69/84 (3)

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COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record No. 1969 / 84

054142

Macquarie Island Geophysical Observatory, Annual Report 1965

by

R.G. Sutton

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS DEPARTMENT OF NATIONAL DEVELOPMENT AUSTRALIA

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ILLUSTRATIONS

1. INTRODUCTION

Magnetic observations were first made at Macquarie Island by Webb in 1911. The Bureau of Mineral Resources (BMR) commenced continuous magnetic recording in 1951. The first seismographs were installed in 1950, also by BMR.

A short-period three-component Benioff seismograph system was installed at the beginning of 1961 (Milne, 1962). The two horizontal seismometers were removed at the end of 1963 and a single BMR recorder was installed for operation with the remaining vertical seismometer.

During the December 1962 staff changeover the insensitive La Cour magnetograph was converted to normal-run, medium-sensitivity operation and a La Cour rapid-run magnetograph was installed. Gregson (1965) describes the magnetographs, which each record H, D, and Z components.

The author was in charge of the observatory between 12 December 1964 and 15 December 1965. He received on-the-spot training from P.M. McGregor until 18 March, when Mr. McGregor returned to Australia.

2. BUILDINGS AND SERVICES

Buildings

The office-darkroom. This is tied to the concrete sectioned seismic vault by a steel hawser. The office is more exposed to wind than the vault and consequently water leaks develop between the two buildings. The liberal application of a roofing compound temporarily corrected the trouble.

A bucket was used to collect water which dripped from the interior of the roof. It is suggested that the extension of the vault roof into Wireless Hill be removed to prevent seepage. Some form of flashing could be provided between the vault and the office-darkroom or one continuous roof constructed to cover both buildings. Some galvanised iron on the storeroom (leeward against the vault) needs replacing.

The exteriors of these buildings were painted and a fire extinguisher box was constructed.

Variometer and Absolute Huts. Both are constructed of panels of 2½" thick 'onozote' (black insulating compound) sandwiched between plywood. The timber frames are brass bolted.

With the aid of a blow lamp and steel scraper the old paint was removed from the eighteen external panels of the huts. In places the plywood panels were wet and the paint just peeled off, but generally only two panels could be scraped clean in a day. Unfortunately, many magnetograms were spoilt by the magnetic effect of the scraper. However, the magnetograms were not disturbed when a plastic pot and copper banded brush were used for painting. Times for scraping and painting were limited by the weather.

The interior of the absolute hut was painted for the first time, for appearance's sake only.

Dry rot was found in the variometer hut north-east corner post and the floor beam below. Several boards retaining the wall panels were similarly affected and were replaced. Most of the rotted timber was removed and creosote was liberally applied.

Both huts were guyed to railway sleepers covered by rocks. At the same time sand was dug clear of the variometer hut. The gaps between the instrument piers and the flooring were then light-proofed using foam rubber and plywood.

3" x 1½" oregon battens were fastened to both roofs and covered by corrugated "Vinlon" P.V.C. sheeting. Unfortunately some of the stainless steel screws sent to fasten the sheeting were magnetic but enough non-magnetic screws were found. The ridges and barges were capped with plastic angles. Mr. McGregor proposed that the walls of the two magnetic huts be covered with P.V.C. sheeting. This would provide improved protection and eliminate painting. The author feels that time spent on interior painting would be better spent maintaining such things as seals around window panes to prevent water running directly into the plywood. Maintenance and painting activity disrupted regular absolute observations.

Although the observatory buildings are old there is plenty of life left in them. The office is small, but certainly cosy.

External shelters. A new BMZ shelter was made to avoid disassembling the instrument when it is taken outside the hut during H and D absolute observations.

A shelter was attached to the absolute hut to hold the proton precession magnetometer (PPM) and its accumulators during intercomparisons. Nearby a PPM station was made in the form of an earthenware pipe set in concrete.

The carpenter constructed a new non-magnetic battery box to house accumulators and charger, standby vibrator supply, and associated switching and protection circuits. Unfortunately there was not time to install this.

Water supply

At times the water stopped flowing from the settling tank through the hose into the storage tank. To restore flow it was found that, besides blowing water quickly through the hose to remove moss etc., the hose needed a continuous fall till just before the storage tank; here it is necessary to have a depression that is always full of water.

Electric power for room heating

At the beginning of the year the total heating load was a continuous 2 kW, comprising 750W for the office, and 1 x 750W plus 1 x 500W for the vault. Later, power was often limited, so the 750W heater was removed from the vault, the 500W was relocated, and the 750W heater in the office was returned to thermostatic control (65-70°F). Because of repeated power failures, provision of standby power supplies for synchronous recorder motors was recommended.

There is no heating in the magnetic huts.

3. SEISMIC OBSERVATORY

Seismograph instrument and operations

The only instrument comprised a short-period vertical Benioff seismometer (free period 1.0 sec), control box, short-period (0.2 sec) galvanometer, and a single-channel BMR recorder operating at 30 mm/minute. Time-marks were recorded every minute from a Mercer chronometer which was checked daily against radio time signals. Minute marks were four seconds' duration, beginning at the fifty-sixth second. Hour marks commenced about 20 seconds before the hour and were about 20 seconds long. The synchronous motor driving the recorder stopped once from lack of lubrication and from the accumulation of worn gear material. A worn bearing was filled with solder and redrilled; after cleaning, lubricating and reassembling it ran a little quieter. Unfortunately the unidirectional mechanism was made ineffective, and after power breaks the motor ran backwards and spoilt the record. This defect was successfully overcome, and a spare motor was ordered.

In May the Officer-in-Charge requested that the seismic control panel be moved into the vault in readiness for the removal of the office and darkroom, which were to be replaced by a new building during the December 1965 changeover. It was subsequently learnt that the project had been postponed, and the control panel was returned to the office so that further detectable record losses could be minimised. The temporary wiring was left intact.

The trace intensity seriously decreased once because the lamp wires were disturbed. The rather loosely-fitting lampholder was adjusted and the intensity returned to normal.

The rim at one end of the recorder drum rests on two cylindrical rollers, one of which provides the rotational drive. At the other end a screw thread, axial with the recording drum, provides support and causes the drum to move axially as it rotates. Several times towards the end of the year the screw jumped a thread and caused overlapping traces. The relative axial position of the two vee-shaped rollers supporting the screw was adjusted and the fault occurred less frequently. The design of the carrier of the roller axles is at fault - the rollers should run in line with the thread and not be continuously inclined to it.

Recording lamp. Power for the photographic recorder lamp was supplied from two 6-volt accumulators in parallel with a battery charger. A decrease of 20 mA in the steady lamp current (580 mA) significantly lowers the trace intensity. This occurs when the 240-V a.c. power fails and the accumulators discharge. Now (1966) that a standby inverter can supply the recorder drive-motor during power failures, a voltage regulator will be required for the lamp.

Time control. The Mercer chronometer 19090 operated satisfactorily. It was checked daily against the radio time signal VNG. The daily rate was variable and erratic but was generally 0.1 to 1.0 sec. The chronometer was observed to slow down till 22 hours after winding, and then to speed up, attaining the same correction after about 33 hours as at zero hours. Normally the chronometer was wound daily.

The circuit supplying time marks from the chronometer was rewired roughly to eliminate unnecessary magnetic relays. A detectable amount of relay release time was removed, giving better timing. Plate 5 shows the new circuit.

Variation in power frequency certainly resulted in timing errors up to 0.7 seconds on the seismograms, and assumptions of clock rate linearity in another 0.2 seconds. There was possibly a constant error due to uncertainty of operation of the chronometer contact relative to the ticks. Maximum scaling errors should only be 0.1 seconds. Provision of a tuning-fork type chronometer and a constant-frequency supply to drive the recorder motor would greatly improve the timing.

Calibrations

System tests. In January 1965 the galvanometer free period, sensitivity, and damping were measured, and the damping was adjusted by modifying the control box circuit. The galvanometer free period was 0.21 seconds, its internal resistance 20 ohms, and its sensitivity 6.9×10^{-8} amps/mm at the recording distance (about 50 cm); these are consistent with the manufacturer's data. The seismometer free period and system damping were also measured and were found to need adjustment. The final adjustment of the system damping and the determination of the system magnification were delayed until October because bad weather produced a high level of seismic noise.

The system magnification at 1 Hz is given by the formula:

$$\text{Magnification} = 800\ X_{1m}/m$$

where X_{1m} mm is the amplitude of the first motion on the seismogram when a weight of m grams is impulsively lifted off the seismometer mass. The following conditions are necessary:

(i) The seismometer free period is 1.00 ± 0.02 sec;
(ii) The galvanometer is short-period (0.2 sec. in this case);
(iii) The galvanometer is critically damped; and
(iv) The system damping ratio (d) is 17:1, where d is the ratio of the amplitudes of successive swings recorded by the galvonometer ($d = X_1/X_2 = X_2/X_3 = \ldots$)

In 1963 Gregson achieved an overall system damping ratio of 4.2:1. Lodwick in 1964 achieved the correct ratio but wrongly assumed that the galvanometer was correctly damped when its damping rheostat was in the same position as that of the seismometer. In both cases, the relation (Mag = 800 X_{1m}/m) was not applicable.

Before any adjustments were made, the author measured the system damping ratio (d) as 5.6:1 whereas Lodwick obtained 17:1. The cause of the discrepancy is unknown.

The damping coefficient (h) of any second-order linear system (a galvanometer is such) is given by: $h = \log_{10}d/(1.862 + (\log_{10}d)^2)^{\frac{1}{2}}$.

The galvanometer was found to be overdamped (h greater than 1) for all positions of its damping rheostat (Gd; see Plate 2). The insertion of 56 ohms' resistance in one of the galvanometer leads gave control of the damping coefficient from 0.6 to greater than 1.

The current for deflecting the galvanometer was supplied to the control box through the test plug by a $1\frac{1}{2}$-volt cell in series with up to 1 megohm. It is always desirable to have $\frac{1}{4}$ megohm in circuit to guard against overloading the galvanometer. Gd was adjusted to make h = 0.7 (or d = 24). At the time it was understood that this was called critical damping within BMR. Plate 3 shows the theoretical change in the amplitude-period response of the galvanometer with change of damping coefficient.

