COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

RECORDS
1956, No.29

RADIOACTIVE INVESTIGATIONS AT LUCAS HEIGHTS, NEAR MENAI, N.S.W.

by

D.F. URQUHART and D.L. ROWSTON

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ABSTRACT

At the request of the Australian Atomic Energy Commission, measurements of radioactivity were made at a few stations around the proposed reactor site at Lucas Heights, near Sydney, and on samples of water from neighbouring rivers; the number and sites of the stations were selected by officers of the Commission. The stations were marked with permanent markers, so that the tests may be repeated precisely at any later date as a check on radioactive contamination of the area during the operation of the reactor. Special equipment was designed and constructed for the measurements.

1. INTRODUCTION.

The first nuclear reactor in Australia is to be built by the Australian Atomic Energy Commission at Lucas Heights, near Menai, which is about 17 miles south of Sydney (Plate 1). Clearing of the site has begun and it is expected that the reactor and associated laboratories will be completed in 1957.

The site is approximately 500 feet above sea level, comparatively flat over the reactor area and falling steeply to the Woronora River in the east. Discharge of atomic waste is to be to the Woronora River along a stream marked on Plate 1 as Effluent Creek.

The Hawkesbury sandstone formation occupies the whole of the area; it crops out over much of the area and in the other parts is covered by a thin layer of sandy soil.

One of the precautions which must be taken in the operation of a reactor is the regular monitoring of the radioactivity of surrounding soil and surface waters. In this way any contamination of the area that may occur can be detected quickly. It is desirable, therefore, to measure the intensity of the natural radioactivity of the area before the reactor begins to operate. At the request of the Australian Atomic Energy Commission such measurements in the area of the proposed site were made by the Bureau of Mineral Resources in October 1955, before the site was cleared for building operations. The measurements were made by one of us (D.L.R.) with the assistance of E.J. Mutch, senior technician.

Soil and selected water samples were tested for radioactivity using specially designed detector units and scaler. The readings taken will be used as a basis for comparison with later observations when the reactor is in operation, to determine increased radioactivity or contamination.

The number and sites of the localities tested were selected by Mr. I. Bisset of the Australian Atomic Energy Commission, due regard being paid to topography, proximity to reactor units and disposal of waste products.

2. DESCRIPTION AND OPERATION OF EQUIPMENT.

(A) Introduction.

As no primary mineralisation occurs in Hawkesbury sandstones in the Menai area, very low levels of natural radioactivity were expected, and the equipment was designed with this in mind. The choice of the various elements of the equipment was based on the following considerations:-

(i) Method of counting.

Accurate measurements of low levels of activity cannot be made with equipment of the ratemeter type, except under laboratory conditions, as the accuracy of instruments of this type is fixed by the time constant of the ratemeter. For this reason, it was necessary to use a scaling counter. As battery-operated portable scalers are not available commercially, the scaler had to be constructed in the laboratory.

The choice of the particular type of scaler to be used involved a balancing of two factors. Scalers using cold-cathode tubes require no heater current, and can be made to have low current drain. They are, therefore, more suited to portable use. However, as the resolution time of such scalers is long, they can be used only for low counting rates. Hard-valve scalers may be made with very short resolution times, but require much more power, and are therefore not suited to portable use.

Considering the low count rates expected, it was decided to use a scaler of the cold-cathode type.

(ii) <u>Choice of Detector</u>.

Measurements of both beta and gamma ray activity were required. Due to the very short range of beta particles, the beta activity counted on any sample is a function mainly of the area of sample exposed to the detector. For this reason, and also to obtain a better figure for average activity, it was decided to test soil samples in situ, using a detector scanning an area as large as could be conveniently arranged. The radiation can be detected by Geiger tubes or by scintillation detectors. Although scintillation detectors are fundamentally much more efficient than Geiger tubes as detectors of gamma radiation, it was decided to use Geiger tubes for the following reasons:-

(a) By using thin-walled Geiger tubes in the detector for testing soild, the beta and gamma counts may be obtained from the same tubes. The use of scintillation detectors would require two separate detectors, as the requirements for efficient beta and gamma counting are quite different.

(b) Using Geiger tubes, it is a simple matter to construct a detector scanning a considerable area. A phosphor of the same area, if it could be obtained, would be extremely costly.

(c) For reliable operation, Geiger tubes should be shielded from direct light, but this shielding is not critical. It is absolutely essential that a scintillation detector be completely protected from any light at all, and this would make the construction of a detector of the type envisaged very difficult.

(d) A scintillation detector of large area would count at a very high rate, far beyond the capacity of any cold-cathode scaler.

(e) It was essential that the tests performed be exactly re-producible at any later date. The response of a scintillation detector depends on several factors, some of which are related to the electronic equipment used. Provision for precise control of these factors would add considerably to the complexity of the equipment.

To avoid the necessity of constructing a stabilised high-voltage supply, low-voltage Geiger tubes were used.

(iii) <u>Shielding</u>.

As stated earlier, it is desirable that the Geiger tubes be shielded from direct light. It is desirable also that the radiation detected should be restricted as far as possible to that coming from the sample itself, extraneous radiation being eliminated as far as possible. For these reasons, it was decided to surround each probe with a lead shield. In order to keep the equipment as portable as possible, it was considered that the thickness of the shielding could not exceed ½ to ¾ of an inch, though a considerably greater thickness would be required to reduce the cosmic radiation to a very low level.

The equipment as constructed consisted of three units, the scaler (type RL300), soil testing detector (type RL100) and water testing detector (type RL101). Details of these units are given below.

(B) Scaler, Type RL300.

A schematic circuit diagram is shown on Plate 2.

A positive input pulse greater than 40V is applied to the trigger electrode of a G1/371K cold-cathode trigger tube (V_2), via a 1L4 cathode follower (V_1). A negative pulse from the plate of V_2 triggers a G10/241E cold-cathode decade counting tube (V_3). A second G1/371K (V_4) couples the output from the No.10 cathode of V_3 to a second G10/241E (V_5). The output from V_5 triggers a third G1/371K (V_6) which drives a mechanical register.

