and mail, and mostly fast express service, for which electric traction is better suited than for heavy freight service. The cost of coal per ton is about one-third that at Otira. Mr. Arnold finds the cost of motive power with electric traction to be only 2·3 per cent. less than with steam locomotives, which of itself would not be enough to warrant the investment in the electric equipment even with the very heavy traffic of the Grand Central Station.

The letter of Mr. F. D. Casanave, general superintendent of motive power of the Baltimore and Ohio Railroad, gives the cost of operating the electric-power plant in the Baltimore tunnel for the month of March, 1902. While the data is not sufficient to make a direct comparison in figures, it is enough to show that the cost of electric motive power is not economical.

With compound condensing-engines in the power-house, the coal-consumption per indicated horse-power hour will be about 2 lb. An efficiency at the motors of 60 per cent. of the indicated horse-power of the engines is as high as can be realised in the case of the Arthur's Pass line, and it would probably be less. This means that at least $3\frac{1}{3}$ lb. of coal will be required to produce a horse-power at the motors. With steam locomotives $4\frac{1}{2}$ lb. of coal per indicated horse-power are required. Therefore, other things being equal, and under favourable conditions, electric traction might save about one-quarter of the annual expenditure for fuel. An inspection of Tables 6 and 9 shows that a saving of a quarter in the cost of fuel will save about one-tenth of the total cost of motive power, and for line A this amounts to about £146 sterling for 500 trains each way per annum, £180 sterling for 700 trains each way per annum, £230 sterling for 1,000 trains each way per annum. Subtracting these figures from those given above we have net excess annual costs of electric traction over steam locomotives of £1,042 sterling for 500 trains each way per annum, £889 sterling for 700 trains each way per annum, £662 sterling for 1,000 trains each way per annum. For comparison with other lines the above figures may be added to the total annual charges of line A in Table 13.

The conclusion is evident that electric traction for line A cannot be further considered from an economic view point. The success and comparative economy of the ventilating-apparatus at the Elkhorn Tunnel of the Norfolk and Western Railway eliminates the principal disadvantages of steam locomotives and the chief reason for investigating electric traction for this long-tunnel line.

Electric Rock-drills.

As confirming my own knowledge that the electric rock-drill for tunnel-construction is still in an experimental stage, I submit letters from Mr. George S. Rice, deputy chief engineer of the New York Rapid Transit Commission; Mr. William Hood, chief engineer of the Southern Pacific Company; and Mr. J. Q. Barlow, of the Oregon Short-line Railroad Company. These gentlemen are at present actually in charge of engineering-works where tunnels are an important element. It is clear that the electric rock-drill should not be seriously considered, under the circumstances, in connection with the tunnels of either of the lines discussed. The engineers of the Rapid Transit Commission visited many places in Europe looking up data for use in the construction of the New York Rapid Transit Subway, which is mostly in rock, with several miles of double-track tunnel.

Electric Plant for Tunnel-construction.

I have investigated the proposition of an electric plant for constructing the long tunnel of line A with a view to the future use of the same for operating the road by electric traction, and find that it is not practicable for the following reasons:—

First, a plant designed for economical results in one service would not be economical in the other, and a plant designed for both would not give the most economical results in either.

Second, by the time a long tunnel could be completed any plant installed in the beginning of construction would have lost much value by ordinary deterioration, and would require considerable outlay for repairs and renewels.

Third, the present "state of the art" in heavy electric traction is such that a plant installed now would probably be out of date, if not antiquated, by the time the work could be completed.

Fourth, the construction of the tunnel can be more economically and expeditiously executed with a steam-driven compressed-air plant and pneumatic drills, a small electric-light plant, and small locomotives. These small locomotives may be either electric or compressed-air, and can be supplied with power by installing a sufficiently large compressed-air plant or electric-light plant as the case may be. The current required for lighting purposes and for the small electric locomotives would only be a small part of that required for the electric operation of the completed road, and for this service direct current would probably be preferable to the high-tension alternating current required for electric traction.

Fifth, electric rock-drills have not been successful on such work as this, and electric air-compressors would be more expensive both to instal and to operate than direct steam-driven air-compressors.

Sixth, it has been shown that electric traction for line A would cost more for annual charges than steam locomotives and a satisfactory ventilating plant combined, and the first cost of the electric installation would add from £60,000 to £70,000 to the total investment.

Conclusion.

The question which I have had the honour to investigate under your direction has now been studied in full view of the experience gained in the operation of grades over various railways, and with such data respecting the physical conditions, probable cost, &c., of the several lines treated as are presented by the surveys made at Arthur's Pass prior to the date of my first report. I have not discovered any reason for changing the recommendations of that report. Indeed, the investigations made have only tended to confirm them. When the surveys and maps are completed, the cost and other elements of lines B and C, or some other line lying between them, can be determined quite definitely, and a choice can then be made.