WIRE ROPE TRAMWAYS,

Quarry Cable Hoists

AND

POWER TRANSMISSIONS.

THE TRENTON IRON CO.,

TRENTON, NEW JERSEY, U.S.A.

1890.

WIRE ROPE TRAMWAYS,

With Special Reference to

THE BLEICHERT PATENT SYSTEM.

ALSO

Single Moving-Rope Tramways,

Quarry Cable Hoists

AND

Transmission of Power,

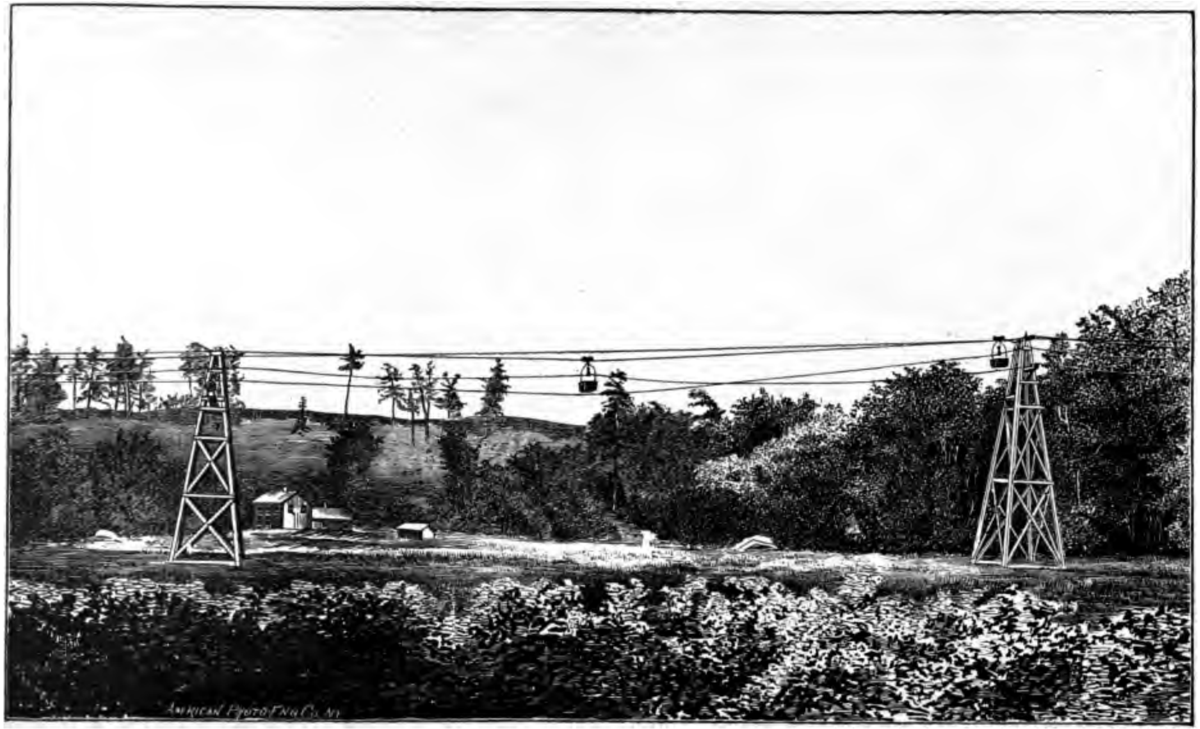
BY

E. GYBBON SPILSBURY.

THE TRENTON IRON CO.,
TRENTON, N. J.

COOPER, HEWITT & CO., 17 BURLING SLIP,
NEW YORK.

1890.



Wire Rope Tramway (BLEICHERT SYSTEM), built by THE TRENTON IRON COMPANY, of Trenton, New Jersey, for the Split Rock Cable Road Company, of Syracuse, New York. Length of line, 3⅛ miles; daily capacity, 750 tons. View of line at 46 foot support. *(From a Photograph.)*

Wire Rope Tramways.

Wire Rope Tramways, as a means of cheap transportation, are too well known already to require any long dissertation on their advantages. As feeders to established systems of railroad or water communication, their low cost of construction through countries where, from the rugged contour of the surface, ordinary railroad, or even wagon-road building would be scarcely practicable, except with long and costly detours, has always made them very attractive to the miner and quarryman, to whose use in this country they have been heretofore almost exclusively confined. The earliest tramways of this kind which were successfully introduced consisted of a single, moving, endless rope, from which the loads were suspended. In the system of Hodgson the buckets or carriers are attached to saddles which ride on the rope, but can be separated from it. In the modification of Hallidie, the carriers are attached permanently to the rope. But in each of these systems one and the same rope both supports and moves the load.

This fact is really the reason that aerial transportation has hitherto not become general in the United States. Lines constructed with the single moving rope, while very efficient for certain purposes, are not available for general use as a means of transportation, because of their limited capacity for carrying individual loads, which in no case can exceed 300 pounds, and in practice have been much smaller. The original Hodgson patent tramway and its modification by Hallidie are the ones chiefly used hitherto in this country. In Europe, however, while these "single" rope lines were also first in vogue, the "double" rope system has of late years almost entirely supplanted them, and has established itself, as a general means of transportation, to an extent we have hardly yet dreamt of.

Railroad companies have adopted these lines as regular feeders to their main roads, and laws have been promulgated in different European countries regulating their construction and traffic, the same as for ordinary railroads. This extension of their application is due principally, if not entirely, to the perfection attained under the Bleichert system. The chief advantages this system presents over all others are as follows:

1st.—While the individual loads to be carried either by the Hodgson or Hallidie lines should, for convenience and economy, preferably not exceed 150 pounds, and are, in fact, seldom over 100 pounds, the lines of the Bleichert system are adaptable to individual loads up to 1,000 pounds each, and in special cases even heavier loads have been carried.

2d.—All single rope systems of tramways, where the moving rope carries the load, must necessarily move slowly, otherwise there is great danger that the rope may jump out of the carrying sheaves. These carrying sheaves are very shallow, so as to permit the passage over them of the saddle or clip. The dropping of the rope from the supporting sheaves has always been a source of more or less trouble and expense in operating these lines. In the Bleichert system this trouble never occurs, since the stationary carrying cable has no tendency to leave the saddle in which it is carried. This being the case, there is no difficulty in moving the cars of these lines at a speed of three or four miles an hour.

3d.—One of the chief advantages of the Bleichert tramways over all others consists in their capability of surmounting any grade.

In the Hodgson system of single moving-rope tramways, no grades in the rope are permissible steeper than 1 in 3½. In fact, 1 in 4 is really about the limit. On steeper grades there is great danger of the load slipping on the rope. To obviate this danger the Hallidie system employs a clip which fastens the bucket permanently to the rope. While this corrects the danger of slipping, it gives rise to the further and still greater objection that the buckets must be both loaded and unloaded while moving, since they cannot be stopped without stopping the whole line.

In the Bleichert system both these objections are perfectly obviated.

Any grade can easily be surmounted, provided the contour of the ground is such that the inclination of the carrying cables is not steeper than 1 in 1. The inclination of these cables does not necessarily follow the contour of the ground in all cases. For instance, in crossing valleys and streams the Bleichert system permits the use of long single spans which, in the case of the single moving-rope tramways, would be impracticable. Again, a precipitous rise in the ground presents no insuperable difficulties, since the curves can usually be laid out so as to bring the inclination of the carrying cables within the proper limits. These points are well illustrated in the profiles of the Bleichert lines built by us for the Granite Mountain Mining Co., at Rumsey, Montana, and for the Bi-Metallic Mining Co., at Granite, Montana, cuts of which are shown on the accompanying chart-sheet.

