The Geodimeter and its Uses

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Introduction.

An electronic distance measuring instrument of geodetic accuracy, known as the Geodimeter which was invented by Dr. Bergstrand of the Geographic Survey Office of Sweden and then developed and manufactured by the A. G. A. Company of Sweden, has now been in use in Australia for three years.

It is the purpose of this paper to describe this model of the Geodimeter and its uses*.

In carrying out this purpose the general principles of the instrument will first be mentioned, the basic design described and details of the operating procedure given.

A report will then be presented on the practical experience obtained with the equipment in Australia and this will be followed by an expression of views on the likely uses of the equipment.

General Principles.

The Geodimeter sends out flashes of light from a transmitter to a distant reflector from whence they are returned to a receiver built into the instrument itself.

At the receiver a reading is made which depends on the time taken by the flashes of light to cover the return journey.

FIGURE I

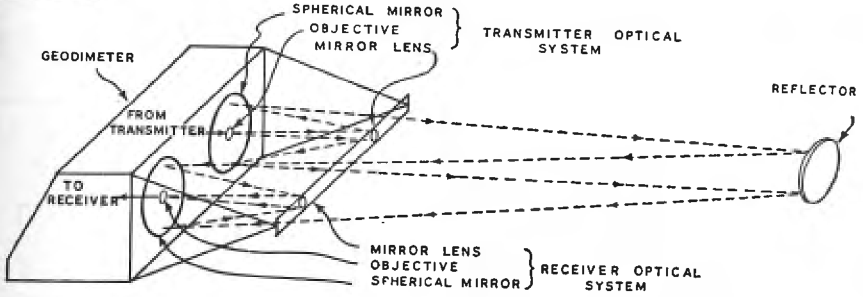


DIAGRAM SHOWING PATH OF LIGHT FLASHES BETWEEN GEODIMETER AND REFLECTOR

*A. G. A. has now developed a smaller and more portable model for use on second and lower order surveys.

FIGURE 2

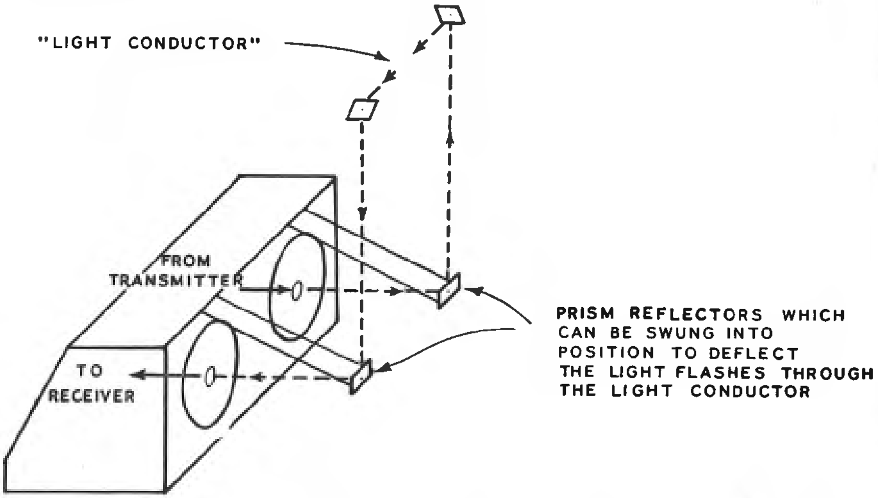


DIAGRAM SHOWING PATH OF LIGHT FLASHES THROUGH LIGHT CONDUCTOR

The light flashes are then deflected through an attached light conductor in which the distance travelled by the light flashes can be accurately varied over a range of distance from about 1.2 to about 10 metres from the instrument zero point.

The setting thus obtained on the light conductor gives the distance from the zero point of the instrument to the commencement of a series of units of measurement of unknown number between this distance and the reflector. These units of measurement are about 7.5 metres long and from the behaviour of the instrument it is possible to tell whether there is an even or odd number of units involved.

FIGURE 3

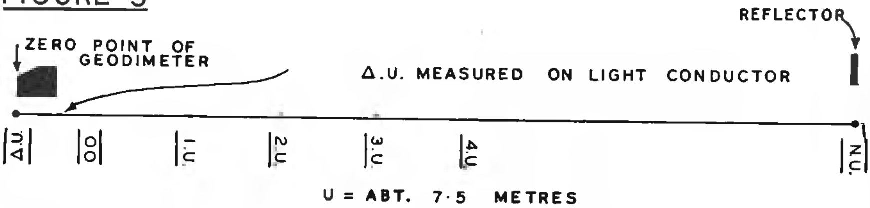


DIAGRAM SHOWING THE TYPE OF MEASUREMENT MADE WITH THE GEODIMETER

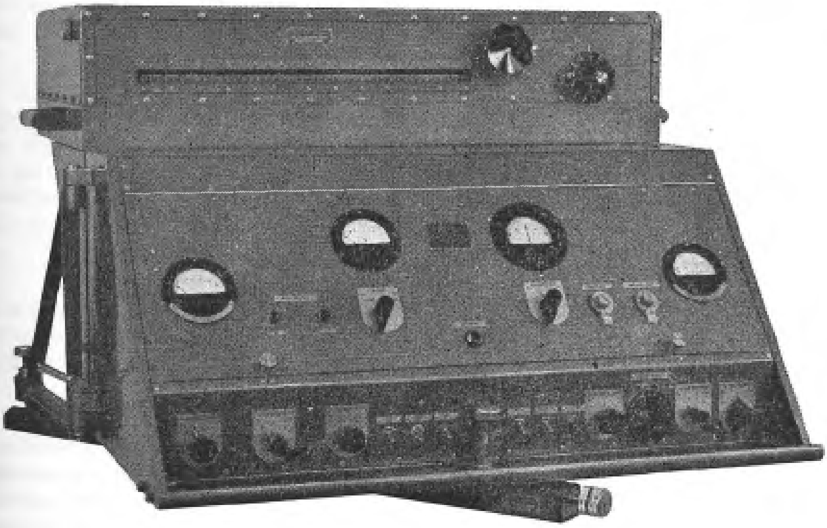
At this stage the surveyor is in an analogous position to that of knowing the odd length at the end of a measured line and that to this must be added an even or odd number of tape lengths.

