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AERIAL ROPEWAYS AND CABLEWAYS

Monocable Ropeway Types & Performance Data—Bicable Ropeway Types and Performance Data—Ropeway Lengths and Speeds—Rope Sizes—Power Requirements—Passenger Ropeways—Comparison of Systems—Loading and Unloading—Automatic Ropeways—Sag Calculations—Cableway Systems—Cable Tension Calculations.

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(Consulting Editor: *International Ropeway Review*)

AERIAL ROPEWAYS

The aerial ropeway is a form of transport in which cars of a special type, also called carriers, suspended from overhead ropes, are employed for conveying materials, goods or passengers from one station to another. The ropes are of steel wire construction and they connect the stations in a straight line, although intermediate angle stations are possible. Along the route the ropes are supported by intermediate trestles, unless the ropeway is in one span, for instance crossing a deep valley. A ropeway car consists of a carriage and a container, the latter suspended from the carriage on a pivot by means of a hanger. There are various types of carriage, their design depending on the system of the ropeway of which they form part. Generally a carriage comprises a device for gripping the hauling (or haulage) rope, and wheels to run on the carrying (or track) rope. In the monocable system, one carrying-hauling rope only is used. The hanger is swan-neck shaped; this enables the car to pass trestles and station supports. The container may be in the form of a bucket, tray, passenger cabin etc. Buckets are usually designed for transport of materials in bulk, and may be of the tipping or bottom opening type.

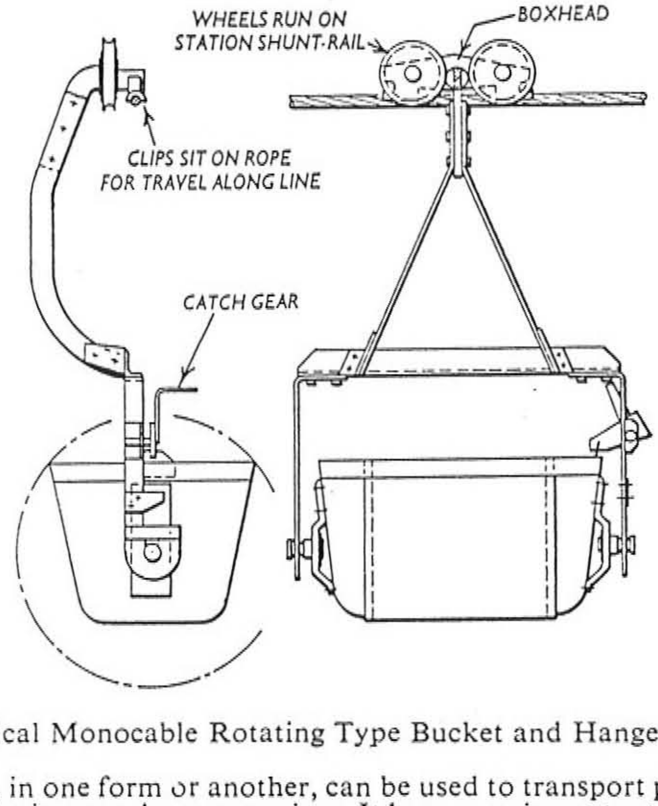

FIG. 1.—Typical Monocable Rotating Type Bucket and Hanger (*B.R.E.Co.*)

The aerial ropeway, in one form or another, can be used to transport passengers or anything that can be slung or put in a carrier or container. It has many important advantages over other means of transport, namely:—(*a*) It is not limited by adhesion between a wheel and a rail as in the case of railways, nor between rubber and road as in the case of road transport. It can therefore negotiate steeper gradients. (*b*) Being practically independent of territorial difficulties

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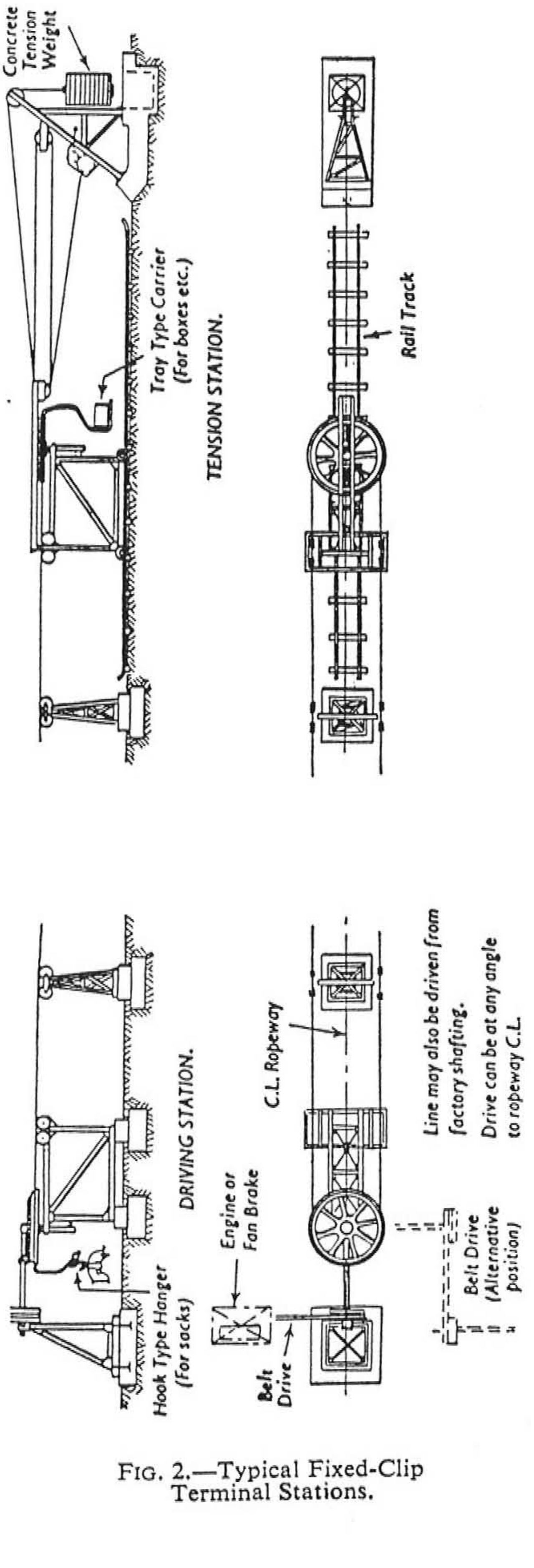


FIG. 2.—Typical Fixed-Clip Terminal Stations.

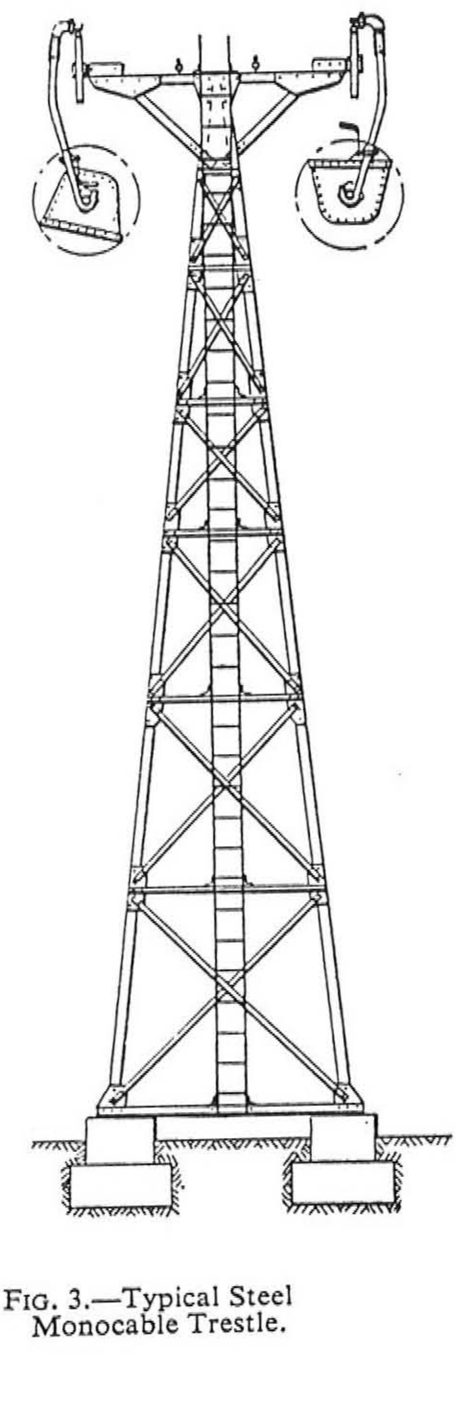


FIG. 3.—Typical Steel Monocable Trestle.

it can take the shortest route between terminals and not be concerned with those gradient problems or bridging worries which influence route selection for roads or railways. (*c*) It is not necessary to acquire the land over which a ropeway will be installed, although nominal wayleave rentals may be payable. (*d*) Visibility along the route is not a criterion for the operation of a ropeway. It can therefore operate efficiently in fog, rain or snow, or at night. (*e*) It is particularly advantageous in hilly, marshy or mountainous country since the installation cost is cheaper than for railways, road transport, or belt conveyors. (*f*) Power consumption for operating an aerial ropeway is less than for any alternative system handling the same duty over the same route.

Ropeway Length.—There is no limit to a ropeway length. This is because an aerial ropeway is composed of sections or units up to 6 miles (10 km) in length, each unit containing its own driving and tension gears. In other words, each section can be compared to an individual ropeway. These sections are connected by divide stations, where the ropeway cars are transferred automatically from one section to the next. The fact that a long ropeway is divided into sections, allows the route to be improved and difficult parts to be avoided by arranging intermediate divide stations as angle stations at no extra cost. It is also possible to provide intermediate loading and/or unloading stations for goods, and alighting or boarding stations for passengers.

The longest bicable ropeway is situated in Sweden and has a length of approx. 60 miles with a capacity of 50 tons per hour. The longest monocable ropeway is in Equatorial Africa and has a length of 48 miles with a capacity of over 200 tons per hour (1.5 millon tons/year).

Ropeway Classification:—This is generally related to the constructional systems employed, which are mainly monocable and bicable, and both can be of fixed clip and detachable grip types. Each of them can be of to-and-fro (jigback) variety, the simplest form of ropeway. These systems and types will be described in more detail and their characteristics analysed and compared.

MONOCABLE SYSTEM

The monocable system is based on the use of one single endless rope which supports and also hauls the load or loads. This rope is the "carrying-hauling rope", or just "the main rope". There are two main groups of monocable ropeways:— fixed clip ropeways, and detachable grip ropeways. The endless, continuously running rope is typical for both groups. This rope passes around a large diameter sheave at each end of the line, or section of the line in case of multi-section ropeways. One of these terminal sheaves is driven by suitable gearing. while the other responds to a floating counter-weight which maintains the tension on the rope. Alone the line the rope is supported on trestles or towers which carry pulleys on which the rope runs. The design of cars (carriers) is similar, generally, for both fixed clip and detachable grip ropeways. The individual differences and particulars of these two main groups and their variants are summarised as follows.

FIXED CLIP MONOCABLE ROPEWAYS.—The carriage of these ropeways is replaced by a clip, permanently fixing the rope to the hanger from which is suspended a carrier. There are three variations of such ropeways.