The second objection is obviated by the arrangement that when the car reaches either terminal, or any switch or turnout on the line, it can be automatically disconnected and run off to any point required for loading and discharging. The Bleichert patent system is also the only one which permits the introduction at any point on the line of movable or temporary switches or terminals, without the erection of special structures for their support.

4th.—The cost of both construction and maintenance is greatly increased for "single moving-rope tramways" by the use of spans longer than 100 feet, or the occurrence of very steep grades. Even if only one such span, or one such grade is present in a whole line, it becomes necessary to make the ENTIRE DOUBLE LENGTH of moving rope strong enough for the special strain due to that one spot, over which in its endless travel every part of the rope must pass; and this necessary increase in the size of the rope affects the dimensions of the supports, sheaves and other fixtures throughout the line, thus requiring a general increase of cost, nearly as great as if all the spans were equally long or all the grades equally heavy. The wear of the rope is also increased by reason of its greater diameter and the more unfavorable conditions of the catenary curve, or "sag," on long spans and steep grades, and these sources of increased cost of maintenance affect every part of the rope.

Now, in the Bleichert system of tramways, the carrying cable, being stationary, can be locally graduated to the strains it has to bear.

The cable for the empty cars does not, of course, require to be as strong as the cable for the loaded cars, and it is therefore made only strong enough for the work it has to perform. In like manner, if one or more long spans occur in the line, it is not necessary that the whole cable should be made strong enough to bear the extra strain at this one point; on the contrary, it is sufficient to so strengthen only the portions exposed to this extra strain. By means of our patent couplings this is easily practicable. On very long steep grades also, where the cable at the head of the incline must be able to bear not only the ordinary working strain due to the cars, but must also sustain the whole weight of the cable on the incline, this is effected, in the Bleichert system, by making the cable in sections of gradually diminishing area, and put together with our patent couplings. In this way great economy in the total weight of the cables is effected. A further advantage is, that the traction rope used, instead of being loaded down by the cars, as in other systems, is itself carried and supported by them, thus lessening greatly the wear on this rope.

The ordinary spans we use in the construction of these lines are from 150 to 200 feet, but there is no real objection to spans of 500 to 600 feet. Many lines built within the last few years have spans up to 1500 feet. The accompanying view (on opposite page), taken from a photograph, represents one of these long spans. It is 1,000 feet in the clear, and forms part of a line nearly seven miles in length, built for the transportation of 250 tons of iron ore per day. This line has been in successful operation for many years.

As a result of all the improvements made during the last ten years' practice, in the details of the Bleichert tramways, the wear and tear and expense of operating our system of lines has been reduced to a minimum, and we are able to compete most favorably even with well equipped surface railroads, in the cost of transportation.

There exists in nature hardly a supposable difficulty or obstacle which would bar the introduction of this system of transportation; in fact, in many cases, it is the only one that can be used. While this is eminently true where the contour of the ground is much broken up and long spans are necessary, the Bleichert system possesses economical advantages even where there are few or no natural obstacles to the building of any kind of road. The service is regular;

stoppages for repairs are rare; no interruptions due either to atmospheric influences or storms are liable to occur; the line being elevated, the service is entirely free from interference with surface traffic; wear and tear and expense of operating are relatively very low; terminals can be so arranged that the material transported can be delivered at the exact spot where it is needed, thus saving all expense of re-handling. This could not be done with a surface road, since, even if the cars could be brought close to the point at which the material is required, there would still be a further expense for unloading, irrespective of the cost of switching and hauling them.

These facts prove the advantages of a wire rope tramway of the Bleichert system over short railroad communication, even under the simplest conditions and where the surface of the ground would offer no difficulties to the construction of the latter.

These lines are constructed in a very substantial manner, with two carrying cables of our special manufacture and an endless traction rope. The cars are fitted with our patent grips, of which we manufacture two kinds—friction and lug grips. Where the grades are moderate the former are employed; in case they are steeper than 1 in 3, the latter are used.

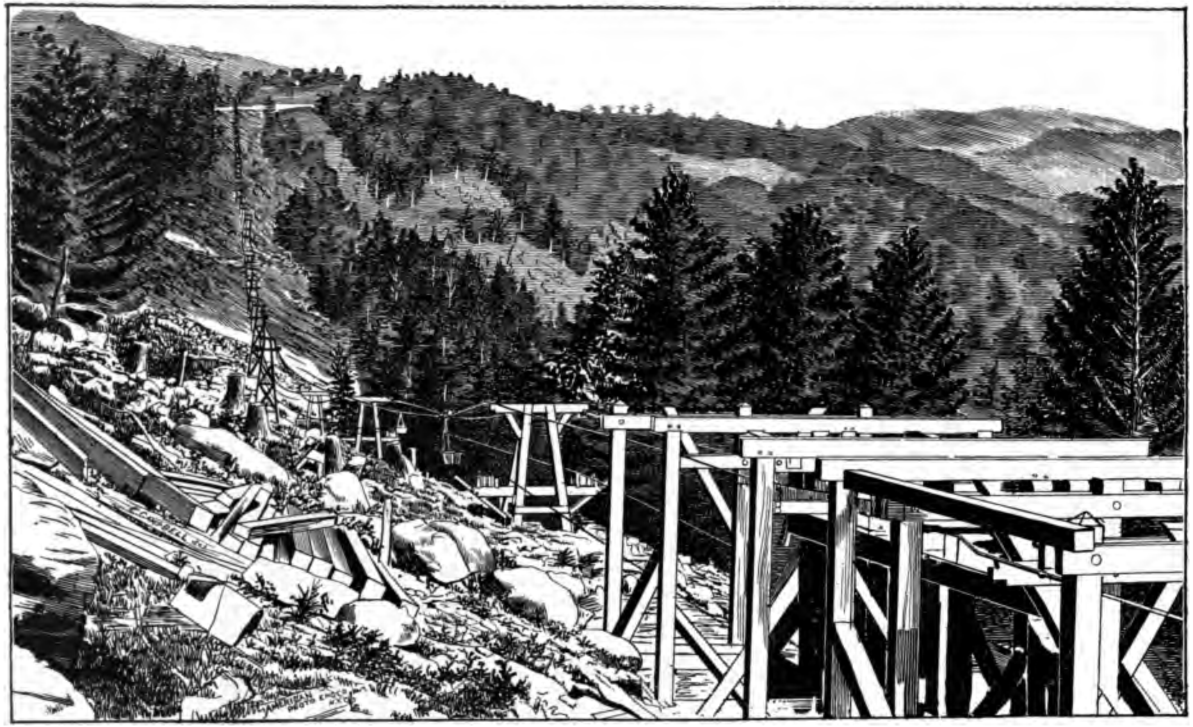
In some cases, where the spans are moderate and the loads to be carried are light, our "special steel" rods may be substituted for the carrying cables. These are joined together with our patent couplings. The cars are hauled by a light, endless traction rope, and fitted with patent friction or lug grips, as the grades may require. Such a line calls for the use of numerous couplings, however, as the steel rods cannot be furnished in lengths of over 50 feet, and its cost does not differ materially from that of a line equipped with the ordinary carrying cables.

For short lines, where the service is light, the single carrying cables may be used, instead of the usual two. In such cases convenient turnouts are arranged along the line, and the trains of cars are spaced equally along the endless traction rope in such a manner that they pass one another at the turnouts. The only advantage possessed by these single track lines is, of course, their comparative cheapness of construction. The cost of operating them is about the same as that of the double track.

