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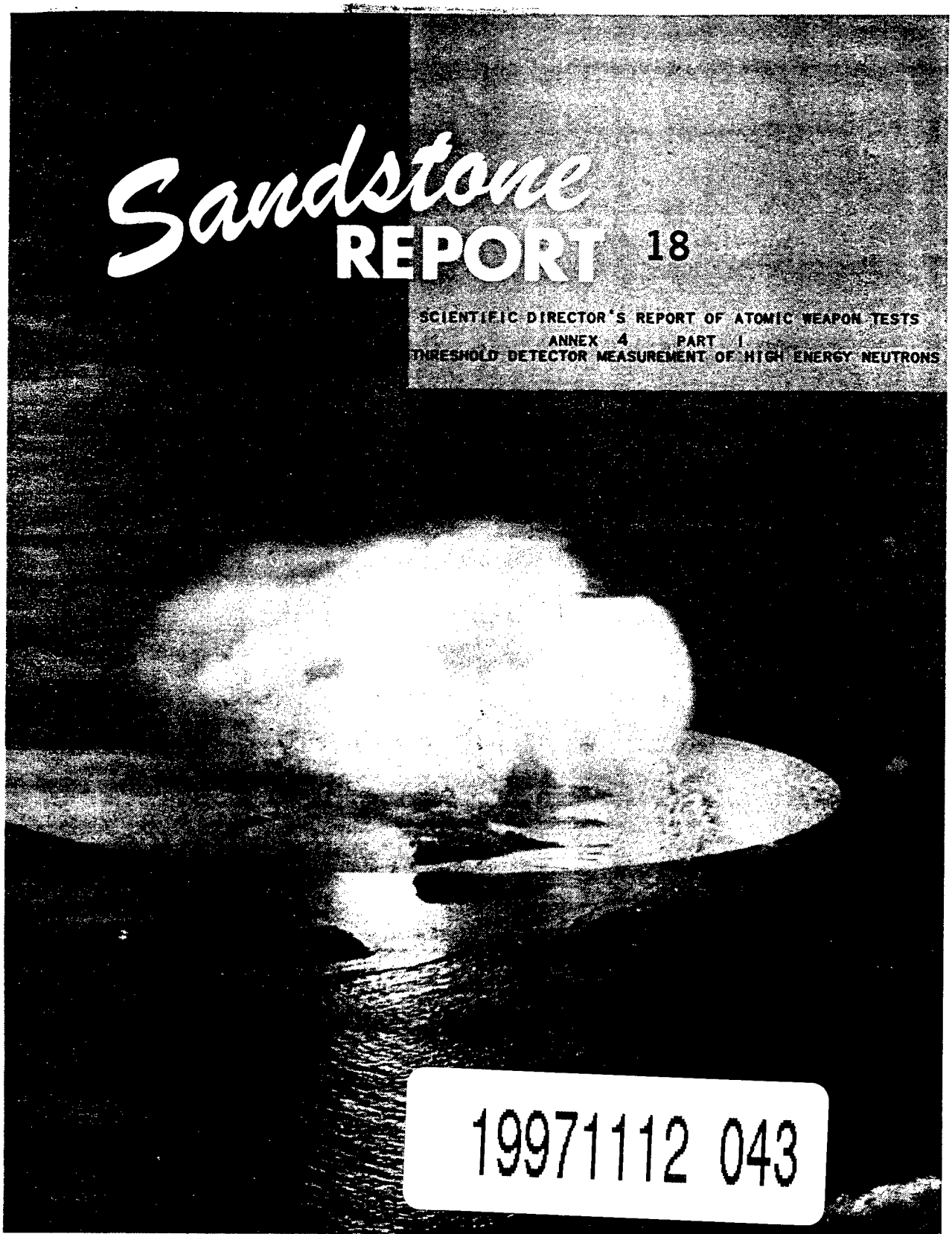
Sandstone REPORT 18

SCIENTIFIC DIRECTOR'S REPORT OF ATOMIC WEAPON TESTS
ANNEX 4 PART I
THRESHOLD DETECTOR MEASUREMENT OF HIGH ENERGY NEUTRONS



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27 March 1997

MEMORANDUM FOR DEFENSE TECHNICAL INFORMATION CENTER
ATTENTION: OMI/Mr. William Bush

SUBJECT: Declassification of Report and Withdrawal of AD-A995436

The Defense Special Weapons Agency (formerly Defense Nuclear Agency) has reviewed and declassified the following report:

OPERATION SANDSTONE REPORT 18, Scientific Director's Report of Atomic Weapon Tests, Annex 4, Part 1, Threshold Detector Measurement of High Energy Neutrons, 1948, written by: G. A. Linenberger and William Ogle.

Since this office has no record of DTIC being on the distribution for this report, we have included a xeroxed copy.

The extracted version of the referenced report which is under AD-A995436 should no longer be sold, since the original version is now declassified and **approved for public release under distribution statement "A."**

This office would like notification of your accession number as soon as possible for our users. If there are questions, please refer them to Mrs. Naomi E. Fields, (703) 325-1038.

for Naomi E. Fields

ARDITH JARRETT
Chief, Technical Resource Center

Enclosure:
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HIGH-ENERGY NEUTRONS FROM THE SANDSTONE NUCLEAR BOMBS AS MEASURED BY THRESHOLD DETECTORS

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February 14, 1949

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SUMMARY

The activity induced in various threshold detectors by the radiation from the Sandstone bombs has been measured. All measurements were made without collimation. The results indicate that the efficiency of a bomb cannot be determined by observing the number of neutrons above three million electron volts energy, but that the tonnage may possibly be proportional to the number of very high energy gamma rays produced.

INTRODUCTION

The fast-neutron measurements carried out by Group LAJ-3 for Operation Sandstone may be divided into two phases. The first phase of the work was the repetition of the type of fast-neutron measurements made at Bikini using sulphur as a detector and reported in LAMS-447. The second phase of the work included the use of several elements as (n,2n) threshold detectors in order to obtain a measure of the neutron flux at relatively high energies, and the use of arsenic as a slow-neutron detector to determine the slow-neutron flux.

The Bikini-Able measurements using sulphur detectors were conducted with two objects in mind: first, to obtain data which would permit a comparison with the neutron flux from the Trinity bomb and hence a comparison of efficiencies; and second, to obtain an attenuation curve for those neutrons detectable by sulphur. No such curve was obtained from the Trinity experiments, and the one result obtained with sulphur was from a detector so much closer to the bomb than the closest Bikini detectors that no reliable extrapolation could be made. Hence, the first objective was not realized. However, a sufficiently good attenuation curve was obtained to consider it worth while repeating the experiment in future tests for the purpose of comparing flux densities; although with changes in bomb models,

these measurements might no longer be simply related to efficiencies.

All Bikini detectors were affixed to ships and hence were over water and perhaps subject to a very different moderating of the neutrons than had they been over land. An analysis of the Bikini results showed no apparent relation (at a given distance) between the activity of a detector and its height above water (which varied from 5 to 135 feet). However, if future tests are to be made where samples can be placed on land, since this is much easier to do, it is important to tie down any significant difference between water and land-based samples. For this reason, in the Sandstone operation sulphur samples were placed over both land and water.

There is strong interest in obtaining a measure of the flux of those neutrons from the bomb in the energy region of 14 Mev. A complete measurement of the neutron-energy distribution and neutron flux is of course desirable; however, at the time this experiment was set up, it was clear that it was necessary to obtain at least a number proportional to the flux above certain energies in order to allow comparison with future bombs. Thus, various (n,2n) threshold detectors were put out to be irradiated by the Sandstone bombs. The method of this experiment, that of using (n,2n) threshold detectors, does not immediately determine the complete neutron spectrum, in that the cross-

sections as a function of energy are not known at this time, but it does give a measure of the high-energy neutron flux. Table 1.1 lists the various detectors used.

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METHOD

Chapter 1

1.1 GENERAL

1.1.1 Materials used as threshold detectors.

As threshold detectors sulphur, carbon, iodine, manganese, arsenic, columbium, nickel, and thallium samples were exposed. Since all of these materials except sulphur are (n,2n) threshold detectors, in which a (γ,n) reaction will produce the same activity, it was decided that duplicate samples would be exposed. One set was shielded by lead in order to discriminate against gammas in the event that a (γ,n) reaction gave an appreciable contribution to the observed activity. Arsenic, which was used as a thermal detector also, was included three times in each set of samples; the third sample being shielded by cadmium and unshielded by lead. For X-ray, at a given distance from the bomb, all of these samples were placed in one large pipe container and half of the container (holding one sample of each material) was shielded by lead.

The various materials were exposed in the following forms:

Sulphur: As sublimed sulphur, Merck, U.S.P. 42667, to be cast into cylinders for counting.

Carbon: As a machined, pile-graphite cylinder of appropriate size to be counted as such. See Fig. 1.1.

Iodine: In crystalline form, to be poured into a thin-walled, cylindrical, lucite container (Figs. 1.2 and 1.3) just before counting.

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Manganese: As finely divided manganese dioxide powder, also to be counted in the same type lucite container.

Arsenic: As a powdered metal, to be counted in lucite holders.

Columbium: As a 20-mil foil, 2-15/32 inches by 3-19/32 inches, to be formed by a special shaping tool (Figs. 1.4 and 1.5) into a cylinder which would slip over a glass-walled Geiger tube.

Nickel: Same as Columbium.

Thallium: As a metal slug about 1/4-inch in diameter and 1-1/2 inches long, to be rolled into a 15-mil foil after irradiation and then shaped and counted in the same manner as the columbium.

The thresholds for these materials are given in Table 1.1. The expected reaction in sulphur is an (n,p). The other reactions are (γ,n) or (n,2n). The (γ,n) thresholds shown for iodine, arsenic, nickel, and carbon have been measured using the Los Alamos 20-Mev betatron. The values shown for thallium, columbium, and manganese are estimated values from incompleted work on the same machine. The cross-section for the $S^{32}(n,p)P^{32}$ reaction has been measured by Klema[1] and is found to be a rapidly increasing function from the threshold, a little above 2 Mev, to where it levels off at about 3 Mev. Thus, for the purposes of this work, the cross-section is assumed to be a step function starting at 3 Mev and of constant value from 3 Mev to the highest neutron energy in the fission spectrum.

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Table 1.1

Threshold Detectors

Detector	Threshold	Half Life
S^{32}	3 Mev (obs.)	14.3 d (P^{32})
Tl^{203}	~6.5	13 d (Tl^{202})
I^{127}	9.45 (obs.)	13.0 d (I^{126})
As^{75}	10.3 (obs.)	16 d (As^{74})
Cb^{93}	~11	10.1 d (Cb^{92})
Ni^{58}	11.7 (obs.)	36 h (Ni^{57})
Mn^{55}	~12	310 d (Mn^{54})
C^{12}	18.7 (obs.)	20.5 m (C^{11})

1.1.2 Sample containers for irradiation.

Sulphur was exposed to the bomb radiation in small pipe nipples, capped on each end. These containers are discussed in detail in section 1.2.1.1. Thin-walled, soft-iron cans, Fig. 1.6, with press-fit brass lids were fabricated to hold the other powder samples. Three such cans (containing arsenic, manganese, and iodine) were stacked end-on, wrapped in the nickel and columbium foils, and bound together as a unit with

scotch tape, one such unit to go in each half of the outer container. The cans were sealed with glyptal. The thallium slugs were inserted in holes in cork spacers, one to each half of the outer container. A third can of arsenic wrapped in 30-mil cadmium foil was placed in the unshielded portion of the outer container. Finally, a carbon cylinder wrapped in steel-wool padding was placed in each end of the outer container. The latter was made of standard 2-inch pipe, fitted with caps on each end and sealed with glyptal. This container is shown in Figs. 1.7, 1.8, and 1.9. A steel ring was brazed to one of the end caps, through which a short length of 1/4-inch steel cable could be fastened with a cable clip, and the 1/4-inch cable was in turn fastened to the main 1/2-inch cable with cable clips. This method of fastening is illustrated in Figs. 1.10 and 1.11.

Multiple-sample units of this type were put out on X-ray at 200,400, 600, 800, and 1000 yards from the base of the tower. Effects of the blast from the X-ray shot on these containers indicated that several changes in design were necessary. There were two main defects: firstly, the inner powder containers were not strong enough to withstand the blast; and secondly, the large outer containers were not strongly enough attached to the main cable. The first difficulty was overcome

by having stronger steel cans fabricated by the machinist of the USS Albemarle. These cans were fitted with screw-in caps. The new-type cans are shown in detail in Fig. 1.12. For fastening the outer containers to the main 1/2-inch cable, 1/2-inch steel rod brackets were welded to each end of the large outer pipe with the intention that these rods be attached to the main cable with cable clips. These brackets proved to be quite satisfactory and are shown in Fig. 1.13. Fig. 1.13 also shows the layout of the large containers as used for Yoke and Zebra.

1.1.3 Lead shielding.

Frederick Reines had calculated that 4 centimeters of lead was an optimum thickness to use in discriminating between (γ,n) and $(n,2n)$ effects. Half-cylinders of lead, 8-3/4 inches long and with a 4-centimeter wall thickness, were cast to shield the multiple land-sample units. These were placed around half of each large outside pipe on the side facing the tower. They were sufficiently loose, so that, when the samples were recovered, the lead shields would detach themselves. This design proved satisfactory and was used for all three shots. No changes were necessary in the dimensions of the shield when the carbon samples were taken out of the large container and put into separate containers. Drawings and

pictures of these shields appear in Figs. 1.10, 1.11 and 1.14.

1.1.4 Distribution of samples on water string.

For each shot, a set of samples was put out both over water and land. The "water string" was made up as follows. A 1/2-inch wire rope was stretched from the base of the bomb tower into the lagoon to a large buoy approximately 2500 yards from the tower. Balsa rafts were fastened to the cable at intervals of approximately 100 yards, from 100 yards to 2000 yards, measuring from the tower end. A container of sulphur was fastened on a mast on each raft. In addition to this, carbon samples were fastened on the 200, 400, 600, 800, and 1000-yard rafts in such a manner that a direct upward pull of about 50 pounds would release them. Carbon samples were put out on the water string only on the first shot. The details of construction will be given later.

1.1.5 Distribution of samples in Land String.

Another set of samples, known as the "land string", was set up on land as follows. A 1/2-inch wire rope was stretched out on the ground from the bomb tower to a winch at the other end of the island. Wooden tripods at 100-yard intervals held a short portion of the cable about 4 feet off the ground. At these points containers of sulphur were fastened to the cable. At the 200, 400, 600, 800, and 1000-yard stations a large

container holding the (n,2n) detectors was fastened to the cable and held in such a manner that some of the samples were shielded by 4 centimeters of lead, while similar samples in another part of the container were not shielded.

1.1.6 Land string detail.

1.1.6.1 Winch

As has been mentioned, the neutron samples on land were attached at 100-yard intervals to a 1/2-inch stranded, steel cable. On each island this cable was laid out over the longest convenient straight-line distance from the base of the tower. This distance varied for the three shots from about 1300 yards to about 1500 yards. The far end of the cable was attached to a large motor-driven winch which was used after each shot to pull the cable out of the highly contaminated area. The winch itself was fabricated by the American Hoist and Derrick Company of St. Paul, Minnesota, and was driven by a 6-cylinder gasoline-power unit manufactured by Minneapolis Moline Company. The winch was capable of exerting a 10-ton pull, which was the breaking load of the 1/2-inch steel cable. The winch drum had a capacity of somewhat over 2000 yards of 1/2-inch cable, and the winch itself was capable of pulling in the length of cable actually used in about an hour. Three such winches were installed, one on each shot island. However,

the X-ray winch, which had its vital parts protected from blast, burning, and fragments, survived the effects of the bomb with very little evidence of damage, and it was used again on both the Yoke and Zebra shots. Although it was not specified that it be designed in this fashion, the winch had a unidirectional drive so that unreeling of the cable was accomplished by disengaging the reel from the driving gear and pulling the cable out with a vehicle. This proved to be no particular disadvantage, and the over-all design and operation of the winch was entirely satisfactory. An idea of the way the winch looked is best obtained by examining Fig. 1.15.

1.1.6.2 Tripods and earth mounds.

All of the materials exposed were detectors of fast neutrons, with the exception of one arsenic sample per each large container which was also used as a slow-neutron detector. Even so, it was thought inadvisable to place the samples directly on the ground for their exposure to the bomb. A simple wooden tripod was designed which consisted of a table about 3 inches thick and 10 inches on a side. Three holes were counter-bored on the underside at an angle of about 30 degrees to the vertical, and three wooden legs were fitted into these to hold the table about 4 feet above the ground (Figs. 1.16 and 1.17). The main cable was pulled out in such

a fashion that sufficient slack was left at each 100-yard station so that the cable could be run up and over each tripod, and the samples were then fastened to the cable in such a position that they would rest on top of the tripod or, in the case of the sulphur, near the top of the tripod on the side facing the zero tower. On X-ray the tripod table was adequate to hold the multiple-sample unit and its lead shield; however, on the Yoke and Zebra setups, where the carbon was placed in separate containers and required additional lead shields, it was found necessary to lay across the tripod a 4-foot length of 2-inch by 12-inch board. The tripods were purposely designed to be sufficiently non-rigid so that those left standing after the blast would be easily pulled over when the winch began to reel the cable in. Experience from the X-ray blast effects indicated that, if something could be done to cut down on the initial velocity given to the samples by the blast, more of the closer-in samples might be recovered. It was decided, therefore, to build up mounds of earth, or bunkers, at the stations from 200 to about 600 yards, and lay the samples near the top of these on the side sloping toward the tower. In addition to this, the main cable was covered with an inch or two of dirt out to about 400 yards. This resulted on Yoke and Zebra in the main cables remaining intact

down to about 100 yards from the base of the tower, and in the recovery of the samples down to and including 200 yards from the base of the tower.

1.1.7 Water-string detail.

1.1.7.1 Rafts and masts.

To support the samples on water, rafts made up of criss-cross laminations of balsa wood were used. Balsa was chosen for this purpose because of its light weight and its relatively high crush-resisting strength. Two sizes of rafts were used. The dimensions for the small rafts were 1.5 by 1.5 by 5 feet and for the large rafts 2 by 2 by 6 feet. It was intended that, on each water string, five large rafts would be used to hold both carbon and sulphur samples. The lead shielding around the carbon samples necessitated the larger raft. A mast was passed through each type of raft, perpendicular to the long dimension. The mast extended some 3 feet above the top of the raft. A lead cylinder 9-1/2 inches long and 1/2-inch thick (Fig. 1.18) was cast around each of the masts used with the large rafts to shield one of the carbon samples. The carbon containers for the water string, described above, held two samples and were placed in the masts in such a way that the lower carbon sample was shielded by the lead. Welded to the side of this type of mast and just above the lead shield was a standard pipe cap

into which the sulphur samples could be screwed. Those masts which held only sulphur samples were fitted at the upper end with a large pipe cap to which a smaller pipe cap was welded back to back and of such a size as to accept the sulphur container. For details of the pipe caps see Fig. 1.19. Pictures and detailed drawings of the two types of masts are shown in Figs. 1.20, 1.21, 1.22, and 1.23.

1.1.7.2 Keels and fastenings.

In order to insure that the rafts would be stable while holding the masts in a vertical position, ballast in the form of one-inch lead sheeting was placed on the under side of the rafts. This ballast was designed to have sufficient weight so that the resultant restoring torque would be at least a factor of two greater than would be necessary to right the rafts from any position. These lead ballasts or keels (Figs. 1.24, 1.25, and 1.26) were fastened to the rafts at three places as follows. A hole just slightly larger than the mast to be used was placed through the center of each type of keel. The keel was then held against the center of the raft by extending the mast down through the keel far enough to screw a standard pipe cap onto the mast. The mast was kept from falling downward through the raft by means of a special pipe clamp placed around the mast and against the topside of the

raft. A picture of this clamp is shown in Fig. 1.20. Near each end of the rafts two 1/2-inch steel studs about 6 inches apart were passed through the rafts parallel to the masts. These studs also passed through the lead keels on the opposite side of the rafts, and were thus used to sandwich the rafts and keels together between two steel plates 1/4-inch thick by 8 inches on a side, the whole assembly being held together by nuts on each end of the studs. The same type of fitting was used for both sizes of rafts, although detailed dimensions varied somewhat between the two.

In order to fasten the rafts to the main 1/2-inch cable, steel eyes were welded to each of the two bottom steel plates (Fig. 1.27) that were used to hold the keels on the rafts. It was planned to loop one end of a 2-foot length of 1/4-inch cable through each of these eyes and fasten it with a cable clip and then fasten the other end of the 1/4-inch cable with cable clips to the main cable. This system was given a trial prior to the X-ray shot and it was found that the constant motion of the rafts due to waves would, in the short time of a day or so, wear the 1/4-inch cable in two. The 1/4-inch cable was hence abandoned and a length of 1/2-inch chain was substituted. The chain was fastened at the raft by means of a shackle through the chain and the above-mentioned eye. The other end of the chain was fastened to the main 1/2-inch

steel cable by means of a shackle and a cable clip. The rafts were thus fastened from the underside at both ends to a main cable and rode with their long dimensions parallel to the main cable. This system of fastening proved to be quite satisfactory and was used for all three shots. Pictures of these chain fastenings are shown in Fig. 1.24.

1.1.7.3 Floating of the cable.

The balsa rafts were sufficiently buoyant that, if placed at 100-yard intervals along the water cable, they would support the entire weight of the water cable, which would hang in catenaries between the rafts. However, due to the presence of coral heads in shallow water for several hundred yards off each shot island, the Navy strongly advised that sections of cable between the rafts be entirely floated by additional buoys if any successful attempt to pull the cable out into deep water after the shot was to be made. It was decided to accomplish this by fastening short lengths of 2 by 4-inch wood to the cable, and it was found that 4-foot lengths of 2 by 4-inch wood placed at 6-foot intervals would adequately float the cable. These were attached by the simple expedient of driving nails into the 2 by 4-inch wood and bending them over the cable to hold it in place. For details concerning the cable floatation see Figs. 1.28, 1.29, and 1.30. In spite of the Navy's pronouncement that

this was a lubberly way of doing things, this system worked admirably in holding the entire length of cable on the surface of the water. The 2 by 4-inch pieces were used out as far as the last sample raft, which was out about 2000 yards. The last section of cable between the last raft and the large anchor buoy was supported by 55-gallon oil drums spaced at approximately 75 or 80-yard intervals.

1.1.7.4 Fastening the cable to the tower.

Winds and currents were such that the water cable, if not fastened to the island, would drift with a quite reasonable velocity away from the island and out into the lagoon. This observation led to the decision that the tower end of the water cable should be fastened to the tower itself so that the heat from the bomb would burn it through and allow the cable to drift out into the lagoon and stream downwind from the anchor buoy. The thought was that this would put the cable in deep and radioactively safe water, and would hence allow quick recovery of the samples after the shot. This turned out not to be the course of events after X-ray, for the blast wrecked the close-in balsa rafts and their lead keels sank and anchored the cable in place. However, it was found that the water in the lagoon two days after the shot was sufficiently inactive that the sulphur samples could be

recovered at that time, so no change in the cable layout was made for the Yoke and Zebra shots.

1.1.7.5 Anchor buoy.

The large anchor buoy referred to, which was used to hold the outer end of the water cable, was made up of an array of two by four standard Navy pontoon cells. This float was sufficiently buoyant to support about a five-ton load and was held in place by means of four anchors attached to its four corners in such a manner that it would resist about a 10-ton horizontal drag.

1.1.8 Foil shaper.

A foil shaper constructed by the Los Alamos shops was used to shape the nickel, columbium, and thallium samples into cylinders. The shaper consisted of a central solid cylinder and two half-cylinders on hinges which fitted around this central cylinder. The flat metal foil was slipped into the foil shaper and the two half-cylinders brought up tight against the center cylinder. This formed the foil into a cylinder of the proper size to be counted on the glass Geiger tubes. Unfortunately the shaper was made of such a size that the foils fitted the glass tubes exactly and did not allow clearance over the pump-out leads on the front of the tubes. It was, therefore, necessary to leave a slight gap at the edges of each

foil in order that it could be slipped onto a counter. The foil shaper is shown in Figs. 1.4 and 1.5.

1.1.9 Counting room.

A counting room having two thin-walled aluminum counters for use with the sulphur and five glass Geiger counters for the other samples was set up on the USS Albemarle, AV-5. Fig. 1.31 shows this room with the seven lead-housed counters and attached scaling and recording apparatus. The laboratory next to the counting room was used to prepare the samples for counting.

1.1.10 Counter tubes.

All of the materials except sulphur were counted on thin-walled glass Geiger tubes obtained from the Radiation Counter Laboratories Inc., of Chicago, Illinois. Their Model 10-A, Mark I was used. These tubes have a plateau approximately 200 volts long and an operating voltage of about 1000 volts. They were operated just slightly above the center of the plateau. The samples used covered a large portion of the active-counting volume of the tubes. Since the counting efficiency varies appreciably toward the end of the active-counting volume, it was necessary to be very careful in reproducing the counting geometry used from sample to sample. This also meant that the uranium glass standards (used to check the constancy of counter

efficiencies) had to be positioned very accurately. Except for this last difficulty, the tubes were found to be quite satisfactory and no tube failures were experienced during the experiment. The Geiger tubes used to measure the sulphur activity were the same tubes as used by Klema at Trinity and by Linenberger and Ogle at Bikini. Each tube has a 7-mil aluminum wall and is 7-3/4 inches long and .889-inch in outside diameter. It is filled with a mixture of 95% argon and 5% ethyl alcohol to a pressure of 15 centimeters of mercury. A drawing for this tube is given in Fig. 1.32.

1.1.11 Scalers and Mechanical counters.

Model 402 power supplies and scalers were used for counting. These were constructed by the Electronics Group at Los Alamos. No effort was made to tropicalize the circuits. However, the only difficulty experienced under tropical conditions was the frequent burning out of the potentiometer controlling the high voltage. When these were replaced with higher wattage potentiometers, very little further difficulty was experienced. Cyclotron Specialties Company mechanical registers were used. The B-plus output of the scaler very soon sparked over to the metal casing of these registers, and it was found necessary to insulate the whole register from ground.

1.1.12 Method of counting.

The counting procedure varied with the material to be counted. Because of the short half-life, the most difficult element to count was carbon. It was expected that ten or twelve carbon samples would be recovered from each shot and since there were only five counting sets available to count the carbon it was necessary to count at least two samples on each counter. In general, the shielded and unshielded samples from any one station were counted on the same counter tube. The two samples were then alternated on that counting tube, counts of five-minute duration being taken on each one. The decay curves were followed to background or until it was no longer profitable to count. A background and standard was taken before counting on the carbon began, and after the counting was finished. The other elements all had sufficiently long periods that all samples of one element could be counted on one counter. For these elements, each point on a decay curve represents approximately 10,000 individual pulses. The samples were counted in rotation on one counter as often as possible. This meant that after three shots as many as 50 individual samples had to be counted on one counting setup. All samples were followed until it was clear that the looked-for activity was determined, or could not be determined due to the presence of contamination.

1.2 DETECTOR DETAIL

1.2.1 Sulphur, irradiation and preparation.

1.2.1.1 Sulphur containers for irradiation.

Powdered sublimed sulphur was exposed to the bomb radiation in two types of containers. One of the sulphur containers used on the land string is shown in Figs. 1.33 and 1.34. It consists of a 1-1/4-inch pipe nipple 5 inches long, with a pipe cap on each end. A 1/2-inch iron rod was welded to the nipple and bent in such a fashion as to present a sloping front surface to any obstacle during the time the cable was being winched in. The 1/2-inch rod was fastened to the main 1/2-inch cable with a single cable clip. The end of the container that was away from the 1/2-inch rod was tied to the main cable with soft iron wire. The container held 100 grams of sulphur. A sulphur container, of the type used on the water string, is shown in Fig. 1.35. It consists of a 1-1/4-inch pipe nipple 5 inches long, with a pipe cap on one end and a cork in the other. Both ends were covered with glyptal to prevent the entrance of sea water. The corked end was screwed into a cap welded on the raft mast as shown in Figs. 1.20 and 1.21. The container held 100 grams of sulphur.

1.2.1.2 Preparation of sulphur samples for counting.

After each shot, the sulphur containers were brought

back to the ship and carefully opened, considerable precautions being taken not to include any contaminating crud from the container itself. The active sulphur was placed in a No. 3 laboratory porcelain casserole which was placed in a drying oven set to a temperature of 140 degrees centigrade. Although this temperature is some 20 degrees above the melting temperature of the sulphur, it was used because it considerably speeded up the time required to melt the sulphur. However, care was taken not to let the sulphur reach the oven temperature, because at this temperature the molten sulphur becomes very viscous, whereas just above its melting temperature it is quite fluid. While the sulphur was melting, a process which took from 20 to 30 minutes, the special mold in which the sulphur was to be cast was cleaned and labelled. This mold was originally designed by Klema to use in counting the Trinity sulphur. It involves a central core of just slightly larger diameter than the outside diameter of the aluminum-walled Geiger tubes on which the sulphur was counted. Concentric with this core is a cylindrical brass tube, the inside diameter of which is roughly 6 mm larger than the outside diameter of the central core. With this device a cylindrical tube of sulphur can be cast having a wall thickness of roughly 3 mm which will just fit snugly over the Geiger tube. To protect the rather fragile sulphur, the outer brass tube was left

around the sulphur cylinder, forming a part of the sample unit itself. Details of the various parts of the mold and the way in which these parts are assembled may be seen in Figs. 1.36, 1.37, and 1.38. Since there was some difficulty with the X-ray sulphur cylinders tending to slip out of the brass tubes, grooves were undercut on the inside near each end of the tubes to hold the sulphur in place for Zebra and Yoke. When the sample in the oven showed signs of melting, the assembled mold was also placed in the same oven to be heated. Experience had shown that preheating of the outer mold was necessary; otherwise the heat capacity of the mold would be sufficiently high that the sulphur would freeze as it was poured in and prevent the formation of a good casting. When the sulphur had completely melted, the casserole and the mold were both removed from the oven, and the sulphur poured into the mold until it was full. The filled mold was then allowed to stand for about 10 minutes before the central core of the mold was extruded by means of a hydraulic press. This waiting period of 10 minutes was found empirically to be the optimum length of time that the sulphur should be allowed to cool before extrusion in order to obtain the best inside surface on the sulphur with a minimum amount of extrusion pressure. The end pieces on the mold were, of course, removed before the extrusion of the central core could be accomplished. In order

to identify each sulphur sample, the iron-pipe containers placed at various distances from the bomb were numbered with steel number dies, and these numbers were recorded as a function of position of the sample. The number of a particular sample after the sample was recovered was then inscribed on the outside of the brass tube into which that particular sample would be cast. In order to know how much sulphur was in a cast sample, a tare weight was taken on the brass tube before the casting, and this weight inscribed on the side of the tube along with the gross weight measured after the sulphur had been poured. The empty brass sample tubes weighed about 190 grams on the average, whereas the tubes with the sulphur sample weighed about 230 grams. The weighings were made on a triple-beam balance which was found to reproduce weighings of this order of magnitude to about one tenth of a gram. All of the sulphur-counting data has been corrected to a sample weight of 40 grams by multiplying the actual counting rates by the ratio of 40 grams to the true weight.

1.2.1.3 Sulphur dilution.

Most of those sulphur samples that were closer to the bombs than 600 yards were too active to count a 40-gram sample right after the tests. A number of these would obviously be too active to count for many months to come; however a

40-gram sample was cast in each case. And, where it was convenient to do so, a small amount of the powdered active sulphur was saved out to be used in making diluted samples from which preliminary data could be obtained while waiting for the 40-gram sample to reach a countable activity. This dilution process was carried out by first making an estimate of the order of magnitude of the counting rate to be expected from a particular 40-gram sample. An appropriate fraction of 40 grams of the active sulphur was then weighed out and added to a known weight of inactive sulphur. The resultant mixture was melted and stirred quite thoroughly and then cast into another 40-gram sample consisting mostly of inactive sulphur with a small amount of active sulphur uniformly distributed throughout it. Since these sulphur samples as cast are thick to their own beta radiation, it is obviously quite important that the active sulphur be uniformly distributed throughout the inactive sulphur in these diluted samples. To check this point, two diluted samples were made up from the original batch of active sulphur and the resulting counting rates of the diluted samples were found to be strictly proportional to the weight of active sulphur included in each sample, indicating that the mixing was good and that questions involving self-absorption could be ignored. The weights of active sulphur used in the diluted samples varied from about 1/2-gram up to

about 5 grams. These were weighed out, for the most part, on an assay balance after returning to Los Alamos; however, a couple of diluted samples were made up at Eniwetok using not less than 5-gram amounts of active material for which it was felt the triple-beam balance would weigh satisfactorily to 1 or 2 percent. Those data taken from diluted samples will be discussed in the results.

1.2.2 Arsenic, Iodine and Manganese.

The arsenic and iodine were in the form of the pure element; however, the manganese was used as the dioxide. All of these were obtained as powders and had to be held in iron containers (mentioned previously) for irradiation. After irradiation the powders were put into lucite sample holders with an innerwall thickness of ten mils for counting purposes. The sample holders are shown in Figs. 1.2 and 1.3. In order to facilitate putting the powders into the sample holders, a special funnel was used as shown in Figs. 1.39 and 1.40. A different funnel was used for each type of sample, and the funnel was carefully washed and cleaned between samples.

1.2.3 Thallium

The thallium was obtained in the form of the metal and was a slug approximately a quarter of an inch in diameter and an inch long, weighing about one ounce. For irradiation the

thallium samples were held in a hole in a cork which fitted into the multiple sample holder. After irradiation the samples were carefully washed and then rolled to approximately 13 mils thickness in a roller provided for that purpose. The samples were then cut in to the proper size to be shaped into a cylinder using the foil shaper so as to just fit around the glass Geiger tubes used. The thallium samples weighed approximately 24.5 grams.

