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Hydrometry — Cableway systems for stream gauging

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

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Foreword

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The committee responsible for this document is ISO/TC 113, *Hydrometric determinations*, Subcommittee SC 5, *Instruments, equipment and data management*.

This third edition cancels and replaces the second edition (ISO 4375:2000), which has been technically revised.

Hydrometry — 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 is only applicable to the cableway systems to be used for hydrometric measurements. Should the cableway installation be required to be certified as lifting equipment, other standards or regulations may apply. This International Standard does not concern methods for making a discharge measurement which are described in ISO 748.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 772, *Hydrometry — Vocabulary and symbols*

ISO 80000-4, *Quantities and units — Part 4: Mechanics*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 772, ISO 80000-4 and the following apply.

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

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 (see 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.

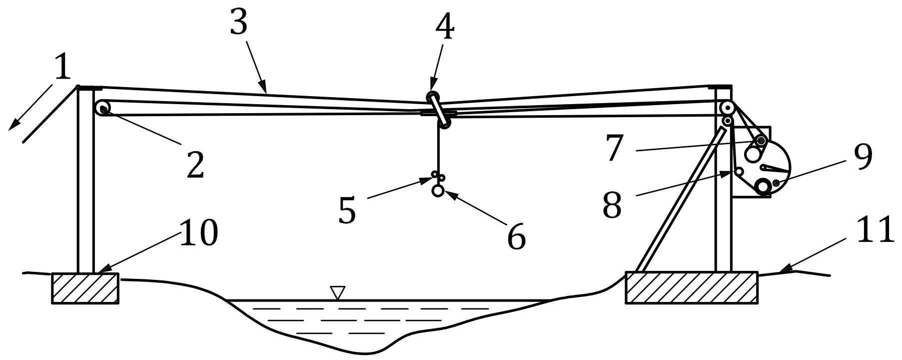
The main differences are:

— 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;

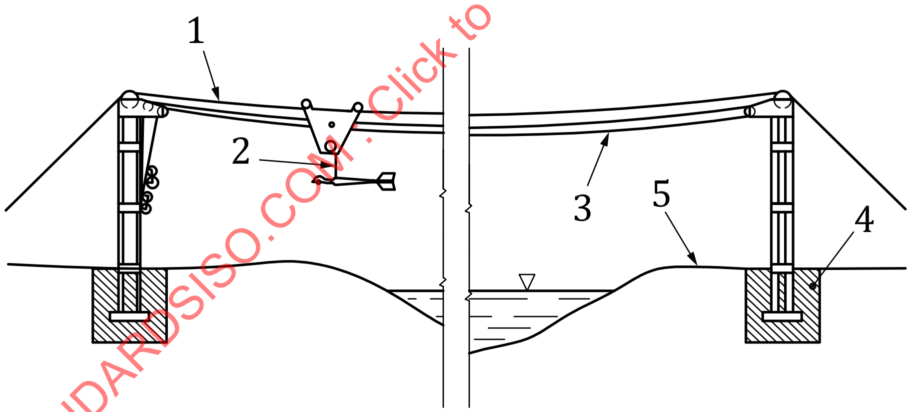
— more stringent design requirements may apply to a system which employs a personnel carriage.



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
10 footing
11 ground level

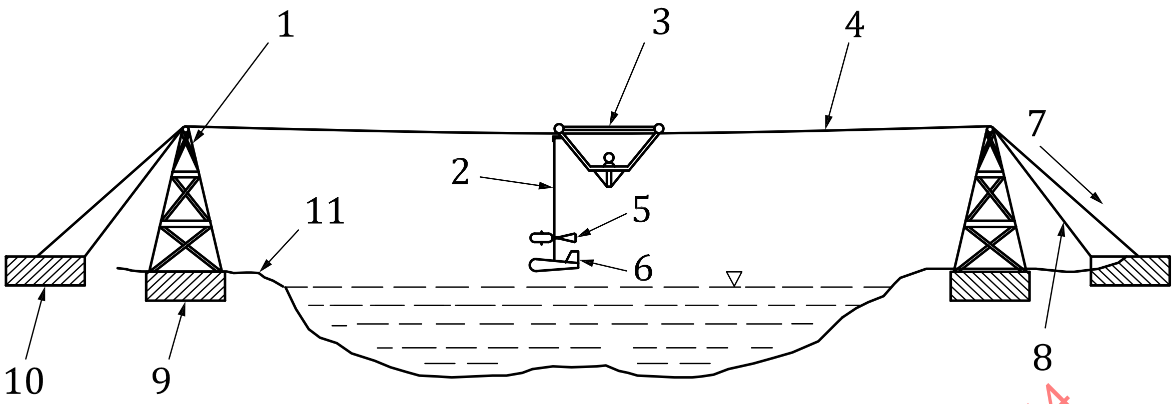
Figure 1 — Cableway system — Bankside operation, with loop-traversing cable and spooled sounding cable



