AERIAL ROPEWAYS.

By Major F. N. Budden, R. E.

I.

An aerial ropeway is a means by which loads can be transported from one place to another in carriers suspended from cables which are supported on standards spaced at various intervals. By this means it is not necessary to prepare an expensive roadway such as is required for motors, railways, etc., nor is it necessary to follow the contour of the ground but gaps can be crossed, mountains climbed without very great expense.

II. Types.

1. Aerial ropeways may be divided into two distinct types—

(*a*). Monocable where a single endless rope is used to support and move the loads.

(*b*) Bicable (or Tricable as it is called on the Continent in Europe) where the loads are supported on two carrying ropes and moved by one endless hauling rope.

2. There are also certain variations of these types such as the "Fixed Clip System" on the Monocable type and the "Jig back" or "To and Fro System" which is applicable to both types. As a general rule both the Monocable and Bicable types are so arranged that it is not necessary to stop the hauling rope to attach or detach loads at the stations at either end of any one section.

III. Choice of System.

1. There is a certain amount of difference of opinion as to which system, the Monocable or the Bicable, is the better. On the Continent the bicable (or the tricable) system is preferred while in England the monocable is generally installed. The reasons for this difference of opinion are that when aerial ropeways were first introduced, the bicable system was adopted by Continental makers and was developed to such an extent by two German Firms that for many years the bicable system was in practice, the better of the two for all heavy work and steep gradients. Since then the monocable system has been improved by English Firms, especially by Messrs. Ropeways, Ltd., so that it is now a serious competitor to the bicable system, and in many cases has ousted it.

2. *The advantages claimed for the bicable system are that—*

(*a*) The carrying and hauling ropes have different functions to perform and can be designed to fulfil them, *i.e.*,

the carrying ropes can be made large and stiff enough to carry heavy loads while the hauling rope can be made flexible. Also in the case where the loads in one direction are heavier than the loads in the opposite direction, the carrying rope for the lighter loads can be made smaller. This is not possible in the case of the monocable system.

(*b*) The life of the ropes is longer.

(*c*) Gradients as steep as 1 in 1 between tops of trestles can be traversed.

(*d*) Heavier loads can be carried.

(*e*) Trestles can be spaced at greater distances.

3. *The advantages claimed for the monocable system are that*—

(*a*) It is cheaper in first cost.

(*b*) Easier to transport and erect.

(*c*) Easier and cheaper to maintain.

(*d*) There is less likelihood of damage to the system in high winds as with the bicable system the hauling and carrying ropes are liable to get caught up together.

(*e*) It is safer as the single rope is always passing under observation at the terminal stations and can be watched for the first sign of wear and moreover can be more easily lubricated. Also when the rope on the monocable system breaks the loads merely sink to the ground, whereas in the bicable system when the carrying rope breaks the hauling rope still goes on and the loads are liable to damage the trestles, and should the hauling rope break the loads still remain on the carrying rope and are liable to crash into each other.

(*f*) For all practical purposes the monocable can traverse all hills that are likely to be met with, as with the improved carriers introduced by Ropeways, Ltd., gradients of 1 in $1\frac{1}{2}$ can be climbed.

(*g*) Loads can now be arranged to be dumped automatically where required, although at first this was only possible with the bicable system.

4. From the above it will be seen that each system has certain advantages, and it depends on the ground to be covered, the loads to be carried, and the total tonnage to be transported per hour whether the monocable or the bicable or a combination of both should be installed, and only an expert can decide this.

5. For instance in case of a long line in which occurs a very large span and which with a monocable might entail the use of a very heavy rope throughout the section, it might be advisable to instal a bicable line and use heavy carrying ropes over the long span only, the remainder of the section having carrying ropes of smaller diameter.

6. In all cases the advice of an expert should be obtained and any extra expense entailed will be repaid many times over by a decrease in the running costs.

IV. Location and Design of Ropeways.

1. After it has been decided that it is desirable to join up two places by an aerial ropeway, various details in connection with the exact location and design of the ropeway have to be settled.

2. *Location of stations.*—In this connection attention must be paid to the following points :—

(*a*) Loading and unloading stations should be at convenient points for transhipment.

(*b*) The straightest route is preferred, provided that it does not entail too great spans. Details of limiting spans are given later.

(*c*) Length and grades of each section should be adjusted so that suitable positions can be found for intermediate stations and the power of the motors selected for use can be fully utilised. Where the gradients are favourable, sections have been made as long as 5 miles on the monocable system such as for the Pure Salt Co., Spain, but the normal section is, of course, less.

3. *Positions of motors and tensioning arrangements.*—A line of considerable length consists of a number of sections each of which is worked by its own motor or motors and for each of which there are separate tensioning arrangements. For convenience of supervision and cheaper cost of running it is generally preferable to have the motors of two adjacent sections together so that in a line of two sections, the tensioning arrangements might be at the loading and unloading stations while the motors working both sections might be situated at the intermediate station for convenience of supervision.

4. But there is another factor which must be taken into account and that is that it is preferable to have the motor if possible at the higher station in order to have direct haulage on the rope. This is said by Italian experts to reduce the power necessary by 20% and also the wear of the rope.

5. *Gradients.*—In the case of the bicable system gradients of 45° or 1 in 1 can be surmounted whereas with the monocable system the limiting gradient is 1 in $1\frac{1}{2}$ and this is only possible with a much improved clip introduced by Ropeways, Ltd., and described under carriers. Previous to this the limiting gradient was 1 in $2\frac{1}{2}$ and this was said to be one of the disadvantages of the monocable system.

6. Italian experts state that for heavy lines the change of grade at any trestle should not ordinarily exceed 3° and the maximum allowable is 4°. For light lines, however, the change of grade may be as high as 8°.

7. *Curves.*—Curves are not desirable on either system but are less harmful on the monocable system. In any case the change of direction at any one standard should not exceed 1°. An example of what has been done in the way of curves can be found at the Shropshire Mines Ropeway, Ministerley, England, built on the monocable system.

8. This line is $25\frac{1}{2}$ miles long and is designed to carry 20 tons per hour. A curve occurs about 13,910 feet from the loading station and is 2,703 feet long. The angle between tangents is 6° 43′ and the curve is completed in 8 spans with a deviation of about 1° at each trestle. On the trestles in the curve the sheaves are mounted as usual on balance beams. The balance beam carrying the sheaves is suspended on a laterally swinging arm which permits the beam and sheaves to swing outwards or inwards from the standard while the load passes, and this obviates any tendency for the rope to mount the flanges of the sheaves owing to change of direction. The wear on the sheaves is admitted to be slightly increased owing to the curve, but it is not great (*vide* sketch 1).

9. *Spacing of Standards.*—It is difficult to lay down any definite ruling on this point. The spacing may vary in the case of a bicable system from 1,500 metres when crossing a gap to 25 metres when changing slope at the crossing of a spur.

10. In the case of a monocable system one of the largest gaps crossed was 1,090 metres between standards on a ropeway for the Porco Tin Mines, Ltd., Bolivia, South America. The longest recorded span however is one of 3,600 feet in the Andes. An average spacing on ordinary ground would be anything between 100ˣ and 200ˣ between trestles.

