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"Surveying with the Omnimeter."

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THE use of specially-constructed instruments for facilitating rapid surveying in difficult country is becoming common; but the engineer has in a great measure to learn from experience the use and capacities of the more modern instruments. The Author therefore thinks that the results of his experience with the Eckhold omnimeter, in making railway surveys in very rough country, may be of service to field-engineers.

Omnimeter.—The Eckhold omnimeter is a transit theodolite with certain additions, and therefore capable of doing all that a transit theodolite can do, and something besides. The additions are a microscope, the axis of which is fixed at right angles to the optical axis of the telescope, and a very finely-divided scale fixed to the upper horizontal parallel plate and capable of being moved end-ways by turning a micrometer screw, attached to which are a circular scale and vernier serving to measure accurately the end motion made by the scale. The scale is placed immediately underneath the microscope, so that when the instrument is truly levelled and the vernier of the micrometer circle at zero, the central hairs of the microscope cut the exact centre of the scale. This point is termed the "point of departure" for levelling. Then also, if the instrument is in adjustment, the optical axis of the telescope is truly level and parallel to the scale, which is

4 inches long, and is divided into 100 principal parts indicated by numbers engraved on it. Each of these divisions is halved by a shorter line. The micrometer screw turning through one revolution moves the scale backwards or forwards exactly the distance of one of these smaller spaces, or $\frac{1}{100}$ inch.

The principle of the instrument is as follows:—C (Fig. 1) is the axis of rotation of the telescope in a vertical plane and AD the scale; and CD, the vertical distance of this axis from the scale, is

known. This is the axis of the microscope when directed to the point of departure D, when the axis of the telescope lies in the horizontal line CD'. Let A' B' be a staff of known length observed at a horizontal distance CD', A' D' being vertical. When the axis of the telescope is directed to A', that of the microscope points to A on the scale, and to B when the telescope is directed to B'. The lengths AB and BD being measurable by the micrometer arrangement, their ratio to CD is known; and as the triangles C A' B' D', C A B D are similar, A' B' : B' D' : CD' as A B : B D : C D, and the horizontal distance CD' of the staff and the distance B' D' of its base above or below the horizontal line are easily calculated. CD is called the "base line" of the instrument and is made as nearly as possible 6 inches, the scale of 4 inches being taken = 100,000, CD = 150,000 approximately, the exact number being different for each instrument and determined experimentally. In the Author's instrument its value was 150,180. The equations used are:—

$$\text{Altitude, or} \quad B' D' = \frac{A' B'}{A B} B D.$$

$$\text{Horizontal distance, or} \quad C D' = \frac{A' B'}{A B} C D.$$

Fig. 2 represents a portion of the scale as seen through the microscope. The thin parallel lines are the hairs of the microscope. They are shown as falling between 57,500 and 58,000, and by turning the micrometer screw, the scale can be moved until the division 57,500 fits exactly between the hairs.

Suppose the reading on the circular scale, which has 500 divisions, to be 132, then the whole reading is 57,632.

Staff.—The staff used should be capable of being easily read off at long distances. The staves used by the Author (*Fig. 3*) were formed of well-seasoned strips of light wood, 12 feet 6 inches $\times$ 3 inches $\times$ 1 inch, to each of which were attached two octagonal disks of sheet metal, the centres of which were fixed exactly 10 feet apart, the lower one being 2 feet from the foot of the staff so as to clear grass, bush, or other obstacles. The disks were divided into four spaces by lines at 45° to the vertical, the spaces being painted alternately black and white so as to give distinct vision. An attachment for a plummet was fixed to each staff to ensure perpendicularity.

Field Practice.—*Fig. 4* is a sketch plan of a portion of a survey along a deep ravine which illustrates the mode of using the

instrument. A section being required along the slope of a ravine, it was found generally most convenient, where distances were not too great, to observe from the opposite side; the advantage thereby gained being that a clear view was more readily obtained of the staff, it being generally possible to find some spot sufficiently clear of obstacles to admit of the lower disk of the staff being seen from the opposite side; the annoyance and error from mirage, especially noticeable in hot climates when the line of sight passes close to the ground, are also avoided. In *Fig. 4* the traverse is supposed to start from A. Three assistant engineers with four staff-

Fig. 3.

Fig. 4.

holders start from A, and one of them with a pocket-level selects positions for staffholders at *a*, *b* and *c*, convenient for observation from the instrument stationed at B and as nearly as can be judged in the line of the gradient fixed upon. The engineer at B having observed the staffholder at A, signals the fact as previously arranged; whereupon the man at A passes on and is placed at *d*. Similarly *a* being observed passes on to C, each staffholder moving on directly he has been observed. The points in small Roman letters are intermediates; and the back-sights and fore-sights are in capital letters, as well as the stations of the instrument. The procedure resembles that of ordinary levelling; but chaining is dispensed

with and the bearing of each observation noted. Two assistants take cross-sections of the ground at the stations, which may furnish fixed points for a rough survey of the ground lying between them if more detail is wanted. At the end of each day the field-book should be reduced and the work roughly plotted, so that correction may be made, if necessary, next day in the field for any deviation which may be observed in the traverse from the gradient fixed upon. As the reduction of the observations requires more time than in the case of an ordinary level-book, it saves time to keep two books, using them on alternate days, a plan possessing other advantages.