Key

1 track or main cable
2 suspension cable
3 tow cable
4 footing
5 ground level

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



Key

1	tower	7	to anchorage
2	suspension cable	8	stayline
3	personnel carriage	9	footing
4	track or main cable	10	anchorage
5	current meter	11	ground level
6	sounding weight		

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 (see 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 (see 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 (FoS) 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 in 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 FoS 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 FoS 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 FoS 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 FoS, 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. At an established site, the use of a suspension cable with a breaking load greater than specified at an established site reduces the FoS 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 personnel 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 plus allowance for 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 dependent 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, shall be at least 1m 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 markers or warning lights 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

Backstays provided as part of the tower design 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 each use of the cableway.

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 design should ensure 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 (cable car) 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 with operating personnel. The carriage 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 FoS of 2.

5.7.2.2 Brake

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

5.8 Winches

5.8.1 General

5.8.1.1 Brake

The winch shall be fitted with a load-activated brake so as to hold the suspended load and stop the handle from rotating when the winch handle 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. This locking device may also be the brake specified in 5.8.1.1.

5.8.1.3 Cable spooling

The winch shall be designed so as to provide even spooling of cable on 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 shall require hand pressure for operation and default to “stop” in the absence of hand pressure. Powered winches shall comply with the machinery regulations of the country in which they are installed.

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 limiting facility in the tow-cable drive 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 provides a FoS 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, including tensioners and locking devices shall, as far as is practicable, be examined for general condition before each use of the cableway. Particular attention should be paid to wire ropes attached to anchorages close to the ground to ensure that waterproof protection is intact. Evidence of any corrosion or deterioration, however superficial, shall be noted and recorded according to the prescribed inspection program.

6.2 Routine inspection

6.2.1 Bankside systems

6.2.1.1 Cables

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 wire rope preservative.

6.2.1.2 Supports

Supports should be checked to ensure that they remain vertical, especially after tension adjustments have been made in the cables. It is useful to maintain a record of tension adjustments. If the sag is excessive, or increasing on successive visits, this can be an indication that creep is taking place that is not obvious from a visual inspection of the support or anchorage.

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. The cableway shall not be used if any foundation movement is detected. In such instances, the foundation shall be investigated, and if necessary be redesigned and replaced.

6.3 Static testing

6.3.1 Bankside system

The complete cableway installation should be subject to a static load test after first assembly or major modification and before being put into use. Thereafter, load testing may be carried out at the discretion of the competent authority as necessary to ensure the safety of the installation. 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 components shall be properly lubricated and observed to operate freely.

6.5 Checking the sag

The sag is the difference in height between the lowest point of the main cable catenary and the saddle or point of attachment of the cable on the support. The working sag is the sag obtained with the maximum working load at mid span. These are characteristics of the cableway which are set by the design. For a cableway set up according to Annex A, the working sag is 2 % of the span. The initial (unloaded) sag is given in Tables A.3 to A.5.

The sag shall be checked at regular intervals, particularly when large changes in temperature occur. Significant changes should be investigated before tension adjustments are made to the cable. Care shall be taken to avoid adjustments that produce excess tension in the cable. Unloaded tension greater than that required to achieve the designed working sag can lead to overloading, a reduction in the FoS, 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 load test has been carried out. The sag may be checked by sighting through between reference marks on the supports set at the appropriate level. Alternatively, a survey level may be used. Set up the level so that the collimation is at the low point of the cable. This can be refered to a reference mark on the support. This check may be applied to either the unloaded sag (initial sag) or working sag. It may be easier and more useful, in practice to check the working sag.

