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ISOTOPES PRODUCTION REACTOR—SUMMARY
OF COMPLETE DESIGN

By
R. K. Winkleblack

April 1955

Argonne National Laboratory
Lemont, Illinois

Technical Information Service, Oak Ridge, Tennessee

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AEC, Oak Ridge, Tenn.

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ISOTOPES PRODUCTION REACTOR-
SUMMARY OF COMPLETE DESIGN

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Numerous others have contributed valuable information and help in the design of this reactor. This is particularly true in drafting and testing. The project engineer wishes to acknowledge the many ideas and fine cooperation given by all who have worked on this design.

*Full time devoted to Project.

April 1955

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ISOTOPES PRODUCTION REACTOR- SUMMARY OF COMPLETE DESIGN

by

R. K. Winkleblack, Project Engineer

I. INTRODUCTION

This is an Isotope Production Reactor. It is hoped that the reactor might be of interest to industrial groups studying the possibilities of entering the radioactive isotopes production field. Argonne has prepared complete detailed drawings and specifications for the construction of the reactor. The architect-engineer firm of Shaw-Metz and Dolio, under AEC contract, has prepared complete drawings and specifications for the building.

The critical mass and other pertinent numbers will change according to the isotopes one chooses to produce in this reactor. These necessary changes can be accommodated over a fairly wide range due to the flexibility designed into the core, cooling system, and material handling arrangement. The percentage of enriched uranium in the U-Al fuel plate alloy can be varied. The number of fuel assemblies and the loading pattern can be varied since flow from the plenum chamber can be made available to each of the positions shown occupied by producer assembly types 1 and 2. Also, the reactor can be operated at a power considerably above 5000 kw if desired.

Many safety features are incorporated in the design to assure reliable and safe operation. These include, among others, a cooling water system that will keep the active fuel plates submersed even if a major break occurs in the heavy water system external of the biological shield; an emergency spray system with three sources of cooling water, one of which does not depend on electrical power, pumps, or high tanks; a large expansion chamber to augment the free volume above the reactor; a fast safety rod system that will "scram" if the reactor reaches a power appreciably above normal operating power or if the rate of change of power should reach a value considered greater than that which is entirely safe; a gastight, blast-resistant building surrounding the reactor but structurally isolated from the reactor and its operating equipment.

This report is intended to be a comprehensive design review and includes pertinent comments and suggestions regarding the construction, installation, initial testing, and operation of the reactor. However, it is not a construction and operation manual. Detailed plans for the critical assembly test work are not reported. Thought has been given this, however, and it is intended that the designers and other staff members of Argonne, skilled and experienced in this type of work, will plan the complete critical testing and flux mapping program at the time when procurement for construction begins.

II. GENERAL DESCRIPTION

The reactor design is a heavy water-moderated and cooled, enriched uranium type. Fuel is contained in twelve plate-type assemblies in the form of a uranium-aluminum alloy which is clad with 2S aluminum. There are five aluminum tube assemblies which contain 48 capsules. In and around this core are placed 134 thin-wall aluminum cylinders having necessary end adapters to position them in the tank. The pattern or loading arrangement is shown on Drawing MJ-1010-F.

The tank in which the fuel and two types of producer elements are arranged is 8 ft in diameter, and the heavy water is 7 ft 10 in. deep. This water level is about an inch up in the top grid. The grid positions the upper ends of the elements and also carries the bearings for the wide, swing type, shim-safety rods (or blades). Four of these shim-safeties travel in 3-inch water filled spaces between the elements.

ANL-RKW-500 is a cutaway isometric view of the reactor with only a few elements shown in place. The regulating rod stationary sheath can be seen where it protrudes into the tank on the center line of the active core. The absorbing section of the regulating rod is moved in and out inside the sheath. The heavy water filled, 1/2 inch wall, aluminum tank is surrounded with 2 feet of graphite and has about 21 inches of graphite under the bottom. There is no graphite reflector over the top of the tank. In fact, the bottom of the grid is a poison plate which causes essentially zero thermal neutron flux at that plane. A blanket of helium is provided in the space above the heavy water. A separate helium system blankets the graphite with inert gas.

A steel tank lined with boral* contains the graphite, and an annular diaphragm seals the opening at the top of the two tanks, thus keeping the atmosphere of the graphite separated from that over the heavy water. Four-inch thick lead bricks are stacked around the tank for a thermal shield. The bottom thermal shield is a five-inch thick steel plate which also serves as a bedplate for construction. Two sets of water tubes are loaded into slots which are between the steel tank and the thermal shield.

Some of the features that could not be shown on ANL-RKW-500 because of space limitations are illustrated on ANL-RKW-501. These two isometrics show the duct which leads to the expansion chamber. The thermal shield bottom plate and the top steel support ring are carried on a conventional structural steel frame. The frame is not shown. The short top shield support beams are bolted to the ring. The stationary segments of the top plug are rested on these beams. There are 24 pieces to the stationary top

* Aluminum-clad boron carbide.

TYPICAL CROSS SECTIONS OF LATCHING ASSEMBLIES
SCALE: 1/2\"/>

SECTION A-A
THRU A OF CORE
ELEVATION 84'-0\"/>

PLAN VIEW
AT TOP OF GRID
ELEVATION 84'-0\"/>

ORIENTATION
UP B REACTOR FACE
TYPICAL ALL VIEWS

SECTION B-B

NO.	DESCRIPTION	DATE	BY	CHKD.
1	REACTOR VESSEL LOADING PLAN	10-1-57	W. J. HARRIS	W. J. HARRIS
2	REACTOR VESSEL LOADING PLAN	10-1-57	W. J. HARRIS	W. J. HARRIS
3	REACTOR VESSEL LOADING PLAN	10-1-57	W. J. HARRIS	W. J. HARRIS
4	REACTOR VESSEL LOADING PLAN	10-1-57	W. J. HARRIS	W. J. HARRIS
5	REACTOR VESSEL LOADING PLAN	10-1-57	W. J. HARRIS	W. J. HARRIS
6	REACTOR VESSEL LOADING PLAN	10-1-57	W. J. HARRIS	W. J. HARRIS
7	REACTOR VESSEL LOADING PLAN	10-1-57	W. J. HARRIS	W. J. HARRIS
8	REACTOR VESSEL LOADING PLAN	10-1-57	W. J. HARRIS	W. J. HARRIS
9	REACTOR VESSEL LOADING PLAN	10-1-57	W. J. HARRIS	W. J. HARRIS
10	REACTOR VESSEL LOADING PLAN	10-1-57	W. J. HARRIS	W. J. HARRIS
11	REACTOR VESSEL LOADING PLAN	10-1-57	W. J. HARRIS	W. J. HARRIS
12	REACTOR VESSEL LOADING PLAN	10-1-57	W. J. HARRIS	W. J. HARRIS
13	REACTOR VESSEL LOADING PLAN	10-1-57	W. J. HARRIS	W. J. HARRIS

CUT AWAY VIEW OF REACTOR

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shield. The rotating top plug is suspended from a circular track mounted on the stationary sections. A coarse and vernier drive rotates the center section of the top plug to position one of the access holes over the fuel or producer element stations.

The main D₂O coolant lines are shown on ANL-RKW-501. At the lower left, a tee will be found. This is where the cooled D₂O from the two heat exchangers enters the 10-inch pipe which flows cooling water to the reactor. The purpose of the loop in this line is to avoid draining the reactor tank if there should be a break in the inlet pipe external of the biological shield. The biological shield does not show in the isometric drawing but is simply ordinary concrete with a radial thickness of 7 feet. The D₂O discharge baffles inside the reactor vessel give the same protection on the discharge as the loop gives on the inlet, i.e., the water must flow down back of the baffle plates to discharge through the outlet lines. If a break should ever occur in the D₂O outlet pipes (there are two, even though only one shows in the isometric view), the water would drain only to the level of the top of the baffleplates.

The design features and the criteria which dictate the details are discussed fully in the sections to follow. A ready reference of pertinent data is given below.

DATA SUMMARY

I. Heat Transfer and Flow

1.	Operating heat output, kw	5,000
2.	Heavy water flow rate, gpm	2,000
3.	Total D ₂ O to fill system, gal	3,101
	(Inventory should be a minimum of 3% greater)	
4.	Heavy water velocity between fuel plates, ft/sec	11.5
5.	Surface area of active sections of plates, sq ft	196
6.	Average heat transfer, Btu/sq ft hr	87,000
	(Conversion factor 13,272) cal/sq cm sec	6.56
7.	Maximum heat transfer, Btu/sq ft hr	132,000
	cal/sq cm sec	10
8.	Maximum allowable before film boiling,	
	Btu/sq ft hr	≈ 600,000
	(see Figure 12, ANL-4268) cal/sq cm sec	≈ 45

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II. Nuclear Data

1.	Total fuel (U^{235}) loading, gm	1,860
2.	Excess reactivity $\delta k/k$	
	Temperature	0.020
	Xe and Sm equilibrium	0.033
	Xe override ≈ 40 min	0.015
	Burn-up (48 grams)	0.011
	Regulating rod, etc.	0.005
	Total	0.084
3.	Maximum effectiveness of shim-safeties	
	see curve	
	Outer 2 rods in reactor, % $\delta k/k$ per rod	5
	Inner 2 rods in reactor, % $\delta k/k$ per rod	8
4.	Rate of withdrawal of shim-safety, degrees/sec	1/2
5.	Maximum effectiveness of regulating rod, % $\delta k/k$	0.45
6.	Rate of regulating rod movement, in./sec	2.4
7.	Maximum neutron flux, $n\text{ cm}^{-2}\text{ sec}^{-1}$	1.35×10^{14}
8.	Average flux in the core, $n\text{ cm}^{-1}\text{ sec}^{-1}$	8.9×10^{13}
	(See axial and radial flux curves)	
9.	Burn-up, gm/day	6.05
10.	Fuel disadvantage factor	0.78
11.	Equivalent cylinder core diameter and height, in.	36 x 42

III. Reactor Materials and Construction

1.	Fuel assembly, plate type, MJ-1620-E	
	Number in the core	12
	Grams of U^{235} per assembly	155
	Number of 2S clad plates (0.060 in. thick)	10
	Active length, width of U-Al alloy	42 x 2.5
	Number of flow channels per assembly	11
	Cooling flow channel dimensions, in.	0.15 x 2.8
	Over-all length of assembly, ft	8
2.	Type 1 producer assembly, MJ-1902-E	
	Total number of assemblies	134
	Length and diameter	48 x 4.438
	Diameter of assembly, in.	4.5
	Sheath thickness, in.	0.031
3.	Type 2 producer assembly, MJ-1914-F	
	Number in the core	5
	Active length, in.	23
	Capsule, MJ-1920-C	
	Inner container ID, wall thickness,	
	length, in.	0.60 x 0.010 x 2.53

Outer container OD, wall thickness, length, in.		0.75 x 0.061 x 2.75
Material is hafnium-free zirconium		
Bursting test pressure, minimum psi		5,000
Number of capsules per assembly		48
Material of assembly is 61S-T6 Al except capsules		
Over-all length, ft		8
4.	Reactor inner vessel, 2S aluminum	
	Inside diameter, ft	8
	Wall thickness, in.	0.50
	Depth of heavy water, in.	93
5.	Graphite reflector, outside the inner vessel	
	Radial thickness, in.	24
	Thickness under the inner vessel, in. (there is no graphite over the inner vessel)	21-1/4
6.	Thermal shield	
	Boral thickness all around, in.	0.25
	Steel tank thickness outside boral and graphite, in.	0.75
	Lead thickness outside steel tank, in. (Cooled by dual system of water tubes)	4
7.	Top plug thickness, in. (Heavy concrete 250 lb/cu ft)	60
8.	Biological shield, ordinary concrete, ft	7

The design work was divided into sections, and each section given a letter designation. For ease of identifying and specifying components, item numbers were given to instruments, vessels, etc. A complete explanation and listing of these is given in the section "Project Construction Recommendations," subsection "Reactor Design Planning." This will be found on page 191. Familiarity with this system is necessary for detailed study of the flow sheet and many of the installation drawings.

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III. INTERNAL DETAILS

A. Fuel Assembly

The drawing of the fuel assembly is MJ-1620-E. The view at the top of the drawing shows the entire assembly, and the three lower views show the upper and latch subassembly, the fuel section, and the lower extension. Ten plates, made up of an enriched uranium-aluminum alloy clad with 2S aluminum, are furnace brazed into milled side plates. The outer plates, 0.051 inch thick, do not have uranium in them. The length of the alloy "meat of the sandwich" is 42 inches, thus establishing the height of the core. The cooling and moderating heavy water flows up through 0.150-inch slots between the fuel plates at an average of 11.5 ft/sec. Twelve of the assemblies make up the preferred core loading. This number gives 196 sq ft of heat transfer surface of active plates. At 5,000 kw, the average heat transfer rate is 87,000 Btu/sq ft hr, and the peak rate is calculated to be 132,000 Btu/sq ft hr. The maximum to average ratio is estimated by the product of the calculated neutron flux maximum to average in the axial direction (1.176) and that in the radial direction (1.288). It is possible that local conditions of flux distortion may occur due to control rods, etc. However, a maximum heat flux much higher than that calculated is tolerable. ANL-4268, Figure 12 gives experimental results. A maximum allowable heat flux of more than 600,000 Btu/sq ft hr is indicated before film boiling is reached.

The cooling water enters the fuel assembly at the bottom via an orifice through a spherical-shaped seat upon which the assembly rests when in position in the reactor vessel. The inside of the bottom ring of the assembly is a 60 degree cone, and a snug line contact is made all around on the spherical seat. D₂O flows up through the bottom extension, through the slots between fuel plates, and out of the holes in the part marked MJ-1633-C on the assembly Drawing MJ-1620-E. The D₂O flowing out of the assembly mixes with the bulk of water in the tank and eventually moves down back of the baffle plates and out the discharge lines. The water level in the reactor vessel is held at approximately the elevation of the bottom of the spring, marked MJ-1626-A on the assembly. Part MJ-1632-C is drilled to eliminate nonessential aluminum and to allow the inside of the piece to be full of D₂O for reflector effect above the fuel. It can be seen that a small amount of water will be trapped as the fuel assembly is rapidly pulled up out of the water. Small holes are provided in part MJ-1633-C to allow this to drip down over the fuel plates and on out of the bottom.

The upper end of the fuel assembly fits into the grid* which is accurately set on top of the reactor tank; thus the center line is held plumb. A boral disc is seal welded into the bottom of part MJ-1628-B and roughly

* The grid is illustrated and discussed in detail in a later section.

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corresponds with the bottom of the grid where boral occurs. Part MJ-1630-C is square with corners rounded off. This mates with a similar hole in the top of the grid, and thus the fuel assembly does not turn when the "T" bar of the handling coffin rotates to bring the "ears" of part MJ-1629-C into the slots in the sides of the hole in the upper grid plate. What this amounts to is a bayonet lock which is latched by remote control from the coffin. It is necessary to compress the spring, part MJ-1626-A, before the "ears" will rotate into the grid slot. In the locked-in position, the spring exerts 135^{+25}_{-0} lb force pushing the fuel assembly down on its seat at the bottom. This is necessary to resist the force tending to lift the assembly as a result of the upward flow of water. Of course, it is necessary that good line contact be made between the conical and spherical seats while the reactor is running to assure adequate flow rates up between the fuel plates. The spring section also serves to relieve a critical tolerance problem that would otherwise exist in holding relative elevations in the tank, grid, and fuel assemblies. The leeway in the spring compression allows some discrepancy in lengths without impairing the integrity of the seat used. More detailed information will be given regarding the latch end in the section which discusses the coffin and material handling.

B. Type 1 Producer Element

1. Description

The purpose of the producer element, MJ-1902-E, is to afford a means of handling and placing the fertile material in the reactor vessel for irradiation. The loading as planned will include 134 of these elements.

The fertile producer material must be sealed in a jacket to prevent the diffusion of radioactive particles into the heavy water and also to prevent corrosion. This jacket is indicated as part MJ-1907-B on the reference drawing. It is a 2S aluminum, 1/32-inch wall can. The upper end (left of center on the drawing) is closed as shown by heliarc welding in a disc and support rod, marked MJ-1905-B, before the material is put into the jacket. The weight is supported during handling with the center line in a vertical position by the support rod anchored in the fertile metal, and the suspension rod which is marked MJ-1906-B carries the load up to the top end casting MJ-1903-C. This casting is an adapter which allows the producer element to be handled by the "T" bar of the coffin similar to that mentioned for the fuel assembly. It differs in that it is not necessary to lock the element down if it has sufficient weight to stay down even though the water pressure tries to push it up. In assembling the type 1 producer, the suspension rod is threaded into the support rod and made tight by using a wrench on the milled flats at the lower end. The subassembly of the guide tube, MJ-1908-B, and the top casting, MJ-1903-C, is then put in place with the suspension rod protruding up through the casting. The nut is run on

MJ-1902-E

NOTES

1. COMPLETED ASSEMBLY MUST BE STRAIGHT TO WITHIN $\pm 1/8$ OF A INCH CENTERLINE & MUST BE ABLE TO PASS THRU A 4.931 DIA. CYLINDRICAL GAGE 12" LG.
2. ALL SEAL WELDS MUST BE PROVEN TIGHT BY AN ACCEPTABLE METHOD OF LEAK TESTING.
3. COMPLETED ASSEMBLY MUST BE FREE OF GREASE AND OTHER FOREIGN MATERIALS.
4. NO ABRASIVES, ABRASIVE PAPERS, OR GRINDING WHEELS CONTAINING BORON CARBIDE MAY BE USED AT ANY TIME IN THE MANUFACTURE OF THE COMPONENTS OF THIS ASSEMBLY.

ANL-RKW-1902

ANL-RKW-1902

REV.	DATE	BY	CHKD.	APP'D.	DESCRIPTION
1	10/15/54	WAS	34		
2	10/15/54	WAS	17		
3	10/15/54	WAS	21		
4	10/15/54	WAS	26		
5	10/15/54	WAS	26		
6	10/15/54	WAS	26		
7	10/15/54	WAS	26		
8	10/15/54	WAS	26		
9	10/15/54	WAS	26		
10	10/15/54	WAS	26		
11	10/15/54	WAS	26		
12	10/15/54	WAS	26		
13	10/15/54	WAS	26		
14	10/15/54	WAS	26		
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98	10/15/54	WAS	26		
99	10/15/54	WAS	26		
100	10/15/54	WAS	26		

ANL-RKW-1902

PRODUCER ROD ASSY

SCALE: FULL

DATE: 10/15/54

BY: WAS

CHKD: 26

APP'D: 26

ANL-RKW-1902-E

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carefully and tightened with a torque wrench. A wrench can be inserted through the hole in the guide tube opposite the flats at the top of the suspension rod. Care must be taken to avoid buckling the guide tube by excessive torque on the nut. The guide tube only serves to keep the section and the top casting aligned. It does not handle any of the load. Aluminum is held to the minimum in the producers and the fuel assembly for a very specific reason. D_2O has a very low neutron capture cross section, and, as designed, aluminum is the principal "poison" in the reactor, even though it is normally thought of as having a relatively low neutron capture cross section. This may not be true for all types of isotope production and changes can be made in the core details as required for whatever material irradiation is being considered. To attain high flux in the type 2 producer assemblies, and thus a minimum inventory in the capsules for the required production, it is necessary to hold the critical mass down because flux is proportional to specific power, kw/kg, if a maximum limit of 5,000 kw is placed on the power. This was the reason that such light sheet metal design was used in the element, i.e., the critical mass could be held low only by minimizing the aluminum poison. It is planned that the type 1 producer element will be handled strapped to a channel or otherwise protected from bending stresses except when being handled in a vertical position. The design is quite strong when handled by the loading and unloading coffin. A prototype has been fabricated, and it seems satisfactory. Part MJ-1910-B is anchored into the producer material to take the stress that can be imposed by the bottom extension, MJ-1909-C, and thus avoid possible trouble that might occur at the weld if the bottom extension had been attached by welding directly to the 1/32-inch wall aluminum jacket which sheaths the producer material. Notice that the bottom seat of the producer is a spun piece of aluminum sheet. This seat seals off the water flow at the position where such an element is placed, and by so doing the flow is diverted to the fuel assemblies, which are the only elements that are open at the bottom.

C. Type 2 Producer Assemblies

Five assemblies, MJ-1914-F, were in the planned loading which is illustrated in MJ-1010-F. The reduced reproduction of this drawing will be found on page 9. The lower extension piece, marked MJ-1911-C on the assembly drawing, is a sheet metal piece having a spun sheet metal conical seat at the bottom similar to the bottom of type 1 producer element. This also seals off the orifice ball seat in the tank so that all flow is diverted to the fuel assemblies, i.e., water does not flow up through the type 2 assembly. The top of piece MJ-1911-C and the bottom of piece MJ-1913-C are spun to a smaller diameter than that of the tubes from which they are fabricated, and six holes are bored to receive the six small tubes marked MJ-1912-B. The small tubes are heliarc welded into the holes in the larger tubes. The small tubes have slots cut out to make entries for the capsules, which will be discussed further along. The detail of the small tubes, MJ-1912-B, shows the 1/4 x 1 inch slots for free movement of water around the capsules

MJ-1914-F
MIL-STD-1914

NOTE —
ASSEMBLY MUST BE STRAIGHT TO WITHIN $\pm \frac{1}{16}$ OF MEAN
CENTERLINE. C MUST PASS THRU A 4.531 DIA CYLINDRICAL
GAGE 12" LONG
NO ABRASIVES CONTAINING BORON CARBIDE MAY BE
USED IN THE MANUFACTURE OF THIS ASSEMBLY

NL-RW-1914

REV	DATE	DESCRIPTION	BY	CHKD	APP'D	REMARKS
1	10/1/54	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4
2	10/1/54	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4
3	10/1/54	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4
4	10/1/54	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4
5	10/1/54	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4
6	10/1/54	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4
7	10/1/54	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4
8	10/1/54	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4
9	10/1/54	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4
10	10/1/54	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4	WAS 50 3/4

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which will be stacked in the tubes; the diametrical clearance between the ID of the tubes and OD of the capsules is $1/8$ inch. The top of the assembly is a spring and latch arrangement, the same as that described for the top of the fuel assembly with one exception. The relation between the ears and the topmost slot in part MJ-1629-C is 90° different from that of the like part on the fuel assembly. This will make it difficult to inadvertently substitute a fuel assembly for a producer assembly because the tee latch of the fuel assemblies must be rotated 90° from the other two types of assembly, and the coffin tee bar will not handle a fuel assembly in sequence with a producer assembly. The sheet metal parts of the type 2 assembly are made of 61S-T4 aluminum.

The drawing of the capsule is MJ-1920-C. This is made of hafnium-free zirconium. This material is used for two reasons. First, it is necessary to use a material with very low cross section to avoid neutron flux depression inside the capsule. This, of course, is extremely important because of its effect on the inventory. Second, the compound and gas in the capsule become very hot, and the compound tends to decompose owing to the heat and radiation damage. This gives a considerable pressure in the container and, hence, the little pressure vessel must be strong. The microscopic cross section of aluminum is 0.22 barn and its atomic density is 6.02×10^{22} atoms/cc, whereas the microscopic cross section of zirconium is 0.18 barn and its atomic density is 4.28×10^{22} atoms/cc. Thus, volume for volume zirconium is 1.7 times as good, absorption-wise, as aluminum. Also, the allowable working stresses are considerably higher for zirconium as compared to aluminum alloys that are low in neutron absorption properties..

The container design, MJ-1920-C, consists of an inner and an outer can. The inner one has a 0.010-inch wall thickness and does not maintain pressure difference from the inside to the outside. A sintered filter disc is spun into the bottom of the inner container, and the 0.010-inch walled cap is pushed on the tapered end. As will be noticed on the drawing, the outer container is 0.750 inch in outside diameter with a $1/16$ -inch wall. When the capped inner can is in place in the outer one, the end plug is pushed into the open end, and the edge of the plug and the tube end are fusion welded by the heliarc process. It will be noticed that the two edges being welded are the same thickness, giving a good condition for this type of weld. Also, no flux is involved which would give inclusions in the weld.

In the development of these zirconium capsules, the ability of the shop to produce consistently strong welds and consistently strong cans was questioned. To answer this question 7 containers were made from hafnium-free zirconium with a small protruding tube machined on the end opposite the weld. High-pressure couplings were installed on these tubes, and a hydraulic test to destruction was performed on these samples. Figure 1 illustrates the test capsules and the typical failure that occurred.

MJ-1920-C

FILTER DISC (MATERIAL TO
BE DETERMINED BY ENGINEER)

CONTAINER ASS'Y
FILL AS SPECIFIED
SCALE - FULL

CAPSULE FOR TYPE 2
PRODUCER ASSEMBLY

-A-
WELD MUST BE MECHANICALLY SOUND AND
PROVEN LEAKPROOF BY AN ACCEPTABLE
TESTING PROCEDURE

DESIGN FILED		APPROVED ENGINEER		DATE	CHIEF ENGINEER	DATE	TEST ASSEMBLY	NO. REQUIRED
		WINKLER, K.W.		7/1/52	CARVER	7/1/52	ARGONNE NATIONAL LABORATORY	
		TOLERANCES UNLESS OTHERWISE NOTED: FRACTIONAL & WH. DECIMAL & WH. ANGLES & UP RESERVE ALL DIMS.						TITLE
		MATERIAL						SCALE
		HAFNIUM FREE ZIRCONIUM						2"=1"
								DRWG. NO.
								MJ-1920-C

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Figure 1 CAPSULE TEST PIECES

Container	I.D.	<u>O.D.</u>	<u>Pressure</u>	<u>Failure</u>
1	0.625 inch	0.745 inch	7,200 psi	Weld failed
2	0.625 inch	0.745 inch	5,000 psi	Weld failed
3	0.625 inch	0.745 inch	5,800 psi	Weld failed
4	0.625 inch	0.745 inch	6,300 psi	Weld failed
5	0.625 inch	0.745 inch	5,800 psi	Weld failed
6	0.625 inch	0.745 inch	9,000 psi	Weld failed

A heavy-walled aluminum capsule was designed and tested. Bursting test pressures on that type capsule were between 500 and 900 psi. These capsules had more free volume than the MJ-1920-C design. One of these capsules was filled with the material to be irradiated in type 2 producers and irradiated in the Materials Testing Reactor; it did not develop enough pressure to give trouble. The conclusion from the tests is that the capsule design is satisfactory provided that careful quality control is maintained during the manufacture. The method of striking the arc seems to be important in making the weld. It is struck at the center of the plug and then rapidly moved to the joint. A smooth, high-quality weld is essential. The welding technique must be proved by the individuals doing the welding. It is also advisable to destructively test samples run through periodically during the production. The need for a very careful leak check is apparent. This leak test must be in accordance with a technique developed and approved by the organization operating the reactor.

D. Reactor Inner Vessel

The reactor tank is a vessel which requires more mechanical precision and care in fabrication than is normally expended on a tank. Concentricity, squareness, flatness, and alignment of critical holes are carefully specified on the drawings. However, effort has been put forth to make the tolerances on these features within the range of practical fabrication techniques, and the vessel can be made economically. MJ-1101-E is the assembly drawing of the vessel.

The tank part of the vessel assembly is illustrated on MJ-1102-E. It will be noticed that the bottom is held flat and true and that the weld, where the wall and the bottom is joined, is four inches up the side. This tank will sit on the bottom graphite reflector. Detail A, section A-A, B-B, and C-C on MJ-1102-E give the details of the D₂O level control. It consists of two slots, 1.5 by 8 inches, and one slot, 1.5 by 7 inches, and a box the depth of which will afford enough head to flow approximately 100 gpm through the 3-inch overflow pipe. The capacity of the D₂O fill pump is 100 gpm, and the high capacity overflow makes it unimportant whether the fill pump is turned off at just the proper time. The four long bosses for the shim-safety rod drive shafts can be seen on the drawing. The 6.375-inch hole in the side of the tank will have the regulating rod sheath mounting flange welded in during

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installation. The small 13/16-inch hole farther down is for the liquid level indicator tube. The plenum chamber plate, marked MJ-1103-E on the assembly drawings, will be bored with, or otherwise made to accurately match up with, the counterbored holes in the bottom of the vessel.

The support pieces, MJ-1106-C, and the shorter supports, MJ-1107-C, are welded into the counterbored positions in the bottom of the vessel and also seal-welded to the plenum chamber plate, MJ-1103-E. Although the assembly drawing does not show the detail of this weld, it should be mentioned that a groove is milled around each hole in the plenum chamber plate, leaving a thin-wall ring next to the support tube for the sake of a good weld; i.e., the heavy plate would be difficult to weld to the thin-walled tube, and the groove relieves this troublesome difference in sections. The inlet pipe is installed before the diffuser plate assembly and the plenum chamber plate are put in place. The incoming D_2O hits the diffuser plate and is slowed down to give a tendency toward uniform pressure throughout the plenum chamber. When producer assemblies are in place, as shown on MJ-1010-E near the front of the report, the openings in the spherical seat (top) of the supports are effectively capped off, and all of the heavy water flows up through the supports that have fuel assemblies resting on them. Section A-A of the assembly drawing shows the method of installing the baffle plates, MJ-1104-D, which form the flow path for the discharge water to reach the two outlet holes near the wall in the bottom of the tank. Notice that the water in the tank can not be drained lower than the top of the baffle plates via the discharge outlets. The top of these baffles is at an elevation slightly higher than the top of the active fuel section of the fuel assemblies. The small plates, MJ-1122-B, near the top of the vessel are deflectors to guide the shim-safety rods as they are lowered into place through the top plug and grid.

E. Reactor Upper Grid

An upper grid, MJ-1117-D, rests on and is accurately doweled to the top flange of the reactor inner vessel described above. The purpose of this grid is threefold. First, it positions the upper ends of the fuel and producer assemblies. Second, it carries the bearing brackets for the four swing-type shim-safety rods. Third, the bottom of the grid, in conjunction with the boral sections of the fuel and producer assemblies, serves as a poison plate to eliminate changes in reactor reactivity due to the turbulent surface of the D_2O which serves as the top neutron reflector of the reactor. The "poison" in the bottom plate is boron carbide, which serves the additional purpose of reducing the gamma intensity that hits the top shield plug above the grid. The boron absorbs thermal and epithermal neutrons in an (n, α) reaction. The resultant 4-Mev alphas are stopped by the material of the plate, causing soft X rays and heat. If the boron did not catch the thermal neutrons, the aluminum of the grid and the steel of the top plug would catch them by an (n, γ) reaction. The gamma produced by neutron capture

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MJ-1117-D

PLAN VIEW OF GRID ASSEM.
SCALE 1"=1'-0"

SECTION A-A
SCALE 1/4"=1"

WELD NOTE:
ALL WELDS INCASED 1/8" ORAL TO BE
GAS TIGHT AFTER ASSEMBLY IS COMPLETED.

REV	DATE	BY	CHKD	APP'D	DESCRIPTION
1	11-10-50	EL			GRID ASSEM.-TANK
2	11-10-50	EL			GRID ASSEM.-TANK
3	11-10-50	EL			GRID ASSEM.-TANK
4	11-10-50	EL			GRID ASSEM.-TANK
5	11-10-50	EL			GRID ASSEM.-TANK
6	11-10-50	EL			GRID ASSEM.-TANK
7	11-10-50	EL			GRID ASSEM.-TANK
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99	11-10-50	EL			GRID ASSEM.-TANK
100	11-10-50	EL			GRID ASSEM.-TANK

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in aluminum is a very hard ray, about 7 Mev, and the gamma from capture in iron is also quite energetic. Thus, these gammas are to be avoided because they would increase the necessary thickness of the top plug, and the plug would have to be cooled. By stopping a high percentage of the neutrons in the boron in the bottom of the grid, this cooling problem is avoided, since the water level is high enough in the tank to cover the poison plate.

MJ-1117-D is the assembly drawing of the grid. The top plate, MJ-1119-E, is 3.5 inches thick and is the load-carrying member of the assembly. The four 11-inch holes for mounting the shim-safety rod bearing brackets can be seen. There are 151 holes, 4-9/16 inches square, for locating the elements, but all of them are not drawn in since all four quadrants are the same. Section C-C shows the typical detail of the milled slots which serve as locks for the ears of the hold-down latch on the top of the fuel elements. The assembly drawing gives a view of the slot recesses where the shim-safety rods are located when they are in the up position and the reactor is running. MJ-1111-B is a detail of one of the pieces which make up the bottom plate. To fabricate this, a strip of boral is wrapped in a 1/8-inch thick, 2S-O aluminum sheet by bending the aluminum to form a narrow "U." The open end of the "U" is tack welded to hold the boral in place. The holes are then punched or bored through both the aluminum and boral. Short lengths, 3/4 inch, of 4-21/32 ID tubing are then pressed into the holes and seal-welded by the heliarc method. The edge seal-weld is completed next. A small aluminum tube is welded into the aluminum sheath to facilitate testing. After a suitable test demonstrates the fact that the weldment has no leaks, the little tube is cut off, and the hole is very carefully welded shut. The other details of the bottom plate are necessarily of different shapes in plan view, but the same type of fabricating technique can be used.

F. Shim-Safety Rods and Mechanisms

The shim-safety rods are patterned after the swing-type rods which have proved successful in CP-3. Duplication of the mechanical design was not advisable because greater than one "G" accelerating force is desirable. These rods are also much heavier and longer than the CP-3 rods and therefore have higher inertia and require considerable force to rapidly accelerate the rods into the reactor. The large spring force required a larger magnetic clutch to carry the load. Accompanying the clutch is a substantial increase in moment of inertia. It is intended that the entire shim-safety assembly will be mocked up and tested in a mechanical laboratory at Argonne before it is installed in the reactor. The tank end of the drive shaft assembly will be raised to simulate actual anticipated bearing mounting movement, etc.

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The complete installation of the shim-safety mechanism is shown on MJ-1437-E. This is subdivided into four main subassemblies and several minor subassemblies.

MJ-1369-F, Drive Mechanism Assembly
 MJ-1418-E, Position Data and Shock Absorber Assembly
 MJ-1420-D, Position Data Assembly
 MJ-1360-C, Shock Absorber Assembly
 MJ-1367-F, Drive Mechanism Assembly
 MJ-1368-D, Shim-Safety Rod Assembly

1. Shim-Safety Control Rod Drive Mechanism Assembly,
 MJ-1369-F

The support bracket for the drive mechanism is clamped to the reactor face and holds the drive motor and allied equipment. The drive mechanism is essentially three telescoping cylinders held together by means of a ball screw and nut and a latching mechanism. Trunnion blocks fastened in slots in the support bracket hold the center cylinder. The trunnions allow for flexibility in movement during operation. A ball bearing secured in the outer cylinder supports the ball screw and nut, which is fastened to the intermediate cylinder, which carries the inner cylinder and the solenoid-operated latch mechanism. A roll pin latch locks the inner cylinder to the intermediate cylinder when the toggle linkage is operated by the solenoid. A floating piston and sleeve, that limits the compression of the light duty spring, provide the thrust to accelerate the inner cylinder when the latch mechanism is de-energized by a signal from the scram circuit. The heavy spring delivers a maximum force of 2600 lb at the beginning of the stroke. After a travel of approximately 1-1/4 inch, the light spring takes over and applies a force of 330 lb which diminishes to zero at the end of the stroke. The lower end of the inner cylinder is attached to the shim-safety rod bell crank by means of a fulcrum pin. After the rod has been scrammed, the mechanism can be recocked by lowering the intermediate cylinder over the inner cylinder until the springs are compressed and the motion is stopped by the "in-travel" limit switch, which is set slightly lower than the switch that energizes the latch solenoid. Adjusting screws permit fine adjustment of movement for these switches and for the out travel limit switch.

After the solenoid has been energized, the pawl and latch are in a fixed position; the shim-safety rod can be raised or lowered by the same reversible motor and ball screw that is used to compress the springs. A universal joint between the ball screw and the motor drive shaft allows for freedom of movement during the operation of the mechanism. Rotation of the intermediate cylinder is prevented by lugs bearing on guide ways on the position data and shock absorber bracket. Terminal strips are provided for convenience in wiring the electrical equipment.