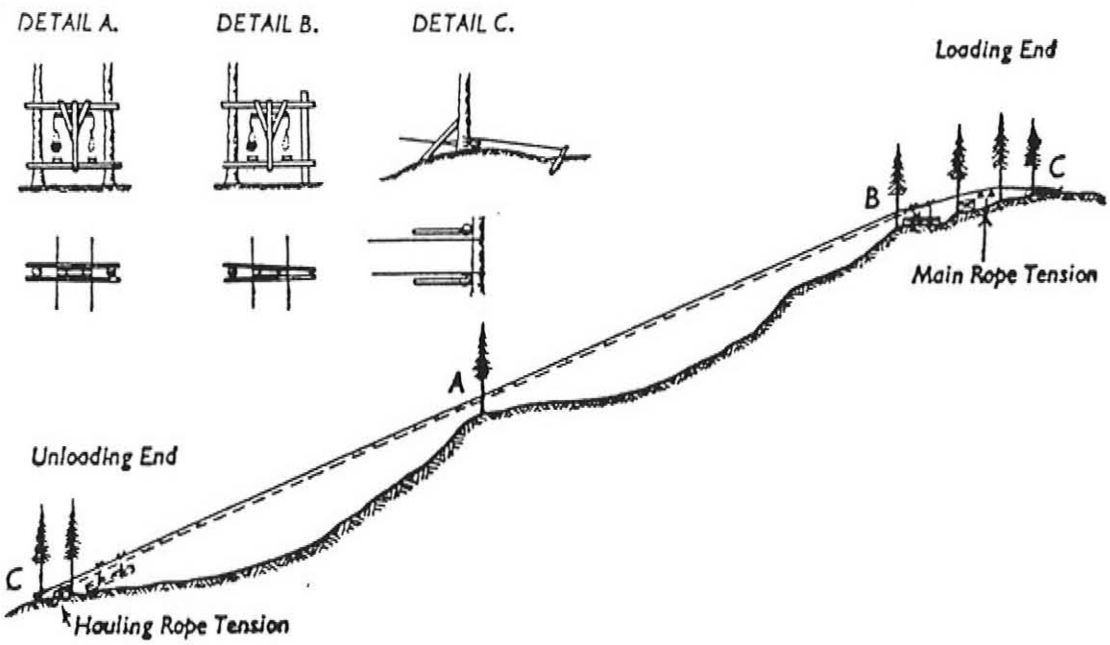


FIG. 4.—Diagram of Double Jig-back Ropeway.

To-and Fro ('Jigback').—This is called 'Reversible' in the USA and is one of the simplest types; a carrier travels forwards and backwards between the loading and unloading positions. Usually there are two cars, clipped to the endless rope. When one is at one terminal the other is at the opposite end terminal. The ropeway is stopped for loading and unloading. The capacity of such a plant is dependent upon the number of trips per hour that can be completed; the number of trips is in turn influenced by the distance the car has to travel. Installations of this type are normally limited to lines of a few hundred yards. Very steep gradients can be negotiated.

Continuously Running Types.—These are equipped with cars evenly spaced along the rope and permanently fixed to it. Here two alternative types are possible.—

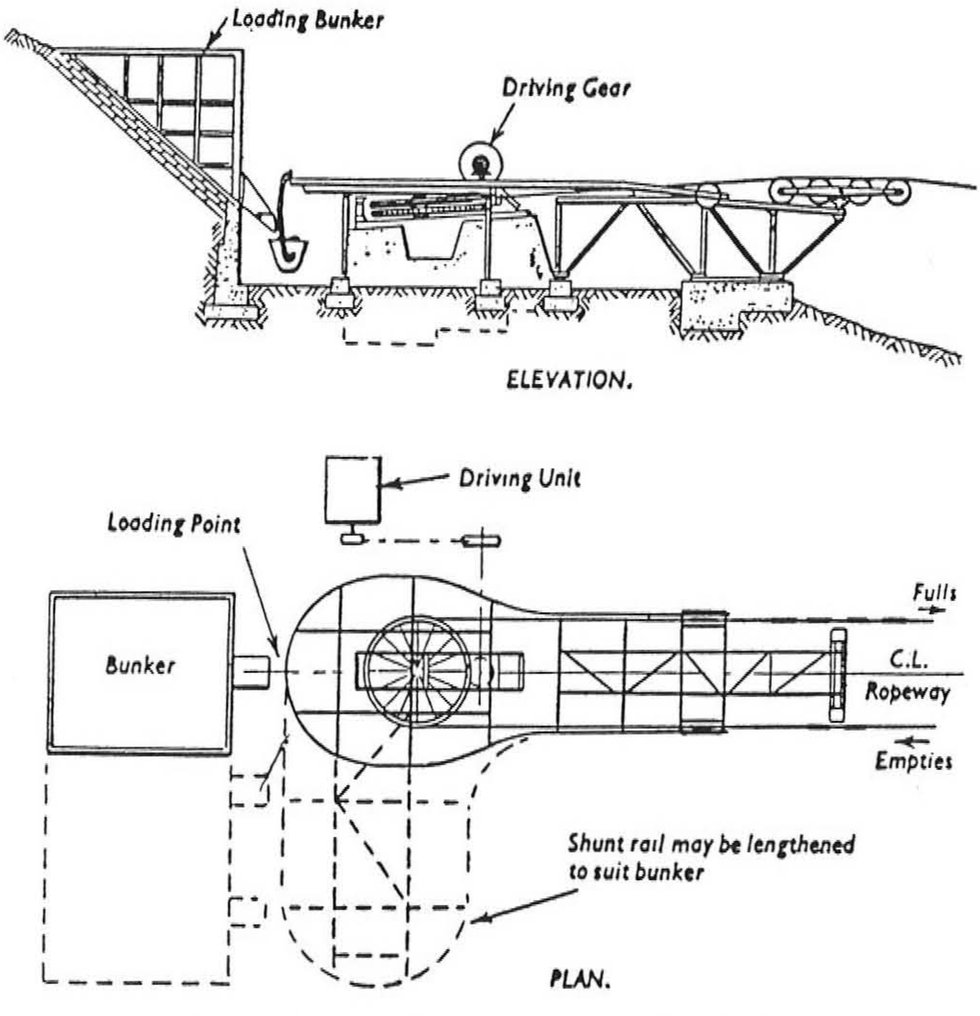


FIG. 5. Diagram of Monocable Loading Station.

Stop and Start System.—Here the rope is running for a few minutes, then stopped when a car arrives into the terminal station for loading and/or unloading. This system is extremely simple and cheap, but is only suitable for light units, easy to load or unload, such as sacks of tea, stems of bananas, etc. A typical example: 400 sacks per hour on a 45° slope. This system can be used for passenger transport.

Non-stop Running System.—With continuous running the rope must run at slow speed, say no more than 260 ft. (80 metres) per min. as passengers have to alight and board the car while the line is in motion; the same applies to loading and unloading the sacks etc. on industrial ropeways. The length of these lines is usually limited to 10,000 ft. (say 3 km), and up to 40-tons per hour.

DETACHABLE GRIP MONOCABLE ROPEWAYS.—These are built with a continuously running endless rope to which the carriages are locked automatically when leaving a station and unlocked automatically when entering a station. Inside the station the carriage, by means of its wheels (which are not used along the line), runs from the rope onto the station shunt rail, and proceeds to the loading or unloading position.

These ropeways can be divided into two groups:— (*a*) gripping type carriages of various designs with a line capacity of approximately 20 tons per hour (max.); and (*b*) the English system (BRECO), allowing 200-tons per hour or more, and characterised by an extremely simple "carriage" called a "boxhead"; this is provided with saddle clips, resembling an inverted

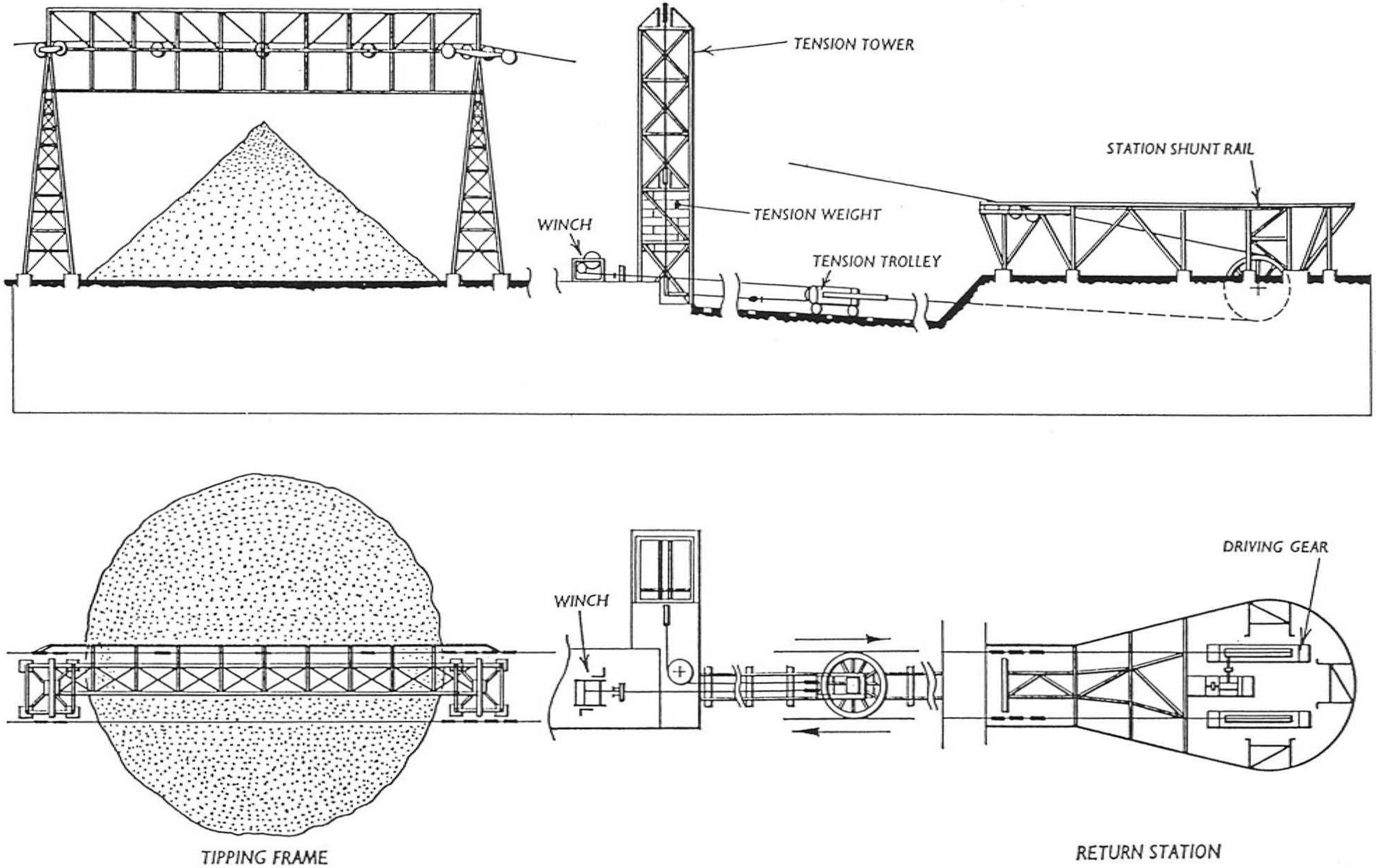


FIG. 6.—Diagram of Monocable Unloading Station, Driving Gear and Tension Tower.

