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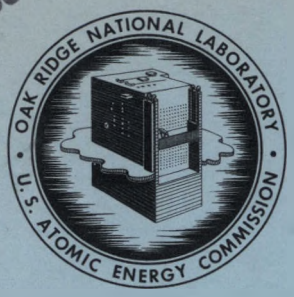

OAK RIDGE NATIONAL LABORATORY
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U. S. ATOMIC ENERGY COMMISSION

ORNL - TM - 1138

OPERATING MANUAL FOR THE HIGH FLUX ISOTOPE REACTOR

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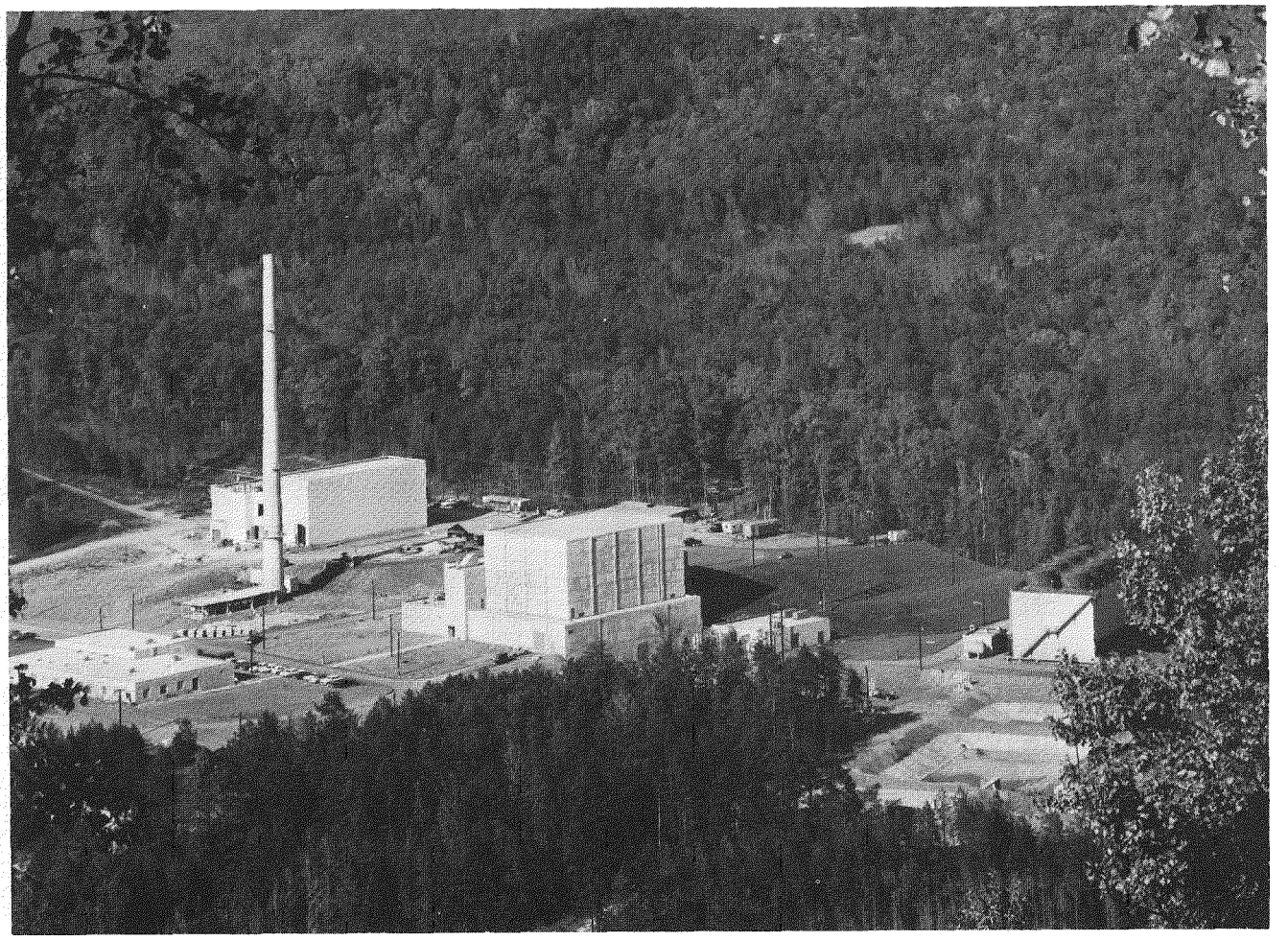

OPERATING MANUAL

FOR THE

HIGH FLUX ISOTOPE REACTOR

Description of the Facility

OAK RIDGE NATIONAL LABORATORY

OAK RIDGE, TENNESSEE

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ORNL-TM-1138

Contract No. W-7405-eng-26

OPERATING MANUAL FOR THE HIGH FLUX ISOTOPE REACTOR

DESCRIPTION OF THE FACILITY

Compiled by
High Flux Isotope Reactor Staff

JUNE 1965

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee
operated by
UNION CARBIDE CORPORATION
for the
U.S. ATOMIC ENERGY COMMISSION

ACKNOWLEDGMENT

The HFIR Staff wishes to acknowledge the contributions of P. Rubel and D. S. Asquith of the Reactor Controls Department who provided the Instruments and Controls section of the manual.

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1. INTRODUCTION

This report contains a comprehensive description of the High Flux Isotope Reactor facility. Its primary purpose is to supplement the detailed operating procedures, providing the reactor operators with background information on the various HFIR systems. The detailed operating procedures are presented in another report.

2. REACTOR DESCRIPTION

2.1. Introduction

The prime purpose of the HFIR is to establish, within a limited volume, an unperturbed thermal neutron flux of 5 x 10^{15} n/cm^2-sec for the purpose of producing milligram quantities of Cf^{252} annually. Analysis of the transplutonium production schemes[1] and design studies[2, 3] led to the conclusion that this could be accomplished, within the scope of existing technology, with a light-water, flux-trap type reactor fueled with uranium highly enriched in U^{235} and reflected by beryllium. The reactor power level was established at 100 Mw by a combination of economic considerations and flux requirements. The size and configuration of the core were determined by nuclear optimization studies. These together with thermal and hydraulic considerations determine the power density to be achieved.

The reactor core, which is shown schematically in Figure 2.1, consists of four concentric regions each approximately 2 ft long. The central region, often called the "island," has the highest flux and constitutes the flux trap. It is approximately 5 in. in diameter and will contain the Pu^{242} target in the form of a bundle of rods. The fuel region, located immediately outside the island, has an inside diameter of approximately 5 in. and an outside diameter of approximately 17 1/8 in. It consists of two cylindrical fuel elements containing initially 9.4 kg of U^{235} in vertical curved

---

[1] J. A. Lane et al., High Flux Isotope Reactor Preliminary Design Study, ORNL CF-59-2-65, March 20, 1959.

[2] R. D. Cheverton, HFIR Preliminary Physics Report, ORNL 3006, Oct. 4, 1960.

[3] N. Hilvety and T. G. Chapman, "Thermal Design of the HFIR Fuel Element," Research Reactor Fuel Element Conference, September 17-19, 1962, Gatlinburg, Tennessee, TID-7642, Book 1.

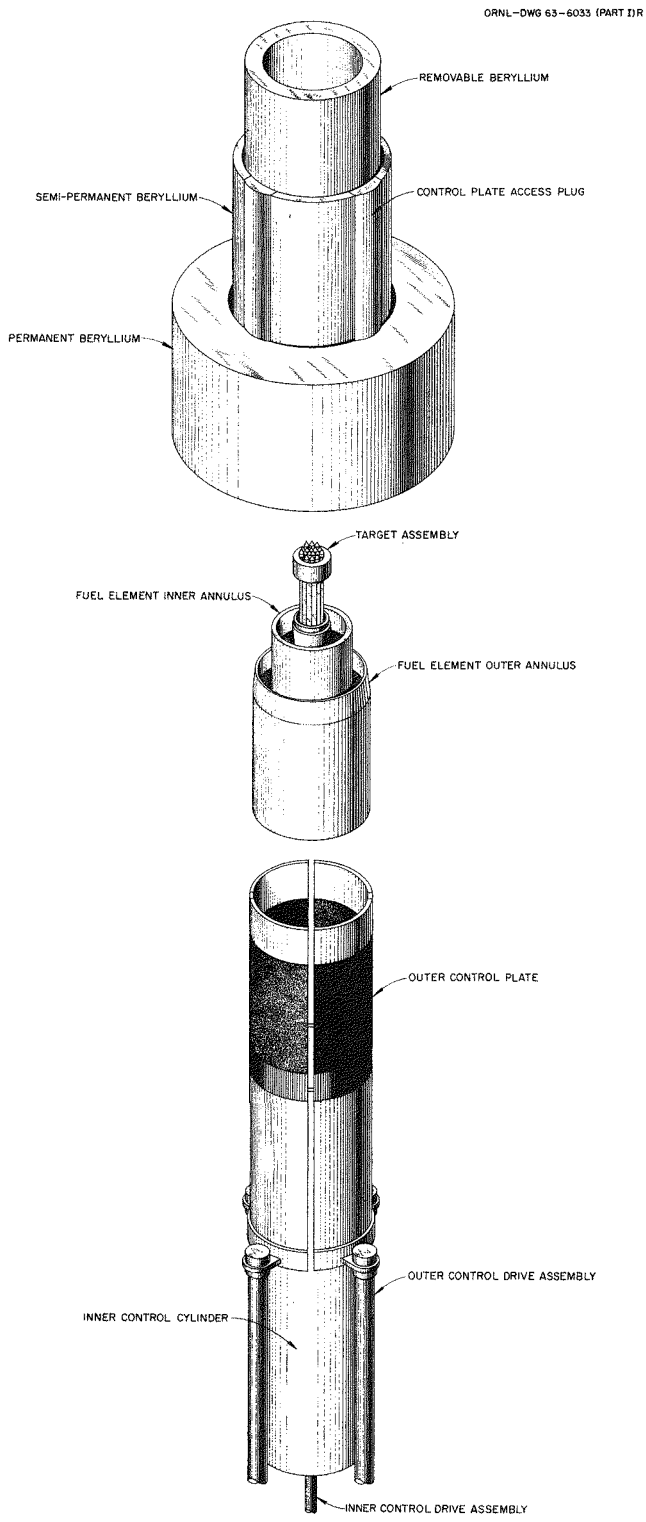


Fig. 2.1. Exploded View of Core.

plates. To minimize the radial peak-to-average power density ratio, the fuel concentration is radially graded. To increase the core lifetime and aid in reactor control, the inner element contains approximately 2.80 g of B^{10}.

The fuel region is surrounded by a concentric ring of beryllium reflector approximately 1 ft thick. This in turn is reflected by water of effectively infinite thickness. Water above and below the core serves as an end reflector.

The control plates, in the form of two thin poison-bearing concentric cylinders, are located between the outer fuel element and the beryllium. Each cylinder contains an axially varied poison to minimize the axial value of the peak-to-average power density ratio throughout the core lifetime.

To increase the usefulness of the reactor, certain experimental facilities have been provided in addition to the flux trap. These include two horizontal beam tubes, one extending radially and the other tangentially from within the beryllium reflector; a horizontal tangential beam tube which passes completely through the reflector; four slant access facilities to the outside edge of the reflector; and thirty-eight vertical holes in the reflector. Various thimbles and access facilities for nuclear instrumentation penetrate the reactor vessel.

The reactor core is contained in an 8-ft-diameter pressure vessel. It is cooled by demineralized water which, under minimum design conditions, is pumped through the system at the rate of 15,000 gpm. This corresponds to a velocity of 42 ft/sec through the fuel region and 40 ft/sec through the target array. The pressure vessel is located in a pool of water 18 ft in diameter and 36 ft deep. This serves as a biological shield and also provides easy access to the reactor. The reactor pool is connected to a

rectangular storage pool 41 1/2 ft long, 20 ft deep, and 18 ft wide. The general arrangement of the reactor components is shown in Figures 2.2., 2.3., and 2.4.

ORNL DWG. 65-5586

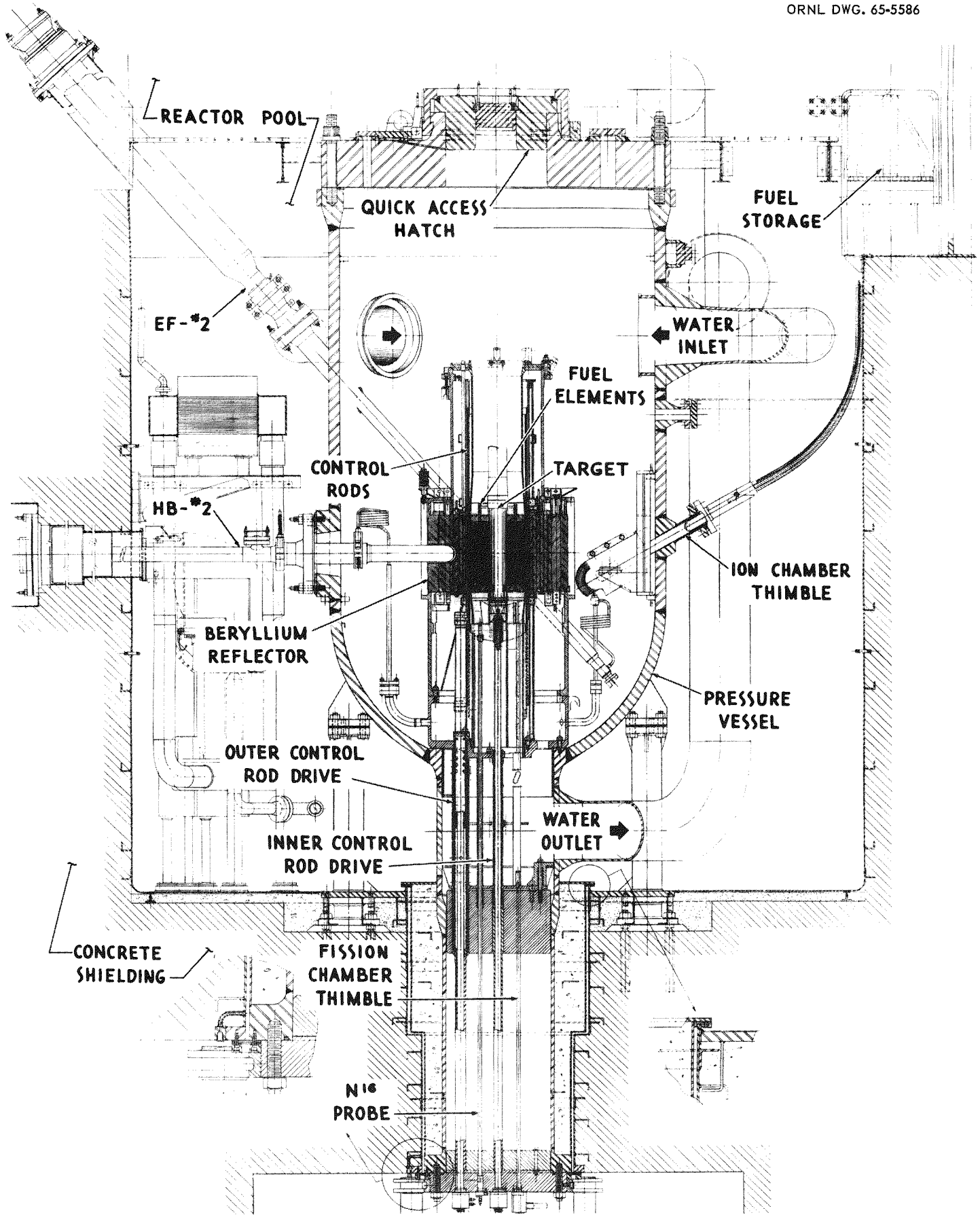


Fig. 2.2. Vertical Section of Reactor Vessel and Core.

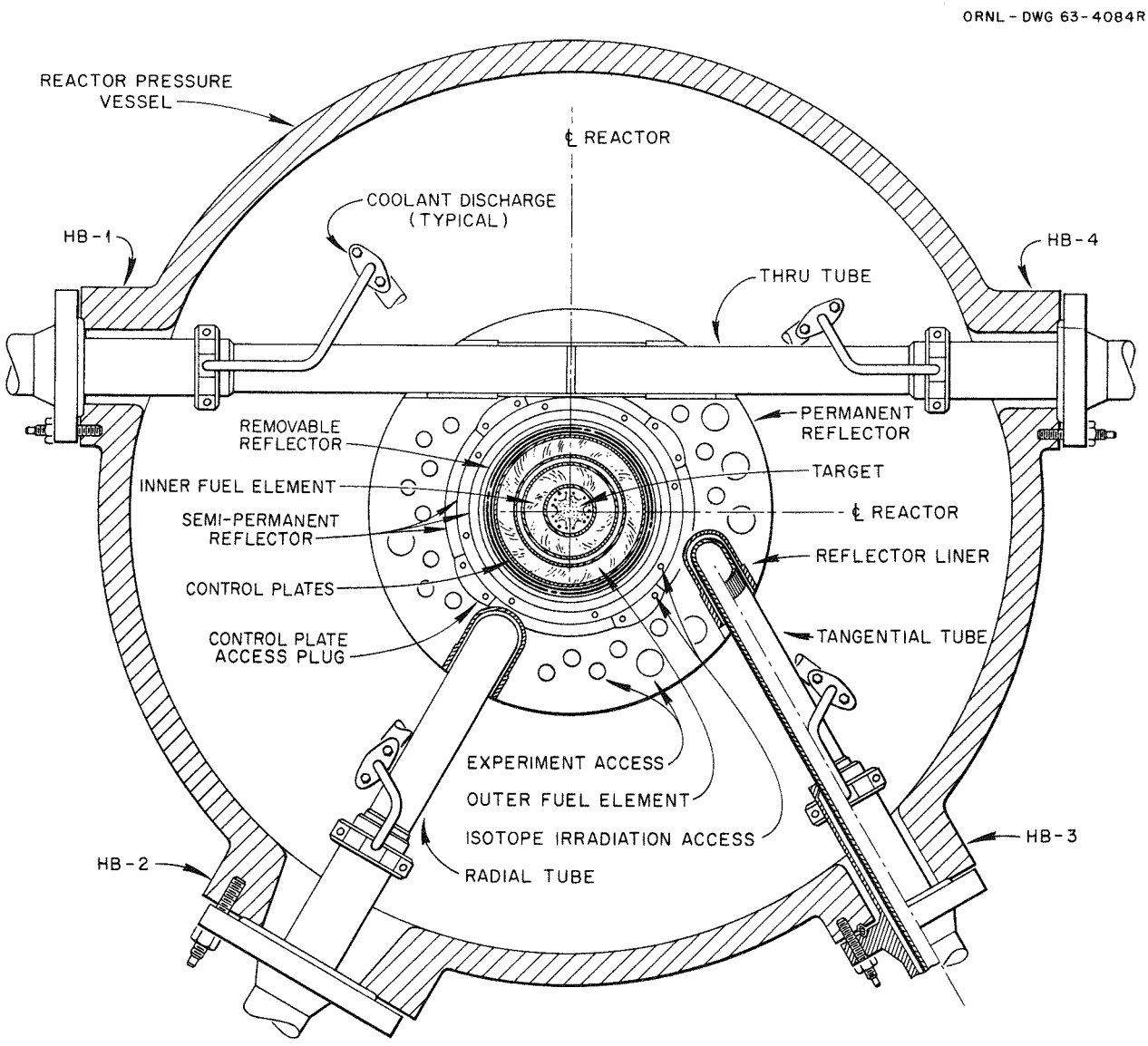
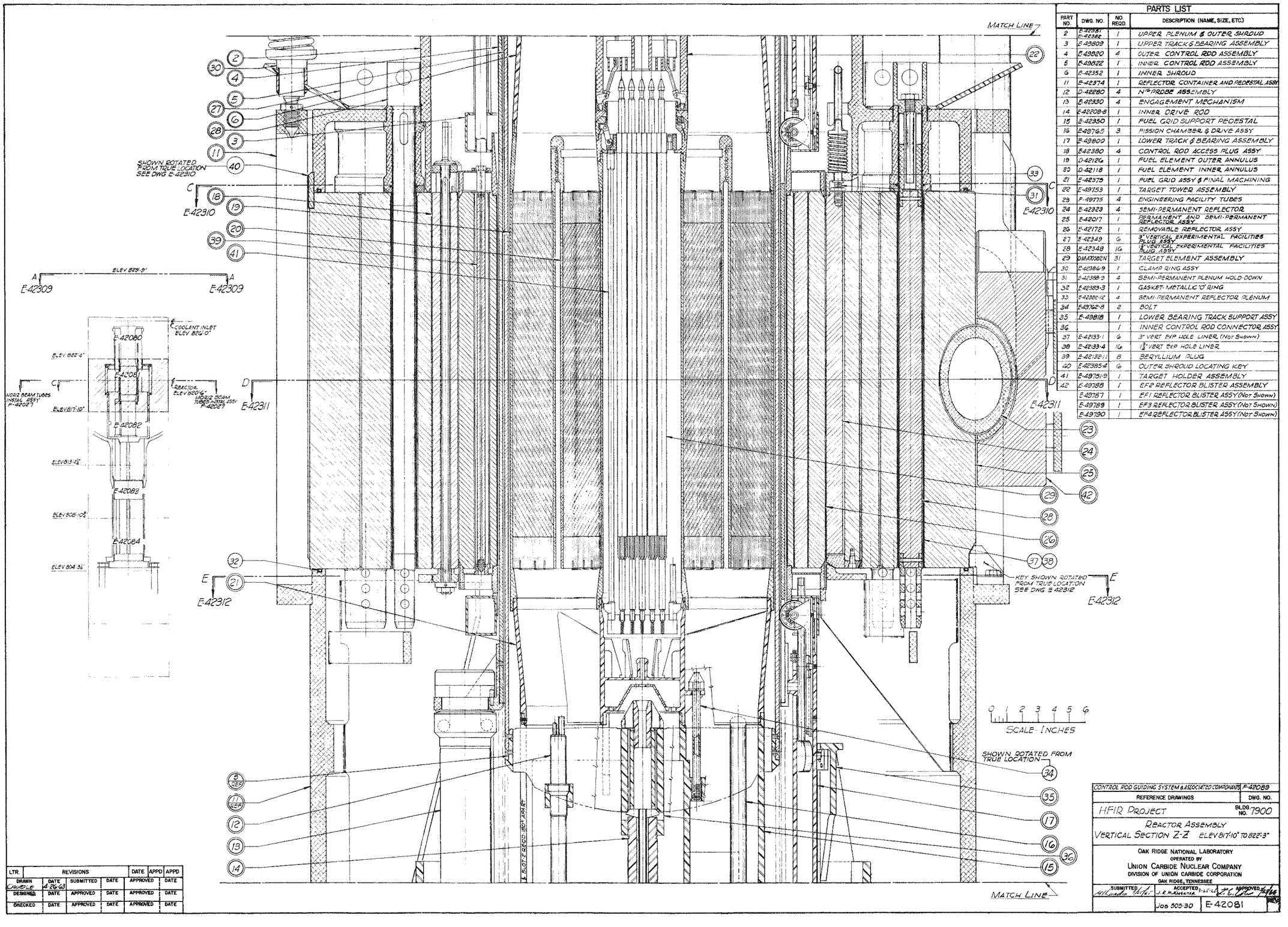


Fig. 2.3. Plan View of Reactor Core.



PARTS LIST			
PART NO.	DWG. NO.	NO. REQ'D.	DESCRIPTION (NAME, SIZE, ETC.)
2	E-42381, E-42382	1	UPPER PLENUM & OUTER SHROUD
3	E-49809	1	UPPER TRACK & BEARING ASSEMBLY
4	E-49820	4	OUTER CONTROL ROD ASSEMBLY
5	E-49822	1	INNER CONTROL ROD ASSEMBLY
6	E-42352	1	INNER SHROUD
11	E-42374	1	REFLECTOR CONTAINER AND PEDESTAL ASSY
12	D-42280	4	N[16] PROBE ASSEMBLY
13	E-42330	4	ENGAGEMENT MECHANISM
14	E-42208-8	1	INNER DRIVE ROD
15	E-42350	1	FUEL GRID SUPPORT PEDESTAL
16	E-49765	3	FISSION CHAMBER & DRIVE ASSY
17	E-49800	1	LOWER TRACK & BEARING ASSEMBLY
18	E-42380	4	CONTROL ROD ACCESS PLUG ASSY
19	D-42126	1	FUEL ELEMENT OUTER ANNULUS
20	D-42118	1	FUEL ELEMENT INNER ANNULUS
21	E-42375	1	FUEL GRID ASSY & FINAL MACHINING
22	E-49753	1	TARGET TOWER ASSEMBLY
23	F-49775	4	ENGINEERING FACILITY TUBES
24	E-42329	4	SEMI-PERMANENT REFLECTOR
25	E-42017	1	PERMANENT AND SEMI-PERMANENT REFLECTOR ASSY
26	E-42172	1	REMOVABLE REFLECTOR ASSY
27	E-42349	6	3" VERTICAL EXPERIMENTAL FACILITIES PLUG ASSY
28	E-42348	16	1" VERTICAL EXPERIMENTAL FACILITIES PLUG ASSY
29	OM-X70582N	31	TARGET ELEMENT ASSEMBLY
30	E-42384-9	1	CLAMP RING ASSY
31	E-42388-9	4	SEMI-PERMANENT PLENUM HOLD-DOWN
32	E-42383-3	1	GASKET-METALLIC 'O' RING
33	E-42386-12	4	SEMI-PERMANENT REFLECTOR PLENUM
34	E-49762-8	2	BOLT
35	E-49818	1	LOWER BEARING TRACK SUPPORT ASSY
36		1	INNER CONTROL ROD CONNECTOR ASSY
37	E-42133-1	6	3" VERT EXP HOLE LINER (Not Shown)
38	E-42133-4	16	1" VERT EXP HOLE LINER
39	E-42132-1	8	BERYLLIUM PLUG
40	E-42385-4	6	OUTER SHROUD LOCATING KEY
41	E-49751-9	1	TARGET HOLDER ASSEMBLY
42	E-49788	1	EF2 REFLECTOR BLISTER ASSEMBLY
	E-49787	1	EF1 REFLECTOR BLISTER ASSY (Not Shown)
	E-49789	1	EF3 REFLECTOR BLISTER ASSY (Not Shown)
	E-49790	1	EF4 REFLECTOR BLISTER ASSY (Not Shown)

LTR.	REVISIONS		DATE	APPD	APPD
DRAWN Caudle	DATE 4-26-63	SUBMITTED DATE	APPROVED DATE	APPROVED	DATE
DESIGNED	DATE	APPROVED DATE	APPROVED DATE	APPROVED	DATE
CHECKED	DATE	APPROVED DATE	APPROVED DATE	APPROVED	DATE

CONTROL ROD GUIDING SYSTEM & ASSOCIATED COMPONENTS F-42089

REFERENCE DRAWINGS — DWG. NO.

HFIR PROJECT — BLDG. NO. 7900

REACTOR ASSEMBLY
VERTICAL SECTION Z-Z ELEV 817'-10" TO 822'-3"

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE NUCLEAR COMPANY
DIVISION OF UNION CARBIDE CORPORATION
OAK RIDGE, TENNESSEE

SUBMITTED M.L. Grindle 5-1-63 | ACCEPTED J.R.McWherter 5-21-63 | APPROVED W.C. Ellis 5/24/63

Job 505-30 | E-42081

Fig. 2.4. Reflector--Elevation.

2.2. Core Components

The reactor core components, which include the target array, fuel elements, control plates, and beryllium reflector, are contained in the reactor vessel. They are supported on two concentric cylinders called pedestals, which are bolted to a cylindrical member called the fuel and reflector support sleeve assembly. This is, in turn, bolted to a support ring in the lower part of the pressure vessel. A pair of cylindrical shrouds extend above the top surface of the fuel element. These shrouds enclose the upper part of the control cylinders and protect them from the turbulence of the coolant flow.

2.2a. Target Assembly

The target assembly, shown in Figure 2.5., is located in the island and contains the Pu^{242} target material. It consists of thirty-one 3/8-in. OD rods, spaced in a triangular pattern. The rods are fabricated from a mixture of PuO_2 and aluminum powder which is pelletized. The pellets are then packed in aluminum tubes, capped, and the tubes collapsed onto the pellets to provide good heat transfer. Appropriate leak tests are applied to each completed tube. The target rods are centered inside 5/8-in. diameter tubes, thereby providing each rod with its own cooling channel of about 1/8 in. The target holder serves to securely hold the array of target rods, to accurately position the assembly, and to facilitate removal and maintenance operations. A typical target rod is shown in Figure 2.6.

Optimization[2] studies indicate that an initial charge of 300 g of PU^{242} is desirable. This will result in a maximum heat generation rate

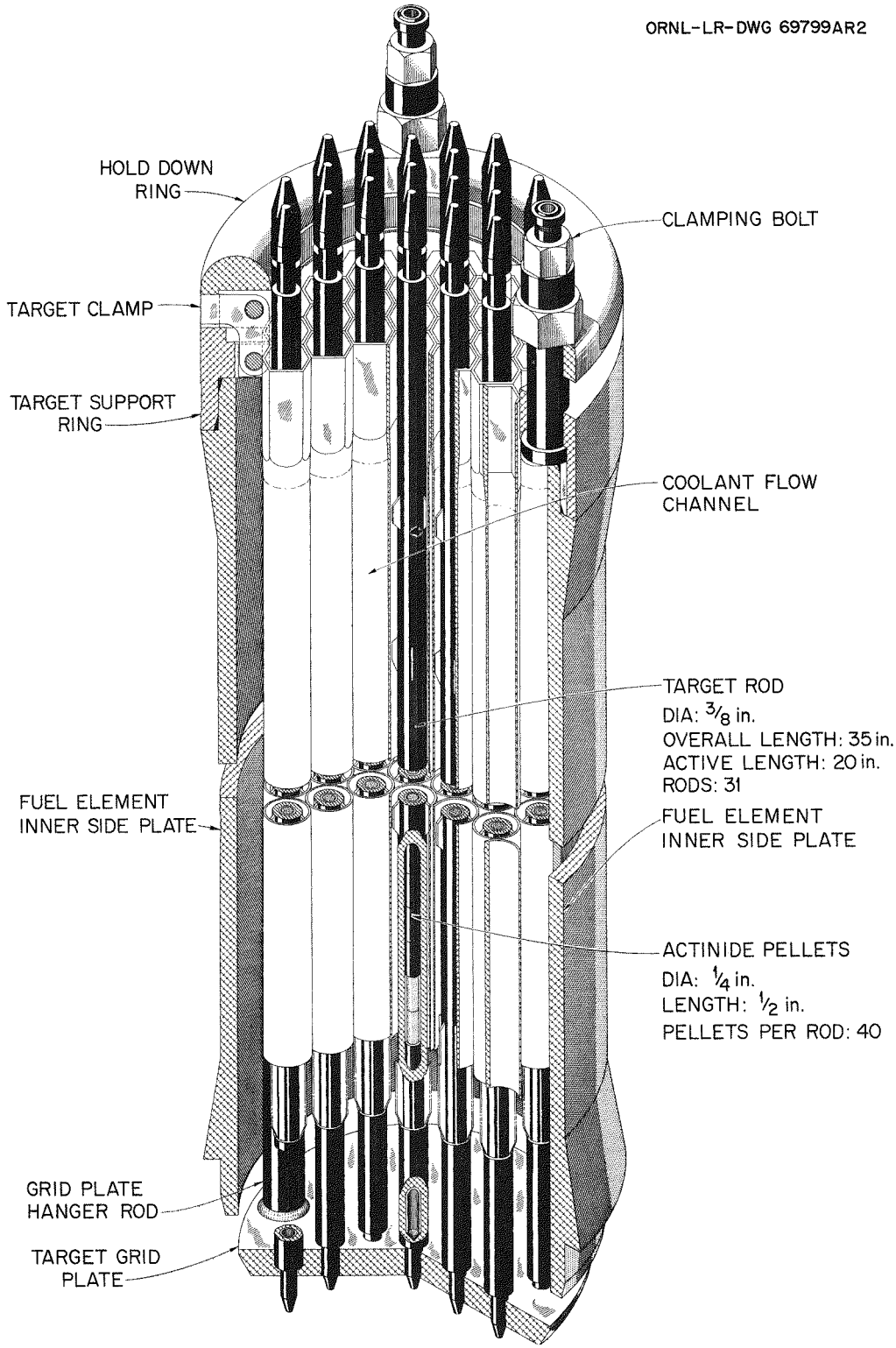


Fig. 2.5. Target Assembly.

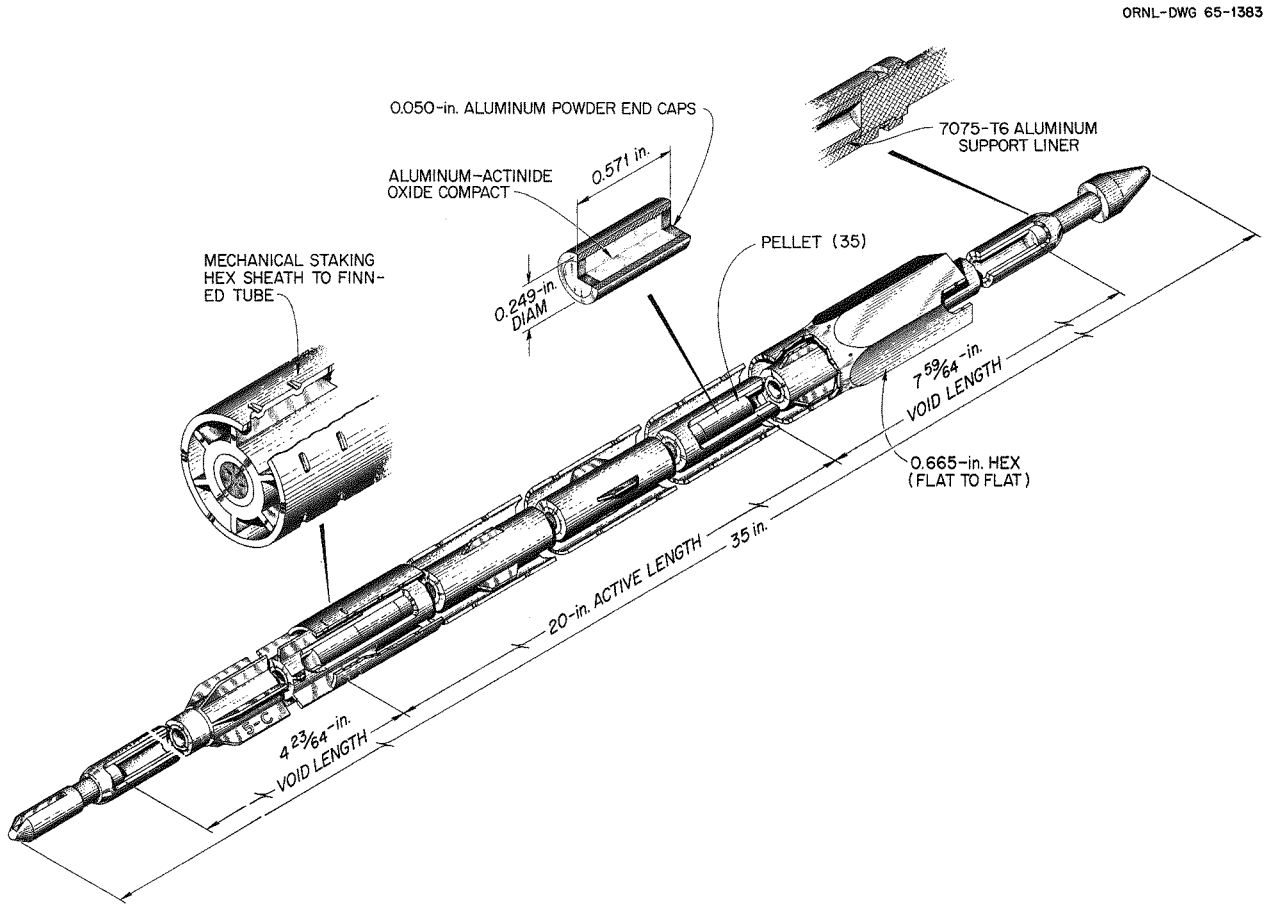


Fig. 2.6. Target Rod.

in the target of approximately 900 kw. The rods provide adequate heat transfer characteristics when positioned on a 5/8-in. triangular pitch.

