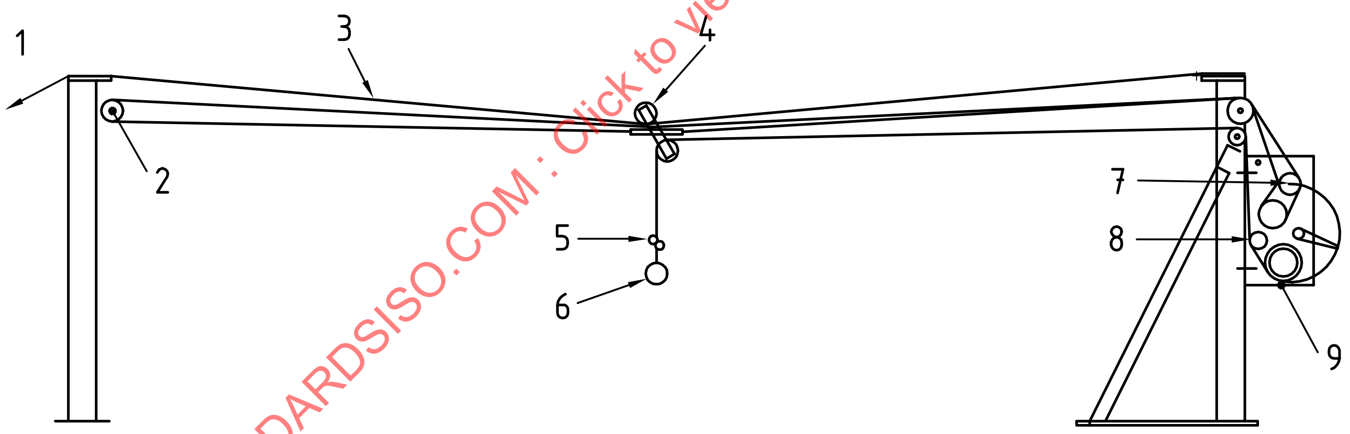
The main differences are:

— the carriage of a bankside system requires a tow cable;

— a bankside system requires a more complicated winch arrangement;

— the personnel carriage has to provide a safe platform for the operator;

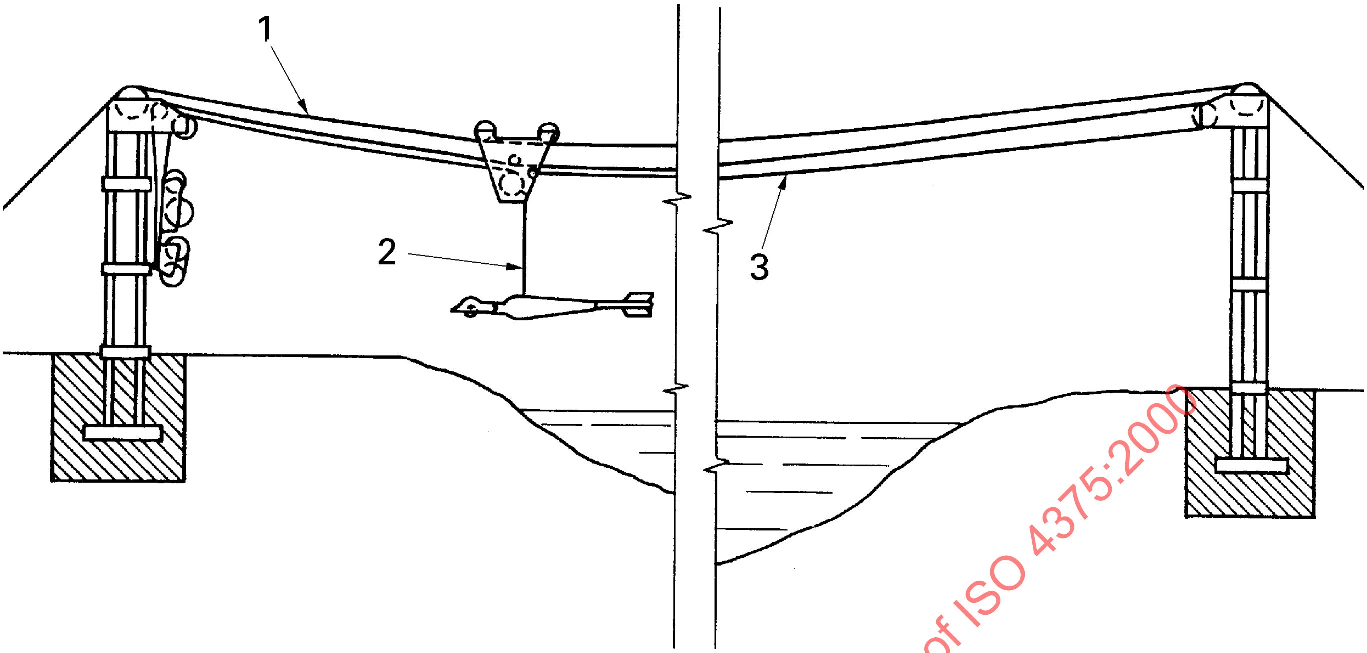
— more stringent design requirements may apply to a system which employs a personnel carriage.



Key

1 Backstay
2 Traversing cable return pulley
3 Track or main cable
4 Traveller and/or instrument carriage
5 Current meter
6 Sinker or sounding weight
7 Distance measurement
8 Depth measurement
9 Cable drum

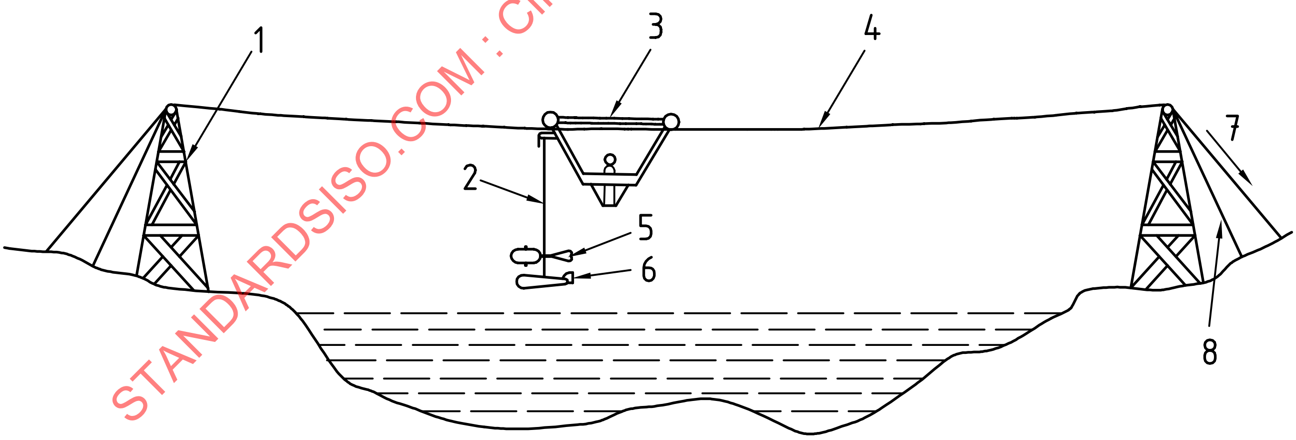
Figure 1 — Cableway system — Bankside operation, with loop-traversing cable and spooled sounding cable