In January 1965, the seismometer free period was measured as 1.03 seconds. Weight lift tests were made with the seismometer damping rheostat Sd in position 10 (as found) and the galvanometer damping rheostat in position 7 (for critical damping). These tests showed the system to be underdamped with damping ratio varying from 4.1 to 6.0 depending upon the control-box attenuator setting. The spread may have been caused by variation of control-box impedance with changing attenuator setting. Column a of Table 1 gives the resulting values of 800 X_{1m}/m.

The seismograph remained in this condition until mid-September when the mass was lowered by the capstan screw to equalise the transducer air gaps. The seismometer free period was adjusted to 1.01 seconds. Only one-fifth of the angular range of the damping rheostat was useful so the 300-ohm rheostat was replaced by one of 100 ohms. Repeated weight lift tests with varying positions of Sd showed that position 6 gave the desired damping ratio (d = 17). However, when Sd was set at 6, d measured 20. This inconsistent positioning of Sd could only be attributed to a slack spindle connexion. Because of wind noise on the seismograms the final adjustment giving d = 17 was not made until mid-October. The adopted spindle position was approached by a clockwise movement. Column b of Table 2 and Plate 4 show the system magnification in mid-October.

During the September tests it was discovered that the seismometer mass jams against the lower stop when pushed down by hand, because of the combined effect of its weight and a net downward magnetic force when the air gaps are grossly unequal. It is wise therefore to check the seismograph after tremors which are felt, to ensure that the mass has not jammed.

Response curves. The seismograph consists of two lcosely coupled oscillatory systems with resonant periods of 1.0 and 0.2 seconds. From normalised curves of amplitude response versus period for a second-order system it can be seen that variations in galvonometer damping have negligible effect on the seismometer response (and hence the system response) about the free period of the seismometer. The two free periods differ by over two octaves. The response curve of the seismograph to ground displacements is therefore dependent mainly on galvanometer response for periods less than 0.2 seconds, on the seismometer response for periods greater than 1 second, and a composite in between. Plate 3 shows the theoretical response at the end of 1965. The improvement of the response in the 0.2 to 0.4 second region may have contributed to the recording of T phases.

Analyses

Seismic phases recorded. Notation:

Epicentral distance	0.9^{o}	: local
	0.9^{o} to 9.0^{o}	: near-local
	9.0^{o}	: teleseism
	9.0^{o}	: regional, being local and near-local

Sixty-one teleseisms and 499 regional shocks were recorded between 12 December 1964 and 15 December 1965. These are classified in Table 2. The majority of the regional shocks occurred after the near-local shock of August 02d 13h 19m 55s of magnitude 6.7 (USCGS). At the station the Modified Mercalli Intensity was estimated as VI. Seventeen of the regional shocks were recorded by the Tasmanian University Network.

Two other local tremors were felt, having intensities II and III. Most of the teleseisms recorded occurred in the band of islands extending from the Philippines and Celebes through New Guinea to the Fiji Islands, Samoan Islands, and New Zealand. Oceanic channel T phases were recorded from three Chilean shocks and eight other nearer shocks. The velocity derived from their travel-times closely agreed with that found by Cooke (1967). This agreement is illustrated in Plate 11.

Distant recording of regional shocks. The problem has existed of not knowing which of the regional shocks recorded at Macquarie Island would be likely to be recorded at other stations. Often P-phases were uselessly reported to BUROMIN MELBOURNE. Later (1966) the Macquarie Island seismic log was compared with bulletins from stations up to twenty-five degrees distant. Toolangi and stations of the University of Tasmania Network were the only ones to report the weaker Macquarie Island regional shocks.

Assuming that waves of regional shocks reach Macquarie Island without frictional attenuation, the expression A(S - P) should give a measure of the amplitude of ground motion near the focus

where A = peak-to-peak P-phase trace amplitude in microns, divided by magnification at 1 Hz.

S - P = time difference between S and P phases in seconds.

Values of A(S - P) for many shocks were tabulated with indicators showing recording or non-recording at other stations. Sometimes the value of A(S - P) for regional shocks recorded only at Macquarie Island significantly exceeded the value for more distant shocks which were recorded elsewhere. This suggested that the amplitude of ground motion varies inversely with distance at a higher power than unity.

The statistic $A(S - P)^2$ was found to distinguish more clearly between shocks recorded only at Macquarie Island and those recorded also at other stations. Shocks with $A(S - P)^2$ less than 300 were not recorded elsewhere. Using $A(S - P)^3$, the distinction was again less sharp.

S-phases are not recorded on the vertical component seismograph where epicentral distances exceed four degrees. The P-phase period is difficult to determine, but it is usually about 0.4 seconds. The criterion, $A(S - P)^2$ less than 300 takes no account of the change in system response with period.

<u>Magnitude determinations</u>. The seven teleseismic P-phases recorded after the final adjustments in October were investigated. The magnitude (m) of a shock as defined by Gutenberg and Richter (1956) is given by:

$$m = \log A/T + Q + B$$

Where A = semi peak-to-peak P-phase amplitude in microns
T = P-phase period in seconds
Q = depth-distance factor
B = station correction (a constant).

Using USCGS magnitude values, B was determined as -0.4, the maximum deviation being 0.5. Further data will provide a more significant value of B. This may permit estimation of local-shock magnitudes.

4. MAGNETIC OBSERVATORY

Two La Cour type magnetographs were in operation in 1965, one normal-run, medium-sensitivity recording at 14 mm/hour, and one high-sensitivity rapid-run at 180 mm/hour. Table 3 gives the scale values of each variometer. These were measured weekly in the case of the normal-run H and Z variometers and monthly in the case of the three rapid-run variometers. A Helmholtz-Gaugain coil could not be left on the normal-run D variometer as it masked part of the H trace. The normal-run D scale value was measured at the times of variometer magnet orientation tests. Control of the normal-run magnetograph baseline values was kept by weekly observations of H, D, and Z using semi-absolute instruments.

Normal-run magnetograph

Operations and adjustments. The variometers and recorder operated well throughout the year.

During March, April, and early May the magnetograph was altered in an attempt to improve the magnetogram traces.

By following notes of previous observers, relative spot intensities and spot quality were improved. Spots were viewed on the ground glass screen fitted to the recorder drum cover. Poorly focused spots appeared brighter on the ground glass than they really were. Viewing spots directly on paper has the disadvantage that the background light level is high so that the lamp currents must be increased which increases the chance of damaging the lamp. Multiple images are common and it is difficult to locate their sources.

The intensities of both the D-trace and its baseline were decreased. D-trace intensity further decreased in the August local earthquake but it was decided not to readjust the variometer.

There has always been ghosting of the Z-trace. This probably comes from a combination of internal reflections in the recorder lamp and poor optics within the variometer. There was no improvement when the back of the lamp was covered with green sticky tape. Rotating the lamp and lamp holder gave ghost images of H and D and no noticeable improvement in Z (see the magnetogram of 25 March). Lamps with a broad filament supporting post might lessen this problem. The post would absorb back radiated light. Alternatively, a separate lamp could be installed for the Z variometer, but its installation could present structural difficulties.

The Z-baseline mirror was found mounted on the recorder side of its holder. When fixed in what appeared to be the intended position, the compensator prism assembly masked the baseline spot. The mirror was returned to its original position and, after partially masking it with tape, a good spot was obtained.

After adjustments the Z trace was too strong, so the cylindrical lens in front of the recorder was reduced in aperture at the mean recording spot ordinate.

The mean H ordinate was increased from 12 mm to 20 mm to keep the ordinate positive for everything but a large storm. The H trace had the weakest spot so this should be kept in mind when making future adjustments of the variometer spot intensities. The H baseline was sharp when the mirror was partially masked with tape.

An attempt was made to locate the H temperature trace, and although the temperature time-marks fell on the H section of the magnetogram, it was thought that the main trace was on the D section and therefore not recording. Tape was applied to the H variometer spherical lens to remove an unknown trace which appeared after the March adjustments and which was subsequently (1966) discovered to be the H temperature trace.

Because record losses and baseline changes are usually associated with magnetograph adjustments, the benefit of further adjustments (with the exception of intensifying the D-trace) may be marginal.

The Meteorological clockwork drive installed by Lodwick in 1964 operated without failure. The possible general use of such drives is being investigated.

Temperature compensation. The H thermograph scale value was determined as $5\frac{1}{4}$°C/mm from the time-marks. These time-marks were used for temperature control at the end of April when the Z thermograph trace was missing.

The H variometer temperature coefficient was adopted as 1.8 gammas/°C (under-compensated). Computed values ranged from 1.1 to 2.3 gammas/°C. If the effective length of the bimetallic strip carrying the compensating prism were increased by 50% the compensation would be close to optimum.

The Z variometer was also undercompensated, having a coefficient of 0.9 gammas/°C. As with H, the baseline value numerically increased with temperature. The Z thermograph scale value was 1.55°C/mm, and the variometer's uncompensated coefficient 14 gamma/°C; the present compensation is therefore satisfactory.

Magnet orientations. The ex-orientation angles of the H and D variometer magnets were determined by applying known fields parallel to the desired magnet orientation using the Helmholtz-Gaugain scale-value coils. The geometric accuracy of these coils was assumed and their desired orientation was achieved by lining up a metre rule, placed on the coils, with a taut string of known direction. The string was stretched between slotted perspex strips mounted on the hut walls. Total reversal fields of 1500 gammas were achieved using alternate positive and negative coil currents of 100 mA.

A magnet of moment 7550 c.g.s. units was used for the Z orientation test. It was supported by a newly mounted bracket on the porch wall (see the lower diagram of Plate 7). The height of the bracket was determined using a Cowley level. The orientation magnet had an end-on configuration with the Z-variometer magnet, and the centre-to-centre distance was 117.1 cm. Reversing the magnet gave a field reversal of 1780 gammas at the variometer magnet. Using the orientation magnet in this position obviated carrying it past the other variometers.

