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MATERIALS TESTING REACTOR PROJECT
PROGRESS REPORT
FOR THE PERIOD ENDING FEBRUARY 28, 1950

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MATERIALS TESTING REACTOR PROJECT PROGRESS REPORT for the Period Ending February 28, 1950

M. M. Mann, Project Engineer
J. A. Lane, Associate Project Engineer

DATE ISSUED APR 10 1950

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SUMMARY

Satisfactory progress has been attained during this quarter in all activities on the MTR Project within the sphere of ORNL responsibility. A brief summary of the work by each of the groups is given below.

Analysis Group. Estimates of the neutron fluxes and heat production in the thermal shield have been completed. The total heat produced in the thermal shield is found to be about 95 kw for 60,000 kw operation. This value is somewhat greater than those previously reported and is believed to be an upper limit. The water flow through the active lattice has been re-calculated and is now estimated to be about 15,500 gpm. Thermal stresses and water flow in the beryllium reflector have been studied in detail. As a result, some design changes have been made.

Air cooling of the graphite reflector is being reviewed, taking into account recent data from Britain and from ANL regarding heat transfer and pressure losses in pebble beds. This work also has caused some design changes.

A thorough analysis of the adequacy of the biological shield has been completed. Although no major changes in the shield design were suggested, slight re-arrangement and addition of shielding material was made in several places; particularly in the vicinity of air and water ducts. The use of barytes aggregate concrete as opposed to a heavy aggregate of iron punchings and Portland cement was studied. Barytes was found to be feasible everywhere in the shield except for a small volume around the shielding facility. Here, the best available shield material, probably "MO" concrete, will be used.

Design Group. A number of design reports have been completed and issued during the quarter. Addenda to those already completed have, in some cases, been written and issued. Only two of the original sixteen reports planned have not been written. These are of minor importance, however.

A total of thirty-six drawings of the reactor structure, including thermal shield, air ducts, water pipes, experimental hole liners, shielding facility, graphite arrangement, etc., were completed, checked, approved, and issued to Blaw-Knox in January. These drawings constitute the Laboratory's final conception of the reactor structure, on which Blaw-Knox is now engaged in engineering design.

Detail drawings of parts inside the reactor tank have started. These parts consist of tanks, grids, locking mechanisms, control rod drives and bearings, etc.

[redacted]

The beryllium reflector is now in process of final design. Conferences with Brush Beryllium Company, Y-12 Shops, and New York Operations Office have been held to establish the best sizes and shapes of beryllium pieces for the reflector.

At a joint meeting of the MTR Steering Committee and Idaho Operations Office in January, it was agreed that ORNL is the logical agent to supply the reactor tank and its contents. On the basis of this agreement, funds are to be allocated to ORNL *via* Oak Ridge Operations for the purchase, fabrication, inspection, delivery, test, and shipment to Idaho of those parts mentioned above, and including the top and bottom plugs. Tanks Sections "*A*" and "*E*", however, are excluded.

Control Group. Major efforts of the Control Group during the past quarter have been devoted to (1) instrumentation for the Mock-Up critical experiment and (2) mechanical design of the top of the reactor and layout of control and instrument rooms, etc. Blaw-Knox personnel have contributed greatly to this second item. The Mock-Up control scheme, essentially the same as that to be used on the MTR, has been very successful. The fission chamber, period meter and safety circuits have all been tested with the servo trails scheduled in the near future.

Experimental Group. Corrosion tests have continued on beryllium, both extruded and hot pressed varieties. It is not yet possible to conclude whether one type is better than another. Some work has been done on induced activity in beryllium and graphite.

The critical experiments in the MTR Mock-Up were begun in January. Criticality was attained February 2 with a fuel complement of approximately 2 kg U^{235} arranged in a 3 × 5 pattern with full beryllium reflector on two sides and partial reflector on two sides. In this geometry the critical mass is not inconsistent with previously reported values. All mechanical components have performed satisfactorily and the performance of the control system has been especially pleasing.

The experimental program outlined previously is now in progress.

Metallurgical Group. About twenty-five complete fuel assemblies have been produced for the MTR critical experiment with an enviably low record of rejections. Work has continued on the problem of blisters in the fuel plates and rather satisfactory progress has been noted.

A large share of the experimental development work on beryllium has been completed. Work now underway involves corrosion, effects of radiation on corrosion and machining tests.

MTR ANALYSIS GROUPS

Heat Production and Temperature Distribution in Thermal Shields. (Reference ORNL Central Files Numbers 49-12-1, 50-1-18, 50-1-45 and 50-1-126) Estimation of the neutron fluxes and heat production in the thermal shield has been completed. The total heat produced in the steel was found to be 95 kw for 60,000 kw operation, a value three times greater than previously reported values. It is believed that the present value is certainly an upper limit.

Using these most recent heat production values as a basis, the Design Group was assisted in preparing designs for the top and bottom thermal shields in which maximum temperatures were limited to 50°F above the air temperature in the outer plates, adjacent to the concrete, and 140°F above the air temperature in the inner plates. The resulting designs were reasonably simple and free from excessive thermal stresses as estimated by Blaw-Knox engineers so it is expected that they will prove satisfactory.

At the present time the design of the side thermal shield is being evaluated. The calculations show that the maximum temperature in the hottest outer plate will be 53°F and that in the corresponding inner plate will be 210°F above the air temperature. It has not been decided yet whether these temperature differences are too great.

Water Flow in the Active Lattice. The water flow through the active lattice has been calculated for a water velocity of 30 ft/sec through all 0.118 in. cooling channels. This flow is obtained with an overall pressure drop of 40 lb/in.^{2} A break-down of the flow for a full slab loading with 4 shim rods is as follows:

23 fuel assemblies	11,230 gpm
4 cadmium shim rods	1,680
18 beryllium pieces (centers only and including 4 cadmium safety rods)	50
Interstices	2,540
	15,500 gpm

Thermal Stresses and Water Flow in the Beryllium Reflector. The problem of redesigning the beryllium reflector to permit the use of large blocks of beryllium and to reduce the large static pressure difference between the water

in the reflector and that in the active lattice has been studied in some detail. The net result of this study is the pattern of 3/16 in. diameter, cooling holes presented in Fig. 1-1.

Calculation of the stresses in the beryllium was based upon premises somewhat different from those used in the past. Formerly, the stresses were estimated solely upon the basis of the temperature distribution in the horizontal midplane. However, a study of the temperatures throughout pieces of beryllium adjacent to the lattice revealed greater temperature differences in vertical planes than those found in the midplane. Consequently, an attempt has been made to take this effect into account in the latest pattern of cooling channels.

The basis for the pattern is that the maximum difference between a local temperature and the average temperature in a given piece of beryllium shall be less than 35°F where a 35°F temperature difference corresponds to a thermal stress of 10,000 lb/in.^{2} In calculating the temperatures it was assumed that the minimum heat transfer coefficient will be 2000 Btu/ft^2 hr °F, with a reasonable amount of scaling, and that the heat production data of Fig. 1-2 are correct. It is expected that the actual thermal stresses will be considerably less than 10,000 lb/in.^{2} A large gain in safety in the design is accomplished at the expense of an increase of less than 20 percent in the total number of holes required.

The total water flow through the reflector and the cooling requirements of the beam holes are being estimated at the present time. Satisfying the condition of minimum pressure difference between water in the reflector and water in the active lattice requires that the pressure drop across the reflector be about 30 lb/in.^{2} Only preliminary estimates of the water flow are available now; however, it appears that the total reflector requirement will be less than the 3000 gpm now considered permissible.

Air Cooling of the Graphite Reflector. Cooling of the graphite reflector is being reviewed taking into account recent data regarding heat transfer and pressure losses in pebble beds and the added cooling surface that became available as a result of the extension of a part of the graphite through the inner thermal shield.

[redacted]

