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ORNL RESEARCH REACTOR PROJECT (ORR)

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Contract No. W-7405, eng. 26

RESEARCH DIRECTOR'S DIVISION

LONG RANGE REACTOR PLANNING GROUP

ORNL RESEARCH REACTOR PROJECT (ORR)

January 22, 1953

Compiled By

Joseph P. Gill

FEB 13 1953

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ORNL RESEARCH REACTOR PROJECT

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ORNL RESEARCH REACTOR PROJECT

1. Introduction

In the early part of 1950, it became apparent that the graphite reactor at the Oak Ridge National Laboratory could not supply the additional neutron irradiation facilities required for various research programs then being undertaken, particularly in the field of reactor development, where irradiation effects studies were especially needed for the Aircraft Nuclear Propulsion and the Homogeneous Reactor Projects.

Even in 1950, the graphite reactor was being used to the limit of its facilities for both fundamental and applied research as well as radioisotope production. A priority system had been adopted so that the reactor facilities would be assigned only to the most urgent and promising of the experiments requiring their use. Completion of the reactor building and facilities renovation in 1950 greatly improved the quality of experimental work areas and made it possible to take better advantage of existing irradiation facilities; however, the need for additional facilities still far exceeded the limitations imposed by the reactor itself.

To help alleviate the situation, the Reactor Design Section of the Research Director's Division was requested to make a proposal for a permanent reactor facility for the Laboratory. The design for the Materials Testing Reactor (MTR), now in operation at Arco, was nearing completion, and it was felt that considerable savings would result if a simplified MTR design were used for the proposed ORNL reactor.

In August of 1950, ORNL submitted to the AEC a report entitled "Proposal for a Research and Isotope Reactor at ORNL," ORNL-809. Included were the

justifications and conceptional designs for a three-megawatt, MTR type reactor that would require the minimum amount of design and development effort. Additional justifications were submitted to the AEC in ORNL Memorandum CF-50-10-112 in October 1950.

Approval of the project was granted in August of 1951, by the Atomic Energy Commission, to the extent of allocating $100,000 for initial design of the reactor and reactor building.

The design group, starting with the completed design for the MTR, held many meetings with members of the research staff to determine what facilities were most urgently needed and how the MTR design could be modified to supply those facilities at minimum cost. As a result of the meetings and of the experience gained in the construction and operation of the reactor at Arco, the original MTR design was simplified to provide a low cost reactor specifically tailored to meet the needs of the ORNL program of fundamental and applied research. The name of the facility was shortened to ORNL Research Reactor or (ORR).

Now that the initial investigation of all phases of the project has been essentially completed, construction, erection of the buildings and installation of equipment could proceed with a minimum of design effort, pending allocation of the necessary funds. Recently completed estimates show that the project would require twenty-four months for completion and could still be held within the original estimate of 2.8 million dollars.

This report covers the work that has been completed on the design and development of this reactor and associated facilities from August 1, 1951, until November 1, 1952.

Although the project has been organized as a joint effort of the Engineering Department and the Long Range Reactor Planning Group of the Research Director's

Division of the Laboratory, contributions have been made by many of the Research Departments. Special mention should be made of the help that has been received from the Reactor Operations Group and from those who have followed the construction and initial operation of the Materials Testing Reactor at Arco.

Previous reports and memoranda concerned with the history of the project are as follows:

1. Oak Ridge National Laboratory Report No. 809, "Proposal for a Research and Isotope Reactor at ORNL," by A. H. Snell and A. M. Weinberg, dated August 17, 1950.
2. Oak Ridge National Laboratory Central Files Document No. 50-10-112, "Revisions to ORNL-809," letter dated October 19, 1950, Director, Oak Ridge National Laboratory to Director, Research and Medicine.
3. Oak Ridge National Laboratory Central Files Document No. 52-2-7, "Proposed Revisions to Programs 2000 through 6000 of ORNL Research and Development Program for Fiscal Year 1953," dated February 15, 1952.
4. Request for Directive No. CR-179, "Research Reactor and Building," dated January 30, 1952.

ORNL RESEARCH REACTOR PROJECT

2. Justification

At present there are three reactors at the Oak Ridge National Laboratory available for radiation research: the Graphite Reactor, the Bulk Shielding Facility Reactor and the Low Intensity Training Reactor (LITR).

The Graphite Reactor, put into operation in 1943, was designed principally to serve the Hanford chemical separation pilot plant, with little regard for large scale neutron experiments. For this reason the reactor experimental facilities are limited. The highest thermal neutron flux available in the graphite reactor for experimental use is 1×10^{12} neutrons/cm^2/sec. and the number of experimental holes giving access to this flux is quite small; other irradiation facilities are limited to somewhat lower neutron fluxes. Because irradiation and neutron beam facilities are entirely inadequate, the radioisotope production and the radiation damage groups have for several years found it necessary to make use of other reactor facilities, especially at Hanford and Chalk River. In addition, many promising research projects have been dropped or postponed because in-pile space was not available.

The Bulk Shielding Facility Reactor, recently increased in power to 100 kilowatts, began operation early in 1950. It has been devoted exclusively to the collection of shielding data, especially with respect to the testing of shields for the aircraft reactor program. Its design and construction limit the possibility of modifying this reactor for other experimental purposes, or of increasing its power level to obtain higher neutron fluxes.

The Low Intensity Training Reactor, in operation since 1950, was originally designed to test the hydraulics of the MTR, and check the mechanical operation of the reactor controls. After this had been completed, the Atomic Energy

Commission approved modifications necessary for critical experiments so that the nuclear characteristics of the MTR could be predicted with more confidence. Later, the facility proved valuable for training reactor operators. Subsequent approvals for additional increases in power level, with structural modifications, have allowed this reactor to become an important tool in conducting numerous experiments at higher neutron flux levels for the Aircraft and Homogeneous Reactor Projects. The operating power level is now 1.5 megawatts, yielding a maximum thermal neutron flux in experimental facilities of 1.2×10^{13} about ten times higher than that of the Graphite Reactor. However, the very limited number of experimental holes available in this reactor has never fulfilled the continually increasing needs of the expanding reactor development projects. Since the LITR was not originally intended to be used as a reactor, a large number of now-irreplacable parts were made of substitute materials whose corrosion and radiation resistance are not acceptable for long term operation. The operational problems connected with the high activity of the process water due to rust particles and loose pigment from painted surfaces have been kept to a tolerable level only at considerable expense. This constitutes one of the more serious factors affecting the life of the reactor. The lack of radiation doors has proved inconvenient and warranted extreme safety precautions in inserting and removing experiments. At best, this reactor provides high flux irradiation facilities for the most urgent experiments required by ORNL only and on a temporary basis until a permanent reactor facility can be completed.

The decision to bear the expense of converting the MTR mock-up into a 1.5 megawatt operating reactor, knowing that it could be operated only for a relatively short time, attests the urgent need for additional reactor experimental space at ORNL.

It is evident that the reactor development program at ORNL has suffered greatly from the lack of adequate irradiation facilities and has only been able to maintain a satisfactory level by using the LITR for radiation research. That the LITR provides only a temporary solution to the problem is evident by the continually increasing maintenance cost of this reactor. Consequently, the necessity for completing the ORR before the LITR has to be shut down should be emphasized if the research program is to be maintained at a constant level.

The justification for a Research Reactor in addition to the MTR is based on the fact that the nature and location of the MTR makes it relatively useless for "quick and dirty" experiments. What is needed at ORNL is a facility available for a wide range of minor or "probe type" experiments. The cost of doing all of these in the MTR would be prohibitive in time and money. In this way the ORR would supplement the MTR, saving the latter for the more carefully planned, higher priority, higher flux work that can not be carried out in ORNL reactors.

The 30-megawatt MTR at Arco is being used as a high-flux test facility by all installations of the Atomic Energy Commission, and therefore will be available for ORNL experiments only to a limited extent.

At 5 megawatts, the ORR will provide a flux about four times greater than the LITR but about 1/6 the flux of the MTR. From the standpoint of space and neutron flux the ORR will more than double the reactor experimental facilities provided by the Graphite Reactor and the LITR. The design presently conceived provides experimental facilities believed to be adequate for most of the investigations now being undertaken by ORNL. The experiments for which it is not intended to be adequate are those higher flux experiments that can be carried

out in the MTR. Otherwise, the ORR will provide a long-needed, permanent reactor facility tailored to fit the present and anticipated requirements of the ORNL research program.

3. General Description of Reactor

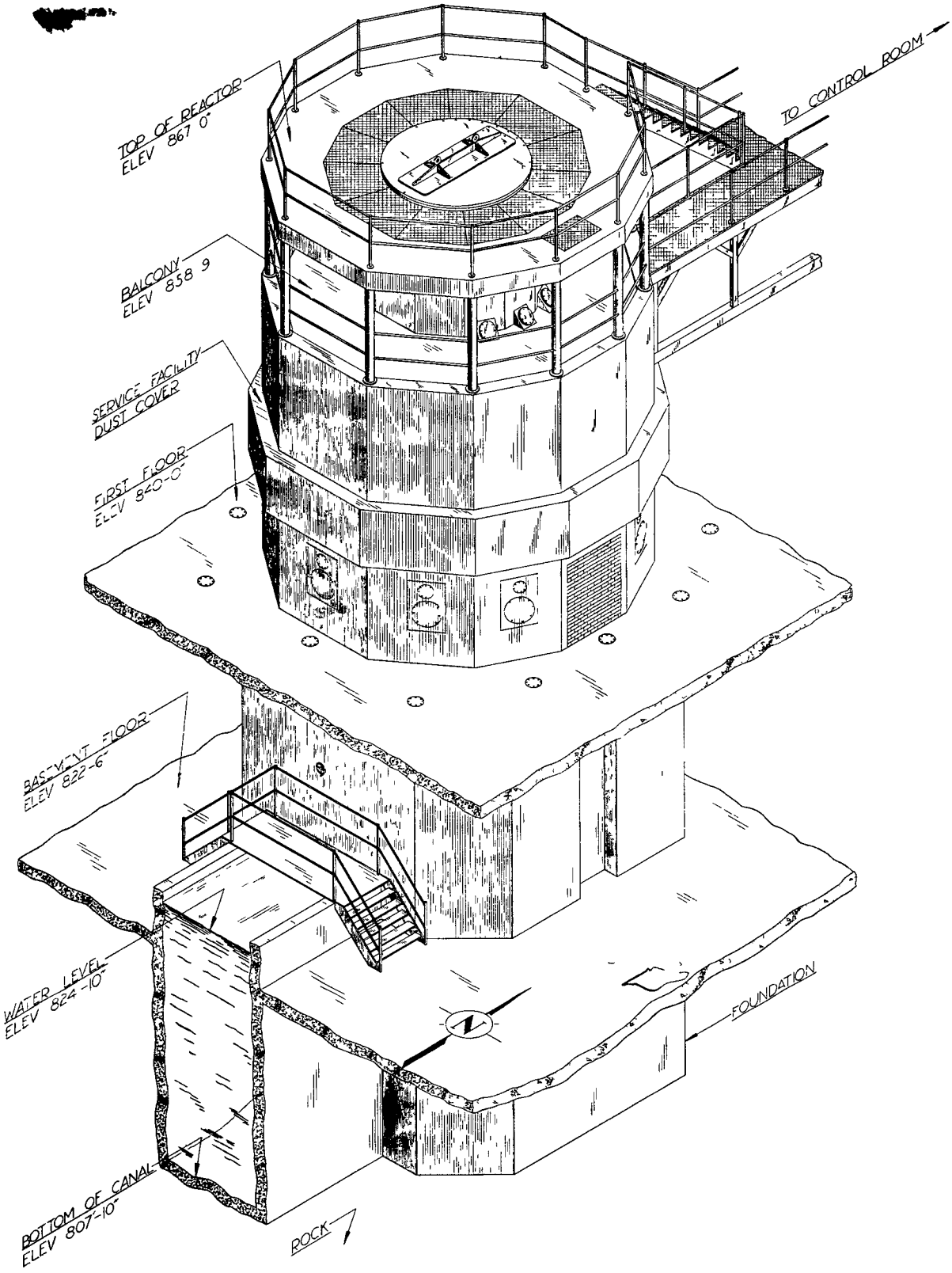
The design of the ORR incorporates a heterogeneous core utilizing enriched uranium fuel and ordinary water as coolant and moderator. The reflector may be a relatively thin layer of beryllium or beryllium oxide, backed by a thick layer (about two feet) of ordinary water. The system is intended to be a source of both fast and thermal neutrons for experimental purposes. Designed for operation at 5 megawatts, it is a simplified version of the 30-mw MTR now in operation at Arco. Frequent comparisons between the ORR and the MTR are included in the subsequent description.

Figure 1 is an isometric view of the reactor structure, which is a twelve sided polygon, twenty-two feet across flats and approximately twenty-six feet high. The core design, method of control, and the size and number of permanent experimental facilities are nearly identical with those of the MTR. Since the ORR is also to be operated as a research facility, development work has been kept to a minimum by adopting the design of a number of items essentially as they were in the MTR. The features that were emphasized during the re-design period were engineering improvements which would substantially reduce the cost of the reactor without sacrificing safety or flexibility. The nature of the MTR design and development did not allow the incorporation of a number of improvements that were suggested during the later stages; however, many of these improvements are used in the ORR design.

