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PROPOSAL FOR A RESEARCH AND ISOTOPE REACTOR AT ORNL

Edited By

A. H. Snell
A. M. Weinberg

Date Issued

AUG 17 1950

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PROPOSAL FOR A RESEARCH AND ISOTOPE REACTOR AT ORNL

The research and production program of Oak Ridge National Laboratory depends primarily upon the intense neutron fluxes available in the X-10 chain reactor. Since the original X-10 graphite reactor was built, those activities of ORNL which require neutrons have increased tremendously. These activities lie in the fields of isotope production, basic and applied physics, chemistry and biology, and reactor development. It is not surprising, therefore, that the Laboratory finds the present graphite reactor inadequate. In order to remedy this inadequacy, the Oak Ridge National Laboratory proposes that a general purpose Research and Isotope Reactor (RIR) be built at the X-10 site.

The RIR reactor would be a simplified version of the Arco MTR. It would require 3 Kg of U^{235}, would run at 3 megawatts, and would have a maximum slow neutron flux of between 2 and 4 x 10^{13} neutrons/cm^2/sec. Because of its lower power output, the auxiliary facilities of the RIR would be much less expensive than those of the MTR; the whole cost of the RIR project is estimated at less than $3,000,000.

Basic justification for an RIR in Oak Ridge at a time when the MTR is being built at Arco rests on the following grounds:

1.) The X-10 reactor is now being used to capacity both for isotopes and for research. If the research and production program at ORNL is to grow normally, an additional research reactor at Oak Ridge is a necessity.

2.) The location of the MTR at Arco, while offering the advantage of higher flux, makes the MTR difficult and inflexible to use. This disadvantage

[redacted]

of the Arco location was recognized at the time the decision to build there was made. Thus the existence of very high flux at Arco, while extremely important, does not satisfy the need for moderately high flux right at the National Laboratories.

3.) The Arco MTR is a reactor for use in reactor development. There are many non reactor development researches at ORNL for which a more general facility not tied to reactor development would be very useful.

4.) The RIR represents an additional, cheap isotope facility which in an emergency could be put to use for military isotope production. In view of the current military situation it is likely that the country will find several separate reactors, each capable of producing significant amounts of Pc extremely worth while.

5.) The radioisotope program, which is one of the most successful enterprises in the Commission, cannot continue to meet growing demands unless more neutrons are devoted to it. Some of these neutrons can be found at other places; it is believed fundamentally sound, however, from the standpoint of operating economy, to maintain centralization of radioisotope production at Oak Ridge.

The following proposal for an RIR at Oak Ridge consists of four parts. Part I is a summary of the research utilization of the X-10 reactor, and a description of research projects which would be made possible by existence of an RIR. Part II is a summary of the radioisotope program at ORNL, and the increase in production which an RIR would make possible. Part III is a brief engineering description of the RIR, and Part IV is a cost estimate of the RIR project.

I. The Research Need for New Reactor Facilities at Oak Ridge National Laboratory

1. Present use of experimental facilities provided by Uranium-Graphite Reactor

The existing ORNL reactor was designed primarily for purposes other than experimentation with neutrons. Consequently, access to the neutron flux is in many cases very inconvenient. In spite of these limitations, the available pile facilities are being actively used to their maximum capacity. In many cases considerable expense and effort have gone into bringing into active use port holes which were considered in the past to be unsuitable for experimental purposes, by making construction alterations such as balcony extensions and shifting obstructing structural beams to less objectional locations. Experimental equipment has in general, been designed so that neighboring projects could proceed simultaneously in close quarters.

The reactor holes are currently being used as follows:

Use	No. of Holes
Pile Control	23
Isotope Production	15
Fundamental and Applied Physics and Chemistry	13
Biology	3
Solid State Studies	10
Pile Physics	2
Training Program	1
Shielding Studies	1
Miscellaneous	1
	69

To list the hole uses more specifically would require three pages of typescript; therefore, we content ourselves with the above summary, together with the assertion that all available holes are in active use.

2. Present Demand for Additional Pile Facilities; Waiting List of Experiments

At the present time there is a great general need for additional pile facilities. It is the opinion of the laboratory that if more holes were available they would very quickly be used for new and useful projects. In fact, there are on hand now the following specific requests for space, which cannot be satisfied at this time.

	Number of Holes	Proposed Use
	2	Homogeneous Pile Studies by Chemistry Division
	4	Radiation Damage
	1	Study of Possible Pile Coolants
	2	Neutron Diffraction
	1	Mechanical Velocity Selector
	2	School of Reactor Technology
	1	Crystal Velocity Selector
Total	13	

The possibility that some experiments could use common holes has always been borne in mind, and to some extent duplication of this kind has been useful; for example, the hole occupied by the fast pneumatic tube is serving also for activation experiments in the laboratory course of the

School of Reactor Technology. Arrangements of this kind are awkward at best, and for the most part have been found to be essentially impossible. Other examples of experiments in which it would be extremely inconvenient to use portable equipment are as follows:

(1) Long-term corrosion studies involving pipes through the pile, with exterior plumbing.

(2) Experiments in which the apparatus can be removed only with an attendant radiation hazard, special handling equipment, and a long pile shutdown. Examples are the "doughnut holes" used in radiation damage work, the uranium parts of which are extremely radioactive.

(3) Experiments which involve extreme accuracy in lining up of heavy equipment in relation to narrow neutron beams. The neutron diffraction equipment is a leading example.

This list might be extended to cover the separate experiments in detail, but these citations may suffice to illustrate the fact that almost none of the experiments are interchangeable on a week-to-week, or even a month-to-month basis.

We are left with the conclusion that the space in the old uranium-graphite reactor is no longer adequate for the current experimental demands.

(3) <u>The Role of the New Reactor; Need for Higher Fast and Thermal Flux</u>

The new reactor proposed herein would do far more than alleviate the shortage of experimental reactor facilities at ORNL. Designed from the beginning as an experimental, as well as isotope producing reactor, it would provide features such as the following, which are at present badly

missed:

(1) Higher thermal flux

(2) Much higher fast flux

(3) Vertical experimental holes

(4) Experimental holes larger than 4" x 4"

(5) More intense neutron beams, as a result of both the higher flux and the shorter distance from outside of shield to reactor core.

The new possibilities which would be presented would recast the whole picture of ORNL, NEPA, ANP, and ANL experimentation now in progress in the Oak Ridge community. The following changes exemplify the strengthening of the research program which would result:

1 Radiation Damage Program: Nearly all of this would move from the old reactor to the new reactor, because of the higher fast flux. Specific experiments would be the following:

(1) "Reciprocity Law" studies: In radiation damage studies thus far the effects of fast neutrons have been considered as a function of n.v.t. One has, however, always been aware of the fact that many effects actually are proportional to the flux n.v. rather than the dosage n.v.t. This applies equally well to effects which reach saturation as to the influence on rate processes such as creep, diffusion, corrosion, chemical reaction. A high-flux reactor will not only give the important convenience of reaching a certain dosage in a shorter time, but it will extend the range of flux available for meaningful experimentation into a region where effects are at present unknown. These regions have

special significance both for the design of power reactors and for a fundamental understanding of the elementary processes of radiation damage.

(2) Creep in structural materials, metals and non-metals: Present facilities including those at Hanford and Chalk River, offer fast neutron fluxes far below those of future power reactors. This fact requires at present large extrapolation from experimental data and extreme accuracy of measurements and control of temperature, load, flux, etc., very difficult to achieve in the special circumstances obtaining inside narrow test or process tubes. A high-flux reactor with larger test holes will be ideally suited for this most important type of experiment. Its availability right at the site where several groups (ANP, NEPA, ANL-Naval Reactor) are actively engaged in the study of creep under irradiation would very greatly expedite progress.