Annex A
(informative)

Cableway characteristics

A.1 Loadings

The stresses in the various components of a cableway system are largely a function of the cable span, suspended load and the allowable 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

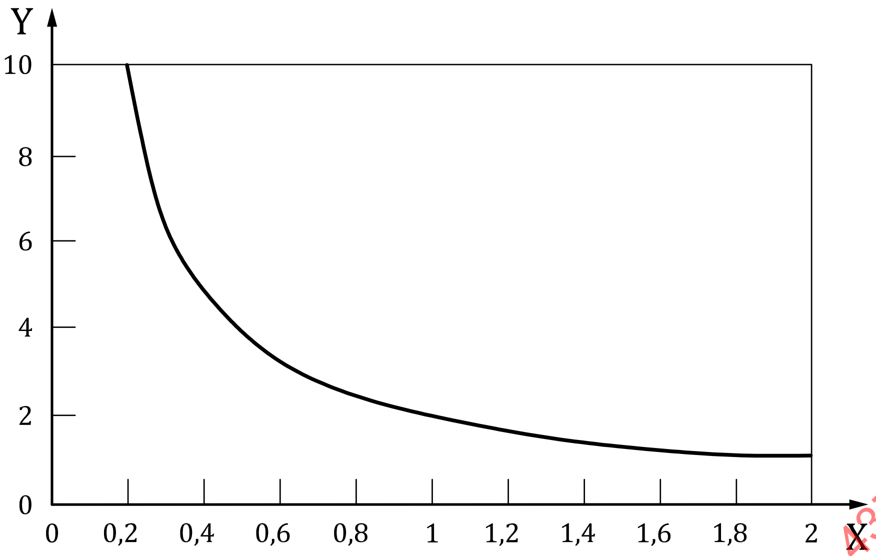
$$F_{at} = \sqrt{F_{ht}{}^2 + \left(\frac{4hF_{ht}}{b} - \frac{F_{ml}}{2}\right)^2}$$

or, to within 3 %, by

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

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 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.5 provide some guidance on the required initial sag to achieve a working sag of 2 % of the span.



Key

X sag (% of cable length)

Y tension (multiple of tension at 2 % sag)

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

For example, for a span of 100 m, 10 mm diameter cable and a sounding weight of 50 kg, the cable should be tensioned to achieve an initial sag of 0,85 m (see Table A.3). 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 FoS 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 suspended load of 50 kg, the sag and tension (values taken from Table A.3) 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	40 m	60 m	100 m	140 m	200 m
Working sag	0,8 m	1,2 m	2,0 m	2,8 m	4,0 m
Tension	7 110 N	7 605 N	8 591 N	9 575 N	11 052 N
Rope diameter	10 mm	10 mm	10 mm	10 mm	10 mm
Factor of safety	9,8	9,2	8,1	7,3	6,3

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

Where the cableway has been set up to achieve a 2 % sag with a working load of 50 kg, the sag and tension in the main cable at the breaking point of the suspension cable (7 100 N for a typical stainless steel signal cable of diameter 3,2 mm) 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	40 m	60 m	100 m	140 m	200 m
Sag	2,24 m	3,34 m	5,54 m	7,7 m	10,88 m
Tension	32 250 N	32 550 N	33 144 N	33 740 N	34 643 N
Rope diameter	10 mm	10 mm	10 mm	10 mm	10 mm
Factor of safety	2,16	2,14	2,10	2,06	2,00

A.3 Safety Factors

As specified in 5.1, the main cable shall be sized to exceed the breaking load of the suspension cable by some safety 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 occur rarely and is not to be considered as normal working conditions. This International Standard provides for a FoS 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 11 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. This guidance is not applicable to cableways with manned carriages. Cableways with manned carriages shall comply with national standards for passenger or man-riding cableways.

A.4 Guidance on cable size selection

Estimates of appropriate cable sizes may be obtained by reference to Tables A.3 to A.5. 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 estimate of tension was calculated using an iterative process to take account of the elongation of the main cable and the consequent change in sag up to the point of failure. The information in Tables A.3 to A.5 relates to a common right-hand, ordinary lay (IWRC), 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 FoS and this should be checked with the manufacturer.