Figures 2 and 3 show the principal components of the reactor and reactor structure in vertical and horizontal sections through the centerline.

Summary of Design Features

In comparison with the MTR the following general features have been incorporated into the design of the Research Reactor:



RESEARCH REACTOR
OAK RIDGE NATIONAL LABORATORY
FIG.-1

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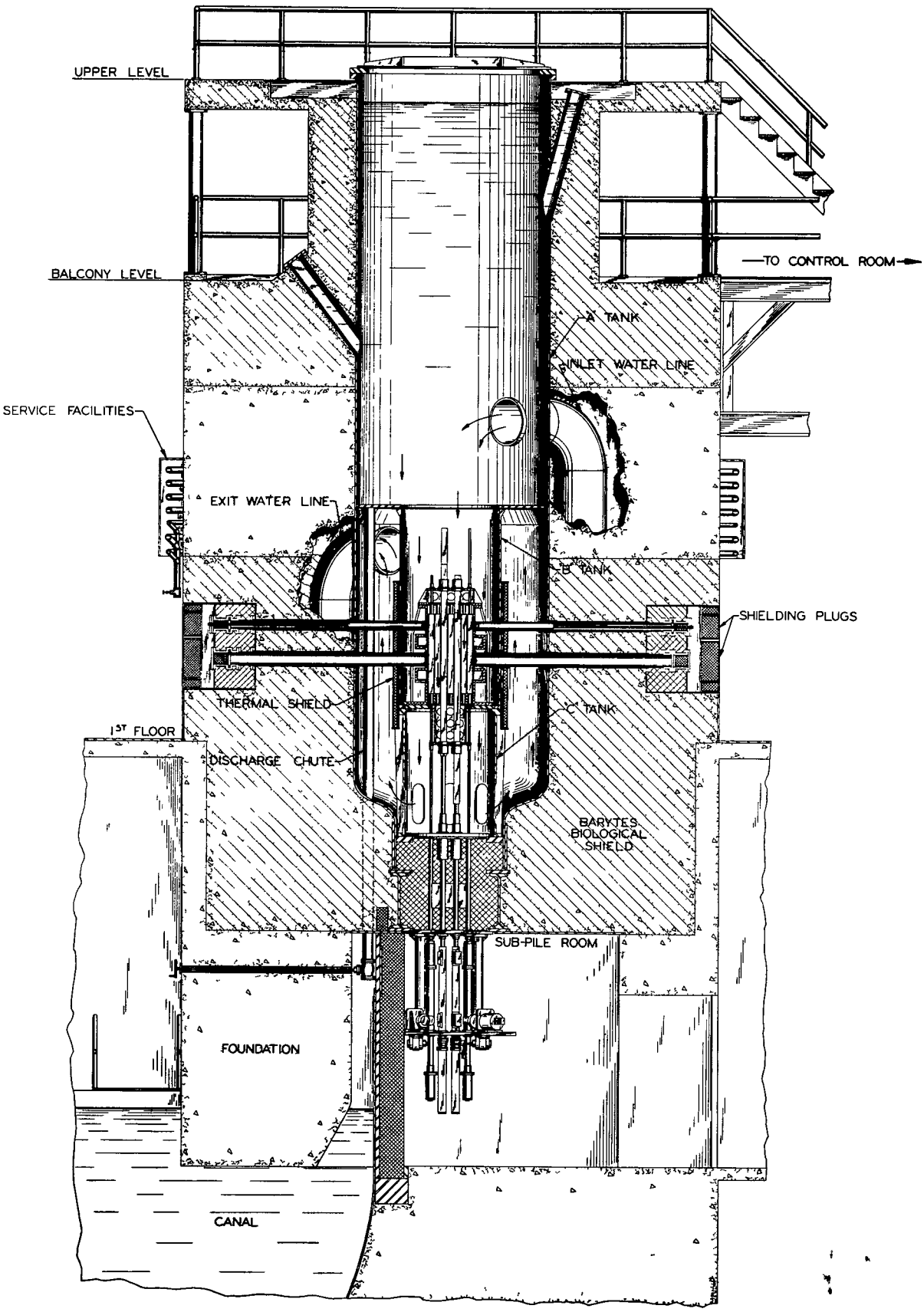

ORNL RESEARCH REACTOR
VERTICAL SECTION
FIG-2

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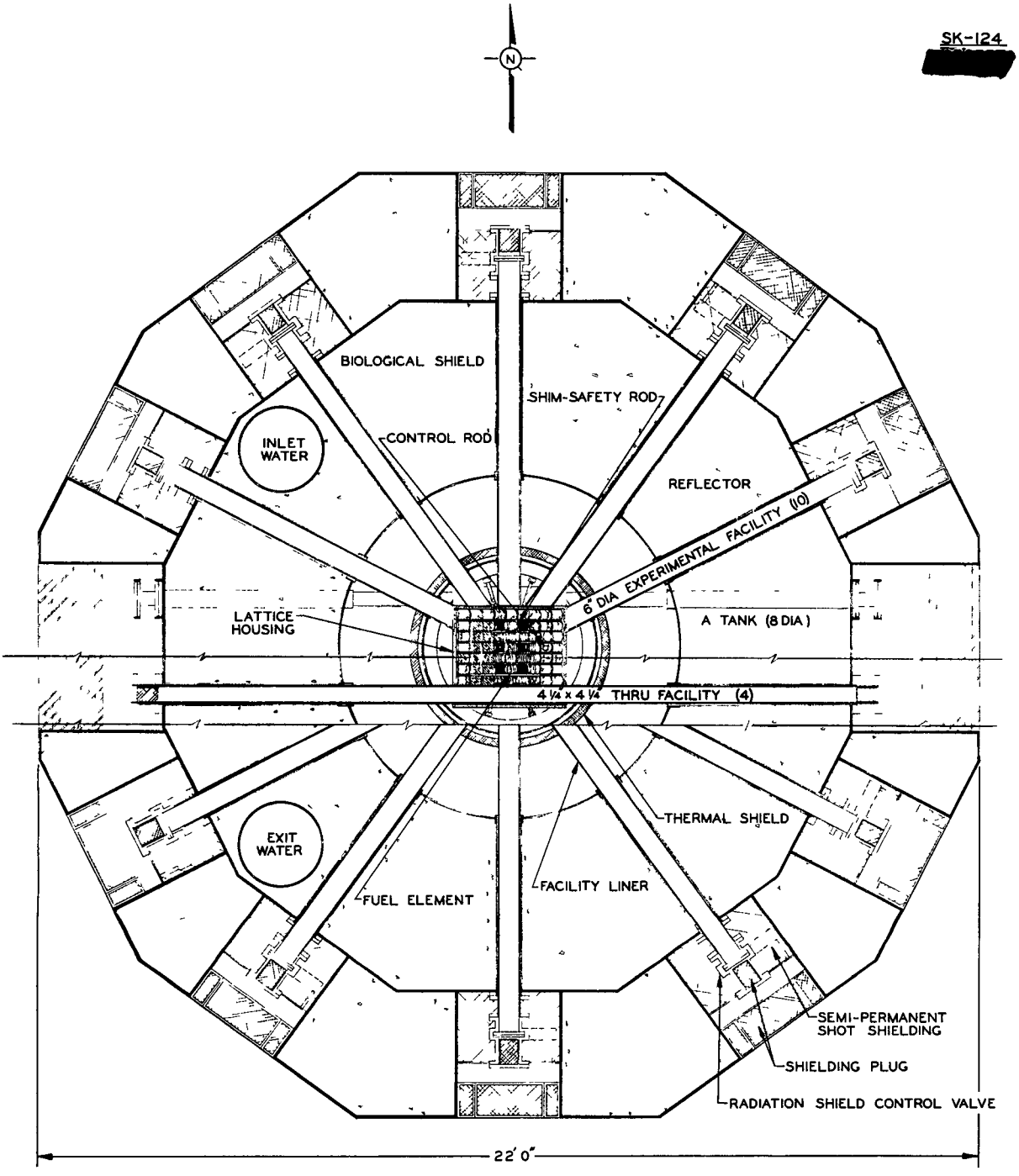

ORNL RESEARCH REACTOR
HORIZONTAL SECTION
FIG-3

A. Shim-Safety and Regulating Rod Drives are now operated from below the reactor in the sub-pile room and are not normally removed except for repair. A number of advantages are realized by this arrangement: (a) During the critical experiments and normal reloading operations, safety rods will be in position for operation; (b) The reactor tank above the active section is made available for insertion of experiments; (c) Reactor and controls components are brought closer together, and during installation are aligned and referenced from a single machined surface in the reactor structure. Misalignment due to repeated removal of control rods is eliminated; (d) A solenoid-operated mechanical release device replaces the magnet assembly; (e) Fabrication and installation costs are reduced.

B. The use of one large stainless steel tank which can be fabricated, pressure tested and installed as a unit has a number of obvious advantages over the reactor tank of five sections used in the MTR. (a) Expensive and troublesome flanged and gasketed joints are eliminated; (b) Tank wall temperature is governed by the temperature of the process water system, eliminating many expansion problems that existed with a tank arrangement closer to the active section; (c) Only the lower flange surface is considered critical in fabrication and installation; (d) A fuel discharge chute to the canal can be incorporated in the main tank, yet be far enough away from the center of the reactor to provide a drop straight to the canal without passing through the sub-pile room. The shielding of this chute is now more convenient; (e) Space is available inside the tank for the storage of fuel, reflector and other reactor components during inspection

and repair.

C. Operation of the reactor at low power levels can be accomplished without the cover plates being on the reactor tank. This is similar to the operation of the ORNL Bulk Shielding Facility Reactor and is made possible by the operation of the process water system at essentially atmospheric pressure.

D. The expensive, permanent and large beryllium reflector of the MTR is replaced with a smaller reflector of beryllium or canned beryllium oxide. The active lattice is somewhat larger than in the MTR design and in most cases the active fuel is surrounded by six inches of reflector in elements similar to the "L" pieces of the MTR.

E. In this reactor, the experimental hole liners which penetrate to the face of the active lattice are made in one piece and are retractable for repair or replacement. The critical and expensive machining that was required on the thimbles and the reactor tank for the MTR is eliminated.

F. The eight-foot diameter reactor tank will require a minimum of supporting steel work, receiving most of its support from the concrete biological shield. Alignment problems dictated that the MTR tank system be supported independent of the concrete.

G. In addition to the top surface of the reactor structure, which has now been cleared of any equipment necessary for the operation of the reactor, a balcony level has been established in that portion of the structure which is not necessary for shielding. At this level and the upper level, a number of holes have been provided for possible access into the reactor core for experimental purposes.

H. The fuel assembly monitoring system, although useful in locating ruptures in the aluminum cladding of the fuel assemblies, and in providing operational information, is not now considered an essential item for the safety and control of the MTR. Considering the remote possibility that a rupture of the fuel element cladding will occur, a system is being designed to include a water temperature indication for each fuel assembly, along with a provision for water sampling at intervals. It will not provide for the continuous recording of temperature, water activity and pressure drops that had been a design specification for the MTR.

J. A new design of liners for the experimental and other facilities that penetrate to the active lattice eliminates the need for expensive and accurately machined liner offsets and relatively complicated radiation door designs. Radiation streaming through liner annuli has been eliminated by filling the annuli with water.

Experimental Facilities

The more important experimental facilities for the ORR are shown in the horizontal section, Figure 3.

Ten radial holes, six inches in diameter, are located in a horizontal plane two inches below the centerline of the reactor core. They extend from the outside of the biological shield to the face of the lattice housing. Four holes, 4 1/4 inches square, adjacent to the north and south faces of the lattice, pass completely through the reactor structure and terminate in common cubicles or recesses on the east and west sides of the structure. These "through facility" holes are located above and below the radial holes as shown in Figure 4.