A minimum design flow rate of approximately 630 gpm is maintained through the target assembly while 200 gpm flows between the target assembly and the inner fuel element. This corresponds to a coolant velocity of 40 ft/sec in the target region, and is more than adequate for heat removal. The maximum heat flux in the target region is calculated[4] to be about 1×10^6 Btu/ft^2-hr; however, peaks are expected, as shown in Figure 2.7., due to buildup and burnup of various isotopes. With low conductivity pellets (11.5 Btu/ft-hr-°F) and a 0.1-mil air gap between pellet and rod wall, the internal temperature is not expected to exceed 1000°F.

Calculations indicate that 215 cc (STP) of gas containing 91.6% Xe, 6% He and 2.4% Kr will be produced during an 18-month irradiation of a target rod initially containing 10 g $Pu^{242}O_2$ with 1% Pu^{241}. Approximately half this volume will be produced in subsequent curium recycle rods. The rods are designed with a 6.5 cc void to accommodate the gaseous fission products. The target tubes have sufficient strength to resist the crushing load of 1000 psi external coolant pressure or internal pressure resulting from fission gas evolution.

Corrosion studies indicate that the corrosion rate of the X-8001 aluminum will not, under the imposed conditions, exceed 0.010 in. per year.

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[4] H. C. Claiborne and M. P. Lietzke, "Californium Production in the High Flux Isotope Reactor," ORNL 59-8-125, August 31, 1959.

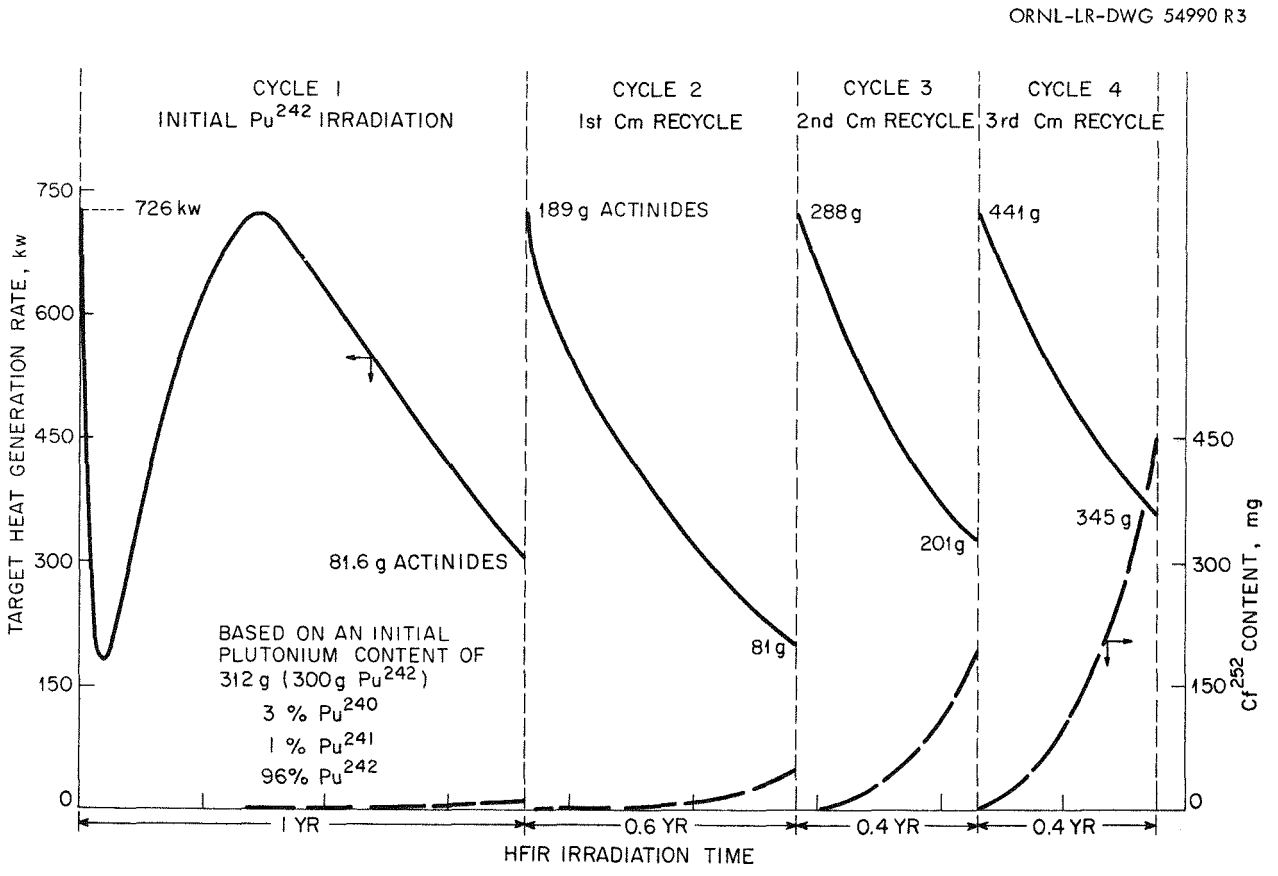

Fig. 2.7. Variation with Time of the Target Heat- Generation Rate and Cross Section.

2.2b. HFIR Fuel Elements

The fuel region of the HFIR, shown in Figure 2.8., is composed of two concentric cylindrical fuel elements containing vertical, curved plates extending in the radial direction. The inner element which contains 171 plates is initially loaded with 2.6 kg of U^{235} and 2.80 g of B^{10} burnable poison. The inner diameter is 5.067 in. and the outer diameter is 10.590 in. The outer element contains 369 plates and initially contains 6.8 kg of U^{235} but no burnable poison. Its inner diameter is 11.250 in. and outer diameter is 17.134 in.

The individual plates are of a sandwich-type construction composed of a fuel bearing cermet hermetically sealed between covers of type 6061 aluminum. The fuel bearing cermet is a mixture of U_3O_8 and aluminum, approximately 35 weight % U_3O_8 in the case of the inner annulus and 40 weight % in the case of the outer annulus. Uranium containing at least 93% U^{235} is used as fuel. Initially each inner annulus plate contains 15.18 g ± 1.0% U^{235}. In addition, each inner annulus plate initially contains 0.0164 g ± 11.0% of B^{10}. The finished plates are 0.050 in. thick and 24 in. long with a nominal active length of 20 in. The maximum thickness of the fuel bearing cermet is 0.030 in. so the minimum cladding thickness is 0.010 in. The plates are curved in the form of an involute to preserve a constant cooling channel width of 0.050 in. between plates. Before bending, the inner plates are approximately 3.8 in. wide and the outer plates are approximately 3.5 in. wide. The fuel cores are centered to provide adequate edge cladding. Both inner and outer plates are fastened between the 29-in. long cylindrical aluminum side plates by welding.

To minimize the radial peak-to-average power density ratio, the fuel loading in each plate is varies along the arc of the involute curve.

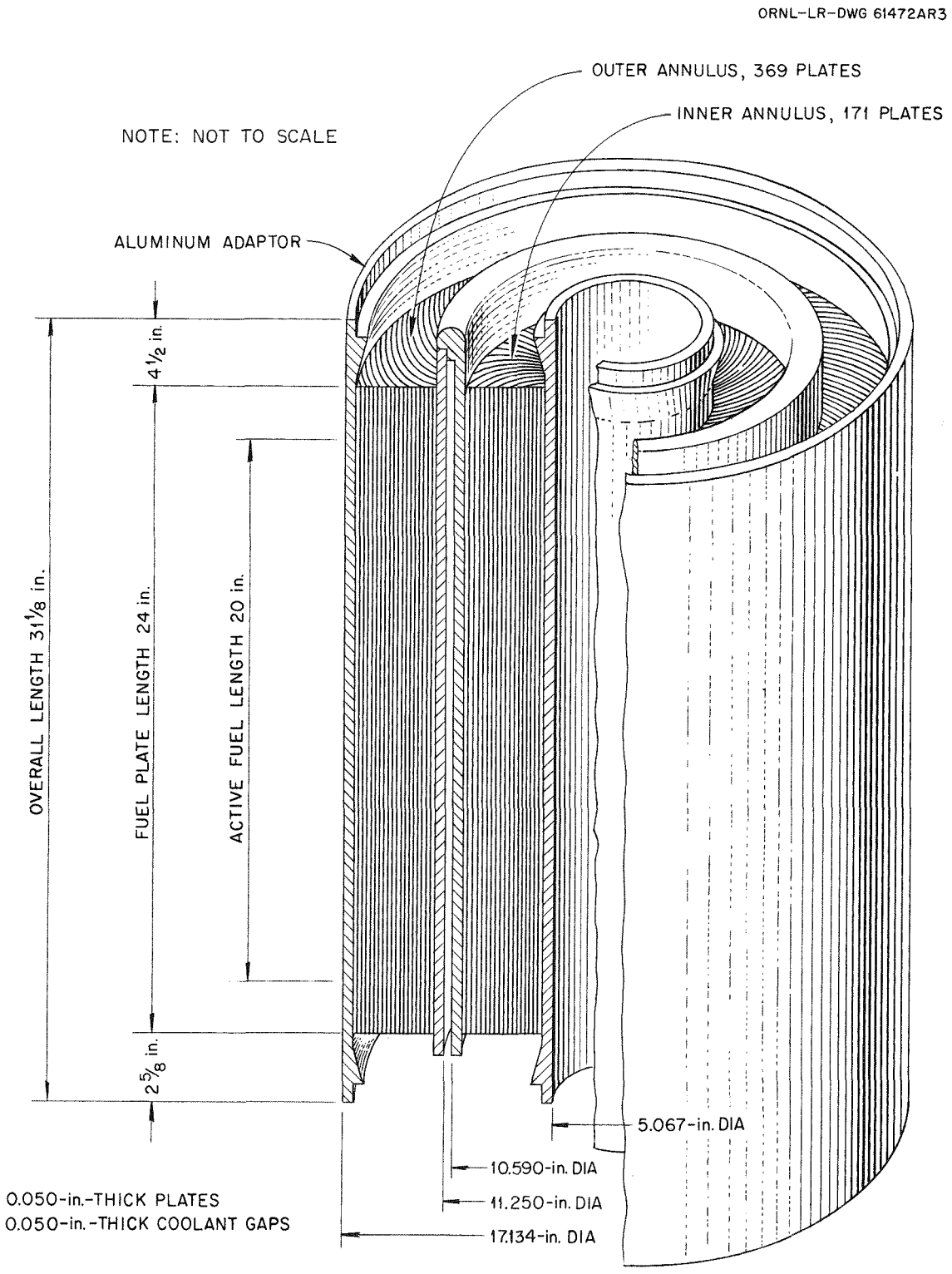

Fig. 2.8. Fuel Element.

The boron-10, included in the inner plates in the form of B_4C, is added to the aluminum filler piece rather than the fuel bearing cermet. The fuel and poison loading of a fuel plate is shown in Figures 2.9. and 2.10.

Each fuel core is expected to have a lifetime, at 100 Mw, of 10 to 15 days. Under minimum design conditions, coolant flow through the fuel is 11,000 gpm which corresponds to a velocity of 42 ft/sec at a core pressure drop of 90 psi. At 100 Mw total heat power the average heat flux is 8×10^5 Btu/ft^2-hr, and the calculated maximum hot spot heat flux is 2.1×10^6 Btu/ft^2-hr. The power level calculated for incipient boiling under typical conditions--600 psi inlet pressure, 51 ft/sec flow, 120°F inlet temperature and 15 days prior operation--is approximately 138 Mw.

2.2c. Beryllium Reflector

The fuel region is radially reflected by a 1-ft-thick beryllium reflector. The inner portion of the reflector is readily removable to permit replacement in case of radiation damage and to allow access to the control-plate drives. The reflector is water cooled but, in order to avoid excess neutron absorption, the volume of water in the reflector is held to the minimum consistent with the cooling requirements.

The inner portion of the reflector consists of a 3.75-in.-thick beryllium section composed of four concentric cylinders with cooling water flowing axially between them. The outer part of the reflector is an 8.25-in.-thick beryllium annulus with axially directed circular coolant channels. Three of the four inner annuli, called the "removable reflector", may be removed from the reactor as a unit thus permitting access to the control drives. The fourth cylinder, called the "semipermanent

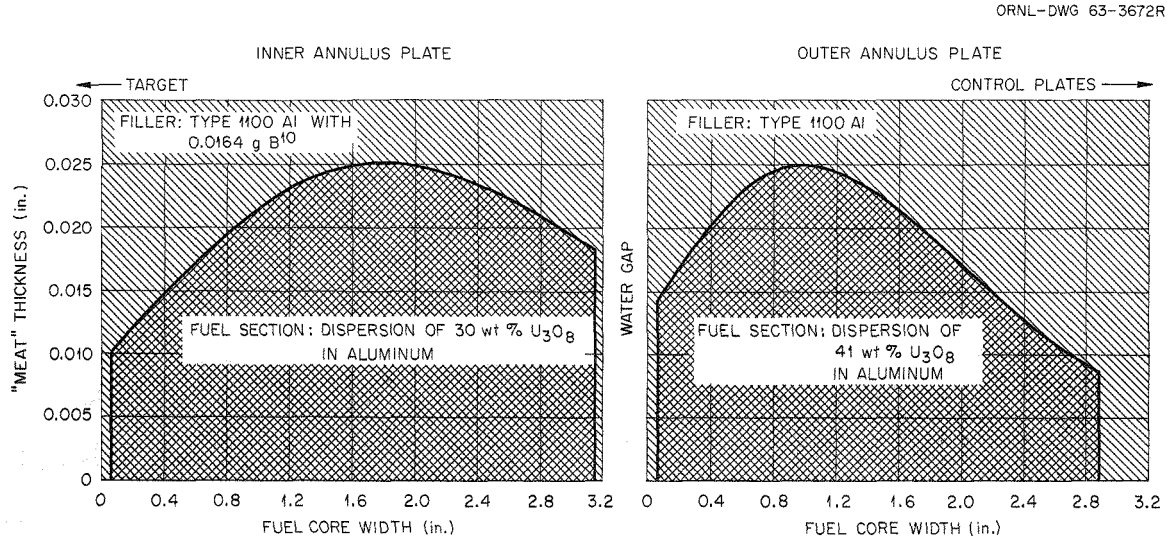

Fig. 2.9. Cross Section of Fuel Plate Before Bending.

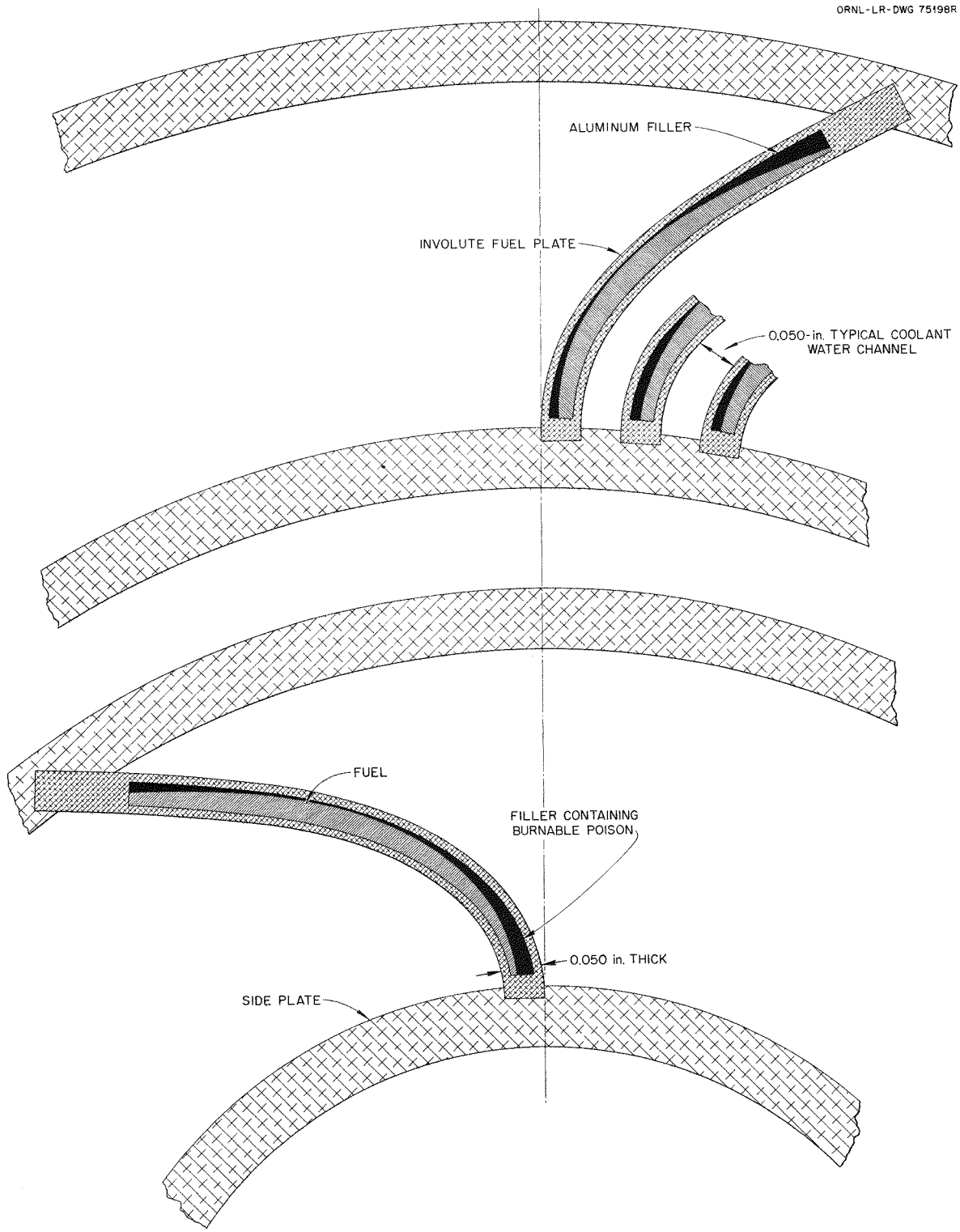

Fig. 2.10. Fuel and Burnable-Poison Distribution in the As-Built Element.

reflector," is removed only when necessary because of radiation damage. Although the thick outer annulus, called the "permanent reflector," may be removed, it is anticipated that this would be done very infrequently. To facilitate access to the control drives, four small pieces of the "semi-permanent beryllium" are, however easily removable.

To minimize the chance of interference with the control plates which are located between the removable reflector and the fuel region, a 1/16-in. thick aluminum liner covers the inner surface of the removable beryllium. The nominal thickness of the coolant annuli between the removable cylinders is 0.027 in. Aluminum rivets located at the top and bottom of each annulus are used to ensure a minimum coolant channel width. A 1/16-in.-thick water gap between the removable and semi-permanent reflectors facilitates removal and replacement of the removable reflector, furnishes cooling, and provides for expansion of the removable reflector. Eight 1/2-in.-diameter vertical irradiation facilities are provided in the middle removable reflector beryllium cylinder and eight others are located in the removable control rod access plugs. They are provided with beryllium plugs which will be in place when the facilities are not in use.

The permanent reflector is cooled by water which flows axially through 1/8-in. diameter holes which are spaced on circles concentric with the reflector. There are five such circles, each containing 80 cooling holes.

The permanent reflector is penetrated by 16 vertical 1.58-in.-diameter and 6 vertical 2.83-in.-diameter experimental facilities similar to those in the removable reflector. Two of the 4-in. beam tubes penetrate the permanent reflector and terminate in the semi-permanent beryllium. One 4-in.-diameter tangential beam tube penetrates all the way through the

reflector assembly. Four slanted grooves in the outer surface of the reflector accommodate the engineering test facilities.

2.2d. HFIR Control Plates

The control plates are located in a 0.869-in.-thick annular region between the outer fuel element and the removable beryllium. The control plates consist of two 0.250-in. concentric cylinders which move in the 0.869-in. gap between the fuel and reflector regions. The nominal water velocity through this gap is 16 ft/sec. The inner cylinder, which is a single piece, is used as a shim-regulating rod. The outer cylinder is divided into four equal quadrants, each used as a shim-safety rod and each having its own drive rod and scram mechanism. The general arrangement is shown in Figure 2.11.

Control of the chain reaction is exercised by alteration of the efficiency of the beryllium reflector as the control rods are moved vertically between the core and the reflector. The single inner cylinder is driven downward out of the reactor to increase reactivity, while the outer quadrants are driven upward out of the reactor to increase reactivity.

In order to reduce axial variations in the power distribution, the cylinders are divided into three longitudinal sections each of which has different neutron absorbing characteristics. The lower section of the inner cylinder and the upper section of the outer cylinder contain 33% by volume Eu_2O_3 dispersed in aluminum. These sections are highly neutron absorbing and are called the "black regions." The central section of each plate contains 40% by volume of tantalum dispersed in aluminum. They are less absorbing than the Eu_2O_3 sections and are called the "gray regions." The upper region of the inner cylinder and the lower region of the outer cylinder are made of aluminum and are called the "white regions." In

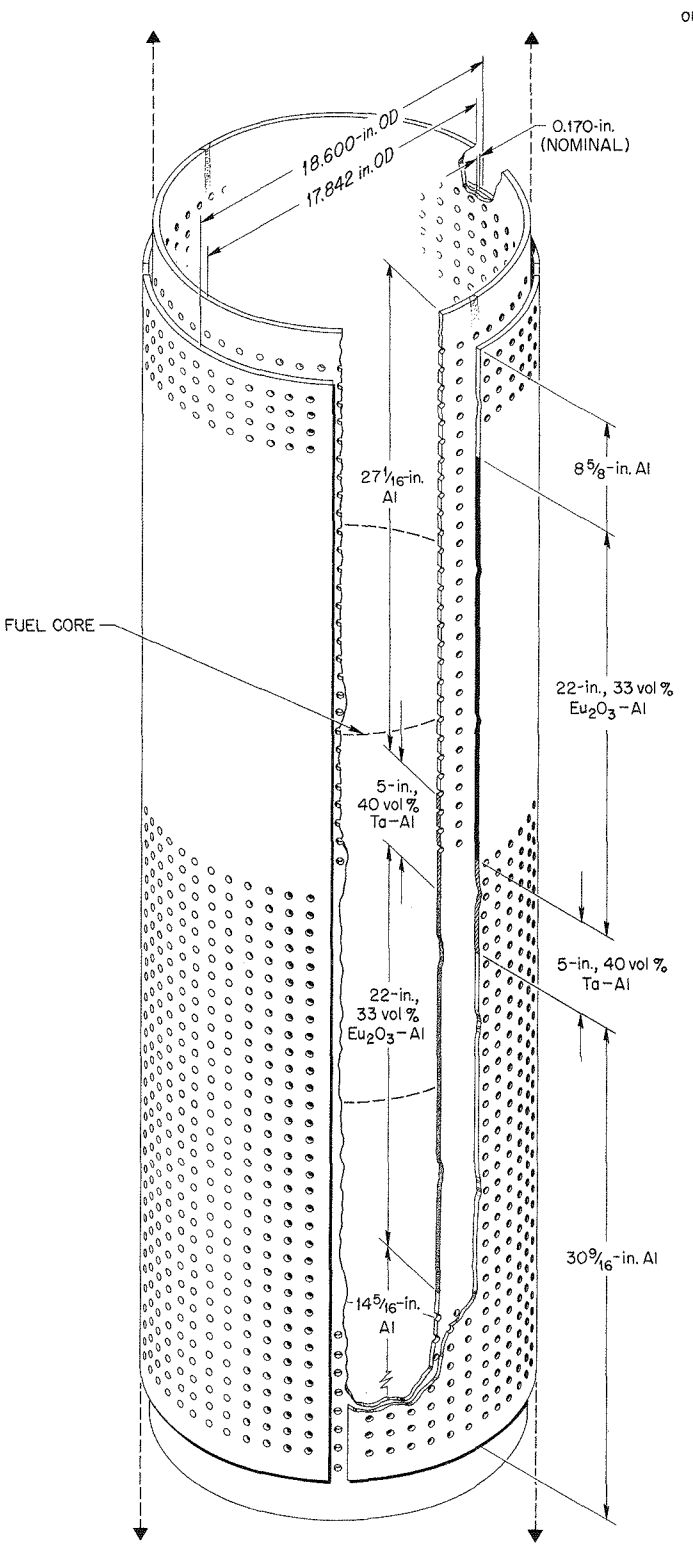

Fig. 2.11. Control Plates.

normal operation criticality is achieved by driving the inner cylinder down and the outer quadrants up in unison. As shown in Figure 2.12., the two control elements are then gradually withdrawn to compensate for fuel burnup throughout the core life. A servo control system maintains constant power by moving the inner cylinder.

In each case the black region is 22 in. long. The absorbing section has a nominal thickness of 3/16 in., and is clad with 1/32-in.-thick aluminum. The gray regions are 5 in. long and have the same thickness of absorber and cladding as is the case in the black region. The white regions are 20 in. long and are of solid aluminum. In order to balance the hydraulic forces, a large number of 1/4-in. holes are drilled through the white and gray regions of each plate. Corrosion studies indicate edge cladding around these holes is not necessary in the gray region.

The inner control plate has an outer radius of 8.921 in. and an inner radius of 8.671 in. The overall length is 68 3/8 in. The lower end of the black region is 14 5/16 in. above the lower end of the plate and the upper end of the white region is 27 1/16 in. below the upper end of the rod. The outer control plates have an outer radius of 9.300 in. and inner radius of 9.050 in. The overall width of each is 13 9/16 in. and the overall length is 66 3/16 in. The upper end of the black region is 6 5/8 in. below the upper end of the plate and the lower end of the white region is 10 9/16 in. above the lower end of the plates.

The plates are driven from beneath the reactor by rods which extend into the subpile room where the drive mechanisms are located. Guidance for an outer control plate is furnished by six ball bearings. Four bearings are attached to each outer control plate, two at each end, and run

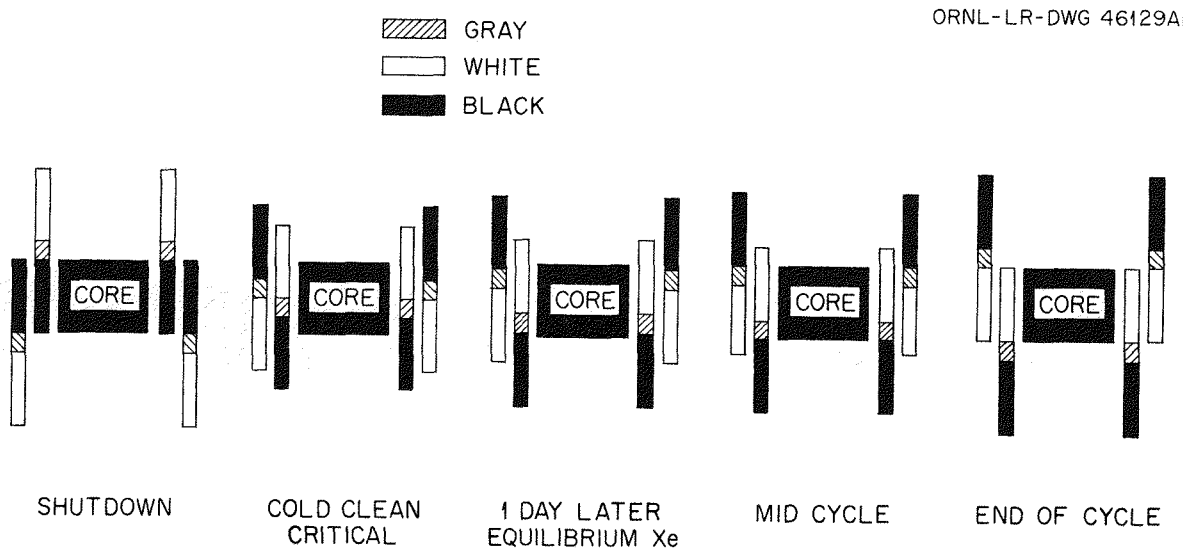

Fig. 2.12. Control Plate Positions During a Cycle.

in stationary tracks which extend above and below the core. The other four bearings are attached to the top of the lower track assembly and bear against the control plate. The single inner cylinder is guided by eight bearings, four of which are attached to the top of the lower track assembly and four are attached to the bottom of the top track assembly. The bearings bear against the inner cylinder through the slots between the four outer plates.

2.3. Core Support and Assembly

The reactor core is supported by an arrangement of pedestals which is fastened to the bottom of the pressure vessel. An exploded view of the various components showing their arrangement is given in Figure 2.13. The main support member is the stainless steel fuel and reflector support sleeve assembly which rests on the tank support ring and extends into the lower tank extension. It is held in place by bolts and provides support for two pedestals which in turn support the core components.

The reflector container and support pedestal is a 6061 aluminum hollow cylinder approximately 3 1/2 ft in diameter by 2 1/2 ft high. It is bolted to the edge of the support assembly. The reflector rests on top of this cylinder and is clamped between the pedestal and outer shroud by external tie plates. A second pedestal, the fuel grid support pedestal, is also in the form of a hollow cylinder. It is located inside and concentric with the reflector pedestal and is bolted to the center of the support assembly. This pedestal is approximately 1 ft 3 in. in diameter and 3 ft high. The stainless steel fuel grid provides mounting surfaces for the fuel elements. It rests on the fuel grid support pedestal.

Two concentric shrouds are located above the core to provide proper distribution of coolant flow and to furnish support and alignment features for various components above the core. The outer shroud is fastened to the reflector support pedestal. A 3-ft-long cylindrical extension surrounds the control region. The lower portion serves as a flow distributing plenum for the reflector. The inner shroud is also cylindrical and fits over the outside edge of the outer fuel element. It extends upward inside the control plate region. The inner shroud is easily

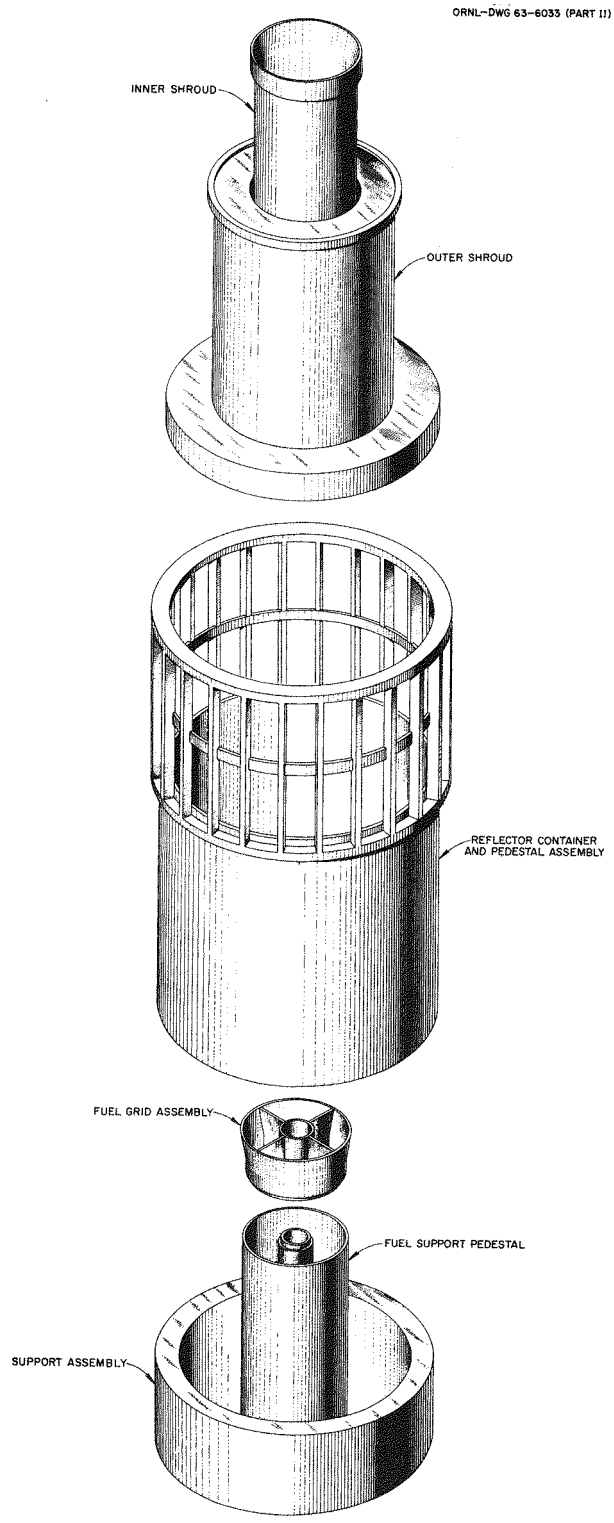

Fig. 2.13. Core and Reflector Support.

removable and must be lifted out to change fuel or to provide access to the control plates and the removable beryllium. The outer shroud may be removed but remains in place during all routine core manipulations. Suitable orifices in the outer shroud and between the inner and outer shrouds ensure adequate cooling to the reflector and control plate regions. The outer shroud is fabricated of 6061 aluminum and the inner shroud of type 304L stainless steel.

