

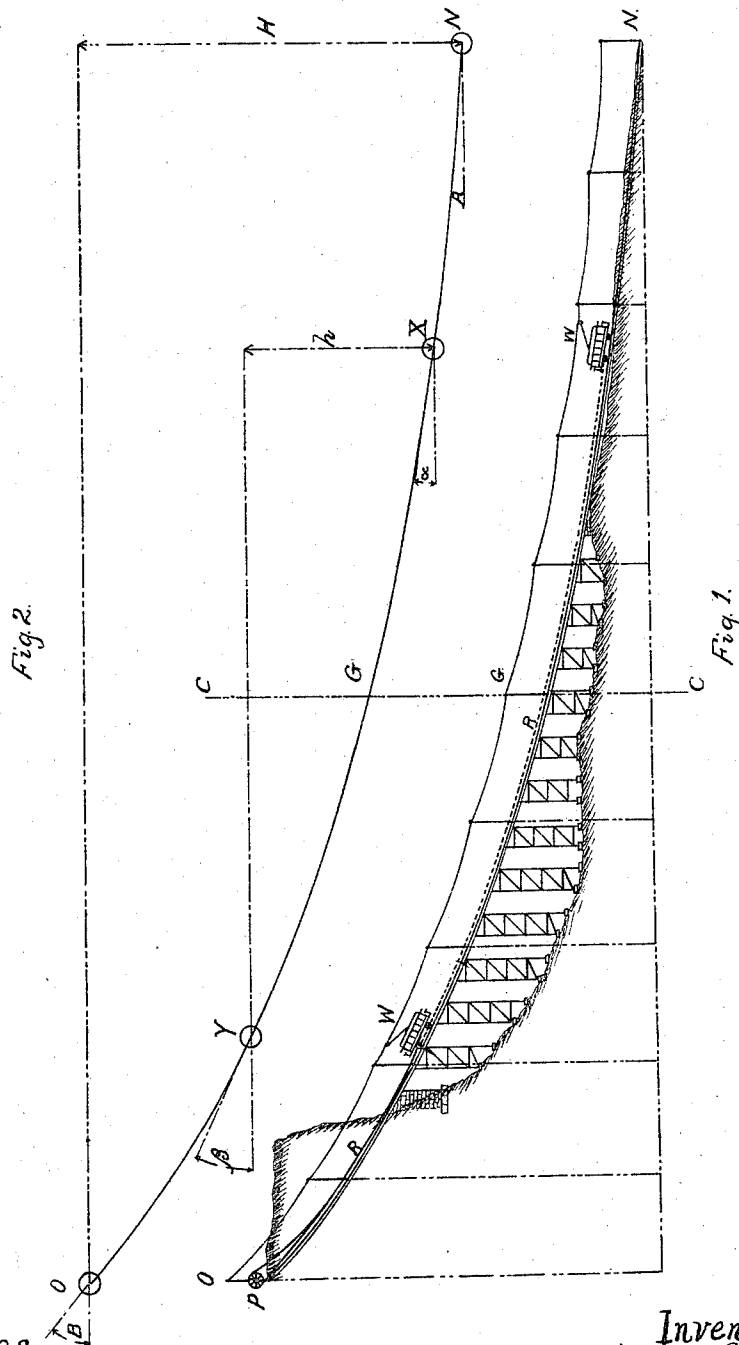
(No Model.)

2 Sheets—Sheet 1.

T. E. BROWN.
INCLINED CABLE RAILWAY.

No. 579,469.

Patented Mar. 23, 1897.



