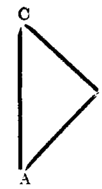
and the errors in graduation of the divided circles, by using the constant angle between the two verniers and finding the readings at intervals of 5° or 10° from 0° to 360°. From these readings the exact angle between the verniers can be determined and the eccentricity can be computed. Then by correcting the readings for eccentricity the remainders represent the errors of graduation and reading.

Surveyors often find that an instrument used for measuring the angles of a traverse, by reading one vernier only, consistently gives the bearings of the lines too great or too small when compared with a check-bearing, and no amount of repeating the work will disclose any appreciable error. Such results are caused by eccentricity, or the centres of the axis of rotation and the divided circles not being coincident. This error is eliminated by taking the mean of both verniers, or by finding the error due to eccentricity, which may amount to 10″ in some cases, and correcting each angle.

The error due to imperfect centring is almost negligible for long lines, but it increases very rapidly as the lines shorten. If a maximum error r is decided on, and A,B,C, three consecutive stations of a traverse, then the mean error of centring is—



$$E_c = \pm \frac{4r \,.\, AC}{3\pi \,.\, AB \,.\, BC} \qquad (10)$$

(For the mathematical investigation of the error of centring, see "Effects of Errors in Surveying," by H. Briggs).

To determine an average value for r, consideration has to be given to the plummet, and deflections by wind or other causes. A value of r = ·05 will be used.

If the angle ABC is denoted by a,

$$AC^2 = \sqrt{(AB^2 + BC^2 - 2\, AB \cdot BC \cos a)}$$

This is greatest when a = 180°, and therefore the mean error of ranging a straight line is greater than that of making a traverse with the same number of stations or sights, a result proved by experience. Having decided on the mean value of the sighting and reading error of the instrument as 15″, the maximum centring displacement as ·05, and the coefficient for the band c = ·0022, the mean error of any traverse can be computed and compared with the actual closing error of the survey. If the actual closing error is not greater than the computed mean error the work can be considered as satisfactory. If, however, the closing error is greater than the computed mean error, a revision of the survey should be made.

The following is from a closed survey by steel band and 5 in. theodolite over hilly country.

Denoting the length of the lines by l_1, l_2, l_3, &c., l_n, the bearings of the lines by B_1, B_2, B_3, &c., B_n, the mean error of the bearings by b_1, b_2, b_3, &c., b_n, the mean error in the latitude of the end point—

$$= \pm \sqrt{\Big\{ C^2 (l_1 \cos^2 B_1 + l^2 \cos^2 B_2 + l_n \cos^2 B_n) + (l_2^2 b_2^2 \sin^2 B_2 + l_3^2 b_3^2 \sin^2 B_3 + l^2_n b^2_n \cos^2 B_n) \Big\}} \qquad (11)$$

The mean error in the departure of the end point—

$$= \pm \sqrt{\Big\{ C^2 (l_1 \sin^2 B_1 + l_2 \sin^2 B_2 + l^2_n \sin^2 B_n) + l^2_2 b^2_2 \cos^2 B_2 + l^2_3 b^2_3 \cos^2 B_3 + l^2_n b^2_n \cos^2 B_n) \Big\}} \qquad (12)$$

The mean error at the end of the traverse—

$$= \pm \sqrt{\Big\{ C^2 (l_1 + l_2 + l_n) + l^2_2 b^2_2 + l^2_2 b^2_2 + l^2_3 b^2_3 + l^2_n b^2_n) \Big\}} \qquad (13)$$

Example of traverse over hilly country—

Peg Number.	Bearing.			Distance.	Latitude.	Departure.	Total Latitude.	Total Departure.
				Links.				
1	271°	49′	20″	1117·2	+ 35·5	− 1116·6	+ 35.5	− 1116·6
2	278	31	00	1093·0	161·9	1081·0	197·4	2197·6
3	346	25	00	391·6	380·6	92·0	578·0	2289·6
4	314	37	00	2017·8	1417·3	1436·3	1995·3	3725·9
5	280	31	00	514·4	+ 93·9	505·8	2089·2	4231·7
6	235	27	00	898·7	− 509·7	740·2	1579·5	4971·9
7	203	08	00	483·2	444·3	189·8	1135·2	5161·7
8	227	57	00	869·6	− 582·4	645·7	552·8	5807·4
9	340	25	00	422·6	+ 398·2	− 141·6	951·0	5949·0
10	8	33	20	3039·5	3005·7	+ 452·2	3956·7	5496·8
11	19	14	00	3913·7	+ 3695·2	1289·3	7651·9	− 4207·5
12	90	00	00	4209·2	...	+ 4209·2	+ 7651·9	+ 1·7
13	180	00	00	7652·3	− 7652·3	...	− 0.4	+ 1·7
Total	...			26622·8	...	...	.	...

The actual error in latitude is 0·4, and in departure 1·7, therefore the total actual error is $\sqrt{\{(0{\cdot}4)^2 + (1{\cdot}7)^2\}} = 1{\cdot}75$.