In which case it would be necessary to know the length of the line to within plus or minus a little less than two tape lengths before the actual length could be deduced.

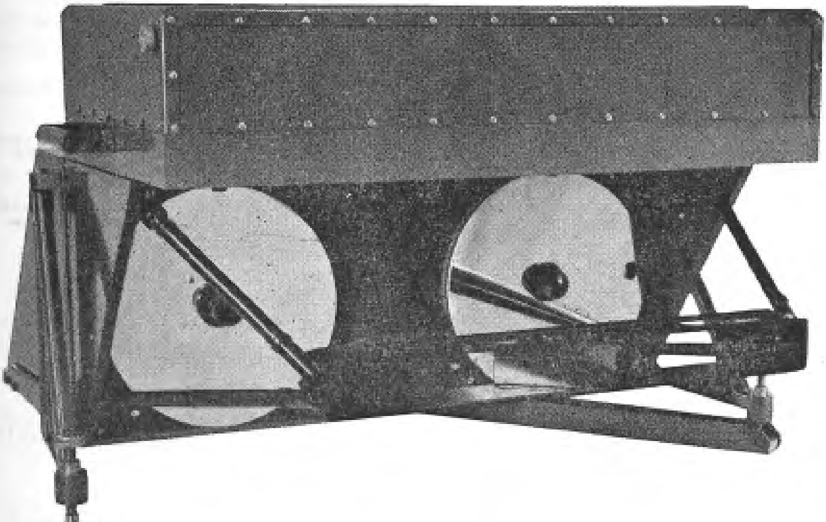
Actually the Geodimeter is provided with two or three units of measurement differing slightly from each other.

For example, if the second unit is one hundredth shorter than the first unit there will be a vernier effect with coincidence only at multiples of 100 and 101 wave lengths. Again it is possible to tell from the behaviour of the instrument whether an odd or even multiple of these groups of wave lengths is involved.

Allowing a certain amount for safety, the distance should be known to within plus or minus 1 kilometre when measuring with the two unit Geodimeter and to within plus or minus 3 kilometres for the three unit instrument.



View of Geodimeter from instrument side (A.G.A. photo No. C9337).



View of Geodimeter from mirror side (A.G.A. photo No. C9338).

BASIC DESIGN.

Apart from the electric circuit, the basic units of the Geodimeter are :—

(a) the transmitter ;

(b) the reflector ;

(c) the receiver ;

(d) the light conductor.

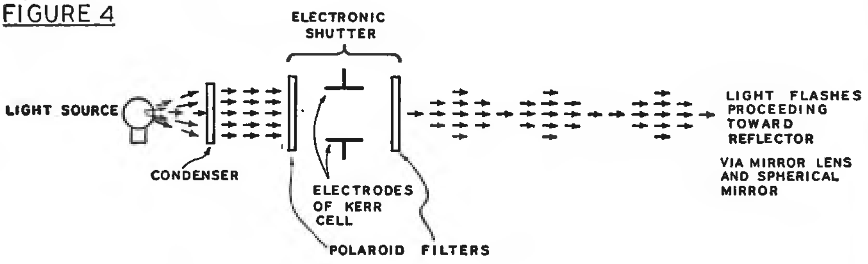
Description of the electric circuit is a subject in itself and cannot be conveniently undertaken in this paper. It is therefore proposed only to deal with so much of the electrical side of the equipment as is necessary to an understanding of the general principles, the basic design and the operating procedure.

The Transmitter consists first of a small electric light, part of the rays emanating from which are transmitted by a condenser through an instantaneous electronic shutter that breaks the light up into a series of flashes. These are in turn passed through an objective on to a mirror lens and thence by means of a spherical mirror to a reflector which directs the flashes back toward the receiver.

The type of electronic shutter used is well known in physical optics and consists of a Kerr Cell interposed between two polaroid filters each with their plane of polarisation at 45° to the electric field of the Kerr Cell and at 90° with respect to each other.

The light after passing the first filter is plane polarised and would not normally pass through the second filter but if there is a difference of potential across the electrodes the plane of polarisation of part of the transmitted light is in effect rotated and part of the light can then pass through the second filter.