A.5 Forces on towers and anchorages

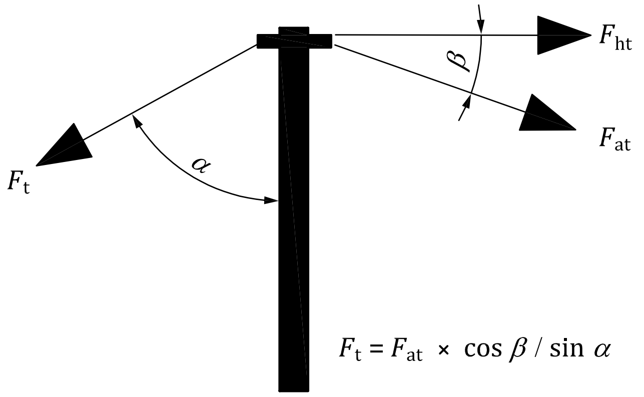
A.5.1 General remarks

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 5.1, 5.2 and 5.4). Horizontal forces on towers are estimated in Tables A.3 to A.5.

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.

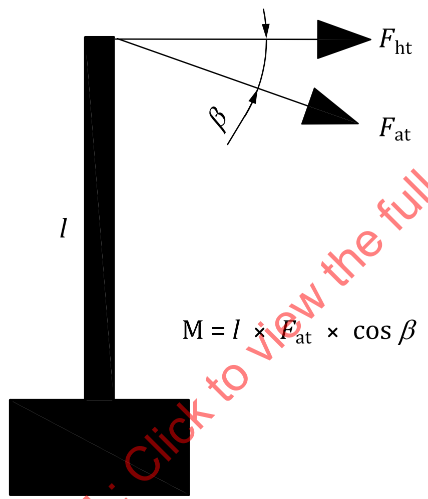
A.5.2 Common configurations

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



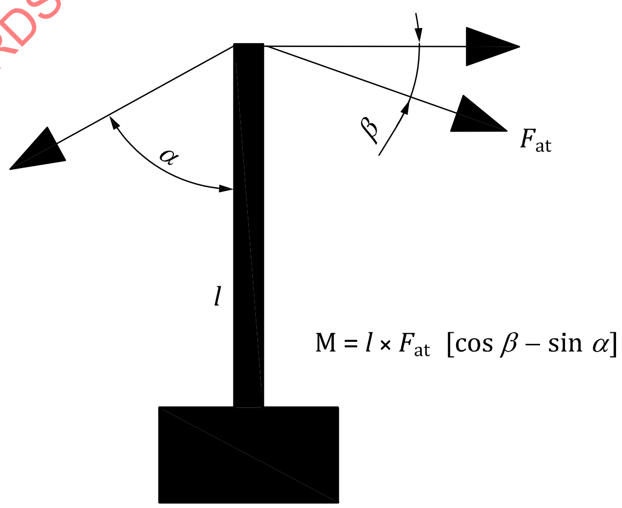
NOTE Base of tower may be considered to be pinned; no moment is transferred to tower.

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



NOTE 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



NOTE 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 base designed to withstand moment