Key

1 Track or main cable
2 Suspension cable
3 Tow cable

Figure 2 — Cableway system — Bankside operation, with spooled tow cable and spooled sounding cable



Key

1 Tower
2 Suspension cable
3 Personnel carriage
4 Track or main cable
5 Current meter
6 Sounding weight
7 To anchorage
8 Stayline

Figure 3 — Cableway system — Suspended personnel carriage

4.2 Cableway supports

The cableway supports, one on each bank, support the main cable span across the stream. They may also provide mountings for the winch and the pulleys (sheaves) carrying the tow and suspension cables.

4.3 Main track or main cable

The track or main cable is designed to carry the whole suspended load. The track may be attached directly to stayed cableway supports or be supported on saddles on the cableway supports and led directly to an anchorage.

4.4 Anchorage

Anchorages are required to carry the loads induced in the cableway and tower system. Depending upon the design of the system, they may be anchorage points for track and backstays or guy-lines, tower foundations subject to compression or tower foundations subject to compression and moment.

4.5 Tow cable for a bankside system

The tow cable is required to move and position the instrument carriage. Generally the tow cable is arranged as an endless loop from the instrument carriage over guiding sheaves on the winch tower, round a driving pulley or drum, across to an idler pulley (sheave) on the tower on the opposite bank and back to the carriage (Figure 1). An alternate arrangement uses a spooled tow cable with a single fixing point on the carriage. This arrangement depends upon the equal and opposite force provided by the suspension cable (Figure 2).

4.6 Suspension cable

The suspension cable provides the means of raising and lowering sensing or sampling equipment in the stream. The free end of the cable is fitted with connectors to attach equipment and sounding weights. The suspension cable is likely to contain an insulated conducting core to provide a signal path from suspended instruments.

4.7 Instrument carriage for a bankside system

The instrument carriage is provided with one or more track wheels running on the main cable (track), a pulley to support the suspension cable and a point of attachment for the tow (traveller) cable.

4.8 Personnel carriage

The carriage from which gauging observations are made, travels along the main cable. It is suspended from track wheels running on the main cable. The carriage may be moved along the main cable manually or by a power unit. The carriage can be designed to be operated from either the standing or sitting position or both. A cableway employing a personnel carriage shall comply with the safety requirements for passenger cableways where such standards exist specially for horizontal fixed cableways, in all aspects not covered by this International Standard.

4.9 Winch arrangements for a bankside system

A double drum winch is one that provides both traversing and sounding functions within one piece of equipment. One drum controls the suspension cable, the other controls the movement of the carriage. The latter may be a spooling drum or take the form of a friction drive pulley driving an “endless” loop. Both drums may be driven simultaneously in traversing mode or, in sounding mode, the traversing drum may be locked to allow operation of the suspension cable drum only. This operation may also be carried out using two single drum winches. Measuring counters may be fitted to record horizontal and vertical cable movement.

4.10 Winch arrangements for a personnel carriage

A winch (sounding reel) is attached to the carriage (cable car) to raise and lower the sounding weight. The winch is required to operate properly under the load of the sounding weight but both the winch and its mountings should be capable of accommodating the breaking load of the suspension cable with a factor of safety of two. The winch may be hand operated or power driven.

4.11 Lightning protection

In areas where electrical storms are considered a risk to cableway operators, provision shall be made to reduce the likelihood of injury from a lightning strike on the cableway system. In countries where lightning is infrequent and lightning protection not considered necessary, work instructions should allow for abandonment of operations in the event of an electrical storm.

5 Functional requirements of cableway components

5.1 Safety factors

5.1.1 General

Factors of safety shall be applied to ensure that the equipment is able to cope with normal working without failure and to protect the operator in case of abnormal but foreseeable incidents.

The most likely risk of failure of properly maintained cableway systems lies with the possibility of the suspended equipment becoming caught up on a large floating object. Trees being carried down on a flood are the most likely source of this danger. The excess loading is applied to the system through the suspension cable. In a bankside system, the tension in this cable is equal to, and balanced by, the tension in the “return” side of the tow cable. In both bankside systems and systems with personnel carriages, the load in the suspension cable is also applied to the main cable (track) through the carriage.

For both arrangements, the factor of safety for normal working shall be achieved by specifying the suspension cable in relation to a maximum working load. The specification of all other cables shall be with respect to the breaking load of the specified suspension cable.

5.1.2 Suspension cable

The suspension cable shall be selected to provide a minimum factor of safety of 5 in relation to the maximum authorized suspended load. The maximum authorized suspended load is the sum of the maximum authorized sounding weight plus an allowance for the mass of sensing/sampling equipment.

5.1.3 Tow cable

The tow (traversing) cable shall be selected to provide a factor of safety of 1,25 with respect to the breaking load of the suspension cable.

5.1.4 Track cable

The track cable shall be selected to provide a factor of safety, with respect to the breaking load of the suspension cable, as follows:

a) bankside cableway system with instrument carriage: 2

b) cableway with suspended personnel carriage: 5

5.1.5 Marking

Cableways shall be clearly marked to indicate maximum authorized sounding weights and approved suspension cable specification. The use at an established site, of a suspension cable with a breaking load greater than specified, reduces the factor of safety with respect to the track cable.

5.2 Cableway supports

5.2.1 Approaches

A safe and convenient approach should be available throughout the year on both banks so that an observer may have easy access to the installation for inspection and operation. It is recognized that access to the far bank may not always be possible in difficult terrain. If this is the case, it should be recognized in the operation procedures for that site.

