# FIELD USE OF THE GEODIMETER

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The Geodimeter (*), when first received in May, 1954, was unpacked and assembled in a darkened room, and with only the handbook as guide; preliminary tests and adjustments were made to the optical system.

Satisfied that the fundamentals were understood, initial field experiments were conducted at Doncaster, near Melbourne, to try out techniques of operating and procedure. These tests proved very encouraging and a full-scale test was planned on a first-order triangulation line near Melbourne, *Mt. Atkinson-Green Hill.* After a week of Melbourne's weather, the remains of the shelter tents were collected, and a gentler climate was sought for further tests.

During these preliminaries, advice was obtained on the electronic side of the equipment from technical authorities. They made valuable suggestions in regard to power supply, etc., and arranged to carry out periodic crystal-frequency checks. Their comment — " It looks as though it were designed for amateur maintenance " — was very heartening.

It is interesting to note that six months after the receipt of the equipment, the frequency of crystal No. 1 had increased by 4 cycles in 10 000 000, while crystal No. 2 had increased 2 cycles in $1.01 \times 10\,000\,000$.

Twelve months later, crystal No. 1 had dropped back 1 cycle, and crystal No. 2 had advanced a further 2 cycles.

**Transport, Equipment and Communications**

While operating near Melbourne, a Holden utility van had been used, and although it proved quite satisfactory for the short distance and light loads involved, it was obviously not the vehicle for extensive field use. An International 10-cwt panel van was finally decided on as most likely to provide a cushioned ride for the equipment while providing space for camping gear, etc. A Land Rover with trailer acts as support vehicle and carries the mirrors. This vehicle arrangement works very well in practice,

(*) A detailed study of this system will appear in the Supplementary Papers to SP 39.

the panel van proving ideal on the roads and across country, while the Land Rover in attendance has been used to carry the Geodimeter short distances where the going was too rough or steep for the International.

Ordinary office tables had been used for both Geodimeter and mirror during the local tests, but were obviously unsuitable for general use. Tables were designed with angle-iron frames and three threaded tubular steel legs, so that the legs could be removed for travelling, and used for roughly orienting the tables when operating.

Auto tents (12 ft by 12 ft) have been used as shelter for both Geodimeter and mirror, and have been moderately successful. The centre pole has been somewhat inconvenient, and the tents themselves a little too light for use on hilltops, a new tent being torn to shreds recently in a high wind. A tent has now been specially designed with a tubular steel frame and with a heavy cotton canvas cover. This is now in use, and there is every indication that it should be satisfactory.

Communications caused no concern. *Reporter* VHF transceivers, such as are in use with triangulation parties, have proved ideal where both Geodimeter and mirror have been *drive-ons*.

Where the mirror has had to be carried, the 12-volt accumulator with the Reporter has made this set inconvenient. Self-contained *Walkie Phones* weighing only 10 lbs complete with dry cells, have solved this difficulty. Attempts to operate using light signals have been slow and unsatisfactory, particularly where the variation of refraction has necessitated frequent alterations of the mirror alignment.

**Initial field tests**

Consequent upon the poor weather conditions encountered on the Melbourne line, it was decided to check the Geodimeter against the *Carrieton Base*. This is one of the four geodetic baselines measured by the Royal Australian Survey Corps just prior to World War II.

For measurement of these particular baselines at Carrieton, South Australia; Benambra, Victoria; Somerton, New South Wales; and Jondaryan, Queensland invar tapes were used and frequently compared with four standard steel tapes which had been standardized by the National Physical Laboratory, Teddington, England, and the temperatures of which were determined by the electrical resistance method.

The Geodimeter withstood the 650-mile trip well, and no trouble was experienced in measuring the 4-mile line. Four sets of two frequency readings were taken over two nights, the result having a probable error of $\pm$ .013 foot, while the Geodimeter distance differed from the measured distance by 0.21 foot.