In the construction of these tramways every detail has been thoroughly worked out and proved by actual practice. The materials used are of the strongest and best, and the workmanship first-class in every respect. All parts of the machinery are made to standard gauges and are interchangeable, so that repairs can be made promptly and cheaply. Every part of the lines is made as nearly automatic as can be, and thus very little labor is required in operating them. If required, the cars may be weighed, and counted automatically, and can be also raised or lowered at any terminal or station by our automatic hoists, from one level to another, or from one floor to another, without the necessity of any handling. Thus, for instance, goods of any description can be brought at one level into a warehouse or factory, raised or lowered to any other floor, and on arriving on that floor can be conveyed, by means of our suspended rail system, to any point desired before unloading from the car. The same system is most economical for loading vessels from docks or wharves. In a similar manner our system permits the unloading of our car-bodies upon specially arranged trucks in such a manner as to form mining cars, which can then be run into the mine or quarry, loaded at the face of the working, run out to the terminus of the tramway, and shipped again without any re-handling of the material.

The enclosed chart-sheet of detailed parts will give a general idea of a few of the various applications to which this system of tramways is adapted. All these applications are illustrated by lines actually constructed and in constant operation.

Preliminary estimates of cost of construction and expense of operating these lines will be furnished in answer to applications made out on the blank forms attached hereto. Definite estimates can be furnished only after an exact profile of the ground has been made. If preferred, we will undertake to make these surveys and profiles by our own engineers, who are specially acquainted with the requirements of our system. This work will be done at the lowest possible cost.



Wire Rope Tramway (BLEICHERT SYSTEM), built by THE TRENTON IRON COMPANY, of Trenton, New Jersey, for the Bi-Metallic Mining Company, of Granite, Montana. Length of line, 9,750 feet; daily capacity, 200 tons.

(From a Photograph.)

TESTIMONIALS.

[COPY.] OFFICE BI-METALLIC MINING COMPANY,
CLARK, MONTANA, August 12th, 1889.
(PHILIPSBURG P. O.)

E. GYBBON SPILSBURY, Esq.,
Managing Director Trenton Iron Co., Trenton, N. J.

Dear Sir: Your letter of July 17th, to President Charles Clark, asking for an expression of opinion concerning the Bleichert Tram system (now in operation between our mine and mill), has been referred to me for reply.

Our line was erected early in the present year, and put in operation May 8th, under the supervision of your engineer, Mr. R. A. Hewitt, and has been running steadily ever since, without any mishaps whatever.

Since starting, we have transported about eighty-five tons of ore per day from the mine, at Granite, to the mill, at Clark, a distance of 9,750 feet, and have also carried up to the mine the greater portion of the supplies used there, running tramway about six hours per day, at an average cost of twenty-two cents per ton. By running tramway for twelve hours per day to its full capacity, we could carry two hundred and forty tons, with practically the same force as is now employed, thus reducing the average cost to from ten to twelve cents per ton.

When the line is carrying its load, it develops sufficient power to run a 9 x 15 Blake Crusher, and crushes all ore raised at the mine.

We have given the tramway a fair trial, and so far it has given entire satisfaction. I can cordially recommend the Bleichert system of tramway, built by your company, to any one requiring a cheap system for the transportation of ore. Yours truly,

JAMES B. RISQUE, Sup't.

[COPY.] POTTSVILLE IRON AND STEEL COMPANY,
POTTSVILLE, PA., May 25th, 1889.

THE TRENTON IRON COMPANY,

Gentlemen: Answering yours 24th inst. The Bleichert Tramway that you built for us is doing very good and satisfactory work. We are carrying forty to fifty tons per day of ashes at present, and could carry, say fifty per cent. more with the same men operating it. We think for situations like our own it is the best mode of carrying away refuse that we know of. You are at liberty to make use of our name as reference.

Respectfully,
WM. ATKINS, Treas'r.

[COPY.] EDGEWATER LIME WORKS,
EDGEWATER, N. J., Sept. 10th, 1889.

TRENTON IRON COMPANY, TRENTON, N. J.

Gentlemen: The Bleichert Tramway has been in operation here about ten months, and has proved itself to be an admirable system for the work we have to do, which is to carry loose slaked lime from the yard down to the barges at the dock. I know of no other system which would do this so well under the circumstances found here.

Yours very truly,
CHAS. F. McKENNA.

[COPY.] THE LAURENTIDE PULP COMPANY (LIMITED),
MONTREAL, CANADA, Nov. 27th, 1889.

Messrs. TRENTON IRON COMPANY, TRENTON, N. J.

Gentlemen: With your tramway we are now handling fifty tons of pulp every ten hours. The tramway runs at the rate of two hundred and fifty feet per minute only, and our experience so far shows that we could easily handle several times more pulp than this at same speed, without the slightest difficulty.

We feel sure, also, that the latter result would not be anywhere near the maximum capacity of the line, but we only speak from actual experience.

When we consider that this tramway takes our product from our wet presses in the mill, carries it across the three channels and intervening islands of the river St. Maurice, the third largest river in Canada, and delivers it 1,500 feet away on the level of our railway siding, and that we do this with three to five horse-power, and the labor of only one additional man, at the very most, we are more than satisfied. If there is any other information you require, we shall be glad to give it. Meantime, we remain,

Yours respectfully,

THE LAURENTIDE PULP CO. (LIMITED).
JOHN FORMAN, Sec'y.

List of BLEICHERT TRAMWAYS contracted for and erected during the year 1889,

By THE TRENTON IRON COMPANY.

FOR WHOM.	LOCALITY.	Material Transported.	Capacity in tons per day of 10 h'rs.	Length of line in feet.	Difference in level between terminals in feet.	Horse-power required.	REMARKS.
Edgewater Lime Works......	Edgewater, N. J....	Lime......	100	360	20	4	
Pottsville Iron & Steel Co....	Pottsville, Pa.......	Cinder....	50	1,100	70	10	The loads are hauled up hill.
Split Rock Cable Road Co...	Syracuse, N. Y.....	Lime rock	750	16,500	239	11½	
Bi-Metallic Mining Co.......	Granite, Mont......	Silver ore.	200	9,750	1,225	Brake used	Line automatic, and develops power sufficient to carry back 50 tons per day and also to run crushers and crush all the ore shipped.
Granite Mountain Mining Co.	Rumsey, Mont.....	" "	200	8,750	1,297	"	Line automatic, and develops power enough to haul back 100 tons per day. For over 2,000 ft. in length of this line the grades are over 1 in 1.
Nowell Gold Mining Co.. ..	Juneau, Alaska.....	Gold ore..	200	11,600	2,135	....	
Laurentide Pulp Co.........	Grande Mére, Can.	Wood pulp	70	1,450	15	4	This line raises the pulp 100 ft. from the lower mill floor and carries it across the Grande Mére Falls of the St. Maurice River.
E. Soler....................	Baracoa, Cuba......	Bananas..	300	12,475	600	Brake used	Automatic. The whole of the descent is in the first three-quarters of a mile of the line. The loads going down this incline operate the balance of the line.
Oregon Gold Mining Co....	Cornucopia, Oregon	Gold ore..	100	5,000	2,000	"	Automatic.
Aspen Public Tramway Co..	Aspen, Colo.........	Silver ore	250	9,850	2,409	"	Automatic.
The Compromise Mining Co	" "	" "	250	3,200	920	"	Automatic Develops sufficient power to operate an elevator at each terminal and at an intermediate station.
Witherbees, Sherman & Co .	Port Henry, N. Y...	Iron "	500	3,668	406	"	Automatic. Develops about 14 horse-power.
Silver Age Mining & Mill'g Co	Idaho Springs, Colo.	Silver "	100	6,240	989	"	Automatic. " " 3 "
Warner's Portland Cement M'f'g Co..............	Warner's, N. Y.....	Clay......	300	1,056	48	4	The loads are hauled up hill.
Keeler, Holcomb & Co	Kelly's Switch, N. M.	Silver ore.	75	7,500	1,850	Brake used	Automatic. Develops about 12 horse-power.
Sunnyside Extension Min'g Co	Ouray, Colo........	Gold "	100	2,800	730	"	Automatic. " " 5½ "

Single Moving-Rope Tramways.