5.2.2 Design load

The cableway supports shall be designed to withstand the breaking load of the track cable selected, together with any relevant wind loading. Attention shall be paid to lateral loading as a consequence of drag on the suspended load and allowance made for the extreme condition as the suspension cable approaches breaking point.

5.2.3 Foundation placement

The foundation of the tower should extend from below the frost line to at least 300 mm above ground level. The size and design of the foundation is dependant on soil conditions and is beyond the scope of this International Standard.

5.2.4 Height

The height of the cableway support shall be such that all parts of the equipment, suspended from the centre of the span, will be at least 1 m above the highest flood level to be measured, but at no time present a hazard to navigation or wildlife. Consideration should also be given to marking the cableway in areas where canoes and aircraft are used in its vicinity. In certain localities, high structures may be governed by regulations requiring the provision of aircraft warning lights and warning signs on the track cable.

5.2.5 Corrosion protection

Materials used in the construction of cableway supports shall be protected against corrosion.

5.3 Selection of main cable or track

The main cable shall be corrosion resistant. Wire rope may be used for spans up to 300 m. For longer spans it may be necessary to use special cables. Guidance on selecting cable sizes is given in annex A.

5.4 Anchorage

5.4.1 Design

Anchorages shall be designed, in accordance with standard engineering practice, to withstand such forces as may be induced upon them at the point of failure of the main cable.

5.4.2 Inspection accessibility

The point at which a cable is attached to an anchorage shall be so placed that it can be easily inspected.

5.5 Backstays

Where backstays are provided as part of the tower design they shall be of corrosion-resistant steel and be able to withstand the forces developed at the point of failure of the main cable.

5.6 Tow cable

Provision shall be made to be able to adjust the tension in a tow cable configured as an endless circuit. The adjuster should be accessible to the operator to allow adjustments to the tension before gauging commences.

5.7 Carriages

5.7.1 Instrument carriage for a bankside system

5.7.1.1 Carriage track wheels

The permissible bending radius of the track cable shall be taken into account in the design of the carriage. This is usually expressed as a multiple of the rope diameter and should be obtained from the rope manufacturer. Where an instrument carriage has more than one track wheel, the carriage should be articulated so that the resultant force is applied mid way between the track wheel axes, or, the geometry of rigid carriages should be arranged so that the load is distributed equally to each track wheel. Traditional symmetrical triangular designs should be considered to transmit the whole load through a single track wheel.

5.7.1.2 Load requirements

The carriage shall be capable of withstanding a load equivalent to the breaking load of the suspension cable.

5.7.1.3 Carriage design considerations

It shall be simple in design, be designed to be captive on the track and effectively retain the sounding cable in the operational position. It shall be corrosion resistant.

5.7.1.4 Carriage operational requirement

It shall permit the operation of equipment without hindrance.

5.7.2 Personnel carriage

5.7.2.1 Design

The carriage can be designed to be operated and used

a) in a standing position; or

b) in a sitting position.

The number of personnel permitted to occupy the carriage shall be clearly indicated on the installation together with the maximum mass of survey equipment and the maximum sounding weight permitted. The materials used in construction should be suitable for operation in the extremes of temperature. This is particularly important in seats and panels which may come into contact operating personnel. The carriage (cable car) shall be designed to withstand the breaking load of the suspension cable together with the specified maximum loaded capacity of the carriage, excluding the sounding weight, with a factor of safety of 2.

5.7.2.2 Brake

The carriage shall be provided with a brake or holding device to secure it in any desired positions on the main cable for the purpose of taking measurements.

5.8 Winches

5.8.1 General

5.8.1.1 Brake

It is desirable for the winch to be fitted with a load-activated brake so as to hold the suspended load and stop the handle from rotating when the winch is released in any mode of operation.

5.8.1.2 Locking device

The winch shall be provided with a locking device for the purpose of holding suspended instruments at a desired depth, in steps not greater than 20 mm.

5.8.1.3 Level wind device

The winch shall be designed so as to wrap the cable evenly around the drum.

5.8.1.4 Mechanical advantage

The gearing of a manually wound winch shall be related to the maximum recommended sounding weight, or be adjustable to provide an optimum relationship between effort at the winding handle and pay-out rate. The effort required on the handle to raise the maximum recommended sounding weight should not exceed 90 N.

5.8.1.5 Drum diameter

The diameter of any drum shall not be less than the minimum winding diameter recommended for the cable.

5.8.1.6 Signal transmission

Where the suspension cable is required to have an electrical signal core to transmit signals from the suspended equipment, the winch shall be provided with a method of transmitting these signals to the recording equipment.

5.8.1.7 Power winch requirements

Electrically or hydraulically driven winches should be provided with a facility to vary operating speed. In case of power failure, the winch shall be automatically braked or employ a gear train which cannot be driven by the load. It should have provision for manual operation to allow the recovery of equipment. Motor controls should incorporate overload protection and include “soft start” to reduce shock loading. Controls should require hand pressure for operation and default to “stop” in the absence of hand pressure.

5.8.2 Winches in bankside systems

5.8.2.1 Torque limiter

To protect the operator in the event of accidental overload, a winch designed for bankside operation should be fitted with a torque limiter in the tow-cabledrive system, set to slip under a load on the tow cable equal to twice the maximum suspended load. If a separate winch is employed to control the tow cable, it should be fitted with a torque limiter set to slip at a load equal to twice the maximum suspended load.

5.8.2.2 Load requirement

The winch shall be able to withstand a loading greater than the breaking load of the suspension cable, applied simultaneously to the suspension cable and the tow cable.

5.8.2.3 Cable deployment

The winch shall be designed to ensure that the tow cable and suspension cable are paid out at approximately the same rate.

5.8.2.4 Interlocking mechanism

It shall be possible to operate the suspension cable drum independently of the tow (traversing) cable drum for depth positioning. The arrangement for engaging and disengaging the two drums shall incorporate an interlocking mechanism so that the tow- (traversing-) cable drive is immobilized in the sounding mode and connected to the sounding cable drive in the traversing mode. It shall not be possible to achieve an intermediate state that allows the tow-cable drive to free-wheel.

5.8.2.5 Mounting design

The mountings used to attach the winch to the tower shall be designed to accommodate a load in shear, equal to six times the breaking load of the suspension cable. This includes a factor of safety of 3.

5.8.3 Winches on personnel carriages

5.8.3.1 Torque limiter

The winch controlling the suspension cable from a personnel carriage should be fitted with a torque limiter to allow the drum to turn and pay out cable, without interfering with the operation of the load-activated brake, which should continue to prevent the handle from rotating under overload conditions.