Witnesses ¹⁰
Henry V. Brown
Bernard J. Becke

Inventor
Thomas E. Brown,
by A. Walter Brown,
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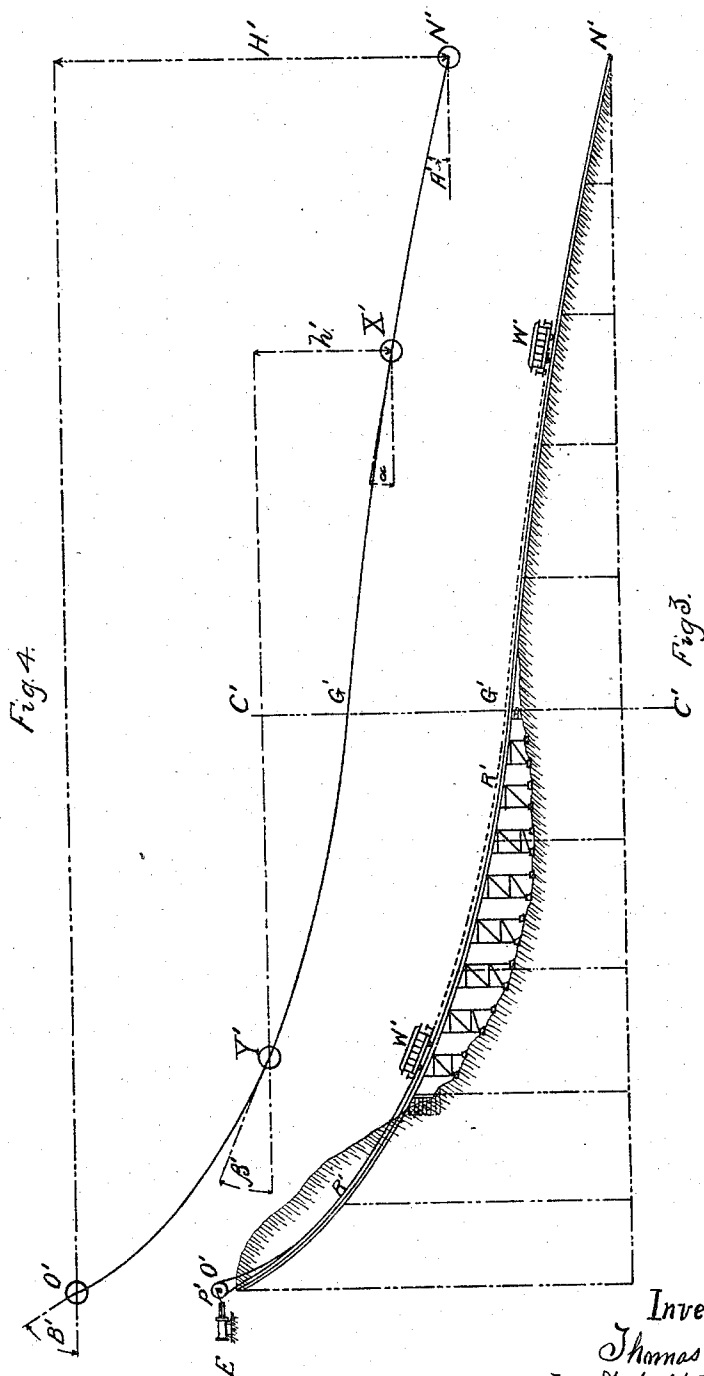
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Witnesses
Henry V. Brown.
Bernard J. Beck.

Inventor,
Thomas E. Brown
by D. Walter Brown
his Attorney

UNITED STATES PATENT OFFICE.

THOMAS E. BROWN, OF NEW YORK, N. Y.

INCLINED CABLE-RAILWAY.

SPECIFICATION forming part of Letters Patent No. 579,469, dated March 23, 1897.

Application filed October 29, 1896. Serial No. 610,470. (No model.)

To all whom it may concern:

Be it known that I, THOMAS E. BROWN, a citizen of the United States, and a resident of the city of New York, in the county and State of New York, have invented certain new and useful Improvements in Inclined Cable-Railways, of which the following is a specification.

My invention relates to improvements in inclined cable-railways of that class wherein a car or train is attached to each free end of the cable.

The invention also applies to the case in which a counterbalance instead of a car or train is attached to one end of the cable, and hereinafter where I use the term "car" it is to be understood that a train or a counterbalance are equivalents.

Particularly it is the purpose of this invention to provide a structure for the road-bed of the incline of such shape and construction that at whatever points the two cars may be at any instant of time the downward pulls on both branches of the cables, due to their own weight and the weight of their cars, shall be equal. Thus the cars and their respective branches of the cables remain balanced at all positions, although the length of one branch of the cable and its resultant weight may be much greater than those of the other branch. The power to move the car is thus reduced to the minimum and rendered practically constant, for with my invention practically the power needed is only that necessary to move the load and overcome the friction, whereas on the common incline with a car at each end of the cable the power must at some positions of the cars be sufficient to overcome the whole or some part of the resultant weight of the cable in addition to moving the load and overcoming the friction. For example, when one car is at the bottom and the other at the top of the incline it might be necessary where my invention is not used to have power sufficient to move the resultant weight of the entire cable in addition to moving the load and overcoming friction. On high inclines, therefore, the power expended in overcoming the resultant weight of the cable may be much greater than that required for moving the load and overcoming friction.