While advocating the use of the Bleichert system for efficient and economical transportation in general, and especially where it is necessary to overcome steep grades and long spans and to carry heavy loads, yet there are many cases where, the grades and the spans being moderate and the service light, the single moving-rope system can be used to advantage.

In this system transportation is effected by an endless moving rope, supported at intervals by pulleys carried by posts or bents. The loads rest upon and travel with the rope, the loaded carriages by this method being conveyed to the desired point by one side of

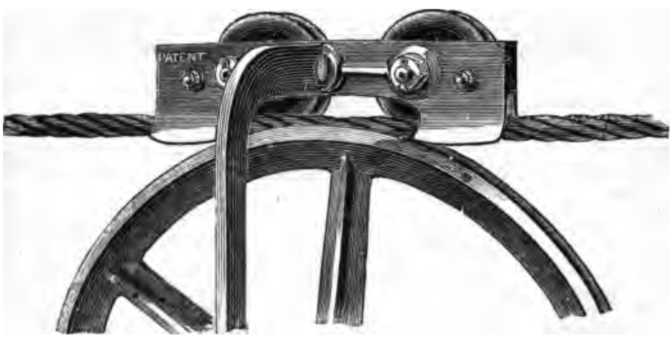


PLATE I.—Box-Head Carriage for Single Moving-Rope Tramways.

the moving rope, while the empty carriers are returned by the opposite side. The rope at the terminals passes around large wheels or sheaves, power being applied at one terminus sufficient to drive the rope at a speed of about five miles an hour.

The material to be transported is carried in buckets suspended from the rope by an elbow-bent hanger or goose-neck, which brings the center of gravity of the load directly under the rope, while the shape of the hanger enables it to pass the supports. The end of the hanger is fitted into what is known as the box-head (Plate I). This consists of two malleable iron pieces of similar form bolted together. At each end there are inserted two pieces of rubber, termed "bearing blocks." The latter, resting upon the rope, are depended upon to prevent the slipping of the loads in ascending grades or passing pulleys. The flared ends or wings at the extremities of the box-head are for the purpose of enabling the box-head to pass the carrying wheels. These wheels are made of various sizes. The depth of the groove is dependent upon the size of rope employed, being so proportioned as to cause the least possible obstruction to the box-head in passing over the wheel. The posts supporting the wheels are ordinarily made of timber, and, in that case, consist of four uprights, slightly tapered on all sides and stiffened with latticing. Iron, however, may be used with advantage under certain circumstances and in certain localities. These supports are ordinarily placed about 100 feet apart, although spans as great as 300 feet have been employed.

The buckets or boxes for coal, clay or minerals, are made cylindrical in outline, and may be proportioned to carry from 50 to 150 pounds of material (Plate II., Fig. 1). The bucket is attached to the hanger by means of a stirrup rod, pivoted to the bucket. In order to facilitate the dumping, the pivot centers are placed slightly below the center of gravity of the bucket. In some instances the buckets are fitted with wheels, to admit of their being moved along the ways of a mine, quarry or clay pit (Plate II., Fig. 2). For the transportation of special goods, other forms of carriers are adopted.

By reference to Plate I. it will be noticed that the box-head is provided with two grooved wheels. The purpose of these wheels is to lift the box-head and bucket free of the rope when it becomes necessary to load or unload. This operation is performed by having at the terminal stations a fixed rail, so placed as to receive the small grooved wheels as they reach the terminal points This arrangement is shown in Plate II., Fig. 3. It is evident that the box-head, in order to be free of the rope, must either run up an inclined terminal rail or must be deposited on the rail by depressing the rope at the point where it meets the terminal rail. The former is the preferable plan and the one generally adopted. The buckets are thus, in either case, suspended from a fixed rail, which may be laid to convenient points of loading or unloading, while the motion of the rope continues unin-

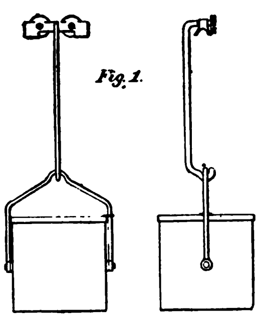


Fig. 1.

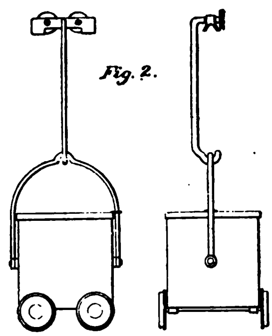


Fig. 2.

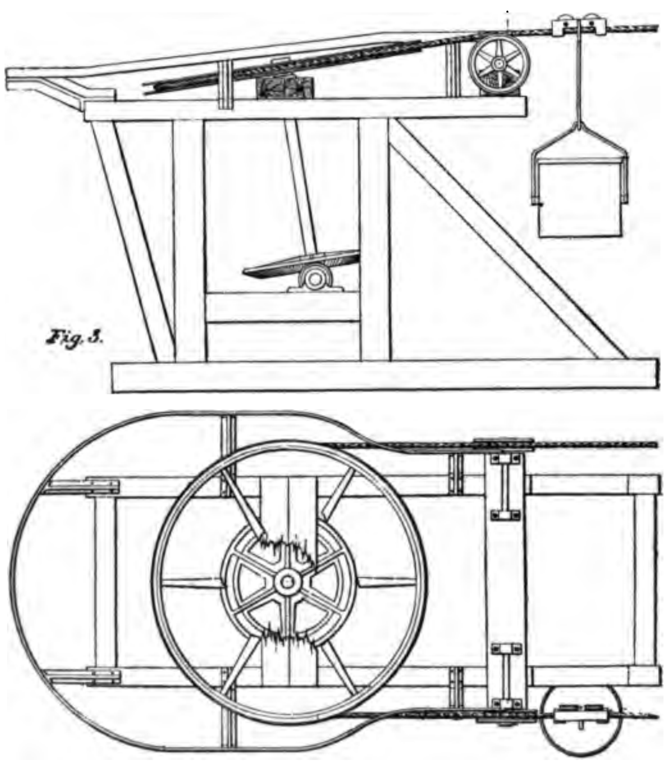


Fig. 3.

PLATE II.—Details; Single Moving-Rope System.

terrupted. Since the level of the rope varies with its tension and the weight of the buckets, it is necessary to locate carrying wheels at the extremities of the rails.

The rope at the power terminus passes round a driving sheave (Plate II., Fig. 3). For lines exceeding half a mile in length vertical drivers are preferable, the particular details being suited to the requirements of the lines.

In order to enable the rope to accommodate itself to a variable tractive force, it is necessary to adopt some expedient for compensating this variation. The most efficient arrangement is that of locating the driving and tightening drums at the same terminal, because the slack rope paying off the driving sheave can then be taken up with ease, since the tension on the rope is least on the outgoing and greatest on the incoming side. The tightening drum is, ordinarily, merely a sheave resting upon a carriage. The axle of the sheave has attached at each side the ends of U-shaped strap, constructed so as to clear the rim of the sheave. The strap is fitted with a hook to take the end of a chain which, passing over a wheel into a pit, is attached to a heavy weight.

The original method of passing curves of slight change in direction was to set the carrying or bearing wheels at a slight angle to the vertical, so as to throw the upper part of the rims outward. It was found, however, that very little irregularity in action would cause the rope to leave the groove of the wheels, and for this reason the method has had a very limited application.

For curves of larger angle, according to one system, horizontal wheels are introduced, the load upon reaching the curve being thrown upon a switch rail similar to that described for the terminus. These horizontal wheels are secured to a frame in such a manner that each divides about 10° of the total curve; they are the same as the ordinary carrying wheels, but in this construction are set horizontally.