5.8.3.2 Release device

The cable termination on the winch shall be such that it will release or break free in the event of the cable becoming fully unwound under overload conditions.

6 Maintenance, examination and testing

6.1 General examination

Cables and anchorages shall, as far as is practicable, be examined for general condition before each gauging exercise. Particular attention should be paid to wire ropes attached to anchorages close to the ground to ensure that waterproof protection is intact. Observation of signs of deterioration however superficial shall be logged according to a specified procedure for consideration by the responsible person.

6.2 Routine inspection

6.2.1 Bankside systems

At intervals of 12 months, each cable and anchorage shall be thoroughly inspected. Wire ropes are most open to corrosion where they are bent round a thimble or pulley. Particular attention should be paid to the tow cable where it lies “parked” over the pulley on the far bank. During the periods when the cableway is not in use, the cable will tend to rest with the same section of rope bent round this pulley and it is common for cables to deteriorate at this point. Similarly the wires in the main cable may be spread due to bending round thimbles and where rope grips are used. These points should receive special attention and be treated with a rope preservative.

6.2.2 Systems with suspended personnel carriage

A thorough annual inspection is required for a passenger cableway system. This inspection is the same as for a cableway system operated from the bank but shall include the safety of the passenger in addition. Particular attention should be paid to potential corrosion of the passenger carriage and the tower or “A” frame supports. Significant corrosion induced pitting of these components requires replacement before the cableway may be used. The foundations of the tower should also be inspected. Significant spalling, cracking, or other deterioration of the foundations requires repairs before use of the cableway. Similarly, should there be any suggestion of movement of the foundations, the cableway shall not be used until they have been checked and, if necessary, redesigned and replaced.

6.3 Static testing

6.3.1 Bankside system

Following inspection and execution of any remedial action required, the complete cableway installation should be subject to a static-load test. The load applied shall be twice the maximum sounding weight approved for the installation. At the end of the test, with the carriage in the “home” position (i.e. close to a support tower) and the test load within 100 mm of the ground, the winch torque limiter (where fitted) should be adjusted so that it just slips under the test load.

6.3.2 Systems with suspended personnel carriage

At prescribed intervals and after repairs or replacement of components, the cableway should be tested with a static load equal to or greater than the breaking strength of the suspension (sounding) cable. Static-load testing, depending on conditions, shall be scheduled at intervals not exceeding 5 years. Cableways subject to severe corrosion or wear should be tested more frequently.

Static-load testing shall be carried out by loading the carriage progressively. This may be conveniently achieved by suspending a tank below the carriage and adding water until the desired load is achieved. A dynamic test can be introduced if required, by allowing the loaded carriage to traverse the cable during the test. As there is clearly a risk of cable failure during the test, all work shall be carried out with personnel in a safe location during testing.

6.4 Lubrication

All mechanical accessories shall be properly lubricated and observed to operate freely. Static ropes shall be treated with a rope dressing, as needed.

6.5 Checking the sag

The sag shall be checked at regular intervals, particularly when large changes in temperature occur. Significant changes should be investigated before re-tensioning the cable. Care shall be taken to avoid over-tensioning the cable. If the unloaded tension is greater than required to achieve the designed working sag, it can possibly lead to overloading, produce a reduction in the factor of safety and cause premature failure of the installation. Where large temperature variations are likely to cause problems of this type the use of a counterweight tensioning system should be considered. The sag should also be checked before and after a test loading has been carried out.

Annex A
(informative)

Cableway characteristics

A.1 Loadings

The stress in the various components of a cableway system is largely a function of the suspended load and the allowable percentage sag in the main cable. As the span increases the mass of the main cable becomes more significant. The horizontal component of the tension, F_{ht}, expressed in newtons, in a cable suspended between supports of equal height, under static conditions and neglecting wind loading, is given by:

$$F_{ht} = \frac{F_c b^2}{8h} + \frac{F_{ml} b}{4h}$$

where

F_c is the mass per metre run of cable, in newtons;

b is the horizontal span, in metres;

F_{ml} is the concentrated moving load, in newtons;

h is the sag, in metres, induced by load F_{ml} at mid span.

The actual tension, F_{at}, expressed in newtons, in the cable is given by,

$$F_{at} = F_{ht} \sqrt{1 + (4h/b)^2}$$

A.2 Cable selection — Examples

The optimum sag under working conditions is considered to be 2 % of the span. It is often difficult to adjust the sag under working conditions and it is often achieved by successive trials. It is important not to over-stress the cables prior to applying the working load to ensure minimum sag. An example for determining values of sag and tension expected during normal working conditions is given in Table A.1 and at the the breaking point in Table A.2. Figure A.1 shows how the tension in the cable increases rapidly and inversely with the reduction in sag below the design sag. Tables A.3 to A.6 provide some guidance on the required initial sag to achieve a working sag of 2 % of the span. Figure A.1 is given as percent of span.

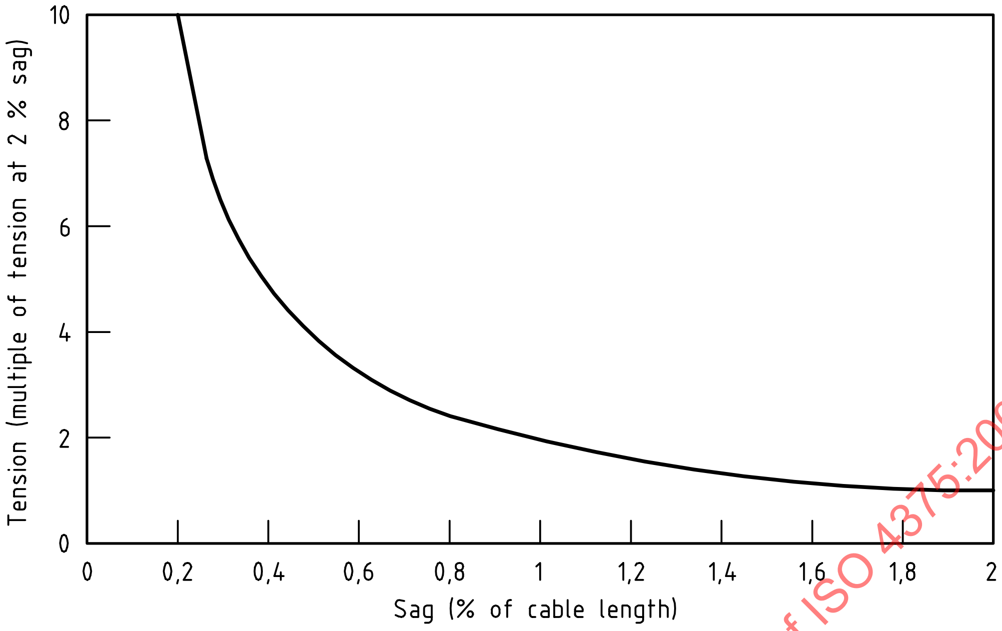


Figure A.1 — Relation between cable sag and tension relative to 2 % design sag

For example, for a span of 100 m, 11 mm diameter cable and a sounding weight of 50 kg, the cable should be tensioned to achieve an initial sag of 0,95 m. This should produce a 2 % (2 m) sag when a 50 kg load is suspended in mid span. It should be noted, however that the factor of safety on the main cable at the breaking point of the suspension cable may be less than the recommended value of 2 if the initial sag is less than that required for a 2 % working sag.

