way route, we should bear in mind that between two points, which are at the same absolute elevation, there should be as little rise and fall as possible, and that between points at different elevations we should endeavor to have no rise while descending, and consequently no fall upon the ascent. These conditions can seldom be exactly complied with in practice, but we may approach them closely. In many cases we have to choose between two systems of grades—the one involving a long but gradual and uniform rise, the other a short but steep ascent, with the remainder of the line level, or nearly so. The total resistance upon the two systems, involving the same amount of ascent, will be the same; but a great difference may be made in the method employed in overcoming that resistance. If we have a grade 10 miles long, rising at the rate of 20 ft. per mile, we adapt our

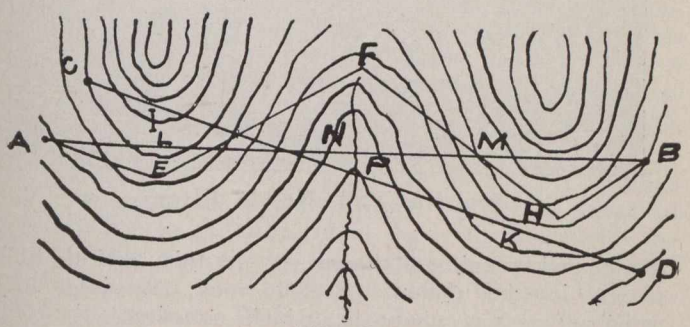

Fig. 2.

machinery to hauling its ordinary load up that incline, and we require from it a constant expenditure of power while ascending, and on the descent it is profitably aided all the way by gravity. If, however, the first 8 miles are level, and the remaining 2 miles ascend at the rate of 100 ft. per mile, an engine to work the incline would be too heavy for the level portion, and in the descent we should have more aid from gravity upon the incline than we required with none at all upon the level.

The effect of the arrangement in detail of the grades upon the amount of work to be done in reducing the natural surface of the ground to the finished roadbed, is shown in Fig. 4. The level grade from *A* to *B* involves a large amount of earth cutting at *D* and *E*, and a large amount of embankment at *C*. By raising the grade lines *D'* and *E'*, in the cuttings, and depressing the level em-

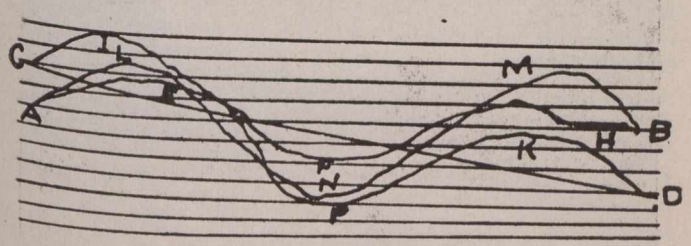

Fig. 3.

bankment from *C* to *C'*, we at once reduce both amounts of excavation and embankment, and by raising the roadbed more, to *D''* and *E''* in the cuttings, and depressing it to *C''* upon the embankment, we reduce still more the quantity of work to be done, but at the same time we render the road more difficult of operation.

There are many points that govern the rate of grade of a new railway. Probably first of all is the capital at disposal of the promoters of the road; for plenty of money will make possible an almost level line. But often the tremendous cost of such a level road would never pay dividends, notwithstanding this advantage. The country through which a road is to pass largely governs the most economical grade. If a comparatively level country, then there is no necessity at all for steep grades on the grounds of economy. If, on the other hand, the country is rough, the grade must be made to conform first with the amount of capital available, and, secondly with operating expenses.

The question of interest at which the money can be borrowed also enters very largely into that of grades.

It is doubtful if it were wise economy on the part of the C.P.R., when building its road across the continent, to make the grade limit so steep. Money was at a much lower rate at that time than now, and the vast sums of high-priced money that have been used in the past few years to ease the gradients might better have been used on the original work. This goes to show that faith in a railway enterprise also governs the gradient. When the C.P.R. line was being constructed a great many people had little faith in the successful outcome of the enterprise, while the problem of crossing the Rockies was

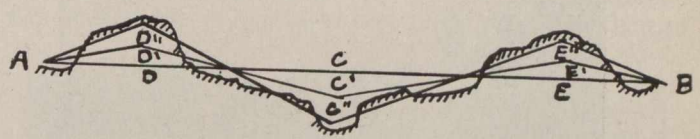

Fig. 4.

considered by many to be almost an impossibility. Money-lenders, not being greater endowed with prophetic powers than any other class of people, held the general view, and it was only with the greatest difficulty that the money could be found to construct the road on the original plan of steep grades. Faith in any enterprise is, therefore, of great importance, and particularly so in the building of a railway.

We think the reconnaissance line of a railway of considerable length is not generally given due importance in this country. Certainly, no decision as to suitable grades and curves should be arrived at before a full report of the exploration or reconnaissance survey has been received. We also think that these exploration surveys are not usually complete enough. Besides determining the most economical ruling grade, the possibilities of the country as to production, available freight and passenger service, contiguity to water transportation, are of almost equal importance with the gradient. These latter points, however, are usually neglected in the exploration line, the whole interest being centered in the grades.

A statistical report on the operation of electric railways throughout Canada in 1913 has recently been published at Ottawa. There are 56 electric railways in Canada, and during the year ending June 30th, they carried 598,662,801 passengers, exclusive of transfers, and 1,957,930 tons of freight. There was an increase in the number of passengers over 1912 of 108,998,119. The mileage of the railways increased during the year by 142 miles. The gross earnings of the electric roads in 1913 was $25,216,111, an increase over 1912 of $4,716,861. In five years the earnings of the electric railways have more than doubled. During 1913 the earnings from passengers was $19,794,400; from mail and express, $72,516 and from freight, $1,211,871. The operating expenses amounted to $17,765,372, leaving $10,450,738 as gross corporate income in addition to $1,318,909 of miscellaneous income, making a total income of $11,769,647. A surplus of $2,958,742 was carried after taxes, debt, interest and dividends were paid; and an addition of $554,324 was made to the reserve.