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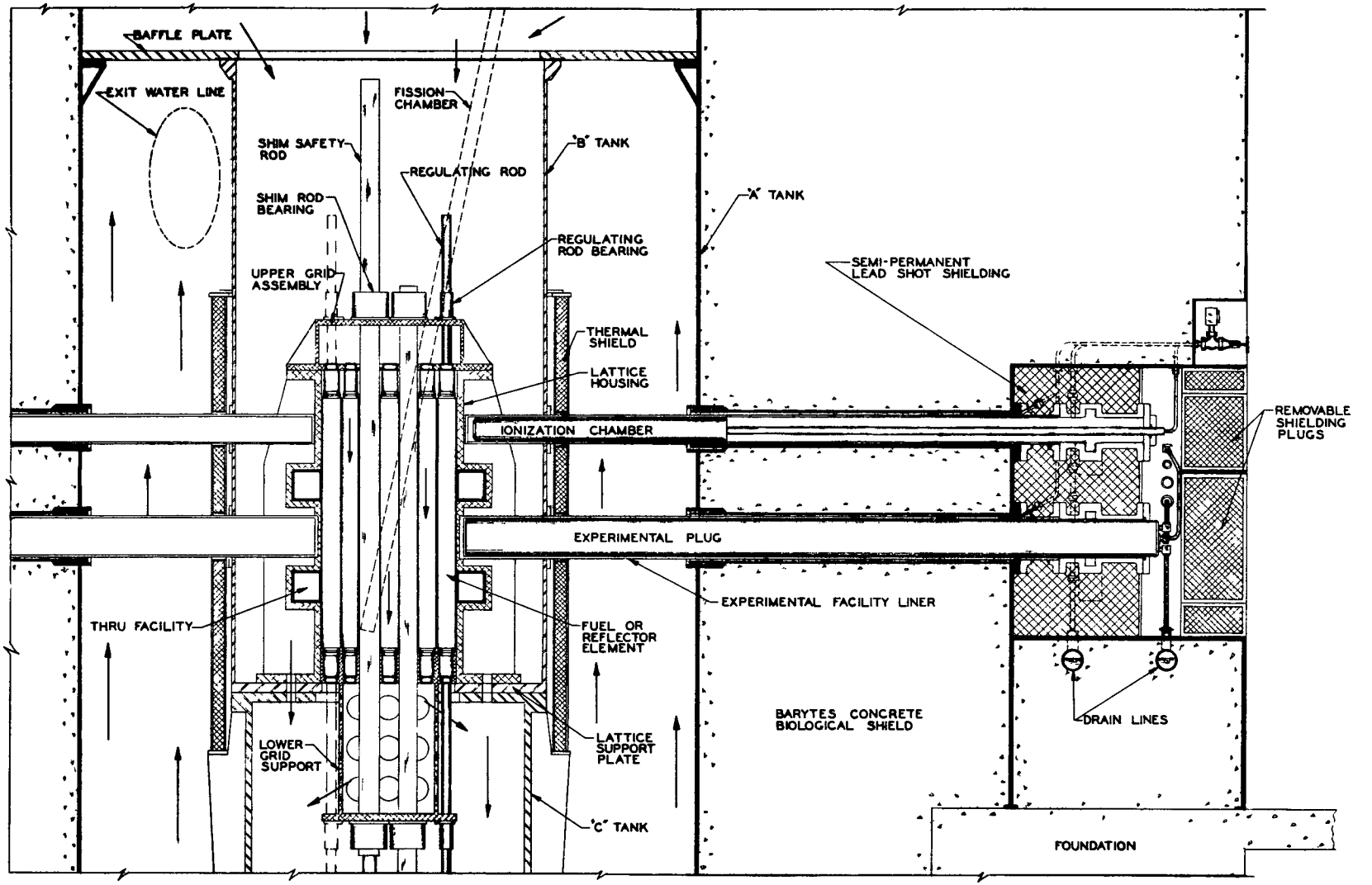

ORNL RESEARCH REACTOR
ACTIVE LATTICE-VERTICAL SECTION
FIG-4

The liners for the radial holes are equipped with remotely operated, commercial, sliding-disc valves that will allow the liners to be filled with circulating water. This liquid shield together with the two removable lead plugs, one at the end of the liner outside the valve and the other at the face of the structure serving as a plug to close the cubicle, will provide sufficient shielding. This method of shielding has advantages over the previous design in economy and simplicity of construction.

It is planned that experimental equipment to be used in the radial holes will be built into a plug that fits into the hole liner.

In inserting a plug which houses an experiment, the lead shielding plugs in both the cubicle and the liner will be removed and the coffin brought into position within the cubicle. The liner will be drained, the sliding-disc valve opened, and the experimental plug inserted. After sealing the experimental plug at the end of the liner, (the sliding-disc valve remains open) the annulus around the plug will be filled with water to act as a coolant for the plug and liner, in addition to its service in preventing radiation streaming.

Services (cooling lines, power, electrical interlocks, etc.) to an experimental plug are available from within the cubicle, as shown in Figure 4.

The availability of experimental space in the reactor tank above the lattice, with access to the lattice, is considered to be one of the most important design features of the Research Reactor. All of the eight-foot diameter cover plate is available for the mounting of equipment that might be used with vertical experiments. In addition, four sleeves, six inches in diameter, penetrate the side walls of the reactor tank at the upper level of the structure. Initially plugged and covered with grating, they

are available for experimental purposes. Six other access sleeves, also six inches in diameter, penetrate the reactor tank at the balcony level, and may be used for experimental purposes.

Reactor Core and Controls

The core of the ORR consists of a lattice of aluminum-clad, curved plate assemblies of aluminum-uranium alloy, identical with those of the MTR. Reflector pieces of beryllium, or high density beryllium oxide in cans, of the same shape as the fuel assemblies, are arranged as a part of the lattice to provide either seven or fifteen centimeters of reflector. The fuel and reflector assemblies are fitted with identical end adapters and are held in position by means of upper and lower grid plates to make up the active lattice as shown in Figure 5. The size of this lattice, approximately 28 1/2 x 21 x 40 inches deep, will allow all of the 6-inch diameter experimental holes to be located in one horizontal plane of the reactor. This lattice arrangement is somewhat larger than that of the MTR because the permanent beryllium reflector and all of the graphite reflector of the MTR have been eliminated and the small reflector that was substituted has been incorporated into the lattice.

In six of the positions within the core, moveable shim-safety rod assemblies are provided to supply additional fuel during burn-up, or to poison the lattice with cadmium when required. Regulation of the reactor is accomplished by a fast acting cadmium regulating rod moving through one of the reflector pieces.

To assure their mechanical operation and maintain the proper clearances required for cooling, the shim-safety and regulating rods are provided with bearings located above and below the upper and lower grid plates of the active lattice. A major departure from the MTR design is that the drive

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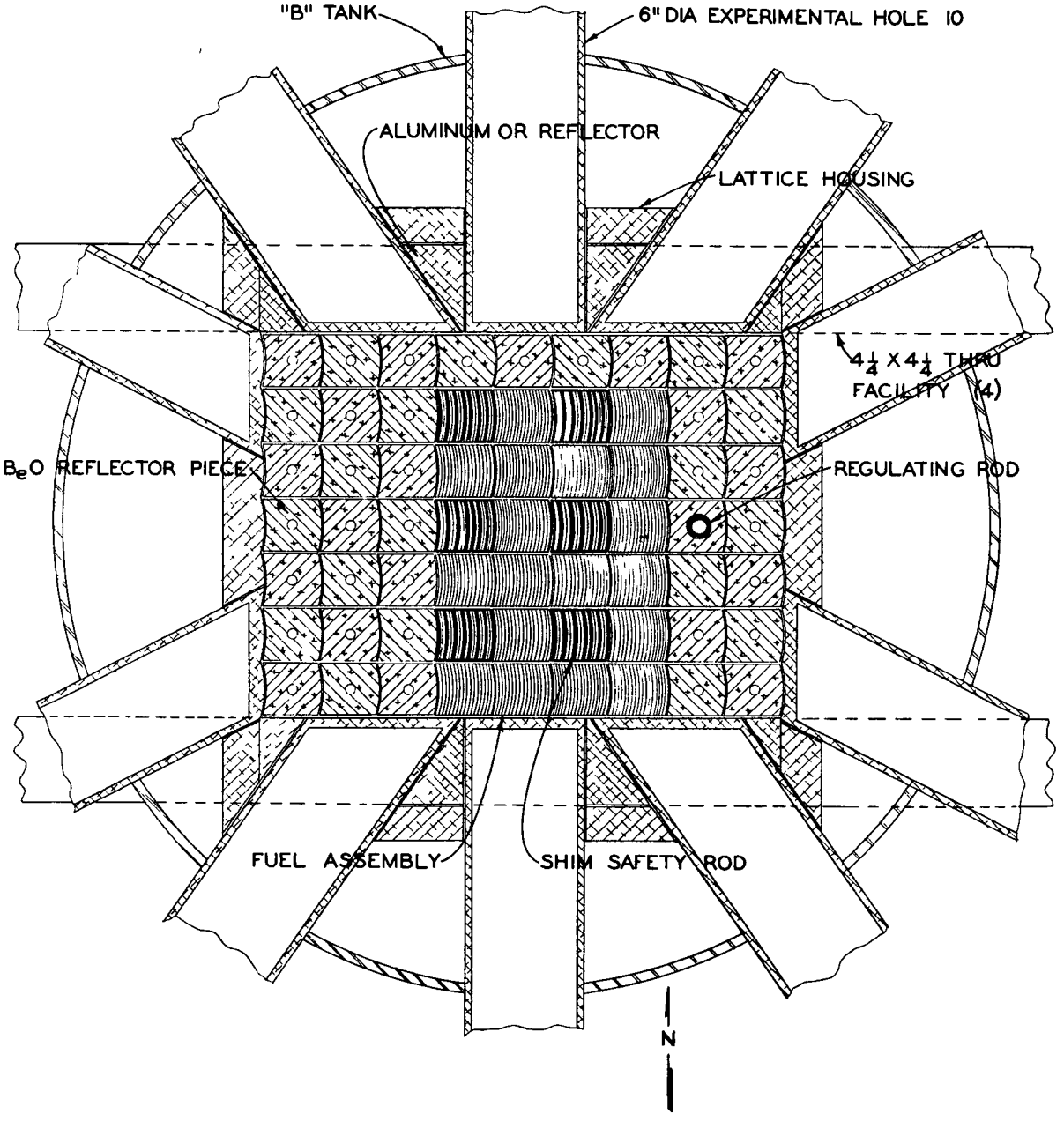


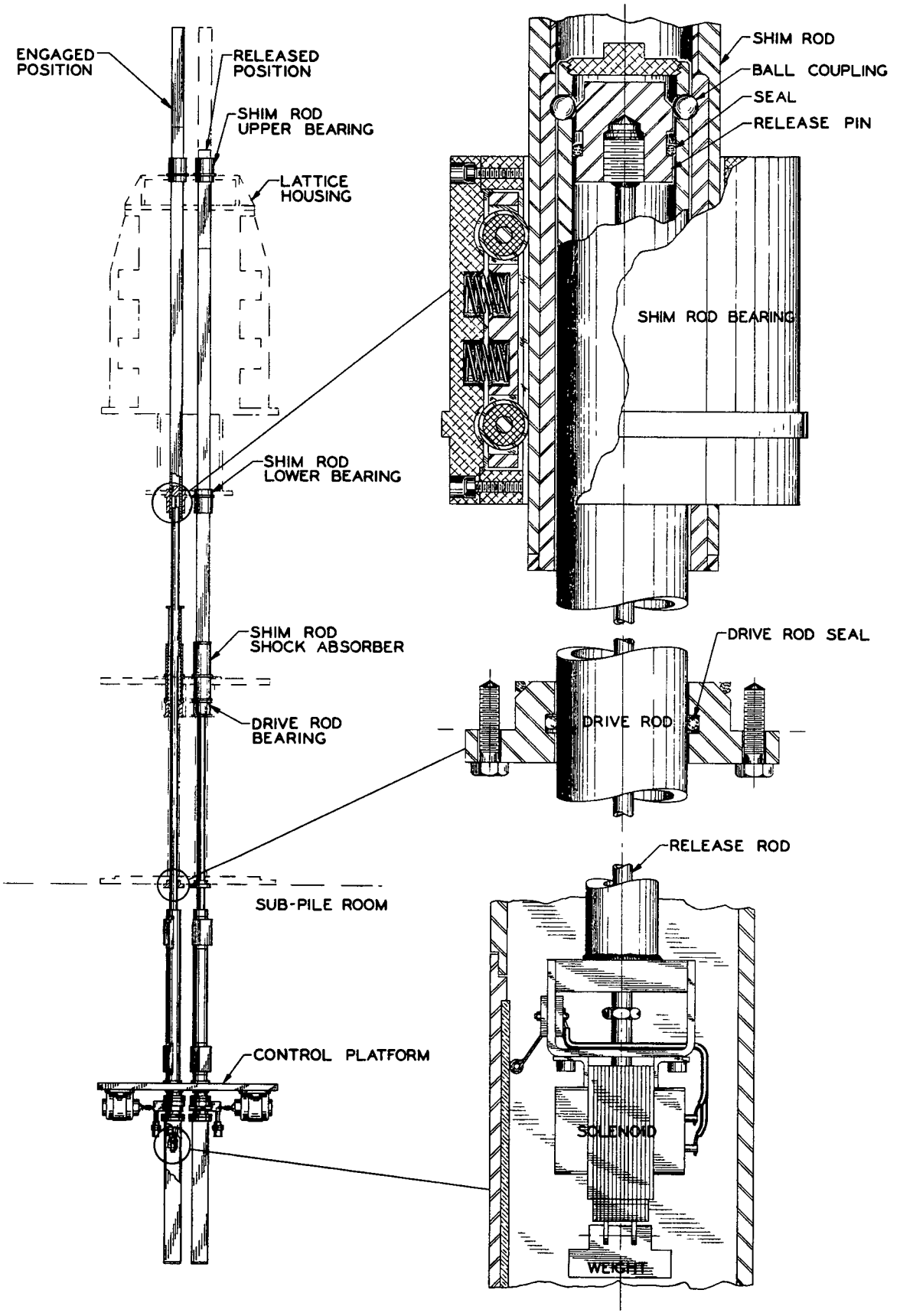
FIG 5
ORNL RESEARCH REACTOR
TYPICAL LOADING PATTERN

mechanisms for the shim-safety and regulating rods are located at the bottom of the reactor tank instead of at the top. This results in far greater accessibility of the lattice and makes it possible to have the top of the reactor clean and unobstructed by equipment as shown in Figure 2. The connections to the drive mechanisms for the safety rods are of a quick release, fall-safe type being developed at ORNL during the course of this reactor design and are illustrated in Figure 6. The safety rods, when released, are driven downward both by gravity and pressure drop to remove fuel and add cadmium to the core, destroying the criticality of the reactor. Shock absorbers located at the bottom of the reactor tank prevent damage to the rods when they are dropped. The drive members are operated through pressure seals and bearings in the bottom plug by means of the mechanical and electrical equipment in the sub-pile room as shown in Figure 7.