Assuming that a system has been set up to achieve this sag with a working point load of 50 kg, the sag and tension (values taken from Table A.4) in the cableway for various spans is given in Table A.1.

Table A.1 — Examples of sag and tension during normal working conditions

Span	50 m	100 m	150 m	200 m
Working sag	1,0 m	2,0 m	3,0 m	4,0 m
Tension	7 517 N	8 895 N	10 272 N	11 647 N
Rope diameter	11 mm	11 mm	11 mm	11 mm
Factor of safety	9,6	8,1	7,0	6,2

The working sag, together with an allowance for the minimum amount that suspended equipment hangs below the cableway, is a guide to the minimum height of cableway support above expected top water level.

At the breaking point of the suspension cable, (7 400 N for a typical stainless steel signal cable of diameter 3,2 mm) the final sag and the tension in the main cable, where it had been set up initially for a 2 % sag with a working load of 50 kg, would be approximately the values given in Table A.2.

Table A.2 — Examples of sag and tension at breaking point of suspension cable

Span	50 m	100 m	150 m	200 m
Working sag	2,7 m	5,3 m	7,9 m	10,4 m
Tension	35 000 N	35 827 N	36 660 N	37500 N
Rope diameter	11 mm	11 mm	11 mm	11 mm
Factor of safety	2,1	2,0	1,97	1,93
Breaking load of 11 mm rope taken as 73 600 N				

A.3 Factors of safety

As specified in 5.1, the main cable shall be sized to accommodate the breaking load of the suspension cable by some margin. It is recognized that during a gauging operation, circumstances can occur which can cause the suspension cable to approach or reach breaking point. Such an event can be expected to rarely occur and is not to be considered as normal working conditions. This International Standard provides for a factor of safety of 2 on the main cable of a bankside system with respect to the breaking load of the suspension cable and is sufficient for most of the cases in the above example. However, it would be necessary to increase the rope diameter to 12 mm to be certain of a safety factor of 2 for longer spans. Alternatively, the safety margin may be restored where a device, such as a torque limiter, has been incorporated into the system, to limit the maximum load at mid span, or by the use of counterweight tensioning.

A.4 Guidance on cable size selection

Estimates of appropriate cable sizes may be obtained by reference to Tables A.3 to A.6. Certain assumptions have been made about the properties of the cables selected, for example the tensile strength, the effective modulus of elasticity and the effective cross-sectional area. The information in Tables A.3 to A.6 relates to a common right-hand, ordinary lay, galvanized, drawn wire rope. Information specifically relating to cables should be obtained from the supplier to allow the calculations to be checked. It should also be noted that cables of special construction may require a higher factor of safety and this should be checked with the manufacturer.

A.5 Forces on towers and anchorages

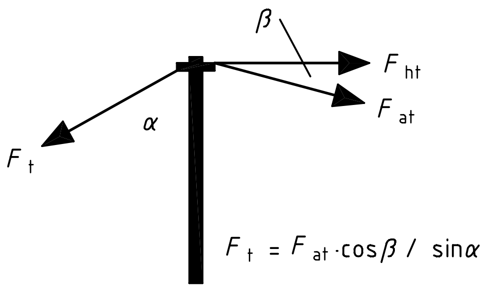
A.5.1 General remarks

Anchorages and tower foundations require a design suitable for ground conditions and for resistance to forces on the cableway system while in use and during extreme conditions while unattended (see 6.1, 6.2 and 6.4). Horizontal forces on towers are estimated in Tables A.3 to A.6.

The principal force on towers and anchorages during operation are due to the mass of the suspended equipment together with a horizontal component parallel to the flow due to drag on the submerged equipment. If partial submergence of the track and tow cable takes place outside the normal operational range, the horizontal component due to drag will be considerably increased, particularly as trash accumulates on the cables. Cyclical shock loading on partially submerged cables due to the “plucking” action on the water surface can also be very significant. It is important to ensure that the towers are restrained in upstream and downstream directions parallel to the flow to resist these forces.

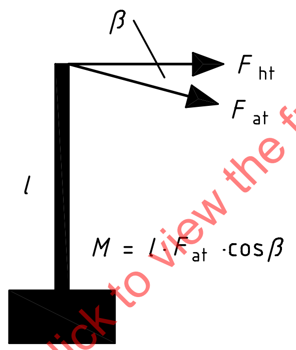
A.5.2 Common configurations

Common configurations of forces on towers and anchorages are given in Figures A.2 to A.4.



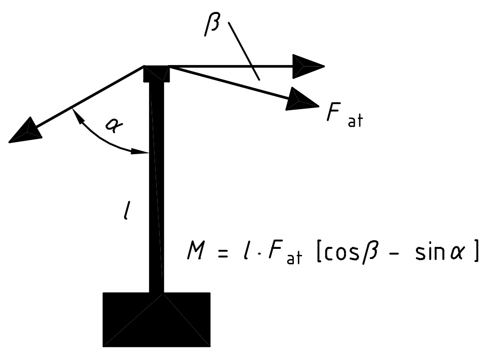
Base of tower may be considered to be pinned; no moment is transferred to tower.

Figure A.2 — Track fixed to tower head with backstay



The tension in the cable is translated wholly into a moment exerted on the foundation.

Figure A.3 — No backstay — Tower and base designed to withstand moment



Main cable passes over and is deflected by the tower. The foundation shall be able to resist the resultant moment.