The scaler is suitable for counting only low levels of radioactivity, the resolving time being about 2 millisecs. For random count rates above 1,000 counts per minute, statistical counting losses become appreciable.

When used with a multi-tube geiger detector, each tube may be selected by the switches S_1 to S_7.

Supply voltages may be monitored by the meter M_1 which has two ranges, 0-500 volts and 0-5 volts.

With new batteries, the following voltages are supplied:-

E.H.T. variable (by S_{11}), + 360V to +450V.

H.T.1., + 135V.

H.T.2., + 360V.

Fil., + 1.5V.

The most stable operating condition for the scaler is obtained by keeping the value of H.T.2 between 310 and 340 volts. It is therefore desirable to replace the 45-volt batteries in stages, e.g. two at a time. To prolong the life of the batteries, the scaler should be switched off immediately after each count has been taken.

As a safety precaution the negative side of the H.T. battery stack should be disconnected while replacing batteries.

(C) Detector, Type RL100.

(1) Description.

This unit has been designed for the detection of low levels of radioactivity at the surface of the ground.

The unit consists essentially of seven (7) B12H beta-gamma Geiger tubes mounted side by side, in a horizontal position (see Plate 3). The bottom of the unit may be left open (for beta counting) or closed by means of a 1/16 inch brass plate (for gamma counting).

K32 cold-cathode trigger tubes are used to step down the output impedance of the Geiger tubes from 10 mohms to 1 megohm. These tubes also provide some amplification of the output pulse (see Plate 4).

The detector is designed for use with the scaler, type RL300, to which it may be connected by means of a 4-foot shielded cable and a 12-pin Jones plug. Power for the detector is obtained from the scaler. Seven switches on the front panel of the scaler enable the output pulse rate from each Geiger tube to be counted separately or together with any of the other six tubes.

The detector is partially screened from extraneous radiation by the lead castle, type RL901. This castle provides a ½-inch thickness of lead shielding round the top and sides of the detector. The castle is made in two sections, weighing 42 lbs. and 45 lbs. respectively.

(ii) Operation.

It is necessary that a set of Geiger tubes be chosen whose plateaus overlap, so that a voltage may be selected which lies on the plateau of each tube.

To obtain a reference level from which the sample counts may be measured, it is necessary to take a "background" count, from which the effect of the sample has been eliminated. To enable this to be done on the site, it is necessary to provide shielding between the probe and the ground. For ease of transportation, this shielding is provided in the form of lead bricks, 8 in. x 4 in. x 1 in. Eight of these are laid out side by side, covering an area 16 in. x 16 in., and the probe is rested on them for the "background" count. Under these conditions the "background" count due to the seven tubes has been determined as 250 per minute in the laboratory.

(D) Detector, Type RL101.

(i) Description.

This unit has been designed for detecting low levels of radioactivity in liquid samples.

The sample is placed in a 1500 ml. beaker, with inlet and outlet tubes, and the Geiger tubes are immersed in the liquid. It is necessary to use separate Geiger tubes for beta and gamma counting, as shielding of a beta-counting tube from the surrounding liquid is impracticable. The gamma counting was performed using four thick-walled Geiger tubes, type G10H, and a single thin-walled tube, type B12H, was used for beta counting. The arrangement of the tubes is shown on Plate 5.

The circuit of the detector, shown on Plate 6, is similar to that of the detector, type RL100. It is designed for use with the scaler, type RL300, to which it may be connected by a 4-foot shielded lead, and a 12-pin Jones plug. Switches are provided for connecting any or all of the tubes for counting.

The detector is shielded by a cylindrical lead castle, type RL902. Provision is made for filling and emptying the sample beaker from outside the castle. The castle is made in two sections, weighing 34 lbs. and 40 lbs. respectively, and provides the equivalent of ¾-inch of lead around the sample.

(iii) Operation.

As with the detector type RL100, it is necessary to obtain a "background" count, to which measurements may be referred. This has been performed, with the sample holder filled with distilled water, and the "background" determined in the laboratory as 23 counts per minute for beta counts, using the B12H tube, and 115 counts per minute for gamma counts, using the four G10H tubes.

This method of testing is recognised as far from ideal, though no better method can be suggested at present. Experience shows that when Geiger tubes are immersed for counting in samples containing radioactive material even in moderate concentrations, they are invariably affected by contamination, which is extremely difficult to remove. The present tests have not been affected by this, but in the event of appreciable contamination being encountered, equipment of this type would have serious drawbacks.

3. PRELIMINARY TESTING OF EQUIPMENT.

After construction of the equipment, it was considered desirable that the soil-testing probe be checked in operation in the field. For this purpose, it was necessary that the tests be performed in an area in which the level of radioactivity was slightly above normal. Such an area was selected near Romsey, Victoria, adjacent to an outcrop of solvsbergite, which is known to be slightly radioactive. Two sets of tests were performed, the results of which are shown in Table 1, as they have a bearing on the deductions which may be made from the results of the tests at Lucas Heights.

TABLE 1

Date	Laboratory Background	Field Background		Sample Gamma Count	Sample Beta + Gamma Count
7/9/55 Weather Showery	250	Reading Excess Probability	259 9 25%	332 82 80%	425 175 > 95%
21/9/55 Weather fine	250	Reading Excess Probability	261 11 25%	307 57 70%	382 132 > 95%

All figures are in counts per minute. The line marked as "Excess" shows divergence from laboratory background.

Observed counts are each the average of four five-minute counts. A portable Geiger ratemeter, type PRM200, gave readings of 2½ to 3 times normal background on the site.

The arrival of radiation at any detector is a purely random process, and the significance of the results must be estimated according to the laws of statistics. For this reason, a probability value has been attached to each reading. This depends on the background count, the excess (or deficiency) of the observed count, and the counting time, and is the probability that the observed count rate indicates a real change in the level of radioactivity and is not derived from normal statistical variation. For example, a probability value of 25% attached to a reading indicates that there is only a 25% probability that the reading represents a real variation from the laboratory background count, and therefore a 75% probability that the reading is due to a normal statistical variation.