1.2.4 Nickel

The nickel used as an (n,2n) detector was in the shape of a foil 3-19/32 inches long, 2-15/32 inches wide and 20 mils thick. The weight was approximately 25.5 grams. The nickel foils were wrapped around the small cans containing the powder samples. This unit was then placed in the large multiple sample container and exposed to the bomb radiation. After removal from the multiple sample container, the nickel was washed carefully with alcohol and then formed into a cylinder (using the foil shaper) to such a diameter that it would just fit over the glass counter tubes used. It was found necessary in the case of some of the more active nickel samples to cut a strip along the three-inch dimension approximately an eighth of an inch wide, which was then fastened on the inside of the large-diameter part of one of the lucite sample holders and counted in this geometry.

1.2.5 Columbium

Columbium metal was in the form of sheets 3-19/32 inches long, 20 mils thick and 2-13/32 inches wide. It was wrapped around the powder containers inside the multiple sample container for irradiation. After irradiation the columbium was washed and formed into a cylinder with the foil shaper of the proper size to fit over the glass-wall counter used.

In the case of some of the 200-yard columbium samples recovered, it was necessary for counting to cut a strip along the three-inch dimension which was fastened in the same manner as the nickel strips mentioned previously.

1.2.6 Carbon

Since carbon^{11} has a 20.5-minute half-life, the rapid recovery of carbon after a nuclear explosion was essential. In order to facilitate this, the carbon samples on the water string were to be recovered by helicopter as soon as possible after the shot. The carbon on the land string was pulled in with the winch and then transferred by helicopter from the island to the laboratory ship for counting.(2)

The carbon samples that were to be exposed over water had to be attached to the supporting rafts in such a manner

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(2) A discussion of the recovery plan is given in Appendix I.

that they could be quickly and easily detached from a helicopter as it hovered over each raft. Tests were made by the Navy using a Sikorsky H03S helicopter which is equipped with a motor-driven winch. It was found that from a height of 20 to 40 feet a vertical ring about 2-1/2 feet in diameter could be picked up with a grapple attached to the winch cable. The carbon containers were thus designed as follows. An iron pipe welded closed on one end and of sufficient length to contain two carbon samples (one to be lead-shielded) was fitted with a standard pipe cap on the other end, to which was welded a steel ring 30 inches in diameter, made of 1/2-inch steel rod. These pieces are shown in detail in Figs. 1.41 and 1.42 and are pictured assembled in Figs. 1.22 and 1.23. For installation on and easy removal of the carbon containers from the rafts, the latter were fitted with pipe masts into which the carbon containers would fit. Spring-steel clips were affixed to the top end of each mast and adjusted so that the carbon container assembly (weighing about 10 pounds) would require about a 40-pound pull to dislodge it. This was to insure that normal wave motion would not throw the samples out, and it was hoped that the blast would not do so either. Detailed drawings of these masts showing the spring clips and the lead shields, and pictures of same, are included in the section describing the rafts.

On both X-ray and Yoke the carbon samples were of the same type; namely, they were cylinders machined from pile graphite 3 inches long, having an inside diameter of 0.80 inches and an outside diameter of 1.15 inches. The inside diameter was dictated by the outside diameter of the glass-walled counter tubes which were to be used to count the carbon.

The carbon activated in the X-ray shot showed the presence of rather large activities of periods other than the 20.5-minute period that was expected from the (n,2n) reaction. It was thought that these activities might be due to contamination from the other samples in the large multiple containers, so for the Yoke shot the carbon was removed from the multiple containers and placed in a separate pipe fitted with standard caps on each end and also having a 1/2-inch rod bracket welded to it by means of which the carbon container could be fastened to the main cable. These carbon containers were satisfactorily used on both Yoke and Zebra and are shown in Fig. 1.43. The placing of the carbon in separate containers required additional lead shields. This was handled quite simply by laying the carbon samples behind lead bricks, 2 by 4 by 8 inches, in such a manner that one sample was behind the brick and one was not. A further consequence of the blast effect from X-ray was the abandonment

of water-carbon samples entirely, for the shock wave threw all of the carbon containers free of the rafts. The decision to omit the water carbon was further abetted by the fact that the X-ray land carbon was collected and delivered to the laboratory ship in a sufficiently short time to enable counting.

The undesirable activities found in the X-ray carbon were also largely present in the Yoke carbon samples, indicating that they were due to impurities in the carbon rather than contamination from other samples. For this reason, it was decided to try to obtain spectroscopically pure carbon for the Zebra test. This was obtained and came in the form of solid rods 1/4-inch in diameter and 1-1/2 inches long. The spectroscopic carbon was irradiated in the same type of container as was used for the land carbon on Yoke, each sample consisting of a bundle of these rods wrapped together in packing material and placed in the iron pipe. Lest there still be difficulties of impurities in the carbon, an additional precaution was taken on the Zebra shot in that the inside of the iron pipes that held the carbon samples were lined with 30 mils of cadmium. The graphite rods were fortuitously of such dimensions as to allow thirteen of the rods to be inserted in one of the lucite holders which had been designed for counting the powder samples, which then formed a convenient geometry

for counting on the glass-walled tubes. It was thought that there might be too much activity from all thirteen carbon rods on the closer stations on Zebra, and if an appreciable amount of this activity were due to longer periods from impurities, the 20-minute activity would suffer by waiting for the over-all sample to decay. On the basis of this line of reasoning only four carbon rods to a sample were put out at the 200 and 400-yard stations.

DATA

Chapter 2

2.1 GENERAL

Sulphur and iodine decayed with periods corresponding to those expected, so the data were obtainable from these materials and are given in Sections 2.2 and 2.3 of this chapter.

Nickel decayed initially with a period which appeared to be the 36-hour expected from the (n,2n) reaction on Ni^{58}. However, it soon became evident that there was a long tail on the decay curve and, when this was subtracted from the short part, the apparent period became about 27 hours. Chemistry on similar samples irradiated by a U^{235} source in the water boiler[3] has shown that this short period is definitely not Ni^{57}, but rather is due to impurities in the sample. Thus, the data on nickel are valueless for determining fast-neutron fluxes from the bombs.

Similarly, the irradiated graphite decayed initially with a period corresponding approximately to the 20.5-minute period expected from the (n,2n) reaction on C^{12}. Later work with water-boiler irradiations,[4] however, has shown that

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(3) LA 724
(4) LA 727

this activity is due entirely to impurities in the spectroscopically pure graphite used. Thus, the data from carbon are also of no value in determining the fast-neutron flux from the bombs used in Sandstone.

At the time of writing (February 14, 1949) it appears that some data will come out of the arsenic, but that it may require several months yet to obtain a good value for the longest period observed. The arsenic appears to have had antimony as an impurity, so that a large portion of the activity observed is due to the (n,γ) reaction on Sb^{123}. These data will be reported when they become available.

Thallium and columbium both had long-period contaminants that became sufficiently active to completely override the activity expected from the (n,2n) reaction, so that no data on the fast-neutron flux will be available from those materials.

Manganese also had contaminating activities, but these may turn out to be short compared to the 310-day period expected of Mn^{54}. Most of the samples irradiated are now completely dead, however, a few from the closer positions are still active and are approaching the 310-day period hoped for.

The atmospheric conditions, at the time of the shots, are given in Table 2.2.

2.2 SULPHUR

The following discussion deals with the results obtained from the neutron-activated sulphur samples. For each shot, as has been mentioned previously, sulphur samples were put out at various distances from the bomb, both along the island and over the water out in the lagoon, so that two attenuation curves were obtained from each shot.

It is expected that the activity induced in a sample of sulphur by neutrons from a nuclear bomb will follow an equation of the form

$$A \sim \frac{e^{-\frac{R}{\lambda}}}{R^2}$$

where R is the distance of the sample from the bomb and λ is the mean free path in air of the neutrons inducing that activity. Thus, the data are arranged in such a manner as to give easily the values of λ and of the activity for R = 1 yard.

The data are given in Table 2.1 (a-g). The distance of the sample from the bomb shown in the second column is calculated on the basis of the bombs being 73.4 yards above ground. The initial counting rate for the sample, uncorrected for weight, is given in the fourth column. The initial counting rate times the square of the distance from bomb to sample, corrected to a 40-gram sample weight, is shown in the fifth column. The last column will be discussed under "Calculations". The data on

various miscellaneous samples put out as neutron monitors for other people are given in Table 2.1 (g).

The resulting six curves are shown in Figs. 2.1 to 2.6. The curves have as ordinates the product of counts per minute from a 40-gram sample (extrapolated back to detonation time) and the square of the straight-line distance between the bomb and the particular sample; this distance, R, being taken in yards. The values of R are plotted along the abscissae.

Table 2.1

(a) X-ray Land Sulphur

Sample Number	Distance from Bomb Yds.	Sample Weight Gms.	Initial Counting Rate C/m	I.C.R x R^2 for 40 gm Sample	Neutrons/cm^2
100*	315	41.4	4.338×10^5	4.158×10^{10}	1.015×10^{12}
120	511	42.5	70,024	1.724×10^{10}	1.60×10^{11}
96	610	44.0	34,188	1.158×10^{10}	7.46×10^{10}
80	709	43.0	14,000	6.54×10^9	3.15×10^{10}
110	808	40.0	7,325	4.786×10^9	1.77×10^{10}
69	908	44.0	3,195	2.394×10^9	7.04×10^9
78	1008	45.0	1,539	1.393×10^9	3.31×10^9
98	1107	44.0	1,153	1.285×10^9	2.54×10^9
127	1307	44.0	248	3.851×10^8	5.45×10^8
132	1407	44.0	157	2.824×10^8	3.46×10^8
108	1499	43.0	171	3.572×10^8	3.85×10^8

* Data from diluted sample.

Table 2.1

(b) X-ray Water Sulphur

Sample Number	Distance from Bomb Yds.	Sample Weight Gms.	Initial Counting Rate C/m	I.C.R. x R^2 for 40 gm Sample	Neutrons/cm^2
24	575	43.7	47,450	1.434×10^{10}	1.05×10^{11}
48	711	42.8	10,800	5.105×10^{9}	2.44×10^{10}
57	816	42.2	5,932	3.747×10^{9}	1.36×10^{10}
41	898	43.0	3,051	2.288×10^{9}	6.86×10^{9}
23	975	43.0	1,778	1.492×10^{9}	4.00×10^{9}
50	1090	43.1	936	1.006×10^{9}	2.1×10^{9}
56	1211	43.0	493	6.22×10^{8}	1.1×10^{9}
144	1342	43.7	344	5.834×10^{8}	7.6×10^{8}
37	1448	42.0	115	2.295×10^{8}	2.65×10^{8}
3	1549	44.8	78.1	1.673×10^{8}	1.69×10^{8}
51	1649	42.5	31.5	8.07×10^{7}	7.17×10^{7}
136	1864	43.4	9.61	3.09×10^{7}	2.15×10^{7}

Table 2.1

(c) Yoke Land Sulphur

Sample Number	Distance from Bomb Yds.	Sample Weight Gms.	Initial Counting Rate C/m	I.C.R. x R^2 for 40 gm Sample	Neutrons/cm^2
125	215.1	41.1	4.22×10^6	1.90×10^{11}	9.94×10^{12}
105	310.3	41.7	1.60×10^6	1.47×10^{11}	3.71×10^{12}
102	400	40.95	5.77×10^5	9.01×10^{10}	1.36×10^{12}
106	605	42.3	95,860	3.324×10^{10}	2.2×10^{11}
124	688	42.5	60,498	2.694×10^{10}	1.38×10^{11}
101	897	41.6	10,990	8.51×10^9	2.56×10^{10}
109	997	42.3	5,695	5.35×10^9	1.30×10^{10}
61	1096	43.0	3,010	3.36×10^9	6.77×10^9
128	1196	42.2	2,042	2.771×10^9	4.68×10^9
104	1296	43.5	888	1.372×10^9	1.98×10^9
66	1701	42.0	83.1	2.29×10^8	1.92×10^8

Table 2.1

(d) Yoke Water Sulphur

Sample Number	Distance from Bomb Yds.	Sample Weight Gms.	Initial Counting Rate C/m	I.C.R. x R^2 for 40 gm Sample	Neutrons/cm^2
53	330	39.9	8.19×10^5	8.919×10^{10}	1.99×10^{12}
60	526	41.8	1.447×10^5	3.833×10^{10}	3.34×10^{11}
27	622	42.9	7.740×10^4	2.794×10^{10}	1.75×10^{11}
139	724	41.9	3.976×10^4	1.99×10^{10}	9.19×10^{10}
44	826	39.9	1.463×10^4	1.00×10^{10}	3.55×10^{10}
5	926	41.7	7.945×10^3	6.54×10^9	1.84×10^{10}
39	1031	42.7	5.746×10^3	5.71×10^9	1.30×10^{10}
138	1127	41.3	2.618×10^3	3.23×10^9	6.13×10^9
21	1223	42.5	1.596×10^3	2.25×10^9	3.63×10^9
2	1317	42.2	7.80×10^2	1.282×10^9	1.79×10^9
22	1428	42.7	461.1	8.80×10^8	1.05×10^9
20	1517	42.6	164.3	3.55×10^8	3.72×10^8
18	1627	42.2	76.5	1.919×10^8	1.75×10^8

Table 2.1

(e) Zebra Land Sulphur

Sample Number	Distance from Bomb Yds.	Sample Weight Gms.	Initial Counting Rate C/m	I.C.R. x R^2 for 40 gm Sample	Neutrons/cm^2
122	214.6	42.9	1.084×10^6	4.65×10^{10}	2.45×10^{12}
79	309.8	42.4	3.243×10^5	2.936×10^{10}	7.41×10^{11}
131	417.3	42.5	1.21×10^5	1.982×10^{10}	2.76×10^{11}
133	506.0	41.6	5.918×10^4	1.433×10^{10}	1.38×10^{11}
88	594.0	41.5	2.672×10^4	9.09×10^9	6.22×10^{10}
116	704.3	42.4	12,329	5.77×10^9	2.82×10^{10}
89	803.7	41.9	5,848	3.608×10^9	1.35×10^{10}
64	903.0	41.8	2,611	2.037×10^9	6.05×10^9
130	1002.7	42.2	1,348	1.284×10^9	3.09×10^9
117	1102.4	42.7	809	9.21×10^8	1.83×10^9
65	1202.2	42.0	527.3	7.26×10^8	1.22×10^9
70	1302	43.2	223.4	3.50×10^8	5.00×10^8
77	1402	43.2	127.0	2.31×10^8	2.84×10^8

Table 2.1

(f) Zebra Water Sulphur

Sample Number	Distance from Bomb Yds.	Sample Weight Gms.	Initial Counting Rate C/m	I.C.R. x R^2 for 40 gm Sample	Neutrons/cm^2
35	296.2	41.2	3.314×10^5	2.824×10^{10}	7.8×10^{11}
82	296.2	42.5	3.235×10^5	2.672×10^{10}	7.36×10^{11}
15	394.0	42.1	1.331×10^5	1.962×10^{10}	3.06×10^{11}
10	491.5	42.6	6.412×10^4	1.454×10^{10}	1.46×10^{11}
113	491.5	41.8	4.80×10^4	1.11×10^{10}	1.11×10^{11}
6	610.4	42.3	2.053×10^4	7.24×10^9	4.69×10^{10}
84	610.4	42.9	2.32×10^4	8.06×10^9	5.24×10^{10}
142	700.9	42.5	8436	3.899×10^9	1.92×10^{10}
42	804.4	42.0	4722	2.908×10^9	1.09×10^{10}
1	903	42.6	2456	1.881×10^9	5.56×10^9
32	903	41.8	2118	1.653×10^9	4.9×10^9
40	988	43.0	1239	1.125×10^9	2.79×10^9
34	1087	42.8	615.9	6.81×10^8	1.40×10^9
33	1189	41.0	333.0	4.60×10^8	7.85×10^8
36	1285	42.6	159.0	2.464×10^8	3.60×10^8
17	1382	39.6	92.8	1.79×10^8	2.27×10^8
11	1703	42.0	24.5	6.76×10^7	5.65×10^7
30	1806	42.0	9.1	2.83×10^7	2.1×10^7

Table 2.1

(g) Miscellaneous Sulphur Samples

Sample Number	Shot	Position	Sample Weight Gms.	Initial Counting Rate C/m	Neutrons/cm^2	Remarks
152	Yoke	Inside Gamma C in line with collimator	41.5	110	2.6×10^8	Error probably large because period shorter than expected.
47	Yoke	Inside Gamma B in line with collimator	43.5	10.5	2.3×10^7	No geometry correction has been made for the Gamma Shelter Samples.
160	Yoke	Inside Gamma A in line with collimator	43.1	735	1.65×10^9	
159	Yoke	In timing station out of coffin	42.8	4.9	1.1×10^7	
164	Yoke	In coffin in timing station	41.8	2.4	5.6×10^6	
156	Yoke	In 500 yd. Water-Animal Tank	40	3.76×10^4	9.1×10^{10}	For Scoville
162	Yoke	Behind 2" steel shield at 700 yds.	40	2.33×10^4	5.6×10^{10}	For Scoville

Table 2.1 (g) cont.

Sample Number	Shot	Position	Sample Weight Gms.	Initial Counting Rate C/m	Neutrons/cm^2	Remarks
151	Yoke	?	40	1.36×10^4	3.3×10^{10}	For Scoville
155	Zebra	Gamma A	42.5	100	2.3×10^8	5° tube, zero absorber. Error large because sample didn't follow correct decay curve.
167	Zebra	Gamma A	42.3	100	2.3×10^8	5° tube, 3" B_4C, 50% calc. atten. Error large for same reason as above.
161	Zebra	Gamma A	42.7	~20	4.5×10^7	Background sample, on floor near entrance.
163	Zebra	Gamma B	42.2	~10	2.3×10^7	Background on forward wall, error large.
171	Zebra	Timing Station	42.1	~30	6.9×10^7	Background on forward wall.
175	Zebra	Timing Station	42.2	~80	1.8×10^8	In coffin.

Table 2.2

Atmospheric Conditions at Time of Shot

	Pressure (Millibars)	Temp.	Rel. Humid.	Mass H_2O (Sat.)	Mass H_2O (Actual)
Trinity	851.7	20° C.	.77	17.12 gm/m^3	13.2 gm/m^3
Bikini-Able	1011.7	28.6° C.	.79	27.84	22.0
X-ray	1011.9	25.5° C.	.96	23.45	22.5
Yoke	941.1	26.1° C.	.83	24.15	20.0
Zebra	1007.5	27.0° C.	.84	25.49	21.4

Figure 2.1

X-ray Land Sulphur

Counts/min x R^2 vs R

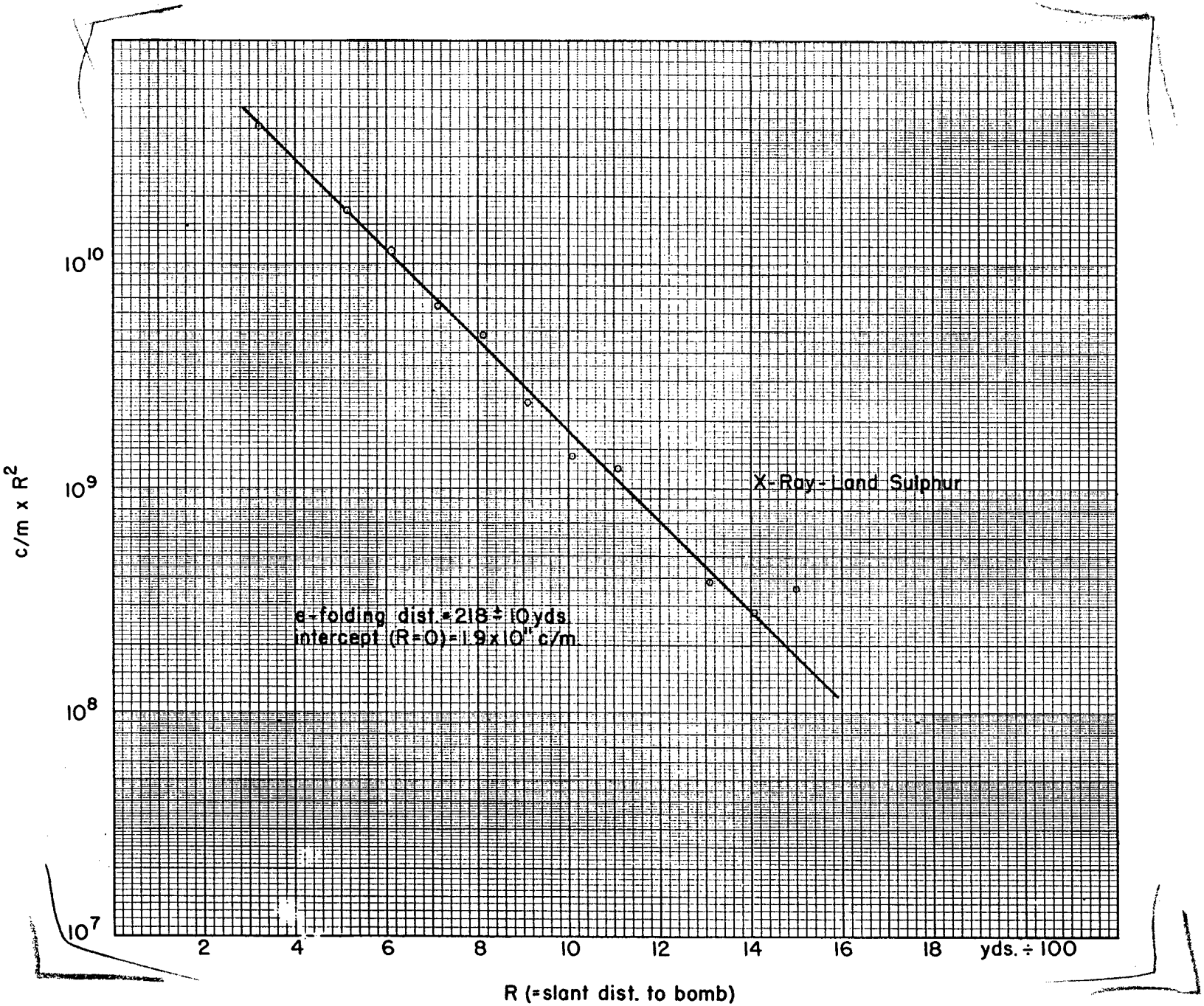

X-Ray - Land Sulphur
e-folding dist. = 218 ± 10 yds.
intercept (R=0) = 1.9 x 10^11 c/m.
c/m x R^2
10^10
10^9
10^8
10^7
2
4
6
8
10
12
14
16
18
yds. ÷ 100
R (= slant dist. to bomb)

Figure 2.2

X-ray Water Sulphur

Counts/min x R^2 vs R

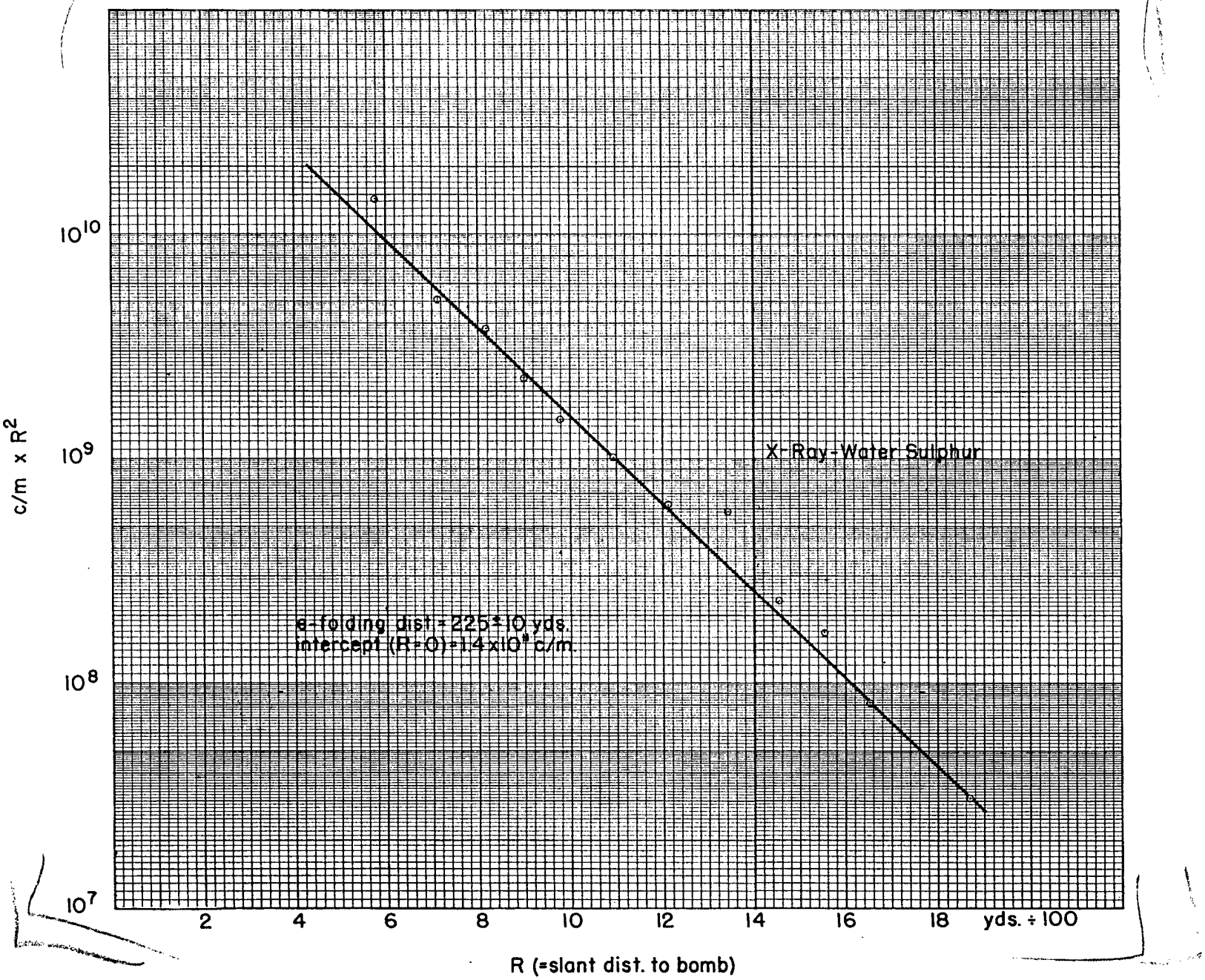

10^{10}
10^{9}
10^{8}
10^{7}
c/m x R^2
X-Ray-Water Sulphur
e-folding dist = 225 ± 10 yds.
intercept (R=0) = 1.4 x 10^{9} c/m
2
4
6
8
10
12
14
16
18
yds. ÷ 100
R (=slant dist. to bomb)

Figure 2.3

Yoke Land Sulphur

Counts/min x R^2 vs R

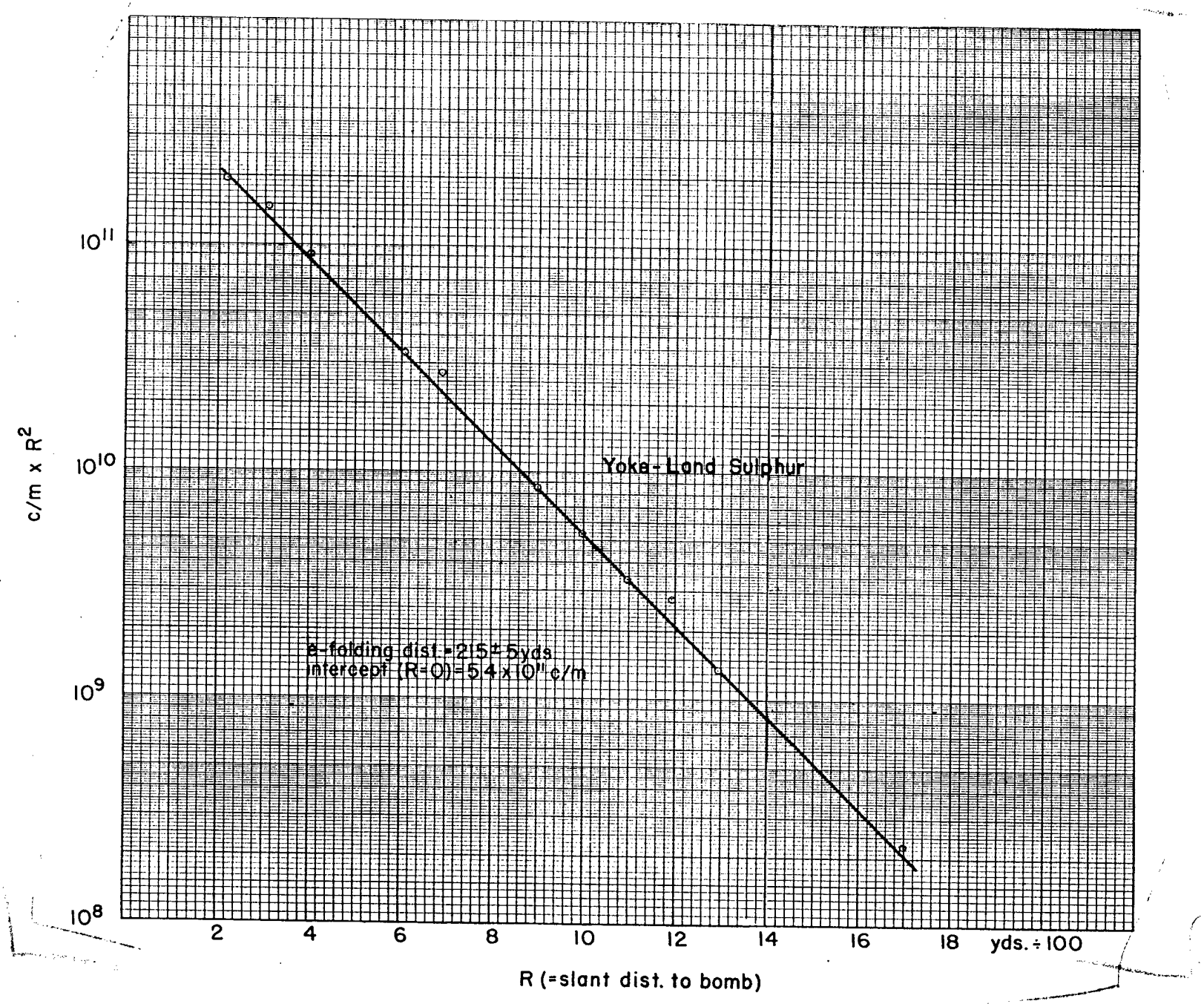

Yoke-Land Sulphur
e-folding dist. = 215 ± 5 yds.
intercept (R=0) = 5.4 x 10^11 c/m
c/m x R^2
10^11
10^10
10^9
10^8
2
4
6
8
10
12
14
16
18
yds. ÷ 100
R (=slant dist. to bomb)

Figure 2.4

Yoke Water Sulphur

Counts/min x R^2 vs R

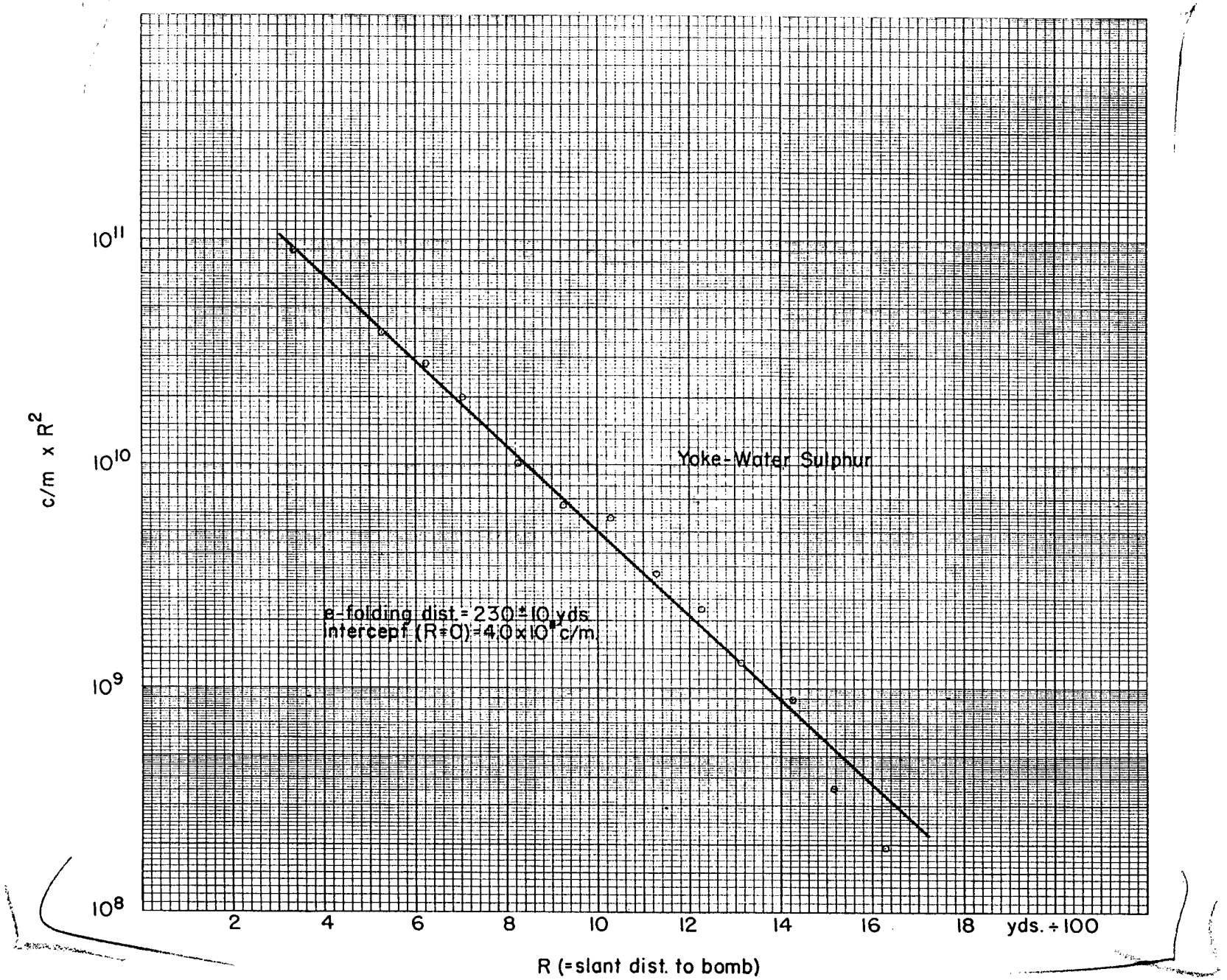

10^{11}
10^{10}
10^{9}
10^{8}
c/m x R^2
Yoke-Water Sulphur
e-folding dist. = 230 ± 10 yds.
intercept (R=0) = 4.0×10^{9} c/m
2
4
6
8
10
12
14
16
18
yds. ÷ 100
R (=slant dist. to bomb)