Because of large variations in the behavior of different samples of the same material, it has been proposed to study creep by measuring the creep rate of one individual specimen alternately outside and inside the reactor. Such a method will be much easier to apply in a reactor devoted predominantly or exclusively to research rather than to production, and at a location where an especially equipped "hot" laboratory is available such as will be at ORNL after January 1. (3 holes required)

(3) Thermal and electrical conductivity changes in materials in which such changes at presently available fluxes are comparatively slight (beryllium metal, oxide and others) will become much more accurately measurable, within reasonable time, in a high flux, and again the effect of

the magnitude of the flux itself will become measurable. (1 hole for Argonne group, 1 hole for Metallurgy Division, 1 hole for NEPA)

(4) Measurements of the energy stored on fast neutron and fission products bombardment, particularly in metals, will be greatly facilitated, if not actually made possible for the first time, by the availability of a high flux. (1 hole, probably containing pneumatic tube at low temperature)

(5) The effect of radiation on diffusion rates, the study of which is being initiated, and on corrosion resistance could be measured in much shorter time with a higher flux. (1 hole required)

(6) Extreme conditions of radiation damage could be investigated both at very low and very high temperatures. The "healing" during, and as a direct effect of, irradiations should be studied as a function of flux as well as of temperature in a much wider range than is possible now. For such studies, the Solid State Physics and Metallurgy groups (including those at NEPA) could permanently use to great advantage at least one, and probably two large test holes maintained continuously at low, subnormal temperature, e.g. of liquid nitrogen. At present, even water-cooled holes have been available to these groups only for small fractions of the time. For instance, during the last two months, vertical hole #12, the only one suitable, was available for studies at dry ice temperature only for one hour every two weeks. All of the groups studying various phases of radiation damage at controlled temperatures would be greatly assisted in their work if more irradiation

facilities were made available at Oak Ridge. (2 holes at low temperature, 1 hole at high temperature)

(7) The study of single metal crystals, fundamental to an understanding of elementary processes in irradiation, requires very careful handling of specimens, and would actually become possible in high-flux reactor attached to a research laboratory. Internal friction measurements on single crystals, both during and after irradiation, already started here, should be extended into the region of larger fluxes. (1 hole required)

(8) Neutron diffraction as a tool to study radiation effects in solids will be useful only with higher flux than available. The possibility of determining the location of the lighter atoms in mixtures, alloys or compounds containing also heavier atoms, the ability of neutrons to penetrate large thicknesses of material, and the easier selection of neutrons from background radiation when very active specimens are under examination, are factors of considerable importance in weighing the advantages of high-flux neutron diffraction against x-ray diffraction in radiation damage studies. (1 hole required)

II <u>Reactor Development</u>

1. The problem of bubbling, solution stability and corrosion in a homogeneous reactor. This is still one of the most important problems in reactor technology, since from the standpoint of economics, homogeneous power breeders which have low reprocessing costs still appear to be very attractive. (1 vertical hole required)

2. Measurements of constants of fissionable materials in the low resonance region. A slow flux of 3×10^{13} neutrons per cm^2 per sec. will make it possible to use a neutron crystal velocity selector up to about 100 electron volts energy. Measurements of the total cross-section to fission cross-section in this range should become feasible. (1 hole required)

3. Measurement of fission product poisoning in thermal reactors. (1 hole required)

III <u>Neutron Beam Experiments</u>

1. Neutron diffraction. The resolution of the diffraction patterns would be improved. At present the beams must be kept wide for reasons of intensity; consequently the resolution is far poorer than that obtained in x-ray patterns. (3 holes required)

2. Extension of range of crystal spectrometers to higher energy. Highly collimated beams of neutrons in the few hundred volt energy range, which would be available at 3×10^{13} flux, would make practicable the studies of cross-sections of non-fissile as well as fissile nuclei in this important energy region.

3. Mechanical velocity selector. This apparatus, at present under construction, would benefit doubly (a) because the higher thermal flux will give better resolution by making possible longer paths of flight, (b) because the larger number of neutrons in the resonance energy region will compensate in part for the decreasing efficiency of the detector. (1 hole required)

4. Neutron radioactivity. The beta-proton angular correlation in neutron decay yields an ideally clean experiment for study of the recoil effect resulting from neutrino emission. Intensity considerations prohibit such an experiment at present. (1 hole required)

5. Capture gamma rays. The rapid development of the scintillation spectrometer opens the possibility of using it to measure capture gamma ray spectra. Such an instrument would be useful in energy regions below about 2 Mev, in which pair spectrometers (such as the Chalk River instrument) are useless. (1 hole required)

IV Induced Radioactivity. All radiochemical studies would, of course, be stepped up as regards intensity, but new fields would also be brought within reach. Examples are:

1. Isotopes made by second order capture.

2. Production of intense photoneutron sources.

Relationship with the MTR

The MTR offers the advantage of higher flux than the proposed RIR; it suffers the disadvantage of remoteness. It is, therefore, natural to expect that only those experiments will be sent to the MTR which require the very highest flux, and which do not require the day to day backing of a completely equipped national laboratory. In this category fall all those experiments which involve long term irradiation -- such as the current Chalk River fuel assembly exposure -- and which do not require continuous monitoring.

The foregoing list of experiments for the RIR left out long term irradiations which could better be done in the MTR. The emphasis instead has been placed upon

(a) experiments in which readings are frequently, if not continuously, taken;

(b) experiments for which the apparatus is in a state of development, requiring occasional modification;

(c) experiments requiring rather short exposures, perhaps repeatedly.

A fourth class:

(d) "quickie" experiments, impossible to foresee, for which the MTR can be hardly used at all has been omitted.

II. RADIOISOTOPE PROGRAM AT ORNL

I. Introduction

The following constitutes an attempt to analyze the current status of the ORNL Radioisotope Program and to estimate both the future demand and the adequacy of available facilities for meeting this demand. The major result of this analysis is that additional high flux irradiation volume is needed even to fulfill present requirements adequately.

II. Current Status

The reputation of ORNL as the main supply of radioactive isotopes in the country (if not in the world) is now sufficiently established as to require no further emphasis here. The Laboratory has equipped itself for efficient production, chemical processing, and shipment of the isotopes; it is, furthermore, practiced in the associated keeping of books and of technical records, and it is familiar with the various Health Physics regulations which have to be observed.

The following two tables summarize the accomplishments of the isotope production program as of June 30, 1950, in a self-explanatory manner:

Radioisotope	No. of Shipments
Iodine 131	4,240
Phosphorus 32	3,396
Carbon 14	487
Sodium 24	599
Sulphur 35	252
Calcium 45	171
Potassium 42	196
Gold 198	217
Iron 55, 59	159
Cobalt 60	169
Strontium 89, 90	100
Others	1,995
	11,981

Field of Utilization	No. of Shipments	Percent of Total
Medical Therapy	3,983	44.7
Animal Physiology	2,391	26.8
Physics	668	7.5
Chemistry	618	6.9
Plant Physiology	435	4.9
Industrial Research	326	3.7
Bacteriology	173	1.9
Others	318	3.6
Total	8,912	100.0

Total number of different research projects to which isotopes have been supplied: 1100.

III. Predicted Demand

Having assembled the machinery for the isotope distribution program as described in the last paragraph, we consider it our responsibility to look ahead to see that we keep in a position to meet future demands.

The best that can be done in predicting future demand is to make a linear extrapolation of previous isotope production history. The distribution is shown in tabular form below. In general, it is anticipated that the January, 1950, production will be doubled within the next two years with an extremely large increase in cobalt 60 sales.

[redacted]

ATTACHMENT

Date	I^{131} (mc)	P^{32} (mc)	C^{14} (mc)	Sr^{90} (c)	Other Fission Products (Actual)(mc)	Miscl. (mc)	Unprocessed Units	Co^{60} (c)
9-46	298	380	8	Negligible	100	50	15	--
9-47	2,107	2,256	61		351	85	38	--
5-48	4,500	3,500	70		700	30	60	--
7-49	*29,800	4,600	300		745	520	100	10
1-50	25,000	9,600	200		*170	820	140	0.5
(Extrapolated)								
1-51	35,000	15,000	400	200	1,000	1,500	250	1,250
1-52	42,000	25,000	600	200	2,000	2,500	350	1,750
1-53	50,000	35,000	750	200	3,000	4,000	500	2,250
1-54	60,000	42,000	900	250	4,000	5,000	600	2,750
1-55	70,000	50,000	1,000	300	5,000	6,000	700	3,000

* Larger than May, 1948, basis by a factor of 1.75 because of a change in method of analysis.