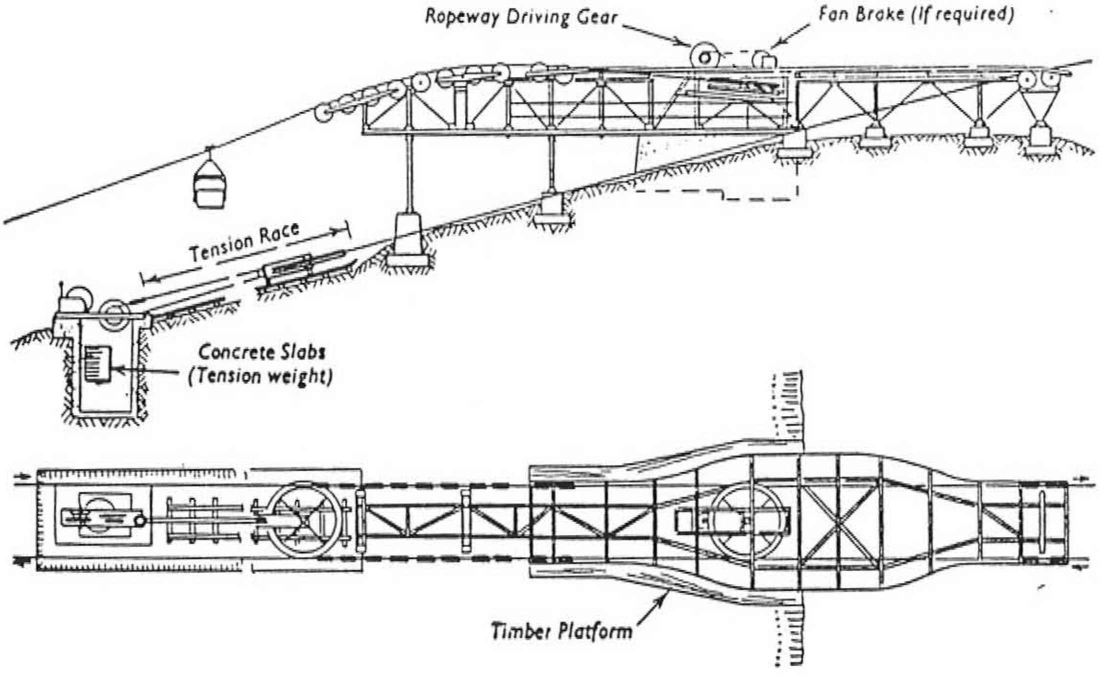


FIG. 7.—Typical Monocable Divide Station.

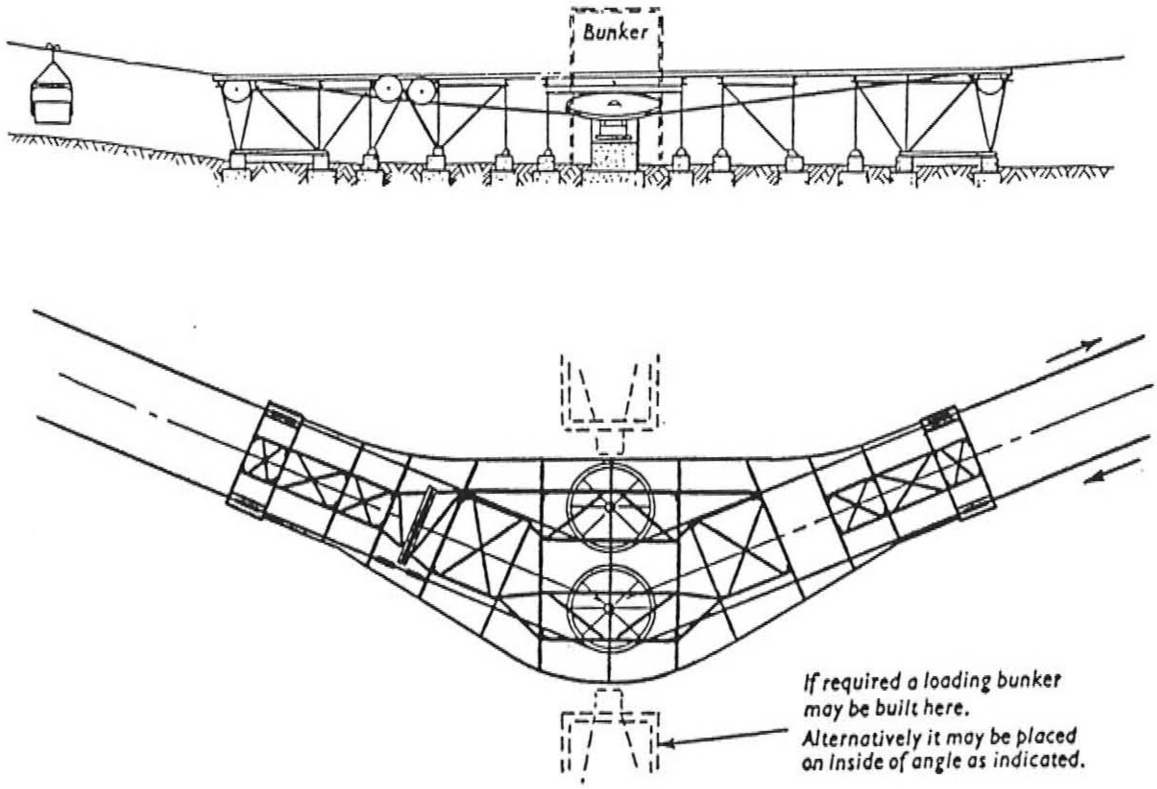


FIG. 8. —Monocable 'Through' Angle Station.

'U' which rest or "sit" on the rope; the boxhead also incorporates wheels, as described above. The limiting factor for this type is the gradient, which must not exceed 23° on the steepest slope anywhere along the line. On a steeper line, clips must be provided with projecting "pips" to ensure better grip of the rope, but this may be detrimental to the rope.

ROPEWAY CAPACITY AND INDIVIDUAL LOADS.—The capacity of a ropeway depends on the number of cars (carriers) sent out per hour, and the pay-load in each carrier. In other words, if a certain output per year is required, first it must be decided how many working days per year the ropeway could be in operation, and how many hours per day, or how many shifts per day. It is usual to take as a base 300 days per year at 8 hours per day = 2400 working hours per year. If, say, it is required to transport 480,000 tons per year with the possibility that output may be doubled, then the ropeway capacity required would be 200 tons per hour. A monocable ropeway would be recommended if the route is not too steep. The doubled output could be achieved by operating for 16 hours per day. If the line is too steep for a monocable line, or if the increase of output be expected, then a bicable ropeway would be considered: such a ropeway would be designed for 400 tons per hour, (960,000 tons/year). At the beginning the line would be equipped with only half the carriers required to handle 400 tons/hour and the line would give half of the above output, i.e., 480,000 tons/year, as in the initial proposal.

In practice the problem is more complicated as practical economic and technical aspects must be taken into consideration, keeping in mind that a monocable ropeway is approximately 40% cheaper than a bicable constructed in the same conditions for the same capacity. On the other hand, a twin monocable line with half capacity in each line may be found preferable to a single line, thus allowing for further flexibility of operation increasing the final capacity when required, carrying various materials at the same time, shutting one line and operating on the other for economy reasons, or, for maintenance. The same considerations apply to the transport of passengers.

A further factor to be taken into account is the method of loading. As 200 tons/hour is about the present limit for a monocable ropeway with mild steel buckets (if transport of material in bulk is considered) and 1-ton individual load per bucket is taken as practical limit for a certain type of ropeway, this would require an 18-second bucket interval (3600 seconds ÷ 200 loads). To load a bucket comfortably 20 to 30 seconds are required, but loading bunkers could be designed to fill two or three buckets at the same time, or an automatic rotating distributing hopper could be provided.

The following table gives examples of time intervals between specified individual loads for given ton/hour capacity of ropeway.

Capacity	Individual Load		Time Interval
ton/hour	cwt.	kg.	sec.
10	3	152	66
20	5	254	45
50	10	508	36
75	12	610	28·8
100	14	711	25
125	16	813	23
150	18	915	21·6
200	20	1016	18

ROPEWAY SPEED.—The practical speed limit is determined mainly by the difficulty of engaging the car with the continuously running rope at the loading end. Engagements should by synchronous, i.e. the clips should engage with the rope without violence, otherwise the projections will break the wires and ruin the rope. It is obvious that this decision becomes more important with heavy loads and for this reason the monocable rope gives better service on ropeways of heavy capacity but without gradients so that the clips can operate satisfactorily without the need for projections.

Increases in ropeway speed have resulted from:— (*a*) The introduction of rotating loaders. (*b*) Decelerating devices which reduce the speed of cars coming into stations. (*c*) Accelerating devices which increase the speed of outgoing cars; these prevent hammering of the rope by the boxhead clips when the car runs from the station rail on to the rope.

ROPE SIZES.—Two main factors influence the selection of rope size for any particular installation, the first is the bending stress in the rope due to the weight of the suspended carrier, and the second is the cumulative tension developed in the rope according to the characteristics of the profile of the line. Ordinarily, a size of individual load to be carried is selected to suit a given hourly capacity as already indicated above. This size of load would in turn suggest a least tension to be applied to the rope. (About 3 tons for a 3 cwt. load and ranging to about 10 tons for an 18 cwt. load). This in turn would indicate a rope size ranging from 2 in. circum. (= 0·637 in. dia.) to 4·25 in. circum. (= 1·375 in. dia.).

If an increase in rope size is found necessary in order to increase wire tension, it is advisable either to reduce the ratio between cumulative and least tensions, or to minimise the rope sag for particular spans, then it is usually economic to adjust the size of individual loads carried to suit. It will be seen that there can be no hard and fast rule regarding rope sizes and that investigation must be carried out before final decisions can be made.

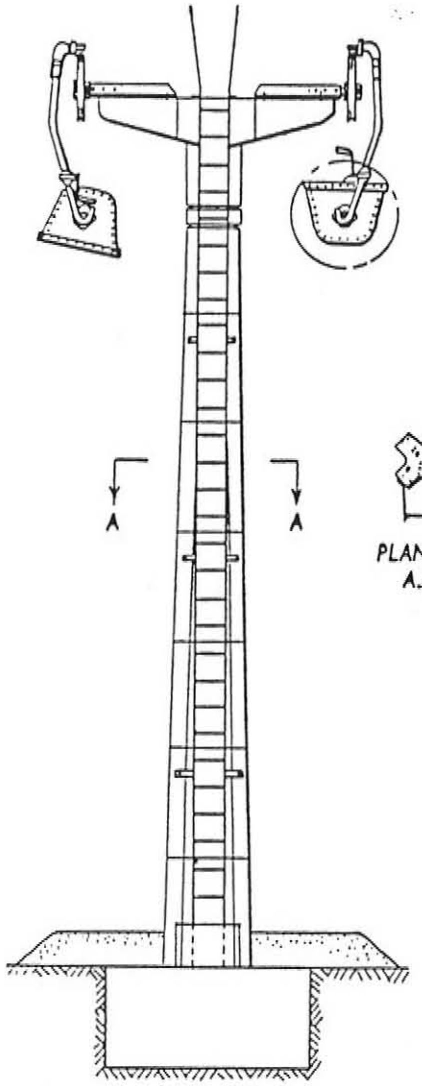


FIG. 9.—Concrete Trestle.