Components exposed to hydraulic loads are designed to withstand a coolant pressure differential of 125 psi and to support the dead weight of the components and loads resulting from normal operation as well as the extra loads which may be encountered due to the malfunction of a control rod.

To minimize the probability of blocking the coolant channels in the reactor core, a strainer is located in the primary coolant loop at the point where the loop branches to form the two inlet lines to the reactor vessel. The strainer, a multilayered sintered stainless steel wire cloth, is designed to retain foreign objects which are larger than 0.023 in. in diameter. It is located in a special spool piece in the primary coolant supply line within the reactor pool. Vertical access to the strainer basket is provided by means of a quick opening hatch. The strainer is located sufficiently far below the pool surface to provide adequate shielding.

2.4. Reactor Pressure Vessel

2.4a. General Description

The HFIR core is contained in a 94-in. ID pressure vessel constructed of carbon steel clad on both sides with austenitic stainless steel. A stainless steel extension is attached to the lower end of the vessel to permit control rod access to the core through the 7-ft-thick pool floor. The carbon steel vessel wall is 2 7/8 in. thick. A minimum cladding thickness of 1/8 in. is provided on the inside with a minimum of 0.1 in. on the outside. The general arrangement is shown in Figure 2.14.

The flat upper head of the vessel is made of 14-in.-thick carbon steel clad with stainless steel. It is secured to the vessel with bolts and sealed with an elastomer O-ring. A 30-in.-diameter quick-opening access hatch has been provided in the head for ease of access in routine operation. It is designed with a breech-lock type of closure and sealed with an elastomer O-ring piston seal. In the center of the quick-opening hatch is a 12-in.-diameter target access plug with a sheer block type closure and an elastomer O-ring piston seal.

The lower head for the control rod access extension is a 6 1/2-in.-thick flat bolted head with an elastomer O-ring seal. All other closures are standard ASA bolted flanged joints with metallic ring joint seals. The top and bottom heads are shown in Figures 2.15. and 2.16.

Aside from the access hatch and the three water inlet and exit lines, the vessel is provided with 57 penetrations. These penetrations are listed in Table 2.1.

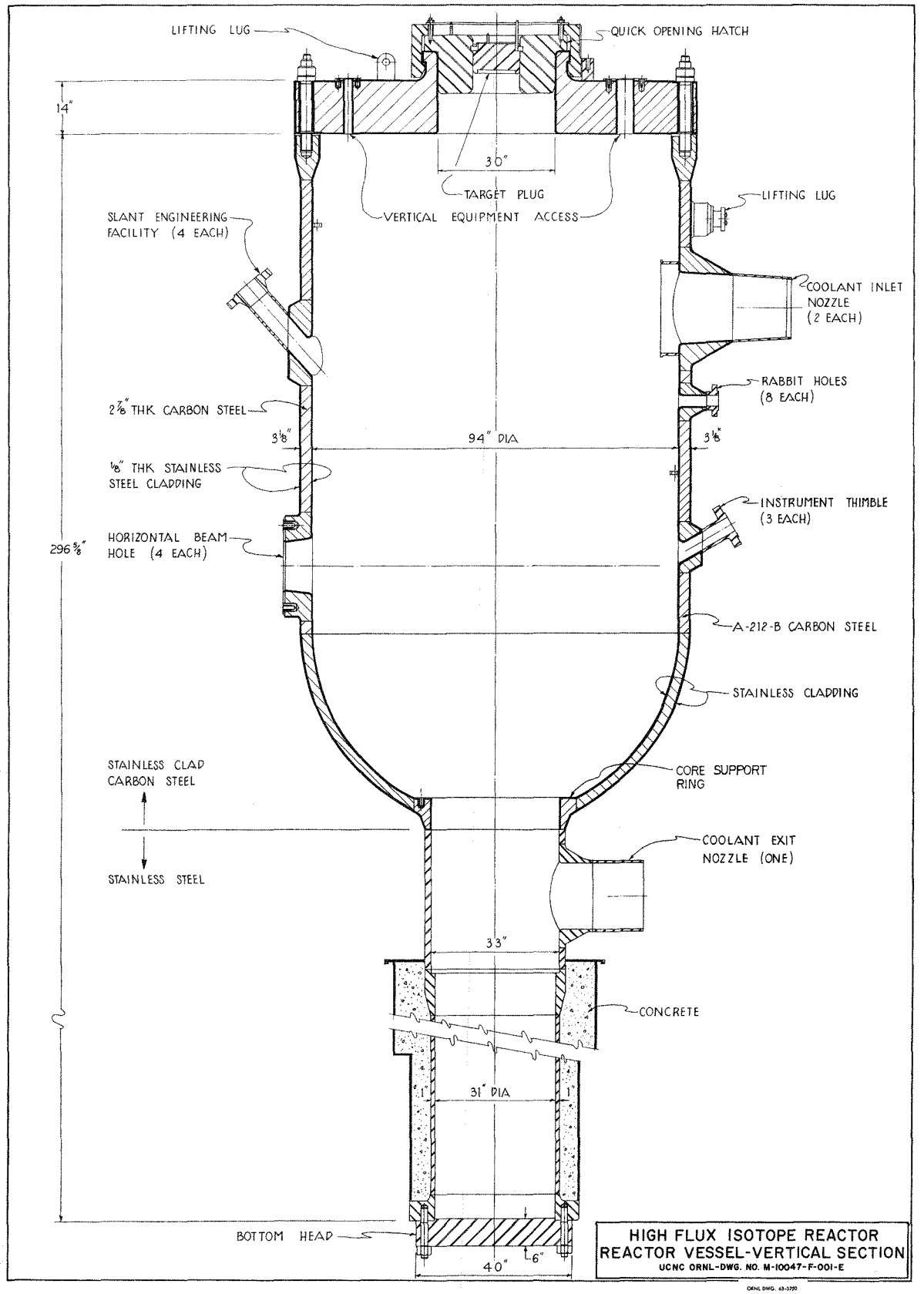

Fig. 2.14 Reactor Pressure Vessel.

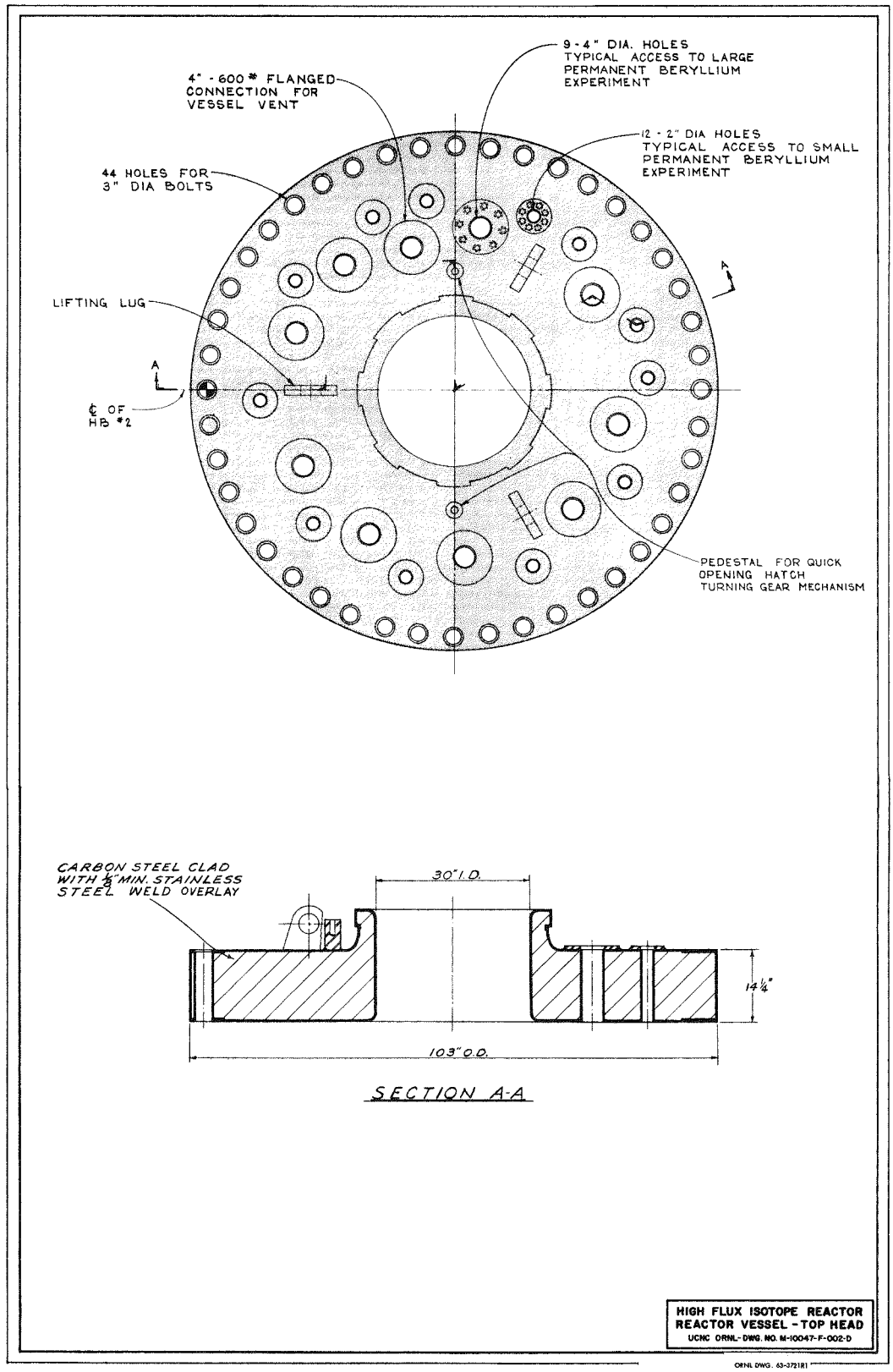

Fig. 2.15. Reactor Vessel Top Head.

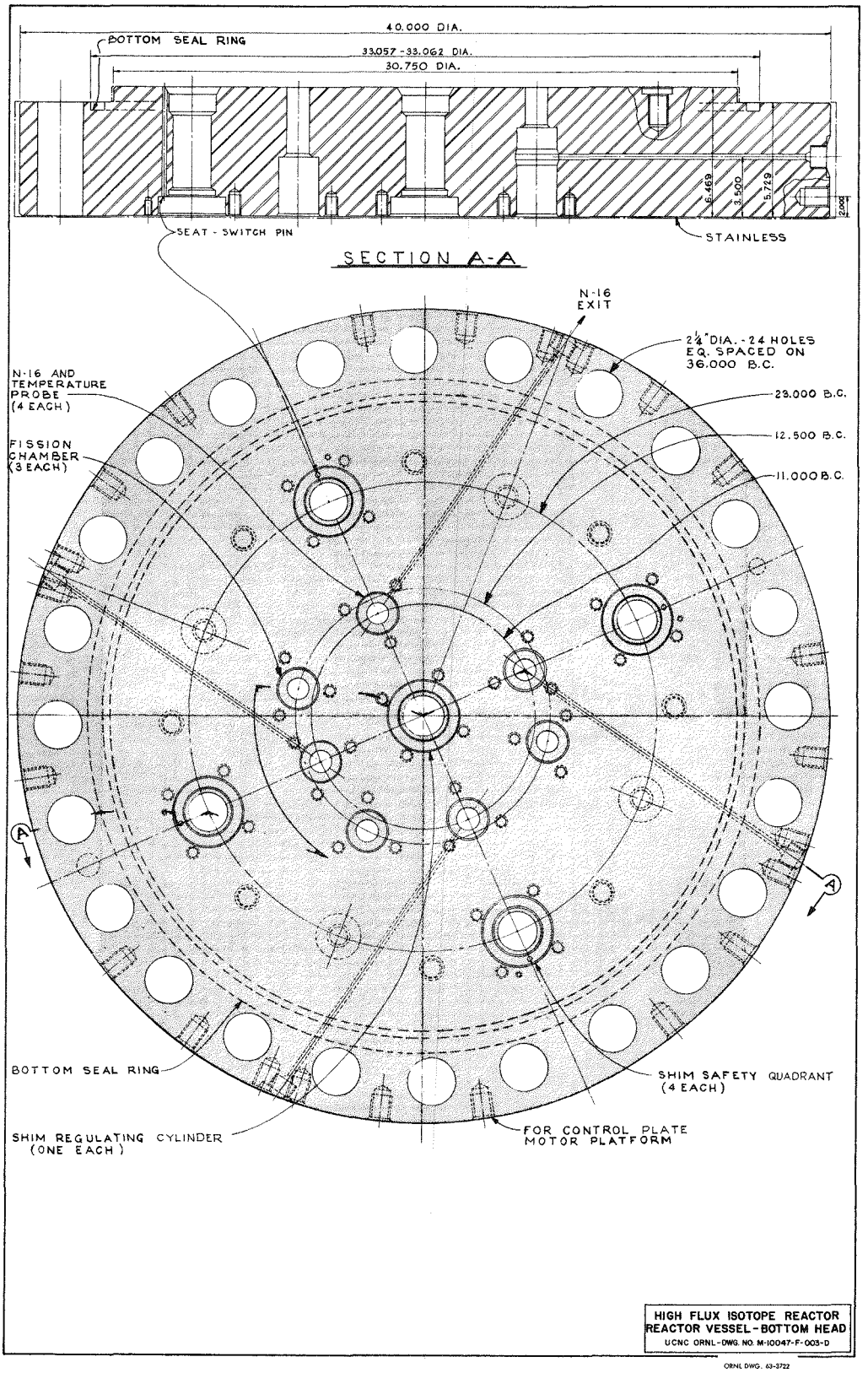

Fig. 2.16. Reactor Vessel Bottom Head.

Table 2.1.

Reactor Pressure Vessel

Nomenclature	Number	Size
Cooling water inlet	2	16" OD pipe
Cooling water exit	1	18" OD pipe
Slant engineering facility penetration	4	6" 600# RJ flange
Ion chamber penetration	3	4" 600# RJ flange
Rabbit hole penetration	8	3" 600# RJ flange
Radial horizontal beam tube penetration	1	14" 600# RJ flange
Tangential horizontal beam tube penetration	3	8" 600# RJ flange
Vertical experimental penetration*	12	2" 600# RJ flange
Vertical experimental penetration*	9	4" 600# RJ flange
Vessel vent*	1	"
Bottom head	1	30" flange
N-16 water exit**	4	1/4" dia
Quadrant thermocouple**	4	1/8" dia
Control rod shafts**	5	1.938" dia
Top head	1	103" OD
Quick-opening hatch*	1	30" dia
Top plug*	1	12" dia
Fission chamber penetrations	3	3/4" dia

*Top head

**Bottom head

2.4b. Vessel Design and Inspection

Materials have been specified in accordance with the ASME Pressure Vessel Code. To eliminate corrosion caused by normal operation and by the action of decontamination solutions, stainless steel has been utilized for surfaces exposed to the primary and pool water.

The vessel has been designed in accordance with section VIII of the ASME Boiler and Pressure Vessel Code and Nuclear Code Cases 1270N, 1271N, and 1273N. The design conditions for the vessel are:

	Operating	Design	Test
Temperature (°F)	120-167	200	~75
Pressure (psig)	600	1000	1550

Structural analysis has been performed by the methods described in the Department of Commerce Bulletin, PB 151987, "Tentative Structural Design Basis for Reactor Pressure Vessels and Directly Associated Components," Dec. 1958 revision. The loading conditions which have been evaluated and the results of the analysis are given in the Allis-Chalmers Design Report for the vessel.

The vessel was inspected in accordance with the requirements of the basic Code and Nuclear Code Case 1273N. Additional inspections performed include dye penetrant and, as applicable, magnetic particle inspection of all welding, including overlay cladding, both before and after stress relief. Additional tests included impact testing of ferritic materials and ultrasonic testing of plates, forgings and other vessel parts. To verify the adequacy of the vessel, hydrostatic tests at 1550 psig and supplementary tests at 1000 psig following 17 cycles from atmospheric pressure to 1000 psig will be performed. Measurements will be made of

the top head bolt tensile stress under pre-load and at 1550 psig and 1000 psig.

After being put into operation, the vessel will be inspected periodically for physical deterioration. Tests will also be performed following each removal and replacement of the vessel closures in order to establish tightness.

The sizing of nozzle openings and the arrangement of the water annulus outside the core has been fixed to limit the fast neutron dose to the pressure vessel. On this basis, vessel materials were used which assure that the nil ductility temperature, as determined by Charpy V-notch impact tests, of any portion of the vessel will never exceed +10°F after 20 years. The operating procedures will require that the vessel temperature be maintained above 70°F whenever the stress level is more than 5000 psi (which corresponds to ~200 psig).

As a further precaution, radiation damage will be monitored by the insertion of a number of actual pressure vessel steel samples at locations corresponding to the areas of highest exposure. Specimens will be removed periodically and tested for strength and notch toughness.

2.5. HFIR Pools

2.5a. General Description

The reactor vessel and the spent fuel storage facilities are located in a system of water-filled pools which furnish biological shielding, and, in the case of the spent fuel elements, also provide a mechanism for removing heat generated by the decaying fission products. The HFIR pool consists of four separate compartments as follows: (See Figure 2.17)

1. A 36-ft-deep reactor pool, the lower portion of which is an 18-ft-diameter by 16-ft-deep cylinder. The upper portion is an 18-ft-wide by 20-ft-long rectangle.
2. Two 20-ft-deep clean pools, each of which is 18 ft wide by 20-3/4 ft long.
3. A 25-ft-deep by 8-ft-diameter critical pool for future use.

The reactor pool contains the reactor vessel, two defective fuel element storage tanks, and two normal spent fuel storage racks. The clean pools contain the long-term spent fuel storage facilities. The critical pool is designed to accommodate a future HFIR critical facility.

The pool walls and floor are constructed of reinforced concrete and are lined with type 304 stainless steel. The lining on the sides of the clean pools, the critical pool, and the rectangular portion of the reactor pools is 1/4 in. thick. The lining on the pool floors and the walls of the cylindrical section of the reactor pool is 3/8 in. thick. The reactor and clean pools are separated by removable aluminum gates which are provided with hatches near the bottom to facilitate the transfer of spent fuel elements between pools. A concrete wall, with a transfer hatch, separates the clean pool and the critical facility pool.

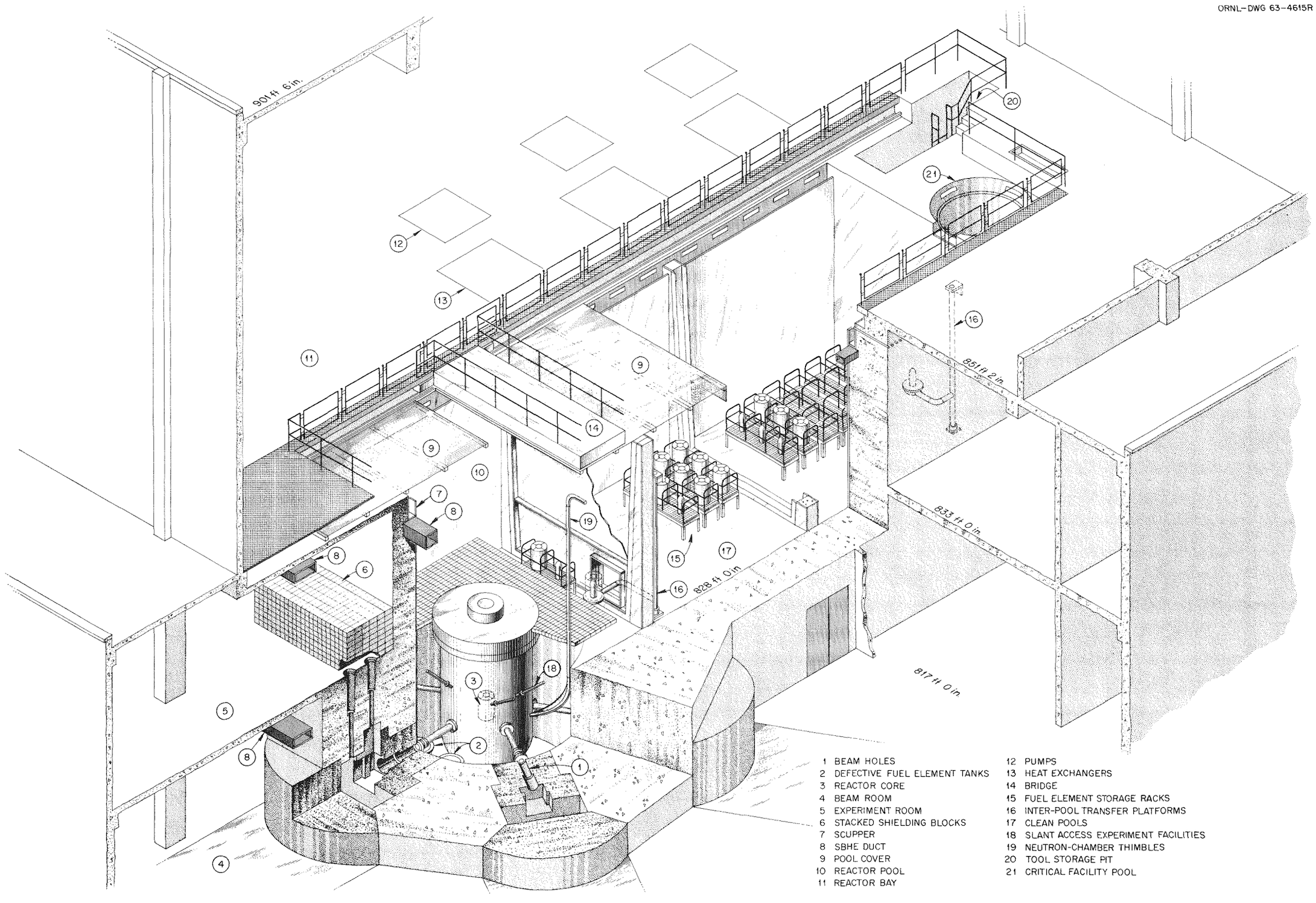

Fig. 2.17. Isometric of Pools and Experimental Facilities.

The walls of the cylindrical section of the reactor pool are of ordinary concrete 12 ft thick. Four beam tube access holes penetrate the reactor pool wall at elevation 820 ft 6 in.; and, in these regions, the wall is of high density concrete 7 1/2 ft thick. Additional movable shielding is provided, as required, around these openings. The walls of the rectangular section of the pool (that section above elevation 833 ft) are of ordinary concrete 3 ft thick. Concrete block, supported by the 12-ft-thick portion of the wall, may be stacked against these walls as required to shield the vertical access facilities to the beam tubes and the slant access penetrations to the pool. The floor of the reactor pool, which is also the ceiling of the subpile room, is of high density concrete 7 ft thick.

The south wall of the clean pool is constructed of ordinary concrete 5 ft thick, and the north wall, which also serves as the south wall of the heat exchanger cells, is 4-ft-thick ordinary concrete. The walls of the critical pool are also of ordinary concrete a minimum of 6 ft thick. Except for the stairwell leading to the subpile room, the area under the clean pool and critical pool is unexcavated. The floor in the unexcavated area is of ordinary concrete and is 3 ft thick under the clean pool and 2 ft thick under the critical pool. The pool floor above the stairwell to the subpile room is of 1-ft-10-in.-thick high density concrete backed up by 14 in. of steel armor plate.

Three 3-in.-diameter pipe sleeves through the north wall of the clean pool, at elevation 837 ft, furnish access to three of the heat exchanger cells. In addition to the experiment facilities, six 6-in. diameter pipe sleeves at elevation 841 ft permit access to the reactor

pool from the experiment room. Four similar sleeves at the same elevation provide access to the clean pools. When not in use these sleeves are plugged with flanges and shielded with bags of lead shot.

The pool liner is fabricated of stainless steel sheets welded together. The wall liner is fastened to the concrete by means of stainless steel rods which are welded to the underside of the liner and which penetrate the concrete walls. The floor liner is plug welded to steel bars set in the concrete floor. These attachments serve the double purpose of holding the liner in place and of providing conducting paths for the removal of heat generated by gamma ray absorption in the concrete.

Stainless steel scuppers are provided along the inner edges of the pool at elevation 848 ft which is 3 ft 2 in. below the reactor bay floor. These scuppers are 10 in. wide and 19 in. deep. They convey the overflow from the pools to the pool cooling system and, by providing a small constant flow, prevent dust from collecting on the pool surface.

2.5b. Pool Cover and Personnel Bridges

The personnel bridge spans the pool from north to south, see Figure 2.18. It is a 6-ft wide, 20-ft long platform covered with vinyl asbestos tile and surrounded by a suitable railing. The bridge is mounted on wheels and is driven on a track in the east-west direction by a 1-hp motor and gear train at a speed of 10 ft/min. The tracks extend the entire length of the pools, thus permitting the bridge to be positioned over any point in them. Although the bridge drive is designed to stop the movement within 2-4 in. after the power is switched off, a manual drive is provided to facilitate accurate positioning. A small manually driven carriage mounted on tracks on the bridge permits accurate positioning of tools or equipment in the north-south direction.

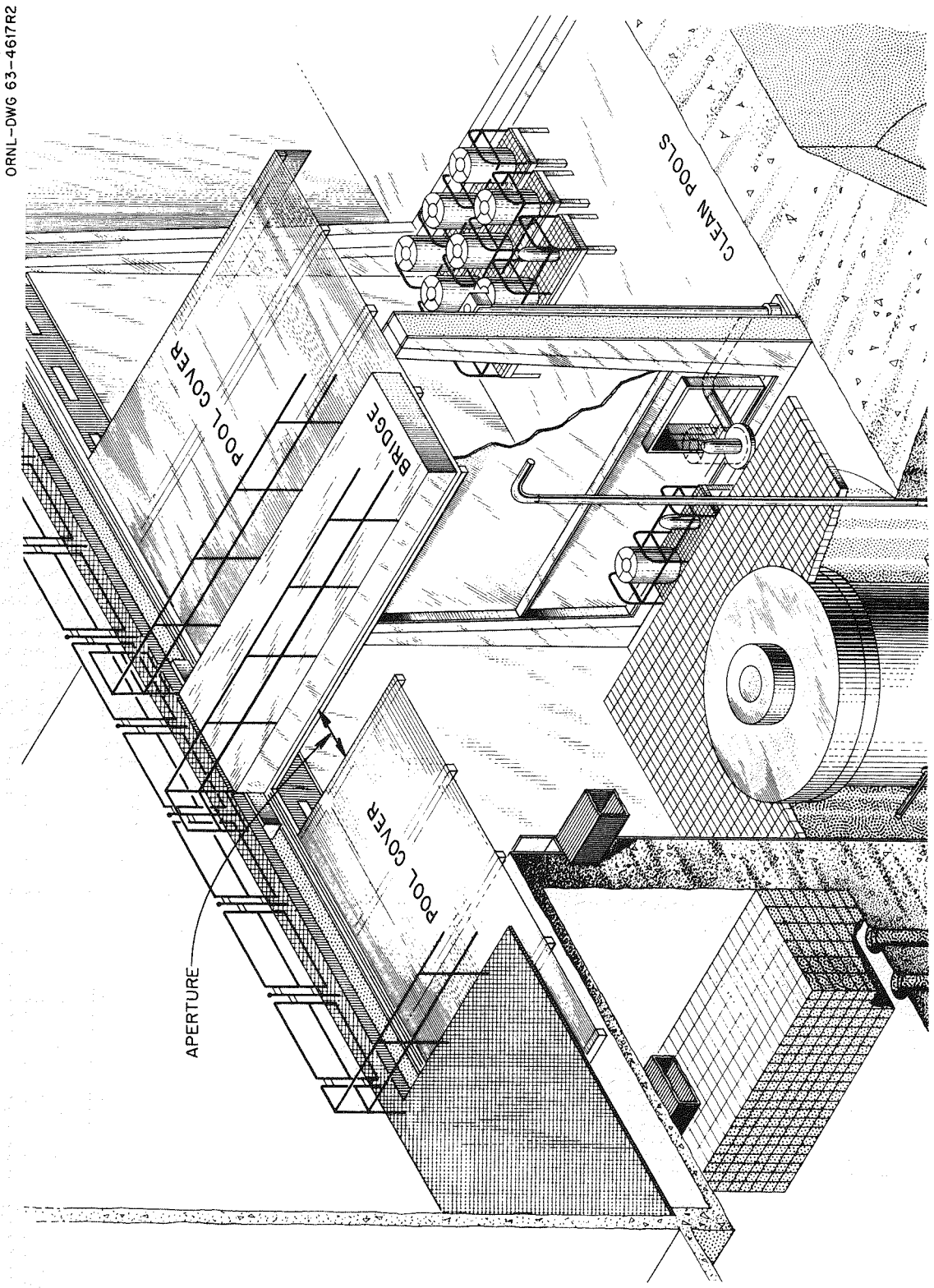

Fig. 2.18. Pool Cover and Personnel Bridge.

To provide additional containment and protection, the reactor pool is covered by a cover fabricated from 1/2-in-thick plexiglass panels supported by aluminum beams. There are two covers each 19 ft 7 in. wide and 20 ft 9 in. long. They are separated by an aperture which extends across the pool under the personnel bridge. Air from the reactor bay is drawn through the aperture and into the SBHE system ducts which are located just above the scuppers in the pool walls. In this way any vapor or gas originating in the pool is prevented from escaping into the reactor bay.

The aperture is norminally 3 ft in width but is adjustable to provide adequate air velocity. The cover itself is carried on a wheel and track arrangement. Two long pins operated from the bridge, one on the east and one on the west side, engage it so that it will follow the bridge as it is moved. The reactor bay floor at the west end of the reactor pool is a steel plate supported on beams with sufficient room underneath to accommodate the west end of the cover, thus permitting the aperture to traverse the entire reactor pool.

Annunciator 4E-6

Condition: Secondary Coolant pH Low

Setpoint: 6.3

Actuator: ApHS-334B

Location: Auxiliary control room

Sensor: ApHE-334

Location: Secondary coolant water line entering the water wing

Possible Causes

1. Failure of ApHC-331, secondary water pH controller
2. Failure of ApHE-334, to which the alarm is connected

Operator Response

1. Read points 4, 8, and 12 of ApHR-1010 which indicate pH as measured by ApHE-334. Compare this with the reading indicated by points 3, 7, and 11 of ApHR-1010 which indicate pH as measured by ApHE-331.
2. Check ApHC-331 which controls the acid metering pumps.

Annunciator 4E-8

Condition: Primary Demineralizer Outlet Conductivity High

Setpoint: 250,000 ohm-cm resistivity

Sensor: CS-217A

Location: Control room process panel board

Possible Causes

1. Depletion of demineralizer resin
2. Chemicals which might remain in lines after demineralizer regeneration
3. Stale water from a demineralizer which has been in standby

Operator Response R

1. In conjunction with this alarm, further control actions occur. Should a surge of chemicals or very low quality water (below 15,000 ohm-cm) exit the demineralizer, CE-291 will cause CSV-291A to close and CSV-291B to open. This diverts the cleanup flow from the exit of the after-after filter to PWD preventing poor quality water from reaching the head tank. If this occurs, lower the pressurizer pump speed to 80 gpm to assure that the primary makeup system capacity is sufficient to replace the volume of poor quality water being diverted to drain.
2. Switch from the depleted demineralizer to the standby unit. The standby unit should be rinsed before it is placed in service.

R

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Technical Section	Reactor Operations Section	Reactor Supervisor

3. INSTRUMENTS AND CONTROLS

3.1. Introduction

Successful operation of the reactor depends on the ability to control both the nuclear reaction and the supporting process functions. Nuclear and process instrumentation develop the information required for such control, which is realized with a high degree of automation through appropriate output elements.

Section 3.2 provides functional descriptions and the rationale of the systems which exercise direct control over the reactor. Section 3.3 describes the instrumentation and automatic controls for the supporting processes, such as heat power and waste removal. The systems controlling the reactor combine nuclear and process information. Since the latter is derived from instrumentation of the same types as, and often intimately associated with, that of the supporting processes, the supplementary detailed descriptions of this particular process instrumentation appear in Section 3.3.

Operation of the reactor and the process equipment is largely centrallized in the control room (Figure 3.1).

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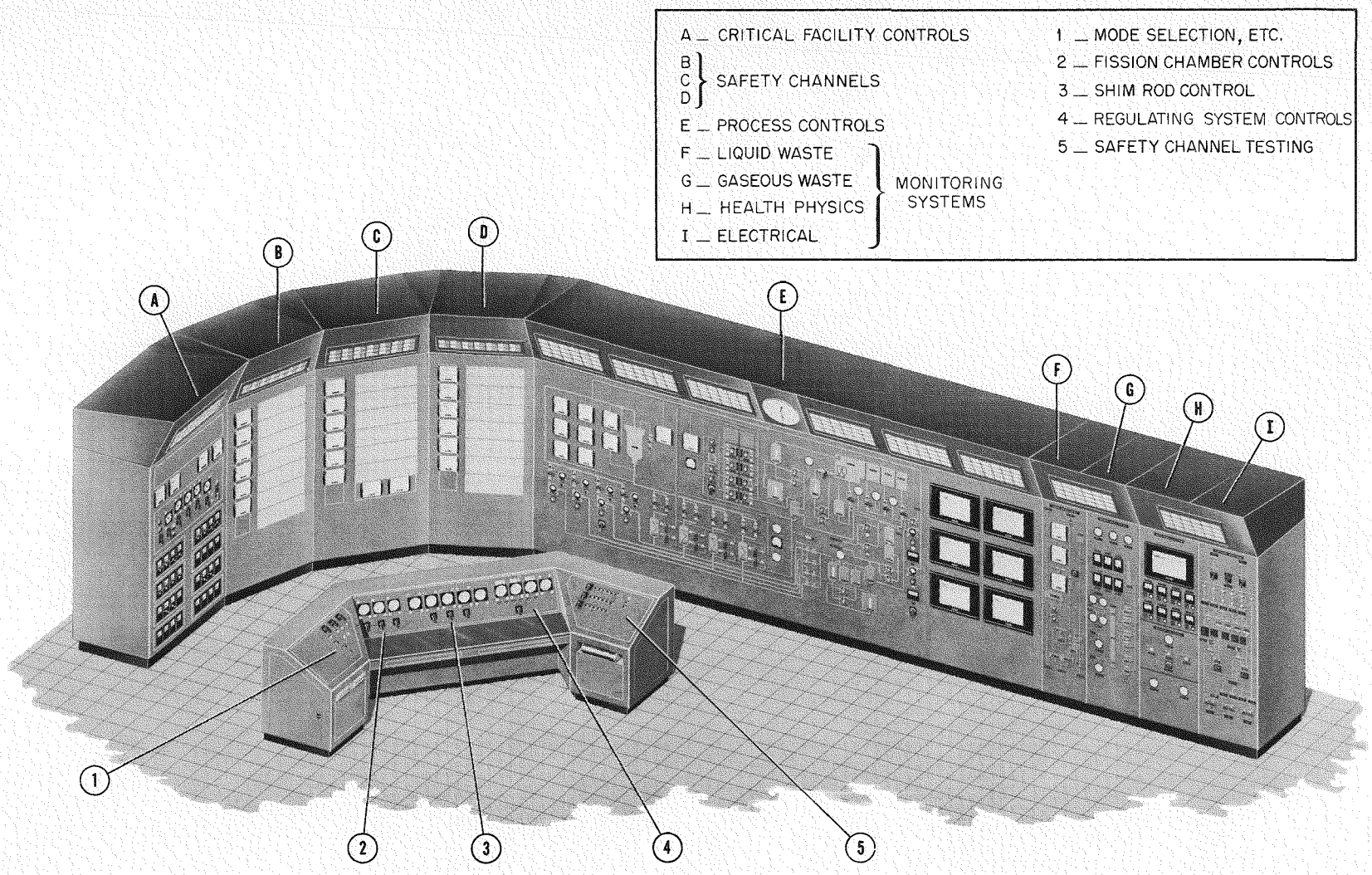

Fig. 3.1. Control Room.