Observed ex-orientation angles must be corrected to the mean monthly (or some other reference) field. The H observation must be corrected for D as well as H. The effect of variometer magnet temperature on orientation was small, being 0.007 degrees of arc/°C for H and 0.01 degrees of arc/°C for Z.

Details of procedures are given in McComb (1952) and type-written notes left at Macquarie Island. Table 4 summarises the results of the orientation tests for the normal-run magnetograph.

Magnetogram parallax. There was no detectable time difference between the Z and D traces and their respective time-marks. The true time of a point on the H trace was the time as scaled from its time-marks less 0.4 minute (0.1 mm). Gregson (1965, Table 2) has apparently listed the corrections to the baseline time-marks rather than to the trace time-marks.

Absolute instruments

Askania declinometer 640505 replaced declinometer DCK 158 in 1965. The two were intercompared through baselines in January, and the DCK was returned to Australia in March. When the Askania telescope was focused on the distant mark so that there was no parallax, there was detectable parallax with the magnet image. Levelling was often erratic and later in the year the fibre clamp did not give clean releases, but in general the instrument was pleasing to use.

A new northern mark was adopted in 1965 because fog or glistening water often made the Anchor Rock mark unusable. All marks were sketched and checked for azimuthal differences. The intercomparison Station C was found in the sand at 26.7 ft on bearing 100.6° (true) from pier East. Unfortunately the reference station of Bunbury's 1949 survey was bulldozed out of position in 1965.

QHMs 177 and 178 gave satisfactory results. Each had an adaptor for mounting on the Askania glass circle. QHM 177's thermometer was difficult to read and QHM 178 had a sticking clamp. It was more convenient to use the QHM telescope than the Askania.

BMZ 64 operated well. Its neutral division was variable even when the telescope was not disturbed. No correlation was found between changes in the neutral division and baseline values.

Observations were made in the order Z, Z, D, 177, 178, D. The main problems of observing in the winter were the shorter daylight period and fogging the telescopes with breath.

Baseline values. Plate 1 shows the relative occurrence of differences between the weekly pairs of observations of each element. The samples are fairly large (approximately 60) and the histograms show a tendancy to normal distribution.

The differences between pairs of observations of a normal population with mean u and variance s^2 is another normal distribution with mean zero and variance $2s^2$. Further, the distributions of the means of two observations of a $N(U,s^2)$ population is $N(u,s^2/2)$.

The histograms are approximated by the $N(0, 2s^2)$ distribution. The histogram means are $(1/n)\ f_i x_i$ and the variance estimates

$$s^2 = \frac{1}{n-1} \sum f_i {x_i}^2 - (1/12)^2 - \left(\frac{1}{n} \sum f_i x_i\right)^2 \simeq 2s^2$$

The low histogram means of Z and D indicate that the conditions have not changed between observations of a pair. With H it further indicates that the difference between the two adopted instrument corrections is most probably correct.

The standard deviations $p/\sqrt{2}$ of the weekly means of pairs of observations are H:0.8 gammas; Z:1.1 gammas; D:0.1'. For a normally distributed population (the means in this case) 95% of values lie within 1.96 standard deviations of the mean.

Therefore, with 95% confidence, the mean of two H baseline values will lie within 2 gammas of the mean, Z within $2\frac{1}{2}$ gammas, and D within 0.25'. This only takes account of random observational errors, scale value errors, and scaling errors. It takes no account of mistakes such as having magnetic material close to the instruments. H and Z have additional errors proportional to the divergence from 5°C of variometer temperature at the time of the observations. This may contribute up to 2 gammas' error, but the effect is absorbed in the baseline adoption if observations over a period have similar variometer temperatures. Accurate determinations of the temperature coefficients would reduce this error.

The scatter of observations decreased to a constant level after three months. In view of the foregoing and the 1965 baseline plots it seems that weekly absolute observations are all that are necessary, once the observer's consistency has been established.

Rapid-run magnetograph

Adjustments. The uniformity of spot arrays was improved by fitting new long plane mirrors and cleaning the prisms of the array with "Calotherm". Tilting these long mirrors altered the amount of light falling on the variometers. Turning them altered the spot positions on the recording drum only slightly; however, this does displace the whole array laterally.

One problem was the relative positioning of traces and their corresponding time-marks. No differences would exist if the time-mark mirrors were centred on the reflected trace beams from the variometers (a height displacement gives parallax whilst horizontal displacement gives an ordinate shift on the magnetogram). The sledge masks reduce the length of some time-marks so that they do not occupy the full space on the magnetograms. The time-mark mirrors were approximately level with the variometer lenses. They were moved as close as possible towards the lens centres without masking traces or producing fixed images. No further adjustments should be necessary.

On two occasions excessive recorder lamp current caused the spring which holds the lamp filament straight to lose tension, with resultant blurred images. The first replacement lamp was mounted low so that half of the filament was masked by the lamp holder. The second replacement lamp was mounted high with its point nearly touching the top cover. The current was significantly reduced.

The Z-traces had been blurred. The variometer was moved 10 cm towards the recorder but no improvement was detected. The Z and H spherical lenses were interchanged, again with no effect. Significant improvement was later obtained from refocusing the cylindrical lens on the sledge. The Z array at the recording drum sweeps diagonally, being lower at the motor end. This is because the rotation axis of the variometer magnet is not perpendicular to the recorder axis.

On two occasions after there had been strong horizontal fields near the Z-variometer magnet, the magnetograms indicated that the magnet was sticking. The assembly was removed. Both of the magnet-bearing knife edges were burred and the eastern agate block was chipped in two places. The assembly was then replaced. By trial and error the magnet was set on its lifter (clamp) so that, when lowered, the knife edges were on smooth agate.

Previously it had been noted that the variometer's scale-value increased with time. However, each time the magnet was lifted clear of the agates and then replaced, the scale value instantaneously decreased.

Thus there is something which increases bearing resistance with time. Perhaps it is the burred knife edges abrading the agates and the resulting powder causing resistance. Alternatively it could be a biological growth. If the instrument were evacuated, any such growth should be lessened.

Since February 1965, the variometer magnet's south end has been lying about ten to fifteen degrees east of the magnetic meridian. The difference of this azimuth from the perpendicular to the variometer-recorder axis causes the non-horizontal spot array at the recorder.

Dynamic response tests. Copper blocks are used to provide eddy current damping for the rapid-run variometers. The response of each variometer is the solution of a second-order differential equation with constant coefficients. This assumes that any damping is porportional to the square of the angular velocity of the variometer magnet. The steady-state frequency response of a second-order system is represented by a family of curves of amplitude versus frequency for various damping coefficients.

Two methods were used to determine the frequency responses of the variometers. In the first, step function fields were applied using the scale-value coils. The resulting waveforms were analysed to get the theoretical responses. This test could not be used with the Z-variometer because its damping was high. The second method involved producing a sine wave field at each variometer. After some experimenting, a constant-amplitude rotating field was produced by spinning the DCK magnetometer magnet. The magnet of moment 600 c.g.s. units was suspended by a piece of cotton so that it was just above the floor and about two metres from the variometers. A piece of 2/3" diameter hexagonal brazing rod 18" long was attached to the magnet to increase its moment of inertia.

Air damping and thread twisting slowed the magnet's rotation and thus produced sinoidal fields of continuously varying frequency. To record this, it was necessary to quadruple the recorder speed to 12mm/minute, which was done by replacing the normal $\frac{1}{2}$-rev/hour synchronous motor by a 1-rev/hour motor driven from a 100-Hz supply derived from the office radio H.T. supply. The radio was located some thirty feet from the hut to eliminate detectable magnetic disturbance. Unfortunately the motor had to be started manually.

a) H-variometer. The ineffective H damping block was replaced by another. Tests were carried out before and after to determine any change in damping. Recalculation of Gregson's (1965) H-variometer damping test gave the amplification at resonance as 24 and not 12 as indicated in his Plate 3. A rotating field test gave a value of 26. Replacement of the damping block reduced this figure to 18. A value less than unity would be desirable.

b) D-variometer. Gregson's adjustment of the D damping block to stop magnet interference unfortunately reduced the damping and increased the amplification factor from 1.3 to 20 (resonance period 1.8 seconds). He considers that readjusting the block may improve the situation (personal communication).

c) Z-variometer. The damping test by Gregson indicated significant damping (coefficient 0.57). Using this he plotted a theoretical response curve (his Plate 2). The result of the rotating magnet test in 1965 fitted Gregson's curve nicely.

There was close agreement between the two methods used to measure frequency response. One interesting feature of the rotating field tests was the waveform produced when the natural decay of the variometer oscillations was comparable with the rate of frequency change of the forcing field. Plate 6 illustrates this and demonstrates a limitation of this testing method.

<u>Magnet orientations</u>. In February the spot array positions were adjusted for optimum recording during storms. In doing so the variometer magnet orientations were altered. Preparations for testing the Z orientation were in hand when the earthquake of 2 August precipitated the making of adjustments and tests of all three variometers.

The H and D tests were made in the same way as those for the normal-run variometers. There being no existing facility for making the Z magnet tests, it was decided to construct an orientation magnet bench between the two sets of variometers. At first a movable three-legged wooden stand was made whose centre was within twenty centimetres of the variometer centre. The orientation field was produced by an energised relay solenoid mounted on a wooden block. The four magnet positions used normally in these tests were achieved using combinations of physical and current directions.

Unfortunately the results were unacceptable because of the uncertainty of the coil height. With the carpenter's aid a permanent wooden bracket was fixed as shown in Plate 7. This gave the desired accuracy. The magnet support plane was accurately levelled and its height adjusted with the three supporting screws. These were set in candle wax and aquaglue. The support plane was adjusted so that the variometer magnet and the deflector were at the same height within 0.7 mm. To obtain sufficient field (200 gammas reversal) it was necessary to use over sixty volts from dry batteries. A suitable orientation magnet has since been supplied; this may require the bench height to be altered.

Table 5 summarises the orientation results. Relevant results of earlier tests by Gregson (1965) and Lodwick (1967) have been included.