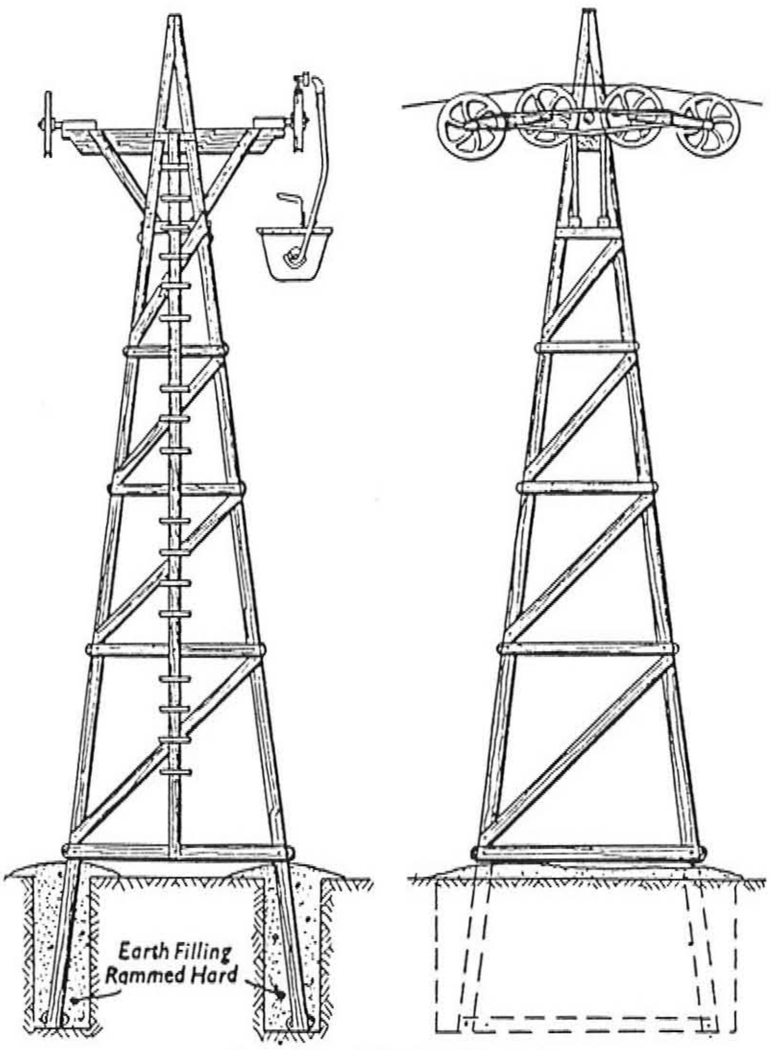


FIG. 10.—Timber Trestle.

HORSE-POWER—(MONOCABLE SYSTEM).—Exact power requirements can only be determined by careful investigation of any particular set of conditions. Such factors as the ratio of the carrier weight to the individual load, or the weight of the moving rope itself, influence the power needed to operate a line but generally the following data will be a close guide. The components to be considered are:—

(*a*) STATION FRICTION.—Frictional losses at the stations vary with layout and plant capacity. Usual range roughly from 2 h.p. to 5 h.p.

(*b*) GRAVITY.—Power involved in transferring material from one level to another is a function of vertical distance 'D' in yards and capacity 'C' in tons per hour. Roughly the horse-power equals:—$\pm$CD/300. (*Note*.—The answer is positive for material travelling uphill, and negative for material travelling downhill.)

(*c*) LINE FRICTION.—The frictional losses along the line due to movement of rope, loads and carriers, assuming ball bearing equipment varies with length of line 'L' (in yards) and capacity of plant 'C' (in tons per hour), and may be said to equal roughly:—CL/22,500.

d) GEARING LOSSES.—To include for the efficiency of the driving gear itself, a factor of from 10% to 25% is allowed on the sum of the above items. Thus for a plant conveying material uphill, the power required becomes $(a + b + c)$ plus say 20%. For a downhill plant it becomes $(+ a - b + c)$ minus 20% when the total is negative or plus 20% when the total is positive. A negative total indicates that the ropeway is self-running. Means must be provided to absorb the surplus power and maintain constant speed of line.

It will be noticed on comparing items (*b*) and (*c*) that for a plant conveying material downhill where the length of line is less than 75 times the fall between the terminals, it is probable that the line would be self-operating.

MONOCABLE PASSENGER ROPEWAYS.—One of the developments in the use of monocable ropeways is for the carrying of passengers and, in particular, for the transport of skiers to a skiing ground. Other types of ropeways have been employed but the monocable appears to overcome many difficulties which have hitherto attended aerial ropeway transport

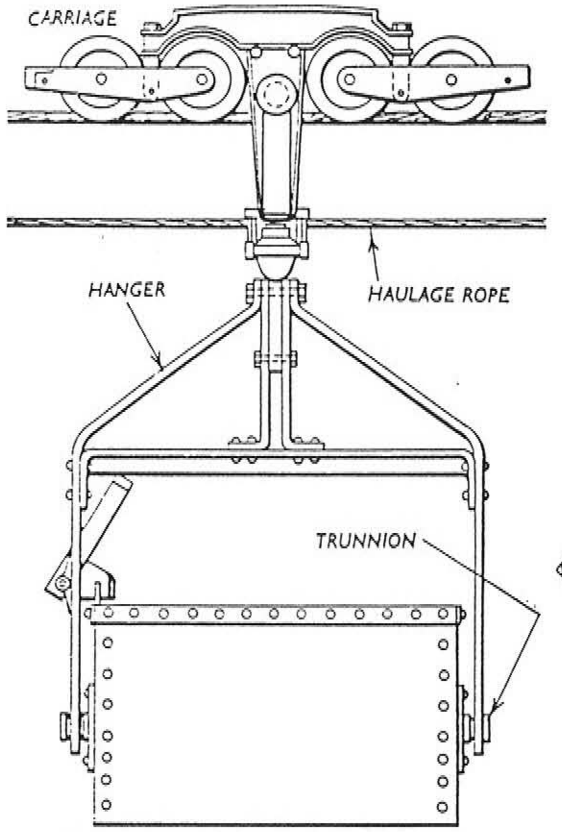


FIG. 11.—Typical 'Undertype' Bicable Car (Four-wheel).

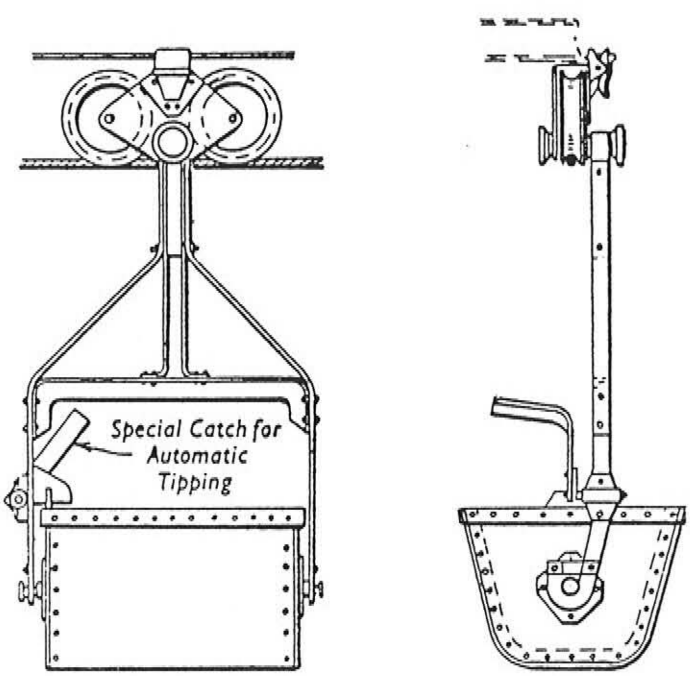


FIG. 12.—Typical 'Overtype' Bicable Car (Two-wheel).

for this purpose. Several grips of special design have been developed which enable the cars to be automatically detached from the rope at the stations to allow the safe mounting and dismounting of travellers. At least one of these grips is in operation on gradients exceeding 45° or 100%, but of course, the grip is expensive to manufacture in view of the great need for complete security. It will be realised that the additional gradient obtainable with this type of grip is even better than that obtained with a bicable grip. The ordinary monocable grip used for industrial purposes is limited to about 23°.

Monocable cabins hold up to six persons. Chairlifts are equipped with single or double seats. Cabinlifts may reach high capacities, such as 2,800 persons per hour in each direction with a twin installation, at Expo '67.

BICABLE SYSTEM

The bicable system is based on the use of two carrying (or "track") ropes and one endless continuously running hauling rope which can be compared to the monocable carrying-hauling rope. As the latter only hauls the cars, without supporting them, the diameter of this rope is smaller than in the case of monocable lines. The carrying ropes are parallel, one on each side of the trestles, and are supported by pivoting saddles fixed on to the trestle tops. One carrying rope is used for full cars, the other for empty cars, although both sides may be used for full cars, e.g. coal from a mine, and sand for back-filling, or other material in the opposite direction.

As in the case of monocable ropeways, there are two main groups of bicable ropeway:—(*a*) fixed clip ropeways, and (*b*) detachable grip ropeways. The first are very similar to those described for monocables and their capacities and applications are similarly limited, although the to-and-fro types have been developed to take cabins carrying 120 passengers. Bicable ropeways of the detachable grip type, allow for heavy traffic, up to 500 tons per hour on a single line, or double this figure on a twin line. These will be dealt with here.

The bicable car comprises the same three main components as the monocable car, but the carriage is more complicated; in particular the automatic gripping device. As a bicable line may take pay-loads reaching 5-tons, the whole carriage and its wheels must be of stronger construction. These wheels run on the rope along the line, and over pivoting steel saddles located on the trestle tops. The incoming car is automatically unlocked when entering a station, it runs on the station shunt rail, as in the case of the monocable system. Also as in the monocable system, the hauling rope passes around large diameter sheaves at each terminal station, and is driven at one end and tensioned at the opposite end.

LOAD CAPACITIES (BICABLE).—The considerations which govern the selection of loads on the monocable system apply equally to the bicable system, but greater freedom exists because the carrying rope can be varied in size to suit the load independent of the capacity.