FIGURE 4



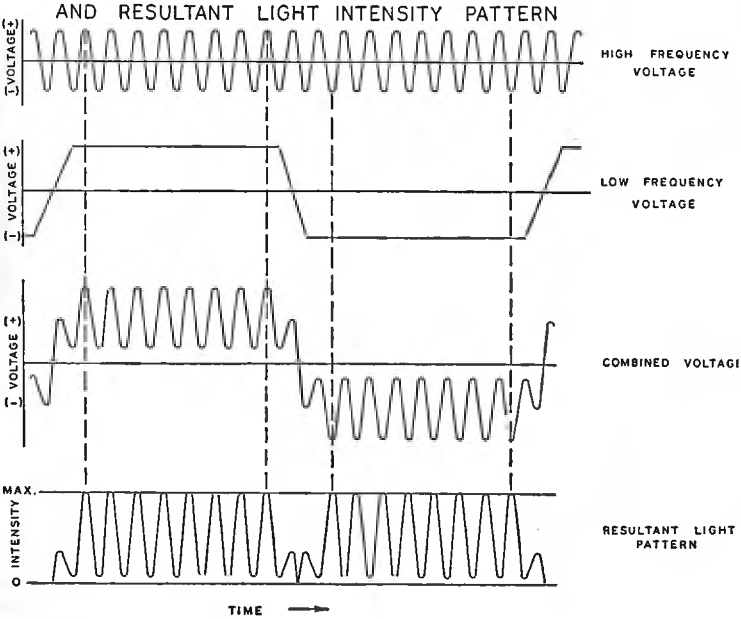
DIAGRAMMATIC PRESENTATION OF TRANSMITTER

The actual intensity of light transmitted is directly proportional to the square of the difference of potential across the electrodes.

A combination of high and low frequency alternating voltages is applied to the electrodes as shown diagrammatically in the following figure.

FIGURE 5

DIAGRAM SHOWING COMBINATION OF VOLTAGES AND RESULTANT LIGHT INTENSITY PATTERN



NOTE THE CHANGE OF LIGHT PATTERN IN ADJACENT GROUPS. THE PEAK OF INTENSITY ALTERNATELY CORRESPONDS WITH THE MAXIMUM & THE MINIMUM OF THE HIGH FREQUENCY VOLTAGE CURVE.

It will be noted that the intensity of light, which depends on the difference of potential without regard to sign, changes its maximum value to coincide with the maximum or minimum value of the high frequency voltage as the low frequency voltage changes from positive to negative.

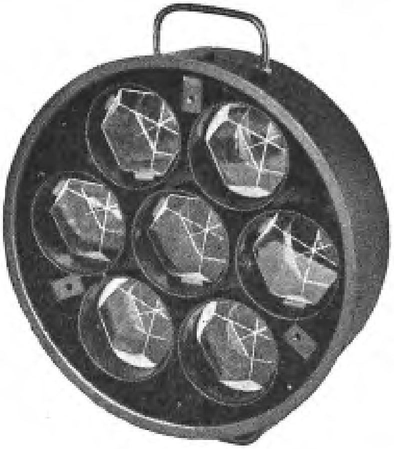
The high frequency is approximately 10,000,000 and the low frequency 50 cycles per second so that there is approximately 100,000 flashes in each alternate group. The flashes in adjacent groups are identical except that the times of emission are displaced $\frac{1}{2f}$ seconds where " f " is the high frequency.

In actual operation the effects of certain small errors of adjustment have to be eliminated by adopting the mean of measurements made with each of four different combinations of phase settings.

The Reflector. Three types of reflector have been developed.

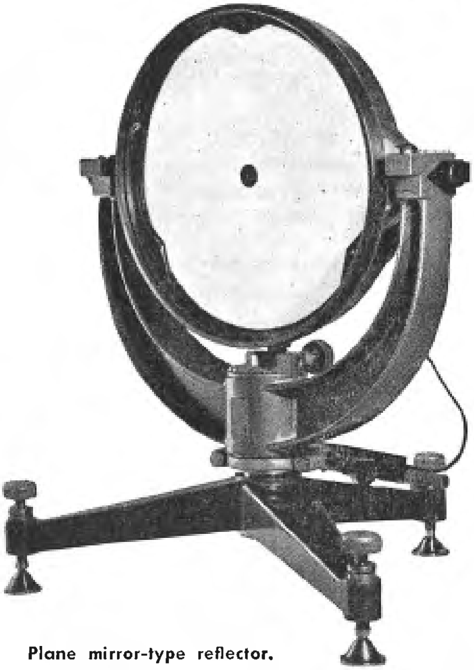
The first developed was the plane mirror type with attached telescope for alignment. This required very careful lining up and constant attention to correct for disturbances in the light path due to atmospheric changes.

The second system consists of a spherical mirror and a plane reflecting surface. Between this surface and the concave mirror, a correcting optical system eliminates spherical aberration, coma and astigmatism within a field of 1°. If correctly adjusted and aligned along the optical axis to within 1° this reflector will automatically return the light flashes back to their source. This system requires little supervision once it has been set up. It has been used very successfully in this country in preference to the plane mirror, in spite of the fact that it returns less light to the receiver.



Prism-type reflector.

Spherical mirror-type reflector.

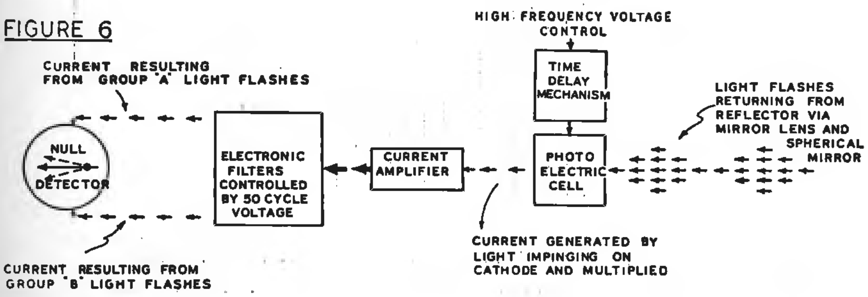


Plane mirror-type reflector.

