For long-range guns the position of a reference point or aiming post was determined in the same way with a surveyor's transit, and the distance and grid bearing from this point to the pivot gun were measured. In the case of field batteries the locations were usually obtained by reading the angles with a box sextant, and the solution was made graphically if time did not permit working it out analytically. The plane table was also extensively used for the positions of the shorter range guns. Sometimes, in the case of forward positions, all trigonometrical points in the vicinity had been obliterated; the location had then to be obtained by a traverse with plane, table and tape, or by some other device.

The accurate survey of battery positions was especially important in case of heavy concentration of artillery for a surprise attack. Under such circumstances, it was obviously impossible to use the older method of registering the gun by trial shots. The positions were usually surveyed and marked with stakes the day before the guns were brought up. In reference to the work of one field survey company, the following may be quoted from the published report of Lord Cavan's despatch of November 15th, 1918, from Italy:—

"At 11.30 on the night of October 26th, the bombardment of hostile positions opened along the whole front. The fact that no single British gun had opened previous to this hour deserves special mention. Both heavy and field artillery were registered by the 6th Field Survey Section, R.E., and the fact that the bombardment and the subsequent barrage were excellent in every way, reflects the greatest credit on all ranks of this company."

Flash-Spotters

The flash-spotting group determined, by the method of intersection, the position of enemy batteries and other targets. Each group consisted of four or five observation posts placed at intervals along a front of some four miles, and a central plotting station usually some distance in the rear of the line of posts. An observation post was usually situated in a trench. It consisted of a small rough hut of wood and galvanized iron, with a shelf for the instruments and a slot in front to observe through. The essential equipment comprised a "Mark V" director or other instrument reading to minutes, a pair of binoculars graticuled in half degrees, and direct telephonic communication with the plotting office. In addition to the usual cross-hairs, the telescope of the director was provided with vertical wires spaced to cover intervals of 5 to 10 minutes. Its field was about one degree. By means of the graticules, the angular distance, right or left of the instrument setting, of any gun-flash appearing in the field of the telescope, could be estimated. This was added to or subtracted from the H.C.R., as the case required. The diaphragm and horizontal circle were provided with small electric lights and another small electric light controlled by a switch from the observation post was placed on a picket some distance in front for checking the orientation of the instrument at night. In connection with the telephone was a push button which operated a buzzer and lit a lamp in the central station.

The equipment of the plotting office was a large scaled grid, mounted on a table, covering the same front as all the posts. On this the position of every post was marked by a small hole. Centered on these holes graduated arcs were drawn for reading grid bearings from the several posts. A silk thread was passed through every hole and a weight attached to each end. The weight underneath kept the string taut and that on top of the table could be moved to place the string on any bearing required. The central station, in addition to its connection with the posts, had direct telephone communication with the counter battery officer and the Intelligence Branch.

The procedure of operation was as follows: Each post was manned day and night by two observers. As soon as the instrument was properly oriented by means of the data supplied by the topographer, a rough sketch panorama was made of the visible country. On this, bearings to prominent marks at intervals of about 5° (the field covered by the binoculars) were noted. By reference to these points, one observer with the graticulated glasses could give the other at the director a sufficiently accurate estimate of the bearing of an observed gun-flash to bring it into the field of the telescope. The next round fired would find the director trained on the battery, and the grid bearing would be telephoned to the plotting office.

By manipulating the threads on the plotting board, the operator would ascertain the approximate bearing of the enemy gun emplacement from the other posts, and warn them to look out for flashes in these directions. Then all the posts being on the alert, every observer would press his button on seeing a flash. If the connected electric lights at the plotting office came on simultaneously, it was known that all posts were observing the same flash. The various bearings were then telephoned to the plotting office where the position was fixed by intersection, the map co-ordinates scaled off the grid and immediately communicated to the counter battery officer and Intelligence Branch.

In this work speed was of the utmost importance, as very often only a few rounds would be fired at one time, especially when ranging shots were being fired to register a gun in a new position. Besides gun emplacements, any other object whose position was required for any purpose, could be located in this way. Every morning when enemy captive balloons went up, their positions were reported. The posts were also used for observing destructive shoots by our own heavy artillery, the battery commander being given the co-ordinates of each shell burst within a few seconds of the time it landed.

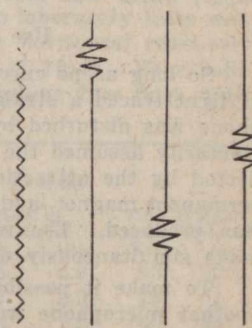

FIG. 2

Sound-Rangers

The methods mentioned above were effective in clear weather. In France and Belgium, however, there were days and weeks together when such a system was rendered useless by fogs. Various devices were also used to screen and blanket gun-flashes. It was for these reasons that sound-ranging was introduced. The writer has no personal knowledge of the British system, but had access to some of the enemy literature on the subject when billeted in the *Artilleriemesschule* at Wahnerheide after the armistice. The methods used on our side are believed to have been much the same.

The fundamental principle was this: If the report of a gun reached a point, A, at a certain time, and a point, B, some time later, the position of A and B being known, the difference between their distances from the unknown gun position could be determined by multiplying the difference in time by a constant for the speed of sound. We had thus the data for plotting an hyperbola of which A and B were the foci. The gun position would lie on this locus. The equation to the curve would be $(4x^2/d^2)-(4y^2/D^2-d^2)=1$, D and d being respectively the distance between the posts and the difference between the distances of the unknown from each post.

The same process being repeated with respect to B and another known point, C, a second hyperbola was found and the gun position was fixed by the intersection of the two. The equations to the hyperbolas could, of course, be solved simultaneously in each particular case. In practice this took too long, as a result to be of any use had frequently to be obtained almost instantaneously. The positions of the posts were, therefore, laid out on a plotting board similar to that used for flash-spotting. On this were plotted a series of hyperbolas in different colors for posts taken in pairs, and for distances corresponding to differences of time from zero up to the limit required, at intervals of 0.5 seconds. For zero, of course, the locus was a straight line.

Certain corrections had to be made for atmospheric conditions and for wind. A sound-ranging headquarters could always be recognized by the presence of wind-gauges and