Table A.3 — 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 mm	Span m	Initial sag %	Factor of safety	Tension N	Horizontal load N	Factor of safety	Tension N	Horizontal load N
10	20	0,06	10,55	6 614	6 608	2,18	31 928	31 725
	40	0,21	9,81	7 110	7 102	2,16	32 249	32 044
	60	0,40	9,17	7 605	7 596	2,14	32 550	32 343
	80	0,61	8,61	8 099	8 089	2,12	32 848	32 638
	100	0,85	8,12	8 591	8 579	2,10	33 144	32 932
	120	1,10	7,68	9 084	9 071	2,08	33 442	33 227
	140	1,36	7,28	9 575	9 561	2,06	33 740	33 523
	160	1,64	6,93	10 067	10 052	2,05	34 040	33 820
	180	1,92	6,61	10 559	10 542	2,03	34 340	34 118
	200	2,21	6,31	11 052	11 034	2,01	34 643	34 418
11	20	0,09	12,57	6 711	6 705	2,50	33 643	33 450
	40	0,27	11,53	7 319	7 311	2,47	34 073	33 878
	60	0,48	10,66	7 913	7 903	2,44	34 454	34 256
	80	0,72	9,91	8 512	8 501	2,42	34 827	34 626
	100	0,98	9,26	9 107	9 094	2,39	35 197	34 992
	120	1,25	8,69	9 703	9 688	2,37	35 566	35 359
	140	1,53	8,19	10 299	10 282	2,34	35 936	35 726
	160	1,82	7,74	10 894	10 876	2,32	36 308	36 094
	180	2,12	7,34	11 490	11 470	2,30	36 680	36 464
	200	2,42	6,98	12 084	12 063	2,27	37 054	36 835
12	20	0,13	14,64	6 826	6 819	2,82	35 437	35 253
	40	0,33	13,25	7 544	7 536	2,78	35 907	35 720
	60	0,56	12,11	8 255	8 245	2,75	36 355	36 164
	80	0,82	11,15	8 964	8 952	2,71	36 798	36 604
	100	1,09	10,33	9 673	9 659	2,68	37 241	37 043
	120	1,38	9,63	10 381	10 365	2,65	37 685	37 484
	140	1,67	9,01	11 089	11 071	2,62	38 131	37 926
	160	1,97	8,47	11 799	11 778	2,59	38 579	38 371
	180	2,28	7,99	12 507	12 484	2,56	39 030	38 818
	200	2,60	7,56	13 216	13 191	2,53	39 483	39 268

Table A.3 *(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
13	20	0,16	16,97	6 951	6 944	3,19	36 968	36 791
	40	0,38	15,14	7 789	7 780	3,13	37 676	37 495
	60	0,63	13,68	8 622	8 611	3,08	38 200	38 016
	80	0,90	12,47	9 455	9 441	3,04	38 725	38 536
	100	1,19	11,47	10 287	10 270	3,00	39 250	39 058
	120	1,48	10,61	11 120	11 101	2,96	39 779	39 583
	140	1,79	9,87	11 950	11 929	2,92	40 309	40 109
	160	2,10	9,23	12 783	12 759	2,88	40 844	40 640
	180	2,42	8,66	13 614	13 588	2,85	41 381	41 172
	200	2,74	8,16	14 446	14 417	2,81	41 921	41 709

Table A.4 — 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 mm	Span m	Initial sag %	Factor of safety	Tension N	Horizontal load N	Factor of safety	Tension N	Horizontal load N
10	20	0,03	7,21	9 672	9 663	2,11	33 007	32 811
	40	0,12	6,85	10 177	10 167	2,09	33 368	33 171
	60	0,25	6,54	10 669	10 658	2,07	33 687	33 487
	80	0,40	6,25	11 165	11 153	2,05	33 999	33 797
	100	0,59	5,98	11 658	11 644	2,03	34 309	34 104
	120	0,79	5,74	12 150	12 135	2,01	34 619	34 411
	140	1,00	5,52	12 643	12 626	1,99	34 929	34 719
	160	1,23	5,31	13 135	13 117	1,98	35 241	35 028
	180	1,48	5,12	13 626	13 607	1,96	35 534	35 319
	200	1,73	4,94	14 118	14 098	1,94	35 852	35 634
11	20	0,04	8,63	9 776	9 767	2,42	34 818	34 632
	40	0,15	8,12	10 383	10 373	2,39	35 232	35 043
	60	0,31	7,68	10 981	10 969	2,36	35 615	35 423
	80	0,50	7,28	11 577	11 564	2,34	35 994	35 799
	100	0,70	6,93	12 174	12 158	2,32	36 337	36 139
	120	0,93	6,60	12 770	12 754	2,29	36 724	36 523
	140	1,17	6,31	13 365	13 346	2,27	37 109	36 905
	160	1,42	6,04	13 961	13 941	2,25	37 495	37 288
	180	1,69	5,79	14 555	14 534	2,22	37 881	37 672
	200	1,96	5,56	15 152	15 129	2,20	38 270	38 058