DWG. # 8468

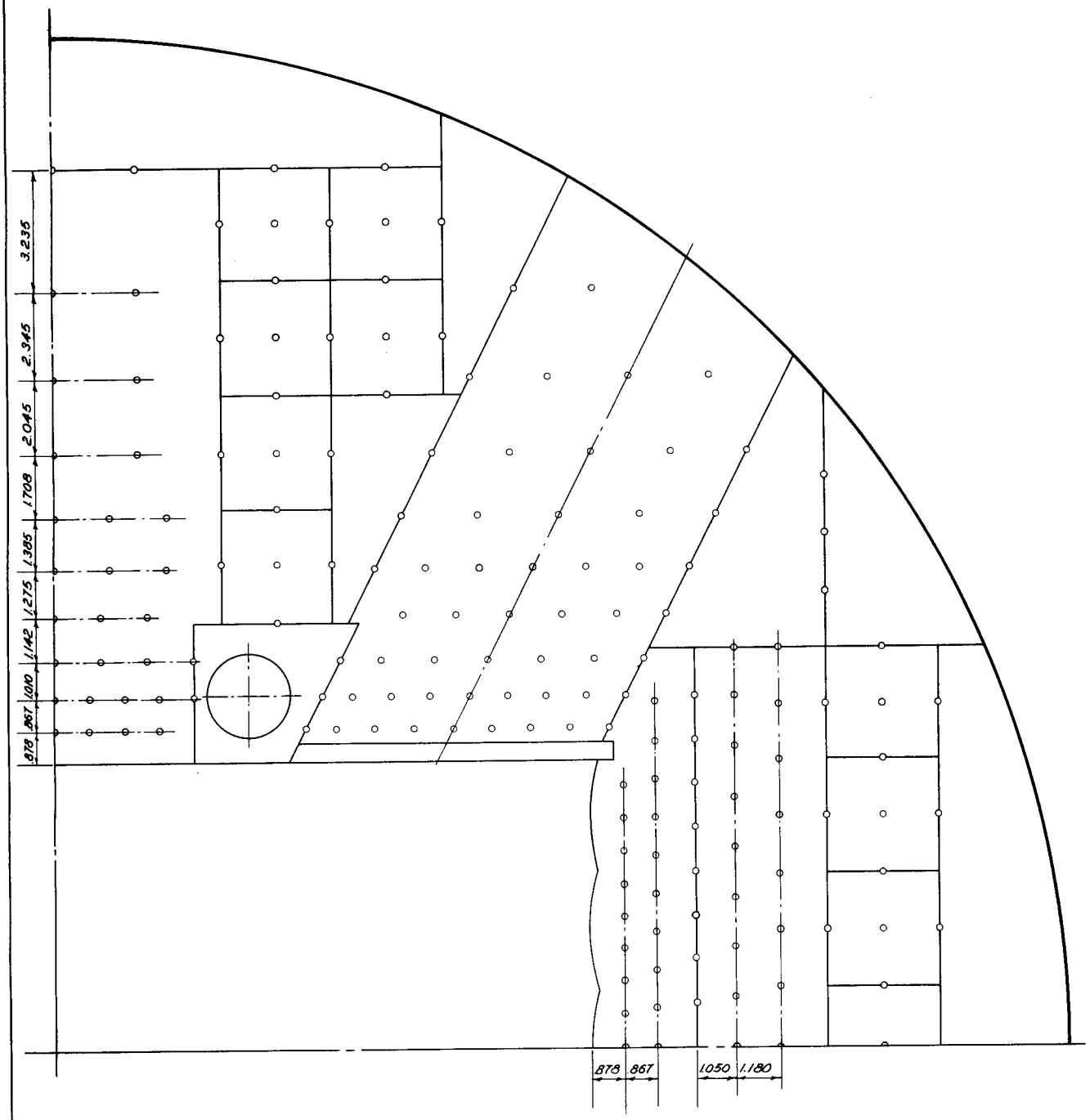

FIG. 1-1
PATTERN OF COOLING CHANNELS IN
BERYLLIUM REFLECTOR

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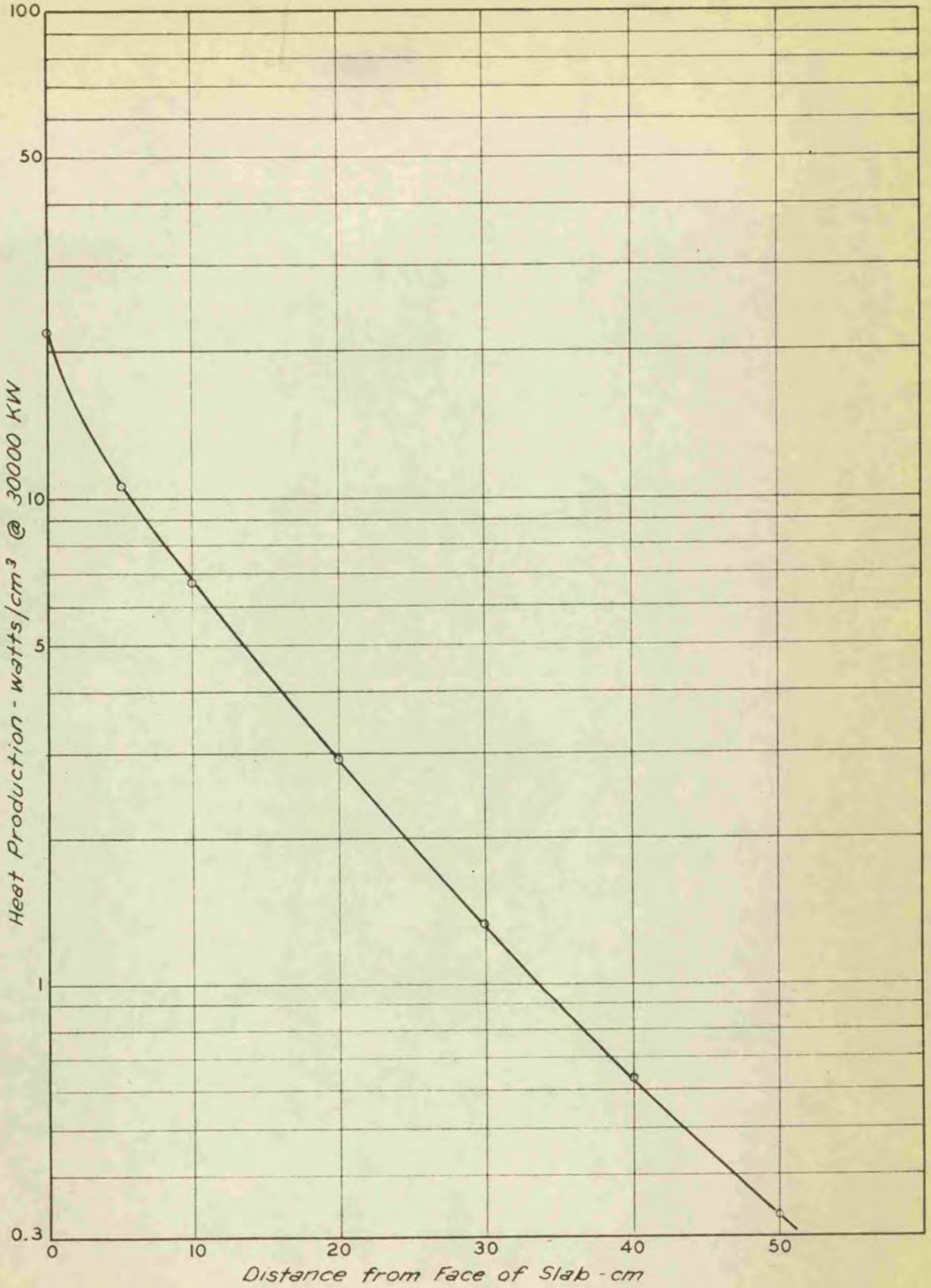

FIG. 1-2

HEAT PRODUCTION IN BE. REFLECTOR

Basis: 1.2 x ORNL 167 + heat from fast neutrons from Mon P 272

Recent British data[1] and data from Argonne[2] show that the heat transfer coefficients used previously in estimating the cooling of the pebble bed were too low and that the estimated pressure losses were too great. Recalculation of temperatures reveals that although the use of markedly greater heat transfer coefficients is permissible, there is no significant decrease in the total air requirement, because the maximum local air temperature is near 570°F, the maximum permissible graphite temperature. It is found that the pressure loss should be in the range of 26 to 30 inches of water instead of the 30 to 40 inches of water reported previously.

Cooling channels in the permanent graphite are in the process of being resized and relocated upon the basis of the lower pressure loss.

Biological Shield Analysis. A thorough analysis of the adequacy of the biological shield has been completed with particular consideration given to the requirements in the vicinity of voids and openings such as air and water ducts. No major problems in the design of the shield were encountered, although additional iron slabs of the order of 2 in. thick will be required around the various ducts to insure that the gamma radiation at the surface of the reactor will not exceed .01 R/8 hours. Details of these calculations will be presented in a report to be issued in the next quarter.

Two reports were issued, "Neutron Streaming Through Pebble Discharge Chute" (CF-50-1-157), and "MTR Shield Survey Report #3" (CF-49-12-18). The latter described the radiation from the active lattice after shutdown, radiation leakage in the vicinity of the top plug during operation, radiation level with the top plug removed after shutdown, and shielding requirements in the vicinity of the shield testing facility.

The use of barytes aggregate concrete instead of a heavy aggregate of iron punchings and Portland cement was examined on the basis of shielding adequacy and found to be feasible in all cases except around the shielding facility. Here the best available shield to prevent neutron and gamma streaming will be used, presumably "MO" concrete. With the use of barytes aggregate the biological shield contains the following approximate amounts of material:

Ordinary concrete	1,000 yds
Barytes concrete	100 yds
MO concrete	10 yds

(1) Denton, W. H., Robinson, C. H. and Tibbs, R. S., *Heat Transfer and Pressure Losses Through Randomly Packed Spheres*, British Report H.P.C. 35.

(2) Leyse, C. F., *Heat Transfer and Pressure Drop Experiments*, Memo ANL-JRH-20.

In the KAPL reactor, the most important source of gamma radiation escaping the biological shield originates from fast neutrons which are thermalized and captured in the concrete shield itself. Although these are not as important in the MTR, further consideration is being given to the fast neutrons which escape the thermal shield from the standpoint of both measurement and analysis.

DESIGN PROGRESS

Design Reports. Table 2-1 summarizes the present status of all design reports being written for transmittal to Blaw-Knox Company for design of components of the reactor structure. This table is an up-to-date version of one appearing in the preceding progress report for the MTR, ORNL 529. It will be noted that some of these reports have remained inactive during this quarter. In all cases this is due to either lack of sufficient information to proceed with the design, or the work has been postponed in favor of other work of higher priority.

Addenda to some of the reports have been issued due to changes or accumulation of more information. An addendum to the graphite reflector report gives a more detailed conception of the supporting structure beneath the graphite. This was a result of completion of the thermal shield calculations. Principal features of the graphite support are shown in Fig. 2-1.

A review of shielding requirements around the air ducts and calculations of heat generation in the upper thermal shield brought about several changes in details of the ducts. These are explained in an addendum to the internal air system report. It was found necessary to provide separate air ducts to cool the top portion of the thermal shield. This was done by placing a divider in the inlet ducts and connecting one of the sections so divided to the space between the two top plates as shown in Figs. 2-3 and 2-4.

Reactor Structure. A total of 36 drawings of the reactor structure, including the thermal shield, air ducts, water pipes, experimental hole liners, shielding facility, graphite arrangement, and other smaller details were completed, checked, approved and issued to Blaw-Knox in January. These drawings constitute the Laboratory's final conception of the reactor structure except for details which will be designed by Blaw-Knox Company. Small scale replicas of three principal sections of the reactor are given in Figs. 2-2, 2-3, 2-4. An exterior view of the structure is given by Fig. 2-5.

Experimental and Service Facilities. During the quarter the most significant change in experimental facilities for the MTR was the addition of recesses joining the ends of HT-1, the horizontal hole through the graphite reflector. These two holes are parallel and only a few feet apart so that with these recesses joining their outer ends it is hoped that it will be possible to circulate fluids through the reactor by way of HT-1 and return