11. *Capacity of line and Individual loads.*—When possible individual loads should be kept to about 1% of the hourly capacity for capacities above 10 tons per hour. Heavy individual loads tend to increase prime costs.

12. Most ropeways are signed for a capacity from 20 to 50 tons an hour, but even with the monocable system, a capacity of 150 tons an hour has been obtained (for the Compagna Espanola Minas del Ref, Spain).

13. If, however, special loads such as timber in log have to be carried, the problem becomes different. In this case the design has to be worked out for the maximum individual load anticipated.

14. Generally the prime cost of the installation is largely dependent on the maximum individual load to be handled.

15. The following table giving a rough idea of the capabilities of the various systems mentioned, shows the maximum lengths, capacities and loads carried on various lines at present working or in course of construction :—

System.	Present maximum lengths.	Present maximum hourly capacity.	Present maximum individual load
	Yards.	Tons.	Tons.
Monocable ..	80,196	200	$1\frac{1}{2}$
Bicable ..	38 800	250	2
Fixed Clip ..	2,330	8	4 cwts.
To and Fro ..	1.850	Passenger's weight unknown.	17 tons.

16. *Speed of hauling Rope.*—The usual speed is about 2 metres per second or about 400 feet per min. although in some cases a speed of $2\frac{1}{2}$ metres per sec. has been allowed. In case of urgent necessity a speed of 3 metres per second can be allowed for a short time, but it has been found that carriers can best be fed on to the rope at a speed of about 400 feet per minute, and as it is very desirable that the carrier should be travelling at the same rate as the hauling rope when the clip engages, this is the usual speed otherwise the hauling rope is liable to be worn out too quickly.

17. In many cases automatic regulators are used to regulate the speed of the motors under a light load.

18. *Dip.*—Italian experts allow in practice a dip of 4 metres vertical in 100 metres of span. It often happens that the dip is the determining factor in calculating the diameter of the carrying rope. In calculating the catenary, the ropes are assumed to be 50% more than the actual total load.

19. The dip can also be obtained from the formula

$$\text{Dip} = \frac{L^2 W}{8\,T}$$

where L = span, W = weight per unit length, 8 = constant, T = tension,

and from this the supporting trestles can be placed.

20. It sometimes happens, however, in practice that when the rope is fully tensioned it floats or rises up from the supporting trestle due to some slight error in calculation. To overcome this

some Italian makers provide clips to hold the carrying rope down on the supporting saddles. This is only done for light lines which are erected in a hurry as often happens in War.

21. Otherwise a so-called factor of safety is employed by continental makers, that is the denominator 8 T in the formula Dip $= \frac{L_2 W}{8 T}$ is multiplied by some constant which varies according to the ropes employed. In the case of locked coil ropes, the factor may be 1·1 and in the case of spiral ropes up to 1·5. By a use of some such factor the calculated dip is less than the actual and so the supporting trestles are made slightly higher than it is theoretically necessary, but any possibility of floating is obviated.

22. *Diameter of Carrying Ropes.*—It has been proved by experience that most trouble is caused by breaking due to bending near the saddles, and for this reason in order to obtain the diameter of the carrying rope required, some firms employ formulæ based on stresses due to bending.

23. A formula often used is

$$\text{Weight per metre of rope} = \frac{0{\cdot}85}{100}\left\{\begin{array}{l}(\text{weight of carrier}) + \\ (\text{distance between carriers in metres}) \times (\text{weight of} \\ \text{hauling rope per metre.})\end{array}\right\}$$

This is for spirally wound ropes.

With locked coil ropes the factor 0·85 becomes 1·05.

This formula works well for small lines up to about 50 tons capacity hourly. For each additional 5 tons 0·05 should be added to the factor 0·85.

24. *Diameter of hauling Ropes.*—The diameter of the hauling rope depends upon the highest tension occurring in it.

Tension of rope in lbs. $=$ (Initial tension $+ \frac{W}{S} H + wH) + (WN \mu_1 + L\mu_2 w + 2R)$, where W = weight of full carrier, S = spacing of carriers in feet; H = difference in level between stations in feet; w = weight per foot of hauling rope; μ_1 = coefficient of friction of cars; μ_2 = coefficient of friction for hauling rope; L = length of line in feet; N = number of carriers on one side of line; R = number of supporting rollers on one side of line.

This tension if multiplied by the factor of safety, 6 to 8, and divided by the breaking stress, gives the area of the rope necessary. This is for the general case with the drive at the upper terminal and the loads ascending. When the loads are descending, the

plus sign in the centre of the formula becomes minus. To obtain the tension when the ropeway is just put into work the second half of the formula should be doubled.

25. The usual breaking stresses of hauling ropes are from 80 to 115 tons per square inch. The surge of the hauling rope tension sheave depends upon the distance apart of the carriers, long spans occurring in the line, etc. As an average, 6 feet play may be allowed for to commence with, and then an additional 12 feet for each mile of length. In some cases in long lines it is necessary to split up the line into sections to avoid excessive tensions occurring.

V. Ropes.

1. *Types.*—There are three main types of ropes used on aerial ropeways—

(*i*) Lock coil and semi-lock coil.

(*ii*) Spirally wound or helicoidal.

(*iii*) Stranded rope with Langs lay.

2. On the bicable system carrying ropes are generally of lock or semi-lock coil in the case of heavy installations and spirally wound in the case of lighter installations.

3. There are three types of lock or semi-lock coil rope as shown in sketches 2, 3, and 4.

The semi-lock coil as shown in A consists of a spiral coil surrounded by a layer of round wires kept apart by wires drawn to a special section. Though not quite so smooth it has the advantage of being cheaper.

4. The special advantages claimed for lock and semi-lock coil ropes are that —

(*a*) There is minimum friction.

(*b*) They have a longer life. Messrs. Spadaccini, an Italian firm, put it at 50% longer than that of stranded ropes.

(*c*) Ropes are not deformed if one strand breaks. Broken strands are liable to derail carriers.

5. The disadvantages are —

(*a*) Greater cost, at least 30% greater than spirally wound ropes.

(*b*) Steel of maximum tensile strength cannot be employed in their manufacture.

(*c*) Cannot be spliced. Special sockets must be used for joining.

6. Spirally wound ropes are cheaper than lock or semi-lock ropes and can be joined by splicing and so are often used for lighter installations as there is not much friction and they are better than stranded ropes with Langs lay.

7. Stranded ropes with Langs lay are used as carrying ropes when other types are not available, but with a hemp core they are nearly invariably used as hauling ropes.

8. Stranded ropes with ordinary lay are not used either as carrying or hauling ropes except as a last resort.

9. *Wear and life of ropes.*—In the bicable system the wear to the carrying rope occurs on the top side of the ropes in spans and on the bottom side in saddles and in addition, the vibration occurring in spans is damped down near saddles causing fatigue in the wires. For this reason to obtain the maximum life out of the carrying ropes, they must be shifted periodically and shortened at couplings so that positions of wear and fatigue may be changed.