The third and latest system consists of a group of seven high precision tetrahedron prisms or " corner cube " reflectors mounted on a housing. If lined up within 20° of the optical path, the light flashes are automatically returned to near their source. As yet there has been no local experience with this equipment but the manufacturers claim that with three such units grouped together the total light returned is equal to that from the plane mirror.

The Receiver consists of a spherical mirror which collects the reflected light flashes and directs them on to a mirror lens from whence they are concentrated through an objective on to the cathode of a photo-electric cell. The anode of this cell is subject, via an electric delay system, to the same high frequency crystal controlled voltage as applied to the Kerr Cell. It in effect acts as another electronic shutter and is sensitive to the reception of light only during positive half cycles of this voltage. This means that it receives light and converts it into electric current for alternate periods of $\frac{1}{2f}$ seconds. However, the commencement of the time of acceptance can be varied by means of the electric delay system. The amount of light actually received is converted into current which for all practical purposes is directly proportional to the intensity of accepted light. The currents so generated are multiplied up within the cell itself and through an amplifying valve. They are then fed into two electronic filters which are controlled by the 50 cycle voltage so that, while one filter accepts the current generated by the flashes controlled by the positive half cycle of this voltage, the other accepts the current generated by those under control of the negative half cycle. The resultant currents are fed in opposite directions through a galvanometer or "null detector" which registers zero when the two currents are equal.

FIGURE 6



DIAGRAMMATIC PRESENTATION OF RECEIVER

It will be seen from the following diagram that equality is achieved only when the time of commencement of light acceptance coincides either with a maximum or minimum of intensity of the respective light flashes in each group.

This means that once the currents are balanced it would be possible to achieve the same balance if the time for the round journey of the light flashes was varied by $\frac{1}{2f}$ seconds or in other words if the distance travelled was altered $\frac{v}{2f}$ metres where $v =$ the velocity of light. This computes at approximately $300,000,000/20,000,000 = 15$ metres. This variation of distance could be achieved by moving the reflector any multiple of 7.5 metres from which it may be deduced that one such point of balance lies within the first 7.5 metres. It is the distance to this point of balance that is determined with the aid of the light conductor.

FIGURE 7

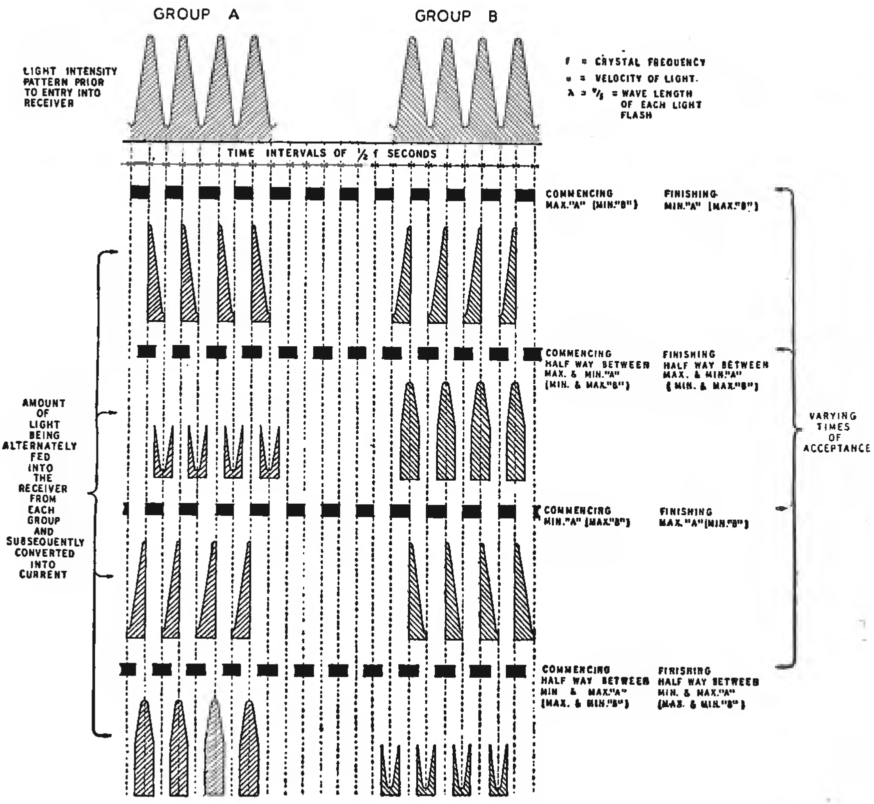


DIAGRAM SHOWING VARIATION IN QUANTITIES OF LIGHT ACCEPTED INTO RECEIVER AS A RESULT OF THE APPLICATION OF DIFFERENT TIME DELAYS

The relative behaviour illustrated in Figure 8 will indicate whether an odd or an even number of units of measurement is involved.