A one-inch thick aluminum housing surrounds the active lattice and tank section "B", provides support for the lattice housing and defines a path for the cooling water. The flow is next directed through openings in the support tank "C", and upward to the exit water line which is located immediately below the baffle plates connecting the "A" and "B" tank sections.

The use of an eight-foot diameter tank provides an additional three feet of water reflector, supplies an excellent neutron shield for the reactor and eliminates a number of expansion problems that would be encountered with the tank closer to the active section.

The electrical control system for the ORR will be essentially the same as that of the MTR. Changes brought about by the substitution of solenoid-operated safety rod release mechanisms for the magnets used in the MTR have little effect on the control circuits.



ORNL RESEARCH REACTOR
SHIM ROD RELEASE MECHANISM
FIG-6

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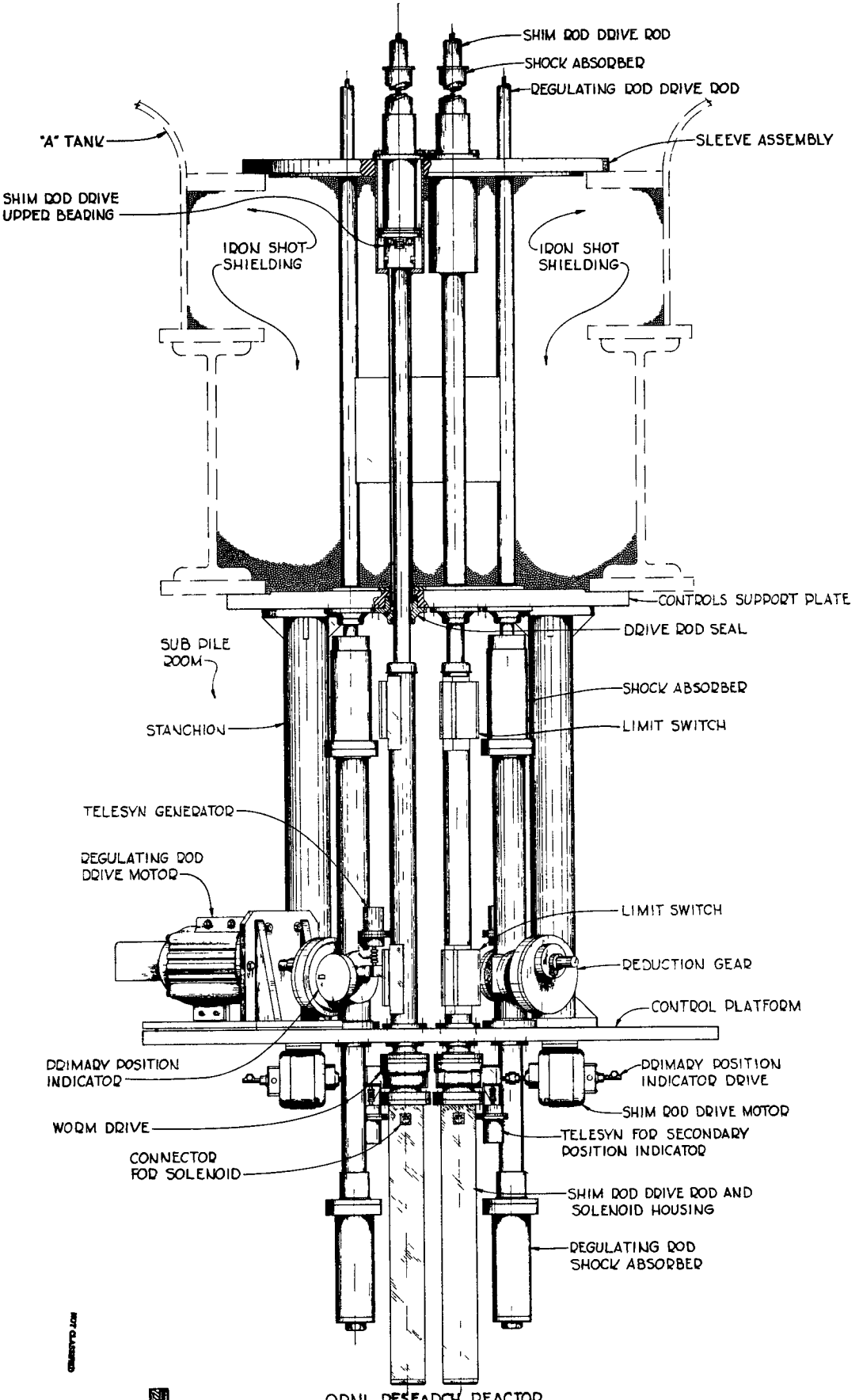


ORNL RESEARCH REACTOR
CONTROL DRIVES
FIG. 7

Provisions will be made for the installation of a retractable fission chamber on either the east or west face of the lattice, with the driving mechanism and associated electronic equipment located at the balcony level of the structure as shown in Figure 8.

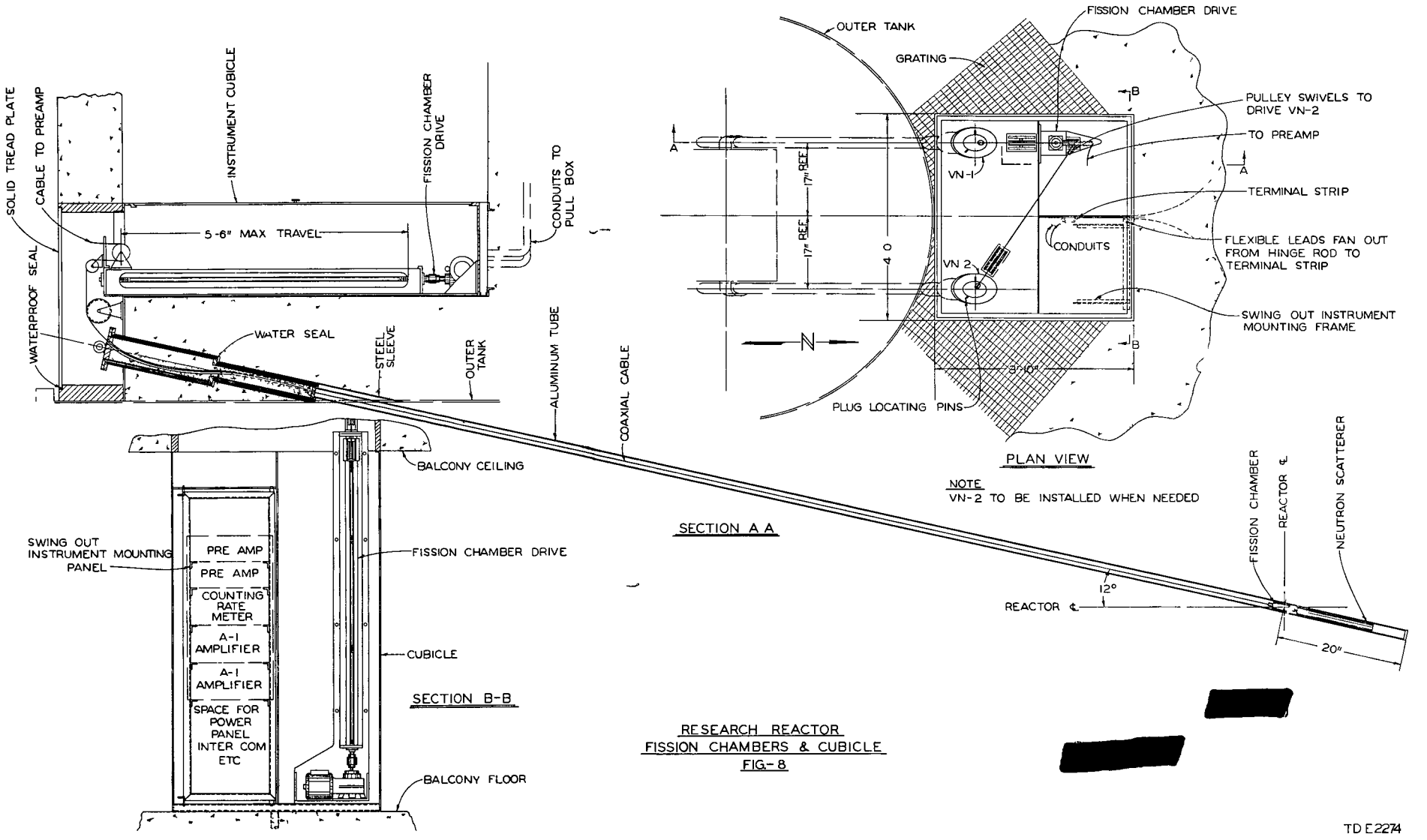
Penetrations of the reactor shield have been made at ten places for the installation of ionization chambers used in the reactor operation and control. Figure 4 shows a typical section through a chamber position, located above each of the radial experimental facilities. Chamber insertions will be made in the same manner as with the experimental plugs, since the liners are equipped with the same type of sliding-disc valves and take advantage of the same type of shielding.

In operation it is intended that four of these four inch diameter penetrations to the face of the lattice will be used as additional experimental facilities.

Reactor Structure and Biological Shield

Considered as part of the reactor structure, the eight-foot diameter tank, approximately thirty-one feet long will be fabricated, pressure tested and installed as a unit. Designed for a maximum internal pressure of 75 psi, the tank will be rigidly supported to serve as the inner form for the pouring of the concrete biological shield. Its design allows for twenty feet of water above the active section during operation of the reactor at the rated power level at essentially atmospheric pressure. Six feet of water below the active section provides neutron shielding for the sub-pile room and allows adequate working room for the control rods.

Two cover plates are provided for the reactor tank as shown in Figure 1. The smaller plate allows access to the active lattice and discharge chute



RESEARCH REACTOR
FISSION CHAMBERS & CUBICLE
FIG.-8

[redacted]

TD E2274

for normal refueling operations, while the larger cover plate will be removed only for major inspection and repair. The cover plates will be designed for low pressure operation (10 psi).

Figure 2 shows a vertical section thru the reactor and shielding. In general the biological shield will provide for a maximum radiation level of 0.1 tolerance (0.7 mr/hr) at 5 megawatt power level. Shielding along the horizontal centerline of the reactor consists of a minimum of three feet of water and seven feet of barytes concrete. Below the active section, six feet of water and a semi-permanent bottom plug filled with four feet of iron shot will provide sufficient shielding. The calculated radiation intensity at the top cover plate of the reactor amounts to 2 mr/hr at 5 megawatts. Additional shielding can be added to the top cover plate after initial operation should this prove to be a hazard.

A diagonal traverse from the reactor to a point five feet below the balcony level shows that a portion of the shield will be poured using ordinary aggregate. If the pre-pack method of pouring the concrete is used, it is believed that considerable savings can be made by substituting ordinary aggregate in place of barytes in those portions of the shield that would otherwise be over-designed.

To prevent an excessive temperature in the concrete immediately outside of the "A" tank, due to the high gamma flux in the vicinity of the centerline of the reactor, a stainless steel clad lead thermal shield surrounds the active section. Located on the outside of the "B" tank, the shield is cooled on each side by the upward flow of water to the exit water line.

Heavy steel plate on the outer face of the shield will be used in the vicinity of the experimental facilities to serve both as forms in the pouring

of the shield and as a supporting and aligning surface for the heavy plug shielding coffins. Above the experimental holes, relatively light plate will form the outer face of the shield.

Taking advantage of the reduced shielding requirements at the upper part of the structure, a balcony level was established with experimental access holes to the reactor. In addition, the balcony level provides space for the location of the fission chamber drive mechanisms and associated electronic equipment normally occupying valuable space at the upper level.

A major part of the upper level is covered with grating that can be removed for inserting experiments into the reactor through the sleeves in the upper part of the "A" tank. This recess provided with large drain lines serves a second purpose in confining accidental tank overflows and other contaminations.

Both levels will be supplied with the same experimental services as the other facilities.