The Field-book.—A specimen page from the Author's field-book is given in the Appendix. In order to avoid error, he kept a separate column for the rise and fall and reduced levels of intermediates; he also introduced the column "sign" as a safeguard against error in making up the book. A column for height of instrument is given, which is useful when the level of the ground at the station is required. The point of departure column is not necessary for rough work; but for very accurate levelling it was found that when the bubble of the telescope was levelled, the microscope did not always read 50,000 exactly. The first difference column is that between the upper and lower readings (A B, *Fig. 1*). The second difference column, between the lower reading and the point of departure (B D, *Fig. 1*), is required for calculating altitudes. The column for remarks should be large enough to allow of a sketch plan of the traverse with notes. This sketch plan facilitates the work of plotting and has been known to reveal an error in the booking of a bearing.

Sources of Error.—Whether from wear or not, it happened that in the instrument used by the Author, the altering of the focal length of the microscope caused a transverse motion of the hairs on the scale. The remedy was to bring the microscope to a focus with the same movement, say, a lengthening. From some cause, probably wear, the scale did not always promptly return when the micrometer screw was turned with a reverse motion, consequently the movement of the micrometer screw did not always represent a corresponding movement of the scale. A similar remedy was adopted in this case, namely, always to bring the scale division to the hairs of the microscope with the same motion, never with the reverse. A slight error arises from the difficulty of telling when the division on the scale is truly centred between the parallel hairs of the microscope. These have an appreciable thickness and are intended to coincide with the edges of the engraved line on the

scale. The Author believes that more accurate readings could be obtained if the hairs were spaced a little further apart, so as to leave light visible between the edge of the line and the adjoining hair. The difficulty is increased if the instrument is at one time in sunlight and at another in the shade, hence the advisability of keeping it shaded. Care must be taken that the general level of the instrument does not alter between the taking of the upper and lower readings. As a check, it will be well to take the first reading, say the lower, over again after taking the upper, for back-sights and fore-sights.

General Remarks.—In the particular survey referred to, the Author had one chief assistant and two junior assistant engineers; and the rate of progress, in very rough country, was 2 miles of traverse per day. The rate will greatly depend upon the amount of detail required, as well as upon the roughness of the country. Sufficient staffholders were provided to keep the Author incessantly occupied, when not climbing, in observing and recording during the whole day. If an assistant can be obtained who is trustworthy and expert in the use of the instrument, the engineer in charge of the survey should hand it over and locate the traverse himself, as he obtains then a more intimate knowledge of the ground passed over. The extreme length of sight preferred was from 12 to 8 chains, according to the light. Sights of 30 or 40 chains for special purposes were often taken. On open plains the advantages of the instrument are small, mirage interfering with long sights. For levelling, the Author considers that it equals the ordinary levelling instrument in accuracy, and for distance measurement exceeds in accuracy the ordinary chain over rough ground, with great advantages in speed. Increased accuracy or speed can be obtained by using a longer staff; but then the staff becomes less manageable in a wind. The instrument requires experience before it can be used with facility and economy.

The Paper is accompanied by a sheet of tracings from which the *Figs.* in the text have been reproduced.

APPENDIX.

FIELD-BOOK.

Position of Instrument.	Stations Observed.			Readings.		Difference.	Dis- tance.	Point of De- parture.	Differ- ence.	Sign.	Back-sight and Fore- sights.			Intermediates.			Remarks.
	Height.	Station.	Back- sight.	Inter- mediate.	Fore- sight.						Bearing.	Upper.	Lower.	Rise.	Fall.	Reduced.	
						Feet.	Feet.	Feet.	Feet.	Feet.							
		J ₁₃	..	..	..	..	..	..	..	..	..	..	..	..	..	..	{ From preceding page.
		K ₁₃	..	L ₁₃	326	0 46, 255 45, 186	1, 069 1, 405	50, 000	4, 814	-	..	..	45-03	274-26	..	258-57	
4-26	M ₁₃	L ₁₃	..	..	225	32 53, 079 51, 765	1, 314 1, 143	50, 000	1, 765	+	..	..	13-43	260-83	..	10-00 250-83	
		a	..	..	57	40 49, 975 42, 552	7, 423 202	50, 000	7, 448	-	..	..	..	..	..	..	
		N ₁₃	..	..	41	0 48, 932 47, 188	1, 744 861	50, 000	2, 812	-	..	..	16-12	244-71	..	237-01	
4-10	O ₁₃	N ₁₃	..	..	157	55 56, 117 52, 196	3, 921 383	50, 000	2, 196	+	..	..	5-60	239-11	..	239-96	
		a	..	..	180	45 54, 018 50, 317	2, 701 406	50, 000	317	+	..	..	..	..	0-85	6-30 232-81	
		b	..	..	141	53, 392 44, 123	9, 269 162	50, 000	5, 877	-	..	..	..	..	..	..	
		P ₁₃	..	..	348	35 51, 616 47, 733	3, 883 387	50, 000	2, 267	-	..	..	5-84	233-27	..	86-02	