1888.
NEW ZEALAND.

THE ABT SYSTEM OF RAILWAYS FOR STEEP GRADE LINES.

(Extract from the *Engineer*, 12th November, 1886.)

Laid on the Table by the Hon. E. Mitchelson, with the Leave of the House.

We called attention last week to some of the disadvantages which are inseparably connected with the use of any "ladder-like" form of rack for steep-grade railways, and we mentioned that a system of rack has been invented by which these difficulties are satisfactorily overcome. We now proceed to describe this system, as most successfully carried out on the Blankenburg-Tanne Railway, in the mountains of the Harz, and which has there afforded a most satisfactory proof of the practicability of working steep gradients in the most economical manner by combining the ordinary system of adhesion with the use of a peculiar form of central rack.

Mr. Roman Abt, the inventor, is a well-known Swiss engineer, who has been previously for some years associated with Mr. Riggenbach in the construction of central-rack railways.

The Blankenburg-Tanne Railway opens up a large district of the Harz, and brings the mines of Huettenrode, the coal-fields and ironworks of Ruebeland, the stone quarries of Elbingerode, and the State ironworks of Rothehuette and Tanne into connection with the network of Prussian State railways, which had, till the construction of the line under notice, terminated at the foot of the mountains owing to the want existing at that time of means for surmounting the steep gradient in an economical and satisfactory manner.

The length of the line, which is of a normal gauge, is 16¾ miles, of which 4¼ miles, or, including terminal ends 4¾ miles, are provided with a central rack in lengths varying from 14 chains to 77 chains, a practical solution being afforded, by the mode of working to be now described, of the very interesting problem of utilising the ordinary adhesion in combination with a central rack.

There are two watersheds to be surmounted, the second and highest of which is 1,000ft. above Blankenburg. The prevailing gradient on the central rack portion is 1 in 16·6 for a total length of 3 miles 8 chains; the steepest gradient on the other portion, worked by adhesion, is 1 in 40. No less than 50 per cent. of the line is in curve, the minimum radius on the rack being 12½ chains, whilst that on the ordinary rail portion is 9 chains. The permanent way consists of steel rails weighing 60lb. per yard, resting on Schneider's improved Vautherin iron sleepers, which each weigh 90lb. The characteristic feature of Abt's system is its departure from the primitive and "ladder-rack" employed by Riggenbach on the Rigi and other railways. Mr. Abt's rack consists of three soft steel bars of rectangular section, ¾in. thick, 4⅜in. deep, and 8¾ft. long, provided with involute teeth, and placed side by side, each being one-third of a tooth in front of its neighbour, as in the well-known Hooke's gearing. In the pitch line of the teeth of the rack the space of the teeth themselves measures 2⅜in., the teeth of the pinions on the pitch line 2¼in., and the spaces 2⅝in. The pinion consists of three separate toothed discs mounted on the same shaft, the teeth being stepped in the same manner as those of the rack, and the discs themselves, being connected to the shaft by means of springs, are thus allowed a slight play relative to each other, to take up any trifling irregularities in the spacing of the teeth. Owing to the plan of placing the bars as described above, a fresh cog is engaged in every ¾in., and at the moment of engagement five other cogs are in complete contact. The advantage of this arrangement is self-evident; a smoothness of motion, quite noiseless even at high speeds, is attained, which was quite impossible with the ladder rack, whilst the fracture of a tooth—an event which would have been disastrous with the latter system—is here, owing to the fact that several teeth are simultaneously in contact, not followed by any serious consequence. The bars are laid so as to break joint with each other, thus giving a practically continuous structure to the rack, and equalising throughout the effect of expansion or contraction from changes of temperature. With the length chosen for the bars, and a distance between the sleepers of 2ft. 10½in., one bar—allowing ⅛in. full for expansion—just covers three spans; consequently one butt joint falls on each chair. On the ladder-rack system the rack had, in the case of curves, to be specially designed and constructed for each radius; with the system under notice the same form of rack can be used for curves as for the straight road, and the strains are considerably reduced. No difficulty whatever has arisen from snow or mud even during very severe winters. A very important feature of the system is the means provided for insuring that the pinion enters the rack, without necessitating a reduction of the speed of the train. The automatic entering rail, about 10ft. long, is hinged at one end to the rack, and towards its other end is in the form of an inclined plane, the teeth gradually increasing in height from 0 to the height of the teeth on the rack. Under this end of the entering rail are placed strong spiral springs to admit of vertical play of the rail. Should the teeth of the pinion not gear immediately on entering they gradually adapt themselves within a few feet of distance travelled over. This arrangement has been found to answer perfectly.