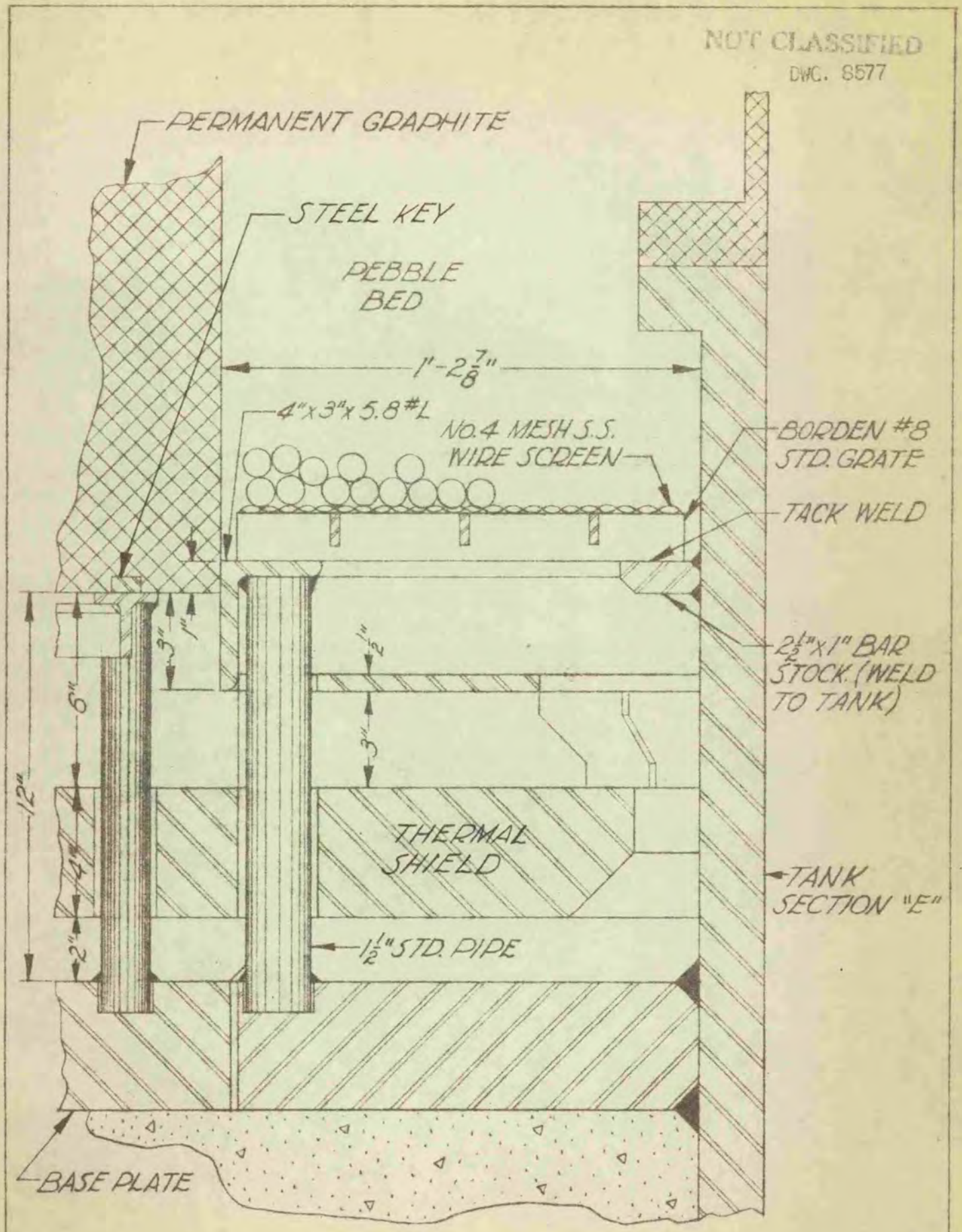

FIG. 2-1
SUPPORT STRUCTURE FOR GRAPHITE REFLECTOR

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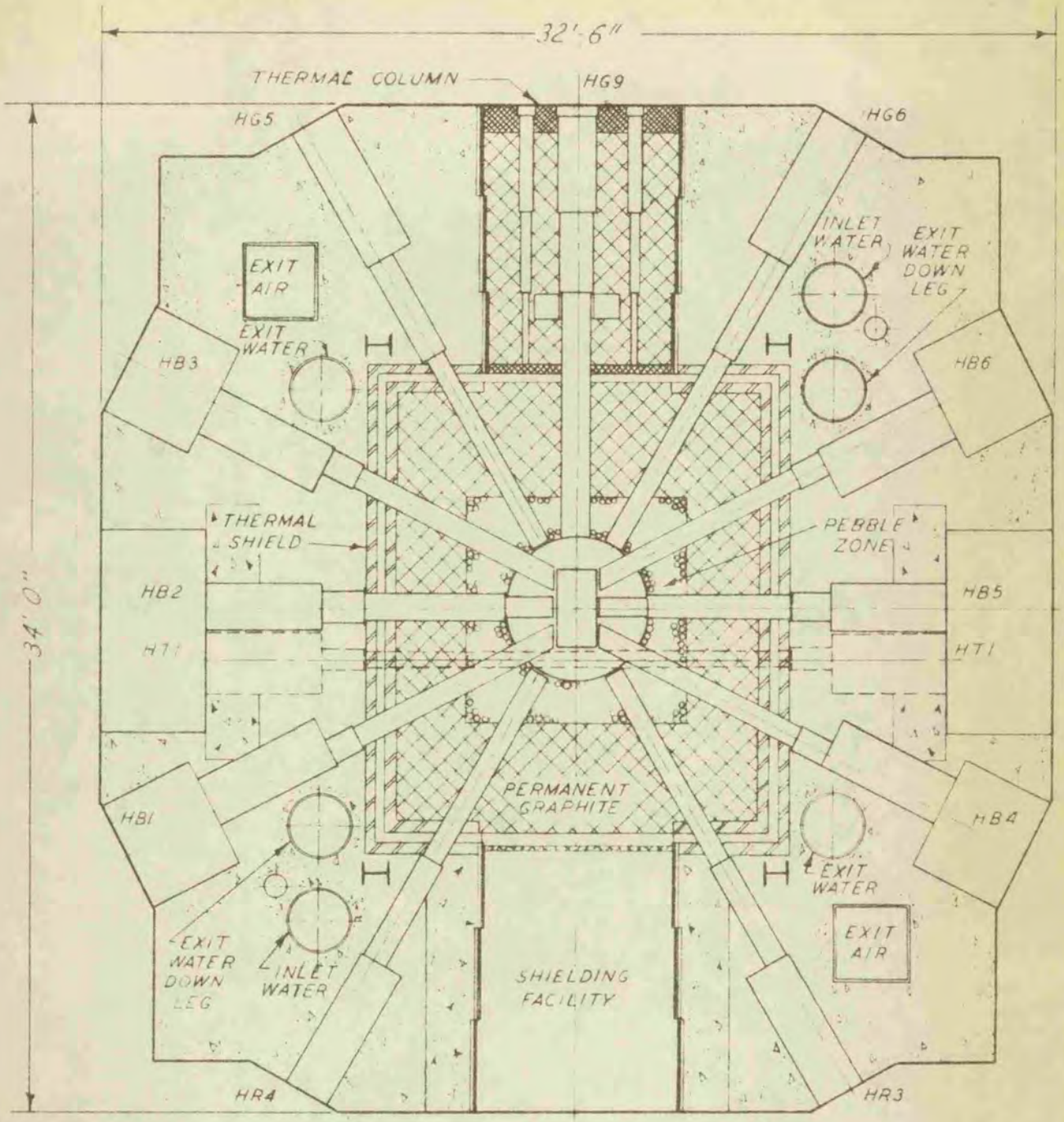

MTR

HORIZONTAL SECTION REACTOR ℄

FIG. 2-2

Scale $\frac{3}{16}$" = 1'-0"

REFERENCE DRAWING DRP-63

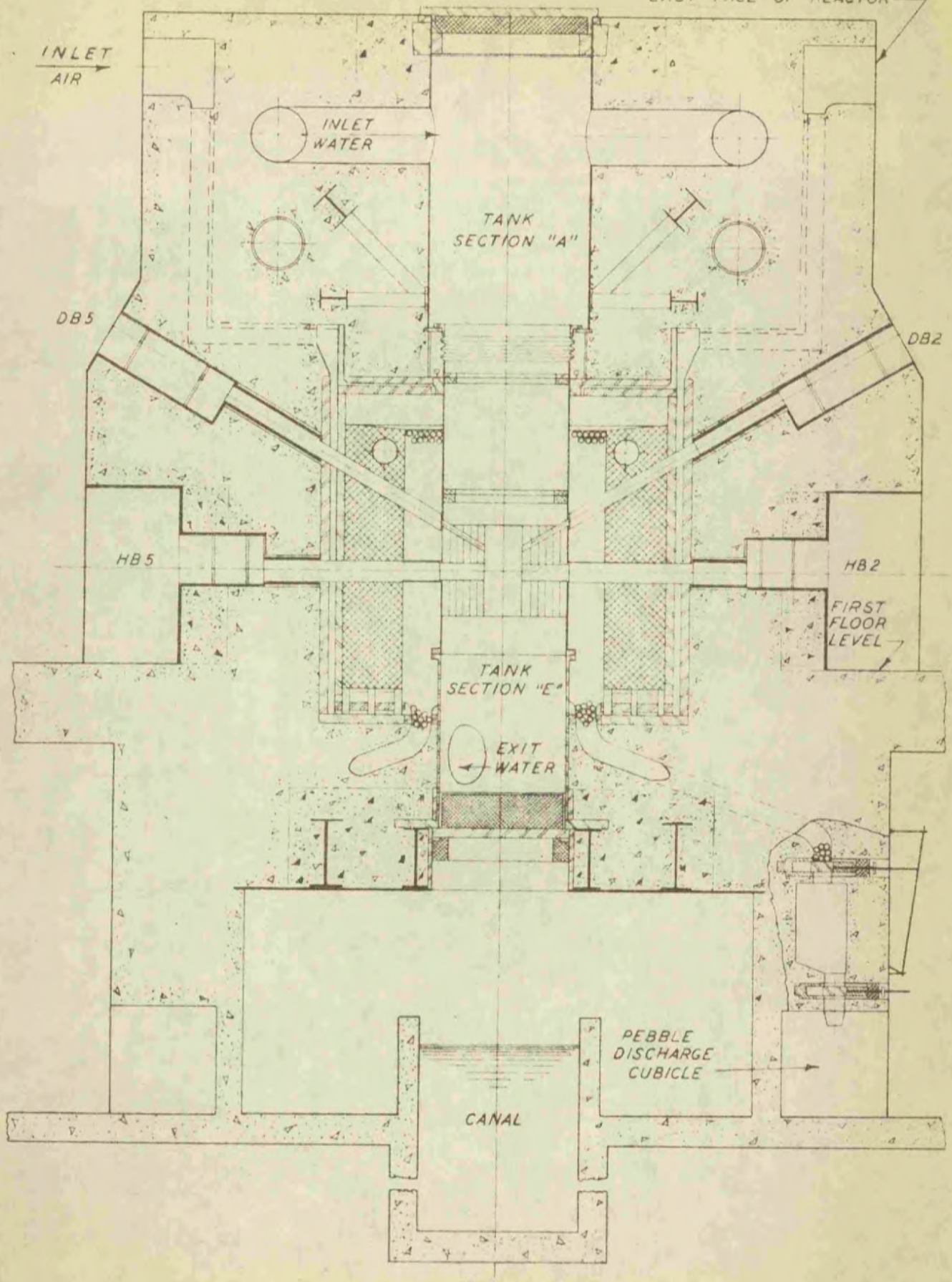

FIG. 2-3
MTR STRUCTURE
E-W SECTIONAL ELEVATION

Scale 3/16" = 1'-0"
REFERENCE DRAWINGS
DRP-65 DRP-67

[redacted]

DWG 8195

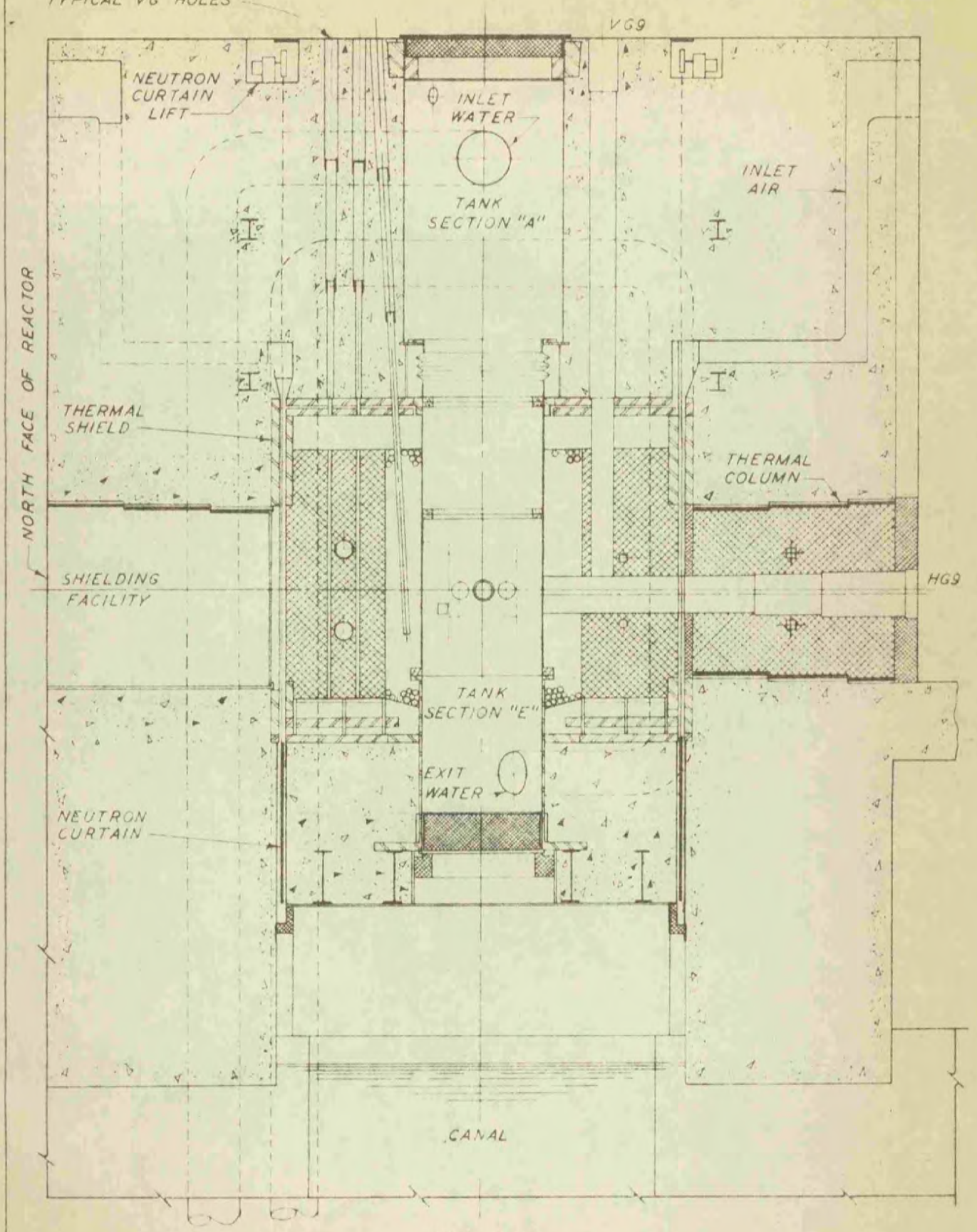

FIG. 2-4
MTR STRUCTURE
N-S SECTIONAL ELEVATION

Scale 3/16" = 1'-0"
REFERENCE DRAWING DRP-66

[redacted]