Satisfied with these initial efforts, it was decided to attempt measurement of a longer line. *Maurice Hill - Black Rock* in the same area provided a line of 19 miles, and also the first hitch. When the modulating voltage was applied, practically no light emerged from the projection. After changing the valves and the Kerr cell, it was discovered that the polaroids were not oriented properly with respect to the Kerr cell.

This difficulty overcome, another was experienced which was not so easily eliminated — moonlight. Extraneous light completely swamped out the signal, and the only solution was to sit it out. Patience was eventually rewarded, four sets of two frequencies being obtained in two nights, the results having a P. E. (*) of .04 foot, i.e. 1 part in 2 600 000. The geodimeter distance was 0.47 foot longer than the geodetic distance.

A portion of a triangulation in the vicinity of Broken Hill was selected for the next measurement. An 8½-mile line, *Feldspar to Twenty Mile,* near Cockburn, was measured, the results having a P. E. of 0.03 foot, i.e. 1 part in 1 400 000.

The Geodimeter party then moved north to the dry semi-desert climate of Marree, travelling over some atrocious roads.

Here, at Marree, on the 12-mile *Attraction Hill to Mt. Alford* line, a first experience of really bad atmospheric conditions was encountered. Variation of refraction caused 30-foot vertical jumps in the return light and it was impossible to keep the light on the receiver long enough to obtain a result. After several weeks of frustrated attempts, a return was made to Melbourne, calling at *Carrieton base* on the way to see if the jolting over the country roads had affected the instrument.

The results differed from the first measurement by 0.01 foot, while the P. E. of 0.013 foot was 1 part of 1 700 000.

Upon return to Melbourne, the accumulated dust collected from two dust storms was removed from the instrument. The quantity collected indicated that some form of dust proofing would be advantageous. The zero indicator instrument had developed an oil leak, so the Geodimeter was despatched for repair and a crystal-frequency check.

**Zero correction**

Mr. G. R. L. Rimington, Chief Topographic Surveyor, and Mr. H. A. Johnson, Senior Surveyor, joined the party for the next line measurement which was at *Benambra geodetic baseline.* Mr. Johnson was engaged on the original measurement of this baseline situated in the Australian Alps in the NE corner of Victoria.

It was decided to measure the line overall, then in two parts as a check against the value for the zero correction. This check indicated that the zero correction should be decreased by .17 foot, and with the amended value, the sum of the parts differed from the whole by 0.01 foot. The results showed a P. E. of 0.01 foot or 1 part in 3 000 000.

At Benambra it was found that the neon glowlamps were not behaving efficiently. To the eye they appeared to be functioning, but the zero indicator was becoming increasingly difficult to balance, so a new set of neon glowlamps was installed. The improvement was immediate and startling.

The measurements of the *Benambra base* were completed by December 1954, and upon return to Melbourne, the equipment was set up in the office to check the value for the zero correction. The null indicator could not however be set on zero, until an electronics mechanic located the trouble as an unserviceable balance control potentiometer. This was replaced and the trouble disappeared.

The balance of the instrument had long been unsatisfactory, so the

(*) Probable error.

photomultiplier was removed for test, which showed that the tube was unstable. The spare tube was completely unserviceable.

Conveniently, a new phototube arrived from Sweden at this time, and a new set of glowlamps was also fitted. This brought about a marked difference.

The flicker that had been in the null indicator since receiving the instrument disappeared entirely. Balance became easy to obtain and was much more definite, and speed of operating rose accordingly.

Results from these tests in the office indicated that the zero correction should have been .04 foot instead of 0.17 foot, and this calibration was apparently borne out by the next field measurements.

**Further field tests**

As the Melbourne weather had improved, a decision was made to measure the *Mt. Atkinson-Green Hill* line that had been so fruitless in 1954.

Here again, with Mr. Rimington's assistance, the Geodimeter party used the same system as developed at Benambra, i.e. measuring the line as a whole, and in two parts, the difference being 0.016 foot, with a P.E. of 0.016 foot or 1 part in 2 700 000 over the 8-mile line.

This differs from the Geodetic distance by 0.41 feet or 1 part in 108 000.