Both the top level and balcony level are enclosed with handrails and are served by stairways to the control room. Service facilities and control conduits are beneath the bridge from the reactor to the control room.

Two six-inch diameter discharge chutes are provided for this reactor. One extends from the baffle plate of the "A" tank, penetrates the shield to a region outside of the sub-pile room, and by means of a valve operated on the south face of the reactor foundation, allows for the disposal of fuel assemblies, safety rods, etc., to the canal. The second chute, on the outside of the "A" tank, extends from the top of the reactor structure to the canal, and should prove valuable in the disposal of radioactive materials connected with experiments at that level.

4. Criticality and Neutron Flux Data

Since the ORR is essentially a low power version of the MTR or a high power version of the LITR, its nuclear characteristics are rather well known from experience with these reactors. Critical experiments in the LITR, the Bulk Shielding Facility and the MTR can be used to establish the minimum critical requirements of the ORR. Actual fuel loadings, fluxes and operating cycles may vary considerably with the demands placed upon the reactor by the experimental program; however, there is now a background of operating experience with both the MTR and the LITR which permits us to describe a typical loading, the resulting fluxes and an operating procedure.

The lattice, shown in Figure 9, consists of 12 spaces for control elements and 51 spaces for replaceable fuel or reflector pieces. In normal operation it is expected that fewer than 7 control elements will be in use so the remaining control spaces may be used as experimental facilities or may be filled with reflector pieces. Irradiation experiments can be performed in any of the fuel or reflector spaces.

It is planned that MTR-type fuel elements and shim rods will be used in the lattice. According to present MTR specifications, each fuel element contains 168 gm of U^{235} and each shim rod 133 gm. The ratio of aluminum to water in a fuel-shim rod loading in the proposed lattice would be 0.69; k_∞ for the cold clean loading would be 1.68; τ and L^2 are estimated to be 60.5 and 3.3 cm^2, respectively.

No firm decision has been made regarding the reflector pieces. They may be made either of beryllium metal or hot pressed beryllium oxide. Beryllium oxide is favored because of its low cost, if it can be made into reflector pieces having satisfactory properties. Hot pressed beryllium

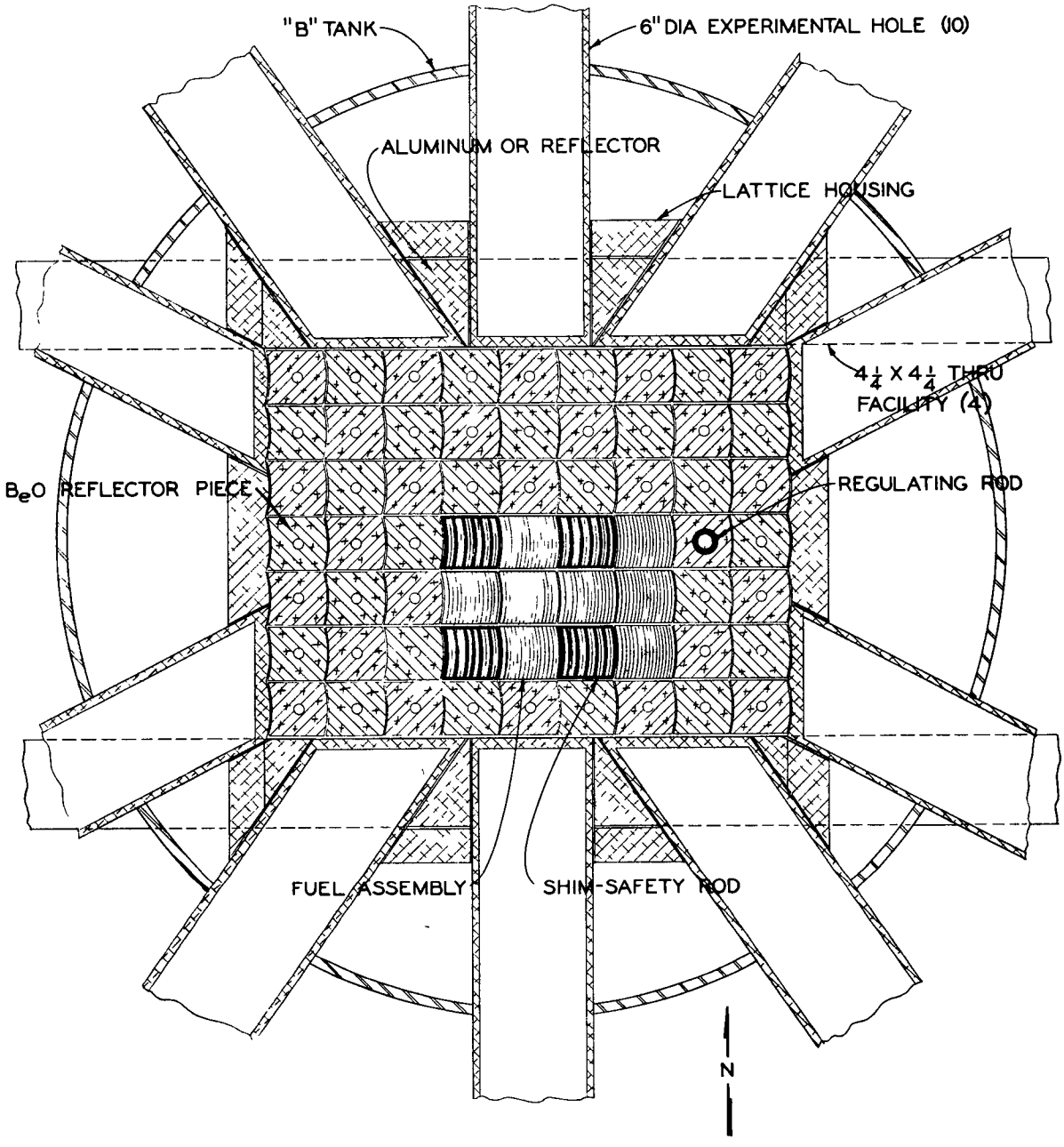


FIG 9
ORNL RESEARCH REACTOR
INITIAL LOADING PATTERN

oxide having a density greater than 2.9 has been made. The estimated reflector characteristics of that material are so nearly those of beryllium metal that no appreciable difference in critical mass and neutron flux calculations is found when one is substituted for the other. However, the effectiveness of the reflector decreases rapidly with decreased beryllium oxide density.

It is proposed that the initial loading be made near the center of the lattice with reflector pieces on all sides. An accurate prediction of the critical mass in this lattice arrangement depends upon accurate knowledge of the quality and properties of the reflector. The MTR went critical with approximately a 4 x 3 fuel element loading containing from 1650 to 1700 gm of U^{235}. Although the core was reflected by beryllium metal on all sides, the reflector on two of the sides contained large amounts of aluminum in the form of end plates on beam hole liners and cover plates on the through facility. In the LITR the critical mass was 1980 gm in a 5 x 3 element loading. The beryllium metal reflector on two sides was penetrated by aluminum beam hole liners. One or two of the beam holes were open or contained wooden plugs which reduced the effectiveness of the reflector. An experiment in the BSF with a beryllium oxide reflector having density of 2.3 and canned in aluminum resulted in a critical mass of 2400 gm in a 5 x 5 element loading. The beryllium oxide was 7.5 cm thick and backed by water.

Fuel elements used in all of those experiments contained only 140 gm of U^{235} per element. The aluminum to water ratio of an assembly of fuel elements and shim rods was 0.73; τ and L^2 are estimated as having been 62.6 and 3.7 cm^2, respectively. Estimated values of k_∞ range from 1.60 to 1.63, depending on the estimate of the quantity of lithium present in brazing

flux inclusions in the fuel elements.

Lithium has been essentially eliminated in the newer MTR type elements proposed for use in the ORR. The reduced aluminum to water ratio and greater fuel concentration favor a smaller loading than would be required with the 140 gm elements. If the reflector is as effective as beryllium metal containing two percent water by volume, it is calculated that the critical mass of the completely reflected ORR core will be less than the 1380 gm present in a 3 x 3 loading containing 5 fuel elements and 4 shim rod fuel sections. The 4 x 3 loading containing 1880 gm of fuel and shown in figure 9 would be required to achieve criticality only if the beryllium oxide reflector were considerably less effective than beryllium metal.

The following proposed operating schedule is derived from the experience with the LITR:

After the critical experiment, the fuel loading would be enlarged as rapidly as required by the experimental program to provide the necessary neutron flux at the experimental facilities. A proposed operating core arrangement is the 6 x 4 element loading shown in Figure 5. The reactivity of this loading would be maintained by replacing one or two spent fuel elements with new pieces during the normal weekly or bi-weekly shut-downs. Thus, between 20 and 25 percent of the fuel would be burned out of each assembly before replacement. The average replacement rate is expected to be one fuel piece per week, so the core would normally contain about 3300 gm of U^{235}. Pertinent flux data for the reactor under these conditions are presented in Table I.

Table I - Neutron Flux Data for ORR

Operating power, kw	5000
U^{235} in core, gm	3300
Avg. thermal flux, n/cm^2-sec	3.6×10^{13}
Max. thermal flux in core, n/cm^2-sec	6.5×10^{13}
Max. thermal flux in reflector, n/cm^2-sec	8×10^{13}
Max. fast flux* in core, n/cm^2-sec	2×10^{13}
Max. fast flux at surface of core, n/cm^2-sec	1.5×10^{13}
Thermal flux at face of beam holes terminating at surface of core, n/cm^2-sec	3×10^{13}
Fast flux at face of beam holes terminating at surface of core, n/cm^2-sec	1.5×10^{13}
Thermal flux at face of beam hole separated from core by one reflector piece, n/cm^2-sec	3×10^{13}
Fast flux at face of beam hole separated from core by one reflector piece, n/cm^2-sec	3×10^{12}

* Refers to neutrons greater than 1 Mev.

The maximum amount of excess reactivity which could be present at one time with the loading shown is 20 percent in $\Delta k/k$. This would require a cold clean core with a complete reflector. Although the control rods provided will control more than 20 percent in $\Delta k/k$, the actual excess reactivity will always be well below this amount. By changing the core size as required for the experiments and by replacing a small part of the loading at frequent intervals, the excess reactivity would be limited to that required to compensate for xenon poison, one or two weeks burn-up and the increase in temperature during operation plus a small operating margin.

In the ORR xenon poisoning will amount to 3.5 percent in $\Delta k/k$. The temperature coefficient will be -0.013 percent per degree Centigrade, so 0.5 percent will be required to permit operation at temperature near 140°F. Two weeks burn-up is equivalent to 0.9 percent. Allowing 1.1 percent as the operating margin, the excess reactivity will be only 6 percent $\Delta k/k$. The amount of reactivity taken by the experiments when the core is operating with 12-1/2 percent burn-up would be approximately 10 percent.

The foregoing operating procedure is that currently in use on the LITR. It has the advantage of maximum safety of operation. Variations in flux at the experimental facilities during the operating cycle are minimized since only a small amount of burn-up is controlled by the shim rods. The procedure is practical as long as the power is low and only a small fraction of the fuel is burned each week. Although incorporating boron in the fuel elements as a burn-out poison would accomplish the same result, use of boron is not suggested for the ORR until it becomes a standard component of MTR type elements.

5. Reactor Building and Related Facilities

Inasmuch as there is no existing building available in Oak Ridge area to house the ORR, it is proposed that a building be constructed at ORNL at the site of the present building, No. 3022, which is considered a temporary structure and is scheduled to be removed. See Plot Plan, Figure 10. Situated near the Graphite Reactor, whose operating staff will also operate the Research Reactor, the facility would adjoin the recently proposed Physics of Solids Annex. The site requires a minimum of excavation for construction and provides the necessary bed-rock conditions at the proper elevation for the reactor foundation and canals.

Existing plant utilities at this site, such as demineralized and filtered water supplies, process drains, tank farm, and proximity of a retention basin, contaminated gas stack, and other services, all contribute to the desirability of this location.

The structure, shown in Figures 11 and 12, would be a mill type building approximately 73' x 84' x 70', with a low section 28' x 84' x 20'. A basement would extend under the entire structure. The framing would be structural steel with either corrugated, asbestos-insulated interior panels, or insulated metal siding, depending upon availability. The floors, foundation, reactor base, basement walls and canal walls would be reinforced concrete.