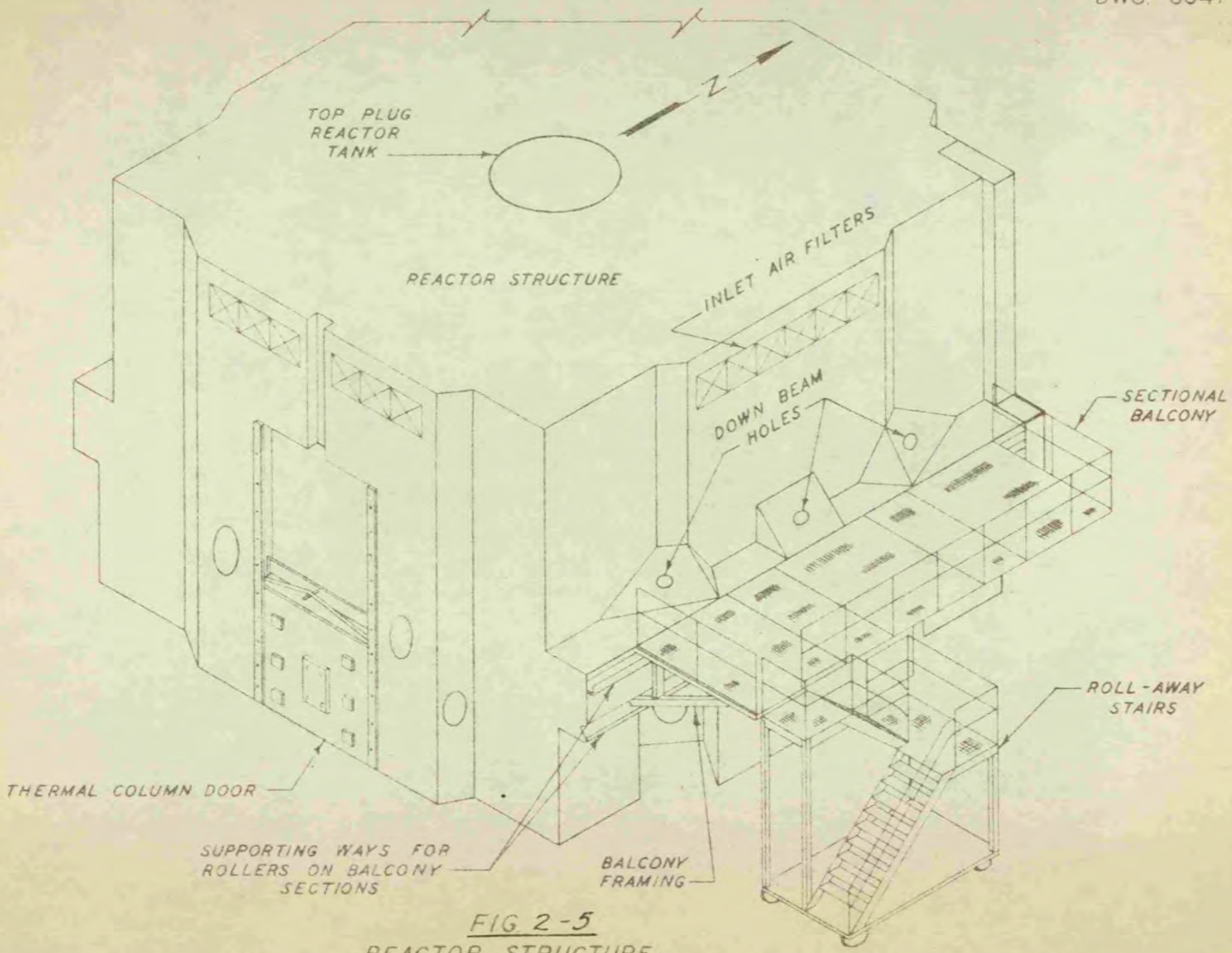

FIG. 2-5
REACTOR STRUCTURE

TABLE 2-1

Status of MTR Design Reports

	TITLE	STATUS
1.	Reactor Cooling Water Monitoring System	Awaiting development data.
2.	Thermal Column	Issued February 6, 1950, CF-50-2-28.
3.	Vertical Hydraulics	Preliminary study only.
4.	Instrument Holes	Rough draft.
5.	Tank Sections "A" and "E"	Issued November 22, 1949, CF-49-11-217.
6.	Graphite Reflector	Issued October 6, 1949, CF-49-10-88.
	Addendum	Issued November 17, 1949, CF-49-11-176.
	Addendum	In reproduction.
7.	Internal Air System	Issued November 21, 1949, CF-49-11-208.
	Addendum	Issued February 13, 1950, CF-50-2-61.
8.	Thermal Shield	Issued January 25, 1950, CF-50-1-125.
9.	Structural Steel (for Reactor Structure)	Issued November 29, 1949, CF-49-11-273.
10.	Neutron Crystal Spectrometer	In preliminary study.
11.	Shielding Facility	Issued December 8, 1949, CF-49-12-30.
12.	Reactor Structure and Experimental Facilities	Rough draft
13.	Design Data Sheets	Issued October 18, 1949, CF-49-10-232.
14.	Mock-Up Design Report	Issued October 27, 1949, CF-49-10-185.
15.	Control Mechanisms	Rough draft.
16.	Service Facilities	Issued January 25, 1950, CF-50-1-148.
	Addendum	In reproduction.

through HG-2. A vertical hole from the top of the reactor structure to the basement passes through one of these recesses so that the loop may be connected with apparatus in the basement.

At the present time all experimental facilities and their services are clearly specified for detailing by Blaw-Knox except for the neutron crystal spectrometer on which efforts are now being renewed to obtain a clear picture.

Service facilities over all surfaces of the reactor have been reviewed and revised frequently during the period with the aid of Blaw-Knox engineers who have worked at the Laboratory laying out drawings of various systems. As now planned the following services will be provided at or near each experimental hole: demineralized water, filtered water, warm drains, steam, compressed air, spare lines for gases, 110 and 220 volt a-c conduits for 300 volt, 200 ampere d-c, spare 1½ conduits, and adequate communication facilities. There will also be high pressure water for hydraulic rabbits, and at two points conduits adequate for 1000 amp d-c will be terminated.

Thermal Shield. The thermal shield temperature calculations were completed during the quarter, and as a result the thermal shield now consists of two-layer walls on all six sides, with a space for cooling air to pass between the layers. The top of the thermal shield will be separately supported from the concrete structure above it instead of resting on the four sides. The arrangement is shown in Figs. 2-2, 2-3, and 2-4. As shown in the figures, the graphite will be supported on stanchions which extend through holes in the inner bottom plate to rest on the outer bottom plate which will be much more stable thermally.

Thermal Column and HG-9 Plug. Some revisions were made in designs of the thermal column and HG-9 plug, principally as a result of a decision to eliminate the HG-9 hole liner and add one more step to the plug. This plug now consists of a simple sectional graphite stringer which fills the hole extending from the reactor tank through the thermal column.

Reactor Tank and Grids. Detail drawings of the various parts located inside the reactor tank have been started. An estimated 40 drawings will be made to cover all details of tanks, grids, locking mechanisms, bearings and miscellaneous items, exclusive of the beryllium reflector and the control rod drives.

Aluminum tank sections *C* and *D*, the reactor tank and the section immediately above it, will have 1 in. thick walls instead of 3/4 in. as in the

Mock-Up. It is now planned that these sections shall be made separately, but a permanent joint between them may be used.

The fuel assembly has been redrawn in complete detail to conform to recent changes, and concurrently a study of a circular lower adapter was made. The present square design is retained on the new drawings, however.

The top plug has been redesigned to be filled with lead shot instead of solid, poured lead as previously planned.

On the basis of Mock-Up experience and consultation with manufacturers of pressure vessels, a new type of seal for tank flanged joints has been decided upon. To insure complete success a full scale model incorporating the aluminum to aluminum, the aluminum to stainless steel and the stainless to stainless joints is to be fabricated using the new type of seal and this model will be subjected to hydrostatic tests.

Beryllium Reflector. Conferences with representatives of Brush Beryllium Company, Y-12 shops, New York Office of AEC, and ORNL, along with comprehensive design studies have established the sizes and shapes of pieces of beryllium to be used in the reflector. The cooling hole pattern has been established and detailing of the parts has started.

Control Rods and Drives. Roller bearings have been designed to replace all present graphite shim rod bearings and sleeve type regulating rod bearings. These are to be thoroughly tested in the Mock-Up.

New position indicators have been designed and are being built for test in the Mock-Up.

Other parts of the rod systems receiving detailed attention are the regulating rod coupling and speed reducer, upper regulating rod shock absorber, shim rod magnetic clutch, shock absorber and limit switches.

Cooling Water Monitoring System. The monitor tube for monitoring activity flow and temperature of water emerging from each of the fuel assemblies has been redesigned following tests of the previous design. It now measures velocity pressure by means of a microformer installed in the tube, temperature by means of a thermocouple and activity by allowing a small stream to flow continuously to the monitor room.

MTR Parts Procurement. At a joint meeting of the MTR Steering Committee and representatives of the Idaho Operations Office, held at Idaho Falls January 17 and 18, it was agreed that ORNL would supply the reactor tank and its contents, as opposed to placing the procurement in the hands of a sub-

contractor. On the basis of this decision funds are to be allocated to ORNL via ORO by the Idaho Operations Office for the purchase, fabrication, inspection, delivery, test and shipment to the site of the parts mentioned, including the top and bottom plugs, but excluding the tank sections *A* and *E*. ORNL thus bears direct responsibility for the quality, adequacy, and completeness of the components and their delivery on schedule to the site.

Commensurate with the cited responsibility, the authority of final decision relating to vendors, types of contract, and technical aspects will be vested in the Laboratory. Technical approvals and approvals for expenditures will rest solely and finally in the MTR Steering Committee, or their officially designated representative.

This program has been approved by both the Idaho Operations Office and ORNL Management. An allocation of $311,000 has been requested, exclusive of the beryllium reflector which is to be handled separately between the Idaho and New York Offices of AEC. The total expenditures, including reflector, will approximate $1,450,000.

Contingent upon the allocation of funds, the following schedule is now in effect:

Start of Procurement	April 1, 1950
Oak Ridge Delivery of all parts (excepting reflector) and start of testing	December 1, 1950
Oak Ridge completion of reflector	February 1, 1951
Completion of testing at Oak Ridge	March 1, 1951
Installation complete at site*	April 15, 1951

* This assumes biological shield to be ready sometime in March, 1951.

MTR CONTROLS SYSTEM

Mock-Up Instrumentation. One of the major concerns of the group during the past three months has been the instrumentation for the Mock-Up. The control scheme for the Mock-Up is very similar to that planned for the MTR; hence we installed instruments which we expect will later be used on the MTR. The fission chamber and associated amplifiers and counting rate meters were installed as originally planned and worked as expected. The sensitivity was more than adequate to detect the neutron source even with no multiplication in the pile.

The log n and pile period meter has performed very much as predicted. The fluctuations in the period recorder were larger than expected and steps are being taken to correct this. The circuit appears to be fundamentally sound.

Much effort has been centered on the safety circuits. It is necessary that the circuits operate quickly (approximately 10 milliseconds). We also demand extreme reliability--one would prefer a circuit that never fails. If this is impossible then a circuit that always fails safe, *i.e.*, so as to scram the pile, even unnecessarily at times, would be a suitable substitute. We have attempted to approach this latter condition as closely as possible. If one could guarantee "fail safe," only a single safety circuit would be required. We do not feel that we have obtained this objective so in addition we seek "statistical safety" in providing many sources of information as to pile level, many safety rods (two on the Mock-Up, seven on the MTR) and two ways of operating the rods (magnetic clutch and motor drive). Considerable redesign of the safety circuits by T. E. Cole and E. E. St. John* was made before they were installed in the Mock-Up. The circuits themselves have given no trouble--one of the ionization chambers developed a short and one of the magnets acted up. In every case the operator was given warning that a fault had occurred. Additional protection for magnet failures has been installed.

The servo has not yet been tried on the Mock-Up. A three inch ionization chamber is now being built and will be used with the servo system when completed.

* NEPA Lonnee

MTR Instrumentation. The laboratory work on instruments is nearing completion except for some cleaning up of the servo system. Work on the servo has been delayed by the resignation of Gorman Nelson, but will be continued by Cole and St. John. The design should be completed in two or three months.

Most of the work on MTR instrumentation is now paper work. The mechanical design of the top of the reactor so as to provide space and access to all of the instruments has been a problem. Provision must be made for associated preamplifiers. Space must be allowed for the fission chamber, amplifier and withdraw mechanism. Terminations for all the cables that connect to the top plug must be provided. It finally appears that two cubicles on the top of the reactor is the best solution to this problem.

A fission chamber has been designed by Gundlach and Jordan, and a model is being constructed. It is planned to locate the fission chamber in VG-8. Automatic positioning mechanism is under design by Blaw-Knox. The problem of introducing a shutter to reduce the neutron flux at the chamber in the withdrawn position has been very simply solved by attaching a neutron scatterer to the lower end of the chamber.

N. F. Lansing has made calculations on the time delay and the neutron flux at several positions in a VN hole. On the basis of these calculations the holes are now three inches in diameter and the chamber will be placed at the thermal shield. A boral tube will bridge the gap between the thermal shield and the graphite, thereby insuring that the neutrons impinging on the chamber come from a region of small time delay.

There has been considerable turmoil over the question of monitoring the temperature, flow, and activity of the water in each fuel channel. It has finally been decided that we will not attempt to measure both N^{16} and impurity-induced activity at the same time. Either can be measured by opening or closing a valve shunting the hold-up coils. This simplifies the problem greatly. The water from six tubes will feed in turn through an ionization chamber and the activity recorded by a Brown electrometer. This is similar to the Hanford "Christmas tree." Temperature differential across each channel will be recorded on a fast scanning instrument, set to alarm when the temperature increases slightly above the norm. Flow will be metered by bringing two static pressure tubes from each plug to the monitor room. The flow will be measured continuously on 36 meters set to alarm when the flow decreases below the normal value.