As the bicable car is much more expensive than the monocable boxhead, the loads are increased so that for the same capacity the number of cars required is fewer. A typical selection of loads and capacities would be:—

Capacity	Individual Load		Time Interval
ton/hour	cwt.	kg	seconds
25	7	355	50·4
50	12	610	43·2
75	15	762	36
100	18	915	32·4
150	21	1066	25·2
200	25	1270	22·5
250	30	1524	21·6
300	32·5	1650	19·5
500	35	1778	12·6

This table can be varied in many ways and economical selection may change according to the different costs of ropes and cars. (Depending on the commodity to be carried so the type of car may vary, also its weight and relative cost). In certain cases the size of individual load is

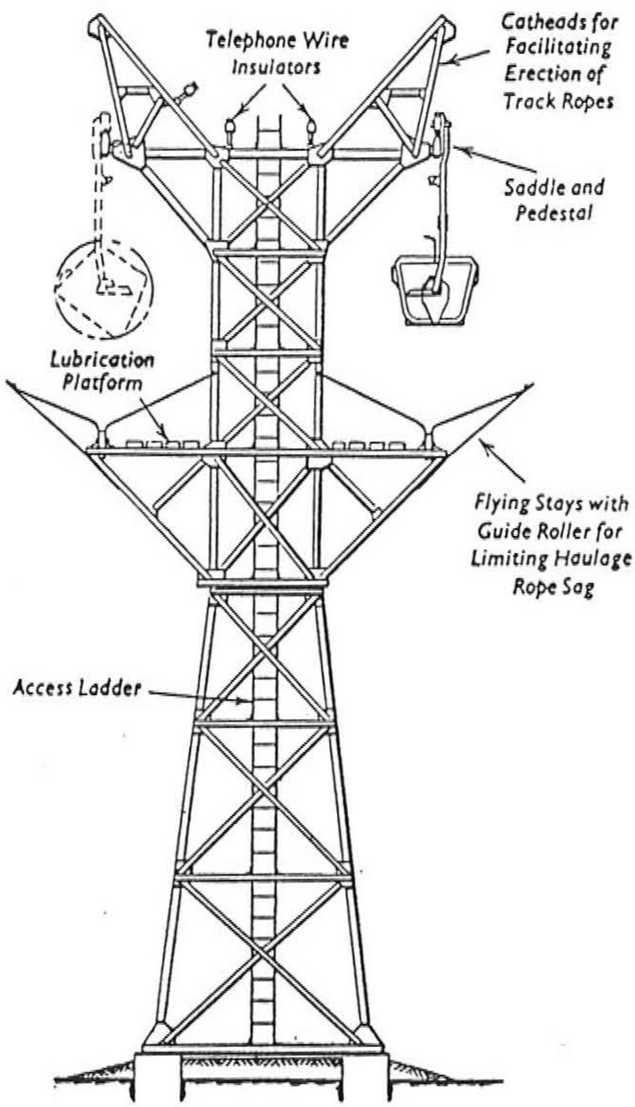


FIG. 13.—Typical Bicable Steel Trestle.

automatically settled by the purpose of the plant and may therefore bear no arbitrary relationship to the capacity. For example a logging ropeway may have a capacity of only five ton per hour and have to carry logs weighing over one ton each.

Speed of Line.—As with the monocable ropeway, the speed at which the line is to run, will considerably influence the initial cost of the plant. However, the factors to be taken into account in settling a speed are different. If there are angle stations along the line, and it is required that they shall be automatic in action, then the speed of the plant must be kept down regardless of the capacity the ropeway must carry. Similarly, where an elevated terminal station is required to be automatic in action, it may be more economic to run the line slowly than to run quickly with additional equipment for controlling the cars round the terminal. For these cases, the line speed would probably range between 250 and 300 ft. per min.

The wheels of the car which carry the load on the station shunt rails also run on the track or carrying) or supporting ropes.

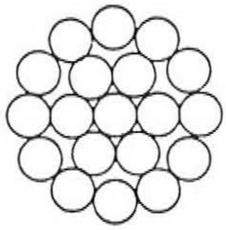
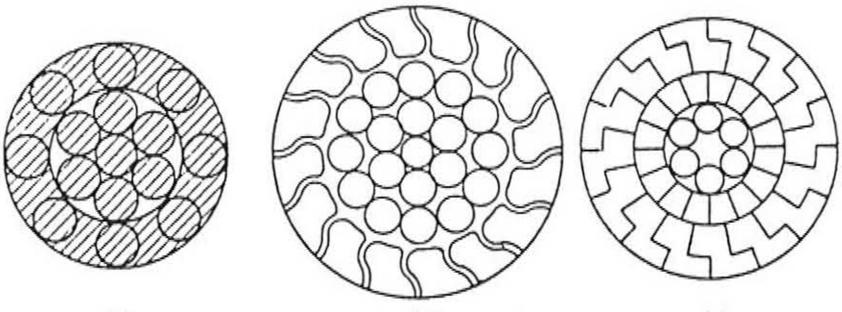


FIG. 14.—Typical Spiral Track Rope.



(a) (b) (c)

FIG. 15.—Typical Locked-Coil-construction Track Rope.

The track ropes can be of spiral construction (Fig. 14) for lines of moderate capacity but for heavier capacities it is preferable to use ropes of locked-coil construction. (Fig. 15 *a*, *b*, *c*).

Ropes of this latter type are much more expensive but they have the advantage of providing a better surface for wear, and if a wire should break, it cannot protrude from the texture of the rope and obstruct the passage of the cars.

Long lengths of track rope are connected by taper couplings, where the ends of the rope are opened out in a conical chamber and secured by wedges or by white metal. (Fig. 16.)

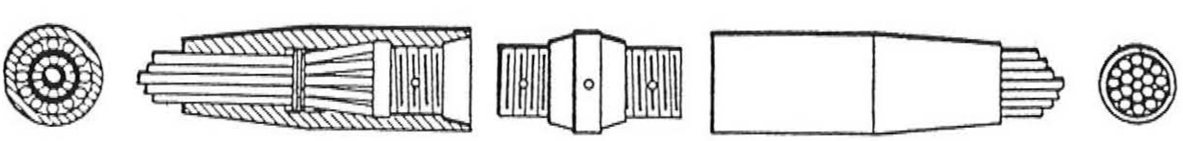


FIG. 16.—Typical Track Rope Line Coupling.

At the points where the ropes are anchored and where they are tensioned, they are socketed in a similar manner (Fig. 17). The cost of these track ropes is considerable and they should be well looked after. From the time of their delivery to the site, they should be well greased, for if surface corrosion is once allowed to set in, it will lead to cracks in the surface, which will eventually cause broken wires.

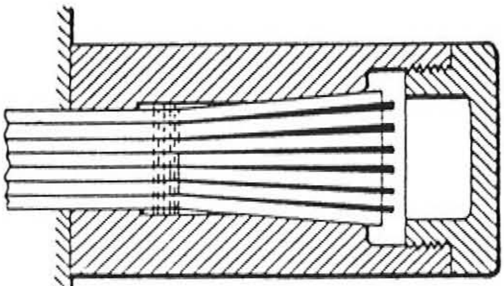


FIG. 17.—Typical Track Rope End

Whilst monocable track ropes can conveniently be oiled and inspected as they pass through one of the stations, it is necessary for a bicable track rope to be oiled from a special oiling car which drips the oil on to the rope and spreads it by means of a brush. For inspection of the rope a man must travel along the line in a bucket, or in a special inspection car. It is usual on long lines to arrange for the line to be driven at a slow speed while inspection is taking place. Oiling should be done about once a month and rope inspection about once a fortnight.

The tension in these track ropes is great and they require a massive tension gear. A box constructed of steel sections is filled with concrete blocks, which are easily handled and which provide a convenient means of adjustment of the weight. Attached to this weight is a flexible rope which passes over deflection sheaves to a position inside the station where it is coupled to the track rope.

HAULING ROPE.—The hauling rope is normally of round strand 6/7 Langs Lay construction, with a hemp or fibre core. This construction gives sufficient flexibility for passing round the driving and tension sheaves, and the various deflection sheaves and rollers, and it also gives a good area for wear on the outer wires. When the hauling rope is gripped to the carriages at regular intervals it moves along parallel to the track rope but when there are no carriages at some sections of the line, it falls down into rollers fixed on the trestles, and is thus prevented from trailing on the ground, or on the trestle steelwork.

The carriages used on a bicable ropeway are provided with two or more wheels according to the weight of the load.

The hauling rope is attached to the carriage by a gripping mechanism which is generally applied by the weight of the load, so that the pressure on the rope is greater with a full load than with an empty bucket. Some makers, however, use a screw grip. In either case, where it is necessary to remove the bucket from the line for loading or unloading, the rope has to be freed from the grip at the unlocking frames and re-engaged at locking frames arranged at the station.

In one simple form of carriage the hauling rope is situated above the track rope. This type is suitable for passing round angle stations, but is best adapted to fairly level lines. More often, the hauling rope is placed below the track rope.

Some carriages of this type are adaptable to all conditions. They are able to pass through angle stations while gripped to the rope, they can climb steep gradients; and can pass over pressure frames or groups of trestles situated at peaks on the line. These universal carriages are somewhat expensive; and when the site conditions are not severe, simpler and cheaper types can be used. The track ropes are supported on saddles carried on trestles at points chosen to suit the configuration of the ground.

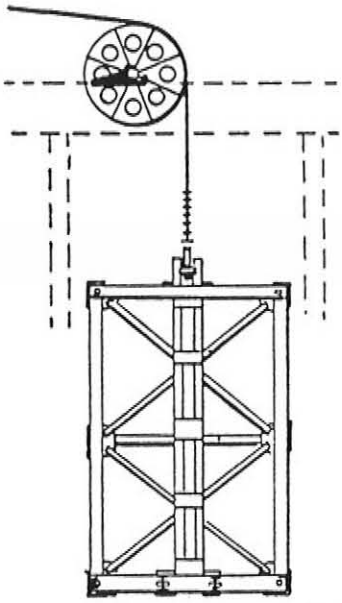


FIG. 18.—Typical Track Rope Tension Gear.

On ordinary transport ropeways the average track rope tension should be between 60 and 70 times the wheel load applied to it. This wheel load is obtained by taking an individual carrier and determining the total load it transmits vertically to the track rope, as follows:—

Full Side. (*a*) Weight of carriage.
(*b*) Weight of hanger.
(*c*) Weight of container.
d) Weight of haulage rope, supported by carriage.
(*e*) Weight of load carried.
TOTAL (Fulls)

Empty Side. (*a*) Weight of carriage.
(*b*) Weight of hanger.
(*c*) Weight of container.
(*d*) Weight of haulage rope, supported by carriage.
(*e*) Nil.
TOTAL (Empties)

The total in each case should be divided by the number of running wheels with which each carriage is equipped (Usually two or four). Having then determined a reasonable working tension, this is multiplied by an average factor of safety (usually about 4) and so obtain break in load for each track rope. Reference to a maker's list will enable the selection of suitable track rope sizes to satisfy the requirements. The rope should be of spiral, or locked coil construction. Spiral ropes are cheaper than locked coil ropes but are generally adopted only on plants equipped with light loads or with loads operating at long time intervals. Selection of a haulage rope is a involved process needing investigations into cumulative tensions and horse-powers.

Rope Life.—As with the monocable system, rope lifes are influenced by the profile of the ropeway alignment and of course, by the degree of maintenance given; however, bicable track ropes should carry three times the tonnage of a monocable rope before replacement is necessary. The haulage rope, which is by far the least expensive rope item, would be expected to haul one million tons before replacement.

LENGTH OF BICABLE ROPEWAY.—There is no limit to the length which can be constructed, but, as with the monocable system, it would be composed of a number of units, linked together Cars would run straight through from one unit to the next. The greatest capacity carried on a single bicable ropeway is 500 long tons per hr., but this is by no means the limit of its capabilities. Much higher capacities, even up to 1000 tons per hour, can be transported by appropriate design.

Operating Costs.—Operating costs for a bicable ropeway are usually more favourable than for a monocable where both plants are arranged with non-automatic terminals. Where a bicable is equipped with an automatic station, then of course, operating costs are even more favourable.

HORSE-POWER (BICABLE SYSTEM).—Horse-power calculations are generally similar to those for the monocable system. Characteristics of the plant will influence the power requirements. The following data will give a close guide for average plants:—(*a*) Station friction allow 2 h.p. to 5 h.p.; (*b*) Gravity approx. $\pm$CD/300; (*c*) Line friction (for ball bearing lines) approx. CL/15,000; (*d*) Gearing efficiency, allow $\pm 20\%$ $(a \pm b + C)$.