Magnetogram peculiarities. The lack of damping in the H and D variometers enhanced the recording of local earth tremors and some short-period magnetic oscillations (example - 4 November 1965).

Unexplained impulses followed by oscillatory decays appeared with time independence on the rapid-run H and D traces alone (See 4, 6, 7, 15, 17 November 1965). These could not be identified with anything on the normal-run magnetograms or seismic records. Tests in which the hut was deliberately bumped suggested that the seal calves which were about at the time could not have produced the effects observed. The possibility of lightning-generated pulses being the cause is discounted because of the time differences between H and D.

5. MAGNETIC HUTS CIRCUITRY

Description

A battery charger and accumulators in a shelter near the variometer hut provide power for the recorder lamps and time-mark circuits. Each magnetograph has a control panel.

Eight No. 6 Eveready cells (1.5 V each) are used in conjunction with a 'Helipot', substandard milliameter, and switches to energise the normal-run scale-value coils (Plate 8). Similarly, an Eveready D cell (1.5 V) in the rapid-run control panel energises its coils.

The time-mark circuit for the normal-run magnetographs is shown in Plate 9. The La Cour pendulum clock provides short-circuit pulses of duration four seconds ending at the beginning of the following minutes of every hour: 00, 01, 05, 10, 15...50, 55, 59. One set of contacts of the transistor-controlled relay A (activated by these pulses) directly controls the rapid-run time-marks. The other set may be switched to operate the normal-run transistor relay B directly or via the absolute hut. Through separate contacts, relay B controls the normal-run time-mark lamp and relay C. Relay C (in the absolute hut) operates a 240-V 250-watt globe which is viewed from the office for time checks.

For absolutes, relay B is switched via the absolute hut. There, S2 is used to open-circuit the clock pulses (from relay A), leaving the pier switch in circuit. S2 also open-circuits relay C to eliminate its magnetic field. A small lamp mounted above S2 indicates when relay B is operated.

Troubles and action

Until the roof was covered with Vinlon sheeting, water dripped onto the normal-run panel. Early in the year, the normal-run scale-value had given unsteady currents during buildup and when nominally steady. The trouble was localised to the control panel and the relevant wiring was replaced. The existing 'Helipots' were replaced by 1000-ohm 'Helipots'.

The normal-run lamp-current meter switch also caused unsteady current. It was dismantled, thoroughly cleaned, reassembled, and sprayed with silicone. As the switch controls only two currents it is intended to eliminate it and provide a second meter.

Both of the clock contacts and a set of relay contacts had to be burnished because of intermittent functioning.

Modifications

The circuit diagrams were brought up to date and redrawn where necessary (Plates 8, 9, 10).

Previously, the time-pulse relay A was powered by a $4\frac{1}{2}$-volt battery in series with the 6-volt accumulator supply. When the battery deteriorated, the relay winding was replaced by one of 530 ohms, giving operation directly from 6 volts.

The 6-volt lamp in the absolute hut loaded the time check lamp relay C, delaying its release by $\frac{1}{2}$ second. Although this error in clock comparisons is small and constant, the circuit deficiency was considered objectionable, so a diode was ordered for placement in series with the 6-volt lamp.

Two modifications were made to the rapid-run lamp circuits. Initially the recorder lamp rheostat was replaced by another to give finer current adjustment. In view of the trouble with slack lamp filaments, the wiring was further altered so that, when the lamp control switch was in the parallax position, ballast currents flowed in both recorder and time-mark lamps. Simultaneously the time-mark pulses were disconnected. The parallax position was used during record changing, the off position being reserved for circuit testing etc. This alteration involved reverting to the original value for the recorder-lamp rheostat.

The daily sense test for the rapid-run magnetograms was reintroduced. Each variometer is pulsed in the direction of numerically increasing field, using the scale-value coils. However, lack of damping in H and D gave dirty pulses, so the scale-value circuit was used instead.

6. OTHER ACTIVITIES

During the 1964-65 summer a programme was recommenced to investigate wave motion and tides. On 18 March the author assumed responsibility for changing and scaling tide gauge records for Dr Brook of the University of Adelaide. Mr. J. George was to maintain the Both pattern recorders. Besides the agreed duties the author made recorder modifications, transferred levels, relocated the sensing tubes in scaffolding tube (for portection) and recalibrated the instrument. Over ninety hours were spent on this project during April and May. Lack of time prohibited much more than record changing and recorder maintenance later in the year. A comprehensive report has been forwarded to the University.

Using the Watts theodolite, a sun observation for azimuth was made from the sunshine recorder on Wireless Hill. The landform above the horizon was mapped in azimuth and elevation. This information was required by the Bureau of Meteorology.

The station map was brough up to date.

The author gave assistance in the power house and physics laboratory as time permitted.

7. ACKNOWLEDGEMENTS

The programme was carried out with the co-operation of the Australian National Antarctic Research Expedition, which was responsible for the accommodation and logistical operations at the Station.

During the year, valuable assistance was rendered by J. Smith (Electrical Fitter) and D.J. Hasick (Physicist) with instrument tests and adjustments. P. Ormay (Carpenter) and others did good work on the buildings. J.R. Dart (Technical Officer - Biology) ably carried on the daily routines during the author's absence from the station on a six-day field trip. C.A. van der Waal at the BMR Melbourne office maintained close co-operation through telegrams.

Finally, thanks must be extended to P.M. McGregor whose guidance and companionship during the first three months undoubtedly contributed to a successful year's work.

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McCOMB, H.E.	1952	Magnetic observatory manual. USCGS Spec. Publ. 283.
MILNE, J.P.	1962	Macquarie Island geophysical observatory work, 1961. Bur. Min. Resour. Aust. Rec. 1962/151 (unpubl.).

TABLE 1

Seismograph Calibrations

Attenuation dB	Magnification (1Hz) (a)	(b)	Mass m grams
18	10750	12800	2
20	9400	10240	2
22	6800	7960	5
24	5100	6330	5
26	4000	5030	5
28	3400	3945	10
30		3160	10
32		2540	10
34		1950	10

(a) From 1965 January 19 to 1965 September 17.

Gd position 7, Sd position 10.

Note: system underdamped and values (800 X_{1m}/m) are not true magnifications - see text.

(b) From 1965 October 15.

Gd position 6.9, Sd position 6.7.

TABLE 2

Seismic Phases Recorded

1964	Local (S-P) ≤ 14 sec	Local (S-P) 14-23 sec	Near-local	Teleseism
December 12-31	9	0	0	3
1965				
January	7	0	1	5
February	12	0	1	5
March	6	0	1	8
April	1	3	0	3
May	7	0	1	9
June	10	3	0	3
July	6	2	0	5
August	21	263	3	8
September	13	34	0	3
October	15	35	2	0
November	9	23	0	4
December	3	8	0	4
TOTAL:	119	371	9	61

TABLE 3

La Cour Magnetograph Nominal Scale Values

Component	Normal-run	Rapid-run	Unit
H	25	5.4	gammas/mm
D	2.3	1.0	minutes/mm
Z	21	5.6 to 8.9	gammas/mm

TABLE 4

Normal-run Magnet Orientations

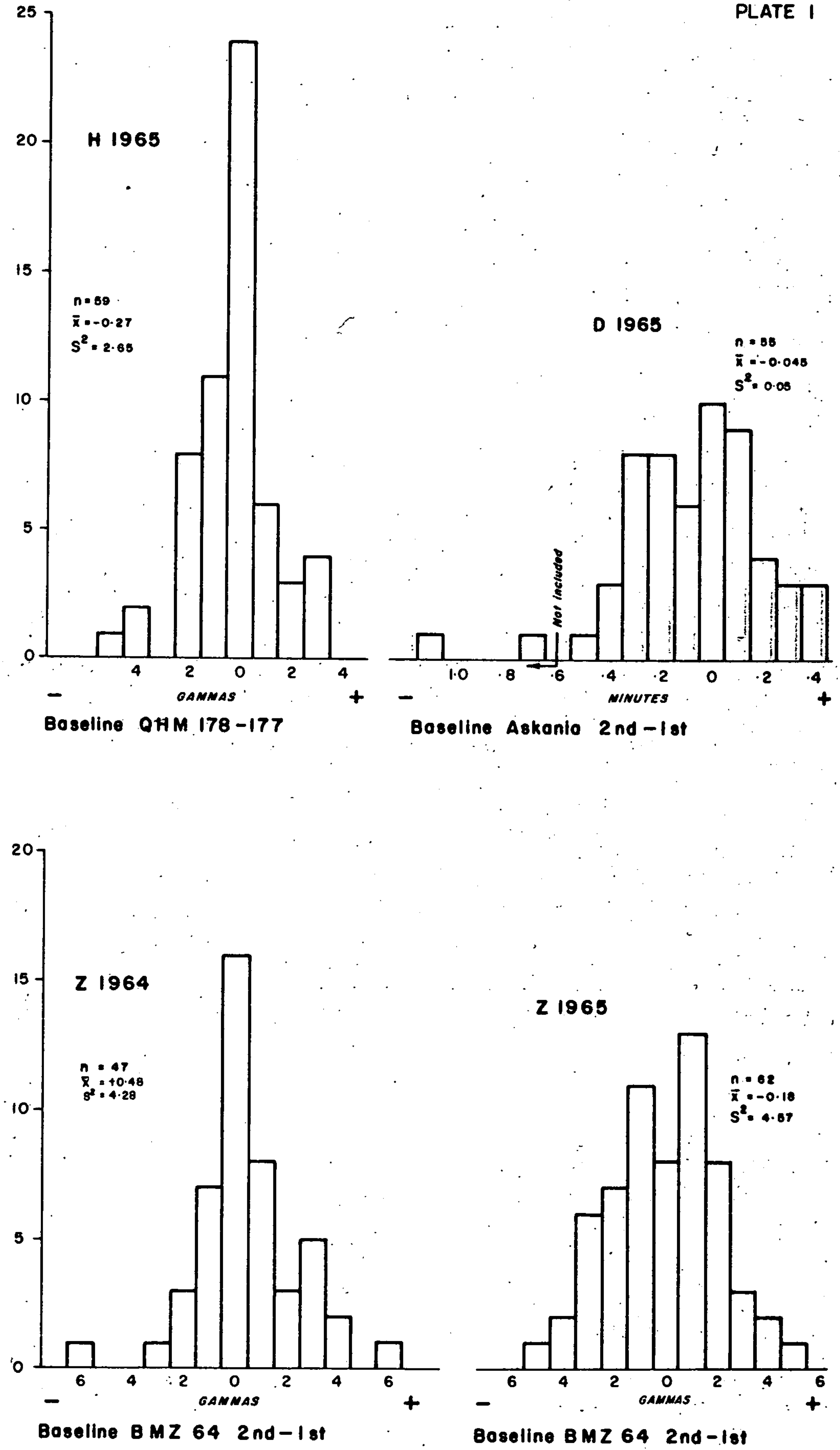
Date	Component	Mean field (and meridian)	Magnet N pole	Remarks
March 16	Z	64227	N 0.2° down	
	H	13160 (26.45°E)	E 1.0° N	Agrees with 1965 result
March 17	H	13160 (26.45°E)	(i) E 1.9° N	Head adjusted wrong direction
			(ii) E 0.6° S	
August 7	H	13146 (26.5°E)	E 0.4° S	Earthquake of 2 Aug may have moved magnet in holder
March 16	D	26.45°E	N 0.5° W	
August 3	D	26.5°E	N 0.3° W	