In addition to the above, resistance thermometer will record the difference between the inlet and outlet water temperature. N^{16} activity of the exit water will be measured at the top of the pile.

E. P. Epler and Lyle Martin* have been working with the Blaw-Knox engineers on the cable ways between the pile and the instrument room. This work is handicapped by not knowing just how many cables there will be, but the schedule is such that cable ways in the basement must be designed first. Raceways and conduit have been discussed. Both have their limitations; however, raceways appear to offer much more flexibility when properly installed. On the other hand the space available is so limited that a proper installation is impossible. A small raceway with a large number of conductors is most undesirable. In view of this, conduit is favored for most of the cable runs between the pile and the instrument room. By using a large number of small conduit with numerous spares, a great deal of flexibility can be regained.

Some work has been completed on the lay-out of the instrument rooms, control room, and monitor room. Much remains to be done, primarily by the Blaw-Knox engineers with our help.

* NEPA Loanee

EXPERIMENTAL

Status of Beryllium Corrosion Testing Program. Several lots of beryllium specimens to be used in evaluating the corrosion resistance of extruded and Q-Process types of beryllium have been received during the last 6 weeks. A list of the material received is shown below:

1) 150 pieces of sintered beryllium, Lot No. Y4460BP QRM.

2) 54 pieces of sintered beryllium, Lot No. Y4460BP QRM. Specimens machined and/or ground in different ways.

3) 15 pieces of sintered beryllium, Lot No. Y4431BP QPT.

4) 1 piece of extruded beryllium, Lot No. Y4407BP QRM, Extrusion No. 90.

5) 1 piece of extruded beryllium, Lot No. Y-4407BP QRM, Extrusion No. 88.

6) 4 pieces of extruded beryllium, Lot No. Y4411BP QRM, Extrusion No. 52.

7) 150 pieces of extruded beryllium, Heat No. 164.

Several static tests were started to evaluate the effects of chemical and metallurgical variations on the corrosion resistance of the beryllium exposed to simulated MTR cooling water. These tests were temporarily interrupted when an analysis revealed that the water contained a copper content of 1 ppm and a sulfate content of 13.5 ppm. Prolific pitting accompanied by large amounts of voluminous corrosion products appeared on all of the specimens.

In order to minimize chemical variations in the water during the lifetime of these tests, approximately 1500 gallons of distilled water had been collected in a porcelain lined steel tank. All previous analysis of the water collected from the distillation apparatus indicated it to be satisfactory for these tests. An analysis of the water in the storage tank for chloride, iron, and aluminum content indicated these constituents were present in tolerable limits, so the tests were started before the complete analysis was received. Unfortunately, the tin plating on the copper condenser began to peel off during the collection of the water, resulting in the high copper content of the distillate. The steam pressure on the heating coils in the still pot had been raised from 25 to 40 psi to increase the capacity. The high sulfate content was probably caused by surges in the pot which carried over water

through the condenser to the reservoir.

Another still which appears to be in good condition has been installed and is now in operation. The specimens which were damaged severely by corrosion are being re-machined to remove the pits. All of the tests will be started again within the next few days.

Aluminum Additions to Beryllium. Several specimens of beryllium containing a wide variation in aluminum content (0.05 to 1.24%) are being subjected to accelerated corrosion tests in distilled water at 485°F in an attempt to evaluate quickly the corrosion effects of this element. Experience has shown that an aluminum content of 0.3 - 0.4% aluminum facilitates the production of QM-V beryllium. It is hoped that these tests will give some indications as to the allowable aluminum content from a corrosion standpoint.

Extruded Beryllium. A dynamic corrosion test of a full scale beryllium assembly (Class II) exposed to simulated MTR cooling water conditions was terminated after 15 months of operation so that the assembly could be inserted in the MTR Mock-Up at Area X-10. It has been previously reported that no significant corrosion occurred during the first 12 months of exposure. Prolific pitting of the assembly occurred during the thirteenth month of the test when the chloride content of the water increased from less than 1 ppm to 8-9 ppm.

The assembly was exposed to distilled water containing less than 0.2 ppm chloride during the last two months of the test. No increase in pit density occurred, although the pits already present exhibited a slight tendency to grow. The pits were shallow, seldom exceeding 8-10 mils in depth. In numerous regions, an extremely adherent black deposit extended 5-10 mils above the surrounding metal surfaces. It is believed that the localized corrosion was probably initiated by the high chloride content of the water during the thirteenth month of the test since no other significant variation in water composition was detected.

Induced Radiation in Graphite. Pile induced activity for CS and GBF graphite was reported in the last quarterly for two and four weeks irradiation time. Figure 4-1 shows the gamma intensity of these materials up to 2400 hours for 8 weeks irradiation time. Another sample is being irradiated for six months.

Analysis of the curves indicate the same components that were reported for the shorter irradiation times (15 hours, 33 hours, 50 days, 100 days half lives).

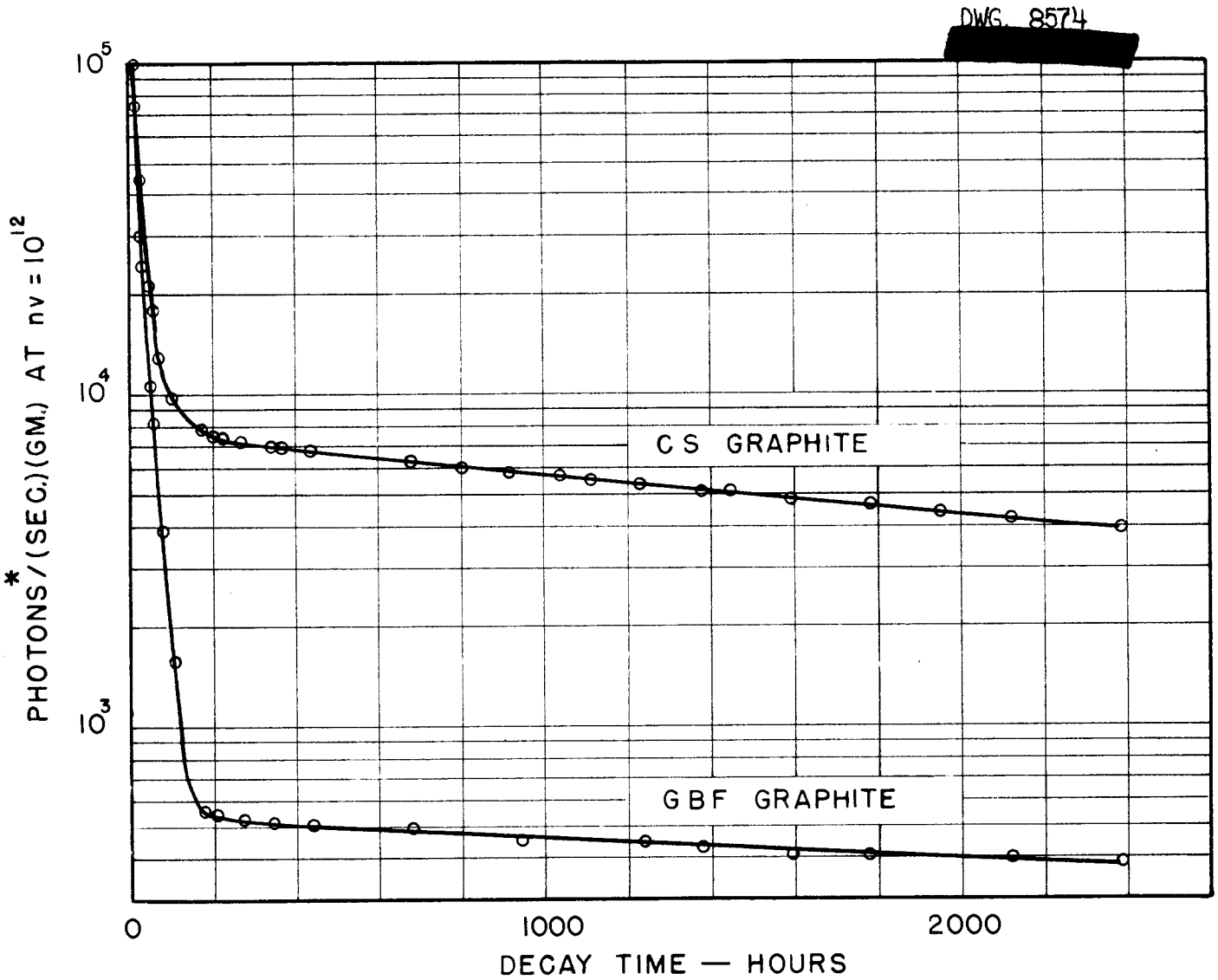

FIGURE 4-1 GAMMA RADIATION FROM GRAPHITE

1363 HOURS IN PILE

*Equivalent to photons of Co^{60} (av. energy 1.2 Mev.)

Induced Radiation in Beryllium. Pile induced activity is being determined for extruded beryllium which was irradiated for 507 days at an average flux of 6.91×10^{11} neutrons/(cm^2)(sec). ($nvt = 3.03 \times 10^{19}$ neutrons/cm^2.) Figure 4-2 shows the gamma intensity up to 3000 hours decay time.

The decay curve was taken with an ionization chamber which was calibrated with Co^{60} standards (average gamma energy of 1.2 Mev). Analysis of the curve shows three principal activities, which are listed in Table 4-1 along with a radiochemical analysis by the Chemistry Division.

Figure 4-3 shows the absorption curves for lead for several decay times. These measurements were made by interposing sheets of lead between the sample and a mica window G-M chamber. Most of the short lived elements had decayed when these measurements were made, and all of the curves have the same slope—corresponding to a half thickness of lead of 0.47 inches

TABLE 4-1

Analysis of Be Decay Curve

Half Life Found	Element Suspected	
2.7 hours	2.7 hr.	Sr^{87}
14 hours	12.8 hr.	Cu^{64}
>100 days	Sc^{46} + Co^{60} + Fe^{59} + RE (see below)	

Radiochemical Analysis of Be Sample. Beta counts are given for total weight of sample (0.5398 gm) but corrected to zero decay time. The samples were mounted on glass and no correction attempted for back-scattering and self-absorption. All results are based on second shelf geometry.

Element	Half Life	Counts/minute
Sc^{46}	85 days	8.10×10^5
Cu^{64}	12.8 hours	5.23×10^6
Co^{60}	5.3 years	1.50×10^5
$Fe^{55, 59}$	4 years - 46.3 days	1.22×10^5