Figure 2.5

Zebra Land Sulphur

Counts/min x R^2 vs R

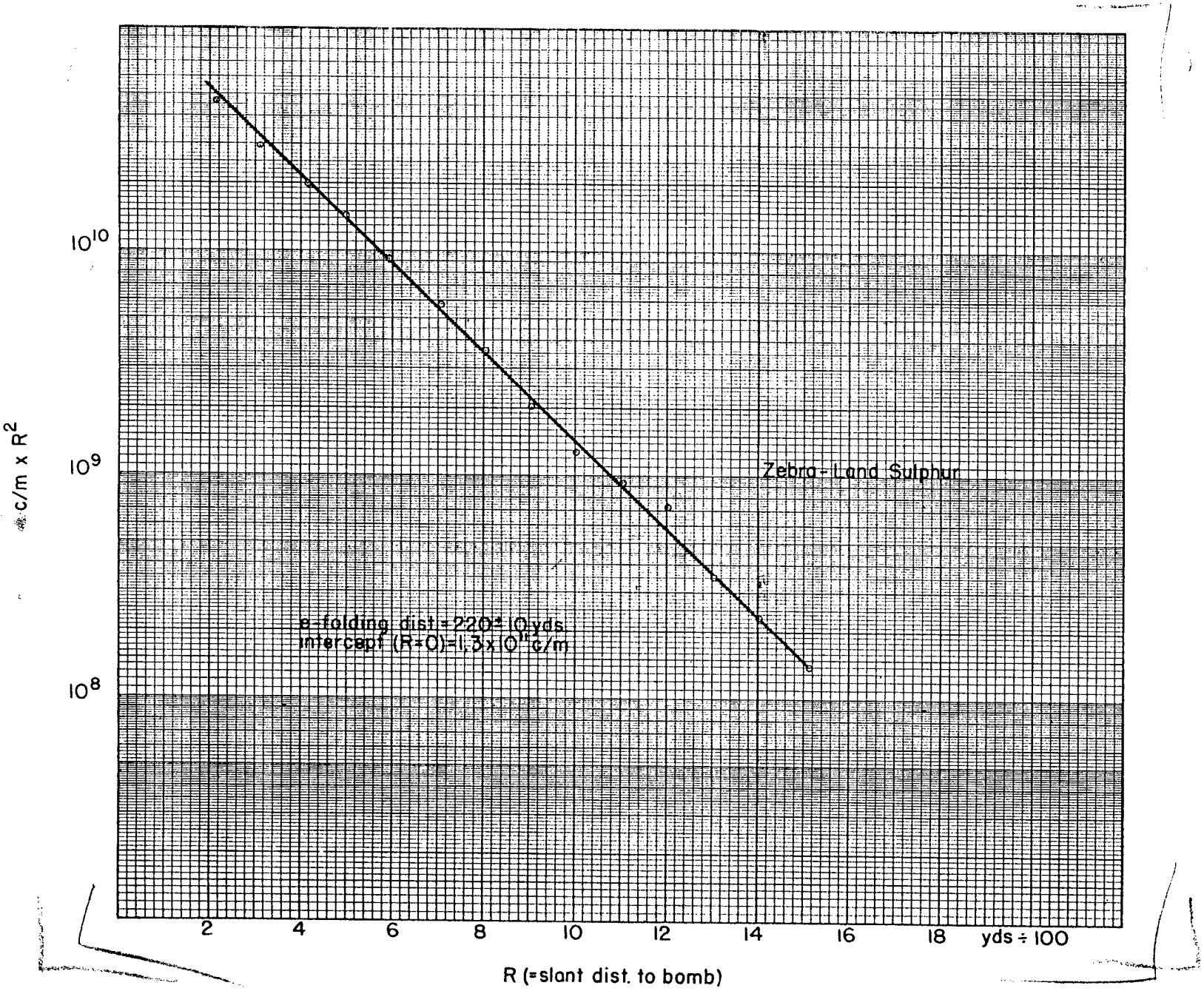
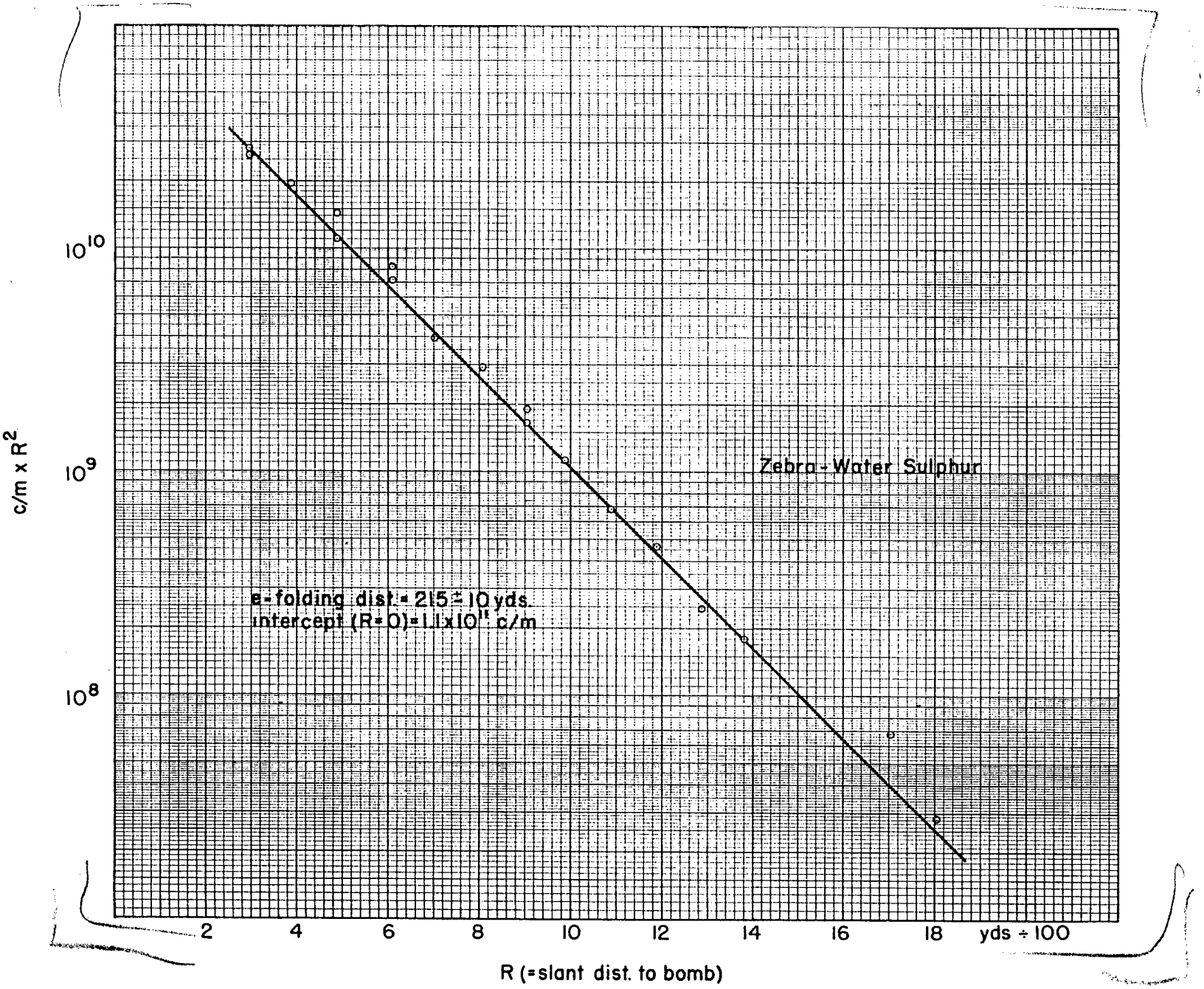

10^{10}
10^{9}
10^{8}
c/m x R^2
Zebra - Land Sulphur
e-folding dist = 220 ± 10 yds.
intercept (R=0) = 1.3×10^{11} c/m
2
4
6
8
10
12
14
16
18
yds ÷ 100
R (=slant dist. to bomb)

Figure 2.6

Zebra Water Sulphur

Counts/min x R^2 vs R


Zebra - Water Sulphur
e-folding dist. = 215 ± 10 yds.
intercept (R=0) = 1.1 x 10^11 c/m
c/m x R^2
10^10
10^9
10^8
2
4
6
8
10
12
14
16
18
yds ÷ 100
R (= slant dist. to bomb)

2.3 IODINE

A summary of the iodine data is given in Table 2.3. The first column lists the number of the sample and the shot (X-ray, Yoke, or Zebra) during which it was irradiated. The shielding used, either 4 centimeters of lead or no lead, is given in the second column. The distance in yards of the sample from the bomb is in column three. Column four is the net weight in grams of the sample counted. Column five is the initial counting rate of the 13-day period. This was determined by calculating the initial counting rate from every observed point on the decay curve after it was obviously on the 13-day-period part of the curve, and averaging these values. The probable errors given were determined by the spread of these points from the average. However, each point on the decay curve represents at least 10^4 pulses of the geiger counter. A typical decay curve is shown in Fig. 2.7. Column six of Table 2.3 gives the product of the square of the distance of the sample from the bomb and the initial counting rate observed. Column seven gives this number corrected to a sample weight of 70 grams. Since the sample containers used in counting were all of the same length and thickness, the differences in weight represent differences in density of the iodine. $Iodine^{126}$ decays with both beta and gamma emission, so it is not completely clear whether the uncorrected or corrected data should be used. However,

the corrected data seem to give more interpretable and consistent results, so are used in the interpretation of the data that follows. The last column is plotted in Fig. 2.8, in which the abscissa is the distance in yards and the ordinate is the initial counting rate times R^2, corrected for weight of sample.

In order to obtain a measure of the actual number of neutrons observed above 9.45 Mev, a sample of iodine in the same container as used for the actual tests was irradiated with 14-Mev neutrons by the Cockcroft - Walton machine at Los Alamos. Assuming that the cross-section is constant from the threshold to the highest energy neutrons present, one gets that one count per minute initial counting rate represents 2.1×10^7 neutrons per square centimeter total flux.

[redacted]

Table 2.3

Sandstone Iodine Data

Sample No.	Shielding	Distance in Yards	Sample Weight (gms)	I.C.R. C/m	$R^2 \times 10^{-6}$ x I.C.R.	R^2 x I.C.R. x 10^{-6} for 70 grams.
X 808	Pb	1008	72.3	4.01 ± 0.26	4.07 ± 0.26	3.94 ± 0.25
X 803	None	1008	70.6	36.5 ± 0.6	37.1 ± 0.6	36.8 ± 0.6
X 810	Pb	808	81.8	12.9 ± 0.7	8.42 ± 0.46	7.21 ± 0.43
X 807	None	808	76.7	91.6 ± 1.3	59.8 ± 0.9	54.5 ± 0.9
Y 851	Pb	1096	70.6	3.6 ± 0.2	4.32 ± 0.24	4.28 ± 0.24
Y 852	None	1096	68.6	27.3 ± 0.4	32.8 ± 0.5	33.4 ± 0.5
Y 823	Pb	897	74.3	7.4 ± 0.5	5.96 ± 0.4	5.62 ± 0.4
Y 850	None	897	74.3	62.8 ± 0.9	50.6 ± 0.7	47.8 ± 0.7
Y 820	Pb	215.1	89.0	5135 ± 7	238 ± 0.3	187 ± 0.25
Y 838	None	215.1	83.3	8946 ± 31	414 ± 1.4	348 ± 1.2
Y 837	Pb	400.0	77.6	460 ± 3	73.6 ± 0.5	66.5 ± 0.5
Y 842	None	400.0	84.1	1346 ± 7	215 ± 1.1	179 ± 0.9
Z 808	Pb	1002.7	70.3	0 + 1 - 0	0	0 + 1 - 0
Z 810	None	1002.7	67.1	13.2 ± 0.3	13.3 ± 0.3	13.9 ± 0.3
Z 807	Pb	803.7	72.9	3.2 ± 0.2	2.07 ± 0.13	1.99 ± 0.13
Z 833	None	803.7	80.6	38.0 ± 0.4	24.5 ± 0.3	21.2 ± 0.26
Z 822	Pb	594.0	78.6	15.6 ± 0.1	5.51 ± 0.04	4.90 ± 0.04
Z 821	None	594.0	73.3	112 ± 1	39.5 ± 0.4	37.8 ± 0.4
Z 806	Pb	417.3	72.9	75.7 ± 0.8	13.2 ± 0.14	12.7 ± 0.14
Z 814	None	417.3	70.9	345 ± 3	60.1 ± 0.6	59.5 ± 0.6
Z 828	Pb	214.6	87.5	1440 ± 11	66.3 ± 0.5	53.0 ± 0.4
Z 813	None	214.6	84.0	2936 ± 20	135 ± 1	112.5 ± 0.8

[redacted]

Figure 2.7

Iodine 837 - 400 yds - Yoke

Example of the 13-day iodine decay curve

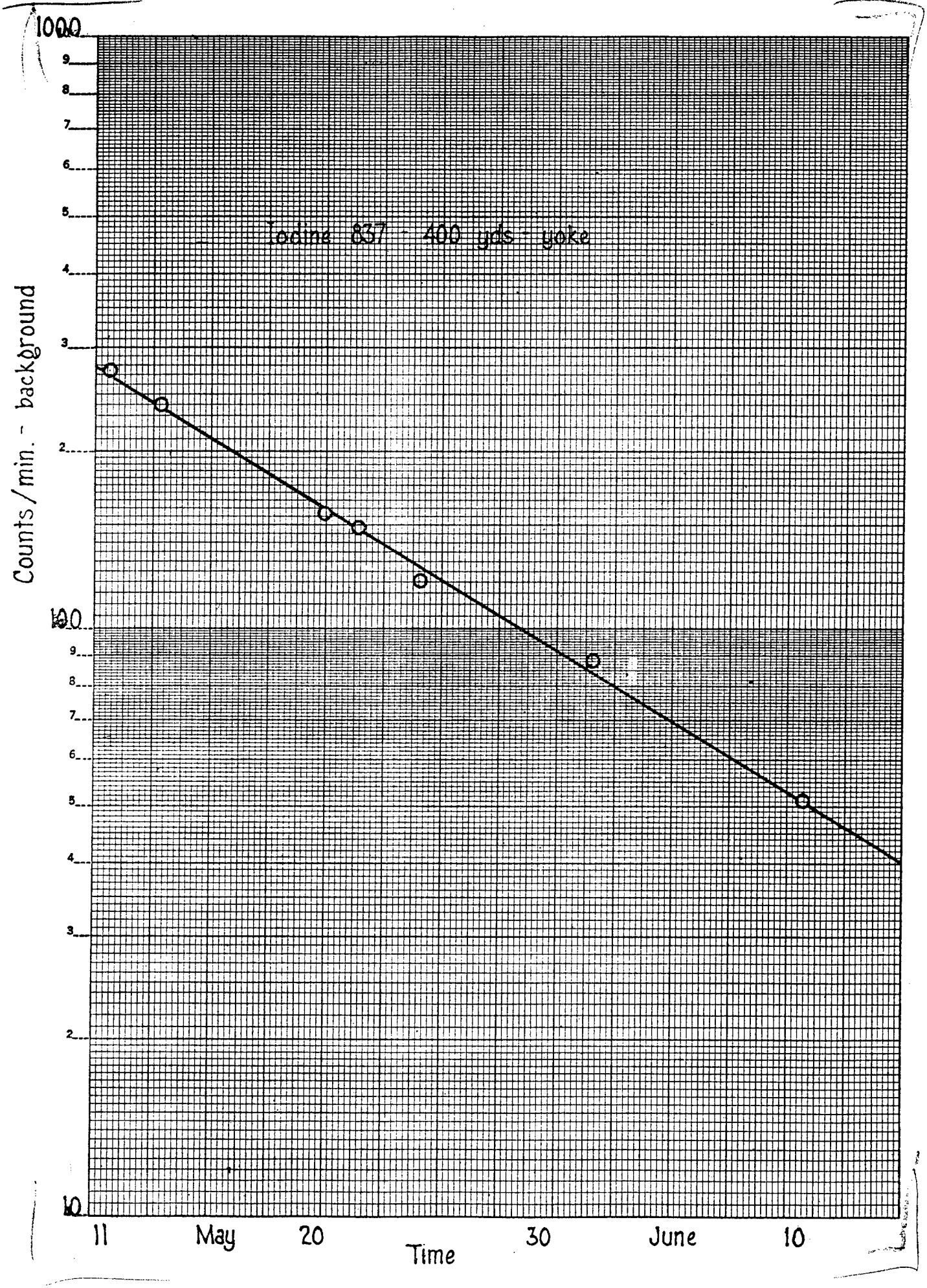
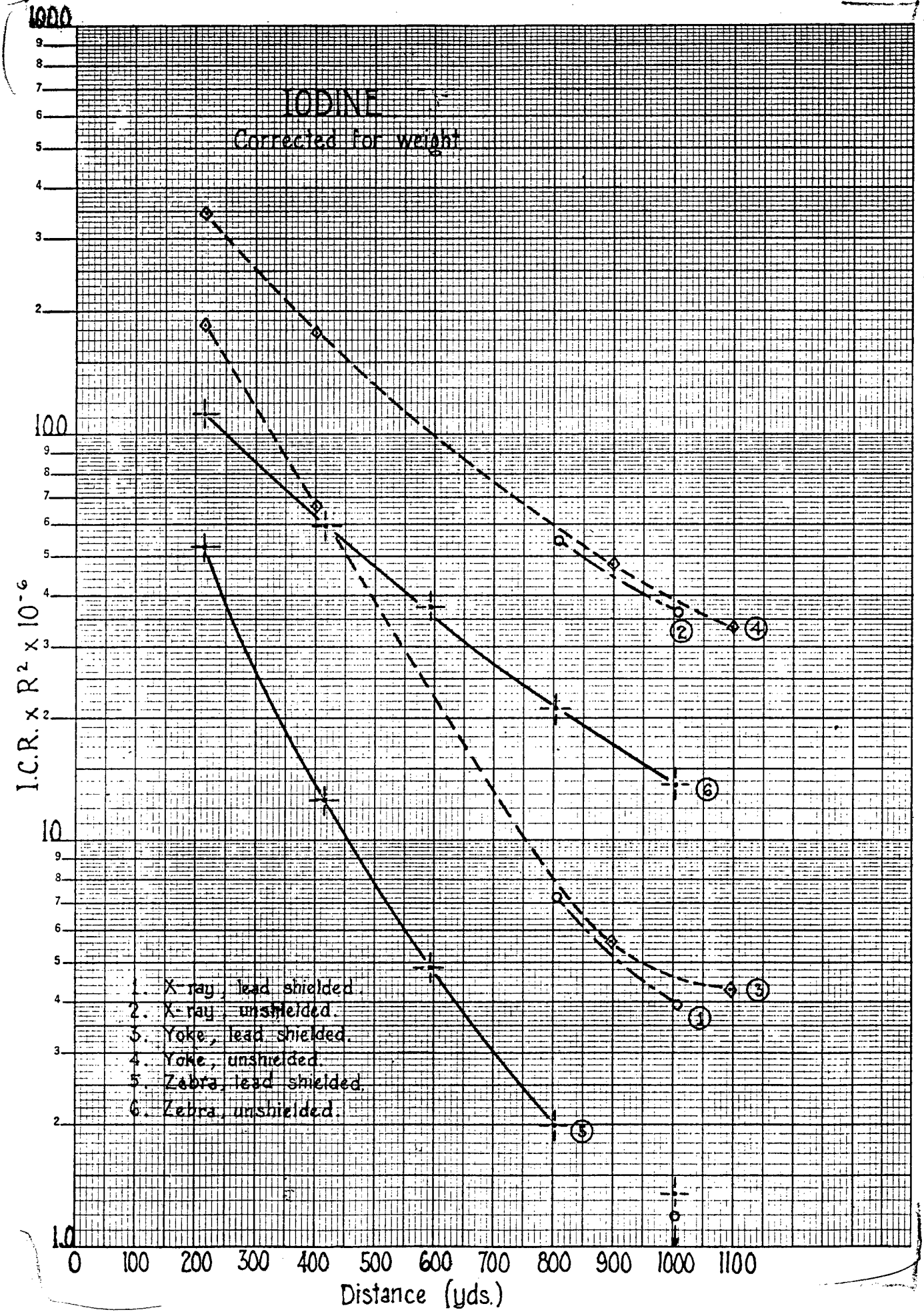

Iodine 837 - 400 yds - yoke
Counts/min. - background
1000
9
8
7
6
5
4
3
2
100
9
8
7
6
5
4
3
2
10
11
May
20
30
June
10
Time

Figure 2.8

Iodine Data

Initial counting rate times R^2 vs R


IODINE
Corrected for weight
1000
100
10
1.0
I.C.R. x R² x 10⁻⁶
0
100
200
300
400
500
600
700
800
900
1000
1100
Distance (yds.)
1. X-ray, lead shielded.
2. X-ray, unshielded.
3. Yoke, lead shielded.
4. Yoke, unshielded.
5. Zebra, lead shielded.
6. Zebra, unshielded.

CALCULATIONS

Chapter 3

3.1 SULPHUR

Figures 2.1 through 2.6 give the sulphur data for the various shots, where the ordinate is the initial counting rate of the sample times the square of the distance from the bomb, corrected to a 40-gram sample weight, and the abcissa is R, the distance from the sample to the bomb.

Klema's Trinity report (LA-361) contains the following calibration relation, namely, that 1.303×10^4 counts per minute per gram of sulphur at the time of activation corresponds to 6.5×10^{21} neutrons passing through a sphere of 202 meters radius. From this empirical relation it can be calculated that one count per minute from 40 grams of sulphur corresponds to 2.42×10^6 neutrons/cm^2 incident on the sample, a number which is independent of R. Using this number and the measured e-folding distance one may calculate, from any point on the observed curve, the number of sulphur-detectable neutrons emerging in 4π solid angle from each of the bombs. Table 3.1 lists the results of these calculations for each curve. The intercepts of the curves for R = 0 are also given in Table 3.1. Using the above calibration value, the neutron flux passing through each sample has been calculated and is given in the sixth column of Table 2.1.

Table 3.1

Sulphur Neutrons

	e-folding distance Yds.	Total no. of sulphur neuts. escaping
X-ray		
Land	218 ± 10	4.8×10^{22}
Water	225 ± 10	3.6×10^{22}
Yoke		
Land	215 ± 5	13.7×10^{22}
Water	230 ± 10	10.2×10^{22}
Zebra		
Land	220 ± 10	3.3×10^{22}
Water	215 ± 10	2.8×10^{22}
Bikini-Able		
Water	207 ± 20	3.6×10^{22}

3.2 IODINE

As has been mentioned in Chapter 1, iodine was exposed to the bomb radiation in unshielded containers and in containers shielded by four centimeters of lead. It is clear from the data that in all cases there is a large difference between the activity of the unshielded samples and the lead-

shielded samples. This difference is much greater than one would expect just due to neutron absorption and scattering in the lead. Moreover, the curves as plotted in Fig. 2.8 are not straight lines as one would expect for the exponential absorption of fast neutrons in air, and the ratio of the unshielded activity to the shielded varies noticeably with distance. Thus, it would appear that both neutrons and gamma rays of energies above 9.45 Mev are present and that the gamma rays must have a longer mean free path than the neutrons. The (n,2n) or (γ,n) threshold of iodine has been measured at Los Alamos to be 9.45 Mev.

In order to separate the effect of the gamma rays from that of the neutrons, the following calculations are made:

For any point let T be the value of the initial counting rate times R^2 for the unshielded sample, and B be the same thing for the lead-shielded sample. Similarly let n be the initial counting rate times R^2 due to neutrons alone, and γ be the same thing for the gamma rays. Then:

$$T = n + \gamma$$

$$B = n + \gamma/A$$

where 1/A is the attenuation of the gamma rays in 4 centimeters of lead. The equations assume that there is no measurable attenuation of the neutrons in lead. Since more data were obtained from Zebra than from any other shot we try to fit it

first. We have that

$$n = \frac{A\,B - T}{A - 1}$$

and

$$\gamma = \frac{A\,(T - B)}{A - 1}$$

and the object is to find a value of A such that both n and γ fall off exponentially with distance. Doing this it is found that the best value of A is 12.8. Table 3.2 gives the values of n and γ for all three shots using this value of A, and Figs. 3.1, 3.2, and 3.3 show these values plotted on semilog paper.

The mean free path for the gamma rays obtained by this method seems to be very insensitive to the value of A. The value obtained for the mean free path for all three shots is the same within the probable error, and seems to be 520 ± 20 yards.

However, the errors intrinsic in this method of determining the number of neutrons are fairly large, so the values for the neutron mean free paths vary appreciably between shots, and the actual value is rather uncertain. The neutron mean free path for X-ray, as determined from the two points at 800 and 1000 yards, is 196 yards with a probable error of about 70 yards. The mean free path observed for Yoke is 166 yards,

and that for Zebra is 119 yards. The Zebra points all fall on a straight line, but no point was obtained at 1000 yards because the 1000-yard lead-shielded sample was not active. However, the most distant point for Yoke is somewhat high, and the long mean free path of X-ray is obtained from two distant points. Thus, there is the possibility that on Yoke there is a small percentage of a longer-range neutron group, and since no points closer than 800 yards were observed there is also the possibility of a shorter-range group on X-ray.

Table 3.2

Iodine Calculations

R	Shot	T x 10^{-6}	B x 10^{-6}	n x 10^{-6}	γ x 10^{-6}
1008 yds.	X-ray	36.8 ± .6	3.94 ± .25	1.15 ± .28	35.8 ± .8
808	X-ray	54.5 ± .9	7.21 ± .43	3.20 ± .47	51.4 ± 1.0
1096	Yoke	33.4 ± .5	4.28 ± .24	1.81 ± .26	31.6 ± .4
897	Yoke	47.8 ± .7	5.62 ± .4	2.04 ± .42	45.8 ± .9
400	Yoke	179.0 ± .9	66.5 ± .5	57.0 ± .5	122 ± 1.1
215.1	Yoke	348 ± 1.2	187 ± .25	173.4 ± .3	175 ± 1.3
1002.7	Zebra	13.9 ± .3	0 + 1 - 0	- - - - -	15.1 ± 1.1
803.7	Zebra	21.2 ± .26	1.99 ± .13	0.362± .14	20.9 ± .33
594	Zebra	37.8 ± .4	4.90 ± .04	2.11 ± .06	35.8 ± .43
417.3	Zebra	59.5 ± .6	12.7 ± .14	8.74 ± .16	50.9 ± .65
214.6	Zebra	112.5 ± .8	53.0 ± .4	47.96 ± .44	64.7 ± .98

Figure 3.1

Plot of the separated neutron- and gamma-ray-induced activities in iodine for the X-ray shot.

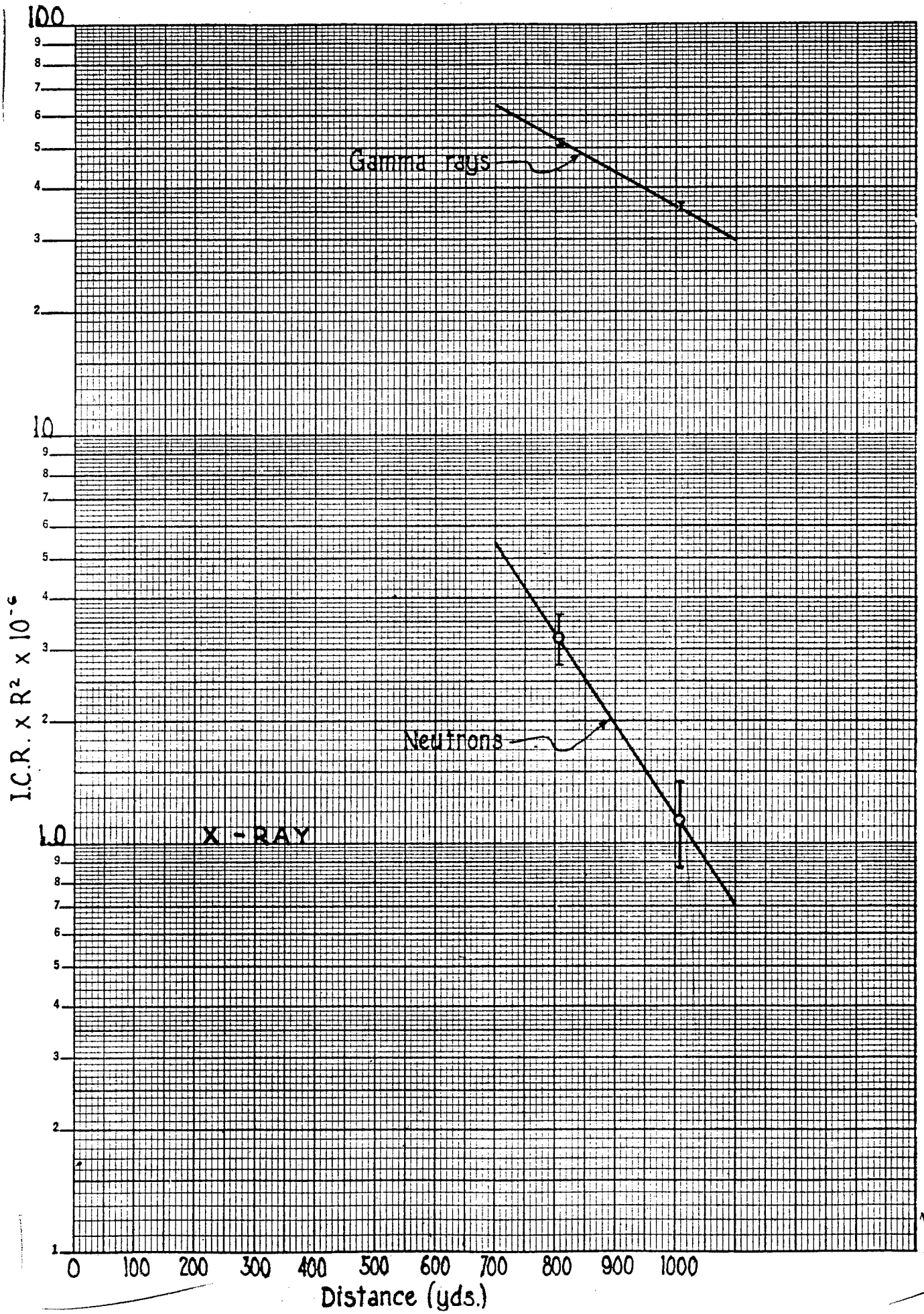

100
9
8
7
6
5
4
3
2
10
9
8
7
6
5
4
3
2
1.0
9
8
7
6
5
4
3
2
1
Gamma rays
Neutrons
X - RAY
I.C.R. x R² x 10⁻⁶
0
100
200
300
400
500
600
700
800
900
1000
Distance (yds.)

Figure 3.2

Plot of the separated neutron-and gamma-ray-induced activities in iodine for the Yoke shot.