An attempt was made to measure a 20-mile line, *Mt. Atkinson-Station Peak,* but poor visibility caused the attempt to be abandoned. Another crystal check was carried out, but no change was noted.

A new cylindrical condensing lens for the received optics was received from A.G.A. to replace the spherical lens originally fitted. This replacement made, the office tests were run to check on zero correction.

These tests showed that the zero correction should in fact be reduced by the .17 feet previously determined at Benambra.

This upset the *Mt. Atkinson - Green Hill* results slightly, making the sum of the parts differ from the whole by 0.115 foot, or 1 part in 385 000, but improved the comparison of the overall distance with the trig distance to 0.28 foot or 1 part in 158 000. This modification of .17 foot has been accepted for the zero correction and applied to all previous and subsequent work, with a consequent improvement of results.

As the behavior of the Geodimeter was now much steadier than it had been previously, a return trip to Benambra was considered advisable in May, 1955. Weather conditions in the Australian Alps had altered radically. The summer weather of December had given way to winter conditions with heavy frosts on the ground and snow on the surrounding mountains. Both Mr. B. P. Lambert, Director of National Mapping, and Mr. G. R. L. Rimington attended these test measurements at Benambra.

The same procedure was adopted as developed at Benambra in December. The sum of the parts differed from the measurement of the whole by 0.03 foot, and the whole distance (P. E. 0.018 foot or 1 part in 1 700 000) differed from the baseline measurement by 0.06 foot, i.e. a comparison of 1 part in 520 000.

After returning to Melbourne and carrying out adjustments to the light conductor, the Geodimeter party was to have measured the baseline at Millicent, South Australia. Heavy rain prevented this measurement, and the party moved on to Carrieton.

| | | |
|---|---|---|
| DATE : 14 Dec. 55 | GEOD. 14.1 / 14.1 TEMP. 14.2 / MIRROR 14.7 14.3°C | GEOD. –.03 ft. ECCE: AT PEG. MIRROR: NIL |
| GEOD. AT: KANGAROO GROUND | GEOD. 29.12 / 29.11 28.42 BARO. 27.73 / MIRROR 27.72 721.9 mm | TIME : 2329 – 2345 |
| REFLEX MIRROR AT: M<sup></sup>t DANDENONG ECCE | GEOD. 95 % / 95 % REL. HUM. 90% / MIRROR 90% 92 % | APPROX DIST. : 61370 |

| FREQ. | PHASE | LC c | LC F | MIRROR c | MIRROR F | LC c | LC F | LC c | LC F |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | 8 | 70 | | | 8 | 70 | 8 | – 50 |
| | 1 | 2 + | 55.0 | | – 60.1 | | 55.7 | (8.7) | 47.0 |
| | 2 | | 63.6 | | 60.2 | | 62.0 | (6.0) | 56.0 |
| | 3 | | 63.0 | | 62.1 | | 63.3 | (7.8) | 55.5 |
| | 4 | | 56.7 | | 56.5 | | 54.8 | (6.8) | 48.0 |
| | | | 238.3 | | 238.9 | | 235.8 | | 206.5 |
| | | | 59.58 | | 59.72 | | 58.95 | | 51.62 |
| 2 | | 8 | 36 | | | 8 | –36 | 8 | – 56 |
| | 1 | 9 | – 20.2 | 9 | 18.7 | | 20.3 | (8.4) | 28.7 |
| | 2 | | 14.0 | | 18.8 | | 14.9 | (7.4) | 22.3 |
| | 3 | | 15.5 | | 19.5 | | 15.5 | (8.0) | 23.5 |
| | 4 | | 19.8 | | 17.1 | | 20.3 | (7.7) | 28.0 |
| | | | 69.5 | | 74.1 | | 71.0 | | 102.5 |
| | | | 17.38 | | 18.52 | | 17.75 | | 25.62 |