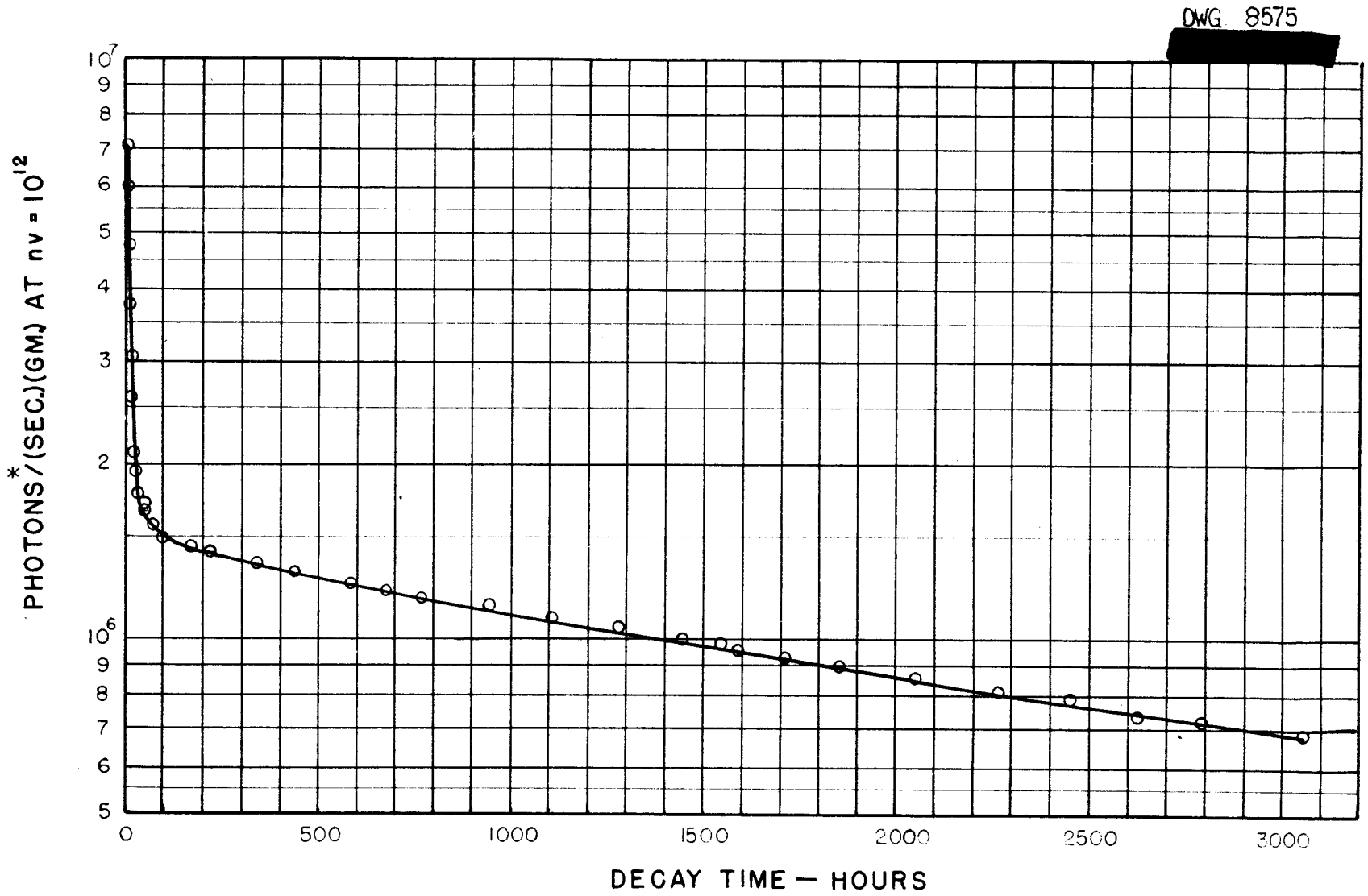

FIGURE 4-2 GAMMA RADIATION FROM BERYLLIUM

507 DAYS IN PILE

*Equivalent to photons of Co^{60} (av. energy 1.2 Mev.)

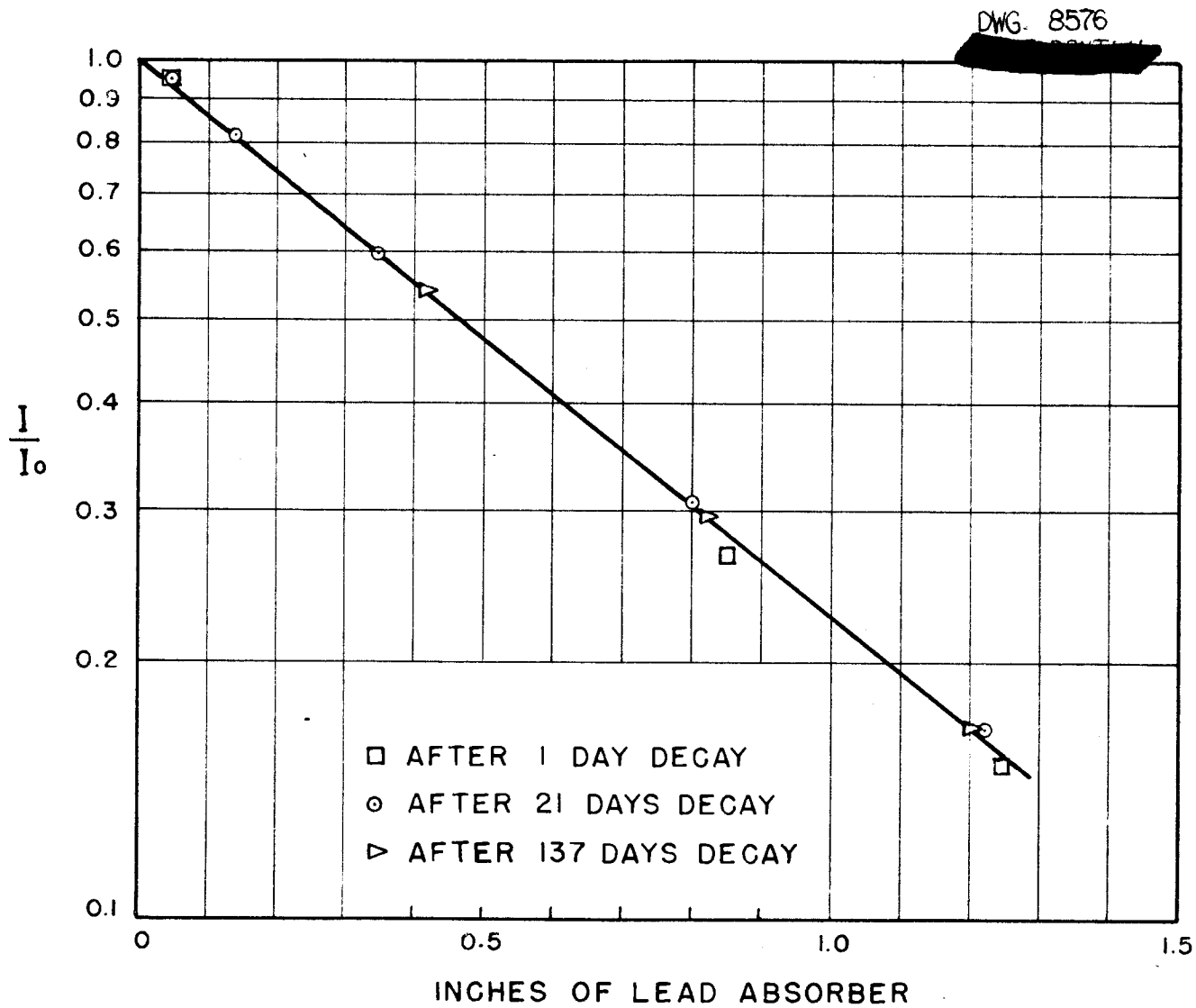

FIGURE 43 ABSORPTION OF GAMMA RADIATION FROM BERYLLIUM

Element	Half Life	Counts/minute
Sr^{89}	55 days	8.50×10^3
Ca^{45}	152 days	2.40×10^4
Rare Earths	~60 days	9.90×10^4

Critical Experiments in MTR Mock-Up. Preparations for the critical experiments in the MTR Mock-Up were completed early in January. Additions and revisions of the Mock-Up facility included the installation of a beryllium reflector inside the reactor tank, a graphite reflector outside the tank, a four-foot shield of concrete block and control instrumentation. The total accumulated cost of the conversion was $60,000, of which some $30,000 was spent for materials which will be returned for credit after completion of the experiments.

Practice loadings with dummy fuel pieces began about January 15, and the loading with active fuel on January 22. Criticality was attained February 2, with a fuel complement of approximately 2 kilograms 235 arranged in a 3 × 5 pattern with full reflector on two sides and partial reflector on 2 sides. Since that time the reactor has been operated 20 to 30 hours at a power level of about 0.1 to 10 watts. All mechanical and electronic components have performed satisfactorily. The experimental program outlined in the previous progress report will be started immediately.

MATERIALS TESTING REACTOR (MTR) COMPONENTS—FUEL PLATES

Fuel Plates for the MTR Critical Experiment. Production of plates for use in the MTR Critical Experiment was started on November 1, 1949. Specifications for the 344 plates ordered are given in Table 5-1.

On January 10, 1950, 514 plates had been produced in 24 runs; of these, 247 were rejected because of blistering. Of the blistered plates, 66 were recycled to later heats, along with the alloy scrap and dross from all except the last six runs. Blistered plates were in excess of the number to be expected on the basis of previous work. A study of humidity data shows a correlation between blistering and the absolute humidity of the atmosphere at time of casting, pre-rolling and cladding, verifying earlier work. The humidity prevailing during the ingot breakdown seems to have no bearing on rejection due to blistering. Table 5-1 lists yields and humidity data for each run. The trend toward poorer yield with increased absolute humidity is further illustrated in the distribution graphs shown in Fig. 5-1. Because of the poor yields obtained, further attempts at fabrication of fuel plates containing enriched uranium were stopped until workable remedies could be applied.

Blistering of Fuel Plates - Brazing Flux Treatment. Previous work indicated that the majority of blisters originated in the core material. It is assumed that these blisters result from the release of hydrogen, which is relatively insoluble in either the aluminum or the U-Al alloy, and which is apparently formed by reaction with water during melting or any operation where the metal is hot. The gas should diffuse if the metal is heated for a period of time at temperature below that at which blisters are formed. It is necessary to heat to about 700°F to produce appreciable blistering in clad U-Al alloy. It has also been shown(1) that there is a gas pickup in aluminum when it is exposed to the atmosphere at room temperatures for long periods of time, and that the gas is driven off by heating to 360°C (680°F) in a dry atmosphere.

Since the preventive measure of vacuum melting and dried air atmospheres in preheating furnaces had proven inadequate, a remedial approach to the

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(1) Keller, Fred and Edwards, J. D., "Composition and Properties of the Natural Oxide Film on Aluminum," *Metals Progress*, 195-200 (August, 1948).

[redacted]
DWG. 8401

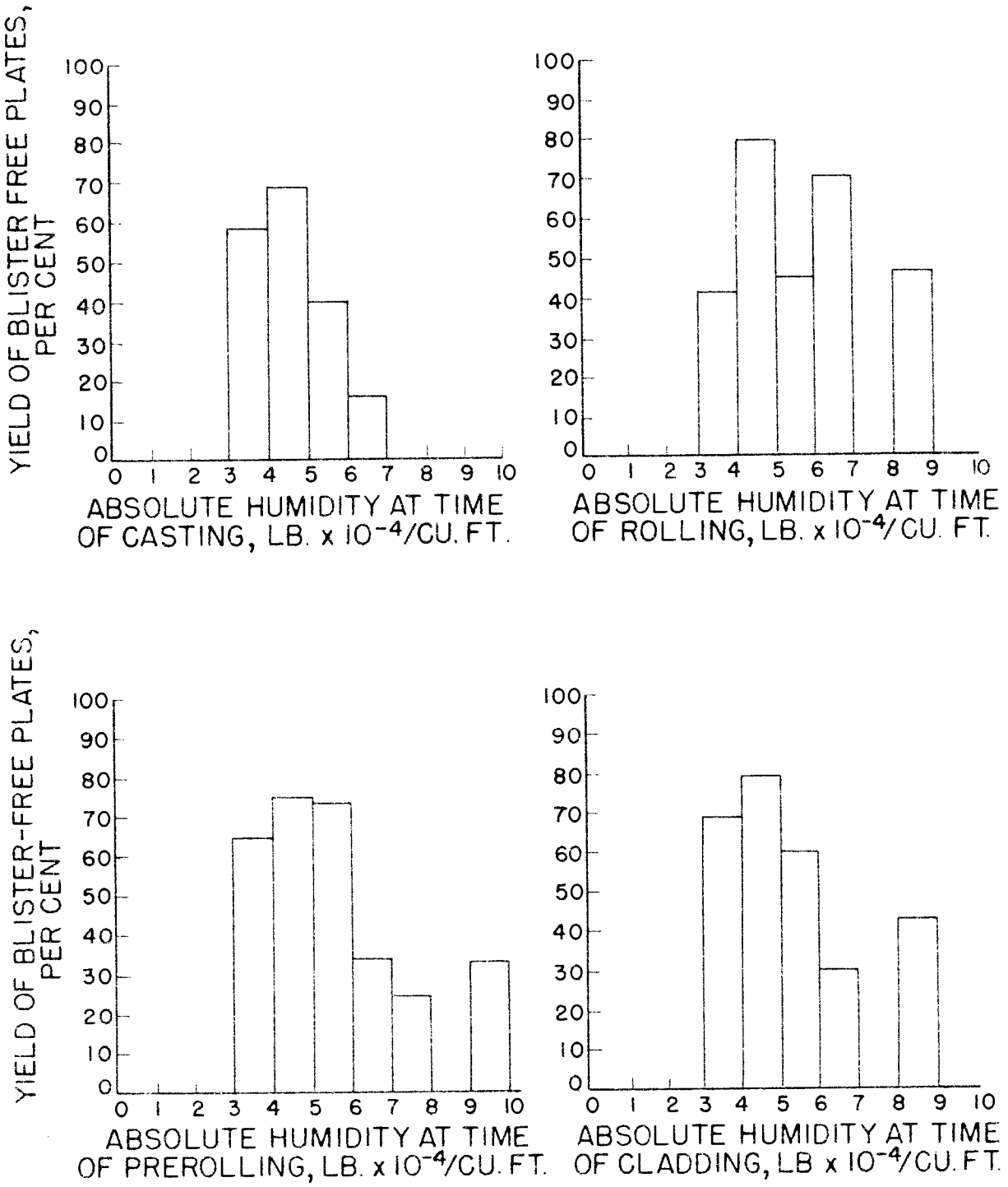

FIG. 5-1
RELATION OF HUMIDITY TO YIELDS OF BLISTER-FREE PLATES

TABLE 5-1

Fuel Plate Specifications for MTR Critical Experiment

Plate

Dimensions

Length	24-5/8 in.
Width	2.845 in.
Thickness	0.060 in.