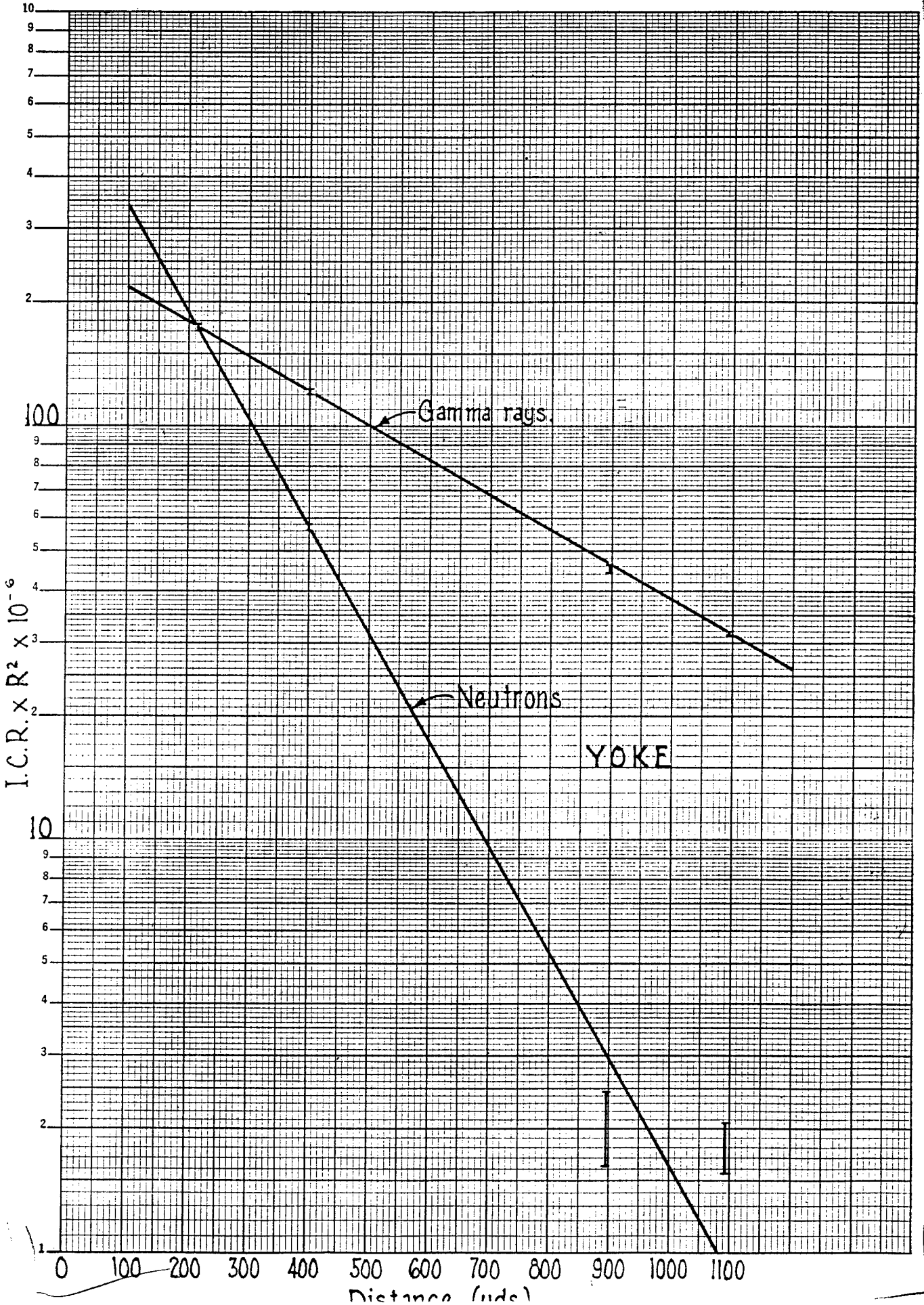
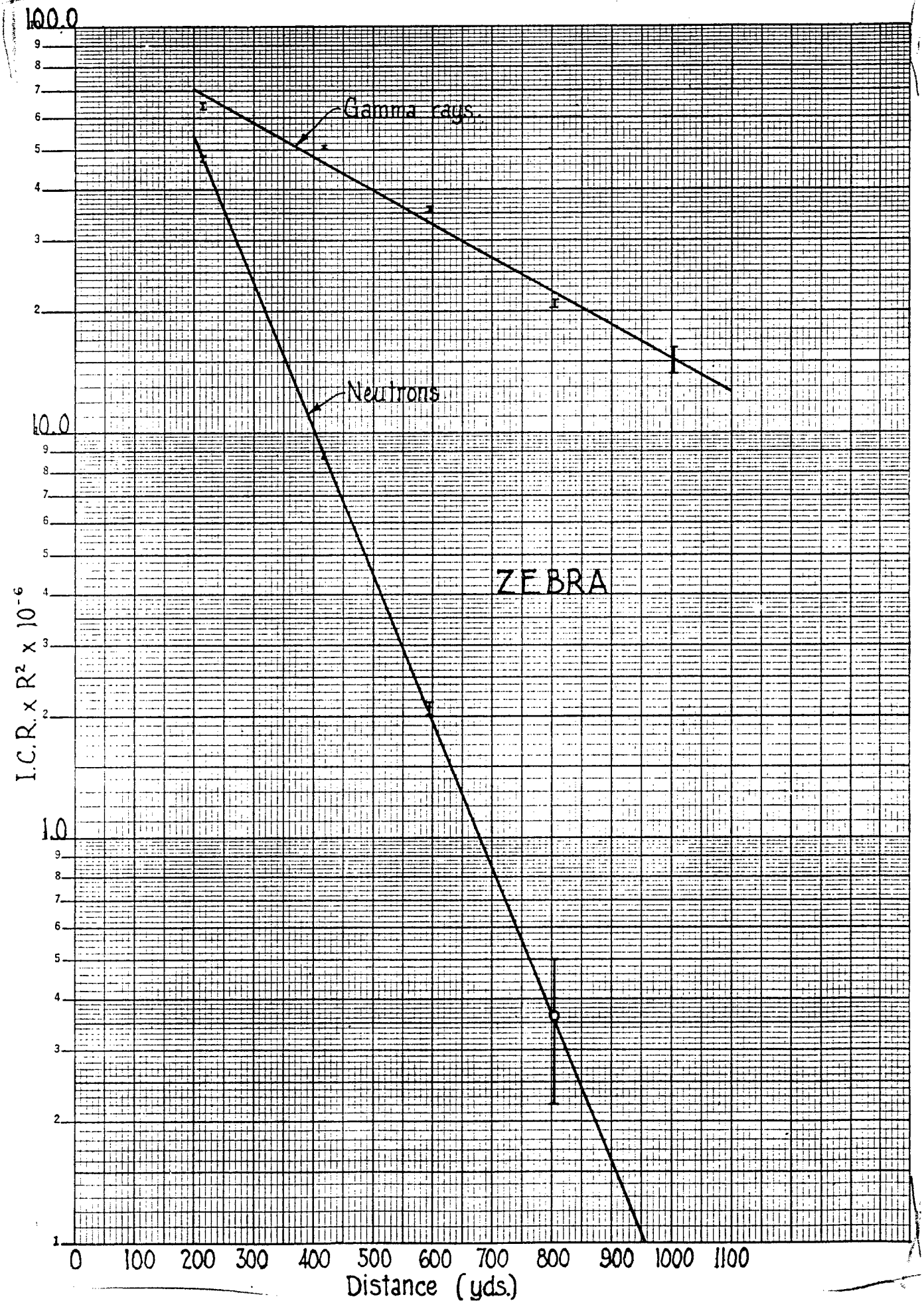

Gamma rays
Neutrons
YOKE
I.C.R. x R² x 10⁻⁶
Distance (yds)
0
100
200
300
400
500
600
700
800
900
1000
1100
1
2
3
4
5
6
7
8
9
10
100

Figure 3.3

Plot of the separated neutron- and gamma-ray-induced activities in iodine for the Zebra shot.


100.0
10.0
1.0
Gamma rays
Neutrons
ZEBRA
I.C.R. x R² x 10⁻⁶
0
100
200
300
400
500
600
700
800
900
1000
1100
Distance (yds.)

We have seen (Chapter 2) that on the assumption of a square cross-section function, one count per minute initial counting rate on the iodine samples represents 2.1×10^7 neutrons per square centimeter flux. We at present have no experimental determination of the number of gammas above 9.45 Mev necessary to give a certain counting rate; however, some estimates can be made. We can assume that the cross-section for the (γ,n) process, at least well above the threshold, is the same as that for the (n,2n) process. We can also assume a conversion factor from gammas to Roentgen units as 0.84R per hour at one meter from a one-curie source. These numbers of course are approximate. Thus, we will assume that one count per minute due to gamma rays represents a flux of 2.1×10^7 gammas/cm^2, and that 1 gamma/cm^2 represents 7.9×10^{-10}R. Using these numbers and the data of Table 3.2, we obtain Table 3.3.

Using the data of Table 3.3 and the e-folding distances calculated from the data, we can determine the total number of neutrons and gammas above the threshold of iodine coming out of the various bombs. The results of this calculation are given in Table 3.4

Table 3.3

Iodine Neutrons and Gammas

Shot	R yds.	$(c/m)_\gamma$	$(c/m)_n$	(neuts/cm^2)	(γ's/cm^2)	Roentgens
X-ray	1008	35.2	1.13	2.37×10^7	7.4×10^8	0.58
X-ray	808	78.7	4.90	10.3×10^7	1.65×10^9	1.3
Yoke	1096	26.3	1.51	3.17×10^7	5.5×10^8	0.43
Yoke	897	56.9	2.54	5.33×10^7	1.2×10^9	0.95
Yoke	400	763	356	7.48×10^9	1.6×10^{10}	12.6
Yoke	215.1	3780	3745	7.86×10^{10}	7.9×10^{10}	62.4
Zebra	1002.7	15.0	- - - -	- - - - - -	3.2×10^8	0.25
Zebra	803.7	32.4	.56	1.18×10^7	6.8×10^8	0.54
Zebra	594	101	5.98	12.56×10^7	2.1×10^9	1.66
Zebra	417.3	292	50.2	105×10^7	6.1×10^9	4.82
Zebra	214.6	1406	1042.	2.188×10^{10}	29.5×10^9	23.3

Table 3.4

Iodine Totals

Shot	Total number of iodine neutrons escaping	Total number of iodine gammas escaping
X-ray	4.35×10^{20}	5.41×10^{20}
Yoke	16.8×10^{20}	5.75×10^{20}
Zebra	6.64×10^{20}	2.32×10^{20}

3.3 YIELD COMPARISONS

In order to compare the number of neutrons and gammas released by the various bombs, we can construct a table, using data of Tables 3.1 and 3.4, and the known radiochemistry and ball-of-fire yields. For convenience, the value of Zebra will be taken as 1. Thus, we get Table 3.5.

Table 3.5

Yield Comparisons

Shot	Sulphur		Iodine		Radio-Chemistry	Ball of Fire
	Water	Land	Neutrons	Gammas		
Zebra	1	1	1	1	1	1
Yoke	3.65	4.15	2.53	2.48	2.66	2.42
X-ray	1.30	1.45	0.656	2.34	2.01	1.95
Bikini-Able	1.30	- - -	- - - -	- - -	1.20	1.07
Trinity	- - -	0.45*	- - - -	- - -	1.20	1.18

* The sulphur data at Trinity consisted of only one point, so there is no check on the datum.

DISCUSSION

Chapter 4

4.1 SULPHUR

A detailed discussion of the attenuation curves will be given here. It should be stated that no attempt has been made to normalize the slopes of these curves to any standard conditions of atmosphere. However, the atmospheric conditions prevailing at Trinity, Bikini, and the three Sandstone shots are listed in Table 2.2 for comparison. In connection with the Bikini data, a calculation was made (assuming a 2-barn cross-section of hydrogen for all processes which might remove a neutron from availability for capture by sulphur) which indicated that the additional hydrogen in the atmosphere of Bikini due to the additional water vapor present over what was present at Trinity would effectively decrease the mean free path by only 1.5% (see Appendix, LAMS-447). No corresponding calculations were made for the oxygen in this additional water vapor. However, it seems likely that the comparison of slopes of these curves for any atmospheric conditions are reasonably accurately made by just correcting for absolute temperature and pressure.

The spread put on the values of the e-folding distance listed in Table 3.1 represents roughly the maximum variation that might be obtained in passing a best straight line through

each set of points. It seems evident from these values that within the accuracy of the results there is no detectable difference in slope between measurements made over water and over land. However, the land curve intercept values are consistently higher than the water curve intercept values, by about 35% in the case of X-ray and Yoke and about 16% in the case of Zebra. It is perhaps possible to resolve these differences on the basis of the spreads in the slopes of the possible lines that can be passed through the experimental points, particularly if there are deviations from the exponential attenuation law for distances near zero. Although no errors are shown on the plotted points, their reliability in terms of maximum error is in each case of the order of 5 - 7%. Contributions to this error include the statistical errors of counting, errors in the weight of samples, and errors in R which are of course doubled in the value of the ordinate. It is obvious from the curves that many points deviate from the drawn lines by much more than 7%. In fact, 31 of the 78 points which are shown in the six figures deviate from the curves by more than 7%. The Zebra water curve shows data from sets of two similar samples irradiated at four different distances which give an idea of the reproducibility of the points. Three of the four pairs of data are internally consistent, if the 7% error is assigned to

each point. However, the data taken as a whole would indicate that such an error of 7% is more nearly a probable error than an estimated maximum error.

Although a number of the close-in sulphur samples were diluted by the process mentioned in an earlier part of the report, data from the diluted samples were used only to give preliminary numbers, and the points shown on the curves included herein, with one exception, include no data taken from diluted samples. That exception is the point at 315 yards on the X-ray land curve. By way of criticism of the dilution process, it should be pointed out that about one quarter of those samples that were diluted did not agree even reasonably well with the results subsequently obtained by counting the corresponding undiluted samples. While this discouraged the use in this report of data taken from diluted samples, it should not be taken as an indictment against the dilution process in principle. On the contrary, since reliable results were obtained from the majority of the diluted samples some experimentation should go into refining the method in order that it may be used reliably in the future, if needed.

Many of the sulphur samples exhibited periods other than that due to the P^{32} activity. These extraneous activities had half-lives both longer and shorter than the half-life of P^{32}.

It seems evident that the source of this trouble lay in contaminating the sulphur after irradiation rather than in activating impurities already present in the sulphur when it was put out. The evidence for this lies in the fact that of several samples, all filled from the same batch of unactivated sulphur, some after activation exhibited only the P^{32} activity while others showed in addition these extraneous activities. There is a further fact in support of this conclusion, namely, practically none of those samples which were close to the bomb, say closer than 500 to 700 yards, exhibited a detectable amount of these extraneous activities, whereas in the samples at greater distances in which the specific activity due to P^{32} was considerably lower, the extraneous activities were most frequently detected. The source of these other activities probably was two-fold. First of all, the sulphur could pick up crud which had sluffed off of the inside of the iron containers in which the samples were put out, in spite of the fact that care had been taken to clean these containers before filling them with sulphur and to watch for the extraneous materials when the sulphur was emptied out of the containers. A second and probably more potent source of the contamination was the sample preparation laboratory on the ship, in which all other samples in addition to the sulphur were prepared for counting. It so happened after each shot that several of the other sample materials

which had initially higher specific activities than the sulphur were prepared for counting before the sulphur samples were molded. Although contamination problems were recognized in advance and definite precautions laid down for isolating the various sample preparation procedures, it seemed inevitable from time to time that various ones of these precautions were violated either through forgetfulness or as a result of the fact that the preparations laboratory was quite a bit too small for the amount of work that had to be done in it. As a result, a number of the sulphur samples (usually from distances greater than 1000 yards) had to be rejected. This was particularly true in the case of the water curves, where samples had been put out to distances up to 2000 yards. In many instances samples from distances beyond 1500 or 1600 yards were unusable, although the curves indicate that had there been initially nothing present but the phosphorus activity these samples would have been countable. The rejection of a sample was made on the following basis, namely, that the lower limit of countability (about five counts per minute above a background of approximately 60 counts per minute) was reached and the sample was decaying not along a true exponential but with an apparent half-life either longer or shorter than the phosphorus half-life. Obviously those samples which showed initially a single extraneous activity having a half-life of the order of one day

(as some did) could be followed until nothing but the phosphorus activity remained, and similarly for those samples found to have extraneous activity with a half-life of the order of 10 to 12 days, provided initially the extraneous activity was only a few percent of the phosphorus activity. The 600-yard X-ray water datum is an exception to the previous remarks in that at the time of writing it is still well above the lower limits of countability and is decaying with an apparent half-life slightly longer than that of the P^{32}. Hence, the point as plotted falls above the line drawn and was not weighted very heavily in drawing this line. It should be pointed out here that one of the bomb-irradiated samples is still being counted as a check on the reported value of the phosphorus half-life, namely, 14.30 days, and there is no evidence to indicate that this value is in error, certainly not by any amount significant to the results reported herein.

The method of calculating the total number of sulphur neutrons from a bomb involves essentially four assumptions:

1. The reliability of Klema's cross-section and counter-calibration results.

2. The constancy of the sulphur cross-section for neutrons of energy above 3 Mev.

3. Comparable detector and counting efficiencies at Trinity and Sandstone.

4. The validity of an extrapolation along the observed exponential to distances less than 200 yards.

So far as (1) is concerned, the Klema results have been accepted at face value. With the help of James Coon and other members of Group P-3 at Los Alamos, a sulphur sample in a field-type container was irradiated in a known flux of 14-Mev neutrons. On the basis of the calibration figure an expected counting rate of this sample was calculated and found to agree within 5% with the actual observed counting rate. The most that can be concluded from this result is that the sulphur cross-section for 14-Mev neutrons is the same to within 10 or 15% as that measured by Klema, and further, that it is probably reasonable to assume (2) that for neutrons between 14 Mev and the highest energy used by Klema, namely about 5 Mev, this cross-section is reasonably constant. Assumption (3) must also be reasonable in view of the fact, as is pointed out elsewhere, that the sulphur was handled in exactly the same manner as was done by Klema and the same Geiger counter and counter standards were used as were used by Klema. There is no experimental evidence at hand for the validity of assumption (4); however, it obviously does not apply to calculations of flux densities based on the experimental range of observations represented by the curves.

4.2 IODINE

Of all the (n,2n) threshold detectors used in the Sandstone tests, iodine gives the cleanest results. It was necessary to allow the 25-minute period of I^{128} formed by a slow-neutron capture to decay before the 13-day period of I^{126} appeared. However, there were no other contaminating periods observed in most cases. A few of the samples exhibited an intermediate period, presumably from iron contamination, however, this did not interfere with the observation of the 13-day period.

It should be pointed out that the numbers of neutrons above the iodine threshold calculated in this work are probably small, since the calibration value was measured at 14 Mev, and the average cross-section between the iodine threshold at 9.45 Mev and 14 Mev is almost certainly less than that at 14 Mev.

4.3 GENERAL

One of the purposes of the sulphur measurements in the past and in these experiments has been as a measure of the energy developed by the bomb in question. However, as can be seen quite clearly from Table 3.5, the numbers of neutrons above 3 Mev, as measured by the sulphur detectors, do not at all agree with the radiochemistry or ball-of-fire measurements. Thus, it seems that the sulphur data are useless for that purpose. However, the data are useful, aside from simply giving the neutron flux, in another connection. It seems clear that if the sulphur

data do not agree with radiochemistry or bombs with the same active material, that the only way to account for this disagreement is to assume that the major proportion of the neutrons that activate sulphur come out very early in the game before the parts of the bomb have had much time to move. Then small changes in the rate of expansion or in the initial geometry may have appreciable effects on the attenuation of the neutrons. Thus, we may have here a tool that will tell a little about what goes on inside of the bomb during the very early stages.

On the other hand, the fact that the iodine gamma-ray numbers do agree fairly well with radiochemistry and ball-of-fire methods indicate the possibility of the gammas being delay gammas, since apparently different bomb absorbers do not affect them. It is difficult to make statements one way or the other about the iodine neutrons, because of the uncertainties in the mean-free-path measurements.

The possibility that the long mean free path of the high-energy gamma rays detected by iodine may constitute a mechanism for getting fairly large doses at reasonable distances should not be overlooked. There is no guarantee that the Roentgen values shown in Table 3.3 are even correct to the right order of magnitude, since the cross-section used in arriving at these

numbers was only an estimate. A factor of ten decrease in the (γ,n) cross-section, and hence a factor of ten increase in the gamma-ray dosage is not at all unreasonable. The fact that large dosages due to these high energy gamma-rays do not show up in Shonka's measurements (Operation Sandstone, Report No. 29) is no indication that such do not actually exist, since his measurements were made in a well collimated system and hence would see only those gamma rays coming in the first few microseconds, after the nuclear detonation. Apparently the iodine gammas come quite late in the game when the bomb has expanded beyond the field of view of the collimators.

CONCLUSIONS AND RECOMMENDATIONS

Chapter 5

The numbers of high-energy neutrons and gamma rays observed during Operation Sandstone are listed in Chapters 2 and 3 of this report. Tables 2.1 and 3.3 list the fluxes of neutrons and gamma rays as a function of distance from the various bombs, and Tables 3.1 and 3.4 give the total numbers of neutrons and gamma rays emitted by the various bombs. These data lead to a number of conclusions which will now be discussed.

The activities of the sulphur samples as a function of distance from the bombs are plotted in Figs. 2.1 to 2.6. It is clear from these figures that the attenuation of the neutrons above the sulphur threshold is exponential with distance within the accuracy of the data. It is also clear from the graphs that the e-folding distance for those neutrons did not vary appreciably from shot to shot and did not depend on whether the samples were placed above water or above land. The average value for the e-folding distance in air of the neutrons above the sulphur threshold is 220 ± 20 yards.

On the other hand, the iodine activity plotted as a function of distance from the bombs (Fig. 2.8) clearly does not show an exponential attenuation. The data also show that the

iodine samples which were shielded by lead have very much less activity in general than the corresponding iodine sample that was not shielded. The ratio of the activity of the unshielded iodine sample and the activity of the shielded iodine sample increased with the distance of the samples from the bomb. This clearly indicates two things. (1) There are high-energy gamma rays, gamma rays above the threshold of iodine, present in the radiation of the bomb. (2) The mean free path of these gamma rays in air is appreciably longer than the mean free path of the neutrons above the iodine threshold. The separation of these two effects, as outlined in the chapter on calculations leads to two further conclusions. (1) That the mean free path of the high-energy gamma rays in air from all three bombs is effectively the same and that the mean free path is 520 $\pm$ 20 yards. (2) That the mean free path of the neutrons above the iodine threshold is somewhat less than the mean free path of those neutrons above the sulphur threshold, and that the evidence may be taken to indicate appreciably different neutron mean free paths from the three shots, and hence, different neutron spectra above 9.45 Mev.

A comparison of the yields of high-energy neutrons and gamma rays from the various shots, as given in Table 3.5, leads to some interesting conclusions. It is very clear in the case of the sulphur neutrons and reasonably clear in the case of the

iodine neutrons that the high-energy neutron yields of the various bombs are not proportional to the total number of fissions as indicated by the radio-chemical results. If these neutrons were produced late in the stage of the bomb explosion after the bomb had blown apart sufficiently that the attenuation of the bomb parts was no larger than that of air one would expect the yield of neutrons to be proportional to the number of fissions. Thus, it appears that the neutrons are produced very early in the stage of the bomb explosion, so early in fact that variations in the attenuation of neutrons in their flight from the active material to the outside of the bomb, as produced by different models of the bomb, show up in the yield of the neutrons observed. Thus, it appears that the neutrons observed by the activation of sulphur and iodine are prompt neutrons. On the other hand, the number of high-energy gamma rays detected seems to be very closely proportional to the total number of fissions taking place in the bomb. Thus, we must conclude that the great proportion of these high-energy gamma rays are produced after the bomb has blown apart. The gamma rays may be either delayed gammas from the process of fission itself, or may be capture gamma rays due to a reasonable number of slow neutrons remaining close to the bomb material after the bomb has blown apart.

It is interesting to note that the actual magnitude of

the activity induced in sulphur at a certain distance from a given bomb is from 18% to 34% higher when the sample is over land than when it is over water. There are two effects that might contribute to this result. (1) The samples in either case are fairly close to the level of the ground or of the water, thus some fraction of the activity induced must be induced by neutrons scattered from the ground or the water. It is to be expected that the scattering of salt water is appreciably different than the scattering of coral. (2) It is entirely possible that the amount of water vapor in the air close to the surface of the ground or the water will vary somewhat, depending upon whether the air is directly above water or directly above the ground. A difference in the amount of water vapor in the air could conceivably change the spectrum to some small degree of the neutrons going through the air.

The conclusions stated above lead to two further conclusions. (1) For a particular bomb model the number of neutrons, either above the sulphur threshold or above the iodine threshold, observed at any distance from the bomb may be a measure of the bomb efficiency. However, the numbers of neutrons observed from different bomb models cannot be used to compare bomb efficiencies. (2) The number of high-energy gamma rays as detected by iodine may be a measure of the number

of fissions taking place and hence, a measure of the efficiency of the bomb, independent of the bomb model.

The experience gained in making these measurements and the results of the measurements themselves lead to several recommendations for future work. These recommendations will now be given.

It is recommended that the use of sulphur as an (n,p) threshold detector be continued in future bomb tests. We have now a quite considerable amount of data concerning the number of neutrons above the sulphur threshold from the various bombs. This data may possibly be valuable to our understanding of the inside workings of the bombs. The sulphur experiment itself, if no collimators are used, is a cheap and simple measurement.

There is no question but what the iodine as an (n,2n) and (γ,n) threshold detector should be used in the next bomb tests. The use of iodine can be made into a reasonably clean method of obtaining a measure of the very high energy neutrons coming from the bomb. This measurement is of course essential to the testing of any booster bomb. The measurement of the high-energy gamma rays coming from the bomb by means of iodine as a threshold detector may well lead to an approximate efficiency determination.

In order to better interpret the measurements made with sulphur and iodine some work should be done at Los Alamos. Attempts should be made by the theoretical department to explain

the discrepancies between the fast-neutron numbers and the tonnages of the various bombs as measured by other methods such as the radio-chemical method, in hopes of explaining this in terms of the initial configuration of the bomb parts and the motion of those parts.

The (n,2n) cross-section curve for iodine should be measured from the threshold up to 18 or 20 Mev, in order to better interpret the iodine data obtained at Sandstone and that which will be obtained in future tests. Similarly an absolute measurement of the (γ,n) cross-section for iodine should be made in order to properly interpret the gamma-ray data given in this report.

It is probable that future tests will require the use of other threshold detectors in order to better bracket the region of 14 million electron volts. It is clear from the measurements made here that any threshold detector should be very carefully investigated before it is used in the field. One must be sure that extraneous activities due to impurities in the material, to contaminants picked up after irradiation, or to long periods produced in the material itself due to other reactions will not ruin the data. In this same vein, better holders for the sulphur should be developed in order to prevent the intrusion of contaminants.

A measurement of the neutrons and gamma rays detected by

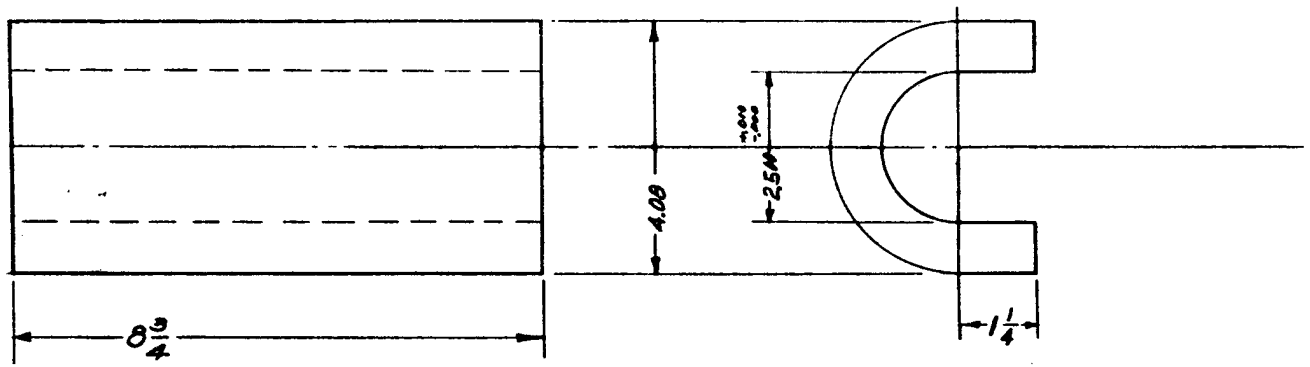
sulphur and iodine as a function of time in a future bomb test would be of great interest in order to check the conclusions as to the time of emission of those neutrons and gamma rays.

PHOTOGRAPHS AND WORKING DRAWINGS

Chapter 6

The photographs and working drawings mentioned elsewhere in this report have been collected into one section in order to facilitate the reading of the rest of the report. The figure numbers shown correspond to the chapter and section in which the figure is first mentioned.

We are indebted to the photographic groups attached to J T F 7.1 for the documentary photographs shown in the chapter. The working drawings were made by the Los Alamos V-shop drafting group.

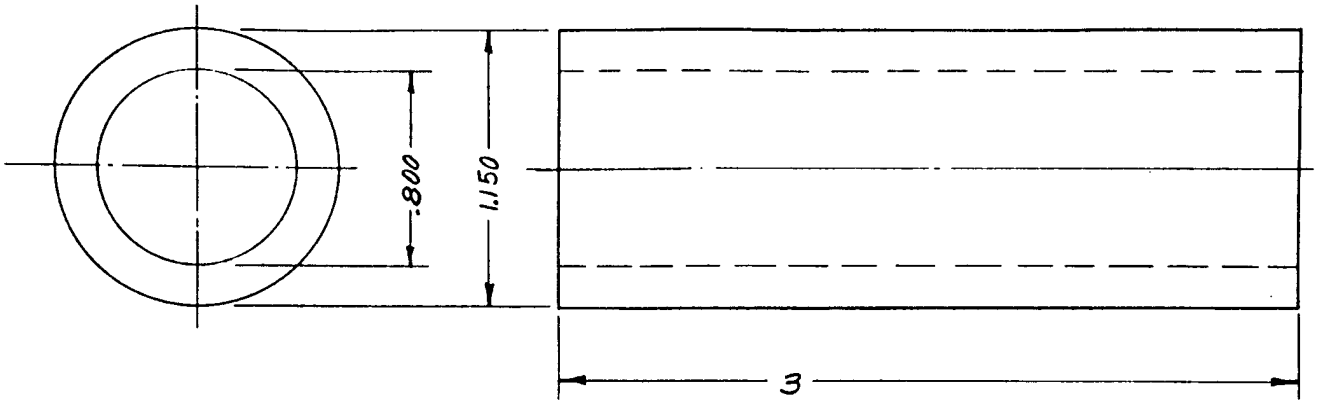


LEAD CASTING

			A_2	3 SHEETS WERE 2	NPA	17 JUNE 48
			A_1	8 3/4 WAS 11 1/8	NPA	17 JUNE 48
			REV. LET.	CHANGED ITEM WAS	BY	DATE
APPROVED FOR CONST.			TITLE: MULTIPLE SAMPLE HOLDERS # LEAD CASTING			
CHIEF ENG.	R.J.H.	Dec. 4 1947				
CH. DRAFTSMAN	L.W.H.	Dec. 3, '47				
CHECKED	R.J.H.	Dec. 3, 1947				
DRAWN	APM	DEC. 3-47				
LAYOUT OR SKETCH						
GROUP J3	REPRESENTATIVE OGLE		SCALE 1/2" = 1"	DRAWING NO. 2Y-50018	SHEET SIZE AND NO. B — 2 TOTAL 3	
FRACTIONAL TOLERANCE ± 1/64 UNLESS OTHERWISE NOTED.						

Figure 1.1

Pile Graphite samples used on X-ray and Yoke.

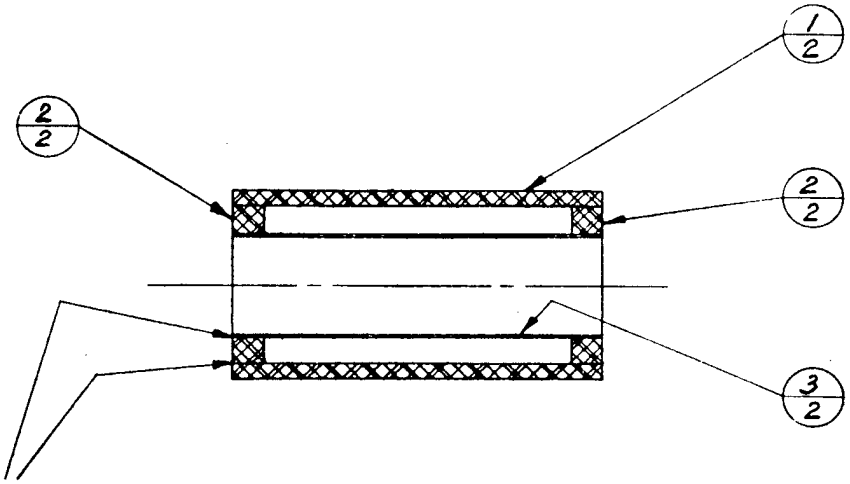


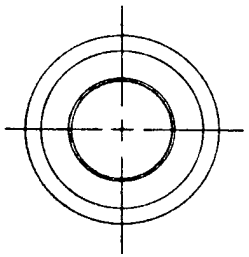
MAT'L. - GRAPHITE

APPROVED FOR CONST.					
CHIEF ENG.			REV. LET.	CHANGED ITEM WAS	BY / DATE
CH. DRFTSMN.	L.H.	Dec. 9, '47			
CHECKED	R.J.M.	DEC. 3, 1947	TITLE	CARBON-SULPHUR HOLDERS- CARBON SAMPLE	
DRAWN	APM	DEC. 2-47			
LAYOUT OR SKETCH			SCALE	DRAWING NO.	SHEET SIZE AND NO.
GROUP J3	REPRESENTATIVE OGLE		2"=1"	2Y-50017	B — 3 TOTAL
FRACTIONAL TOLERANCE ± 1/64 UNLESS OTHERWISE NOTED.					

Figure 1.2

Assembly drawing of lucite sample holder used to count powder samples.





SLIP FIT (.001 TO .002 CLEARANCE)

NOTE; TO BE ASSEMBLED BY USER. MUST BE FREE OF TOOL MARKS

APPROVED FOR CONST.		
CHIEF ENG.	R.J.H	Dec. 18, 1947
CH. DRFTSMN.	L.H.K.	Dec. 18, 47
CHECKED	JAS	Dec. 18-47
DRAWN	J.A.R.	Dec. 18-47
LAYOUT OR SKET.		
GROUP P-11	REPRESENTATIVE OGLE	
FRACTIONS TO ERRANCE ± 1/64 UNLESS OTHERWISE NOTED.		