3.2. Reactor Instrumentation and Controls

3.2a. References

Drawings:

RC 11-1-1C	Control Block Diagram
RC 11-1-2A, -2B, -2C, -2D	Elementary Diagram of Rod Controls on "A" ("B," "C," "D") Bus
RC 11-1-2E, -2F	Elementary Diagram Rod Controls on A-C Bus, Sheet 1 (2)
RC 11-1-2G	Elementary Diagram Shim Rod Drives
RC 11-1-2H, 2P	Elementary Diagram Contact Tabulation, Sheet 1 (2)
1546-01-E-2130	Elementary Control Diagrams Annunciators B, C, D, F, G, and HI
RC 11-9-51	HFIR Safety System "A Channel" Block Diagram
RC 11-9-53	HFIR Safety System No. 1 Channel (Typical) Circuit Diagram
RC 11-12-51	Regulating Channel Block Diagram
RC 11-12-53	Regulating Channel (Typical) Circuit Diagram
RC 11-13-51	Wide-Range Counting Instrument Block Diagram
RC 11-13-53	Wide-Range Counting Instrument Circuit Diagram

Singmaster and Breyer Specifications: Section 112 Instrumentation and Auxiliary Equipment

Section 115 Process Systems Instruments

3.2b. Reactor Safety, Servo, Count-Rate and Control Systems--Introduction

The subject four systems were conceived to meet the rigorous protection, control, and service reliability requirements that arise mainly from the high power density in the HFIR core. Prominent in the systems are several features intended to prevent core overheating and damage due to curtailment of coolant flow or loss of coolant pressure. The effects of rapid fuel burnup, poison growth, etc., necessitate continuous automatic calibration of the neutron flux measurements used for both protection and control purposes; this is accomplished by means of heat-power instrumentation. The same burnup and growth considerations also indicated that automatic shimming, under control of a special computer, would greatly facilitate operation of the reactor. With power densities approaching burnout level, unusual reliance is placed on the accurate functioning of the protective and control equipment. Moreover, a shutdown from operation at high power may result in economic loss of the remaining core life, due to xenon growth. The consequent emphasis on reliable performance gave rise to several other important features of the systems: (1) provision for testing the safety system with the reactor in service, (2) independent, redundant subsystems with final control and protective actions on a two-out-of-three basis and (3) modular arrangement of instrumentation to facilitate repairs. Special provisions were also made to permit test operation of the reactor at low power, subject to appropriately simplified control criteria.

Control of the reactor is exercised by four outer quadrant shim-safety plates which can be scrammed, and one inner shim-regulating cylinder which does not scram. The shim-regulating cylinder has both shim drive over its entire travel span and regulating servo drive, which operates

within a narrow range about the position set by the shim drive. The safety, servo, count-rate and control systems together determine the plate positions as described in the following sections of this procedure; their essential functions are summarized below:

1. Control system.

   Includes all relaying and switching equipment necessary to effect gross control of the reactor subject to (a) direct requests by the operator and (b) automatic requests and restrictions from the servo, safety, and wide-range counting systems. The automatic operating features, restrictions, and safety criteria are selected through the control system, appropriate to the following operation situations: (a) Mode 1, Start--automatic startup to 10 Mw level, with full primary coolant flow; (b) Mode 1, Runn--servo controlled progression to and operation at power levels between 10 Mw and 100 Mw (N_F); shimming initially by manual control, and ultimately automatic, subject to shim calculator control; (c) Mode 2--operator controlled startup and operation to 2.5 Mw; at least 10% of full rated primary coolant flow is required, with or without pressurization; (d) Mode 3--operator controlled startup and operation with 100 kw; no coolant flow or loop pressurization required.

2. Servo system.

   Automatically controls reactor power at demand levels above 10 Mw, by rapid positioning of the shim-regulating cylinder by the regulating drive. When reactivity changes greater than the amount available from the regulating drive are

required, the servo system initiates shim insert action through the control system or annunciates the need for shim withdrawal.

3. Wide-range counting system.

Primarily used for control of reactor startup and operation up to the 10-Mw power level. The system develops count-rate confidence and period information from fission chambers, which is realized as shim withdrawal permissives or insert requests in the control system.

4. Safety system.

Recognizes impending unsafe conditions which may develop in the reactor, and scrams the shim-safety plates to minimize hazards and core damage. The scram criteria are (a) excessive core power; (b) excessive rate of power increase; (c) high temperature of coolant entering core, in Modes 1 and 2; (d) coolant flow less than amount normally provided by two pumps driven by pony motors, in Modes 1 and 2; (e) primary loop pressure low, in Mode 1; and (f) high radiation in primary coolant water. The effectiveness of the nuclear portion of the safety system is realized primarily at power levels where appreciable neutron flux signals are obtainable from the uncompensated ion chambers. Auxiliary circuitry in the safety system initiates prompt, controlled plate insertion via the control system when core power exceeds intermediate limits, with the intent of eliminating the necessity for scram whenever possible.

The safety, servo, and count-rate systems each consist of three identical, independent subsystems or "channels," arranged so that most of the output actions of a system require concurrence of two channels. This redundancy feature permits any one channel of each system to fail or to be disabled for tests and maintenance, without affecting operation of the reactor. The "scram" outputs of the three safety channels are combined only at the shim-safety plate latch magnets; each magnet has three coils, any two of which will hold the latch armature. The output of each servo channel is the motion of one servo motor; the three motors are geared together so that the regulating action is the net result of all three shaft rotations. Many of the automatic shim plate control signals that originate in the three safety, three servo, and three count-rate channels, are combined in the control system in two-out-of-three switching configurations. Three independent 64-volt batteries each supply all power requirements of one safety, one servo, and one count-rate channel. The battery loads include certain ac powered process instrumentation in the servo and safety channels, which are supplied via dc/ac inverters.

The shim plate drives and controls are primarily ac powered, with their normal supply backed up by an emergency diesel-generator. Provision is also made for fast insertion of the quadrant plates independent of the ac power supply, with actuation by air motors fed from the instrument air system.

The overall safety of the reactor operation is enhanced by employing different types of process instrumentation for the corresponding functions in the servo and safety systems. Thus, the coolant flow and temperature information is handled by all-pneumatic instrumentation in the servo system and all-electric instrumentation in the

safety system. Air for the servo channels is normally supplied from the instrument air system, via individual reservoirs; the reservoirs share an emergency compressor whose power supply is backed up by a diesel-generator.

The testing and two-out-of-three output features built into the safety system enable virtually complete routine checking of the system performance, including the sensors, before and during operation of the reactor. There are only a few installed arrangements specifically for testing the servo and count-rate systems; however, the response of these systems to certain operations of the manual controls affords some indication of their performance.

Continuous monitoring of essential functions of the systems is provided directly by special control permissive circuitry, alarms, and indicator lights. Additional monitoring is effected through certain fail-safe features and provisions for observing agreement among the various readouts.

Although portions of each of the systems are deactivated automatically when the reactor is shut down, there is no explicit provision for "turning off" any of the systems. When it becomes necessary to de-energize any of the equipment, this may be accomplished on a large scale by interrupting the appropriate power supply bus(es), or to a limited extent by removing modules from the cabinets.

3.2c. Shim Plates, Drives, and Drive-Motor Controls

The control elements consist of two vertical concentric cylinders, located in the annulus between the fuel and reflector regions in the core. The outer cylinder is divided into four quadrants, which withdraw upward; these are referred to as shim-safety plates

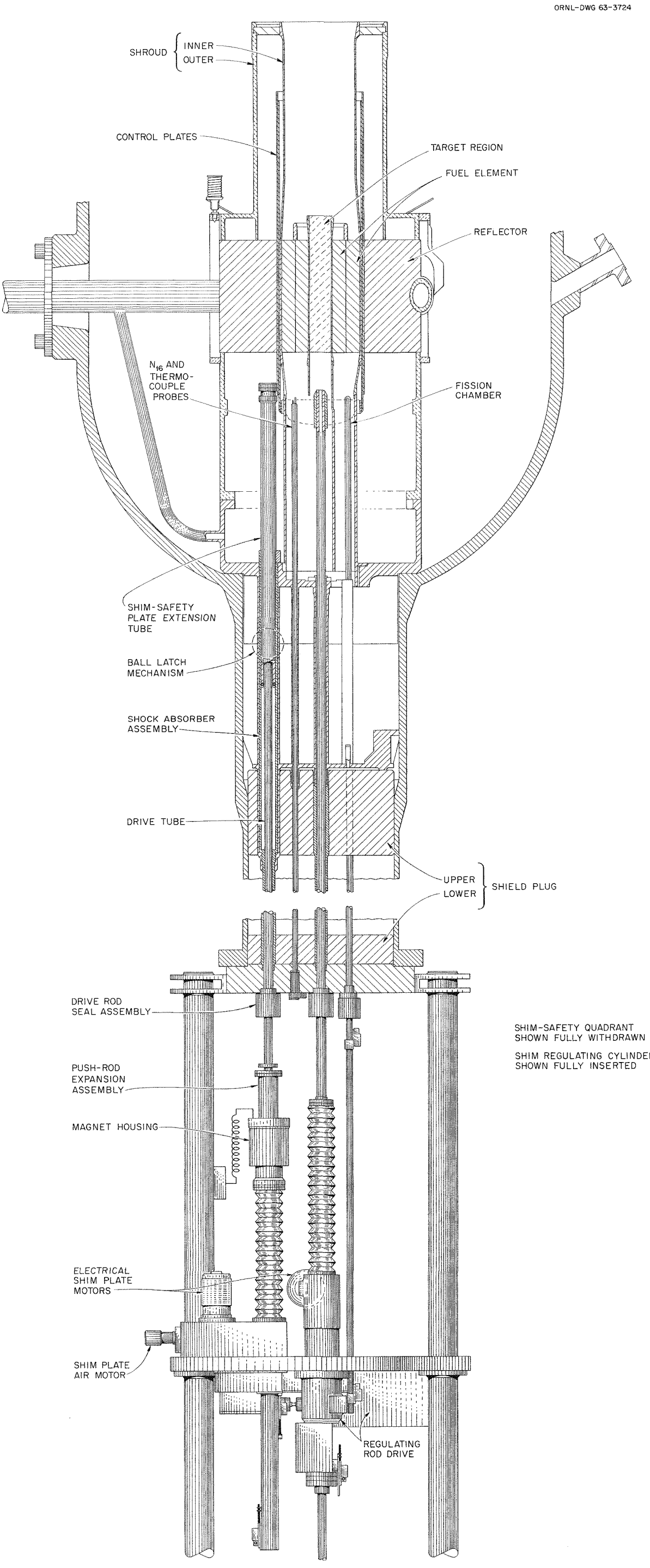

Fig. 3.2. Control Plate Drives.

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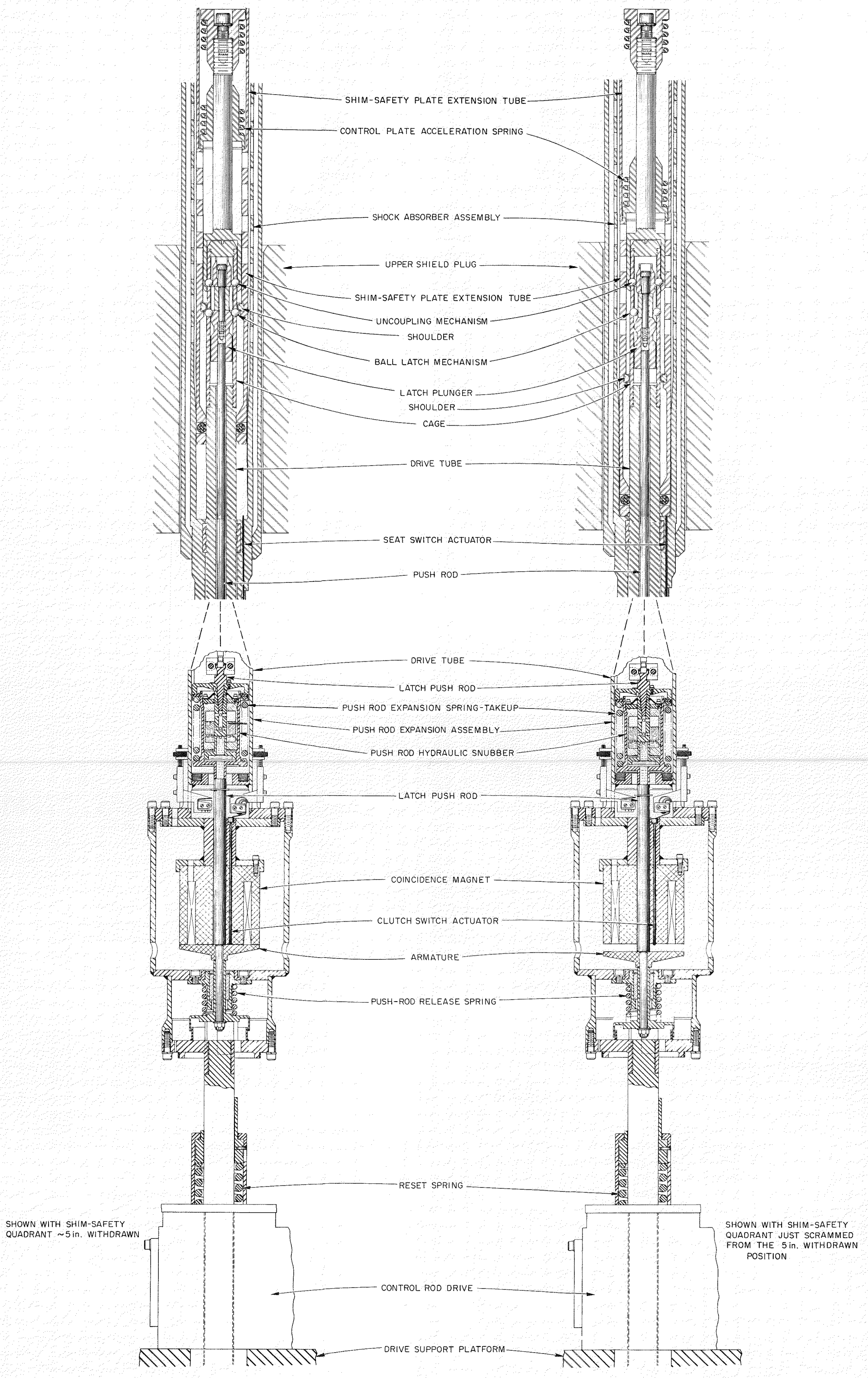

Fig. 3.3. Scram Plate Magnet and Latch Mechanism.

Nos. 1 through 4. The inner element is a cylinder, withdraws downward, and is called the shim-regulating cylinder or the No. 5 cylinder. The poison content is graduated, to some extent, along the length of the cylinders, so that minimum core reactivity (greatest poison value) is effective when the cylinders are fully inserted. In their fully withdrawn positions, about 27 inches from the respective seats, the inner and outer cylinders still overlap in the core annulus but present a minimum poison effect. In order to secure vertical flux symmetry in the reactor core, it is necessary that the plate drive mechanisms position the plates symmetrically.

The inner cylinder is solidly attached to its drive shaft, which extends through a seal in the reactor vessel to the subpile room. The shaft is positioned by both shim and servo drives, the former being a motor-driven lead screw, and the latter a movable platform upon which the shim drive assembly is supported. A hydraulic pressure-balance cylinder acts directly upon the No. 5 cylinder drive shaft, relieving both drive mechanisms of much of the loading which results from weight and from core cooling water flow friction and pressure forces. In the event of failure of the lead screw, the pressure-balance cylinder acts as a dashpot to limit the rate at which the No. 5 cylinder is forced out of the core.

The outer cylinder quadrant sections attach to individual drive shafts by means of ball latches, which are a part of the safety system. The drive shafts extend through seals in the reactor vessel to their lead-screw positioning mechanisms in the subpile room. Push rods to control the safety-release ball latches operate inside the hollow drive shafts, terminating at the magnets which are attached to the lower ends of the drive shafts.

Reversible ac electric motors normally actuate the shim drive lead screws, providing plate motion at the rate of ~six inches per minute. The lead screws for the quadrant plates also can be driven in the insert direction by air motors, at plate speeds of ~50 inches per minute. The electric and the air motor driving each quadrant plate are geared together and can operate simultaneously; however, neither can be backdriven by its opposite through the gears. The platform drive of the No. 5 shim-regulating cylinder is discussed with the servo system.

The shim drive electric motors are energized from reversing starters, the action of which represents the primary output function of the control system. Solenoid valves admit instrument air to the air motors when energized from the control system.

A key-operated lockout device is provided for each electric shim motor. The devices disconnect motor leads and mechanically prevent rotation of the motor shafts. They are required to be used when there is fuel in the core, but no target.

3.2d. Reactor Control System

The control system is essentially a switching matrix, intended to position the plate shim drives automatically under many reactor operating conditions and by manual control or with operator permission under other conditions. A block diagram of the control system is shown on Figure 3.4. Normal requests for plate withdrawal or insertion are developed by "Auto Shim" limit switches on the regulating drive of the No. 5 cylinder, or by manual controls on the console. The limit switches are actuated whenever the regulating drive passes beyond its optimum range in attempting to satisfy servo demands for reactivity

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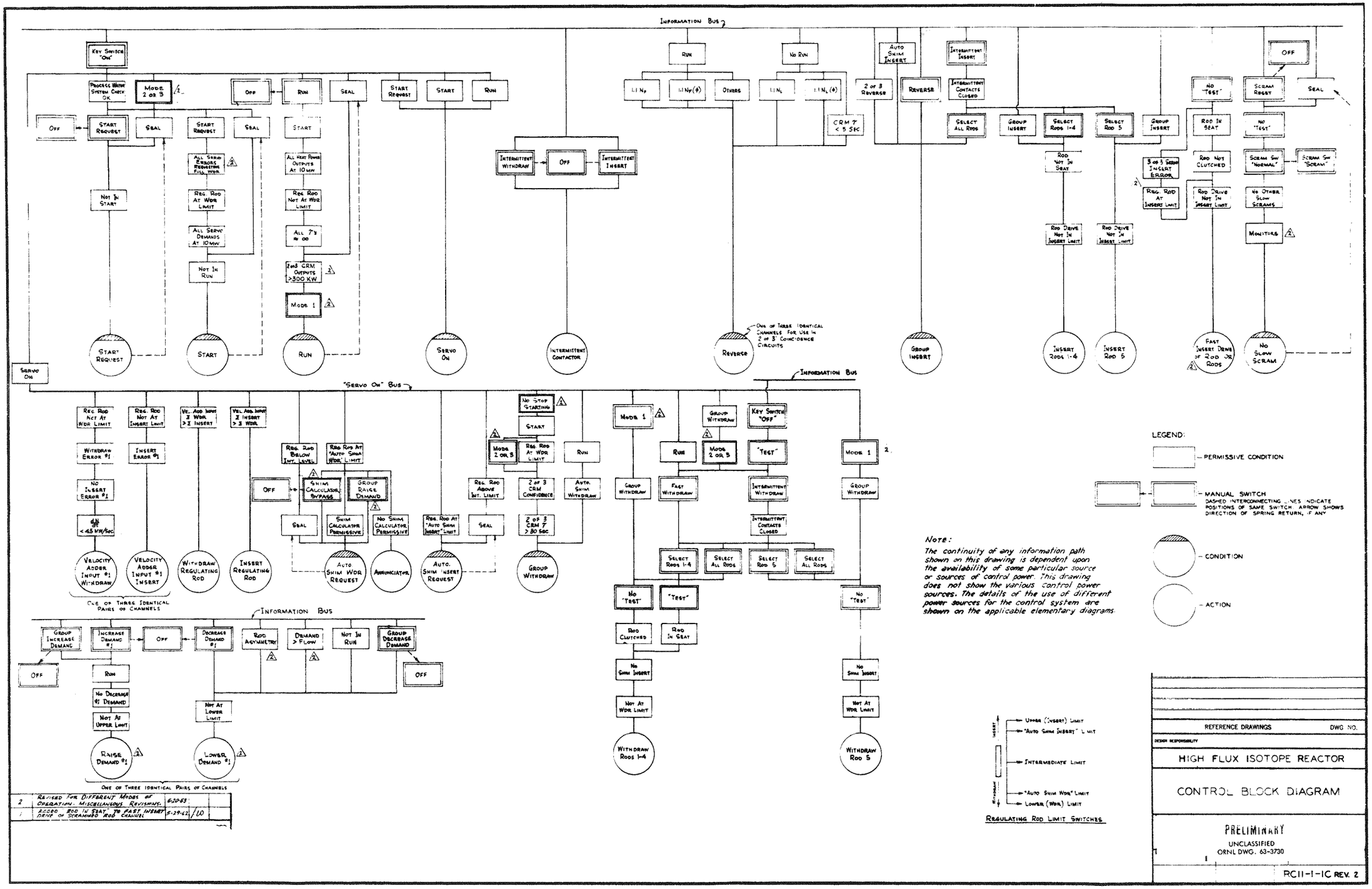

Fig. 3.4. Block Diagram of Control System.

change. Insert requests, whether "normal" or originated by "Reverse" circuitry, are always granted, provided the drives are operable and not already fully inserted. Withdrawal requests from the limit switches are satisfied conditionally during Mode 1 startup, which is automatic up to 10 Mw of reactor power. In Modes 2 and 3, the automatic withdraw requests are not recognized, and all shim withdrawal is by direct-manual control. In Mode 1--Run, until the shim computer is available, each withdrawal is initiated with operator permission and thereafter is automatically controlled. The manual controls serve also for trimming operations to adjust and balance the plate positions.

The count-rate system and auxiliary relaying in the safety and servo systems permit or inhibit control plate withdrawal, or initiate plate insertion, as required. Other components of the control system itself automatically regulate plate withdrawal. The matrix is so arranged that only those restrictions appropriate to the "Mode" of reactor operation are effective. Details of the control system functions are presented below, arranged generally as they are encountered in the operation of the reactor.

Control System Preparation, Operating Mode Selection, and Automatic Reactor Startup.--

1. Key Switch (S-1).

   Provides administrative control over reactor operation; in the "Off" position, the key switch prevents all withdrawal of control plates but does not prevent test withdrawal of the shim-safety plate drives; also in the "Off" position, prevents magnet amplifiers from being energized.

2. Mode Switch (S-22).

   Invokes control actions and restructions governing reactor operation, appropriate to the "mode." "Mode 1" position is for intended automatic startup through 10 Mw of Power (N_L), and subsequent automatic progression to and operation at any power level set into the servo system, up to 100 Mw. "Mode 2" position is for intended manually-controlled operation, at low power levels consistent with the conditions of reactor vessel open or sealed closed, and at least a minimum circulation of primary coolant. "Mode 3" position is for intended manually-controlled operation, at power levels permissible with the reactor vessel open and with no coolant flow.

3. Start Request Pushbutton Switch (S-2).

   Places the control system in "Start Request" condition, from which automatic startup or permission for manually-controlled plate withdrawal will develop automatically as described below.

4. Automatic Control Actions for Mode 1 Start.

   a. "Start Request" does not take effect in Mode 1 unless a normal complement of coolant pumps is in operation; this includes one pressurizer pump, one primary cleanup pump, three primary main circulating pumps, and two secondary main circulating pumps.

   b. When "Start Request" condition becomes effective, the servo regulating drive motors are turned on, and will remain on as long as the control system is in "Start Request," "Start," or "Run" condition.

c. Whenever the reactor is shut down, the demand settings in all three servo channels automatically proceed to their minimum levels of 10 Mw. Since this value is greater than the actual power (0 Mw), the error in each servo channel will request full-speed withdrawal of No. 5 cylinder by the regulating (platform) drive. When "Start Request" condition turns on the regulating drive motors, they will, therefore, withdraw the shim regulating cylinder to the extent of the limited regulating drive range. A sequence of contacts representing completion of the above actions (i.e., three demand settings, three withdraw errors, "Start Request" in effect, and regulating drive fully withdrawn), constitutes a permissive circuit condition to the control system entering "Start" state.

d. When the permissives in (c) above are all satisfied, provided the control system is not in "Run" state, the control system will automatically enter "Start" condition; "Start Request" then drops out. "Start" condition remains in effect until either (a) system enters "Run" condition, (b) coolant pump fails, or (c) key switch is turned off.

e. Effecting "Start" condition automatically turns on the intermittent timer to regulate all shim withdrawals, and initiates automatic group withdrawal of all plates via their shim drives.

f. Group withdrawal proceeds intermittently, subject to restrictions from the count-rate and servo systems. At least two count-rate channels must signal both "Confidence"

and period greater than 30 seconds; "Confidence" signifies that the count-rate meter is switched to "Use" mode, the fission chamber is on automatic servo position control, and measured counts are at a rate greater than 10 per second and less than 50,000 per second. At least two servo channels must signal that power is increasing at a rate less than 5 Mw per second.

g. Group withdrawal normally continues automatically until the servo system recognizes a reset flux signal equivalent to reactor power of 10 Mw. At that point the servo demand setting is satisfied and the servo motors operate the regulating drive in the direction to insert No. 5 cylinder. Consequently, the regulating drive will no longer remain at its withdraw limit, and the limit switch will no longer grant permission for further plate withdrawal by shim action. Note that the actual reactor power (heat power) lags the reset flux, due to action of the reset mechanism (Section 3.2e).

h. Automatic "Reverse" or any manual request for plate insertion will override all shim withdrawal requests. The automatic "Reverse" is described under "Automatic Reverse Features."

5. Plate Actuate Switch (S-7), Push-Pull Motion of Handle.

In "pulled" position, all plate withdrawals by shim drives are prevented. This feature is provided expressly for manual interruption of the Mode 1 automatic shim withdrawals, whether the control system is in "Start" or "Run" condition.

6. Automatic Control Actions Preparatory to Modes 2 and 3 Operation.

   a. "Start Request" becomes effective when the pushbutton is depressed. Although there are no explicit requirements for any coolant pumps to be in operation to obtain "Start Request," it is necessary in Mode 2 to have sufficient primary loop flow to prevent the safety "Low-Low-Flow" elements from causing safety trip action.

   b. "Start Request" leads to "Start" condition of the control system exactly as for Mode 1. In "Start" condition, the control system is prepared for all subsequently manually-controlled operation. It is not necessary that the fission chambers be on automatic control to obtain count-rate "Confidence."

Reactor Normal Operation above 10 Mw in Mode 1.--

1. Run Request Pushbutton Switch (S-3).

   Requests transfer of the control system from "Start" to "Run" condition, preparatory to raising power above 10 Mw in Mode 1.

2. Automatic Control Actions Preparatory to Raising Power Above 10 Mw in Mode 1.

   a. Completion of the Mode 1 automatic startup is intended to satisfy the requirements for transferring to "Run" condition. The requirements are (a) an auxiliary relay in each of the three safety channel signals that the channel recognizes reactor heat power in excess of 8 Mw, (b) regulating drive of No. 5 cylinder is not at its withdraw limit, and (c) all three count-rate channels recognize practically

"infinite period." If the above qualifications are fulfilled, the control system will transfer from "Start" to "Run" condition when the run request pushbutton is depressed.

b. Having entered "Run" condition, the control system will remain so until any one of the following actions causes it to drop out: (a) key switch turned "Off," (b) mode switch turned to "Mode 2" or "Mode 3," or (c) "Sag" occurs, whereby two of the three count-rate channels fail to recognize core power greater than 300 Kw, and the heat power auxiliary relays in two of the three safety channels fail to recognize core power greater than 8 Mw.

3. Control of Power above 10 Mw.

a. Power demand instructions are manually set into the servo system (see "Servo System" description, Section 3.2e).

b. Servo system withdraws or inserts regulating drive of No. 5 cylinder.

c. When regulating drive reaches "Auto Shim Withdraw" or "Auto Shim Insert" limits, appropriate group shim action is requested. Insert requests are always effective. Withdraw requests can initiate group shim withdrawal only if either (a) shim computer bypass switch is placed in "Bypass," or (b) group demand control switch is placed in "Raise"; both of these switches are spring-return to "Off," but need only be placed momentarily to the indicated positions to set up a shim withdraw request latching circuit (Relay K-512).

Once initiated, as just described, "continuous" withdrawal (i.e., not regulated by intermittent timer) will proceed, subject to temporary interruption (a) by any manual or automatic insert request, (b) when two servo channels signal that neutron flux is increasing at a rate exceeding 5 Mw per second, or (c) plate actuate switch "pulled" to block withdrawal. Such interruptions do not cancel the latched-in withdraw request, and hence do not terminate the withdrawal. The withdrawal is normally terminated only by the regulating drive inserting to its "Intermediate" position, where it actuates a limit switch that drops out the withdraw latching circuit. The conditions of servo system requesting withdraw and no permission granted via the bypass or group demand switches, is annunciated.

4. Shim Calculator Bypass Switch (S-18).

   Allows operator to enter permission into the control system for automatic shimming to proceed.

5. Group Servo Demand (S-11).

   (Described more completely under "Servo System.") In "Raise" position, demand control switch has an auxiliary function exactly the same as the shim calculator bypass switch; this function is provided as an operating convenience.

6. Plate Actuate Switch (S-7).

   Push-pull operation handle is intended for manual blocking of automatic shim withdrawal in Mode 1. Blocking is effected when the handle is in the "pulled" position. Rotary positions of the handle call for actuation of the shim drives; "Fast Insert"

automatically affects the group of five, while the other positions affect either individual drives or the group, as selected by the shim rod drive selector switch (S-8). "Intermittent Insert" or "Fast Insert" requests may be made regardless of whether the handle is "pushed in" or "pulled out," and take precedence over automatic shim withdraw request. "Intermittent Withdraw" or "Fast Withdraw" requests are prevented by a mechanical stop when the handle is in "pulled," ("block") position. Under normal "Mode 1--Run" conditions, this switch is intended primarily for plate position balancing or trimming operations. The withdraw settings of the switch have no effect when the control system is in "Mode 1--Start" condition. There are no other restrictions on manual withdraw requests, except that automatic reverse features always take precedence. These are described under "Automatic Reverse Features."

7. Shim Plate Drive Selector (S-8).

   Selects the individual plate, or the entire group of five plates, to be actuated by switch S-7 described above. This switch has no effect when "Fast Insert" is requested by switch S-7.

Reactor Normal Operation in Modes 2 and 3.--(Control system prepared as described above, see "Automatic Control Actions Preparatory to Modes 2 and 3 Operation.")

1. Plate Actuate Switch (S-7).

   In addition to the "Block" and trimming operations described above for Mode 1, switch S-7 is intended to initiate all normal shim actuations of the plates in Modes 2 and 3. Since there

is no automatic shim withdrawal in Modes 2 and 3, the "Block" (pulled position) function is redundant. "Intermittent Insert" and "Fast Insert" requests, by rotary position of handle, are effected without restriction. "Intermittent Withdraw" and "Fast Withdraw" requests are effective subject to the following permissives, which are also among those imposed for Mode 1 automatic startup: (a) at least two count-rate channels must signal both "Confidence" and period greater than 30 seconds; "Confidence" signifies that the count-rate motor is switches to "Use" mode and measured counts are at a rate greater than 10 per second and less than 50,000 per second, and (b) at least two servo channels must signal that power is increasing at a rate less than 5 Mw per second. "Fast Insert" request by the switch affects all five plate shim drives. The other drive actuation requests affect individual plates or the group of five, as selected by switch S-8.

2. Shim Plate Drive Selector (S-8).

   Selects the individual plate, or the entire group of five plates, to be actuated by switch S-7 described above (i.e., same function as in "Mode 1--Run"). Switch has no effect when switch S-7 requests "Fast Insert."

Automatic Setback.--Setback is an automatic reduction in servo power demand, as described under "Servo System." The servo system attempts to satisfy automatic demand reductions in the same manner as manual reductions, by regulating drive action applied to the No. 5 cylinder.

Supplementary shim insertion is requested when the regulating drive reaches the "Auto Shim Insert" limit. The "Plate Asymmetry" feature of the control system initiates setback. This feature is a comparison network which recognizes (a) any quadrant plate is withdrawn more than one-half inch further than any other quadrant plate, or (b) the withdrawal distance of the shim-regulating cylinder is more than one inch different from that of any quadrant plate.

Automatic Reverse Features: Normal Speed, by Electric Shim Drive Motors.--There are three identical "Reverse Channels" in the control system. When any two request reverse, group shim insertion of the plates is initiated, taking precedence over any other requests in the system. Reverse requests do not seal in, and the reverse action terminates when the initiating condition is eliminated. Each reverse channel may develop its request in response to either of two conditions: (a) its associated count channel signals period shorter than 5 seconds, with control system not in "Mode 1--Run" condition, or (b) core power exceeds 110% of nominal limits appropriate to each mode. For Mode 1, the latter condition is signaled from either of two auxiliary relays in the associated safety channel, one representing "reset" neutron flux and the other representing heat power. For Modes 2 and 3, the first memtioned relay represents unmodified neutron flux, and the second relay is ineffective. Each reverse channel handles the requests from one safety channel and one count-rate channel, e.g., requests originating in safety channel No. 1 and count channel No. 1 enter the control scheme via reverse channel No. 1.