The deductions from the results shown in Table 1 are as follows:-

(a) The fact that the difference between field background readings and the laboratory background is not significant indicates that the equipment is functioning correctly, and has not suffered contamination.

(b) The presence of the slight radioactivity in the ground is shown by the fact that the sample gamma count is significantly higher than the laboratory background, and the sample beta + gamma count is significantly higher than the sample gamma count.

4. RESULTS OF TESTS AT LUCAS HEIGHTS.

Tests were made with the soil detector at six stations, and with the water detector on samples from three locations. The sites were selected by Mr. Bissett, of the Australian Atomic Energy Commision, and are described in Tables 2 and 3 below.

TABLE 2

Soil Testing Stations

Station No.	Position	Marker	Plate
1	AAEC Survey Peg 31	Cement Pillar	7
2	" " " 32	" "	7
3	" " " 49	" "	7
4	" " " 44	" "	7
5	" " " 39	" "	7
6	Junction of Woronora River and Effluent Creek, west bank	-	1

TABLE 3

Water Samples

Station No.	Position	Plate
7	Pool at junction of Woronora River and Effluent Creek. Fresh Water	1
8	Centre of Woronora River at low tide, 0900 hours, 7/10/1955. Salt Water	1
9	Mr. J. Giles landing, Bonnet Bay at low tide, 0900 hours, 8/10/1955. Salt Water	1

The results are shown in Tables 4 and 5, in counts per minute, based on a five-minute counting period.

TABLE 4

RESULTS OF TESTS ON SOIL SAMPLES

Station No.	Laboratory Background	Station Background			Sample Gamma Count			Sample Beta + Gamma Count		
		Reading	Excess	Probability	Reading	Excess	Probability	Reading	Excess	Probability
1	250	264	+14	30%	360	110	95%	481	231	>95%
2	250	238	-12	30%	271	21	40%	367	117	95%
3	250	237	-13	30%	321	71	70%	435	185	>95%
4	250	249	-1	9%	334	84	80%	459	209	>95%
5	250	262	+12	30%	361	111	95%	514	264	>95%
6	250	-	-	-	248	-2	10%	244	-6	15%

<u>Note</u>: Readings at station 6 were taken without the lead castle surrounding the probe.

TABLE 5

RESULTS OF TESTS ON WATER SAMPLES

Station No.	Laboratory Background		Sample Background						Sample Beta Count			Sample Gamma Count		
	Beta	Gamma	Beta	Excess	Probability	Gamma	Excess	Probability	Reading	Excess	Probability	Reading	Excess	Probability
7	23	115	-	-	-	-	-	-	39	+16	60%	113	-2	10%
8	23	115	28	+5	35%	105	-10	35%	36	+13	60%	121	+6	25%
9	23	115	45	+22	70%	112	-3	15%	34	+11	55%	129	+14	40%

<u>Note</u>: Sample background readings were taken on tap water from the Woronora reservoir.

5. DISCUSSION OF RESULTS

(A) Soil Samples.

The differences between station background and laboratory background are small and have low significance, indicating that the equipment was functioning satisfactorily. At stations 1 to 5, sample counts are higher than laboratory background, with a high degree of significance. For each sample, beta + gamma counts are greater than gamma counts with a high degree of significance. These facts show that the soil at these stations contains a small amount of radioactive minerals, derived probably from the Hawkesbury sandstone. By analogy with the results obtained on the test site near Romsey, it is to be expected that readings of three times normal background or greater would be obtained over these areas, using a portable Geiger ratemeter of the type used in prospecting for radioactive minerals. At station 6, the beta + gamma counts are not significantly different from laboratory background which indicates that the soil there contains practically no radioactive minerals.

(B) Water Samples.

At station 9, the difference in the beta count between sample background and laboratory background was appreciable and of rather high significance. The cause of this is not known. It is clear that it was not due to contamination of the equipment, as a sample beta count closer to the laboratory background was observed immediately afterwards. The sample beta counts are greater than laboratory background, with moderate significance, but the sample gamma counts are closer to background, and the significance of the differences is low.

6. CONCLUSIONS & RECOMMENDATIONS.

The tests performed give a sufficiently accurate estimate of the general levels of radioactivity in the area, bearing in mind that any dangerous contamination from the reactor would produce levels of radioactivity very much higher than those measured.

It is to be expected that building operations will cause small local disturbances of the surface activity recorded at the various stations. If high precision in measurement is required, it is recommended that the tests should be repeated at different stages during the construction programme.

7. ACKNOWLEDGEMENTS.

It is desired to acknowledge the assistance rendered to the party by Mr. Bissett, of the Australian Atomic Energy Commission.

The equipment was designed by one of the authors (D.F.U.), and constructed in the geophysical laboratory by Mr. E.J. Mutch.