Core

Dimensions

Length	23-3/4 in
Width	2.50 in.
Thickness	0.021

Composition

Total U in U-Al alloy	13.3%
U^{235} enrichment	95%
U^{235} content	(7.70 gm ± 1%)/plate

Clad

Type	Composition	Thickness	No. of Plates
Standard	2S		200
Duplex	2S 72S (outside)	0.005 in.	144
		Total	344

Quality: Blister-free

problem was tried. In ORNL 407[2] it was reported that clad U-Al plates which had not blistered when annealed in air at 1100°F for three hours could be made to blister by cleaning in NaOH and HNO_3 solutions, then coating with brazing flux and heating to 1100°F. However, these blisters occurred in the adjacent unfluxed areas, not in the area which had been covered by flux. Accordingly, two ingots, N23 and N24, were cast in air and rolled according to standard procedures substituting natural for enriched uranium and with the modifications in heat treatment shown below. To insure blistered cores, both ingots were quenched in water immediately after casting.

Heat N23 - 20 cores total

- 4 - Standard procedure
- 4 - Cores and frames preheated 2 hours in dry air at 360°C prior to cladding
- 4 - Vacuum annealed at 1100°F, after cladding
- 6 - Dipped in alcohol slurry of Eutectic No. 190 flux and heated through the following cycle:
  - ½ hr at 300°F
  - 1 hr at 850°F
  - 38 min at 1100°F
- 2 - As above without flux

Heat 24 - 20 cores

- 4 - Standard procedure
- 4 - Cores and frames preheated 2 hours in dry air at 360°C prior to cladding.
- 12 - Dipped in alcohol slurry of Eutectic No. 190 flux and heated through the following cycle:
  - ½ hr at 300°F
  - ½ hr at 1100°F

All of these plates were subsequently annealed at 1100°F for one hour. Neither the plates which had been fluxed and heated nor those vacuum annealed were blistered whereas all of the others were. Four of the blistered plates from run N24 were cold rolled to flatten the blisters, then fluxed, dried and heated ½ hr at 1100°F. The blisters then reappeared but were considerably smaller.

From these experiments, it appears that:

(1) Coating clad plates with a flux slurry and heating to 1100°F removes the blister-forming gas.

(2) Frye, J. H., Jr., *Metallurgy Division Quarterly Progress Report for Period Ending July 31, 1949*, ORNL 407 (October 14, 1949).

(2) Heating at lower temperatures in dried air, prior to cladding, had no effect on blistering.

Two additional natural uranium heats were cast, rolled and clad. These were then treated with flux and annealed. Yield of blister-free plates was 95%.

Production of fuel plates containing enriched uranium was then resumed with modifications in procedure as indicated by the work with natural uranium. Two hundred thirty-five plates were rolled with the modified procedure. Of these 201, or 85.5%, were blister-free. In all, 749 plates were produced, of which 468 were blister-free, giving an overall yield of 62.5%. A breakdown of uranium distribution is as follows:

Charge as U_3O_8		5,572.82 gm U
Acceptable Plates	3,797.36 gm U	
Blistered Plates	1,551.95	
Scrap Alloy	93.98	
Samples	79.49	
Slag, Dross	50.04	

(3) Heating previously blistered plates with flux at 1100°F does not eliminate the blisters.

(4) Vacuum annealing at 1100°F removes the blister-forming gas.

Purity of Aluminum. Spectrographic analysis of samples from heats 1, 2, 3, 4, 5, 12, 13, 14, 22 showed that elements with very high cross sections, such as Cd, Li, and B, were not present. Ca, Cu, Fe, Mg, and Si were the principal constituents, all being present in trace amounts. There seemed to be a slight build-up in Fe and Cu with continued alloy recycling up to a saturation value corresponding to that of 2S aluminum. This is to be expected, since 2S aluminum is used as a cover and frame material.

The 1/8 inch 2S aluminum cover plates used in heats 1 through 12 had been annealed 8 hours at 800°F. As a further check, additional plates from this same batch were annealed for 8 hours at 1100°F. Examination of these plates showed areas which either had been attacked by some corrodant or had fused locally, possibly due to some low melting impurity. No difference in analysis implies that whatever caused the attack was no longer present. All plates showing this condition were rejected.

Health Physics Considerations. Air samples were taken during the various production operations to determine if any hazard due to radioactive contamination existed. This work was under the supervision of R. L. Clark and W. H. Ray of the Health Physics Division. Results showed that with careful handling there was no hazard. The principal source of trouble was in transferring the U_3O_8 from its original container to a mixing bottle. It was suggested that a hood or enclosure for this operation would constitute an improvement. No activity was found on smears taken from rolls or clad plates. This work will be presented in more detail at a later date.

Fuel Assemblies--MTR Critical Experiment. Several assemblies containing plates with natural uranium cores were fabricated. Because of minor changes made in furnace baffle adjustments, it was found necessary to reestablish the brazing cycle:

(1) Assembly drying, two hours at 295° - 305°F.

(2) Assembly preheat, fifty minutes at 845° - 855°F.

(3) Assembly brazing, thirty-eight minutes at 1100° - 1110°F.

ORNL 511[3] describes modifications made to the plate forming die and hydraulic press. These have resulted in more uniform active plate curvature, but assemblies fabricated from these plates show somewhat smaller final assembly width. Comparison of dimensions indicate that an increase in plate curvature has resulted from the changed forming conditions, necessitating a 0.006 inch increase in plate width to produce assemblies of desired overall size. Future assemblies will be made from plates machined to a width of ± 0.001 inches.

Twenty-five assemblies have been produced for the MTR Critical Experiment. All of these contain enriched uranium; however, four contain less than standard amounts of the enriched U. These are the "partial" fuel units requested. In addition, three uranium sections have been completed for shim safety rod fabrication. Two of these are now in use in the experiment. The third is being fitted with the necessary additional components.

Of the twenty-five assemblies, four showed plate spacing beyond the established limit of ± 10% of nominal, and, since these instances were in the upper or lower annulus, the external dimensions were somewhat affected. In each of these instances, such variation existed only in one annulus, and only for a short section of that annulus. These assemblies will be observed after flow tests have been made. Satisfactory joining was noted on all assemblies

(3) Frye, J. H., Jr., *Metallurgy Division Quarterly Progress Report for Period Ending October 31, 1949*, ORNL 511 (January 12, 1950).

fabricated. No blistering developed during brazing. The ranges of the key dimensions for all twenty-five of the assemblies are as follows:

Width	2.987 in. to 2.996 in.
Vertical Center Height	3.045 in. (*) to 3.084 in.
Sagitta	0.219 in. (*) to 0.250 in.
Upitta	3.296 in. to 3.315 in.
Plate Spacing	0.097 in. to 0.130 in.

(*) This value corresponds to the occurrence of narrow plates spacing.

These values are also typical of the ones obtained on natural uranium fuel assemblies fabricated for the MTR Mock-Up.

Brazed Joint Examination. Satisfactory joining has been accomplished, but some irregularities of brazing have been noted on six of the assemblies:

(1) Poor fillets were found at the ends of active plates.

(2) Portions of braze metal strips were noted adjacent to joints within the assembly.

(3) Excessive metal build up, or "run-through," was observed in the bottom annulus, extending out some 3/8 to 1/2 in. from the side plates.

Investigations are planned to determine the causes of these variations in metal flow. From previous experience it should be noted that:

(1) Insufficient cleaning results in poor brazing.

(2) Incomplete removal of degreasing solvents hampers braze metal flow.

(3) Variations in flux composition may cause irregularities in brazed joints.

(4) Variations in filler metal composition may cause poor metal bonding and flow.

Several assemblies showing irregularities were again fluxed and subjected to a second operation. It was found that brazed assemblies after such recycling showed improved metal flow and fillet formation. Typical of these assemblies is No. 197 (Fig. 5-2), which has been photographed along the brazed joints before and after a second brazing cycle. It can be seen that spotty, irregular fillets have been replaced by uniform ones, due to more regular metal distribution.

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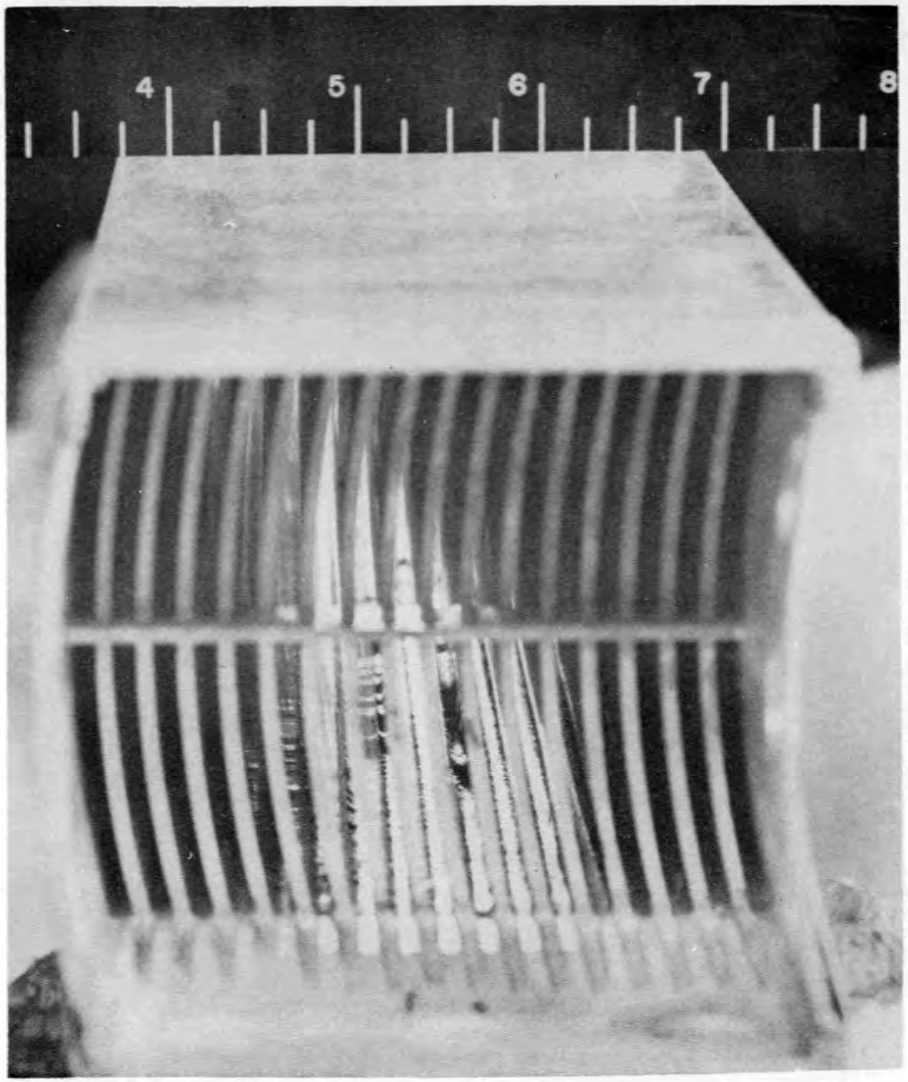
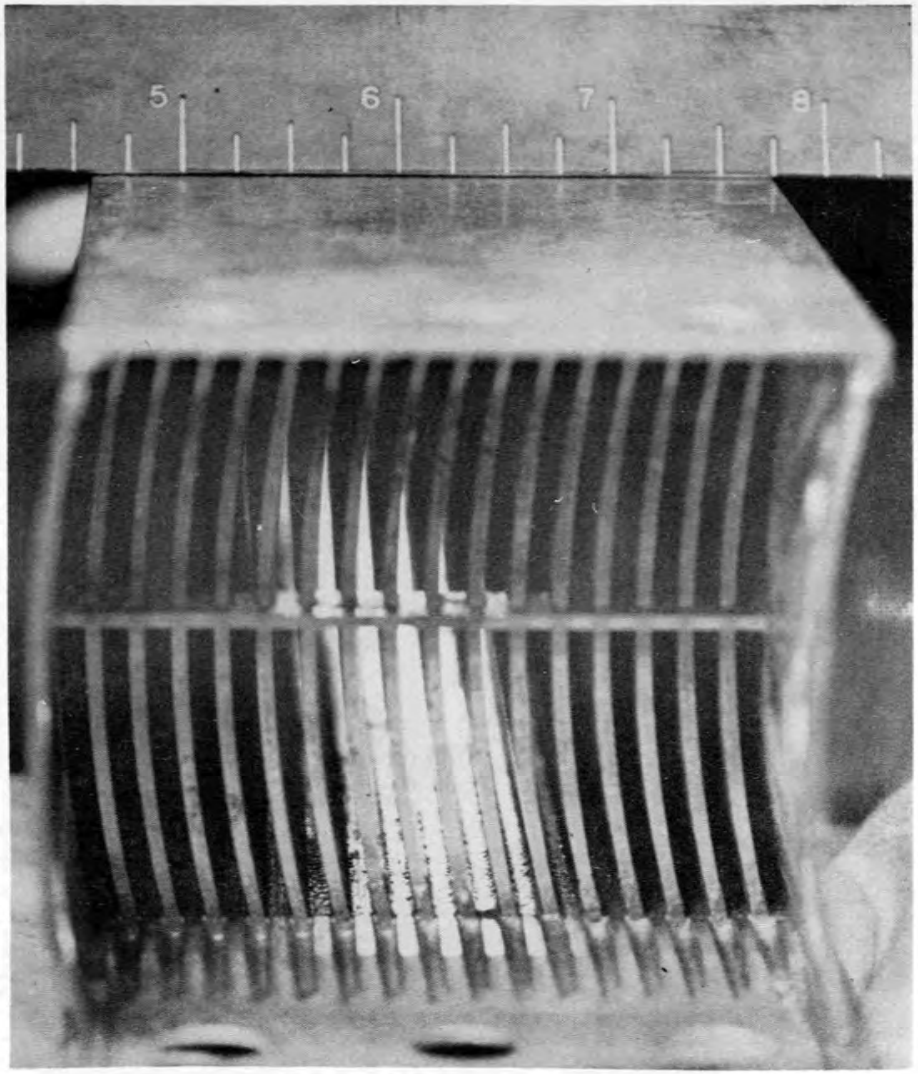
Y-930