MJ-1437-E

RIGHT HAND AS SHOWN
LEFT HAND OPPOSITE

[illegible]

49

MJ-1360-C

MIDWEST FILM STAMP				DESIGNED BY		DATE	CHECKED BY		DATE
				DRAWN BY		DATE	APPROVED BY		DATE
				STAMP APPROVAL		DATE	REVISIONS		DATE
				REPRESENTATIVE		DATE	BY		DATE
				NICKOL		DATE	J. SCHIEBER		4-16-52
				TOLERANCES UNLESS OTHERWISE NOTED:			TITLE		
				FRACTIONAL: 1/16, 1/8, 3/16, 1/2, 5/8, 3/4, 1			SHOCK ABSORBER		
				MATERIAL			SCALE		
				SEE MJ-1360 B/M			FULL		
				DATE			DWG NO.		
				CHANGE			MJ-1360-C		

53

MJ-1368-D

MJ-1367-F		ONE
ARGONNE NATIONAL LABORATORY		REV. 10/19/52
TITLE: SHIM SAFETY ROD ASSEMBLY		SCALE: FULL
DATE: 10/19/52		DESIGNER: MJ-1367-B/M
CHECKED: MJ-1367-B/M		APPROVED: MJ-1367-B/M
TOLERANCES UNLESS OTHERWISE NOTED:		
FRACTIONS: 1/16, 1/8, 1/4, 3/8, 1/2, 5/8, 3/4, 7/8, 1		
DIMENSIONS: 1/16, 1/8, 1/4, 3/8, 1/2, 5/8, 3/4, 7/8, 1		
MATERIAL: S.S. MJ-1367-B/M		

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2. Position Data Transmitter and Shock Absorber Assembly, MJ-1418-E

The support bracket for the position data transmitter and shock absorber is fastened to the reactor face. It carries the shock absorber, MJ-1360-C, and the position data transmitter, MJ-1420-D, and associated parts. Located on the transmitter plate is the gearing and Selsyn for locating the position of the shim-safety rod. Thirty-five degrees of movement of the rod corresponds to one revolution of the Selsyn. Since approximately two revolutions of the Selsyn are required to cover a full stroke of 56 degrees, compensating features are built into the position indicator dial. This is accomplished by means of a cam and micro switch to control the bank of lights that indicate the position of the rod. The transmitter plate also carries the micro switch that limits the amount of withdrawal of the rod during initial start-up of the reactor. The upper and lower stops for the shim-safety rods are also fastened to the bracket. These stops can be changed if critical test work indicates that full travel should be nearer to 50 degrees below horizontal.

3. Shock Absorber, MJ-1360-C

The shock absorber consists of a piston and a cylinder partially filled with oil. It can be divided into two sections. The upper or larger section consists of a taper plunger whose tip is immersed in oil when at the top of its stroke. The lower or smaller sections consist of a smaller straight piston that has a clearance of less than one thousandth of an inch when the piston is injected into its cylinder. A spring maintains and returns the plunger against the cover when not in operation. When the shim-safety is dropped during a scram of the reactor, the roller, secured to the inner cylinder of the drive mechanism, strikes against the plunger and forces the piston into the cylinder, thus displacing the oil, causing it to flow in the annulus between the piston and cylinder. As the plunger penetrates deeper into the cylinder, the tapered section decreases the annulus, thus increasing the resistance to the flow of oil. The energy acquired during the fall of the rod is thus dissipated into kinetic energy and heat. Calculations indicate that the upper section is capable of exerting a force greater than fourteen hundred pounds or an equivalent pressure of 800 psi in the cylinder. When the lower section of the plunger enters into its cylinder, the oil trapped in the cylinder is forced through a small hole into a connecting hole that leads to the upper cylinder. This section is capable of exerting a force of 1200 lb or an equivalent pressure of 1600 psi in the cylinder. Thus, at the lower end of the stroke, the combined load is greater than 2200 pounds. A unique feature of this design is its ability to absorb the energy from the drop of the rod at its maximum stroke; or from a minimum stroke of a sixteenth of an inch.

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4. Drive Shaft Assembly, MJ-1367-F

The drive shaft assembly, MJ-1367-F, shows the method for connecting the drive mechanism to the shim-safety rod. The rod is supported by ball bearings mounted to plates secured in the cover of the top grid. The shim rod clamping sleeve has a splined hole to receive the end of the drive shaft. The other end of the drive shaft is supported by a spherical bearing that is secured in a bracket which fastens to a shield sleeve at the reactor face. Surrounding the shaft is a housing that is supported by the aluminum vessel at the inner end and by a spherical bearing at the outer end. The spherical bearings compensate for more than $1/4$ inch of movement of the aluminum vessel during the operation of the reactor. A steel ring surrounding the shaft and the removable plugs surrounding the housing protect personnel against the hazard of radiation. A series of "O" rings and shaft seals, located back from the high radiation, prevents the escape of helium gas. The bell crank lever shown on the drawing connects to the lower end of the inner cylinder of the drive mechanism.

5. Shim-Safety Rod, MJ-1368-D

The construction of the shim-safety rod is shown by MJ-1458-D and 1368-D. MJ-1458-D shows the method for inserting the cadmium between aluminum tubes. The layer of cadmium is 0.020 inch thick and extends back 79 inches from the tip of the rod. MJ-1368-D shows the rod mounted to the splined sleeve.

Physical characteristics are as follows:

Weight	36-1/2 lb
Center of Gravity	2.17 ft from fulcrum point
Moment of inertia	364 lb ft ²
Length, over-all	87 in.
Width	7 in.
Thickness	1 in.

6. Time Response

Figure 2 shows the space-time characteristics for the shim-safety rod when scrambled from 4 degrees below horizontal, which is indicated as zero travel. The torque curve is a maximum at the start of the drop. It is better than 900 ft-lb and is produced from a spring force of 2600 lb plus gravity. After a travel of 17 degrees, or approximately 1.25 inch, the light spring takes over and applies a force of 330 lb which diminishes to zero at the end of the stroke. The torque at the start of the light spring is approximately 50 ft-lb. The torque is zero after a rod travel of 26 degrees. It then decreases at a slight rate until the rod strikes the shock absorber.

DRILL + REAM THRU 6 HOLES
EQUALLY SPACED LOCATE IN
ASSEM. WITH MJ-1458-B & MJ-1458-C

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Figure 2

RE.7. 11003 A

The maximum torque applied by the shock absorber is 700 ft-lb. The angular velocity increases rapidly for the first 8 degrees, reaching a maximum of 5 radians per second after traveling 25 degrees. The angular velocity is practically constant for the next six degrees or until the shock absorber is actuated. The decrease in velocity is rather abrupt when both shock absorber sections are actuated.

Figure 3 shows a comparison of the space-time diagrams for the shim-safety rods and a simulated rod which was tested. Two curves are for the simulated rod. One is obtained from a series of tests reported in ANL-4897, and the other is a calculated curve for the same rod. These are shown to give a comparison for the actual designed rod. The calculated curve assumes a coefficient of drag of 1.2 for the rod when drawn through water. This is evidently too low, as shown by a comparison of the test with the calculated curve for the simulated rod. During normal operation of the shim-safety rod, the torque required to raise the rod varies from 40 to 80 ft-lb, which is equivalent to 0.002 and 0.004 in.-lb respectively at the motor shaft. The torque required at the ball screw to raise 2500 lb is approximately 90 in.-lb. This is equivalent to 0.62 lb-in. at the motor shaft. The maximum drive speed for the shim-safety rod is 0.6 degree per second and the slowest is 0.3 degree per second.

G. Regulating Rod and Mechanism

The over-all design of the regulating rod is best illustrated on MJ-1500-F. The sheath, MJ-1554-C, surrounding the rod becomes an integral part of the reactor vessel. It is located at the center line of the reactor and is displaced 2-15/16 inches from the vertical center line and penetrates to within 18 inches of the center of the core. Ample clearance has been provided in the design for expansion and movement of the reactor vessel. A flexible bellows connection, MJ-1551-C, is secured by flanges to the aluminum vessel and the steel tank. The function of this connection is to provide for relative motion between the steel tank and aluminum vessel and to contain the heavy water in case the sheath should become ruptured. Such a leak is highly improbable.

The regulating rod bearing housing, MJ-1552-C, is attached to the shielding liner, MJ-1548-C, that extends from the steel tank to the reactor face. The bearing housing supports the bushing which in turn supports the regulating rod. The inner bushing is graphite, while the outer one is bronze, which will withstand a greater thrust load and act as the "in" position stop. The shielding plug, MJ-1549-D, and bearing housing are constructed to facilitate insertion and removal of the regulating rod. Special hand tools will be required to facilitate this operation. These tools have not been drawn.

Figure 3

TIME RESPONSE FOR SHIM-SAFETY ROD SCRAM

RE-7-11002-A

[illegible]

Technical drawing of a Sheath Rod assembly, showing a side view and a top view.

Side View Dimensions:

- Overall Length: $30 \frac{13}{16}$
- Overall Diameter: 4.656 DIA
- Inner Diameter: 4 DIA
- End Flange Thickness: $\frac{1}{16}$
- End Flange Outer Diameter: 6.373 DIA (6.370 tolerance)
- End Flange Inner Diameter: $\frac{1}{16}$
- End Flange Hole Diameter: $\frac{1}{16}$
- End Flange Hole Spacing: $5 \frac{1}{16}$ B.C.
- End Flange Hole Diameter: $\frac{17}{32}$ DRILL THRU
- End Flange Hole Diameter: $\frac{17}{32}$ DIA C-BORE
- End Flange Hole Spacing: 6 HOLES EQUALLY SPACED ON $5 \frac{1}{16}$ B.C.
- End Flange Hole Diameter: $\frac{17}{32}$ DIA
- End Flange Hole Spacing: $5 \frac{1}{16}$ B.C.
- End Flange Hole Diameter: $\frac{17}{32}$ DIA
- End Flange Hole Spacing: $5 \frac{1}{16}$ B.C.
- End Flange Hole Diameter: $\frac{17}{32}$ DIA
- End Flange Hole Spacing: $5 \frac{1}{16}$ B.C.

Top View Dimensions:

- Overall Diameter: 4.656 DIA
- Inner Diameter: 4 DIA
- End Flange Thickness: $\frac{1}{16}$
- End Flange Outer Diameter: 6.373 DIA (6.370 tolerance)
- End Flange Inner Diameter: $\frac{1}{16}$
- End Flange Hole Diameter: $\frac{1}{16}$
- End Flange Hole Spacing: $5 \frac{1}{16}$ B.C.
- End Flange Hole Diameter: $\frac{17}{32}$ DRILL THRU
- End Flange Hole Diameter: $\frac{17}{32}$ DIA C-BORE
- End Flange Hole Spacing: 6 HOLES EQUALLY SPACED ON $5 \frac{1}{16}$ B.C.
- End Flange Hole Diameter: $\frac{17}{32}$ DIA
- End Flange Hole Spacing: $5 \frac{1}{16}$ B.C.
- End Flange Hole Diameter: $\frac{17}{32}$ DIA
- End Flange Hole Spacing: $5 \frac{1}{16}$ B.C.

Notes:

- GASKET SURFACE FLAT WITHIN .005
- NO RADIAL TOOL MARKS OR SCRATCHES
- TOLERANCES UNLESS OTHERWISE NOTED:
- FRACTIONAL $\pm .001$ DECIMAL $\pm .001$ ANGLES $\pm .1^\circ$
- REMOVE ALL BURRS

Material: 25 ALUMINUM

Scale: FULL

Drawing No.: MJ-1554-C

Revision: ONE

Argonne National Laboratory

Sheath - Rod

Approved: [Signature]

Checked: [Signature]

Drawn by: E.A. KUPKA

Scale: FULL

Drawing No.: MJ-1554-C

Revision: ONE

Argonne National Laboratory

Sheath - Rod

MJ-1551-C

MICRO FILM STAMP				APPROVED CONECT				DATE	CHIEF ENGINEER	DATE	MJ-1500-F	1	
				STAFF APPROVAL				DATE	CHIEF ENGINEER	DATE	ARGONNE NATIONAL LABORATORY	NO. REQUIRED	
				RECOMMENDATION				DATE	CHIEF ENGINEER	DATE	THIS DRAWING IS THE PROPERTY OF THE ARGONNE NATIONAL LABORATORY		
				D. NICOLL				DATE	CHIEF ENGINEER	DATE	TITLE FLEXIBLE CONNECTION ASSEMBLY		
				TOLERANCES UNLESS OTHERWISE NOTED:									
				FRACTIONAL $\pm$ 1/16									
				DECIMAL $\pm$.005									
				ANGLE $\pm$ 1/2°									
				REMOVE ALL DIMS									
				MATERIAL									
				SEE MJ-1500-B/M									
				SCALE									
				HALF									
				DRWS NO									
				MJ-1551-C									

1. Regulating Rod

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The regulating rod and detail, MJ-1553-C and MJ-1563-C, consists of 1/32-inch thick Cd tubular section enclosed between two stainless steel tubes. The rod has a rectangular cross section 2-1/8 inches high by 3/8 inch wide with 3/16 inch outside radius for the corners. The tip of the cadmium extends within 18-13/16 inches of the center of the core when "full in." The absorbing section extends a distance of 28 inches and reaches to the aluminum vessel wall. The length from the flange or stop for "full in" position is 55-3/4 inches. The outer or drive section of the regulating rod assembly has a coupling device that allows the drive to be separated. The coupling device consists of a tapered male shaft fastened to the rod and a female sleeve and ball coupling arrangement secured in the drive shaft section. Locking and unlocking of the device is performed at the face of the reactor by means of a handle (see MJ-1501-F Drive Assembly and MJ-1543-C Gear Case Cover Assembly). Turning the handle clockwise engages the rod; turning counterclockwise disengages the rod. Motion from the handle is transmitted through compound gearing to a gear and shaft (marked MJ-1527-B on the assembly MJ-1501-F) that extends from the ball screw. The inner end of the shaft fits into a female spline which permits sliding of the ball nut and drive rod during operation. The inner end of the female spline engages a male member of the shaft that operates the nut for raising or lowering the ball housing sleeve, MJ-1536-B. When the sleeve is raised, the balls can be forced into a larger diameter, thus disengaging the regulating rod from the drive rod whenever necessary to remove the drive mechanism or control rod.

2. Drive Mechanism

MJ-1501-F illustrates the assembly of the drive mechanism and the transmitter system for the indication of rod position. The drive mechanism consists of a direct current, shunt-wound, 1/15-HP, 1725-rpm motor directly coupled to a bevel gear drive. The gear is keyed to the ball screw shaft, which is supported by a ball bearing retained in the gear housing. The ball screw engages a nut that is secured to the operating rod. The casing enclosing the rod serves as a keyway and contains the bearings. An oil seal pressed into the gear casing prevents leakage of oil past the ball screw. A secondary oil wiper confines the smear of oil from escaping beyond the bearing section.

A spur gear pinion secured to the ball screw shaft drives a reduction gear and worm for the operation of the Selsyn and micro switch cams. The function of the cam and limit switch housing, MJ-1545-D, is to enclose the unit and provide means for securing micro switches for the electrical interlocks of the control system. Six micro switches are secured in the housing. The cams operate the switches and are adjustable with respect to each other. This will allow a change in normal operating position

A SURFACES MUST BE CONCENTRIC, PARALLEL, FLAT, SQUARE AND TRUE (AS APPLICABLE) TO EACH OTHER WITHIN .002 FULL INDICATOR READING.

MJ-1501 F

MJ 1500 F		1
ASSEMBLY NATIONAL LABORATORY		
REGULATING ROD DRIVE ASSEMBLY		
SEE MJ-500 B/M		
MJ-1501 F		

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REGULATING ROD ELECTRICAL CONNECTION SCHEDULE

AMPHENOL CONNECTOR				
INSERT NO. 24-7		INSERT NO. 24-19		
INSERT CONNECTION	TERMINAL CONNECTION STRIP NO.	CONNECTION	TERMINAL STRIP NO.	
A	MOTOR FIELD	1	SELSYN STATOR	17
B	MOTOR FIELD	2	SELSYN STATOR	18
C	IN LIMIT SWITCH	3	SELSYN STATOR	19
D	IN LIMIT SWITCH	4	SELSYN FIELD	20
E	LIGHT SWITCH COMMON	5	SELSYN FIELD	21
F	WITHDRAWAL SWITCH	6	TACKONETER	22
G	WITHDRAWAL SWITCH	7	TACKONETER	23
H	WITHDRAWAL SWITCH	8		
I	LIGHT SWITCH	9		
J	LIGHT SWITCH	10		
K	INSERTION SWITCH	11		
L	INSERTION SWITCH	12		
M	OUT LIMIT SWITCH	13		
N	MOTOR ARMATURE	14		
O	OUT LIMIT SWITCH	15		
P	MOTOR ARMATURE	16

MJ-1545-D

WORK-FILE NUMBER		APPROVED SERIAL		DATE	RECEIVED BY	TIME	MJ-1501-C 1
							MOST ACCURATELY NO.
		NAME D. J. [unclear]		DATE 1/25/48	BY [unclear]	TIME 6:52	ARGONNE NATIONAL LABORATORY THIS DELIVERED IN THE PROPERTY OF THE U.S. NATIONAL LABORATORY
		ADDRESS 6000 [unclear]		CITY E. A. RUMBA	STATE ILL.	TIME 7:25	THIS CAN AND LIMIT SWITCH HOUSING ASSEMBLY
		TOLERANCES UNLESS OTHERWISE NOTED FRACTIONAL 2 IN. DECIMALS 2 DIG. ANGLES 2 IN.					
		REMOVE ALL BURRS					
		SEE MJ-1500-B/H					
DATE	TIME	CHANGE	DATE	BY	INITIALS	SCALE	FINAL MJ-1545-D

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 DRAWING NO.
 MJ-1577-B

MICRO FILM STAMP		SYN.		ZONE	CHANGE	DATE	BY	CHE	APPROVED CONST.	DATE	CHIEF DRAFTSMAN	DATE	MJ-1544-C	1
									STAFF APPROVAL	DATE	CHECKED	DATE	NEXT ASSEMBLY	NO. REQUIRED
									D. NICOLL	4/7/53	M. J. K.	6/9/53	ARGONNE NATIONAL LABORATORY	
									REPRESENTATIVE	GROUP	DRAWN BY	DATE	THIS DRAWING IS THE PROPERTY OF THE ARGONNE NATIONAL LABORATORY	
											N. Meier	3-25-53	TITLE	
									TOLERANCES UNLESS OTHERWISE NOTED: FRACTIONAL $\pm 1/64$, DECIMAL $\pm .005$, ANGLE $\pm 1/4^\circ$ REMOVE ALL BURRS				ASSEMBLY - BALL NUT AND SCREW	
									MATERIAL				SCALE	DRWG. NO.
									SEE MJ-1500-B/M				FULL	MJ-1577-B

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if tests indicate that a change is desirable. Two switches serve as the lower and upper limit switch. Two other switches are tied in with the interlock system. One of the remaining switches is a spare, and the other one operates the lights on the position indicator. Two terminal strips and amphenol connectors are provided to facilitate wiring and disengaging the drive mechanism from the electrical control system.

A position indicator is built into the gear casing for convenience during initial start-up and as a check against the Selsyn position indicator system. A crank arrangement is also provided for independent operation of the mechanism and also to facilitate inspection of the coupling and operating mechanism.

Physical Data for Regulating Rod

Weight of Regulating Rod	11 lb
Length of Active Section	28 in.
Connection of Rod	$3/8 \times 2-1/8$ in.
Over-all Length	$59-3/4$ in.
Weight of Drive Section	35 lb
Over-all Length of Drive Section	65.7 in.
Total Weight of Drive Mechanism and Casings	310 lb
Maximum Travel of Rod	$26-1/2$ in.
Normal Travel of Rod	15 in.
Speed of Travel	2.4 in./sec

H. Graphite Reflector

The graphite assembly, shown on MJ-2341-D, is essentially a 2-ft-wall hollow cylinder, 9 ft $8-3/8$ in. high, with a $21-1/4$ -inch thick bottom. It is built up of machined blocks varying in length up to 48 inches. The finished cross section is 4.187 by 4.187 inches in most cases. There are a great many drawing numbers, and these are carefully tabulated for each plan or layer of blocks. Actually, the machining will be simple because most of the blocks are included in a few types, and the variation is in a dimension or two rather than the shape of the blocks. It is believed that the required machine setup for the production of these blocks will be near a minimum.

The rough blocks are $4-3/8$ by $4-3/8$ by 48 inches nominal. Some shorter "scrap" pieces can also be utilized. GBF reactor grade graphite is preferred; however, AGOT can be tolerated. The material should have a ΔI_H of 0.90 or better (corresponding to zone B material), although graphite with a ΔI_H of 0.70 (zone A grade) will be acceptable. The density of the machined blocks should be 1.63 gm/cc or higher.

NOTE -

- 1- ALL DIMENSIONS ARE FOR REFERENCE ONLY
- 2- SEE ASSEMBLY CHART DRG. WJ-2342-D
- 3- MARK EACH INDIVIDUAL BLOCK WITH ITS CORRESPONDING NUMBER SHOWN ON THE BLOCK PLANS AND MARK EACH BLOCK ITEM "A 6".

[illegible]

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Graphite absorbs considerable light water vapor from the air. To avoid the exchange of H_2O and D_2O in the D_2O -saturated helium blanket system that covers the heavy water in the tank, the graphite zone is sealed off and supplied from a separate helium source. The graphite reflector helium atmosphere is allowed to breathe to a floating head gasometer outside the reactor.

I. Thermal Shield and Biological Shield

1. Steel Tank and Thermal Neutron Shield

The graphite is stacked in a boral-lined steel tank. The design is simple and straightforward, so it is not necessary to include a drawing of it in this report. The bottom is the type shown on the reactor inner vessel. The weld between the bottom and the wall is 6 inches up from the bottom. Hot-rolled steel, $3/4$ inch thick, is used to construct the tank, which is 12 ft 3 in. in inside diameter and 9 ft 9-7/16 in. in over-all height. A flange 2 inches thick and 13 ft-1/2 in. in outside diameter is welded at the top.

The boral liner is made of 1/4-inch thick, aluminum-clad, boron carbide plates, 24 by 48 inches. These are punched with four holes, 3/16 inch in diameter, and then pressed to a curvature to match the tank inside radius. The plates are fastened to the inside of the tank by the use of a Nelson stud welder. Similar flat plates line the bottom. Cutting and fitting around the holes through the wall and bottom will be done during field installation. The function of the boral is very similar to that in the bottom of the grid, i.e., thermal neutrons are stopped by an (n, α) reaction to avoid very hard secondary capture gammas which would increase the shield thickness requirement.

A diaphragm is welded to the reactor inner vessel and covers the top of the graphite. The outside edge of the diaphragm laps over the steel tank flange and is pinched against it. This forms the separation between the helium atmosphere over the D_2O and the graphite, as was mentioned previously.

2. Gamma Shield and Cooling Tubes

Outside of the steel tank wall is a 4-inch thick lead shield. The lead is in the form of bricks, shown on MJ-2401-D, and is stacked around the steel tank in a manner shown on the same drawing. Two types of blocks are used. One is a straight brick 4 by 4 by 9-3/4 inches. The other is a keystone affair sized for easy production by extrusion. The keystone blocks wedge between the rectangular bricks and are pulled tight with ordinary "Band-it" steel binding tape, often used on large heavy shipping boxes. Steel

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PLAN
SCALE - 1/4"

MJ-3501-F		NOTED
NEXT ADDRESS		NO. REQUIRED
ARGONNE NATIONAL LABORATORY THIS ADDRESS IS THE PROPERTY OF THE ARGONNE NATIONAL LABORATORY		
BRICK		
NOTED	MJ-2401-D	

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wedges, similar to those used in the end of a hammer handle to keep the head on, will be driven into the two types of blocks at the interface between the two. Such an installation method will produce tight joints in the vertical plane, and the weight of the lead will cause some creep and thus give good tight horizontal joints. Excessive creep over a period of time will not occur because the lead will be restrained on one side by the tank wall and on the outside by the concrete biological shield.

In the plan view of the lead block arrangement, shown on MJ-2401-D, cooling tubes come out radially from under the steel tank and then vertically up the outside of the tank wall. Lead is melted and poured into the clearance between the tubes and wall and the bricks. The purpose of the lead is to attenuate gamma rays that would otherwise cause cracking in the concrete due to thermal stress. Only one of the tubes per slot is used to begin with, the other being a spare system to be used if trouble such as leaks should ever occur in the first system of cooling tubes.

Drawing MJ-3502-F shows two cross section views, one vertical and one horizontal, through the reactor. The scheme of the bottom thermal shield and its cooling tubes can be seen by studying these views. The bottom thermal shield is a 14 by 14 ft square, hot-rolled steel plate, 5 inches thick. For the sake of fabrication and handling, it is procured in two 7 by 14 ft pieces and welded together when it is in place. In the course of construction, this bottom plate is rested on a conventional "I" beam frame (see MJ-5400-D), and the prefabricated thermal shield cooling water inlet manifolds are suspended at the center. Copper tubes, 5/8 inch-OD and sufficiently long to reach the top elevation of the steel tank, are laid in a radial pattern and sweated into the manifold fittings. As can be seen in the drawing, there are two separate inlet manifolds and thus two parallel cooling systems. The plan section view shows three sizes of one-inch thick, cold-rolled steel plates, carefully leveled and shimmed to the same elevation, and tacked into place between the radial tubes. These constitute an economical method of establishing a flat plane to support the bottom of the steel tank. However, lead must be poured between the one-inch plates to fill the voids around the cooling tubes before the steel tank is placed. Thus, the heat generated by absorption of gamma rays in the base plate and thinner spacer plates will be carried to the cooling tubes. Following this operation, the open ends of the tubes are plugged, and all joints made thus far are checked for leaks. Next, the steel tank is set in place, and the tubes are bent to lay against the side of the tank and mate with prefabricated outlet manifolds at the top. Actually the lead blocks should have been described at this point rather than first because the lead is supported on the base plate and obviously cannot be placed until the cooling tubes are sweated into the top outlet manifolds and tested.

MJ 3502-F

- NOTES
- FOR GENERAL LOCATION OF PIPING SEE DWG MJ-3002-D
 - ALL PIPING TO BE FIELD FABRICATED
 - ALL GASKETS TO BE 1/16" THICK NEOPRENE RUBBER
 - FLANGE STUDS TO COMPLY WITH ASTM SPEC #108
 - TEST PRESSURE 100 PSI
 - VALVE SPECIFICATION NUMBERS CORRESPOND TO VALVE NUMBERS ON DRAWINGS
 - ALL WELDING ON STAINLESS PIPE AND FITTINGS ETC., TO BE PERFORMED WITH COLUMBIUM STABILIZED WELDING ROD
 - ALL FLANGES TO BE 150# ASA 1/16" R F UNLESS OTHERWISE SPECIFIED
 - ALL WELDING ELBOWS TO BE ASA LONG RADIUS
 - PIPE SPECIFICATIONS
- A D/D LINES
PIPE - STD WEIGHT 615-TS ALUM
FLANGES - 25 SCS ON 615 ALUM 150# ASA F & D, 1/16" R F SLIP-ON TYPE
FITTINGS - 25 ON 35-F
- B VACUUM BREAKER LINE, EMERGENCY WATER LINES, HELIUM GAS LINES, CONTROL
ROD DRAIN LINES, GRAPHITE DRAIN
PIPE - TYPE 304 SST 150# ASA F & D 1/16" R F SLIP-ON TYPE
FLANGES - TYPE 304 SST 150# ASA F & D 1/16" R F SLIP-ON TYPE
FITTINGS - 3000# PATTERN TYPE 304 SST FORGED SOCKET WELD TYPE
- C THERMAL SHIELD COOLANT LINES
TUBING - TYPE "K" OR "L" HALF HARD NOMINAL SIZE COPPER WATER TUBE

- FITTINGS - WROUGHT COPPER SOLDER TYPE
FLANGES - TYPE 304 SST 150# ASA F & D 1/16" R F SLIP-ON TYPE
- 11 FOR SECTIONS "A-A" & "C-C" SEE DWG MJ-3001-F
FOR SECTIONS "E-E" THRU "Y-Y" SEE DWG MJ-3003-F

SECTIONAL ELEVATION D-D

PLAN SECTION B-B

MJ 3002-D			
DATE	REV	BY	CHK
10/1/54	1	J. H. H.	J. H. H.
10/1/54	2	J. H. H.	J. H. H.
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10/1/54	92	J. H. H.	J. H. H.
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10/1/54	95	J. H. H.	J. H. H.
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10/1/54	97	J. H. H.	J. H. H.
10/1/54	98	J. H. H.	J. H. H.
10/1/54	99	J. H. H.	J. H. H.
10/1/54	100	J. H. H.	J. H. H.

NOTED

1/10 MJ 3502 F

MJ-3501-F

FOR SECTIONS 'B-B' & 'D-D' SEE DRWG. MJ-3500-F
FOR SECTIONS 'E-E' THRU 'V-V' SEE DRWG. MJ-3500-F
FOR GENERAL NOTE SEE DRWG. MJ-3501-F

MJ-3502-D		AS NOTED	
ARGONNE NATIONAL LABORATORY SECTION: INTERNAL PIPING SECTIONS 'A-A' & 'C-C' NOTED: MJ-3501-F

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The thermal shield cooling tube arrangement is workable and can be made free of leaks. However, it can be criticized owing to the number of joints which are inaccessible when the reactor construction is complete. It has been suggested that both the inlet and outlet manifolds be placed in the subreactor room where the joints would be accessible and each parallel water flow path would be a continuous tube with no joints other than at the manifolds. This is a change that might well be considered when construction planning is started.

3. Biological Shield

Plan section "B-B" on MJ-3502-F gives an idea of the proportions and configurations of the biological shield. Its outside appearance is that of a modified octagon with three sides of the octagon replaced by an arc of approximately 31-ft radius. The arc is quite close to the building wall. No one will be able to go into the narrow space between the reactor and the wall after construction is completed; hence, the shield does not need to be as thick in that direction. The octagon is $27\frac{1}{2}$ ft across the flats, thus giving a minimum thickness of 7 ft of ordinary concrete between the $\frac{1}{2}$ -inch steel outside form plate and the lead thermal shield. Due to pipes and instrument holes, the gamma shielding on two sides was found to be marginal. Thus, supplementary shields made of hot-rolled steel plate and masonite layers are added to the design. These can be seen on both MJ-3502-F or MJ-2500-F. Faces 4 and 5 of the reactor make up some of the walls of the "pump room." The activity is too high in the pump room to allow anyone in the room while the reactor is running. For this reason, supplementary shielding is not needed in those two directions.

J. Instrument Holes and Liners

It is necessary to have neutron-sensitive ion chambers installed in optimum places in the reactor structure to furnish signals proportional to neutron flux density and rate of change of neutron flux for the control of the reactor, safety interlocks, and power indication. The access holes and plugs for the chambers are shown on MJ-2500-F. Notice how the boral lining of the steel tank is cut away to form a neutron "window" at the point where the ion chamber can be pushed into a steel box welded to the outside of the tank. There are no holes through the tank at these points. As can be seen, the lead blocks are omitted where the three steel boxes are welded to the outside of the tank. A 6 by 18 by 45-inch steel slab is supported back of each of two of the boxes to make up for the lack of lead at these points. This is not necessary back of the box near face 2 because the active storage well is located at that position and affords adequate shielding. The scheme of the plug design is to allow the ion chamber, which is supported on the end of the plug, to be inserted all the way in for maximum sensitivity during "cold-clean" start-up and then be pulled back to a relatively permanent position where the neutron flux will be of the order of 10^9 n/cm² sec at full

INSTRUMENT HOLE ASSEMBLY —
3 REQUIRED THIS POSITION
ELEVATION 5 90 6 1/2, 89 0 1/2, 87 4 1/2

SEE DETAIL V EV
AT PILE FACE #3

FILE PAGE # 2

— SUPPLEMENTARY SHEILD 9 9 $\frac{1}{2}$ LONG
BOTTOM ELEVATION 84 15
MATERIAL H+S + MASONRY /
✓ REQ REQ AS SHOWN
SUPPORT AS NECE* SARY

INSTRUMENT HOLE ASSY
3 REQUIRED THIS POSITION
ELEVATIONS 91 3/4 89 9/16 88 5/8

87 2 ELEVATION OF THE
OUTSIDE BOTTOM OF BOX

—8711 ELEVATION OF OUTSIDE
BOTTOM OF BOX

BORE 6 DIAM ON 90 2 ELE
FOR CONTROL ROD ASSY

SEE DETAIL VIEW
AT PILE FACE #

REMOVE BORAL FOR 4x2
AREA ON AXS OF EACH INST HOLE

INSTRUMENT HOLE ASSY
3 READ THIS POSITION
ELEVATIONS 912 1/2 894 1/2 882 1/2

LIBORAL ATTACH WITH SCREWS

6 x 10 x .43" STEEL MAY BE LAMINATED FROM PLATES
LOCATE CENTRALLY BEHIND HOLE WELD IN PLACE
2 REQUIRED AS SHOWN SUPPORT AS NECESSARY
12 x 2 x .44" NSIDE BOX DIMENSIONS BOX IS TOTALLY CLOSED BY TOP & BOTTOM COVER
WELD TIGHT & TO TANK MATERIAL 1/2" W R STEEL
FELD CUT TUBE LENGTH TO SUIT

FIELD CUT TUBE LENGTH TO SUIT
- 57' 11" ELEVATION OF THE OUTSIDE BOTTOM
OF THE BOX

VIEW OF HOLES
AT PILE FACE #3
SCALE 1" = 12'

VIEW OF HOLES
AT PILE FACE #1
SCALE 1" = 12'

NAMEPLATES TO IDENTIFY
INSTRUMENT HOLES

③ DETAIL
OUTER PLUG
SCALE $\frac{1}{2} = 1"$

MATERIAL CARBON STEEL

8 10 $\frac{1}{2}$ WALL TUBE

A-A DETAIL

③ DETAIL
INNER PLUG ASSEMBLY
SCALE 1/2" = 1"

INSTEAD OF HOLE LINERS MAY BE MADE OF SEAMLESS TUBING UNMACHINED
IF COMMERCIAL TOLERANCES ARE HELD MATERIAL CARBON STEEL
ASSEMBLIES MUST BE STRAIGHT WITHIN $\pm \frac{1}{16}$ "
HOLE LINERS MUST BE FREE OF RUST AND SMOOTH ON THE I.D.
HOLE LINERS & PLUGS ARE OF WELDED CONSTRUCTION
AS SHOWN
FIRST FLOOR ELEVATION IS 100'-0"

[illegible]

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power operation. The one-inch-diameter tube carrying the coaxial leads is left long at first and is later cut off to the proper length to make a neat installation at the outside face. The leads loop into a junction box installed close to the holes on the outside face of the reactor. The chambers and the sheaths of the lead plugs are aluminum. A lead plug and chamber can be pulled back into the hollow steel plug for easy handling when it is necessary to service a chamber. The outside end of the steel plug flares out to a slightly larger diameter to give an interference fit in the hole liner. No attempt is made to completely seal these holes, but the rate of diffusion of argon, contained in the air, from the holes is limited to a low value.

IV. REACTOR TOP PLUG

A. Stationary Section and Support

MJ-3501-F shows a 3-in. thick steel ring fastened to the upper I-beam of the reactor support structure. This is accurately shimmed and leveled to match the elevation of the top flange of the steel thermal shield tank containing the graphite. To this is welded a deep-stepped ring which comprises of the concrete inner form at the top of the reactor. The top of the reactor is first floor level, elevation 100 ft. This is an arbitrary datum, and all reactor elevations given on the drawings are consistent with this datum plane as 100 ft. Plan view "A-A" of MJ-3501-F shows the eight short I-beams which are bolted to the 3-in. thick ring that was mentioned first. These short beams have slotted mounting bolt holes and inside ends that are cut to form a shallow point. The points will be accurately located, by means of a transit, when construction is in progress. This will establish 8 shim points for centering the inner reactor vessel. The principal function of the short beams is to support the stationary top plug sections, MJ-1218-D and MJ-1225-D. There are 8 segments in each of the three layers. The segments are essentially steel boxes filled with heavy aggregate concrete. The bottom ones have a 3-in. layer of 90% lead ballast shot, 8% lead powder, and 2% by weight boron carbide grains. Referring to the assembly drawing, MJ-1212-F, a large steel ring track can be seen in place on the top of the stationary segments. A sheet metal sealing diaphragm is installed before the concrete, which grouts the heavy ring into place, is poured. The seal diaphragm, in conjunction with the mercury and mechanical ring seal, assures the integrity of the helium atmosphere over the D_2O in the reactor tank.

B. Rotating Plug and Seal Assembly

The rotating plug, MJ-1224-E, is a stepped steel cylinder filled with heavy concrete, about 250 lb/cu ft, and penetrated with access holes. These holes are in turn plugged with stepped steel tubes that are similarly filled and then sealed at the top of the rotating plug. Eight wheels, on tapered roller bearing mounts, roll on the large ring track and support the rotating top plug. Thus, the various reactor core and reflector positions are accessible by rotating the top plug until a given access hole is in line with the position.

