arrangement allows the sighting lines to be more readily centered and bisected than a vertical wire. An adjustable head for centering is also essential.

Fig. 1 shows a triangulation made for the purpose of determining the line of a tunnel about 3,200 ft. between shafts. This tunnel was driven through blue clay and presented no particular construction difficulties. When the junction was made the centre lines were found to be practically parallel and about ¼ in. apart. The district under which the tunnel was located was thickly populated and covered with houses and trees and no direct sight could be obtained between the shafts. A triangulation was, therefore, necessary.

The line paralleled a steep side hill which sloped to a river, upon the opposite bank of which were extensive flats. These offered an exceptional chance for securing a good level base and points D, E, F and G were established across the river.

The only line upon which a traverse could be run along the top of the hill was along a winding lane and a check triangulation was made on this route.

Starting at a point west of the first shaft which we will call A, another point, C, was established down hill on the left bank of the river and a point D was established on the right bank on the same line. The river was too wide for a direct measurement. A point H on the tunnel line was fixed by the position of a manhole and could be seen from A.

The angle A H D was then noted and also an angle P A D taken to connect the survey with other work, and the distance between A and C was measured as previously described. The outfit was then moved across the river to D and a line ranged and measured to point F and also from F to G. The angle A D F was then noted and an intermediate point E established at 200 ft. from D to enable the distance C D to be calculated. The angle D E C was then read. A point B east of the second shaft could be seen from both F and G, and angles were taken at these points to this station from the bases D F and F G.

The measured bases are shown full in the diagram and the calculated sides are shown dotted. Sufficient information having been secured to complete the preliminary triangulation, the work was plotted in the office and the calculations started.

The base measurements were first corrected for temperature and then reduced to horizontal distances and the survey was plotted from the information obtained. It was first necessary to calculate the distance C D across the river so as to secure a continuous measurement from A to D. This was done by solving the triangle C D E from which the distance was found to be 179.69 ft., which, added to the distance A C, gave a total distance of 870.50 ft. from A to D.

The triangulation system was then divided into three triangles, A D F, F G B, and A F B, which were solved in the order named, care being taken to make any adjustments necessary, any differences being divided out proportionately. The distance between the points A and B was thus computed and found to be 3,245.60 feet and the angles which it was necessary to turn at the points A and B from the bases to establish the centre line were determined.

The traverse was then checked by latitudes and departures and the distance A B computed to be 3,245.61, which was practically a dead check. A summary of this check is given.

Bearing.	Length of course. Feet.	Lat.	Dep.	Diff. Lat.	Diff. Dep.
S.	870.50	870.50	.....	.....	.....
N. 73° .25′ E.	2,447.12	698.43	2,345.33	172.07	2,345.33
S. 89° .56′ .46″ E.	496.25	0.50	496.24	172.57	2,841.57
N. 13° .54′ .54″ E.	1,125.88	1,092.83	270.85	920.26	3,112.42
S. 73° .31′ .44″ W.	3,245.61	920.23	3,112.41	0.03	0.01

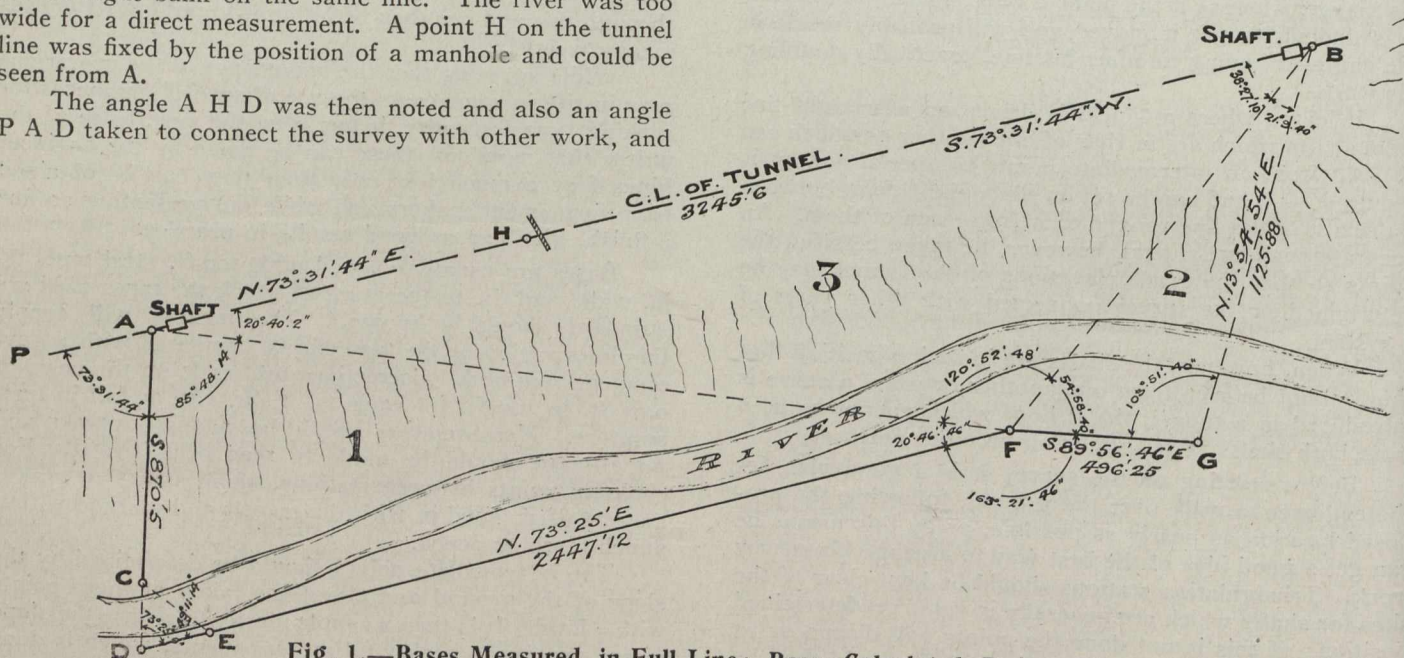

Fig. 1.—Bases Measured, in Full Line; Bases Calculated, Broken Line.

Upon working up the check traverse made between the points A and B along the hillside the results were found to agree very closely with those previously obtained.

The triangulation described is a fairly simple one, but the methods adopted can be applied to a more elaborate system if required.

Before construction starts, bench marks should be established well clear of each shaft for the purpose of fixing the grade elevations. They should, as far as possible, be placed so that the levelman can see both the bench mark and the shaft, from his initial set-up, midway between the points.

When a tunnel is projected under a city, following or crossing street lines, it is sometimes advisable on account of traffic interference, to make the surveys at night. The temperature is then more equable and the sight when illuminated, can be clearly seen by the observer. A box about 12 in. square with a front of tracing linen or frosted glass is used behind the sighting points and is illuminated in any convenient manner.