

approaching line B proper, until it overtook it, probably opposite Dyer's. This would be merely a modification of line B, which I believe to be fully practicable; and although it might cross the Otira twice west of the summit tunnel—once at Cape Horn and then back to the south side—it would materially shorten the summit tunnel. The slight increase of length required in getting down around the Rolleston, and gaining the flat below the point opposite Dyer's, would not be of much moment. In any further discussion of the above modified line B in this report it will be referred to as line B1.

The physical characteristics of line B1 do not materially differ from those of line B. It would be 22 ft. higher at the summit, have a few more degrees of curvature, and be a few chains longer, making its total length ten miles. Its maximum grade would be 1 in 30 on the west approach, instead of 1 in 32; while the summit tunnel would be 18,216 ft. long, with a grade of 1 in 32, 2,112 ft. less than that of line B. Its cost of construction would be slightly, though not materially, less than that of line B.

Either of the B lines avoids most of the difficulties west of the summit tunnel, and reaches an elevation sufficiently low at the flat opposite Dyer's to be in embankment, or mostly so, instead of cutting. This is important in view of the opinion that has been expressed that the slope of the mountain above the flat mentioned would be an undesirable place upon which to build.

The slopes along the south side of the Otira, from the west end of the tunnel on either of the proposed B lines, are safe and comparatively smooth; and the same remark applies to the slopes of the Rolleston Spur, through which there would be a short tunnel. The bridge across the Rolleston would be from 15 ft. to 25 ft. high.

In making the survey the situation should be studied with care, so as to get the best out of it; and in this connection I take the liberty of suggesting that the map of the survey—at least, of the part from the summit tunnel to Otira—should be a contour map, on a scale of 100 ft. to an inch. On such a map the effect of slight changes of gradient can be tried, and the best possible location determined. In doing this I can see no reasonable objection to such slight increase of the rate of grade as might lessen the cost of construction, especially between the flat at the point opposite Dyer's and the proposed Rolleston Creek bridge. On the grade of 1 in 30 a slightly heavier locomotive than a class B would be required. Any line at Arthur's Pass will require at least one assistant locomotive. This being the case, there can be no reasonable objection to getting the most out of the matter by using such assistant engine as will make it feasible to adjust the grades to the local situation by such slight increase of the 1-in-30 grade as might effect any material saving in first cost.

In connection with this matter of grades it is proper to direct attention for a moment to what is done in the mountains in other parts of the world. In America, on the Atchison, Topeka, and Santa Fe Railway, the ascent to Raton Tunnel, at the summit of the Raton Mountains, has a maximum grade of 1 in $28\frac{2}{3}$, or 185 ft. per mile. Between Salt Lake City and Denver the ascent to the tunnel at Soldier Summit of the Wahsatch Mountains, on the Denver and Rio Grande Railway, has a maximum grade of 1 in 25, which is practically continuous for seven miles. On the Colorado Midland Railway, another important line, which crosses the Continental Divide at the Hagerman two-mile tunnel, the maximum grade is about 1 in 24. Between San Francisco, California, and Portland, Oregon, the ascent to Siskiyou Tunnel, at the summit of the range, of which Mount Shasta is a part, has many miles of 1-in-30 grade, the curves having a minimum radius of $6\frac{1}{2}$ chains. These are a few of many instances. They are important because of the vast traffic which annually passes over them.

In Mexico there are other numerous instances of the use of such grades, the most notable, perhaps, being that of the Vera Cruz and Mexico City Railway, the English line, upon which the maximum grade is 1 in 25.

In South America there are few, if any, lines of any considerable length where there are not, more or less, maximum grades of from 1 in $33\frac{1}{3}$ to 1 in 25.

In Europe the ascent to Mount Cenis Tunnel has maximum grades of 1 in $33\frac{1}{3}$, while that of St. Gothard is 1 in $38\frac{1}{3}$.

In the effort, therefore, to conform with nature's topographical features rather than to attempt to cut them down to some Procrustean rule, New Zealand will be doing what is done in all other parts of the world.

My view of the whole subject is, as will be gathered from the above, that in line B or line B1, with such modifications of either as actual survey may demonstrate as desirable, we have the best attainable line at Arthur's Pass. While this is so, I am not prepared to say that construction of either of them should begin until such survey has been made, as suggested, and the various details have been worked out.

Next to the B line, line C offers the best solution. This line also can be modified to some advantage by making the grade in the summit tunnel a little steeper from the summit west, and reducing slightly the grade of the west approach. It would be a good plan, however, to have the grade in the tunnel a little easier than that of the west approach.

The summit tunnel of this line is but 2 miles 47 chains (13,662 ft.) long, 4,554 ft. less than that of line B. On both approaches, however, it is more difficult and costly to construct than a B line would be. Between Otira and Rolleston Creek it crosses the slope opposite Dyer's, previously mentioned. I do not share in the views respecting that slope, and should have no hesitation in building along it if there were anything to be gained thereby, and would prefer line C, with its short summit tunnel, to a six-mile-tunnel project. The maximum grade of 1 in 25 (it would probably be a little less) could be worked with entire success, as such grades are worked elsewhere, and the whole project, if completed, would be satisfactory.

In my judgment, artificial ventilation of the summit tunnel of line C would not be required. This tunnel would have an adit near Kea Creek, 2,000 ft. from its west entrance, which would materially aid in the matter of ventilation.