November 23, 1858.

JOSEPH LOCKE, M.P., President,
in the Chair.

No. 990.—“On the use of Locomotive Power, on Gradients of 1 in 17, and Curves of 300 feet radius, on Railways in America.”¹ By THOMAS SEBASTAIN ISAAC.

IN the discussion that followed the reading of Mr. Drysdale's Paper before the Institution, in April 1856, “On the Steep Gradients of Railways,”² doubt was expressed, whether locomotives would be able to surmount an inclination of 1 in 20, or 1 in 17. The Author is enabled to furnish evidence, not only that the locomotive has successfully surmounted these gradients, but that it has actually scaled an incline of 1 in 10, with a load greater than its own weight. The inclines described are on railroads in America, with which the Author has been professionally connected; and the facts adduced have come under his own immediate observation.

The extension of railroads has been so rapid in America, and the demand for speedy construction so urgent, that Civil Engineers have been compelled to resort to various expedients to facilitate the execution of the works. Time has been an element of so much importance, that the work of track-laying has been pressed forward, with the utmost possible rapidity; and where the iron and other materials for the track could only be delivered from one end, as fast as the track itself was laid, the delay of only a few months, from the non-completion of any portion of the road-bed, would have been, in many cases, too serious a matter to be willingly submitted to. Where bridges were unfinished, rivers were trestled, to admit of the passage of the locomotive, with its burden of iron; where tunnels were behind-hand, the hills were scaled by inclines, in order that the pressing exigencies of the moment might be met. Of the expedients thus resorted to, the introduction of unusually steep gradients has probably furnished the most interesting results to the Engineer. The information gained from this source is the more valuable, on account of the great range of the gradients that have been submitted to actual experiment.

¹ The discussion upon this Paper extended over portions of two evenings, but an abstract of the whole is given consecutively.

² *Vide* Minutes of Proceedings Inst. C.E., vol. xv. pp. 349 to 364.

The Company that has pre-eminently taken the lead in the application of locomotive power to steep gradients, is the Baltimore and Ohio railway, which extends from the city of Baltimore, on the Chesapeake bay, to Wheeling, on the Ohio river. Of all the lines of railway which extend westward, from the Atlantic coast to the great valley of the Mississippi, and have had to grapple with the various ranges of the Alleghany Mountains, there is not one which has had to encounter so many and such formidable obstacles, both in its location and in its construction, as this road. Though somewhat of a digression, it may not be altogether devoid of interest to state, that the Baltimore and Ohio Railway Company was the first chartered in America, the first in operation there for passengers and merchandise, and has been the pioneer in almost all improvements that have been introduced upon American railroads. The Company was organised under its charter in 1827, and a portion of the line was opened in May 1830.¹ Horses were at first used as the motive power, but locomotives were employed as early as August 1830. When it is considered, that the railroad system in England was but then in its infancy, and that locomotives were running on this section of the Baltimore and Ohio Railroad before the opening of the Liverpool and Manchester line, one cannot fail to be struck with the daring enterprise which, at that early day, could project and undertake the construction of a railway 380 miles long, through a region where the difficulties, even in the present advanced state of engineering science, seem to be of the most gigantic kind.

Although the railway was undertaken at this early period, legislative and financial difficulties prevented the commencement of the western half, until 1849, and it was not until 1851, or three years prior to the opening of the Sömmering incline, that the great incline over the main range of the Alleghany Mountains was completed, and successfully worked by locomotives. The maximum gradient of this incline is so much exceeded by that of the Giovi, which was opened in December 1853, and falls so far below the gradients which it is the more immediate object of this Paper to describe, that only a passing sketch will be given. The Author considers a brief notice to be due, however, on account of its great

¹ It should be stated, that a deputation from the Board of Engineers of the United States, consisting of W. G. MacNiel, G. W. Whistler, and J. Knight, visited this country in the year 1828, for the purpose of examining the Public Works, but more especially the existing railways, and those in course of construction. (*Vide* Memoir of W. G. MacNiel, Minutes of Proceedings Inst. C.E., vol. xiii. p. 140.) As a consequence of this visit, Messrs. Stephenson and Co., of Newcastle-upon-Tyne, received an order for a locomotive engine from "The Delaware and Hudson Canal Company," which was delivered on the 20th October, 1828. Subsequently, on the 25th June, 1851, they supplied a locomotive engine to "The Mohawk and Hudson Railroad Company."—EDITOR.