Table A.4 *(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	20	0,06	10,10	9 891	9 882	2,74	36 379	36 200
	40	0,20	9,42	10 606	10 595	2,70	36 951	36 769
	60	0,38	8,83	11 321	11 309	2,67	37 438	37 253
	80	0,59	8,31	12 031	12 016	2,63	37 906	37 717
	100	0,82	7,85	12 738	12 721	2,60	38 368	38 176
	120	1,07	7,43	13 447	13 429	2,57	38 830	38 635
	140	1,33	7,06	14 156	14 135	2,54	39 293	39 094
	160	1,60	6,72	14 864	14 842	2,51	39 756	39 555
	180	1,88	6,42	15 575	15 550	2,48	40 223	40 018
	200	2,17	6,14	16 283	16 256	2,45	40 690	40 482
13	20	0,08	11,79	10 006	9 996	3,09	38 102	37 930
	40	0,25	10,87	10 851	10 839	3,04	38 715	38 539
	60	0,45	10,09	11 690	11 676	3,00	39 274	39 095
	80	0,68	9,42	12 522	12 506	2,96	39 821	39 638
	100	0,93	8,83	13 354	13 336	2,92	40 367	40 180
	120	1,19	8,31	14 185	14 164	2,88	40 913	40 722
	140	1,47	7,85	15 017	14 994	2,84	41 462	41 267
	160	1,75	7,44	15 849	15 824	2,80	42 013	41 814
	180	2,05	7,07	16 680	16 652	2,77	42 566	42 363
	200	2,35	6,73	17 513	17 482	2,73	43 123	42 916
14	20	0,11	13,50	10 142	10 132	3,44	39 750	39 584
	40	0,30	12,31	11 120	11 108	3,38	40 423	40 253
	60	0,52	11,33	12 086	12 071	3,33	41 064	40 890
	80	0,77	10,49	13 052	13 035	3,28	41 701	41 523
	100	1,03	9,77	14 018	13 998	3,23	42 339	42 156
	120	1,31	9,14	14 983	14 960	3,18	42 979	42 792
	140	1,59	8,59	15 947	15 922	3,14	43 623	43 431
	160	1,89	8,10	16 911	16 883	3,09	44 269	44 073
	180	2,19	7,66	17 875	17 844	3,04	44 920	44 719
	200	2,50	7,27	18 841	18 806	3,00	45 574	45 369

Table A.5 — Cableway set up to achieve a sag of 2 % with a working load of 100 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
10	20	0,02	5,48	12 727	12 716	2,04	34 199	34 010
	40	0,08	5,27	13 236	13 224	2,01	34 578	34 387
	60	0,17	5,08	13 736	13 723	1,99	34 910	34 716
	80	0,29	4,90	14 230	14 215	1,98	35 233	35 037
	100	0,44	4,74	14 724	14 708	1,96	35 555	35 357
11	20	0,03	6,57	12 840	12 829	2,34	35 978	35 798
	40	0,10	6,27	13 444	13 431	2,31	36 411	36 228
	60	0,22	6,00	14 048	14 034	2,29	36 811	36 626
	80	0,36	5,76	14 645	14 629	2,26	37 203	37 015
	100	0,53	5,53	15 238	15 221	2,24	37 559	37 367
	120	0,72	5,32	15 836	15 817	2,22	37 961	37 767
	140	0,92	5,13	16 431	16 410	2,20	38 360	38 163
	160	1,14	4,95	17 026	17 004	2,17	38 760	38 560
	180	1,37	4,78	17 622	17 599	2,15	39 160	38 958
	200	1,61	4,63	18 220	18 194	2,13	39 562	39 357
12	20	0,04	7,72	12 946	12 935	2,65	37 681	37 508
	40	0,13	7,31	13 676	13 662	2,61	38 187	38 011
	60	0,27	6,95	14 385	14 370	2,59	38 598	38 418
	80	0,44	6,62	15 097	15 080	2,55	39 089	38 906
	100	0,63	6,32	15 806	15 787	2,52	39 570	39 384
	120	0,84	6,05	16 514	16 493	2,49	40 048	39 859
	140	1,07	5,80	17 223	17 200	2,46	40 526	40 334
	160	1,31	5,57	17 933	17 908	2,43	41 006	40 810
	180	1,56	5,36	18 641	18 614	2,41	41 486	41 287
	200	1,82	5,16	19 349	19 321	2,38	41 969	41 767
	220	2,09	4,98	20 058	20 027	2,35	42 453	42 248
	240	2,37	4,81	20 766	20 733	2,32	42 940	42 731
	260	2,65	4,65	21 476	21 441	2,30	43 430	43 218
	280	2,94	4,50	22 185	22 148	2,27	43 921	43 706
	300	3,24	4,36	22 896	22 857	2,25	44 415	44 197
	320	3,54	4,23	23 605	23 563	2,22	44 912	44 690
	340	3,84	4,11	24 311	24 268	2,20	45 395	45 171
	360	4,15	3,99	25 021	24 976	2,17	45 900	45 673
	380	4,47	3,88	25 726	25 679	2,15	46 404	46 174
	400	4,78	3,78	26 435	26 385	2,13	46 912	46 678