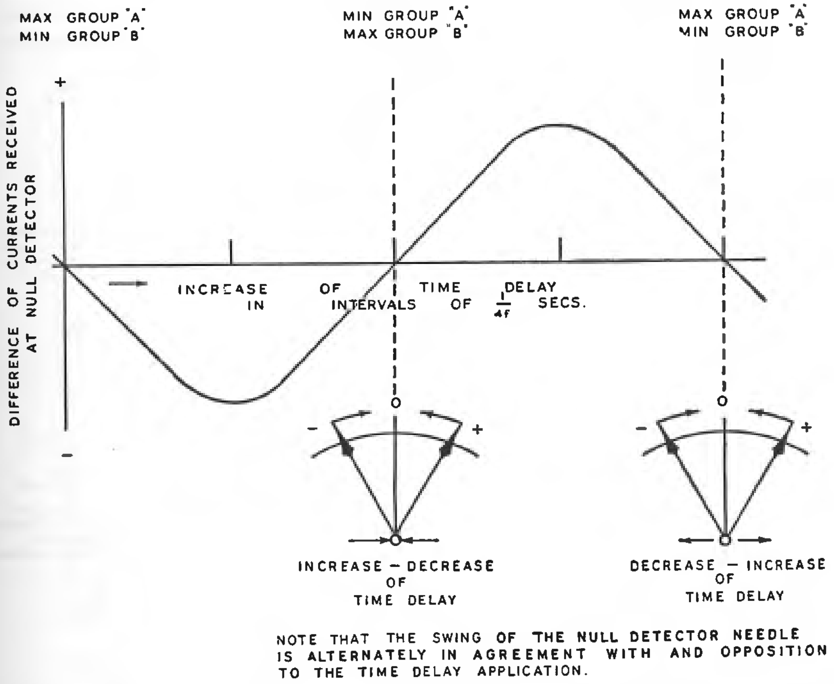
The number of units of measurement is deduced from a sufficiently approximate knowledge of the actual distance in conjunction with the vernier effect derived from use of two or three frequencies.

It will be appreciated that the whole accuracy of the measurement is dependent on the timing device. This is a quartz crystal which must be specially heated to a standard temperature before commencing measurement.

The Light Conductor. The light flashes emerging from the transmitter are deflected up into the light conductor where they pass through a series of internally plated metal tubes. Eleven such pairs are provided and a small deflection mirror can be swung into the light path after the flashes have passed through any number of these pairs of tubes.

The light flashes are then deflected to an adjustable length which can be set against a scale at any distance between 0 and 80 cms.

FIGURE 8 DIAGRAMMATIC PRESENTATION OF BEHAVIOUR OF NULL DETECTOR IN RESPONSE TO APPLICATION OF TIME DELAY



After passing through this adjustable length the flashes are directed into the receiver. Each pair of tubes adds a distance of approximately 80 cms to the light path so that the light path can be extended to total distance of about 9.60 metres to which must be added an index correction of about 1.2 metres the exact value being peculiar to the particular instrument in use.

In actual fact the double tubes and the design of the adjustable length ensure that the light flashes travel over a distance equivalent to the return journey that would have been made if a reflector had been set at an equivalent distance along the normal light path.

Operating Procedure.

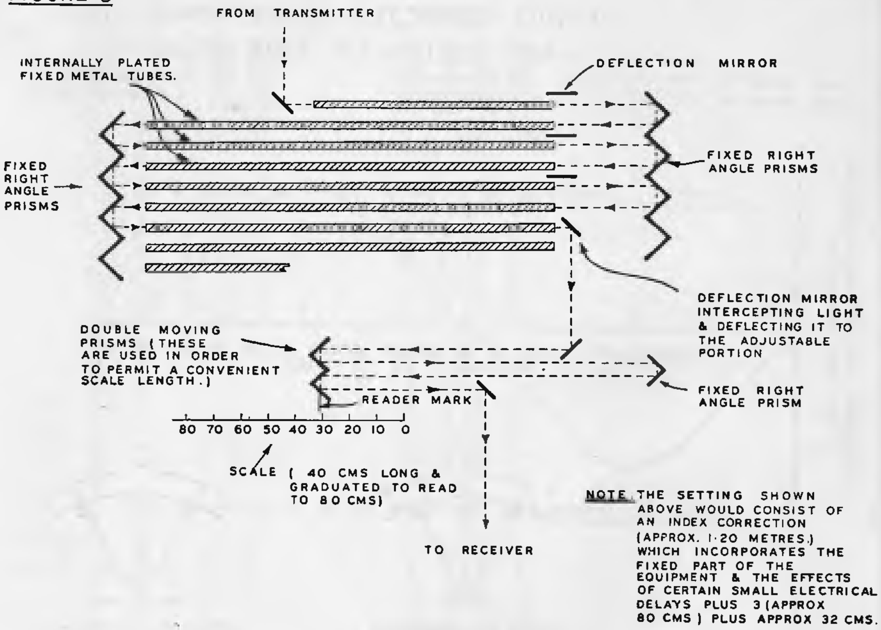
The Geodimeter itself must be assembled on a firm support near one end of the line to be measured and then connected to the power supply.

In practice it has been found worthwhile to have a special metal table made as a support for the Geodimeter.

The reflector is set up at, or close to, the other end of the line and any necessary eccentricity measurements made at each end.

The Geodimeter is roughly aligned on the reflector, the lamp, condenser and polaroid filters swung out of position and a telescope inserted. With this telescope in position it is possible to sight the reflector between the

FIGURE 9



DIAGRAMMATRIC PRESENTATION
OF
LIGHT CONDUCTOR

electrodes of the Kerr Cell via the mirror lens and the spherical mirror. By this means the Geodimeter can be further adjusted to bring the image of the reflector centrally between the electrodes.

Final adjustment is made in darkness, or semi-darkness, using the light beam obtained from the lamp with the polaroid filters swung out of position. This beam is finally guided into correct position by the operator at the reflector end. Communication is by means of portable radio transceiver.

Before measurement may commence the crystal heaters have to be switched on, polaroid filters swung into position, standard checks and adjustments made to electrical apparatus, the sensitivity of the photo-electric cell adjusted to an optimum and the incoming light flashes focussed on to the centre of the cathode.