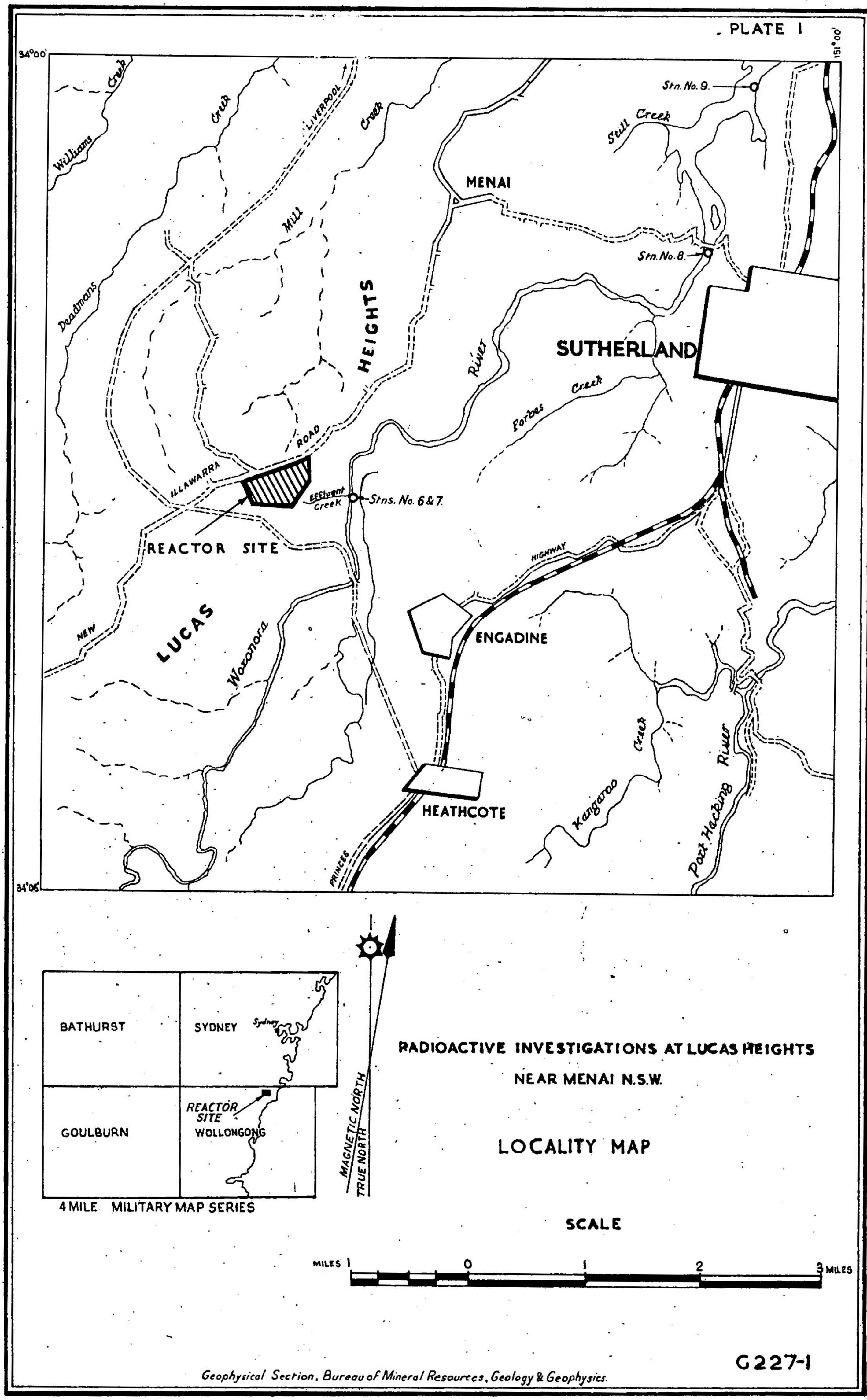
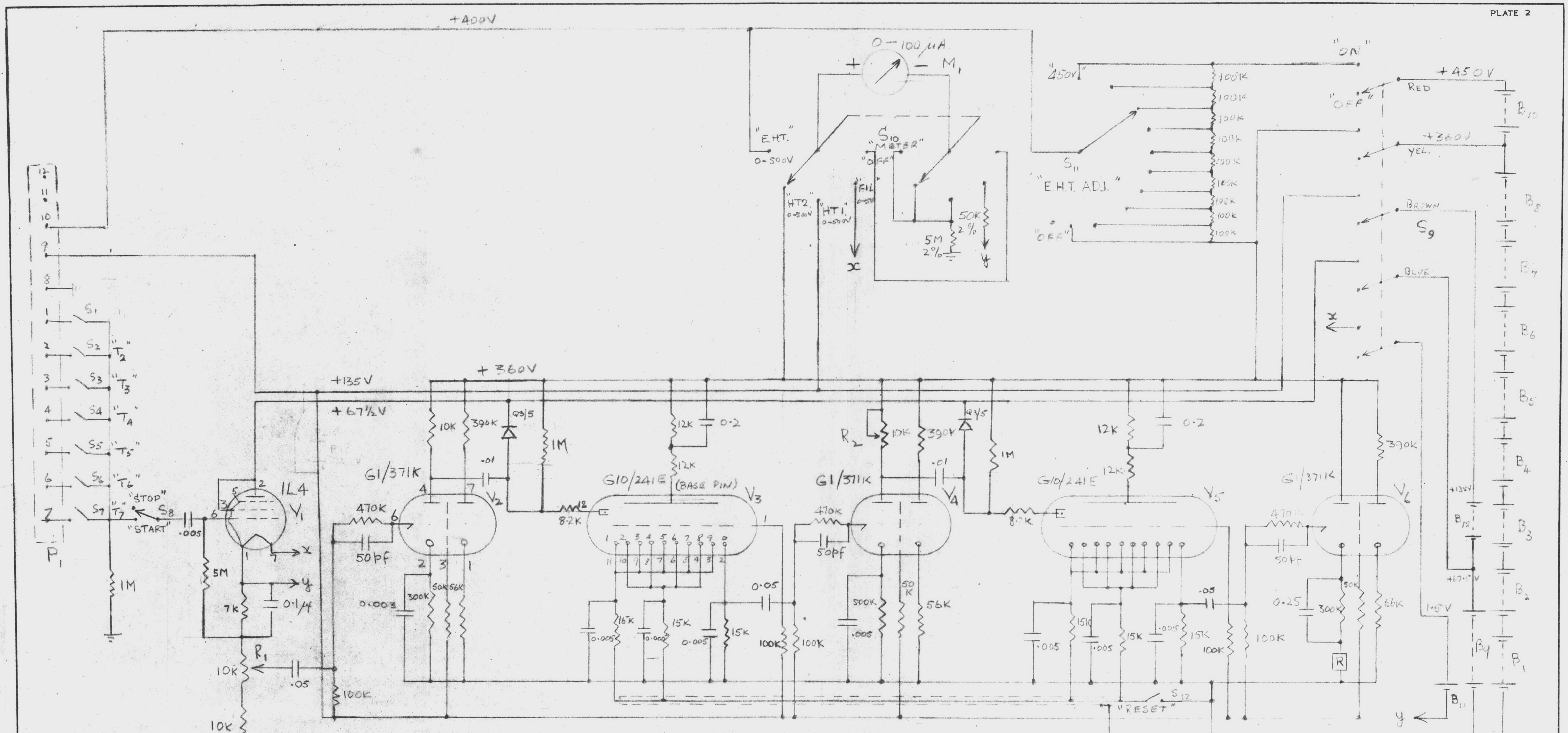