The basement area, Figure 13, provides for the pile foundation, a sub-pile room (which is located beneath the reactor and houses the reactor controls and safety drive mechanisms), a fuel assembly monitoring room, and a series of transfer and storage canals. The basement ceiling height is

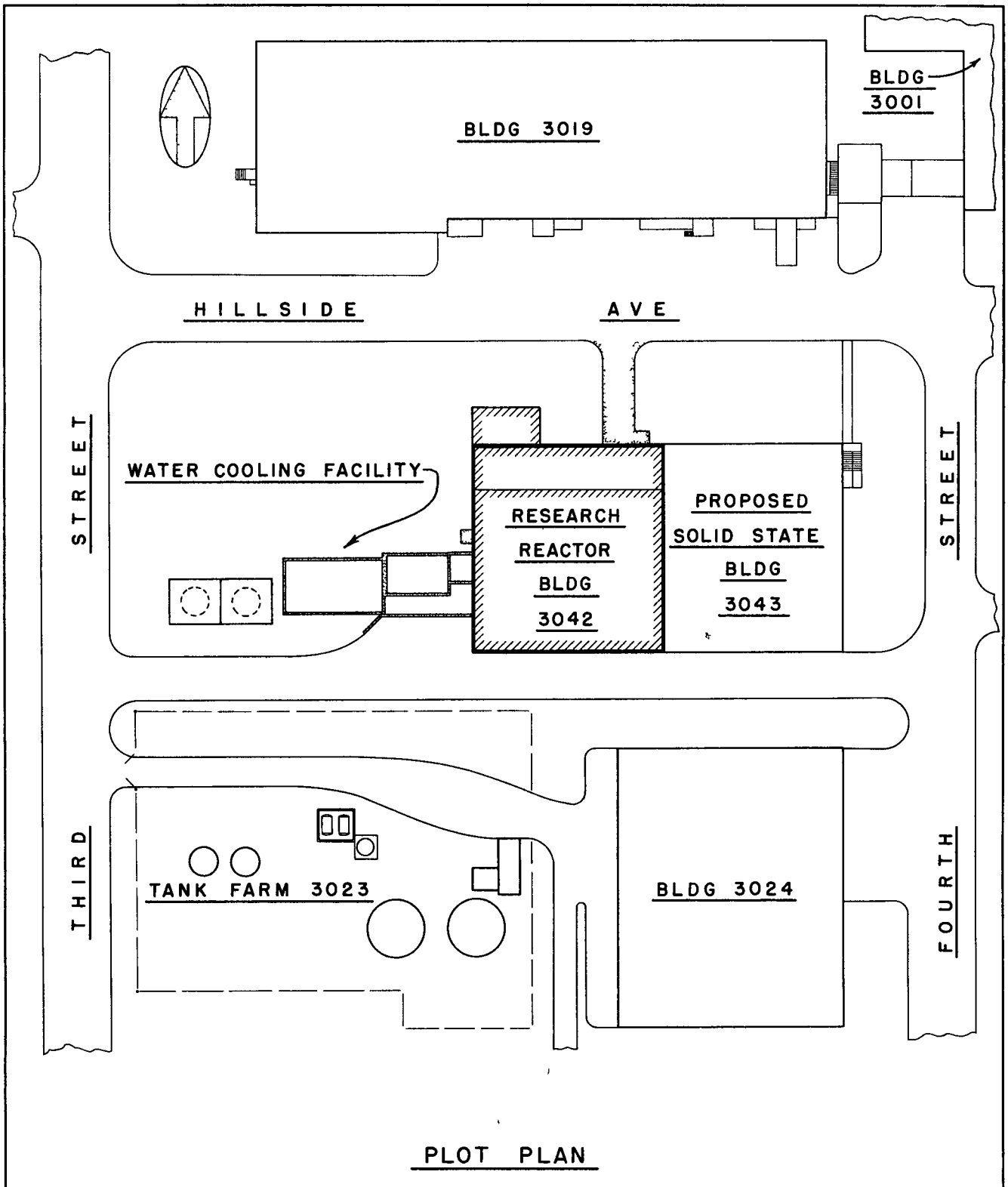


FIG. 10

PLOT PLAN

RESEARCH REACTOR BUILDING 3042

OAK RIDGE NATIONAL LABORATORY

DRAWING A

0 25 50 75 100 150

SCALE IN FEET

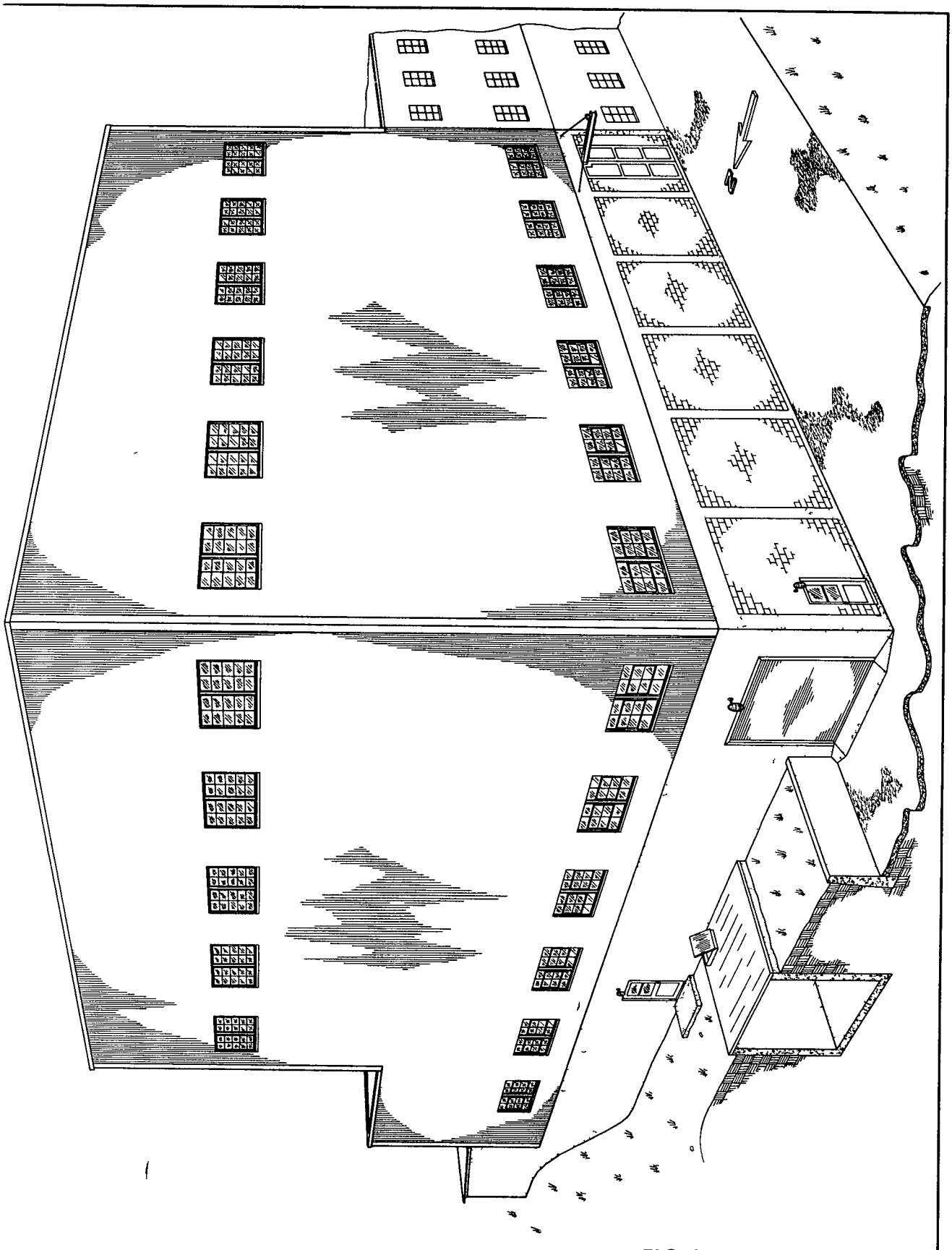


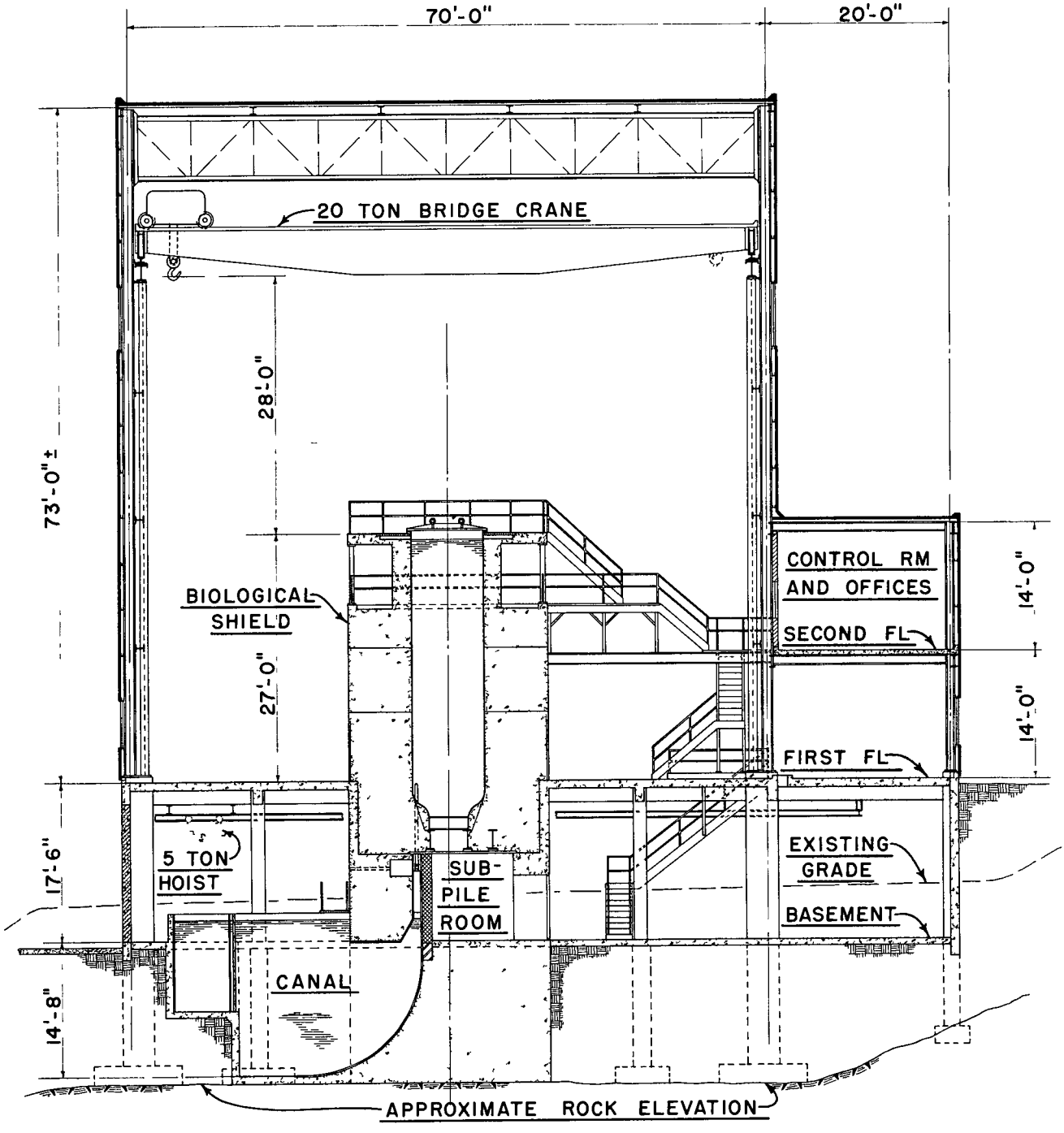
FIG. 11

PERSPECTIVE VIEW

RESEARCH REACTOR BUILDING 3042

OAK RIDGE NATIONAL LABORATORY

DRAWING B



CROSS SECTION "A-A"

FIG. 12

CROSS SECTION "A-A"

