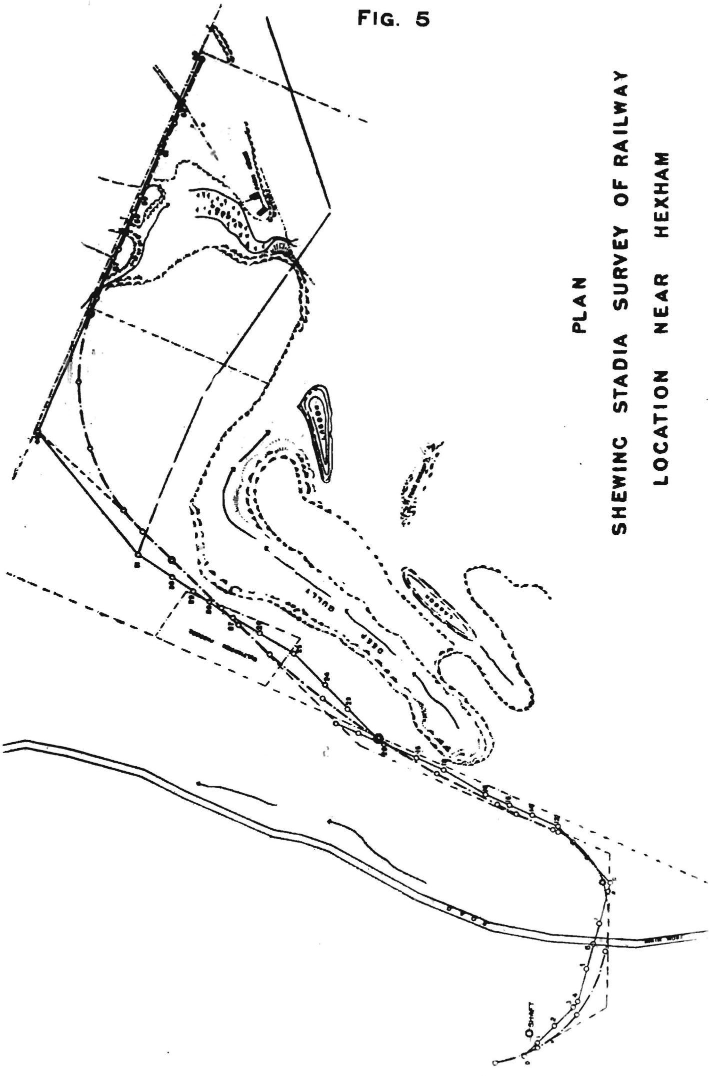
that only moderately long sights could be used, and consequently the work took longer than would otherwise be the case.

The experiment was made on a section of the Ironbark Mineral Railway survey near Hexham.

FIG. 5



The railway location referred to above is shown on fig. 5. This portion of the line is in fairly steep, undulating country, and a preliminary survey was necessary in order to secure a suitable grade from the Hexham Flats over the divide to the Shaft site, which had previously been selected.

Starting from the Shaft site, a stadia traverse was run on the approximate grade towards Hexham for a distance of 208 chains 66 links, cross sections being taken en route, so as to embrace a strip of country of variable width within which it was expected a final location could be made.

When the final location had been decided on the tangents and curves were run out in the opposite direction towards the starting point, and closing on the stadia work at the Shaft site. Intermediate connections with the stadia survey were made en route, the latter being performed with the same theodolite and chain and level, so that a complete check was obtained of the angular work, the horizontal distance and the difference of elevation at many intermediate points. A comparison of the coordinates by stadia and theodolite and chain survey respectively are shewn on Table 1.

It will be seen that the error in closure amounts to 14.2 lks. in latitude and 14.8 links in departure in a total surround of 417 chains 32 links $= \frac{1}{2034}$ or say 4 links per mile, the error being about twice as great as that usually allowed in theodolite and chain surveying in similar country. But if part of the error is assigned to the theodolite and chain check, which may reasonably be assumed as cumulative and at the rate of two links per mile, then the ratio of error is reduced to $\frac{1}{2725}$ or three links per mile nearly.