REV. LTR.	CHANGED ITEM WAS	BY	DATE

TITLE
SAMPLE HOLDER
LUCITE SLEEVES AND SPACERS

SCALE 1"=1"

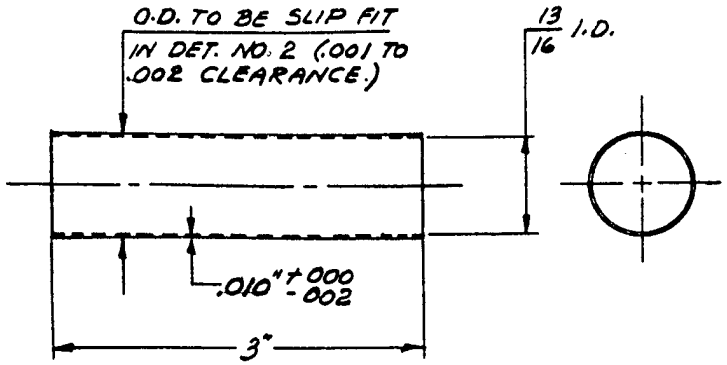
DRAWING NO. 2Y50042 — 1

SHEET SIZE AND NO. B

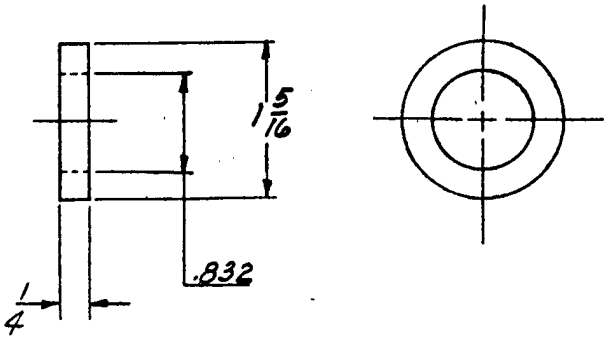
TOTAL 2

Figure 1.3

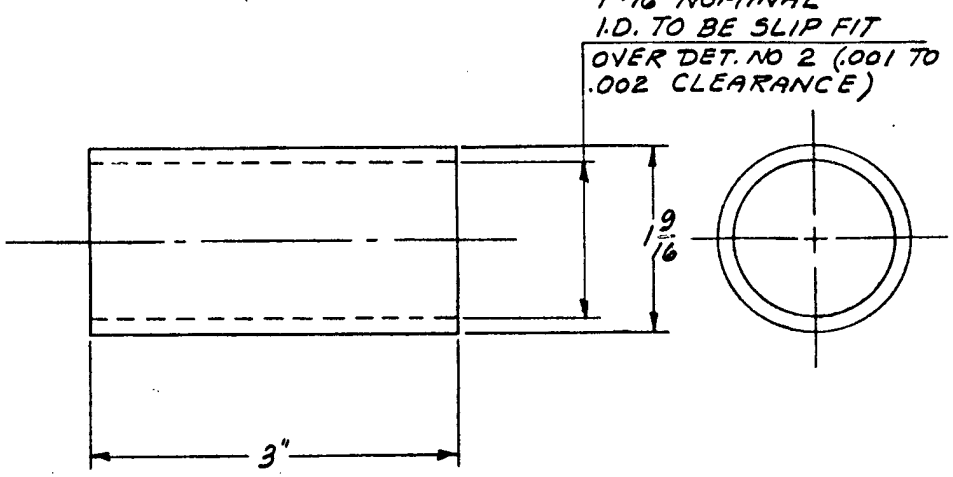
Detail drawing of lucite sample holder used to count powder samples.



(3) 1 REQ'D. MAT'L. LUCITE



(2) 2 REQ'D. MAT'L. LUCITE



(1) 1 REQ'D. MAT'L. LUCITE

NOTE; ALL PIECES MUST BE FREE OF TOOL MARKS

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			REV. LET.	CHANGED ITEM WAS	BY	DATE

APPROVED FOR CONST.		
CHIEF ENG.	R.S.H.	DEC. 18, 1947
CH. DRFTSMN.	L. H.	Dec. 18, 47
CHECKED	VRS	18-47 DEC.
DRAWN	JAR.	18-47
LAYOUT OR SKETCH		
GROUP P-11	REPRESENTATIVE OGLE	

FRACTIONAL TOLERANCE ± 1/64 UNLESS OTHERWISE NOTED.

TITLE
SAMPLE HOLDER
LUCITE SLEEVES AND SPACERS

SCALE	DRAWING NO.	SHEET SIZE AND NO.
1"=1"	2Y50042 — 2 TOTAL	B

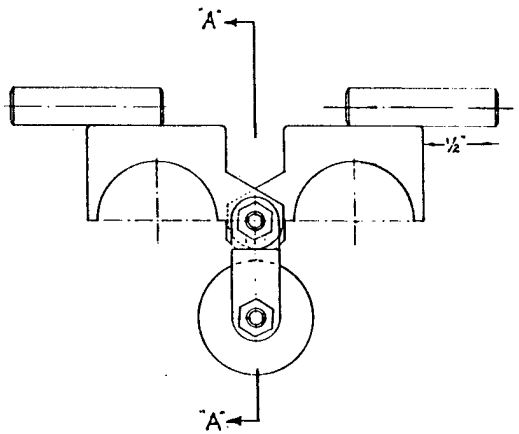
Figure 1.4

Foil shaper used to prepare metal samples for counting.

INDEPENDENCE
SAFETY MATCH
AMERICA'S
OWL MFG. CO

Figure 1.5

Working drawings of foil shaper used to prepare metal samples for counting.



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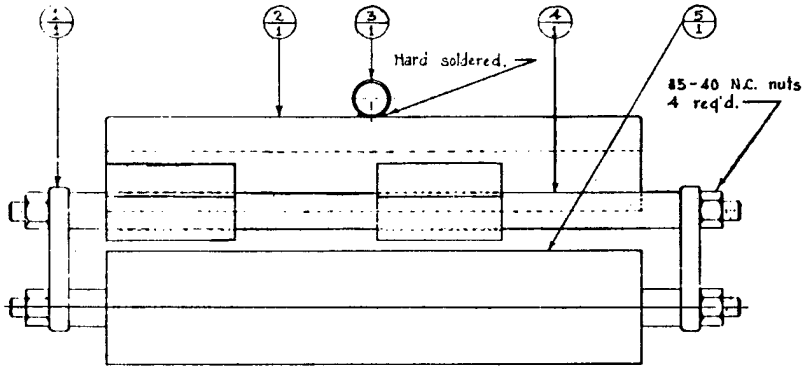
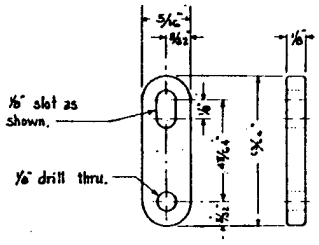
Scale : 2" = 1



Section "AA"



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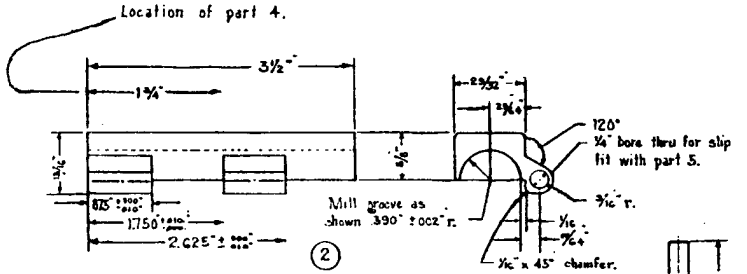

(2)

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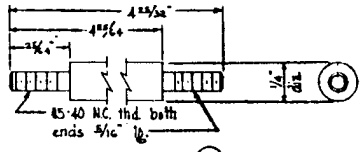

(4)

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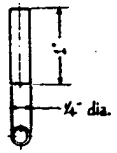
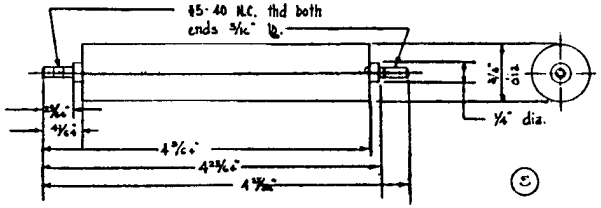
Req'd : 1
Scale : 2" = 1"



(3)

Mat'l : Steel Rod
Req'd : 2
Scale : 1" = 1"



(5)

Mat'l : Steel
Req'd : 1
Scale : 1" = 1"

A	Part 1 redesigned			
A	Old part 2 eliminated			
A	Current part 2 redesigned			
REV. LET.	CHANGED ITEM WAS		BY	DATE

TITLE
FOIL SHAPER

SCALE as shown

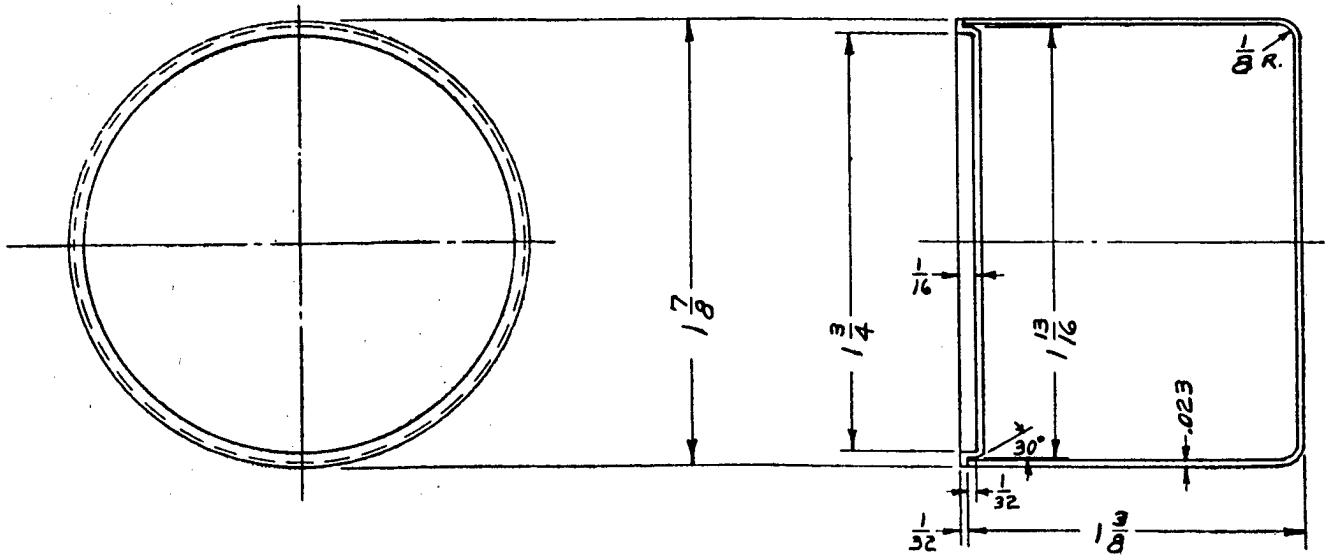
DRAWING NO. 2Y-50025

SHEET NO. 1 TOTAL 1

SIZE C

Figure 1.6

Thin-walled sample can used to hold powders for irradiation during X-ray.



BRASS IF MACHINED
COPPER IF SPUN

APPROVED FOR CONST.			
CHIEF ENG.	G.P.H.	Dec. 4, 1941	
CH. DRFTSMN.	L. Hk	Dec. 4, 41	
CHECKED	H.J.R	DEC. 4 1941	
DRAWN	APM	DEC. 2-41	
LAYOUT OR SKETCH			
GROUP J3	REPRESENTATIVE OGLE		
FRACTIONAL TOLERANCE ± 1/64 UNLESS OTHERWISE NOTED.			

REV. LET.	CHANGED ITEM WAS	BY	DATE

TITLE
CABLE HOLDER & TEST PARTS - SAMPLE CANS

SCALE	DRAWING NO.	SHEET SIZE AND NO.
2"=1"	2Y-50022 — 4 TOTAL	B

Figure 1.7

Disassembled view of large pipe holder showing arrangement of individual samples.

Figure 1.8

Assembled view of large pipe sample holder.

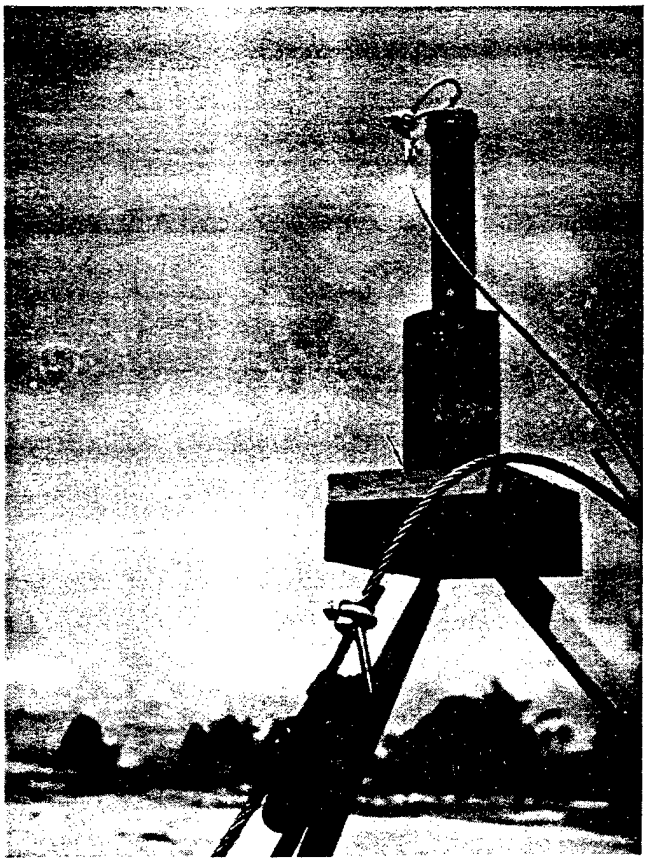
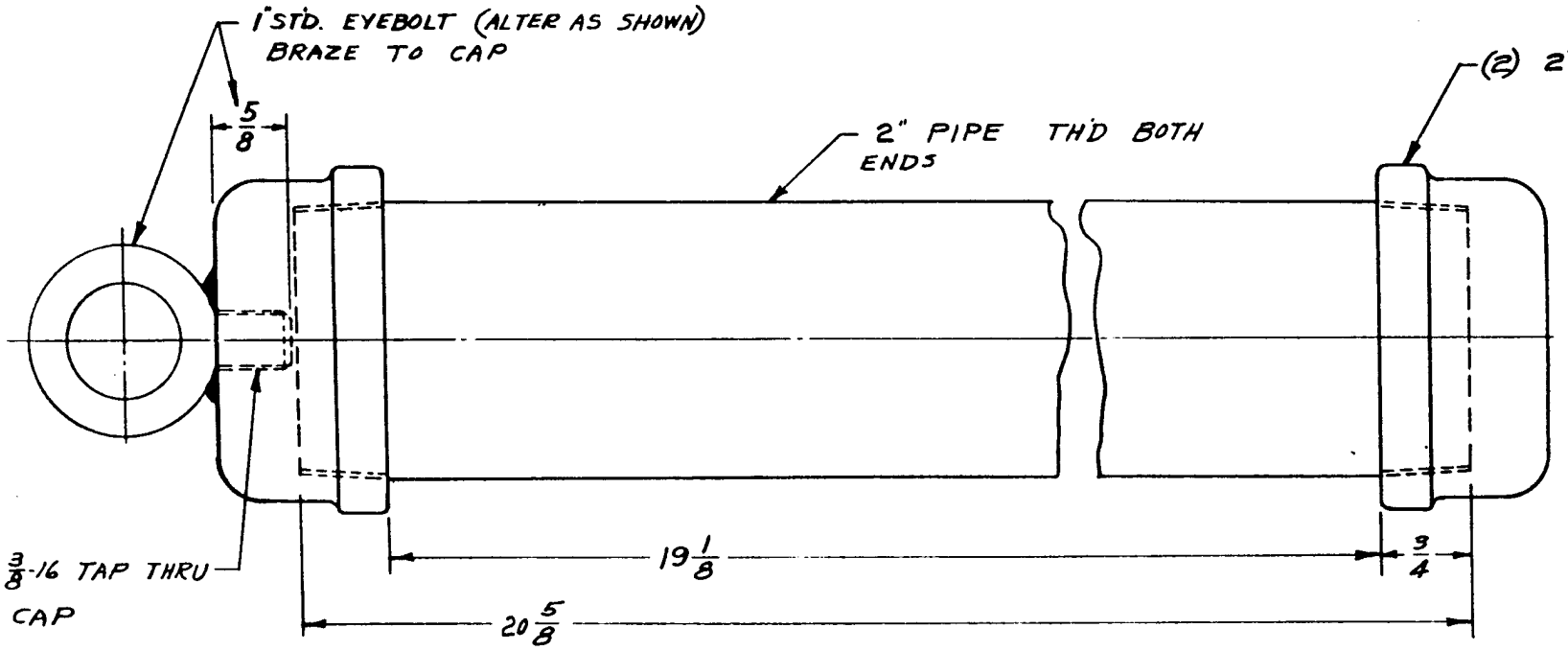


Figure 1.9

Working drawing of large pipe multiple sample holder.



APPROVED FOR CONST.		
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CHECKED	R.T.I	Dec. 3, 1957
DRAWN	APM	DEC. 3-57
LAYOUT OR SKETCH		
GROUP J3	REPRESENTATIVE OGLE	

FRACTIONAL TOLERANCE ± 1/64 UNLESS OTHERWISE NOTED.

REV. LET.	CHANGED ITEM WAS	BY	DATE

TITLE
MULTIPLE SAMPLE HOLDERS & LEAD CASTING

SCALE 1"=1"

DRAWING NO. 2Y-50018 — 1

SHEET SIZE AND NO. B

TOTAL 2

Figure 1.10

Showing method of fastening large multiple sample holder to land cable.

Figure 1.11

Multiple sample holder in place with lead shield. Sulphur sample fastened to main 1/2" land cable also shown.

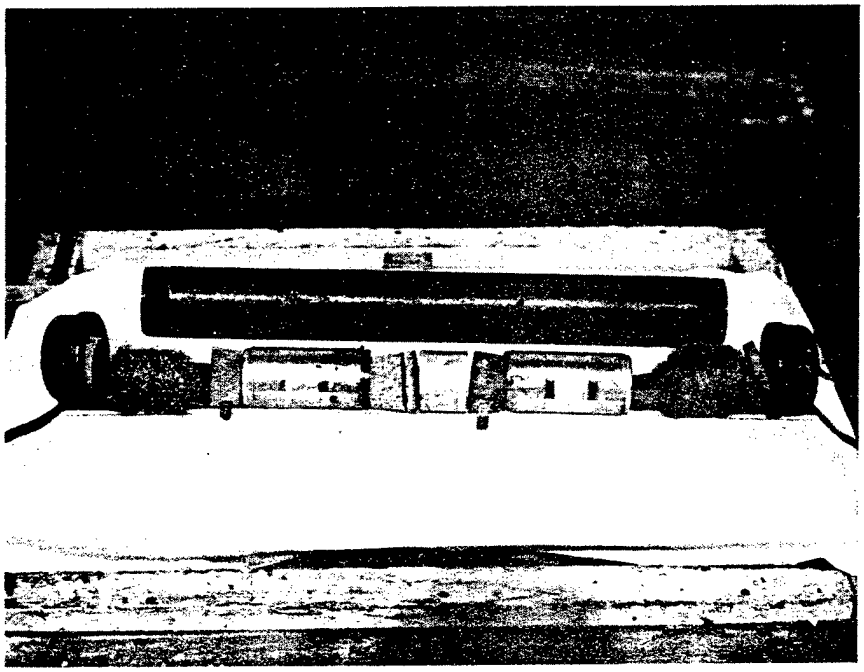
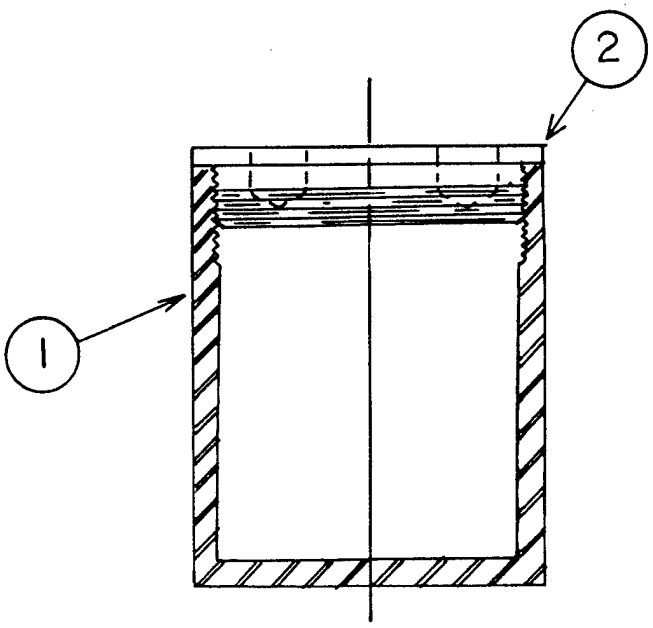
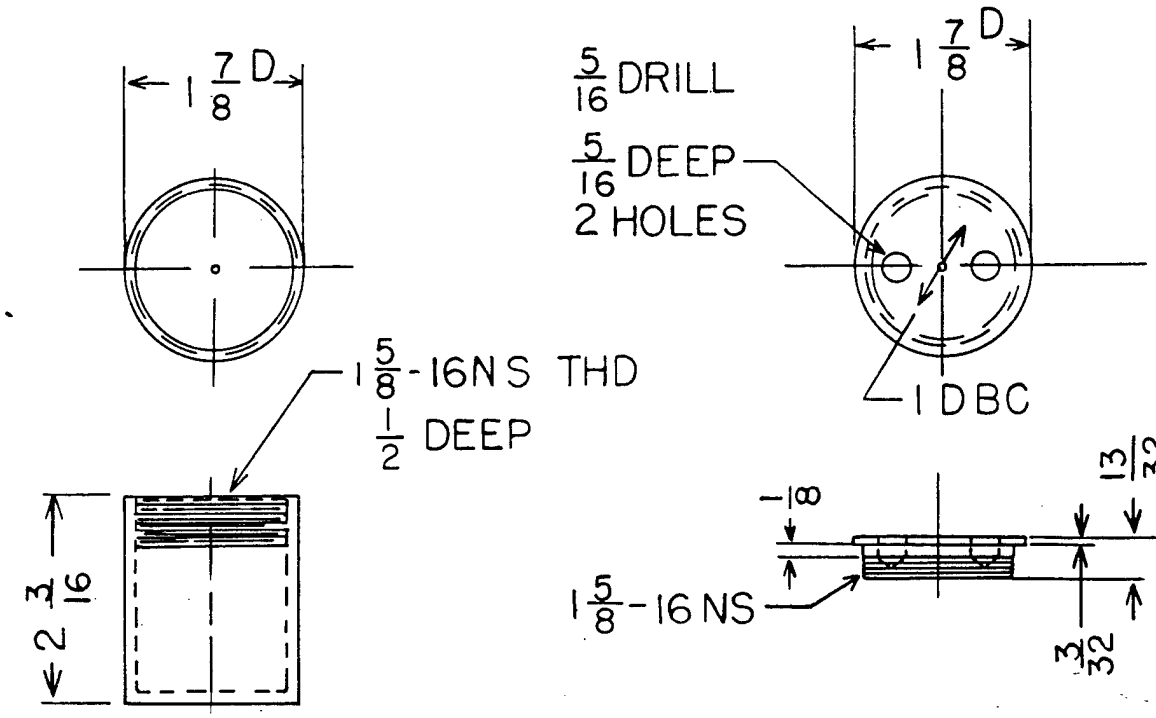


Figure 1.12

Stronger sample can for powders used on Yoke and Zebra. These cans were made for LAJ-3 by the machinist of the Albemarle.



SECTIONAL ASSEMBLY



SAMPLE CAN

FIG. 1.12

Figure 1.13

Multiple sample holder as used on Yoke and Zebra.

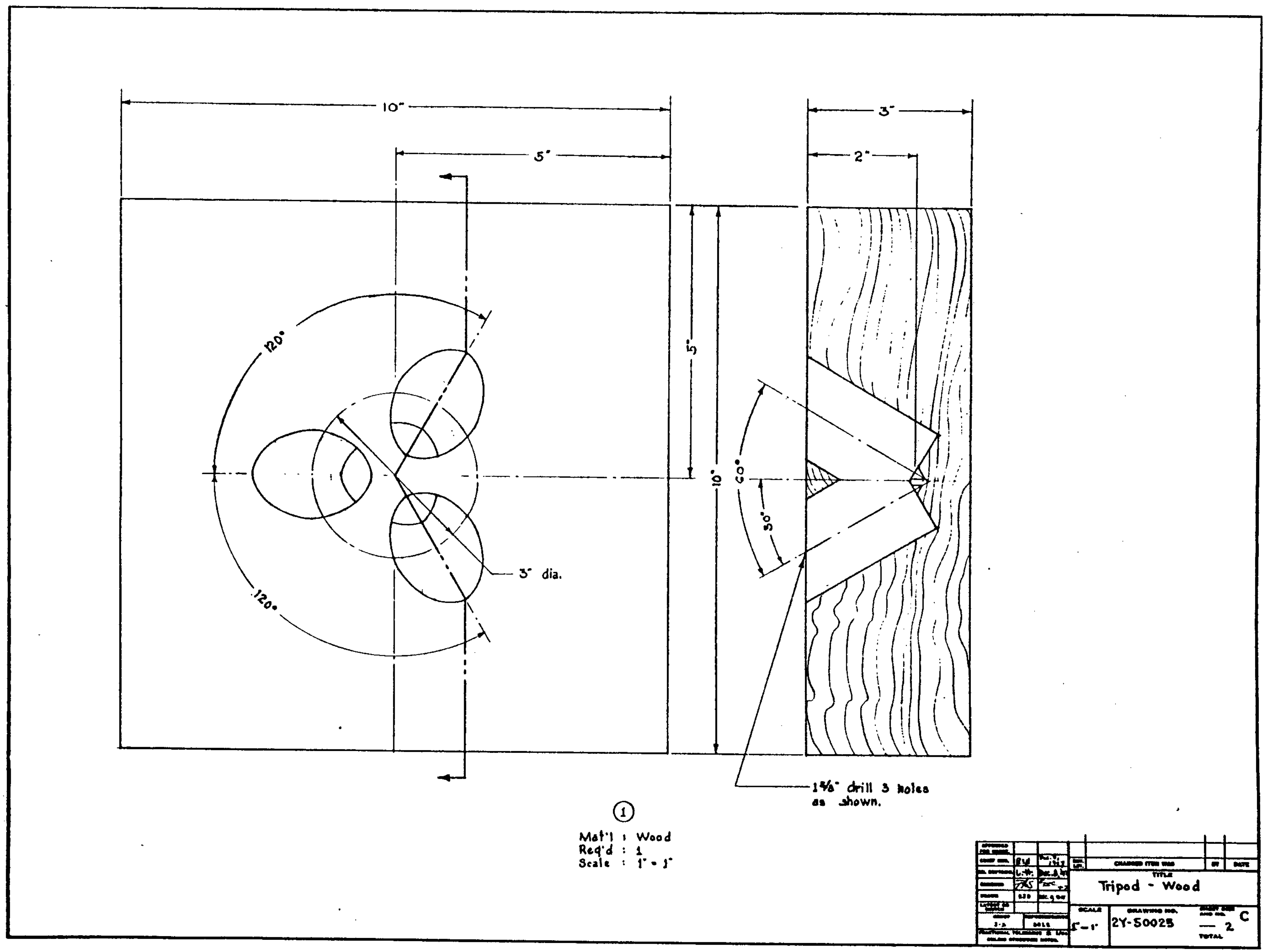
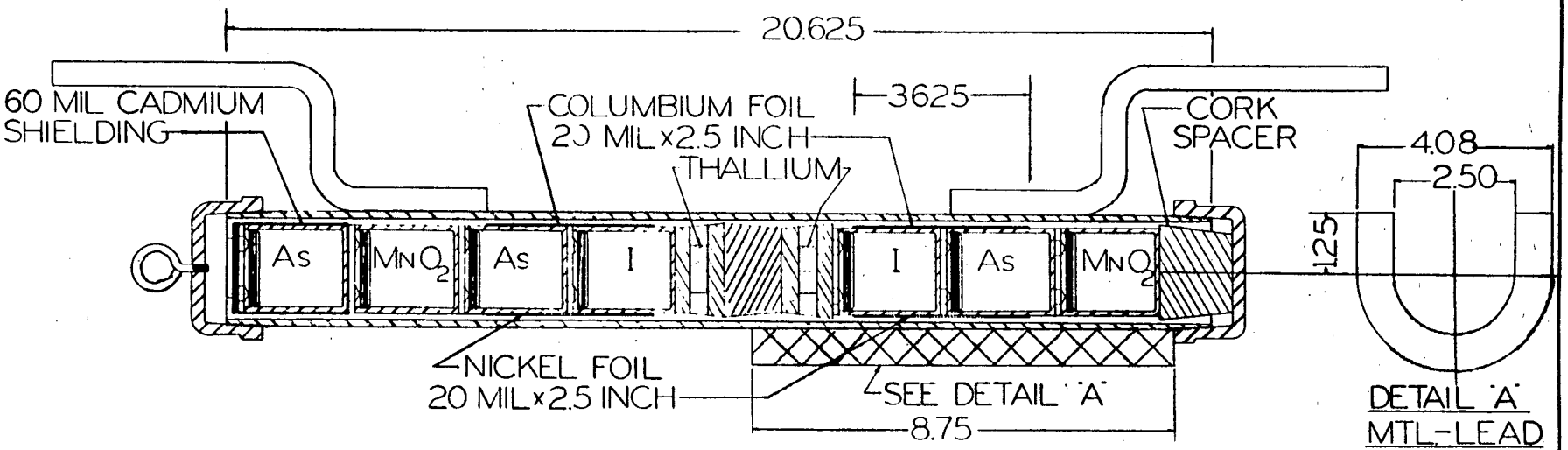

10"
5"
3"
2"
5"
10"
60°
30°
120°
120°
3" dia.
1 5/8" drill 3 holes as shown.
1
Mat'l : Wood
Req'd : 1
Scale : 1" = 1"
Tripod - Wood
2Y-S0025
C
2

Figure 1.14

Lead shield used around multiple sample holders.



MULTIPLE SAMPLE HOLDER

REPORT DRWG. TAKEN FROM 2Y 30018

Figure 1.15

Gasoline driven winch used to pull in the land cable after a shot.

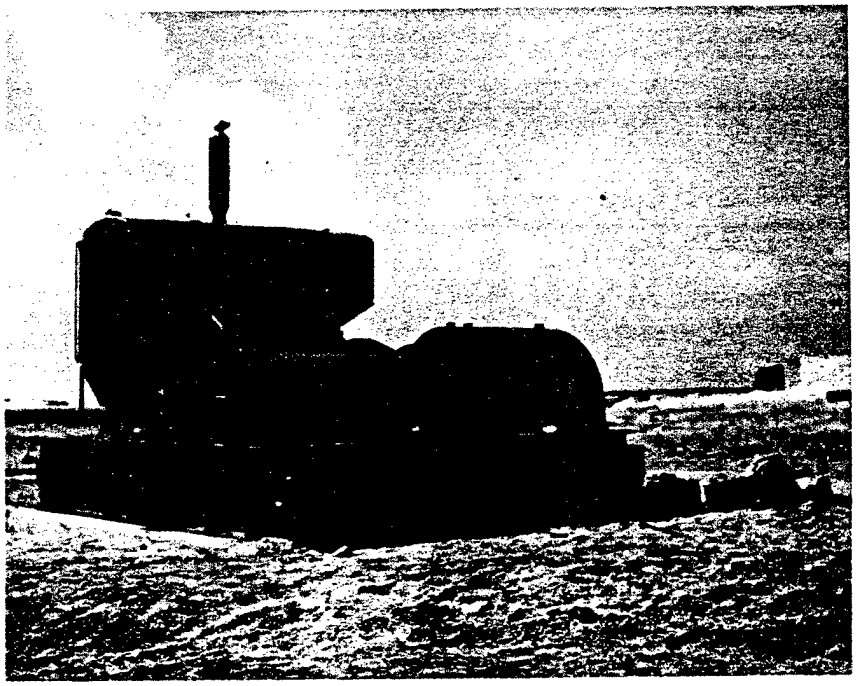
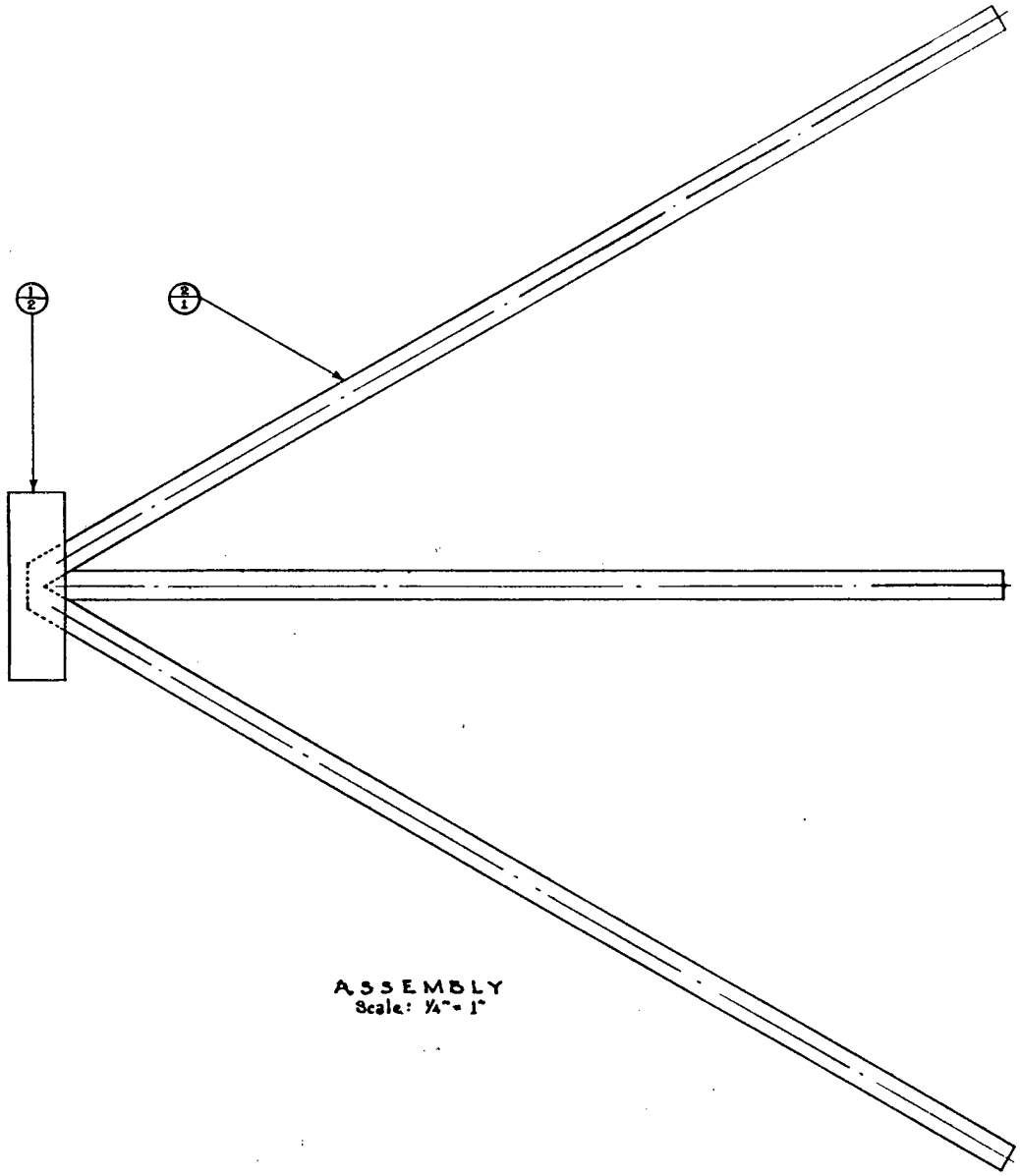
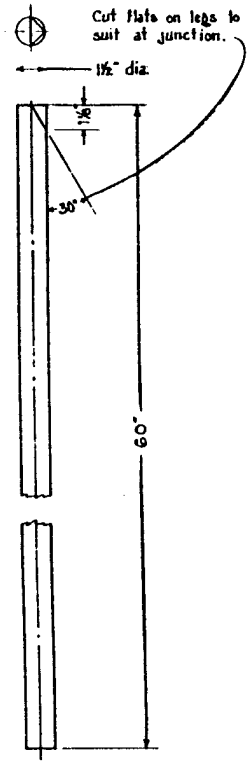


Figure 1.16

Tripod used to keep samples off the ground.