Automatic Reverse Features: Fast Speed, by Air Shim Drive Motors.--Provision is made for fast insertion of the quadrant plates, independent of the ac power supply, for two purposes: (a) in the event of an unnecessary scram or a latch release of a single plate, the drive(s) may be inserted to retrieve the plate(s) as rapidly as possible, so that xenon poison buildup will not prevent a restart and (b) in the event of failure of the main ac power supply, to enable prompt reduction of reactor core power to a level consistent with the emergency heat removal capability of the coolant circulating pumps. When functioning to retrieve a dropped plate, the air motors are individually controlled. Insertion is begun when the clutch switch signals separation of plate and drive and the seat switch indicates the rod is seated. It continues until the drive reaches the insert limit. The power reduction function is effected by group control of the four quadrant plate shim drive air motors. Insertion is initiated when at least two servo channels have large insert errors and the regulating drive of No. 5 cylinder has inserted to the "Auto Shim Insert Limit," and continues as long as these conditions hold. The "large insert error" means a difference of about 2 Mw between demand setting and actual reactor power. Operation of the air motors is blocked as a group by the raise test switch (S-9) during test operations of shim-safety plate drives. The air motors are individually turned off by actuation of the shim drive insert limit switches. The group fast insert response may also be called upon when normal ac power is available. Since the "Auto Shim Insert Limit" switch would then have been actuated, both air and electric shim drive motors would operate together to insert

Table 3.1. Reactor Control System Readouts and Manual Controls.

Item	Description	Location	Remarks
1	*Key Switch (S-1)	Console	Main Administrative Permit for Reactor Operation
2	*Mode Select Switch (S-22)	Console	Select control features and safety criteria appropriate to: (a) Mode 1--normal operation; (b) Mode 2--test operation, reactor vessel closed; and (c) Mode 3--test operation, reactor vessel open.
3	"Start Request": Integral Pushbutton Switch (S-2) and Lamp	Console	Switch prepares control system for operation in any mode; initiates automatic startup in Mode 1. Lamp glows while request is in effect, before system actually enters "Start" condition.
4	"Start" Lamp	Console	Glows to indicate that control system is in "Start" condition.
5	*"Servo On" Lamp	Console	Glows to indicate that the No. 5 cylinder regulating drive servo motors are turned on, ready to respond to servo channel signals.
6	"Run": Integral Pushbutton (S-3) and Lamp	Console	Switch requests control system to enter "Run" condition; lamp glows when "Run" condition is reached.
7	Shim Plate Drive Selector Switch (S-8)	Console	Switch selects any one or the entire group of five shim drives, to respond to actuating switch (Item 8) requests.

Table 3.1. (Continued)

Item	Description	Location	Remarks
8	Shim Plate Drive Actuator Switch (S-7)	Console	Switch handle rotary motion (in pushed-in position) actuates plate drives selected by selector switch (Item 7). With handle in pulled-out position, switch blocks all plate withdrawals.
9	*Raise-Test Switch (S-9)	Console	In "Test" scrams reactor and permits manually controlled test withdrawal of plates No. 1 through 4 (quadrant) drives (plates remain seated).
10	Plate Drive Position Dial Indicators (5)	Console	Each indicates inches withdrawn from full-insert position of respective plate drive. Two pointers, one each for coarse and fine scales; one complete revolution of fine pointer represents one inch of travel.
11	Plate Insert and Withdraw Limit Lights: One pair for each plate	Console	Indicator lamps glow when respective travel limits are reached by plate drives.
12	*Plate Seat Lamps: one for each of plates 1-4	Console	Indicator lamps glow when respective plates are seated.
13	*Plate Clutch Lamps: one for each of plates 1-4	Console	Indicator lamps glow when respective plates are released from drives (i.e., de-clutched).
14	Shim Computer Bypass Switch (S-18)	Console	Permits automatic shim withdrawal to be initiated without shim calculator permission.

Table 3.1. (Continued)

Item	Description	Location				Remarks
15	Annunciator Points					
	A) Reverse: No. 1 Channel	Ann.	Panel	B	Point 3	See Volume 2, Section 2.4,
	B) Reverse: No. 2 Channel	"	"	C	" 3	Annunciator Procedures
	C) Reverse: No. 3 Channel	"	"	D	" 3	
	D) Shim request, no permit	"	"	C	" 1	
	E) Plate Asymmetry	"	"	C	" 10	
	F) AC Control Bus Power Off	"	"	C	" 19	

*Items have safety or servo system functions as well as the indicated control functions; safety and servo functions are described under "Safety System" and "Servo System."

the plates at a rate representing the sum of the two drive speeds. There is no intended way in which the air and electric drives of any plate can be caused to oppose each other.

Plate Shim Drive Test Features.--Provision is made for testing the shim-safety plate drives, with the reactor shut down and with the plates seated. Shim withdrawal of the cylindrical plate is prohibited when the reactor is shut down.

Raise-Test Switch (S-9).

In "Normal" position, establishes normal control system functions for operation of the reactor; in "Test" position, scrams the shim-safety plates and permits operation of the shim-safety plates and permits operation of the shim drive electric motors to be manually controlled by the shim plate actuate switch (S-7) and the shim plate drive selector switch S-8). Changing the raise-test switch from "Test" to "Normal" position will also initiate fast (air motor) insertion of any shim-safety plate drive that is withdrawn. Test operation of the drives is restructed in either direction only by their travel limit switches; test withdrawal is prohibited unless the plate is seated and the seat switch made up.

3.2e. Servo System

The three independent servo channels together provide the primary automatic control of reactor power at levels above 10 Mw. Each functions essentially as a proportional controller, comparing measured power with demand and developing a servo motor shaft output of speed and direction corresponding to the difference or "error." The servo motor outputs are combined through differential gears, and the resultant

motion directly applied to the regulating drive of the No. 5 shim-regulating (cylindrical) plate. Continuous, fine, fast-response adjustment of core reactivity is thus obtained. Limit switches on the regulating drive sense requirements for reactivity changes greater than the amount available from the servo system, and signal these needs to the control system.

At reactor power levels considerably below 10 Mw, the servo system measurement functions are "blind," or not sufficiently accurate for control purposes. Consequently, all reactivity changes in the 0 to 10 Mw range are effected by shim action only, under control of the counting channels and control system. The servo system meanwhile automatically holds the regulating drive of No. 5 cylinder in its fully withdrawn position.

Each servo channel also continuously compares its reactor power level measurement with a flow-derived signal representing the heat removal ability of the primary coolant system. Should the primary coolant circulation be curtailed to the extent it cannot support the reactor power level, the servo system will immediately initiate power reduction to safe levels. Under conditions of severe coolant deficiency, e.g., main ac power failure occurring during reactor operation at high power, the servo system will call upon the fast-insert air motors of the shim-safety plates to expedite the required large scale power reduction. The reductions in all cases must be sufficiently rapid to avoid safety scram action by the flux/flow ratio elements (see "Safety System").

Additional details of the servo system operation, including several auxiliary control functions, are presented below, and in Figures 3.5 and 3.6.

Power Demand Signals.--Separate potentiometers one for each servo channel, develop the normal demand signals. The potentiometers are motor driven, the motors being controlled manually from the console. The demand signal voltages are indicated at the console on scales calibrated to demand megawatts. Three "Setback" conditions, described below, will cause the potentiometers automatically to be driven toward their minimum demand positions. The maximum demand setting is 100 Mw, the nominal capability of the reactor. The minimum setting is 10 Mw, a level far above that permitted during manually controlled operation in Modes 2 and 3; 10 Mw is also the level at which automatic startup in Mode 1 terminates.

The first of the setback provisions is expressly to terminate automatic startups (Mode 1) at 10 Mw. Accordingly, a single relay requests setback for all channels whenever the control system is not in "Mode 1--Run" condition. The control system also initiates setback when it recognizes "Plate Asymmetry" condition. Finally, each servo channel automatically reduces only its own demand setting whenever the demand signal exceeds the indicated heat removal ability of the primary coolant system. All of the setbacks terminate when their initiating cause is removed, or when the demand potentiometers reach their 10 Mw (minimum) settings.

Under conditions of primary coolant flow deficiency, special circuitry in each channel brings about the required power reduction in advance of the above-described setback action. This circuitry causes the signal representing heat removal capability to take immediate precedence over the normal demand potentiometer output, whenever the capability is less than the demand. The coolant capability signal

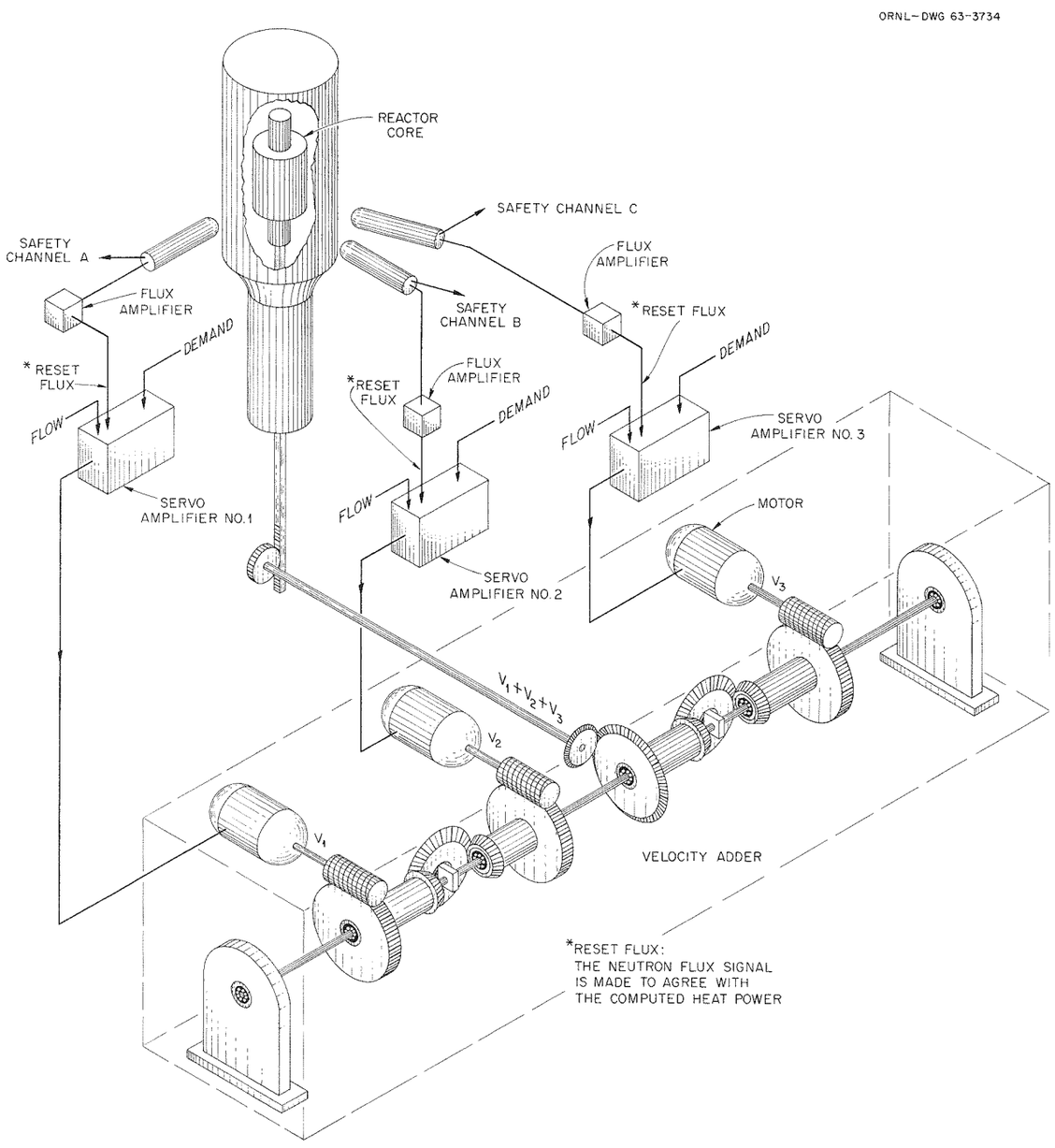

Fig. 3.5. Multiple Channel Regulating System.

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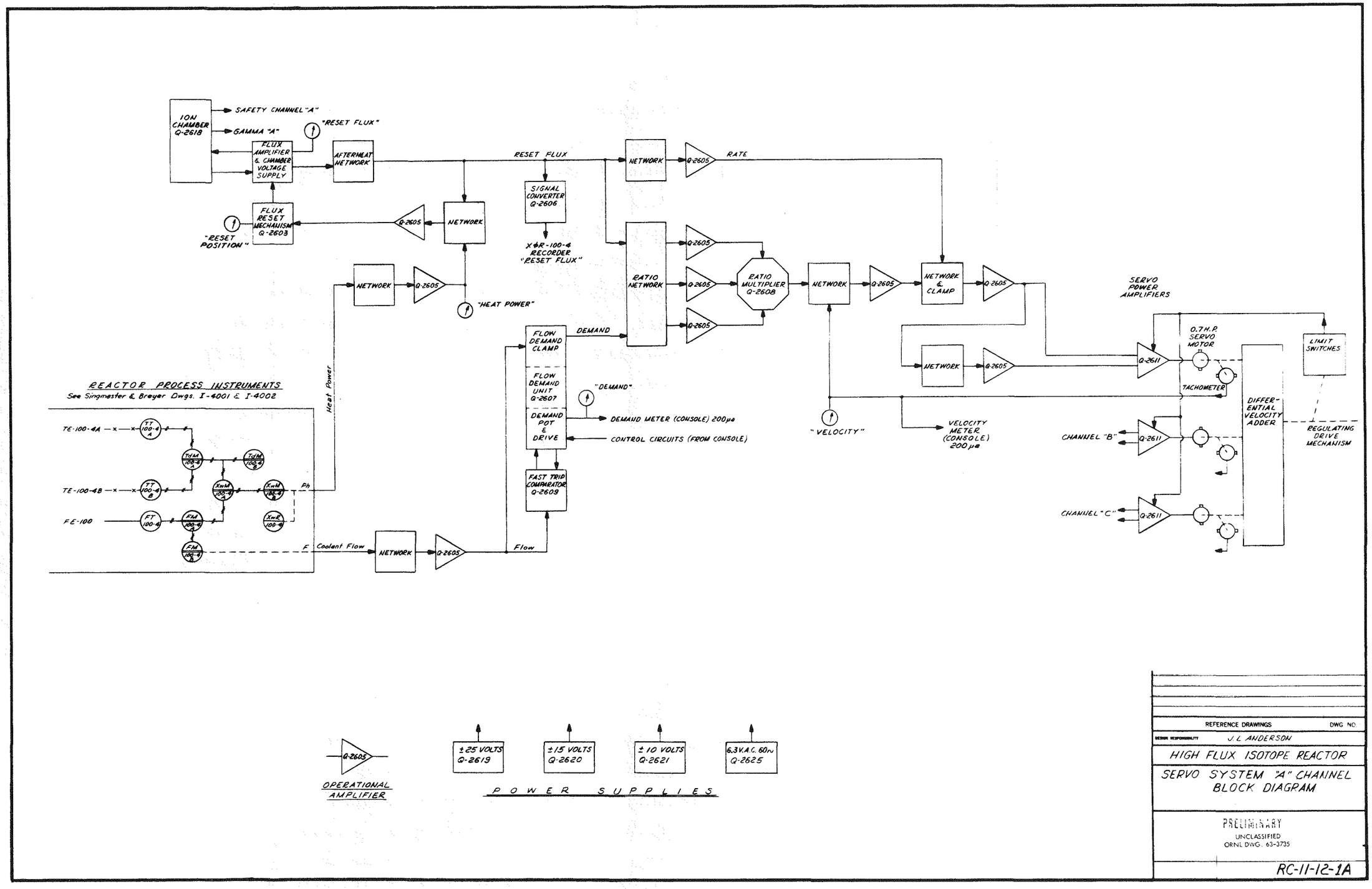

Fig. 3.6. Block Diagram of Regulating Channel A.

then becomes temporarily the effective demand, resulting in a large "error" signal and prompt servo and control response to reduce the reactor power.

Group servo demand switch (S-11) controls as a group three small motors, one for each channel, which position the demand potentiometers. "Raise" position increases demand and "Lower" decreases it. Automatic reductions of demand, or "Setbacks," take precedence over raise requests by this switch.

Individual channel servo demand pushbutton switches (S-4A and S-4B for channel A; S-5A and S-5B for channel B; and S-6A and S-6B for channel C) actuate the potentiometer positioning motors individually in the same manner and subject to the same restrictions as the group servo demand switch (S-11). These momentary contact "Raise" and "Lower" switches are intended for trimming the individual demand settings in order to obtain exact agreement among the channels.

Measurement Signals.--Power level, power rate-of-increase, and coolant flow: The reactor power signal of each channel originates as current in an uncompensated ionization chamber (Figure 3.7), proportional to neutron flux. Each servo chamber shares the same housing with the dual safety chamber of corresponding channel number, but is otherwise independent. The "raw" flux current signals are introduced into flux amplifiers, each of which modifies the signal in two ways and amplifies it to the level required for the various applications in the channel. The final, corrected output of each flux amplifier is called "Reset Flux."

The major correction to each flux signal in Mode 1 consists of a continuous calibration against an accurate heat power measurement. This

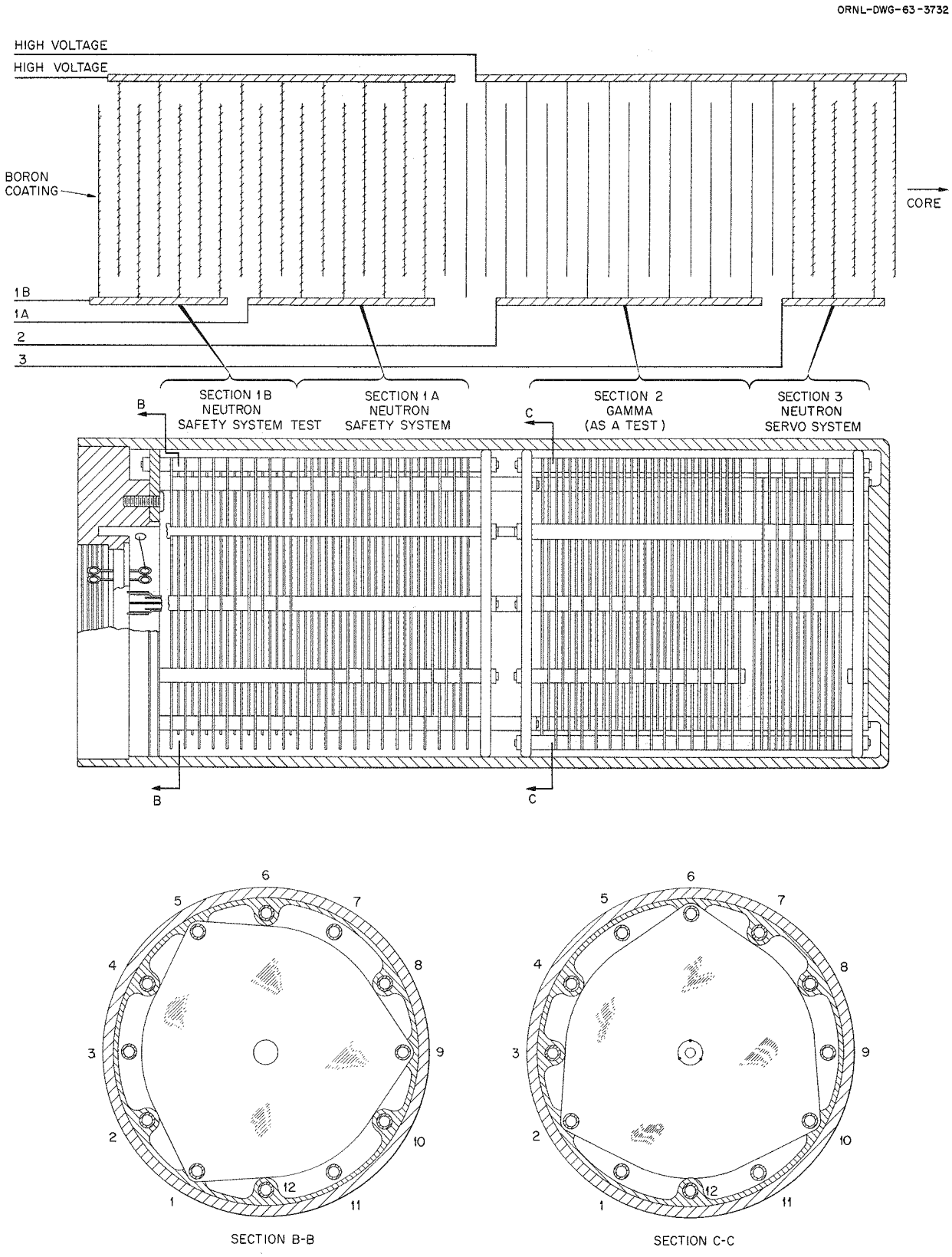

Fig. 3.7. Multisection Ionization Chamber.

is necessary to offset wide variations in the relationship between measured flux and actual core power. The variations are mainly a consequence of gradual changes in neutron flux distribution over the core volume, due to fuel burnup and poison accumulation. A slow-response servo system in each channel continuously compares the flux amplifier output signal with the output of a heat power computer, and effects agreement between the two signals by causing a motor-driven potentiometer to change the flux signal amplification factor. In Mode 1, the potentiometer is driven automatically in the direction to realize maximum amplification when the reactor power level is below the range in which the heat power instrumentation has good accuracy, in order that the servo channels may always have maximum sensitivity when they begin to exercise control during a startup.

A secondary correction to each flux signal is for afterheat, necessary mainly during rapid, large scale power reductions. Under those conditions, the lag in reduction of gamma heating may cause power from that source to assume temporarily a large proportion of total power generated in the core. The flux amplifier, responsive only to neutron flux, would then provide an output signal much smaller than necessary to represent true core power. Eventually the heat power correction would take effect but, without afterheat correction, the servo channels would meantime attempt to hold the actual core heat power at levels higher than the demand. When the rapid demand reduction is for reasons of cooling curtailment, such interim excesses of generated power could cause damage in the core by overheating. The afterheat correction is applied as a supplementary signal, developed in a special delay network and added directly to the chamber signal at the flux amplifier.

Process instrument systems 100-4, 100-5, and 100-6 provide the heat power and flow signals for channels A, B, and C, respectively, as shown in Figure 3.8. Each of these systems derives primary coolant flow information from a separate differential pressure measurement across the common venturi, FE-100. Temperature rise across the core is determined from gas bulb temperature elements in the core inlet and discharge lines. All of the information is handled pneumatically, and the final output signals are converted to dc electric form for use in the servo channels. These systems are discussed in greater detail in Section 3.3.

A reactor power rate-of-increase signal is derived by means of a differentiating network.

Regulating Action of Plate No. 5.--The speed of the shaft output applied by the servo motor of each channel to the regulating drive is proportional within limits to the "error," or difference between demand and "Reset Flux" signals. Maximum speed of each servo motor is achieved when the error is 2 megawatts or greater. All three servo motors operating at maximum speed in the same direction will cause the regulating drive to move at the rate of 15 inches per minute.

When one channel fails to a servo motor runaway condition, the runaway speed is limited by the motor characteristic. The servo motors of the other two channels will override the runaway easily. When one or two channels fail so that their servo motors are entirely stopped, the remaining channel(s) will continue to regulate but the response of the servo system will be correspondingly slower. The arrangement of the gears that combine the servo motor actions is such that there is no backfeed to an idle servo motor from the other two.

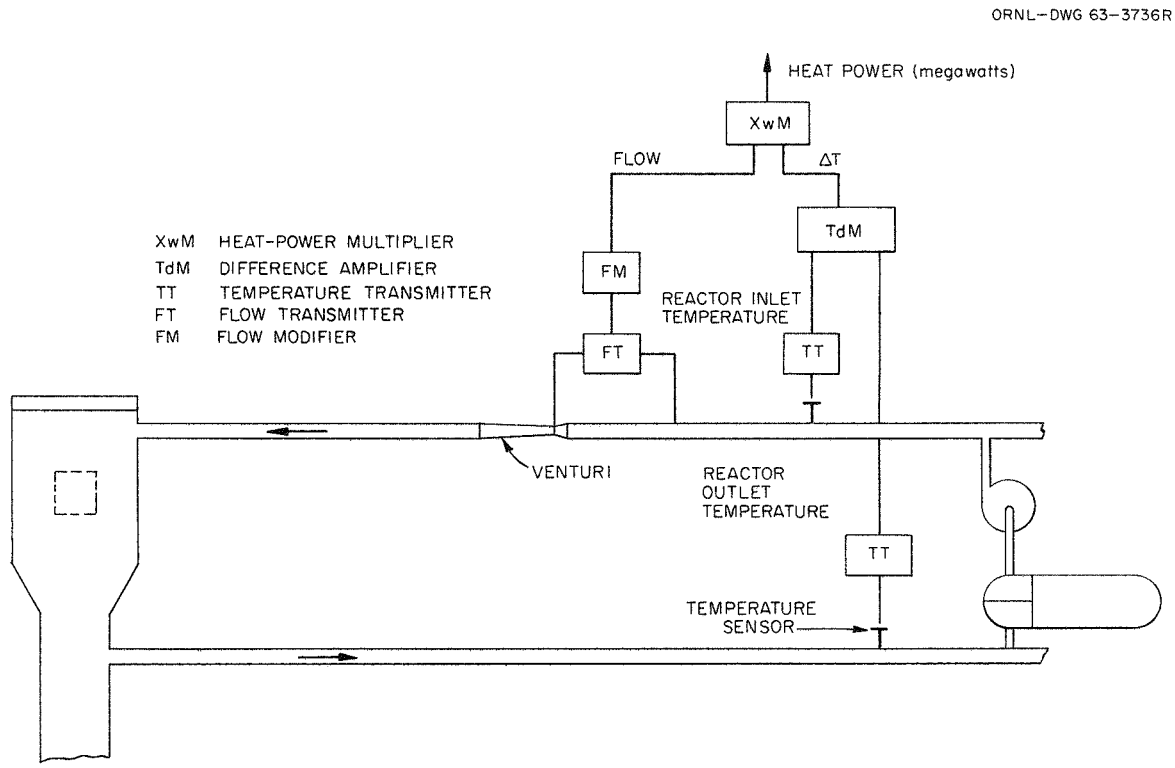

Fig. 3.8. Typical Heat-Power Computer Block Diagram.

Limit switches and relays prevent the servo motors from attempting to position the regulating drive above or below its normal travel range.

When the rate circuit of any channel recognizes that reactor power is increasing faster than 5 megawatts per second, operation of the servo motor of that channel is blocked in the withdraw direction.

Other Control Output Actions.--The travel span, or stroke, of the regulating drive is restricted to about one inch by limit switches and mechanical stops. Adjustable "Auto Shim Insert" and "Auto Shim Withdraw" position switches initiate requests for shim action; shim withdrawal when the regulating drive has withdrawn beyond about one-half inch from its fully inserted limit, or shim insertion when the drive has inserted to within one-tenth inch of its fully inserted limit. Automatic shimming, once begun, continues until the regulating drive reaches about one-quarter inch from the full-insert limit. At that point the "Intermediate" position switch is actuated and cancels the shim request.

Relays driven from the channel-rate circuits are arranged so that when any two channels recognize that reactor power is increasing faster than 5 megawatts per second, group automatic shim withdrawal is prevented.

The error signals in the servo channels are used in two control schemes, both described under "Control System." In one, maximum withdraw error in all three channels is required for the control system to enter "Start" condition. The second scheme is among the measures employed to reduce reactor power level rapidly when required because of primary coolant flow deficiency. Accordingly, when maximum insert error occurs in two channels at the same time that the

Table 3.2. Servo System Readouts and Manual Controls.

Item	Description	Location	Remarks
1	Recorder: 2 Pen: X R 100-4 XWR 100-4	Panel B	X R reads "Reset Flux" scaled in % of 100 megawatts (same for all modes).
	Recorder: 2 Pen: X R 100-5 XWR 100-5	Panel C	XWR reads "Heat Power" scaled in % of 100 megawatts.
	Recorder: 2 Pen: X R 100-6 XWR 100-6	Panel D	
2	Recorder: 1 Pen: TdR 100-4	Panel E	TdR reads temperature difference between reactor inlet and outlet coolant water, in degrees F.
	Recorder: 1 Pen: TdR 100-5	Panel E	
	Recorder: 1 Pen: TdR 100-6	Panel E	
3	Meter Module: Heat Power Indicating Instrument	1 each, Panels B, C, D*	Instrument reads heat power in % of 100 megawatts (See Item 1, XWR).
4	Flux Amplifier and Chamber Voltage Supply Module: Reset Flux Indicating Instrument	1 each, Panels B, C, D*	Instrument reads "Reset Flux" scaled in % of 100 megawatts (no change for modes 2 and 3).

Table 3.2. (Continued)

Item	Description	Location	Remarks
5	Flux Reset Module: a) Reset Gain Indicating Instrument b) Maximum Gain Indicating Lamp (amber) c) Minimum Gain Indicating Lamp (amber)	1 each, Panels B, C, D*	Instrument reads "relative" flux amplification factor to a scale of 1 to 3, which is same in all modes. Maximum and minimum gain lamps are energized by limit switches at the extremes of the reset servo travel.
6	Meter Module: Servo Motor Speed Indicating Instrument	1 each, Panels B, C, D*	Instrument indicates velocity of regulating drive servo motor for associated channel. (Same as Item 15).
7	Servo Demand Drive Unit Module: Demand Indicating Instrument	1 each, Panels B, C, D*	Instrument indicates reactor power demand potentiometer setting for associated channel (Same as Item 13).
8	Fast Trip Comparator Module - Auxiliary Control (A) "Normal" Indicating Lamp (B) "Trip" Indicating Lamp (C) Trip "Latch" Indicating Lamp (D) Latch "Reset" Pushbutton (E) "Trip" Test, Screwdriver Actuated Switch	2 each, Panels B, C, D* (1) Demand rundown when demand exceeds flow signal (2) Inhibit all plate withdrawals when reactor power increase rate exceeds 5 Mw/sec	Lamps (A) and (B) are lit to indicate condition existing. Lamp (C) follows lamps (B) and pushbutton (D) has no function, since the comparators do not latch in this application. Test switch (E) is intended to provide a quick test of the comparator ability to develop the "trip" output signal.
9	Recorder: 1 Pen: RG 422	Panel C	Reads position of platform drive of No. 5 (cylindrical) control plate.

Table 3.2. (Continued)

Item	Description	Location	Remarks
10	Recorder: 1 Pen: X R 100-7	Panel C	(For future application with shim computer.)
11	Group Demand Control Switch (S-11)	Console	Raises or lowers demand setting, simultaneously in all three servo channels.
12	Individual Channel Demand Control Pushbuttons: S-4-A: Channel A, Raise S-4-B: Channel A, Lower S-5-A: Channel B, Raise S-5-B: Channel B, Lower S-6-A: Channel C, Raise S-6-B: Channel C, Lower	Console	Raise or lower demand of individual servo channel (primarily for trimming or testing).
13	Demand Indicating Instrument	Console (3 instruments: 1 for each channel)	Each instrument indicates reactor power demand potentiometer setting for associated channel (same as Item 7).
14	Demand Limit Lamps (A) Upper (B) Lower	Console (3 pairs of lamps; 1 pair for each channel)	Each lamp glows when travel limit is reached on associated demand potentiometer.
15	Servo Motor Speed Indicating Instrument Channel A (1) Channel B (1) Channel C (1)	Console	Each instrument indicates velocity of regulating drive servo motor for associated channel (same as Item 6).

Table 3.2. (Continued)

Item	Description	Location	Remarks
16	Regulating Drive Position Indicators: (A) Indicating Instrument (B) Insert Limit Lamp (C) Withdraw Limit Lamp	Console	Instrument (A) indicates position of plate No. 5 regulating drive, and lamps (B) or (C) glow when drive travel limits are reached.
17	Chamber Position Adjustment Handwheels (3)	Poolside: (See Figure 3.9)	Position chambers so that chamber response to range of neutron flux intensity is within correction span of flux reset device.
18	+"Servo On" Lamp	Console	Glows when servo drives are turned on, ready to respond to servo channel signals.

*Modules are located in servo section of each panel, in the drawers designated "R" (similar modules appear in the safety and count sections, as described in Tables 3.3 and 3.4). Items listed are on front panels of modules; additional test and calibration facilities are inside modules or drawers, and are described in the maintenance procedures.

+Also listed under "Control System," in Table 3.1.

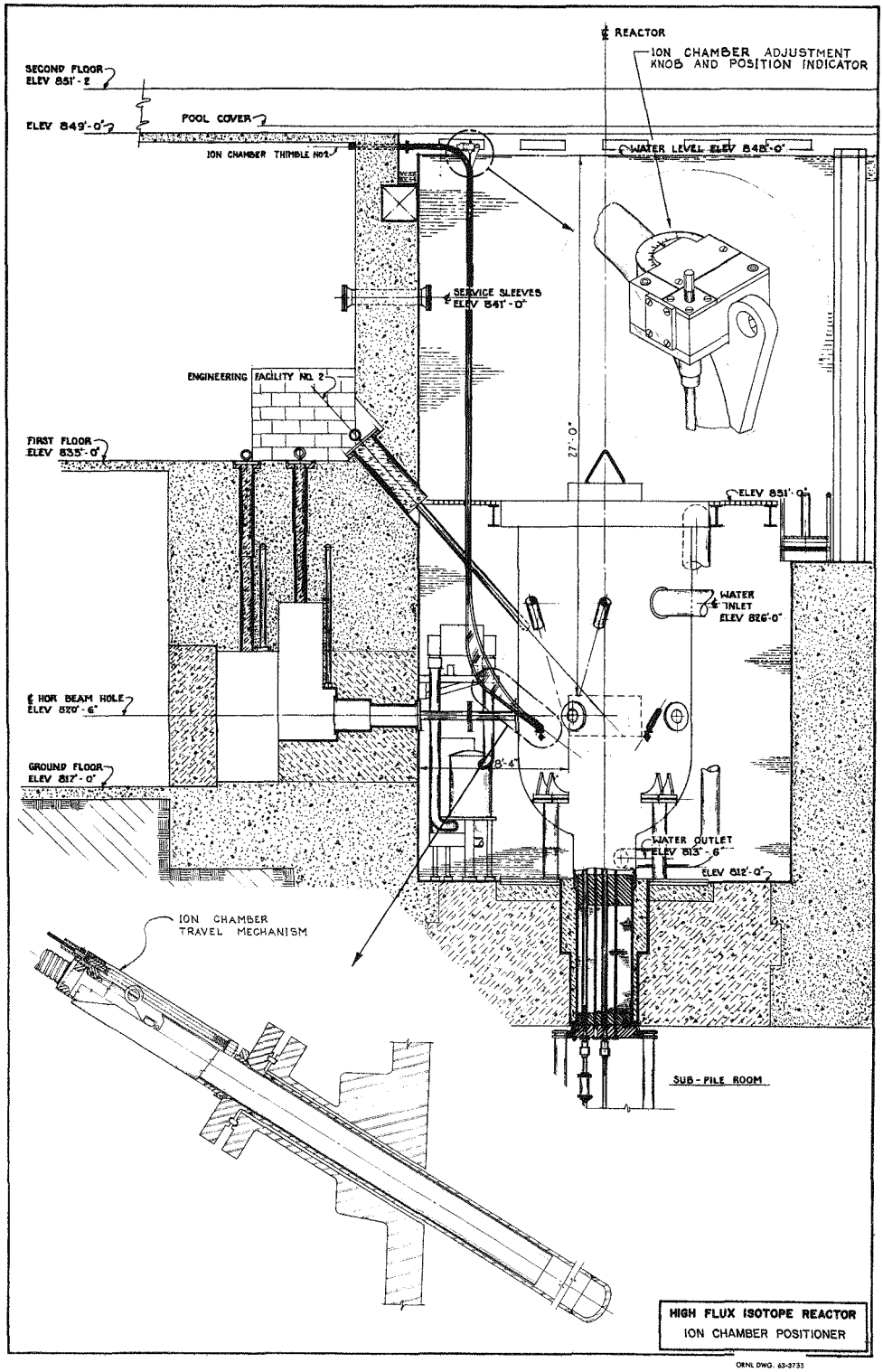

Fig. 3.9. Ion Chamber Positioning Mechanism.

regulating drive is beyond the "Auto Shim Insert" limit, group fast shim insertion of the shim-safety plates is initiated via the air motors. "Maximum" error in both schemes is any difference larger than 2 megawatts between effective demand (i.e., potentiometer output or flow-derived signal, whichever is smaller) and reset flux power measurement. Relays associated with each channel are actuated when the maximum error conditions exist.