length, and the ease and success with which it is worked. This incline rises 1,690 feet in fifteen miles, eleven continuous miles of which have an inclination of 1 in $45\frac{1}{2}$. It reaches a height of 2,626 feet above the sea, and after winding amongst the summits of the Alleghanies, for a distance of twenty miles, descends on the western side, with an inclination of 1 in $45\frac{1}{2}$, for nine continuous miles. The passage of this mountain-chain involves altogether sixty miles of railway, twenty miles of which have a gradient of 1 in $45\frac{1}{2}$, and nine miles have a gradient of 1 in 50; both are worked by locomotive power, at a speed of from fifteen to twenty miles per hour for passenger trains, and of from ten to fifteen miles per hour for goods trains. In addition to the disadvantages arising from its great length, this incline labours under others connected with its curves, the character of the region which it traverses having necessitated the frequent introduction of curves of 600 feet radius; so that at the time of its construction, the difficulties in the way of its successful operation were altogether unprecedented. The Author cannot state the exact amount of traffic that annually passes over it. To convey some idea, however, it will suffice to say, that it is situated near the middle of one of the main thoroughfares of American commerce; and that the tonnage of goods carried on the Baltimore and Ohio Railway in 1857 was equivalent to two hundred millions of tons carried one mile. The Company own two hundred and thirty-six engines, and their rolling stock, if coupled together, would cover a length of twenty miles.

With the exception of a few locomotives especially constructed for passenger trains, no extra provision has been made for the working of this incline, beyond increasing the number of the engines. The same engines are used to work it, as were previously employed for the ordinary traffic of the line. They weigh, when in running order, about 24 tons each, and run on eight wheels, all of which are coupled. The diameter of the cylinders is 17 inches, the length of the stroke is 2 feet, and the diameter of the wheels is $4\frac{1}{2}$ feet. Each engine is provided with a tender, the weight of which, when furnished with the full complement of fuel and water, is about 13 tons. Several of these engines are stationed at the foot of the mountain on both sides, and as the goods trains arrive, an assistant engine is employed to take over a portion of the train, or is coupled on to the regular engine, to aid in the transit.

Before returning to the more immediate object of this Paper, it will be necessary to state, that while Mr. Latrobe, the chief Engineer of this line, was pushing the western portion to completion, he encountered, in 1852, at two different tunnels, difficulties altogether beyond control, which seemed to threaten serious delay

in the westward extension of the line. To provide for the passage of the trains, he caused temporary inclines to be constructed over both the tunnels. The one first made was that over the Kingwood Tunnel. It had a maximum gradient of 530 feet per mile, or a rise of more than 1 in 10. Over this incline, which was in operation for several months, the iron and other materials for upwards of forty miles of railway, and the United States mails, were conveyed by locomotive power. The same engines were employed as have been already described. One car, weighing with its load of iron about 13 tons, was allotted to an engine; and as each tender, with sufficient fuel and water for the passage of the hill, weighed 12 tons, the total load dragged up this unparalleled gradient was 25 tons, at a speed of from eight to ten miles per hour.

At the second point, called the Board Tree Tunnel, instead of a continuous incline to the top, Mr. Latrobe deemed it advisable to adopt a series of inclines of a zigzag form, on which the upward motion of the train was alternately reversed, the engine at one time pulling, and at another pushing the cars. There were three of these zigzag inclines on the eastern ascent, and five formed the descent on the western slope of the hill. The greatest height above the tunnel was 300 feet, and the total length of the inclines was 12,000 feet, or about $2\frac{1}{4}$ miles. The gradients varied from 293 to 340 feet per mile, or nearly 1 in 18 to 1 in $15\frac{1}{2}$, and the minimum radius of curvature was 300 feet. The ordinary freight engines were employed. Two loaded cars, weighing together 25 tons, were allotted to an engine; the load, therefore, including the tender, was 37 tons.

Mr. Latrobe, in his report of 1853, speaks thus of this incline. "The working of the switch tracks, at the Board Tree Tunnel, was successful and safe: on one, or two occasions, as many as fifty cars, with 400 tons of freight, and two passenger trains, have been taken over the hill in a day, by four first-class locomotives; each round trip making a run of ten miles. No accident, involving more than a short detention, happened during the working of these gradients, for nearly five months."

