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“Winter Working, Argentine Transandine Railway.”

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THE Transandine Railway is the connecting link between the Argentine and Chilian railway systems.¹ Leaving Mendoza, 2,520 feet above sea level, the line follows the course of the Mendoza and Las Cuevas rivers to the Chilian frontier, where the highest point (10,521 feet) is reached in the Summit tunnel (3,463½ yards long) (*Fig. 1*). From the summit, it follows the valley of the Caracoles and Aconcagua river to Los Andes (2,723 feet).

The line is partly adhesion and partly rack (Abt system). After leaving Zanjón Amarillo (7,237 feet), the valley rises in a series of terraces, and seven separate stretches of rack are used to surmount these terraces, the intervening parts having comparatively easy adhesion gradients. The total length of rack on the Argentine side is 15,381 yards, with a maximum gradient of 6·37 per cent, or 1 in 15·7, while that of the adhesion sections is 1 in 40. There are no reverse gradients on the rack sections. The line is 1 metre gauge (3 feet 3⅓ inches), and the permanent way consists of 50-lb. rails on hardwood sleepers, laid originally at the rate of 1,810 per mile, but since 1909, when heavier engines were put in service, strengthened by the gradual addition of sleepers at intervals of 8 metres on straight and 4 metres on curves. A 56-lb. rail on steel sleepers, laid at the rate of 1,828 per mile, is used on the rack sections. The rack itself consists of three vertical slotted bars, each 0·787 inch thick, fixed to cast-iron chairs which are bolted to the sleepers. The bars are 8 feet 8 inches long, and are laid so that the teeth break joint. The entrance pieces to each rack section are set on springs, and have teeth of special design to facilitate the engagement of the rack with the engine-pinions.

¹ B. H. Henderson, M. Inst. C.E. “The Transandine Railway.” *Minutes of Proceedings Inst. C.E.*, vol. cxv, p. 151.

Engines.—The engines used, namely, the Kitson (90 tons), the Borsig (48 tons), and the Beyer-Peacock (45 tons), are combined rack and adhesion locomotives.

The Kitson engines were put in service in 1909, and hauled trains of 140 tons regularly until October 1912, when, following an experiment made in substituting rigid keys for the spring keys with which the engine-pinions were originally fitted, many rack bars failed and distortion of the rack appeared throughout. In consequence of this, the train load was reduced to a maximum of 120 tons (excluding the engine) and, even under this load, the number of rack bars renewed from time to time has been very large. The boilers are set so as to maintain a proper water-level when working on the steep grades, the engines running with the chimney at the upper end, both ascending and descending. Engines do not run through from the Argentine to Chile or vice versa, otherwise they would have to be turned at the summit. Provision, however, has been made for turning engines and snow-ploughs should the necessity arise. The engines are fitted with Westinghouse and represson brakes, as well as with hand brakes, and there are hand brakes on all pinions. The greatest care has to be exercised in handling them when running down grade, as any strong and sudden application of the brakes is liable to result, if not in actual derailment, at any rate in damage to the rack, causing the train to skid to the bottom of the grade. On one occasion, this occurred when the train was near the end of a section of rack. It was, however, got under control on the comparatively flat grade at the bottom of the steep bank, with no worse result than a few broken and damaged rack bars and a number of badly flattened tires. The carriage and wagon stock is fitted with the Westinghouse and hand brakes.

Water-Supply.—The first winter's experience showed that the original water services on the upper sections were not reliable, and interruptions, caused by the intake chamber and pipes becoming frozen, occurred to the gravitation supply at Las Cuevas. At kilometre 168, the water was pumped direct from the Las Cuevas river and the main and tank froze under low temperatures. These difficulties were overcome by the construction of a deep frost-proof intake chamber at a spring about 1,000 feet above Las Cuevas station, from which a well-covered 3-inch pipe was laid, the water passing through the supply tanks at Las Cuevas and at kilometre 173 and the surplus overflowing to waste at kilometre 168. An arrangement of a similar kind was made at Puente del Inca, and all supply tanks were fitted with frost-proof coverings.