The locomotives are constructed as tank-engines. The three axles of the adhesion wheels, which are in front of the fire-box, are coupled. A Bissel truck is placed under the foot-plate. In working order each of the driving axles has a load of 14·5 tons, and the Bissel axle of 12·4 tons. The fuel and water are carried principally by the latter, so that the variation in quantity has very little influence on the adhesive power of the engine. There are two pairs of cylinders—one for the adhesive and one for the cogged-wheels—with separate steam pipes and independent action, the former outside, the latter inside of the smoke-box. Steam is only admitted to the latter pair of cylinders when the engine has entered the rack-sections of the line.

The toothed gearing is supported by an entirely separate frame resting on the two outside axles of the adhesion wheels, so that the grip of the toothed wheels is in no way affected by the play of the springs. The frame can be lifted to allow for wear and tear of the tires, and instead of the whole being a dead load when not in action, it adds to the adhesive power of the engine when working as an ordinary locomotive.

The two rack wheels are coupled, the rear one being the driver. With the ladder rack it was found to be impossible to couple thus two toothed wheels, owing to the inequalities in the pitch of the teeth. Each of the pinions is fitted with two disc brakes worked from the same spindle; a second spindle brakes the leading and trailing wheels of the adhesion axles. In addition to this there are two separate air brakes, one for the adhesion cylinders and the other for the rack cylinders. The other fittings are much the same as in an ordinary locomotive, except that, owing to there being two complete engines under one boiler, many of them are duplicated. The weight of the engines in working order is 55·9 tons.

The engine can haul a train of 120 tons up the gradient of 1 in 16·6 at a speed of 7½ miles per hour, or the same train up the gradients of 1 in 40 at a speed of 15½ miles per hour, it being thus possible in every case to develope the full power of the locomotive, and so to gain time, and diminish the cost of working. In descending the gradients it is not found necessary to brake the coaches, as the air brakes on the cylinders are sufficient to control the speed of, and stop the train, when required. By this arrangement the usual wear and tear of the tires is considerably diminished, but provision has also been made for emergencies by fitting the whole of the rolling stock with Heberlein friction brakes, which are under the immediate control of the engine-driver by means of a friction reel and continuous cord, and which also apply themselves automatically on any coupling breaking.

The cost of the Blankenburg-Tanne Railway (including four locomotives, six passenger coaches, two post wagons, thirty open trucks, six covered trucks, one saloon carriage, and six ordinary trollies, amounting to £28,500; purchase of land £7,000; stations, £11,000; permanent-way, £49,000), was only £175,000, or about £10,458 per mile. A very careful estimate has been made to show what would have been the cost of constructing, in this case, a simple adhesion railway instead of a combined rack and adhesion line, considering the smaller area of land required for the latter and the economies of construction. The result showed a saving of about £1,600 per mile in favour of the Abt system, the economy being especially noticeable in the items of excavation and masonry, the former being about three and a-half times and the latter about six times larger for the simple adhesion line than for the Abt system. Railways upon the Abt system are being constructed at Lehesten, and at the extensive slate quarries of Mr. Oertel in Bavaria. We understand that Mr. Abt has also submitted to the Swiss Federal Council a proposal to built a line of railway on his system up the Rhone Valley from Brieg, the present terminus of the Western Railway of Switzerland, to join the St. Gothard line at Airolo, in Italy, thus opening up the Upper Valais, and bringing the Western Railway into direct communication with the railways of Northern Italy. The estimated cost of this line of 38 miles is £920,000—about £24,210 per mile.

Those of our readers who desire further particulars as to the Abt system, all the details of which appear to have been most carefully and ingeniously worked out, we would refer to the very valuable paper on the subject read in March, 1886, before the American Society of Civil Engineers, by Mr. Walton W. Evans, M. Am. Soc. C.E., and published in the fifteenth volume of the "Transactions" of that Society. To this paper we have to acknowledge our indebtedness for some of the data given above. Mr. Evans sums up the advantages of the Abt system by stating that, in his opinion, "the rack, which thus far had been regarded more as a sort of makeshift to be applied in extraordinary cases which required extraordinary means, has been advanced by Mr. Abt into a most important element in the planning of new roads, or in the economical operation of old ones. New and vast fields are thus opened up to railway enterprise, and roads which never could have been thought of on account of enormous expense, can now be built and operated at so much lower cost, that they will prove safe and paying investments for capital."

NOTE.—A reference to the minutes of proceedings of the Institution of Civil Engineers shows that the speeds obtained on the above railway are, in one case, on the rack portion 4·65 miles per hour, and on the other portion 9 miles per hour; and in another case 5 to 6 miles per hour on the rack. Also that the cost of the Abt engines is about £3,500 each; and the gauge of the railway is 4ft. 8½in. None of the books which I have seen so far contain any information as to cost of working. It is scarcely necessary to say, however, that the cost of haulage on the steep inclines must be very much greater than on an ordinary railway. In cases where incline is carried over steep hill sides, in order to avoid a tunnel, the question of relative cost of maintenance, including possible difficulty with snow drifts and shingle slides, &c., is also a matter for consideration.—JOHN BLACKETT, Engineer-in-Chief.