The track over both these inclines was taken up as soon as the tunnels were completed; but it was relaid in 1855 and in 1857, respectively, in consequence of the necessity of arching the tunnels throughout. The maximum gradient at the Kingwood Incline was reduced, on this second occasion, from 530 to 300 feet per mile. Over this the traffic of the road was carried, until the arching was completed. These two inclines, therefore, although unprovided with engines especially adapted for the purpose, fully demonstrate the feasibility of traversing gradients, altogether unprecedented, by the locomotive alone. The experience gained in working them, not only establishes the fact, that a rise of 300 feet

per mile, and curves of 300 feet radius, can be worked with comparative facility; but seems to point also to a limiting gradient, beyond which it is impossible for the locomotive to go, with any useful effect, even for a temporary purpose.

Since the construction of the Kingwood Tunnel and the Board Tree Tunnel Inclines, evidence has been accumulating from other sources. Steep gradients and sharp curves have been introduced upon the Virginia Central Railroad, on a more extended scale; and such uninterrupted success has attended their operation, for a period of more than four years, that indisputable proof is now furnished, of the possibility of extending railways into localities, where economical considerations will not admit of the ordinary method of construction, and into regions which, without the introduction of such expedients, must otherwise, from their physical conformation, be for ever debarred from the advantages of the railroad system. The Mountain Top Incline, on the Virginia Central Railroad, crosses the Blue Ridge Mountains, at Rock Fish Gap, in Virginia, at an elevation of 1885 feet above the sea. The supervision of its location and construction was intrusted to the Author, by Mr. Charles Ellet, the chief Engineer of the road. Its object was to connect the eastern and western portions of the line, interrupted at this point by the Blue Ridge Mountains, through which a tunnel had been in the course of construction for four years, at the time this incline was commenced, in 1853. As the track over the mountain was expected to be in operation for four years, it was substantially built, and especial provision was made to adapt the locomotives to their unusual duty. The introduction of zigzags was avoided, although merely economical considerations would have urged their adoption. They involve unnecessary delay, and increase the liability to accident. The portion of the incline, therefore, immediately crossing the mountain, is a continuous track, of four miles and one-third in length. From the points of connection with the termini of this incline, the main line of railroad descends for several miles on both sides, with gradients varying between 70 and 80 feet per mile. The maximum gradient, on the Mountain Top Track, is 1 in 17·86, and is employed on the lower half mile of the eastern slope, upon straight lines and curves with a radius of 570 feet, and upwards. With this exception, the gradient upon all straight lines and similar curves is 1 in 18·87. The minimum gradient, with a single exception, is 1 in 22·22, and is introduced upon curves of 300 feet radius. It has one curve with a radius of 234 feet, upon which the gradient is also 1 in 22·22. The general character of the line may be judged from the following Table :—

Total length of curves of 300 feet radius	1.100 mile
" " 320 "	.189 "
" " 360 "	.189 "
" " 440 "	.113 "
" " 478 "	.237 "
" " 570 "	.237 "
" " of a greater radius } than 570 feet }	1.070 "
" of straight lines . . .	1.194 "
Total length . . .	4.329 miles.

On the eastern slope, from the point of connection with the main line, an elevation of 610 feet is surmounted, in a distance of 2.37 miles. The average gradient on this portion therefore is 1 in 20½. The western slope makes a descent of 450 feet in 10,000 feet. The introduction, for a short distance, of a gradient of 1 in 30, reduces the average on this side to the ruling minimum of 1 in 22.22. In addition to this main incline over the mountain, it was found necessary to introduce steep gradients and sharp curves at four other points, to pass a second tunnel and certain unfinished portions of the main line; so that the distance worked by the mountain engines is 8 miles. The average gradient over the whole 8 miles is 1 in 29½. The westward trip makes a total ascent of 900 feet, with a total descent of 531 feet; so that, in the round trip of 16 miles, a height of 1,431 feet is surmounted, and an equal descent is made.

The engines chiefly used to work these gradients are mounted upon six wheels, all of which are coupled. The wheels are set near together, in order to facilitate turning round the sharp curves of the road; the distance between the centres of the forward and hindmost axles being only 9 feet 4 inches. By a peculiar arrangement, in the method of connecting the wheels, a certain amount of flexibility is obtained, which is of additional advantage in traversing the curves. The diameter of the cylinders is 16½ inches, the length of the stroke is 20 inches, and the diameter of the driving-wheels is 3½ feet. These engines are furnished with a tank over the boiler, capable of holding 100 cubic feet of water, and on the top of the tank there is storage space for 100 cubic feet of fuel. The foot-board is also lengthened, and is provided with suspended side boxes, for the further storage of fuel. When supplied with sufficient wood and water, for a trip of eight miles, each engine weighs about 24½ tons. The regular mountain-train consists of three loaded cars, on eight wheels; or four, or five cars, when only partly loaded. When the track was first opened, the weight of each loaded car was a little more than 14 tons, but an