When all these adjustments are complete measurement on the first frequency may commence.

An approximate zero balance is first made on the light received from the reflector by applying an appropriate number of course delays plus a fine delay setting. This is repeated on a second phase and a corresponding setting established on the light conductor.

A set of readings on the four phases is then completed with the light conductor set at the centimetre reading nearest the approximate value previously obtained.

Four readings are then made on the reflector followed by a further four against the light conductor setting previously used.

The light conductor is then altered 20 cms and a fresh set of readings taken to provide an interpolation factor.

Observations of atmospheric pressure, temperature and humidity are made at each end of the line at the commencement and termination of a measurement.

FIGURE 10

DATE 14 DEC. 55	GEOD 14·1 14·1 / TEMP 14·2 MIRROR 14·7 14·3°C	ECCE AT PFB / GEOD -·43ft. MIRROR NIL
GEOD AT KANGAROO GROUND	GEOD 29·12 29·11 28·73 / BARO 27·73 MIRROR 27·72 721·9mm	TIME 2329 - 2345
REFLEX MIRROR AT MT. DANDENONG ECCE	GEOD 95% 96% / 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
	+·0216	+·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 U_1	2530 U_2

FOUR PHASE POSITIONS ON FREQUENCY 1

FOUR PHASE POSITIONS ON FREQUENCY 2

CALCULATION OF INTERPOLATION FACTOR

(8-1) COARSE READINGS (EACH = 79·87 CMS)

FINE SCALE READINGS OF FIRST LIGHT CONDUCTOR SETTINGS

INSTRUMENT INDEX ERROR

REFLECTOR INDEX ERROR

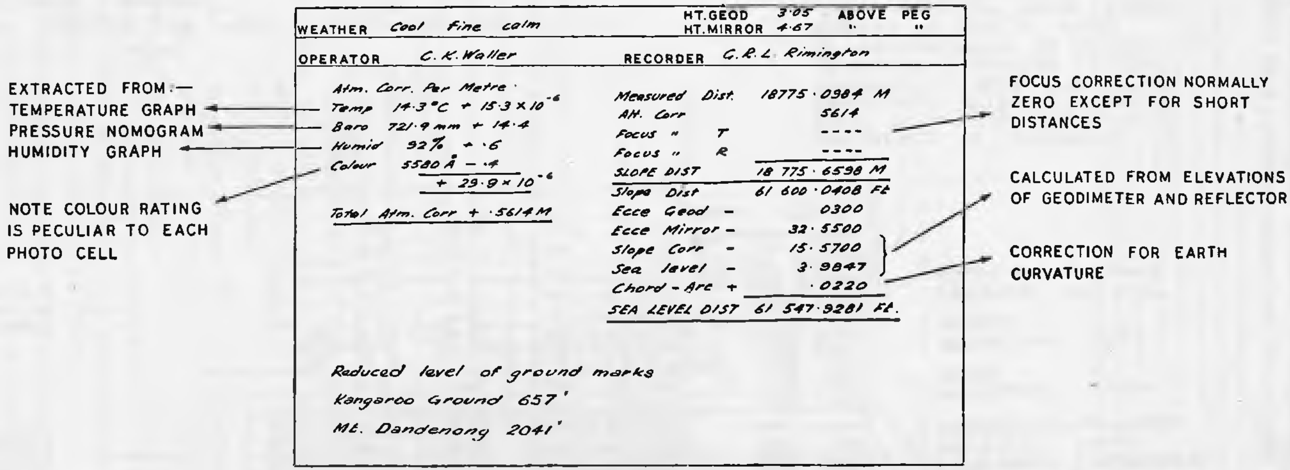
DISTANCE TO FIRST POINT OF BALANCE

TIME DELAY READINGS

1. FIRST READINGS ON FIRST LIGHT CONDUCTOR SETTING
2. REFLECTOR READINGS
3. SECOND READINGS ON FIRST LIGHT CONDUCTOR SETTING
4. READINGS ON SECOND LIGHT CONDUCTOR SETTING (TO PROVIDE INTERPOLATION FACTOR)