PLATE I
34°00'
151°00'
34°05'
Stn. No. 9.
Still Creek
Williams Creek
Creek
LIVERPOOL
Creek
MENAI
Mill
Stn. No. 8.
Deadmans
HEIGHTS
SUTHERLAND
River
Forbes Creek
ROAD
ILLAWARRA
Effluent Creek
Stns. No. 6 & 7.
REACTOR SITE
HIGHWAY
NEW
LUCAS
Woronora
ENGADINE
Creek
Kangaroo
Port Hacking River
HEATHCOTE
PRINCES
BATHURST
SYDNEY
Sydney
GOULBURN
REACTOR SITE
WOLLONGONG
4 MILE MILITARY MAP SERIES
MAGNETIC NORTH
TRUE NORTH
RADIOACTIVE INVESTIGATIONS AT LUCAS HEIGHTS
NEAR MENAI N.S.W.
LOCALITY MAP
SCALE
MILES 1
0
1
2
3 MILES
G227-1
Geophysical Section, Bureau of Mineral Resources, Geology & Geophysics.



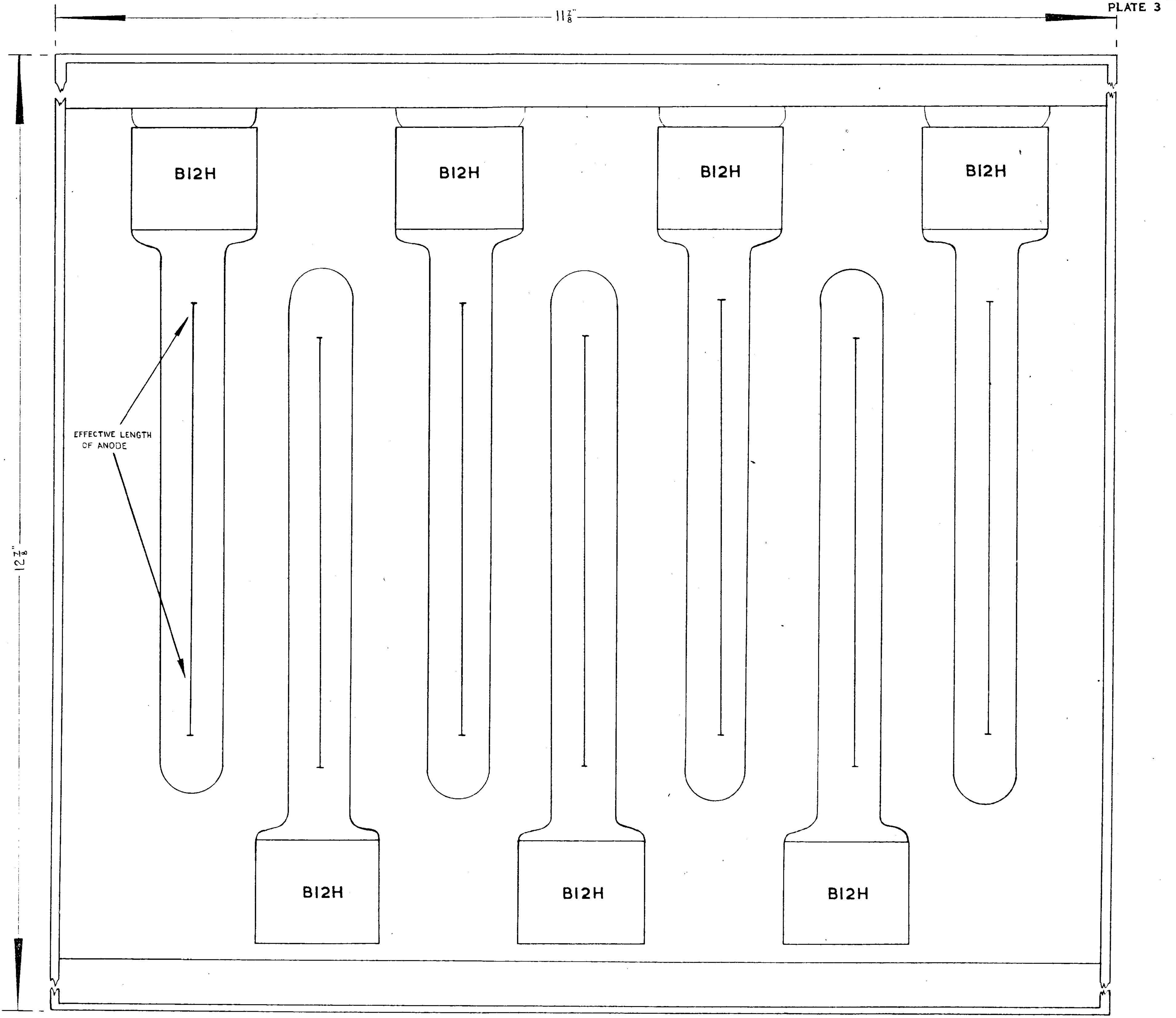
S_1 - S_8	TOGGLE SWITCH 2 AMP.	B_1-B_8 BATTERY TYPE	482 (45v.)
S_9, S_{10}, S_{11},	OAK WAFER SWITCH	B_{10} " "	490-P (90v.)
S_{12}	PRESS BUTTON SWITCH (PAINTON CAT. Nº 501404)	B_{11} " "	742 (1.5v.)
P_1	JONES SOCKET (12 PIN)	B_9, B_{12} " "	467 (67.5v.)
R	MECHANICAL REGISTER (CYCLOTRON SPECIALTIES)		

BATTERY OPERATED SCALER
TYPE RL300

Geophysical Section, Bureau of Mineral Resources, Geology & Geophysics.