Figure A.4 — Track passing over saddle or sheave and designed to withstand moment

Table A.3 — Cableway set up to achieve a sag of 2 % with a working load of 25 kg

			Under normal conditions			Failure of suspension cable		
Rope diameter mm	Span m	Initial sag %	Factor of safety	Tension N	Horizontal load N	Factor of safety	Tension N	Horizontal load N
11	20	1,12	19,95	3 620	3 608	2,16	33 493	32 696
	30	1,16	18,52	3 898	3 885	2,15	33 655	32 857
	40	1,20	17,31	4 172	4 159	2,14	33 813	33 013
	50	1,23	16,23	4 448	4 434	2,13	33 972	33 172
	60	1,26	15,29	4 722	4 707	2,12	34 135	33 334
	70	1,29	14,44	5 000	4 984	2,11	34 295	33 493
	80	1,31	13,69	5 275	5 258	2,10	34 454	33 650
	90	1,33	13,01	5 549	5 531	2,09	34 612	33 808
	100	1,35	12,40	5 824	5 805	2,08	34 772	33 967
	110	1,37	11,84	6 098	6 078	2,07	34 932	34 126
	120	1,39	11,33	6 374	6 353	2,06	35 093	34 286
	130	1,40	10,86	6 649	6 628	2,05	35 254	34 446
	140	1,41	10,43	6 924	6 902	2,04	35 416	34 607
	150	1,43	10,03	7 198	7 175	2,03	35 577	34 767
	160	1,44	9,66	7 472	7 448	2,02	35 739	34 928
	170	1,45	9,32	7 747	7 722	2,01	35 901	35 089
	180	1,47	9,00	8 022	7 996	2,00	36 064	35 251
	190	1,48	8,70	8 297	8 271	1,99	36 228	35 414
	200	1,49	8,42	8 572	8 545	1,98	36 392	35 577
12	20	1,23	23,04	3 726	3 714	2,44	35 245	34 487
	30	1,26	21,17	4 055	4 042	2,42	35 440	34 680
	40	1,29	19,59	4 382	4 368	2,41	35 631	34 870
	50	1,32	18,23	4 710	4 695	2,40	35 824	35 061
	60	1,34	17,04	5 037	5 021	2,38	36 016	35 253
	70	1,37	16,00	5 364	5 347	2,37	36 209	35 444
	80	1,39	15,08	5 691	5 673	2,36	36 402	35 636
	90	1,40	14,26	6 019	5 999	2,35	36 596	35 828
	100	1,42	13,52	6 348	6 328	2,33	36 790	36 022
	110	1,44	12,86	6 674	6 653	2,32	36 985	36 215
	120	1,45	12,26	7 002	6 980	2,31	37 181	36 410
	130	1,46	11,71	7 328	7 305	2,30	37 376	36 603
	140	1,48	11,21	7 655	7 630	2,28	37 571	36 798
	150	1,49	10,75	7 983	7 957	2,27	37 769	36 994
	160	1,50	10,33	8 311	8 284	2,26	37 966	37 190
	170	1,51	9,93	8 641	8 613	2,25	38 169	37 391

Table A.3 — Cableway set up to achieve a sag of 2 % with a working load of 25 kg *(continued)*

			Under normal conditions			Failure of suspension cable		
Rope diameter mm	Span m	Initial sag %	Factor of safety	Tension N	Horizontal load N	Factor of safety	Tension N	Horizontal load N
12	180	1,52	9,57	8 970	8 941	2,24	38 368	37 589
	190	1,53	9,24	9 293	9 263	2,23	38 565	37 785
	200	1,54	8,92	9 622	9 591	2,21	38 765	37 984
13	20	1,32	26,31	3 841	3 828	2,74	36 920	36 195
	30	1,34	23,90	4 227	4 214	2,72	37 153	36 426
	40	1,37	21,92	4 610	4 596	2,70	37 393	36 665
	50	1,39	20,23	4 994	4 979	2,69	37 622	36 893
	60	1,41	18,79	5 378	5 361	2,67	37 852	37 121
	70	1,43	17,54	5 761	5 743	2,65	38 081	37 349
	80	1,45	16,44	6 144	6 125	2,64	38 312	37 578
	90	1,46	15,48	6 528	6 508	2,62	38 544	37 808
	100	1,48	14,62	6 912	6 890	2,61	38 776	38 038
	110	1,49	13,85	7 296	7 273	2,59	39 008	38 269
	120	1,50	13,15	7 686	7 662	2,57	39 247	38 506
	130	1,51	12,52	8 069	8 043	2,56	39 480	38 738
	140	1,52	11,95	8 453	8 426	2,54	39 715	38 971
	150	1,53	11,44	8 835	8 807	2,53	39 949	39 204
	160	1,54	10,96	9 220	9 190	2,51	40 186	39 439
	170	1,55	10,52	9 605	9 575	2,50	40 423	39 675
	180	1,56	10,12	9 988	9 956	2,49	40 660	39 910
	190	1,57	9,74	10 371	10 338	2,47	40 898	40 147
	200	1,58	9,39	10 756	10 722	2,46	41 137	40 384
14	20	1,38	29,45	3 964	3 951	3,03	38 552	37 857
	30	1,40	26,47	4 410	4 396	3,01	38 824	38 127
	40	1,43	24,06	4 851	4 836	2,99	39 094	38 395
	50	1,44	22,03	5 299	5 282	2,97	39 365	38 663
	60	1,46	20,33	5 744	5 725	2,95	39 636	38 933
	70	1,48	18,86	6 188	6 169	2,93	39 908	39 203
	80	1,49	17,60	6 632	6 611	2,91	40 184	39 478
	90	1,50	16,48	7 083	7 060	2,89	40 464	39 755
	100	1,52	15,51	7 527	7 503	2,87	40 737	40 027
	110	1,53	14,64	7 971	7 946	2,85	41 011	40 299
	120	1,54	13,87	8 416	8 389	2,83	41 286	40 572
	130	1,55	13,17	8 863	8 835	2,81	41 563	40 847
	140	1,56	12,55	9 305	9 275	2,79	41 838	41 120

Table A.3 — Cableway set up to achieve a sag of 2 % with a working load of 25 kg *(continued)*