The linear extrapolation attempted in the second half of the above table is, of course, at best, a guess. It is, nevertheless, true that as of today there is no indication that the demand for isotopes will level off for several years at least. We can see the following sources of increasing demands:

(1) Growth of radioactive research in universities, hospitals and other institutions.

(2) Growth in industrial uses (e.g., beta-ray thickness gauges).

(3) The Radiological Warfare Program (sudden heavy demands may arise here).

(4) Substitution of strong gamma emitters (e.g., Co^{60}, Ta^{182}) for hard x-rays and radium in medicine and industry.

[redacted]

(5) Possible price reductions resulting from per millicurie economies which are to be expected as production increases.

(6) Availability of new isotopes, such as rare fission products, resulting from the use of higher neutron fluxes.

IV. Present Limitations in Relation to Future Demands

1. Space limitations

The stringers used for irradiation units (small isotope samples) are at present used to about 75% capacity. With some consolidation, demands can be filled for one to two years in the future.

The space required for isotopes produced by (n p) reactions is large, because bulky parent samples have to be used. There are two very important products which fall into this class: (a) P^{32}. At present made in the required high specific activity by (n p) reaction on sulphur. Two large holes now are devoted to this use, and no others are available without cutting into the research use of the pile. Production at present is approximately equal to demand. (b) C^{14}. At present made by loading 400 peripheral fuel channels with calcium nitrate. Production in X-10 reactor is below demand. Relief is being sought by Hanford irradiation of beryllium nitride.

Cobalt 60 production has adequate space for the estimated increased demands for at least the next two years.

Fission products (including I^{131}, our most vital single product) have essentially no limitations, so long as one is content to use the uranium metal rather inefficiently by irradiation in rather low flux.

2. Reactivity Limitations

At present there are 145 excess inhours in the X-10 reactor. If all of this were to be devoted to isotope production, the latter would rise to 167% of its present rate. A further increase of 25 inhours can be expected when the calcium nitrate is completely discharged and Hanford assumes all of the C^{14} production. This would increase the production capacity to 180% of the present rate. Any further increase will require loading of more uranium metal, to the extent of a few tons. If the canned metal can be made available, there would seem to be no pressing reactivity limitation on the isotope production in the graphite reactor.

3. Specific Activity Limitations

Slow neutron produced isotopes are limited in specific activity by the available slow flux. The maximum available slow flux (10^{12}) in the X-10 pile is even now insufficient to meet many current specific activity measurements. How badly we are outclassed by Chalk River is a matter of common knowledge.

Numerous requests are being received for higher specific activities than are available at ORNL. These can in principle be met in some cases (e.g., Ca^{45}, Fe^{59}, Co^{60}, $Hg^{203,205}$, Te^{204}) by making use of (n,p) reactions; in practice this device has limitations so serious as to make it essentially unusable.

The limitations arise from the circumstance that (n p) reactions require fast neutrons (exception: C^{14}) and have low cross sections; the yields in the (thermal) graphite pile are accordingly so low that large amounts of parent element must be used. This wastes pile space and pile reactivity. A second obstacle

[redacted]

arises from the expensive "hot" chemical separation, which has to follow the irradiation.

Another class of isotopes, exemplified by Cl^{36}, Fe^{55}, Zn^{61}, Na^{24}, and K^{42} cannot be made by (n,p) reactions either because no appropriate Z + 1 parent isotope exists, or becuase the half-life is too short to permit the chemical separation. For these there is no choice but to use the (nγ) reactions.

The above considerations lead to the conclusion that the best way to produce isotopes with acceptably high specific activity is to employ the (nγ) reaction in a reactor which furnishes sufficiently high thermal flux.

The following table outlines the actual specific activities in current demand, and the conditions under which they could be attained in a reactor such as the RIR.

Radioisotope	Half-Life	Required Specific Activity, mc/Gram	Time Required if at Maximum Flux (3×10^{13}) 3-MW Pile
Na^{24}	14.8 h	7,500	43 hours
*Cl^{36}	4.4×10^5 y	2.5	4.2 years
K^{42}	12.4 h	500	17 hours
Fe^{55}	~4 y	5	1 month
Zn^{65}	250 d	1,500	1.5 years
Ca^{45}	180 d	10	0.6 month
Fe^{59}	46.3 d	5	1.3 month
Co^{60}	5.3 y	10,000	5.2 months
Hg^{203}	43.5 d	100	87 hours
Tl^{204}	2.7 y	1,000	1.0 year

* Arco can furnish this specific activity by a 7.3-month irradiation, but it is expected that this specific activity will be requested only rarely.

[redacted]

The need for high specific activity Co^{60} will be acute soon. It is expected that teletherapy units for medical research will require one to two thousand curies per month at a specific activity of ten curies per gram. This cannot be reached in the Hanford piles which have a limitation of approximately three curies per gram per year. Chalk River is the only existing reactor which can produce this specific activity.

V. Summary of Current Isotope Production Situation

The present X-10 reactor will be at its production limit with respect to available irradiation space by the time a new RIR can be put into operation. It is now at its limit for P^{32} production, and it has been found inadequate to fulfill demands for C^{14}. It is far below modern requirements with respect to specific activity induced by (n γ) reactions.

VI. Relief Afforded by RIR

The comparative fluxes in the present X-10 reactor and the proposed 3 MW RIR are as follows:

	X-10 Reactor	3 MW RIR	Ratio $\frac{RIR}{X-10}$
Thermal Flux	5×10^{11} n/cm /sec*	2×10^{13} †	40
Fast Flux (>1 Mev)	2×10^{11}**	2×10^{13} ††	100

* Average flux position

** In hole inside uranium slug

† In beryllium reflector, assuming a realistic flux depression resulting from presence of absorbers.

†† In shim rod, presumed to contain the material under irradiation. Corresponding figure in the beryllium is about 3×10^{12}.

The improvement to be expected in specific activities is obvious; the thermal flux would be sufficient to abandon most thoughts of (n p) production in favor of more efficient (n γ) production. The space available for production is described in Section III of this paper; we shall state here that it would be sufficient to meet production requirements for as far ahead as we can see.

III. DESIGN CONSIDERATIONS

In submitting a proposal for a new experimental pile for research and isotope production it might be well to review briefly the general considerations involved in such a design. Inasmuch as it is imperative in an experimental pile to approach the maximum neutron flux per watt, materials suitable for the active lattice are decidedly limited in number. Highly enriched uranium appears to be the proper fissionable material. Fast piles appear to suffer from inflexibility without any compensating advantages even in fast neutron flux. It has been pointed out by Wigner that a thermal pile, moderated entirely or partially by light hydrogen, is a good source of 1 Mev as well as thermal neutrons. Experimental pile designs, using both light and, light plus heavy water, moderators, have been extensively considered by this laboratory. The design using both light and heavy water has been revived recently at ANL and forms the basis for a new experimental pile for that laboratory. Inasmuch as it is desirable that experimental piles exist in some variety, we have no sensible alternative to the choice of an experimental pile moderated entirely by light water. The design of such a pile has already been worked out in detail for the MTR and much effort and engineering cost may be saved by adopting that design insofar as it is applicable. This is particularly desirable in view of the heavy commitments of the laboratory to other parts of the reactor program. These commitments would make it extremely difficult to undertake the design of an entirely different type of experimental pile.