G227-2

PLATE 3



BETA GAMMA BACKGROUND DETECTOR, TYPE RL100

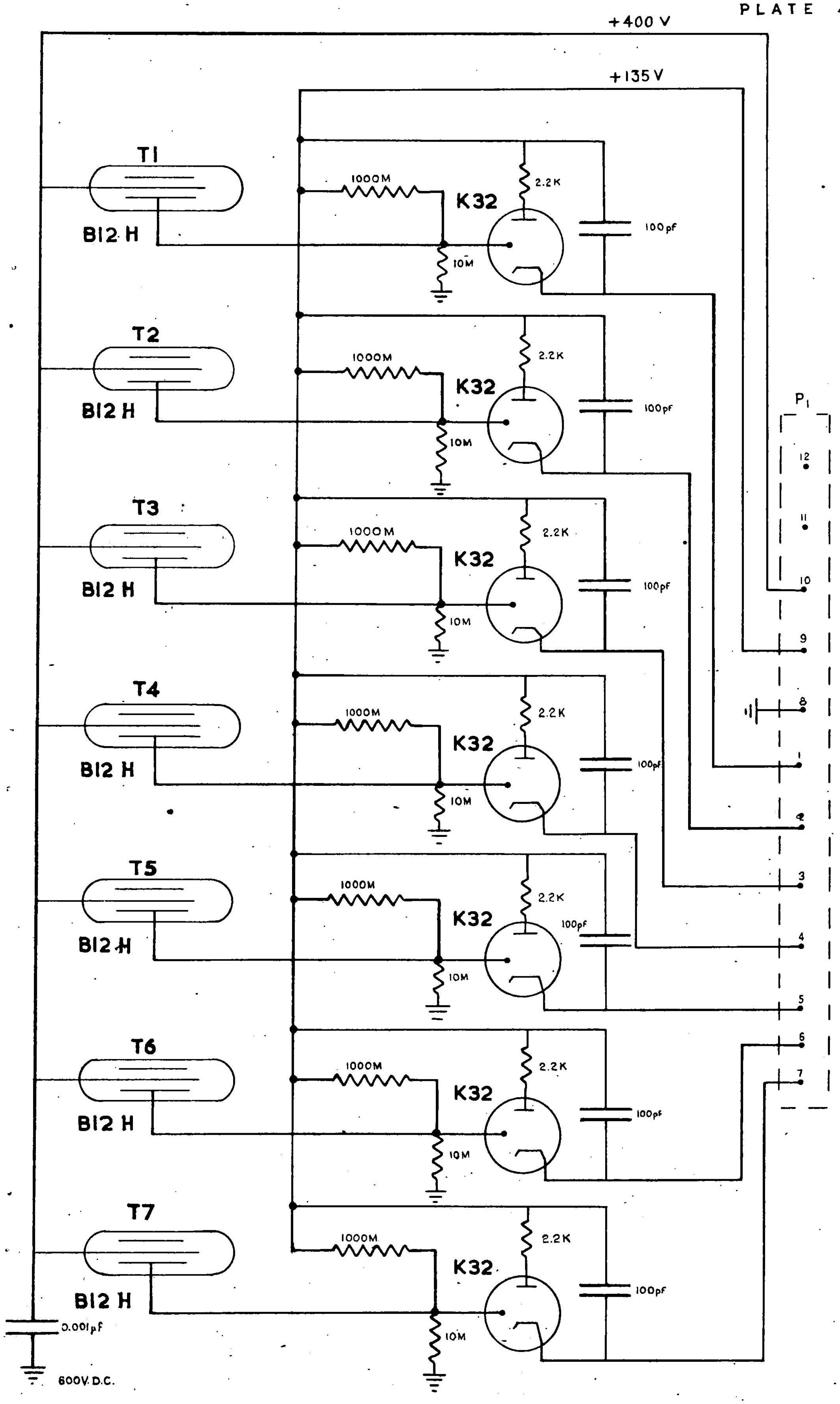
SKETCH PLAN OF BOTTOM OF DETECTOR SHOWING POSITION OF G.M. TUBES

NOTE: *When the detector is placed in position for making measurements the G.M. Tube anodes are approximately 1 1/2" above the ground.*