TABLE 5

Rapid-run Magnet Orientations

Date	Component	Mean field (and meridian)	Magnet N pole	Remarks
1963 Jan 20	Z	64322	S 1.9° down	Gregson
1965 Feb 20	Z	–	S $3\frac{1}{2}$° down	Estimated (after adjustment)
1965 Oct 4	Z	64211	S 0.2° down	From 14 Sept
1963 Jan 20	H	13192 (26.1°E)	W 0.3° S	Gregson
1964 Nov	H	13172 (26.3°E)	W 0.7° N	To 1965 Feb 18
1965 Feb	H	13150 (26.45°E)	W 1.4° N	To 1965 Aug 2
1965 Aug 7	H	13146 (26.5°E)	W 0.0° N	
1963 Jan 20	D	26.1°E	N 0.8° W	Gregson
1964 Nov	D	26.3°E	N 0.9° E	Lodwick
1965 Aug 6	D	26.5°E	N 0.2° E	

PLATE I



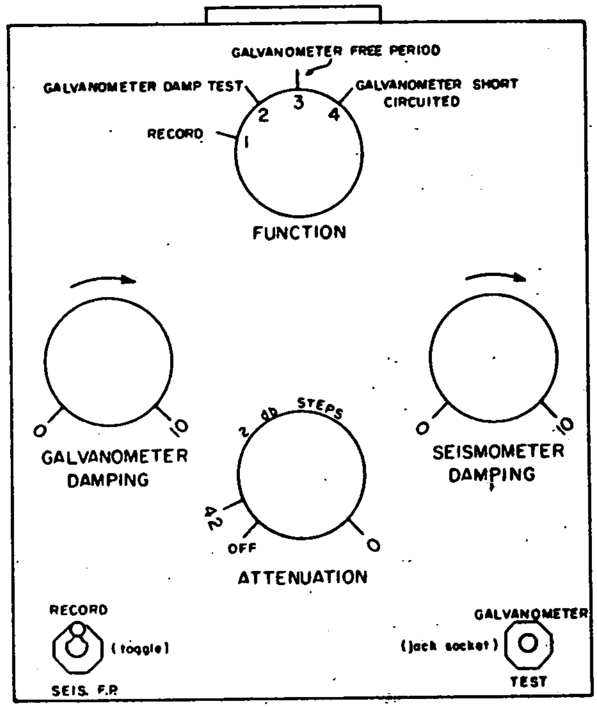
BASELINE DIFFERENCES HISTOGRAMS

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

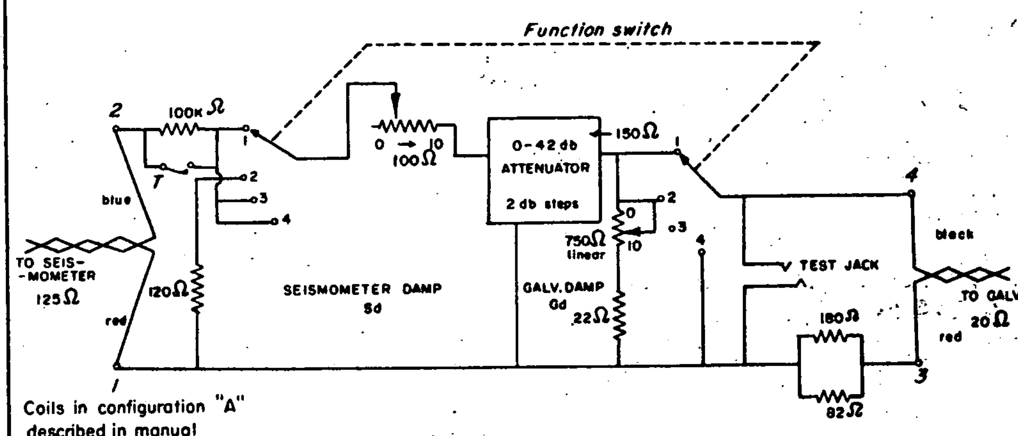
G 54-73

TO ACCOMPANY RECORD NO. 1969/84

PLATE 2



LAYOUT



Function switch positions:

1. *Record*
2. *Galvanometer damp test*
3. *Galvanometer free period*
4. *Galvanometer short circuited*

T = Toggle switch
Closed - Record
Open - Seismometer free period

SCHEMATIC

MACQUARIE ISLAND 1965

SHORT-PERIOD VERTICAL BENIOFF SEISMOGRAPH

CONTROL BOX

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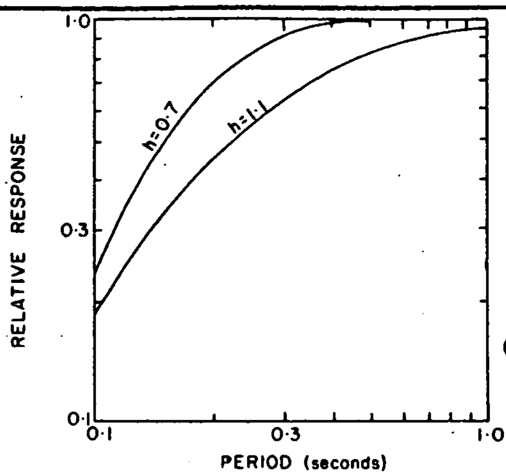
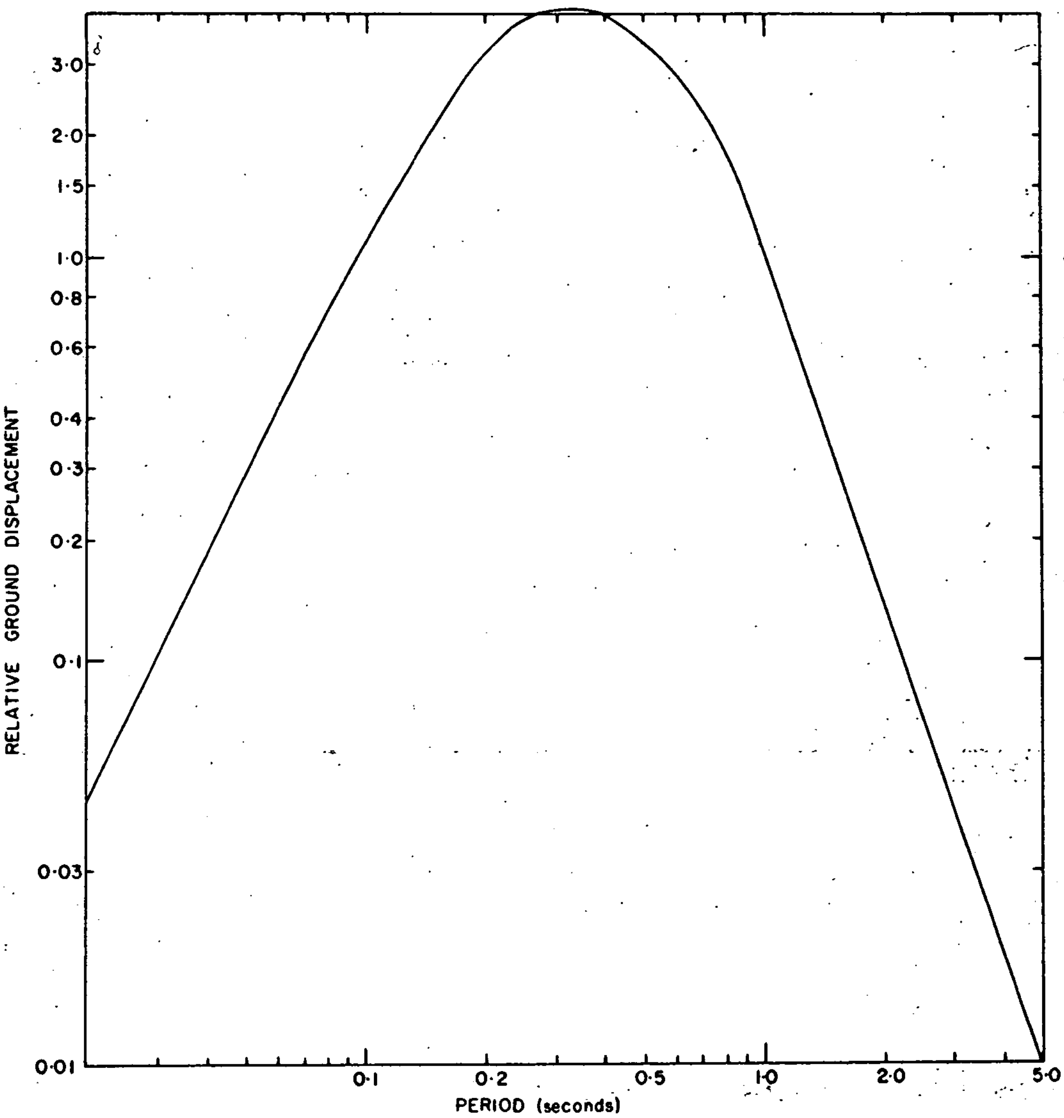
PLATE 3