| | FREQ. 1 | FREQ. 2 |
|---|---|---|
| L.C. 1 | 59.58 | 17.38 |
| " 2 | 58.95 | 17.75 |
| Mean | 59.26 | 17.56 |
| Mirror | 59.72 | 18.52 |
| Δ | + .46 | + .96 |
| Corr. | .46 × .2 | .96 × .2 |
| | 7.33 | 7.87 |
| | + .0126 | + .0244 |
| L.C. c | 5.5909 | 5.5909 |
| " f | .7000 | .3600 |
| Corr. | .0126 | .0244 |
| Z | 1.1330 | 1.1330 |
| | 7.4365 | 7.1083 |
| R | – .6588 | – .6588 |
| | 6.7777 | 6.4495 |
| | 18 768.3248 | 18 768.6447 |
| | 18 775.1025 | 18 775.0942 |
| Mean: 18 775.0984 M | 2505 U1 | 2530 U2 |

WEATHER : Cool Fine Calm — HT GEOD. 3.05 ABOVE PEG; HT MIRROR 4.67 " "

OPERATOR : C. K. Waller — RECORDER : G. R. L. Rimington.

Atm. Corr. Per Metre :

| | | |
|---|---|---|
| Temp | 14.3°C | $+ 15.3 \times 10^{-6}$ |
| Baro. | 721.9 mm | + 14.4 |
| Humid. | 92 % | + .6 |
| Colour | 5580 Å | – .4 |
| | | $+ 29.9 \times 10^{-6}$ |

Total Atm Corr. + .5614 M.

| | | |
|---|---|---|
| Measured Dist | | 18 775.0984 M |
| Atm Corr. | | .5614 |
| Focus " T | | --- |
| Focus " R | | --- |
| Slope Dist | | 18 775.6598 M |
| Slope Dist | | 61 600.0408 Ft. |
| Ecce Geod | – | .0300 |
| Ecce Mirror | – | 32.5500 |
| Slope Corr. | – | 15.5700 |
| Sea Level | – | 3.9847 |
| Chord - Arc | + | .0220 |
| Sea Level Dist. | | 61 547.9281 Ft. |

Specimen of field book showing observations and computations

At Carrieton, the system of measuring used at Benambra was repeated, the intermediate station being about ½ mile from the Western terminal.

**Spherical mirror**

The A. G. A. Spherical Reflex System had recently been received and for the first time this was put into operation seriously.

Both plane and spherical mirrors were used at each station. With the plane mirror, the sum of the parts differed from the whole by 0.16 foot, while with the spherical mirror, the agreement was exact, but unknown systematic errors were evident when using the plane mirror over the short line.

The probable errors over the 4 miles were :

Plane mirror 0.003 foot, i.e. 1 part in 7 600 000.

Spherical mirror 0.009 foot, 1 part in 2 500 000.

The plane-mirror distance differed from the measured distance by 0.07 foot, and that of the spherical mirror by 0.03 foot, giving comparisons of 1 part in 327 000 and 764 000 respectively.

Reasonably satisfied, the party proceeded to Eyre Peninsula, where an attempt was made to measure a 12-mile line near Cleve : *Mt. Nield to Mt. Priscilla.*

Here the party met with the first trouble that could not be coped with in the field, so the equipment was returned to Melbourne.

The trouble was traced to the photocell box, a dry solder joint appearing to be the culprit.

Serviceable once more, it was decided to postpone the attempt at Cleve, and instead to move north to Mildura.

While preparing to measure this line, trouble struck again. Symptoms similar to those at Cleve reappeared. A thorough investigation of the photocell box revealed that a loose screw was causing an intermittent short circuit.

**Horizontal refraction**

The only line suitable in the Mildura area was *Paschendale to Yelta,* a 5½-mile line over fairly flat country. Nowhere is the line of sight more than about 30 feet above the ground, while at both ends of the line, level ground stretches for a considerable distance before falling away, and to complete the picture, there is a bad graze in the middle. The spherical mirror was used and vertical refraction did not prove very troublesome, but horizontal refraction was severe. At the mirror end of the line, horizontal movement of the projected beam was of the order of 30 feet.