APPROX. SCALE 1:1

Geophysical Section, Bureau of Mineral Resources, Geology & Geophysics

G 227-3

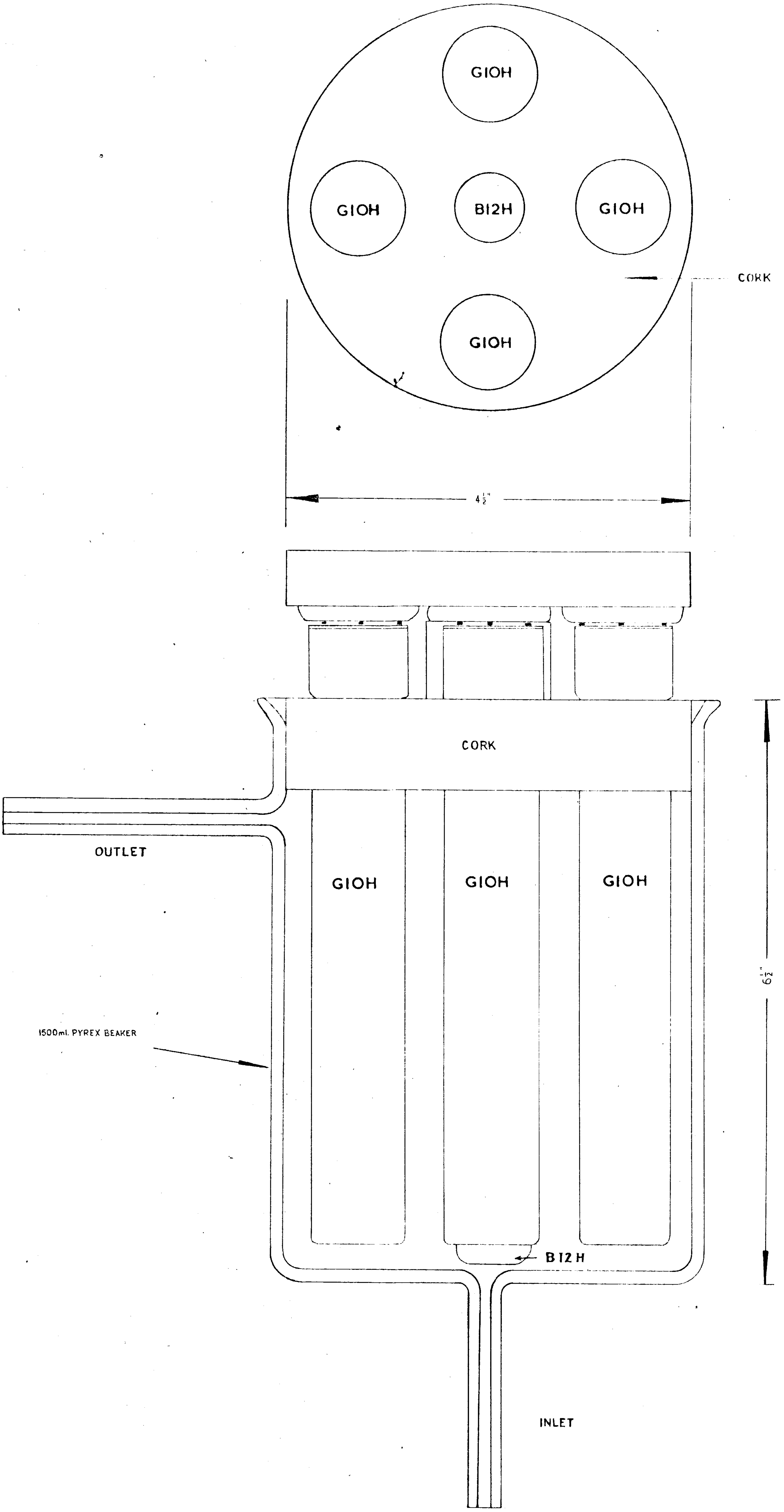


P1 - 12 PIN JONES PLUG (CABLE TYPE)

BETA-GAMMA BACKGROUND DETECTOR

TYPE RL100

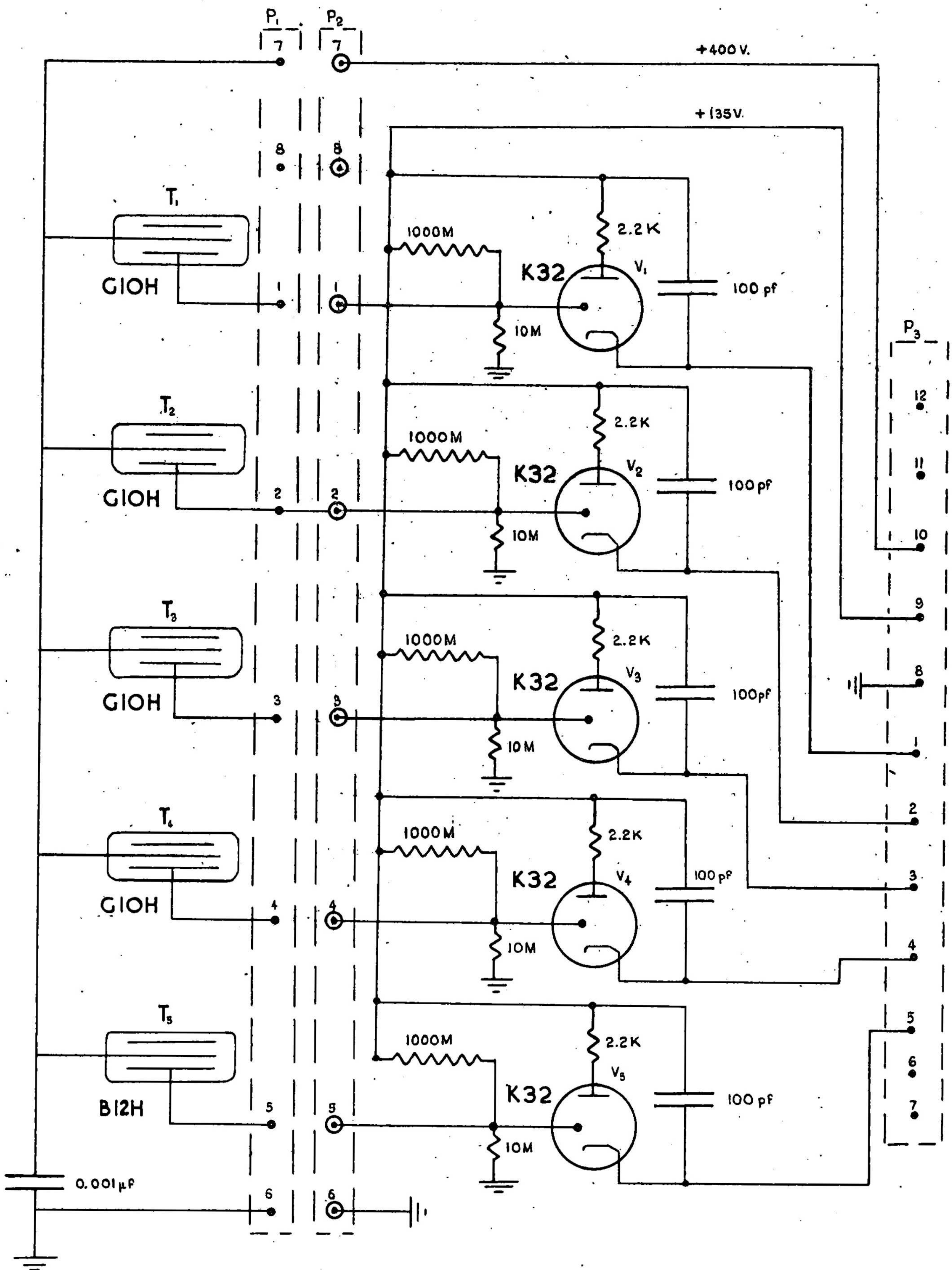
Geophysical Section, Bureau of Mineral Resources, Geology & Geophysics G 227-4