MEMORANDUM ON THE PROPOSED ABT SYSTEM AT ARTHUR'S PASS.

Prepared for information of Committee of Legislative Council on the subject of the Midland Railway.

In considering the subject of adopting a steep incline in preference to a comparatively flat grade, the point to be ultimately settled is, whether the additional cost of working the former will compare favourably with the saving in interest on the large capital to construct the latter.

The experience gained in working the Rimutaka incline, which is conducted on the Fell system, with a grade of 1 in 15, will be of some use. As much misapprehension prevails about the capacity of such a line as the Rimutaka for carrying a large traffic, it may be remarked that, given the proper siding accommodation at the foot and summit, and enough engine-power, and working twelve hours a day, there would be no difficulty in taking up it 200,000 tons of goods per annum; that is, four times as much traffic as now goes over it in both directions. The length of this is about three miles.

The Abt system, which has been well tested of late years, is considered by competent authorities to be superior to the Fell system, and there can therefore be no doubt of the sufficiency of such a system for carrying on a much larger traffic than is likely to develop for many years on the Springfield–Brunner line.

It may be well to note, however, the different circumstances in the cases of the Rimutaka incline and the proposed Arthur's Pass incline. The former was adopted as an alternative to a circuitous and expensive route some twenty-five miles longer on ordinary grades, as it was quicker in point of time for transit of traffic, and cheaper to work to an extent equal to 2s. 6d. a ton on the present traffic than the longer and more expensive route would have been. In the case of Arthur's Pass, however, the proposed incline does not shorten the route, and it gives a slight disadvantage in point of time.

In my opinion the adoption of a steeper grade than 1 in 15 on the Abt system, with 130-ton loads, would be a mistake, because it would introduce great practical difficulties in working, through the strength of the stock and draw-bars of the Government stock being insufficient to bear greater strains than this grade and load would entail, and the through transit of the Government stock would be thus prevented. This is a point which the company building the line would necessarily be as much interested in as the Government, and which would no doubt influence them in considering the advisability of adopting a steep grade.

The only means I have of arriving at a rough estimate of the cost of working the Abt incline is by comparing it with the Fell incline. A Fell engine, weighing 35 tons, takes habitually 65 to 70 tons gross load up it. I find it stated that an Abt engine of 55 tons would take 120 to 130 tons gross load up an incline of 1 in 16 up the Blankenberg–Tanne Railway, in the Harz district, in Prussia. The latter probably has a considerable advantage, but it cannot be expressed accurately with the data available. The cost of locomotive power on the Fell incline, Rimutaka, is equal to about 4d. per ton per mile on the present traffic. As, however, the rate of wages and the price of fuel govern the cost of working, it is necessary to make a considerable modification in estimating the cost of working an incline at Arthur's Pass by the company: first, because fuel would probably cost less than half the price of that at the Rimutaka; and secondly, because the company would probably command cheaper wages.

Taking these three items—better loads, cheaper fuel, and lower wages, and allowing a large traffic of 150,000 tons—we should probably be safe in estimating the locomotive charges at 2d. per ton per mile, and allowing a length of Abt line of six miles for the two inclines, one on each side of the saddle, and making a deduction for the alternative of working an ordinary line,* we should find that the extra annual cost of working the Abt line, for locomotive charges, would be about £6,000, which, capitalised at 5 per cent., represents £120,000. If more than this sum would be saved by adopting Abt inclines of 1 in 15 to work 130-ton loads on a total length of incline about six miles, instead of having the 1 in 50 grades and a long tunnel, it would be reasonable to adopt the Abt system.

This is a very rough estimate, but it would probably be found sufficient. If a longer length of incline were adopted,† about £1,000 per extra mile should be added for working such a traffic as I have indicated; some additional charge would be entailed by extra maintenance charges on this incline.

I have no very intimate acquaintance with the locality, or with the trial surveys or sections, and can, therefore, offer no opinion as to the possibility of crossing the saddle with such a gradient or of approaching it so as to cross it with inclines of moderate length.

J. P. Maxwell, M. Inst. C.E.,
General Manager, N.Z. Railways.

7th June, 1888.

* The locomotive charges on an ordinary line, with 1 in 50 grades, and wages at rates current on New Zealand railways, should not exceed ½d. per ton per mile.

† I am since informed that it is unlikely that the length of inclines would be less than 8 miles.

[*Approximate Cost of Paper.*—Preparation, nil; printing (1,575 copies), £2 7s. 6d.]

By Authority: George Didsbury, Government Printer, Wellington.—1888.