additional ton of freight, per car, has since been added, so that the usual weight of a mountain-train is $45\frac{1}{2}$ tons. Greater loads have been taken over, and a speed of sixteen miles per hour has been attained; but no experiments have ever been made to determine the maximum power of the engines. The speed of the ordinary trains has been limited, by regulation, from the very commencement, to a maximum of eight miles per hour. The total weight of engine and train is about 70 tons. This mass is moved over the westward trip, overcoming an ascent of 900 feet, and making a descent of 531 feet, with a consumption of three-quarters of a cord of wood. The return trip, in which the ascents and descents are reversed, is made with a consumption of one-half a cord. One-third of a cord is consumed in one portion of the westward trip, in overcoming an elevation of 660 feet in 2.62 miles.

In the system of working that has been adopted, and brought to such perfection, on this incline, one feature, altogether novel in its application to such steep gradients, is the method of accomplishing the descent. All the cars, which cross the mountain, are provided with a break to each wheel, of sufficient strength to lock the wheel, if necessary; and a breaksman is stationed at each end of every car, who is not allowed to leave his post during the transit. No steam is used on the descent, except on an emergency, but the motion of the train is regulated entirely by the breaks; those of two cars being found sufficient for that purpose, in ordinary weather. When the ground is covered with snow, or ice, it is necessary either to have recourse to the air-cocks of the engines, or to supply sand to the breaks. Although the introduction of such a system of breaks is a very necessary precaution, it is questionable whether their too exclusive use is advisable. Judging from personal observation of the use of the air-cocks, on the steep inclines of the Baltimore and Ohio Railroad, and subsequently, of the system of breaks on the Mountain Top Track, the Author is inclined to think a judicious combination of the two systems far preferable to the exclusive use of either. On inclines worked by stationary engines, a trail-piece has frequently been appended to the rear car, which prevents the descent of any portion of the train, in case of the breaking of a coupling during the ascent. On the Mountain Top Incline, this trail-piece has been dispensed with; but to prevent the possibility of accident, two short pieces of strong chain are hooked between the contiguous carriages, which on an emergency would act as a powerful additional coupling.

There is a superintendent of this incline, whose duty it is to accompany the trains, to see that all the regulations are observed, and to exercise a vigilant supervision of the whole operation. No precaution is neglected to insure safety, and the ascent and descent

are made so smoothly, that but for the diminished rate of speed, there is nothing in the motion of the train itself, to indicate to the passengers, that such steep gradients, or sharp curves, are being traversed.

On the main portion of the incline, there are six viaducts of trestle-work, across six mountain gorges, of a total length of nearly half a mile. They are of timber, and, with one exception, are situated on sharp curves. Three of them are on curves of 300 feet radius. On these, for the sake of greater security, a guard-rail is placed parallel to and immediately inside the inner rail, to prevent the carriages from leaving the track.

The only point of access to this incline, by an ordinary road, is at the summit; and as, in order to avoid great delay, it was necessary that the rails should be laid over the mountain, before a connection could be made with the main track of the railway, all the iron and other materials had to be hauled a great distance by teams, to the summit, the last two miles overcoming an ascent of 1,100 feet. From the summit, as the track progressed, the materials were distributed on each side of the mountain, by small four-wheel cars, which were regulated in their descent entirely by breaks.

This line has been worked for upwards of four years, without a single accident, since the opening of the road to the public; and the engines have only failed to perform their allotted daily duty on one occasion, when the train was caught in a snow-drift near the summit. The winters have been unusually severe, and the mountain has been covered with snow for months together, but neither snow nor ice has presented any impediment to the safe passage of the mountain-trains.

The tunnel was completed and the rails were laid through it in September, 1857; and yet, when the Author left America, in April, 1858, more than six months after the completion of the tunnel, the Virginia Central Company were still using the incline over the mountain. The cause of this was the refusal, on the part of the Company, to accept the tunnel and its approaches, from the hands of the State authorities, by whom the tunnel was constructed, unless the State would agree to refund a comparatively trifling outlay, contingent upon a possible sliding of a portion of the road-bed. The fact of its being preferred to work the incline over the mountain, rather than run the risk of a trivial expenditure, is a sufficient proof, in itself, of the facility and economy of the working of the incline.