10. In the monocable system the wear to the rope is distributed and as the rope is continually passing round the terminal sheaves, inspection is easy and a broken wire is easily detected and can be repaired before any damage is done. So with the monocable system complete rope failure with efficient inspection is practically unheard of whereas even with the most careful inspection, the carrying rope in the bicable system may fail completely as it is very difficult to find out the state of the rope.

11. Italian experts attach great importance to the fact that in the monocable system the rope tends to revolve during its passage, but is prevented at the points where it is gripped by the carrier clips, and for this reason they allege the life of the rope is very short. English experts, however, deny this, and point out that if that the Italian view was correct the hauling rope in the bicable system would be short lived which apparently is not the case.

12. Messrs. Spadaccini and other Italian firms estimate the life of lock and semi-lock coil rope at 12 years and of other types at about 8 years when used on a bicable system, but put the life of a rope on a monocable system at about 1 year.

13. English firms however disagree and put the life of a rope in a monocable system at about two years and a lock coil rope on a bicable system at about 8 years. These figures are calculated on a basis of 8 hours work a day and 250 working days in a year under peace conditions.

For war the above figures showing the average life of a rope should be halved.

14. The number of years a rope lasts is not altogether a true criterion of the life of a rope as in the case of a heavy installation, the life of the rope is shorter and the total tonnage moved must be taken into consideration.

15. It has been found that for locked coil rope a breaking stress of about 65 tons per square inch is about the best and for spiral ropes about 95 tons per square inch. This is much the same as has been found by Italian firms who state that the breaking strain of a rope in kilos is

In case of lock and semi-lock coil ropes :—

Number of wires × cross sectional area of a wire+100.

In case of other ropes :—

Number of wires × cross sectional area of a wire+150.

16. *Lubrication.*—The hauling rope of a bicable system and the rope of a monocable system are lubricated at the terminal sheave by some form of drip feed, while to lubricate the carrying ropes of a bicable system it is either necessary to send a man standing in a carrier at a slow speed or to use automatic lubricating machine attached to a carrier, but the latter is not altogether satisfactory as the lubrication is not under observation, although with large spans it is often necessary to use it.

17. A mixture of Swedish oil, tar, tallow and pine resin is often used for lubricating the ropes. The tar acts as a waterproofing agent.

18. *Splicing of ropes.*—Lock and semi-lock coil ropes cannot be spliced, and for them special clips are necessary and examples are shown in the accompanying sketches 5 and 6. The individual wires of the rope can be opened out and wedges driven in and a cap screwed on or molten lead run in. For all other ropes splicing is used. One Italian expert stated that they allowed 1 metre of splicing for each m.m. in the diameter of the rope.

19. *Cost of ropes.*—Post-war figures of the cost for ropes are not available, but ropes should only be bought from well-known wire rope and cable firms. Lock coil ropes are the most expensive and are probably not less than 30% more expensive than spirally wound ropes.

20. *The relative position of the carrier and hauling ropes in the bicable system.*—Some firms prefer the hauling rope above the carrying rope as the type of coupling used is lighter and cheaper, and the length of the stations is shorter because the hauling rope may be led in and out of the jaws without interfering with the shunt rails.

21. But the overhead type of coupling has one great disadvantage when ascending a steep gradient as the hauling rope reaction falls outside the wheel base and this tends to make the

carrier rock and in some cases forces it off the carrying rope. In such cases the undertype grip should be used. Italian practice as a whole is in favour of the undertype coupling, while English practice prefers the overhead type except on steep gradients.

22. *Varying stresses caused by hauling rope in the bicable system when the hauling rope is below the carrying rope.*—It sometimes happens at a trestle on either side of which there are long spans that there is a considerable downward pressure at the trestle caused by the hauling rope, and not only has the trestle itself to be strengthened but in some cases the carrying rope where it passes over the saddle has to be protected by means of a steel plate cap over which the carrier runs as the pressure on the rope is greater than that allowe l for. Some authorities recommend the use of a steel cap when the hauling rope reaction exceeds 450 lbs. per square inch, but there is a difference of opinion whether steel caps are necessary or not.

23. An opposite reaction occurs at the centre of a long span as the hauling rope tends to bear part of the wear of the carrier and this makes the runners less secure on the carrying rope and more liable to be blown off by high winds.

VI. Carriers.

1. These may be divided into—

(*a*) those used on a bicable system.

(*b*) those used on a monocable system.

2. Taking the former (*a*) first, carriers may be divided into—

(*a*) those employing screw grips depending on the weight of the load, and

(*b*) those employing counterweighted lever grips, each group being sub-divided into those employing the overtype or the undertype grips.

3. It is not proposed to give a detailed description of every type of carrier in use but only to describe certain typical examples. The advantages and disadvantages of the overtype and undertype grips have already been discussed under " Ropes."

4. A carrier on the bicable system consists of three parts :—

(*a*) The runners.

(*b*) The box or receptacle.

(*c*) The hanging frame with coupling.

5. *Runners.*—The runners consist of one, two or four wheels deeply grooved which run along the carrying ropes. The usual runner has two wheels.

6. The running wheels should be of high quality steel, and the diameter of the wheels depends on the load and type of rope. Larger wheels are required with spiral ropes than with lock coil ropes.

7. The following table gives, according to one authority, average size of wheels for carriers with two wheels on lock coil ropes :—

Weight of load and carrier.	Diameter of wheel.
14 cwts.	8 inches.
30 ,,	10 ,,
40 ,,	12 ,,

8. The wheels may or may not have ball bearings. Such bearings are said to reduce by $\frac{1}{3}$ the traction power required but their cost is double that of the ordinary type.

9. Italian firms state that on lines with small gradients where practically all the traction force is used in overcoming friction, the use of ball bearings is worth the extra cost, but that this is not the case on lines with steep gradients where the greater part of the traction force is used in raising the load. Whatever type is chosen the runner pins should be self-oiling to reduce friction as much as possible.

10. *Boxes of receptacles.*—These are of various types and are made to suit the loads to be carried.

Common forms are :—

(*i*) Open wooden boxes with low sides.
(*ii*) Iron bucket pattern.
(*iii*) Long iron stretcher shaped frames with wire netting bottoms and sides.

11. Special single loads such as baulks of timber or guns are carried by using two sets of runners to which the loads are slung by means of ropes.

12. *Couplings.*—The advantages of couplings employing counterweighted lever grips are —

(*a*) The cost is much lower than those with screw grips depending on the load.

(*b*) On small installations where shunting devices are not used, the coupling and uncoupling can be done by hand without stopping the motor.

(*c*) Certainty of action and easy regulation of the grip on the hauling rope.

13. Its disadvantages are that it cannot be used on steep gradients or for very heavy loads.

14. The coupling is actuated by the counterweight lever which, as the load is pushed forward by hand along the shunting rail,

at the loading station meets and bears against an inclined plane which turns the lever over 1/3 of a circle and force the jaws to grip the rope. On reaching the unloading station it similarly meets an inclined plane which reverses the process. The jaws open and the carrier runs on to the shunt rail. The system is automatic and simple.