BETA-GAMMA DETECTOR TYPE RL.101

SKETCH SHOWING POSITIONS OF G.M.TUBES IN SAMPLE HOLDER

APPROXIMATE SCALE 1:1



P1 8 PIN PAINTON PLUG (CABLE TYPE)

P2 " " " SOCKET (CHASSIS TYPE)

P3 12 " JONES PLUG (CABLE TYPE)

BETA – GAMMA DETECTOR
TYPE RL 101

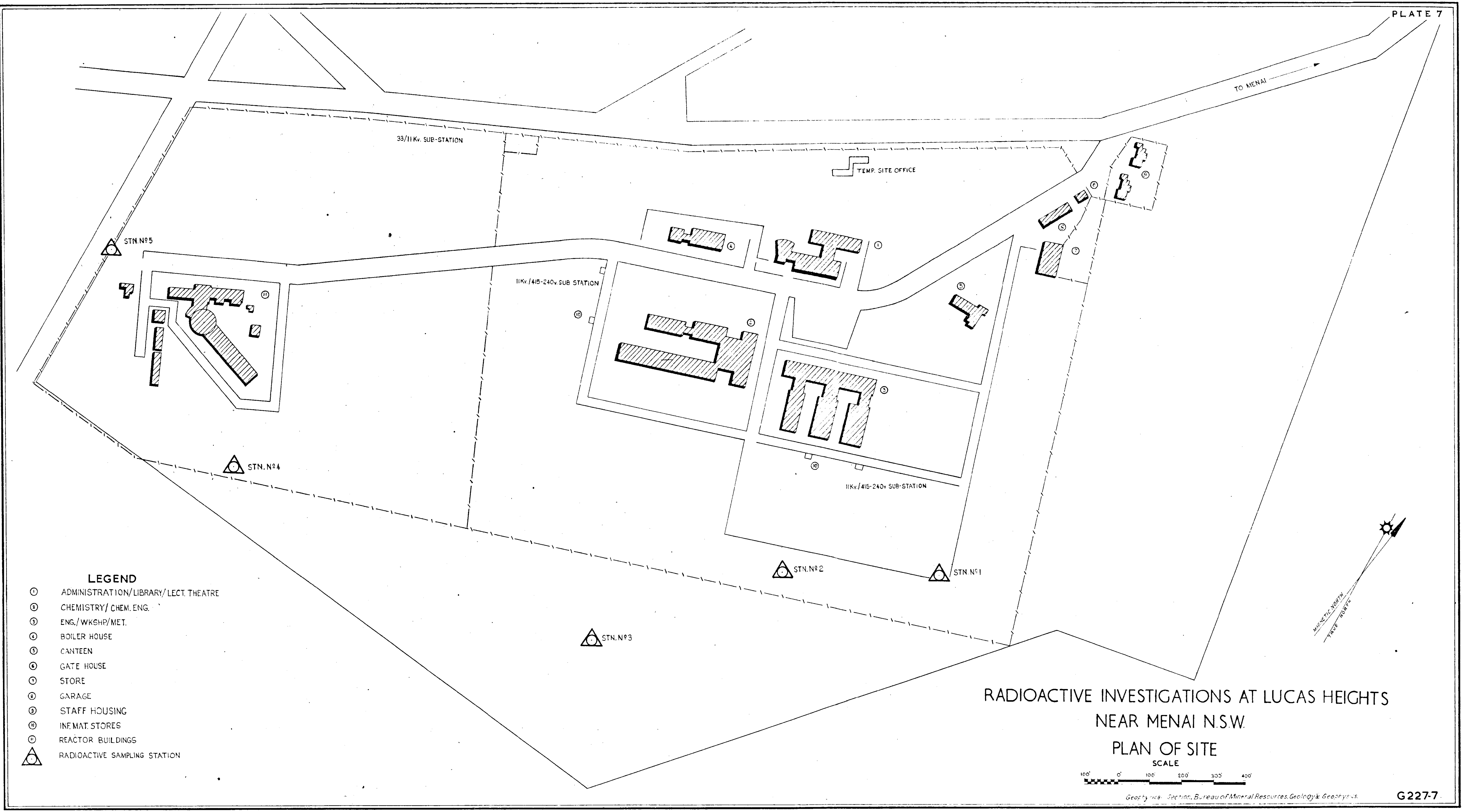


PLATE 7
TO MENAI
33/11 Kv. SUB-STATION
TEMP. SITE OFFICE
11 Kv./415-240v SUB STATION
11 Kv./415-240v SUB-STATION
STN. Nº 5
STN. Nº 4
STN. Nº 3
STN. Nº 2
STN. Nº 1
MAGNETIC NORTH
TRUE NORTH
LEGEND
1 ADMINISTRATION/LIBRARY/LECT. THEATRE
2 CHEMISTRY/CHEM. ENG.
3 ENG./WKSHP/MET.
4 BOILER HOUSE
5 CANTEEN
6 GATE HOUSE
7 STORE
8 GARAGE
9 STAFF HOUSING
10 INF. MAT. STORES
11 REACTOR BUILDINGS
RADIOACTIVE SAMPLING STATION
RADIOACTIVE INVESTIGATIONS AT LUCAS HEIGHTS
NEAR MENAI N.S.W.
PLAN OF SITE
SCALE
100' 0' 100' 200' 300' 400'
Bureau of Mineral Resources, Geology & Geophysics.
G227-7