The sealing method used in the design is of some interest. The primary seal, which functions when the rotatable plug is not moving, is a very large "O" ring made of a 1-3/8-in. OD heavy-wall neoprene hose. This "O" is carried on the ID of a steel ring having a cross section similar to a small I-beam with an overly thick web. The inside diameter of this ring is such that the "O" ring is compressed between it and the wall of the rotatable plug. Eight gas-operated piston assemblies, having a short (1/2-in.) stroke, press the bottom of the steel ring against another large "O" ring which is fixed at the stationary ring track. Thus, a tight seal is made which will

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MJ-1218-D

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ASSY FILE GROUP		ASSY GROUP		ASSY NUMBER		ASSY DATE		ASSY TIME		ASSY BY		ASSY CHECKED		ASSY APPROVED		ASSY REVIEWED		ASSY REVISION		ASSY STATUS		ASSY COMMENTS		ASSY ACTION		ASSY RESULT		ASSY SUMMARY		ASSY TOTAL		ASSY AVERAGE		ASSY STANDARD		ASSY VARIATION		ASSY TOLERANCE		ASSY SPECIFICATION		ASSY REQUIREMENT		ASSY COMPLIANCE		ASSY CONFORMANCE		ASSY DEFECTS		ASSY REWORKS		ASSY SCRAP		ASSY WASTE		ASSY EFFICIENCY		ASSY PRODUCTIVITY		ASSY QUALITY		ASSY QUANTITY		ASSY VALUE		ASSY COST		ASSY PROFIT		ASSY RISK		ASSY IMPACT		ASSY SIGNIFICANCE		ASSY IMPORTANCE		ASSY PRIORITY		ASSY URGENCY		ASSY DEADLINE		ASSY SCHEDULE		ASSY TIMELINESS		ASSY RELIABILITY		ASSY DURABILITY		ASSY STABILITY		ASSY CONSISTENCY		ASSY ACCURACY		ASSY PRECISION		ASSY CLARITY		ASSY COHERENCE		ASSY CREDIBILITY		ASSY AUTHORITY		ASSY INFLUENCE		ASSY POWER		ASSY FORCE		ASSY ENERGY		ASSY MOTION		ASSY ACTION		ASSY REACTION		ASSY RESPONSE		ASSY FEEDBACK		ASSY EVALUATION		ASSY ASSESSMENT		ASSY ANALYSIS		ASSY SYNTHESIS		ASSY CONCLUSION		ASSY RECOMMENDATION		ASSY SUGGESTION		ASSY PROPOSAL		ASSY PLAN		ASSY STRATEGY		ASSY TACTIC		ASSY METHOD		ASSY TECHNIQUE		ASSY TOOL		ASSY EQUIPMENT		ASSY MATERIAL		ASSY RESOURCE		ASSY CAPABILITY		ASSY POTENTIAL		ASSY OPPORTUNITY		ASSY CHALLENGE		ASSY OBSTACLE		ASSY PROBLEM		ASSY SOLUTION		ASSY ANSWER		ASSY RESULT		ASSY OUTCOME		ASSY IMPACT		ASSY SIGNIFICANCE		ASSY IMPORTANCE		ASSY PRIORITY		ASSY URGENCY		ASSY DEADLINE		ASSY SCHEDULE		ASSY TIMELINESS		ASSY RELIABILITY		ASSY DURABILITY		ASSY STABILITY		ASSY CONSISTENCY		ASSY ACCURACY		ASSY PRECISION		ASSY CLARITY		ASSY COHERENCE		ASSY CREDIBILITY		ASSY AUTHORITY		ASSY INFLUENCE		ASSY POWER		ASSY FORCE		ASSY ENERGY		ASSY MOTION		ASSY ACTION		ASSY REACTION		ASSY RESPONSE		ASSY FEEDBACK		ASSY EVALUATION		ASSY ASSESSMENT		ASSY ANALYSIS		ASSY SYNTHESIS		ASSY CONCLUSION		ASSY RECOMMENDATION		ASSY SUGGESTION		ASSY PROPOSAL		ASSY PLAN		ASSY STRATEGY		ASSY TACTIC		ASSY METHOD		ASSY TECHNIQUE		ASSY TOOL		ASSY EQUIPMENT		ASSY MATERIAL		ASSY RESOURCE		ASSY CAPABILITY		ASSY POTENTIAL		ASSY OPPORTUNITY		ASSY CHALLENGE		ASSY OBSTACLE		ASSY PROBLEM		ASSY SOLUTION		ASSY ANSWER		ASSY RESULT		ASSY OUTCOME		ASSY IMPACT		ASSY SIGNIFICANCE		ASSY IMPORTANCE		ASSY PRIORITY		ASSY URGENCY		ASSY DEADLINE		ASSY SCHEDULE		ASSY TIMELINESS		ASSY RELIABILITY		ASSY DURABILITY		ASSY STABILITY		ASSY CONSISTENCY		ASSY ACCURACY		ASSY PRECISION		ASSY CLARITY		ASSY COHERENCE		ASSY CREDIBILITY		ASSY AUTHORITY		ASSY INFLUENCE		ASSY POWER		ASSY FORCE		ASSY ENERGY		ASSY MOTION		ASSY ACTION		ASSY REACTION		ASSY RESPONSE		ASSY FEEDBACK		ASSY EVALUATION		ASSY ASSESSMENT		ASSY ANALYSIS		ASSY SYNTHESIS		ASSY CONCLUSION		ASSY RECOMMENDATION		ASSY SUGGESTION		ASSY PROPOSAL		ASSY PLAN		ASSY STRATEGY		ASSY TACTIC		ASSY METHOD		ASSY TECHNIQUE		ASSY TOOL		ASSY EQUIPMENT		ASSY MATERIAL		ASSY RESOURCE		ASSY CAPABILITY		ASSY POTENTIAL		ASSY OPPORTUNITY		ASSY CHALLENGE		ASSY OBSTACLE		ASSY PROBLEM		ASSY SOLUTION		ASSY ANSWER		ASSY RESULT		ASSY OUTCOME		ASSY IMPACT		ASSY SIGNIFICANCE		ASSY IMPORTANCE		ASSY PRIORITY		ASSY URGENCY		ASSY DEADLINE		ASSY SCHEDULE		ASSY TIMELINESS		ASSY RELIABILITY		ASSY DURABILITY		ASSY STABILITY		ASSY CONSISTENCY		ASSY ACCURACY		ASSY PRECISION		ASSY CLARITY		ASSY COHERENCE		ASSY CREDIBILITY		ASSY AUTHORITY		ASSY INFLUENCE		ASSY POWER		ASSY FORCE		ASSY ENERGY		ASSY MOTION		ASSY ACTION		ASSY REACTION		ASSY RESPONSE		ASSY FEEDBACK		ASSY EVALUATION		ASSY ASSESSMENT		ASSY ANALYSIS		ASSY SYNTHESIS		ASSY CONCLUSION		ASSY RECOMMENDATION		ASSY SUGGESTION		ASSY PROPOSAL		ASSY PLAN		ASSY STRATEGY		ASSY TACTIC		ASSY METHOD		ASSY TECHNIQUE		ASSY TOOL		ASSY EQUIPMENT		ASSY MATERIAL		ASSY RESOURCE		ASSY CAPABILITY		ASSY POTENTIAL		ASSY OPPORTUNITY		ASSY CHALLENGE		ASSY OBSTACLE		ASSY PROBLEM		ASSY SOLUTION		ASSY ANSWER		ASSY RESULT		ASSY OUTCOME		ASSY IMPACT		ASSY SIGNIFICANCE		ASSY IMPORTANCE		ASSY PRIORITY		ASSY URGENCY		ASSY DEADLINE		ASSY SCHEDULE		ASSY TIMELINESS		ASSY RELIABILITY		ASSY DURABILITY		ASSY STABILITY		ASSY CONSISTENCY		ASSY ACCURACY		ASSY PRECISION		ASSY CLARITY		ASSY COHERENCE		ASSY CREDIBILITY		ASSY AUTHORITY		ASSY INFLUENCE		ASSY POWER		ASSY FORCE		ASSY ENERGY		ASSY MOTION		ASSY ACTION		ASSY REACTION		ASSY RESPONSE		ASSY FEEDBACK		ASSY EVALUATION		ASSY ASSESSMENT		ASSY ANALYSIS		ASSY SYNTHESIS		ASSY CONCLUSION		ASSY RECOMMENDATION		ASSY SUGGESTION		ASSY PROPOSAL		ASSY PLAN		ASSY STRATEGY		ASSY TACTIC		ASSY METHOD		ASSY TECHNIQUE		ASSY TOOL		ASSY EQUIPMENT		ASSY MATERIAL		ASSY RESOURCE		ASSY CAPABILITY		ASSY POTENTIAL		ASSY OPPORTUNITY		ASSY CHALLENGE		ASSY OBSTACLE		ASSY PROBLEM		ASSY SOLUTION		ASSY ANSWER		ASSY RESULT		ASSY OUTCOME		ASSY IMPACT		ASSY SIGNIFICANCE		ASSY IMPORTANCE		ASSY	
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MJ-1224-E

1 45° CHAMFER
4 TAIL WELD
AFTER FILLING
FIELD (TYPICAL
ALL COVERS)

1/2" D DRILL - 2 5/8" DEEP
DOT TAP - 1/4" UNC x 2 1/2" DEEP
16-HOLES EQUALLY SPACED
ON 9 5/8" Ø C

SECT A-A
SCALE-1/4"

DET F (TYR)
SCALE-1

DET B
SCALE - 1

DET E
SCALE-

SECT. D-D
MATL - 304 SST
SCALE - $\frac{1}{2}$ "

SECT C-C
MATL - 304 SST
SCALE - 1

NOTES: STRESS RELIEVE AFTER WELDING, BEFORE FINAL MACHINING

(B) HOLES MUST BE CONCENTRIC AND STRAIGHT TO WITHIN 0.031 TOTAL INDICATOR READING AND BE PERPENDICULAR TO SURFACE 'A' TO WITHIN 0.031 AT 80 INCHES

ALL WELDS MUST BE PROVED GAS TIGHT BY TEST ACCEPTABLE TO PURCHASER, THIS INCLUDES THE WELD AT THE BOTTOM WHICH SEALS IN THE BORE.

THIS WELDMENT (MJ-1224-E) AND REACTOR TOP PLUG SUPPORT PLATE (MJ-1223-E) SHOULD BE MACHINED FROM THE SAME TEMPLATE OR SOME OTHER MEANS USED TO ASSURE TRUE ALIGNMENT OF THESE TWO PARTS.

[illegible]

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withstand internal pressure up to that required to lift the access hole plugs off their sealing gaskets. A mercury trough is placed outside this seal and serves to separate the helium atmosphere from the air of the building when the "O" ring seal is pulled up to allow the movable top plug to rotate. It is absolutely essential that the mercury container does not leak and that it be filled carefully. Mercury leaking down into the reactor would cause a very serious problem. A rubber wiper is installed between the rotating top plate and the stationary surface external to the mercury seal to keep dirt and foreign material from the trough and also to lessen the mercury vapors that might diffuse into the room. This area of the building is well ventilated, and so a health hazard does not exist.

The top plug is rotated by a coarse and a vernier drive motor via a common gear box (see MJ-5001-F title "Gear Box Assembly"). Indexing over a particular position is done by energizing the larger motor and electric clutch and watching the marks on the periphery of the rotating plug top support plate and bull gear assembly. Each of these marks is scribed and numbered for the correct access hole over a corresponding fuel or producer assembly position. The angular location of these marks will be determined near the completion of construction and before critical test work is begun. The index mark with which these are aligned is fixed near the push-button station for the drive motors. The operator can watch the index closely while his finger is on a drive button. The coarse drive gives a periphery speed of 3 in./sec for the top speed of the rotating plug. When the operator removes his finger from the coarse drive button, the electric clutch disengages, and the motor coasts to a stop. The vernier driver is declutched except when the small motor is energized. The plug rotates at a periphery speed of about 1/64 in./sec on the vernier drive and can be positioned very accurately.

The largest of the access hole plugs is for installation and removal of the swing-type shim-safety blade assemblies. The smaller ones, including the square ones, are for access to the various fuel and producer assemblies in the reactor inner vessel. These small ones are handled by the large loading and unloading coffin (called transfer coffin in many places in this report). A single bolt adapter, MJ-5056-D, having a calibrated protractor base, is fastened to the top of the access hole plugs. The adapter is set at the proper angle so that its latch slot will line up with the equivalent part of the element below it in the reactor. The same "T" bar in the coffin handles both the access hole plug and the fuel, or producer assembly. This handling will be described in detail in another section.

MJ-5001-F

MJ-1211-E	1
MJ-5060-E	1
ANGONIE NATIONAL LABORATORY	
GEAR BOX ASSEM.	
SEE MJ-5001-F	

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MJ-5056-D

MJ-1210-F		1
MJ-5030-F		1
ARMY MATERIAL LABORATORY THE ARMY OF THE UNITED STATES T. Sullivan RELEASED UNDER EXECUTIVE ORDER PROHIBITION 2.4. ORIGINAL 2. AND. AMPLS 2. N° REMOVE ALL STAMPS		
SEE MJ-5056		8/24
PULL		MJ-5056-D

V. COOLING SYSTEM

The reactor is moderated and cooled with heavy water. The capacity of the entire system is 3,101 gallons. It seems reasonable to procure 3% more than the calculated requirement. This makes 3,200 gallons required.

A. Flow Sheet and Piping

A schematic of the primary (D_2O) water system, secondary (cooling tower) water system, helium system, emergency water system, and waste water is shown on the flow sheet, MJ-3001-D. The reader who is interested in the details of these various systems will find that the flow sheet and the piping drawings that follow are sufficient to give most of the detailed information desired. Complete specifications and the necessary detailed drawings for procuring the various pumps, valves, heat exchangers, etc., are made up and are on file. Rather than verbally trace through the flow sheet and piping, the principal installation drawings are included in this report, and certain main features are pointed out below. The general equipment location plan, MJ-3002-D, shows the orientation of the equipment relative to the reactor. The installation of D_2O pumps, heat exchangers, control valves, etc., is shown on MJ-3128-D, " D_2O Circulating System, Pump Room." MJ-3130-D is an isometric installation drawing of the D_2O drain and sampling piping in the pump room. The cooling tower light water pipes and valves in the pump room are laid out for installation on MJ-3131-D. The subreactor room pipes, tanks, valves, pumps, and instrument locations are shown on MJ-3132-D. The ion exchange cleanup system for D_2O is shown on MJ-3135-D. The internal reactor piping is shown on MJ-3501-F, MJ-3502-F, and MJ-3503-F.

B. D_2O Pumps

Three main heavy water circulating pumps are located in the pump room (see MJ-3128-E). The capacity of each pump is 1000 gpm at 100 ft total dynamic head when pumping heavy water at 125°F. Two of these pumps will be run for a normal flow of 2000 gpm when the reactor is operating at 5000 kw. The third is stand-by equipment. All parts in contact with the D_2O are type 304 or 316 stainless steel with the exception of the graphite seal ring. The pumps are a single-stage centrifugal type with a mechanical seal with no packing. The shaft seal employed is a self-contained unit assembled on a shaft sleeve so that it is entirely self-aligning. A graphite primary seal is lapped smooth and is run against a stellite-coated stainless steel face. It is necessary to have a very slight seepage through such a seal to assure durability. Great care must be exercised to obtain just the right spring pressure to allow this slight seepage without excessive loss of heavy water. The correct rate is so low that most of the D_2O that comes through between the graphite and stellite will evaporate rather than drip. It is estimated that this loss of D_2O will amount to about 1/2 gal per year for each pump. Argonne plans to test each pump in the laboratory before using them to circulate the heavy water. It will be noticed on the

- FLOW LEGEND**
- PRIMARY WATER SYSTEM
 - SECONDARY WATER SYSTEM
 - HELIUM SYSTEM
 - EMERGENCY WATER SYSTEM
 - WASTE WATER
- INSTRUMENTATION MARKING**
- F — HEAVY WATER
 - G — EMERGENCY WATER
 - K — THERMAL SHIELD COOLING WATER
 - M — HELIUM GAS
 - P — COOLING TOWER WATER
 - — LOCAL INDICATION
 - — REMOTE INDICATION
- IT1 — INSTRUMENT TEMPERATURE INDICATING
 ITR — INSTRUMENT TEMPERATURE RECORDER
 ITC — INSTRUMENT TEMPERATURE CONTROLLER
 IP — INSTRUMENT PRESSURE GAUGE
 IPI — INSTRUMENT PRESSURE INDICATOR
 IPR — INSTRUMENT PRESSURE RECORDER
 IPC — INSTRUMENT PRESSURE CONTROLLER
 IF — INSTRUMENT FLOW GAUGE
 IFI — INSTRUMENT FLOW INDICATOR
 IFR — INSTRUMENT FLOW RECORDER
 IFC — INSTRUMENT FLOW CONTROLLER
 ILI — INSTRUMENT LEVEL INDICATING
 ICR — INSTRUMENT CONDUCTIVITY RECORDING

APPROVED CONST.		DATE	CHIEF DRAWING	DATE	NO. REQUIRED
CHECKED					
STATE APPROVAL					
REPRESENTATIVE					
HAMMOND					
DRAWN BY					
R. TUMA					
TOLERANCES UNLESS OTHERWISE NOTED:					
FRACTIONAL ± 1/16" DECIMAL ± .005" ANGLES ± 1/8°					
REMOVE ALL DIMS					
MATERIAL					
ITEM	ZONE	CHANGE	DATE	BY	CHK
1	79	WAS MID-15, 16, 17			
2	78	WAS MID-18, 19, 20			
GENERAL REVISION					
REDEAWN					
ARGONNE NATIONAL LABORATORY					
THIS DRAWING IS THE PROPERTY OF THE ARGONNE NATIONAL LABORATORY					
TITLE					
COMPOSITE FLOW SHEET					
SCALE		DRWG. NO.			
		MJ-8001-D

MJ-3002-D

APPROVED	DATE	CHECKED	DATE	NO. REQUIRED
STAFF APPROVED	4/1/53	4/1/53	3-27-53	
REPRESENTATIVE	HAUMOLD	R. TUMA	2/12/53	
TOLERANCES UNLESS OTHERWISE NOTED: FRACTIONAL: 2/16, DECIMAL: 2/100, ANGLES: 2/16 REMOVE ALL DIMS				
MATERIAL				SCALE
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ARGONNE NATIONAL LABORATORY THIS DRAWING IS THE PROPERTY OF THE ARGONNE NATIONAL LABORATORY				
TITLE GENERAL EQUIPMENT LOCATION (PLOT PLAN)				
DRAWING NO. MJ-3002-D

MICRO FILM STRIP										APPROVED CONTY		DATE	CHRT CHARTERMAN	DATE	NEXT ASSEMBLY		NO. REQUIRED
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										TOLERANCES UNLESS OTHERWISE NOTED						TITLE	
										FRACTURAL ± .001		FRACTURAL ± .001		ANGLE ± .1°		D/C FILTRATION TANKS INSTALLATION	
										RESERVE ALL SURF							
										MATERIAL		AS NOTED				SCALE	
SYN	ZONE	CHANGE		DATE		BY		CHK								DRWG. NO. MJ- 3135-D	

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pump room drawing that check valves are installed to avoid pressurizing the seal of the pump that is not in use. Also, remote control valves are in the lines to enable the operator to select pumps at will from the control room. A shield window is placed in the pump room wall to allow observation while the reactor is running. The pumps, valves, heat exchangers, etc., are protected, so to speak, by a leak detector system which will give an alarm in the control room if a leak occurs at any seal, gasket, or diaphragm in the system. A drain system (see MJ-3130-D), is piped to the D₂O storage tanks from each pump, valve, heat exchanger, etc., that might need servicing. Thus, heavy water will not be lost when it is necessary to remove an item which would otherwise hold up heavy water.

C. Valves

In general, all of the valves in the heavy water system are Saunder's Patent diaphragm-type valves. These have cast 18-8 stainless steel bodies and cast iron bonnets. The diaphragms are heavy duty, radiation-resisting neoprene W, which is free of magnesium oxide, and have a stainless steel stud bonded in between the laminations. Although neoprene will not stand up indefinitely under gamma radiation, tests indicate that the diaphragms will last for an equivalent of ≈ 100 years in the gamma intensity coming from the nitrogen-16 in the primary water.

This type of valve was chosen for three reasons (see Fig. 4 for illustration of this valve type)

- a. There is no packing to permit leaks.
- b. Positive shutoff.
- c. Low pressure drop (almost as low as a gate).

Such valves are used extensively in the chemical industry where leaks are a hazard to equipment, personnel, or economy. As a secondary precaution against leaks that could possibly occur due to cracks in a diaphragm, the bonnet of the valve is sealed by means of "O" rings. The large valves have a 10-millimeter tapped hole for installation of a 10-mm automobile spark plug which is wired to give an electrical signal if water gets into the bonnet. Some of the main valves have position transmitters mounted on them to give an indication of the valve setting in the control room.

D. Heat Exchangers

Two heat exchangers operated in parallel are specified for the primary D₂O cooling system. These are located in the pump room as indicated on MJ-3128-D. The schematic relations of the heat exchangers relative to other equipment and the reactor can be seen on the flow sheet MJ-3001-D. An external view and certain pertinent data are shown on the drawing, MJ-6110-B, which will accompany the specification when invitations to bid are sent out to heat exchanger manufacturers. A number of

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NO	DESCRIPTION
2	HANDWHEEL
3	BONNET
4	SLEEVE
5	SPACER
6	STEM
96	COMPRESSOR
8	COMPRESSOR PIN
10	NAME PLATE
17	HEX HD. CAP SCREW & NUT
20	ALEMITE FITTING
22	HANDWHEEL RETAINER SCREW ASSEM.
23	STUDS & NUTS
25	THRUST WASHER
76	TELL TALE
78	HEX. JAM NUT
80	STOP COLLAR
79	LOCKWASHER
97	"O" RING
98	"O" RING
600	DIAPHRAGM
700	BODY

Figure 4

DIAPHRAGM VALVE WITH "O" RING
SECONDARY SEAL USED IN D₂O SYSTEM

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MAJ-6110-B

DOUBLE TUBE SHEET HEAT EXCHANGER
1 TUBE MAT'L: 304 SST SEAMLESS TUBES
2 MINIMUM TUBE SIZE: 1/2 INCH OD.
3 MINIMUM TUBE GAUGE: #18 BWG (0.049" WALL)
4 MINIMUM BEND RADIUS: 1 1/4" R.
5 TUBES TO BE ON TRIANGULAR PITCH
6 MINIMUM LIGAMENT 3/16 INCH

EXCHANGERS TO BE MARKED
F-1 OR F-1-Z SEE PLAN VIEW

MICRO FILM STAMP										APPROVED CONST		DATE		CHIEF DRAFTSMAN		DATE		MJ-312B-D		SEE PLAN VIEW			
										STAFF APPROVAL		4/11/53		CHECKED		3/27/53		NEXT ASSEMBLY		NO. REQUIRED			
										DWH				6F				ARGONNE NATIONAL LABORATORY					
										REPRESENTATIVE		DRAWN BY		2/20/53				THIS DRAWING IS THE PROPERTY OF					
										HAMMOND		RTUMA						THE ARGONNE NATIONAL LABORATORY					
										TOLERANCES UNLESS OTHERWISE NOTED										TITLE			
										REMOVE ALL SURFS										D ₂ O HEAT EXCHANGER			
										MATERIAL										SCALE		DRWG. NO	
										SEE SPECIFICATION # F-1-1 & # F-1-2										1" = 1'-0"		MJ-6110-B	
SYM		ZONE		CHANGE				DATE		BY		CHK											

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prominent heat exchanger manufacturers were consulted to establish an economical specification that would meet the performance requirements and eliminate any possibility of mixing light water into heavy water. A vertical "U" tube with double tube sheets will be used. All parts in contact with the D₂O are type 304 stainless steel. The heavy water enters at the bottom 6-in. inlet flange and flows up through hairpin tubes, which are 1/2-in. OD, and down to the bottom outlet flange diametrically opposite the D₂O inlet. The light water from the cooling tower flows in at the 8-in. pipe at the top; internal baffles direct the flow across the tubes in the shell; and the outlet is at the bottom of the shell just above the double tube sheet. The following is a summary of the performance characteristics required for each exchanger.

<u>Fluid</u>	<u>Hot Fluid</u> <u>Heavy Water</u>	<u>Cold Fluid</u> <u>Light Water</u>
Flow Rate, gpm	1000	1000
Shell Side		x
Tube Side	x	
Temperature In	125	83
Temperature Out	109	100
Specific Gravity	1.1	1
Pressures, psi		
Operating	50	35
Hydrostatic Test	150	70
Freon and CO ₂ or Helium Test	100	
Maximum Pressure Drop	3	10

The shell of the exchanger is removable from above without disconnecting the heavy water lines. The carbon steel shell and flange are unbolted from the upper stainless steel tube sheet, leaving the tube bundle, double tube sheets, and stainless inlet-outlet header still in place. The tubes are rolled into both tube sheets according to accepted high-quality heat exchanger practice. The tubes are the only connection between the two tube sheets. Any leakage from either the shell side through the top sheet or the heavy water header through the bottom tube sheet will be into the open space between the two tube sheets and, hence, will not mix the light water and heavy water. The 1/2-in. tube size was chosen to minimize the heavy water holdup in the heat exchanger within the limits of practical size for fabrication. Normal practice is a 5/8-in. minimum tube size. However, the manufacturers give assurance that 1/2 inch can be rolled in satisfactorily. All of them recommended that tubes smaller than 1/2 in. be avoided. The high flow on the shell side (cooling tower water) was selected to reduce the heavy water inventory holdup in the exchanger by keeping the LMTD as high as possible and thus holding down the surface area requirements. In view of the investment required for heavy water, it is considered economical to have the pumping power a little high and save on the investment by doing so.

E. Cleanup System

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To obtain corrosion-free operation and avoid build-up of radioactivity in the D_2O system, it is necessary to start with a clean system and demineralized water. Also, the D_2O in the reactor is dissociated to some extent by the radiation but recombines at about the same rate if kept pure. The water is maintained pure (less than 3 ppm total dissolved solids) by means of a filter and ion exchange system located along reactor face 5 in the pump room. Orientation can be obtained by referring to MJ-3002-D. The flow sheet, MJ-3001-D, indicates how the system, which is actually a by-pass off the mainline, takes pressure off of the heavy water line between the main circulating pumps and the heat exchangers. The cleaned up water flows back into the main system just above the dump valve and before the heavy water flow-metering venturi. During the initial cleanup, before the reactor is made "critical," the heavily shielded filter (item F-7 on the flow sheet) will not be installed. An unobstructed run of pipe will be in its stead. Thus the unavoidable fine (and not so fine) particulate matter that will be in the pipes from the construction work will be filtered out in item F-6. This, of course, is after a flushing with light water with open connections here and there at convenient places in the large piping system. After the system is thoroughly cleaned and dried, the shielded filter will be installed. This filter is to pick up any radioactive particulate matter that may be transported in the system after operation is begun.

Drawing MJ-3135-F shows the assembly of the system other than the shielded filter, which is located out farther away from the reactor face at a point where it is accessible through a hatch in the main floor above. The reason for this location of the shielded filter is the weight of the unit. The lead is 7 inches thick, and so mechanical handling is required. The water enters the system at item F-4, which is a flow regulator. The flow rate is held to 3 gpm to avoid disturbing the resin beds in the ion exchangers. The water from the flow regulator is cooled in a small heat exchanger, item F-5 on the drawing. This is required because the ion exchange resins are not stable above $110^{\circ}F$. Following the cooler is a porcelain candle-containing filter vessel. The porcelain filter candles have a maximum pore size of 5 microns. These candles can be replaced when the local reading pressure gauges indicate that they are becoming clogged. Items F-8-1 and F-8-2 are the small columns that contain the mixed bed resins. The assembly of a unit is shown on MJ-6203-C. Screens, marked MJ-6207-A, stop the resin grains from washing out of the basket. The columns require 0.5 cu ft of cation resin and 1.0 cu ft of anion resin of the type proven for mixed bed use. These resins have a history of successful application in the chemical process industry, and considerable experience in their use exists at Argonne National Laboratory. Water purity that gives a specific resistivity of $2,000,000 \text{ ohms/cm}^2/\text{cm}$ at $20^{\circ}C$ is readily obtainable from such ion exchange columns. These resins are received wet with H_2O and completely swollen; if allowed to dry they lose their effectiveness. The double valve arrangement is required to make it possible to install and remove the

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columns, or resin baskets as they are titled on the drawings, full of heavy water. When the resins are received, a "deuterization" technique of displacing the light water with heavy water must be applied before the mixed resin bed is ready for use. When a column is removed from the system after the resin has reached a reduced effectiveness due to the dissolved solids which it has absorbed, the deuterization process must be reversed using H_2O to carefully displace the D_2O . The technique is such that the contamination and loss of D_2O is minimum. The D_2O and H_2O mixture at the diffused interface between the displacing and displaced water is saved and reprocessed. Once the entire D_2O system is clean, a resin charge may have to be replaced no oftener than once a year. This makes it impractical, from the economic standpoint, to install a regenerating system for the resin, and hence it is planned to make no attempt to save and re-use resin. Since it very likely will be somewhat radioactive, it is doubtful whether it would be practical from this standpoint even if the regenerating equipment did not cost more than the resin.

F. Gas Blanket System

The drawing of the D_2O recombination unit, MJ-3415-D, also serves as installation information for the helium gas bottles, pressure reducing stations, and 50-cu ft dry seal gasometer which supplies pressure-regulated helium to the space above the D_2O in the reactor tank. Drawing MJ-3400-D shows the assembly of the D_2O recombination unit, which consists of a canned lobe type blower to circulate the helium with no moving seals or packings involved, a condenser to dry the gas, a controlled heater to raise the temperature to a value where the catalyst is effective, a chamber of palladium on aluminum oxide pellets for catalytic recombination of D_2 and O_2 , plus a rotometer type flowmeter and temperature and pressure gauges. The flow rate through the system is 8 cfm of helium. This helium circulates across the space between the top grid on the reactor inner vessel and the bottom of the rotating plug. The catalyst chamber not only recombines any small amount of decomposed D_2O but also serves as a meter to measure the amount of recombination, and hence net decomposition in the reactor, which takes place. The recombination is, of course, an exothermic reaction. The chamber is insulated, and the dry gas inlet and outlet temperatures are accurately measured by sensitive resistance thermometers.

G. Thermal Shield Cooling

The thermal shield with its cooling tubes has been described. The reactor internal piping arrangement shown on MJ-3501, 3502, and 3503 includes the thermal shield inlet and outlet lines, both regular and stand-by. The external equipment, such as a pump, heat exchanger, small ion exchanger, flowmeter, temperature and pressure gauges, valves, is mounted on the wall of the active storage well shield. As will be noticed by referring to MJ-3002-D, the storage well is against face 2 of the reactor, faces being numbered counter clockwise beginning on the right side as we face the plan drawing.

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The cooling is based on 40 kw heat generation in the thermal shield and 17°F temperature rise in the water. This heating is not necessarily accurate, but it makes very little difference since the temperature rise selected on the estimated value is quite low. A conservative figure is necessary because the thermal shield cooling tubes are parallel paths, and there is no assurance of uniform distribution of flow between the various tubes. The flow rate is 16 gpm, and this is taken from the cooling tower water lines via a pipe trench in the equipment room (basement) floor which leaves the subreactor room in front of reactor face 3, runs under the helium blanket equipment (helium supply, gasometer, and recombination meter assembly described previously), and over to the thermal shield equipment location.

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VI. SAFETY PROVISIONS

One of the hazards of a high flux reactor is the possibility of melting the fuel and releasing gaseous fission products if the cooling water is lost from the inner reactor vessel. The reactor would automatically shut itself down if this happens because it needs the slowing down effect which the water has on fission neutrons to continue the self-sustaining chain reaction. However, the heating effect of the radioactive fission fragments is sufficient to melt fuel metal if it is not cooled. If water covers the active part of the fuel assembly, thermal convection is sufficient to cool the plates. Therefore, a scheme for maintaining a minimum water level in the reactor tank is imperative or else other auxiliary cooling means must be available. It is possible to allow the water level to drop about 22 inches in the reactor tank and still maintain the level one inch or a little more above the active fuel plates. The water loss, down to this level, would decrease the reactivity of the reactor and hence shut it down.

A. Inlet Loop and Baffled Drain

A look at MJ-3502-F and ANL-RKW-501 will show one of the features of the design that takes care of the possible hazard of losing all of the water from the inner reactor vessel due to a break in a valve, pump, pipe, or other D₂O equipment external to the biological shield. It will be noticed that the center line of the 10-inch inlet pipe is at a reference elevation of 92 ft 8 in. The top end of the active fuel plates is at an elevation of 91 ft 11 in. A small pipe comes out of the top of the large pipe loop and goes through the shield to the top of the grid (grid not shown on MJ-3502-F) where it turns and flows D₂O into the reactor tank through a hole in the grid. The valve in this line will be locked open at all times. The purpose of this pipe is to break the vacuum which would otherwise siphon D₂O back through the loop if an external break should occur. The reason for the valve in the vacuum break line is that a siphon is the only way the reactor vessel can be entirely drained when such draining is required. Under such circumstances, the valve to the storage tanks in the subreactor room is opened, and the heavy water is siphoned over the loop and down to the tanks by virtue of the helium pressure maintained above the water in the inner reactor vessel. The tanks are vented to the space above the reactor to assure rapid flow without becoming gas bound. These vent lines are shown schematically on the flow sheet, MJ-3001-D, and in actual installation drawings for the subreactor room, MJ-3132-D, and for the reactor internal structure and piping, MJ-3501, 3502, and 3503.

A break in the D₂O outlet pipes external to the biological shield will not cause a loss of water below the level of the top edge of the discharge baffle plates in the reactor tank (see MJ-1101-E and ANL-RKW-501). The top edge is at an elevation of 92 ft whereas the tops of the fuel plates are at 91 ft 11 in.

B. Emergency Water System 128

The loop and baffle arrangement described above is entirely adequate for a D_2O break external of the biological shield. The heavy water lines in the concrete are to be heavily coated with tar to protect them (the pipes are 61S aluminum) from galvanic corrosion with the concrete when it is wet and also allow slight movement between the concrete and pipes without straining the metal of the pipes. Although it is very improbable, it is not impossible to have severe cracks in the concrete of the biological shield due to bombing or earthquakes. One might imagine a catastrophe in which the D_2O inlet line inside the biological shield or the reactor vessel might rupture. To provide for such extreme eventualities an emergency spray system is designed into the reactor. ANL-RKW-500 and 501 show an emergency water rupture disc assembly with a pipe leading to a flat spray nozzle located at the periphery of the grid on top of the reactor vessel. There are two of these nozzles installed diametrically opposite each other in such a manner that water from them sprays into the space between the grid and the under side of the rotating plug. The water will drip down through the holes in the grid and "drool" down over the fuel and producer assemblies. Under such conditions, i.e., no water in the tank other than the emergency flow from the spray nozzles, the fuel assemblies will become quite hot but will not melt. The water that flows down the outside of the fuel elements will probably boil, and also radiation and convection will take place between the fuel elements and the cooler assemblies, grid, tank walls, etc.

Reference to the flow sheet, MJ-3001-D, will reveal three sources of water supply for these emergency spray nozzles.

- a. D_2O from the subreactor room sump.
- b. H_2O from the emergency water tanks.
- c. H_2O from the domestic or plant water lines.

Before we describe these three sources, a work of explanation of the rupture discs is in order. A section through the rupture disc assembly is shown on MJ-3510-C. Under normal circumstances the disc closes off the emergency system from the pipe leading to the spray nozzles, and there is little or no pressure against either side of the disc. When water is pumped or otherwise forced against the disc with sufficient pressure, the disc breaks, and water flows to the spray nozzles. A screen is placed across the downstream side to catch the broken pieces of the disc. The bursting pressure of the disc is 22.5 to 30 psi. Such discs are available from a commercial company which has considerable experience with rupture disc manufacture and application. The rupture disc assembly is installed in a cubical near the top of the reactor biological shield and is covered by a removable plug; hence it is accessible for test and service (see MJ-3502-F).

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The first alternate water supply for the emergency sprays is D_2O from the subreactor room sump (see MJ-3132-D). The subreactor room is the place where most of the D_2O would go if there were a major break in the inner vessel or main lines. The floor of the subreactor room is sloped toward the sump. Two pumps are located in the sump on a common mounting plate. One takes its suction from the lowest point in the sump, and this one is the normal waste water pump to handle building seepage, etc., that might occur. The other pump is installed a little higher to get the suction up out of any dirt that might collect in the bottom of the sump. This latter one would be used to pump D_2O into the emergency spray line. The flow sheet adequately illustrates the scheme; notice the location of check valves in the line from this pump and the emergency H_2O lines that tie into it.

The second alternate supply of water to the nozzles is the emergency water tanks (see MJ-3500-D). There are two 500-gal light water tanks pressurized by nitrogen from high-pressure bottles and a suitable reducer and regulator system. A definite operation, other than just opening an ordinary valve, is required to avoid inadvertent dumping of H_2O into the D_2O system via the emergency lines. A "spectacle" flange or valve is designed into the system. This is essentially a plate, a part of which is a blind flange and the other part a flange with a hole in it, each flange having a bolt circle and sharing one common bolt hole. The idea is that normally the blind flange will be in place in the pipe line to the reactor, thus making it impossible to flow light water to the rupture disc. If water flow from the emergency tanks is ever required, all bolts but the common one are removed, and the "spectacle" plate is rotated to place the open flange in the line.

At the time this feature was incorporated the peak neutron flux being considered was lower and hence the time allowed for this operation was longer. It is possible that the hottest fuel plate might begin to melt in less than five minutes if there was a sudden total loss of water from the inner reactor vessel. This feature will be re-evaluated when construction planning is started. The uncertain status of the construction phase of this reactor is such that it is not considered economical to expend further engineering review and improvement effort at this time.

Going back to the description after that slight digression, there is a flow controller on the line from each emergency tank. Each controller will be adjusted at the time of installation to give 1.5 gpm. Thus, the emergency supply will last about 5.5 hours.