The reduction in the power effected through my invention produces large saving in first cost and operating expenses. The great reduction in the power, and therefore in the necessary traction force, also enables me to place a motor, such as an electric motor, on one or both the cars or trains, doing away with the power plant at the top of the incline. This general use of such motors on inclines has been heretofore impracticable, because the adhesion of the driving-wheels on the rails, especially on the steeper parts of the inclines, has been insufficient to actuate the cables and cars or trains, particularly if, as is frequently the case, the steeper part is near the lower end of the incline. With my invention, however, the total pull on both branches of the cable being balanced there will be sufficient adhesion, even on the steepest grade that is likely to be used, to operate the cars successfully.

The invention therefore renders it possible to connect an incline with an electric car, carrying the electric currents up the incline and to move the cars up the incline by their own regular motors. The expense of operating such a road is reduced to a minimum and such inclines are practicable where other inclines cannot be built.

The invention consists, essentially, in an inclined structure so constructed and shaped on its rail-bearing surface that when a car is at any point whatever on the incline it, together with its branch of the cable, will balance the other car and its branch of the cable, and the possibility of constructing such an incline depends on a discovery which I have made that when a flexible cable is laid on rollers along the surface of an incline the downward pull at the upper end of the cable is equal to the weight of a unit-length of the cable (supposing it to be of uniform diameter and material) multiplied by the vertical distance between the upper and lower end of the cable. In other words, I have discovered that (disregarding friction) the total downward pull exerted by a length of cable which reaches from the drum at the top of the incline to any point on the incline is proportional to the perpendicular distance of the point below the up-

pend of the cable no matter what the angle or shape of the slope of the incline may be. Applying this discovery I have so constructed and shaped the rail-bearing surface or slope of the incline (along which the cable is extended) that at any point the sine of the angle of the slope with the horizontal is such that that sine multiplied by the weight of the car at that point plus the weight of a length of the cable which would reach perpendicularly from that point to the top of the incline (which weight I call the "perpendicular" or "resultant" weight of the cable) equals the product of the weight of the other car into the sine of the angle of the slope with the horizontal at the place of such other car plus the perpendicular weight of its branch of the cable, as aforesaid. In other words, I have so constructed and shaped the slope of the incline that the sines of the angles of inclination of the slope at corresponding positions of the cars differ by the quantity obtained by multiplying the quotient arising from dividing the weight of a unit-length of cable by the weight of one car (both cars being of equal weight) by the vertical distance between the position of the two cars, and I have demonstrated that on such an incline the cars and branches of the cable will be in balance at every position.

In the first place, therefore, the invention consists in an inclined structure the slope of which is so constructed and shaped that the sine of the inclination of the slope at a point a given distance from the upper end of the incline exceeds the sine of the inclination of the slope at a point which is equally distant from the lower end of the incline by the quotient obtained by dividing the perpendicular weight of the cable between the said two points by the weight of the car. The shape of the incline also may be such that not only shall the cars or trains and their cables be always in balance, but that the pull exerted at the top of the incline shall be a constant quantity.

Now referring to the drawings which accompany the specification to aid the description, Figure 1 is a side view of my incline used in connection with an electric-trolley system. The cars are connected with the ends of the cable, which extends around a drum or sheave P at the top of the incline. Fig. 2 is a diagrammatic representation of the curve of the rail-bearing surface and on the same scale as Fig. 1. Fig. 3 is a side view, on the same scale as Fig. 1, of an incline applied to ground of a somewhat different contour. This figure shows how my discovery provides for the construction of inclines in varying conditions without departing from the controlling features which determine the balance of cable and cars. Fig. 4 is a diagrammatic representation of the curve of Fig. 3 and on the same scale.

