It may be argued that to depart from established precedent, and attempt by the vertical-angle method to measure a base-line with such steep grades as have been introduced into this one, would simply be to court complete disaster; and, were it not that the writer had had a good deal of experience in standard surveys, where often, to "close" circuits or for other reasons, much steeper grades than any on this line were faced in this way with most satisfactory results, no such attempt would probably have been made in this case. It must be admitted that there are risks attached to the method, and some of these risks increase rapidly with increases in the inclinations observed. The reference plane for angle observations is itself not a stable one, as it depends wholly on the accuracy of the level-bubble; but, notwithstanding the apparent difficulties, it was nevertheless felt, in the light of past experience, that the advantages of the method, when practised with the required care, more than counterbalanced the risks; and I think that this confidence has been fully justified by the results obtained. It must always be kept in mind that any vertical angle measured in this method is pivoted directly on the axis of the vertical arc, to which all lineal measurements are also referred; that no intermediate processes are introduced to obtain the angle; and that errors caused by refraction are very small, and largely compensating in action.

When eight readings are taken, the average error per angle will probably not be more than 3″. (See Fig. No. 3 for a diagram of an actual test carried out to check the readings of vertical angles.)

As a further check, however, on the direct measures of section 9, an auxiliary base of about 114½ chains was measured on the plain.

The measurement of this auxiliary base was made with all the accuracy of that of the main baseline, there being only two cases in it where the angles of inclination exceeded half a degree, one of about 2½° on a length of 3 chains, and the other of about 1¼° on a length of 262 links.

Details of the four measurements are given on Table No. 1.

One side of the triangle off this base is coincident with section 9, but about 1 chain shorter, and, as all the angles were measured with a 10 in. Everest theodolite, the measure of section 9 thus verified is very satisfactory. Mean value of the four direct measurements, reduced to sea-level, is 7151·6126 links, and the value derived from triangle off the auxiliary base is 7151·6225 links, or a difference of 0·0099 link, or 1 part in 716,000. (See Fig. No. 4.)

Marking. — The terminal marks at each end of the base were constructed as follows: Holes 4 ft. 6 in. in depth from the ground-surface, by 2 ft. 6 in. square, were sunk. In the bottom of these, 12 in. of 3-to-1 concrete was placed. On the top of the concrete, blocks of Malmsbury bluestone, 12 in. long by 8 in. square, were bedded as concealed marks, and surrounded with concrete to their surfaces. The centres of the stones are marked by brass circular plugs, 3 in. by ½ in., run in with lead, their centres again being further marked by a $\frac{1}{16}$ in. hole, drilled ¼ in. in depth, which final centre is in each case the true terminal mark of the base-line. On the tops of these stones, for surface marks, galvanized trig. tubes 2 in. in diameter by 2 ft. 6 in. long, with footplates, were placed, and 6 in. of clay was well rammed round them. On the top of the rammed clay concrete was placed to the ground-surface, care being taken throughout that the tubes were kept centred over the stone marks, the actual surface-marks being ¼ in. holes drilled in the brass plugs riveted into the tops of the tubes. Small removable plugs with fine centre points, fitting into the ¼ in. holes, gave true points for starting and finishing the measuring on. (See Fig. No. 5.)

Intermediate Marks.—The line was broken up into nine sections by the placing of eight intermediate marks, constructed of trig. tubes, with brass plugs in their tops having fine centre holes, each tube being bedded and packed in concrete.

APPARATUS.

The apparatus consists of the following:—

First: Two 5-chain (330 ft. or 100·5821 metres) nickel-steel (Invar) tapes, ⅛ in. (3·175 mm.) by $\frac{1}{50}$ in. (0·508 mm.) thick. Modulus of elasticity supplied by the makers = 20,900,000 lb. per square inch. Coefficient of expansion supplied by the makers = 0·00000016 per degree Fahr. Weight = 0·61558 lb. per chain-length.

Second: One 5-chain Invar tape, ¼ in. (6·35 mm.) wide by $\frac{1}{50}$ in. (0·508 mm.) thick. Modulus of elasticity supplied by the makers = 20,900,000 lb. per square inch. Coefficient of expansion supplied by the makers = 0·00000016 per degree Fahr. Weight = 1·18027 lb. per chain-length. Adopted sag on 50 links = 0·0031 link with 15 lb. tension.

This tape was only used for one measurement of sections 1 and 2, as it was found to be too susceptible to the action of the wind.

As the elastic extension of the ⅛ in. tapes was found frequently by experiment, this value of 0·001844 link per pound pull per chain-length was adopted.

The horizontal sag on 50 links of ⅛ in. unsupported tape under a tension of 15 lb. was found experimentally to be 0·0008 link, and this was the value used throughout the computations, covering work done under this tension. When, towards the end of the work, owing to the weakening of the balance, the nominal tension of 15 lb. was not the real tension, the sag on 50 links or other length of unsupported tape altered accordingly, and was computed by the formula $S = \frac{lw^2}{24t^2}$

Third: A 5 in. transit theodolite, having a vertical circle reading to 20″, with a specially divided brass scale attached to the end of the horizontal axis of the vertical limb. (See Fig. No. 6.) This brass scale carries a sliding steel scale divided to 0·001 of a link, which can be made to coincide with any of the tenth-of-a-link spaces on the brass scale.

In using the scales with the tape coming from the left as the instrument is faced, the *link-reading* is always that of the mark on the tape, immediately to the *left* of the zero. If this link-mark is *on the*