Note increased relative response at period 0·3 seconds with reduced damping

GALVANOMETER AMPLITUDE RESPONSE



Seismometer Geotech Model 1051
Free Period 1 second
Galvanometer Free Period: 0·2 seconds
Curve based on smoothed response of shaketable tests for properly damped seismometer and the theoretical galvanometer response with T_g = 0·2 seconds and h = 0·7 (see above)

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SHORT-PERIOD VERTICAL BENIOFF SEISMOGRAPH AMPLITUDE RESPONSE

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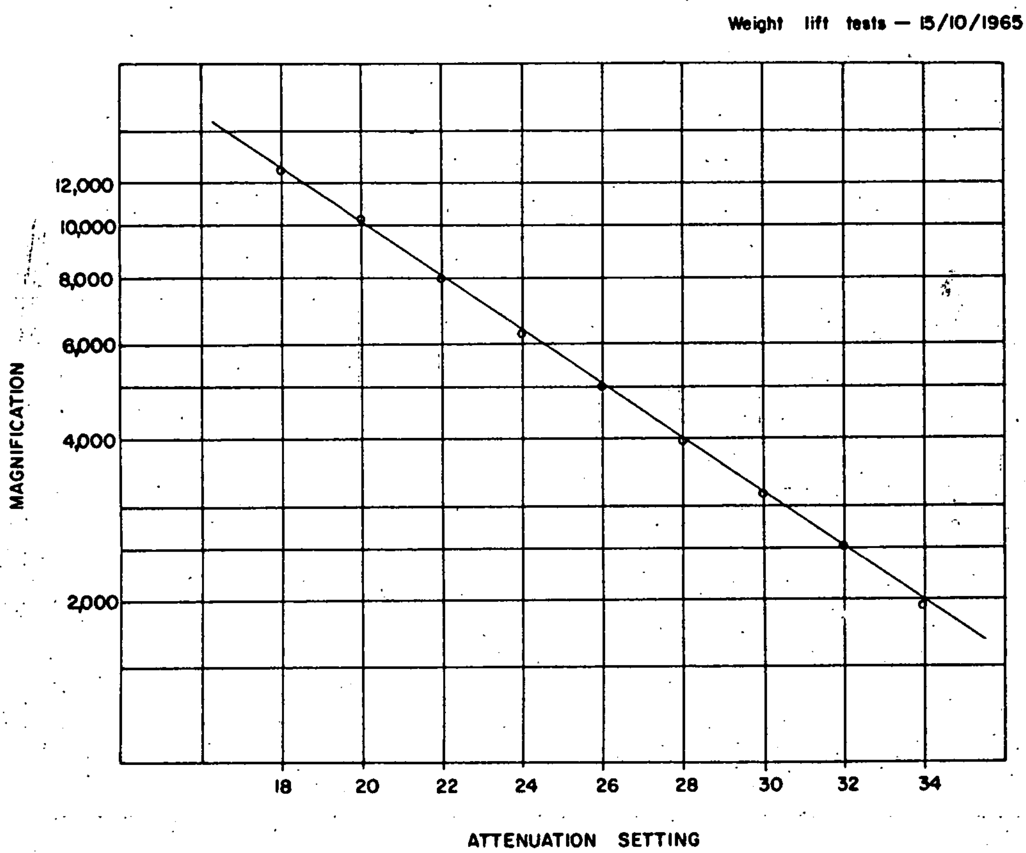

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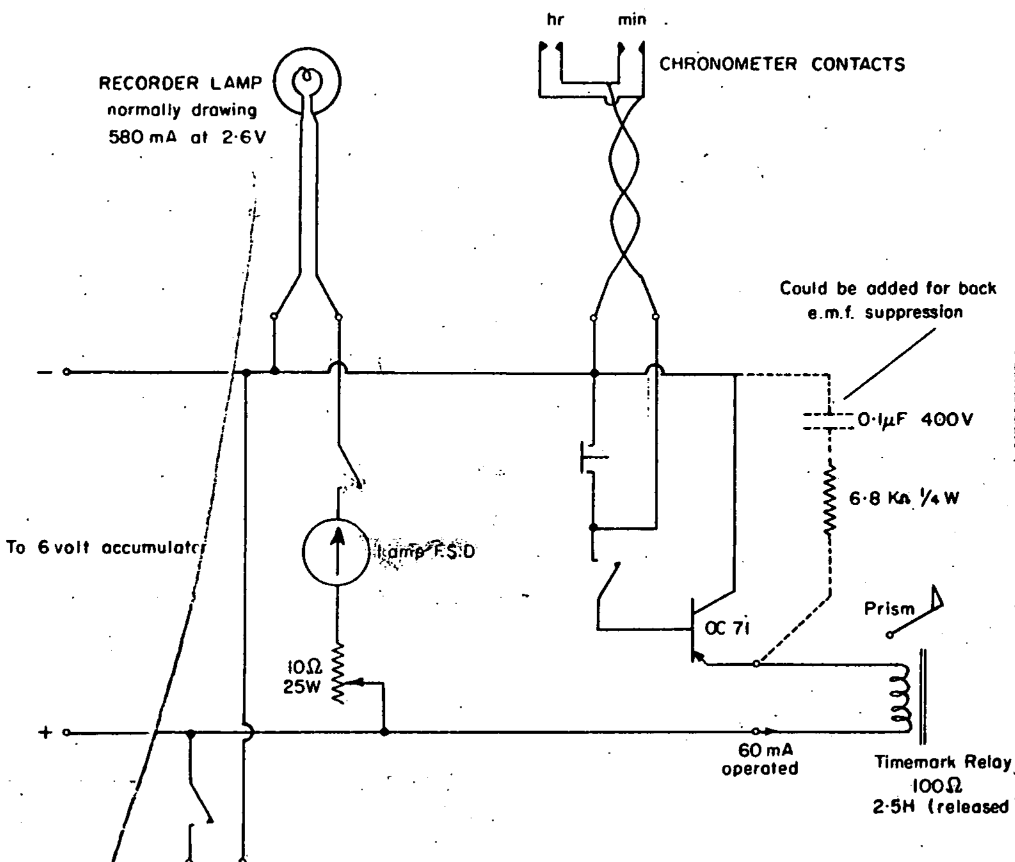
BENIOFF VERTICAL SEISMOGRAPH MAGNIFICATION AT 1Hz



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SHORT-PERIOD VERTICAL BENIOFF SEISMOGRAPH

LAMP AND TIMEMARK CIRCUIT

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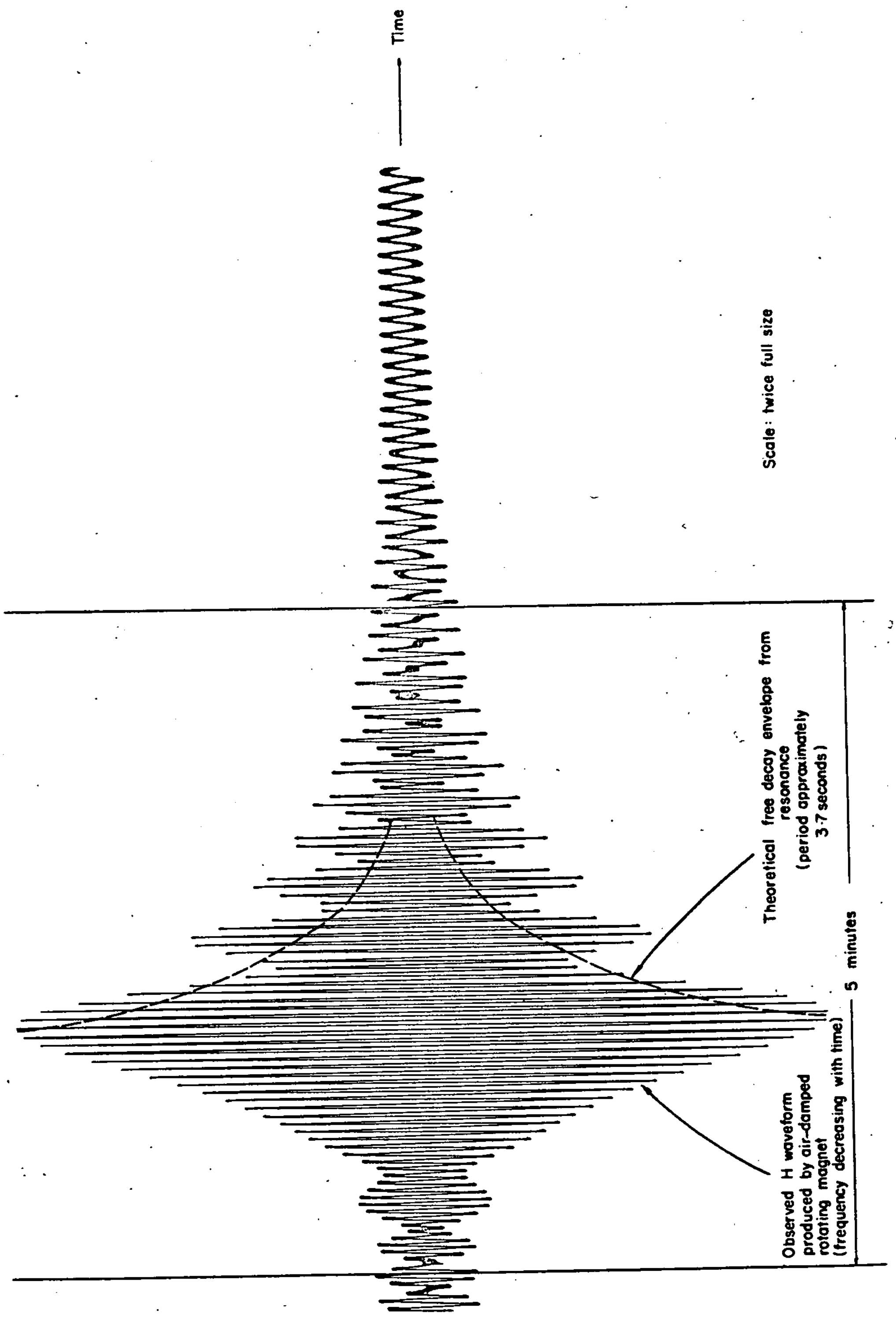
PLATE 6