After single fluxing and brazing

Y-913



After second fluxing and brazing

M T R Fuel Assembly No. 197

FIG. 5-2

It was also found that additional braze metal could be supplied at points of insufficient filler material. On the other hand, excessive amounts of braze metal in some locations could be distributed by slight mechanical agitation of the molten metal surface. This was accomplished by inserting and quickly removing narrow strips of aluminum.

Cleaning after Brazing. Post-cleaning has been a production problem, as reported previously. Water quenching of hot assemblies results in distortion. Assemblies made for the MTR Mock-Up were cleaned in hot water, followed by cold water, but this does not provide a chemically clean surface. Considerable oxidation of aluminum takes place during the removal of the residual flux, giving the surface a dusty white film. Several methods of cleaning were were investigated. Use of hot aviation type soapy aluminum cleaners, hot sodium silicate solutions, and hot phosphoric acid-chromic acid mixtures were equally unsatisfactory. Alcoa's "Welding and Brazing Alcoa Aluminum" suggests the use of 10% nitric acid containing 1-4% hydrofluoric acid. Use of this bath following water washing cleaned assemblies free of the white powdery film in less than a minute.

MTR Type Long Fuel Assemblies. The problem of producing MTR-Type fuel assemblies having cores up to 140 cm in length is being studied. Preliminary tests were made on the forming of long plates by successive pressings in the present die.

This method produced irregular plates, considerably twisted along their length. It will be necessary to obtain suitable dies, press equipment, and furnaces.

Jiggings equipment must also be prepared to handle the longer units. The ORNL shops will fabricate the drying fixture. The brazing jigs can be supplied in rough shape by American Lava Company, subject to final machining to tolerance.

Degreasing equipment bids were received recently, covering the size unit required.

Consideration will be given to a double acting press in order that the operation of blanking out the plates can be achieved either just prior to or after the forming operation.

A larger surface plate will be required to inspect the active plates and assemblies.

Beryllium for the MTR. Most of the experimental work in the development of beryllium for the MTR has been completed, and the work has now advanced

largely to the planning and procurement stages. It is presently planned that hot-pressed beryllium will be used for about 90% of the pieces. After production at the Brush Beryllium Company Plant, the blocks will be cut to approximate size and autoclaved before shipment to Oak Ridge. The autoclave test specifications are being developed in the Technical Division of ORNL. Acceptable beryllium will be machined at Y-12 and flow-corrosion tested by the ORNL Technical Division. The beryllium reflector sections are being redesigned to take advantage of the ability of the hot-pressing method to produce larger pieces than can be done by extrusion. Each reflector section will be made from a single piece, thereby eliminating bolting or brazing of the beryllium. Deep drilling of off-center holes in beryllium is a major fabrication problem in the new design. Further work on this is planned.

Irradiation-Corrosion. Samples for studying effects of irradiation on beryllium corrosion have been sent to Hanford. After an autoclave test, samples of several types of extruded and of hot-pressed beryllium will be exposed to process cooling water in process holes for periods of three months and of ten months. Additional samples will be subjected to flow corrosion laboratory tests concurrent with the pile exposure tests.

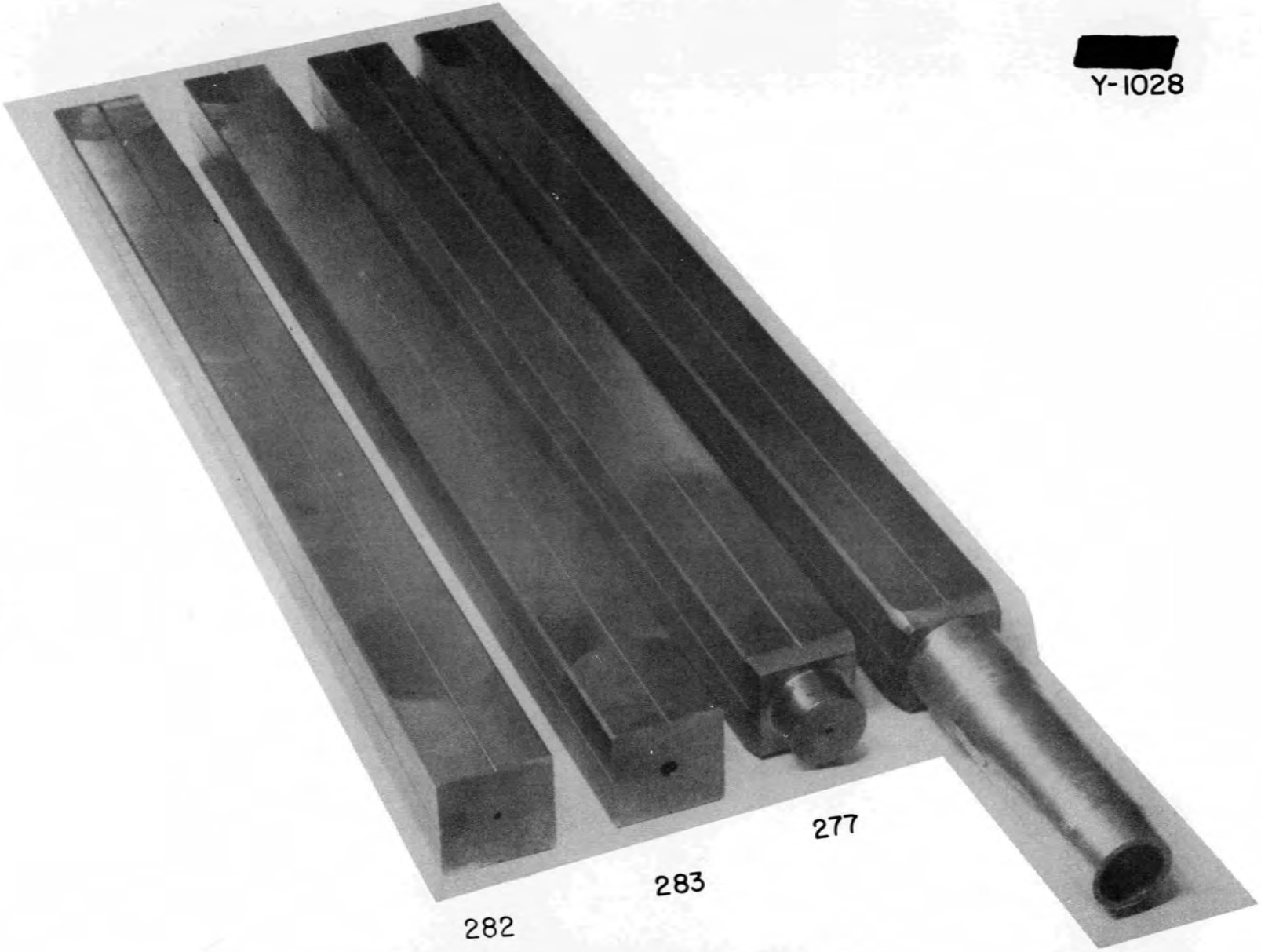
Extrusion. One series of extrusions was made at ORNL. Four billets, in steel cans, were pushed through the 1-3/8 in. round-cornered square insert die at 1800°F. This die is a two-piece die with the center insert made from a cobalt-chromium alloy cast by the Doss Die Company of Detroit. All these rods were good and the die stood up very well. However, with present practice the plain steel dies are proving satisfactory and are much cheaper.

Three copper-jacketed billets were extruded at temperatures of 700, 800 and 900°F, respectively. All rods were rattlesnaked, but the quality improved slightly with decreasing extrusion temperature. These billets were all pushed without difficulty; in fact, less than two-thirds of the press capacity was required. One billet was to be extruded at 650°F, but a can with a copper plated steel nose was used in error. This billet stalled the press before the beryllium started through the die.

Machining. During the past quarter, three removable and six new "A" type reflector units were fabricated for the Mock-Up critical experiments. Figure 5-3 shows four of the six "A" type units in various stages of completion. The 1/2 in. hole shown in extruded billet 283 is actually the short length loading and unloading tap found on the upper end of the unit.

[redacted]

Y-1028



"A" Type Beryllium Reflector Units

FIG. 5-3

Pertinent deep hole drilling data on fabricating the narrow 3/16 in. water cooling channel in each "A" unit are tabulated below:

MATERIAL	BILLET NUMBER	HOLE DIAMETER		OFF-COURSE BETWEEN DRILL AND WORK AXIS (inches)	RUN OUT AFTER RECENTERING (inches)
		DESIRED (inches)	ACTUAL (inches)		
Vaccum Cast and Extruded	269	0.1875	0.171	1/4	0.005
Vacuum Cast and Extruded	277	0.1875	0.177-0.178	3/16	0.010
Vacuum Cast and Extruded	282	0.1875	0.183-0.187	7/32	0.015
Vacuum Cast and Extruded	283	0.1875	0.181-0.184	3/16	0.015
Vacuum Cast and Extruded	284	0.1875	0.178-0.180	1/16	0.010
Hot-Pressed	4405	0.1875	0.178-0.179	1/32	0.010

The machining time required to fabricate the new "A" type unit design is only 48 hours. This is a reduction of approximately 1/3 the number of hours required for a similar unit of three-piece bolted construction.

MTR Top Plug. The Metallurgy Division was requested by the Design Section of the Technical Division to make recommendations on a procedure for filling the top plug of the MTR with lead. The following recommendations were made:

(1) The shell should be constructed from a stabilized stainless steel, such as 347.

(2) A system for venting the air from the blind compartments should be incorporated into the design.

(3) The shell should be heat treated by heating to between 1950-2050°F and water quenching.

(4) A sound lead casting without voids or pipe is feasible.

MTR Neutron Window. Tests to produce a value that will permit estimating the creep to be expected in the large slabs of lead to be used in the neutron window have been continued during this period. Two series of tests are being run, one with the specimens loaded to the expected load (30 psi), and the other at twice the load. Both sets are maintained at 150°C, which is the anticipated operating temperature.

[redacted]

The creep does not appear to be the serious problem that was originally expected. The tests were set up to measure changes of length of the order of tenths of a millimeter and since the actual changes are of the order of only 0.03 millimeter, poor checks are being obtained. It appears, but is not yet certain, that creep of the order of 0.15% of the length per year, may be expected. The tests are being repeated using SR-4 strain gages to obtain a more accurate measure of the creep.

[redacted]