The positive sign is used when material is conveyed uphill and the negative sign when material is conveyed downhill. The sum of (*a*), (*b*), (*c*) and (*d*) gives the ultimate power required. It will be seen that where the length of line is less than 50 times the difference in level of the terminals and where traffic is downhill, the final answer will be negative. This means that the line would develop power, and would therefore be self-running.

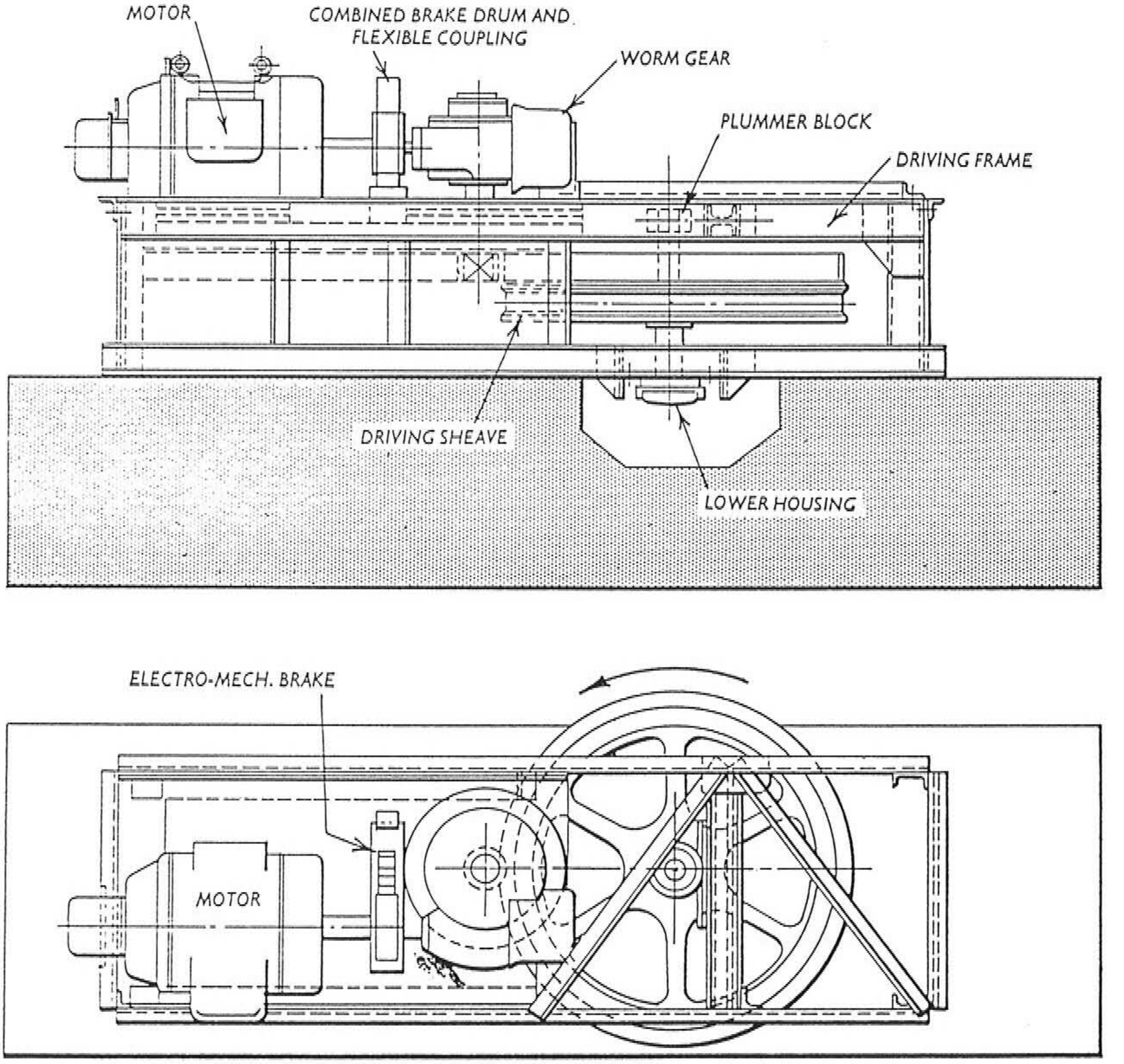


FIG. 19.—Typical Bicable Driving & Braking Gear (*B.R.E.Co.*).

BICABLE PASSENGER ROPEWAYS.—Large passenger ropeways with cabins taking up to 120 passengers are operated on the to-and-fro bicable system, usually over large spans in high mountains. Special security systems must be incorporated to ensure passenger safety. These usually include the duplication of carrying ropes and hauling rope, in some cases the provision of a special brake rope, and even a separate rope for the rescue cabin. Carriages, with twelve or even more wheels, are of extremely strong construction and an emergency stand-by motor is provided to ensure power supply in case of mains failure. Each cabin is provided with its own brake, and is in telephone communication with terminal stations. Speeds of up to 1400 ft. (420 m.) per minute are normal practice.

Smaller cabins, holding up to 30 passengers, operating on bicable system, fixed clip or detachable grip type, with additional carrying ropes, are also in existence.

COMPARISON OF ROPEWAY SYSTEMS:—Each ropeway is specially designed and built to provide a particular service. This means that capital charges (interest and amortisation as well as running costs (operation and maintenance), play an important part in the choice of the more suitable system. Capacities and loads of both monocable and bicable types have been detailed in earlier paragraphs.

In such cases, for instance, as the construction of a dam, or working a limited ore field, the first cost may be the deciding factor, as the recovery value of a ropeway in a remote region is not easy to ascertain. In deciding on the system most suited to a particular transport problem, the experienced ropeway engineer must take into consideration not only the many and often difficult technical features involved, but also the economic factors.

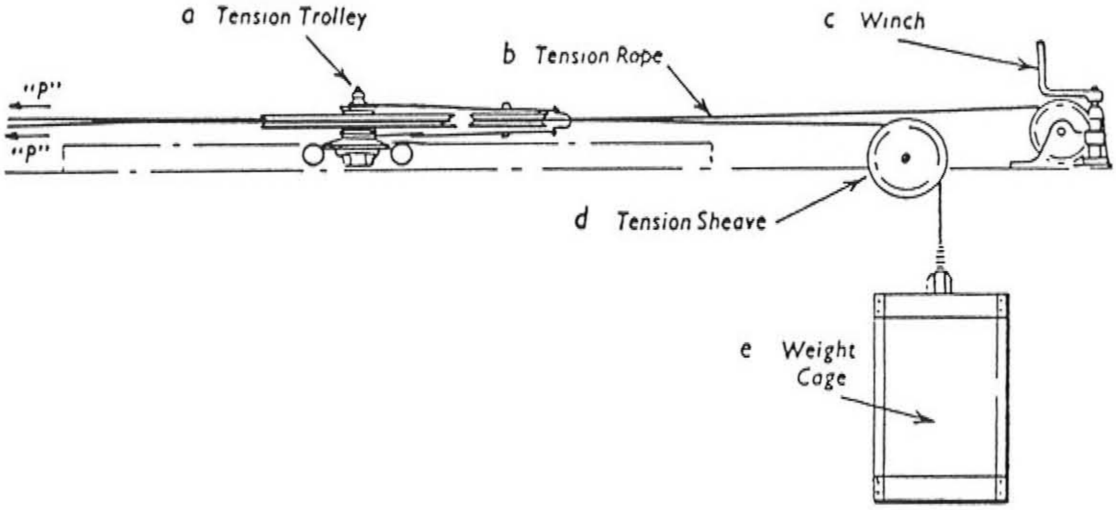


FIG. 20. Typical Bicable Hauling Rope Tension Gear.

SAG CALCULATIONS.—When preparing profile drawings for a ropeway indicating trestle positions and heights, it is customary to draw a rope curve between trestle mounts. This curve is a radial line roughly representing the path taken by the cars as they travel along the line. Use of the curve provides a ready check for clearances over the ground, over roads, buildings, etc.

Sag calculations are taken for the mid-point in the span. The span is measured horizontally and the sag vertically, regardless of the relative levels of the trestle tops.

The number of carriers that can be in a span at one time, influence the calculations, as sometimes the concentrated load formula is applicable and sometimes the distributed load formula, thus:—

Where two or less carriers may appear in the span.	Where more than two carriers will be in the span.
Rope sag $= wS^2/7T$ Load sag $= WS/4T$	Distributed sag $= RS^2/7T$

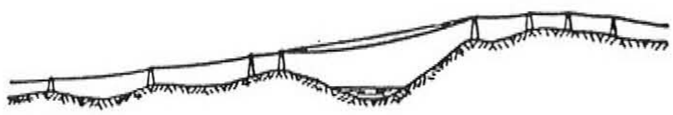


FIG. 21.—Typical Section of Profile.

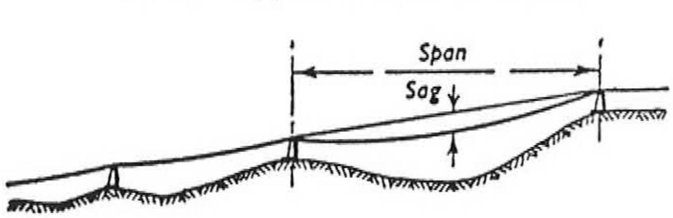


FIG. 22.—Sag Diagram.

where, S = Horizontal span between trestles;
T = Rope tension in lb.;
w = Rope weight in lb. per yard;
W = Weight of complete car (and load) as supported by the rope (lb.);
R = Average weight rate in lb. per yard of ropes and carriers. (Carrier weight rate equals total weight of car (and load) divided by the car spacing).

Note.—It will be appreciated that the sag calculated will be in yards but that other units could be adopted throughout in which case the answer would be in relevant units.

STRUCTURES.—Normally the structural work for the stations and trestles is fabricated from standard mild steel sections, but where timber is plentiful the structures may be economically constructed on site from that material. In some cases, mass concrete, or reinforced concrete structures are adopted. They may form part or the whole of the structural work but usually will be more expensive than the equivalent steel or timber structures. Where the ropeway is built for a cement works or a gravel pit, concrete structures will be economic as the cost of materials and transport will be reduced and local labour would be employed.

METHODS OF LOADING MONOCABLE AND BICABLE.—Incoming cars upon arrival at a loading station will run freely on a rigid rail and automatically become disengaged from the moving rope. The loading operation may therefore be carried out before the car reaches the exit side of the station and departs on its journey along the line. The method of loading will depend upon the material being conveyed.

(*a*) Shoot Loading.—Bulk materials, such as coal, limestone, sand etc., which will flow freely, would be delivered to ropeway buckets through shoots attached to a storage bunker. The shoots would be fitted with hand or power-operated gates for controlling the flow of material and would be correctly related in position to the ropeway station to allow buckets to be filled while the cars are at rest momentarily on the shunt rail.

(*b*) Transfer Loading.—Where a ropeway is being served by a clay pit or quarry, the constantly moving working face requires a flexible link between it and the Ropeway. Bunkers are not practical, particularly if the material is wet or sticky, and therefore it becomes expedient to deliver the materials as dug, directly into the ropeway buckets. The ropeway buckets are therefore removed from the ropeway carriers after reaching the loading terminal, and are trammed on bogies running on decauville tracks, up to the working face. After being filled, they are trammed back to the loading station for re-engagement with the ropeway carriers. A flow of buckets is kept circulating between the working face and the ropeway terminal. A transfer mechanism is usually employed for removing an empty bucket from a hanger on to a bogie and for speedily putting a full bucket from a bogie, back on to the hanger, in order to re-equip it, and to enable the complete car to depart within its allotted time cycle.