The third alternate supply to the emergency nozzles is the normal plant water system. This supply line ties in after the discharge valves from the emergency water tanks and before the "spectacle" flanges and the flow regulators.

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C. "Whoof" Tube and Expansion Chamber

Much has been said about the pro's and con's of whether a prompt critical water-cooled reactor with aluminum-clad fuel will reach temperatures high enough to make the aluminum react violently with water. It is true that under certain conditions molten aluminum dumped into water will give a violent reaction. Argonne and many others have done experiments attempting to find the answer to the question, is the aluminum-water reaction one to be concerned with in reactor design? It is not our purpose to argue this question in this report. However, it is the well thought out opinion of many that this reaction will not occur in a thermal, water-cooled, plate-type reactor. The main reason for this opinion is that boiling water would probably be expelled from between the plates by steam formed before the plates melt. This would lower reactivity, and the power would drop to below normal. The feeling is that a "boiling non-boiling" oscillating cycle would occur. An experiment is under way to test these characteristics in an actual prompt critical assembly. However, for a number of reasons, it is highly improbable that a detonation can possibly occur, and it is probable that only a small portion of the aluminum would react if the reaction did occur. At the worst a "whoof" might occur but not a detonation. A device for containing such a "whoof" is designed into the reactor. ANL-RKW-500 shows a 24-inch pipe with rectangular inlet adapters near the flange of the inner reactor vessel. MJ-1140-D is a drawing of this duct and shows the flexible expansion joint on the end which fastens to a flanged 24-inch pipe that goes out through the building wall. This flexible joint is necessary to obtain the isolation of the reactor from the building shell insofar as the transmitting of an appreciable force is concerned. The 24-inch pipe is connected tangentially at the lower end of a buried stainless steel clad tank which is 8 ft in diameter by 45 ft long. This entire tank is open via the expansion duct or "whoof" tube to the top of the reactor. This will greatly increase the free volume which can contain steam without reaching pressures that would lift the access hole plugs or rupture the inner reactor vessel. The expansion tank is buried just outside the building with its 45-ft axis just slightly tipped below the horizontal. The expansion tube connection is tangential to the circumference at the low end. There is a slope from the expansion tank end of the "whoof" tube down to the reactor end. Small drain lines will carry the condensate that forms from the D₂O-saturated helium atmosphere back into the reactor tank. There are no blowout discs in the expansion duct.

D. Dump Tank

This tank serves as a scram device to supplement the shim-safety rods. It is sized to hold most of the volume which is equivalent to the heavy water top reflector over the core. The 6-inch quick-opening valve which fills the dump tank is opened by hitting the dump scram button on the console in the control room, or it is opened automatically by an interlock in the scram circuit of the reactor controls. Full pressure off the line from the heat exchanger to the reactor pushes the D₂O into the dump tank.

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Since the heavy water system is a closed system, the water level in the reactor drops at the same rate that the moderator flows into the dump tank. A 2-inch pipe serves as a helium vent to the reactor from the dump tank. The outlet valve from the dump tank is interlocked with the dump valve to be sure that it is closed when the dump valve is open.

E. Gastight Building

The construction features of the building are discussed in another section. It will suffice to only mention here that the building design criteria were based on blast-resistant construction to withstand 1000 pounds/sq ft and be gastight. Also, the building shell is isolated from the reactor to eliminate the transmission of large forces from the building to the reactor structure and vice versa. Should a catastrophe occur and serious quantities of radioactivity escape from the reactor, the building is expected to contain the activity and protect the surrounding area.

VII. NUCLEAR PHYSICS CONSIDERATIONS

The objective of this reactor design was to irradiate two particular materials concurrently to produce given minimums of two particular isotopes within the limitation of 5000 kw of energy released from fission. The properties of any other materials to be irradiated in the reactor will be different and will require some changes in the core fuel loading and other details. These changes can probably be accomplished with very little mechanical change. The power of the reactor can also be changed if desired with very little mechanical change.

One of the most difficult parts of a critical analysis is obtaining the correct nuclear constants for the mixtures involved. Time, costs, and non-availability of heavy water at the time dictated the decision to do the best that could be done with available cross sections of the various materials involved. The following is a tabulation of pertinent values used in calculating criticality, flux distribution, disadvantage factors, production, etc.

Core Values

L^2	248.5
D_s	0.8978
τ	162.2
D_f	1.182
K^2 , total buckling	0.0014225
Radius, cm	46
Height, cm	106
D ₂ O, vol. %	84
Type 1 Producer Material, vol. %	10.9
Al, vol. %	4.1
Type 2 material and voids in capsules, vol. %	1

Intermediate Radial Reflector Values

L^2	2751.2
D_s	0.9840
τ	269
D_f	1.8358
Outer Radius, cm	122
Height, cm	106
D ₂ O, vol. %	68.3
Producer Material, vol. %	30.9
Al, vol. %	0.8

Graphite Radial Reflector Values

L^2 , adjusted for $\frac{1}{2}$ -in. thick tank wall	1670
D_s	0.8885
τ	387
D_f	1.113
Outer Radius, cm	184.2

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Top and Bottom Reflector Average Values

L^2	3367.7
D_s	0.8249
τ	131
D_f	1.230
Thickness, cm	63.5

The method used to calculate criticality and flux distribution is essentially two-group diffusion theory as outlined in ANL-4352. However, it was necessary to adjust the neutron age, τ , in the core and radial intermediate reflector because it is known that heavy water-moderated reactors do not follow the two-group diffusion model close enough to obtain accurate values of criticality. This is believed to be due to the fact that heavy water has a lower scattering cross section as compared to light water and the neutrons are slowed down less per collision, i.e., it takes more collisions to slow down from the fast group to the slow group. An attempt to analyze the reactor by a three-group method consisting of a fast diffusion group, an intermediate continuous slowing down group, and a slow diffusion group met with considerable mathematical difficulty due to the fact that one real root and two imaginary roots were obtained. Some effort was expended trying to solve the problem with five diffusion groups. No particular confidence could be placed in the method because the τ 's and the D_f 's could not be determined for the intermediate groups to sufficient accuracy to warrant the refinement in method. A three-diffusion group problem was solved, and it resulted in a critical mass lower than that of the adjusted two-group method which was adopted. This seems to indicate that the method used is conservative relative to the three-diffusion group method as far as production figures are concerned since a lower critical mass would result in higher fluxes at the design power, 5000 kw.

The method used to adjust τ in the core is simple and straightforward.

By two-group diffusion theory

$$k_{\infty} = (1 + L^2 K^2) (1 + \tau \bar{K}^2)$$

and by continuous slowing down theory

$$k_{\infty} = (1 + L^2 \bar{K}^2) e^{\tau_1 \bar{K}^2}$$

where $\bar{K}^2$ is the total buckling of the core. By equating the two, we have

$$\tau = \frac{e^{\tau_1 \bar{K}^2} - 1}{\bar{K}^2}$$

When τ_1 is computed by the normal method

$$\tau = \int_{E_0}^E \frac{\lambda_{tr}}{3\Sigma_s \xi} \frac{dE}{E}$$

and then substituted into the equation to solve for τ , the adjusted age is obtained for use in the two-group diffusion method. The total buckling of the core is 0.0014225, and so the adjustment increased age by 11%.

Section A-A on drawing MJ-1010-F shows the preferred loading pattern with five Type 2 producer assemblies and 12 fuel assemblies. It will be noticed that each Type 2 producer assembly is in the center of a local cross pattern of fuel. The core can be divided into roughly representative unit cells. This was done and the flux for a cell was plotted. The thermal flux drops off in the region occupied by the fuel owing to the fact that the uranium and the quantity of aluminum in the fuel assembly is by far the greatest absorption in the cell. The thermal flux increased toward the middle of the cell owing to moderation of fast neutrons and nearly negligible absorption. It was found that the flux drops very little in the capsules. Even though the material has a high capture cross section relative to heavy water and the zirconium of the capsules, it is spread out through such a large volume that its actual effective macroscopic cross section is quite low. The disadvantage factor in the fuel is defined as

$$\text{d.f.} = \frac{\text{Volume average of thermal flux in the fuel}}{\text{Volume average of thermal flux in the entire cell}}$$

The d.f. in the fuel is 0.78.

The flux distribution is shown on Figures 5 and 6. The critical mass and excess reactivities are tabulated on the data summary sheets, pages 12-14. The effectiveness of the shim-safety rods is shown on Figure 7. These curves were determined by perturbation theory and must be checked carefully during the critical assembly test work prior to operation. It is anticipated that it may be necessary to change the full-in stops to somewhere nearer 50 degrees below the horizontal. The calculated maximum reactivity absorbed by the regulating rod in its full-in position is 0.45%, which is below the delayed neutron effect.

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Figure 5

RADIAL FLUX PLOT

RE-7-11012-A

RE-7-11011-A

Figure 6
AXIAL FLUX PLOT

Figure 7

REACTIVITY ABSORBED BY SINGLE
SHIM-SAFETY BLADE
SIZE 7 x 1 x 83 IN.

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VIII, LOADING AND UNLOADING PROGRAM

The reactor loading is based on the calculated hot equilibrium critical mass plus an allowance for thirty minutes' xenon override and 48 grams for burnup. These two excess reactivity requirements were kept to a minimum to make the neutron flux for irradiating as high as possible.

To remove a type 1 or type 2 producer assembly the rotating plug is positioned accurately above an access hole over the element to be removed, and the coffin is rolled into place, evacuated, and purged with helium before the reactor is shut down. Removal of an irradiated type 1 or type 2 producer assembly and replacement will require a shutdown time of ~ 5 minutes. The handling of these assemblies is based on frequent shutdowns, approximately once per day, but of short duration. This eliminates the need for high excess fissionable material loading to overcome xenon build-up after shutdown and allows each assembly radiation cycle to be scheduled for optimum production. Such a program will be worked out with the use of experimentally determined flux maps that will be obtained during the initial critical assembly test work at the completion of the construction of the reactor.

Unloading and loading fuel assemblies can be done one per shutdown the same as the producer pieces are handled. However, this requires a wait of 25 minutes after shutdown while the fuel plates cool. After 25 minutes the heat generated in the hottest fuel assembly can be as high as 10 kw with roughly 45% being gammas and the remainder being short-range particles, alphas and betas. The coffin cools the fuel plates by means of high-velocity helium jets. In case of an emergency, such as mechanical sticking or something similar, a spray of heavy water is available in the coffin at all times. The 48 grams of U^{235} excess for burn-up will last 7.7 days. Here again a loading and unloading program will be carefully worked out, once the tests have made accurate flux data available.

/4/

IX. INSTRUMENTATION AND CONTROL

The continuous operation required of a reactor facility intended for production purposes established certain fundamental requirements for this installation. These are as follows:

- a. Maximum production utilization of reactor facility.
- b. Reliability of instrumentation and control components.
- c. Safety.
- d. Simplified and low cost maintenance.
- e. Minimum manpower requirements for full-time operation at low cost.
- f. Centralized operation and control, largely dictated by e. above.
- g. Functional arrangement of instruments with respect to system and operation.

Any increase in cost of this type of installation over one in which the instrumentation is dispersed throughout the facility and mounted locally will be realized many times over in savings in operational costs, reduced manpower requirements, increased safety, and minimum reactor down time. Also, much of the equipment is in a radioactive area where local reading instruments are not accessible.

A. Control Room

The instrumentation and control of this reactor installation is centralized in the control room. The panel board arrangement has been planned so that the instruments are grouped in accordance with the system served and so that they are readily visible from the operator's chair at the console (see drawing MJ-4780-D, Pictorial of the Control Room).

The controls for the reactor and certain instruments are located on the console panels so that the operator has complete information relative to the performance of the reactor and its auxiliaries at a glance. Reactor scram and push-button controls for all important process system motors are also provided on console panel "C." This permits the operator to take action in the shortest possible time in an emergency.

Instrumentation and controls are provided either at the console or on the panel board for the following systems:

- a. Reactor neutron density level
- b. Reactor period
- c. Reactor coolant, D₂O system
- d. Secondary coolant, H₂O system
- e. Helium system
- f. Radiation monitoring
- g. Utilities
- h. Instrument and control power

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In the interests of low cost maintenance and in order to keep parts inventory at a minimum both as to number of items stocked and investment, it is recommended that a standard basic instrument design by one manufacturer shall be specified where possible. This also has the advantage of uniform scale and instrument appearance. However, the specifications are written to enable competitive bidding.

Flexibility and convenience in wiring installation for the instruments and control circuits is provided by two 4 x 4-in. raceways. These raceways or wireways are located on the back of the panel boards with the control power distribution duct at the extreme top and the duct for the instrument cables and wires at the bottom. A covered 6 x 15-in. wiring trench is provided in the floor between the console and the panel boards (see drawings MJ-4714-D, Panel Board Elevations, and MJ-4716-D, Panel Board Layout Floor Plan).

Distribution of the instrument and control wiring from the control room to the reactor and other systems is provided by two 6 x 10-in. raceways extending along the ceiling of the equipment room to reactor face 3. From this point the raceway is extended around the perimeter of the biological shield and vertically downward to the subreactor room (see drawing MJ-4604, Raceway and Electrical Equipment Plan). These raceways are compartmented to provide isolation and shielding of conductors in circuits which might be adversely affected by inductive or capacitive effects which would be detrimental to low level signals transmitted in such cables.

B. Reactor Control

The control system is similar to that being built into CP-5 and that which was used in CP-3'. The same type of rod controls is used in all three of these installations with the exception that the regulating rod for this reactor is located on the side on a horizontal center line of the reactor rather than on the vertical axis of the reactor as in the case of the other two installations.

The basic requirements for the control system are as follows:

- a. Safety - scram control from neutron density level, rate of change, and process system.
- b. Continuous long time operation at rated power level.
- c. Close regulation of reactor power level.
- d. Control rod rate of withdrawal limited to avoid fast periods. Individual rod withdrawal - group or individual insertion.

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ELEVATION - FRONT OF PANELBOARD - DEVELOPED VIEW

- NOTES**
- FOR DETAILS OF CONSTRUCTION, INSTALLATION AND WIRING REFER TO INDIVIDUAL PANELS, SERIES 4710 THROUGH 4725.
 - CURB IS TO BE SUPPLIED AS PART OF INSTALLATION - BRACKET AIR DUCTS FROM TOP OF SUBCABLES TO BUILDING BRIMMEST AIR DUCT ARE TO BE DRIVEN BY INSTALLATION CONTRACTOR AFTER INSTALLATION OF PANELS.
 - LOCATIONS AS SPECIFIED (SEE DRAWING 15 MJ-4711-D) TO DRIP CURTAIN WALL.
 - POWER & INSTRUMENT RACEWAYS (TO BE INSTALLED IN FIELD AFTER PANELBOARD INSTALLATION) SERVICE ANCHORS 8" TYPICAL BETWEEN PANELS TO SUIT.

- REFERENCE DRAWINGS**
- MJ-4715-D INSTRUMENT SCHEDULE
 - MJ-4715-D PANELBOARD LAYOUT FLOOR PLAN
 - MJ-4717-D PANELBOARD DETAILS

ELEVATION - SECTION SHOWING BACK OF PANELS - DEVELOPED VIEW

RACEWAYS ARE TO BE INSTALLED AFTER PANELBOARD INSTALLATION

TRANSITION PIECE FROM INSTRUMENT RACEWAY TO SLUT CABLES PANELS SEE MJ-4711-D FOR DETS

15" x 6" SLOT (4) (BY OTHERS)

WIRING TRENCH TO CONDUIT (BY OTHERS)

MJ-4714-D

DATE	12/1/68	BY	J. A. SPALDING	CHECKED	J. A. SPALDING
DESIGNED	J. A. SPALDING	DATE	12/1/68	BY	J. A. SPALDING
CHECKED	J. A. SPALDING	DATE	12/1/68	BY	J. A. SPALDING
APPROVED	J. A. SPALDING	DATE	12/1/68	BY	J. A. SPALDING
PANELBOARD LAYOUT ELEVATIONS MJ-4714-D

MICRO-FILM STRIP						APPROVED CHECK		DATE	CHECK SIGNATURE	88	7/27	NEXT ASSEMBLY	NO. REQUIRED
						FOR SPENDING N-2P SPENDING DROLS HOFFMANN		7/27 7/27 7/27 7/27 7/27				ARGONNE NATIONAL LABORATORY THIS DRAWING IS THE PROPERTY OF THE ARGONNE NATIONAL LABORATORY TITLE	
						TOLERANCES UNLESS OTHERWISE NOTED FRACTIONAL $\pm$ 1/16, DECIMAL $\pm$.005, ANGLE $\pm$ 1/2° REMOVE ALL SURF.		RACEWAY AND ELEC. EQUIPT.-PLAN					
SYN. ZONE		CHANGE		DATE		BY		MATERIAL		SCALE 1/2" = 1'-0" 1/4" = 1'-0"		DRWG. NO. MJ-4604-D	

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- e. Automatic power level control with manual override.
- f. Temperature control - regulation of D₂O temperature inlet to reactor.
- g. Centralized control of all rods and scram at console.
- h. Reliable long service life components - plug-in relay racks.

The most important single factor in designing a reactor control system is evaluation of the response time characteristics of the reactor. The size of the control rods, or rather the total reactivity effect of the control rods, is established by the amount of "absorber" necessary to effect positive "shutdown" with minimum xenon and other effects in a core with maximum new fuel loading.

The maximum rate of shim rod withdrawal is established by maximum motor speed at 0.6° per second. This represents a change in reactivity of 0.0018 per second (see curve, Figure 7, "Reactivity Absorbed by Single Shim-Safety Blade," page 109). This amount of reactivity control is somewhat greater than will actually be achieved, since shadowing by other rods will reduce single rod effectiveness. The estimated response of the reactor to 0.6° (0.0018 reactivity) movement of the shim rod is a 39-second period.

$$T = \frac{\beta - \rho}{\lambda \rho}$$

T = pile period

β = delayed neutron effect, 0.0075

λ = decay constant = 0.08 sec.

ρ = reactivity or

$$T = \frac{0.094}{\rho} = 12.5 \text{ sec.}$$

This formula is applicable only for reactivities substantially less than the delayed neutron effect. These are calculated values, and the proper rate of movement of these rods will be determined during the criticality tests.

The effectiveness of the regulating rod can hardly be calculated accurately because of its location; however, calculations indicate the amount of reactivity controlled to be about 0.45%. The time response of the reactor with respect to insertion or withdrawal of this rod will be much less than that for the shim-safety rods. This is on the basis of much faster movement of this rod as compared to that of the safety rods and much lower reactivity control per increment of movement. Calculated rate of travel is 2.4 in./sec.

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1. Shim-Safety Rod Control

The circuit for control of the shim safety rods is shown in drawing MJ-4760, Schematic Diagram Scram Circuit and Shim Safety Rod Control. This drawing includes the individual rod drive controls as well as the rod scram control which is common to all rods. The individual shim rod control will be discussed first. Essentially, the shim rod circuit control consists of a special single-pole, double-throw toggle switch with spring return to center "off" position, which energizes the coils in a reversing type of motor control contactor. The contactor is located adjacent to the actuator at the reactor. By moving the switch to either side of the "off" position, the contactor energizes the control rod actuator motor for "in" or "out" movement of the rod. Various limit switches are provided on the actuator assembly to perform the functions outlined below.

- a. Limit "In" travel
- b. Limit "Out" travel
- c. Rod latch switch
- d. Intermediate position limit switch

Several electrical interlocks are provided in the circuit by means of relays which are assembled on a panel. The interlocks perform the functions outlined below.

- a. Group insertion of all rods
- b. Permit withdrawal of only one rod at a time
- c. Limit withdrawal of any individual rod beyond a predetermined position until all rods are leveled to that position.

The interlock relays are assembled on a "plug in" panel assembly and mounted in Cubicle 12 in the control room (see drawing MJ-4748).

Two-speed control of the shim-safety rod motors is accomplished by a resistor and relay combination. The resistor is in series with the armature of the actuator motor. Upon moving the control switch to either extreme of its travel, a relay is energized and closes a set of contacts which are in parallel with the resistor, thus shorting it and increasing the voltage to the motor armature. The resistor is so proportioned that a motor speed ratio of 1:2 is provided. This can be varied by changing the resistor. Dynamic braking is provided for precise rod positioning. This is accomplished by shorting the actuator motor armature through a pair of normally closed contacts in the reversing contactor. The controls and pilot lights for the shim rod actuators are located on the right-hand center panel section of the console (see MJ-4765-D).

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MJ-4748-D

NOTES-

- 1 ALL WIRING AND COMPONENTS TO BE INSTALLED IN ACCORDANCE WITH N.E.C. AND PREVALENT LOCAL CODES.
- 2 RACKMOUNTING FRAME TO BE INSTALLED AFTER PANELBOARD INSTALLATION.
- 3 RELAY RACKS & RESPECTIVE SUB-PANEL ASSEMBLIES BY OTHERS.

REFERENCE DRAWINGS-

- MJ-4702-D TYPICAL PANEL AND CUBICLE
- MJ-4740-B ROD CONTROL & SCRAM CIRCUIT SCHEMATIC
- MJ-4700-B SCRAM RELAY PANEL WIRING DIAGRAM
- MJ-4750-B CONTROL ROD RELAY WIRING DIAGRAM

ALL DIMENSIONS IN INCHES UNLESS OTHERWISE INDICATED				MJ-4748-D	
REV	DATE	BY	CHK	NO. APPROVED	NO. PROVIDED
1	10/1/68	J. J. J.	J. J. J.	1	1
T. SPALONK (DRN) BENNETT (E) B.				ARGONNE NATIONAL LABORATORY	
TOLERANCE UNLESS OTHERWISE NOTED				THE ARGONNE NATIONAL LABORATORY	
FRACTIONAL & DECIMAL DIMENSIONS IN INCHES				ROD CONTROL RELAYS -	
ABOVE ALL DIMENSIONS				PANELBOARD NO. 12	
SEE MJ-4748-B FOR				TECH. N.E.C.-13	
SCALE				3/8" = 1"	
DATE OF CHG.				MJ-4748-D	

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- NOTES:
1. DIMENSIONS SHOWN ON THIS DWG. AND ON DWG. MJ-4767-D APPLY TO EQUIPMENT SPECIFIED IN MJ-4765-B/M. IF SUBSTITUTIONS ARE MADE DIMENSIONS SHOULD BE ALTERED TO SUIT.
 2. ALL SUBSTITUTIONS TO BE APPROVED BY PURCHASER.
 3. INSTALLATION REQUIREMENTS - ALL WIRING AND COMPONENTS TO BE INSTALLED IN ACCORDANCE WITH N.E.C. AND PREVAILING LOCAL CODES.
 4. ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.

REF. DWG. - MJ-4766-D CONSOLE PANEL
B-RIGHT WIRING DIAGRAM

APPROVED SHEET				MJ-4761-D		ONE
<div style="border: 1px solid black; padding: 2px; width: 100px; height: 100px; display: flex; align-items: center; justify-content: center;"> <div style="border: 1px solid black; padding: 2px;"> <div style="border: 1px solid black; padding: 2px;"> <div style="border: 1px solid black; padding: 2px;"> <div style="border: 1px solid black; padding: 2px;"> <div style="border: 1px solid black; padding: 2px;"> <div style="border: 1px solid black; padding: 2px;"> <div style="border: 1px solid black; padding: 2px;"> <div style="border: 1px solid black; padding: 2px;"> <div style="border: 1px solid black; padding: 2px;"> <div style="border: 1px solid black; padding: 2px;"> <div style="border: 1px solid black; padding: 2px;"> <div style="border: 1px solid black; padding: 2px;"> <div style="border: 1px solid black; padding: 2px;"> <div style="border: 1px solid black; padding: 2px;"> <div style="border: 1px solid black; padding: 2px;"> <div style="border: 1px solid black; padding: 2px;"> <div style="border: 1px solid black; 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"Scram" is accomplished either by dropping the shim-safety rods into the core, or by dumping 500 gal of D₂O from the reactor tank, or a combination of both. The circuit for scram control is shown in drawing MJ-4760, Schematic Diagram Scram Circuit and Shim-safety Rod Control. A holding type of relay is provided for each scram control point. One normally open contact on each relay is connected in series arrangement with all the sets of like contacts on the other relays, and in turn, this series circuit is connected to the "rod trip solenoids" which are a part of each shim rod actuator or drive assembly. Whenever the coil circuit in any one of these relays is de-energized, the "rod trip solenoids" are de-energized, and the shim-safety rods are driven into the reactor core by a spring which is a part of the drive assembly.

The scram control panel is a part of the console and is shown on MJ-4769-D, Console Panel "C" Subassembly. This panel includes manual scram control and reset push buttons. Indicator lights are provided to inform the operator when "scram" has been initiated and what portion of the control system initiated the "scram." A light is also provided to indicate when the rods are latched to the drives in the actuator permitting rod withdrawal. As a safety feature, the rod latching limit switches are all connected in series, and this series combination is in series with the rod trip solenoids. Thus, all rods must be latched before one can be withdrawn.

The reactor can be scrambled by dumping a portion of the D₂O from the reactor tank. This effectively removes the top reflector from over the reactor core. This is accomplished by the operator from console panel "C." A scram button is provided which de-energizes the holding circuit in a relay which controls the solenoid air valve for the main dump valve. The solenoid air valve is connected to a pair of normally open contacts on the control relay. When the operator de-energizes the holding circuit of the control relay, the main dump valve opens. The "Dump" scram push button is also connected to actuate the shim-safety rod scram. In this way, fast scram is accomplished since the effectiveness of both the rods and loss of reflector is accomplished simultaneously.

The time response of the rod scram system is quite fast. Approximately 20 milliseconds are required for the scram relays to actuate the rod trip solenoids and for the rod trip solenoids to release the rods. The relay response time is approximately 12 milliseconds, and the rod trip solenoid response time is approximately 8 milliseconds.

The control points or systems from which scram control actuation can originate were chosen with careful attention to the safety of operation of the reactor and protection of the facility and personnel. The reactor can be scrambled by any one of the following:

MJ 4760-E

SHIM SAFETY ROD CONTROL

REVISION	DATE	BY	CHKD	APP'D
1	10/1/60	J. J. B.	J. J. B.	J. J. B.
2	10/1/60	J. J. B.	J. J. B.	J. J. B.
3	10/1/60	J. J. B.	J. J. B.	J. J. B.
4	10/1/60	J. J. B.	J. J. B.	J. J. B.
5	10/1/60	J. J. B.	J. J. B.	J. J. B.
6	10/1/60	J. J. B.	J. J. B.	J. J. B.
7	10/1/60	J. J. B.	J. J. B.	J. J. B.
8	10/1/60	J. J. B.	J. J. B.	J. J. B.
9	10/1/60	J. J. B.	J. J. B.	J. J. B.
10	10/1/60	J. J. B.	J. J. B.	J. J. B.

ARGONNE NATIONAL LABORATORY
THE UNIVERSITY OF CHICAGO
5-1000
SYNTHETIC DIAGRAM FOR
SCRAM CIRCUIT & SHIM
SAFETY ROD CONTROL
REVISED 10/1/60
MJ-4760-E

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- NOTES:
1. DIMENSIONS SHOWN ON DRWG. ABOVE & ON DRWG. MJ-4771-D APPLY TO EQUIPMENT SPECIFIED IN MJ-4768-B/M. IF SUBSTITUTIONS ARE MADE DIMENSIONS SHOULD BE ALTERED TO SUIT.
 2. ALL SUBSTITUTIONS ARE TO BE APPROVED BY PURCHASER.
 3. INSTALLATION REQUIREMENTS - ALL WIRING & COMPONENTS TO BE INSTALLED IN ACCORDANCE WITH N.E.C. & PREVAILING LOCAL CODES.
 4. ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.

REFERENCE DRWG.
MJ-4770-D CONSOLE PANEL 'C' WIRING DIAGRAM

APPROVED FOR				MJ-4761-D		ONE
DATE				REVISION		NO. DESCRIPTION
11/17/71				1		ARGONNE NATIONAL LABORATORY
11/17/71				2		THIS DRAWING IS THE PROPERTY OF
11/17/71				3		THE ARGONNE NATIONAL LABORATORY
11/17/71				4		CONSOLE PANEL 'C'
11/17/71				5		SUB-ASSEMBLY
11/17/71				6		SEE MJ-4768-B/M
11/17/71				7		DATE
11/17/71				8		HALF
11/17/71				9		MJ-4768-D

- a. Reactor period, 8 sec minimum
- b. Reactor power level, 5500 kw (three trips on neutron density)
- c. D₂O flow
- d. D₂O temperature
- e. D₂O dump
- f. Exhaust air monitor
- g. Building power
- h. Manual by operator

Fail safe provisions are built into the scram control by actuation of scram on "power off" condition to any component, and by providing multiple safeties on critical items such as neutron density.

2. Regulating Rod Control

The control system for the regulating rod is more complex than the one just described for the shim-safety rods because provisions for both manual and automatic control are built into the system for the operation of this rod. There is no provision for automatic adjustment of the shim-safety rods. The function of the regulating rod is quite different from that of the shim rods. It is used primarily to compensate for small changes in reactivity and to maintain relatively constant reactor power level. It provides a fine control which can be used for exploratory purposes during start-up to determine trend in reactor reactivity or for regulation of reactor power level at a particular value.

The regulating rod controls approximately 0.45% reactivity for full travel excursion. Its total travel distance is 26 inches. Approximately 15 inches of this travel is most useful for control purposes. The rate of movement of this rod is 12 ft per minute, or 2.4 inches per second.

Assuming that 70% of the effective control of this rod is over 50% of its travel from full in to one-half out position, the maximum rate of change of k per second by this rod may be approximately 0.10%. The minimum "period" caused by moving this rod for 1 sec from the full "in" position outward would be

$$\frac{0.094}{0.00101} - 12.5 = 81 \text{ sec}$$

* - THESE CAPACITORS (NO C-102) ALL HAVE THE SAME VALUE OF 1 MFD , 500 VOLTS

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The minimum period for full rod travel from full "in" to full "out" position would be

$$\frac{0.094}{0.0045} - 12.5 \approx 8.4 \text{ sec}$$

It must be understood that these are calculated values which will be checked during the critical tests.

The circuit for control of the regulating rod is shown in MJ-4742-E, Schematic Diagram for Regulating Rod Control. The controls for the operation of the regulating rod are located on the console (see MJ-4765-D, Console Panel B).

The purpose of the automatic control is primarily to relieve the operator of the duty of continuous vigilance in holding a constant power, and, secondly, to make start-up of the reactor a comparatively simple process requiring a minimum of manipulations on the operator's part. The principal of design of the system is that it will obtain a critical reactor rod position at any power setting made by the operator between 10% and 100% of design power. It will hold the power to about $\pm 1/2\%$ at the 100% power setting and about $\pm 4.5\%$ at the 10% power setting.

Reactor start-up can be accomplished at the operator's discretion by making a power setting, readying the regulating rod, selecting "automatic" operation, and manually removing shim-safety rods until a reactor flux period of plus 20 seconds is obtained. When the power setting is reached (as determined by signal from neutron flux sensing ion chamber), the reactor will come under control automatically. Period regulation during start-up is done by the operator, and no operational overrides are used. Changing power will be done, under automatic control, at a constant period of about 20 seconds or longer, depending upon the total effectiveness of the rod. This period demand is built into the demand potentiometer by using a constant-speed motor drive. Automatic operation and power changing will not be permitted when the regulating rod is not properly positioned to control the reactor. Limit switches, interlocking relays, and circuit fault detectors will prevent improper operation. Automatic control is to be obtained by setting up relays which will drop out of the automatic position to the manual or operator position if trouble is detected in any circuit connected with automatic operation.

A d-c motor is provided for driving the regulating rod with a gear train between it and the rod. Dynamic braking of the motor is necessary for system stability. Limit switches connected with the regulating rod will operate at the "all in," "all out," "80% in," "80% out" positions. These are readily adjustable with the drive in operating position. The control system pertaining to the regulating rod is shown on MJ-4749-E. These

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MJ-4745-D

NOTES -
 1. ALL WIRING AND COMPONENTS TO BE INSTALLED IN ACCORDANCE WITH N.E.C. AND PREVAILING LOCAL CODES.
 2. LOCATING SLEEVES & PLUGS MUST MATE WITH SUB PANEL MJ-4750-D.
REFERENCE DRAWINGS:
 MJ-4745-D PANELBOARD NO. 12 RED CONTROL RELAYS
 MJ-4750-D ROD CONTROL & BREAKER CIRCUIT SCHEMATIC
 MJ-4750-D BREAK RELAY PANEL WIRING DIAGRAM
 MJ-4750-D CONTROL ROD RELAY SUB PANEL
 MJ-4750-D CONTROL ROD RELAY WIRING DIAGRAMS

MJ-4745-D		4
REVISIONS		
REV.	DATE	DESCRIPTION
1	10/1/79	INITIAL ASSEMBLY
2	10/1/79	ARGONNE NATIONAL LABORATORY THE DESIGN IS THE PROPERTY OF THE ARGONNE NATIONAL LABORATORY
3	10/1/79	RELAY ASSEMBLY - SHIP
4	10/1/79	SAFETY ROD
5	10/1/79	SAFETY ROD
6	10/1/79	SAFETY ROD
7	10/1/79	SAFETY ROD
8	10/1/79	SAFETY ROD
9	10/1/79	SAFETY ROD
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97	10/1/79	SAFETY ROD
98	10/1/79	SAFETY ROD
99	10/1/79	SAFETY ROD
100	10/1/79	SAFETY ROD

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limit switches make provision for interlocking shim rods with the regulating rod position in a secondary control loop which can be used to extend the regulating rod's range if it is not effective enough for satisfactory regulation of power in the final design.

The control board, MJ-4765-D, indicates regulating rod position, automatic or manual operation, and power error on a microammeter which is connected into a differential circuit. Push buttons are provided to run the regulating rod into or out of the reactor and establish automatic operations as desired. A warning bell indicates failure to follow procedure or improper circuit operation. Silencing is done by pressing the manual push button.

Manual or operator control is provided by operating the regulating rod motor at not more than about $0.001 \text{ } \delta k/\text{sec}$. Error in power for manual operation is indicated by a differential galvanometer. Total power is indicated with the power galvanometer. These galvanometers are fed by ion current chambers. Use of this setup makes possible ready switching between automatic and manual control without disturbing either circuit.

3. Temperature Control (see MJ-3001, Flow Sheet)

The temperature coefficient of the reactor is sufficient that a wide diversion of temperature cooling water would require a considerable amount of correction by the shim-safety rods. It is possible for the water temperature from the cooling tower to vary as much as 10 degrees per hour, or more. Special precautions have been taken to regulate the amount of water supplied to the heat exchangers in proportion to the temperature of the D_2O out of the heat exchangers. This will regulate the temperature of the coolant into the reactor.

The temperature regulation is accomplished by a resistance bulb mounted in the main D_2O inlet line to the reactor. The signal from the resistance bulb unit actuates a proportional type controller which operates two valves in the tower water line to the heat exchangers. Flow is controlled in proportion to temperature of D_2O . A D_2O temperature scram control is provided.

C. Nuclear Instrumentation

The nuclear instruments in the installation design are those instruments which measure neutron flux density or rate of change of neutron flux density in the reactor. Several instruments are used for this purpose, and a complete list of them is given on MJC-4715-D, Nuclear Instrument Schedule, Sheets 1 and 2.