3.2f. Wide-Range Counting System

The wide-range counting system consists of three independent channels which develop neutron flux information from fission chambers, primarily to control the reactor during startup. The control actions, effective only at reactor power levels below 10 Mw, are to prohibit shim plate withdrawal when the power increase period is shorter than 30 seconds and to initiate reverse when the period becomes less than 5 seconds. Automatic positioning of the chambers enables the system to monitor and provide readout of reactor power and period from source level to maximum power of the reactor, about 10 decades. The system elements are illustrated in Figure 3.10.

The fission chambers for each channel are located with their preamplifier and positioning servo drives in separate thimbles at the bottom of the reactor vessel. Raw pulse information from each chamber is initially screened by a pulse height discriminator, and the "fission pulses" counted on a conventional scaler. The pulses thus selected are then converted to two signals, one linearly proportional to count rate and the other proportional to the logarithm of count rate.

The linear signal enters the chamber-positioning servo system, where it is compared to an adjustable reference signal. The reference

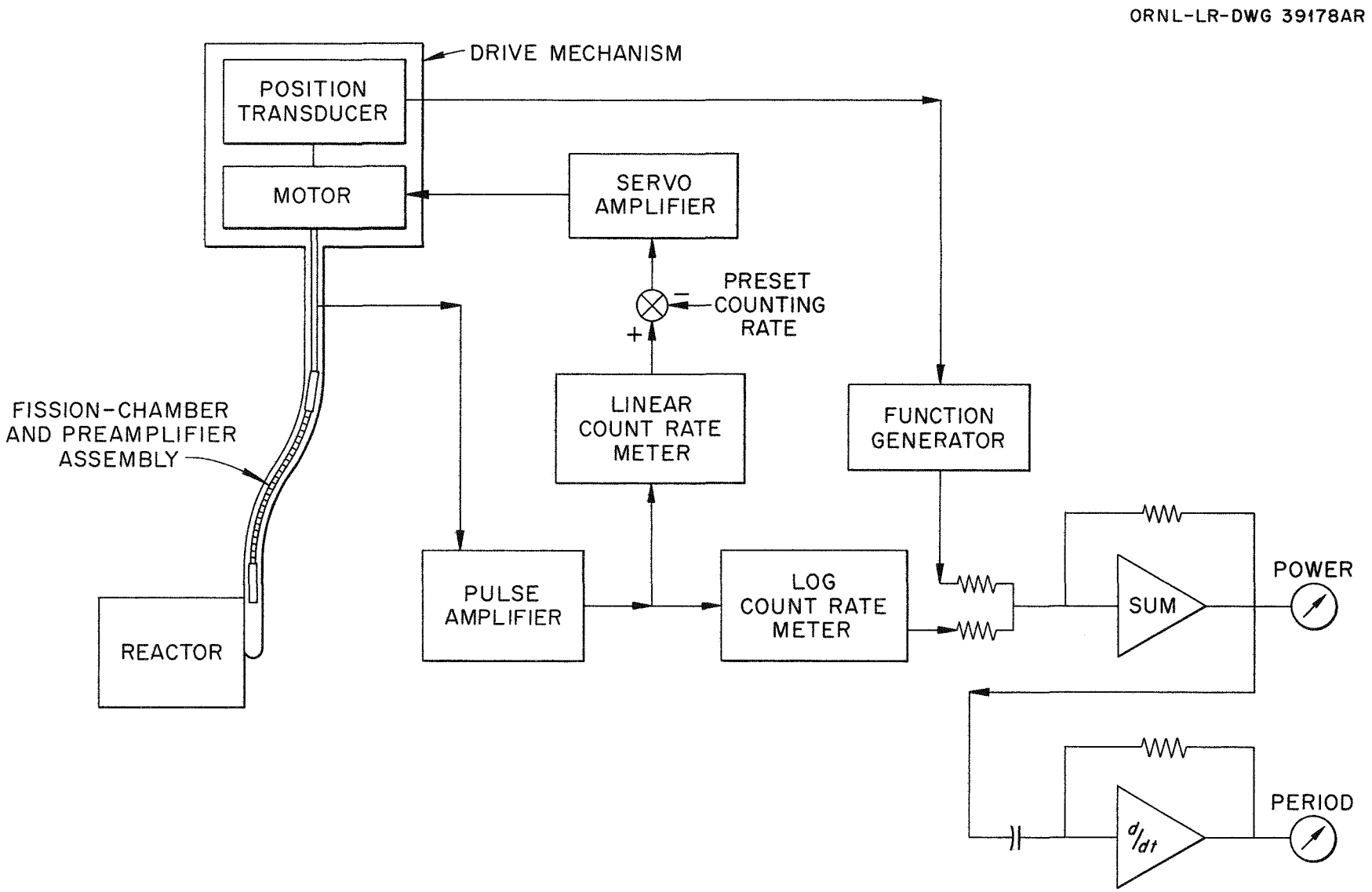

Fig. 3.10. Wide-Range Startup Channel Block Diagram.

signal represents some desired pulse measurement rate; the difference between the measured and reference signals ("error") instructs the servo to insert the chamber to a position of greater exposure or to withdraw it to a more shielded position, as required to minimize the error. Thus, the servo system attempts to position the chamber so that it will count at a constant rate, usually adjusted for 10,000 counts per second.

Fission chamber position information in each channel is converted to a voltage which is used to correct the log count-rate signal for flux attenuation at the chamber. The corrected signal, after proper calibration of the chamber position compensating network, is proportional to the logarithm of the actual neutron flux of the reactor.

The uncorrected log count-rate signal in each channel operates two relays whose contact closure in the control system represent confidence (a) that the channel is measuring an accountable neutron flux, i.e., more than 10 counts per second, and (b) that the chamber is not subject to such a high flux intensity that the measuring and counting system cannot resolve the individual pulses, i.e., count rate within 50,000 counts per second. The position-corrected log count-rate signals in the three channels operate the "Sag" relays, whose contacts cause the control system to drop out of "Run" condition when the flux goes below the level corresponding to 300 Kw of power. The corrected signals drive the log count-rate recorders, and also are further processed to obtain the reactor period signals. The period signal of each channel drives the channel period recorder, and operates three relays whose contacts are in the control system: (a) "Period Infinite," which condition is required to proceed to

"Run" condition, (b) "Period greater than 30 seconds," required for shim rod withdrawal in start condition, and (c) "Period less than 5 seconds," which initiates reverse in start condition. The actual control actions just mentioned are effected only in response to combinations of individual requests, some originating in the safety, servo, and control systems. These combinations are described under "Control System."

Fission Chamber Drive Controls (S-12, S-13, S-14 for Channels 1, 2, 3, respectively).--Push-pull and rotary motion of switch handles; rotary motion only when in handle pulled-out position. Pushed-in position permits normal servo control of chamber position; pulled-out position disconnects servo amplifier from servo motor. Rotary operation of switch handle (when pulled out) provides direct manual control of fission chamber drive motor. Springs provide automatic return to center of rotary motion. The switches are intended for use in testing and calibrating the counting channels, and to withdraw chambers from regions of damaging flux intensity in the event that a servo system malfunction attempts to insert the chamber.

Monitoring, Testing, and Calibration.--The controls and readouts in the count channel section of panels B, C, and D facilitate monitoring of the count channels performance, and include integral test and calibration gear.

Basic count-rate information is obtained from the pulse amplifiers output via decade scaler arrangements for each channel. This permits the scalers to count the same pulses which are supplied to the linear and log count-rate meters. Each scaler may be gated to count for indefinite periods by means of its direct "Start" and "Stop"

pushbutton switches, or for any desired interval up to 9,999 seconds by means of an automatic timer. The clock "Start" pushbutton initiates each timer cycle, which will then run its preset duration unless interrupted by the clock "Stop" pushbutton. The scaler is reset to 0 and the timer to its preset interval value by means of the scaler "Reset" pushbutton. A control knob adjacent to the clock must be depressed and rotated one quarter turn clockwise to free the timer adjustment dials, prior to setting the timer cycle duration. The "Gate On" lamp glows whenever the scaler input has been opened to accept pulses, either by manual or timer switching. The "Trigger Level" adjustment determines the minimum voltage level of pulses to be counted, usually above background and below the normal level of the standardized pulses generated by the pulse amplifier. An "Operate-Test" switch substitutes a 60 count per second test signal at the gate input. The scaler and clock assembly may be de-energized by the "On-Off" switch.

An array of indicating instruments summarizes the operating condition of the reactor and the count system. These include, for each channel: (1) reactor power, representing log count-rate corrected for chamber position, and duplicating respectively the reactor power recorders RLR 100-1, -2, and -3; (2) uncorrected log count-rate, (3) chamber position; and (4) period, duplicating respectively period recorders RTR 100-1, -2, and -3.

Located with the foregoing array are the "channel test" push-buttons, "In" and "Out." While depressed, each removes control of the associated chamber from its servo and initiates insertion or withdrawal of the chamber directly. Response of the readout instruments to chamber motion is of interest, as described in Volume 2.

An "Operate-Calibrate-Off" selector switch is provided in conjunction with each pulse amplifier and count-rate meter. In the "Operate" range, the switch may be set to attenuate incoming pulses by whatever factor necessary to accommodate the chamber and preamp characteristic. In the "Calibrate" range, the output of either a 10 cps or a 10,000 cps oscillator is substituted for the chamber preamp pulse signal; alternatively, a circuit is completed whereby a simulated 5-second period signal may be introduced directly to the period measuring element. The "Calibrate" lamp glows when the selector switch is in "Calibrate" range. With the switch in either "Calibrate" range or "Off" position, "CRM Trouble" annunciation appears and the count-rate confidence chain is broken. The "Pulse Height Selector" adjustment next to the selector switch determines the minimum level of pulses acceptable for neutron counting; this control is adjusted to discriminate between fission energy pulses and those due to lesser ionizing events.

A linear count-rate indicating instrument is provided. It reads directly the output of the linear count-rate circuit, the same signals that is used by the chamber positioning servo. A range switch is provided adjacent to the instrument, and a "time constant" switch inside the module. The latter allows the instrument response to be smoothed at times when the count rate is low. This instrument is intended for use in Mode 2 and Mode 3 operation, to facilitate fine control adjustments.

Other readouts and controls are summaried in Table 3.3.

Table 3.3. Count-Rate System Readouts and Manual Controls.

Item	Description	Location	Remarks
1	Recorder: 1 Pen: RLR 100-1	Panel B	Reads reactor power scaled in % of 100 megawatts (same as Item 3).
	Recorder: 1 Pen: RLR 100-2	Panel C	
	Recorder: 1 Pen: RLR 100-3	Panel D	
2	Recorder: 1 Pen: RTR 100-1	Panel B	Reads period in seconds (same as Item 6).
	Recorder: 1 Pen: RTR 100-2	Panel C	
	Recorder: 1 Pen: TRT 100-3	Panel D	
3	Power Indicating Instrument	1 each, Panels B, C, D	Reads reactor power, scaled in % of 100 megawatts (same as Item 1).
4	Log Count-Rate Indicating Instrument	1 each, Panels B, C, D	Reads uncorrected log count rate scaled in counts per second.
5	Chamber Position Indicating Instrument	1 each, Panels B, C, D	Reads chamber position to scale of 1 to 7 feet, withdrawal distance from fully inserted position.
6	Period Indicating Instrument	1 each, Panels B, C, D	Reads reactor period (same as Item 2).

Table 3.3. (Continued)

Item	Description	Location	Remarks
7	"Channel Test" Push-buttons: (A) "In" (B) "Out"	1 pair each, Panels B, C, D	Each pushbutton removes associated fission chamber from automatic servo position control. "In" pushbuttons cause chambers to insert; "out" pushbuttons cause chambers to withdraw.
8	Scaler Assembly (A) Clock (B) Clock "Start" Pushbutton (C) Clock "Stop" Pushbutton (D) Power "On-Off" Switch (E) "Gate On" Lamp (F) Decade Scaler (G) Scaler "Start" Pushbutton (H) Scaler "Stop" Pushbutton (I) "Reset" Push-button (J) "Trigger Level" Adjustment (K) "Operate-Test" Switch (L) Clock Set-Operate Switch	1 group each, Panels B, C, D	Decade scaler (F) counts those output pulses from the pulse amplifier which are above "Trigger Level" (J) setting when the "Operate" and "Gate On" condition exists. "Gate On" is determined by manual or timer control. For manual control, the "Start" (G) and "Stop" (H) pushbuttons are used. For timer control, clock "Start" (B) and "Stop" (C) are used; however, if not stopped manually, the clock will run out the time initially set in. Clock (A) and Scaler (F) are both reset by the "Reset" pushbutton (I), the clock to its preset interval of up to 9999 seconds. Clock settings may be obtained by dial controls inside its case, when the clock set-operate switch (L) is in set position. A 60 cps test pulse rate signal is substituted for the pulse amplifier output when the "operate-test" switch (K) is in "Test."

Table 3.3. (Continued)

Item	Description	Location	Remarks
9	Pulse Amplifier and Count-Rate Meter Module: (A) "Operate-Calibrate-Off" Selector Switch (B) "Calibrate" Lamp (C) "PHS" Adjustment	1 each, Panels B, C, D	Controls are for maintenance calibration and test of count channels. Selector switch (A) in "Operate" sector sets input pulse attenuation, in accordance with chamber characteristics. In the "Calibrate" sector, various switch positions substitute a 10 cps or a 10,000 cps test signal input to the amplifier, or permit a period test signal to be introduced directly to the period circuitry (via pushbutton inside drawer W-1). Also when switch (A) is in calibrate sector, lamp (B) glows and control "Count-Rate Confidence" is interrupted. "PHS" adjustment (C) determines the minimum height of pulses which are to be counted.
10	Fast Trip Comparator Module-Auxiliary Control: (A) "Normal" Indicating Lamp (B) "Trip" Indicating Lamp (C) Trip "Latch" Indicating Lamp (D) Latch "Reset" Pushbutton (E) "Trip" Test, Screw driver actuated switch	6 each, Panels B, C, D: (1) Count rate less than 10 cps. (No Confidence) (2) Count rate greater than 50,000 cps (No Confidence) (3) Reactor power less than 300 kw (no "Run" permitsag) (4) Period less than 100 seconds, positive (no "Run" permit)	Lamps (A) and (B) are lit to indicate condition existing. Lamp (C) follows lamp (B) and pushbutton (D) has no function, since the comparators do not latch in this application. Test switch (E) is intended to provide a quick test of the comparator ability to develop the "trip" output signal.

Table 3.3. (Continued)

Item	Description	Location	Remarks
		(5) Period less than 20 seconds, positive (No withdraw permit in "Start") (6) Period less than 5 seconds, positive (Reverse, in "Start")	
11	Linear Count-Rate Meter Moduel: (A) "Counts Per Second" Indicating Instrument (B) "Range" Selector Switch	1 each, Panels B, C, D	Instrument (A) reads uncorrected count-rate, scaled 0 to 1 times multiplier opposite "Range" switch (B) pointer.
12	Fission Chamber Position Controls and Readouts: (A) Fission Chamber Auto-Manual Drive Switches: S-12: Channel A S-13: Channel B S-14: Channel C (B) Position Indicating Instruments (3) (C) "Insert Limit" Lights (3) (D) "Withdraw Limit" Lights (3) (E) "Auto" Control Lights (3)	Console: 1 each of elements A, B, C, D, and E for each channel	Handles of switches (A) are spring return to central rotary position. Pulling out handle removes automatic control; handle rotation in pulled-out position initiates insert or withdrawal of chamber. Instruments (B) read chamber positions in feet withdrawn from full insert. Limit lights (C) and (D) glow when respective limits are reached. Count rate confidence is interrupted when handle of switch (A) is pulled out, in Mode 1 only. Lamp (E) glows when corresponding switch (A) handle is centered and pushed in.

Table 3.3. (Continued)

Item	Description	Location	Remarks
13	Annunciator Points		
	(A) 5-Second Period, CR Channel A	Ann. Panel B Point 6	See Volume 2, Section 2.4, "Annunciator Procedures"
	(B) 5-Second Period, CR Channel B	Ann. Panel C Point 6	
	(C) 5-Second Period, CR Channel C	Ann. Panel D Point 6	
	(D) CRM Trouble, CR Channel A	Ann. Panel B Point 17	Any one or more of the following conditions: (a) In Mode 1 only, chamber drive not on "Automatic," i.e., switch handle S-12, S-13, S-14 not centered and pushed in; (b) count-rate meter "Operate-Calibrate-Off" switch not in "Operate," i.e., not in "Use" per control block diagram; (c) count rate less than 10 cps; and (d) count rate greater than 50,000 cps.
	(E) CRM Trouble, CR Channel B	Ann. Panel C Point 17	
	(F) CRM Trouble, CR Channel C	Ann. Panel D Point 17	

3.2g. Safety System

Each of the three identical, independent channels of the safety system measures and analyzes core flux and primary coolant flow, temperature, pressure, and radiation to determine the existence of potentially unsafe conditions. The primary output of a single channel is current from four magnet amplifiers to four magnet coils, one each in the scram latch assemblies of the four outer, shim-safety plate drives. On recognition of any of several scram conditions, a channel will turn off the current in its associated magnet coils (Figure 3.11) by control of the magnet amplifiers. Scram condition obtains when two or three channels simultaneously turn off coil current, releasing the armatures in all four shim-safety plate latches from their magnets. The plates in turn are released from the drive assemblies. Springs accelerate the insertion of the four plates during their initial travel, and thereafter the acceleration is by gravity alone. Withdrawal of the shim-regulating cylinder is prohibited when scram is in effect. The safety system functions are shown in Figure 3.12.

The safety system process and nuclear measurements are described below, in association with the safety scram criteria. Further details are given under "Process Instrumentation," in Section 3.3, and in Figure 3.8. The "raw" process information is ultimately combined and/or reduced to voltage signals representing the reactor conditions of interest. These signals are fed to the comparator elements, each of which determines by comparison with a reference signal whether one particular variable is within a prescribed limit. The reference signals are constant dc voltages except in the flux/flow ratio comparator elements, where flux and flow signals are compared.

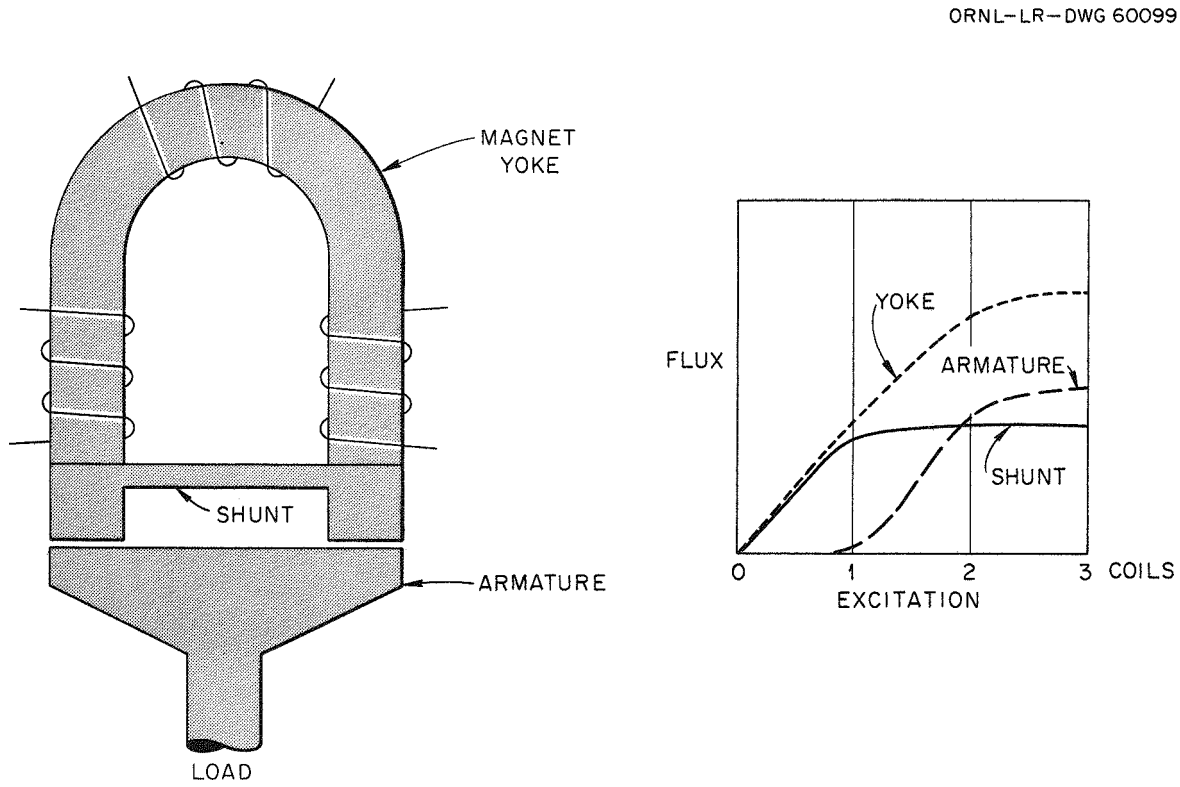

Fig. 3.11. Coincidence Magnet.

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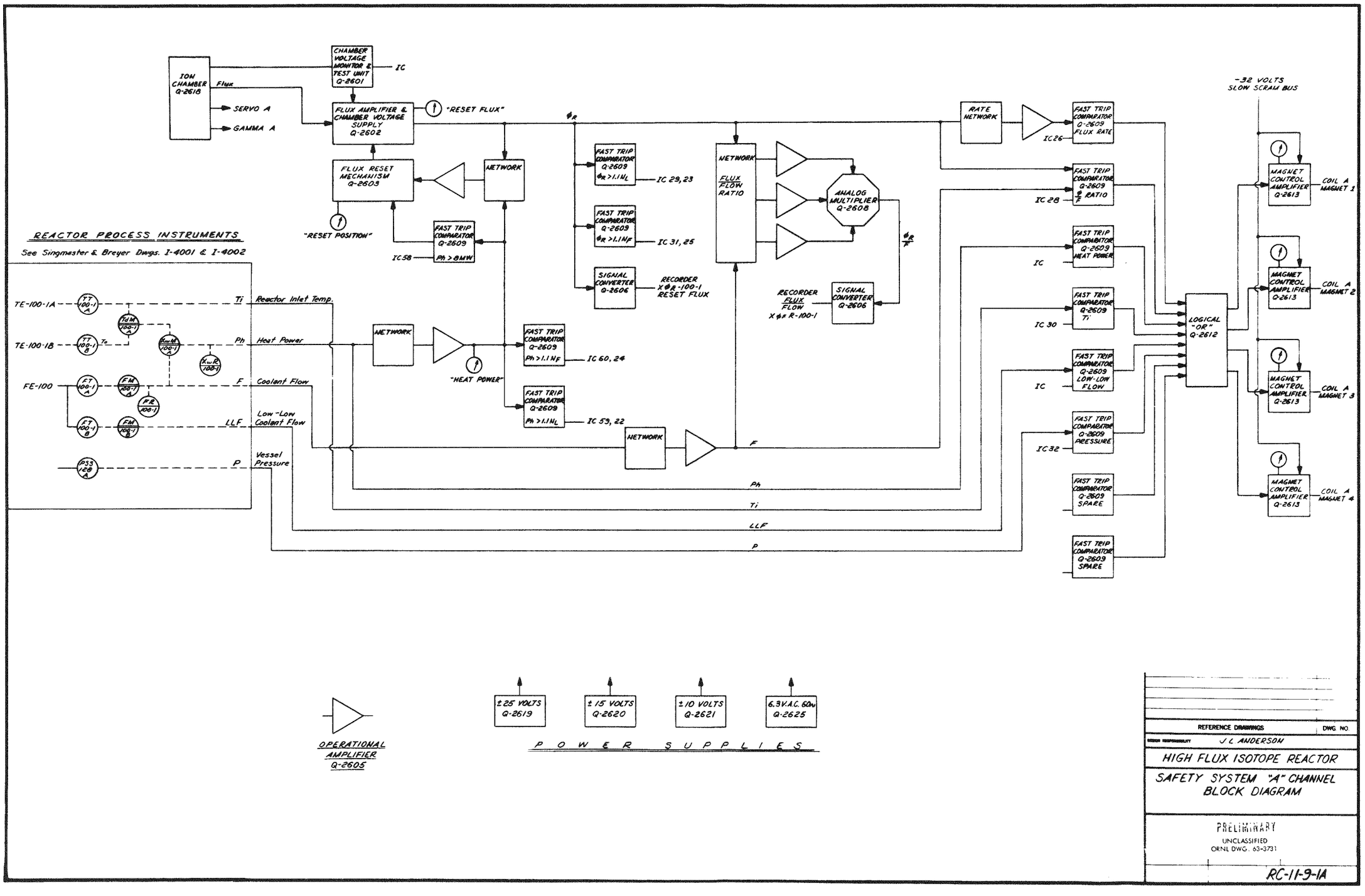


Fig. 3.12. Block Diagram of Safety Channel A.

Seven comparator elements in each channel are specially connected to initiate fast scram request. In this application, each comparator develops a d-c output signal of -10 volts when the monitored condition is "normal." When the condition changes to beyond tolerance, the comparator output changes instantly to 0 volts d-c. The latter signal constitutes a fast scram request, which does not latch. Panel lights describe the condition of each comparator to identify the origin of any fast scram request. Auxiliary relay contacts in the comparators actuate the scram request annunciators.

A logic "OR" network in each channel accepts all of the fast scram comparator output voltage signals for that channel, and turns off the four associated magnet amplifiers when one or more comparators request scram. Auxiliary relays sense the outputs of the three "OR" networks; when any two channels request scram, the relay contacts prohibit shim withdrawal of the No. 5 shim-regulating cylinder. The withdraw-prohibit relays latch after a scram request, and must be reset.

Auxiliary Control Action.--Three other comparator elements are applied in each channel to perform auxiliary control functions. Although they share power supplies and some of the input information signals with the fast scram comparators, they are not considered a part of the safety system. Their outputs are relay contact operations only, representing respectively: (1) reverse request for excess power, based on reset flux measurement, (2) reverse request for excess power, based on heat power measurement, and (3) permit for control system to enter and remain in "Run" condition when heat power is above 8 megawatts. The control actions are affected only upon like requests by two or three channels, or upon concurrent requests of different origin,

as described under "Control System." The reverse-initiating comparators are intended to control power excursions, thereby eliminating the necessity for scram response in some instances.

A relay matrix recognizes when two out of three of failed fuel element detector fast scram comparators have tripped, and thereby initiates closure of (a) the primary coolant letdown block valves, (b) a block valve in the N^{16} detector system sampling line, and (c) a block valve in the sampling line for failed fuel element radiation detector systems 200 and 253 (see Section 3.3).

"Mode" Selection of Criteria.--Certain of the above described safety and control response criteria are determined by the control system, through the mode selection feature. The changes essentially affect the quantities seen by the comparators, in one or more of the following ways: (1) a measurement-proportional input signal voltage may be blocked, disabling the comparator entirely, (2) corrections to a measurement signal may be applied or removed as necessary to modify response criteria, (3) the proportionality of a signal to its primary measured quantity may be changed, or (4) the level of a constant reference signal may be changed. The effects of such changes are summarized for the scram comparators in the descriptions of the individual scram criteria. The auxiliary comparators that monitor heat power and reset flux are subject to change of their reference signals, such that in "Mode 1--Run" condition they initiate reverse at 110 Mw and in "Mode 1--Start," at 11 Mw. In Modes 2 and 3, the permissible reactor power is below the sensible level for heat-power measurement, and no further change is made to secure heat power comparator response under these conditions. Valid flux measurements

are available, however, and appropriate changes are made in the flux signal amplification factor in order that the flux comparator may initiate reverse at 110% of the respective Mode 2 and Mode 3 power limits. The flux signal is further modified by eliminating the heat power and afterheat corrections in Modes 2 and 3, so that the signal is no longer "Reset" flux. These corrections are discussed in further detail in conjunction with the scram criteria.

Slow Scram.--Administrative control of the reactor is exercised by conventional slow-scram arrangements. Thus, the main power to all of the safety magnet amplifiers is interrupted by any of the following control system conditions: (1) key switch (S-1) "Off," (2) raise-test switch (S-9) in "Raise," or (3) scram switch (S-10) in "Scram." The magnet amplifiers are also de-energized in an individual safety channel when, (1) the voltage output of the power supply for the neutron flux ionization chamber falls below 60% of the normal 250-volt level or (2) "module continuity" is broken by disconnecting one of the modules for that safety channel from the plug in its panel drawer. Under all of the foregoing conditions, the amplifiers which are de-energized remain so until the initiating condition is cleared and the reset pushbutton (S-15) is actuated. Each channel has two slow-scram annunciator points on its associated annunciator panel; one signals all of the above described scram requests, and the other signals "chamber low voltage" and "module discontinuity." Thus, a general slow scram such as that from the scram switch will be annunciated by three "slow scram" points, each on a separate annunciator panel, and either form of single channel trouble slow scram request is annunciated by two points on the same annunciator panel.

A severe drop in the voltage of the battery supplying one safety channel can produce a slow-scram request from that channel by any of several mechanisms, depending on the magnitude and duration of the disturbance. In addition, power is interrupted to all of the magnet amplifiers associated with any shim-safety plate (i.e., one amplifier in each channel) when that plate is separated from its drive (i.e., not "clutched") and is not seated.

Fast Scram.--The following summarizes the fast scram criteria recognized by each channel:

1. Reactor heat power excessive.

   Process instrument system 100-1, -2, and -3 provide signals proportional to the rate of heat power generation in the reactor, for safety channels A, B, and C, respectively. Each process system derives coolant flow information from a differential pressure cell across the common venturi flow element FE-100, measures core inlet and outlet temperatures by resistance devices, and combines the information electrically in a heat power computer. The computer outputs enter the trip comparators directly for comparison with fixed reference signals. Scram request obtains when the reactor power reaches 120 Mw in Mode 1 operation, or 12 Mw in Modes 2 and 3. However, the systems do not actually function during Mode 3 operation since there is no effective measurement of heat power.

2. Reactor neutron flux excessive and/or flux/flow ratio excessive

   The neutron flux scram systems provide the basic fast-response shutdown protection against reactor power excursions. Added

features enable the systems, during Mode 1 operation, to recognize reductions of primary coolant flow and reduce their power-limiting trip settings proportionally. Core damage thus may be prevented through prompt shutdown of the reactor whenever the servo and control systems are unable to effect an orderly power reduction as intended, during a reduction in cooling capacity. During Modes 2 and 3 operation, fixed scram trip levels are substituted for the flow dependent power limits.

In Mode 1 operation, for each channel, a signal representing core power is compared with a coolant flow signal. Scram request obtains when the core power exceeds: (Fraction of full coolant flow) x (130 Mw). The primary measurement of core power is by electric current in an uncompensated ionization chamber, proportional to neutron flux. Each safety chamber shares the same housing with a servo system chamber of corresponding channel number, but is otherwise independent. From each "raw" flux measurement a "Reset Flux" signal is developed exactly as for the servo system described in Section 3.2e. The signal processing consists of amplification, continuous calibration against an accurate heat power measurement, and correction for afterheat. Process systems 100-1, -2, and -3 provide the coolant flow and heat power information to these systems as well as for the above outlined heat power scram.

The neutron flux scram systems are modified as follows for reactor operation in Modes 2 and 3:

a. A fixed reference signal is substituted for the flow signal in the trip comparator, so that the scram circuit then responds to flux level alone, without regard to flow. At the low power levels permitted, there is no coolant flow requirement at all in Mode 3 and only "pony motor" flow necessary for Mode 2. During Mode 2 operation, the low-low-flow trip element (Item 5 below) continues to monitor for the condition of coolant flow less than required for the Mode 2 power limit.

b. The flux reset systems, which calibrate the "raw" flux signals against heat power measurements and correct them for afterheat, are abandoned, so that the reactor power signals applied to the comparators are in simple proportion to the "raw" flux measurements. Neither form of correction would contribute significantly to the safety system effectiveness at the reduced power levels. In addition, the power limits are below the level of sensible heat power measurement.

c. The amplification applied to the "raw" flux signals is changed for Mode 2 and again for Mode 3. The changes scale the flux amplifier output signals so that, when compared with the fixed reference signal of (a) above, they will effect scram requests in the comparators at 130% of the respective mode power limits. The amplified "raw" flux signals are displayed on the "Reset Flux" and "Flux/Flow Ratio" readout instruments, the readings appearing directly in terms of percent or fraction of the power limit for the mode in effect.

3. Core power rate-of-increase excessive.

The most severe accident considered in the development studies involved a sudden addition of reactivity resulting from a void being swept into the core target region. The studies indicated that the consequent power excursion would be terminated by level trip safety action (i.e., "Reactor Neutron Flux Excessive"), promptly enough to avoid any serious damage to the core. However, for accidents initiated at full power, the safety action can be advanced significantly by initiating scram when the core power rate-of-increase exceeds a pre-set value, 20 Mw per second for Mode 1 operation. The Mode 1 setting of 20 Mw per second is substantially above the maximum power increase rate permitted by correct automatic control action, which includes prohibiting all plate withdrawals when the rate exceeds 5 Mw per second.