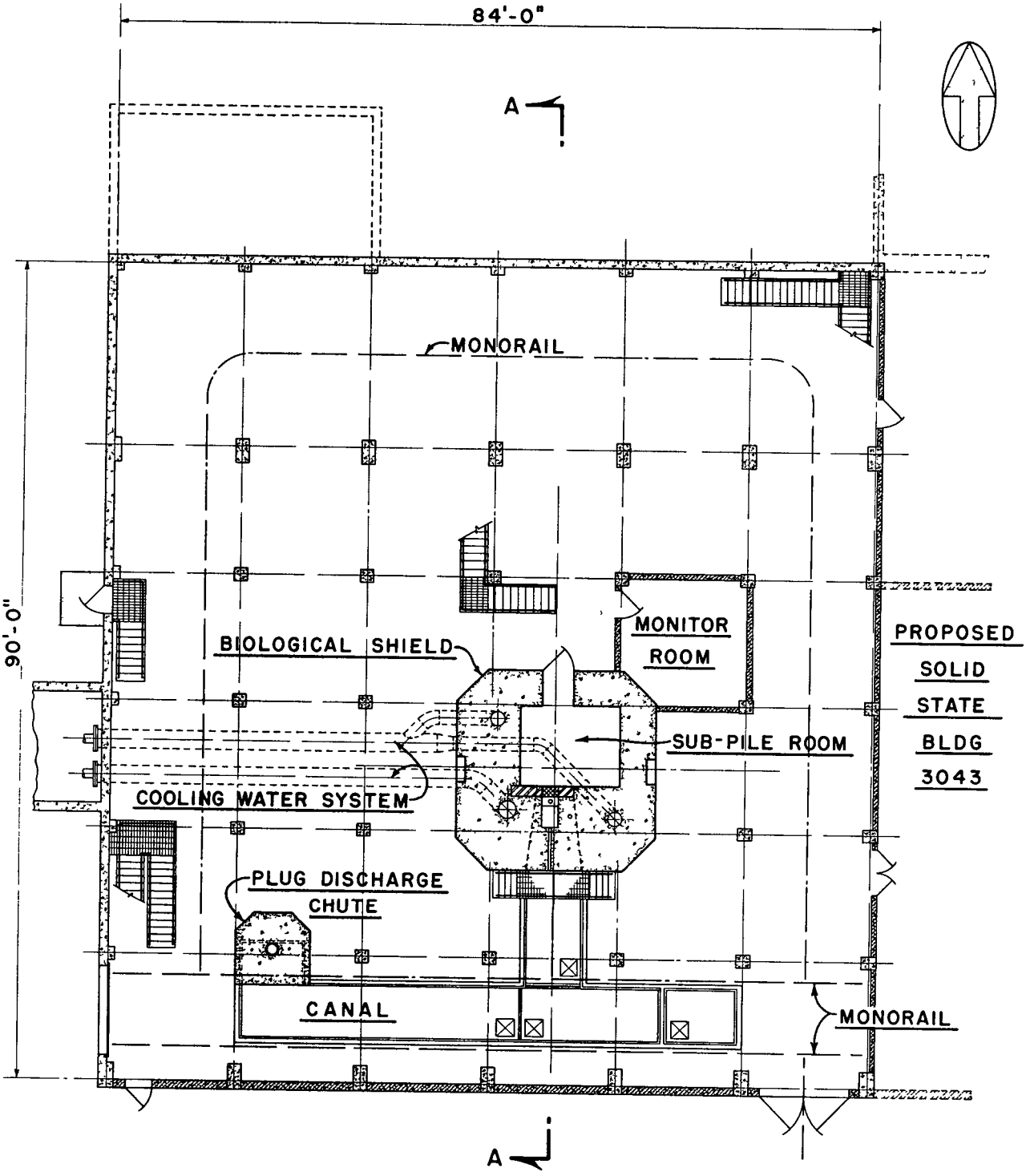
RESEARCH REACTOR BUILDING 3042

OAK RIDGE NATIONAL LABORATORY

DRAWING G

0 5 10 20 30 40

SCALE IN FEET



BASEMENT PLAN

0 5 10 20 30 40

SCALE IN FEET

FIG. 13

BASEMENT PLAN

RESEARCH REACTOR BUILDING 3042

OAK RIDGE NATIONAL LABORATORY

DRAWING C

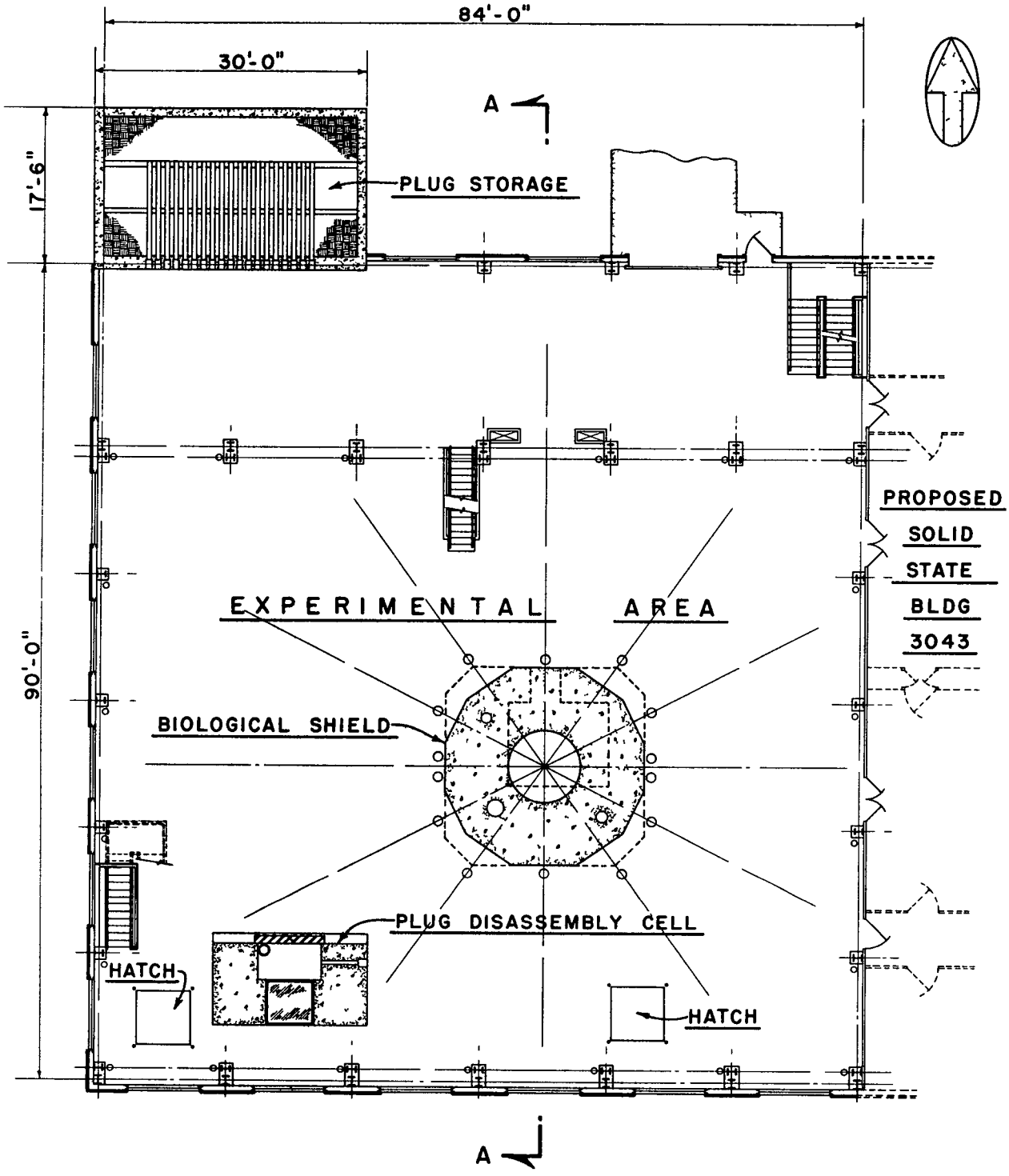
approximately seventeen feet and the entire area is serviced by a five ton monorail system.

Figure 14 shows the arrangement of the first floor area. This constitutes the main experimental area and houses the reactor structure and plug disassembly cell. Access to the plug storage cell is made on the north end of this room. The high portion of the experimental floor area is serviced by a twenty ton bridge crane with a 55-foot vertical hook travel. Removable hatches over two sections of the floor allow for crane service to the canals and basement areas.

The second floor area, Figure 15, consists principally of the low section of the building, providing space for control room, equipment room, and offices. A combination bridge and service channel is to provide access from the second floor to the top level of the reactor.

Hot Cells, and other laboratory facilities, along with toilet and locker rooms for the use of personnel located in this building are to be provided in the new Solid States Building, No. 3043.

The Reactor Cooling System would occupy an area approximately fifty feet by one hundred forty-five feet west of the reactor building, as shown in Figure 10. Essentially, this system consists of the 12,000 gallon reactor tank, a 16,000 gallon decay tank, circulating pumps and dry-air-cooled heat exchangers, arranged as shown in Figure 16. Demineralized water leaving the reactor tank passes to a shielded hold-up tank which allows for a sufficient time delay in the effluent circulating water for the decay of short half life radioactive particles formed in the reactor. A gas purging unit, consisting of a cyclone separator at the exit of this tank, continually purges the gas formed in the reactor. These contaminated gases along with gases collected



FIRST FLOOR PLAN

0 5 10 20 30 40

SCALE IN FEET

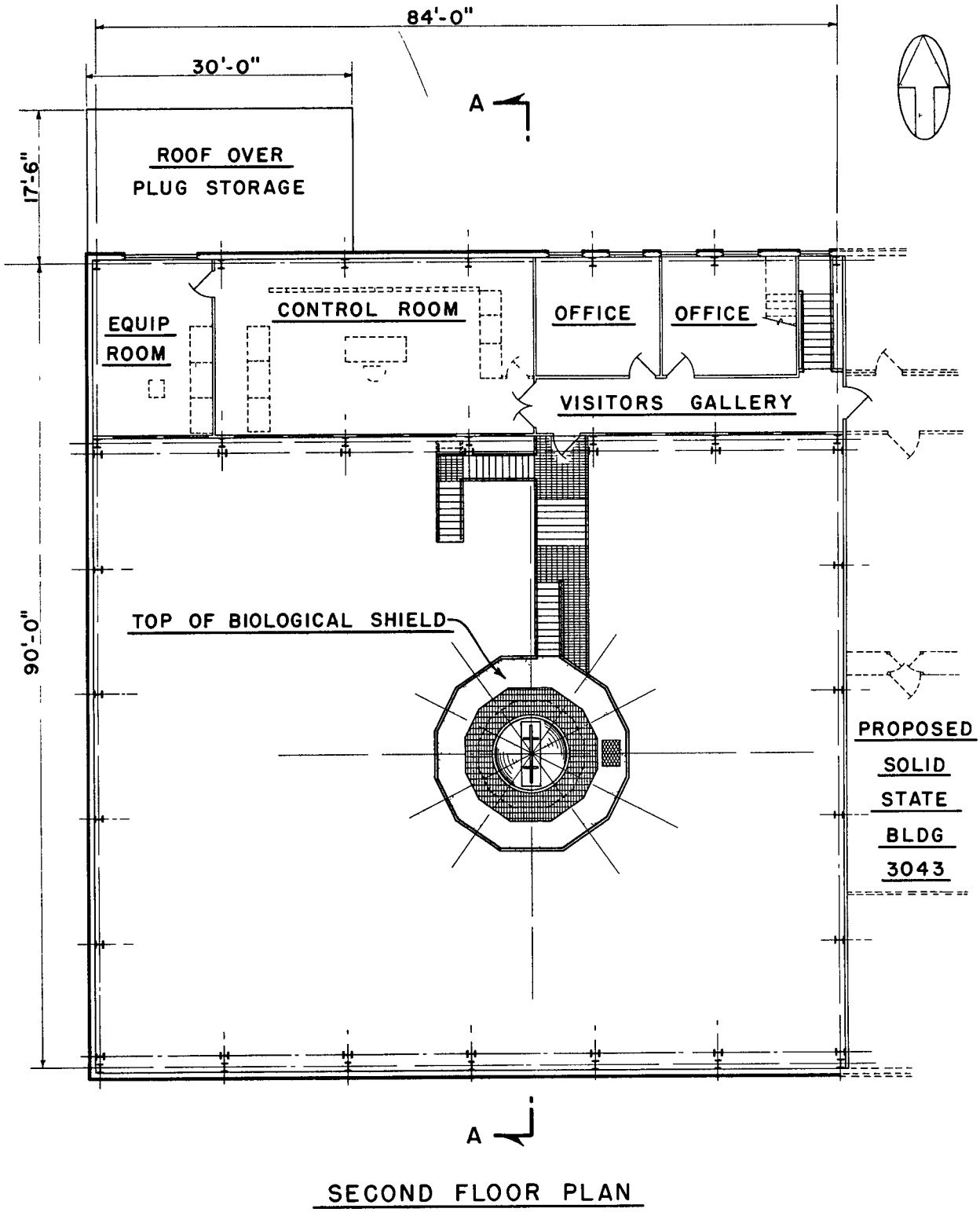
FIG. 14

FIRST FLOOR PLAN

RESEARCH REACTOR BUILDING 3042

OAK RIDGE NATIONAL LABORATORY

DRAWING D



SECOND FLOOR PLAN

0 5 10 20 30 40

SCALE IN FEET

FIG. 15

SECOND FLOOR PLAN

RESEARCH REACTOR BUILDING 3042

OAK RIDGE NATIONAL LABORATORY

DRAWING E

DWG. NO. SK-90 [redacted]