We propose the construction of a Research and Isotope-producing Reactor (RIR) to be operated at about 3 megawatts. At this power level the RIR will deliver a maximum thermal flux of about 2 to 3 x 10^{13} and a virgin fission neutron flux of about 1.5 x 10^{13}. It was assumed in the design of the MTR that any flux of 10^{13} or more should be exploited to as great an extent as possible. This condition required a complicated pattern of experimental holes which penetrated a large graphite block surrounding the active lattice and its beryllium reflector. When the MTR power is reduced by a factor of 10, this graphite block becomes essentially useless since the maximum flux in the graphite is then reduced well below 10^{13}. A further saving may be made in the quantity of beryllium reflector since the bulk of this material simply served as a neutron transmitter to the graphite block. On this basis the adaption of the MTR design involves some very considerable simplifications.

Fig. 1 is a horizontal cross section of the proposed RIR showing the active lattice, reflector, shield, and major experimental holes. Twelve experimental holes suitable for either beam or bombardment operations penetrate through a thick layer of water to the outside of a beryllium reflector 7-1/2 cm thick. It has been shown in critical experiments leading to the MTR design that 7-1/2 cm of beryllium plus 15 cm or more of water is almost as efficient a reflector as an infinitely thick layer of beryllium. We thus eliminate the bulk of the beryllium in the MTR at a saving of about half a million dollars. This may be accomplished without any sizeable increase in the critical mass of the active lattice.

Fig. 2 shows a vertical cross section of the pile. It will be noted that this section is nearly identical with the MTR except that the graphite block previously mentioned has been replaced by a thick layer of ordinary water. The discharge water from the pile flows upward through this region and cools a layer of iron thermal shielding. The arrangement in the drawing is adequate to form the basis for an estimate, but further study and some mock-up experimentation is planned to determine the optimum arrangement. Nine feet of ordinary concrete is provided for biological shielding. A column of water about twenty feet high and directly above the active lattice serves as a transparent shield for the manipulation of active samples while the pile is shut down.

Aside from the change in thermal shielding and the elimination of most of the beryllium, the design is identical with the MTR. It will be noted that the section also shows two of twelve experimental holes which penetrate to the surface of the beryllium but are inclined at an angle of 36° with the horizontal. One of these smaller holes is directly above each of the horizontal holes. Suitable balconies for the use of inclined holes will be built if and when the need arises. It is felt that 6 more holes about 4 inches in diameter will be needed for control instruments. They will be incorporated into the design after further study; smaller holes for special purposes will also be installed to about the same extent as the MTR. These additional holes have not been shown in the blueprints but were included in the cost estimate.

The fuel loading problem of a pile of the RIR power will be very much simpler than in the MTR because it will not be necessary to change the active assemblies

more than once or twice a year. However, the isotope program will require frequent removal of highly activated samples, and for this purpose an outlet chute and a small canal have been included. It will be noted in Fig. 2 that the first 20 feet of this canal will have a width of only 2 feet and in Fig. 3 it will be seen that this portion of the canal slopes at a 45° angle so that a sample discharged from the active lattice slides down this inclined portion of the canal and reaches the bottom at a point considerably beyond the outside of the shield. At this point the canal widens to six feet and continues 15 feet beyond the wall of the building where shielded samples may be removed and loaded into trucks.

The controls of the proposed RIR may be simplified as compared to those in the MTR for several reasons: (1) Heat transfer at the active lattice is no longer a critical point of design and the instrumentation on the water system may be greatly simplified. (2) The total number of shim rods will be reduced from 8 to 4 and a very considerable part of the MTR control system may therefore be decreased by a factor of 2. (3) A servo mechanism for control does not appear to be strictly necessary. (4) In addition, since the active lattice will remain in the pile for long periods of time and therefore provide a very large source of neutrons even after a shut-down of considerable duration, some of the complicated interlocks intended to prevent start-up accidents in the MTR may be eliminated. The nuclear instrumentation will remain essentially unchanged but the simplifications mentioned should reduce the cost of the control system at least as much as indicated in the estimate. Three to six holes of special design for differential ion chambers may be necessary. The design of these holes

must be worked out with the aid of mock-up experiments and cannot be indicated at this time.

Figs. 1 and 2 show the active lattice surrounded by the minimum amount of beryllium required to attain a loading of approximately two kg of U^{235}. It will be noticed that the experimental holes in Fig. 1 lead to the beryllium reflector and not directly to the active lattice. This arrangement will not be practical for all purposes inasmuch as the fission neutrons will suffer considerable moderation before reaching the experimental hole and the flux of neutrons of energies above a million volts will consequently decrease very markedly. Where it is desirable for the purposes of a particular experiment to have a high fast flux, the arrangement may be changed slightly and an active assembly exchanged with a piece of beryllium in front of the experimental hole in question. It is anticipated that the pile will be started up with the arrangement shown inasmuch as this makes it unnecessary to insert reflecting material into the experimental hole when the hole is not in use. Additional beryllium will be necessary both for the manufacture of isotopes and to increase the available flux in the experimental holes somewhat above that obtainable with the arrangement shown. An additional mass of beryllium equal to that shown in the drawings should be amply sufficient for these purposes at the present time and has been covered by the estimate. The detailed design of this beryllium arrangement will again require mock-up experiments and we have consequently not attempted to show the arrangements in these preliminary drawings. As the needs of the isotope program increase, additional beryllium may be added from time to time. If the

demands from the isotope program warrant it, the complete block of beryllium (five feet in diameter as used in the MTR) may be installed. A block of this size will allow the exploitation of all neutrons at a flux of 10^{13} or more. Thus the desirability of utilizing fluxes above 10^{13} sets the diameter of 'D' of the tank and those above it at five feet as in the MTR. In any case, an appreciable reduction in this diameter would hinder underwater manipulation of active material. The reduction of power by a factor of 10 does not affect the height of the water column in tanks A, B and C to any great extent. Similarly the water passages in the MTR fuel assemblies contain about the optimum volume of water for moderation. It appears then that it is not only expedient to copy the MTR design for the fuel assemblies and tanks A, B, C and D and their contents, but that a reduction of MTR power by a factor of ten does not change the important dimensions enough to make a re-design desirable. These considerations lead us to a design which will permit a very large rate of flow of cooling water. If future developments make it desirable, the power may be increased to the maximum level consistent with the safety of the Oak Ridge area without any changes in the pile itself.

Space for Isotope Production

As implied in the last paragraph, materials for activation will be placed in the beryllium and will be loaded and unloaded from above. All of the flexibility of the MTR design is available for the purpose; that is, beryllium blocks can be removed from one place or another and replaced by isotope-bearing units, and the possibility of ultimate expansion to the limits of the tank will provide ample space for future needs.

Pile Coolant System

The design of the cooling system is similar in principle to the MTR cooling in that heat and gas removal are effected by a vacuum flash cooler. Heat is removed from the reactor by circulating 2000 gpm of demineralized water in a closed circuit of stainless steel. This heat is extracted from the pile coolant in the flash cooler condenser by 2000 gpm of filtered water which is circulated over an open cooling tower. The design capacity of the system is 3300 kw under severe summer conditions and with a temperature rise of 11.3°F in both circuits. There is sufficient capacity in the system to permit 5000 kw operation with no changes other than an increase in the temperature rise. Demineralized water will be piped to the system from an existing facility.

Housing for the water system is provided by a 20 ft. x 30 ft. x 50 ft. high addition to the reactor building. Part of the construction will be similar to that of the main building and the remainder will be concrete with walls 12 to 15 inches thick for shielding against radiation emitted by the process water. Space is provided in the structure for the service panels for the main building and for the blowers for the pile air system.

The cooling tower will be located at grade level adjacent to the process water building.

Air System

The air system for this reactor performs a limited function. Because none of the reactor is air cooled the air system is required only as a means of disposing of active gases produced in the beam holes and non-condensibles removed from pile coolant in the flash coolers. This is to be accomplished using two blowers, each capable of delivering 3500 cfm with a negative suction pressure

of 10 to 15 inches of water, and necessary ducts. Gases will be filtered by filters simila to those used in the air system of the ORNL graphite pile and exhausted to the atmosphere thru one of the existing stacks. The blowers and filters will be located in the process water building.