LA COUR H RAPID-RUN VARIOMETER FREQUENCY RESPONSE TEST

Maquarie Island 1965

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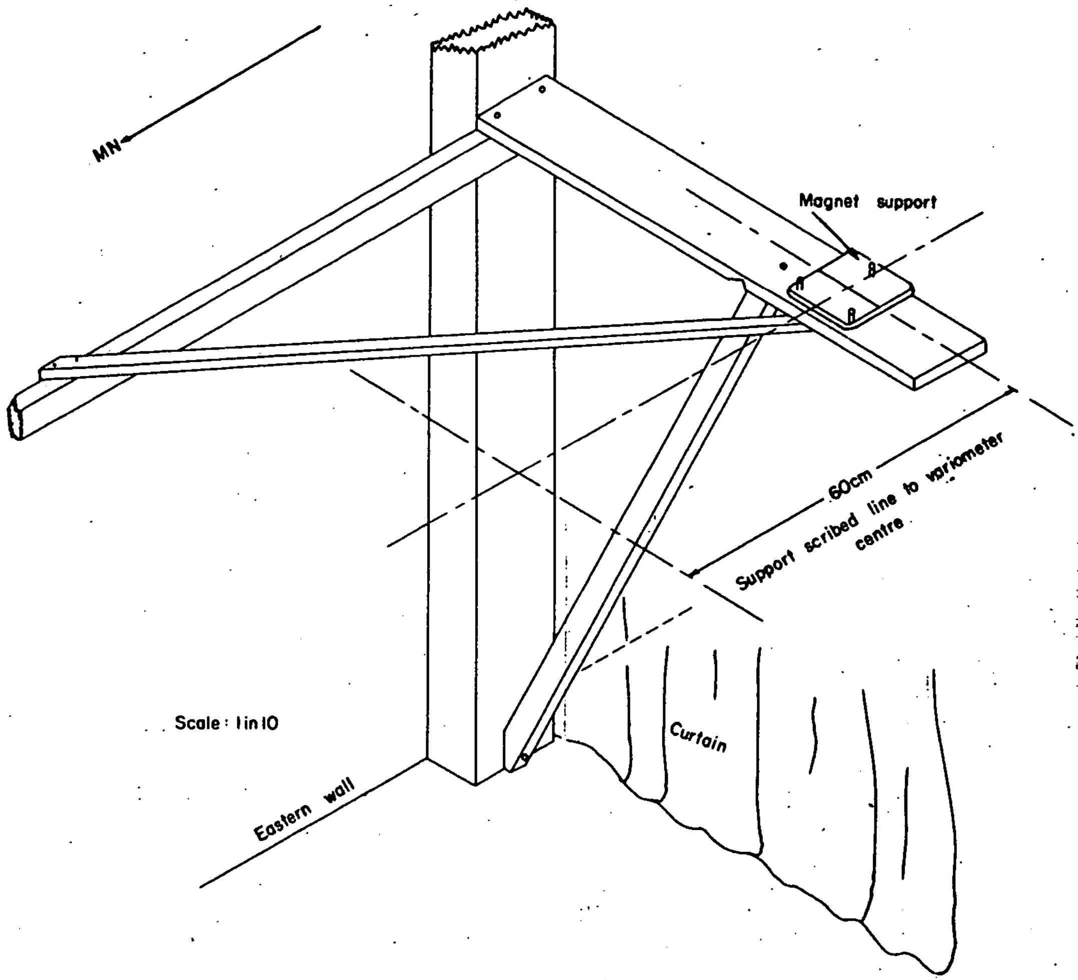
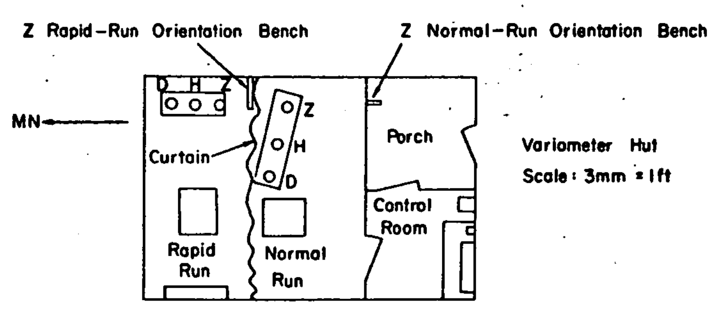
PLATE 7





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Z RAPID-RUN ORIENTATION BENCH

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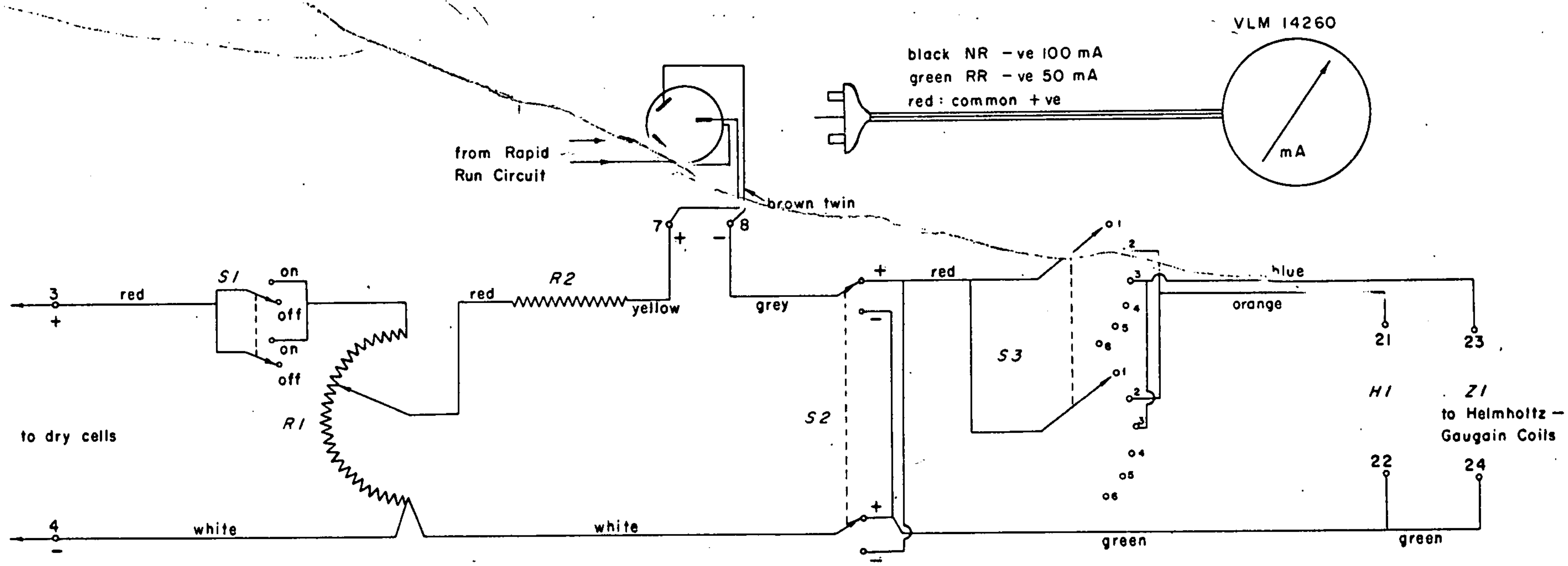

S1 ON-OFF SWITCH - Bulgin S27 ORD - D.P.D.T.

S2 CURRENT REVERSING SWITCH - Bulgin S27 ORD - D.P.D.T.

S3 COIL SELECTOR SWITCH - 2 pole 6 position ceramic : 1-off, 2-H1, 3-Z1, 4,5 and 6 spare

R1 CURRENT ADJUSTING POTENTIOMETER : Beckman Helipot Model A 1000 Ω

R2 AMMETER PROTECTION RESISTOR : 50 Ω wire wound

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LA COUR NORMAL-RUN MAGNETOGRAPH