15. An example is shown in the accompanying sketch 7.

16. Typical examples of couplings employing a screw grip depending on the load are shown by the "Ideal" couplings made by Ceretti and Tanfani and another form of coupling where the grip acts through a simple system of levers.

17. The "Ideal" coupling is actuated as follows, *vide* sketches 8 and 9 :—

When running on the carrying rope the weight of the carrier keeps the jaws of the grip closed. As the carrier reaches the unloading station the runners leave the carrying rope and are run along a shunt rail. As they do so, a wheel fixed at one side meets an inclined plane up which it is forced, and thus takes the weight off the runners, releases the jaws and moves the grip clear of the hauling rope.

18. To ensure that the runner wheels shall not rise from the shunt rail at the time when the side wheel engages the inclined plane an upper guard rail is fixed to keep them in place.

19. The following are some of the advantages claimed by the makers for this type :—

(*a*) Simplicity, in that there are no levers or springs to weaken the device.

(*b*) By varying the slot the speed at which the grip is applied at the moment of starting can be regulated. Sudden jar on the hauling rope can thus be avoided, and life of the rope thereby lengthened.

(*c*) The force of the grip remains constant whatever the gradient of the carrying rope. The type is effective up to gradients of 1 in 1 (according to makers).

(*d*) Certainty of action.

20. In the second type the pressure of the grip is applied by the weight of the carrier and the load acting through a simple system of levers to give a multiplied pressure on the jaws. The grip is released by lifting the load which is accomplished by means of small rollers running on the rails in the stations (*vide* sketch 10).

21. Another type of coupling in which the grip is a function of the load is the "Vatellina" coupling made by the B. B. B. firm (*vide* sketch 11). The arrangement is as follows :—

22. The runner wheel has a hook below it. In this hook are two rings held together at the bottom by the eye of a second hook in which hang the carrying chains.

23. The hauling rope passes between the rings, and the weight of the load forces the latter to grip it.

This form of coupling cannot be used on the automatic system as the hauling rope must be stopped when the carrier gets near the end of its run. It is therefore only suitable for short lines of small capacity.

24. It is cheap, simple and reliable, and a very convenient one for carrying long loads such as guns, as two couplings can be used, one at each end.

25. In case the runner should jump off the carrying rope, a safety is chain passed round the hauling rope and both ends hooked through the ends of the supporting chains. In case of a break of the carrying rope, the hauling rope would, within the limits of its strength, support the load.

26. In conjunction with this coupling a small clip is fixed on the hauling rope close to each grip as a further safeguard against clipping.

27. The B.B.B. make a speciality of a form of grip to reduce tensional friction both for the monocable and bicable systems.

28. The grip which is actuated on the counterweight principle consists of a single roller which holds the rope against a jaw, or of two rollers which grip the rope between them : in either case the rope, though gripped, is allowed to rotate.

29. The grip has to be adjusted to each rope by means of packing pieces, a somewhat clumsy expedient. The design however overcomes what Italian firms call an important defect especially of the monocable system.

30. This coupling was not seen at any of the installations visited, but the single roller and jaw type was said to have been largely used in the installations (bicable type) at Monte Pesubic, and to have been effective on gradients as steep as 4 in 5 and to be capable of taking loads up to 800 kilos using a special heavy coupling.

31. Among the best known couplings for the monocable system are Roe's patent Toggle and Saddle clips.

32. The clip shown in sketch 12 is capable of sustaining a load at an angle of about 45° and in theory is the most efficient of all clips actuated by the load, as the whole of the tare weigh also is used for gripping. Another type which is more usually employed as it is cheaper on gradients which do not exceed 1 in $2\frac{1}{4}$, is shown in sketch 13.

33. The gripping in this type is performed by two cast chilled saddles the sides of which are in-lined, one side having a feather projection. It is so formed that it disengages itself without damaging the strands when the carrier enters a station.

34. A rough sketch of a type seen at an Austrian Installation at Matarello in the Trentino is given in sketch 14.

When the wheel A is on the shunt rail it supports the carrier and the jaws are open. As it leaves the shunt rail the jaws are closed by the pressure of the cable on the two forked prongs at the mouth of the jaws.

VII. Trestles.

1. Trestles can be of steel, iron or wood and may have one, two, three or four legs. Some typical examples are shown in sketches 15 to 19.

2. Trestles are usually set in concrete, but this is not done in light portable installations. On the large lines it is the Italian practice to erect the trestles vertical; but on the lighter lines they prefer to have the trestles normal to the line of the rope though this is not always done. When crossing a span it is important that the trestles should be adjusted to form equal angles with the rope on either side.

3. Trestles vary in height from a theoretical minimum of $2\frac{1}{2}$ metres upwards.

4. In an aerial ropeway between Manizales Columbia and Mariquita over the Andes, there are eight steel trestles over 130 feet in height, two of which are 317 feet high.

5. Along ordinary ground of even grade the height is regulated by—

(*a*) The desirability of keeping the grade as even as possible.

(*b*) The headroom required in the centre of the span.

6. When there is a large difference of level between two points the line of the catenary is plotted on the profile as already explained, and the heights of the standards regulated to suit this.

7. Some firms make standards which can be heightened by increments of 1 metre, but this is not universal and would be suitable only for light installations.

8. The chief point of interest in a trestle is the method by which it supports the carrying rope.

9. In the bicable system the carrying rope is supported in grooved, fixed or oscillating saddles, whereas in the monocable system the rope is generally supported on revolving sheaves arranged in groups of 2, 4 or 8 according to the calculated pressure the trestle is expected to bear.

10. These sheaves are mounted on balance beams in such a way that each sheave takes its correct share of the pressure. Their use enables a trestle in a monocable line to take pressures which in case of a bicable would have to be met either by putting in an extra trestle or by providing rail supports. A monocable line may, therefore, be constructed with less trestling than a bicable and thus save in material and expense. An example of a balance beam is shown in sketch 2, and examples of trestles for a monocable line in sketches 18 and 19.

11. In the bicable system pairs of saddles are employed where there is a great change of slope at any one trestle or where the pressure is more than one saddle can bear.

12. Oscillating saddles are as a rule preferred, and to save the wear on the ropes the ends of the arms of the saddles are sometimes made with soft iron so that the saddle should wear and not the rope.

13. In the bicable system the trestles are fitted with pulley wheels over which the endless hauling cable runs and with guides to ensure that the hauling rope returns to its position on the pulley wheel after the carrier has passed. Examples of these are shown in sketches 15 to 17.

14. To prevent wear of the hauling rope the pulleys are often fitted with removeable soft iron treads which can be replaced when worn. This tread is a ring made in two sections which can be replaced without dismantling the complete pulley.

VIII. Stations.

1. Stations can be either—

(*a*) terminal stations for loading and unloading,

(*b*) intermediate motor stations,

(*c*) intermediate tension stations,

(*d*) angle stations,

or a combination of two of the above.

2. Stations on the bicable system are much bigger and more complicated affairs than on the monocable system, but the bicable has the advantage that, as the carriers are always gripped by the hauling rope, the working at stations where there is no unloading or loading can be made automatic.