NUCLEAR INSTRUMENT SCHEDULE
SHEET ONE OF TWO

	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	REMARKS
1	ITEM NO	SYSTEM	DESCRIPTION	FUNCTION	VENDOR	VENDOR PART NO	RANGE	SCALE	CALIBRATION	MOUNTING	POWER VOLTS FREQUENCY	ACCESSORIES	SENSING ELEMENT	PANEL CUTOFF	INSTRUMENT LOCATION	
2	PERIOD METER															
3	AINC 80	REACTOR	STRIP CHART RECORDER 2 SECOND FULL SCALE SPAN SINGLE	TO RECORD REACTOR PERIOD	BROWN INST CO	Y180 X 17	INSTANT TO 1 SEC	LOGARITHMIC 4 DECADES	CENTER TO 10 1 RECORDED	FLUSH	115 60	AINC 80A 80B 80C	AINC 80A		PANEL 8	PERIOD METER TRIP ON 8 SEC PERIOD
4	AINC 80A	REACTOR	ION CHAMBER COATED CONCENTRIC CYLINDERS ARGON FILLED 4" O.D. X 12" L	TO MEASURE RATE OF NEUTRON DENSITY	ARGONNE NATIONAL LAB	EL 3									INST HOLE 1 1	
5	AINC 80B	REACTOR	PREAMPLIFIER AND CHAMBER POWER SUPPLY	TO AMPLIFY CURRENT OUTPUT OF CHAMBER	ARGONNE NATIONAL LAB	MODEL COME CIRCUIT EL 1467				RACK					CABINET AT REACTOR FACE 1	
6	AINC 80C	REACTOR	MAIN AMPLIFIER AND SAFETY TRIP	TO PROVIDE SIGNAL TO RECORDER & TO ACTIVATE SAFETY TRIPS	ARGONNE NATIONAL LAB	MODEL CD-47 CIRCUIT EL 1468				RACK					CIRCUIT 7	
7	LOW POWER LEVEL RECORDER															
8	AINC 81	REACTOR	STRIP CHART RECORDER 1 SECOND FULL SCALE 25 MV SPAN	LOW POWER LEVEL RECORDER	APPLIED PHYSICS CORP	MODEL 32 ASSEMBLY	10 12 AMPS TO 10 7 AMPS	LOGARITHMIC 3 DECADES	1 10 100	FLUSH	115 60	AINC 81A 81B 81C 81D 81E	AINC 81A		PANEL 8	
9	AINC 81A	REACTOR	ION CHAMBER	TO MEASURE NEUTRON LOW LEVEL DENSITY	ARGONNE NATIONAL LAB	EL 3									INSTRUMENT HOLE 1 3	
10	AINC 81B	REACTOR	POWER SUPPLY 5 800 V DC 20 15 0 10 MA	TO SUPPLY HI VOLTAGE TO CHAMBER	BETA ELEC CORP	SPEC 281				RACK					CABINET AT REACTOR FACE 1	
11	AINC 81C	REACTOR	ELECTROMETER HEAD	TO MEASURE CURRENT OUTPUT OF CHAMBER	APPLIED PHYSICS CORP	MODEL 32	10 12 AMPS TO 10 7 AMPS			SHELF					CABINET AT REACTOR FACE 1	
12	AINC 81D	REACTOR	MAIN AMPLIFIER	TO PROVIDE SIGNAL TO RECORDER	APPLIED PHYSICS CORP	MODEL 32				RACK					CABINET AT REACTOR FACE 1	
13	AINC 81E	REACTOR	REMOTE RANGE CONTROL	TO PROVIDE RANGE CHANGING FROM CONSOLE (10 CONTROLS, 200V)	APPLIED PHYSICS CORP	MODEL 32				PANEL					CONSOLE PANEL "A"	
14	POWER LEVEL RECORDER & SAFETY TRIPS															
15	AINC 82 1 82 2	REACTOR	STRIP CHART 12 SEC FULL SCALE TRAVEL 10 MILLIVOLT SPAN	TO RECORD NEUTRON DENSITY LEVEL AS POWER LEVEL	BROWN INST CO	Y180 X 11	0 750 X 10	LINEAR	KILOWATTS	FLUSH	115 60	AINC 82A 82B			PANEL 10	
16	AINC 82A	REACTOR	ION CHAMBER	TO MEASURE NEUTRON DENSITY	ARGONNE NATIONAL LAB	EL 3									INST HOLES 3 2 3 4 3 3	
17	AINC 82B	REACTOR	AMPLIFIER WITH SAFETY TRIPS (2 CHANNEL)	TO AMPLIFY ION CHAMBER SIGNALS & TO ACTIVATE SAFETY CIRCUIT ON HI LEVEL	ARGONNE NATIONAL LAB	CIRCUIT EL 1467	1 INPUT 0 10 MA			RACK					CIRCUIT 10	3 SAFETY TRIPS AND CHAMBER POWER SUPPLIES BUILT INTO ONE CHASSIS
18	GALVANOMETER															
19	AINC 87 1 87 2	REACTOR	POWER LEVEL & DIFFERENTIAL GALVANOMETER ASSEMBLIES	TO INDICATE REACTOR POWER LEVEL	MILICON INST CO	SPEC 39363	10 15 AMPS TO 10 3 AMPS	0 800 MH 250 0 250 MH	MILLIMETERS	SPECIAL	BATTERIES	AINC 87A 87B			CONSOLE PANEL "M"	
20	AINC 87A	REACTOR	ION CHAMBER	MEASURE NEUTRON DENSITY	ARGONNE NATIONAL LAB	EL 3									INSTRUMENT HOLE 1 2	
21	AINC 87B	REACTOR	"B" BATTERY BANK 14 CELLS 48 WCELL	TO SUPPLY HI VOLTAGE TO CHAMBER	BURGESS BATTERY CO	2300X				SHELF					CABINET AT REACTOR FACE 1	
22	AUTOMATIC CONTROL															
23	AINC 86	REACTOR	DIAL TYPE REACTOR POWER DEMAND INDICATOR	TO INDICATE REACTOR POWER DEMAND SETTING	ARGONNE NATIONAL LAB		10 100	LOGARITHMIC	PERCENT	FLUSH					PANEL 9	
24	AINC 86A	REACTOR	ION CHAMBER	TO MEASURE NEUTRON DENSITY FOR REACTOR POWER CONTROL	ARGONNE NATIONAL LAB	EL 3 MJ 4797 B										
25	AINC 86B	REACTOR	ION CHAMBER SUPPLY 200 MA 500 V 20 1% RES 0 2 MA	TO SUPPLY REGULATED HI VOLTAGE SUPPLY TO ION CHAMBER	BETA ELECTRIC CORP	MODEL 284	700 1800 VOLTS DC			SHELF					REACTOR FACE 3	
26	AINC 86C	REACTOR	AMPLIFIER UNIT 11 2 AUTOMATIC CONTROL POWER DEMAND	TO AUTOMATICALLY REGULATE REACTOR POWER LEVEL	ARGONNE NATIONAL LAB	MJ 4791 EQUIP OF RCD 397 4				RACK					CIRCUIT 11	
27	AINC 86D	REACTOR	POWER SUPPLY TWO UNITS 1000 VDC -200 VDC	TO PROVIDE 60 & 20 SUPPLY TO AINC 86C & FILAMENT POWER	LAMBDA ELECTRIC CO	MODEL 28	1200 VDC 4 3 CT 6 9 V AC			RACK					CIRCUIT 11	
28	ROD POSITION INDICATORS															
29	AINC 88	REACTOR	DIAL TYPE ROD POSITION INDICATOR SELVSHY DRIVEN	TO INDICATE POSITION OF REGULATING ROD IN REACTOR	ARGONNE NATIONAL LAB	MJ 4791	0 20"	LINEAR	INCHES	FLUSH					PANEL 9	
30	AINC 88	REACTOR	DIAL TYPE ROD POSITION INDICATOR SELVSHY DRIVEN	TO INDICATE POSITION OF REGULATING ROD IN REACTOR	ARGONNE NATIONAL LAB	MJ 4791	0 40"	LINEAR	DEGREES	FLUSH					PANEL 9	
														</		

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NUCLEAR INSTRUMENT SCHEDULE
SHEET TWO OF TWO

A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	REMARKS
ITEM NO.	SYSTEM	DESCRIPTION	FUNCTION	VENDOR	VENDOR PART NO.	RANGE	SCALE	CALIBRATION	MOUNTING	POWER VOLTS FREQUENCY	ACCESSORIES	SENSING ELEMENT	PANEL CUTOFF	INSTRUMENT LOCATION	
1	RADIATION MONITORS														
2	AIRC 54	BUILDING EXHAUST AIR	STRIP CHART, SINGLE PEN, 24 SEC PER SPEED 10 MV SPAN	BROWN INST CO.	Y193 X 60	10-15 AMP 10-10 AMP	LOGARITHMIC	1-10-100	FLUSH					PANEL 1	
3	AIRC 54A	BUILDING EXHAUST AIR	TO MEASURE ACTIVITY OF BUILDING EXHAUST AIR	ARGONNE NATIONAL LAB.					HAMMERS					PIPE TUNNEL	
4	AIRC 54B	BUILDING EXHAUST AIR	ELECTROMETER - VIBRATING REED & PREAMPLIFIER	BROWN INST CO.		10-15 AMPS 10-10 AMPS			SHLF					PIPE TUNNEL ON COLUMN	
5	AIRC 54C	BUILDING EXHAUST AIR	CHAMBER POWER SUPPLY	BETA ELEC CORP. SPEC 191		0-500 V DC 10-100 V AC			SHLF					PIPE TUNNEL ON COLUMN	
6	AIRC 55	AREA	COUNTER AND AMPLIFIER ASSEMBLY	RADIATION COUNTER LAB.	MODEL 11 MODEL 27				SHLF					IN BUS REACTOR ROOM & PUMP ROOM	
7	AIRC 55A	AREA	ROBERTS INDICATING METER & RELAY	RADIATION COUNTER LAB.	MODEL 11 MODEL 27				WALL						

APPROVED DESIG		DATE	CHECKED	DATE
DESIGNED BY		DATE	CHECKED	DATE
DRAWN BY		DATE	CHECKED	DATE
TOLERANCES UNLESS OTHERWISE NOTED		FRACTIONAL & DECIMAL DIMENSIONS		
MATERIAL		SCALE		
SHEET NO.		SHEET TOTAL		

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TITLE
NUCLEAR INST SCHEDULE

SCALE
AS SHOWN

DRAWN BY
MJC-4715-D

MJC-4715-D

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The instruments are classified as follows:

- a. Neutron Flux Density or Power Level.
Power Level Galvanometer and Safety.
Differential Galvanometer.
Vibrating Reed Electrometer and Recorder.
Power Level Recorder and Safety.
- b. Rate of Change of Neutron Flux Density.
Period Meter and Recorder.

Each of these instruments is a combination of several components, which are matched and calibrated to provide the desired result. Probably the most important item is the ion chamber. The range of performance desired and the types of instruments chosen permit the use of one ion chamber design for all instrument and control purposes. The range over which reactor neutron flux density must be measured is determined by the maximum flux. Reactor power level can be approximated closely from operating neutron flux density for a given reactor design.

The ion chambers are normally located in the biological shield in a zone where the flux level is approximately 10^9 nv at full power operation. For cold and clean start-up, it will be necessary to push the chambers into their instrument holes to a point where flux is maximum.

The full power output being 5×10^6 watts, the range to be covered by the power level instruments is established as seven decades. The sensitivity of the instruments is determined by the output of the ion chamber used, and it is discussed below.

1. Ion Chamber

The ion chamber intended for use in this reactor is a concentric-cylinder, argon-filled design with boron-coated active surfaces. Total active area is approximately 2000 sq cm, and the sensitivity is about 3×10^{-14} amp per incident unit neutron flux per second. Spacing between electrodes is about 1/4 in. The maximum current output of the chamber at 10^9 flux is approximately 30 microamp. The minimum output will vary with background flux in the reactor. With completely new core loading the minimum flux will be essentially zero since photoneutron production will be essentially zero. However, the situation will be quite different after the core has produced power and photoneutron production, under shutdown conditions, is up. Neutron flux density in the chamber zone after shutdown will be approximately 10^3 nv. Chamber current output under this condition will be about 3×10^{-11} amp. The performance of the ion chamber for these various conditions is tabulated on page 132.

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<u>Reactor Power, watts</u>	<u>Flux In Core, nv</u>	<u>Flux At Chamber, nv</u>	<u>Chamber Current, amp</u>
5×10^6	10^{14}	10^9	3×10^{-5}
0	10^8	10^3	3×10^{-11} by photo neutron production

The above data is estimated and assumes uniform chamber response at saturation voltage.

The instruments specified for this reactor provide a total range coverage equivalent to that shown for the chamber. However, no single instrument specified will cover the complete range. The instruments and their respective ranges are tabulated below.

<u>Instrument</u>	<u>Range, amperes</u>	
	<u>Minimum</u>	<u>Maximum</u>
Vibrating Reed Electrometer and Recorder	10^{-13}	10^{-7}
Galvanometer - Power Level	6×10^{-10}	3×10^{-4}
Power Level Recorder	10^{-8}	3×10^{-5}

The period meter cannot be classified on the same basis as the other instruments since it functions as a rate instrument. It must respond, however, at very low power levels since the greatest use for this instrument is during start-up. This instrument as specified will operate satisfactorily over the entire power range of the reactor from zero power to full power. A safety scram control is built into the period amplifier, which also operates the recorder. Scram safety controls are also built into the power level instrument installation. The power level instrument assembly incorporates three amplifiers, each of which controls a scram-actuating relay assembly. These controls are individually adjustable for scram at any desired power level. The components required for each of the instrument installations discussed are given below.

Galvanometer

- a. Ion Chamber
- b. Battery Power Supply (500 v)
- c. Control Unit & Differential Supply Voltage
- d. Galvanometers

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Vibrating Reed Electrometer

- a. Ion Chamber
- b. Chamber Power Supply
- c. Electrometer Head and Preamplifier
- d. Amplifier
- e. Range Selector - Remote
- f. Recorder

Power Level Recorder

- a. Ion Chambers
- b. Amplifier and Power Supply Chassis*
- c. Recorder

Period Meter

- a. Ion Chamber
- b. Preamplifier
- c. Amplifier
- d. Recorder

Scram control is built into the amplifier assemblies of both the Power Level Recorder and Period Meter Circuits.

* This assembly includes three amplifiers.

X. PROCESS INSTRUMENTATION AND CONTROL

The Process Instrumentation for this reactor includes instruments for all primary and secondary systems which serve the reactor, as listed below:

Primary Systems

- a. D₂O System
- b. D₂O Cleanup System
- c. Helium System
- d. Thermal Shield Cooling System

Secondary Systems

- a. H₂O System
- b. Leak Detector System
- c. Graphic System

The general arrangement of the instruments in the control room groups these instruments with respect to system and functional importance of indicated or recorded data. For instance, the instruments for D₂O flow and temperature are located on the same panel board directly in front of the operator and above the top of the left center of the console. This permits the operator to observe these two important functions at a glance.

The instruments specified for the process system, as defined above, are standard designs that are available from several vendors. Also, instruments of the same general type have established a satisfactory service record in industry for performance and reliability.

A complete list of the process instruments is given on drawings MJA-4715-D, Instrument Schedule of Process Instruments, and MJB-4715-D, Sensing Elements - Schedule of Process Instruments.

The selection of these instruments was influenced by several factors, as follows:

- a. Reliability
- b. Type - Local or remote - Indicating or recording
- c. Performance, Sensitivity - Accuracy and life
- d. Availability
- e. Standardization

INSTRUMENT SCHEDULE
PROCESS INSTRUMENTS

A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	REMARKS
ITEM NO.	SYSTEM	DESCRIPTION	FUNCTION	VENOR SUGGESTED	VENOR PART NO.	RANGE	SCALE	CALIBRATION	MOUNTING	POWER SUPPLY	ACCESSORIES	ROUTING ELEMENT	PANEL OUTLET	INSTRUMENT LOCATION	
1	P100-100	FLOW RECORDING CONTROLLER - BROWN INSTR CO - STRIP CHART OR EQUAL	RECORD FLOW OF H ₂ O TO SECTION 8 TO INITIATE REACTOR FLOW	BROWN INSTRUMENT CO	7150 x 17 (14-17-48)	0-4000	0-200	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
2	P100-100	ELECTRIC RECORDING & INFORMATION FLOW METER - BROWN INSTR CO OR EQUIV	TO INDICATE & RECORD FLOW AT P. 1 TO REACTOR EXCHANGER	BROWN INSTR CO	202 (12) x 18	0-4000	0-200	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
3	P100-100	DIRECT INDICATING RATIO MOUNT	INDICATE FLOW OF H ₂ O IN REACTOR	FISCHER MOUNT		1 1/4-16	1 1/4-16	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
4	P100-100	INDICATE FLOW OF H ₂ O IN REACTOR	INDICATE FLOW OF H ₂ O IN REACTOR	FISCHER MOUNT	770-8	0-22 1/2	0-22 1/2	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
5	P100-100	INDICATE FLOW OF H ₂ O IN REACTOR	INDICATE FLOW OF H ₂ O IN REACTOR	FISCHER MOUNT	770-8	0-22 1/2	0-22 1/2	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
6															
7															
8	P100-100	PRESSURE INDICATING CONTROLLER - BROWN INSTR CO - STRIP CHART OR EQUAL	RECORD & RECORD PRESSURE AT REACTOR INLET & REACTOR OUTLET	BROWN INSTRUMENT CO	7150 x 17 (14-17-48)	0-4000	0-200	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
9	P100-100	PRESSURE INDICATING CONTROLLER - BROWN INSTR CO - STRIP CHART OR EQUAL	RECORD & RECORD PRESSURE AT REACTOR INLET & REACTOR OUTLET	BROWN INSTRUMENT CO	7150 x 17 (14-17-48)	0-4000	0-200	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
10	P100-100	PRESSURE INDICATING CONTROLLER - BROWN INSTR CO - STRIP CHART OR EQUAL	RECORD & RECORD PRESSURE AT REACTOR INLET & REACTOR OUTLET	BROWN INSTRUMENT CO	7150 x 17 (14-17-48)	0-4000	0-200	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
11	P100-100	PRESSURE INDICATING CONTROLLER - BROWN INSTR CO - STRIP CHART OR EQUAL	RECORD & RECORD PRESSURE AT REACTOR INLET & REACTOR OUTLET	BROWN INSTRUMENT CO	7150 x 17 (14-17-48)	0-4000	0-200	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
12	P100-100	PRESSURE INDICATING CONTROLLER - BROWN INSTR CO - STRIP CHART OR EQUAL	RECORD & RECORD PRESSURE AT REACTOR INLET & REACTOR OUTLET	BROWN INSTRUMENT CO	7150 x 17 (14-17-48)	0-4000	0-200	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
13	P100-100	PRESSURE INDICATING CONTROLLER - BROWN INSTR CO - STRIP CHART OR EQUAL	RECORD & RECORD PRESSURE AT REACTOR INLET & REACTOR OUTLET	BROWN INSTRUMENT CO	7150 x 17 (14-17-48)	0-4000	0-200	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
14	P100-100	PRESSURE INDICATING CONTROLLER - BROWN INSTR CO - STRIP CHART OR EQUAL	RECORD & RECORD PRESSURE AT REACTOR INLET & REACTOR OUTLET	BROWN INSTRUMENT CO	7150 x 17 (14-17-48)	0-4000	0-200	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
15	P100-100	PRESSURE INDICATING CONTROLLER - BROWN INSTR CO - STRIP CHART OR EQUAL	RECORD & RECORD PRESSURE AT REACTOR INLET & REACTOR OUTLET	BROWN INSTRUMENT CO	7150 x 17 (14-17-48)	0-4000	0-200	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
16	P100-100	PRESSURE INDICATING CONTROLLER - BROWN INSTR CO - STRIP CHART OR EQUAL	RECORD & RECORD PRESSURE AT REACTOR INLET & REACTOR OUTLET	BROWN INSTRUMENT CO	7150 x 17 (14-17-48)	0-4000	0-200	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
17	P100-100	PRESSURE INDICATING CONTROLLER - BROWN INSTR CO - STRIP CHART OR EQUAL	RECORD & RECORD PRESSURE AT REACTOR INLET & REACTOR OUTLET	BROWN INSTRUMENT CO	7150 x 17 (14-17-48)	0-4000	0-200	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
18	P100-100	PRESSURE INDICATING CONTROLLER - BROWN INSTR CO - STRIP CHART OR EQUAL	RECORD & RECORD PRESSURE AT REACTOR INLET & REACTOR OUTLET	BROWN INSTRUMENT CO	7150 x 17 (14-17-48)	0-4000	0-200	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
19															
20															
21	P100-100	TEMPERATURE RECORDING CONTROLLER - BROWN INSTR CO - STRIP CHART OR EQUAL	RECORD TEMPERATURE OF H ₂ O IN REACTOR	BROWN INSTRUMENT CO	7150 x 17 (14-17-48)	0-4000	0-200	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
22	P100-100	TEMPERATURE RECORDING CONTROLLER - BROWN INSTR CO - STRIP CHART OR EQUAL	RECORD TEMPERATURE OF H ₂ O IN REACTOR	BROWN INSTRUMENT CO	7150 x 17 (14-17-48)	0-4000	0-200	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
23	P100-100	TEMPERATURE RECORDING CONTROLLER - BROWN INSTR CO - STRIP CHART OR EQUAL	RECORD TEMPERATURE OF H ₂ O IN REACTOR	BROWN INSTRUMENT CO	7150 x 17 (14-17-48)	0-4000	0-200	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
24	P100-100	TEMPERATURE RECORDING CONTROLLER - BROWN INSTR CO - STRIP CHART OR EQUAL	RECORD TEMPERATURE OF H ₂ O IN REACTOR	BROWN INSTRUMENT CO	7150 x 17 (14-17-48)	0-4000	0-200	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
25	P100-100	TEMPERATURE RECORDING CONTROLLER - BROWN INSTR CO - STRIP CHART OR EQUAL	RECORD TEMPERATURE OF H ₂ O IN REACTOR	BROWN INSTRUMENT CO	7150 x 17 (14-17-48)	0-4000	0-200	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
26	P100-100	TEMPERATURE RECORDING CONTROLLER - BROWN INSTR CO - STRIP CHART OR EQUAL	RECORD TEMPERATURE OF H ₂ O IN REACTOR	BROWN INSTRUMENT CO	7150 x 17 (14-17-48)	0-4000	0-200	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
27	P100-100	TEMPERATURE RECORDING CONTROLLER - BROWN INSTR CO - STRIP CHART OR EQUAL	RECORD TEMPERATURE OF H ₂ O IN REACTOR	BROWN INSTRUMENT CO	7150 x 17 (14-17-48)	0-4000	0-200	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
28															
29															
30	P100-100	LEVEL INDICATING CONTROLLER - BROWN INSTR CO - STRIP CHART OR EQUAL	RECORD LEVEL OF H ₂ O IN REACTOR	BROWN INSTRUMENT CO	7150 x 17 (14-17-48)	0-4000	0-200	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
31	P100-100	LEVEL INDICATING CONTROLLER - BROWN INSTR CO - STRIP CHART OR EQUAL	RECORD LEVEL OF H ₂ O IN REACTOR	BROWN INSTRUMENT CO	7150 x 17 (14-17-48)	0-4000	0-200	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
32	P100-100	LEVEL INDICATING CONTROLLER - BROWN INSTR CO - STRIP CHART OR EQUAL	RECORD LEVEL OF H ₂ O IN REACTOR	BROWN INSTRUMENT CO	7150 x 17 (14-17-48)	0-4000	0-200	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
33															
34	P100-100	CONDUCTIVITY RECORDING CONTROLLER - BROWN INSTR CO - STRIP CHART OR EQUAL	RECORD CONDUCTIVITY OF H ₂ O IN REACTOR	BROWN INSTRUMENT CO	7150 x 17 (14-17-48)	0-4000	0-200	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100

MJA-4715-0

APPROVED DESIGNED	DATE	DESIGNED BY	DATE
CHECKED	DATE	CHECKED BY	DATE
ARGONNE NATIONAL LABORATORY TITLE: INSTRUMENT SCHEDULE OF PROCESS INSTR. SCALE: 1/4" = 1'-0" MATERIAL: 1/4" BRASS DRAWING NO: MJA-4715-0			

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- f. Appearance
- g. Maintenance costs
- h. Industrial Application and Use
- i. General Usage and Service History by Industry

A considerable number of local reading pressure gauges have been specified where the information provided was not directly important to the operation and a periodic inspection would suffice. All important flow, temperature, and other information is transmitted to the control room where it is recorded and/or indicated for use by the operator.

The successful application and use of the instruments chosen is to a large measure dependent on proper location of the sensing element. It must be located so that the measurement taken is representative of operating conditions and provides a reliable indication of the function being measured.

The quantities being measured in the various systems by the process instruments are as follows:

- a. Flow
- b. Temperature
- c. Pressure - Vacuum
- d. Liquid Level
- e. Conductivity

The type and location of the sensing elements for the important flow, temperature, and other quantities will be discussed for both primary and secondary systems (see drawing MJ-3001-D, Composite Flow Sheet).

A. Primary System

1. D₂O Flow into Reactor

The sensing element for this application is actually a combination of a special type of venturi called a "flow tube" and a differential pressure type of transducer equipped with electrical transmitter. The flow tube is located in the vertical riser portion of the piping leading to the reactor inlet. The transducer transmits a signal to a flow recorder in the control room proportional to flow. The instrument is equipped with a controlling switch which is set to scram the reactor under low flow conditions.

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2. D₂O Temperature to Reactor

Resistance bulbs are used as the sensing elements for measuring the temperature of the D₂O at the inlet and outlet of the reactor. They are located at the points of entrance and exit of the D₂O piping at the biological shield. The response time of these bulbs is important since the D₂O circulates through the system in 39 seconds, and the response time for temperature indication must be considerably less than the circulation time. These resistance bulbs are installed so that the bulb sheath is directly in contact with the D₂O, and a conventional well is not used. The response time for 90% indication of any change should be approximately 12 seconds under this condition. The assembly of these resistance bulbs is shown on drawing MJ-4798-D, Transducer Installation Process System.

The resistance bulbs transmit a signal proportional to temperature to the recorder in the control room. This instrument records and indicates inlet, outlet, and differential D₂O temperatures, and it is equipped with a controlling switch which is set to scram the reactor on high temperature.

3. Liquid Level - Reactor Tank

Two types of installations are provided to measure the D₂O level in the reactor tank during operation.

a. Sight Glass: The sight glass is mounted on reactor face 3. It is so located that it will indicate the maximum water level and all levels down to a minimum level which is just below the elevation of the top of the baffle plates in the reactor inner vessel.

b. Level Recorder: The level recorder is located in the control room; however, it receives its intelligence from a differential pressure transducer which is located on reactor face 3 at approximately bottom elevation of the reactor tank. This instrument will indicate tank level over the full tank height. A sensitive diaphragm is provided in the vent line from the low pressure side of the transducer to the top of the reactor. This is to prevent an accumulation of moisture by condensation in this line. (See drawing MJ-4798-D, Transducer Installation - Process System.)

4. Conductivity

Conductivity of the D₂O is measured by temperature-compensated cells at the inlet and outlet of the cleanup system. This provides information on the quality of the D₂O circulating through the reactor and also the quality of the D₂O being processed in the cleanup system. The information is transmitted from the conductivity cells to a two-point recorder in the control room.

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NOTES:
1 ALL PIPE & FITTINGS TO BE 306 SST
2 ALL JOINTS TO BE WELDED EXCEPT
CONNECTIONS TO CONVERTER (2 CONV)
MAY BE SCREWED
3 USE 1" THICK NEOPRENE RING
GASKET FOR FLANGED JOINTS

INSTALLATION INSTRUMENT NR FIPC-100A

TYPICAL INSTALLATION INSTRUMENT N° FIPI 12 A,B,C

ALL JOINTS TO BE SCREWED

INSTALLATION INSTRUMENT NO PIFI-102A

SEARCHED INDEXED	SERIALIZED FILED	APR 19 1970	FBI - NEW YORK
NAME SPALANZA, C. R. ALIASES C. R. TUMA		DATE APR 19 1970 TIME 10:10 AM	NEW YORK ARMSHOW NATIONAL LABORATORY FOR BUREAU IN THE PROPERTY OF THE ARMY NATIONAL LABORATORY TITLE TRANSMITTER INSTALLATION PROCESS SYSTEM
FILED	CHARGE	DATE BY FILED	REMARKS MJ-479B-D

5. Helium System, Catalyst Chamber Temperatures

The temperature rise across the catalyst chamber is an indication of the rate at which deuterium and oxygen are being recombined. Two resistance bulb thermometers are installed at the inlet and outlet of the catalyst chamber to measure the temperature rise across this unit. The differential of these two resistance bulbs is transmitted to a recorder in the control room. The helium is brought down to saturation conditions at cooling tower water temperature (maximum 83°F) by means of a small condenser to minimize the effect of water vapor carried with the gases.

6. Thermal Shield Cooling System

Temperature drop across the heat exchanger is indicated on a multipoint selective indicator in the control room. The same indicator is used for other purposes as well.

B. Secondary Systems

1. H₂O System

Temperature in and out of the heat exchangers is measured by thermocouples mounted in wells in the main H₂O lines. The signal is transmitted to a recorder in the control room. Flow of H₂O is measured by a differential pressure type of transducer working in conjunction with a "flow tube" in the H₂O line to the heat exchangers. The transducer is equipped with an electrical transmitter which sends a signal proportional to flow to a recorder located in the control room. A local reading pressure gauge is installed in the H₂O line. The efficiency of the heat exchangers can be checked directly by comparing the mass flow of H₂O with the mass flow of D₂O with respect to respective temperature differential.

2. Leak Detection System

An extensive system for the detection of leaks is installed throughout the D₂O piping system. This is shown on the following drawings:

MJ-4602-D, Leak Detection and Instrumentation Isometric Diagram

MJ-4606-D, D₂O Leak Detector System Wiring Diagram

MJ-4706-D, D₂O Leak Detector Wiring Schematic

MJ-4705-D, Leak Detector Annunciator Panel #3

MJ-4614-D, Leak Detector Installation and Assembly

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MJ-4706-D

D.O. LEAK DETECTOR ANNUNCIATOR, TYPICAL SCHEMATIC

* PANALAM PRODUCTS INC. ANNUNCIATOR, OR EQUIV
† ALL CODE DESIGNATIONS PERTAIN TO PA-3 UNIT

LEGEND
H - HORN
PA - PANALAM UNIT
PS - PUSH BUTTON STATION
RE - RECEPTACLE
RL - RELAY

RECEPTACLE WIRING

NOTES:

1. SUBSTITUTIONS ARE TO BE APPROVED BY PURCHASER
2. INSTALLATION REQUIREMENTS ALL WIRING & COMPONENTS TO BE INSTALLED IN ACCORDANCE WITH N.E.C. AND LOCAL CODE.

REFERENCE DRAWINGS:

- MJ-4705-D PANEL NO. 3 D.O. LEAK DETECTOR PANEL ITEM X-B-3
- MJ-4700-D PANEL NO. 15 INSTRUMENT AND CONTROL POWER DISTRIBUTION CENTER ITEM X-B-15
- MJ-4701-D INSTRUMENT & CONTROL ROOM POWER SUPPLY WIRING SCHEMATIC
- MJ-4702-D TYPICAL PANEL & CUBICLE
- MJ-4714-D PANEL BOARD LAYOUT - ELEVATIONS
- MJ-4718-D PANEL BOARD LAYOUT - FLOOR PLAN
- MJ-4712-D LEAK DETECTOR RELAY PANEL - PUMP ROOM
- MJ-4713-D LEAK DETECTOR RELAY PANEL - SURRECTOR ROOM

TO ADDITIONAL ANNUNCIATORS - IN PARALLEL

TO PANEL BOARD NO. 15-AC4 BREAKER 115 V. A.C.

ELECTRONIC RELAY UNIT RL-1 SCHEMATIC

(GENERAL ELECTRIC NO. CR-7511-A11222 OR EQUAL)

DATE	BY	REVISION	DESCRIPTION
11-15-60	SPALDING	1	REVISION
11-15-60	SPALDING	2	REVISION
11-15-60	SPALDING	3	REVISION
11-15-60	SPALDING	4	REVISION
11-15-60	SPALDING	5	REVISION
11-15-60	SPALDING	6	REVISION
11-15-60	SPALDING	7	REVISION
11-15-60	SPALDING	8	REVISION
11-15-60	SPALDING	9	REVISION
11-15-60	SPALDING	10	REVISION
11-15-60	SPALDING	11	REVISION
11-15-60	SPALDING	12	REVISION
11-15-60	SPALDING	13	REVISION
11-15-60	SPALDING	14	REVISION
11-15-60	SPALDING	15	REVISION
11-15-60	SPALDING	16	REVISION
11-15-60	SPALDING	17	REVISION
11-15-60	SPALDING	18	REVISION
11-15-60	SPALDING	19	REVISION
11-15-60	SPALDING	20	REVISION
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11-15-60	SPALDING	23	REVISION
11-15-60	SPALDING	24	REVISION
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11-15-60	SPALDING	26	REVISION
11-15-60	SPALDING	27	REVISION
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11-15-60	SPALDING	52	REVISION
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11-15-60	SPALDING	57	REVISION
11-15-60	SPALDING	58	REVISION
11-15-60	SPALDING	59	REVISION
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11-15-60	SPALDING	61	REVISION
11-15-60	SPALDING	62	REVISION
11-15-60	SPALDING	63	REVISION
11-15-60	SPALDING	64	REVISION
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11-15-60	SPALDING	68	REVISION
11-15-60	SPALDING	69	REVISION
11-15-60	SPALDING	70	REVISION
11-15-60	SPALDING	71	REVISION
11-15-60	SPALDING	72	REVISION
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11-15-60	SPALDING	74	REVISION
11-15-60	SPALDING	75	REVISION
11-15-60	SPALDING	76	REVISION
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11-15-60	SPALDING	78	REVISION
11-15-60	SPALDING	79	REVISION
11-15-60	SPALDING	80	REVISION
11-15-60	SPALDING	81	REVISION
11-15-60	SPALDING	82	REVISION
11-15-60	SPALDING	83	REVISION
11-15-60	SPALDING	84	REVISION
11-15-60	SPALDING	85	REVISION
11-15-60	SPALDING	86	REVISION
11-15-60	SPALDING	87	REVISION
11-15-60	SPALDING	88	REVISION
11-15-60	SPALDING	89	REVISION
11-15-60	SPALDING	90	REVISION
11-15-60	SPALDING	91	REVISION
11-15-60	SPALDING	92	REVISION
11-15-60	SPALDING	93	REVISION
11-15-60	SPALDING	94	REVISION
11-15-60	SPALDING	95	REVISION
11-15-60	SPALDING	96	REVISION
11-15-60	SPALDING	97	REVISION
11-15-60	SPALDING	98	REVISION
11-15-60	SPALDING	99	REVISION
11-15-60	SPALDING	100	REVISION

MJ-4614-D

1. EDGES OF PIPE FLANGES MUST BE UNPAINTED AND REASONABLY SMOOTH. GASKET PROTRUSIONS MUST BE ELIMINATED.
2. A METAL SCREEN CAN BE PLACED NEXT TO THE PIPE FLANGE IF FLANGE IS PAINTED OR ITS SURFACE IS A NON-CONDUCTOR. THE TERMINAL SHOWN CONNECTED TO FLANGE WOULD THEN BE CONNECTED TO METAL SCREEN INSTEAD.

MJ-4602-C LEAK DETECTION & INSTRUMENTATION (ISOMETRIC DIAGRAM.
 MJ-4606-0 D₂O LEAK DETECTOR SYSTEM WIRING DIAGRAM
 MJ-4706-D PANEL #3 - D₂O LEAK DETECTOR - WIRING SCHEMATIC
 MJ-4709-D LEAK DETECTOR RELAY PANEL WIRING DIAGRAM (PUMP ROOM)
 MJ-4713-0 LEAK DETECTOR RELAY PANEL - (SUB REACTOR ROOM)

[illegible]

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MJ-4703-D

FRONT VIEW

SIDE VIEW
(SIDE COVER PLATE REMOVED)

NOTES.

- NOTES:**
1. DIMENSIONS GIVEN IN DWG APPLY TO EQUIPMENT SPECIFIED IN B/M. IF SUBSTITUTIONS OF EQUIPMENT ARE MADE, DIMENSIONS MAY BE ALTERED TO SUIT.
 2. SUBSTITUTIONS ARE TO BE APPROVED BY THE ENGINEER.
 3. INSTALLATION REQUIREMENTS: ALL WIRING AND COMPONENTS TO BE INSTALLED IN ACCORDANCE WITH N.E.C. AND PANEL BUILDING CODES.
 4. THE PITCH OF HORN (ITEM #10) IS TO BE SET AT A DIFFERENT FREQUENCY THAN HORN ON PANEL NO. 5.
 5. REAR PANEL TO BE INSTALLED AFTER PANELBOARD INSTALLATION.

REFERENCE DRAWINGS:

REFERENCE DRAWINGS

MJ-4704-D PANEL NO 16-UTILITIES AND BUILDING POWER TROUBLE ANNUNCIATOR WIRING SCHEMATIC
MJ-4705-D PANEL NO 17-TEL AND CUBICLE
MJ-4707-D BATTERY ROOM FLOOR PLAN AND WIRING SCHEMATIC
MJ-4700-D PANEL NO 18- INSTRUMENT AND CONTROL POWER DISTRIBUTION CENTER- ITEM X-B-15
MJ-4701-D PANEL NO 15- INSTRUMENT & CONTROL POWER SUPPLY WIRING SCHEMATIC
MJ-4715-D PANEL NO 19- ELEVATIONS
MJ-4718-D INSTRUMENT SCHEDULE
MJ-4719-D PANELBOARD LAYOUT-FLOOR PLAN

NOTE

ALL DIMENSIONS ARE IN INCHES
UNLESS OTHERWISE INDICATED

[illegible]

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A typical leak detection installation is comprised of three components:

- a. Leak Detector Grid and Plate.
- b. Sensitive Relay - Usually electronic.
- c. Annunciator.

The three components perform as follows in announcing the occurrence of a leak. The D_2O makes contact between the grid or screen and the plate of the detector. This then energizes the input circuit of the electronic relay. The relay actuates the annunciator which is located in the control room. The annunciator provides both audible and visual alarms and indicates the location where the leak occurred. Controls are provided for silencing the audible alarm; however, the visual alarm continues to indicate until the condition is corrected.

Fail-safe provisions are built into the system so that the annunciator will alarm in the following conditions:

- a. Loss of power to relay.
- b. Malfunctioning of electronic components.
- c. When the detector is not plugged in.

Special precautions have been taken in the design of the detector to accomplish the following:

- a. Indicate small leaks - 2 drops of D_2O will energize the circuit.
- b. Minimize evaporation loss from seepage leaks. This is done by a "wrap-around" type detector which seals the area from general air circulation.
- c. Low cost construction.
- d. Ease of cleaning or drying and replacement.
- e. Foolproof operation - Completely shielded and insulated installation.