Retention Basin

A simple retention basin is required to provide 24 to 48 hour holdup of the radioactive effluent from the reactor and emergency hold up of the entire volume of the coolant system. A 120,000 gal. basin formed by earthen dikes and divided into two sections is considered adequate to fulfill the requirements. Water leaving the basin will be monitored continuously and discharged thru the existing retention basin to White Oak Creek.

Location

The RIR will be housed in a 75' x 75' square building made of metal siding and will contain the essential services and utilities. One or two offices for the use of direct supervision will be required, but no laboratories are contemplated.

The building is to be located just east of the present Pile Building and on the location of the present 101 Shops. The Shops are scheduled to be removed under Plan 'H'. This location was chosen for the following reason:

1. Demineralized water for pile cooling can be obtained from the 807 Demineralization Building which is located about 150 feet north of the proposed reactor site. No increase in the capacity of the demineralizers will be necessary.

2. The small amount of exhaust gas and cooling air from the reactor can be led to the 900 Area stack which is just south of the proposed site. Actually, the small amount of air to be handled in the RIR could probably be discharged into the ORNL graphite reactor exit air duct to be discharged through the Filter Building and 115 Stack without materially reducing the air flow through the ORNL reactor.

3. The location of the RIR in an established section of the Laboratory will eliminate the need for extensive additions to utility distribution systems. Fire water, process and potable water, steam, process and sanitary sewers, hot drains, and electrical distribution lines are already available for convenient tie-ins. No additional Security personnel would be required. Also, the unit would be convenient for maintenance work.

4. Since the operation of the RIR will be the responsibility of the Operations Division, a considerable saving in manpower could be realized if the two reactors were close together. A technical shift supervisor could be assigned to both reactors and the present day shift supervisor of the ORNL reactor could probably handle both reactors with the aid of possibly one more technical man. No more than two more operators on each shift and two more operators on straight days, added to the present Pile Department crews, would be required to operate both reactors and to handle peak load jobs such as shutdowns, provided the shutdowns were scheduled at different times for the two piles. The number of people required to operate the unit would not be increased appreciably if at some time a very large increase in power level were made.

Time Estimate

Approximately fifteen months would be required for the construction of the proposed reactor.

IV COST ESTIMATE

An estimate of the cost of the project has been made using current information on the costs of parts for the MTR and current construction costs at ORNL as the basis.

The estimate is divided into five sections. The first includes the reactor building, the building and pile foundations, the canal and all services. This part of the estimate was made by the Plant Engineering Division. It was revised upward to conform to differences between their estimates and bids on current construction of a similar nature and to take into account a 15 percent increase in construction costs expected during the next few months.

Reactor and controls are considered in the second section. Costs are based upon current procurement costs for the MTR and current construction data at ORNL corrected for expected price increases.

The water system, air system and retention basin are estimated in the remaining sections. Equipment costs for those items were obtained from manufacturers during the month of August and reflect price increases expected during the next few months. Construction costs were based upon ORNL construction data.

In addition to the direct cost, 50 percent of the direct cost has been added to cover contingencies, engineering, construction fees and overhead. Because much of the engineering has been done in designing the MTR and a minimum of special construction facilities will be required, about half of the added cost is available to meet contingencies.

Summary

Reactor Building, Foundations, Canal and Services	467,600
Reactor and Controls	1,053,400
Coolant System and Housing	266,400
Air System and Housing	42,500
Retention Basin and Effluent Control	35,000
TOTAL	1,864,900
Indirect Costs, Design and Contractor Fees and Contingencies 50%	932,500
TOTAL	2,797,400

Reactor Building

Foundations and Sub Pile Room	61,000
Canal Structure	39,000
Canal Water System	7,100
Storage Facilities	6,000
Canal Cranes	15,000
Building Structure	207,000
Power, Lighting, etc.	21,000
Plumbing, Fire Protection, Water Supply and Services	15,000
Heating and Ventilating	8,500
Overhead Crane	48,000
Miscellaneous Equipment and Installation Expenses	40,000
TOTAL	467,600

Reactor and Controls

Top Plug and Superstructure	22,500
Tank Section "A"	24,000
Tank Section "B"	4,000
Tank Section "C"	3,600
Tank Section "D"	22,000
Bottom Plate and Plugs	15,000
Tank Section "E"	28,800
Tank Section "F" and Sleeves	50,000
Control Rod Assemblies	90,000
Aluminum Castings	30,000
Top Plug Electrical Wiring	2,000
Handling Tools	5,000
Gaskets, Nuts, Bolts, etc.	2,000
Be Reflector	250,000
Beam Hole Liners and Plugs	35,000
Control System	180,000
Thermal Shield	25,000
Concrete Shield	60,000
Stainless Steel Water Lines	35,000
Pile Framing and Installation of Tanks	35,000
Rabbits	35,000
Discharge Chute	2,000
Services to Beam Holes	7,500
Air Ducts on Pile	5,000
Miscellaneous Equipment and Installation Expenses	85,000
TOTAL	1,053,400

Coolant System

Housing	75,000
Seal Tank	13,000
Sump Tank	16,000
Process Water Pumps	7,500
Process Water Cooler	60,000
Cooling Tower	20,200
Cooling Tower Pumps	4,500
Kates Regulator	12,000
Piping	38,800
Instrumentation	19,400
TOTAL	266,400

Air System

Blowers, Motors and Starting Equipment	15,000
Filters	5,000
Duct Work	15,000
Housing	7,500
TOTAL	42,500

[redacted]