These far from ideal conditions made balances particularly difficult to obtain, and each set of two frequencies took 1 to 1½ hours to complete instead of the usual 30 to 45 minutes of operation. The P. E. for this measurement was 0.012 foot or 1 part in 2 400 000.

Next step was at Ouyen, where an 11-mile line, *Kulwin to Blue Hill,* was measured under conditions much the same as at Mildura. The operating time was still 1 to 1½ hours per set, but the measurements finished with a P. E. of 0.021 foot or 1 part in 2 800 000.

The next measurement, a 13-mile line, *View Hill to Mt. Alexander,* had been selected near Bendigo, with high terminal marks and a good fallaway at each end; conditions looked about ideal, so it was something of a shock when the same frustrating conditions as at Mildura and Ouyen occurred.

Next night, however, produced perfect conditions; operating time was reduced to 20-30 minutes per two frequency sets, with a P. E. of the results of ± 0.012 foot or 1 part in 5 800 000.

Three lines were selected in Gippsland, Victoria, for measurement. These measurements presented no difficulties, apart from poor visibility.

From Thorpdale, two lines were measured : the first of 13 miles, *Thorpdale-Eccles Minor,* produced a P.E. of ± 0.029 foot or 1 part in 2 300 000; the second of 15 miles, *Thorpdale-Hooghly,* a P.E. of 0.029 foot or 1 part in 2 100 000.

The third side of this triangle, *Hooghly-Eccles Minor,* is a first-order trig line, and the distance computed from the two measurements and the included angle differs from the original trig distance by 0.06 foot.

The third line of 12 miles, *Camp Hill Gentle Annie,* yielded a P.E. of ± 0.017 foot, 1 part of 3 700 000.

After returning to Melbourne, 14-mile and 21-mile lines were attempted close to the city; with the Geodimeter sited near Epping. No trouble, apart from visibility difficulties, was experienced with the 14-mile line, *Quarry Hill-Mt. Disappointment,* which was finished in three nights of operating, but poor visibility prevented measurement of the 21-mile line, *Quarry Hill to Mt. Dandenong.* After several abortive attempts, this direct measurement was abandoned, and a hill located about halfway along the line, near Kangaroo Ground, was used, from which the distance was measured in two steps, in three nights of observing, with P.E.'s for the 10-mile and 11-mile sections of 0.005 foot, i.e. 1 part in 10 000 000.

**Improved operating procedure**

Up to the time of operating from Kangaroo Ground, the procedure had been : four phases against the distant mirror, four phases against the light conductor; light conductor moved 20 cm and four more phases taken for an interpolation factor, then 4 more phases against the mirror. The mean of the 8 mirror readings was taken and compared with the mean of the four light conductor readings for the distance to the first null point.

This system of operating was timewasting, particularly under difficult conditions. Most of the time involved was used against the distant mirror, and on many occasions a set had to be discarded because atmospheric conditions deteriorated, and it was impossible to get a final mirror reading.

Then, too, the time factor, and consequently the delay drift, was far from linear, especially when the plane mirror was being used, and frequent realignment was necessary. By sandwiching one set of mirror readings between two sets of light-conductor readings, these conditions are immediately overcome. It is only the work of a moment to obtain an approximate delay value for the mirror (two phases suffice) so that a light-conductor value can be obtained. The system then is : four phases against the light conductor, four against the mirror, and four more against the light conductor. The light conductor is then moved 20 cm and four phases taken for the interpolation factor.

This has further reduced the time taken to obtain a set of two frequencies to 15 to 20 minutes under good conditions. Fig. 1 shows a page of the fieldbook with all the actual observations, together with the calculations involved.

The Kangaroo Ground lines, measured in December, 1955, completed a sequence of measurements, and the rather formidable task of finalizing the fieldbooks was tackled.

**Velocity of light**

Up to this stage Bergstrand's value of the velocity of light (299 793.1 km/sec) has been used, but after analysis of the results of local and overseas Geodimeter measurements of first-order baselines, together with recent laboratory determinations, a decision was made to adopt tentatively a value of 299 792.5 km/sec. The following tabulated results are expressed in terms of that value.