ASSEMBLY
Scale: ¼" = 1"



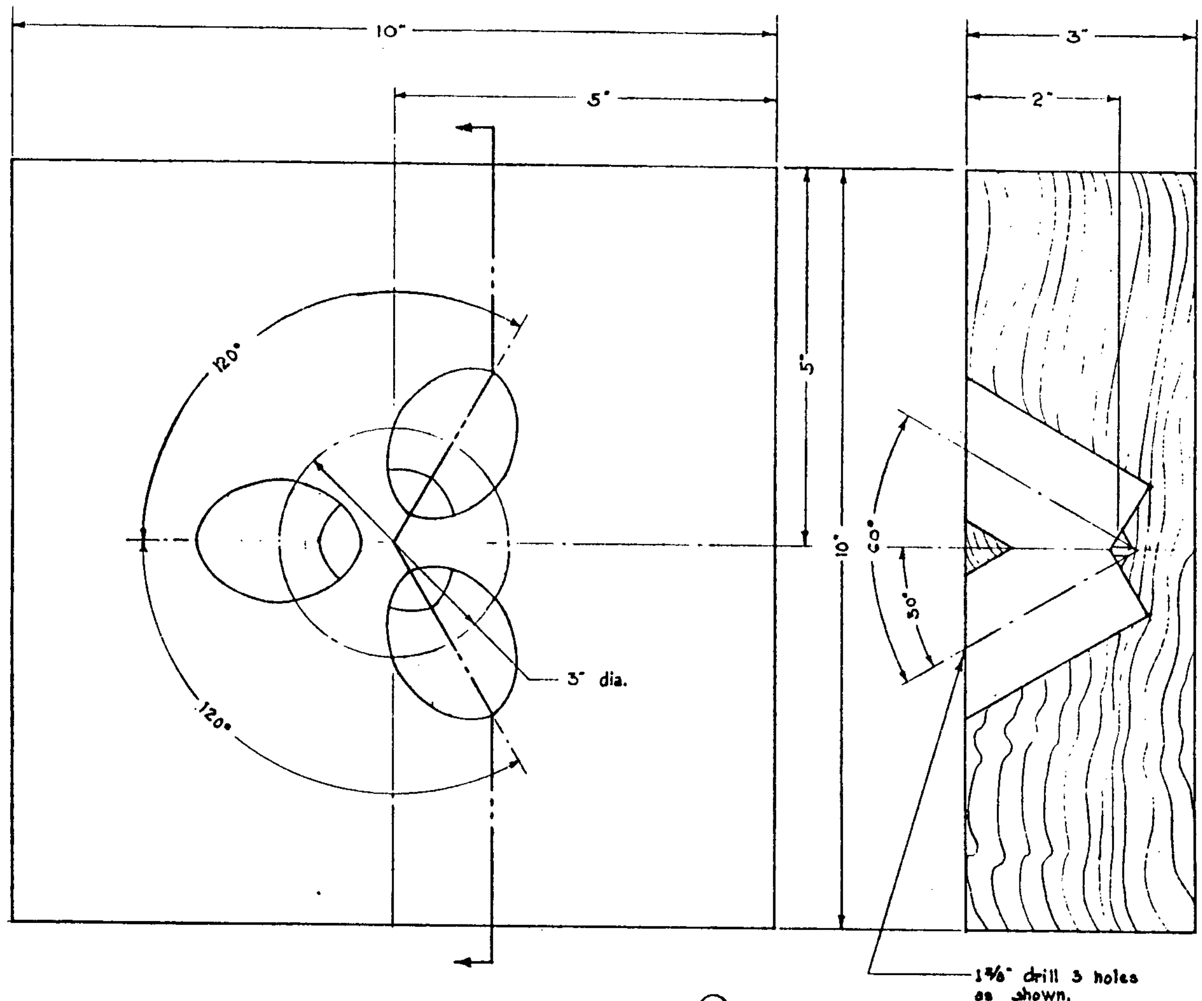
(2)

Mat'l : Wood
Req'd : 3
Scale : ¼" = 1"

			REV. LET.	CHANGED ITEM 1948	BY / DATE
			TITLE	Tripod - Wood	
			SCALE	DRAWING NO.	SHEET SIZE AND DIA.
			¼" = 1"	2Y-50025	C — 1 TOTAL 2

Figure 1.17

Tripod table top.

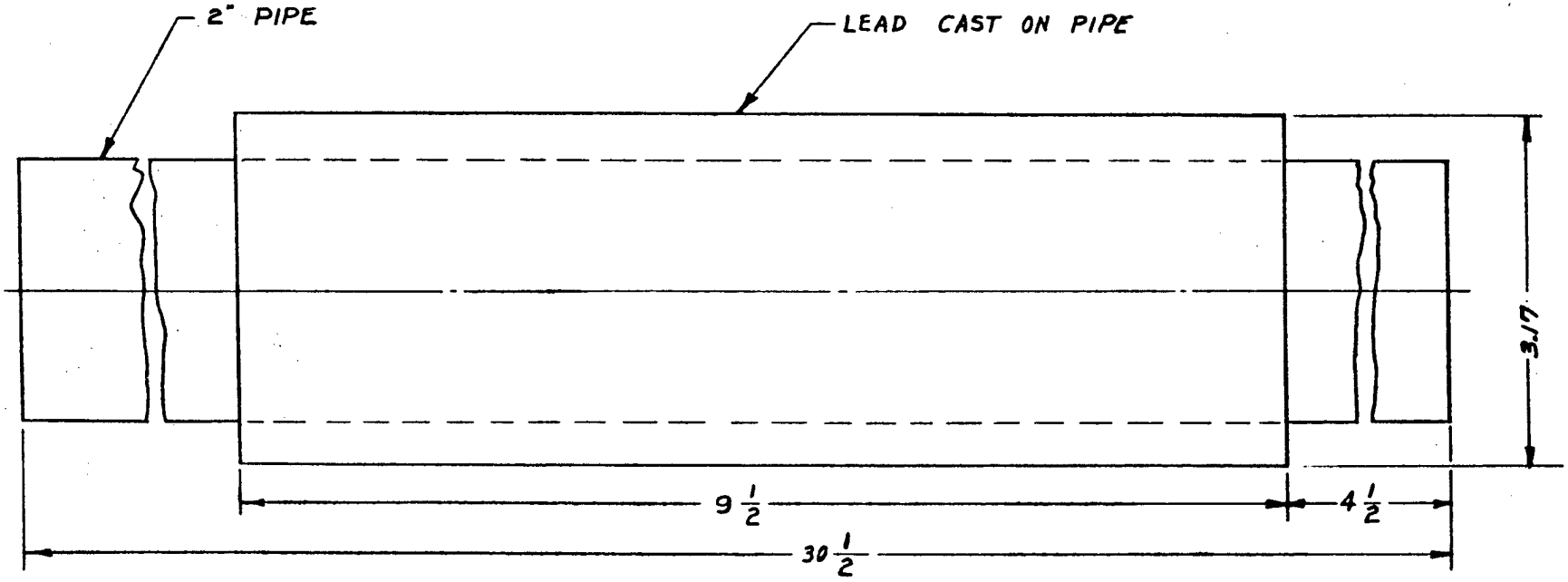


(1)
Mat'l : Wood
Req'd : 1
Scale : 1" = 1"

TITLE	Tripod - Wood
SCALE	1" = 1"
DRAWING NO.	2Y-50025
SIZE	C
TOTAL	2

Figure 1.18

Lead shield for water string carbon samples.



APPROVED FOR CONST.		
CHIEF ENG.	R.J.H.	Dec. 6, 1941
CALIBRATIONS	L.W.	Dec. 4, 41
CHECKED	RJH	DEC. 4, 1941
DRAWN	APM	DEC. 4-41
LAYOUT OR SKETCH		
GROUP	REPRESENTATIVE	
J3	OGLE	

FRACTIONAL TOLERANCE ± 1/64 UNLESS OTHERWISE NOTED.

REV. LET.	CHANGED ITEM WAS	BY	DATE

TITLE
CABLE HOLDER & TEST PARTS
- CARBON LEAD SHIELD

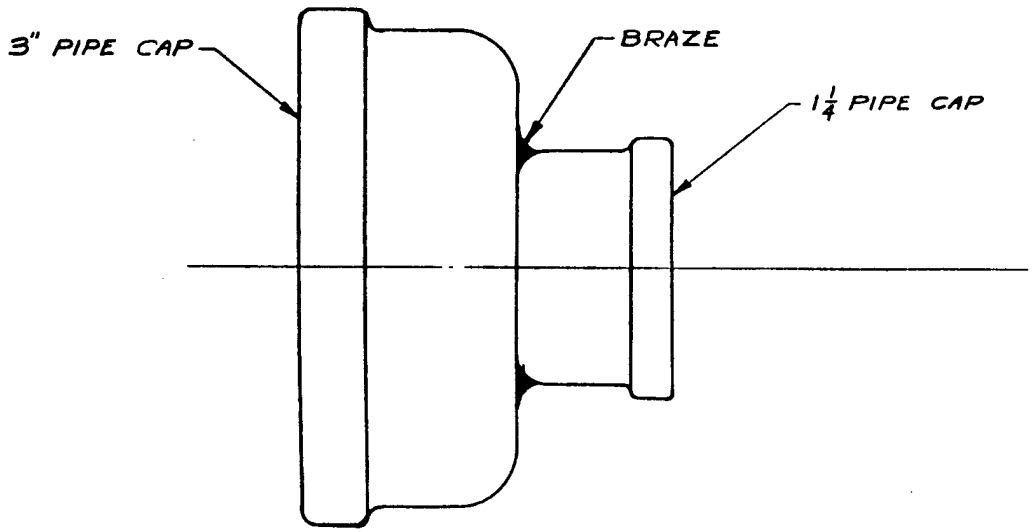
SCALE	DRAWING NO.	SHEET DASH AND NO.
1"=1"	2Y-50022	— 3 TOTAL

B

Figure 1.19

Fitting for top of raft masts

to hold sulphur samples.



APPROVED FOR CONST.		
CHIEF ENG.	R.S.H.	Dec 4, 1947
CH. DRFTSMN.	L.H.	Dec 3, 47
CHECKED	R.M.	DEC. 3, 1947
DRAWN	A.P.M	DEC. 3-47
LAYOUT OR SKETCH		
GROUP J3	REPRESENTATIVE OGLE	

FRACTIONAL TOLERANCE ± 1/64 UNLESS OTHERWISE NOTED.

REV. LET.	CHANGED ITEM WAS	BY	DATE

TITLE
CARBON - SULPHUR HOLDERS
- SULPHUR HOLDER MOUNT

SCALE	DRAWING NO.	SHEET SIZE AND NO.
1" = 1"	2Y-50017	B — 2 TOTAL

Figure 1.20

Small raft showing method of fastening sulphur container.

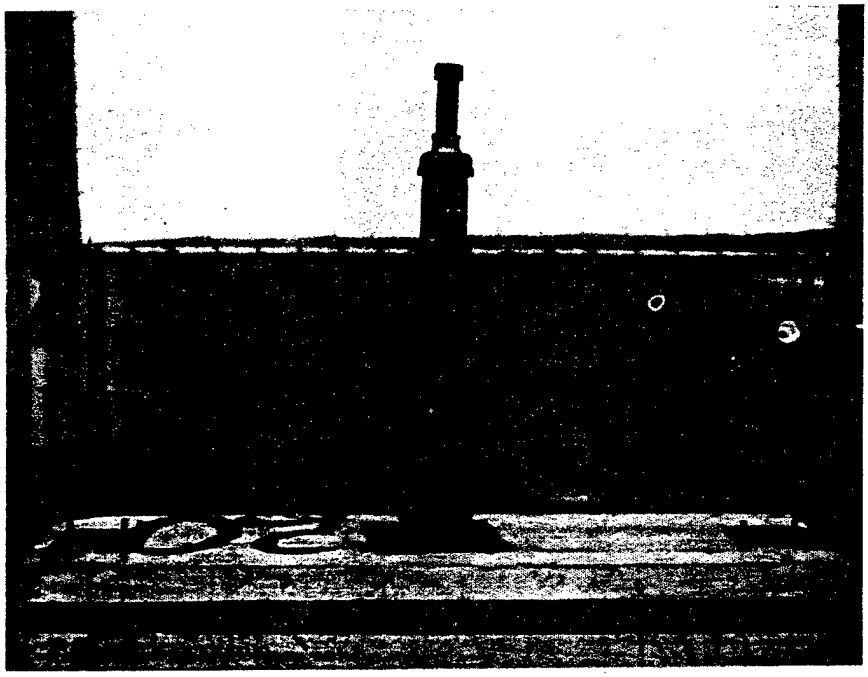
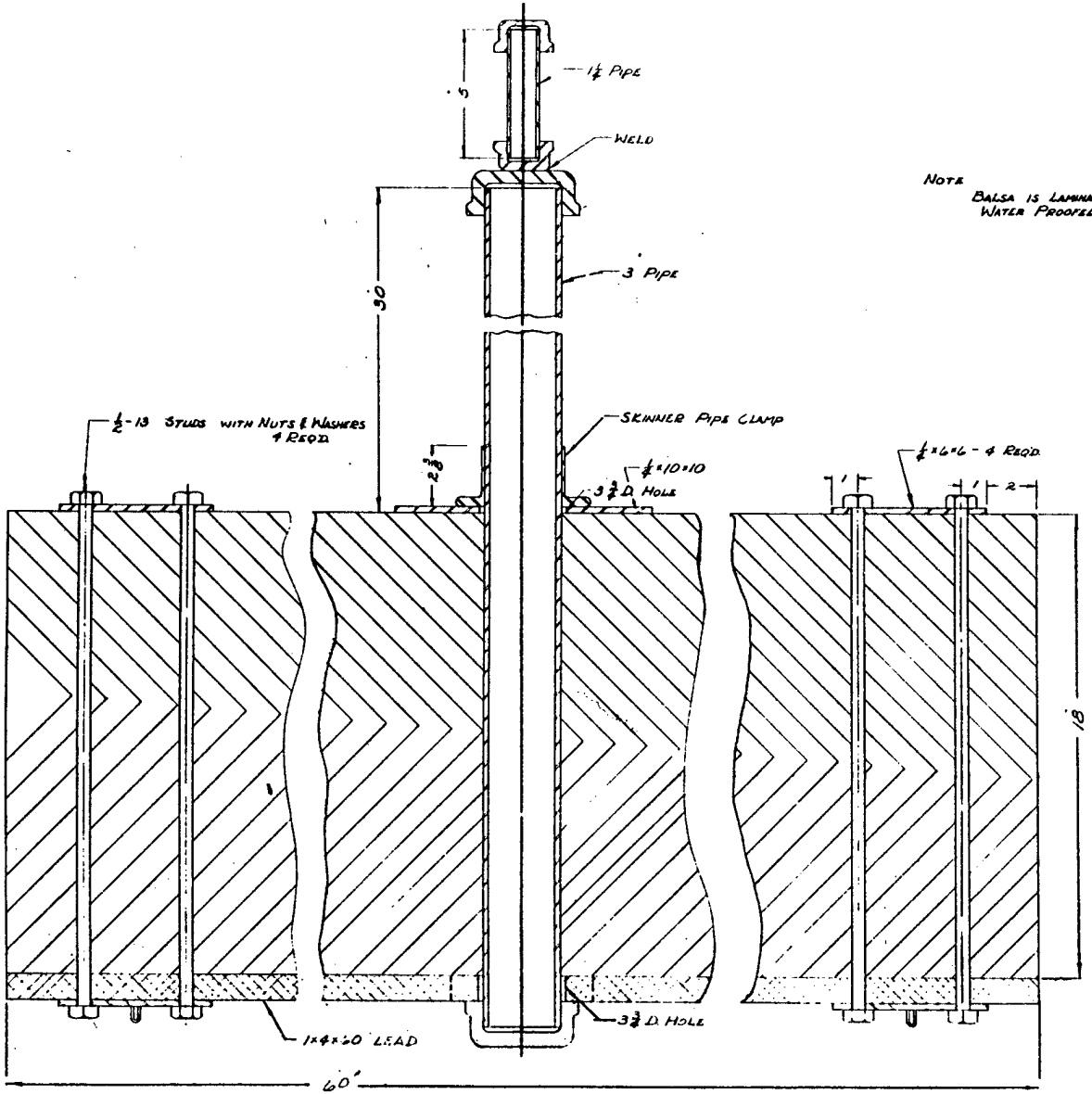
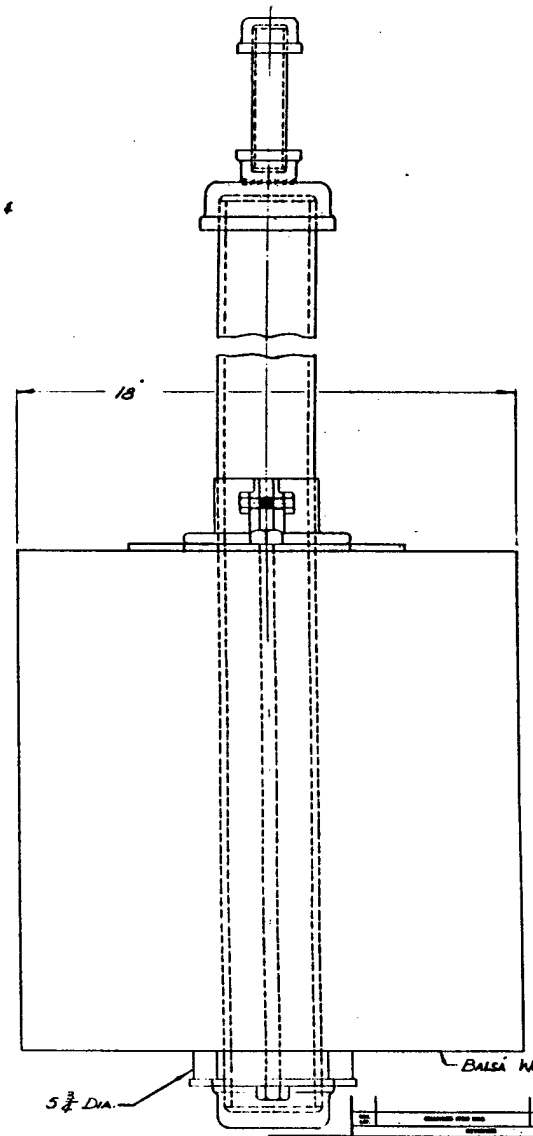


Figure 1.21

Working drawing of small raft, showing mast and sulphur container.



Note
Balsa is Laminated & Water Proofed



SULPHUR RAFT.

2:1

Figure 1.22

Working drawing of large raft, showing keel, mast, sulphur container, carbon container, and lead shield.

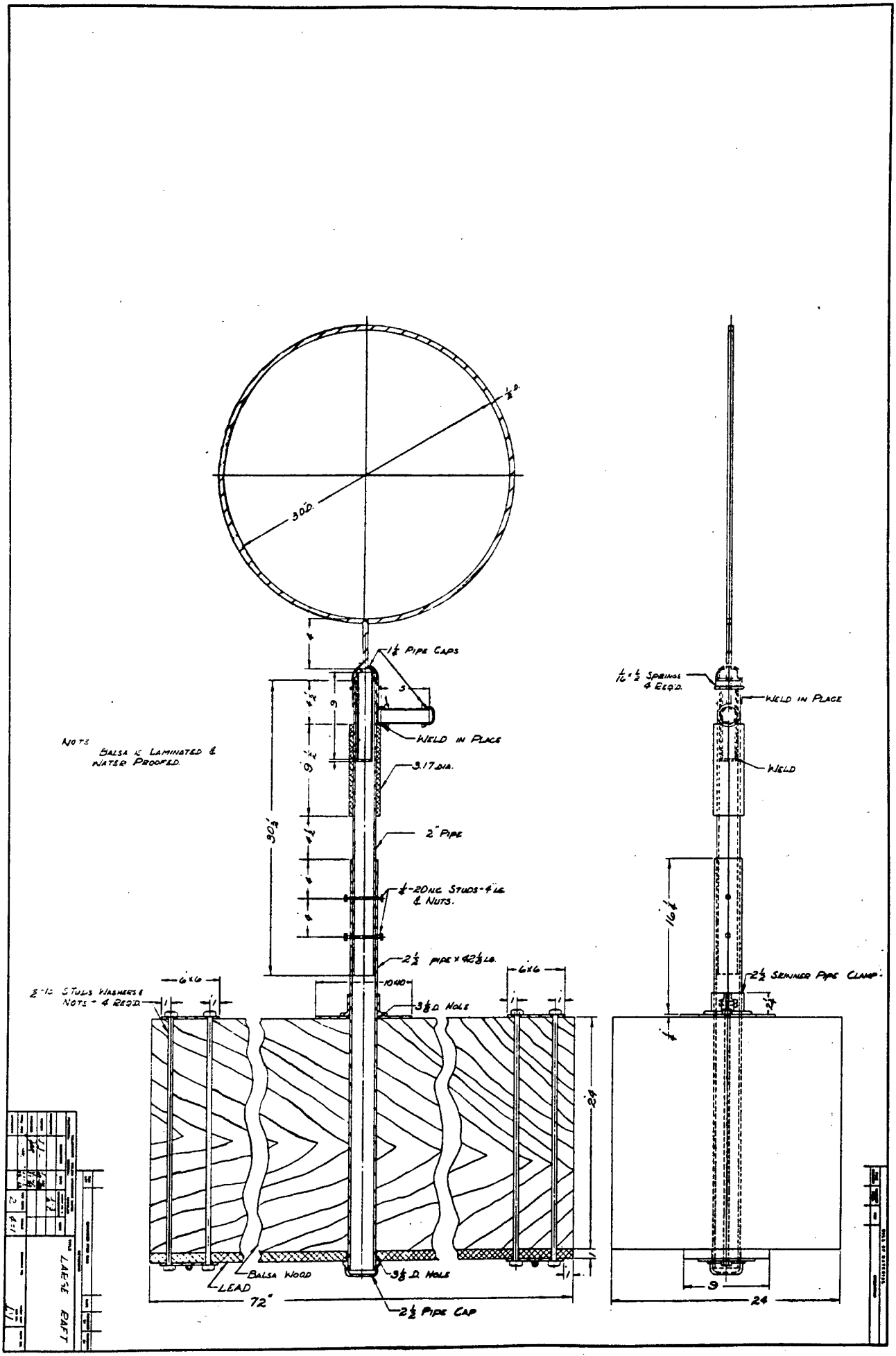

30"D.
1/8" Pipe Caps
3
Weld in Place
3.17 dia.
2" Pipe
1/4-20 N.C. Studs - 4" Lg. & Nuts.
2 1/2 Pipe x 42 3/8 Lg.
10 HD
3 1/8 D. Holes
6"x6"
6"x6"
2-1/2 Studs Washers & Nuts - 4 Reqd.
Balsa Wood
Lead
3 1/8 D. Holes
2 1/2 Pipe Cap
72"
24
1/2 x 1/2 Springs 4 Reqd.
Weld in Place
Weld
16"
2 1/2 Skinner Pipe Clamp
9
24
Note
Balsa is Laminated & Water Proofed.
Lake Raft

Figure 1.23

Large raft in place. Linenberger is attempting a practice recovery of the carbon samples.

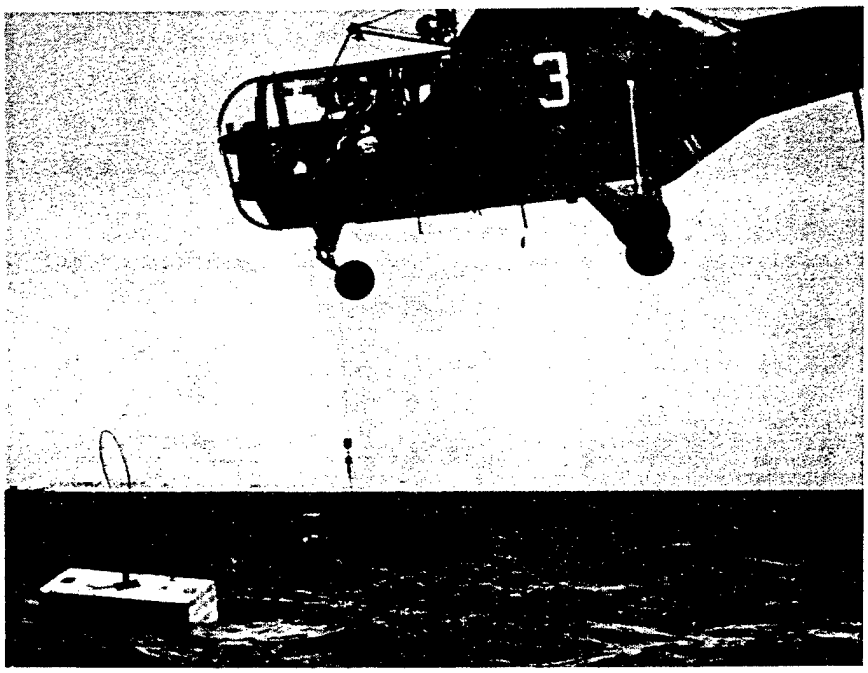
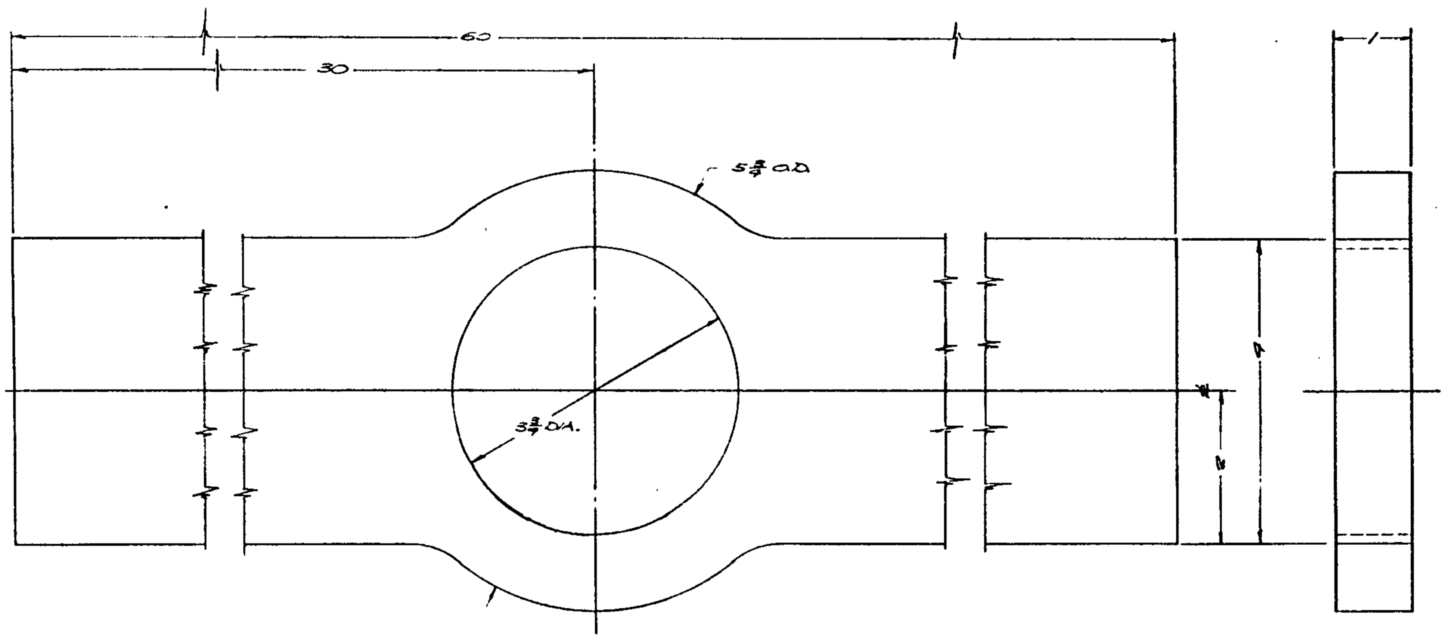

3

Figure 1.24

Bottom of small raft, showing lead keel and method of fastening raft to main cable by means of chains.

Figure 1.25

Working drawing of keel for small raft.



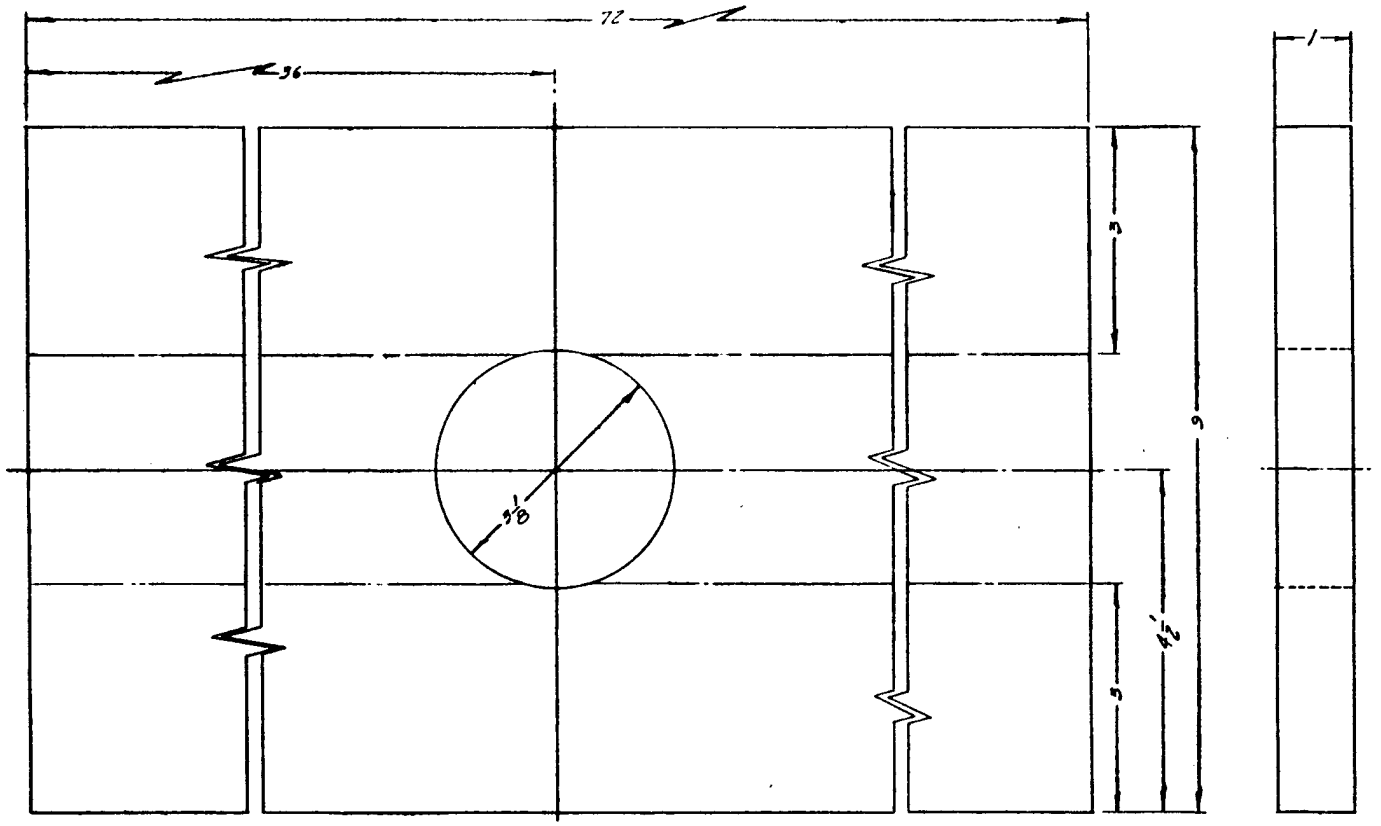
MAT'L : LEAD
95 REQ'D

NOTE:
IF ½ INCH LEAD IS USED, THE TWO PIECES SHOULD BE FUSED TOGETHER AT ALL EXPOSED EDGES.