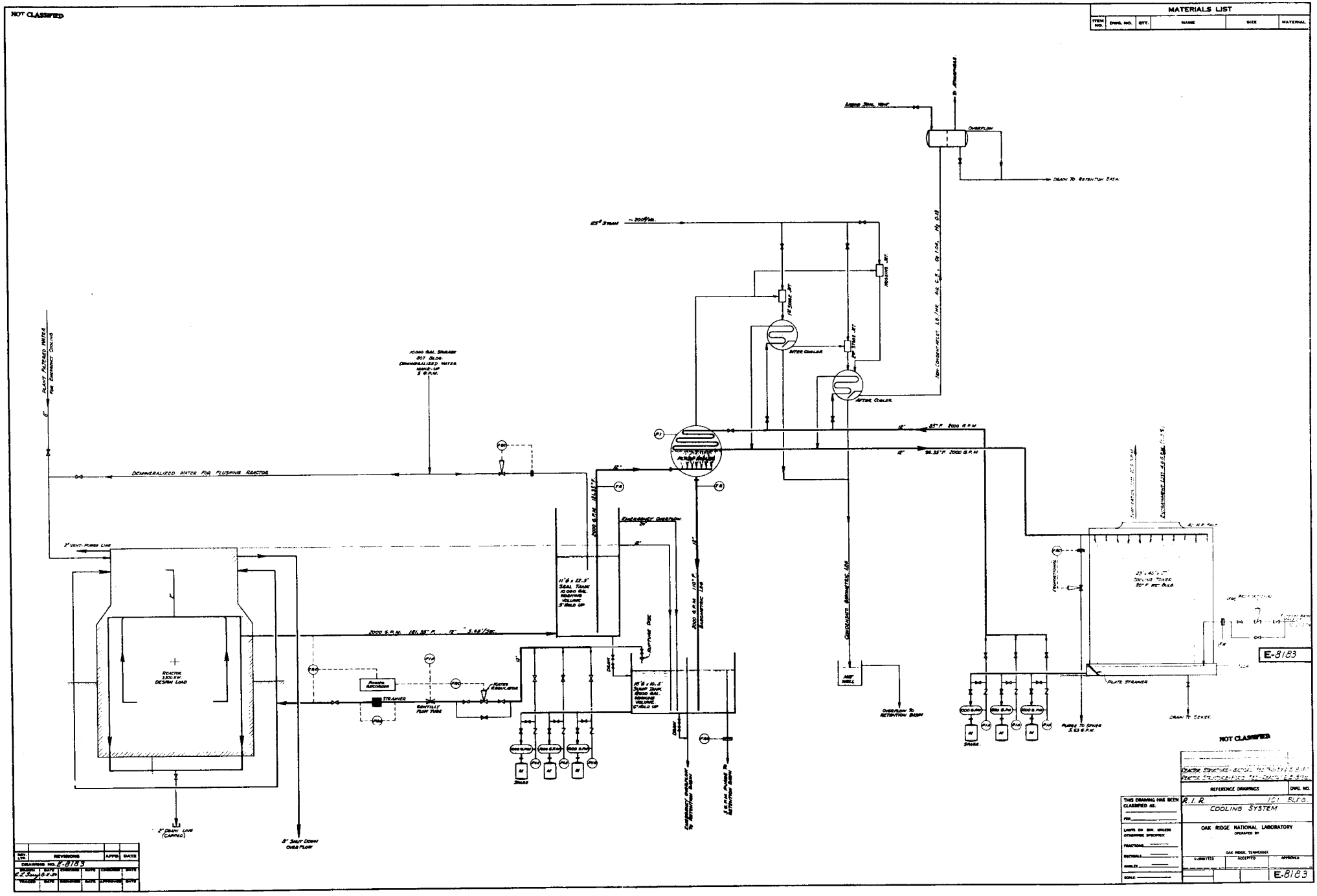
Retention Basin

120,000 Gallon Earth Basin	17,500
Piping	11,500
Effluent Control	6,000
TOTAL	35,000

[redacted]

NOT CLASSIFIED

MATERIALS LIST					
ITEM NO.	DWG. NO.	QTY.	NAME	SIZE	MATERIAL



NOT CLASSIFIED

REV. LTR.	REVISIONS	APPD.	DATE
DRAWING NO. E-8183			
DESIGNED R. J. Sanger	DATE 6-8-49	CHECKED	DATE
TRACED	DATE	SUBMITTED	DATE

REACTOR STRUCTURE - BOTTOM PORTION OF SHIELD
REACTOR STRUCTURE - TOP PORTION OF SHIELD

REFERENCE DRAWINGS	DWG. NO.
R. I. R.	101 ELEC.

THIS DRAWING HAS BEEN CLASSIFIED AS:
FOR:
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FRACTIONS
DECIMALS
ANGLES
SCALE

COOLING SYSTEM

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
OAK RIDGE, TENNESSEE

SUBMITTED	ACCEPTED	APPROVED

E-8183

MATERIALS LIST					
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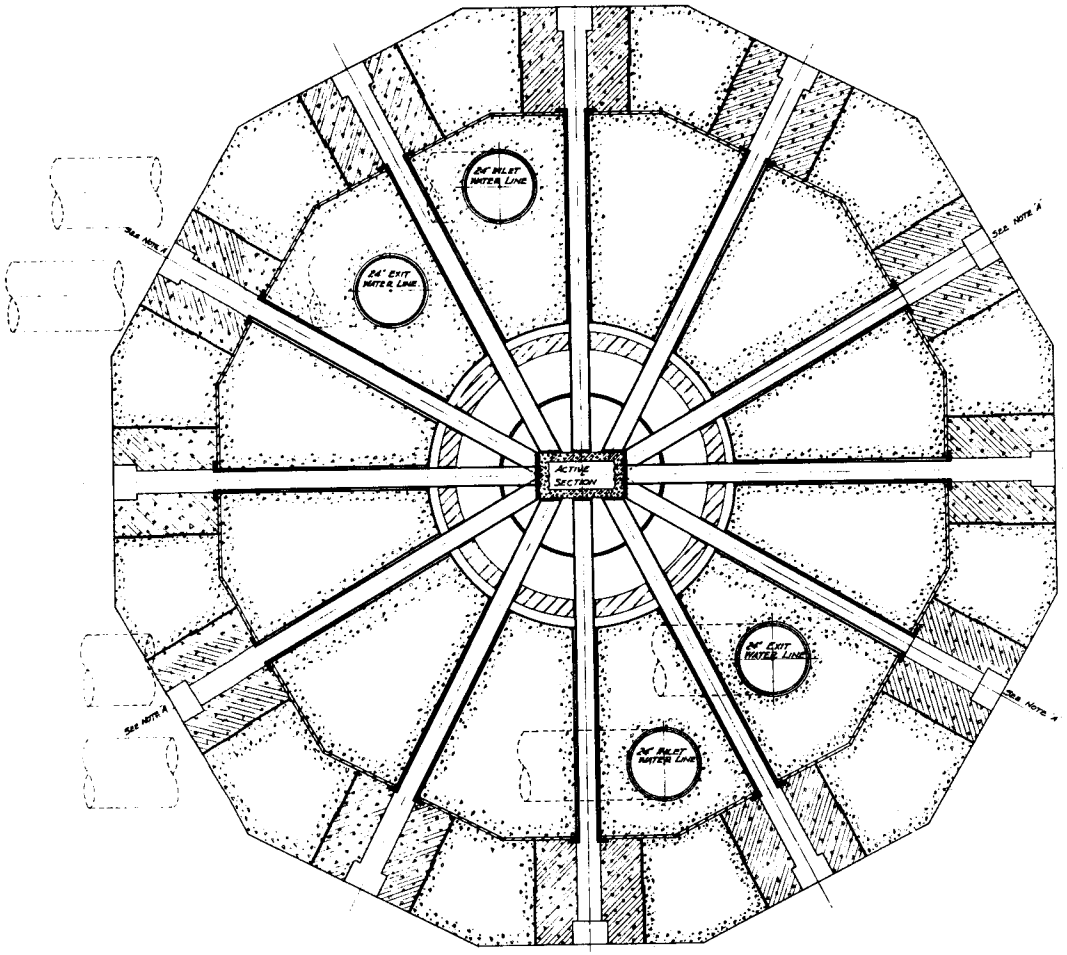

NOTE A:
HOLES MARKED "SEE NOTE 'A' ARE 6" BELOW OTHER HORIZONTAL HOLES.

E-8139

RESTRICTED DATA

CAUTION

SECRET

VERTICAL SECTION THRU E-W ℄	E-8143
REFERENCE DRAWINGS	DWG. NO.
R.I.R. 101 ELDG.	

REACTOR STRUCTURE
HORIZONTAL SECTION
REACTOR ℄

OAK RIDGE NATIONAL LABORATORY
OPERATED BY

OAK RIDGE, TENNESSEE

SUBMITTED	ACCEPTED	APPROVED

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FOR [signature]

LIMITS ON DIM. UNLESS OTHERWISE SPECIFIED:
FRACTIONS
DECIMALS
ANGLES
SCALE: 3/4" = 1'-0"