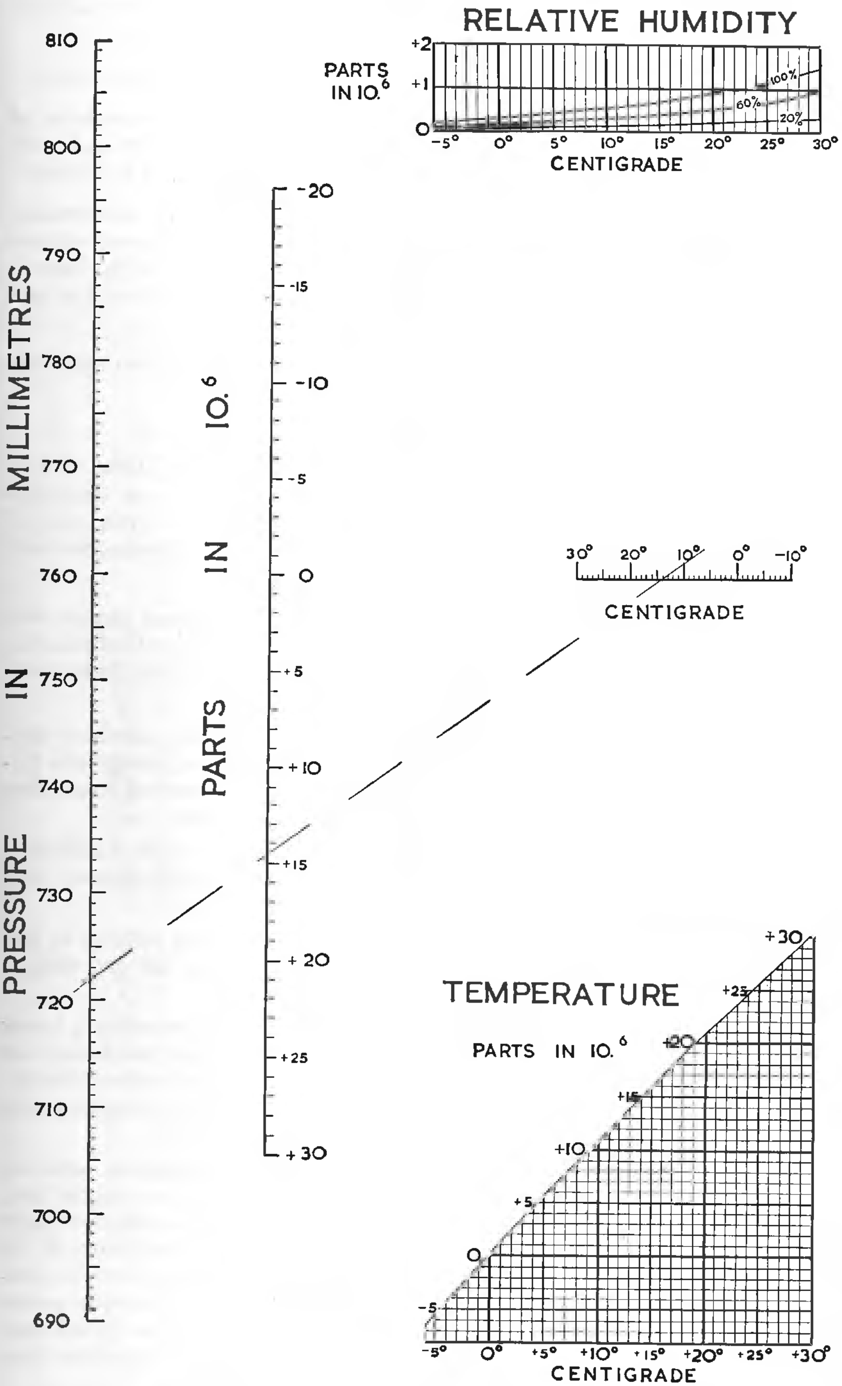
DIFFERENCE OF DISTANCES TO FIRST POINTS OF BALANCE IS CALCULATED. INTERPOLATION IN PREPARED TABLES THEN GIVES APPROPRIATE NUMBER OF UNITS OF MEASUREMENT (5) WITHIN GROUPS OF 100U_1 & 101U_2. THE NUMBER OF THESE GROUPS IS DEDUCED FROM THE KNOWN APPROXIMATE DISTANCE.

25 (100) U_1 =	18730·8631	25 (101) U_2 =	18731·5525
5 U_1 =	37·4617	5 U_2 =	37·0922
ΔU_1 =	6·7777	ΔU_2 =	6·4495
	18775·1025		18775·0942



SPECIMEN OF FIELD BOOK SHOWING OBSERVATIONS AND COMPUTATIONS

FIGURE 11



PRESSURE CORRECTION NOMOGRAM RELATIVE HUMIDITY AND TEMPERATURE CORRECTION GRAPHS

The mean of the reflector readings is obtained and the corresponding length on the light conductor is interpolated.

The measurements are then repeated on one or two more frequencies.

Tables would have been prepared in advance showing the number of measuring units against the difference between frequency readings and with the aid of these tables the distance as measured by the instrument is deduced.

Graphs are available for interpolation of atmospheric corrections. These corrections together with the index correction, eccentricity corrections and, if necessary, corrections for focus adjustment are applied to the instrument measurement to give the final line of sight distance between the end marks.

It is desirable to repeat this procedure at least four times to complete a night's observations.

PRACTICAL EXPERIENCE WITH THE EQUIPMENT.

Operational use of the equipment commenced in August, 1954, and in the ensuing 2 years, 44 line measurements have been made over distances varying from 1 to 19 miles and situated in the south-east quadrant of Australia. However, during this period quite a lot of experimental and developmental work has been carried out.

In the last two months of this period a straight operational project was undertaken involving a trip of 3,600 miles from Melbourne to Oodnadatta, Eyre Peninsula and back to Melbourne, during the course of which 9 measurements were made.

Experience has shown that under good operating conditions the equipment can be set up and four pairs of measurements made (using two frequencies), within a period of 3 hours. In very adverse weather conditions several nights may be required to get four pairs of readings.

Difficulty was experienced when using the plane mirror type of reflector, but the spherical mirror type of reflector has proved very satisfactory over distances of up to 17 miles long.

When bright moonlight or light from other sources is shining in the general direction reflector to Geodimeter, measurement is not practicable over long lines.

Alignment is very difficult when operating with the reflector on a tower due to the operator at that end being unable to move around and locate the light beam as a preliminary to finally guiding the beam on to the reflector. Re-alignment is necessary when slow changes of refraction are encountered and rapid changes make satisfactory alignment impossible.

