trenches with great accuracy. The flash-spotters and sound-rangers reported daily the positions of active enemy batteries. Intelligence was received from kite balloons and other observers.

Photographical experts of the field survey company, either working at headquarters or attached to an aerodrome produced the "mosaics" and other prints. New information secured from these was transferred to the map by the *camera lucida.*

Special maps were prepared for the different branches of the service, emphasizing only the particular features required. Thus, the counter battery map, issued twice a month, showed which hostile gun positions had been active and which silent during the previous fortnight. The harassing fire map brought out distinctly the main arteries of traffic used by the enemy. The organization map gave the locations of trenches, aerodromes, hospitals, dumps of ammunition, provisions and material, etc. The bulk of this work was done by men who had formerly been architectural draughtsmen, and the results were admitted by enemy literature to be superior in accuracy and clearness to anything produced on the German side.

### Topographers

The principal duty of the topographers was to determine, by survey on the ground, the map locations of battery positions for the artillery, and of observation posts and reference points for the artillery, flash-spotters and sound-rangers. In the case of observation posts this was always done by resection, or the "three-point problem." It was the most accurate method available, because it was usually impossible to occupy a trigonometrical station, and it would have been highly impolitic to have erected, at the point whose location was desired, a signal sufficiently conspicuous to admit of intersection from two such stations. The primary reference points were church-spires, head-works of mines and similar prominent land-marks whose position was given in the lists of metre co-ordinates previously mentioned in connection with the ordnance maps.

The instrument generally used was a "Mark V" director, an "observation of fire" instrument, a French or a captured German instrument of similar type. The characteristic differences between all these military instruments and a theodolite were that the graduations were on the upper plate and instead of a vernier there was a fixed tangent screw with a graduated drumhead at the zero point on the lower plate. The threads of this screw engaged teeth on the upper plate arranged so that a complete revolution of the drum moved the telescope one degree in azimuth. Degrees were read on the upper plate and minutes on the drum. There was a lever to disengage the tangent screw from the upper plate for reading large angles.

Following is the reduction of a survey of an observation post, showing the amount of calculation that was involved:—

Data from list of metre co-ordinates:—

$A$, Fosse 14, Fouquières Puits, $W$103908.5 $N$4079.1.

$B$, Factory chimney, Brebières, $W$ 96184.6 $S$6138.3.

$C$, Bailleul, highest point of ruins of church ........ $W$107989.4 $S$5678.8.

Angles read at observation post, $P$ (see Fig. 1):—

$\alpha = 49° 48'$ $\beta = 11° 56'$

Formulae:—

$x+y = C-(\alpha+\beta)$.

$\tan \frac{1}{2}(x-y) = \tan \frac{1}{2}(x+y) \tan (\phi-45°)$.

$\tan \phi = a \sin \alpha / b \sin \beta$.

Solution of bearings and sides of triangle, $A\ B\ C$:—

*(Side b)*

| | | |
|---|---|---|
| Log 4080.9 = | 3.6107560 | |
| " 9757.9 = | 3.9893564 | |
| " tan 22° 41′ 43″ = | 9.6213996 | (Bearing $b$). |
| " 9757.9 = | 3.9893564 | |
| " cos 22° 41′ 43″ = | 9.9649993 | |
| " 10576.9 = | 4.0243571 | (Length $b$). |

*(Side a)*

| | | |
|---|---|---|
| Log 11804.8 = | 4.0720586 | |
| " —459.5 = | 2.6622855 $n$ | |
| " tan 92° 13′ 45″ = | 1.4097731 $n$ | (Bearing $a$). |
| " sin 92° 13′ 45″ = | 9.9996712 | |
| " 11804.8 = | 4.0720586 | |
| " 11813.7 = | 4.0723874 | (Length $a$). |

*(Side c)*

| | | |
|---|---|---|
| Log 7723.9 = | 3.8878366 | |
| " —10217.4 = | 4.0093404 $n$ | |
| " tan 142° 54′ 44″ = | 9.8784962 $n$ | (Bearing $c$). |
| " cos 142° 54′ 44″ = | 9.9018472 $n$ | |
| " —10217.4 = | 4.0093404 $n$ | |
| " 12808.4 = | 4.1074932 | (Length $c$). |

$\therefore A = 59° 46' 59''$

$B = 50° 40' 59''$

$C = 69° 32' 02''$

$\alpha+\beta = 61° 44'$. Therefore, $(x+y) = 7° 48' 02''$, and $\frac{1}{2}(x+y) = 3° 54' 01''$.

*(Auxiliary Angle, ϕ)*

| | |
|---|---|
| Log $a$ = | 4.0723874 |
| " sin 49° 48′ = | 9.8829774 |
| | 3.9553648 |
| " $b$ = | 4.0243571 |
| " sin 11° 56′ = | 9.3154947 |
| | 3.3398518 |
| " tan 76° 22′ 32″.5 ($\phi$) = | 0.6155130 |

*(Angles x and y)*

| | |
|---|---|
| Log tan 3° 54′ 01″ $\{\frac{1}{2}(x+y)\}$ = | 8.8336445 |
| " tan 31° 22′ 32″.5 $(\phi-45°)$ = | 9.7852020 |
| " tan 2° 22′ 51″ $\{\frac{1}{2}(x-y)\}$ = | 8.6188465 |

$\therefore x = 6° 16' 52''$ $y = 1° 31' 10''$

Solution of triangle $A\ P\ B$ for side $PA$:—

$APB = (\alpha+\beta) = 61° 44'$

$PAB = (A+x) = 66° 03' 51''$

$PBA = (B+y) = 52° 12' 09''$

$PA = c \sin (B+y)/\sin (\alpha+\beta)$.

| | |
|---|---|
| Log 12808.4 = | 4.1074932 |
| " 52° 12′ 09″ = | 9.8977270 |
| | 4.0052202 |
| " sin 61° 44′ = | 9.9448541 |
| " 11491.2 ($PA$) = | 4.0603661 |
| Grid bearing of $CA$ = | 22° 41′ 43″ |
| Angle $x$ = | 6° 16′ 52″ |
| Grid bearing of $PA$ = | 28° 58′ 35″ |

Latitude and departure, $A$ to $P$:—

| | |
|---|---|
| Log 11491.2 = | 4.0603661 |
| " sin 28° 58′ 35″ = | 9.6852482 |
| " cos 28° 38′ 35″ = | 9.7419184 |
| " 5566.9 = | 3.7456143 |
| " 10052.7 = | 4.0022845 |

| | | |
|---|---|---|
| Metre co-ordinates of $A$ = | 103908.5$W$. | 4079.1$N$. |
| Lat. and dep., A to $P$ = | 5566.9$W$. | 10052.7$S$. |
| Metre co-ordinates of $P$ = | 109475.4$W$. | 5973.6$S$. |
| Metre co-ordinates (from tables) $E$ by $B$.20.$d$ = | 109601.2$W$ | |
| Metre co-ordinates (from tables) $S$ by $B$.20.$d$ = | | 6360.2$S$ |
| Differences (metres) = | 125.8 | 386.6 |
| Differences (from tables) in terms of sides of a map square ........ = | 0.28 | 0.85 |

Map location of observation post = $B$.20.$d$.28.85

Bearings to Fosse 14, Fouquières = 28° 58′ 35″

" " Bailleul church = 78° 46′ 35″

" " Brebières chimney = 90° 42′ 35″