3. Graphic System

In the interests of keeping the operator informed at all times of the operational status of the various pumps and valves, a graphic panel has been provided. This graphic panel is a simplified flow diagram, on panel 14, with "on" - "off" lights for the various pumps and valves in the D_2O and H_2O systems. The operator can see at a glance which pumps and valves are

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operating and which are off (see drawing MJ-4746-D). The proper use of this graphic panel indication will provide the highest efficiency of operator control and use of the system components. It will contribute to the maximum full-time operation of the reactor facility, and consequently, maximum production.

4. Building Service Facilities Annunciator

Certain building service facilities are important to the operation of the reactor and contribute directly to full production efficiency. An annunciator panel is provided on panel 16 in the control room which will provide both audible and visual alarms when the system to which it is connected fails. This annunciator panel is shown on drawing MJ-4703-D, Utilities and Building Power Trouble Annunciator. Several systems are served by this annunciator as follows:

- a. Compressed Air.
- b. Building Ventilation Supply.
- c. Building Ventilation Exhaust.
- d. Air Conditioning.
- e. Water Supply.
- f. Cooling Tower Basin Water Level.
- g. Emergency Generator - "On"
- h. Control Power for Reactor.

XI. RADIATION MONITORING INSTALLATIONS

These installations, limited to the minimum requirement consistent with normal safe operation, provide for continuous general area and critical area monitoring.

A. General Area Monitoring

This installation, providing for the monitoring of the air exhaust from the building, will continuously sample a portion of this air, measure and record the activity, and actuate alarms and air locks to seal the building in the event of a measurement exceeding a predetermined value. The air sample taken at the discharge of the building exhaust fan is returned to the suction side of the fan through an annular ion chamber. For this installation at the fan, including the chamber power supply and preamplifier, refer to drawing MJ-4616-D, Exhaust Air Monitoring System Wiring Diagram.

It is calculated that the pressure differential across the fan will permit approximately 10 cfm of the 16,000 cfm of exhaust air to pass through the chamber. The installation of the specified ion chamber with the close-coupled preamplifier provides a sensitivity for measuring currents of the order of 10^{-13} amp/dis/sec/cc.

A strip chart recorder is mounted in control room panel number one which, together with the previously mentioned preamplifier, may more properly be referred to as a recording electrometer with response characteristics down to 10^{-13} ampere. Contacts in the recorder may be set to simultaneously operate an alarm in the control room and cause closure of the building inlet and exhaust air ducts.

B. Monitoring of Critical Areas

This instrumentation for monitoring the activity within the pump room and sub-reactor room during operation comprises modified radioactivity meters. In addition to gamma detection, suitable end windows are supplied with the instrument's 1.6-liter "air wall" type ionization chamber to permit the detection of alpha and beta radiation. The modification of these instruments, in each case, provides for the remote installation of a rate meter and a warning light. Location of the radioactivity meters, rate meters, and warning lights is indicated on drawing MJ-4604-D, Raceway and Electrical Equipment Plan. (page 152)

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ISOMETRIC VIEW OF INSTALLATION

WIRING PLAN

NOTES:

1. SEE ARCHITECT'S DRAWINGS FOR CONDUIT INSTALLATION TO CONTROL ROOM AND FOR LOCATION OF WORK BUILDING EXHAUST FAN.
2. FLOW CALIBRATION TO BE DONE WITH PISTON TUBE IN PIPE EXTENSION ON CHAMBER & WATER MANOMETER.
3. TUBING CONNECTIONS TO LOW CHAMBER ISOLATE THE CHAMBER FROM VIBRATION OF AIR DUCT.

PROJECT NAME	PROJECT NO.	DATE	BY	CHKD BY	APPROVED BY
EXHAUST AIR MONITORING EQUIPMENT & WIRING PLAN	184	11/7/50	J. H. B.	J. H. B.	J. H. B.
THE DRAWING IS THE PROPERTY OF THE ARIZONA NATIONAL LABORATORY TUCSON, ARIZONA IT IS TO BE KEPT IN THE ARIZONA NATIONAL LABORATORY AND NOT TO BE LOANED, REPRODUCED, COPIED, OR IN ANY MANNER DISSEMINATED OUTSIDE THE ARIZONA NATIONAL LABORATORY WITHOUT THE WRITTEN PERMISSION OF THE ARIZONA NATIONAL LABORATORY DIRECTOR					
TITLE: EXHAUST AIR MONITORING EQUIPMENT & WIRING PLAN SCALE: NONE DRAWING NO.: MJ-4616-D					

XII. POWER FOR INSTRUMENTS AND CONTROL

Reliable functioning of the instrumentation and control installations for the reactor preclude any direct association with plant power systems. The function of these installations must be unaffected by conducted or induced extraneous voltages or power outages experienced to some degree in normal power systems.

The power system designed to the foregoing requirements for operation of the instrumentation and control equipment of the reactor is sized to the power requirement of the load analyses included at the end of this section. A functional description of the system includes components, voltages and regulation, supply and distribution, and load analysis.

1. Components

The principal components of the system are a lead-acid storage battery of suitable capacity, and conversion and inversion devices. These provide both a-c and d-c power.

The conversion equipment, continuously providing energy as required to maintain the battery "floating," embodies a three-phase step-down transformer and selenium rectifier unit. This equipment operates from the 480-v, 60-cycle plant power system with a capacity of 15 kva. The inversion equipment, likewise operating continuously, is a motor generator unit with a capacity of 6 kva. This unit drawing power from the battery provides power to the a-c equipment. The lead-acid storage battery is composed of sixty industrial type cells to provide 120 v of d-c with sufficient capacity to maintain its full load for a period of four hours.

2. Voltages and Regulation

Since it is recognized that the plant power supply system voltage may be subject to irregularities, the step-down transformer of the conversion unit is provided with a saturable reactor voltage regulating arrangement to insure a regulated output through the rectifier of 120 v d-c. The voltage of the d-c output of the system is inherently assured or regulated to 120 v by the capacity of the batteries. The alternating-current voltage and frequency output of the motor generator unit are both closely regulated to insure continuous power of 120 v, 60-cycle to the instrumentation. The close regulation is particularly desirable in connection with the determination of nuclear measurements and control.

3. Supply and Distribution

The instrument and control power supply components are located in the battery room on the equipment floor (basement) as indicated in drawing MJ-4707-D, Battery Room Floor Plan and Wiring Schematic. Two power

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feeders, one for a-c and one for d-c, extend from the equipment room through conduits to the appropriate section of panel number 15 in the control room. Power is extended from this panel through circuit breakers to the instrument and control unit installations, as indicated in drawing MJ-4701-D, Instrument and Control Power Supply Schematic.

4. Load Analysis

Alternating-Current Data

Connected Load	4.3 kva
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MG Set	
--------	--

size	6 kva
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efficiency	65 %
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d-c required = $4.3 / .65 = 6.6$ kva

Direct-Current Data

Direct Load	3.6 kva
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Indirect (or a-c) Load	6.6 kva
------------------------	---------

Total d-c Load	10.2 kva
----------------	----------

LEGEND
PB - PUSH BUTTON STATION
M - MAGNETIC COIL
MC - MAGNETIC CONTACT
PL - PILOT LIGHT
VM - VOLT METER
FM - FREQUENCY METER
BR - BREAKER
SW - SWITCH (MANUAL)

NOTE:
ALL A.C. EQUIPMENT MARKED WITH * IS LOCATED ON M-G SET OR IN BATTERY ROOM. ALL D.C. EQUIPMENT MARKED WITH * IS LOCATED ON RECTIFIER ASSEMBLY OR IN BATTERY ROOM. OTHER EQUIPMENT IS LOCATED IN CONTROL ROOM ON PANEL BOARD 15.

REFERENCE DRAWINGS:
MJ-4700-D PANEL NO. 15
INSTRUMENT AND CONTROL POWER DISTRIBUTION CENTER-ITEM X-8-15
MJ-4702-D TYPICAL PANEL AND CUBICLE.
MJ-4101-D LINE DIAGRAM-INSTRUMENT AND CONTROL POWER SUPPLY.
MJ-4707-D BATTERY ROOM FLOOR PLAN AND WIRING SCHEMATIC.

APPROVED	DATE	CHIEF DRAFTSMAN	DATE	NO. REVISED
SPALDING	12 21	SPALDING	12 21	1
TOLERANCES UNLESS OTHERWISE NOTED FRACTIONAL & DECIMALS & ANGLES & DIMENSIONS REMOVE ALL DIMENSIONS				
MATERIAL				
PANEL NO 15 INSTRUMENT & CONTROL POWER SUPPLY WIRING SCHEMATIC				
SCALE NTS				MJ-4701-D

MJ-4701-D

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Tabulation of Loads		Watts		
		Units	Per	Total
Description	Req.	Unit	a- c	d- c
<u>Reactor Instruments</u>				
Safety	3	200	600	
Period	1	200	200	
Electrometer	1	250	250	
Glavanometer	2	20	40	
<u>Reactor Controls</u>				
Shim-Safety Rod				
Position Indicator	4	25		100
Motor	4	200		800
Contactactor	4	40		160
Relays	24	12		248
Lights	24	2		48
Regulating Rod				
Position Indicator	1	25		25
Motor	1	200		200
Contactactor	1	40		40
Lights	10	6		60
Scram				
Solenoids	4	25		100
Relays	11	12		132
Lights	11	6		66
Automatic Control	1	700	700	
<u>Processes</u>				
Solenoid Valve	6	40		240
Instruments	15	100	1500	
Graphic Panel Lights	67	10		670
Leak Detector				
Relays	28	15	420	
Annunciator Lights	60	8		480
<u>Special Instruments</u>			500	200
<u>Power Supervisory</u>				
Lights a- c	6	6	36	
Lights d- c	5	6		30
Total a- c Load			4246	
Total d- c Load				3599

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XIII. MATERIAL HANDLING

A. Materials to be Handled

Since this reactor is designed as a production unit, it is feasible to plan the operations for the entire reactor. The major equipment, supplies, and materials to be handled in the operation of the reactor are as follows:

New Fuel Elements - These are relatively light, are relatively nonradioactive, and the only real precautions in handling are the security problems and possible dirt, grease, etc. which might be carried into the reactor; plus the fact that too many cannot be piled together on account of fission characteristics.

New Type 1 Producer Elements - These are neither radioactive nor of security importance, but their weight and lack of rigidity will make it necessary to handle them hung vertically, or with suitable stiffeners. The same precautions on freedom from dirt and grease will exist as for the fuel elements.

Ion Exchange Resin - While relatively unimportant in frequency of handling, the ion exchange resin handling involves some unusual details. This resin is received wet with ordinary water, and it is necessary to remove the water and replace it with D_2O (deuterizing, as it is usually termed) before installing into the reactor system. Similarly, when a spent resin chamber is removed, the D_2O contained therein must be recovered insofar as possible (or de-deuterized). It is intended that these operations will actually be carried out in one of the laboratories of a Service Building, and special equipment will be required for this purpose as part of the general reactor operations.

Helium - A considerable quantity of helium will be required for the reactor operations. The reactor itself will be an essentially closed system, and the helium requirements during the time the reactor is at power should be nil. However, each time an element of any kind is introduced into or removed from the reactor, it will be necessary to purge the coffin with helium to prevent the introduction of air into the reactor. Also, when a fuel element is being removed, it will be necessary to use a blast of helium gas to cool the element while in the coffin. Hence, it is not possible to calculate accurately the quantity required, but an estimate is a cylinder a day.

Nitrogen - Several cylinders of nitrogen are contained in the installation, but their function is such that they would be used only in an emergency. Hence, the actual usage of nitrogen is practically zero.

Heavy Water - While the quantity of heavy water required to charge the system is approximately 3,100 gallons, the actual usage will be very low, since many precautions have been taken to save the D_2O and avoid loss through leakage, etc. A unit has also been designed for the helium system to recombine free deuterium and oxygen to form D_2O and return it to the reactor system. The D_2O will probably be received in stainless steel drums, and a connection has been provided in the helium recycle system to permit the D_2O to be added to the reactor system.

B. Receiving and Storage

The equipment and construction incorporated into the building for handling these materials consist of the following:

1. Storage Vault for Fuel Elements

The security restriction on these elements requires the use of a poured reinforced concrete walled vault equipped with a heavy burglar-proof steel door. The fuel elements are suspended in cadmium-coated aluminum tubes (coated on the outside where cadmium cannot rub the fuel element) spaced to prevent any possibility of the formation of critical masses. Since these elements are quite light, they can be handled with gloved hands, and no mechanical lifts are required.

2. Storage Cabinet for Producer Elements

The reactor operating staff will work out the details of the equipment for handling the producer elements, since the exact design will depend upon the type of fork-lift truck selected for their operations. The elements will be received either strapped to a steel or aluminum channel stiffener, or else suspended vertically, and can be stored in the storage cabinet or rack just inside the personnel entrance (see the S.M. & D. drawing A-5, Operating Floor Plan).

3. Storage Coffin for Type 2 Producer Assemblies

As noted above, it is necessary to provide shipping and storage coffins for these assemblies. The same shielded container will be used for the short-time storage necessary between the time when the assembly is filled and then placed in the reactor, and the transporting coffin for moving from processing to reactor and vice versa.

C. Transfer Coffin

The transfer coffin loads the new fuel and producer elements into the reactor and removes the highly radioactive irradiated elements from the reactor and places them in the storage well. It also removes the

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various elements from the storage well, after cooling for an adequate time, and places them in the various types of shipping coffins or containers. The coffin consists of two principal parts, a carriage or transport mechanism for moving the coffin and shielded loading and unloading mechanism section.

It might be mentioned here that the coffin design has progressed through the initial layout stage to assure feasibility. The design has not been carried through the detail stage. The following is a description of the components.

1. General Description of Design

Carriage Construction - The arrangement of the carriage consists of a flatcar sort of arrangement which rolls along rails in the floor of the building and an upper transfer section which rolls along cross rails on the lower carriage and permits cross motion of the coffin. The upper carriage carries a set of four mechanically operated and synchronized screw jacks by which the coffin proper can be raised and lowered. Since the entire operation of the coffin and reactor depends upon precisely duplicable settings over the fuel of producer assembly stations in the reactor, one of the rails in the floor and one of the rails on the lower carriage are grooved, and will have a closely mating ridge on the periphery of the wheels which roll on them. Two speeds will be provided for each of the horizontal movements, a fast speed of 3 inches per second (15 ft per min) and a very slow locating speed of approximately 1/64 inch per second. The jacking speed will be approximately 2 inches per minute. The power for the various motors will be through cables suspended from ceiling outlets centrally located over the coffin travel. The general arrangement of the coffin transport mechanism is shown on the drawing MJ-181-X, Elevation of Transfer Coffin.

Coffin Construction - The coffin consists of a vertically mounted cylinder approximately 13 ft high and 5 ft in diameter, with the walls of steel construction lead filled, having an absorption equivalent to 12 inches of lead. Threaded holes in the outside steel wall make it possible to add additional shielding if it is required. This is surmounted by a 21-inch diameter tubular shaft approximately 19 ft long which contains the hoisting mechanism. The construction of the coffin may be divided into the following parts:

a. The shielded section, equal to 12 inches of lead, forms the bottom part of the coffin. The details of this section are planned to permit the installation of an additional girdle of 3-3/4 inches of lead and steel in case further shielding is required. The main shield is somewhat over 8 ft long, with thinner shielding and observation windows on the top. The window will be a periscope arrangement. This massive unit is supported by the four screw jacks mounted on the upper carriage.

MJ-181-X

b. The inner basket consists of an assembly centered inside the shielded section and supported by wheels running on a circular rail on the top of the shielded section. This unit can be rotated to bring any of three stations over the hole in the bottom of the coffin, and thus afford space for a new element, the access hole plug, and an irradiated element, during the operation of the coffin. The basket assembly is mechanically rotated to the positions required for the various operations. It is also arranged with a helium system for cooling a fuel element when it is removed from the reactor. There is also an emergency heavy water cooling spray ready for use if it should be needed.

c. The superstructure consists of a 21-inch diameter tube containing guide rods and a "T" rod mechanism which can be raised or lowered by means of a chain drive. This apparatus serves to lock into the top of the various elements or access hole plugs and lift them from, or lower them into, the reactor. The general arrangement of this and the other coffin parts is shown in layout form on drawing MJ-181-X.

2. Operation

The following is the general plan for the operation of the coffin. Since detailing is not complete on this equipment, the actual installation will vary somewhat, but the general scheme of operation will be the same. The plan as now visualized includes some 64 steps or operations, all controlled by a stepping switch. The following description does not list all of the steps but only the over-all operation.

a. Setting the Coffin Carriage

The coffin carriage will be centered over the proper access hole, first using the high speed movement and then making the final precision adjustment with the slow speed. Similarly, the cross ways centering of the coffin is accomplished by means of the upper carriage movement.

b. Coffin Operation

There are three types of materials handling operations for the coffin, i.e., handling the fuel elements and the two types of producer elements. These operations may be divided into the charging and discharging from the reactor to the storage well and the transfer from the storage well to the various types of shipping coffins or containers.

c. Coffin - Reactor Operation

The basic steps in the removal of a spent fuel element and replacement by a new element are carried on as itemized below. The same procedure is followed for a producer element with the exception that the "T" is turned 90 degrees out of phase with its positions in the fuel handling sequence and cannot be changed till the step cycle is complete.

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Loading New Element - The fresh element is positioned in a coffin or special holder in the transfer well hoist opening. This is an opening in the main floor between the tracks just beyond the active storage well. An insert frame will be required to hold the element at the proper location and level in this hoistway. The coffin will then be moved over the element, the "T" rod lowered and latched into the element, and the element drawn up into the coffin and placed on the basket turntable in the transfer coffin.

Helium Flushing of Coffin - The coffin is rolled to the point over the spent fuel element position in the reactor. Before the reactor can be opened to the coffin, it is necessary to flush the air from the coffin. This is done by holding the access hole plug down with the "T" rod of the coffin and then exhausting the air from the coffin by means of a large vacuum pump mounted on the carriage and adding helium from a cylinder also mounted on the carriage, building up the pressure to that existing in the reactor (3 to 5 in. w.c.). Then little or no air will get into the reactor.

Access Hole Plug Removal - The "T" rod is latched into this small plug and then raised into the coffin and set in one of the positions in the basket. The plug is then removed from under the "T" rod by rotating the basket inside the coffin.

Spent Fuel Element Removal - The "T" rod is then lowered completely to the bottom of its travel, and in this position it is locked into the latching device on the top of the fuel element. The "T" bar turns the top piece of the latch, freeing the assembly from its locked down position relative to the reactor grid. The element can then be raised from its position in the reactor and hoisted into the coffin. At the same time, a stream of helium gas is directed around the element to keep it cool. After it is raised into the coffin, the basket is again rotated, and the element lowered into the helium circulating nozzle. This circulates a stream of helium gas through the element and thence through a helium gas cooler, thereby removing the heat from the element while it is in the coffin. This system is a closed loop recirculating the helium atmosphere of the coffin. The "T" rod is then removed from the element, and the basket rotated to clear the rod.

Fresh Fuel Element Replacement - The section of the basket carrying the fresh fuel element is next rotated into the line of action, and the "T" rod engaged in the latch. The element is then lifted, the basket rotated, and the element lowered with the rod until it seats on the D₂O flow orifice in the bottom of the reactor inner vessel. The element is then locked into the grid in the reactor by rotating the "T" rod. The rod is then raised out of the reactor.

Access Plug Replacement - The basket position carrying the plug is again turned to position under the rod, and the plug latched on the rod. The plug is then lowered to its position in the large top plug of the

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reactor, closing off the access hole. The rod is uncoupled and drawn up into the coffin. The reactor can again be brought into operation, and the coffin is jacked up and moved off the top of the reactor.

d. Coffin - Storage Well Operation

The operation of lowering the spent fuel element into the storage well is carried on essentially by the same sequence of steps, although the preliminary helium flushing will not be required since the storage well has a normal air atmosphere above the water. Hence, the operational plan would be to remove the access hole plug, lower the fuel element into the storage well, and then replace the plug.

3. Safety Features of Coffin

The design of the coffin includes a number of safety features which will prevent certain operational troubles by reducing the possibility of human errors. Some of these are as follows:

a. Stepping Switch Selector

The present plans are to use a stepping switch to control the operational steps of the coffin. Analysis of the operation shows a total of 64 steps or stages, all of such nature that each step must logically follow another. It will be possible to arrange a warning signal (bell and/or light) which will indicate if the proper sequence is not followed. Hence, the stepping switch will establish the proper order of operation and at the same time make it necessary for the operator to follow this sequence.

b. Cooling Methods

Under the normal operational plan, the element will be cooled by the blast of helium gas from a cylinder as it is drawn into the coffin and by the recirculation of helium through the fuel element and the heat exchanger once the fuel element is set on the nozzle. As an additional precaution in case there is an unexpected delay in placing the fuel element on the nozzle that blows helium through between the plates, provisions are incorporated in the coffin design for spraying D_2O over the element for emergency cooling. It is not contemplated that this would normally be used, but it is a safety in case the fuel element has been partly removed and the mechanism jams. The heavy water simply runs down through the access hole back into the reactor. The producer elements do not require such cooling in the coffin.

c. Torque-Limiting Devices

The design philosophy is to make the mechanism fool-proof and jam-free and then prepare for eventualities in case there should be a malfunction. One of such preparations is a torque-limiting device on the "T" rod drive. This will prevent excessive thrust on the top of an element if the drive should continue after the element is seated in the reactor.

d. Additional Shielding for Coffin

The usual methods of calculating heavy shielding are not entirely rigorous, and "build-up" factors must be applied to such a calculation. One set of calculations on the shielding requirements indicates the need for the equivalent of 12.6 inches of lead immediately adjacent to the element. Another set of calculations calls for an additional 3 inches of lead shielding. The present design is based on construction of a coffin with the 12.6 inches of lead equivalent, but provisions are made for hanging a 3-inch thick lead girdle around the active area if tests indicate that it is necessary.

e. Radiation Monitor

Normally the atmosphere in the coffin is exhausted directly into the air in the operating area. Since the capsules in the Type 2 producer assemblies will contain a mixture of radioactive gases at between 10 and 40 atmospheres, there is a remote possibility of a gas leak, even though tests indicate that the capsules are very strong. To prevent the escape of activity into the workroom in case of a leak, a monitor is planned for the coffin atmosphere. This will be located near the outside of the coffin shield so that it is protected from the normal radiation from the element, but in the helium circulating system so that adequate warning signals can be given in case the helium becomes radioactive. The design of the coffin does not include any necessary cleanup system, but the connections required for such a system are included. The reactor operator will design the system based on his processing experience with the irradiated material. If the monitor sets off an alarm indicating activity in the coffin atmosphere, the coffin remains sealed against the reactor top plug; the bottom coffin door is shut; an auxiliary dolly transporting the scrubber and trap is rolled into place; and lines are attached to the vacuum pump discharge.

f. The entrance slot in the "T" latch assembly in the top of the fuel element is 90 degrees to that in the producer elements. As was previously mentioned, the "T" is orientated at the beginning of a sequence of steps and cannot be changed until a complete sequence has taken place. This reduces the possibility of inadvertently placing a fuel element where a producer element is removed.

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D. Active Storage Well

The active storage well is a shielded and cooled storage facility for the irradiated fuel and producer assemblies or elements. It is located against reactor face 2. The top surface of its shield plug is flush with the main operating floor, and it is positioned between the transfer coffin tracks. The building drawings A-4 and A-5 show the location relative to the reactor, etc. The shielding is ordinary concrete on the outside, and it forms a large column between the basement and the main or operating floor. It is planned that the building contractor will build the concrete structure, the inner 8-inch steel shield, the tank, and the cooling coil. The reactor contractor will install the grid, plug assembly, and plug drive. These are shown on MJ-5030-F. The top plug is a rotating arrangement similar to that over the reactor. However, it is simply cast steel since gammas are the only shielded activity. The fuel elements will be stored in the grid positions near the center, and the Type 1 producer elements will be stored near the tank wall. The grid support tubes, MJ-5035-C on the assembly drawing, are made of two concentric aluminum tubes with 0.020-inch thick sheet cadmium between them. The top and bottom are seal-welded to prevent water contact which otherwise would give galvanic corrosion. These serve as poison to eliminate any possibility of going critical in the storage well. The water in the tank will be kept clean and the pH controlled by anion exchange clean-up system external to the shield. As was previously mentioned, the charging and discharging of elements in and out of the well is done by the same step sequence as that followed at the reactor with the exception that there is no need to helium purge since the atmosphere over the light water in the well is air.

E. Shipping Operations

The actual amount of material received and shipped is of course quite small, but the radioactivity makes it necessary to use heavily shielded coffins. The building design is based on using a 28,000-lb (14-ton) shipping coffin, and tracks extending through the air-lock doors and out to the loading dock are provided for moving the dolly carrying this coffin. A 15-ton capacity crane is also installed on the loading dock for transferring the coffin to a truck or a lowboy. The design of a dolly is included in the Shaw, Metz and Dolio plans, and the reactor operating organization will have available a fork-lift truck which can double as a tractor for moving the dolly. The operating group will also provide the detailed plans for the various shipping coffins, since these will be intimately associated with other operations outside the reactor building. It will be necessary to coordinate the design of the shipping coffin doors with the handling equipment in the transfer coffin in order to open and close these openings without radiation hazard. The shipping coffin construction must also be integrated with the hoisting mechanism and yoke system planned by S. M. & D., since this is part of the building contract. This hoist is operated through a hatch located next to the active storage well between the coffin tracks in the main floor.

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1. Shipping Fuel and Producer Elements

a. Type 1 Producer Assemblies

While these will not be highly radioactive, it will be necessary to shield them and also provide adequate support for handling the elements in a horizontal position. The shipping coffin will be lowered into the hoistway, with the coffin centered in the opening. The element is hoisted from the storage well into the transfer coffin by the usual procedures, then moved over the hoistway, centered, and lowered into the shipping coffin. After the transfer coffin is moved away, the shipping coffin dolly, with any modification necessary for it to handle the Type 1 container, is moved into place, and the element and shipping coffin are raised and placed thereon. The unit is then moved out of the building and into a truck.

b. Type 2 Producer Elements

The handling of these elements is essentially the same except that a much heavier coffin will be needed because of the shielding requirements.

c. "Fuel Element"

The spent fuel elements will be shipped only after they have had a considerable cooling period in the storage well. The physical manipulations will be the same, except that the arrangement of the "T" slot in the element will require a 90-degree shift in the transfer coffin "T" rod. The actual movements of the coffin, hoist, and dolly are described above.

XIV. BUILDING DESIGN

A. Introduction

The architectural firm of Shaw, Metz and Dolio was engaged by the AEC to prepare the detailed plans and specifications for a building to house the reactor and the operations. The choice of this firm was based on their successful planning for the building to house the Argonne Research Reactor (Building No. 330). Many of the design features of this building are incorporated in the present plans, together with improvements which have seemed desirable, and the close resemblance between these buildings is immediately apparent. It was Argonne's responsibility to establish the design criteria for the reactor section of the building. Since the planning and detailing of the building took place simultaneously with that of the reactor, close coordination of design and plans was required, and the personnel of Shaw, Metz and Dolio were very cooperative and receptive to the needs of the Argonne group.

B. Basic Design Considerations

The fundamental design premises for the building were established by the Atomic Energy Commission, recognizing the fact that this reactor was probably going to be built near populated areas. The design is based on the following criteria:

1. The building should be designed for blast resistance (bomb near miss) of up to 1000 lb per square foot (7 psi).
2. The building should be shock resistant from either earthquakes or shock wave from a bomb explosion. Even if the shell of the building were to crack, the reactor and its associated components should be isolated so that damage would not result to the reactor.
3. The building and the entrances or exits should be so planned that if a reactor incident (runaway) occurred, any radioactive products or gases could be confined within the building.

The original plans for the building were for an above-ground structure, and preliminary design was on this basis. However, the second set of instructions received from the AEC required that the main section of the building, which houses the reactor and its auxiliaries, be planned as an underground installation. A large amount of planning and detailing was done on this basis. Re-evaluation of the problems and cost involved for this type of construction caused the return to a grade-level structure, and on January 8, 1953, the Architect-Engineer and Argonne were instructed to review the plans and make any changes necessary for a structure with the main floor at grade, and the entire operating area above the ground. The final details and plans have been prepared on this basis.

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C. Project Layout

The entire facility has been considered as an operating entity, complete in itself except for the utilities (water, steam, and electrical power) which are to be supplied from an existing installation. The facility has been divided into three major areas.

1. The reactor building is considered as an area, since in normal operation it would be desirable to screen and control the personnel in and around the reactor. Both the construction and operation details of the reactor are significantly different from the normal plant. Criteria for this area were established by Argonne.
2. The service building is planned, as the name implies, to handle the analytical, water quality control, maintenance, and administrative work of the facility. Criteria for this area were established by the organization that was to be the operator of the facility.
3. The cooling tower and the associated pump house are separated to get full advantage of air circulation, and while designed by the Architect-Engineer, the size and general arrangement are as recommended by the Argonne group.

D. Reactor Operation Criteria

The correlation between the reactor and building planning was done through the preparation of Design Criteria. These were a series of reviews of the operational details and considerations of the reactor which would affect the building and equipment. The Architect-Engineer used these as a guide in his planning, and they established the basis for the detailed design. The operational concepts upon which these criteria were based are as follows:

1. This reactor is a production and not a research unit; hence it was possible to definitely plan the operational procedures and details. Nor is it considered necessary to incorporate special experimental facilities or equipment.
2. This reactor can be loaded and unloaded from the top, and access to the sides of the reactor will be required only for instrument and control purposes.
3. It is possible and advisable to operate a transfer coffin on wheels and rails across the top of the reactor.

4. A shielded storage well is required to permit the fuel and producer assemblies to be stored until the radioactivity is reduced or the processing unit is ready to handle the producer elements.
5. A cooling system capable of handling a heat load of 17,000,000 Btu per hour throughout the year is required.

Reference is made to the detailed Design Criteria for the specific information, requirements, and suggestions transmitted to the Architect-Engineer.

This list is as follows:

<u>No.</u>	<u>Title</u>	<u>Date</u>
MJS 33	Cooling Water Requirements	4-25-52
MJS 33, Rev. 1	Cooling Water Requirements	10-28-52
MJS 34	Air Cleanup System	10-15-52
MJS 35	Materials and Equipment Handling	8-29-52
MJS 140	Electrical Power System	7-31-52
MJS 160	Vault for New Fuel Elements	3-19-52
MJS 160, Rev. 1	Vault for New Fuel Elements	1-6-53
MJS 161	Subreactor Room	9-17-52
MJS 162	Active Element Storage Well	11-25-52
MJS 162, Rev. 1	Active Element Storage Well	5-4-53
MJS 164	Reactor Equipment Floor	12-9-52
MJS 165	Control Room Area	9-26-52

These are not included in this report because the volume of criteria makes it impracticable to do so. However, copies are available in the Master File at Argonne if a need should arise to refer to them.

E. Reactor Building Plan

The building is to be built of reinforced concrete by the slip-form method of construction, and the roof is a completely self-supported dome. The inside is divided into three floors.

1. Operating or Main Floor

The operating floor is located at truck bed level height above grade at the service building entrance, thus putting the entire Service Building floor at the level of the reactor operating floor. The operating floor is on a level with the top of the rotating plug located above the reactor vessel. Since at the time the building and reactor were being planned the location of this facility was in question, the level of the operating floor was arbitrarily set at 100 feet, and all dimensions are taken from this datum. The plan of

[illegible]

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the operating floor as finally evolved is shown on the Architect's Drawing A-5, Operating Floor Plan. The layout consists of a circle 66 ft in diameter bisected by a pair of tracks to carry a special dolly for the shipping coffin (see the section on Materials Handling). The reactor will be located in one half of this area, with tracks for the transfer coffin extending at a 45° angle to the shipping coffin tracks. The control room, a vault for the secure storage of new fuel elements, and a stairway leading to the basement or reactor equipment area occupy the other half. Personnel access to the equipment area is thus under immediate supervision and control by the reactor operator. The side of the control room on the reactor side is glass windows permitting complete observance of the reactor operating floor from a position at the control console. Also included on this floor are the truck and personnel air-lock areas, with an emergency escape air lock directly opposite; a small storage section, for the new producer elements, the top of the active assembly storage well; a coffin lift for handling the shipping coffin as well as an equipment lift; and a 4 ft by 4 ft shielded hatch cover opening into the pump room below. Because of the type of roof construction selected it is possible to eliminate any columns, and the choice of reactor equipment made it possible to omit any type of bridge crane in this room. The reactor expansion tank and its retaining wall outside the building are also shown on this plan.

2. Equipment or Basement Floor

The reactor equipment floor plan is shown on the Architect's Drawing A-4, Equipment Floor Plan. An effort was made to keep as much as possible of the reactor mechanical, electrical, and instrument equipment in this area, thus ensuring a neat and orderly operating floor. Equipment to be supplied under the building contract is shown in solid outline, while that which is under the reactor contract is dotted. This space includes the pump room area containing the heavy water circulating pumps, associated heat exchangers, and water purification equipment. Since this area is quite radioactive while the reactor is running, a shielding wall is to be built around this room, thereby permitting access to the remainder of the equipment floor while the reactor is operating. A liquid-filled radiation window in the shield wall will enable the operator to look into the pump room at any time. Spotted around the equipment floor are other equipment necessary for the operation and safety of the reactor: the air scrubbing tower for building air cleanup should it become contaminated with radioactivity, the emergency water tanks, a sump tank to catch and check any water pumped from the subreactor room sump, the storage battery area, helium storage tank, etc. These are all connected to the reactor itself by piping run in trenches in the floor, thereby maintaining a neat and readily maintained area. The necessary hydraulic equipment (pumps, reservoirs, and pistons) for the coffin and equipment lifts is also located in this room. The elevation of this floor is 81 ft. It is 19 ft from the operating floor to the equipment floor. The pump room floor is two feet lower.

O P E R A T I N G F L O O R P L A N

SCALE 1/4" = 1'-0"

OPERATING FLOOR PLAN	
FACILITY "F"	
SHAW METZ & DOLIO	
ARCHITECTS	ENGINEERS
200 SOUTH LA SALLE STREET • CHICAGO 4, ILLINOIS • TELEPHONE CENTRAL 6-6010	
SHEET	A-5

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ELEVATIONS	
REVISIONS	FACILITY "F"
NO.	DATE
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
SHAW METZ & DOLIO	
ARCHITECTS	
200 SOUTH LA SALLE STREET • CHICAGO 4, ILLINOIS • TELEPHONE CENTRAL 6-6114	
SHEET	A-6

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3. Subreactor Room

The subreactor room is an area directly under the reactor. After the reactor construction is complete, access to the subreactor room will be by an access ladder for personnel, or for equipment by removing the shielding slabs in the floor of the equipment room. The subreactor room is to contain the heavy water storage tanks, reactor dump tank, etc. The walls of the subreactor room are below the structural steel of the reactor and have been designed to carry the load of the entire reactor.

F. Separation of Reactor and Building

The requirement of blast resistance and the disputed possibility of an aluminum-water reaction in a prompt critical reactor prompted the AEC to consider it desirable to separate the shell of the building from the reactor structure. Since a review of the reactor and associated equipment construction indicated that the footings of the equipment should be integral with the reactor structure, it was decided that the entire internal structure (i.e., both the floors and all of the reactor components) should be separated from the shell of the building. The final design is essentially that of a dome-topped shell set over a completely separate structure. This is shown in the Architect's Drawing A-12, Section Through Work Building.

Other considerations made it desirable to separate the actual planning of the reactor from that of the building. The design of the building was carried on concurrently with that of the reactor, and it was desirable to keep the planning separate so that a change in details in the reactor plans would not have to be reflected in the Architect's Drawings each time. Hence, early in the planning, it was decided that the building construction would terminate with a steel plate wall around the reactor, thus forming the "faces," and the Argonne group would plan the reactor inside this enclosure. Similarly, decisions were made to separate the mechanical piping, electrical work, etc., in a similar manner, thus preserving flexibility in reactor design while at the same time allowing the Architect to proceed with his planning. This procedure was eminently satisfactory to both groups and avoided much discussion on minute details between the organizations. As will be discussed in the section of this report on Project Construction Recommendations, this separation also serves to divide the conventional building construction from the more specialized and precise construction required for much of the reactor.