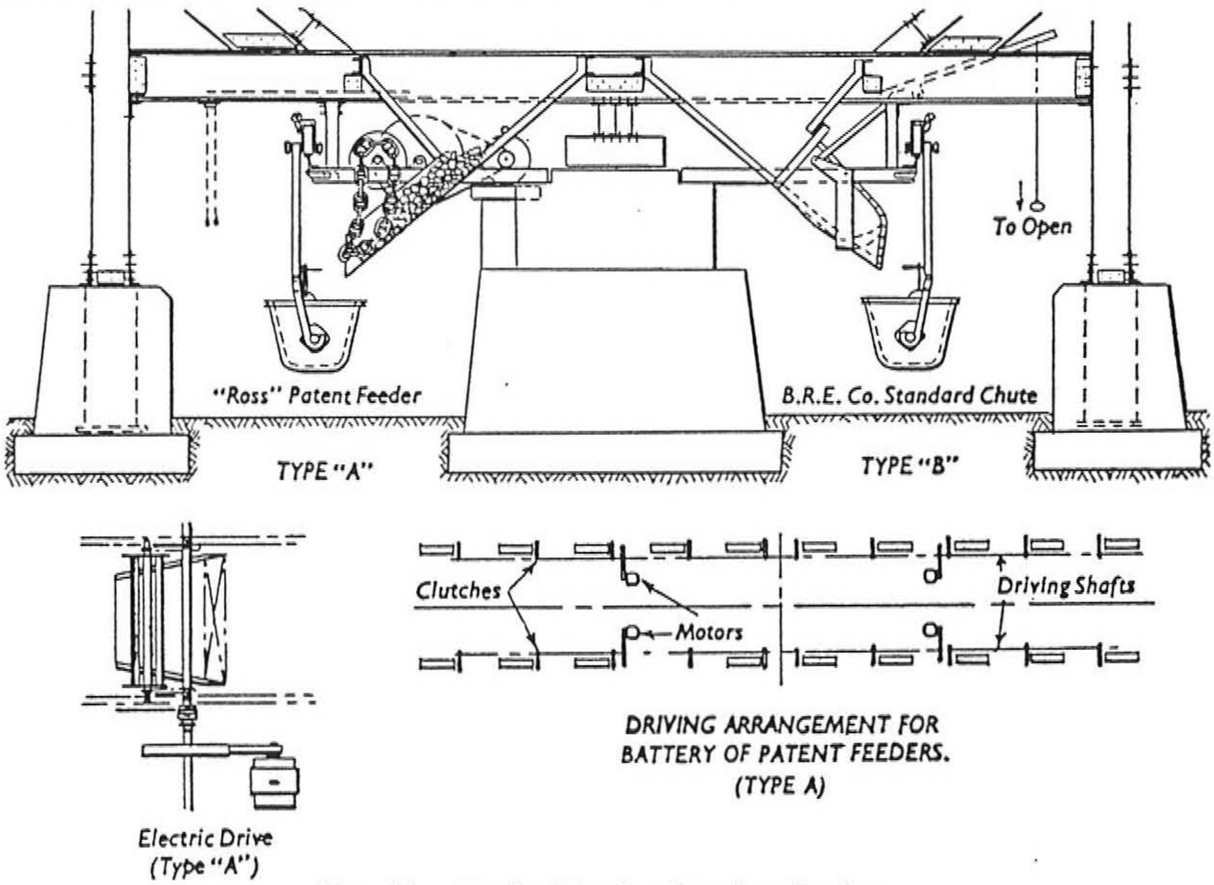


FIG. 23.—Typical Bucket Loading Station.

(*c*) Unit Loading.—Where the ropeway is carrying particular loads such as heavy tree trunks, sacks of tea, packed goods etc., special loading arrangements are employed. These may be entirely manual or may be power assisted. Long tree trunks, lengths of pipe, bundles of planks etc., are usually carried by twin carriers with slings. Chain blocks are frequently incorporated with the carriers for enabling the load to be raised clear of the ground or delivery ramp. Sacks packed goods etc., are usually carried on tray or platform carriers. They are brought to rest with the tray adjacent to and level with the edge of the loading bay floor on which the loads are waiting. The loads can then be slid on to a ropeway carrier without the effort of lifting.

METHODS OF UNLOADING.—Unloading is usually automatic, by means of a trip lever placed at the required position over a bunker or pile; the trip lever acts on the bucket catch lever and causes the contents to be tipped or emptied.

One of the more elaborate applications is a shiploading plant. This is employed where conditions do not allow a vessel to come alongside a wharf. In such cases it is advantageous to build a sea terminal on a caisson fixed on to the sea bed at a certain distance from the shore, so that vessels may anchor for loading or unloading. An aerial ropeway connects the shore with this sea terminal; thus demurrage, harbour duties etc. are reduced. This solution is also useful in view of the overcrowding of ports.

LABOUR-SAVING DEVICES.—The demand for greater ropeway capacities and also the need for a greater degree of automatic running, has led to improvements in ropeway designs and to the introduction of auxiliary equipment for eliminating operative labour.

(*a*) Auxiliary Haulages.—Auxiliary haulages have been perfected for ensuring the continued movement of cars round the free shunt rail of the stations. The haulage may be by rope or chain and operates at a slow speed. At loading stations the cars will automatically disengage and come to rest at a pre-selected loading position. After loading, re-engagement with the auxiliary haulage will take place and the car will proceed to the exit side of the station.

(*b*) Automatic Spacing Gear.—To handle a given capacity a ropeway carries a certain size of load every so many seconds. This time interval should be maintained carefully for smooth running and maximum rope life. Normally, the cars are despatched by hand against a visual or audible signal. Automatic spacers have been produced to receive a car or cars and to despatch them one at a time at predetermined time intervals. This ensures accuracy and eliminates labour.

(*c*) Automatic Bucket Loading.—Various manufacturers have produced their own solutions of the problem of loading buckets automatically. Some treatments are partially automatic and some completely automatic. The devices include power-operated shoot gates; balanced hoppers which pre-weigh a correct bucket load and discharge it automatically when a bucket arrives; rotary or rocking valves which measure by volume correct bucket loads and discharge them to the buckets as they arrive; a revolving hopper divided into compartments each with a shoot, and rotating at such a speed that passing buckets are in contact with a shoot long enough to receive their correct capacity; electrically interlocked feeders which are set in operation by arrival of a bucket and switched off when bucket is full as indicated either by a weigh-rail or a time switch.

(*d*) Self-Righting Buckets.—Where the material being transported by the ropeway is suitable for carrying in skips or buckets, the bucket employed is usually of the rotating type mounted on trunnions set below the centre of gravity. Release of a catch will therefore allow the bucket to discharge its contents, but before reloading, the bucket must be righted. This act is usually done by hand, but automatic devices have been produced.

Where the nature of the material allows a clean emptying of the bucket, it is possible to so balance the bucket in relation to its trunnion position that it will self-right when empty, but will be top heavy when loaded. Where clean emptying of the bucket is not assured, attachments to the bucket will engage with a 'scroll' upon entering a station. The scroll will cause the bucket to rotate to its upright position. Automatic latching can then be effected. Where the material is of a particularly sticky nature, fixed buckets with bottom-opening doors are usually employed. Ramps can then be employed for guiding the doors to their closed position, or alternatively, the doors may be linked and counterbalanced so that they are self-closing after the material has been discharged.

Suspension Railways.—These are a variant of a bicable ropeway in which the carrying rope is replaced by a rail, curved as required and supported from roof or wall to save ground space, Capacities, for passengers or freight, of up to 1,000 tons per hour are possible.

AUTOMATIC ROPEWAYS.—Automatic ropeways are increasingly being introduced. In this country the first fully automatic ropeway was installed in 1953 at Wyllie Colliery, South Wales. This ropeway was described in '*International Ropeway Review*, Oct.-Dec. 1963.

On the Continent automation has been introduced to the operation of passenger ropeways. The advantages are the reduction of labour costs and the avoidance of human error. On the other hand, automatic installations are more expensive to install and maintenance is more costly.

CABLEWAYS

A cableway is a machine having operating motions similar to a transporter crane but with an extended range outside the economic limits of normal crane design. The main essentials required to form a cableway comprise the following:—(1) One main track cable. (2) Means of supporting the track cable at either end at a suitable height. (3) One load carriage complete with lifting blocks. (4) One double drum winch complete with operating ropes for travelling the load carriage in either direction and hoisting and lowering the suspended load.

Fig. 24 shows typical cableway of the fixed type, and also a typical cableway of the travelling type.

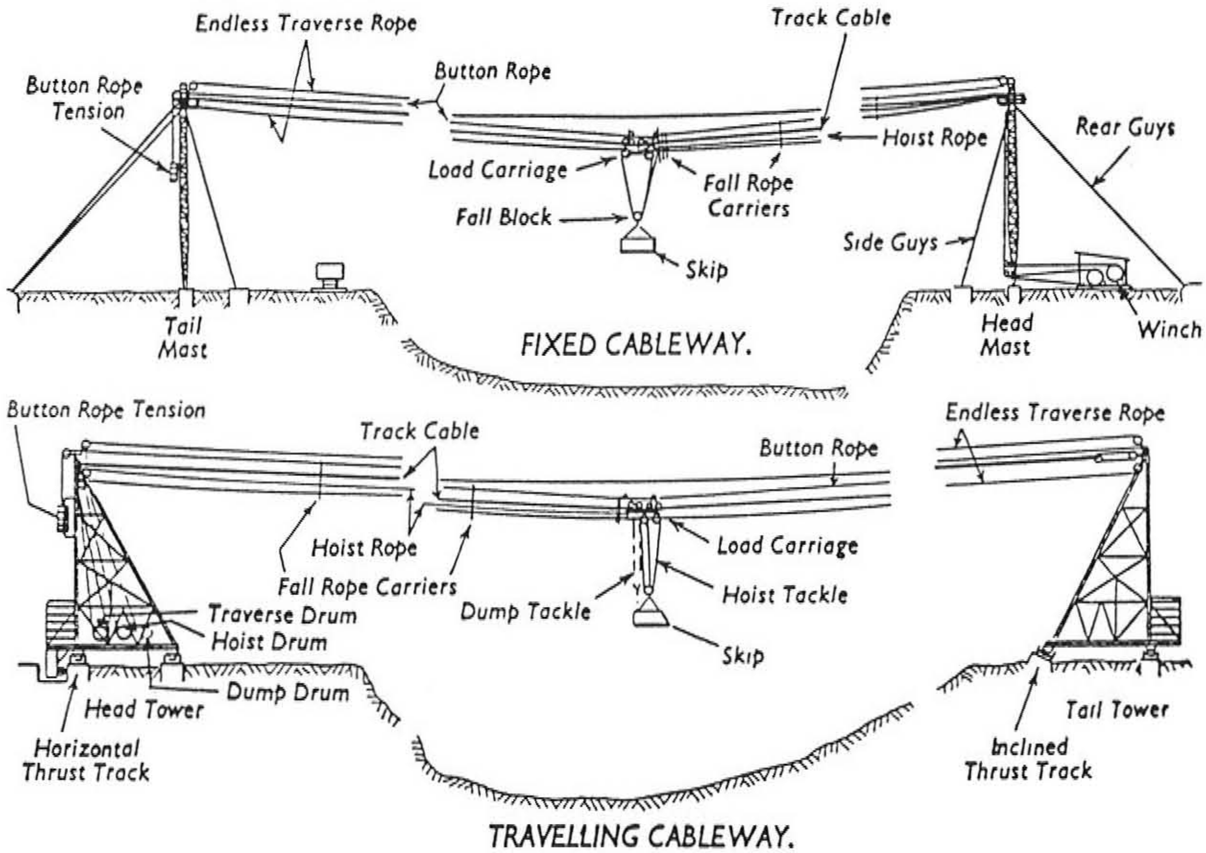


FIG. 24.—Examples of Fixed and Travelling Cableways.