The power rate-of-increase signal is obtained for each channel by measuring changes of the output voltage of the flux amplifier. For Mode 1 operation, the flux amplifier output is "Reset Flux" and is scaled so that N_F on the readout instruments is equivalent to 100 Mw of power.

The rate-of-change signals enter the respective rate trip comparator elements which individually request scram when the power rate-of-increase reaches 20 Mw per second. As explained in (2) above, the flux amplifier outputs are not corrected, or "reset," for Modes 2 and 3 operation, and the amplification factors are increased in inverse proportion

to the reduction in the power limits. The amplification changes reduce the effective rate trip settings in the same proportions as the level trip limits, since the rate trip comparator reference signal remains the same for all modes.

4. High inlet temperature.

High core inlet temperature is probably evidence of primary heat exchanger or secondary cooling system difficulties. It may be a secondary and somewhat delayed indication of excess core power or reduced flow of primary coolant. Electrical resistance elements, one each in process instrument systems 100-1, -2, and -3, measure the core inlet coolant temperature for safety channels A, B, and C, respectively. The temperature information, which is utilized also in developing the safety system heat power signals, is entered directly in the inlet temperature trip comparator. The reference signals remain constant in the comparators for all three operating modes, resulting in scram requests when the inlet temperature reaches 135 degrees Fahrenheit.

5. Low-Low Flow.

On loss of the main a-c power supply, the primary coolant pumps continue to be driven by d-c "pony" motors, at reduced speed. The resulting flow is about 15% of the normal amount, and the core power limit imposed by the servo and control systems in Mode 1 operation is reduced in the same proportion. Loss of battery energy or failures of pony motors can cause the flow to decrease further. Below about 10% flow, the

process instrumentation is no longer sufficiently accurate to assure regulation of the reactor total power, including afterheat, within the heat removal capability of the coolant system. Accordingly, the reactor is scrammed when the coolant flow decreases to 10%, which is between the expected pumping rates with one and two pony motors operating. The same low-low-flow scram is effected in Mode 2 operation, although the reactor power limit is then well within cooling capability at the flow trip point. The scram is disabled for Mode 3 operation, since no flow is required. The low-range differential pressure cells of process systems 100-1, -2, and -3 provide the flow measurements for this application. The cells are similar to the high range units that serve the heat power and flux level safety installations, and share the same taps across the common venturi flow element No. 100. The flow signals enter the trip comparators directly in Modes 1 and 2 operation, but are blocked in Mode 3. Fixed reference signals are supplied to the comparators, calibrated to effect scram requests when the coolant flow is about 1700 gpm.

6. Primary coolant loop low pressure.

The primary coolant system pressurization pumps are intended to maintain the loop pressure at 600 psi in Mode 1 operation, substantially above the 300 psi level at which boiling might begin in the core at full power. Direct acting pressure switches of process systems 128-A, -B, and -C signal the trip comparators in safety channels A, B, and C, respectively,

to request scram when the loop pressure decreases below 350 psi. The switch signals are blocked in Mode 2 and 3 operation, where pressurization is not required.

7. Contamination from faulty fuel element.

Hot spots or material defects may cause local failures of the fuel cladding, with consequent contamination of the primary coolant loop. Prompt detection of such failures, followed by shutdown of the reactor, will both minimize the release of radioactive material from the initial small ruptures and prevent minor failures from becoming major ones. Each of the safety channels monitors for the rise of gamma radiation in the pipe tunnel which would indicate a fission product release. This is done by means of Reuter-Stokes ionization chambers, located adjacent to the coolant main outlet line from the core. The power supplies for the chambers and the chamber signal amplifiers are essentially the same as for the servo and safety systems neutron flux measurements; however, there are no corrections applied automatically to the radiation signals. The amplified radiation signals proceed directly to the trip comparator elements, where they are compared with reference signals. Scram requests obtain when the radiation reaches approximately 140% of the steady-state background level, which is produced mainly by N^{16} decay.

Test Arrangements.--Special installations facilitate virtually complete functional tests of the safety system, both before and during reactor operation. Most of the tests consist of

perturbing the quantity measured by one sensor of one safety channel, and observing the appearance of the appropriate scram request and other responses. The perturbations are apparent only to the sensor being tested, and in no way affect the reactor operation. Tests of the neutron flux measurement systems involve either changing the effective area of the ionization chambers or artificially supplementing the signals from the chambers, to simulate flux perturbations. Combinations of the various tests are required to evaluate fully the performance of each safety channel with regard to those scram criteria involving more than one measurement.

The individual channel scram requests are each indicated by: (1) drop in output current of four magnet amplifiers, (2) annunciation of source of trip action, (3) trip comparator pilot lights, and (4) one of three "central plate inhibit" lamps on console being extinguished, signifying that the affected channel requests inhibit of No. 5 cylinder withdrawal. The latter is a safety action, and can be confirmed by means of the three console indicators of shim drive motor current. Thus, when one safety channel requests scram, all current to actuate the motor in the withdraw direction will be indicated on only one of the three ammeters.

Each of the tests is initiated from a separate pushbutton on the console, the selection of which determines the type of test and the channel to be tested. The pushbuttons are further classified according to reactor operating mode, thereby limiting the application of each test to the appropriate modes and, in the case of the neutron flux systems tests, selecting the proper magnitude of simulation signals. Details of the individual tests are presented below:

1. Chamber add.

   The ionization chambers that measure neutron flux for the safety channels are each housed with an "add-on" chamber and an entirely independent chamber that drives a servo channel. The "add-on" chambers each use the same high-voltage power supplies as their associated main safety chambers, but their outputs are normally blocked. Depressing any of the three console "Chamber-Add" pushbuttons for a particular channel connects the output of the "add-on" chamber in parallel with the output of the main chamber, effectively adding the chamber outputs. The correct response of the affected safety channel is equivalent to that resulting from a sudden increase in pile power of 40%, and will depend on control system status (i.e., Modes 1, 2, 3, and start/run), pile power level and primary cooling system status. The possible primary responses include scram request for (1) neutron flux (i.e., "Flux/Flow Ratio") excessive, and (2) power rate of increase excessive. Reverse request annunciation may appear as 1.1 N_F or 1.1 N_L, with or without the scram request. Additional responses are increased levels displayed on the reset flux and flux/flow readouts and for Mode 1, actuation of the flux reset system in the direction to make the flux readings agree with the heat power.

2. Current test.

   Circuitry is provided whereby a ramp signal may be added to the chamber signals in each channel, simulating for each operating mode a core power rate of increase of about 5%

of N_F per second. The ramps are initiated by the "Current-Test" pushbuttons on the console. As with the above-described "Chamber Add," the response of safety channel tested will depend upon the status of the reactor control system. However, this test does not require the reactor to be operating at a significant power level, and is, therefore, useful as a prestart check. The current test will not actuate rate scram, since the ramp increase rates are less than the required 20% of N_F per second. Other responses are as described above for "Chamber Add."

3. Rate test.

   Similar to "Current Test," described above, but provides ramps to simulate a core power increase rate of 25% of N_F per second, for each mode. All safety channel responses are the same as described above for "Chamber Add," including rate scram indication. The console pushbuttons are designated "Rate Test."

4. Temperature measurement systems tests.

   On command from pushbuttons on the console, a small flow of hot water is injected into the primary coolant system on any selected temperature sensor of the safety system. The pushbuttons designated "Inlet Temperature" (Modes 1 and 2 only) control injection at the inlet temperature sensors, for which the primary test response is inlet temperature scram request in the affected channel. The scram request should develop regardless of reactor or coolant system operating status, if sufficient injection water pressure is available. Other significant responses of the affected

channel include (1) reduction in readout indications of heat power, (2) increase in indicated inlet temperature, and (3) actuation of the safety flux reset mechanism to reduce the reset flux signal, provided the reactor is operating in Mode 1 and power is above the minimum sensible heat power measurement level. Injection at the outlet temperature sensors is controlled by the "Heat-Power" pushbuttons, for Modes 1 and 2 only. The primary heat power scram request response in this case depends on the reactor operating mode and the pressure and flow of primary coolant. In Mode 1, scram request should obtain when the simulated core heat power exceeds 1.2 N_F, or 120 Mw. However, the fixed temperature of the water injected at the core outlet may not be sufficiently higher than the core inlet temperature to simulate 120 Mw when the flow of coolant water is reduced (i.e., heat power is proportional to flow times temperature differential). In Mode 2, the heat power trip level is 12 Mw, which is far above the established power limit and neutron flux trip level. Since the temperature of the injected water was determined on the basis of simulating 120 Mw, it should be high enough to ensure the scram request response in Mode 2 (assuming sufficient injection pressure) even with coolant flow reduced to the pony motor level. Additional responses of the affected channel include increase of indicated heat power and, in Mode 1 and at power levels above the minimum level for sensible heat power measurement, actuation of the safety flux reset mechanism to increase the reset flux signal.

5. Flow measurement systems tests.

Each of the console pushbuttons marked "Low-Low Flow" (Modes 1 and 2 only) causes a bypass valve to open and relieve the flow-induced differential pressure across both high and low range flow sensors of the indicated safety channel. This test simulates a drastic reduction in flow, resulting in a scram request by the low-low-flow trip comparator. In Mode 1 only, if there is appreciable power being generated in the core, the affected reset flux/flow ratio trip comparator will also request scram. Further response to the bypass of a high range flow element will be (1) a decrease in indicated flow, (2) a decrease in indicated heat power, (3) in Mode 1 only, an increase in indicated reset flux/flow ratio, and (4) in Mode 1 only, actuation of flux reset in the direction to decrease the reset flux signal.

6. Pressure switch test.

The pressure switches that signal loss of primary coolant pressurization for each safety channel are each connected via small diameter tubing to an individual tap in the reactor outlet line. There is normally no flow in the connecting tubing, and the entire loop pressure is transmitted directly to the switch pressure element. A test valve in each of the instrument lines opens on command from a console pushbutton designated "Pressure" (Mode 1 only), thereby allowing that instrument line to discharge to the ILW system. The consequent throttling in the line reduces the pressure

at the switch element to about 300 psi, well below the trip point. The only safety channel response observed in this test is scram request by the low pressure trip comparator.

7. Radiation measurement systems test.

The ionization chambers that detect radiation from failed fuel elements are each shielded from the core outlet pipe by a thickness of one-half inch of lead. This reduces the normal background gamma by a factor of 35%. The console pushbuttons designated "Failed Fuel Element Detector" (Modes 1 and 2 only) each initiate withdrawal of the chamber shield from in front of the chamber for the selected safety channel. A limit switch terminates each withdrawal at the intended "test" position and energizes an "FFED test" lamp. Release of a pushbutton at any time during withdrawal or after the shield is in the "test" position causes the actuation to reverse and restore the shield to the "operating" position; when the shield is replaced, another limit switch terminates the travel and energizes an "FFED operate" lamp on the console. The observable responses are an increase of flux amplifier output, as indicated on the panel meter, and a scram request by the affected failed fuel element detector trip comparator.

Shim-safety plate drop and time-of-flight tests are facilitated by built-in controls, response switches, and timers. On command, the system initially provides the "OR" gate of each selected safety channel with a "start" signal that is equivalent to a scram request from a trip comparator; a simultaneous signal starts three digital-readout timers. If two or three channels are selected, the magnet of

of each of the four shim-safety plates should release promptly after the start signal, in the same manner as for a scram. A limit switch on each plate drive is actuated by motion of the push rod that connects the magnet armature to the ball-latch release device; this switch operation represents "Push Rod Response." As each plate separates from its drive, a second switch, equivalent to the control system "Clutch" switch, is actuated to provide "Plate Declutched Response." Arrival of the plate at its seat actuates the seat switch, which represents "Plate Seated Response." A manual selector switch determines which plate is to be monitored. Each timer then is stopped by one of the "Response" limit switches of the selected plate. The timers are each equipped with a reset switch. All of the controls and timers are in the auxiliary control room.

System Readouts and Controls.--The readouts and controls that are a part of, or affect the operation of, the safety system are summarized in Table 3.4. Each is intended to serve in one or more of the following ways: (1) establish criteria for initiating safety and control actions, (2) monitor reactor or cooling system performance, (3) control slow scram, (4) monitor safety system and identify responses, (5) reset latch-out elements, (6) facilitate tests, and (7) calibrate system elements. Many of the applications are referred to in the preceding descriptions of the safety system functions.

Table 3.4. Safety System Readouts and Manual Controls

Item	Description	Location	Remarks
1	Recorder: 2 Pen: X R 100-1 XWR 100-1	Panel B	X R reads "Reset Flux" scaled in % of reactor rated power for the operating mode (in Modes 2 and 3, reading is actually uncorrected flux).
	Recorder: 2 Pen: X R 100-2 XWR 100-2	Panel C	XWR reads "Heat Power" scaled in % of 100 megawatts.
	Recorder: 2 Pen: X R 100-3 XWR 100-3	Panel D	
2	Recorder: 2 Pen: FR 100-1 X $\frac{\phi}{F}$ R 100-1	Panel B	FR reads "Flow" of primary coolant in % of rated flow (i.e., all circulating pumps operating). X $\frac{\phi}{F}$ R reads $\frac{\text{flux}}{\text{flow}}$ ratio in Mode 1 only; in Modes 2 and 3 it reads flux to scale of fraction of rated power for the mode.
	Recorder: 2 Pen: FR 100-2 X $\frac{\phi}{F}$ R 100-2	Panel C	
	Recorder: 2 Pen: FR 100-3 X $\frac{\phi}{F}$ R 100-3	Panel D	
3	Recorder: 1 Pen: TR 100-1A	Panel B	TR records reactor inlet temperature of primary coolant, in degrees F.
	Recorder: 1 Pen: TR 100-2A	Panel C	
	Recorder: 1 Pen: TR 100-3A	Panel D	

Table 3.4. (Continued)

Item	Description	Location	Remarks
4	Recorder: 1 Pen: TR 100-1B	Panel E	TR records reactor outlet temperature of primary coolant, in degrees F.
	Recorder: 1 Pen: TR 100-2B	Panel E	
	Recorder: 1 Pen: TR 100-3B	Panel E	
5	Magnet Control Amplifier Module: (A) Output Current Meter (B) "Test" Switch (screwdriver actuated) (C) "Magnet Current" adjust (screwdriver actuated potentiometer)	4 each, Panels B, C, D*	"Test" switch simulates input scram request signal, which drives output current to (near) 0. "Magnet Current" adjustment sets running current to magnet. The four magnet amplifiers of each channel each supply one of the three magnets in one of four shim plate latches.
6	Meter Module: Heat Power Indicating Instrument	1 each, Panels B, C, D*	Instrument reads heat power in % of 100 megawatts (see Item 1, XWR).
7	Flux Amplifier and Chamber Voltage Supply Module: Reset Flux Indicating Instrument	1 each, Panels B, C, D*	Instrument reads "Reset Flux" scaled in % of reactor rated power for the operating mode (in Modes 2 and 3, reading is actually uncorrected flux; see Item 1, X R).

Table 3.4. (Continued)

Item	Description	Location	Remarks
8	Flux Reset Module: (A) Reset Gain Indicating Instrument (B) Maximum Gain Indicating Lamp (amber) (C) Minimum Gain Indicating Lamp (amber)	1 each, Panels B, C, D*	Instrument reads "relative" flux amplification factor to a scale of 1 to 3, in Mode 1 operation; reset mechanism is not effective in Modes 2 and 3; so reading is of no significance then. Maximum and minimum gain lamps are energized by limit switches at the extremes of the reset servo travel.
9	Neutron Flux Measurement Ionization Chamber: Voltage Monitor and Test Unit Module: (A) Chamber voltage "Normal" indicating Lamp (green) (B) Chamber Voltage "Low" Indicating Lamp (red) (C) Chamber Voltage Low, "Latch" Indicating Lamp (amber) (D) Chamber Voltage Monitor "Test" Pushbutton (E) Chamber Voltage Low, Latch, Indicating Lamp "Reset" Pushbutton (F) Chamber Output Current Simulator "Test" Pushbutton (G) Chamber Output Current Simulator "Adjust" Vernier Control	1 each, Panels B, C, D*	Voltage monitor test pushbutton (D) simulates low chamber voltage condition, in order to test monitor. Lamps (A), (B), (C) are lit to indicate condition existing. "Reset" (E) extinguishes lamp (C), after chamber voltage is restored to normal. Chamber output current simulator "Test" pushbutton (F) adds a voltage signal to the flux amplifier output. The magnitude of the signal is adjustable by means of the "Adjust" vernier (G). Controls (F) and (G) are intended for use in calibrating and checking other safety system elements that respond to chamber signals. The signal range of the vernier corresponds to Mode 1 operation, and the sensitivity of adjustment is somewhat coarse in relation to the low power modes, 2 and 3.

Table 3.4. (Continued)

Item	Description	Location	Remarks
10	Failed Fuel Element Detector Module: Meter Indicating Radiation in Coolant Discharge from Reactor	1 each, Panels B, C, D*	Reads β and γ radiation from water in core discharge line.
11	Fast Trip Comparator Module--Scram Request: (A) "Normal" Indicating Lamp (B) "Trip" Indicating Lamp (C) Trip "Latch" Indicating Lamp (D) Latch "Reset" Pushbutton (E) "Trip" Test, Screwdriver actuated switch (F) Pressure: 3 pushbuttons (G) Failed Fuel Element Detector: 6 pushbuttons (H) Low-Low-Flow: 6 pushbuttons (I) Mode Indicating Lamps: 9 (J) Failed Fuel Element Detector Position Indicating Lamps: 6	8 each, Panels B, C, D* Rate, $\frac{\text{Flux}}{\text{Flow}}$, Heat Power, Inlet Temp., Low-Low-Flow, Pressure, Faulty Fuel Element Detector, spare (1).	Lamp (A) is lit when the monitored variable is "Normal" and the module is reset. Lamps (B) and (C) light and lamp (A) extinguishes when the monitored variable causes the comparator to request scram. Lamp (C) remains lit, after the monitored variable has returned to normal and until (Reset" (D) pushbutton is depressed.

Table 3.4. (Continued)

Item	Description	Location	Remarks
12	Fast Trip Comparator Module--Auxiliary Control: (A) through (E) same as 11 above	5 each, Panels B, C, D* "P_H: N_F and N_L", "ϕ_R: N_F and N_L", "$P_H > 8$ Mw", spares (2)	Same as (11) above, except that there is no latch action (i.e., "Latch" lamp merely follows the "Trip" lamp). "Reset" pushbutton has no function. In "$P_H > 8$ Mw" unit, trip condition obtains when heat power exceeds 8 Mw. Outputs of these units are in control system.
13	Logic "Or" Module: "Trip Lock" (screwdriver actuated switch)	1 each, Panels B, C, D*	Switch places "Or" gate in tripped condition. Each switch may be used to test the magnet control amplifiers response to scram request in one channel. Switch is also intended to secure a malfunctioning channel in scram condition when this is required.
14	Test Panel: (A) Chamber Add: 9 pushbuttons (B) Current Ramp: 9 pushbuttons (C) Rate: 9 pushbuttons (D) Heat Power: 6 pushbuttons (E) Inlet Temp.: 6 pushbuttons	Right-hand Panel of Console: Items A through G arranged by columns according to functions A through H, and by three groups of 3 rows each. Group corresponds to channel, and row corresponds to operating mode, which is identified by lamp (I).	Pushbutton switches initiate tests. Function (column) selection is intended only for mode (row) opposite energized lamps (I). Pushbuttons must be depressed and held while test is in progress. Pushbutton for failed fuel element detector must be held until corresponding position lamp (J) "FFED Test" is energized, indicating shield completely withdrawn. When FFED pushbutton is released, shield is restored and "FFED Operate" lamp turns on.

Table 3.4. (Continued)

Item	Description	Location	Remarks
15	Test Panel--Central Plate Withdraw Inhibit: (A) Motor Current Indicating Meters (3) (B) "Reset" Indicating Lamp (3) (C) "Reset" Pushbutton (3)	Right-hand Panel of Console	When the cylindrical plate is being withdrawn by the shim drive the drive motor current is normally divided equally among three metering circuits and is indicated on the three ammeters (A). Two of the circuits are interrupted when one safety channel effects slow or fast scram. All three circuits are interrupted when two channels scram, thereby inhibiting shim withdrawal. Operation of the relays, one for each channel, that effect the circuit interruptions is identified by the "Reset" indicating lamps (B) which extinguish when the relay trips. The affected relay latches out after a scram request, and must be restored by its "Reset" pushbutton "C" following clearance of the scram request.
16	Time-of-Flight Test (A) Plate Selector Switch (B) "Initiate Test" Pushbutton (C) Channel Selector Switches (3) (D) Digital Timer Readout--"Push Rod Response" Time (E) Digital Timer Readout--"Plate Declutched Response" Time	Auxiliary Control Room	Channel selector switches (C) are closed to determine which channels will request scram (i.e., three channels or any two), in response to "Initiate Test" pushbutton (B). The latter also starts interval timers (D), (E), and (F), which stop automatically when their respective measurement cycles are completed. The timers monitor the plate selected by switch (A), and are reset manually by switches (G).

Table 3.4. (Continued)

Item	Description	Location	Remarks
	(F) Digital Timer Readout--"Plate Seated Response" Time (G) Digital Timer Reset Pushbutton (3)		
17	Scram Switch (S-10)	Console	Manual control of "Slow Scram."
18	+Key Switch (S-1)	Console	Administrative control of reactor, by control of main power supply to magnet amplifiers.
19	+Raise-Test Switch (S-9)	Console	Automatic slow scram in "Test" position.
20	Scram Reset Pushbutton (S-15)	Console	Restore power to magnet amplifiers, after key switch is turned "On" or slow scram conditions have been removed.
21	+Mode Select Switch (S-22)	Console	Establishes function criteria consistent with operating mode limits and conditions.
22	+Plate Clutch Lamps (4)	Console	Monitors shim-safety plate clutched to drive (extinguished when plate clutched).
23	+Plate Seat Lamps (4)	Console	Monitors shim-safety plate seated (energized when plate seated).
24	+Chamber Position Adjustment Handwheels (3)	Poolside	Position chambers so that chamber response to range of neutron flux intensity is within correction span of flux reset device.

Table 3.4. (Continued)

Item	Description	Location		Remarks
25	Annunciator Points:			See Volume 2, Section 2.4, "Annunciator Procedures."
	(A) Fast Scram Requests:			
	Rate Trip -			
	Channel A	Ann. Panel B	Point 5	
	Channel B	Ann. Panel C	Point 5	
	Channel C	Ann. Panel D	Point 5	
	Level Trip (i.e., $\frac{\text{Flux}}{\text{Flow}}$ Ratio or Excessive Flux) -			
	Channel A	Ann. Panel B	Point 8	
	Channel B	Ann. Panel C	Point 8	
	Channel C	Ann. Panel D	Point 8	
	High Inlet Temperature Trip -			
	Channel A	Ann. Panel B	Point 11	
	Channel B	Ann. Panel C	Point 11	
	Channel C	Ann. Panel D	Point 11	
	Low Pressure Trip -			
	Channel A	Ann. Panel B	Point 14	
	Channel B	Ann. Panel C	Point 14	
	Channel C	Ann. Panel D	Point 14	
	Heat Power Trip -			
	Channel A	Ann. Panel B	Point 7	
	Channel B	Ann. Panel C	Point 7	
	Channel C	Ann. Panel D	Point 7	
	Low-Low-Flow Trip -			
	Channel A	Ann. Panel B	Point 15	
	Channel B	Ann. Panel C	Point 15	
	Channel C	Ann. Panel D	Point 15	

Table 3.4. (Continued)

Item	Description	Location	Remarks
	Failed Fuel Element Detector -		
	Channel A	Ann. Panel B	Point 20
	Channel B	Ann. Panel C	Point 20
	Channel C	Ann. Panel D	Point 20
	(B) Reverse Requests		
	1.1 N_L:		
	Channel A	Ann. Panel B	Point 9
	Channel B	Ann. Panel C	Point 9
	Channel C	Ann. Panel D	Point 9
	1.1 N_F:		
	Channel A	Ann. Panel B	Point 12
	Channel B	Ann. Panel C	Point 12
	Channel C	Ann. Panel D	Point 12
	(C) Slow Scram Request -		
	Channel A	Ann. Panel B	Point 2
	Channel B	Ann. Panel C	Point 2
	Channel C	Ann. Panel D	Point 2
	(D) Ionization Chamber Voltage Low, or Loss of Module Continuity -		
	Channel A	Ann. Panel B	Point 18
	Channel B	Ann. Panel C	Point 18
	Channel C	Ann. Panel D	Point 18

*Modules are located in safety section of each panel, in the drawers designated "S." (Similar modules appear in the servo and count-rate sections, as described in Tables 3.2 and 3.3.) Items listed are on front panels of modules; additional test and calibration facilities are inside modules or drawers, and are described in the maintenance procedures.

+Items have control functions as well as the indicated safety functions; control functions are described under "Reactor Control System."

3.3. Process Instrumentation

3.3a. References

Drawings:

1546-01-E-2117	Elementary Control Diagram, Process Water Equipment
1546-01-E-2118	Elementary Control Diagram, Process Water Equipment
1546-01-E-2119	Elementary Control Diagram, Process Water Equipment
1546-01-E-2120	Elementary Control Diagram, Process Water Equipment
1546-01-E-2125	Elementary Control Diagram, Process Water Equipment
1546-01-E-2128	Elementary Control Diagram, Miscellaneous Equipment
1546-01-E-2129	Elementary Control Diagram, Annunciators 1E thru 4E
1546-01-E-2192	Schematic Block Diagram, Heat Power Calculators and Miscellaneous Instrumentation
1546-01-I-4001	Instrument Application Diagram, Reactor Primary Coolant Loop
1546-01-I-4002	Instrument Application Diagram, Reactor Primary Coolant System (Heat Power Systems)
1546-01-I-4003	Instrument Application Diagram, Reactor Primary Coolant Cleanup System
1546-01-I-4004	Instrument Application Diagram, Pool Coolant System
1546-01-I-4005	Instrument Application Diagram, Pool Coolant Cleanup System
1546-01-I-4006	Instrument Application Diagram, Secondary Cooling System
1546-01-I-4007	Instrument Application Diagram, Secondary Cooling System, Tower and Plant Demineralizer System

1546-05-U-7146	Flow Diagram, Compressed Air
E-I-43930	Hot Water Injection, HFIR Reactor
RC11-8-2	Instrument Air, One Line Diagram
RC11-10-9	Instrument Application Diagram, SBHE, OHOG, and CHOG Systems
Q-2288-1 thru 40	(N^{16} System)
Q-2350-1	Liquid Waste Monitoring--Block Diagram
Q-2351-1	Gaseous Waste Monitoring--Instrument Plan, Stack Area

Singmaster and Breyer Specifications:

62	Open and Closed Hot Off-Gas Systems
67	Special Building Hot Exhaust System and Exhaust Stack Breeching
87	Reactor Primary Coolant Flow Element Assembly
112	Instrumentation and Auxiliary Equipment
115	Process System Instruments

3.3b. Introduction

Extensive instrumentation has been provided to control and monitor the process systems upon which the reactor depends. These systems include the coolant loops, off-gas handling and ventilation, liquid waste disposal facilities, and subsidiary systems.

Many of the instrument applications are mentioned or described briefly in other sections of this operating manual, where necessary to explain the function of an associated process system or the reactor control and safety system. This section summarizes the instrumentation and provides whatever additional information is necessary to impart a

basic understanding of the control actions, alarms, and readouts derived from the process instrumentation. The information is presented by instrument functional groupings, which are classified according to related main and subsidiary process systems.

Except for special-purpose radiation monitoring installations, essentially all of the process instrumentation is of conventional types. The simplest instrumentation includes the familiar direct-reading pressure, flow, level, position, and temperature indicators, and corresponding devices that directly actuate switches. The switches, many of which are integral with indicators, produce various alarm, pilot light, control, and safety actions via appropriate circuitry. Many remote temperature indication or recording applications consist only of local thermocouples with leads extended to the readout instrument, which usually incorporates a null-balance potentiometer device.

Water conductivity, pH, and certain radiation measurements require special piping to obtain samples from desired locations. The measurements themselves are complex, involving calibrated power supplies and electronic signal detection, amplification, and discrimination circuitry. Both local and remote readout arrangements may be provided, as well as alarm or control relay functions.

More complicated instrument systems are required to achieve (a) continuous control of process variables, (b) remote continuous signal transmission, (c) multiple control and readout responses, and (d) continuous derived signals, which are combinations of primary signals or are functions of single primary signals. These systems are of the conventional forms in which all information is converted to, and handled at, air pressure signals in the 3- to 15-psig range or

electric direct current signals in the 10- to 50-milliampere range. The wide variety of standardized equipment available for such systems and the insensitivity of the large signals to external disturbances account for the great advantages of flexibility, reliability and accuracy. The systems are comprised of combinations of the following functional elements:

1. Measurement.

   Sensor responds to the measured variable, providing a signal which is then converted to the standard pneumatic or electric form. In a pneumatic temperature transmitter, for example, a bulb, capillary tube, and mechanical linkage actuate a flapper valve over a nozzle in the associated pneumatic system; the resultant pneumatic pressure variations are transmitted to, and utilized at, other points in the system. The electric form of temperature transmitter detects changes in resistance of its sensor; the primary signal modulates a magnetic amplifier to produce the proportional standard current signal output. Flow sensors are generally differential pressure cells across flow restrictions in the main piping; the cells produce mechanical force outputs. Pressure sensors are also cells, and produce similar mechanical outputs. Level measurement is usually by displacement, with resulting flotation force output.

2. Power supply and signal transmission.

   a. Pneumatic.

      Air is delivered by the main instrument air system to regulators at various locations, each of which reduces

pressure to 20 psig and supplies a group of instruments. Each signal-transmitting element (e.g., the flapper/nozzle arrangement mentioned in (1) above) continuously draws a small quantity of air from a supply regulator, through an orifice, and bleeds it to atmosphere via its flapper/nozzle valve. The degree of nozzle closure determines the air pressure that is built up back of the nozzle, and this varying pressure constitutes the intelligence signal that is transmitted over the remaining closed system to one or more receivers (usually bellows).

b. Electric.

Each electric signal transmission system may be thought of as a direct current loop, with a series variable resistance as the sending element, a source of dc voltage, and several fixed resistances representing transmission lines and one or more receiving elements. The dc source in each loop is a rectifier, which is supplied from the separate 110-volt instrument ac power system. The sending element is not actually a variable resistance but instead is any one of several complex circuits which may include differential transformers, transistorized and magnetic amplifiers, oscillators, etc., and which act together like a resistor varying in proportion to the transmitted variable.

3. Transmission signal modification and combination.

Standard current or pneumatic "primary" signals, directly proportional to some measured quantity, may be combined with

other primary signals to produce "secondary" signals proportional to sums, differences, products, quotients, or other functions of the input primary signals. The most common example is the "error" signal, usually the difference between a primary and a manually controlled setpoint signal. Individual primary signals may also be modified in several manners such as extraction of the square root of a differential pressure primary signal to obtain a secondary signal proportional to flow. Primary signals of one standard form, pneumatic or electric, may be converted to the other standard form, or may be inverted. The servo heat power computer exemplifies several of the above operations: (1) two primary standard pneumatic signals representing temperature are subtracted to produce a secondary standard pneumatic signal proportional to temperature difference; (2) square root extraction is performed on a primary standard pneumatic signal, representing differential pressure in the main flow venturi, to produce a standard secondary pneumatic signal proportional to flow; (3) the flow and temperature difference signals are multiplied together to produce a standard pneumatic signal proportional to heat power; and (4) the pneumatic signal for heat power is converted to a standard electric current signal for final utilization in the servo system.

4. Simple readout or control function.

A standard electric transmission signal may be utilized directly to actuate a pen or switch via galvanometer movement.

The corresponding pneumatic output is by means of a spring-loaded bellows and linkage.

5. Continuous process control function.

Controllers develop the "error" signals described above and put out signals of standard form to the final control devices. Continuous regulation of the controlled process variable is thus obtained. In essentially all of the HFIR applications, the controller outputs are pneumatic and the final control devices are process valves. The reference quantities for the error signals are set manually, in most applications, either at the controller or remotely, but may be other variable process signals in cascade or ratio control applications. The controllers respond to error signals in different manners and at different speeds, depending on the proportional, reset, and derivative mode features and adjustments. Almost all of the controllers are housed with or located adjacent to instruments which indicate both the process variable and the final control element position. Except for most of the level controllers, transfer switches and external adjustments are usually provided which enable the operator to cut out the automatic control function and to position the final control element from the controller location. Most of the level controllers are integral with the local measurement elements and develop their error signals directly instead of from a remotely transmitted signal.

6. Final control actuation.

The pressure output of a controller may be applied directly to the spring-loaded diaphragm of a control valve, thereby regulating position of the valve stem as a direct and known function of the controller output pressure. Where more accurate and more rapid valve positioning is required, secondary controllers are applied. These compare position with input signal and develop an output error signal which is fed to the diaphragm of the valve actuator. The secondary controllers are equipped with indicators of air supply pressure, pressure signal from the primary controller, and pressure in the actuator diaphragm.

Those instrument systems which directly affect control or safety of the reactor are in triplicate, each powered from an independent battery/inverter or air storage supply, and are arranged on a two-out-of-three functional basis. Details of the reactor control and safety system are presented in Section 3.2. The process control instrumentation electric power is supplied from separate instrument power distribution centers P1-A and P1-B. These centers are fed normally from an independent 13.8-kv/240-v/120-v transformer, No. 7. They are automatically switches to a 480-v/240-v/120-v transformer, No. 7A, on failure of the normal source; this alternate source is fed from motor control center "I," which has both normal supply and emergency backup from diesel-generator No. 1. The process instrumentation pneumatic supply is from compressors C1-A and C1-B via air receiver 6 which stores a substantial reserve supply. The compressors are fed from different power supplies, one with backup from No. 1 diesel-generator and the other with backup from No. 2 diesel-generator. The instrumentation

systems are generally arranged so that component or power supply failures will detract as little as possible from reactor safety or operability.

3.3c. Primary Coolant System

The instrumentation for the subject system monitors and/or provides information for the automatic control of the flow, pressure, temperature, and contamination of the water which circulates through the reactor core.