3. On the monocable, however, when a carrier leaves the rope it must be pushed by hand although the labour of pushing the carriers on the shunt rails can be minimised by grading the shunt rails.

4. *Shunt rails.*—For a line to have any large capacity it is necessary to have some means of loading and unloading without having to stop the motor. This is done by the use of shunt rails on to which the carrier runs when it reaches the unloading station and from which it is launched from the loading station.

5. Two small rollers are provided on one side of the coupling which are not in use when the load is on the carrying rope. On re-entering a station these two rollers run along the shunt rail which is at a different angle to the carrying rope and so take the weight of the carrier and at the same time allow the jaws of the grip of the coupling to open and disengage from the hauling rope. The carrier is then run along the shunt rail to some suitable place for unloading or on to the next section of the ropeway.

6. Stations can be large closed in buildings built with concrete and iron roofs, or small open buildings with some light form of roof. Some form of light roof is always provided.

7. *Driving power.*—Various types of power can be utilised for driving a ropeway, such as petrol and electric motors, oil and steam engines, etc.

8. The amount necessary is obtained from the following formula:—

$$\text{Power in feet lbs.} = \left(W_1\ W_2 \mu_1 \frac{NV}{2} + 2\ wL\mu_2 V \div 2RV + F\right)$$

$$+\text{or} - \text{theoretical power}$$

where

W_1 = weight of full carrier.

W_2 = weight of empty carrier.

μ_1 = coefficient of friction for cars.

N = total number of cars on line.

V = velocity in feet per minute of cars.

w = weight per foot of hauling cable.

L = length of line in feet.

μ_2 = co efficient of friction for hauling cable.

R = number of supporting pulleys.

F = power required for station friction.

9. The first four factors give the power necessary to overcome friction, and the theoretical power required or developed depends upon whether loads are ascending or descending.

10. The factor for station friction varies greatly for different lines and is solely a matter of experience, although 0·02 of the total weight of the moving parts in the station multiplied by the speed may be taken as a good mean.

11. As already explained, some motors are fitted with a governing arrangement so that the speed of the hauling rope should not increase under a light load.

12. Special motors have been designed for light portable installations to work over lengths of 1 to 2½ kilometres with individual loads not exceeding 180 kilos. and spans not exceeding 250 metres by Messrs. Spadaccini of Milan and Messrs. Badoni Bellari and Benazzoli of Lecco and Milan.

13. In permanent installations the motor is as a rule set in concrete. In light installations, however, the underframe is often bedded into the ground for a few inches and filled with boulders, the motor itself being bolted to the underframe and in some cases further steadied by sand bags piled on the top of the upper frame.

Types of Tensioning Arrangements.

14. *Carrying Rope.*—The Italians and the Austrians tension the carrying ropes by hand winch block and tackle, the strain being applied to the rope by a separate wire rope clipped on to it.

15. After getting the requisite tension, the rope is, in the case of light installations, made fast either to the framework of the motor bed or to some anchorage.

16. In the case of heavy lines is made fast to a counterweight. In Italian practice this counterweight is usually a large box loaded with stone or other weighty material. The Austrians employ in their large installations counterweights made up of layers of concrete segments which can be added as required to get the desired weight.

17. *Hauling Rope.*—On light lines tension is got by adjusting the distance between the driving and idle pulleys at the motor station by means of a wheel actuating a screw threaded tension bar.

18. On heavy lines tension is applied by adjusting the idle pulley wheels at the tension station by block and tackle, and then either making fast to some anchorage or attaching a counterweight as in the case of carrying ropes.

19. If the station is not raised, a well must be dug to allow for the rise and fall of the counterweight. In the case of the Austrian Installation at Calliano the passage of a light load was seen to cause a rise of 6 feet.

20. The tension of the carrying rope is generally about 3 to 4 tons per kilometre. That of the hauling rope is of course less.

21. An instrument for registering the tension is often provided.

22. *Frame-work of stations.*—Both timber and iron are used, according to local conditions. The light Italian installations seen were mostly built up of L. iron.

A light roof as protection from the weather is always provided.

23. Sketch 20 shows an arrangement used by Ropeways, Ltd., which combines a multiplying and taking up device. The two sheaves at A are attached to the tension trolley, the winch and the differential drum being mounted on an independent frame placed over the tension pit, one end of the rope B is anchored, the other being made fast to the tension which drum. By this arrangement the resultant pull at A is 4 times the dead-weight applied at C and the weight can always be kept in suspension without the necessity of a deep pit by taking in the slack with the winch.

IX. Automatic Dumping.

One of the most common uses for ropeways in commercial work is the automatic dumping of refuse from mines.

Until recently the automatic dumping was possible only on the bicable system but the principle has now been applied with success to the monocable. How this is carried out is shown in sketch 19 of a monocable installation at Tredegar.

X. Fixed Clip Single Rope System.

This type of ropeway is only applicable for light capacities, and is used largely on plantations and for the transport of valuable ores, where comparatively small quantities are handled.

2. The carrier head, fig. 21, is permanently attached to the rope by means of a spring steel strap, and is designed in such a way that it can pass freely over trestle sheaves, under depression wheels and round the terminals, without being detached from the rope. As both rope and carriers are in constant motion, loading has to be done by hand, or by means of a travelling hopper, which is usually hung from overhead rails at the terminal. The terminals are extremely simple and compact, as all shunt rails are done away with. The tension terminal is usually mounted on a trolly or on skids, the whole being movable by means of tension gear, to allow for stretch of rope, etc. Angles can be worked with the fixed clip system, but they should be preferably avoided as they tend to produce excessive rope and gear wear at such places.

This type of line is run at a slow speed, namely, about 200 feet per minute, and the only advantages it can claim are its simplicity, adaptability to steep grades, and its low prime cost when light capacities and moderate lengths have to be dealt with.

XI. Jig-Back or To and Fro System.

1. This type of ropeway is useful for short distance, and is operated a pair of carriers that travel in reverse directions and are loaded or brought to rest alternately at the opposite stations, but which do not pass round the terminals: it is, therefore, intermittent in its action, and the direction of travel is reversed after each

journey. Where loads are to be carried which are heavy individually in relation to the capacity, and where the distance is short, the "To and Fro System" is particularly applicable. A high carrier and rope velocity may be adopted during the run, especially where a clear span occurs between terminals, and where there are no intermediate trestles.

2. These installations may be on the "Monocable" or "Bicable" principle, and in either case the moving rope is clamped to the carriers, and is not usually disconnected from them at the terminals.

3. It should be mentioned that, up to the present, the "To and Fro" ropeway is the only system that is used for regular passenger traffic, as the carriers lend themselves to the adoption of a safety grip used in conjunction with an auxiliary standing rope, but with such appliances these installations are very costly and present mechanical difficulties on lines of any length.

XII. Costs.

1. Post war costs are not available, but as a general rule a bicable line is more costly in the first instance than a monocable.

2. The bicable has twice the length of rope that the monocable has, its carrier couplings are heavier and more complicated and its stations are larger, have heavier anchorages and involve much frame-work and foundation masonry.