Further, a length of 7509 links was checked by direct chainage and the stadia measurement was found to be exactly 4 links too long. The error in the stadia levels varied from about 5 ft. to 3 ft. in the same distance (for details see table 2), which is considerably more than that allowed for level work and may in part be due to the defects of the instrument used, but quite sufficiently good for preliminary survey and even for permanent railway work in the generality of cases.

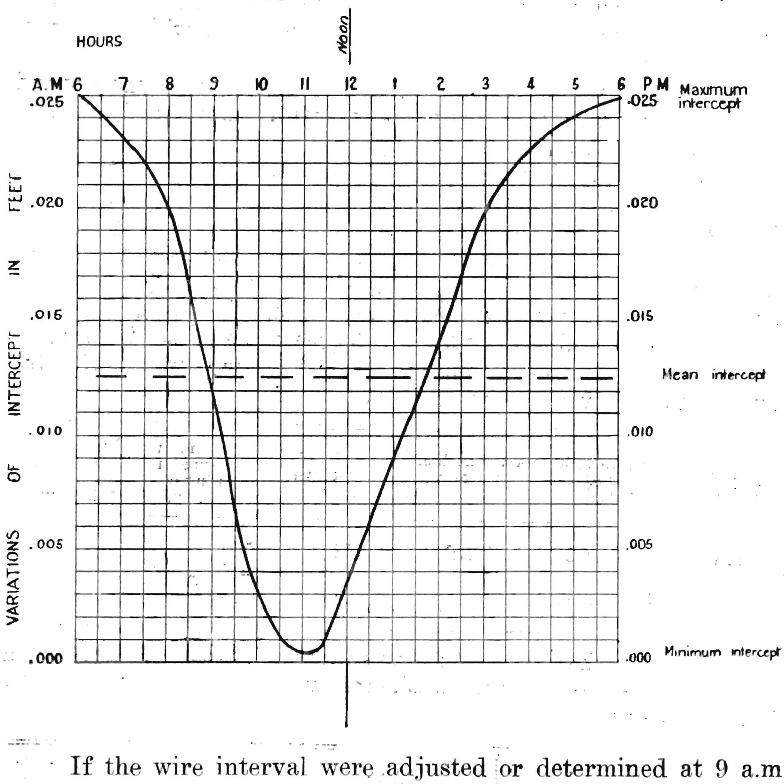
The method adopted in the field was to set the instrument up at a constant height, the axis being set 5 ft. above the peg, the central wire was then set at 5 ft. on the staff and the upper and lower wires read, and the angle of elevation; in order to eliminate instrumental errors the angles were observed on both faces of the instrument.

The reduction of the observations to horizontal distance and vertical height were calculated by the formulae (7) and (8) and the results are given in Table 1.

It was observed during the progress of the work that the wire interval varied at different times of the day, but at the time no definite tests were made to determine what laws governed the variations; the question is an important and interesting one, and Professor Johnson alludes to it in his work "Theory and Practice of Surveying," and gives a diagram which illustrates the variation at different times of the day.

In fig. 6 the diagram is reproduced, but reduced from the metre to the foot unit. He states that the rod intercept is least during the middle of the day and greatest in the morning and evening, the mean being about 9 a.m. and 1.30 p.m.

FIG. 6



If the wire interval were adjusted or determined at 9 a.m. or 1.30 p.m. the intercept of the staff would be too large from 6 a.m. to 9 a.m., and from 1.30 p.m. to 6 p.m., having a range of 6½ hours, whilst between 9 a.m. and 11 a.m. and 11 a.m. and 1.30 p.m. the intercept of the staff would be too small, the range being for 5½ hours.

Thus the distances deduced from the direct readings of the staff would be excessive during 6½ hours, and deficient during 5½ hours, but under the ordinary hours of working, say from 7.30 a.m. to 4.30 p.m., we should have an increasing intercept of 4½ hours and a decreasing intercept of 4½ hours, and thus the errors from this cause would be practically compensated.