For illustration, referring to Fig. 2, the points X and Y on the incline structure N O

are respectively at equal distances from the bottom and the top of the incline h , representing the perpendicular distance between said points. Therefore the natural sine of the angle β of the incline at Y is made to exceed the natural sine of the angle α of the incline at X by the quotient obtained by dividing the weight of a length h of the cable, which is the perpendicular distance from X to Y, by the weight of the car, and so on for all other points of the incline. Thus the sine of the angle B of point O exceeds the sine of the angle A at point N by the quotient obtained by dividing the weight of length H of cable by the weight of a car.

I have also discovered a further property of the curve which determines the shape to be given to the slope of the incline, which property enables me to so shape the incline as to adapt it to the contour of the ground with the least amount of cutting and filling without departing from those essential properties which produce the balance of the cables and cars. For, supposing the slope of the incline to be divided into two equal parts, the balancing condition will be fulfilled when the sine of the angle of the slope at every point on the upper part differs from the sine of the angle of the slope at every corresponding point on the lower part by an amount determined by the proportion which the corresponding vertical weight of the cable bears to the weight of a car or train. Consequently I can give to the upper or the lower part such a slope as will best adapt it to the contour of the ground and minimize the cutting and filling, and can then determine the proper slopes and elevations for the corresponding points on the other part of the incline.

For example, referring to Figs. 3 and 4, with the profiles of the ground there shown, the lower half of the incline or from G' to N' is made to conform closely to the ground and the elevations and sines of the angles ascertained for as many points as are necessary. The slope of the upper part of the incline or from G' to O' is then determined in such manner that at all corresponding points on the upper and lower parts, as X' and Y', the sine of the angle β' of the slope at the point Y' shall exceed the sine of the angle α' of the slope at the point X' by the quotient obtained by dividing the weight of a length h' of the cable by the weight of a car. Of course if the conditions should render it desirable the upper half of the curve might be adapted to the contour of the ground and the lower half shaped and constructed with reference to that.

The determination of the slope of the incline for a given case is readily made upon applying my discoveries. Thus, referring to the case illustrated in Figs. 1 and 2 in which the pull of each car and branch of the cable is a constant quantity, the surveys inform the engineer of the total vertical height of

the incline and also of the length of the curved surface of the incline. The weight of the car is determined by good practice in such cases, and the weight of the cable per running foot is adapted to suit the circumstances. From these data sufficient points are determined to fix the curve from the following formula:

$$y = \left\{ \frac{e^{\frac{ws}{W}} - 1}{\frac{w}{W}} \right\} \sin. \alpha. \quad (I)$$

In this formula W is the weight of the car; w , the weight of a running foot of cable; s , distance of any point on the incline from the bottom, measured on the curve; y , the vertical height of any point above the lower end of the incline; α , the angle between the tangent of the curve, at the lower end of the incline, and the horizontal; e , the base of the Napierian system of logarithms. Said Equation I is derived as follows: The curve shown in Fig. 1 has such a form that the relation of the sines at corresponding points on the upper and lower halves of the curve is as herebefore stated, and also that the pull of either car and its branch of the cable is constant for all positions. The use of this latter property simplifies the derivation of the equation, and a structure possessing this property is the best wherever natural conditions admit of its economical construction. Let P equal the constant pull on cable. Let $\sin. (y)$ equal sine of angle of slope at a point whose ordinate is y . Let H equal total height of the incline. Let the car be at a point distant s from the bottom of the incline, the ordinate of said point being y . Then the pull of the car down the slope equals $W \sin. (y)$. By my discovery the pull of the branch of the cable pertaining to said car equals $w (H - y)$, and therefore the total pull is

$$P = W \sin. (y) + w (H - y). \quad (1)$$

When the car is at the bottom, where the angle of the slope is α and $y = 0$, we have for the total pull

$$P = W \sin. \alpha + w H. \quad (2)$$

Subtracting the equation 2 from equation 1, we have

$$0 = W \sin. (y) - W \sin. \alpha - w y.$$

Transposing and dividing by W , we have

$$\sin. (y) = \sin. \alpha + \frac{w}{W} y.$$

By the calculus

$$\sin. (y) = \frac{dy}{ds}.$$

Substituting, we have

$$\frac{dy}{ds} = \sin. \alpha + \frac{w}{W} y,$$

in which we will consider s (the length along

the curve) as the independent variable. By transposition we get

$$\frac{dy}{\frac{w}{W} y + \sin. \alpha} = ds. \quad 70$$

Multiplying both sides of this equation by $\frac{w}{W}$ and expressing integration, we get

$$\int \frac{\frac{w}{W} dy}{\frac{w}{W} y + \sin. \alpha} = \int \frac{w}{W} ds. \quad 75$$