The arrangement for the outer curve is comparatively simple, as the hanger passes around outside the rope, while the curve wheels are inside. For this reason it is only necessary to bend the switch rail around the outside of the wheels. With the inside curve the horizontal wheels come between the rope and the hanger bar; consequently, the rail has to be curved so as to clear the box-head away from the rope and bring it out behind the rim of the wheels, down again to the rope.

In order that the action of the box-head, in following the switch rail on a curve, may be automatic, it is necessary that the rail should have a fall of not less than 1 in 15. To obtain this slope the outgoing side of the rope must be depressed sufficiently to furnish the necessary fall to the switch rail. For this purpose a depressing wheel is placed over the rope near the last horizontal curve wheel. The action of the curve is then as follows: the box-head and bucket advance with the rope, the little side wheels run on the rail and along it down the incline on the rope again.

This depressing wheel has proved itself in many cases to be highly detrimental to the accurate working of curves; aside from this the operation of the above curve expedient has not proved itself entirely satisfactory. For this reason The Trenton Iron Company have adopted several new curve devices, suitable to various requirements. Their action is positive and automatic, and their introduction greatly simplifies the problem of curvature.

In locations where the line of tramway crosses a valley and the change from descent to ascent is sudden, it has been found necessary to introduce what is termed a "holding down" apparatus. The device usually applied is simple and inexpensive in construction.

Now, a few words as to the general action of the plant when in operation. The power sheave being started, the line of rope begins to move almost simultaneously along its entire length; the box-heads, with loaded buckets attached, are allowed to drop upon the rope and are carried to the discharge terminal, when the box-head wheels are run upon the terminal rail and the bucket is carried automatically down to the unloading point. Angles either slight or sharp are passed and inclines as heavy as 1 in 4 ascended. After unloading, the box-head and empty bucket are run upon the opposite side of the rope and returned to the loading point.

The question is often asked as to what would be the result if the rope should happen to break. The view is sometimes advanced that, in such an event, all the boxes on the line would fall to the ground, but this is evidently not the case. One or two spans only, located near the point of break, would be affected to such an extent, while for the remainder of the line a gradually diminishing effect would be produced, until the degree of slackness would become imperceptible.

Preliminary estimates of cost of construction and expense of operating these lines will be furnished in response to applications made out on the blank forms attached hereto. Definite estimates can be furnished only after an exact profile of the ground has been made. If preferred, we will undertake to make these surveys and profiles by our own engineers, who are specially acquainted with the requirements of the system. This work will be done at the lowest possible cost.

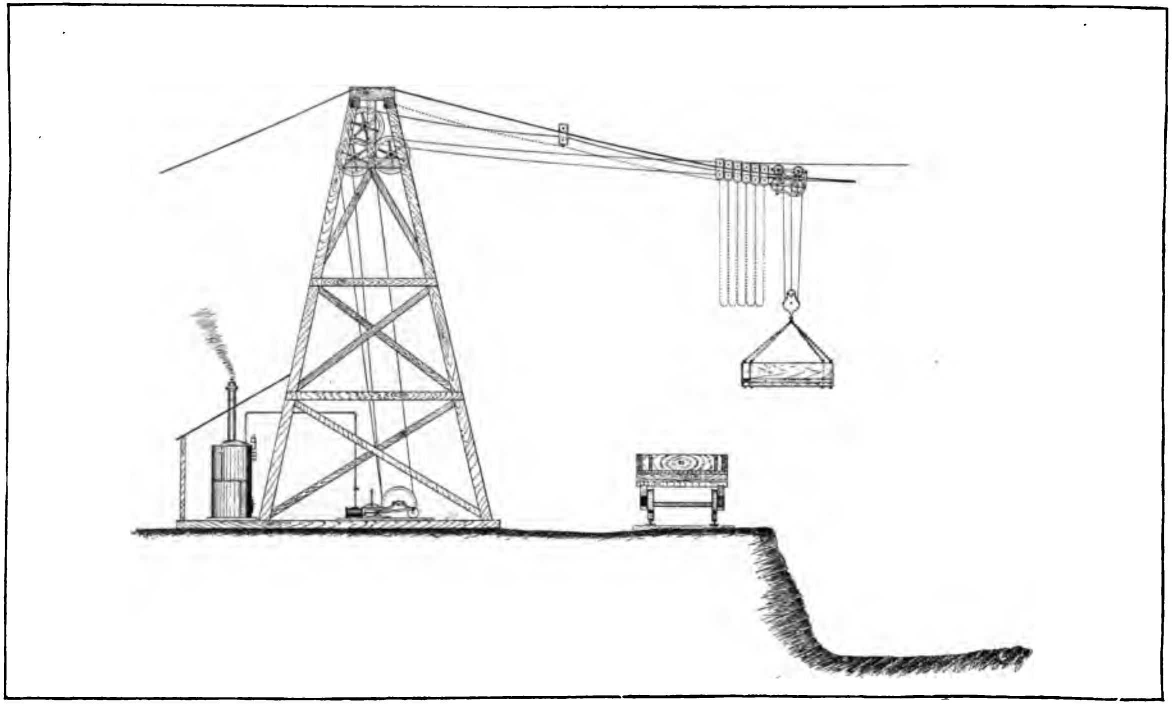
The following are some of the single moving-rope tramways constructed by us:

LIST OF

SINGLE MOVING-ROPE TRAMWAYS

BUILT BY THE AUTHOR.

FOR WHOM.	LOCALITY.	Material Transported.	Capacity in tons per day of 10 hours.	Length of line in feet.
G. H. Nichols & Co.	Capelton, Can.	Copper pyrites	100	4,475
J. P. Clark	Shooter's Hill, Jamaica,	Bananas	30	14,125
Reading Iron Co.	Reading, Pa.	Wrought iron pipe,	100	1,320
Reading Iron Co.	" "	Coal	....	660
Juniata Sand Co.	Lewiston. Pa.	Sand	150	7,920



Endless rope "Quarry Cable Hoist," built by The Trenton Iron Company, of Trenton, New Jersey.

Quarry Cable Hoists.

In quarrying, rock cutting, dam building, and many other operations where it is necessary to hoist and convey large individual loads economically, it frequently happens that the use of the derrick system, by reason of the limited area of its efficiency, is impracticable.

To meet such conditions our Quarry Cable Hoist system is admirably adapted, for it can be efficiently operated in spans up to 1,000 feet, and in lifting individual loads up to fifteen tons.

These hoists are divided into two classes; the "endless rope" and the "inclined." In both of them a carriage, with a block attached, travels upon a suspended cable, which, after passing over a tower or towers, is firmly anchored in the ground at each end. These cables are fitted with turnbuckles to give them the requisite tension, and where they pass over towers are provided, if necessary, with saddles of special design, containing rollers which lessen the strain on the towers and also the wear on the cable.

By means of an endless traction rope, attached to the carriage and wound on a drum, the carriage can be moved forward and backward upon the carrying cable and stopped at any given point.

A hoisting rope, supported by trolleys, is connected with the block, and lifts the load, which can then be conveyed to, and lowered from any point on the line.

Both the traction and the hoisting ropes are operated by an engine specially designed for the purpose, which may be located at either end of the line.

The construction of the "endless rope" hoist is clearly shown by the cut on opposite page.

