mark these positions. The lengths of the lines were measured in the following manner: A telescopic tripod is placed over the initial point. A scale, divided to $\frac{1}{200}$ of a link, capable of being adjusted within a range of $1\frac{1}{2}$ in., is carried by the tripod, to which is attached a heavy plummet, the point of which is adjusted exactly over the initial mark. A similar tripod, scale, and plummet is placed over a centred bolt at a number of chains in advance, and supports aligned on the grade are placed at each chain-mark. An $\frac{1}{8}$ in. invar steel tape equal in length to the distance between the tripods is placed on the supports, with one end at each tripod. The zero end of the tape is adjusted over the centre of the scale at the initial point by means of a tape-stretcher. A second similar tape-stretcher carrying a spring-balance is attached to the forward end of the tape. The standard tension is then applied—viz., 15 lb.—and the exact distance between the centres of the initial and the forward bolts is read off the leading scale and entered in the field-book. The vertical angles are observed from each end of the measured distance by setting the theodolite over each chaining-tripod and sighting to a division on a graduated scale at the same height above the other tripod as the horizontal axis of the theodolite is above the tripod under it. Fig. 2 shows the chaining-scales, plummets, spring-balances, centre-punches, graduated grade-scales, spring tapes, and a small telescope for aligning the tape-supports at each chain-mark. Fig. 3 shows the chaining-tripods, supports which are usually placed at each chain-mark, and the tape-stretchers. In windy weather these tape-stretchers are also used to protect the plummets from the effects of air-currents when they are being adjusted over the exact centre of the bolts. The invar steel ribbon was imported and made up into tapes of lengths of 1, 2, 3, 4, and 5 chains each. The leading chain length of each tape is graduated to 10 links, and the balance to chains. Fig. 1 shows five of these tapes in their cases, also two 5-chain $\frac{1}{16}$ in. steel tapes on Littlejohn's patent drums, and a form of wind-shade on the right, which was used when the work was commenced, but is now superseded by using the tape-stretcher as a breakwind.

The performance of the invar tapes in the field has been very satisfactory. They were controlled by monthly comparisons with No. 11 Imperial standard band. These comparisons showed that a new tape contracted about $\frac{1}{10}$ in. per chain before it was seasoned, but that after a time it settled to a constant length at a constant temperature. The coefficient of expansion between 32° and 70° F., derived from the monthly comparisons, is about one-fifteenth of that of a steel band, and is fairly well represented by Dr. Glazebrook's formula, which in the centigrade scale is $L_t = L_0 (1 + 0{\cdot}00000074T - 0{\cdot}0000000089T^2)$. A length of 1 chain of the tape is altered by $\frac{1}{100}$ in. for a difference of temperature of 30° F., and, as this represents nearly the extreme variation of temperature during the year, it is obvious that the length of the tape obtained at each comparison will be sufficiently accurate for practical use without any further correction, excepting on a few days when the temperature is abnormal.

Fig. 4 shows the micrometer microscope used for the most refined comparisons; the instrument labelled 1 is a Beck microscope fitted with a Grayson micrometer reading to $\frac{1}{1000}$ in.

A valuable report was issued by the International Bureau of Weights and Measures, Breteuil, in 1906, giving details of the experiments conducted by M. Benoit and Dr. Guillaume on the use of invar for rapid base-line measurements.

At the commencement of the work the angular measurements were made by a special 5 in. repeating theodolite, shown on the right in Fig. 5. The horizontal circle is graduated from 0° to 180° in opposite directions, and it is fitted with a double vernier. The telescope carries an eye-piece micrometer and has anallatic lenses. This proved to be an excellent form of instrument for alignment purposes and for setting off right angles, but it was not powerful enough to give satisfactory results for the bearings of irregular traverses or for long lines. An 8 in. vernier theodolite was supplied by the Department (shown on the left in Fig. 5) to accomplish this purpose. The results obtained by the 8 in. instrument over long lines were excellent, but, on account of the plummet being suspended from the tripod instead of from the vertical axis, it was unreliable for short lines. The specification of a special 7 in. micrometer theodolite designed for work of this class was sent to Messrs. Troughton and Simms with an order for the instrument. On the arrival of this instrument, about a year after the work started, all the bearings were revised, and the results were entirely satisfactory.

The instrument as used for horizontal angles is shown in Fig. 6, and in Fig. 7 it is shown with its auxiliary telescope with vertical circle, micrometer, eye-piece, and Talcott level. An examination of the horizontal circle and an analysis of the results gave the mean error of a set of six readings $\pm 0{\cdot}5''$. Such accuracy cannot be expected from the results of actual observation, on account of the uncertainty arising from the effects of lateral refraction, which vitiate the measurement of all angles to a certain extent. The correction for refraction is so important that it will be made the subject of a separate investigation. The formulæ for the computation of the alignment and the corrections to reduce the field measurements to their horizontal value at sea-level will also be the subject of a separate report.*

The theodolite on the right in Fig. 9 is a standard pattern of the 5 in. micrometer size, and was found useful for observing the bearings of irregular traverses with very short lines.

(3.) *Offset Survey.*—This work consists of a rapid measurement with a $\frac{1}{4}$ in. steel tape, 1 chain long, of the distances between the permanent monuments along each street, and noting the offsets to buildings, fences, &c. It also serves as a check by disclosing any mistakes that may have been made in the precise measurement or in building the permanent mark in an erroneous position. In most cases both sides of the streets are measured, and the offsets obtained by readings from the staff. Fig. 8 shows a portion of the offset staff, which is 15 links long, and the large aperture dumpy telescope capable of reading it to distances of 10 chains.

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