TITLE	LEAD BALLAST (SMALL)
SCALE	1"=1"
DRAWING NO.	ZY-50088 — 2
SIZE	C
TOTAL	2

Figure 1.26

Working drawing of keel for large raft.



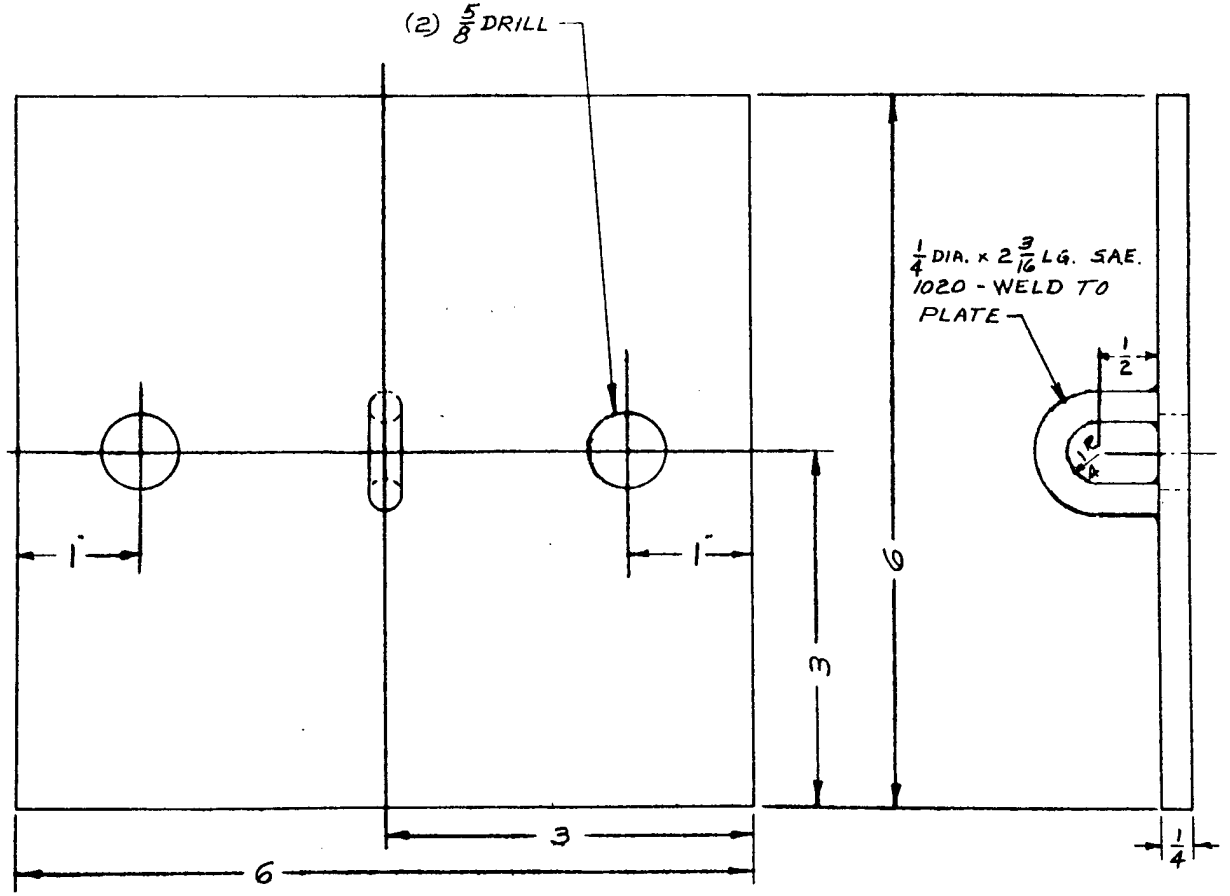
15 REQ'D MAT'L. LEAD

NOTE:
IF PIECE IS FABRICATED FROM ½ LEAD SHEET'S THE TWO PIECES SHOULD BE FUSED TOGETHER ALONG ALL EXPOSED EDGES AND LINES FROM 3" DIMENSIONS.

	LEAD BALLAST LOCKE	
V-S	LOCKE	C
1=1	24-50038—1	2

Figure 1.27

Steel base plate to hold keel on raft, showing eye used to fasten raft to main cable.



S.A.E.-1020 OR EQUIV.

NO. REQ'D.___ WITH U-BOLT
NO. REQ'D.___ WITH OUT U-BOLT

APPROVED FOR CONST.		
CHIEF ENG.	R.J.H.	Dec. 6, 1947
CH. DRFTSMN.	L.T.T.	Dec. 4, 47
CHECKED	R.J.H.	DEC 4, 1947
DRAWN	APM	DEC 4-46
LAYOUT OR SKETCH		
GROUP J3	REPRESENTATIVE OGLE	
FRACTIONAL TOLERANCE ± 1/64 UNLESS OTHERWISE NOTED.		

REV. LET.	CHANGED ITEM WAS	BY	DATE
A	Sheet 5 added.	R.J.H.	Sept. 23, '48

TITLE
CABLE HOLDER & TEST PARTS

SCALE	DRAWING NO.	SHEET SIZE AND NO.
1"=1"	2Y-50022 — 1	B
	TOTAL 4	

Figure 1.28

Fastening 2" x 4" x 4' boards to water cable as a means of floating the cable.

Figure 1.29

Showing water cable with supporting 2" x 4" floating off Engebi.

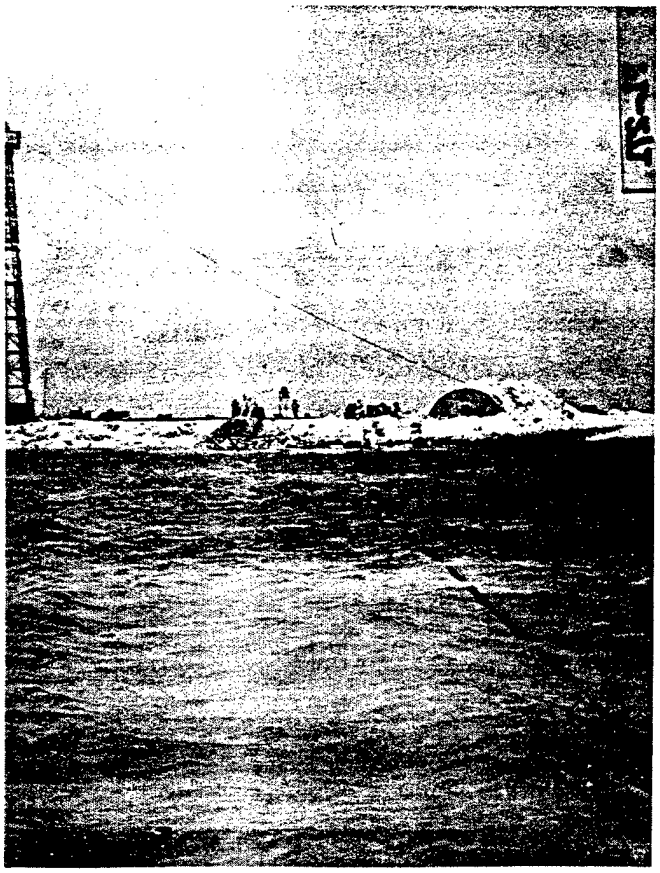


Figure 1.30

Water cable off Engebi, showing floatation by 2" x 4"'s and raft fastened to cable.

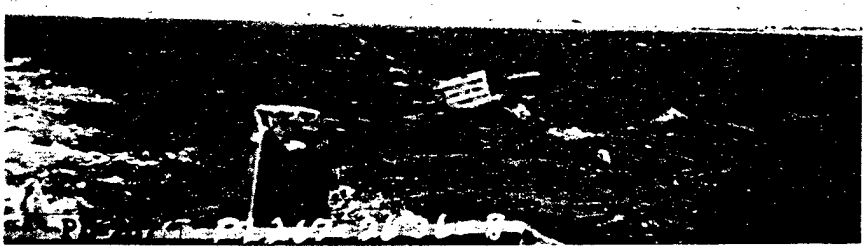


Figure 1.31

Counting room. Showing lead counter shields, scalars, and mechanical recorders. Sulphur was counted on the two outfits on the right.

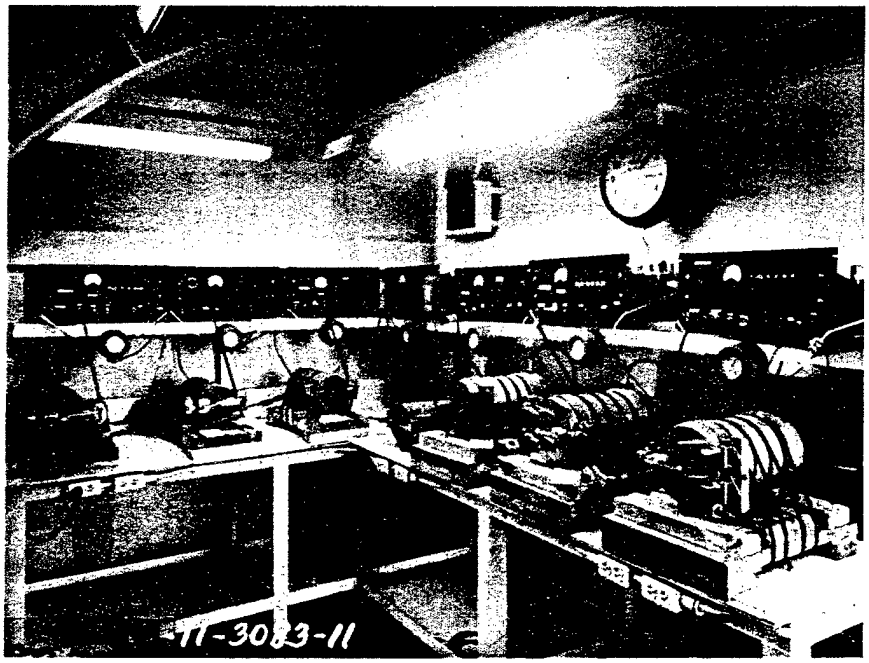
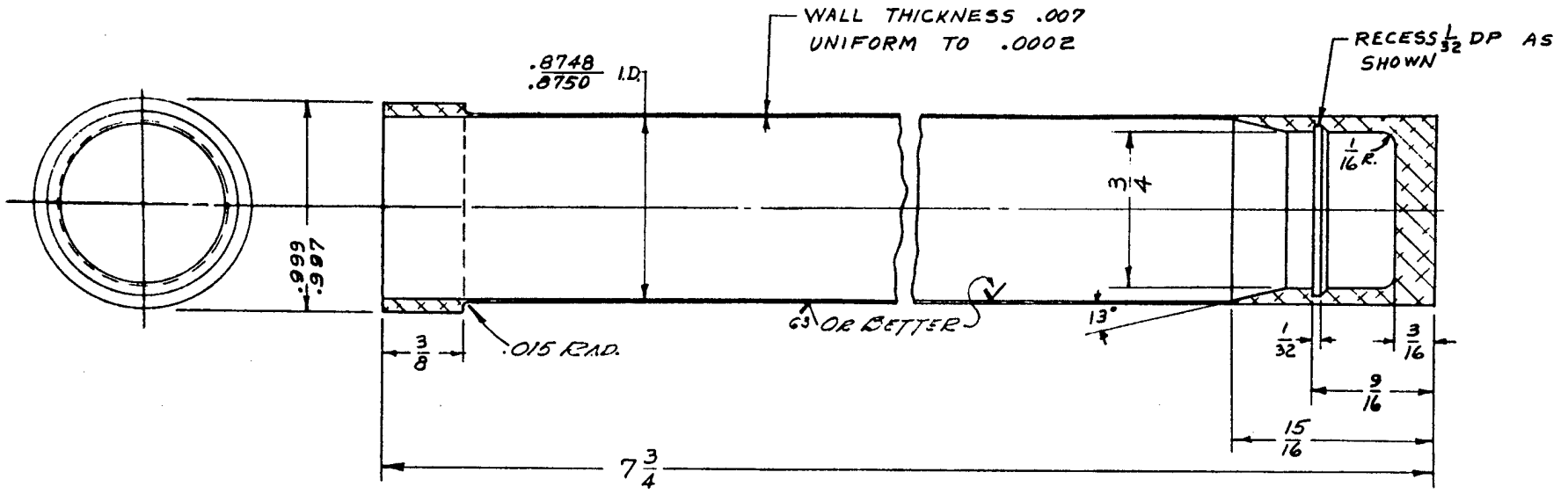

-11-3083-11

Figure 1.32

Geiger tube used in sulphur counters.



PART NO. - 1
MATERIAL:- R-303-T AL. OR 24 ST ALCOA
NO. REQ'D. - 1

APPROVED FOR CONST.			A	.013 RAD. & OUTSIDE FIN. MARKS ADDED	LP	MAR. 1-48
CHIEF ENG.	R.J.H.	Dec. 2, 1947	REV. LET.	CHANGED ITEM WAS	BY	DATE
CH. DRFTSMN.	L.H.S.	Dec. 1, '47	TITLE	G. M. COUNTER-TUBE- MODEL-B		
CHECKED	RRC	DEC. 1-47				
DRAWN	APM	DEC 1-47	SCALE	DRAWING NO.	SHEET SIZE AND NO.	
LAYOUT OR SKETCH			2" = 1"	2Y-50011	B — 1	
GROUP J3	REPRESENTATIVE G. A. L. Jr.				TOTAL 1	
FRACTIONAL TOLERANCE ± 1/64 UNLESS OTHERWISE NOTED.						

Figure 1.33

Land-sulphur container.

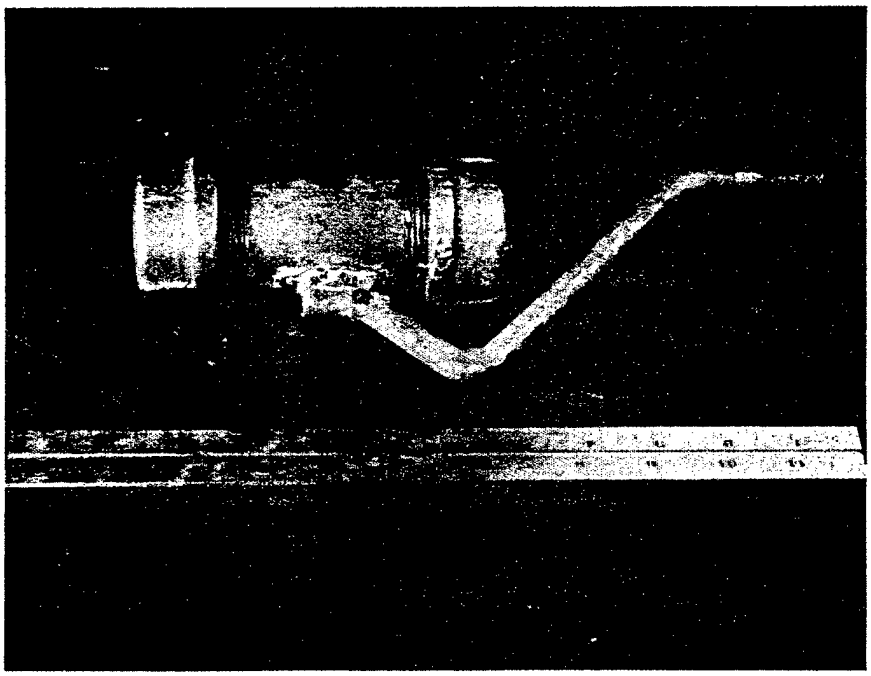
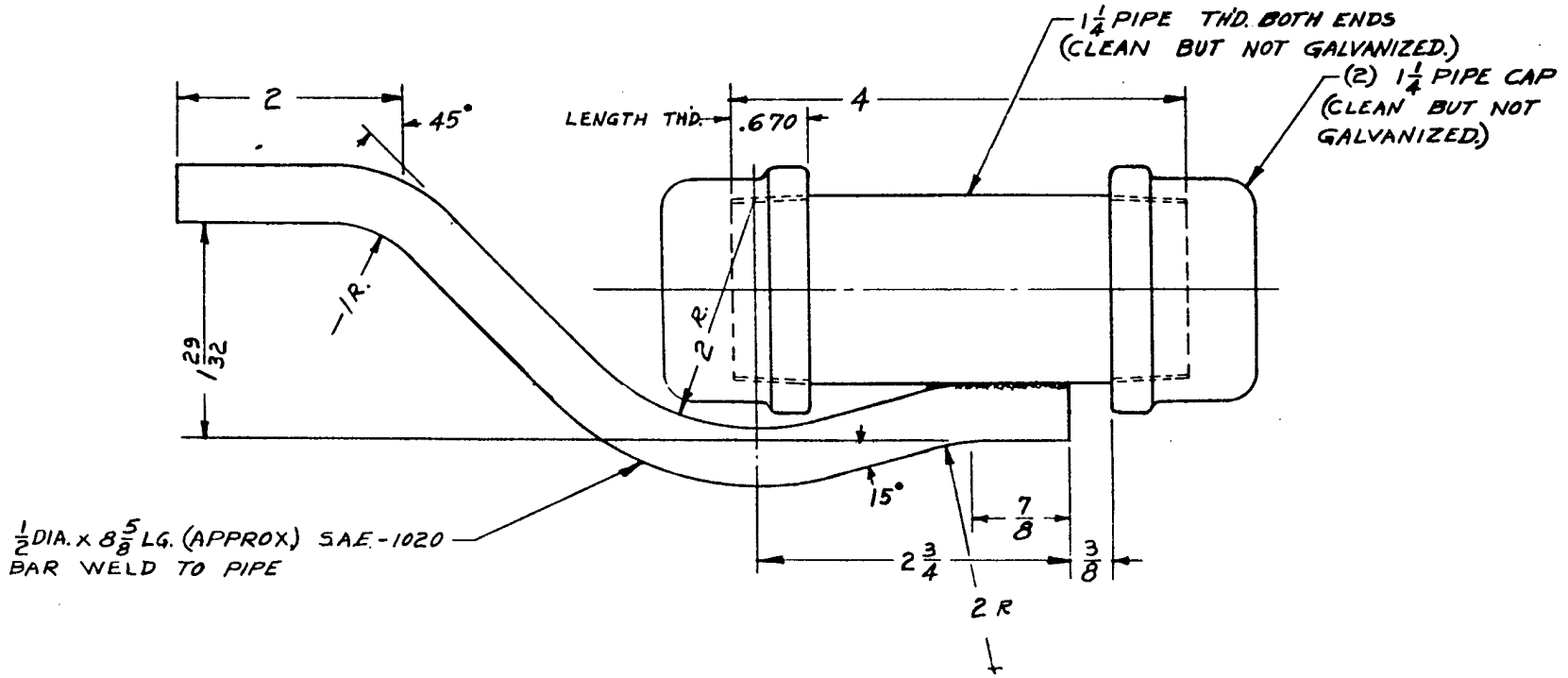


Figure 1.34

Detail drawing of land-sulphur container.



APPROVED FOR CONST.		
CHIEF ENG.	R.S.H.	Dec. 4, 1947
CH. DRFTSMN.	L.H.	Dec. 3, 1947
CHECKED	W.C.R.	DEC. 3, 1947
DRAWN	A.P.M.	DEC. 3-47
LAYOUT OR SKETCH		
GROUP J3	REPRESENTATIVE OGLE	
FRACTIONAL TOLERANCE ± 1/64 UNLESS OTHERWISE NOTED.		

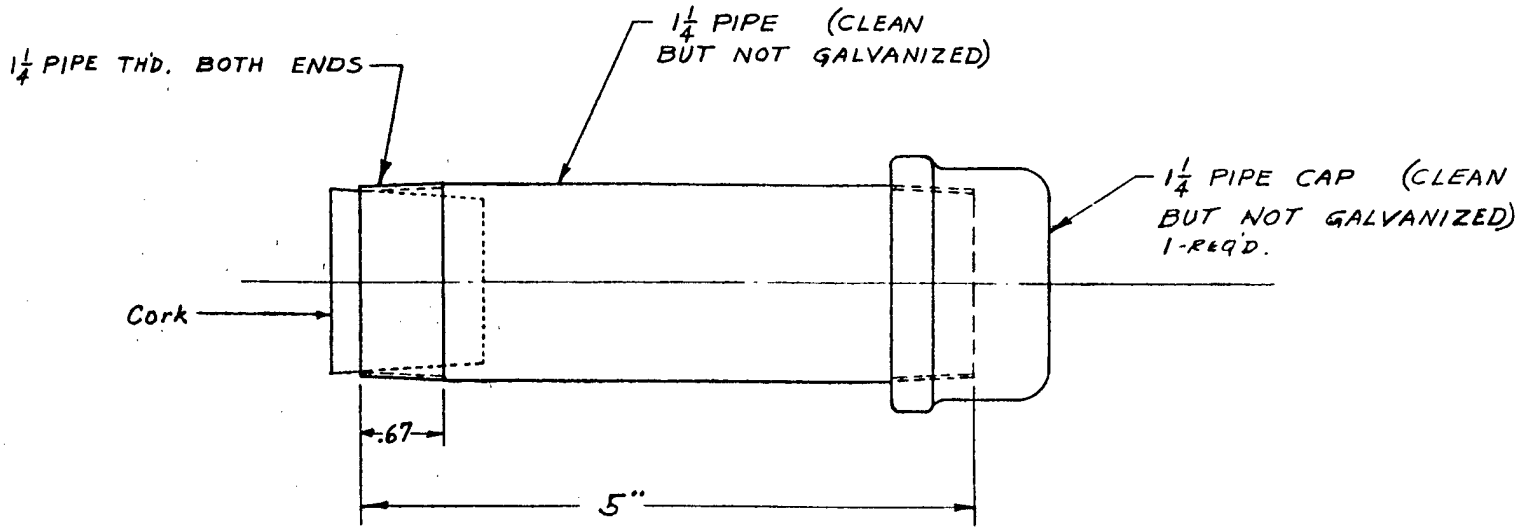
REV. LET.	CHANGED ITEM WAS	BY	DATE

TITLE
CARBON-SULPHUR HOLDERS-
CABLE SULPHUR HOLDER

SCALE	DRAWING NO.	SHEET SIZE AND NO.
1"=1"	2Y-50017 — 5 TOTAL	B

Figure 1.35

Sulphur container used on water string.



REV. LET.	CHANGED ITEM WAS	BY	DATE
A	Sheet 6 added.	RJH	June 23 1948
A	Cork added.	RJH	June 23, 1948
A	Pipe cap was 2 req'd.	RJH	June 23, 1948

APPROVED FOR CONST.		
CHIEF ENG.	R.J.H.	Dec. 4, 1947
CH. DRFTSMN.	Litt.	Dec 3, 47
CHECKED	R.J.H.	DEC. 3 1947
DRAWN	APM	DEC 2-47
LAYOUT OR SKETCH		
GROUP J3	REPRESENTATIVE OGLE	
FRACTIONAL TOLERANCE ± 1/64 UNLESS OTHERWISE NOTED.		

TITLE
CARBON - SULPHUR [redacted]LDERS

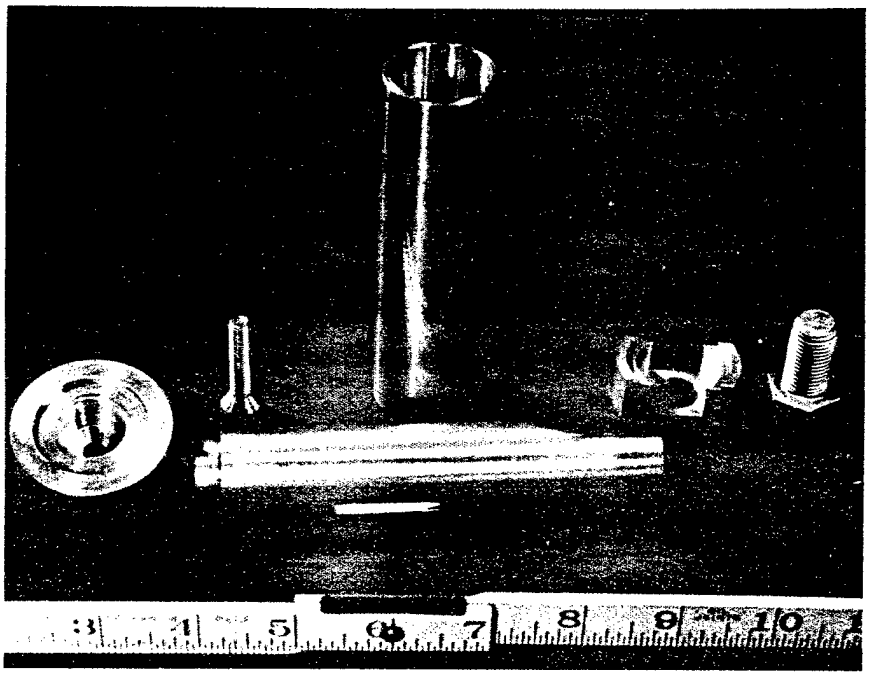
SCALE	DRAWING NO.	SHEET SIZE AND NO.
1"=1"	2Y-50017 — 1	B
	TOTAL 6	

Figure 1.36

Sulphur mold disassembled.

Figure 1.37

Sulphur mold assembled.



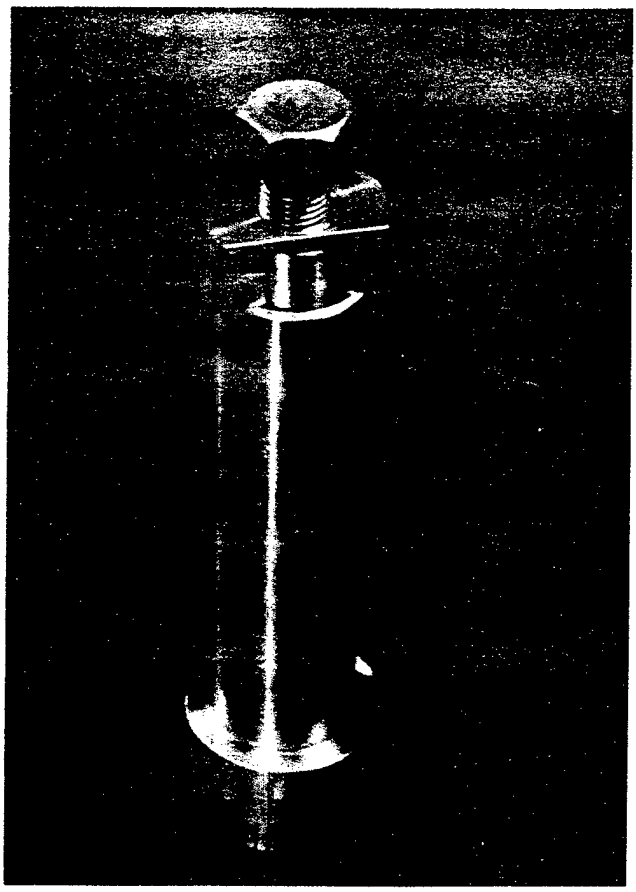
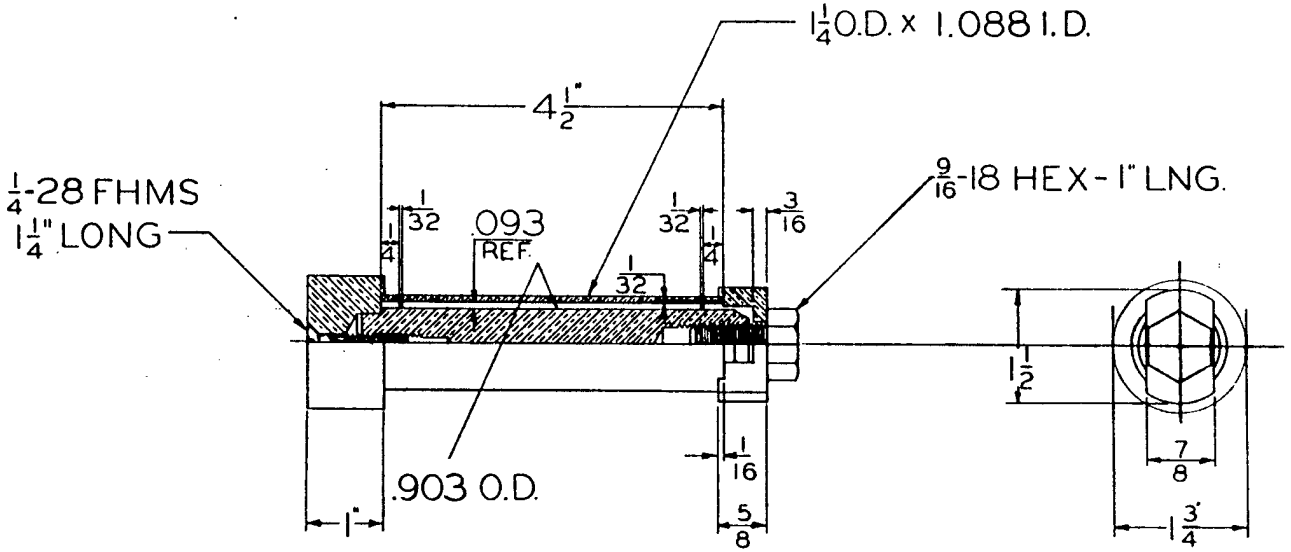


Figure 1.38

Working drawing of sulphur mold.



BILL OF MATERIAL

PART NUMBER	NUMBER REQ.	PER	DESCRIPTION

REV. LTR	CHANGES ITEM NO.	DATE	APPROVED BY

REVISIONS

TOLERANCES - UNLESS OTHERWISE NOTED
FRACTIONAL ± DECIMAL ± ANGULAR ±

	SIGNATURE	DATE	DRAWING NO. OR IDENTIFICATION	DATE
DESIGNATED				
DRAWN	[illegible]	12-68		
CHECKED	[illegible]	12-68		
FINAL APPR.				
APPROVED				

TITLE: SULPHUR MOLD

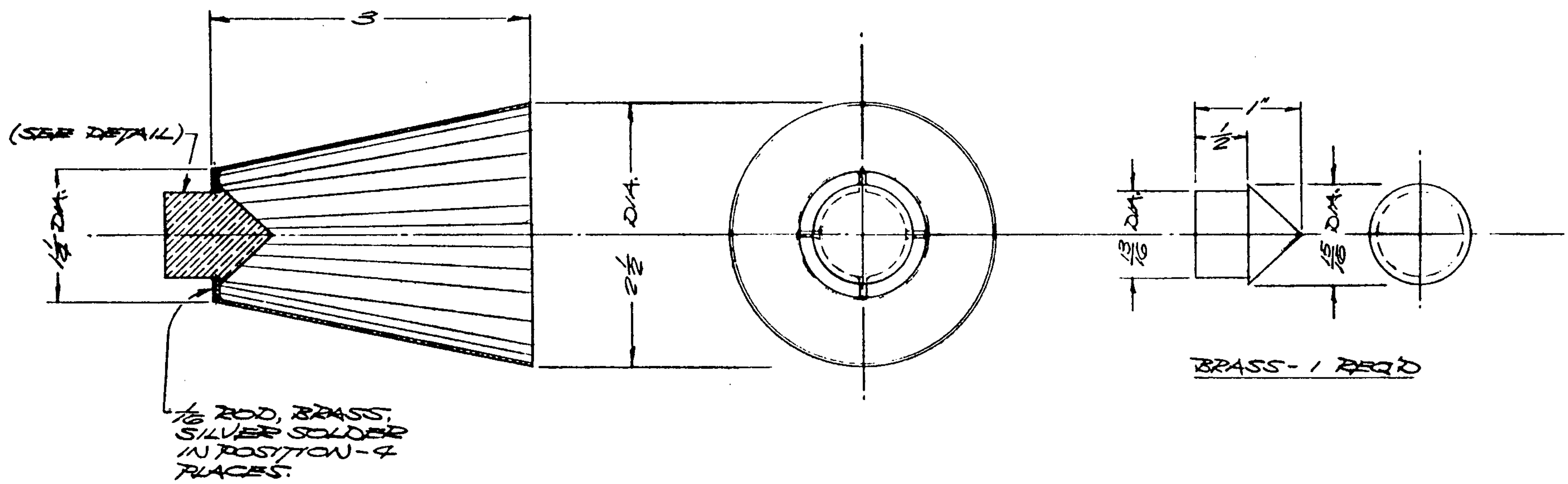
MATERIAL | SCALE | DRAWING NO. | SIZE | PART NO.

REPORT DW 4 REF 2Y-5092

Figure 1.39

Special funnel in place in lucite sample holder.

BILL OF MATERIAL			
PART NUMBER	NUMBER REQD.	PER	DESCRIPTION



NOTES:
1. FUNNEL TO BE MADE FROM 1/32 BRASS
2. FUNNEL DIMENSIONS GIVEN ARE OUTSIDE DIM.