The separation between the two designs was based upon the freedom required for finalized reactor design; upon logical construction divisions; and upon the hypothesis that the building contract should preferably include, insofar as possible, only those elements common to normal industrial building construction. Elements or items which required precision setting handling, or might involve security were put into the reactor

SECTION THRU WORK BUILDING

SCALE 1/4" = 1'-0"

0 1 2 3 4 5 6 7 8 9 10

[illegible]

COOLING TOWER PIPING

REVISION

FACILITY "F"

SHAW METZ & DOLIO
ARCHITECTS ENGINEERS
306 SOUTH LA SALLE STREET • CHICAGO 4, ILLINOIS • TELEPHONE CENTRAL 6-2614

SHEET
M-5

SCRUBBING TOWER ASSEMBLY
SCALE 1/2"=1'-0"

— LOWER FILTER PLATE
SCALE 1 1/2" = 1'-0"

- TOWER SUPPORT & OPNG: DETAIL
SCALE 1 1/2" = 1'-0"

—ELEVATION- SCRUBBING TOWER & SUMP PUMP
SCALE 1/4"=1'-0"
SEE SHEET M-

ELEVATION- SCRUBBING TOWER & BLOWER
SCALE PL= 1"= 5'
SEE SHEET M-

- PREHEAT COIL PIPING DETAIL
NO SCALE

REHEAT COIL PIPING DETAIL
NO SCALE

PIPING DETAIL - CONTROL ROOM HEATING COILS
NO SCALE

PIPING DETAIL - WATER CONTROL LAB HTG. COIL
NO SCALE

ISOMETRIC DETAIL OF CONVERTER PIPING
NO SLABS

ISOMETRIC DETAIL OF PIPING AROUND H.W. GENERATOR
NO SCALE

ISOMETRIC DETAIL OF STEAM SERVICE PIPING
NO SCALE

[illegible]

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portion. The architect's plans and specifications call out the limits of responsibility for the construction. Every effort has been made to match up the ANL drawings with these limits.

G. Architectural Details

It is not the purpose of this report to review completely the architect's plans and details. However, those portions of the design which affect the operation or safety of the reactor will be discussed briefly.

1. Size and Headroom

The over-all size of the building was determined largely by the area requirements for the equipment in the basement or equipment floor. The necessity of providing adequate shielding around the reactor establishes its size, and the space required for the circulating pumps, heat exchangers, etc., determines the amount of auxiliary space. The result is that while the operating floor is roomy and ample, the equipment floor is rather completely filled. The ceiling height above the operating floor, 32 ft from the floor to the spring line of the dome, is determined by the over-all height of the transfer coffin.

2. Floor Loading Shielding

The normal operating floor loadings in this building will not be excessive, except in the areas covered by the coffins. In these specific areas the loads are very high. The original design of the handling coffin called for approximately 9 inches of lead shielding, and the coffin then would weigh an estimated 80,000 lb. The design of the building was based on this load supported on tracks 14 ft 10 in. apart and spread over a length of approximately 6 ft, or an average load of roughly 1000 lb/sq ft. More recent shielding estimates, based on higher peak neutron flux and less shutdown time before a fuel element is removed from the reactor, indicate that 12 to 14 inches of lead are required, and the new transfer coffin layouts indicate a probable weight of the order of 120,000 lb. The estimated weight of the shipping coffin is now 28,000 lb. The location and spacing of the columns in the equipment floor are planned to handle these loads. The balance of the floor has been designed of flat slab construction with beam reinforcing integral with the slab. The floor above the pump room is designed 3 ft thick, with inserts by which an additional shielding up to 3 inches of lead could be suspended on the ceiling in order to provide supplementary shielding from the heat exchangers and D₂O pumps and piping if required. This was considered advisable rather than to design the maximum amount of shielding over the pump room as dictated by a calculation which is necessarily ultra-conservative since N¹⁶ activity is difficult to calculate with high accuracy and the geometry of the source is anything but simple.

3. Construction Around Reactor Area

As was stated above, the reactor is separated from the building by a steel plate wall except for several columns which are to be encased in the reactor concrete. Any special holes, openings, attachments etc., required for the reactor are to be field-cut as required. These steel plates will be the form for the reactor shielding concrete when this is poured. The use of this steel plate wall acts as a sharp line of demarcation between the two contracts and serves as an excellent mounting surface for the various equipment that will be installed on the reactor faces.

4. Air-Lock Doors

The requirement that the building contain radioactivity in case of a reactor runaway (but not an internal detonation) makes it necessary to provide air-lock doors in all openings. In this building the personnel doors are planned as manually operated heavy doors locked shut with hardware similar to that on refrigerator doors. The doors will be interlocked so that only one door can be opened at a time. The truck air-lock doors will be mechanically opened and closed by rolling in a horizontal direction and will be held shut by an air piston design worked out by the Architect-Engineer. These will also be interlocked so that only one door can be opened at a time. This design is believed to be relatively inexpensive and still positive in operation.

5. Storage Vault

Because of the nature of the materials in the reactor fuel rods, it is necessary to provide a storage vault which is acceptable from the security standpoint and also is of a design which will prevent the formation of a critical mass. A vault constructed of reinforced, poured concrete walls and with a standard vault door has been provided. The fuel elements are to be stored in a series of tubes in the floor. These tubes are so spaced and provided with sufficient cadmium coating, on the outside away from the fuel elements, that criticality is not possible. Forced ventilation is also provided for this vault.

6. Materials Handling

The theory and method of materials handling has been covered in another section. As previously noted, no bridge crane has been provided. A hydraulic platform lift is used to move equipment and materials to the equipment floor, and another hydraulic lift will be used to handle the shipping coffin. The use of this type of equipment has simplified the design and construction of the building shell, with considerable economy in building costs. The use of rails in the floor for both the handling and shipping coffin dollies has localized the areas subjected to excessive floor loadings and permitted economies in the building.

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7. Grooves for Track, Plugs, etc.

Grooves or trenches in the floor will be provided for the tracks and for the plugs. The precise and accurate location and leveling of the tracks will be done under the reactor contract. Similarly, the construction for the reactor and storage well top plugs and associated drive mechanisms will be done in depressions left in the operating floor, and then grouted in level. Thus, all of the interrelated segments of the reactor and those which must fit and line up accurately will be installed under a single contract and supervision.

8. Shielding Wall

Only a portion of the shielding wall around the pump room will be built under the building contract, and these parts will serve as columns to support the main floor. The opening will be left to give easy access to this area for the installation of the pumps and piping. The rest of the wall will be built of solid concrete blocks under the reactor contract, after the equipment is moved into the pump room. Also, the building contract will leave only a steel sleeve in the wall for the viewing window, and the special construction inherent in such windows will be under the reactor contract.

H. Mechanical and Piping Details

The mechanical and plumbing installation for a building is very important for the successful operation of a reactor. Much care has been taken to establish adequate criteria for these details. The most important points covered in the design are as follows:

1. Cooling Tower, Pumps, and Controls

An adequate supply of high-quality cooling water is essential for the proper operation of the reactor heat exchangers. A cooling tower of suitable size has been specified, and the general arrangement follows the advice and recommendations of several large cooling tower designers and users and is shown on S.M. & D. Drawing M-5, Cooling Tower Piping. A deeper than normal (3 ft 6 in.) basin is planned so that dust and debris will have a chance to settle out. A series of six double screens is planned which have ample filtering capacity to remove any large material in suspension. The cooling water circulating pumps are sump type pumps installed at the cooling tower, thus reducing the space requirements in the service floor of the Service Building and eliminating pump packing problems. This arrangement also makes it possible to plan a bypass around the cooling tower section for use in mild or cool weather. Under such atmospheric conditions, an automatic valve, controlled by the temperature of the water in the basin of the tower, opens up and permits a part of the water to drop directly into the basin and not pass over the cooling tower unit. By this plan, it is hoped that

controlled water at 65° plus or minus 5° can be obtained during much of the year from this tower, thereby smoothing out the reactor operation. To further even out the operation, a two-cell tower with a two-speed fan has been specified, with operation controlled from the control room. Contrary to what it might seem, cooling water temperatures appreciably lower than the design value are undesirable, particularly when burnup and xenon are low, because the shim-safety rods must be run in to absorb the excess reactivity caused by low moderator temperature. This would depress the neutron flux at the upper ends of the producer elements and decrease production.

2. Compressed Air

The compressed air for the entire building is provided by a unit in the Service Building. This unit has a chemical drier attached so that completely dry air will be available for all of the controls and operations. As a simple but reliable method of supplying an emergency quantity of air, a large compressed air tank is installed on the equipment floor, with a check valve on the inlet, and if anything happens to the compressor, sufficient air is available to operate for a day.

3. Water Treatment

Successful operation of the cooling system can be obtained only with adequate control of the feed water to the system. Provisions are incorporated for a Zeolite water softening system for the building, and a blend of softened water and raw water of the proper proportions will be added to the tower system. A chemical proportioning pump for the continuous addition of inhibitor is also planned. Provision for a "blowdown" or continuous bleed to the sewer from the system is installed to prevent the undue accumulation of dissolved solids or carbonate in the water. It is believed that the cooling system planned can handle the reactor at full power with no difficulties from sludging, corrosion, or scale formation when the proper addition agents are used.

4. Storage Well Cooling

The radioactive elements (fuel and producer) in the active storage well will require some cooling, and an aluminum pipe coil is installed within the well. A small circulating pump is planned, and this will take suction from the cooling tower supply and discharge to the return line. The water in the storage well is thereby kept separate from the cooling water circuit, and there is no danger of radioactive contamination to the cooling tower system.

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I. Ventilation

Since the reactor building is a completely sealed unit, with no windows and with air locks and doors so arranged that only one can be opened at a time, a complete mechanical ventilation system becomes a necessity.

1. Supply System

The supply system is located in the service floor of the Service Building and consists of a double filter system using an industrial type paper or felt dry filter. Since it is desirable to reduce the amount of atmospheric dust in the Reactor Building to a minimum in case of radioactive contamination, a high filter efficiency has been specified. The supply fan is also located in this area, which will reduce the noise and vibration in the Reactor Building to a minimum. The air is introduced to the Reactor Building by a ring duct which extends around the operating floor of the building. The supply air will be heated as required, but no air conditioning is planned for the general building air.

2. Exhaust System

The exhaust fan is also in the Service Building and discharges to a 30-ft stack on the side of the Service Building. No provisions for filtering the exhaust air have been incorporated into the system, nor have the fans been selected for such service. An exhaust air monitor to check the gamma activity in the air is installed around the exhaust fan system and will actuate recorders and a warning system in the control room. Should the activity in the exhaust air exceed normal background, doors automatically close the inlet and exhaust ducts. The exhaust air is removed from the Reactor Building by a grill in the center of the dome and also by a series of exhaust grills at floor level around the sides of the operating floor. The equipment floor and subreactor room have a separate system of supply and exhaust ducts.

3. Control Room Air Supply

Only the control room is supplied with conditioned air, and a maximum of 55% relative humidity has been established for this area in order to ensure reliable instrument operation at all times. The air-conditioning unit and supply fan are located in the Service Building. The air from the control room discharges, for the most part, into the reactor area, thereby producing a slightly higher static pressure in the control room than in the operating area. A portion of the exhaust is taken out through the instrument panel board and cubicles, thus removing any heat load on the system. The air supply to the control room is through perforated ceiling panels, eliminating any drafts which might be unhealthy for the operator at the console.

4. Air Sealing Doors in Ducts

In accordance with the design philosophy that this building is to be capable of retaining any radioactivity in case of a reactor accident, both of the main ducts have been provided with sealing doors which are normally held open by an electromagnet, but these doors will close and lock against a soft gasket on signal from the exhaust air monitor. The motors driving the circulating fans are automatically turned off at the same time. This should prevent the discharge of large amounts of radioactive gas or air-borne dust from the building in case a reactor catastrophe should occur.

5. Air Scrubbing System

If an incident as mentioned above ever does actually take place, it will be necessary to clean the air within the building. A scrubbing tower, caustic tank, circulating pump, and circulating fan are installed in the equipment floor, but can be controlled from outside. This system takes suction from the far side of the equipment floor, draws the air through a ring-packed tower, and discharges it into the supply system serving the operating floor, thus reducing the recycling to a minimum. A 500-cfm blower is provided, and it has been estimated that in a period of several days of operation this unit will remove the acidic radioactive gaseous material and dust from the air in the building.

J. Electrical System

The major portion of the instrumentation and control systems for the reactor is electrical in nature, and so the power supply and distribution system for this facility are of paramount importance. As have been previously covered in this report, a completely separate system for reactor instruments and control is being provided, but the construction of the building is such that other special features are required as well.

1. Normal Power Supply

Two separate feeders from outside will serve this building, and the supply will be through a double-ended distribution system, with two 500-kva transformers being used, arranged in such a way that either can take the power load for the building. Normal distribution is at 480 volts, and additional transformers will be spotted throughout the building to supply the 220 and 120-volt power or lighting requirements. This system will also provide desirable flexibility in case of operational changes.

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2. Emergency Power

The nature of the operations and the design of the building make it necessary to have a source of emergency power. A direct-connected Diesel motor generator set is being provided. This is to be a 125-kw, 480-volt unit, capable of handling the emergency pumps, ventilation fans, and other equipment throughout a power failure of short duration, and/or permitting the reactor to be shut down in an orderly manner.

3. Battery Power Lights

Because there are no windows in the reactor building, it is essential that some artificial light be provided at all times for the sake of personnel safety. Hence, a few lights, powered by batteries floating on the supply power line, are provided at strategic locations throughout the building. These will give a certain amount of light at all times until the Diesel generator has a chance to start and pick up the load.

K. Special Features

The specialized nature of the reactor has made it necessary to incorporate some unique features in the building. Some of these, such as the sealed doors in the air locks, the sealing doors in the ducts, and the separation between the reactor and building, have been mentioned previously. Still others are listed on the following page:

1. Expansion Tube and Tank

The design of the reactor is such that only a very small free space or volume exists above the water. In order to provide some room for expansion and prevent blowing the seal on the top plug if a prompt critical excursion should occur, the reactor is provided with an expansion tube or duct. This is connected to a large stainless steel tank buried outside the Reactor Building. Normally this tank will be filled with helium gas saturated with heavy water vapor at the pressure (3 in. w.c.) existing in the reactor, and D₂O condensation will flow back to the reactor tank. If a sudden formation of steam occurs in the reactor, this tank affords room for expansion and subsequent condensation and prevents a blowout into the operating room.

2. Wall Seals for Pipes, Ducts, and Conduits

Since this building is to be gastight, even when subjected to shock or a blast wave, all of the piping passing through the wall is planned to have flexibility, or else expansion and shock-absorbing joints are provided. Also, all of the conduits passing through the wall are being provided with standard explosion "seal-offs." Experience on Building No. 330 at Argonne has demonstrated that design and construction of this type can result in a structure which, to all intents and purposes, is actually "gastight."

3. Construction Details for Reactor Components

The planning for the reactor has resulted in a thermal shield tank which is 13 ft 1/2 in. in outside diameter and 9 ft 9-7/16 in. high and hence is larger than the door openings normally required. Doors of this size would be difficult to construct and seal to withstand the 1000 lb/sq ft requirement. The plan is to omit certain walls in the truck air lock, leaving an opening of adequate size to permit this tank to be brought into the building. The walls will then be poured, and 8 ft by 10 ft doors built in.

It has also been necessary to plan two openings in the Reactor Building wall below the operating floor level to permit installing the 14 ft 6 in. shim-safety rod actuating shaft. After these rods are installed, these openings can be covered over and sealed.

XV. PROJECT CONSTRUCTION RECOMMENDATIONS

A. Separation of Building and Reactor Contracts

It has been previously indicated in this report that a separation was made between the building design and that covering the reactor. Review of this procedure suggests that this same separation be maintained in the actual construction of this facility. It is strongly believed that this will result in considerable economies in the construction and will produce a more satisfactory operating unit. The basis of this belief is the following points:

1. Differences in Fundamental Design

While the building is of somewhat unusual appearance, the general construction is straightforward and similar to that used in many types of industrial construction. Hence, this portion could be done by any number of building contractors who are accustomed to doing work of this magnitude, but who may not have in their organization much technical help. On the other hand, it is inconceivable that the successful construction of the reactor proper could be carried out by an organization lacking technical and scientific "know-how," because of the numerous unusual and novel design and construction features. Hence, it is suggested that the building contract be let to a contracting firm in direct competitive bidding against the plans and specifications as prepared by the Architect-Engineer, but the reactor and related equipment be handled by another type of contract where closer control and direction can be administered. In this way, the cost of the building would not be penalized by the much more exacting requirements for the reactor. Since all of the A-E drawings and specifications have been prepared on this basis and separated from the reactor design but matched up with it, no major conflicts or interferences are believed to exist, and such a separation appears quite feasible.

2. Difference in Materials of Construction

The building proper is of normal industrial materials of construction (reinforced concrete), and the service equipment (ducts, piping, electrical, etc.) is almost entirely of conventional construction. Few, if any, specialized metals, alloys, paints, etc., are called for. However, the reactor is replete with special equipment. Highly specialized aluminum and alloys are specified and must be used, and only certain types of stainless steel are acceptable. Only certain types of welding rod or fluxes can be employed, and certain types of grinding compounds and abrasives must be strictly avoided. Rather than educate a contractor on such unusual or novel (but very necessary) requirements, it appears easier to separate the two contracts.

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3. Greater Precision in Reactor Construction

The building design and construction is such that normal construction tolerances are generally acceptable and satisfactory. Such is definitely not the case for the reactor. A high degree of precision must be maintained, even with equipment weighing many tons, if the success of the reactor is to be ensured. Thus, it seems advisable to use normal construction procedures and tolerances for the building and pay the premium only for that part of the construction that requires such careful work. Such precision will also require a higher degree and quality of supervision, and the reactor contractor must be competent to supply such supervision.

4. No "Q" Cleared Personnel Required for the Building

An important economic fact in recruiting the contractor and his labor force for the building construction is that no classified information would be handled, and so no "Q" cleared personnel are required. Hence, it seems possible to avoid the cost and time required for a large number of security investigations by dividing the work into a building contract and a separate reactor contract. The latter would involve far fewer men than the labor force required for the building itself.

5. Difference in Inspection

The inspection of the building construction could be carried out by a capable inspector versed in normal types of industrial construction and spending only a normal amount of time on such a project. The inspection of the reactor construction must be done by capable, scientifically trained observers who have adequate knowledge of why certain requirements were established. They must carry out their work with the full realization that substitutions of materials in many cases cannot be tolerated, and improper clearances or adjustments may vitiate the entire operation of the reactor. The building construction could go on without the services of more than one resident or liaison reactor inspector and thus avoid overhead costs and the jurisdictional question which might otherwise arise.

6. Changes in Reactor Design

The design of the reactor is in accordance with the best knowledge of the present time (1952-53), but it is recognized that the entire field of reactor technology is shifting and changing rapidly. The separation of the building and reactor contract will probably permit additional changes to be made in the reactor construction without altering to any large extent the building plans. Excessive back charges by a building contractor operating on a "lump sum" bid can thus be avoided, and yet it is conceivable that the actual functioning of the reactor might be appreciably improved. In this report, two or three things have been mentioned that the designers feel will

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require further review and possible change to arrive at the best design possible. Project status is such that further engineering at this time is not warranted.

B. Building Construction Inspection

No recommendations will be made on the inspection of the building itself beyond the suggestion that it be adequate and the contractor be required to comply with the drawings and specifications prepared by the Architect-Engineer. The following recommendations are made with relation to the reactor installation:

1. Reactor Resident or Liaison Inspector

It is recommended that a competent engineer thoroughly familiar with the reactor plans and background be on hand during the major portion of the building construction. He should review all of the Architect-Engineer's plans and details as the construction progresses, and must be in a position to approve of any changes or alterations in the plans during construction. Such inspection and review can more than repay the cost in the reduction of conflicts and interferences during the reactor construction.

2. Building Operation

Inspection to determine the physical presence of equipment is not adequate, and sufficient tests must be run on the ventilation equipment, electrical systems, cooling tower installation, etc., to ensure satisfactory and trouble-free operation. Past performance has indicated that the initial operation of a nuclear reactor is fraught with sufficient unknown and unanticipated problems not to have common construction difficulties added thereto. Hence, all of the mechanical and electrical devices and equipment must be subjected to operational tests of sufficient duration to prove operability under normal working conditions. Failure to make such tests can easily prolong the start-up period for the reactor and hinder efficient production. In brief, the building and its equipment are to house and serve the reactor, and every effort must be made to see that such service is accomplished.

C. Divisions of Reactor Construction

The reactor design, in general, has been based upon the normal construction divisions, and the following could be used as a breakdown for subcontract work. Some overlapping has been inevitable, but the design drawings are generally divided into these fields of construction:

1. Architectural and Structural

The general construction of the reactor shield, associated steel tank, and large plugs, pouring the concrete, etc., can all be part of an architectural contract, as is the fabrication and assembly of the supporting structure, the installation of the base plate, etc. Much of this work must of course be integrated with the piping and some of the mechanical details.

2. Mechanical and Piping

The mechanical and piping features are closely related. Much of the piping is straightforward, although it does involve specialized materials and some unusual techniques. There are other parts of the mechanical devices which are quite independent, such as the control mechanisms. Also, the mechanical details must be closely correlated with the reactor construction for precision alignment and installation. Except for the process piping and installation, no sharp division is possible in this phase of the construction.

3. Electrical and Instruments

The electrical portions of the design are well segregated and organized and include all power, control, instrument, and alarm wiring. The installation of a complex panel board and console assembly is included in this portion of the plans, but the decision as to whether the panel board is to be field-wired or purchased as a factory-assembled unit must be made. It is strongly urged that this be sent out as a factory-assembled, wired, and piped unit. Especial care must be exercised to make certain that the building contractor installs the conduits and wires called for on the Architect-Engineer's drawings, even if nothing is connected to the ends in the building construction.

D. Reactor Security Classification

It should be emphasized that the items and equipment pertaining to the reactor are not, per se, classified or restricted. It is estimated that at least 75%, and probably nearly 90%, of the reactor construction can be accomplished without "cleared" personnel in any other than supervisory positions. The vast majority of the drawings is not classified, and only a few of the specifications are restricted. Practically all of the piping, structural work, mechanical assembly, etc., can be carried out without reference to any classified information. Indeed, much of the electrical and instrument work can be completed with uncleared labor. The only time when access must be restricted will be at practically the completion of construction when actual loading is started and the nuclear core pattern established. It is believed that a full appreciation of these security measures and understanding of the classification involved will not only speed up the construction of the reactor but also can offer very appreciable economies in construction.

E. Reactor Design Planning

Early in the design of the reactor it appeared desirable to divide the planning into a series of logical divisions or sections. These would serve to divide the work of the design group and also permit an orderly plan for specifying, with eventually procuring, expediting, receiving, and finally installing and checking. Since it was necessary to prepare the specifications simultaneously with the planning, item numbers based on these sections were assigned early in the design phase, allowing blank numbers where it seemed additional equipment might be introduced. While this resulted in some gaps in the numerical order, it has offered a flexible system for identifying and specifying the equipment or materials. Following is a brief review of the identification system:

1. List of Sections

The various sections were given letter designations, although some letters were not used because of possible confusion as changes were made during the design, and to permit the insertion of some sections at a later date. The following is a list of the sections now in use:

- A - Reactor Tank Section
- B - To Plug (Reactor)
- C - Storage Well
- D - Coffin (Transfer)
- E - Elements
- F - Heavy Water
- G - Emergency Water
- K - Thermal Shield Cooling
- M - Helium Section
- P - Cooling Water Section
- X - Panel Board, Console, and Instrument Power

This is not intended as an exhaustive list, and further detailed planning for construction may indicate the need for some other sections.

2. Item Numbers and Specifications

To provide a simple but flexible system for identifying the major items of equipment, etc., a system of "item numbers" has been adopted based upon the section division listed above. Numerical designations following the section letter were used for the specialized pieces of equipment or where only a single unit was used. The following additional letters were employed to designate classes of equipment, followed by a number to identify a specific unit or type of unit.

M - Motor
P - Pump
V - Valve
VA - Valve (automatic or controlled)
CV - Check Valve
T - Tank

Thus, F-V-1 denotes a type of valve in the heavy water section of the reactor, and the piping drawings will show this number at the proper valve. The instruments are also identified by a similar code as follows:

ITI - Instrument-Temperature Indicating
ITR - Instrument-Temperature Recording
ITC - Instrument-Temperature Controlling
IP - Instrument-Pressure Gauge (local)
IPI - Instrument-Pressure Indicating (remote)
IPR - Instrument-Pressure Recording
IPC - Instrument-Pressure Controlling
IF - Instrument-Flow Gauge (local)
IFI - Instrument-Flow Indicator (remote)
IFR - Instrument-Flow Recording
IFC - Instrument-Flow Controlling
ILI - Instrument-Level Indicating
ICR - Instrument-Conductivity Recording
INC - Instrument-Radiation Activity, Recording
IRI - Instrument-Radiation Activity, Indicating
IDC - Instrument-Leak Detector Indicating

This instrument number system is also related to the section of the reactor in which it is used by prefixing the section designation; thus, F-ITC is a temperature controller in the heavy water section of the reactor.

The above item designations were used to identify the specifications for the equipment. It was intended that specifications would be written covering all parts or items for which commercial items are available, or for which a certain performance standard was desirable for optimum reactor operation. Thus, these are performance type specifications, and the listing of a vendor would be merely to show a standard of quality for the item. Owing to the press of time in completing the design, not all of the items were covered by specifications, but the detail drawings which are made are sufficient in themselves where specifications have not been written, with the exception of the transfer coffin, which has not been detailed. Specifications and details for the coffin will have to be completed when construction is authorized. The points covered in the specifications are approximately as follows. The same general order was used in all of the specifications in order to simplify the checking.

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- a. Name: The name as used on the drawings, flow sheets, etc., for identification.
- b. Item Number: Established as outlined above.
- c. No. Required: The exact number as called for on the drawing. No allowance was made for operating spare parts, etc.
- d. Description: A brief description such as would appear in a listing, purchase order, etc.
- e. Size: Physical dimensions and over-all characteristics.
- f. Materials: Materials of construction, with any special precautions on types of metals, etc.

Note: The instrument specifications contain such points as rating, chart, performance characteristics, and accuracy in this portion of the specification.

- g. Details: In some cases this reiterates notes and information which are shown in part on the drawings, but it is again spelled out for emphasis. Any special finishes, painting, or greasing, etc., is covered in the details.
- h. Reference Drawing: All of the drawings covering the item are listed as being included with and part of the specification.
- i. Safety: Any special safety features, as the "fail safe" provisions of a valve or operating mechanism, are included as an important feature.
- j. Electrical: Any electrical information is included.
- k. Test and Inspection: Special requirements for testing and inspection by the purchaser before shipping are included.
- l. Tagging: Every specification includes a statement that the item or box or crate is to be plainly marked or tagged with the appropriate item number.
- m. Delivery: Each specification includes a request for a definite date on the equipment, since it is recognized that this might change the selection of the vendor in case of a tight construction schedule.

- n. Warranty: The vendor is requested to supply an adequate guarantee to secure satisfactory equipment.
- o. Vendor's or Shop Drawings: The specifications require (generally) four sets of shop drawings, assembly prints, or catalog sheets. In addition, certified installation drawings, capacity curves, performance data, etc., are requested.
- p. Representative Type: A brief description of related industrial equipment or an available standard product is listed. This should serve as a guide in going out for bids on these items, and at the same time does list a known source and type.
- q. Suggested Suppliers: The names of several possible suppliers are listed. If there has been a discussion with a possible vendor, that name is given at the top of the list.

It was the intention of the reactor design group that the purchasing department use the specifications as a buying guide, and that they also be used as a check in receiving, installing, and operating the reactor. Any changes made by the purchasing department or deviations from specifications as written may result in reactor operational troubles.

3. Item Listing Sheets

A series of sheets (ANL Drawings MJ-900-B to MJ-924-B) has been prepared as an index to this item system. These "MJ Item Listing" sheets serve as a guide to the specification, and the latter should be grouped in the order shown on these sheets. These also serve as a convenient guide to the major assembly or reference drawings. It was originally intended that these would also serve as a check list for ordering, receiving, and inspecting the equipment on the construction site. In general, the item number refers to equipment or material supplied by a single vendor on a purchase order; hence, this item number affords a method of tying together many of the construction functions.

4. Bills of Materials

The Bills of Material (B/M) have been prepared covering all of the items. Where covered by specifications, these Bills of Materials are made part of the specification. Where no specification is prepared, the B/M will serve as a guide for purchasing and receiving the material. The number on the B/M corresponds to the main assembly or reference drawing, and where no item number occurs this can be used as a reference. In numerous cases the Bills of Material information will have to be expanded in

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REACTOR TANK SECTION							DWG. COMPLETED	SPEC. COMPLETED	ASSEMBLY OR REFERENCE DRAWING
ITEM NO.	FLOW SHEET COORD.	NAME OF ITEM	NO. REQ'D	LOCATION	DESCRIPTION, TYPE, CAPACITY, ETC.	SUGGESTED VENDOR			
A-1	d-5	Reactor Vessel	1	Reactor Enclosure	Vessel or Al Tk., 8'-1" OD x 8'-8" high, including inner vessel, Plenum chamber plate, Baffle plate, Diffuser plate etc. and Al seal ring and graphite reflector seal plate	Stacey Brox. Const. Co.			MJ-1101-E
A-2	d, e-5	Thermal Shield Tank	1	Reactor Enclosure	Steel tank, 12'-3" dia x 11' high, 3/4" shell and bottom				MJ-6320-D
A-3	---	Base Plate plus Spacer Blocks	1	Reactor Enclosure - Ceiling of Sub-reactor room.	Steel plate, 14' x 14' x 5" thick, plus 1" thick Spacer Blocks				MJ-2410-C
A-4	---	Structural Steel	1 SET	Reactor Enclosure	Structural Steel, Prefabricated, for Reactor Structure and Support. Assembled with high tensile bolts				MJ-5400-D
A-5		Grid Assembly	1	Top of Reactor Tank					MJ-1117-D
A-6	d-5	Graphite Reflector	1 SET	Inside Thermal Shield Tank	Prefabricated graphite blocks of special graphite, Approx. 4-3/8" x 4-3/8" x 4" long - Cut and dressed	Hanford Engr. Works			MJ-2341-D
A-7		Boral Liner Plates	1 SET	Inside Thermal Shield Tank	Boral Plates, 1/4" thick, 24" x 48", Flat and Curved Plates	Oak Ridge National Laboratory			
A-8	---	Lead Brick	1 SET	Reactor Enclosure - Outside of thermal shield tank	Lead extrusions, curved to thermal shield tank, 4" x 4" x approx. 12" long				MJ-2401-D
A-9		Instrument Hole Liners and Plugs	9	Reactor Enclosure	6" I.D. Tubes and Box on Thermal Shield Tank plus plugs as detailed				MJ-2500-F
A-10	---	Steel Ring	1	Top of Reactor Tank	Sectional Steel Ring, 2 sections, 3" thick x 12'-3" I.D. x 14'-6" O.D.				MJ-2411-C
A-11	---	Shell - Top Plug Retainer	1	Top of Reactor Tank	Sectional Steel Weldment, 2 sections, 3/4" thick x 13' dia x 5'-2" high				MJ-1203-E
A-13	e-5	Expansion Duct	1	Reactor to Exp. Tank	Stainless Steel Duct, 1/4" thick x 24" dia x approx 10' long, including flexible connection				MJ-1140-D
A-14	---	Spray Nozzle	(2)	Inside Reactor Vessel					
A-15	---	Rupture Disc.	(2)	Operating Floor					MJ-3510-C
A-16		Ball Check Valve		Inside Reactor Vessel					
A-17		Isolation Diaphragm	1	Face 3 of Reactor	In conjunction with F-111-320				
A-20-1,2,3,4	---	Shim Safety Rod Assembly	(4)	Reactor Faces 1 and 5					MJ-1437-E
A-21	---	Regulating Rod Assembly	1	Reactor Face 1		Brown Instrument Model Y153 X 17--			MJ-1500-F
A-INC-50		Period Meter	1	Control Room - Panel #8	Strip Chart, single pen, 2 sec. full scale travel, span 10 millivolts, chart speed 6" per hour, special scale, with SPDT control switch.	Argonne National Laboratory Model EL-3			
A-INC-50-A		Ion Chamber	1	Reactor	Concentric Cylinder or Parallel Plate, Boron coated, Gas filled, 4" O.D. x 13" long chamber. For 10^2 to 10^{10} neutrons per cm^2	Argonne National Laboratory Model CD 42 Circuit EL 1467			
A-INC-50-B		Preamplifier and Chamber Power Supply	1	Reactor Face #1		Argonne National Laboratory Model CD 47 Circuit EL-1496			
A-INC-50-C		Amplifier	1	Control Room - Cubicle #7 Unit 7-1		Brown Instrument Model Y153 X 18 (Applied Physics Corp.)			
A-INC-51		Low Power Level Recorder	1	Control Room Panel #8	Strip chart, single pen, 1 sec full scale travel, span 25 mv, chart speed 2"/minute				

REACTOR TANK SECTION							DWG. COMPLETED	SPEC. COMPLETED	ASSEMBLY OR REFERENCE DRAWING
ITEM NO.	FLOW SHEET COORD.	NAME OF ITEM	NO. REQ'D	LOCATION	DESCRIPTION, TYPE, CAPACITY, ETC.	SUGGESTED VENDOR			
A-INC-51-A		Ion Chamber	1	Reactor Face #1, Hole 1-3	Same as A-INC-50A	Argonne National Laboratory Model EL-3			
A-INC-51-B		Chamber Power Supply	1	Reactor Face #1	0-500 Volt D.C. output @ 10 MA. Regulation $\pm 0.1\%$	Beta Elect. Corp. Spec. 251			
A-INC-51-C		Electrometer Head	1	Reactor Face #1		Applied Physics Corp. Model 32			
A-INC-51-D		Amplifier	1	Reactor Face #1		Applied Physics Corp. Model 32			
A-INC-51-E		Range Controller	1	Console, Panel A	Range Adjustment for Electrometer (-51-D)	Applied Physics Corp. 1			
A-INC-52-1,2		Power Level Recorder - Controller	2	Control Room - Panel #10	Strip Chart, single pen, 12 sec. full scale travel, span 10 mv chart speed 2"/hour with change gears for 10" and 40"				
A-INC-52-A (1,2,3)		Ion Chamber	3	Reactor	Same as A-INC-50-A	Argonne National Laboratory Model EL-3			
A-INC-52-B		Power Supply and Amplifier	1	Control Room - Panel #10	Special Amplifier and Power Supply Assembly with Safety Trips for Max Power Level	Argonne National Laboratory Circuit EL-1497			
A-INC-52-C (1,2,3)		Indicators	3	Console, Panel A	Microammeters, Range 0 to 100 microamps.	Simpson - Model 122			
A-IRC-54		Exhaust Air Radiation Monitor	1	Control Room Panel #1	Strip Chart, Single pen, 24 sec full scale travel, scale 0-100, Span 10 millivolts, SPDT switch, for use with A-IRC-54-C	Brown Instrument Co. Model 153 X 60			
A-IRC-54-A		Ion Chamber	1	Pipe Tunnel - Service Bldg.	Annular Ion Chamber, Gamma sensitive, 30 L. capacity, Argon gas filled at 20 atmos., Sensitivity 1.5×10^{-13} amps.	Argonne National Laboratory Dwg. No. MTR-3076-D			MJ-4615-D
A-IRC-54-B		Power Supply	1	Pipe Tunnel - Service Bldg.	Power Supply, 0-500 volts D.C. $\pm 0.10\%$, at 10 ma	Beta Electric Corp. Spec. 251			
A-IRC-54-C		Electrometer	1	Pipe Tunnel - Service Bldg.	Electrometer Head and Preamplifier	Brown Instrument Co.			
A-IRI-55-(1,2)		Area Radiation Monitor	2	Pump Room (1) Sub-reactor Room (1)		Radiation Counter Lab. Model Mark 11, Model 27			
A-IRI-55-A (1,2)		Indicators for Monitor	2	Pump Room Entrance (1) Sub-reactor Room Entrance (1)		Radiation Counter Lab.			
A-INC-56		Reactor Power Demand Indicator	1	Control Room Panel #9					MJ-4790-D
A-INC-56-A		Ion Chamber	1	Reactor Face #3 Hole 3-6	Same as A-INC-50A	Argonne National Laboratory Model EL-3			MJ-4797-D
A-INC-56-B		Ion Chamber Power Supply	1	Reactor Face #3	Power Supply to operate on 115 volt 60 cycle A.C. and to provide 700-1500 volts D.C. $\pm 0.1\%$ REG.	Beta Electric Co. Spec. 256			
A-INC-56-C		Amplifier	1	Control Room Panel #11-2	Automatic Control Power Demand Amplifier	Argonne National Laboratory			MJ-4791-D
A-INC-56-D (1,2)		Amplifier Power Supply	2	Control Room Panel #1, Units 11-3; 11-4	Rack Mounted Power Supply to operate on 115 volt 60 cycle A.C., and to provide 300 volts D.C. $\pm 1/2\%$	Lambda Elect. Corp. Model 28			
A-INC-57-(1,2)		Power Level Galvanometer Differential Galvanometer	1	Control Room - Console	Taut Suspension Type Galvanometers, with a Sensitivity of 0.0005 Microamps/mm	Rubicon Instrument Co. Spec. 39363			
A-INC-57-A		Ion Chamber	1	Reactor					