The wire interval should be determined frequently, by setting out a base line, say 300 or 400 ft. from a point distant f + c from the centre of the stadia instrument; hold the staff at the end of this base line and read the intercept thereon. If we call the base line b and the intercept s then we have

$$b = \frac{f}{i} s$$

$$\text{or } i = \frac{s}{b} f$$

The determination should be made for different distances about 9 a.m. or 1.30 p.m., and over a base line, which is somewhat similar to the country being surveyed.

In practice the reading of the lower wire near the ground should be avoided, on account of the variableness of the refraction near the ground.

Professor Johnson also states that the Mexican Boundary survey was executed by the stadia method, both for the measurement of the boundary line and for the topography, and it was found by comparison with the true triangulated distance to be far more accurate than the work performed by the chain, and the conditions being very unfavourable for accuracy.

He gives a table shewing the degree of accuracy both as regards errors in azimuth and in linear measurement. The following table gives the mean results:—

No. of Circuits.	Agg. Length of Lines in Metres.	Av. Length of Courses in Metres.	Av. No. of Courses per Circuit.	Av. Error in Distance on Closing = 1 inch in.	Av. Azimuth Error Closing per Kilo or Line Run.
118	826515·9 or 509 Miles.	386·2	18·1	752 Metres = ¼ lk. per Mile.	0' 59''·6

As regards the accuracy of levels run by the stadia, the following table gives the mean results as taken from the report of the Mexican Boundary Survey :

No. of Circuits.	Agg. Length of Lines.	Sum of the Vert. Components of Courses.	Av. Vertical Angle of Lines.	Error in Elevation on Closing per Kilo, of line run in feet.
114	819543 Metres, or 500 Miles.	37038·9 Metres.	3° ·03'	0·40 ft. = 0·64 ft. per mile.

The errors in levelling by means of the stadia is a function of the average vertical angle employed, and it has been demonstrated by the above survey that the errors increase quite rapidly as the average vertical angle increases.

The accuracy of stadia surveys may be gauged by the results of surveys made under the Missisippi River Commission. In 1896, thirty-six circuits, averaging 1.7 miles each in length, were run over rough hilly country ranging in elevation from one to three hundred feet, with an average error of 0.59 foot per mile of the line run.

In seventy-four other circuits, averaging each 1.8 miles in length, the average error was 0.31 foot per mile of line run. Of the above seventy-four circuits thirty-eight of them gave too high results and twenty-nine gave too low, whilst on seven circuits there was no error at all, seemingly indicating that in general the errors are compensating and not cumulative.

Another survey in Mexico run from the west coast near Culiacan across the Sierra Madre to Durango, and back by a different route, illustrates the accuracy of stadia work.

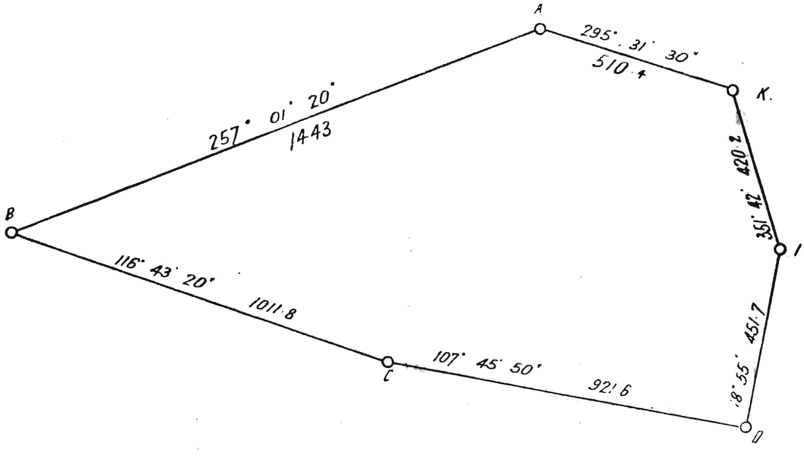
The total distance closed as a circuit 606 miles in length. It was computed by latitudes and departures, which closed within 1100 feet or $\frac{1}{2909}$ and the average cost was only $3 per lineal mile.

The evidence forthcoming from America is overwhelmingly in favour of stadia work for topographic and railway surveys.