E-8139

REV LTR	REVISIONS	APPD	DATE
DRAWING NO. E-8139			

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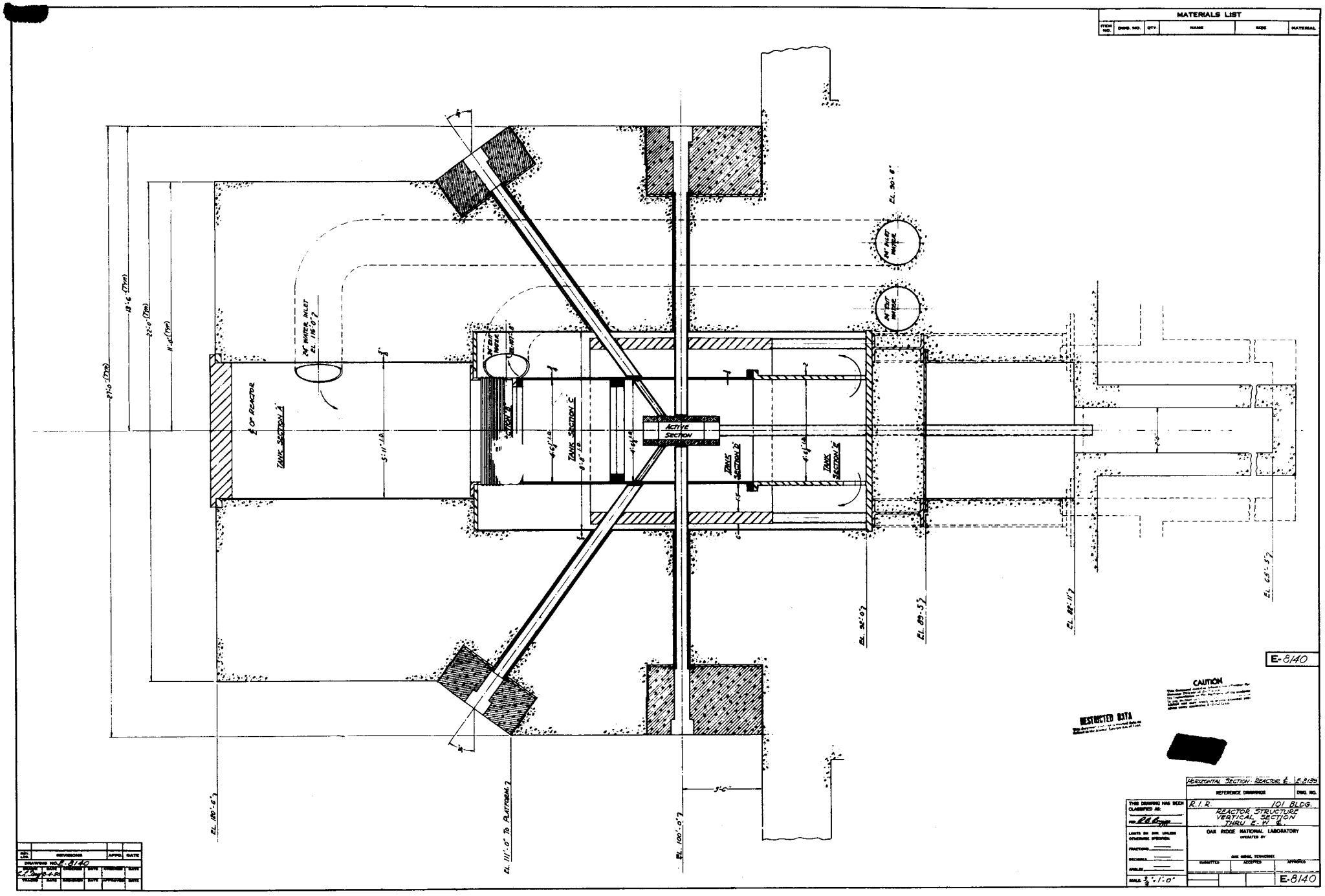
TRACED	DATE	DESIGNED	DATE	APPROVED	DATE


MATERIALS LIST
ITEM NO.
DWG. NO.
QTY.
NAME
SIZE
MATERIAL
℄ OF REACTOR
TANK SECTION A
TANK SECTION C
TANK SECTION D
TANK SECTION E
ACTIVE SECTION
24" WATER INLET EL. 116'-0"
24" INLET WATER
24" EXIT WATER
EL. 90'-6"
EL. 92'-0"
EL. 89'-5"
EL. 82'-11"
EL. 65'-5"
EL. 180'-6"
EL. 111'-0" TO PLATFORM
EL. 100'-0"
27'-0" (TYP)
13'-6" (TYP)
22'-0" (TYP)
11'-0" (TYP)
5'-11" I.D.
3'-6"
E-8140
CAUTION
RESTRICTED DATA
HORIZONTAL SECTION - REACTOR ℄
E-8139
REFERENCE DRAWINGS
DWG. NO.
THIS DRAWING HAS BEEN CLASSIFIED AS:
R.I.R.
101 BLDG.
REACTOR STRUCTURE
VERTICAL SECTION
THRU E-W ℄
OAK RIDGE NATIONAL LABORATORY
OPERATED BY
OAK RIDGE, TENNESSEE
SUBMITTED
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SCALE: 3/4" = 1'-0"
E-8140
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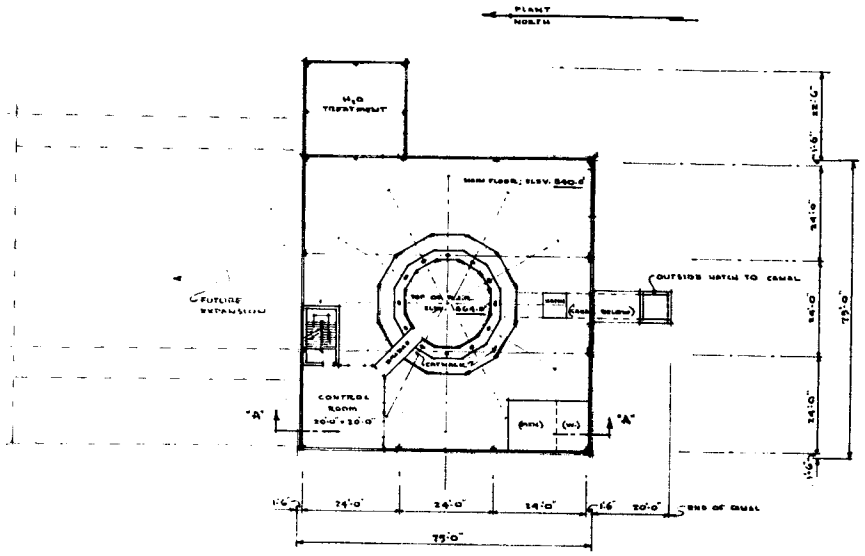
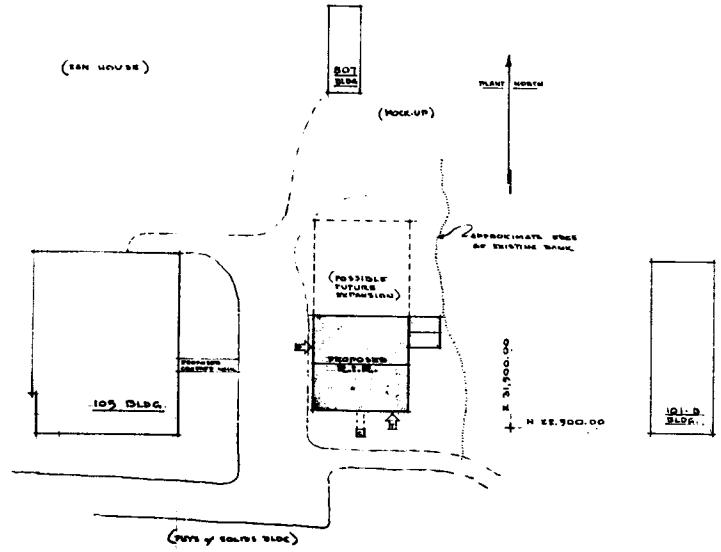
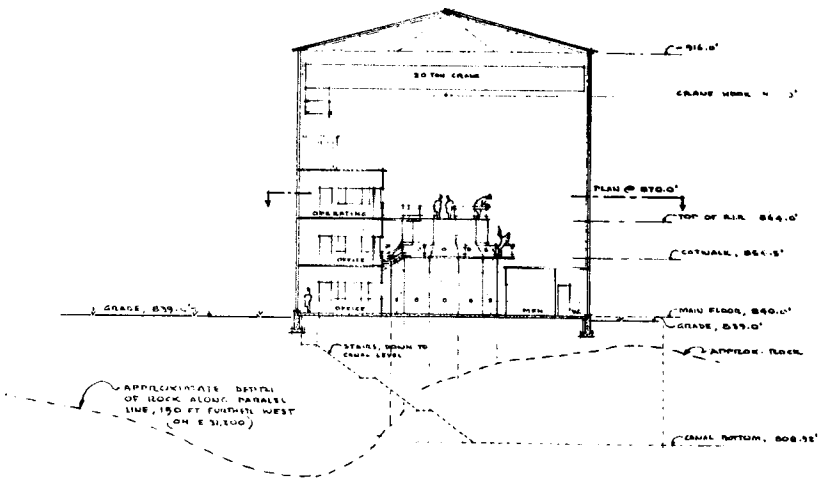