			Under normal conditions			Failure of suspension cable		
Rope diameter mm	Span m	Initial sag %	Factor of safety	Tension N	Horizontal load N	Factor of safety	Tension N	Horizontal load N
14	150	1,57	11,97	9 751	9 720	2,77	42 117	41 398
	160	1,58	11,45	10 195	10 162	2,75	42 395	41 674
	170	1,59	10,97	10 638	10 604	2,74	42 674	41 951
	180	1,60	10,53	11 083	11 048	2,72	42 955	42 230
	190	1,61	10,13	11 529	11 493	2,70	43 237	42 510
	200	1,61	9,75	11 973	11 935	2,68	43 519	42 790
16	20	1,47	36,16	4 233	4 219	3,67	41 685	41 039
	30	1,49	31,78	4 815	4 800	3,64	42 027	41 378
	40	1,50	28,29	5 410	5 393	3,61	42 410	41 758
	50	1,52	25,55	5 989	5 970	3,58	42 775	42 121
	60	1,53	23,29	6 570	6 549	3,55	43 122	42 465
	70	1,55	21,40	7 151	7 128	3,52	43 487	42 828
	80	1,56	19,79	7 735	7 710	3,49	43 851	43 189
	90	1,57	18,41	8 313	8 286	3,46	44 221	43 557
	100	1,58	17,21	8 894	8 866	3,43	44 590	43 923
	110	1,59	16,15	9 474	9 444	3,40	44 959	44 290
	120	1,60	15,22	10 054	10 022	3,38	45 330	44 658
	130	1,61	14,39	10 635	10 602	3,35	45 707	45 033
	140	1,62	13,64	11 218	11 182	3,32	46 083	45 406
	150	1,63	12,97	11 801	11 764	3,29	46 459	45 780
	160	1,64	12,36	12 381	12 342	3,27	46 836	46 154
	170	1,64	11,81	12 961	12 920	3,24	47 214	46 530
	180	1,65	11,30	13 542	13 499	3,22	47 593	46 907
	190	1,66	10,84	14 122	14 077	3,19	47 973	47 284
	200	1,66	10,41	14 707	14 661	3,16	48 358	47 667

Table A.4 — Cableway set up to achieve a sag of 2 % with a working load of 50 kg

			Under normal conditions			Failure of suspension cable		
Rope diameter	Span	Initial sag	Factor of safety	Tension	Horizontal load	Factor of safety	Tension	Horizontal load
mm	m	%		N	N		N	N
11	20	0,44	10,83	6 669	6 648	2,09	34 496	33 722
	30	0,56	10,38	6 957	6 935	2,08	34 668	33 893
	40	0,65	9,98	7 238	7 215	2,07	34 835	34 060
	50	0,72	9,61	7 517	7 493	2,06	35 001	34 225
	60	0,78	9,26	7 793	7 768	2,05	35 166	34 389
	70	0,83	8,95	8 070	8 044	2,04	35 332	34 554
	80	0,88	8,65	8 346	8 319	2,03	35 497	34 718
	90	0,92	8,38	8 618	8 591	2,02	35 661	34 881
	100	0,95	8,12	8 895	8 867	2,02	35 827	35 046
	110	0,98	7,87	9 172	9 142	2,01	35 993	35 212
	120	1,01	7,64	9 447	9 417	2,00	36 160	35 377
	130	1,04	7,43	9 720	9 689	1,99	36 326	35 543
	140	1,07	7,22	9 997	9 966	1,98	36 494	35 709
	150	1,09	7,03	10 272	10 240	1,97	36 662	35 876
	160	1,11	6,84	10 548	10 515	1,96	36 830	36 043
	170	1,13	6,67	10 825	10 791	1,95	36 999	36 212
	180	1,15	6,51	11 097	11 061	1,94	37 166	36 378
	190	1,17	6,35	11 372	11 335	1,93	37 336	36 546
	200	1,18	6,20	11 646	11 609	1,93	37 505	36 715
12	20	0,62	12,66	6 778	6 756	2,37	36 238	35 501
	30	0,72	12,06	7 116	7 093	2,36	36 442	35 704
	40	0,80	11,52	7 449	7 425	2,34	36 644	35 904
	50	0,87	11,04	7 777	7 752	2,33	36 841	36 101
	60	0,92	10,59	8 107	8 081	2,32	37 042	36 300
	70	0,96	10,18	8 435	8 409	2,30	37 241	36 498
	80	1,00	9,80	8 763	8 735	2,29	37 440	36 696
	90	1,04	9,44	9 090	9 061	2,28	37 640	36 894
	100	1,07	9,11	9 419	9 389	2,27	37 841	37 094
	110	1,10	8,81	9 743	9 712	2,26	38 041	37 293
	120	1,12	8,52	10 073	10 041	2,24	38 244	37 494
	130	1,15	8,25	10 401	10 368	2,23	38 446	37 696
	140	1,17	8,00	10 729	10 695	2,22	38 648	37 897
	150	1,19	7,77	11 053	11 018	2,21	38 850	38 097
	160	1,21	7,54	11 382	11 346	2,20	39 054	38 300

Table A.4 — Cableway set up to achieve a sag of 2 % with a working load of 50 kg *(continued)*

			Under normal conditions			Failure of suspension cable		
Rope diameter	Span	Initial sag	Factor of safety	Tension	Horizontal load	Factor of safety	Tension	Horizontal load
mm	m	%		N	N		N	N
12	170	1,23	7,33	11 709	11 672	2,19	39 259	38 504
	180	1,24	7,13	12 038	12 000	2,18	39 464	38 707
	190	1,26	6,94	12 367	12 327	2,16	39 670	38 912
	200	1,27	6,76	12 695	12 654	2,15	39 876	39 117
13	20	0,79	14,66	6 894	6 872	2,67	37 901	37 195
	30	0,88	13,87	7 287	7 264	2,65	38 144	37 437
	40	0,94	13,17	7 674	7 650	2,63	38 383	37 674
	50	0,99	12,54	8 059	8 034	2,62	38 621	37 911
	60	1,04	11,97	8 444	8 417	2,60	38 859	38 147
	70	1,08	11,44	8 829	8 801	2,58	39 098	38 384
	80	1,11	10,97	9 214	9 185	2,57	39 342	38 627
	90	1,14	10,53	9 595	9 565	2,55	39 578	38 862
	100	1,17	10,12	9 982	9 950	2,54	39 819	39 101
	110	1,19	9,75	10 365	10 332	2,52	40 057	39 338
	120	1,21	9,40	10 750	10 715	2,51	40 298	39 577
	130	1,24	9,07	11 134	11 099	2,49	40 539	39 817
	140	1,26	8,77	11 519	11 482	2,48	40 781	40 057
	150	1,27	8,49	11 904	11 866	2,46	41 024	40 299
	160	1,29	8,22	12 288	12 249	2,45	41 264	40 538
	170	1,31	7,97	12 673	12 632	2,43	41 509	40 781
	180	1,32	7,74	13 056	13 014	2,42	41 753	41 023
	190	1,34	7,52	13 439	13 396	2,41	41 998	41 267
	200	1,35	7,31	13 821	13 777	2,39	42 243	41 511
14	20	0,94	16,60	7 031	7 009	2,95	39 525	38 847
	30	1,00	15,61	7 480	7 456	2,93	39 807	39 127
	40	1,06	14,73	7 925	7 899	2,91	40 084	39 403
	50	1,10	13,95	8 370	8 343	2,89	40 363	39 680
	60	1,14	13,24	8 815	8 787	2,87	40 642	39 957
	70	1,17	12,61	9 260	9 230	2,85	40 922	40 234
	80	1,20	12,02	9 710	9 679	2,83	41 204	40 515
	90	1,23	11,50	10 151	10 119	2,81	41 483	40 792
	100	1,25	11,02	10 595	10 562	2,80	41 765	41 073
	110	1,27	10,58	11 035	10 999	2,78	42 045	41 350
	120	1,29	10,17	11 481	11 445	2,76	42 329	41 632