One feature in the Mountain Top Track, that will not have failed to excite attention, is the unusual severity of the curves. It is to be regretted, that a series of experiments, which it was at one time intended to institute, with regard to the resistance of the

curves, should have been prevented, by unforeseen circumstances. It has, however, been clearly proved, that this resistance has been underrated in America. Mr. Latrobe, in his calculations for the zigzag tracks over the Board Tree Tunnel, made an allowance of 31 feet per mile, between the straight portions of the line and the curves of 300 feet radius. This allowance was based on the results of some experiments made by him, which seemed to indicate, that the resistance to traction on a level, was doubled by a curve of 400 feet radius. On the Mountain Top Incline a difference of 43 feet, and on a portion of the eastern side of 58 feet, per mile was allowed, between the straight lines and curves of 300 feet radius; and yet even this was found to be insufficient. The speed was always diminished on leaving a straight portion of the track, and on entering a curve of minimum radius, although the resistance of gravity, on the latter, was $25\frac{1}{2}$ lbs. per ton less than on the former; a fact evidently proving, that the resistance of the curve must have exceeded $25\frac{1}{2}$ lbs. per ton of engine and train. It is probable, that Mr. Latrobe's experiments give a sufficiently approximate measurement of the increase of friction of the curves, due to carriages of American construction. Assuming, therefore, his allowance of 13 lbs. per ton, as the additional friction of the train, on a curve of 300 feet radius, the additional friction of the engine, due to such a curve, must have exceeded 49 lbs. per ton of its own weight. This friction will of course vary in engines of different construction. No experiments have been instituted, as far as the Author is aware, to find the increased resistance offered by curves to locomotives themselves.

While on this subject, it may be as well to mention two expedients that have been resorted to, for diminishing this friction. On the Baltimore and Ohio Incline, and on the Mountain Top Track, it was found necessary to elevate the outer rail far above the height deduced from any formula, previously employed. The ordinary formula gives results sufficient to counteract centrifugal force, but not to prevent the friction, due to the parallelism of the axles, which is produced by the flanges of the outer wheels against the inner edge of the outer rail. On the Baltimore and Ohio Inclines, for a speed of ten miles per hour, instead of about 2 inches, as required by the formula, the outer rail, on a curve of 300 feet radius, was gradually raised till it was about 9 inches above the inner one. On the Mountain Top Track, for a speed of eight miles per hour, an elevation of $6\frac{1}{2}$ inches was given. Besides this, on the latter road, a sponge, saturated with oil, was kept in contact with the flanges of the two forward wheels of each engine, by which means the inner edges of both rails were slightly lubricated. These expedients so far reduced the friction on the latter road, as to cause no perceptible diminution of speed on

leaving a straight portion of the line, with a gradient of 296 feet per mile, and on entering a curve of 300 feet radius, with a gradient of 238 feet per mile.

Shortly before his return to this country, the Author revisited the Mountain Top Track, for the express purpose of examining its condition. He was agreeably surprised to find, that the wear and tear, in spite of a combination of circumstances tending to produce greater destruction, was less than upon the other portions of the line. It is laid with a T rail weighing about 62 lbs. to the yard, and although the friction previously mentioned seemed, at first, to threaten a comparatively speedy destruction, the greater elevation of the outer rail and the use of oil have proved effectual remedies against undue depreciation arising from this source.

The Virginia Central Company have also constructed a shorter incline, at a point about 100 miles further west. This second track is one mile and a half in length: the gradients vary between 250 and 300 feet per mile, or from 1 in 21.12 to 1 in 17.6, and the curves have a minimum radius of 400 feet. This minimum has been adopted, partly because local circumstances did not necessitate a less one, and partly to admit of the use of the ordinary engines of the line, which do not traverse curves of 300 feet radius with facility. This incline has been in operation for two years, and it is likely to be in use for several years to come, as the traffic at this point will not justify the expense of constructing the more costly works, which the incline is built to avoid, until the western connections of the road are completed. Over this incline, one of the common freight-engines in use on the main road, running on eight wheels, only four of which are coupled, and with not more than 16 tons available for adhesion, has taken a load of 36 tons, at a speed of five miles per hour, according to information obtained from Mr. Whitcomb, the present chief Engineer of the line. The same engine has drawn a similar load over the Mountain Top Track.

The success that has attended the working of these inclines, and especially of the one over the Blue Ridge Mountains, has exceeded the most sanguine expectations. The annual reports of the Company speak in glowing terms, of the satisfaction with which the Company and the public have witnessed the regularity and safety of the entire operation.