SCALE-VALUE CIRCUIT

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G54-71

PLATE 8

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NORMAL–RUN MAGNETOGRAPH TIMEMARK CIRCUIT

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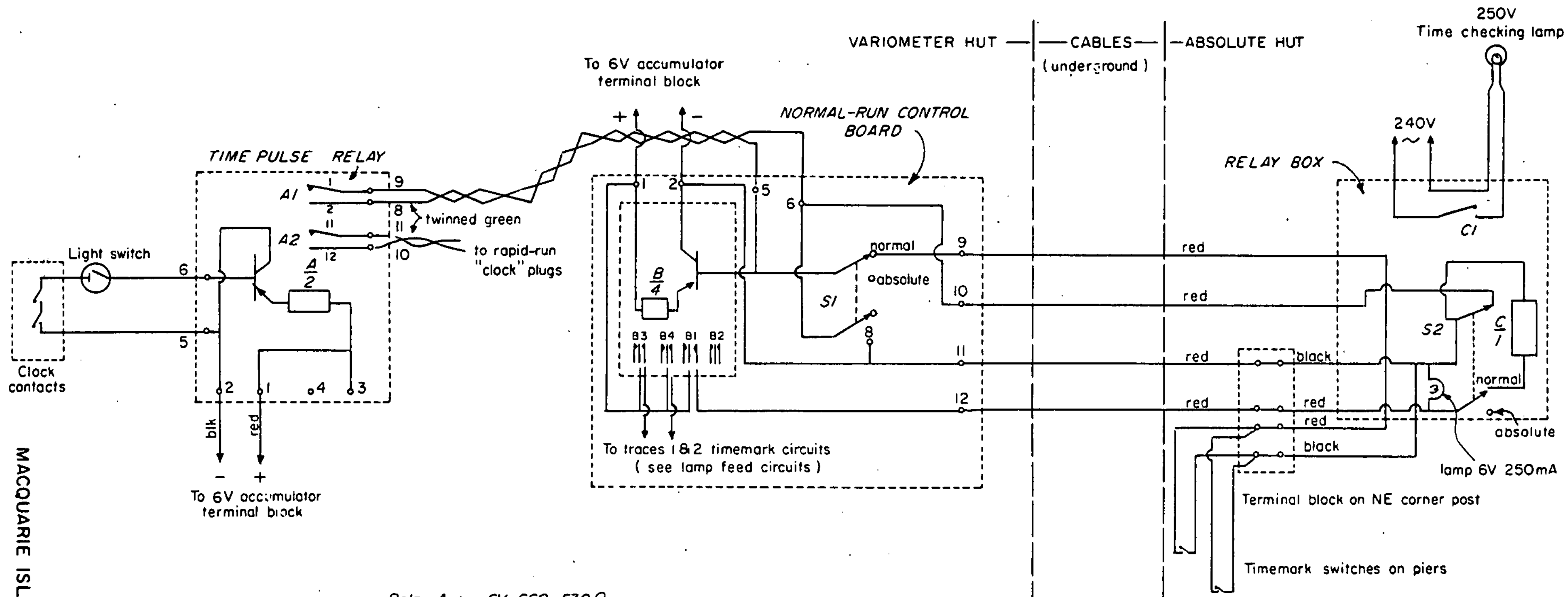


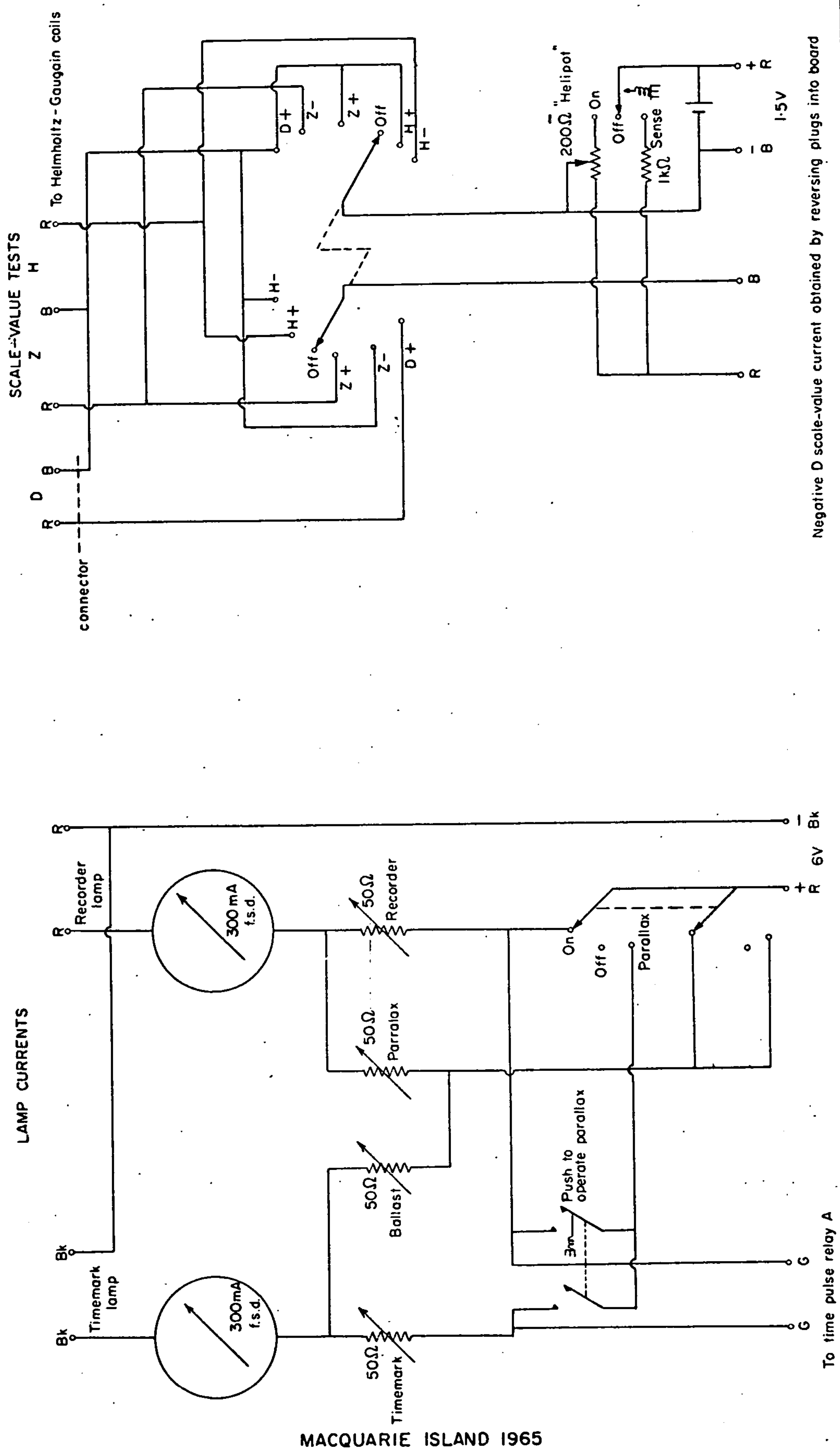
Relay A : *6V SCO 530Ω*
Relay B : *Relays Pty Ltd Type 7R/T 12volt - 4 sets changeover contacts*
Relay C : *Relays Pty Ltd 160Ω 6V*
S1 : *Timemark control switch D.P.D.T. Bulgin S270RD*
S2 : *Normal timemark cut-off switch DPST Peha 972*

NOTES: 1. Numbers refer to relay contacts or board terminals as appropriate
2. This circuit is inaccurate regarding wiring layout e.g., strictly the lower pole of S1 joins terminal 10 and not 6 (as shown)

PLATE 9

G54-70

PLATE 10



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RAPID-RUN MAGNETOGRAPH

LAMPS AND SCALE VALUE CIRCUITS

G54 -66

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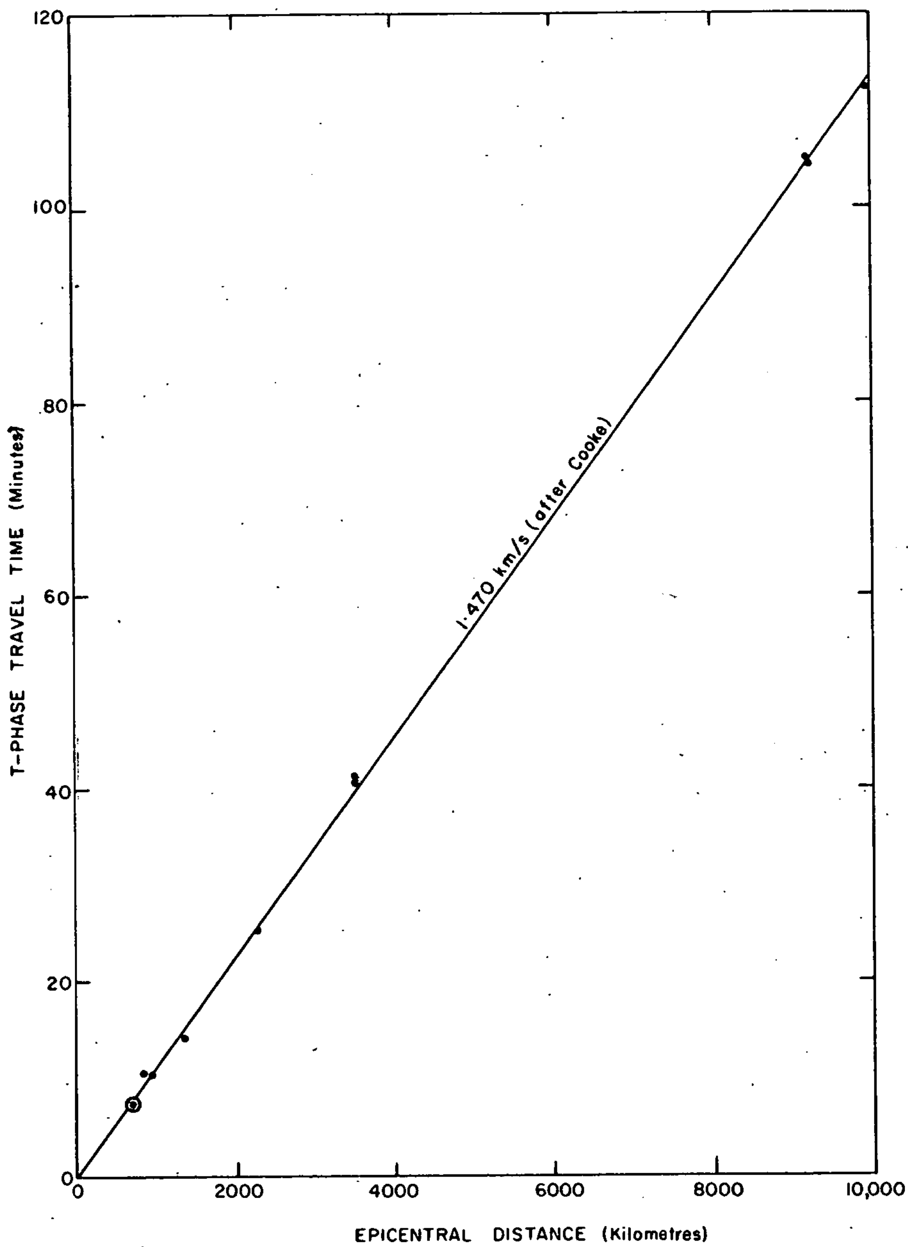
TO ACCOMPANY RECORD No 1969/84

PLATE II



• 1965 observed points

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SEISMIC T-PHASE TRAVEL TIMES

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TO ACCOMPANY RECORD No. 1969/84