turbed. Whilst the actual measuring is taking place two men carry up a spider and place it at the next spider point ahead.

At the starting point and all rivet stations, instead of one of the spiders being placed over the rivet it was placed a foot or two ahead merely as a support for the tape, and the reading on the tape was obtained by transferring the point on the rivet up to the tape by means of a transit placed a short distance away and at right angles to the tape.

This method of measuring required ten men, namely, chief of party, transitman, recorder, two chainmen, two spider-placers, one thermometer reader, one man for forestay and one man for tension wheel. Under favorable conditions as many as 15 to 18 stations were measured in an hour, but 10 stations per hour would make a good average for a day's work.

The majority of the work was done in the daytime but in the busy sections of the city it was done during the night, no difficulty being experienced from the darkness, acetylene miners' lamps being used.

Having made the measurements in the field, the correct distances between the stations were computed in the office, making the necessary corrections for the reduction of the distance to horizontal, for temperature, and the tape correction to standard, the two former being obtained from diagrams plotted for that purpose.

Great care had now to be taken in reading the angles of the transverse. A Berger transit, 7-inch plate reading to 10 seconds was used. In setting the instruments up over the angle points a second transit was used to insure the vertical axis of the instrument being exactly over the centre of the cross on the rivet. At the two points sighted at, wooden targets were used, being set up vertically and precisely over the points by means of a transit. These targets were made of wood 4 inches wide and about 3 feet high, and were divided into red and white triangles. Adjustable tripod legs were used to support them. In reading the angle one observer would read the angle once, and then wrap it up five times, and then go backwards until zero was reached again on sighting at the first target, to insure that the plates had not slipped. This would give a very close determination of the angle to 2 seconds, and this process was repeated by an independent observer, thus giving a mean determination down to 1 second. Every precaution was taken to eliminate any instrumental errors, and also to protect the instrument from the heat of the sun. In a circuit five miles long with 33 angles there was only an error of closure of .1 second, and in another of three miles and 10 angles the transverse closed exactly by the angles, and in none of the circuits was there an error of more than a few seconds. All the important transverses were duplicated by independent routes giving a complete series of closed transverses, and from the base line measurement an average degree of error was found to be about 1 in 40,000.

The measurements around the mountain being completed, it was necessary to project a line over the mountain in the same vertical plane as the tunnel centre line.

To do this the minimum number of transit points were selected and permanent concrete monuments built to hold the line. In setting up a transit at a monument plumb-bobs were discarded entirely and the transit was bucked into line until the cross hairs intersected both the far away back sight and also the cross scratched on the monument close to it. The line was then projected to the monument ahead time after time, reversing the instrument between each sight.

A mean was taken of all the points obtained at the foresight monument and the line thrown ahead from that point in the same way.

The surveys for the whole work were tied into the same system of base lines and a series of co-ordinate lines was adopted so that the latitude and departure of any point could be readily obtained, hence its distance and bearing from any other known point. All the survey alignment points in the tunnel are also being referred to the same co-ordinate lines. The levels were transferred from the city to the west portal in as accurate a way as possible with standard instruments; 18-inch wye levels were used with target rods. The level was set up three times for each turning point, these never being more than about 100 feet from the instrument and equidistant therefrom. The whole operation was repeated four times with independent observers. The difference in their elevations of corresponding bench marks being only a few thousandths of a foot.

In the city itself it was decided to put in permanent survey monuments at the more important and strategic stations. These monuments (Fig. 4) were made by digging a hole about 7½ feet deep and filling the bottom to a depth of about 2½ feet with concrete, in which was set the monument proper, made of 6-inch cast iron pipe at the bottom, with a 4-inch pipe inserted into it at the top with a leaded joint, the object of this being to enable the top of the pipe to be easily lowered again in case the whole pipe should be heaved by frost. This, of course, is an unexpected contingency. In the top of the smaller pipe a piece of brass was cemented and on this the precise cross scratch was made, and also the precise elevation taken. After the concrete had set, the space surrounding the pipe was rammed with earth or sand taken from the hole, and on top of this a cast iron cover plate and base set with concrete into the sidewalks was placed, thus making a good permanent point free from disturbance and easily accessible.

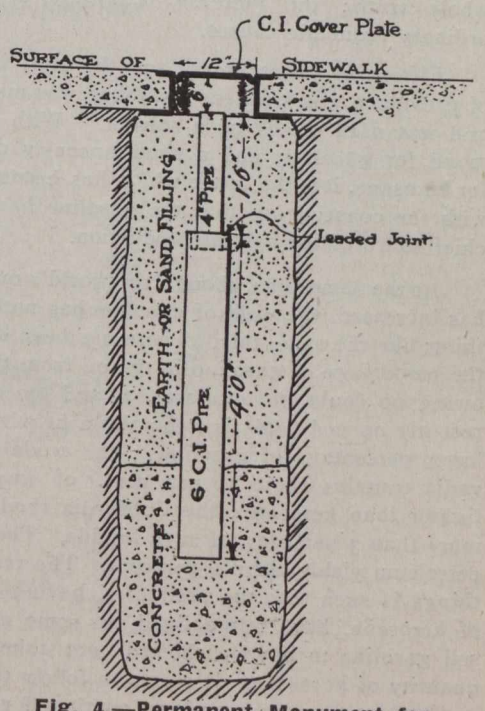

Fig. 4.—Permanent Monument for Tunnel Survey.

The surveys and measurements for the tunnel, which were all carried out under the immediate supervision of the writer, although requiring great accuracy, were comparatively simple, compared to the alignment work in the tunnel, because frequent checks on the work could be obtained, whereas in the tunnel no checks are obtainable until the headings are run into one.

The government owned telephone system of Alberta yielded a surplus of receipts over operation and maintenance expenses during 1912 of $62,283, while the earning capacity of the system on a basis of the capital expenditure amounted to 12.1 per cent. In the six years, 1907-1913, the system has yielded a profit of $407,592.