## AUSTRALIAN GEODIMETER MEASUREMENTS TO DECEMBER 1955

| Date | Place | Line measured | No. of pairs of readings $\frac{(f_1 + f_2)}{2}$ | Approx. length of lines (miles) | Probable error (± foot) | Geod. minus survey (foot) (V = 299 792.5 km/sec.) |
|---|---|---|---|---|---|---|
| Aug. 1954 | Carrieton, S. A. | Geodetic baseline | 4 | 4 | 0.01 | .00 |
| Aug. 1954 | Carrieton, S. A. | Maurice Hill - Black Rock (Triangle side) | 4 | 19 | 0.04 | — .01 |
| Aug. 1954 | Cockburn, S. A. | Feldspar - Twenty Mile (Triangle side) | 4 | 8½ | 0.03 | + .22 |
| Nov. 1954 | Carrieton, S. A. | Geodetic baseline | 4 | 4 | 0.01 | — .01 |
| Dec. 1954 | Benambra, Vic. | Geodetic baseline | 6 | 6 | 0.01 | + .01 |
| Mar. 1955 | Melbourne, Vic. | Mt. Atkinson - Green Hill (Triangle side) | 4 | 8 | 0.02 | + .20 |
| May 1955 | Benambra, Vic. | Geodetic baseline | 9 | 6 | 0.02 | .00 |
| July 1955 | Carrieton, S. A. | Geodetic baseline (Plane mirror) | 8 | 4 | 0.00 | + .03 |
| July 1955 | Carrieton, S. A. | Geodetic baseline (Spherical mirror) | 5 | 4 | 0.01 | — .01 |
| Sept. 1955 | Mildura, Vic. | Paschendale - Yelta | 8 | 5½ | 0.01 | — |
| Sept. 1955 | Ouyen, Vic. | Kulwin - Blue Hill | 8 | 11 | 0.02 | — |
| Sept. 1955 | Bendigo, Vic. | View Hill - Mt. Alexander | 8 | 13 | 0.01 | — |
| Oct. 1955 | Thorpdale, Vic. | * Thorpdale - Eccles Minor | 6 | 13 | 0.03 | — |
| Oct. 1955 | Thorpdale, Vic. | * Thorpdale - Hooghly | 6 | 15 | 0.03 | — |
| Oct. 1955 | Thorpdale, Vic. | Camp Hill - Gentle Annie | 8 | 12 | 0.02 | — |
| Nov. 1955 | Melbourne, Vic. | Mt. Disappointment - Quarry Hill | 12 | 14 | 0.01 | — |
| Dec. 1955 | Melbourne, Vic. | Portion of Quarry Hill - Mt. Dandenong | 9 | 10 | 0.00 | — |
| Dec. 1955 | Melbourne, Vic. | Portion of Quarry Hill - Mt. Dandenong | 6 | 11 | 0.01 | — |
| Mar. 1956 | Somerton, N.S.W. | South Base - Baldwin | 6 | 14 | 0.01 | — .06 |
| Mar. 1956 | Somerton, N.S.W. | ** Geodetic baseline | 6 | 4 | 0.01 | — .08 |
| Mar. 1956 | Jondaryan, Q. | ** Geodetic baseline | 6 | 7 | 0.01 | — .09 |

* The distance Eccles Minor-Hooghly (27 miles) as computed from the Geodimeter measurements was 0.35 foot less than the distance as determined by first-order triangulation.

** These last two measurements, made after this article was written, complete the comparison between the geodimeter measurements and the four precise geodetic baseline measurements made by the Royal Australian Survey Corps prior to the Second World War.

### Conclusion

Looking back over 18 months of field work, it emerges that the Geodimeter is definitely a surveyor's instrument of outstanding accuracy and consistency, and not just a laboratory curiosity. It simplifies baseline measurement, and makes the lot of the reconnaissance surveyor much happier, as he is not concerned with level areas for the base itself and a complicated basenet system. The only requirement is that one hill be a " drive-on ", and I feel that even this stipulation will be ultimately removed as lighter and more portable models become available.