Working Conditions.—Throughout the winter, the weather conditions are telegraphed daily from each station to Mendoza, and, whenever unusually bad weather is reported, passenger trains are held up until conditions are more favourable. As a rule, trains do not leave stations in the snow zone until the next section is reported clear. When, however, there is much drift, they follow the snow-ploughs as closely as possible, in order to avoid being isolated by the drift which accumulates after the plough has passed. For some time after the inauguration of through traffic, an engine was used at each end of the train, but this was discontinued, and all the trains are now operated with the engine at the upper end when ascending, and at the lower end when descending. From the point of view of safety, it is essential that, on a rack railway, the engine should be at the lower end of the train, especially when the latter is stopped and started on a steep grade, an occurrence by no means rare on the Transandine Railway. All passenger trains carry portable telephones to enable them to communicate promptly with stations in case of accident.

Although a general idea of winter conditions had been formed during construction, continuous observations were not made, nor were regular records kept, as, previous to the completion of the Summit Tunnel, the line was not worked above Zanjón Amarillo, except on one or two occasions, when extraordinarily mild weather was experienced.

The snowfall varies considerably in different winters, but, on the Summit section, it has rarely exceeded 8 feet. In 1911 it did not exceed 3 feet, but, in the exceptionally severe winter of 1914, the Author found, from measurements taken after each storm, that the aggregate of the season totalled about 19 feet. The actual depth of snow did not exceed 14 feet, except where drifts occurred, the deepest of these being about 35 feet. During that winter, the almost continuous blizzards, the depth and density of the snow, and the number of snow slides made working impossible, and the line was closed from June to December. In spite of the fact that £50,000 has been spent on the erection of snowsheds at various points on the rack sections, winter traffic has been suspended on other occasions for similar reasons, but for much shorter periods.

Temperatures are subject to rapid and unusual variations, and although a minimum of -26° Fahrenheit has been registered, the average may be estimated at about -5° Fahrenheit. Snowfall is almost invariably accompanied by exceptionally strong winds.

When through traffic was inaugurated in 1910, it was found that

the actual conditions affecting the practical working of the railway were of a much more formidable nature than had been anticipated. The prevailing winds, which blow from the Pacific towards Mendoza, are, at the summit of the Uspallata Pass, fairly regular in force and direction, but conditions are entirely different along the valley of the Las Cuevas river. The deep narrow gorges which enter the main valley at frequent intervals, cause a series of baffling cross currents which produce drifts that seldom occur twice in the same place. Although experiments have been made with the object of preventing the formation of drifts on the line, results have not been satisfactory, on account of the exceptional force of the winds, and uncertainty as to where the drift would actually form. Reasonably calm weather occurs at infrequent intervals and then only for limited periods. The force and persistence of the wind is such that drift is almost continuous, even under a perfectly clear sky, and this has given much trouble, especially in cuttings. Where the line is on an embankment, very little difficulty is experienced, as the track is usually swept clear by the wind. It was thought that, by removing the lower sides of cuttings and by leaving the line on an open bench, drifts would be eliminated or considerably modified. The only result of this experiment, however, was to cause the snow to take the same slope as the cross section of the country. The drift is composed of ice particles closely resembling Epsom salts in appearance and in density. The snow, which falls on the higher Cordillera, is as a rule, similar in density, large soft flakes being of rare occurrence except at the beginning of a storm. This drift and its abnormal density is the chief obstacle to a regular and uninterrupted winter service. In regard to the adhesion sections, no great difficulty has been experienced, as the work of clearing the permanent way is done entirely by the ploughs and by the flangers and ice-cutters with which they are fitted. In the case of the rack, however, the snow, necessarily left by the ploughs between and around the rack bars, has to be removed by hand scrapers and wire brushes, no effective mechanical means having yet been devised for its removal. It was found that, when an engine was run over the rack before the partially compressed snow was removed, further compression resulted in distortion and, in some cases, fracture of the outer bars, the centre bar being little affected.

Experience also showed that under low temperatures the snow between the rack bars froze, and traffic was held up until the ice was chipped out by hand. In these circumstances, the progress

of the ploughs has been governed by the length of rack which the gangs, distributed at short intervals, could clear sufficiently to allow the next engine to pass without damaging its pinions or the rack. About 150 men were used for this work when the ploughs made good progress. Under favourable conditions, the plough is capable of clearing, before the snow hardens, a much greater length of rack than the gangs, but when it is working at full cutting capacity, the men have comparatively little to do.