The Author does not propose to institute any comparison, between the results obtained on the inclines described in this Paper, and those which have been previously laid before the Institution. Indeed, it is extremely difficult to procure sufficiently reliable data, on which to base an estimate of the performances and the cost of working in each case. In many instances, the statements furnished

are so evidently obtained from experiments made under the most favourable circumstances, with every precaution taken to insure the exertion of a maximum power and the attainment of a maximum speed, as to be clearly inadmissible for the purpose. So many inclines, on the other hand, are worked in connection with the other portions of the lines on which they are situated, as to preclude the possibility of keeping separate returns, and the data obtained from these sources are therefore uncertain and not to be relied upon. But even if accurate data were procurable, so little similarity exists between the conditions of the inclines themselves arising from diversities of climate, differences of curvature, and other local circumstances, that the most justly-drawn comparison would still be liable to objection. The Author will therefore content himself with presenting the following calculations of the ordinary performances of the engines on the Mountain Top Track. The usual weight of each train is $45\frac{1}{2}$ tons, and of each engine $24\frac{1}{2}$ tons, making a total weight of 70 tons. The speed reaches eight miles per hour up the eastern slope, which is $2\cdot37$ miles in length, with an average gradient of 1 in $20\frac{1}{2}$. The resistance due to this speed and gradient is $121\cdot64$ lbs. per ton. Therefore

$$\frac{121\cdot64 \times 70 \times 8 \times 88}{33000} = 181\frac{1}{2} \text{ horse-power, including the engine in the load.}$$

$$\text{Or } \frac{121\cdot64 \times 45\cdot5 \times 8 \times 88}{33000} = 118 \text{ horse-power, not including the engine; giving,}$$

$$\text{in the latter case, } \frac{118}{24\frac{1}{2}} = 4\cdot8 \text{ horse-power per ton of motor.}$$

To overcome the maximum gradient on the Mountain Top Track, with an ordinary load, requires an exertion of $5\cdot4$ horse-power per ton of motor.

With regard to the question of adhesion, it will be found, from an examination of the facts already given, that on the Baltimore and Ohio Incline, with a gradient of 1 in 10, the weight of the engine was about four and three-quarter times the resistance of gravity and the friction of the load. On one, or two occasions, when the rails were very greasy, the engine and the train slid backwards with locked wheels, from near the top to the bottom of this incline, without damage. The wheels of the engines had chilled tyres, a circumstance which considerably decreased their adhesion. When to this is added the difficulty of furnishing sand behind the train, without previous provision for that purpose, the sliding of the train with locked wheels is satisfactorily accounted for.

The engines on the Mountain Top Track, with an ordinary train, exercise an adhesive power of one-sixth of their weight. This power is always maintained, in the severest weather, by the use of a fine clean sand. The Author has witnessed their working,

in every emergency due to climate, and has noticed that a little sand, supplied in front of the engines, has always enabled them, with ease and without delay, to overcome the effects of fog, snow, sleet, and rain frozen on the rails. Trains have been taken over, which required an adhesion of nearly one-fourth of their weight, but this was in fine weather. From his own observation, he thinks that an adhesion of about one-sixth of the available weight of the engine, can always be relied on; and that the use of a fine clean sand will maintain it in the most severe weather. During the winter of 1856-57, the snow filled many of the cuts on this incline, to the depth of several feet. To open a passage for the trains, two of the engines were coupled together, and they worked their way up, with the greatest ease, without any snow-plough and without sand.

Stationary power seems to be so generally superseded by the locomotive, that it is almost needless to draw any comparison between them. There are so many practical inconveniences necessarily attendant upon the former, that the latter must, in spite of any disparity in the item of cost, always maintain a superiority. The rope cannot well be applied where curves are necessary, and the localities, mostly in need of inclines of any length, generally require curves. There are probably few mountain passes that cannot be overcome by the introduction of gradients of 1 in 17; and since experience has satisfactorily proved, that the locomotive can draw a load nearly double its own weight up such a gradient, at a speed of eight miles per hour, and that it is possible even to traverse curves of 300 feet radius, by reducing the inclination to 1 in 22·22, there can be but little occasion for the adoption of a motive power altogether out of the control of those on the train.

In conclusion, the Author would state, that the experience gained on the Mountain Top Track furnishes additional evidence to that already gained from other sources, of the superiority of light engines with light loads, over heavy engines with heavy loads.

The Paper is illustrated by a diagram plan and section of the Virginia Central Railway.