3. The first cost of a bicable line is said to be generally about 20 per cent., but may be as much as 40 per cent. more than that of a monocable. As a general rule a bicable is considered by English firms to be more expensive to maintain than a monocable, but it is doubtful if Italian firms would agree to this.

4. There can be no doubt that in favourable circumstances with a well designed ropeway there is a considerable saving in transport costs over other means of transport; and in many cases it is possible to construct a ropeway over ground over which it would not pay to construct a road railway, etc.

XIII. Method of Erection.

1. After the line has been surveyed, stations sited, and height and position of standards decided on, the work in the stations is started and standards erected.

2. Whenever possible both carrying and hauling ropes and engines are taken to the upper station by tractor, etc. One of the carrying ropes is then unwound from the upper terminal, placed in the standards, tensioned, and used to help in unwinding the other carrying rope, and hauling rope downhill. These latter are then tensioned and erected.

3. Sometimes, however, it is difficult to carry up the heavy carrying ropes and motor. In this case the hauling rope is only

taken up. It is then unwound downhill from the drum, placed in position on the standards, tensioned by a hand winch placed round the terminal wheels, and used to haul up one carrying rope at a time by means of manual power applied to the hauling rope. Subsequently when all these ropes are in position and tensioned, the motor is taken up in parts by means of the ropeway, operated by hand. Carriers loaded with stones on the down rope are used to help the motor up.

4. If there is no need, or if there are any other circumstances which prevent the transport of the ropes on their drums to the upper terminal, the hauling rope is carried up along the intended line by a file of men each carrying a portion of the rope in a small coil. When the hauling rope has been put in position, the carrying ropes are hauled up as already described.

5. The Italians seldom employ mules for carrying up ropes; if tractors cannot be used they prefer men. If, however, mules are employed they are loaded with a small coil. For a 20 mm. rope they would be spaced about 20 metres apart.

6. *Time required for erection.*—The Italian technical officers state that 100 skilled men can erect and complete 2 killometres of light lines in 10 days.

The transport and erection of the standards is the most difficult part of the work. This and the erection of the terminal stations takes about six days. The ropes can be laid and tensioned in another four days.

XIV.—Author's Note.

The Author is indebted to Lieut.-Col. Winsloe, C. M. G. D.S.O., R. E., and Major E.C. Sandes, D.S. O., M. C., R. E., for certain notes on English practice and for descriptions of the Shropshire Mines Ropeway Ministerley, and Dorada Ropeway, and to Kempe's Engineer's Year Book for 1920 for certain of the calculations and some extracts.

The following firms have very kindly supplied information to Lieut.-Col. Winsloe, Major Sandes or to the Author :—

Messrs. Ropeways, Ltd., of Eldon St., House Finsbury Circus, London.

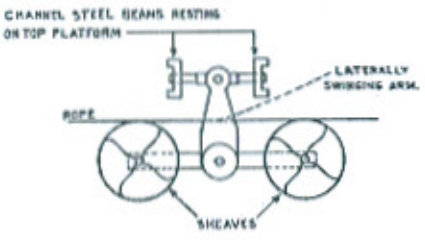
Messrs. British Ropeways of 34 Fenchurch St., London.

Messrs. Luigi Spadaccini of Milan.

Messrs. Ceretti Tanfani of Milan.

Messrs. Badoni Bellani and Benazzoli of Lecco and Milan.

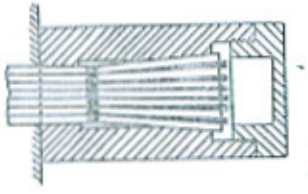
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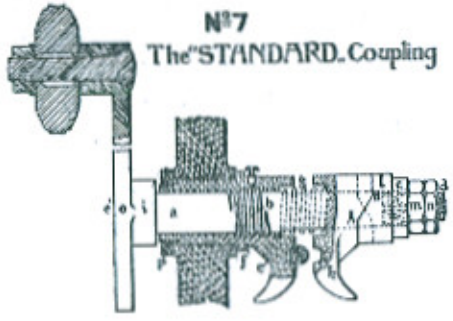
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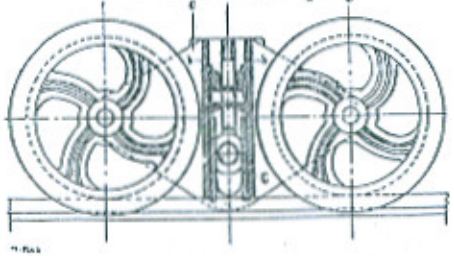
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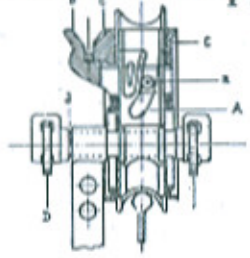
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The "STANDARD" Coupling



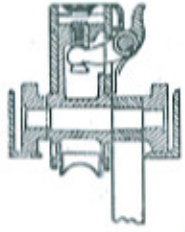
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The "IDEAL" Coupling



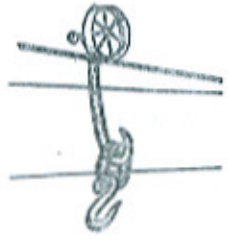
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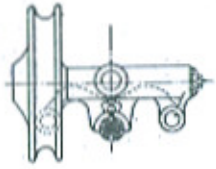
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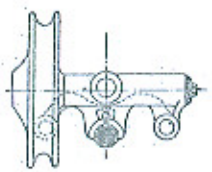
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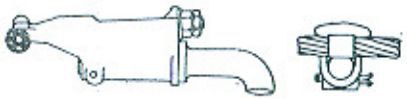
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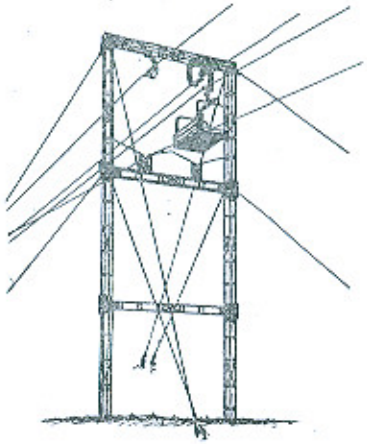
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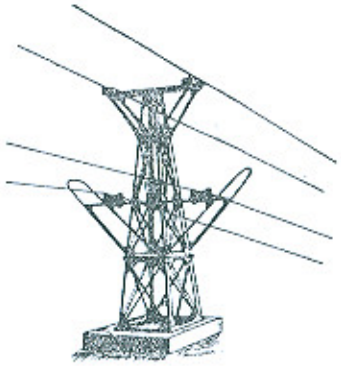
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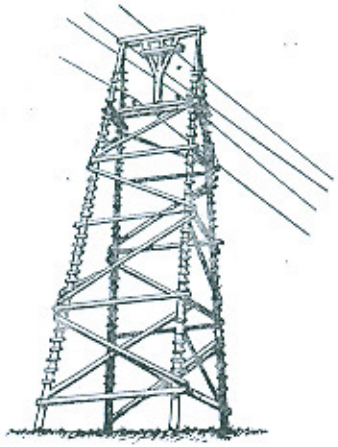
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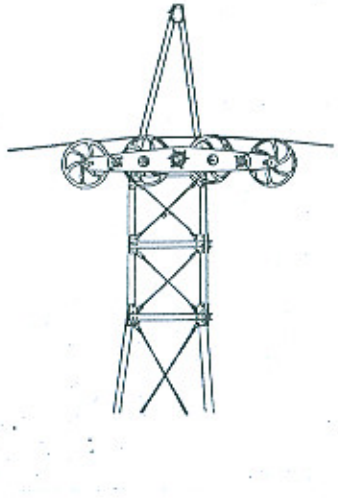
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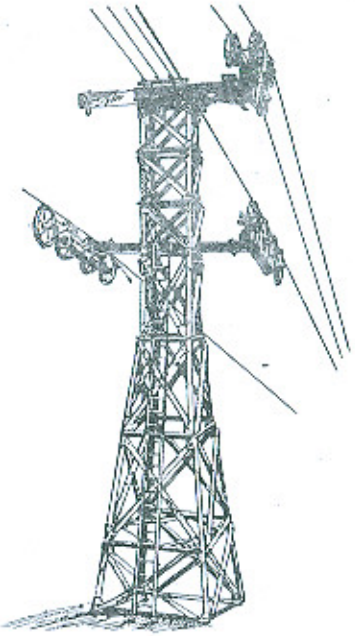
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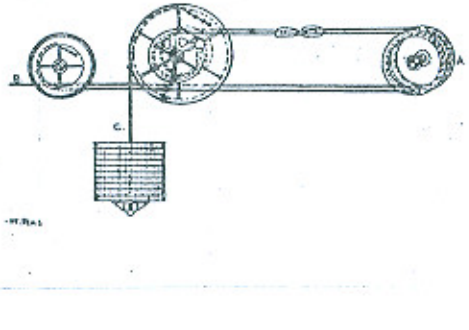
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DISCUSSION.