Under winter conditions, it has not been possible to run to time-table, except during comparatively calm weather when the wind has not been sufficiently strong to cause drift. In the light of experience the only sure way of running to time-table is by preventing the accumulation of snow on the rack, and this apparently can only be done by the provision of sheds. As, however, the average cost of the existing sheds is £19 per linear metre, and the probable effective life of a timber and galvanized-iron shed under these conditions is 20 years, the benefit derived from covering the rack, except at points where the line could not be cleared by the rotary plough, would not justify the cost of the undertaking.

Avalanches and snow-slides occur with varying frequency above Las Vacas (7,855 feet), but have caused no difficulty, except between kilometre 166 and the summit. The avalanches and slides are remarkably free from rock or rubble, but between kilometres 169 and 171 there are two points where the slides contain so much debris that, at times, the only effective method of clearing has been by hand. This section, as it exists, will always be difficult to work, on account of its comparatively flat cross section, and its proximity to the long mountain slopes. If the ground had sufficient slope to permit the erection of sheds with roofs conforming approximately to the cross section, so as to allow a clear run over for the avalanche, the problem would be a simple one, but on the existing location any structure, whether of timber or masonry, would be exposed to the full force of the avalanche and consequently to certain destruction. After a long experience of the Cordillera, including 8 years under actual winter working-conditions, the Author is of the opinion (in cases where the line could not be kept clear of the long slopes where avalanches occur) that had it been built, where possible, on banks running into short sections of tunnel or cut-and-cover, no great difficulty would have been experienced in keeping the way clear with the snow-ploughs except in severe winters. No heavy expenditure would then have been required for the construction of sheds, which only really provides a temporary measure of protection.

Snow-ploughs.—Three kinds of snow-ploughs are used, namely, the small light nose-plough, the heavy push-plough, and the steam rotary plough. The former is bolted to the engine and can be removed in a few minutes. When the engine is used solely for snow-clearing, the ploughs are fixed at the back as well as in front, so that any drift which has accumulated after it has gone up grade can be cleared away on the return journey. This type of plough does useful work in freshly fallen snow not exceeding 3 feet in depth. The push-plough is built on bogies, and is used when the snow is too hard or too deep for the nose-plough. When worked by a Kitson engine or by two of the smaller engines, this plough gives good results where the snow is neither too hard nor more than 6 feet deep. Although the push-plough works quickly and cleanly on the comparatively flat, straight gradients, where it can be run at sufficiently high speed, it loses much of its efficiency when working against the rack grades, over almost continuous, short radius curvature, at a speed rarely exceeding 5 miles per hour. In this case, the snow, instead of being thrown clear of the cut, forms a ridge on either side, and when the cut drifts up again the depth of snow equals the original depth in addition to that of the snow pushed out on either side. Although the push-plough is worked at such a low speed, derailments are of frequent occurrence where the line is located on sidelong ground, these being caused by the greater resistance on the upper side of the slope as compared to the lower. Where the surface is level, and the resistance equal on both wings of the plough, derailment rarely occurs.

At one time, it was suggested that better results would be obtained by working the push-plough downhill. The idea, however, was abandoned when it was shown that, quite apart from experience on sidelong ground, nothing but disaster could result from running a coupled vehicle in front of an engine down 6 per cent. grades over a frozen rail and short-radius curves through snow of varying depths and resistances. Another serious objection to working downhill is the great difficulty of backing the heavy ploughs out of a deep snow-cut against such grades.

All heavy work is done by the rotary plough, which is worked by two engines, and makes steady progress in hard or soft snow not exceeding 12 feet deep. It throws all material clear and gives no trouble through derailment.

This Paper deals only with conditions as experienced on the Argentine Transandine Railway. These are usually the same on both sides of the mountains, but winter working on the Chilean Transandine Railway is attended with much greater difficulties and

danger on account of the heavier snowfall, the greater prevalence of snow-slides and avalanches, the 8 per cent. maximum gradient, and the fact that considerable stretches of the line are located in the open on very steep cross section, with long shingly slopes impending above the line, which carry snow from April to October.

The Paper is accompanied by thirty-three photographs and one tracing, from which the Figure in the text has been prepared.