A test survey was made in the University grounds by two students attending the Surveying Course, Messrs. Mackenzie and Winters, on a traverse shown in following diagram, with a new Troughton and Sims latest pattern of a tacheometer, and the theodolite, chain and level, with the following results:—

In a total surround of 4760 links the errors in distance amounted to the rate of 4 links per mile, or $\frac{1}{1984}$

The levels deduced from these observations gave an error of 0.18ft., or a probable error of $\pm$ 0.3 feet per mile.



It will be seen that I have not attempted to draw a fancy picture of the advantages of stadia or tacheometrical surveying, but have pointed out both arguments pro and con, and it must be conceded that in this system, we have a means at our disposal of performing trial surveys, route surveys and topographical work with greater rapidity, greater economy and greater efficiency than under the present system, perhaps with some loss of mechanical precision, but with sufficient accuracy, and it would be absolute folly to neglect it any longer.

But how is reform going to be effected, and how is the conservatism I have referred to going to be broken down? Only by the higher education of politicians and professional men.

In reading this paper before the U.E. Society, I know I am appealing unto Caesar, because the power that education and knowledge places in your hands is as real and effective as that which created imperial Rome, and when the graduates of our University are found pervading the high places of our great State Departments, we may reasonably hope for intelligent and efficient reforms, not only in the direction the paper indicates, but also in many others.

TABLE I.

ANALYSIS OF STADIA SURVEY.

	Latitude.		Departure.		Difference.	
	Stadia.	Theodolite and Chain.	Stadia.	Theodolite and Chain.	Latitude.	Departure.
Peg. 1	0	0	0	0	0	0
6	S 179·2	S 181·4	E1620·5	E1625·8	2·2	5·3
14	N1731·7	N1728·5	E2949·8	E2951·1	3·2	1·3
49	10202·4	10212·5	5155·3	5175·4	10·1	20·1
59	10187·7	10200·7	8601·0	8607·4	13·0	6·4
66	10166·3	10180·5	12665·0	12679·8	14·2	14·8

Error $= \sqrt{14{\cdot}2^2 + 14{\cdot}8^2} = 20{\cdot}51$ in a total surround of 417.32 chains

$$\text{Ratio of Error} = \frac{20{\cdot}51}{41732} = \frac{1}{2034}$$

Assigning part of the error to the chain and theodolite survey at the rate of 2 links per mile we have

$$\text{Ratio of Error due to Stadia} = \frac{20{\cdot}51 - 5{\cdot}2}{41732} = \frac{1}{2725}$$

TABLE II.

ANALYSIS OF STADIA WORK. LEVELS.

△	Level by Dumpy Level.	Stadia △ Level.	Difference.	
1	105·52	105·52	0	N.B.—Principal error seems to be between 1 – 25, from there on the difference remains fairly constant.
20	91·16	92·44	+ 1·28	
25	92·79	96·91	+ 4·12	
26	88·62	92·65	+ 4·03	
28	77·05	81·97	+ 4·92	
54	29·88	32·40	+ 2·52	
56	23·60	27·11	+ 3·51	
57	22·45	25·92	+ 3·47	
58	13·90	13·32	– 0·58	
59	21·60	24·72	+ 3·12	
61	22·81	25·79	+ 2·98	
63	21·08	24·25	+ 3·17	
64	20·57	23·59	+ 3·02	

TACHEOMETER MEASUREMENTS IN UNIVERSITY GROUNDS, 6TH AUGUST, 1910.

SURROUND.

Bearing.	Distance.	N.	S.	E.	W.
257· 01′ 20″	1443·0		324·3		1406·1
116· 43′ 20″	1011·8		455·0	903·7	
107· 45′ 50″	921·6		281·4	877·6	
18· 55′ 00″	451·7	427·2		146·4	
351· 42′ 00″	420·2	415·7			60·6
295· 31′ 30″	510·4	219·8			460·6
	4758·7	1062·7	1060·7	1927·7	1927·3

Allowable error $= 1·4$ or $\frac{1}{3400}$

Error in above $= 2·4$ or $\frac{1}{1984}$

A misclose $= 4·0$ lks. per mile.

The levels deduced from these observations gave a closing error of 18 ft. in 4760 links (Perimeter) or a probable error of $\pm$ 3 ft. per mile.