LIEUTENANT-COLONEL A. S. HOLME said that in the absence of Major Budden in America, he had been asked to introduce Major Budden's paper on Aerial Ropeways.

Ropeways had not, as yet, made much headway in the Punjab. The main object that they fulfilled was the economical transport of goods over ground that was too steep for the construction of a road, or across gaps that it would be very costly to bridge. An essential condition to their success was a continuous traffic of goods for a considerable length of time, not fluctuating from day to day.

Permanent ropeways were eminently suited for forest work in the hills, provided there was no more economical method of handling the timber, such as sliding or floating it. The monocable line from Patriata to Charchan, near Murree, was an instance in point. It was worked during the cold weather, and he believed, answered very well.

For quarry work a ropeway would be found to answer if there were difficulties in laying a tramway, owing to broken country or very steep gradients.

A temporary ropeway would come in useful in many kinds of large engineering works, such as a large dam, or bridges, particularly in mountainous country.

In their own work in the P. W. D. he saw little prospect of their being called upon to construct ropeways of any but the simplest kinds.

The construction of a ropeway of any considerable size or carrying capacity was a matter for experts. There were so many details to be considered that it would best to leave the alignment and erection of a line entirely in the hands of a firm that specialised in this class of work.

British firms usually recommended a monocable, with an ordinary stranded steel rope, as being cheaper and more economical to work. They had specialised in this type of ropeway for years, and had brought every detail as near perfection as possible, and were inclined to look askance at other types.

Continental firms, on the other hand, made a speciality of bicables, and though they admitted that these were more costly in the first instance, they maintained that they were more economical in the long run.

As members saw from Major Budden's paper, there was some difference in opinion in the past among makers as to the life of a wire rope. The general tendency was for makers to give a maximum life to their own system and a minimum life to rival systems.

Taking the paper as it stood, a reference was made on page 38 (§ 34) to a type of grip seen in an Austrian installation, shown in sketch 14. By an oversight this sketch was omitted.

Sketch 13 was hardly clear enough to be intelligible.

At the end of § 10, on page 39, reference was made to a balance beam shown in sketch 2. This evidently was a mistake for sketch 1 or else sketch 18.

On page 40, § 8, a formula was given for working out the necessary power for driving a ropeway. This formula appeared to be wrong ; and, in any case, as it depended upon two unknown co-efficients of friction, it would be best to leave the calculation for the motive power to the erecting firm.

On page 42, sub-head IX, the author referred to an automatic dumping arrangement of a monocable installation at Tredegar. They were referred to sketch 19, but it showed something very different.

Sketch 21, referred to on page 42, sub-head X 2 showed two illustrations. The left hand one conveyed nothing whatever to his mind.

LIEUTENANT-COLONEL B. C. BATTYE pointed out that few engineers in this country had yet appreciated the extraordinary usefulness of steel wire rope. He had been sent up to G. H. Q. towards the end of the war to deal specially with the problem of transportation in front of the light railways. After considering many different forms of transportation it had been decided to purchase not less than 150 miles of portable ropeways.

An interesting example of the general usefulness of steel wire rope occurred during the construction of the Simla hydro-electric scheme where a single span of 2,000 feet enabled them to deliver surki from the top of a hill to the reservoir site instead of being carried round on mule's back, along a hill road 3 miles long. The steel wire rope used for this span was afterwards used for staying transmission line poles, so that the whole scheme cost practically nothing and saved a large sum of money. The bags of surki were slid down on wooden blocks, which were carried up at the end of the day by a couple of coolies. Quotations had recently been obtained from two Italian firms for a steel wire ropeway for the transportation of 10 ton loads over the range of hills, 2,000 feet high, through which the tunnel in the main Sutlej Project would run. It was found however that an ordinary mine haulage and 2′ 6″ gauge track would prove cheaper. He was of opinion that the difference between British and Italian practice with regard to the use of a single or double system was largely due to the difference in the type of country in which these two systems had been developed. The British system was

very satisfactory for a large number of small loads in undulating country whereas the monocable system was originally developed in the Alps, and was best suited for rough mountainous country and heavy loads, like guns, etc.

It was a great pity Mr. Gibson was not present to give the meeting some information with regard to the new forest ropeway now contemplated to connect Tara Devi with Rampur-Bushahr.

MR. W. P. SANGSTER in closing the discussion said that a cursory perusal of this paper led one to assume that an aerial ropeway was a very elaborate costly and troublesome means of transport. A glance at the plates illustrating the paper tended to confirm that assumption. He only wished to say that this useful means of transport could be used in much more simplified form. They had them on many of their canal weirs, and they had had occasion to use one in connection with the construction of the Malakand Tunnel to convey tools and materials from the Central Workshop to the tunnel tail. For their standards they used trees felled from canal plantations. They got a discarded cable from the canal headworks and the rest of the ropeway was made up locally more by rule of thumb than by calculation. The hauling rope was worked by a small 6 H. P. electric motor.

CORRESPONDENCE.