When the difference in elevation of the terminals is considerable, one of the towers may usually be dispensed with, the carrying cable being anchored directly in the ground. In such cases, where the cable is inclined sufficiently to permit the carriage to run down by

To illustrate: Let us suppose a bar of iron, having a cross-sectional area of one square inch, to move end-long at a rate of two feet per second. If the resistance overcome is, say, 5,000 pounds, work will be performed at the rate of 10,000 foot-pounds per second. But, if we double the velocity of the bar, we shall transmit twice the amount of work with the same strain, or the same work may be produced with only half the former strain; i. e., by a bar having an area of only half a square inch. In a similar manner, if we move the bar with the velocity employed in wire rope transmission, viz., about eighty feet per second, then, while doing the same amount of work, the strain on the bar will be reduced from 5,000 to 125 pounds, and the bar will need a section of only $\frac{1}{40}$ square inch. To use an extreme illustration, we might conceive of a speed at which an iron wire, as fine as a spider's web, would be able to transmit the same amount of work as the original one-inch bar.

By the application of these simple principles the greater part of the force is first converted into velocity, and at the place where the power is required the velocity is changed back into force.

The Rope.

The section of wire rope best suited, under ordinary conditions, for the transmission of power is composed of six strands of seven wires each, laid together about a hempen center. Ropes of twelve and nineteen wires to the strand are also used. They are much more flexible, and may be applied with advantage under conditions which do not allow the use of large transmission wheels, but admit of high speed. They are not as well adapted to stand surface wear, however, on account of the smaller size of the wires.

Both iron and steel wire ropes are employed for the transmission of power, but iron is to be preferred, as it is better adapted to withstand the rapid bending and vibration to which the rope is subject; but special care is necessary in the selection of the material, and only the toughest and best grades of iron should be used. Our extensive experience in the manufacture of wire, covering a period of over thirty years, is a sufficient guarantee of the excellence of the material used in our ropes.

THE DRIVING WHEELS.

The driving wheels (see Figs. 1 and 2) are usually of cast iron, and are made as light as possible consistent with the requisite strength. Wheels with wrought iron spokes have been used, but the increased cost of these renders their application limited to exceptional cases, where it is important to have wheels as light as possible. Various materials have been used for the filling, such as tarred oakum, jute yarn, hard wood, India rubber and leather. The filling which gives the best satisfaction, however, for transmission purposes, consists of

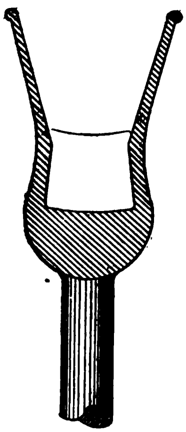


Fig. 1.

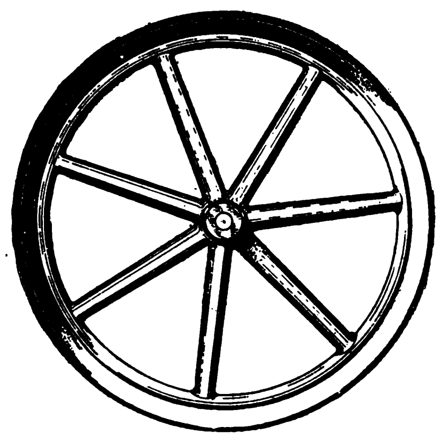


Fig. 2.

segments of leather and blocks of India rubber, soaked in tar and packed alternately in the groove, and then turned out to a true surface. Where the rope is subject to considerable lateral vibration, the flanges are sometimes lined with sole leather by riveting; but such cases are rare.

INTERMEDIATE SUPPORTS.

In long spans, intermediate supporting wheels (see Figs. 3 and 4) are frequently used, and it is usually sufficient to support only the slack or following side of the rope; but whatever the distance that the power is transmitted, the driving side of the rope will require a less number of supports than the slack side. The sheaves supporting the driving side, however, should in all cases be of equal diameter with the driving wheels; for it makes no difference whether the rope laps half way round or only quarter way round these sheaves, the tension induced by bending is the same. With the slack side, however, smaller wheels may be used, owing to the fact that there is less tension on this side, and the rope is therefore better able to stand the additional tension due to the bending; but the diameter of the supporting sheaves in this case should not be less than one-half that of the driving sheaves.

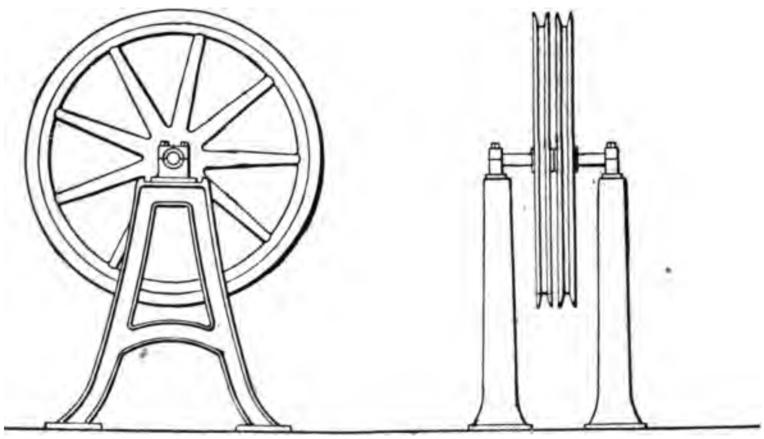


Fig. 3. Fig. 4.

The system of carrying sheaves may generally be replaced to advantage by that of intermediate stations. The rope thus, instead of running the whole length of the transmission, runs only from one station to the other; and it is advisable to make the stations equidistant, so that a rope may be kept on hand, ready spliced, to put on the wheels of any span, should its rope give out. This method is greatly to be preferred where there is sometimes a jerking motion to the rope, as it prevents sudden movements of this kind from being transmitted over the entire line.

MATHEMATICAL PRINCIPLES INVOLVED.

NOMENCLATURE.

D = diameter of rope, in inches.
δ = diameter of individual wires.
E = modulus of elasticity = for iron 28,500,000.
F = resistance due to journal friction.
g = force of gravity in feet per second = 32.19.
h = deflection of rope at center, when at rest, in feet.
h_1 = deflection of driving side of rope at center, in feet.
h_2 = deflection of following side of rope at center, in feet.
K = force transmitted.
K_1 = force transmitted after allowing for centrifugal force.
k = safe stress per square inch on wires = for iron 25,700 lbs.
k_1 = stress per square inch due to $S_1 = k - k_2$.
k_2 = stress per sq. in. due to bending of wires around sheaves
N = actual horse-power transmitted.
N_0 = gross horse-power transmitted.
N_1 = loss of horse-power due to centrifugal force.
N_2 = loss of horse-power due to journal friction.
n = number of wires in rope.
P = force necessary to overcome journal friction.
Q = applied weight or pressure on wheels.
q = weight of rope per foot = $1.5\ D^2$.
R = radius of wheels in inches, assuming both of same size
r = radius of shaft or axle.
S = Span between axes of wheels, in feet.
s = tension of rope at rest.
s_1 = tension of driving side of rope.
s_2 = tension of following side of rope.
V = number of revolutions of wheels per minute.
v = velocity of rope in feet per second.
W = total weight of rope.
w = weight of wheel and axle.
x = ratio of radius of wheel to diameter of rope.
φ = coefficient of journal friction = .08.

TENSION OF THE ROPE.

Referring to Weisbach, we have,

$$s_1 = 2K = \frac{1100\ N_0}{v}, \dots\dots (1)$$

$$s_2 = K = \frac{550\ N_0}{v}, \dots\dots (2)$$

$$s = 1.5\ K = \frac{825\ N_0}{v}; \dots\dots (3)$$

we also have

$$s_1 = \frac{\pi\delta^2 n}{4} k_1, \dots\dots (4)$$

hence

$$N_0 = \frac{\pi\delta^2 n k_1 v}{4400} = .0003702\ D^2 v k_1; \dots\dots (5)$$

but

$$k_1 = k - k_2, \dots\dots (6)$$

and referring again to Weisbach, we find,

$$k_2 = \frac{E\delta}{2R}.$$

For rope best suited for the transmission of power, we have,

$$\delta = \frac{D}{9},$$

hence

$$k_2 = \frac{ED}{18R}. \dots\dots (7)$$

Combining the above equations, 5, 6 and 7, we have,

$$N_0 = .0003702\ D^2 v\ (k - \frac{ED}{18R}), \dots\dots (8)$$

the ordinary formula for determining the total gross horse-power developed.