REV. LET.	CHANGED ITEM WAS	DATE	CHANGED BY	CHECKED BY

REVISIONS

TOLERANCES - UNLESS OTHERWISE NOTED
FRACTIONAL: 1/64 DECIMAL: ANGULAR:

	SIGNATURE	DATE	GROUP NO. & REPRESENTATIVE	DATE
ORIGINATED			V-8 OS/e	Jan. 19, '48
DRAWN	FES	19 Jan. 1948		
CHECKED	L.H.	Jan. 19, '48		
PROJ. ENG.	L.H.	Jan. 19, '48	TOT. SHTS. 1	SCALE 1=1
APPROVED	R.D.H.	Jan. 19, 1948		

TITLE: FUNNEL-BRASS

DRAWING NO.	SHEET SIZE AND NO.	PART NO.
2Y50073	B1	

Figure 1.40

Working drawing of special funnel

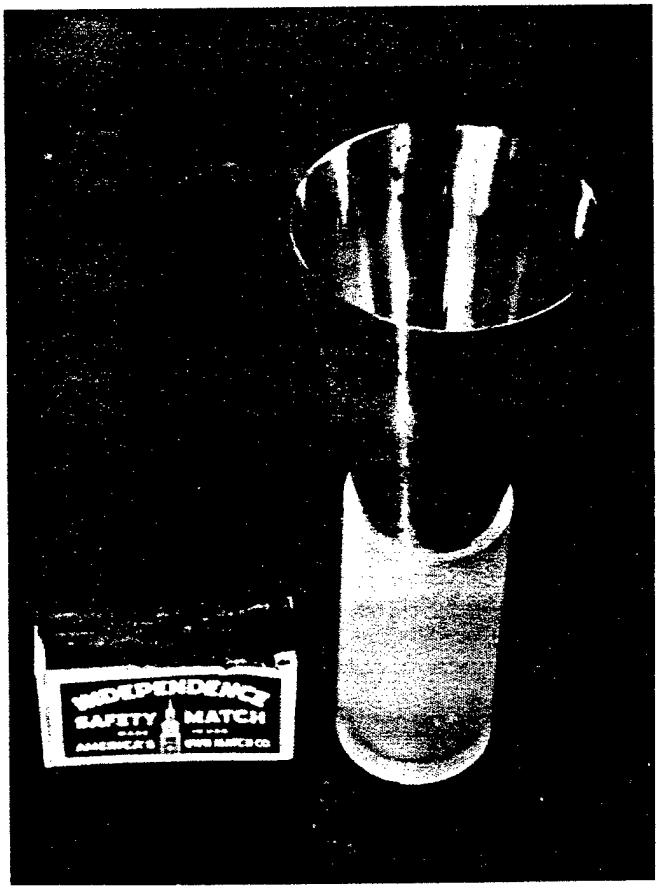
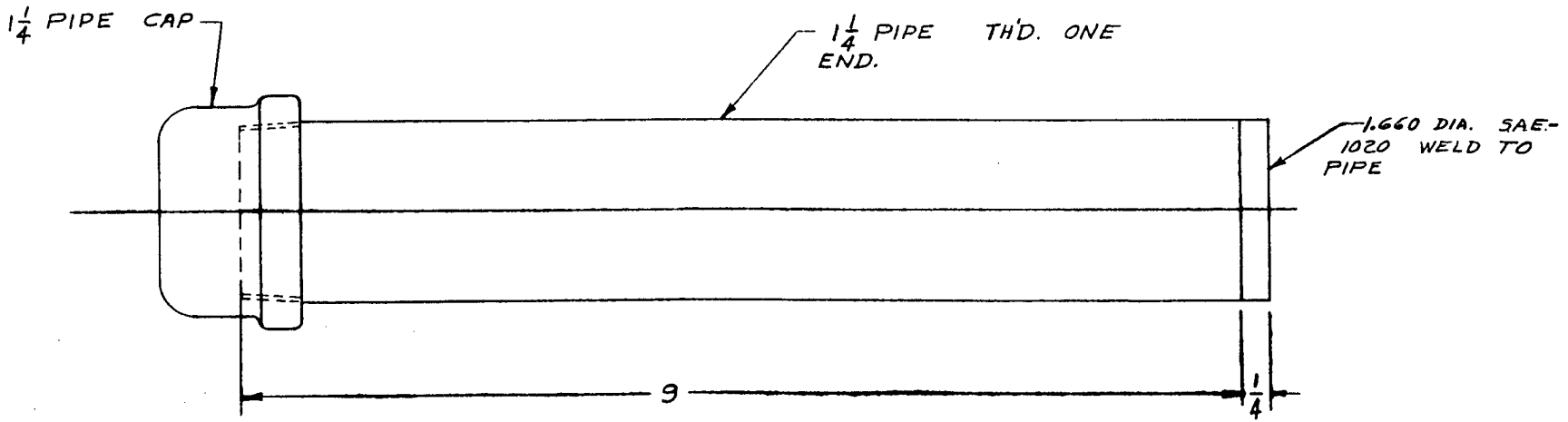

SAFETY MATCH

Figure 1.41

Carbon sample holder for use on water string.



1-ASSEMBLY AS SHOWN

1-ASSEMBLY WITH PIPE CAP TURNED TO 2" O.D.

APPROVED FOR CONST.		
CHIEF ENG.	R J H	Dec. 4, 47
CH. DRFTSMN.	L.H.	Dec. 4, 47
CHECKED	R.T.H	DEC 4, 1947
DRAWN	A F M	DEC 4-47
LAYOUT OR SKETCH		
GROUP J3	REPRESENTATIVE OGLE	
FRACTIONAL TOLERANCE ± 1/64 UNLESS OTHERWISE NOTED.		

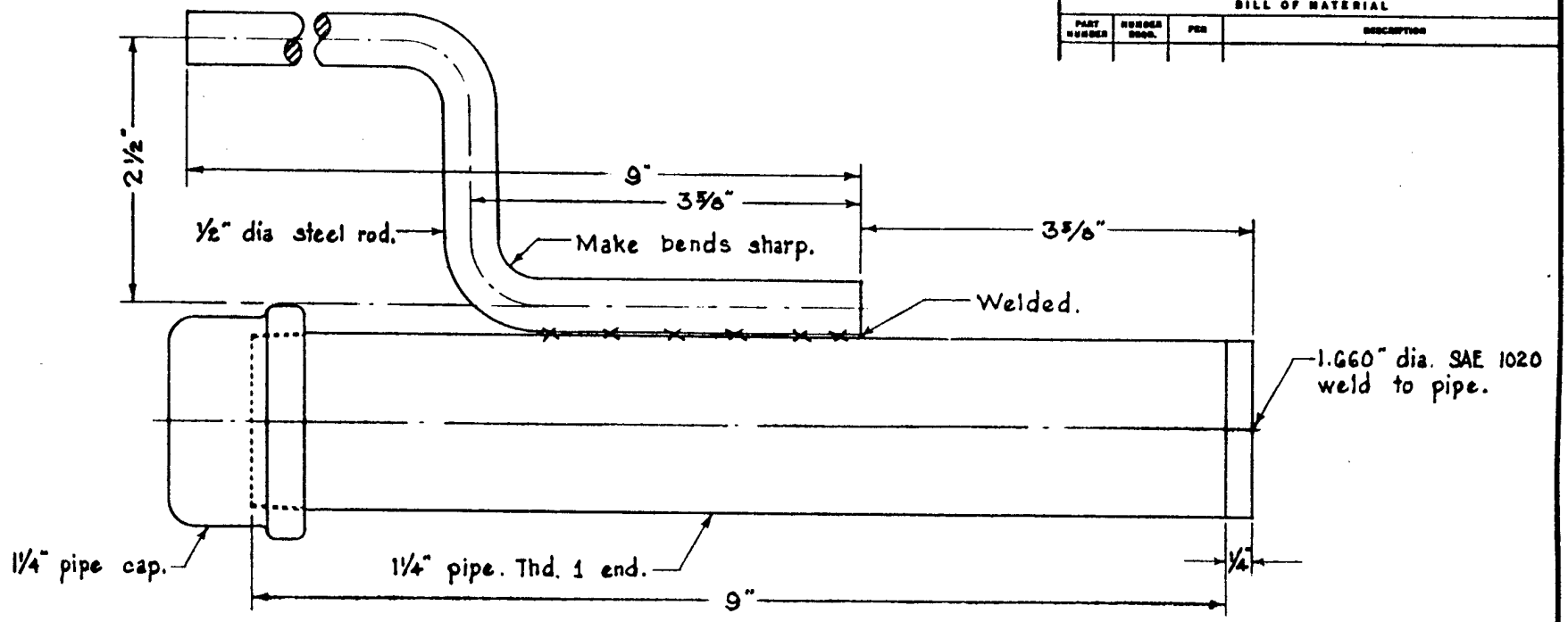
REV. LET.	CHANGED ITEM WAS	BY	DATE

TITLE: CABLE HOLDER & TEST PARTS - CARBON HOLDER

SCALE	DRAWING NO.	SHEET SIZE AND NO.
1"=1"	2Y-50022 — 2 TOTAL	B

Figure 1.42

Ring to fasten on carbon holder for quick recovery.



BILL OF MATERIAL

PART NUMBER	NUMBER REQD.	PER	DESCRIPTION

DEV. LET.	CHANGED ITEM WAS	DATE	CHANGED BY	CHECKED BY

REVISIONS

TOLERANCES - UNLESS OTHERWISE NOTED
FRACTIONAL: DECIMAL: ANGULAR:

	SIGNATURE	DATE	GROUP NO. & REPRESENTATIVE	DATE
ORIGINATED			J-3 Holt	June 25, '48
DRAWN	RJH	June 25, '48		
CHECKED	L.H.	June 25, '48		
PROJ. ENG.	L.H.	June 25, '48		
APPROVED				

TOT. SHTS. 5 | SCALE 1" - 1"

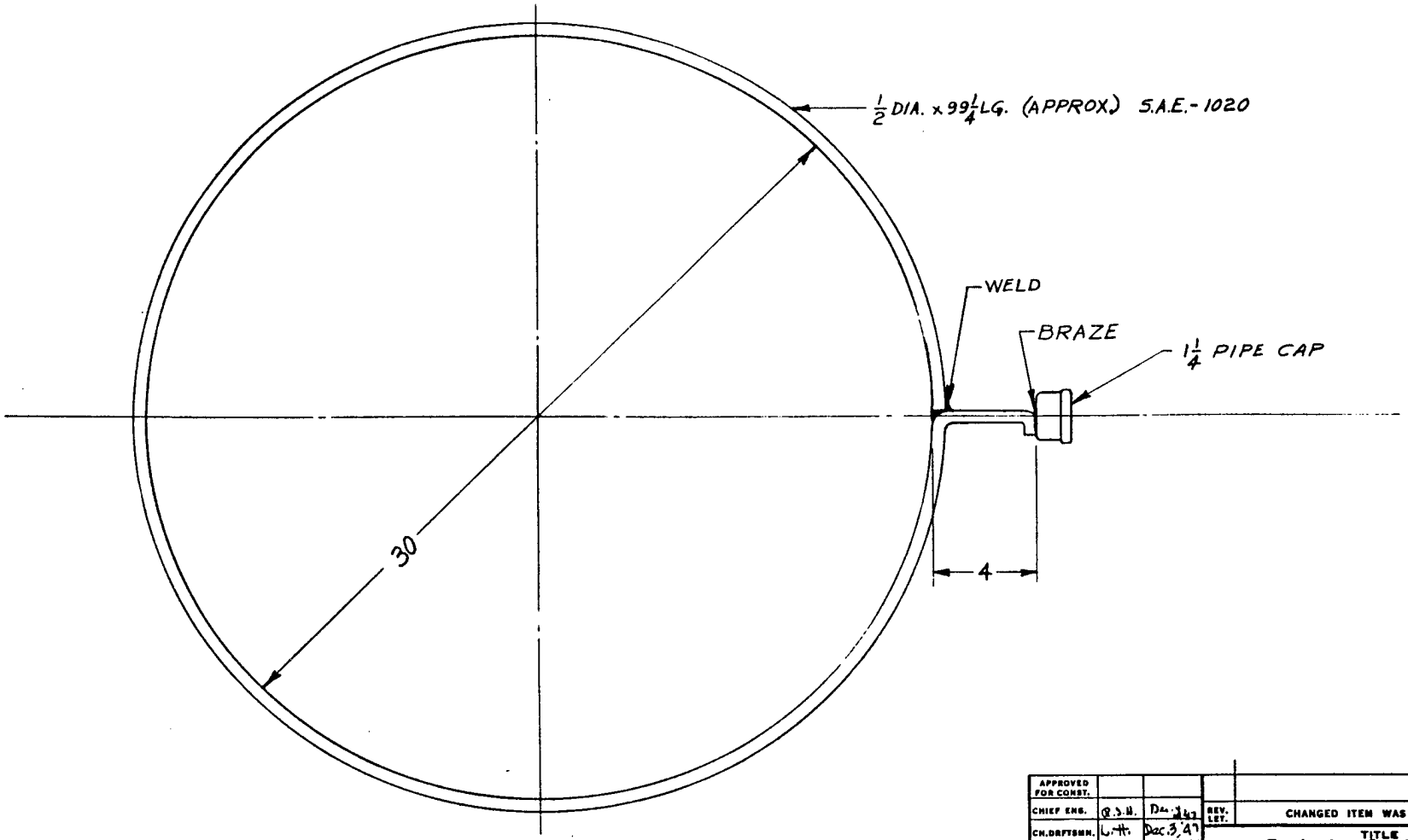
TITLE:
Cable Holder & Test Parts
Carbon Holder

DRAWING NO. 2Y-50022 | SHEET SIZE AND NO. B-5 | PART NO.

Figure 1.43

Carbon holder with bracket

for fastening to land cable.



APPROVED FOR CONST.		
CHIEF ENG.	R.S.H.	Dec. 3 '47
CH. DRFTSMN.	L.H.	Dec. 3, '47
CHECKED	R.H.	Dec. 3, 1947
DRAWN	APM	DEC. 3-47
LAYOUT OR SKETCH		
GROUP J3	REPRESENTATIVE OGLE	

FRACTIONAL TOLERANCE ± 1/64 UNLESS OTHERWISE NOTED.

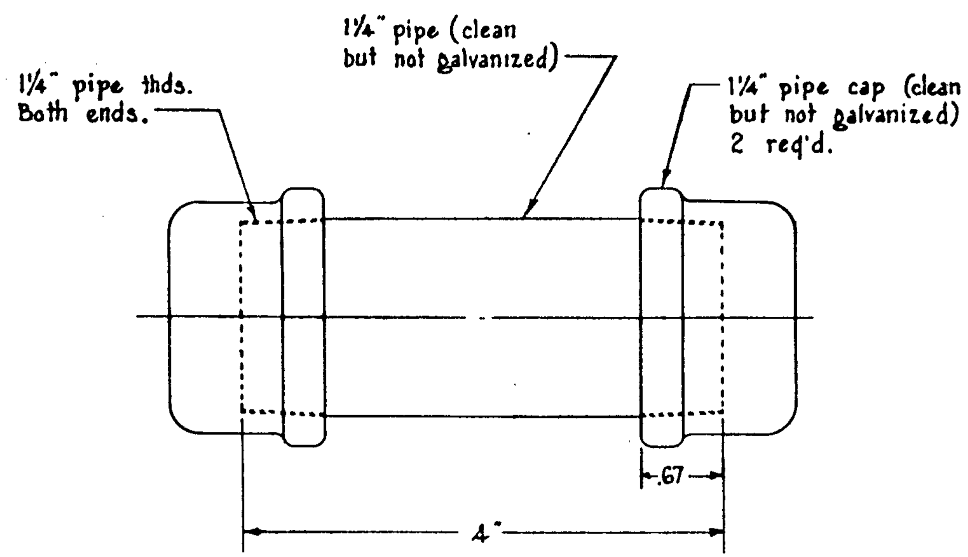
REV. LET.	CHANGED ITEM WAS	BY	DATE

TITLE
CARBON-SULPHUR HOLDERS-
QUICK REMOVAL CARBON ATTACHMENT

SCALE	DRAWING NO.	SHEET SIZE AND NO.
1/4" = 1"	2Y-50017 — 4 TOTAL	B

Figure A.1

Sulphur containers used for Scoville's samples.



BILL OF MATERIAL

PART NUMBER	NUMBER REQD.	PER	DESCRIPTION

REV. LET.	CHANGED ITEM WAS	DATE	CHANGED BY	CHECKED BY

REVISIONS

TOLERANCES - UNLESS OTHERWISE NOTED
FRACTIONAL: DECIMAL: ANGULAR:

	SIGNATURE	DATE	GROUP NO. & REPRESENTATIVE	DATE
ORIGINATED			3-3	June 24
DRAWN		June 1948		
CHECKED	L. H.	June 25 48		
PROJ. ENG.	L. H.	June 25 48		
APPROVED				

TITLE: Carbon-Sulphur Holders

TOT. SHTS.	SCALE	DRAWING NO.	SHEET SIZE AND NO.	PART NO.
6	1" = 1"	2Y-50017	B-6	

HISTORY OF FAST-NEUTRON MEASUREMENTS

Appendix A

Sulphur was first used as a detector of fast neutrons from the atomic bomb at Trinity by E. D. Klema. The reaction of interest here is an (n,p) reaction leading to beta-active P^{32} with a 14.3-day half-life. Klema measured the cross-section of this reaction as a function of energy up to 5 Mev. The results of these measurements, reported in LA-515, have led to the use of sulphur as a detector with a constant cross-section for neutrons above 3 million volts. Klema recovered samples from a distance of 200 yards only; hence, nothing concerning the mean free path of the sulphur neutrons could be obtained. A calibration was made which permits an interpretation of counts per minute from the irradiated sulphur in terms of neutrons from the bomb. Klema's measurement, described in LA-361, thus establishes a point of comparison between the neutron output of the Trinity gadget and later bombs.

Sulphur samples were irradiated at the Bikini-Able test. Here, the same counters, the same sample geometries, and the same counter standards were used as were used by Klema at Trinity. The purpose of these measurements was to obtain a comparison of efficiency with the Trinity gadget and also to obtain a measure of the mean free path of the sulphur-activating neutrons. With the latter idea in mind, several samples were

irradiated at various distances from the point of detonation. The results of the Bikini measurements are reported in LAMS-447. Since no samples were recovered at distances closer than 500 yards to the point of detonation, one could only compare the extrapolated Bikini attenuation curve with Klema's measurement at 200 yards. Data obtained at distances from 500 to 1300 yards indicated that the neutron flux was attenuated exponentially with a mean free path of about 217 yards in air. The Trinity point fell somewhat below the extrapolated Bikini curve so that, from these data alone, it was not possible to decide whether the two bombs were different or whether the attenuation of neutrons at these close distances no longer followed an exponential law. These data were felt to be of sufficient value that future measurements of a similar nature should be made as a means of intercomparing the neutron output of bombs to be tested in the future.

Because of the available data from Bikini and Trinity, it was decided that fast-neutron measurements using sulphur as a detector should also be made at Sandstone. However, since the type of bombs to be used at Sandstone were different from the Bikini and Trinity bombs, the measurements would now give a value of the fast-neutron flux only and would not necessarily give a direct efficiency comparison between the bombs.

Since there was little information available on the

spectrum of fast neutrons from a bomb, it seemed appropriate to also use threshold detectors at Sandstone to make at least a qualitative measure of the high-energy spectrum of the neutrons from the bombs used in Sandstone. The high-energy neutron detectors to be put out were elements having (n,2n) thresholds between 7 and 19 Mev. The materials finally used as threshold detectors were carbon, thallium, columbium, nickel, manganese, iodine and arsenic, although carbon was not originally considered.

The sulphur samples used at Bikini were put over water only, and since in the future probably land-based samples alone would be used, it was decided at Sandstone to use samples both on water and land in order to determine whether or not there was any difference in the observed activation. It was originally planned that in addition to the sulphur the (n,2n) threshold detectors would also be put out both on water and land. From the Bikini data it appeared sufficient to place sulphur samples at 100-yard intervals out to a distance of 2,000 yards from the bomb. It seemed adequate to put the (n,2n) threshold detectors at 200-yard intervals out to 1,000 yards.

The problem of recovering the activated samples within a reasonable length of time after the bomb was detonated, and at the same time not requiring personnel to enter into highly radioactive areas, led to the device of fastening the samples

to a long length of half-inch stranded steel cable. Obviously, on land such a cable could be laid out and samples attached at desirable positions with no difficulty. For the water string plans were originally made to attach the samples to buoys which would be fastened to the cable at 100-yard intervals and which would be sufficiently buoyant to entirely support the weight of the cable. The individual sample-supporting buoys could have each been anchored separately; however, the use of such an interconnecting cable served to maintain the relative positions of the samples and in addition facilitated the recovery of the samples. It was originally planned that the distant end of the land cable would also extend out into the water and that both the water and land cables would be reeled in by means of a winch on board some sort of boat or ship. However, the Navy felt that shallow water and coral off the end of the island would make such a recovery of the land cable impractical. After considering estimates of how hot the island would be after the shot, the conclusion was reached that it would be feasible to recover the land cable using a winch placed on the far end of the island.

The decision was made at this time, in line with the philosophy of using only land samples in future tests, that there was little point in putting (n,2n) threshold detectors both on water and land. The decision to put the (n,2n) detectors only on the land string also greatly simplified the installation and recovery of the water cable.

Because of the rather short time between the proposed shots and because of the comparatively short half-life of nickel, it was decided that all counting of samples should be done on one of the laboratory ships. This required that a counting laboratory be set up on the ship Albemarle (AV-5) before sailing in order that any failures of equipment could be detected and spare equipment could be brought from Los Alamos. A counting laboratory consisting of seven counting sets was set up in the two-week period prior to sailing.

The presence of a counting laboratory on the AV-5 opened up the possibility of using carbon as an (n,2n) threshold detector for fast neutrons. The threshold for carbon is about 18.7 Mev. The half-life is 20.5 minutes. The short half-life, therefore, required that the samples be recovered very soon after the shot, preferably within an hour. In order to facilitate this recovery, the Navy suggested that personnel land on the end of the shot island by means of helicopters as soon after a shot as possible, and that the land samples, after recovery, be sent back to the counting laboratory by helicopter. It was also proposed that carbon samples be fastened to some of the rafts on the water string in such a manner that they could be lifted from the raft into a helicopter. This helicopter could then transport the samples back to the AV-5 to be counted. In order to do this, the carbon samples were to

be fastened to the rafts in such a manner that a pull of approximately fifty pounds was required to lift them from the raft. The sample was fastened to a ring approximately three feet in diameter made of half-inch steel rod. The sample recovery was then effected by catching this ring with a grapple, pulling the sample up into the helicopter, and transferring it back to the counter laboratory. It should be pointed out that all samples with the exception of sulphur were put out in duplicate, one set being unshielded, a second set being shielded by lead. This was in order to distinguish between neutron and high-energy gamma effects.

The time between the sailing of the AV-5 on March, 1948 and the arrival at Eniwetok was spent in checking over the counters and taking frequent backgrounds. Upon arrival at Eniwetok the winches were checked and put into operation and work was begun on the water-cable installation. The water cable was to be fastened at one end to a large, well-anchored buoy which was approximately 2500 yards from the shot tower, and at the other end to the shot tower itself. Since the water close to the shot island on the lagoon side was found to be rather shallow and there were large numbers of coral heads, it was thought necessary to float the entire cable. It was our hope that after a shot the cable would drift away from the island so that recovery of the samples could be effected in a

small boat with a minimum of danger to personnel. So four-foot two-by-fours were nailed to the cable at sufficiently close intervals to float the cable. In order to determine how fast and how far the cable would drift, the water cable was installed and then cut at the edge of the island. In approximately four hours the cable had swung around and was drifting downwind from the anchored buoy. The cable was then pulled up onto the island in order to prevent water soaking of the two-by-fours.

In order to be sure that the winch would operate satisfactorily, the land cable was strung out as far as practicable on Engebi and pulled back in several times using the winch. On Peter X-ray minus three, the land cable was again stretched out and the full number of samples fastened to the cable. However, tripods, which would be put in later to hold the samples off the ground, were not installed; nor were the lead shields. At about the same time, five of the carbon-supporting rafts were fastened to buoys to be used for practice on Peter day.

The Peter-day operation then consisted of using four helicopters to land four LAJ-3 personnel plus a monitor on the end of Engebi near the winch, and the recovery of the samples from the land cable by this party. At the same time one man in a helicopter attempted to recover the carbon samples from

the five rafts anchored in the lagoon. Simultaneously a second recovery party, consisting of four LAJ-3 members and a monitor, left Parry by AVR for the shot island. Upon arrival they landed using an LCVP. This second recovery party was to take over the land-recovery operation in case the first party had too much radiation by this time.

On the ship, while these operations were taking place, there was a group of four LAJ-3 people whose responsibility it was to receive and prepare for counting those samples delivered by helicopter. In the counting lab were five LAJ-3 people standing by, taking background and standard counts preparatory to receiving and counting the samples as they were delivered.

The distribution of personnel for these operations was as follows:

In the land-recovery party that went in by helicopters were Dodds, Sergeant Wade, Captain Nixon and Linenberger. In the stand-by recovery party which came in on the AVR were Carson, Captain Cooper, Captain Graves and Captain Newman. Ogle was in the helicopter which recovered the water-carbon samples. To receive the samples and prepare them for counting were Everhart, Sergeant Pudil, Sergeant Chase and Sergeant Logan. In the counting laboratory were England, Nyer, Captain Waters, Captain Weston and Captain Kellogg.

The Peter-day operation went through fairly successfully. The helicopter-borne party pulled in the land cable, detached the sample units from it and those units containing carbon were returned to the AV-5 by helicopter. The helicopter recovering the water-carbon samples recovered two of the samples and, to simulate possible conditions that might arise in an actual test, reported that the water was too hot for this particular helicopter to complete its mission. In this circumstance, one of the helicopters that had landed on the island took over the water-recovery mission; recovered no carbon samples but was almost successful in being lost itself. Zero time on Peter day was at 0621. The water-carbon samples were returned to the ship at 0734 and land-carbon samples at 0813.

The day after Peter day the water cable was returned to place. The same day all rafts were attached to the cable by means of short lengths of chain and cable clips. The positions for the land samples were also marked. The positions of the rafts were then determined by surveying from stations on the island. The sulphur and carbon samples were put on the water string on X-ray minus five days. On X-ray minus three days, the land cable was pulled out and the sulphur and multiple samples fastened to it. These samples were supported four feet off the ground by tripods. Sulphur samples were

also put in Krause's coffin to measure the fast-neutron flux inside the building.

The zero hour on X-ray day was 0617. The helicopters were in the air at plus four minutes and landed on the island near the winch. The radiation level there was ten to fifteen mr per hour. The winch was started immediately. The multiple samples from the 600-yard, 800-yard and the 1,000-yard stations were recovered. One carbon was broken in the 600-yard container. Cans containing the arsenic, iodine, and manganese powders in both the 600-yard and 800-yard containers had broken open. The sulphur samples from 300 yards out on the land string were recovered. All of the water carbons had been thrown from the rafts by the blast. The water cable remained in place because of the keels on the near rafts sinking to the bottom after the rafts were demolished. The landing party returned to the Albemarle by AVR. The water-sulphur samples were recovered on X-ray plus two. At this time the activity of the water was sufficiently low that no attempt was made to pull the cable out. Two DUKWs were used to remove the sulphur samples. All samples down to and including the 500-yard sample were recovered. All rafts were charred from the explosion and the flagstaff on the anchor buoy at 2300 yards was also charred. The 400-yard raft was sheared off at the water level leaving keel studs and masts protruding.

The experience of X-ray led to the following experimental changes:

The water-carbon samples were abandoned completely. The land-carbon samples were put in individual containers which were fastened directly to the main cable. New and stronger containers for arsenic, manganese, and iodine were constructed in the ship's machine shop. It was decided to use the same winch for Yoke as was used in X-ray and Benson undertook to have the winch moved. The relief-landing party was reduced to one man who was responsible for seeing that a DUKW got onto the island if it was needed. The multiple sample containers which on X-ray had been fastened by a quarter-inch cable to the main half-inch cable now had half-inch steel rods welded to them in order that they could be fastened to the main cable by cable clips. It was also decided to place the near land samples on piles of dirt instead of the wooden tripods used on X-ray, in order that the sample would not be free to move but instead would be backed up by the mass of the dirt. Plans were also made to fasten extra sulphur samples to the water cable on the near rafts by means of a half-inch cable directly from the sample container to the main cable. Since the X-ray land cable was burned off between 200 and 300 yards from the tower, the Yoke land cable was to be covered with a couple of inches of sand from the nearest station out to about 400 yards.

The preparations for Yoke began several days after X-ray. On Yoke minus nine the water cable was put out and most of the rafts attached. The remaining rafts were attached on Yoke minus eight and the land-sample stations were measured off. It was decided that the land cable would lie across the channel between Aoman and Biijiri instead of going across the causeway. This meant that the cable would have to be pulled through the water for the recovery of the samples. The cable was laid out and pulled in across the channel with several samples tied to it and the samples all came across intact. On April 27th and 28th the land samples were fastened to the cable, the first 400 yards of the cable being covered with several inches of sand. The winch was prepared for the blast. In addition to the rubber sheet that was put over the front of it on X-ray, an asbestos sheet was put over the rubber to prevent burning. Additional sulphur samples were put out in Shonka's gamma stations A, B, and C to attempt to measure the unscattered fast neutrons coming through the unshielded tubes pointed at the bomb. Sulphur samples were also put in Krause's coffin. Gold foils were put in Krause's coffin and in other places in the timing station.

After the Yoke shot, six members of LAJ-3 plus two monitors landed by helicopter on Biijiri. The winch was started and the cable reeled in. Carbon samples were ferried to the

AV-5 by helicopter as fast as they were recovered. Three shuttle trips were made. After the samples were recovered the landing party returned to the AV-5 by AVR. Two days later the sulphur samples were recovered from the water string using a DUKW and an M-boat. Again it was not necessary to pull the cable out. In this test all carbon samples were recovered. The nearest carbon samples recovered from the land string were in a container that was deformed appreciably by the blast. It was impossible to get one of the samples out and the other sample was very badly crushed. The multiple samples from 200 yards, 400 yards, 900 yards and 1100 yards were recovered. Sulphur samples from the land string were recovered up to and including 200 yards. The water-string sulphurs were recovered up to and including 300 yards. The personnel involved in the Yoke recovery were as follows. The helicopter party consisted of Linenberger, Dodds, Carson, Ogle, Sergeant Wade and Captain Graves. Captain Cooper accompanied the AVR from Parry to the shot island. The samples were prepared, after being transferred to the AV-5, by Everhart, Sergeant Chase, Sergeant Pudil and Sergeant Logan. The counting was done by England, Nyer, Captain Newman, Captain Nixon and Lieutenant Mahin.

The carbon samples from both X-ray and Yoke exhibited a short half-life of the order of 25 to 30 minutes on top of a

very much longer half-life. It was not clear on X-ray whether this long half-life was due to contamination on the carbon because of the breaking open of the powder containers, or whether it was an impurity in the carbon. The experience of Yoke indicated that the long half-life was due to an impurity in the carbon. It was therefore planned that on Zebra spectroscopically pure carbon would be obtained from the ZI and used instead of the pile graphite that had been used on X-ray and Yoke. J.M.B. Kellogg arranged for the carbon to be sent out. It was carried out by Norris Bradbury.

Since a large proportion of the preparations for Zebra were completed before Yoke, it was found possible to release the sergeants from duty with LAJ-3 on Yoke plus two. Their help during the period in which they were with us was greatly appreciated.

The preparations for Zebra began as soon as the Yoke samples were prepared. The water string with rafts and sulphur samples was put out. The water string consisted largely of the Yoke water string which was cut off at about 400 yards and towed to Runit and used again. It was found that the rafts out to about 600 yards had to be replaced because the connectors had been strained in the Yoke shot. A new cable was put out from the tower to the end of the Yoke cable. The same winch that was used on Engebi and Aoman-Biijiri was moved to Runit

and used again. The land string was installed as before on Zebra minus three and minus two. The multiple samples and carbon samples were fastened in the same manner as on Yoke. The containers made by the ship for the powder samples on Yoke were found to be satisfactory and another set was made for use on Zebra. The spectroscopically pure carbon arrived in time to be used for the Zebra shot.

After the Zebra shot, a helicopter-landing party consisting of Linenberger, Holloway, Carson, Dodds, Nyer and Captain Cooper landed near the winch and began to reel in the samples. The 1100-yard, 1000-yard and 800-yard carbon samples were recovered by driving up to them in a jeep and taking them off the main cable. These three samples were then flown back by helicopter. While these samples were being transferred an attempt was made to recover the rest of the carbon samples. The main cable apparently fouled and it was found necessary to cut the cable in order to pull in the nearest samples. The 600-yard and 400-yard carbons were eventually recovered, by going in this far in a jeep, and were then transferred back to the AV-5 by helicopter. On the AV-5 the samples were caught and prepared by Everhart, Ogle, Burriss and Lieutenant Kratz. The counting was done by England and Captains Reitman, Nixon, Irvine and Lieutenant McBride. The carbon curves from the spectroscopic carbon were much more

satisfactory than in previous shots. The curves exhibited only a short half-life of approximately 25 minutes. In the Zebra test the carbon samples up to 400 yards were recovered, the 200-yard carbon was still on the cable a day later but was not recovered in time to be counted. All five multiple samples were recovered. The sulphur from the land string was recovered down to and including 200 yards. The sulphur on the water string was recovered down to and including 300 yards.

The remaining AFSWP men assisting LAJ-3 were released the evening of Z-day. Captain Cooper was released on Zebra plus seven. Counting was continued on most of the samples except carbon until the day before the ship docked in Oakland. The counters and samples were then transferred by plane to Los Alamos where counting began again the day after the docking of the ship. Counting will continue until no longer profitable.

The personnel involved in the work of LAJ-3 were as follows: G. A. Linenberger, Group Leader; William Ogle, Alternate Group Leader; Arthur Carson, Ed Dodds, Warren Nyer, Robert England and George Everhart. Assisting the group from the time the ship left Terminal Island until the time of their release was a group of AFSWP personnel consisting of Captain

[redacted]

K. B. Cooper and Sergeants D. B. Wade, W. C. Chase, H. M. Pudil and W. A. Logan. Assistance was also obtained during the times close to shot time from the following men: Captains D. A. Kellogg, F. B. Waters, A. E. Weston, R. H. Reitman, R. W. Newman, E. Graves, J. Irvine and R. T. Nixon, and Lieutenants R. W. McBride, D. T. Mahin and W. G. Kratz. Assistance was also obtained during the Zebra shot from Marshall Holloway and Stan Burriss.

At the request of Dr. H. Scoville, it was agreed to furnish and subsequently count twelve sulphur samples which were to be exposed on X-ray and Yoke behind various types of shielding, including some of the O.C.E.concrete structures. These containers (see Fig. A.1) were similar in construction to the land-cable sulphur containers; however, no fastening brackets were provided. Eight samples were put out for the first test and four for the second. The counting rates of these samples were reported to Dr. Scoville, who will submit an interpretation of the results.

[redacted]