Major Budden wrote that it was regretted that some of the drawings were not as clear as they should have been, partly because the author had to leave India before the drawings had been completed and so was not able to check them, and partly because too much ink had been used in some cases in the reproduction. There was very little, if any, useful literature on the subject of ropeways and much of the available up-to-date knowledge could only be found with the firms who specialised in this work. Members should not, however, think that there was anything very complicated in building or running a simple ropeway for transporting material between two points with no, or few, intermediate supports. The calculations necessary in such cases could be made by any one with an engineering training. But in the case of a longer ropeway, it was advisable to have expert advice in order to obtain the best results ; otherwise money might be wasted in high capital expenditure and high running costs during operation.

Italian firms had experimented with portable installations of one kilometre length with maximum spans of 150—200 metres and loads of 50—60 kilos. The whole of such an installation seen by the author, was intended for transportation by motor lorry and erection within a few hours.

It was difficult within the limits of a paper, to go much into detail or to supply sufficient illustrations of the various parts which went to make up a ropeway and this paper was only intended to describe the general details of a ropeway and to show what had been accomplished in other parts of the words.

PROPOSED SIMLA-NARKANDA ROPEWAY.

BRIEF NOTE BY F. MIDGLEY, ENGINEER-IN-CHARGE.

Name of firm undertaking survey:
Messrs. British Ropeway Eng. Co., Ltd.,
34, Fenchurch St., London, E. C. 3.

Agents:
Gillanders Arbuthnot & Co., Calcutta.

Type of ropeway decided upon:
Monocable.

Details of capacity loads and power to be used:

Capacity.

The total estimated amount of traffic is 22,000 tons per annum, of which about one-half goes in each direction, *i.e.*, to and from Simla to Narkanda.

Total number of working days per annum=220 at 10 hours per day, or 2,200 working hours per annum.

Hourly capacity of ropeway = 10 tons per hour, 5 tons per hour each way to and from Simla. Assuming that the traffic will probably double itself in 20 years, provision should be made accordingly, and the ropeway will be designed for an ultimate capacity of 10 tons per hour in each direction or 20 tons per hour in both directions. The carriers and sheave mounts for trestles, rope, etc., required, will be designed in the first instance for an hourly capacity of 5 tons in each direction and all the main structures and heavy gearing for 10 tons per hour in each direction. It is estimated that after 5 years the ropes will require renewing, the new rope and sheave mounts then required will be designed for 10 tons per hour in each direction. The number of carriers may be increased according to the demands of the traffic.

Maximum nett loads=5 cwts.

Spacing of loads=270 yards for 10 tons per hour.

Speed of ropeway=180 yards per minute.

Occasional nett loads of 10 cwts. may be carried, provided double-carriers are used.

Power.

The ropeway will be driven from four different stations. The total B. H. P. of the engines will be 230.

Length of ropeway.

In plan the horizontal length of the ropeway will be 29·8 miles from Tara Devi to Narkanda (39th mile on H. T. Road).

Estimated cost.

(Rs. 16=£ 1).

		Rs.
Cost of ropeway material—		
C. I. F. Indian Port=£ 75,575	..	12,09,200
Freight on material to site ..	..	1,78,200
Cost of erection ..	..	450,000
Contingencies ..	..	1,83,740
Buildings ..	..	2,50,000
Grand Total	..	22,71,140

Estimated return on capital.

		Rs.
(*a*) Depreciation per annum—		
Rope 5 years=£ 4,545 ..	..	72,720
Other ropeway material=£ 1,884	..	30,144
Buildings ..	..	9,000
Total ..	..	1,11,864

		Rs.
(*b*) Annual running expenses—		
Labour and maintenance staff	..	69,120
Lubrication ..	..	2,200
Fuel ..	..	17,600
(*c*) Loss of interest at 4% on Capital of Rs. 25 lakhs spread over 5 years	..	20,000
Total Annual Expenditure	..	2,20,184

The present cost of transport by mules between Simla and Narkanda averages about 1 anna per maund per mile. To eliminate all competition, the ropeway transport charge should not exceed ½ anna per maund per mile. Working on this basis for revenue, the total earnings of the ropeway per annum should average 1/32×55/2×22,000×29·8=Rs. 5,67,000 on the present estimate of traffic volume.

The nett profit=Rs. 567,000 – Rs. 2,20,184=Rs. 3,46,816.

This represents a return of 13·9% on a capital of Rs. 25 lakhs.

Goods despatched by ropeway from Tara Devi would be delivered in Narkanda within 6 hours of despatch at a cost of about 15 annas per maund.

As the volume of traffic increases the returns on the capital would increase almost in proportion.

Other Ropeways in India.

Until recently, nothing more than a few ferry ropeways had been tried in India. In 1910 the Kanandevan Produce Company built a monocable ropeway in High Range (Travancore). In a total length of $3\frac{1}{4}$ miles it drops through 6,100 feet, and inspite of an average grade of one in three has been running successfully.

Khyber monocable ropeway which is provably one of the largest in the world, is the first successful attempt on a large scale in India. Between Jamrud and Landikhana it is $19\frac{1}{2}$ miles long. In the first 6 miles it rises 900 feet, then in $1\frac{3}{4}$ miles it drops 140 feet to Ali Masjid. From here to Landikotal, a distance of $9\frac{1}{2}$ miles, there is steady rise of 1,160 feet and finally a rapid drop of 900 feet in $2\frac{1}{4}$ miles to Landikhana.

The success of the Khyber ropeway gives reason to believe that ropeways, if sufficiently encouraged, should altogether revolutionise the transport difficulties across 4000 miles of Indian Frontier where owing to engineering difficulties and prohibitive cost railways are out of the question.

General utility ropeway.

General utility, commonly known as the G. U. Ropeway belongs to the monocable class.

A length of $3\frac{3}{4}$ miles has been erected between Kingsland and Shobden (England) and is used to carry timber.

Since July 1919, 77 miles of this type has been received in India out of which two stations were supplied for Kang Ghat forest ropeway a part incorporated in the Khyber Ropeway, and sixteen miles reserved by the Military Works.

Specification.

A. System—Monocable.

B. Normal spacing of supports (trestles) over level ground is one hundred yards and generally averages 15 and 18 trestles per mile in hilly and flat country respectively.

C. Height of supports (trestles) above ground, in flat countries 22 feet at normal spacing, in hilly country the trestles may vary from 9 feet to 130 feet (No. 2 Section Khyber Ropeway which is $3\frac{1}{4}$ miles long there are 44 trestles of an average height of 28 feet the lowest being 9 feet (Peak) and the highest 58 feet and two of 50 feet each).

D. Horizontal distance between ropes—6 feet $6\frac{3}{4}$ inches.

E. Spacing of carrier—55 yards

F. Load per carrier—5 cwt.

G. Length of normal operating section 3 miles (Length of a drive (section) may perhaps be only 1 mile in bad country, whereas in easy country it may be as much as 5 miles).

H. Engine Power—30 to 40 H. P. Patrol Paraffin Engines.

J. Weight of equipment per mile approximately—30 ton.

K. Weight of heaviest part (excluding Crossley Engines which are 54 cwt. each)—3 cwt.

L. Speed of rope—120 yards per minute.

M. Rope Tension—4 tons.

N. Sag under load—(Tare—Load=6 Cwt.) 7 feet in 100 yards span approximate.