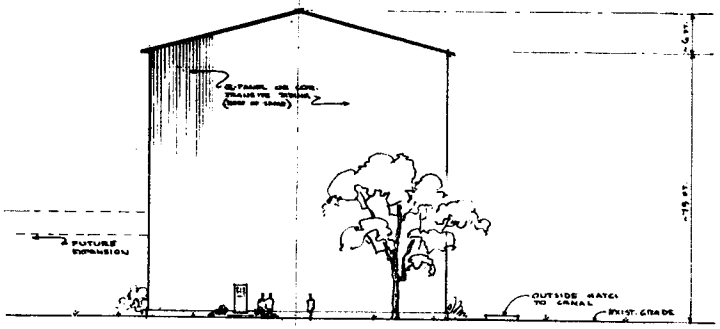
FLOOR PLAN AT ELEV. 870.0' SCALE 1" = 1/16" = 1'-0"



LOCATION ON SITE SCALE 1" = 50'-0"



SECTION "A-A", LOOKING EAST, SCALE: 1/16" = 1'-0"



WEST ELEVATION SCALE 1/16" = 1'-0"

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DRAWN A. P. MACKINTOSH DATE: 8/10/50	DESIGNED DATE:	CHECKED DATE:	APPROVED	
HEALTH PHYSICS	MEDICAL	OPERATIONS	SAFETY	
FIRE PROTECTION	RESEARCH SHOP	MAINTENANCE		

REFERENCE DRAWINGS	DWG. NO.
PLANS, SECTION, & ELEVATION	

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FRACTIONS
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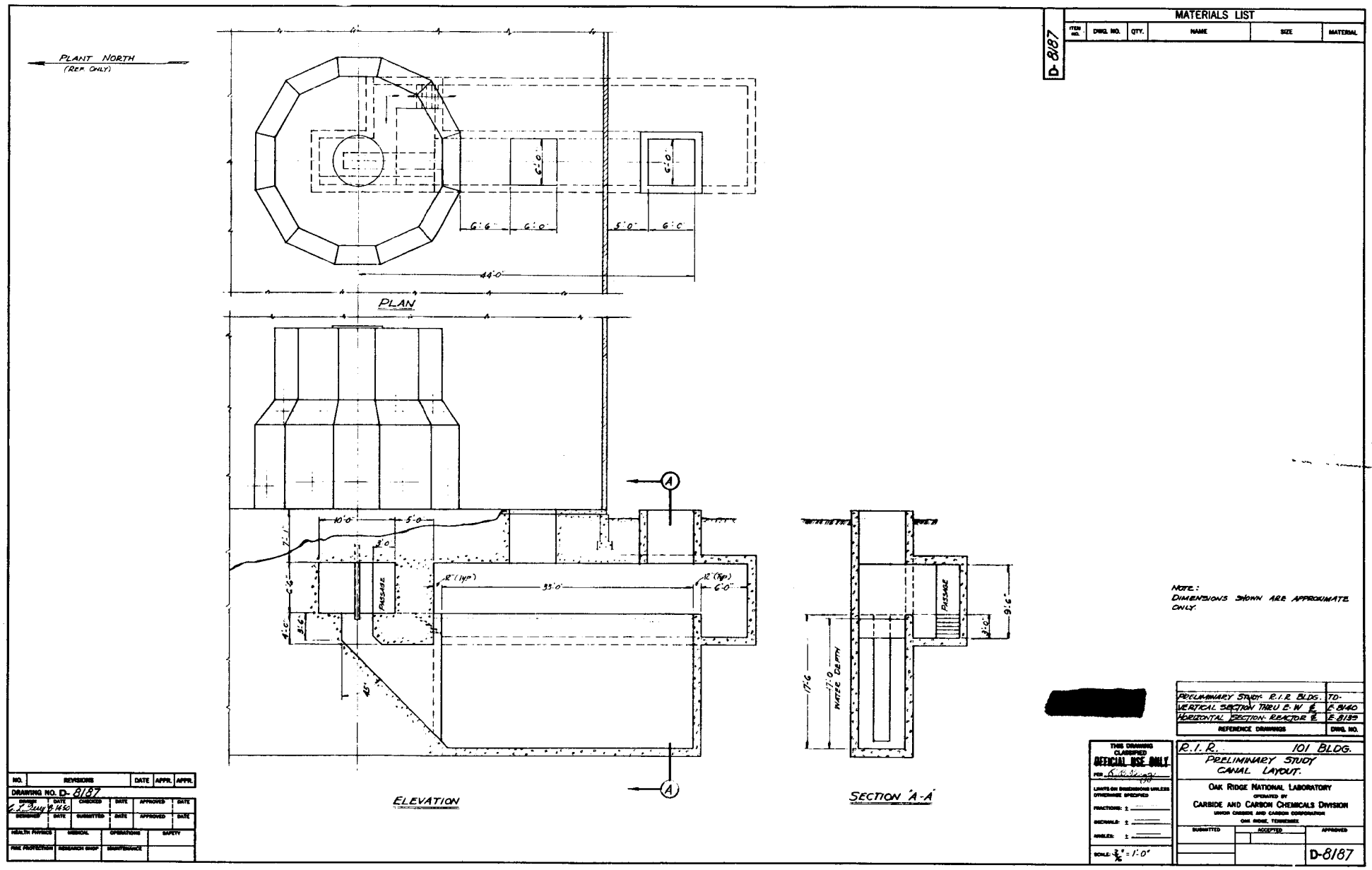
ANGLES
SCALE AS NOTED

PRELIMINARY STUDY for R.I.R. BUILDING

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
CARBIDE AND CARBON CHEMICALS CORP.
FOR THE
ATOMIC ENERGY COMMISSION
OAK RIDGE, TENNESSEE

SUBMITTED	ACCEPTED	APPROVED
		TD-1881

R:


PLANT NORTH
(REF. ONLY)
PLAN
6'-0"
6'-0"
6'-6"
6'-0"
5'-0"
6'-0"
44'-0"
ELEVATION
10'-0"
5'-0"
3'-0"
7'-1"
6'-6"
4'-0"
3'-6"
PASSAGE
12" (typ)
33'-0"
12" (typ)
6'-0"
45°
A
A
SECTION 'A-A'
PASSAGE
9'-6"
3'-0"
17'-6"
17'-0"
WATER DEPTH
D-8187
MATERIALS LIST
ITEM NO.
DWG. NO.
QTY.
NAME
SIZE
MATERIAL
NOTE:
DIMENSIONS SHOWN ARE APPROXIMATE ONLY.
[redacted]
PRELIMINARY STUDY- R.I.R. BLDG. TO-
VERTICAL SECTION THRU E-W ℄ E-8140
HORIZONTAL SECTION- REACTOR ℄ E-8139
REFERENCE DRAWINGS
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FRACTIONS: ±
DECIMALS: ±
ANGLES: ±
SCALE: 3/16" = 1'-0"
R.I.R. 101 BLDG.
PRELIMINARY STUDY
CANAL LAYOUT.
OAK RIDGE NATIONAL LABORATORY
OPERATED BY
CARBIDE AND CARBON CHEMICALS DIVISION
UNION CARBIDE AND CARBON CORPORATION
OAK RIDGE, TENNESSEE
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APPROVED
D-8187
NO.
REVISIONS
DATE
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DRAWING NO. D-8187
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HEALTH PHYSICS
MEDICAL
OPERATIONS
SAFETY
FIRE PROTECTION
RESEARCH SHOP
MAINTENANCE