In order to arrive at the actual horse-power transmitted it will be necessary to determine the losses due to centrifugal force and journal friction.

The loss due to the resistance of the air is so slight that it may be neglected.

LOSS DUE TO CENTRIFUGAL FORCE.

Referring once more to Weisbach, we find for the measure of centrifugal force,

$$\frac{qv^2}{g},$$

hence

$$S_1 = 2K_1 + \frac{qv^2}{g}, \qquad (9)$$

in which K_1 represents the force transmitted, after allowing for the influence of centrifugal force.

But

$$K_1 = \frac{550\,(N_0 - N_1)}{v}, \qquad (10)$$

and

$$S_1 = \frac{1100\,N_0}{v},$$

from which, after substituting in equation 9 and transposing, we find that the loss due to centrifugal force is

$$N_1 = .0000424\,D^2\,v^3. \qquad (11)$$

LOSS DUE TO JOURNAL FRICTION.

Loss of power from this cause varies directly as the pressure of the journals on the bearings, due to the tensions of the driving and following sides of the rope, and to the weight of the wheels and axles; that is,

$$PR = Fr;$$

but $$F = (s_1 + s_2 + w)\,\varphi = (3K + w)\,\varphi,$$

and $$K = \frac{550\,N_0}{v} \text{ (see equation 2)},$$

hence $$P = \frac{\left(1650\,\frac{N_0}{v} + w\right)\varphi r}{R}.$$

Assuming $\varphi = .08$ and $\dfrac{r}{R} = .03$,

$$P = \left(1650\,\frac{N_0}{v} + w\right).0024, \qquad\qquad (12)$$

and we have for the amount of horse-power absorbed

$$N_2 = \frac{Pv}{550} = .0000045\,(1650\,N_0 + wv). \qquad\qquad (13)$$

The foregoing determination applies only to the driving and driven wheels. At an intermediate station the friction is due principally to the vertical pressure of the weight of the wheels, axles and rope between the two stations, on account of the neutralization of the nearly horizontal tensions. The loss in terms of horse-powers, due to this cause, is expressed by

$$.0000045\,(W + w)\,v.$$

To find the pressure on the bearings at any intermediate station, the simplest method is by construction (Figs. 5 and 6). Make $AB =$

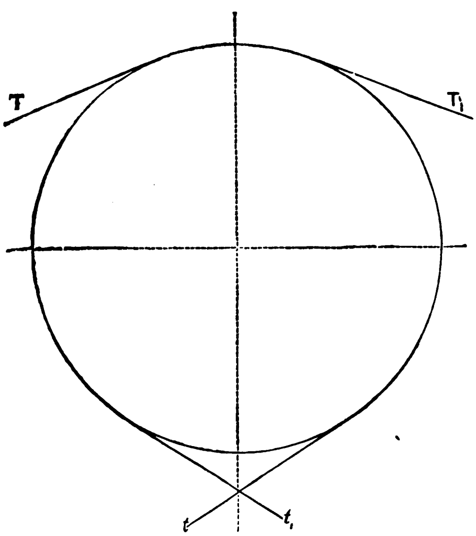


Fig. 5.

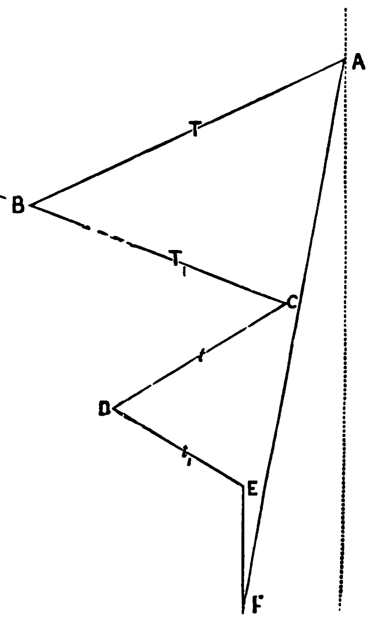


Fig. 6.

and parallel to T; $BC =$ and parallel to T_1; $CD =$ and parallel to t; $DE =$ and parallel to t_1; and EF vertical and $=$ the weight of the wheel and axle. Then the line connecting A and F will give the intensity and direction of the resulting pressure.

Actual Horse-Power Transmitted.

Combining the equations 8, 11 and 13, we obtain for the actual horse-power transmitted

$$N = N_0 - N_1 - N_2 = D^2 v \left[.0003675\left(k - \frac{ED}{18R}\right) - .000424v\right] - .0000045\, wv. \ldots (14)$$

It is evident from the above formula that a certain ratio must exist between D and R which will give a maximum value to N. Let us suppose

$$D = \frac{R}{x},$$

and for convenience

$$a = .0003675,$$

$$b = .0000424,$$

$$c = .0000045.$$

The above formula then becomes, approximately,

$$N = aR^2 v\left(\frac{k}{x^2} - \frac{E}{18x^3}\right) - cwv. \ldots\ldots\ldots\ldots\ldots (15)$$

It is evident that the value of N will be a maximum when the expression in the parenthesis becomes a maximum. Differentiating this expression, therefore, and placing the first differential coefficient equal to 0, we obtain

$$\frac{du}{dx} = \frac{54E}{324x^4} - \frac{2k}{x^3} = \frac{E}{6x^4} - \frac{2k}{x^3} = 0, \ldots\ldots (16)$$

hence

$$x = \frac{E}{12k} = 92.413, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (17)$$

or, the diameter of the wheels should be, approximately, 185 times the diameter of the rope. In other words, *the ratio between the diameters of the wheels and rope should be about a foot to a sixteenth of an inch.*

Substituting this value of x in equation 15, we find

$$\frac{k}{x^2} - \frac{E}{18x^3} = 1,$$

and $N = (aR^2 - cw)\,v \ldots\ldots\ldots\ldots (18)$

Assuming an average value for w of $\frac{6}{10} R^2$, which is allowable, since the influence of w is trifling in any case, we have

$$N = .0003648R^2 v, \ldots\ldots\ldots\ldots (19)$$

or, substituting the value of $R = 92.413D$,

$$N = 3.1154D^2 v, \ldots\ldots\ldots\ldots (20)$$

but $v = \frac{\pi}{360} RV = .8065DV, \ldots\ldots\ldots\ldots (21)$

hence $N = 3.0148\, D^3 V \ldots\ldots\ldots\ldots (22)$

That is, *the actual horse-power transmitted approximately equals three times the cube of the diameter of the rope, expressed in inches, multiplied by the number of revolutions of the wheels per minute.* This rule, of course, is based on the assumption that the diameters of the wheels are equal, and about 192 times, or not less than 185 times the diameter of the rope.

DEFLECTION OF THE ROPE.

It is evident that the tensions on the rope depend upon the deflections, consequently it is necessary to determine the latter before we can give the rope the above calculated tensions. The formulæ for determining these deflections are as follows (Weisbach, vol. iii., pages 240 and 241):

$$h_1 = \frac{qS^2}{8s_1} = \frac{qS^2}{16K}, \ldots\ldots\ldots\ldots (23)$$

$$h_2 = \frac{qS^2}{8s_2} = \frac{qS^2}{8K}, \ldots\ldots\ldots\ldots (24)$$

and $h = \frac{qS^2}{8s} = \frac{qS^2}{12K}, \ldots\ldots\ldots\ldots (25)$

but $q = 1.5D^2$ and $K = \frac{550N_0}{v}$.