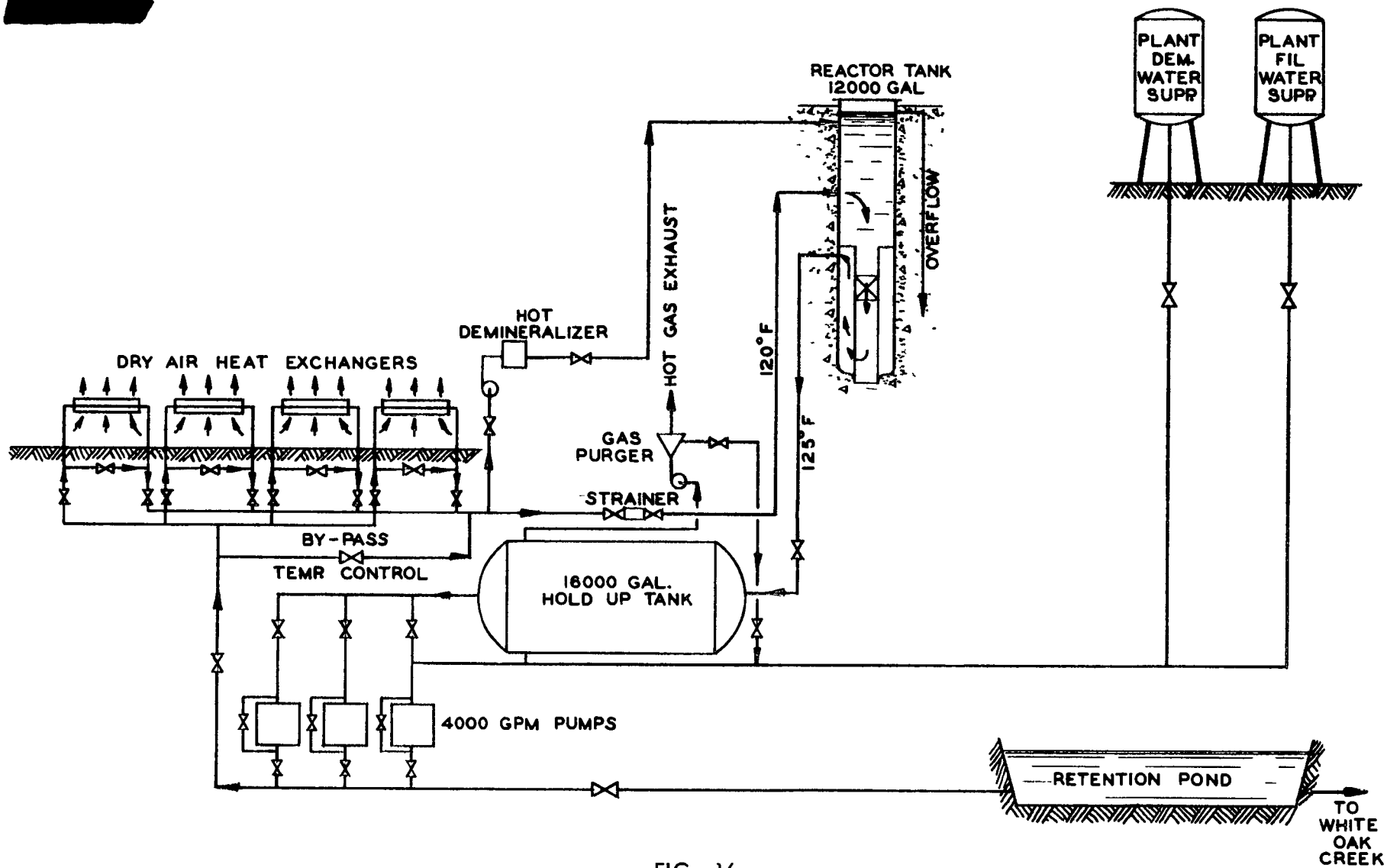


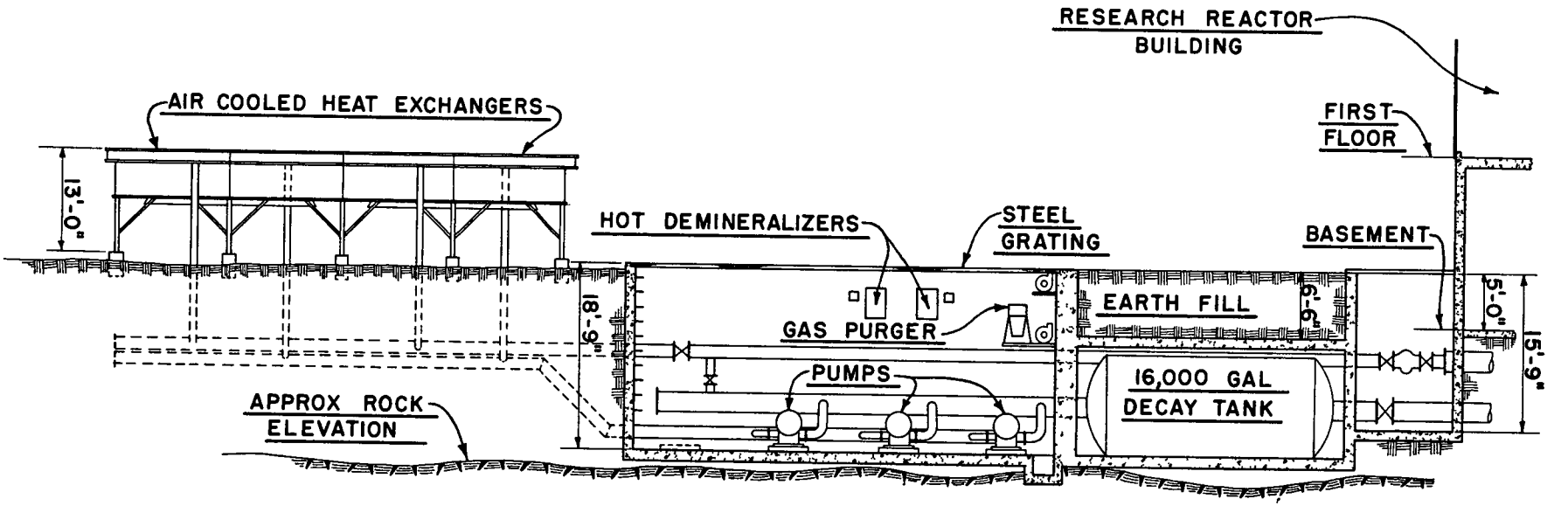
FIG.-16
RESEARCH REACTOR
FLOW DIAGRAM-PROCESS WATER SYSTEM

at the top of the reactor tank are then exhausted to the plant stack. From the decay tank, the relatively low activity water is pumped to a series of fin type air cooled heat exchangers, and recirculated through the reactor. The quality of the water is maintained by a resin bed demineralizer.

The system has a capacity of approximately 35,000 gallons, and with a circulating rate of 8,000 gallons per minute, allows for a 5° F temperature rise, with an overall exit water temperature not exceeding 125°F.

Figures 17 and 18 show a possible arrangement of the cooling equipment.

The Low Intensity Training Reactor at ORNL is being equipped with this type cooling system and demineralizer unit. Their operating experience will prove valuable in the final design of process water system for the Research Reactor.



SECTIONAL ELEVATION

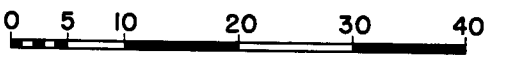


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FIG. 17

WATER COOLING SYSTEM

RESEARCH REACTOR BUILDING 3042

OAK RIDGE NATIONAL LABORATORY

DRAWING J

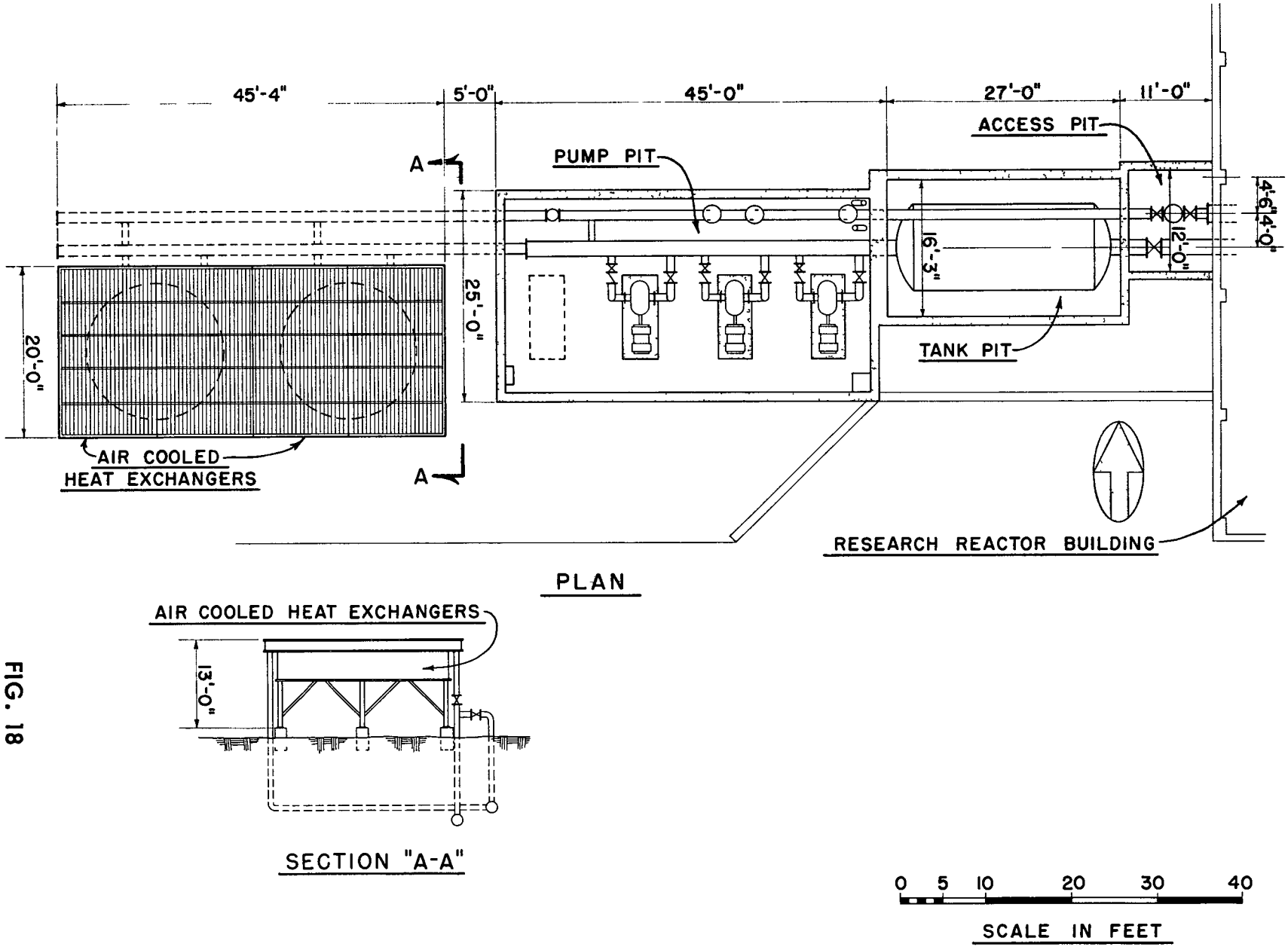

FIG. 18

WATER COOLING SYSTEM

RESEARCH REACTOR BUILDING 3042

OAK RIDGE NATIONAL LABORATORY

DRAWING H

6. Summary of Construction Estimates

Early in the investigations of the proposal for the construction of a research reactor at the Oak Ridge National Laboratory it became evident that the site should be convenient to a number of existing plant and laboratory facilities in order to keep construction and operating costs to a minimum. The site selected meets this requirement and has the following additional advantages: it requires a minimum of excavation; it has the proper bed-rock conditions for the reactor and building foundations; it can take advantage of an existing demineralized and filtered water supply, contaminated gas stack, tank farm and retention basin; the site is convenient to the hot cell and physics laboratories in addition to the present reactor operating staff.

The following table presents a summary of the detailed construction estimates as prepared by the ORNL Engineering Department, and is reliable only if the ORR is located at the above mentioned site.

TABLE II

SUMMARY OF ORNL RESEARCH REACTOR ESTIMATES

A. Reactor Building		
1) Design	$ 83,000	
2) Construction	439,000	
3) Overhead	110,800	
4) Contingencies	52,200	
Total Cost	685,000	685,000
B. Reactor		
1) Design	175,000	
2) Structure and Shield	405,000	
3) Reactor Components	385,000	
4) Controls	225,000	
5) Overhead	210,000	
6) Contingencies	125,000	
Total Cost	1,525,000	1,525,000
C. Process Water System		
1) Design	60,000	
2) Equipment and Controls	320,000	
3) Overhead	80,000	
4) Contingencies	35,000	
Total Cost	495,000	495,000
D. Contaminated Gas System		
1) Design	10,000	
2) Equipment and Controls	60,000	
3) Overhead	17,000	
4) Contingencies	8,000	
Total Cost	95,000	95,000
E. Total Project Cost	[redacted]	$ 2,800,000

[redacted]

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ORNL RESEARCH REACTOR PROJECT

7. List of Reference Reports

1. "Proposal for a Research and Isotope Reactor at ORNL." ORNL-809, August 15, 1950.
2. "ORNL Research Reactor Design Data." ORNL-51-8-216, August 30, 1951.
3. "Calculations for the Cooling Water Activity of the Research Reactor." ORNL 52-4-39, April 8, 1952.
4. "Shielding Requirements and Heat Generation in the Research Reactor." ORNL 52-4-157, April 28, 1952.
5. "Gamma Ray Distribution through Water in the Research Reactor and Bulk Shielding Facility." ORNL-52-3-134, March 14, 1952.
6. "ORNL Research Reactor Design Studies." (in process of being published)
7. "Materials Testing Reactor Project Handbook." ORNL-963, May 7, 1951.
8. "The MTR Safety System and its Components." ORNL-1139, April 4, 1952.

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