Results obtained indicate that distances can be measured with an error not greater than $\pm .06+$ (distance $\times 1/10^6$) feet on one night but, that although a series of measurements can usually be made on the one night with extreme consistency, there may occasionally be a decided jump if the line is measured again on a different night. This is possibly due to accidental weather and/or instrumental vagaries. The above formula seems wide enough to cover these odd jumps and in general it will be found that the error of the mean of two night's measurements is not greater than $\pm .03\pm$ (distance $\times 1/10^6$) feet*.

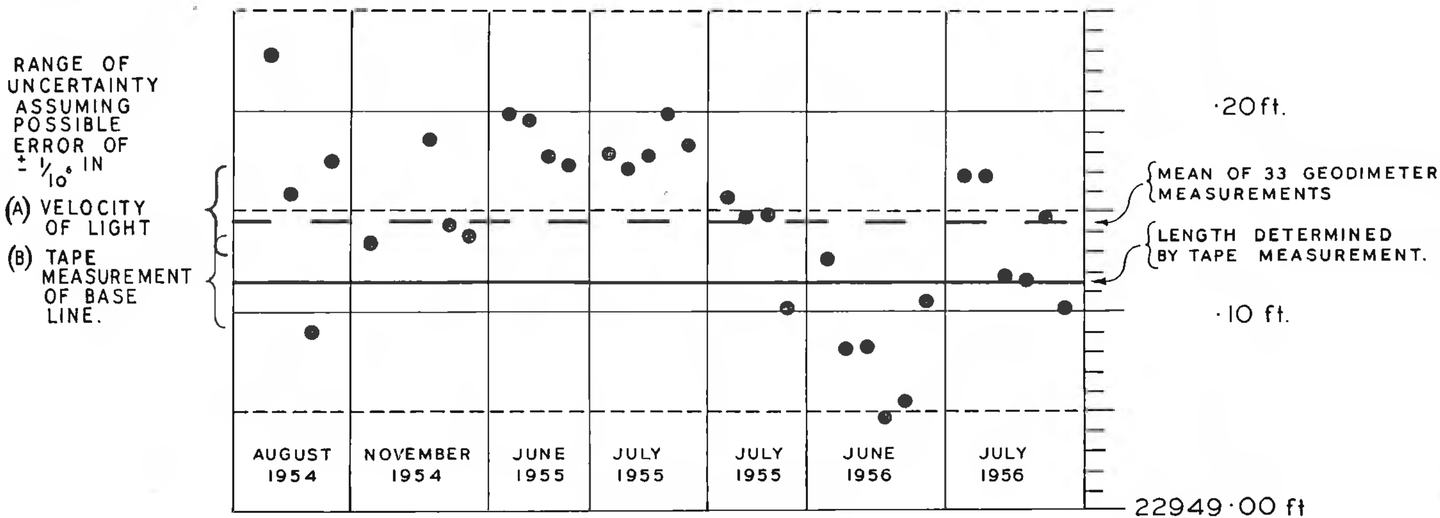
*A. G. A. has now developed a slight modification of the equipment which is expected to eliminate most of the instrumental error.

FIGURE 12

CARRIETON BASE LINE

GRAPHICAL PRESENTATION OF GEODIMETER MEASUREMENTS

(V = 299 793·1 KM/ SEC.)



In the two years of actual experience the operators have acquired an intimate practical knowledge of the equipment and its operation. On the basis of this experience it has been found possible to train surveyors to the stage of making measurements after one month's instruction. For a start, a surveyor so trained would need to be able to contact the more experienced operators when knotty problems arise but after six months' practical experience he should be fully self reliant.

Likely Uses of The Equipment.

The sides of a main triangulation scheme can be measured directly with an accuracy greater than that usually obtained at the end of a normal base net expansion and extra base lines can be readily included in a triangulation scheme. Adoption of these procedures has already increased the accuracy of triangulation survey.

No local experience of traversing with the equipment has as yet been obtained but it is anticipated that a satisfactory and speedy technique will be evolved.

The availability of the Geodimeter permits greater flexibility in the planning and execution of horizontal control surveys. Where frequent bases are practical, chains of single triangles can be used and in difficult areas, single point connections or sections of transverse can be introduced.

The Geodimeter has a particular application in control surveys over city areas or large engineering projects where numerous long lines can be measured several times to provide the basis of an extremely accurate survey.

Conclusions.

The large model Geodimeter is capable of measuring distances between intervisible points, from 5 to 20 miles apart, with extreme accuracy.

The bulk and weight of the Geodimeter and its necessary auxiliary equipment are to a certain extent disadvantageous to its full employment. However, this disadvantage must be fairly considered in relation to the alternative methods of measuring and in any case can be largely overcome by intelligent planning.

In the light of local experience it must be concluded that the large Geodimeter is a proven survey instrument capable of greatly facilitating and expediting primary control surveys.

APPENDIX A.

Statistics.

Power Requirement—

220-230 Volts. 50-60 Cycles.

Power Consumption—

Heating only 37 Watts.
Measuring, 140 Watts.

Weights and Dimensions—

Measuring unit—108 lbs. and 35 × 17 × 14 inches.
Optical unit —113 lbs. and 34 × 18 × 21 inches.

APPENDIX B.

Auxiliary Equipment.

Portable petrol driven generator.
" Stabilac ".
2 Portable radio transceivers.
Theodolite.
Calculating machine.
2 Sets of barometers.
2 Thermometers.
2 Hygrometers.
Special metal table to support Geodimeter.
Signal lamp.
Heliograph.
Tape, plumb bobs, etc.
Tents, camp table and chairs.
Panel van type motor vehicle.
Land Rover type motor vehicle.

APPENDIX C.

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