CABLEWAY APPLICATIONS.—Fig. 24 shows that cableways provide a means of handling loads at all points between the track cable supports. As spans up to 3,500 feet have been successfully operated and loads up to 25 tons lifted on one track cable, their practical use is extensive. One of the main advantages of a cableway is its ability to operate without interfering with any other work that may be in progress inside the operating area. This feature makes a cableway the ideal means of handling materials for the construction of large dams, bridges, filtration plants and similar types of work. It is also useful for handling stone in quarries, timber in stockyards and bulk materials in general.

Passenger Cableways.—These may be single cabin type or two cabin type, the latter having a cabin starting at each end and crossing mid-way. They could be compared to a 'to-and-fro' ropeway, but the cableway principle allows the cabin to be lowered at the stations. These 'aerial ferries' can carry loads and passengers at high speeds (2,000 ft./min.) and long spans are possible.

CLASSIFICATION AND SYSTEMS.—The three cableway systems in general use are the 'American'; the 'English'; and the 'Travelift'. They are briefly described below.

THE AMERICAN SYSTEM is that shown in Fig. 24 where the hoisting rope is reeved through the fall blocks and is anchored on the load carriage. This system operates with a single motor-driven winch and provides only a rectangular trajectory for the load across the span.

THE ENGLISH SYSTEM differs in that the hoisting rope passes through the fall blocks on the load carriage but is anchored at the end cable support remote from the operating winch. The winch is fitted with separate motors for each motion of hoisting and traversing, thereby allowing a diagonal trajectory being carried out, if required, across the span.

NOTE.—With both the above systems, a button rope operating fall-rope carriers, to prevent tangling of the hoist and traverse ropes, is required on spans above 500 ft. In the case of the 'English' system duplicate sets are required on each side of the load carriage.

THE 'TRAVELIFT' SYSTEM operates with a single motor winch and enables both motions to operate simultaneously and provides a diagonal trajectory if required, but without the need of fall-rope carriers and button rope. Three operating ropes are used—the transmission, hoisting and conveying ropes. Both the transmission and the conveying ropes are endless. The transmission rope passes around three operating sheaves geared to a hoisting drum on the load carriage. A two-part fall block arrangement from the hoisting drum completes the system. Fig. 25 shows a diagrammatic layout of the 'Travelift' system.

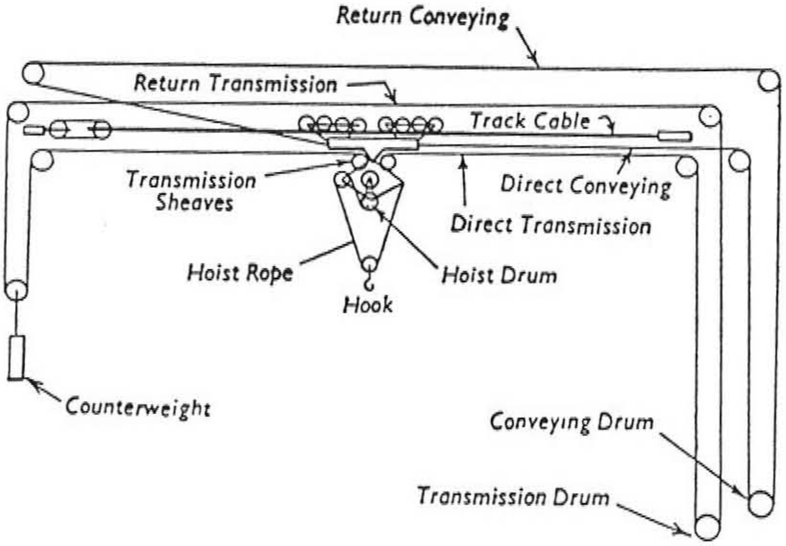


FIG. 25.—Travelift—Cableway.

In addition to the above systems, cableways have been built having the complete winch unit mounted on the load carriage enabling grabs and similar appliances to be effectively employed.

It is of interest to mention that the cableway capacity is quoted differently in this country and in the U.S.A. In the U.K. the hook load capacity means the normal working load which the cableway carries. Under test conditions it will carry 25% in excess of this figure (possibly at reduced speed). In North America it is normal to quote the test or maximum load as the "size" of cableway.

MAIN TRACK CABLE SUPPORTS.—These are of a general standard type of either timber or steel construction.

FIXED MASTS are of the 'needle' type requiring side supporting guy ropes in addition to the main rear anchorages, or the 'pyramid' type which require rear anchorages only.

MOVABLE MASTS OR TOWERS are of the 'pyramid' type, self-supporting by means of rear counter-ballast, all mounted complete on wheeled bogies suitable for moving on rail tracks. Power travelling can be effected by either rope haulage or by power gearing on the bogies themselves. Horizontal thrust loading applied to the towers by the main track cable etc. is resisted by inclining the forward rail tracks, or alternatively by means of additional horizontally mounted bogies running on a rail at the rear of the towers. The two methods are indicated in Fig. 24.

Load Carriages.—All load carriages are of the fully articulated pattern and vary from 3-wheeled units for small loading up to 12-wheeled units for suspended loads of 25 tons. Track wheels and rope sheaves are usually mounted on ball or roller anti-friction bearings.

Track Cables.—Track cables for light duties may be of flattened strand flexible construction, but for the larger loads lock coil construction is usual. On occasions means of turning the track rope are provided to evenly distribute the wear from the load carriage track wheels.

Operating Ropes.—Hoisting and travelling ropes are of flexible construction, best plough steel having six strands of 19 wires per strand.

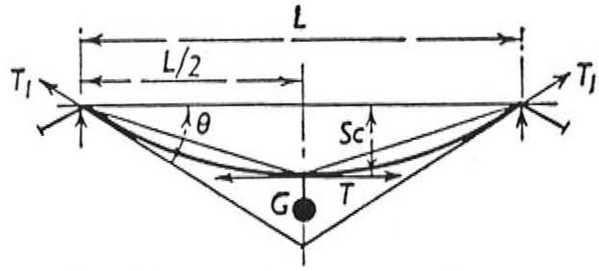


FIG. 26.—Sag for Lead in Mid-span.

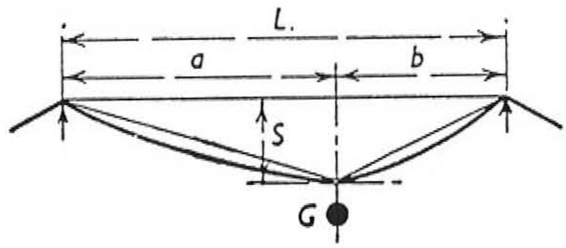


FIG. 27. Sag for Load not in Mid-span.

Winches.—Winches may be of the single or two motor types having a hoisting drum preferably able to coil the operating rope in a single lap without over-riding, a travelling drum of the fleeting type, or alternatively a full coiling drum similar to the hoisting motion. On installations where skip dumping is used an additional drum similar to the hoist will be required for the dumping rope.

TRACK CABLE TENSIONS.—Maximum conditions of tension occur with the concentrated load at the centre of span, and experience has proved that an allowance for sag or deflection of 4½% to 5½% of the span between cable supports is practical. The horizontal tension for these maximum conditions may be determined from the following formula for systems where the cable supports are at the same level (see Fig. 26) and the cable is anchored at each end:—

$$T = (2G + W)L/8Sc$$

where T = Horizontal tension
G = Concentrated load
W = Total weight of track cable between supports
L = Span between track cable supports
Sc = Sag of track cable at centre of span

The maximum track cable tension T_1 occurs at the ends adjacent to the cable supports and is determined by $T_1 = T \sec. \theta$; and $\operatorname{Tan} \theta = (G + W)/2T$. To suit working conditions and clearances it is usually necessary to know approximately the path that the loaded carriage takes while moving across the span. Knowing value T for maximum conditions at the centre as above the sag or deflection S at any other position of the concentrated load may be determined from Fig. 27 and the formula:—

$$S = ab(W + 2G)^2/[2T\{4G\sqrt{(ab)} + WL\}]$$

This formula is only approximate as it assumes constant length of cable and neglects the elastic properties of the cable. The results obtained however are in excess of actual deflections and therefore safe for practical use. A quick graphical method of determining the loaded carriage path closely following the above formula results, is shown in Fig. 28.

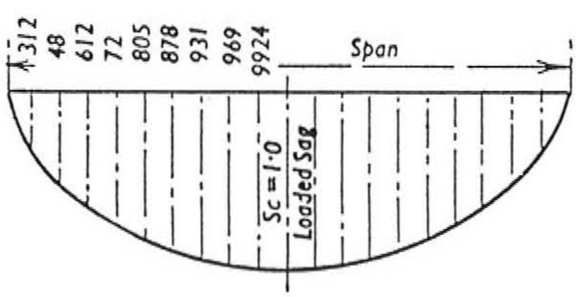


FIG. 28.—Determination of load path. Ordinates on half-span for ten equal divisions when loaded sag Sc. = 1·0.

Leading Particulars of Some Typical Cableway Installations

CASTELO DO BODE DAM. PORTUGAL.—Four radial travelling Cableways (American Standard system). 10 tons load. 1,660 ft. span.

ROXBURGH DAM. NEW ZEALAND.—Two 4 cubic yard travelling Cableways (English System). 10 tons load. 1,605 ft. span.

NORRIS DAM. UNITED STATES OF AMERICA.—Two 6 cubic yard travelling Cableways (American Standard System). 15 tons load. 1,925 ft. span.

ORKNEY ISLANDS. SCOTLAND.—Five luffing type Cableways (American Standard System). 10½ tons load. 1,700 to 2,550 ft. spans.

DETROIT RIVER DAM. U.S.A.—Two 8 cubic yard travelling Cableways (Travelift System) 25 ton load. 1,980 ft. span.

PERIBONKA RIVER DAM. CANADA.—One 8 cubic yard radial travelling Cableway. (Travelift system.) 25 ton load. 2,140 ft. span.

SOLINA DAM, POLAND.—Two cableways, hook load 20-tons, capacity of concentrating bucket 8 cu. yard (6 cu. metres), span between masts 2300 ft. (701 m).

SEFID ROUD DAM, IRAN.—Three cableways, radial type, 11-ton hook load each, 2000 ft. (610 m.) span each, two-motor design.

TIGRIS RIVER, IRAQ.—Ropeway transporter carrying vehicles, etc., up to 24 tons gross. Main span 160 ft (500 m.).

BIBLIOGRAPHY

SCHNEIGERT, Z. *Aerial Ropeways and Funicular Railways*. (Edited by Z. Frenkiel). Pergamon Press (Oxford 1966).

SPAIN. R. E. *Aerial Cableways* (London 1948).

DEAN, F. E. *Famous Cableways of the World.* Frd.k. Muller (London 1958).

GIORDIANO G. *Logging Cableways* U.N. Food and Agriculture Organisation (1959).

International Ropeway Review. Quarterly. London.