By substituting these values in equations 23, 24 and 25, we would obtain expressions for the deflections in terms of N_0, but by combining equations 8 and 21, we find

$$N_0 = 3.1791 D^3 V, \quad\quad (26)$$

hence $K = 2168 D^2, \quad\quad (27)$

and $h_1 = .0000432 S^2, \quad\quad (28)$

$h_2 = .0000864 S^2, \quad\quad (29)$

$h = .00005765 S^2. \quad\quad (30)$

From the foregoing formulæ we deduce the following

TABLE OF HORSE-POWERS.

$2R$	δ	$V=$ 75	100	125	150	175	200	225	250
4	$\frac{1}{4}$	3.51	4.69	5.86	7.03	8.20	9.37	10.55	11.72
5	$\frac{5}{16}$	6.87	9.16	11.44	13.73	16.02	18.31	20.60	22.89
6	$\frac{3}{8}$	11.86	15.82	19.77	23.73	27.69	31.64	35.60	39.55
7	$\frac{7}{16}$	18.84	25.12	31.40	37.68	43.96	50.24	56.52	62.80
8	$\frac{1}{2}$	28.12	37.50	46.87	56.25	65.62	75.00	84.37	
9	$\frac{9}{16}$	40 04	53.39	66.74	80.09	93.44	106.79		
10	$\frac{5}{8}$	54.93	73.24	91.55	109.86	128.18			
11	$\frac{11}{16}$	73.11	97.48	121.85	146.23				
12	$\frac{3}{4}$	94.92	126.57	158.20					

The proper deflections corresponding to the above, when the rope is at rest, are as follows:

Span, in feet .	50	100	150	200	250	300	350	400	450	
Deflection....	1¾″	7″	1′ 3½″	2′ 3⅝″	3′ 7¼″	5′ 2¼″	7′ ⅝″	9′ 2⅝″	11′ 8″	

LIMITS OF SPAN.

It becomes interesting to ascertain between what limits of span the transmission of power by wire ropes is practicable. When the deflections are very small, it is impossible to splice the rope to such a degree of nicety as to obtain exactly the required deflection, and it becomes necessary to apply means for giving the proper tension to the rope. The rope is also subject to a certain amount of stretch, and tightening sheaves are resorted to in order to avoid frequent splices, which are objectionable; but care should always be exercised, in using tightening sheaves, that they do not become the means, in unskilled hands, of overstraining the rope. When it is inconvenient to apply tightening sheaves, the wheels may be re-filled with a thicker filling, or a temporary lining of wooden blocks put in, by nailing to the filling already in the wheels, and the rope run on these until it has stretched to a constant length, when this lining is removed, the rope re-spliced, and placed again on the original filling. On the shorter spans, moreover, the rope is more sensitive to every irregularity in the wheels and amount of power transmitted, and it is apt to sway to such an extent beyond the narrow limits of the required deflections as to cause a jerking motion, which is very injurious to the rope. It has been found in practice that when the deflection of the rope at rest is less than three inches the transmission cannot be effected with satisfaction, and that shafting or belting is to be preferred. This deflection corresponds to a span of about 54 feet.

In regard to the maximum limit of span, the available height of the towers or supports for the wheels must be taken into consideration. It is for this reason that it is customary to make the under side of the rope the driving side, as in this case the greater deflection in this side occurs when the rope is at rest. When in motion the under side rises and the upper side sinks, thus enabling obstructions to be avoided which otherwise would have to be removed, or necessitate very high towers. The maximum limit of span, therefore, is determined by the maximum deflection that may be given to the upper side of the rope when in motion. Assuming that the clearance between the upper and lower sides of the rope should not be less than two feet, and that the wheels are at least ten feet in diameter, we have

$$h_1 + 10 = h_2 + 2,$$

and since $$h_2 = 2h_1,$$

we have $$h_1 = 8 \text{ feet}.$$

This deflection corresponds to a span of about 430 feet.

INCLINED TRANSMISSIONS.

It generally happens that the two wheels are not on the same horizontal plane, but that one occupies a higher elevation than the other. There will be a difference in the tensions in this case at the two wheels, the upper one being subject to a greater tension, but this difference is so slight, for all practicable spans, that it may be neglected as far as it affects the amount of horse-power that may be transmitted. It is evident, however, that when the angle of inclination is very great, the proper deflections cannot be readily determined, and the rope becomes more sensitive to the ordinary variations in the deflections, so that tightening sheaves must be resorted to for producing the requisite tension, as in the case of very short spans. In other words, the span to be considered in such cases is really the horizontal distance between the two wheels, and practice has shown that when this is less than sixty feet, or when the angle of inclination exceeds thirty to forty-five degrees, it will be found desirable to use tightening sheaves. The limiting case of inclined transmissions occurs when one wheel is directly above the other. The rope in this case produces no tension whatever on the lower wheel, while the upper is subject only to the weight of the rope, which is usually so insignificant that it might be neglected altogether without materially affecting the problem, and tightening sheaves are therefore an absolute necessity. If the rope and wheels are proportioned according to the preceding rules for maximum efficiency, the proper load for the lower wheel is given by the equation,

$$S_1 = 2K = Q + w = 4336D^2 \text{ (see equation 27)} \ldots (31)$$

VARIATIONS IN SIZE OF WHEELS.

The foregoing formulæ and table of horse-powers have been estimated on a basis of maximum efficiency upon the assumption that the diameters of the wheels are not less than 185 times the diameter of the rope. It frequently happens, however, that it is impracticable to use wheels of such large diameter, and smaller ones may be used; but of course it will be understood that the efficiency of the transmission is lessened and the wear on the rope correspondingly increased.

Referring to equation 7, we find

$$k_2 = \frac{ED}{18R} = 1583333 \frac{D}{R},$$

from which, substituting some of the most probable values of $\frac{D}{R}$, we deduce the following table:

$\frac{R}{D}$	k_2	$\frac{R}{D}$	k_2
19.2	82463	60.	26388
24.	65971	64.	24739
28.8	54975	67.2	23561
32.	49478	72.	21990
36.	43980	76.8	20616
38.4	41232	80.	19791
40.	39582	84.	18849
48.	32986	86.4	18326
56.	28273	88.	17992
57.6	27488	96.	16493

This table is interesting, as it clearly indicates the cause of the rapid wear of the ropes when running on small wheels. When the ratio $\frac{R}{D}$ is large, the tension varies but slightly, with small changes in this ratio; while, if the ratio is small, the tension increases at a much faster rate than $\frac{R}{D}$ decreases.

Hitherto we have assumed that the two wheels are of equal size, and it is always desirable to have them so if possible, but it is frequently convenient to make them of different sizes in order to obtain the requisite speed in the driven mechanism. In this case the power transmitted will be the same as if the two wheels were of the same size and equal to that of the smaller wheel, running with a speed corresponding to the speed of this wheel.

EQUIVALENT BELT.

Weisbach gives

$$N = \frac{bv}{1100}$$

as the value of the number of horse-powers which may be transmitted by a belt of the breadth b in inches, and of the velocity v in feet per minute. When it is desired to transmit by means of a wire rope the entire power of a belt, the above formula will be found convenient.

CONCLUDING REMARKS.

Transmission wheels should be nicely balanced; otherwise uneven wearing will result in the bearings, as also in the filling, causing the rope to sway violently. If the splice is poorly made, the filling roughly inserted, or the wheels not keyed at right angles to the shaft, similar irregularities in motion will result.

It must be borne in mind that no pains should be spared at the outset to the careful alignment and equal balance of the wheels, on account of the high velocities at which they are run.