Table A.5 *(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
13	20	0,05	9,02	13 076	13 064	3,01	39 126	38 959
	40	0,17	8,47	13 922	13 908	2,96	39 823	39 652
	60	0,33	7,99	14 751	14 735	2,91	40 412	40 238
	80	0,52	7,56	15 589	15 571	2,87	40 985	40 807
	100	0,73	7,18	16 418	16 398	2,83	41 549	41 367
	120	0,97	6,83	17 252	17 229	2,80	42 114	41 929
	140	1,21	6,52	18 084	18 059	2,76	42 680	42 491
	160	1,47	6,23	18 917	18 890	2,72	43 248	43 055
	180	1,74	5,97	19 749	19 719	2,69	43 818	43 621
	200	2,02	5,73	20 579	20 547	2,65	44 390	44 190
	220	2,30	5,51	21 410	21 375	2,62	44 966	44 761
	240	2,59	5,30	22 243	22 206	2,59	45 545	45 337
	260	2,89	5,11	23 076	23 036	2,55	46 127	45 915
	280	3,19	4,93	23 906	23 864	2,52	46 710	46 495
	300	3,50	4,76	24 740	24 696	2,49	47 299	47 080
	320	3,81	4,61	25 572	25 525	2,46	47 875	47 652
	340	4,13	4,46	26 404	26 355	2,43	48 472	48 246
	360	4,45	4,33	27 233	27 181	2,40	49 070	48 840
	380	4,77	4,20	28 066	28 012	2,37	49 673	49 439
	400	5,10	4,08	28 900	28 843	2,34	50 278	50 041

Table A.5 *(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	20	0,06	10,37	13 204	13 192	3,36	40 762	40 600
	40	0,20	9,66	14 181	14 166	3,30	41 511	41 345
	60	0,39	9,04	15 151	15 134	3,24	42 186	42 016
	80	0,60	8,49	16 119	16 099	3,19	42 848	42 674
	100	0,83	8,01	17 083	17 061	3,14	43 506	43 327
	120	1,08	7,59	18 048	18 023	3,10	44 165	43 983
	140	1,35	7,20	19 013	18 985	3,05	44 827	44 640
	160	1,62	6,85	19 978	19 947	3,01	45 492	45 301
	180	1,90	6,54	20 944	20 911	2,96	46 161	45 966
	200	2,19	6,25	21 907	21 871	2,92	46 833	46 633
	220	2,49	5,98	22 871	22 832	2,88	47 508	47 304
	240	2,79	5,74	23 838	23 796	2,84	48 188	47 980
	260	3,10	5,52	24 802	24 757	2,80	48 872	48 659
	280	3,41	5,31	25 765	25 718	2,76	49 539	49 322
	300	3,73	5,12	26 731	26 680	2,72	50 233	50 013
	320	4,05	4,94	27 696	27 642	2,68	50 932	50 707
	340	4,38	4,78	28 659	28 602	2,65	51 632	51 403
	360	4,71	4,62	29 623	29 564	2,61	52 336	52 103
	380	5,04	4,47	30 592	30 530	2,58	53 046	52 809
	400	5,37	4,34	31 557	31 492	2,54	53 757	53 516