Performing the integration, we have

$$\text{Log.} \left(\frac{w}{W} y + \sin. \alpha \right) = \frac{w}{W} s + C,$$

C being the constant of integration. When $s = 0$, then $y = 0$. Substituting these values and solving for C , we have

$$C = \text{log.} (\sin. \alpha).$$

Substituting this value of C and reducing, we get

$$\text{Log.} \left(\frac{\frac{w}{W} y}{\sin. \alpha} + 1 \right) = \frac{w}{W} s. \quad 80$$

Whence

$$\frac{\frac{w}{W} y}{\sin. \alpha} + 1 = e^{\frac{w}{W} s}. \quad 85$$

Transposing and solving for y , we obtain Formula I:

$$y = \frac{W}{w} \left(e^{\frac{w}{W} s} - 1 \right) \sin. \alpha. \quad 90$$

The sine of the angle α is determined by the following equation, derived from the previous Equation I by substituting for y and s their values H and S at top of incline and solving for $\sin. \alpha$, S being total length and H total height of incline:

$$\sin. \alpha = \frac{H}{\frac{W}{w} \left\{ e^{\frac{w}{W} S} - 1 \right\}} \quad (II) \quad 95$$

Say it is decided to fix points on the curve every fifty feet apart, (for such a distance the length of the curve varying by an inappreciable amount from the length of the straight line between the points,) then starting from the lower end of the incline we measure fifty feet and fix the terminal point at the elevation determined by the formula. Then we measure fifty feet from there, again fixing the terminal point at the elevation determined by the formula for a length of curve equal to one hundred feet, and so on. Then sweeping a fair curve through these points we obtain the desired curve. 100

Referring to the case of Figs. 3 and 4, we have given the elevation, angle of slope, and position from the end of the incline of every point on the one half of the incline, and from these any number of points sufficient to determine the other half of the incline can be found, either by deriving the equation of said other half of the incline from the known elements of the established half and finding the elevations of the different points from this equation or by a very simple method which gives an approximation that is sufficiently close for all practical purposes, and which is as follows: I assume that for a short distance, as, say, fifty feet, on each side of the central point G' the slope remains the same. Thus I determine the difference of elevation of two corresponding points, one fifty feet below, the other fifty feet above the point G'. On this data I can then determine the slope for the next section of fifty feet and fix the next point, and so on to the end of the incline.

Now, having described my improvements, I claim as my invention—

1. In inclined cable-railways, an inclined rail-bearing structure shaped on such a curve that the sine of the angle of inclination of the said surface at a point a given distance from the upper end of the structure exceeds the sine of the angle of inclination of said structure at a point an equal distance from the lower end of the structure by the quotient obtained by dividing the weight of a length of cable equal to the vertical distance between said points by the weight of a car which is operated by the cable, substantially as and for the purpose described.

2. The combination with a cable led around

a sheave or drum at the upper end of the incline, a car attached to each end of the cable, and a motor on one or both cars for operating the same, of an inclined structure having its rail-bearing surface shaped on such a curve that the sine of the angle of inclination of such surface at a point a given distance from the upper end of the structure exceeds the sine of the angle of inclination of said surface at a point an equal distance from the lower end of said structure by the quotient obtained by dividing the weight of a length of the cable equal to the perpendicular distance between said points, by the weight of a car, substantially as described.

3. The combination with a cable led around a sheave or drum at the upper end of the incline, a car attached to each end of the cable, and a motor for operating the said cable, of an inclined structure having its rail-bearing surface shaped on such a curve that the sine of the angle of inclination of such surface at a point a given distance from the upper end of the structure exceeds the sine of the angle of inclination of said surface at a point an equal distance from the lower end of said structure by the quotient obtained by dividing the weight of a length of the cable equal to the perpendicular distance between said points, by the weight of a car, substantially as described.

In testimony that I claim the foregoing as my invention I have signed my name, in presence of two witnesses, this 17th day of October, 1896.

THOMAS E. BROWN.

Witnesses:

HARALD RAASLOFF,
BANCROFT G. BRAINE.