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REACTOR TANK SECTION							DWG. COMPLETED	SPEC. COMPLETED	ASSEMBLY OR REFERENCE DRAWING
ITEM NO.	FLOW SHEET COORD.	NAME OF ITEM	NO. REQ'D	LOCATION	DESCRIPTION, TYPE, CAPACITY, ETC.	SUGGESTED VENDOR			
A-INC-57-B		Power Supply		Reactor Face #1	Batteries, Set of 14-45 volt, Series Connection	Burgess Battery Corp. Model 230MX			
A-INC-65		Regulating Rod Position Indicator	1	Control Room Panel #9					MJ-4790-D
A-INC-66 (1,2,3,4)		Shim Safety Rod Position Indicator	4	Control Room Panel #9					MJ-4790-D
<u>TOP PLUG (REACTOR)</u>									
B-1		Plug Housing							
B-2									
B-3									
B-4									
B-5		Plug Filling		Inside Top Plug on Reactor	3 inches of Lead shot plus $B_{4}C$. Balance of filling to be 250 lbs/cu. ft. concrete				
<u>STORAGE WELL</u>									
C-1		Plug Housing							
C-2									
C-3									
C-4		Storage Well Plug Filling							
C-5									
<u>ELEMENTS</u>									
E-1		Producer Assembly		Reactor Vessel or Storage Rack	4-1/2" O.D. over-all 94-1/2" long, 275 lbs				MJ-1902-E
E-2		Fuel Assembly		Reactor Vessel or Vaults	4-1/2" O.D. Maximum, 2-1/2" dia active element, 42" active, 95-7/8" long over-all				MJ-1620-E
E-3		Assembly		Reactor Vessel or Cave	4-1/2" O.D. Maximum, 95-7/8" long over-all 6 tubes for Containers				MJ-1914-F
E-4		Container		Assembly	Zirconium (Hf. free) thimble, 0.750" dia by 2-3/4" long, including filter disc. For use with Item E-3				MJ-1920-C
<u>HEAVY WATER SECTION</u>									
F-1 1,2	c-3	Heat Exchanger	2	Pump Room	Vertical "U" tube exchanger, 1000 gpm @ 17 F Rise, Double Tube Sheet, SST tubes, 1/2" #18 gauge, 860 sq. ft. approx.	Patterson-Kelly			MJ-6110-B
F-4	b-4	Flow Regulator	1	Pump Room	Flow Regulator, adjustable variable orifice, all Stainless, Adjustable 1 to 12 gpm at 125 F and 50 psig	W. A. Kates Co. Size 2-GA			MJ-6201-D
F-5	b-4	Heat Exchanger, D ₂ O Filtration System	1	Pump Room	Coil Shell Type, 11 turns each 7" dia 3/4" O.D. SST Tubing, 10" dia x 36" long steel shell				MJ-6209-B
F-6	a-4	Filter, Inlet	1	Pump Room	Porous Porcelain Filter in SST case, 3 sq. ft. area, 3 gpm at 2.5 psi drop, 5 micron pores	Salas Corp. 7 Candle Porosity #10			

HEAVY WATER SECTION							DWG. COMPLETED	SPEC. COMPLETED	ASSEMBLY OR REFERENCE DRAWING
ITEM NO.	FLOW SHEET COORD.	NAME OF ITEM	NO. REQ'D	LOCATION	DESCRIPTION, TYPE, CAPACITY, ETC.	SUGGESTED VENDOR			
F-7	b-4	Filter, Inlet Lead Shielded	1	Pump Room	Ditto #6 except no mounting clips. For Shield see F-14	Ditto Item F-6			MJ-6209-B
F-8 1,2	a-4	Ion Exchange Resin basket	3	Pump Room	42" long by 5" dia Resin column, SST, with 1" flanges top & bottom, less ion exchange resin				MJ-6203-C
F-9	c-5	Flow Tube	1	Pump Room	Flow Tube, 10" size, Stainless Steel const. for 3000 gpm flow, 100" W.C.	Foster Engr. Co.			
F-10	a-4	Filter, Outlet	1	Pump Room	Ditto Item F-6	See F-6			MJ-6209-B
F-11		D ₂ O Sampling Device	1	Reactor Equip. Area	Lead Shielded Door Sampling Device with flow control, for sampling radioactive liquid				MJ-3118-D
F-12 1,2	b-1	Storage Tank Heavy Water	2	Sub-reactor Room	60" O.D. x 12'-12" long SST Storage Tank, on kgs, with special safety plug. Capacity approx 1600 gal	Pfautler Co.			MJ-6100-C MJ-6101-C
F-13	c-2	Dump Tank	1	Sub-reactor Room	60" O.D. x 5'-2" Vertical Tank, 8"-1-1/2" over-all on legs, with nozzles	Pfautler Co.			MJ-6000-C
F-14		Shield around Item F-7	1	Pump Room	Lead Shield				MJ-2627-D
F-15		Viewing Window	1	Reactor Equip. Area - Pump Room	18" x 18" x 24" thick Liquid filled viewing window				
F-16		Ion Exchange Resin	1.5 cu ft	Pump Room (Item F-8)	Polystyrene Type Cation and Anion Synthetic Resins, high exchange capacity, for mixed bed use	Rohm and Haas Co. Types IR-120 and IRA-400			
F-VA-1	c-4	Diaphragm Operated Saunders Valve, 6"	1	Pump Room	6" Flanged SST; Diaphragm operated and solenoid Controlled. Spring open, air to close	Hills-McCanna Co. 408, KM Type 1550			
F-VA-2	c-1	Piston Operated Saunders Valve - 2"	1	Sub-reactor Room	2" Flanged SST; Piston Operated, Solenoid Controlled. Spring to close, air to open	Hills-McCanna Co. Model 8108			
F-VA-3	c-2	Piston Operated Saunders Valve - 4"	1	Sub-reactor Room	4" Flanged SST; Piston operated, Solenoid Controlled, Spring to close, air to open	Hills-McCanna Co. Model 8108			
F-VA-4	b-4	Piston Operated Saunders Valve - 2"	1	Sub-reactor Room	2" Flanged SST; Piston operated, Solenoid Controlled. Spring to open, air to close	Hills-McCanna Co. Model 4108			
F-VA-5 1,2,3	b, c-3	Piston Operated Saunders Valves - Air Controlled 6"	3	Pump Room - Control from Control Room	6" Flanged, Piston operated, proportioning type with Moore Nullmatic Positioner	Hills-McCanna Co. Model 3608			
F-VA-6 1,2	---	Solenoid Operated Valve, 1/4"	2	Pump Room	1/4" Electrically operated Solenoid Valve, #V5-2, Elect. Outlet "C", Option B	Skinner Electric Valve Division			
F-CV-1 1,2,3	b, c-3	Check Valves, 6", Sealed	3	Pump Room	6" Flanged SST Disc type Spring Loaded Silent check valve	Williams Gauge Co.			
F-CV-2	b-3	Check Valve, 1-1/4" Sealed	1	Pump Room	1-1/4" Flanged SST, Disc type Spring Loaded Silent check valve	Williams Gauge Co.			
F-CV-3	a-1	Check Valve 1-1/2", Sealed	1	Sub-reactor Room	1-1/2" Flanged SST, Disc type Spring Loaded Silent check valve	Williams Gauge Co.			
F-FR-1	---	Filter - Pressure Reducer	1		Compressed air filter and reducing station, 3/8" IPS, 3/8" IPS, 25 psi inlet, 5 psi discharge (adjustable)	Norgren Series 5 A-X-3			
F-V-1 1,2,3	b, c-3	8" Saunders Type Valves	3	Pump Room	8" Flanged SST, Saunders Type Valve, Open-Shut Indicator, Sealed Bonnett	Hills-McCanna Co. Model 12,208			
F-V-2 1,2,3,4	b, c-3	6" Saunders Type Valves	4	Pump Room	6" Flanged SST, Saunders Type Valve, Open-Shut Indicator, Sealed Bonnett	Hills-McCanna Co. Model 12,208			
F-V-8	a-1	2" Saunders Valves	1	Pump Room	2" Flanged SST Saunders Type Valves. Sealed Bonnett Neoprene Diaphragm, with Open-Shut switches	Hills-McCanna Co. Model 6608			
F-V-9	a-1	1-1/2" Saunders Valves	1	Sub-reactor Room	1-1/2" Flanged SST Saunders Type Valves	Hills-McCanna Co. Model 6608			
F-V-10	---	1" Saunders Valves	16	Varies	1" Flanged SST Saunders Type Valves. Sealed Bonnett Neoprene Diaphragm, with Open-Shut switches	Hills-McCanna Co.			

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HEAVY WATER SECTION (Instrumentation)							DWG. COMPLETED	SPEC. COMPLETED	ASSEMBLY OR REFERENCE DRAWING
ITEM NO.	FLOW SHEET COORD.	NAME OF ITEM	NO. REQ'D	LOCATION	DESCRIPTION, TYPE, CAPACITY, ETC.	SUGGESTED VENDOR			
F-V-11		1/2" Packless Stop Valves	10	Pump Room	1/2" SST Packless Stop Valve	Associated Valve Mfg. Co. Type 1064			
F-V-12		1/4" Packless Stop Valves	6	Pump Room	1/4" SST Packless Stop Valve	Associated Valve Mfg. Co. Type 1064			
F-V-14	a, b-1	2" Saunders Valve	2	Sub-reactor Room	2" Weld-end Saunders Type Valve. Sealed Bonnet, Neoprene Diaphragm, with "open-shut" switches	Hillis-McCanna Co.			
F-P-1-1, 2, 3	c-3	D ₂ O Circulating Pump	3	Pump Room					
F-P-4	a-1	D ₂ O Fill Pump	1	Sub-reactor Room					
F-M-1 1, 2, 3	c-3	On Pump F-P-1	3	Pump Room					
F-M-4	a-1	On Pump F-P-4	1	Sub-reactor Room					
F-IP1-10	c-5, 3	Pressure Recorder	1	Panel Board #6	Pressure Recorder, Electronic, Strip-Chart 2 point, Range 0-100 psi, Scale 0-100 psi, for use with Microsen Pressure Transmitter.	Brown Instrument Co. Y153 X 60 (x2)-x-31			
F-IP1-10 A	c-5, 3	Pressure Transducers	1	Pump Room	Pressure Transducers Range 0-100 psi, Stainless steel construction, for use on 1" pipe flange.	Brown Instrument Co. Model 145 & Microsen Transducer			
F-IP1-12	Multiple Points	Multiple Point Pressure Indicator	1	Panel Board #4	Pressure Indicator, Dial Type Multiple Point (15 stations) Range 0-100 psi, Scale 0-100 psi, Push Button Assembly	Automatic Temp. Control Co. 6104-A1A-000-2			
F-IP1-12 A, B, C, D, E, F	Multiple Points	Pressure Transducers	6	Pump Room & Subreactor Room	Pressure Transducers, Bourdon Tube Type, Range 0-100 psi, stainless steel construction	Automatic Temp. Control Co. 6001-6-1C-8			
F-IP-26	Multiple Points	Pressure Gauges	6	Pump Room	Pressure Gauges, Bourdon Tube Dial Type, 4-1/2" dial, Range and Scale, 0-60 psi, Stainless Steel Tube, Mounted on 1" SS Flange	Manning-Maxwell & Moore Ashcroft-1072W but on 1" SS Flange			
F-IFC-100	c-5	Flow Recorder-Controller	1	Panel Board #7	Flow Recorder-Controller, Electronic Type, Strip Chart, Range 0-3000 gpm -Scale 0-300, for use with Differential Converter on Flow Tube (Item F-9)	Brown Instrument Co. Y-153 X 17 KAW 7-6KI			
F-IFC-100 A	c-5	Differential Converter	1	Pump Room	Differential Converter, Electric Meter Body Type, Range 0-60" to 0-300" H ₂ O, stainless steel, for use on Foster Flow Tube - Item F-9	Brown Instrument Co. 356944-2			
F-IFC-105		Flow Indicator-Recorder	1	Coffin	Flow Gauge-Controller, 1" Size, Stainless Steel Range 0.7 to 7.0 gpm, with alarm feature	Fischer Porter Co. Magnesite Flow Gauge			
F-ITC-200	c-3, 4	Temperature Recorder and Controller	1	Panel Board #7	Temp. Recorder-Controller, Strip Chart, Range 0-200°F, Scale 0-200°F, for Resistance Thermometer Bulbs.	Brown Instrument Co. Y153 X 12 (W)-X-(1V)			
F-ITC-200 A & B	c-3, 4	Resistance Thermometer Bulbs	2	Pump Room	Resistance Thermometer Bulbs in Special Well-Range 0-200°F All Stainless parts-Mounted on 1" Pipe Flange	Brown Instrument Co.			
F-ITI-202	Multiple Points	Temperature Indicator Multiple Point	1	Panel Board #6	Multiple Point Temperature Indicator, Scale 0-200°F, Range 0-200°F, for use with Copper Constantin Thermocouples	Brown Instrument Co. 156 X 63 P24			
F-ITI-202 A	a-3	Thermocouples	3	Pump Room	Thermocouples, Copper Constantin, Range 0-200°F, in stainless steel well on 1" Pipe Flange	Brown Instrument Co.			
K-ITI-202 B & C	f-3, 4			Equipment Room					

HEAVY WATER SECTION (Instrumentation)							DWG. COMPLETED	SPEC. COMPLETED	ASSEMBLY OR REFERENCE DRAWING
ITEM NO.	FLOW SHEET COORD.	NAME OF ITEM	NO. REQ'D	LOCATION	DESCRIPTION, TYPE, CAPACITY, ETC.	SUGGESTED VENDOR			
F-ITC-206	c-5	Temperature Recorder and Controller	1	Equipment Room (Pump Room Wall)	Temp. Recorder-Controller, Circular Chart, Range 50-150°F, Scale 50-150°F, for use with Resistance Thermometer Bulbs.	Brown Instrument Co. 152 P13W 96-11			
F-ITC-206 A	c-5	Resistance Thermometer Bulb	1	Pump Room	Resistance Thermometer Bulb in special well on 1" Pipe Flange: Range 0-200°F all Stainless steel parts	Brown Instrument Co.			
F-ICR-302	a-2,4	Conductivity Recorder, Two Point	1	Panel Board #5	Conductivity Recorder, Strip chart, 2 point, Scale 0-10, Range 0-10, for use with conductivity cells	Industrial Instrument Co.			
F-ICR-302 A & B	a-2,4	Conductivity Cell	2	Pump Room					
F-ILI-320	e-4	Level Indicator	1	Panel Board #5	Recorder Circular Chart, Range 0-100", Scale 0-100", for use with diff. converter	Brown Instrument Co. 153x14BC-x-11			
F-ILI-320 A	e-4	Differential Converter	1	Reactor Equipment Room (Face 3 of Reactor)	Differential Converter, Electric Meter Body Type, Range 0-60" to 300" H ₂ O, Stainless Steel	Brown Instrument Co.			
F-ILI-321	c-4	Level Indicator - gauge glass	1	Reactor Equipment Room (Face 2 of Reactor)	Gauge Glass Level Indicator, 40" length	Jerguson Gauge and Valve Co. Size 220R5			
F-ILI-322	b-2	Level Indicator - gauge glass	1	Sub-reactor room.	Gauge Glass Level Indicator - 60" length	Jerguson Gauge and Valve Co.			
EMERGENCY WATER									
G-1-1,2	g,h-2	Nitrogen Gas Cylinders	2	Reactor Equipment Area	Nitrogen cylinder, 220 cu ft Oil Pumped Nitrogen				
G-2-1,2	f-2	Blind Valves	2	Reactor Equipment Area	Blind Valves, Union Type	Hamer Oil Tool Co. 3-4" -#L150			No Drawing
G-3-1,2	f-2	Flow Regulator	2	Reactor Equipment Area	Flow Regulator, cast iron, screwed, 1/2" size, Flow 0.1 to 1.5 gpm @ 40 psig max	Kates Regulator Co. #0-0A			No Drawing
G-5-1,2	f,g-3	Gas Reducing Station	2	Reactor Equipment Area	Two Stage Gas Cylinder Reducing Station, for Reducing Nitrogen gas from 2500 to 40 psig	Victor Equip. Co. Model VTS46-974			MJ-2625-B
G-7-1,2	f-3	Excess Pressure Relief Valves	2	Reactor Equipment Area	Stainless Steel, Teflon seat, relief valve, 1/4" IPS, Adjustable to 50 psig	Associated Valve and Engr. Co. Type 1034D			No Drawing
G-CV-1 1,2	d,e-2	1/2" check valve (on Emerg. Water Lines)	2	Sub-reactor Room	Sealed silent check valve, brass, 1/2" threaded low pressure drop, "O" ring seal	James-Pond-Clark Co. 1/2", Part No. 259B-4PP			No Drawing
G-CV-2 1,2	c-1	1" Check valve (on pump discharge)	2	Sub-reactor Room	Ditto G-CV-1 except 1" size	Ditto G-CV-1			No Drawing
G-CV-3 1,2	g,f-2	1/4" check valve (above Emerg. Water Tank)	2	Reactor Equipment Area	Ditto G-CV-1 except 1/4" size	Ditto G-CV-1			No Drawing
G-T-1	e-2	Waste Sump Tank	1	Reactor Equipment Area	Tank, Vertical, on legs, 3 ft dia x 4'6" high over-all, steel construction, complete with gauge glass	Any Steel Tank Fabricator			MJ-6300-C
G-T-2-1,2	f-2	Emergency Water Tanks	2	Reactor Equipment Area	Tank, Vertical, on legs 4'6" dia x 6' high over-all, steel construction, for 60 psig, test	Any Steel Tank Fabricator			MJ-6301-C
G-P-1	c-1	Waste Sump Pump	1	Sub-reactor Room	Sump Pump, Iron Body Brass trim, 25 gpm @ 25' head at 1750 rpm. 30" setting. Including 40" x 40"-1/4" Steel cover plate	Yeoman Bros. Co. Chicago, Ill. #3153G			No Drawing
G-P-2	c-1	Emergency Sump Pump	1	Sub-reactor Room	Sump Pump, Iron Body Brass trim, 25 gpm @ 75' head at 1750 rpm. 18" setting	Yeoman Bros. Co. Chicago, Ill. #3153M			No Drawing

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EMERGENCY WATER							DWG. COMPLETED	SPEC. COMPLETED	ASSEMBLY OR REFERENCE DRAWING
ITEM NO.	FLOW SHEET COORD.	NAME OF ITEM	NO. REQ'D	LOCATION	DESCRIPTION, TYPE, CAPACITY, ETC.	SUGGESTED VENDOR			
G-P-3	e-1	Waste Pump	1	Reactor Equipment Area	Close coupled horizontally mounted 50 gpm @ 45' head iron body, Brass mounted, 1-1/2" suction, 1-1/4" discharge	Bell and Gossett Co., Size 1-1/4 AA			No Drawing
G-M-1	c-1	On Waste Sump Pump (G-P-1)	1	Sub-reactor Room	3/4" H.P., 1750 rpm 60 cycle, 440 volts, 3 phase open vertical motor	With G-P-1			No Drawing
G-M-2	c-1	On Emergency Sump Pump (G-P-2)	1	Sub-reactor Room	2 H.P., 1750 rpm, 60 cycle, 440 volts, 3 phase open vertical motor	With G-P-2			No Drawing
G-M-3	e-1	On Waste Pump (G-P-3)	1	Reactor Equipment Area	1 H.P., 3450 rpm, 60 cycle 220/440 volts, 3 phase open type, close coupled to G-P-	With G-P-3			No Drawing
<u>THERMAL SHIELD COOLING</u>									
K-1	f-4	Heat Exchanger	1	Reactor Equipment Area	Shell and Tube Heat Exchanger ip' tubes, 13'8" long over-all 10" shell diameter, 76-3/4" Brass tubes, 175 sq ft exchanger surfaces	Pfautler Co.			MJ-6302-A
K-2	f-4	Expansion Tank	1	Reactor Equipment Area	Dished End Horizontal Tank, 12" dia x 30" long, Complete with gauge glass				MJ-6225-C
K-3	f-4	Anion Exchanger	1	Reactor Equipment Area	12" long x 3.5" O.D. Chamber, complete with screens, less resin				MJ-6220-C
K-4	---	Anion Exchange Resin	1/2 cu ft	Reactor Equipment Area	Resin, Polystyrene Type Anion Synthetic Resin high Exchange capacity	Rohm and Haas Co. Type IRA-400			
K-P-1	f-4	Thermal shield Circulating Pump	1	Reactor Equipment Area	Horizontal Side Suction Centrifugal Pump, Iron Body, 20 gpm at 60' head, 1-1/2" inlet, 1-1/4" discharge, screwed connections, Top Horizontal discharge	Byron Jackson Bilton Pump 1-1/4" TLM, 2 H.P.			No Drawing
K-M-1	f-4	Motor for Pump K-P-1	1	Reactor Equipment Area	220/440 Volt, 2 H.P., 3600 rph 3 phase, 60 cycle	On Pump K-P-1			No Drawing
K-IF-104	f-4	Flow Indicator	1	Reactor Equipment Area	Variable orifice F.I. meter, 1-1/2" Flanged, Range 0-20 gpm water @ 125°F.	Fischer & Porter Flowrator-#736-8			
K-ITI-202 B,C	f-4	Thermocouples (See item F-ITI-202)	2	Equipment Room	Thermocouples, Copper Constantan, Range 0-200°F, in steel well	These items covered in F-ITI-202-A			No Drawing
<u>HELIUM SECTION</u>									
M-1 1,2,3,4	g-7,f-7	Helium Cylinder	4	Reactor Equipment Area	Helium Cylinder, 200 cu ft	U.S. Bur Mines, Soncy, Texas. (by Mounds)			
M-2 (1,2)	g-7,e-7	Helium Gas Holder	2	Reactor Equipment Area	Wiggins Laboratory Gas Holder 50 cu ft, 5' dia x 4'7" high-Stainless Steel Tank	General Am. Transportation Corp.			MJ-6310-A
M-3	g-5,6	D ₂ O Recombination Meter Assembly	1	Reactor Equipment Area	Unit Assembly-8 cfm Blower, 1/2 H.P. 220V 1 phase motor, cooler, catalyst chamber and condenser				MJ-3400-D
M-4 (1,2)	g-7,f-7	Helium Gas Regulator	2	Reactor Equipment Area	Two Stage, Reducing Station, 3000 psi to 30 for Helium Service, 6 cfm capacity	Victor Equipment Co. Model VTS 46-974			MJ-2626-B
M-5	g-7,f-7	Regulator (Helium)	2	Reactor Equipment Area	Regulator and Relief Valve, 1" size Reduce 6 cfm from 30 psig. 3 in W.C., with relief valve	Fisher Gov. Co., Type 739C			No Drawing
M-6	g-6	Catalyst	4 kg.	Reactor Equipment Area	Palladium Catalyst on 1/8 in Al oxide pellets, approx 0.1% active ingredients	Baker and Co.			No Drawing
MIP-15 A,B	g-7,f-7	High Pressure Gage on Helium Manifold		On Item M-4	Indicating Pressure Gage, 2-1/2" dial, 0-3000 psi, for Helium Service	Parts of Items M-4,5			MJ-2626-B

HELIUM SECTION							DWG. COMPLETED	SPEC. COMPLETED	ASSEMBLY OR REFERENCE DRAWING
ITEM NO.	FLOW SHEET COORD.	NAME OF ITEM	NO. REQ'D	LOCATION	DESCRIPTION, TYPE, CAPACITY, ETC.	SUGGESTED VENDOR			
MIP-16 A, B	g-7, f-7	Intermediate Pressure Gage on Helium Manifold		On Item M-4	Indicating Pressure Gage, 2-1/2" dial, 0-100 psi, for Helium Service	Parts of Items M-4, 5			MJ-2626-B
MIP-17 A, B	g-7, f-7	Low Pressure Gage Helium Gas to System			Indicating Pressure Gage, 2-1/2" dial, 0-10 psi, for Helium Service				
MIP-18	f-5	Helium Gage on D ₂ O Recomb. Unit		On Item M-3	Indicating Pressure Gage	Part of Item M-3			MJ-3400-D
MIF-103	f-6	Flow Indicator for Helium System		On Item M-3	Indicating Flowmeter (Rotameter), Range 1.3 to 14 cfm. Helium gas	Part of Item M-3			MJ-3400-D
MITR 204A	g-6	Temp. Recorder Unit on Inlet to Catalyst Chamber		Sensing unit on M-3 Recorder-Control Room	Circular chart single pen Indicating Recorder, 0-100°F, for diff., temp. across catalyst	Part of MITR-204			
MITR 204B	g-5	Temp. Recorder Unit on Outlet of Catalyst Chamber		Sensing Unit of M-3 Recorder-in Control Room	Ditto above	Part of MITR-204			
MITC 207A	g-6	Temp. Control Unit on Heater of D ₂ O Recomb. Unit		On M-3					
<u>COOLING WATER SECTION</u>									
P-1	d-7	Cooling Tower Cell #1	1	On Cooling Tower Basin	1/2 of Cooling Tower (Cooling Tower 2000 gpm Total (cap. 102°F Entering (83°F Leaving (78°F W.D. design	Tower by Building Contractor			See SM & D Dwgs. or Specs.
P-2	d-7	Cooling Tower Cell #2	1	On Cooling Tower Basin					
P-3	d-7	Gear Box on P-1	1	On Induced draft fan on P-1		By Building Contractor			See SM & D Dwgs. or Specs.
P-4	d-7	Gear Box on P-2	1	On Induced draft fan on P-2		By Building Contractor			See SM & D Dwgs. or Specs.
P-5	d-7	Screens in Cooling Tower Basin	6 prs	In Cold Well of Cooling Tower	6 prs, each screen 5' high x 4'-9" wide, and 1/8" x 1/8" wire mesh	By Building Contractor			See SM & D Dwgs. or Specs.
P-6		Flow Tube	1	On Cooling Tower Pipe In Pipe Tunnel	Flow Tube, 12" Flanged, Iron Body, 3000 gpm capacity at 119.5" W.C. differential - For use with PIFI-102	By Building Contractor			See SM & D Dwgs. or Spec.
P-P-1	c-7	Circulating Pump #1	1	Pump House at Cooling Tower	Vertical Wet Pit Centrifugal Pump, Iron Construction - 1000 gpm @ 100' head	By Building Contractor			See SM & D Dwgs. or Spec.
P-P-2	c-7	Circulating Pump #2	1	Pump House at Cooling Tower	Vertical Wet Pit Centrifugal Pump, Ditto above	By Building Contractor			See SM & D Dwgs. or Spec.
P-P-3	c-7	Circulating Pump #3	1	Pump House at Cooling Tower	Vertical Wet Pit Centrifugal Pump, Ditto above	By Building Contractor			See SM & D Dwgs. or Spec.
P-P-4	d-7	Emergency Circulating Pump	1	Pump House at Cooling Tower	Vertical Wet Pit Centrifugal Pump, 100 gpm @ 110' head	By Building Contractor			See SM & D Dwgs. or Spec.
P-P-5	b-5	Pump on Active Storage Well Cooling Coil	1	Reactor Equipment Floor		By Building Contractor			See SM & D Dwgs. or Spec.
P-M-1	c-7	Motor on P-P-1	1	Pump House	30 H.P., 440 volt, 3 phase, 60 cycle, Vertical motor 1750 rpm	By Building Contractor			See SM & D Dwgs. or Spec.
P-M-2	c-7	Motor on P-P-2	1	Pump House	30 H.P., 440 volt, 3 phase, 60 cycle, Vertical motor 1750 rpm	By Building Contractor			See SM & D Dwgs. or Spec.
P-M-3	c-7	Motor on P-P-3	1	Pump House	30 H.P., 440 volt, 3 phase, 60 cycle, Vertical motor 1750 rpm	By Building Contractor			See SM & D Dwgs. or Spec.
P-M-4	d-7	Motor on P-P-4	1	Pump House	5 H.P., 440 volt, 3 phase, 60 cycle, Vertical motor. 1750 rpm, on the emergency electrical system	By Building Contractor			See SM & D Dwgs. or Spec.
P-M-5	b-5	Motor on Pump P-P-5	1	Reactor Equipment Floor		By Building Contractor			See SM & D Dwgs. or Spec.
P-M-6	d-7	Motor on P-F-1	1	Top of Cooling Tower, Cell #1	20 H.P.	By Building Contractor			See SM & D Dwgs. or Spec.

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COOLING WATER SECTION							DWG. COMPLETED	SPEC. COMPLETED	ASSEMBLY OR REFERENCE DRAWING
ITEM NO.	FLOW SHEET COORD.	NAME OF ITEM	NO. REQ'D	LOCATION	DESCRIPTION, TYPE, CAPACITY, ETC.	SUGGESTED VENDOR			
P-M-7	d-7	Motor on P-F-2	1	Top of Cooling Tower Cell #2	20 H.P.	By Building Contractor			See SM & D Dwgs. or Specs.
P-F-1	d-7	Fan on Cell No. 1	1	Top of Cooling Tower Cell #1		By Building Contractor			See SM & D Dwgs. or Specs.
P-F-2	d-7	Fan on Cell No. 2	1	Top of Cooling Tower Cell #2		By Building Contractor			See MS & D Dwgs. or Specs.
P-V-1	c-7	12" Gate Valve, Hand Wheel Operated		Pump Room	12" Flanged Solid Disc. Wedge Gate Valve, Iron Body, Brass trim and stem, Handwheel operated	Crane #465-1/2-12"			No Drawing
P-V-2 (1,2,3,4)	b-4 c-4	8" Gate Valve { 2 Hand Wheel 2 Chain		Pump Room	8" Flanged Solid Disc Wedge Gate Valve, Iron Body, Brass trim and stem, Handwheel or Chain operated	Crane #465-1/2-8"			No Drawing
P-V-3	c-6	3" Gate Valve, Handwheel Operated		Pump Room	3" Flanged Solid Disc. Wedge Gate Valve, Iron Body, Brass trim and stem, Handwheel operated	Crane #465-1/2-3"			No Drawing
P-V-10	d-7	4" Gate Valve, Handwheel Operated		Cooling Tower Bypass	4" Flanged Iron Body Manual Control Gate Valve	By Building Contractor			See SM & D Dwgs. or Specs.
P-VA-1	c-5	6" Flow Control Valve, Diaphragm Motor Operated	1	Pump Room	6" Flanged, Iron Body Bronze trim, Double Seated, Diaphragm Motor Operated with valve Positioner, with 5" trim, 1300 gpm @ 25 psi	Minneapolis Honeywell - Brown. Type 100 R - 6" size with 5" trim			No Drawing
P-VA-2	c-5	4" Flow Control Valve, Diaphragm Motor Operated	1	Pump Room	4" Flanged, Iron Body Bronze trim, Double Seated, Diaphragm Motor operated with Valve Positioner	Minneapolis Honeywell - Brown - Type 100R			No Drawing
P-VA-3	d-7	6" Flow Control Valve, Motor operated	1	Cooling Tower Bypass	6" Flanged, Iron Body Bronze Trim, Double Seated, 1500 gpm @ 10 psi	By Building Contractor			
P-IP-27	c-7	Pressure Gauge	1	Pipe Tunnel	Pressure Gauge, Bourdon Tube Type, Range 0 to 100 psi, 6" Dial	By Building Contractor			See SM & D Dwgs. or Specs.
P-IFI-102	c-7	Recording Flow Meter	1	Control Room, Panel Board #2	Recording Electric Flowmeter, Circular chart, Range P-3000 gpm, Scale 0-300, for use with Electric Flowmeter Body	Brown Instrument Co.			
P-IFI-102A	c-7	Flow Meter Transmitter	1	Pipe Tunnel	Flowmeter Transmitter, Range 0-119-5" W.C., for use with Foster Flow Tube (Item P-6)	Brown Instrument Co. Model 293 EIC S-23-B-5			
P-ITI-201	c-5	Temperature Recorder	1	Control Room-Panel Board #2	Temperature Recorder Strip Chart, 2 point, Range 0-200, Scale 0-200, for copper-constantin thermocouples	Brown Instrument Co. 153 x 60 P2X-32			
P-ITI-201 A, B	c-5	Thermocouples	2	Pump Room	Thermocouples Copper Constantin, 12" longwell on a 1" pipe flange, for 0-200°F Range	With Item P-ITI-201			
P-IT-208	b-6	Thermometer		Discharge side of Storage Well Coil	Thermometer, Direct Reading, 45° Angle, Range 32-212°F	By Building Contractor			See SM & D Dwgs. or Specs.
PANEL BOARD, CONSOLE AND INST. POWER									
X-P		Panel Board	1	Control Room	Entire Panel Assembly, complete with all instruments - Includes all of X-B items				MJ-4714-D
X-B-1		Panel #1 and Cubicle		Control Room					
X-B-2		Panel #2 and Cubicle	1	Control Room					
etc. thru X-B-16									
X-C		Console	1	Control Room	Entire console assembly, complete with instruments and wiring - Includes all of X-C-1 thru X-C-4				MJ-4761-D

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PANEL BOARD, CONSOLE AND INST. POWER							DWG. COMPLETED	SPEC. COMPLETED	ASSEMBLY OR REFERENCE DRAWING
ITEM NO.	FLOW SHEET COORD.	NAME OF ITEM	NO. REQ'D	LOCATION	DESCRIPTION, TYPE, CAPACITY, ETC.	SUGGESTED VENDOR			
X-C-1		Console - Panel A		Left hand side of Console					
X-C-2		Console - Panel B (Left)		Left hand of center section of Console					
X-C-3		Console - Panel B (Right)		Right hand of center section of Console					
X-C-4		Console - Panel C		Right hand side of Console					
X-D-1		Rectifier Assembly	1	Reactor Equipment Floor (Battery Area)	Selenium Type Rectifier Assembly, to deliver 15KVA 120 volts DC from 440 volt 3 phase 60 cycle power supply	Fansteel Metal Corp.			MJ-4707-D
X-D-2		Battery (60 Cells)	60	Reactor Equipment Floor	Lead Acid Storage Battery, 23 plates/cell, 450 amp hours to 1.75 volts on 3 hour discharge cells max 12-1/4" lg. by 11" wide by 20" high	Electric Storage Batt. Co. 60-E23 cells			MJ-4707-D
X-D-3-1		Battery Rack #1	2	Reactor Equipment Floor	Iron Frames, Wood Rails, standard construction Racks, painted to resist corrosion	Electric Storage Batt. Co. #37310 Rack			MJ-4707-D
X-D-3-2		Battery Rack #2	2	Reactor Equipment Floor	Ditto above	Ditto above #37315 Rack			MJ-4707-D
X-D-4-1,2,3,4		Battery Connectors		Reactor Equipment Floor	Intercell, Interstep, and interrack connectors for the above battery, heavy duty design	Electric Storage Batt. Co.			MJ-4707-D
X-D-5		Motor Generator Set	1	Reactor Equipment Floor	MG set, frequency and voltage regulated, 1800 rpm 10 H.P., DC motor, directed connected to AC generator to give 6KVA, 120 volt, 60 cycle 1 phase AC	Century Electric Co. Type DM and Type ARC			MJ-4707-D
X-D-6-1 to 6		Switches and Contactors		Reactor Equipment Floor					

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purchasing in order to obtain the specific item required for the reactor. It will also be necessary to include specific statements on marking, tagging, etc., since these are not covered other than in the specifications.

F. Procuring Materials and Equipment

There will be several sources from which information for ordering may be obtained. Since the reactor is a moderately complex unit with many specialized parts, it is essential that the buyer or purchasing agent have a good background in the construction of industrial chemical, electrical, or instrumental plants. Purchasing can be done from two listings:

1. Purchase from Specifications

The Item Listing Sheets can be used as a source of ordering information, and purchasing of the equipment for which item numbers are given should be relatively simple when backed by the drawing information.

2. Purchase from Bills of Materials

For equipment not covered by item numbers, the B/M can be used. As indicated above, care must be taken to make certain that adequate information is given to the vendor. There will be many questions raised by the supplier if the B/M is not carefully evaluated. The limits of responsibility of the supplier as to final installation or field work must also be covered in the ordering details. No attempts have been made to combine duplicated parts in the B/M's, nor have any spare parts been considered.

3. Delivery to Site

One of the prime purposes of the Section designation is to permit segregation of the components as they are delivered to the construction site. The specifications call for clear marking and tagging, and this should be reiterated in every purchase order. By dividing the warehouse or storage area into appropriate areas or sections, the incoming material can then be properly separated and organized. This should greatly simplify the receiving, storage, and subsequent installation of the equipment. Close checking to guarantee conformance to the specifications, drawings, etc., must be constantly carried out. It is especially important to see that the vendor has used the proper alloys or other materials. The entire successful operation of the reactor may depend upon strict adherence to the materials called for on the drawings or otherwise specified.

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4. Tests on Specialized Mechanisms

Some of the equipment required for the reactor is of unique and highly specialized design. Because the entire operation of the reactor, and indeed the safety of the installation, depends upon some of these devices, it is necessary that they be given a complete testing before installation. Two such typical pieces of equipment are the regulating rod and the shim-safety rod mechanisms. It will be necessary to mock up this equipment and run tests for time of response, reliability, and in some few cases wear tests, etc., all before they are ever installed. Similar mock-up and operating tests will be required of coffin mechanisms, some instrument assemblies, etc. It is assumed that the final construction contract will be such that experimental testing and development work similar to the above will be done by Argonne in order to obtain the benefit of the experience and background of the design and development personnel. Under no circumstances should critical equipment be installed until it has been completely demonstrated that it is workable and has a satisfactory life expectancy.