Table A.4 — Cableway set up to achieve a sag of 2 % with a working load of 50 kg
(continued)

			Under normal conditions			Failure of suspension cable		
Rope diameter	Span	Initial sag	Factor of safety	Tension	Horizontal load	Factor of safety	Tension	Horizontal load
mm	m	%		N	N		N	N
14	130	1,31	9,79	11 926	11 888	2,74	42 613	41 915
	140	1,33	9,44	12 371	12 331	2,72	42 898	42 198
	150	1,34	9,11	12 816	12 775	2,70	43 184	42 482
	160	1,36	8,80	13 261	13 219	2,69	43 470	42 767
	170	1,37	8,52	13 707	13 663	2,67	43 758	43 053
	180	1,39	8,25	14 152	14 107	2,65	44 047	43 340
	190	1,40	8,00	14 597	14 550	2,63	44 335	43 627
	200	1,41	7,76	15 041	14 993	2,62	44 625	43 915
16	20	1,16	20,95	7 304	7 280	3,59	42 587	41 955
	30	1,20	19,40	7 889	7 863	3,56	42 965	42 330
	40	1,23	18,07	8 470	8 443	3,53	43 339	42 701
	50	1,26	16,91	9 053	9 024	3,50	43 714	43 074
	60	1,29	15,89	9 634	9 603	3,47	44 098	43 455
	70	1,31	14,98	10 215	10 182	3,44	44 473	43 829
	80	1,34	14,17	10 801	10 767	3,41	44 851	44 204
	90	1,36	13,45	11 381	11 345	3,38	45 228	44 579
	100	1,37	12,79	11 961	11 923	3,36	45 607	44 955
	110	1,39	12,20	12 542	12 502	3,33	45 987	45 333
	120	1,41	11,66	13 123	13 081	3,30	46 368	45 711
	130	1,42	11,17	13 704	13 660	3,27	46 751	46 092
	140	1,44	10,71	14 287	14 242	3,25	47 135	46 474
	150	1,45	10,29	14 868	14 821	3,22	47 521	46 857
	160	1,46	9,91	15 448	15 399	3,19	47 907	47 240
	170	1,47	9,55	16 025	15 974	3,17	48 293	47 624
	180	1,48	9,21	16 611	16 558	3,14	48 684	48 013
	190	1,49	8,90	17 190	17 135	3,12	49 073	48 400
	200	1,50	8,61	17 778	17 721	3,09	49 469	48 794

Table A.5 — Cableway set up to achieve a sag of 2 % with a working load of 75 kg

			Under normal conditions			Failure of suspension cable		
Rope diameter	Span	Initial sag	Factor of safety	Tension	Horizontal load	Factor of safety	Tension	Horizontal load
mm	m	%		N	N		N	N
12	20	0,28	8,71	9 850	9 818	2,30	37 287	36 571
	30	0,38	8,42	10 190	10 158	2,29	37 503	36 786
	40	0,47	8,16	10 522	10 488	2,28	37 712	36 993
	50	0,54	7,91	10 852	10 818	2,26	37 919	37 200
	60	0,60	7,67	11 187	11 151	2,25	38 127	37 407
	70	0,66	7,45	11 515	11 478	2,24	38 334	37 612
	80	0,71	7,25	11 839	11 802	2,23	38 539	37 817
	90	0,75	7,06	12 166	12 127	2,22	38 745	38 021
	100	0,79	6,87	12 496	12 456	2,20	38 954	38 228
	110	0,83	6,69	12 825	12 785	2,19	39 162	38 436
	120	0,86	6,53	13 148	13 106	2,18	39 368	38 641
	130	0,89	6,37	13 476	13 433	2,17	39 578	38 849
	140	0,92	6,22	13 801	13 757	2,16	39 785	39 055
	150	0,94	6,08	14 126	14 081	2,15	39 994	39 263
	160	0,97	5,94	14 459	14 413	2,13	40 206	39 474
	170	0,99	5,81	14 787	14 739	2,12	40 417	39 684
	180	1,01	5,68	15 116	15 068	2,11	40 629	39 895
	190	1,03	5,56	15 443	15 394	2,10	40 842	40 107
	200	1,05	5,44	15 768	15 717	2,09	41 053	40 316
13	20	0,39	10,16	9 948	9 916	2,59	38 942	38 255
	30	0,50	9,76	10 352	10 319	2,58	39 197	38 509
	40	0,59	9,40	10 745	10 711	2,56	39 446	38 756
	50	0,66	9,07	11 136	11 100	2,55	39 693	39 002
	60	0,72	8,77	11 520	11 483	2,53	39 937	39 244
	70	0,78	8,49	11 905	11 867	2,51	40 181	39 488
	80	0,82	8,22	12 286	12 247	2,50	40 425	39 730
	90	0,86	7,97	12 676	12 636	2,48	40 674	39 977
	100	0,90	7,74	13 059	13 018	2,47	40 919	40 221
	110	0,93	7,52	13 444	13 401	2,45	41 167	40 467
	120	0,97	7,31	13 824	13 780	2,44	41 413	40 712
	130	0,99	7,11	14 211	14 166	2,43	41 662	40 959
	140	1,02	6,92	14 596	14 550	2,41	41 911	41 208
	150	1,04	6,74	14 983	14 935	2,40	42 162	41 457
	160	1,07	6,58	15 363	15 314	2,38	42 411	41 704