1. Loop Pressurization.

All pneumatic system 127 (Figure 3.13) actuates (a) the loop high pressure annunciator switch, (b) a switch that both provides low pressure annunciation and simultaneously starts the standby main pressurizer pump if the pump control is in "Standby" mode, and (c) recorder-controller PRC-127 in the control room. PRC-127 positions, as a group, the four pneumatically-operated pressure letdown valves, one at each heat exchanger outlet, which regulate the flow of water into the loop cleanup system. The controller setpoint for automatic operation is adjusted by an index just above the recorder face. The same index may be used by the operator to position the letdown valves directly when he has elected to switch the controller to manual mode. Output of the controller to the valves is indicated on a scale above the control index. The single pressure-operated switch, PSS-127 B, operates independently and directly from loop pressure; on low pressure, it causes all of the letdown block valve in each letdown line to close. Note that each letdown line has three valves in series, the flow control valve and two pneumatic block valves.

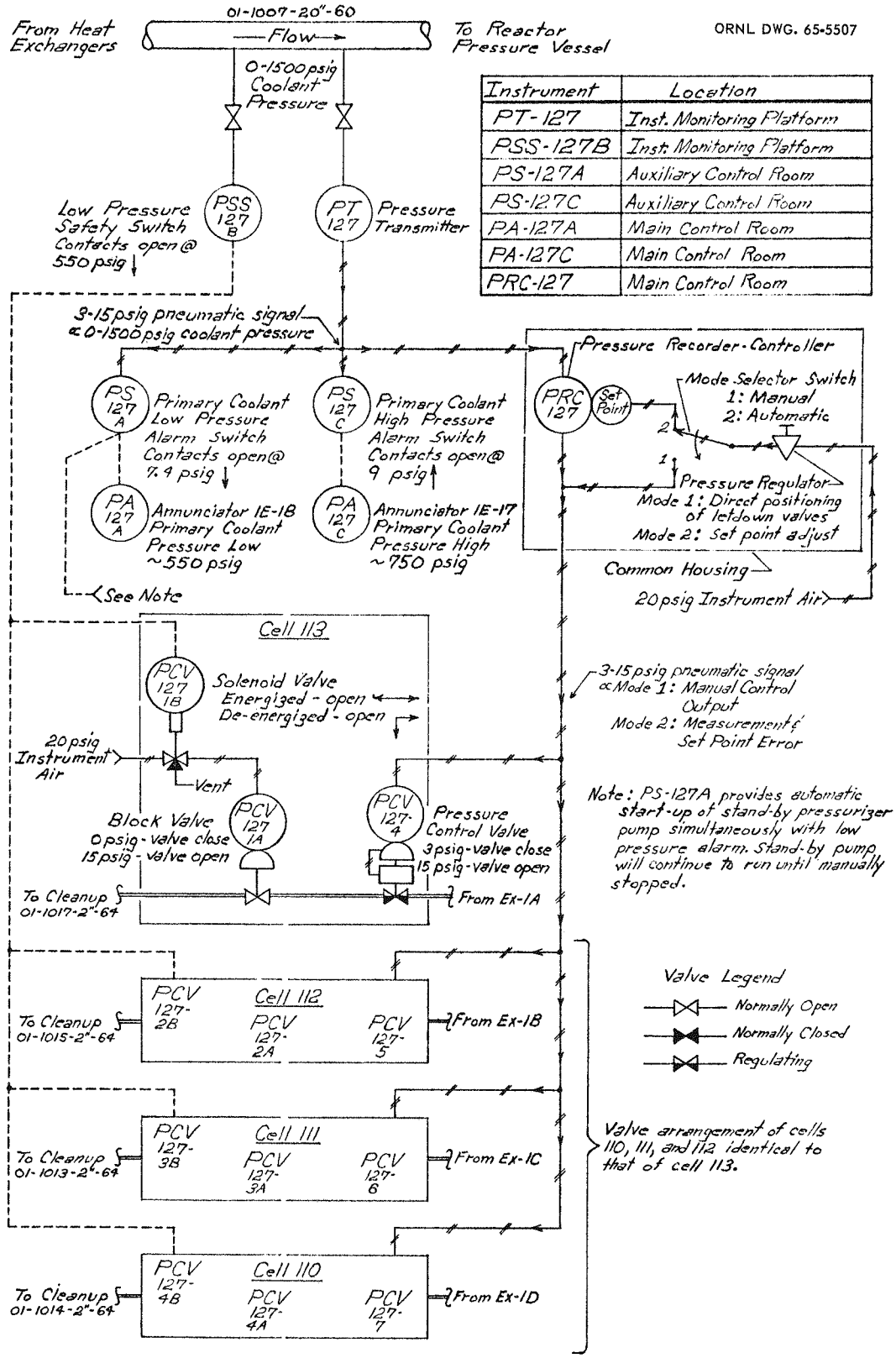


Fig. 3.13. Primary Coolant Pressure Control System 127.

All of the block valves also close when two (out of three) safety system failed fuel element detectors recognize high radiation. Failures of system 127 will generally lead to valve closures. Independent spring-loaded relief valves (PSV-150 and -157) will open on excessive pressure. Pressure switch 127 A alarms at pressure below 500 psi on annunciator point 1E-18, and switch 127 C alarms at pressure above 700 psi on annunciator point 1E-17. Systems 128 A, B, and C are primarily independent pressure switches, operating directly from loop pressure. Each switch has two poles, one of which actuates the "Low Pressure" trip comparator to produce scram request in one safety channel during Mode 1 operation, and the other which produces a relay request to shut down all of the main circulating pump ac motors on low loop pressure at any time. Actual reactor scram in Mode 1 requires either two pressure switches to request scram, or one pressure switch plus some other scram request in a different safety channel. Pump shutdown is effected only by request from two pressure switches. Since safety action is involved, provision has been made to test system 128 during reactor operation. Each "Pressure Test" pushbutton on the console actuates a solenoid valve which, in turn, causes a pneumatic-actuated valve to open and relieve pressure on the pressure switch associated with that channel. Hand valves are provided for isolating each pressure switch from the high pressure loop. They could be used to test operation of the pressure switches in the event the regular test system did not function.

2. Loop main flow.

Regulation of the loop main flow is effected by manual control of motor-driven valves. The flow instrumentation provides information to the operator and to the reactor control and safety system which governs the reactor operation. All of the main flow information derives from Flow Element 100, a special venturi in the reactor vessel approach piping. Multiple taps in the piezometer rings of the venturi provide the differential pressure signals, characteristic of flow, to six flow-measuring systems (Figures 3.14 and 3.17).

Each of systems 100-1, 100-2, and 100-3 has two differential pressure cell flow measurement devices, derives its actuating signal from a separate pair of pressure taps, and serves a different safety channel. The high-range "A" flow transmitter in each system develops a standard 10- to 50-milliamp current signal which is utilized in the associated safety channel, in the heat-power computer, the flux/flow ratio computer, the flux/flow comparison scram element, and the flow recorder. The "B" flow transmitters are low-range devices, calibrated to develop 10 to 50 milliamps for flows in the range of 0 to 20% of full-rated amount. Their output signals are utilized only in the "Low-Low Flow" scram elements of the associated safety channels. Provision is made to test each pair of flow transmitters (i.e., A and B of each channel) simultaneously, by means of pneumatically actuated valves which bypass the flow transmitters. Opening of each of these valves is initiated by depressing the "Low-Low-Flow" pushbutton

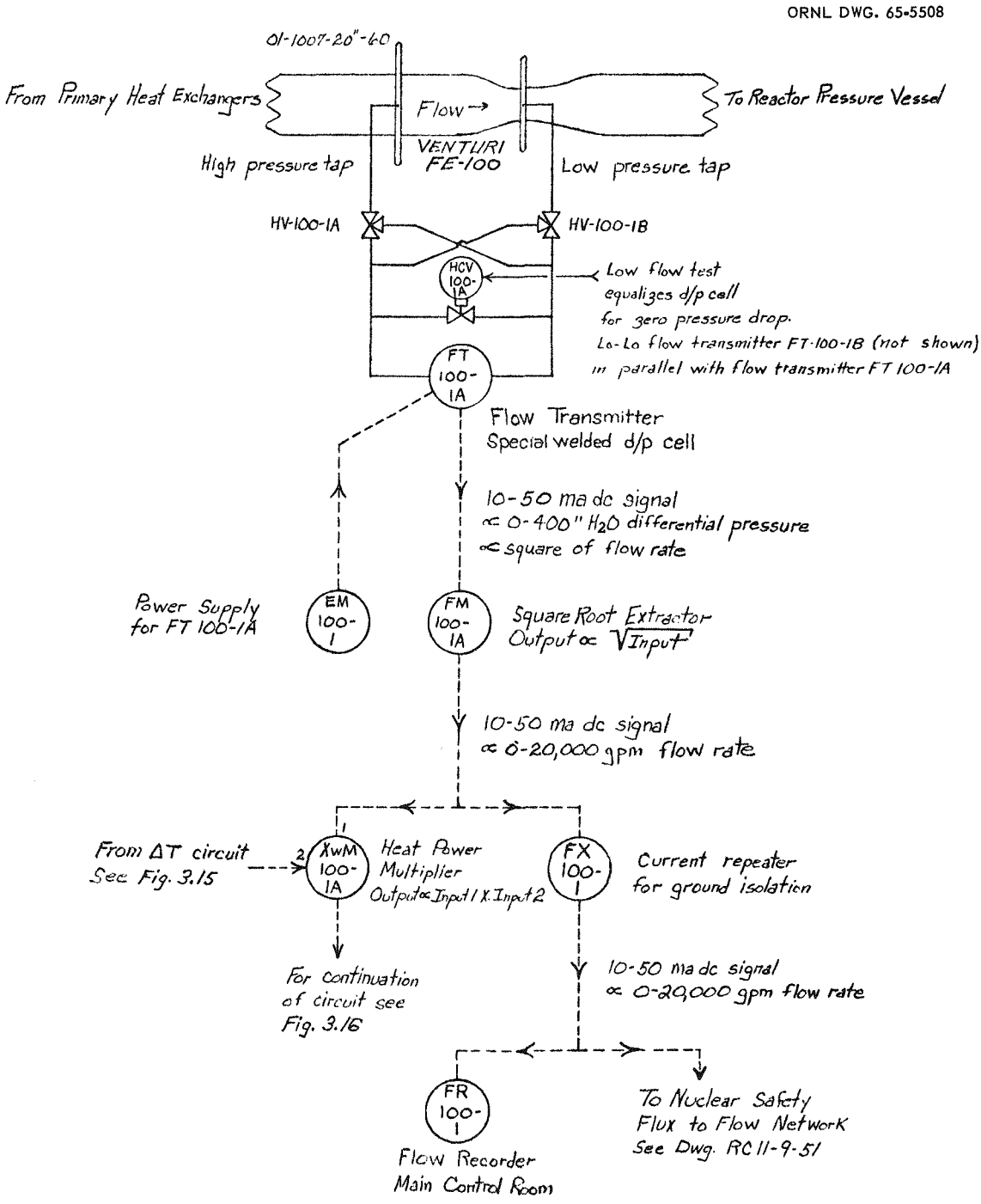


Fig. 3.14. Process Safety Primary Flow Instrumentation.

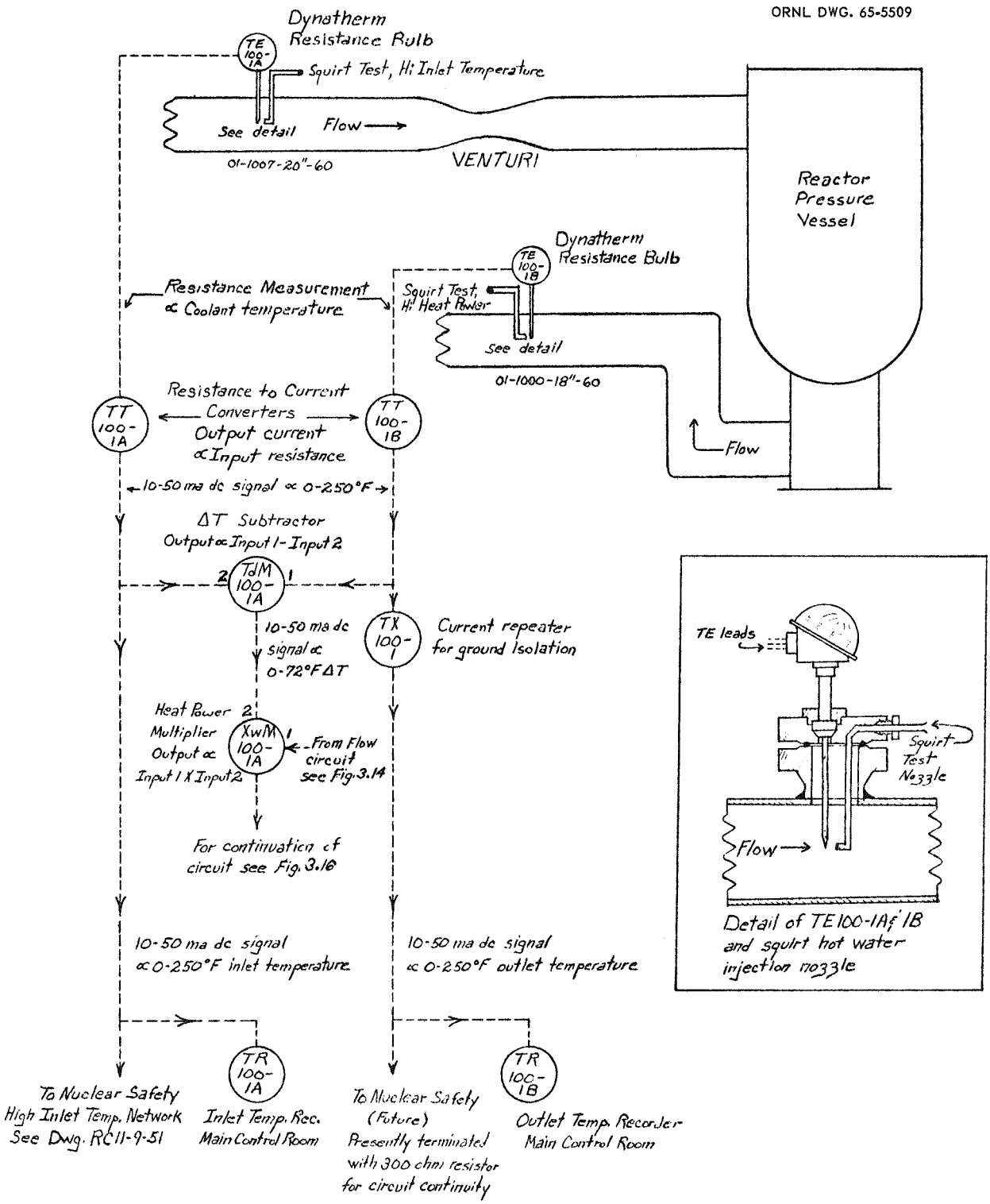
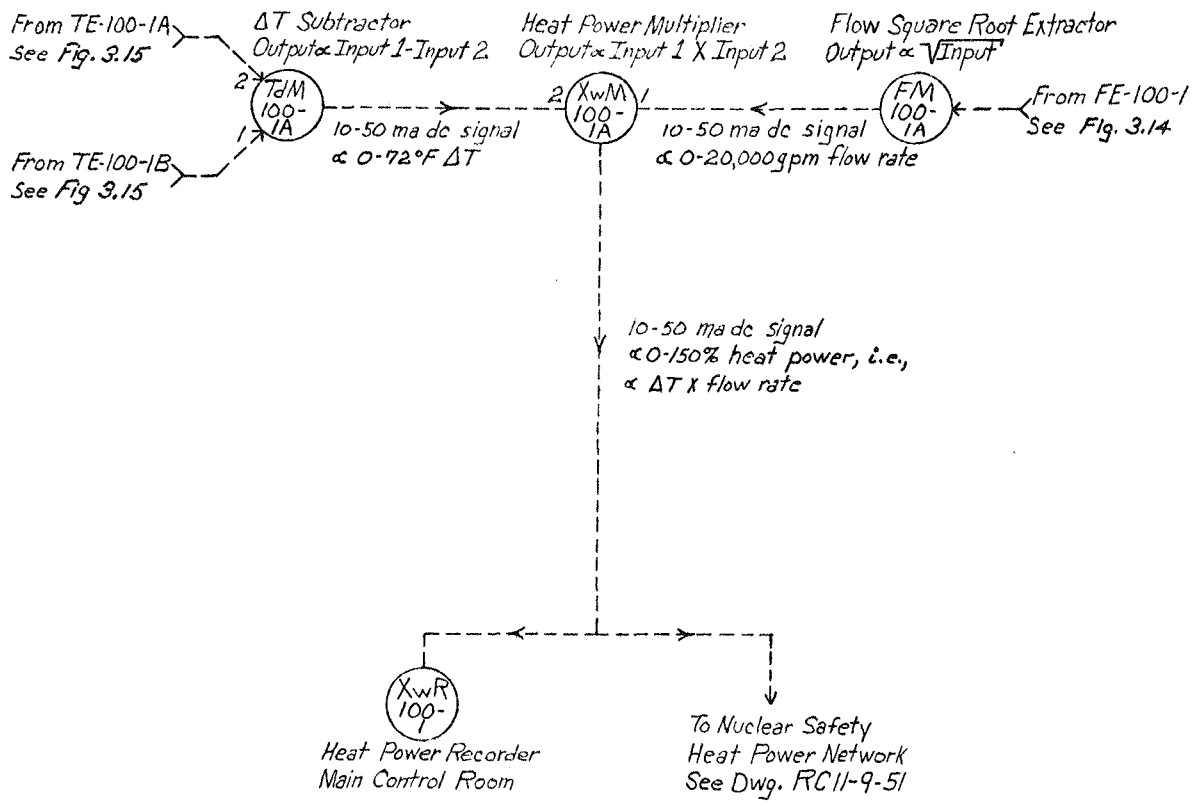


Fig. 3.15. Process Safety Primary Inlet and Outlet Coolant Temperatures and Core ΔT Instrumentation.

ORNL DWG. 65-5510



Instrument	Location
FT-100-1A	Inst. Monitoring Platform
EM-100-1	Auxiliary Control Room
FM-100-1A	Auxiliary Control Room
FX-100-1	Auxiliary Control Room
FR-100-1	Main Control Room
TE-100-1A	G-10 Pipe Tunnel
TE-100-1B	G-10 Pipe Tunnel
TT-100-1A	Inst. Monitoring Platform
TT-100-1B	Inst. Monitoring Platform
TdM-100-1A	Auxiliary Control Room
TX-100-1	Auxiliary Control Room
TR-100-1A	Main Control Room
TR-100-1B	Main Control Room
XwM-100-1A	Auxiliary Control Room
XwR-100-1	Main Control Room

Fig. 3.16. Process Safety Reactor Heat Power Instrumentation.

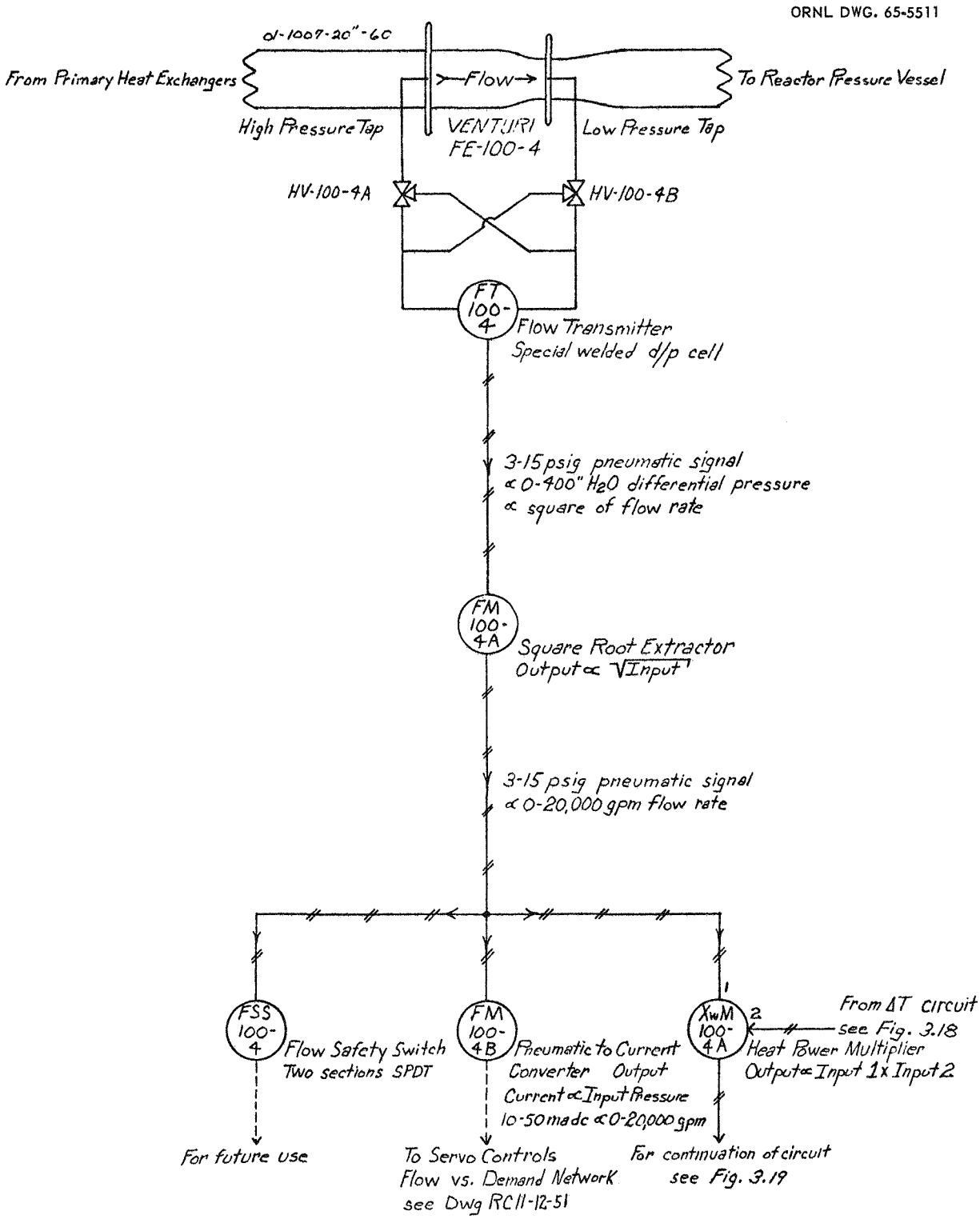


Fig. 3.17. Process Servo Primary Flow Instrumentation.

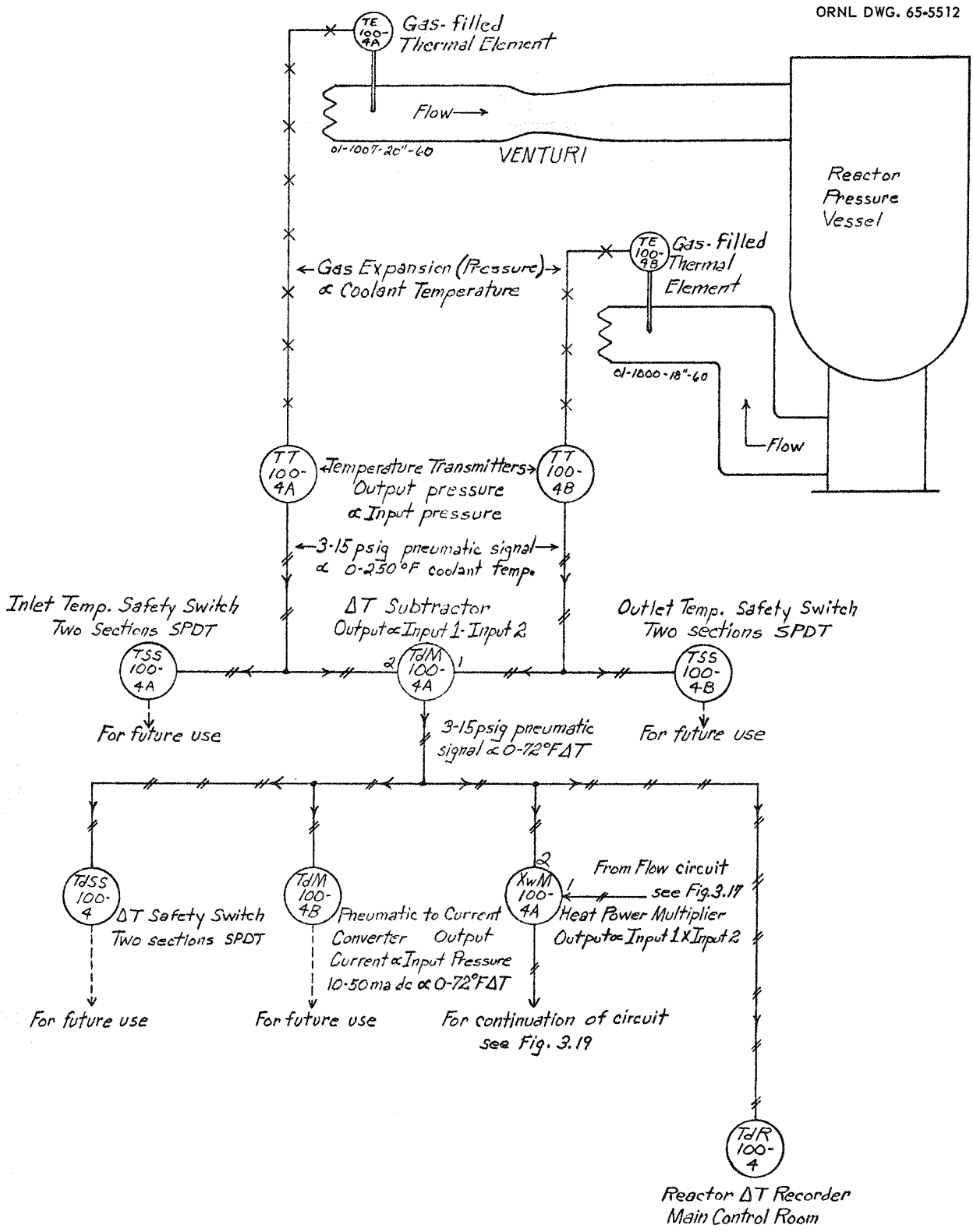
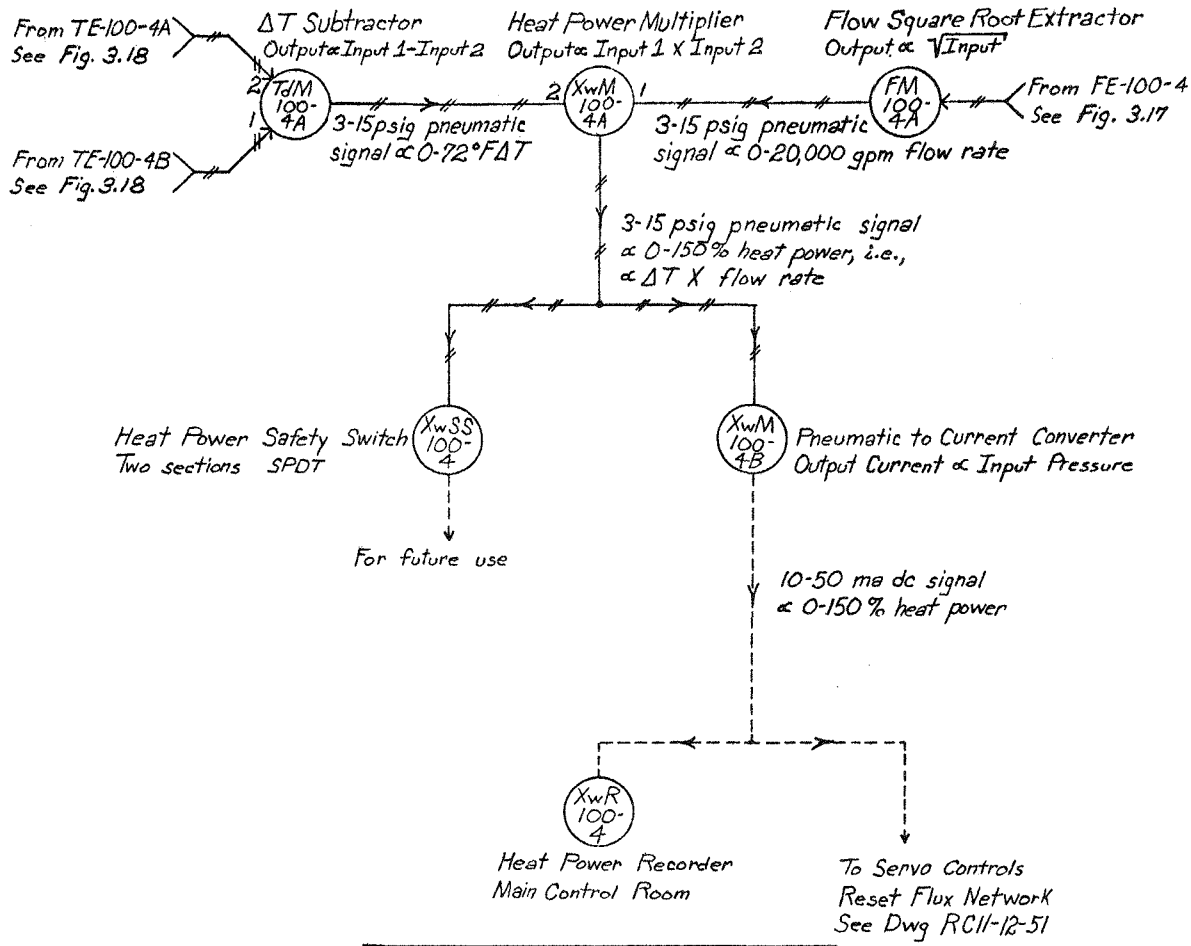


Fig. 3.18. Process Servo Primary Inlet and Outlet Temperatures and Core ΔT Instrumentation.

ORNL DWG. 65-5513



Instrument	Location
FT-100-4	Inst. Monitoring Platform
FM-100-4A	Auxiliary Control Room
FM-100-4B	Auxiliary Control Room
FSS-100-4	Auxiliary Control Room
TE-100-4A	G-10 Pipe Tunnel
TE-100-4B	G-10 Pipe Tunnel
TT-100-4A	Inst. Monitoring Platform
TT-100-4B	Inst. Monitoring Platform
TSS-100-4A	Auxiliary Control Room
TSS-100-4B	Auxiliary Control Room
TdM-100-4A	Auxiliary Control Room
TdM-100-4B	Auxiliary Control Room
TdSS-100-4	Auxiliary Control Room
TdR-100-4	Main Control Room
XwM-100-4A	Auxiliary Control Room
XwM-100-4B	Auxiliary Control Room
XwSS-100-4	Auxiliary Control Room
XwR-100-4	Main Control Room

Fig. 3.19. Process Servo Heat Power Instrumentation.

of the associated safety channel, which energizes a solenoid valve to relieve diaphragm pressure in the bypass valve operator.

Each of systems 100-4, 100-5, and 100-6 has a single differential pressure cell flow measurement device, derives its actuating signal from a separate pair of pressure taps, and serves a different servo channel. The flow transmitter in each system develops a standard 3- to 15-psig pressure signal, which is utilized in the reactor heat power calculator of the associated servo channel. Each pressure signal is also converted to a 10- to 50-milliamp current signal, which is utilized as a limiting servo demand signal and as a variable reference signal in a portion of the servo system which automatically reduces the regular servo demand setting to a level permitted by coolant flow. There is no provision for in-service testing of servo flow measurement systems, nor is there any readout of flow.

Related to the primary flow instrumentation is the "water system check," an arrangement of starter auxiliary contacts and relays whereby all of the primary loop circulating pumps, in addition to certain other pumps, must be in service before reactor startup is permitted.

3. Loop temperatures.

Control of the primary loop temperature is effected by manual control of the heat exchangers secondary water flow and indirectly by automatic control of the secondary loop cooling tower discharge water temperature entirely independent of

primary loop instrumentation. The primary loop temperature instrumentation provides information to the operator and to the reactor control and safety system (Figures 3.15 and 3.18). Each of systems 100-1A, -2A, and -3A measures reactor inlet temperature in the approach piping; and corresponding systems 100-1B, -2B, and -3B measure reactor outlet temperature in the vessel discharge piping, all by means of resistance elements. The temperature signals are converted to standard 10- to 50-milliamp current signals which are utilized in the associated safety channels to drive the inlet and outlet temperature recorders (TR-100-1A, etc.) to develop the heat power signals in the channel heat power computers and to actuate the "high inlet temperature" scram elements. A series of hot-water injectors is provided in order to test the safety system temperature responses; individual injectors discharge on command from the "Inlet Temperature Test" and "Heat Power Test" (outlet temperature) pushbuttons on the console. Instrumentation is provided to monitor the performance of the test system, as described below under "Primary Coolant System - Auxiliary."

Elements 100-4A, -5A, and -6A, inlet, and 100-4B, -5B, and -6B, outlet, are the servo system temperature sensors corresponding in location to the above safety system sensors. They are of bulb-and-capillary type and actuate pneumatic transmitters directly. The temperature pneumatic signals are utilized only in the servo system heat power computers.

(Recordings are provided of each inlet-outlet differential temperature by means of TdR 100-4, -5, and -6 on Panel E.) There is no provision for perturbing the loop water temperature in order to test the servo temperature response, as for the safety system.

Thermocouples 105-1A and -1B,, -2A and -2B, -3A and -3B, and -4A and -4B are installed in the pairs indicated, at the tips of the four water-sampling probes of the N^{16} monitor system. By virtue of their quadrature locations directly beneath the core, these sensors are intended to supplement the N^{16} sampling system in determining power unbalance (flux tilt) or instability conditions in the core. The "A" sensors are read on multi-point recorder TR-129, and the "B" sensors are connected to points on the console selector switch, whereby they may be read individually on TI-1040. Additional temperature instrumentation in the primary loop is described below in association with the particular equipment monitored.

4. Radioactivity due to fuel element cladding failures.

In addition to the core outlet gross activity monitors associated with the safety system (see Section 3.2g), systems 200 and 253 provide sensitive detection of fission-product activity. Both of the latter systems monitor the same sample stream, which is withdrawn from the primary coolant loop just beyond the core exit. Flow in the sample line is regulated and indicated locally by pneumatic instruments including a flow transducer, indicator-controller, and control valve; flow is blocked automatically by another pneumatically operated valve, which closes

when any two safety system faulty fuel element detectors request scram.

Following the valves in the sample line are (1) a delay section, (2) the counting volume and BF_3 neutron detector of system 200, (3) a second delay section, and (4) the dual-GM tube beta-gamma detector of system 253. The line discharges to the letdown system.

The total delay from core exit to the system 200 counting volume is 18 seconds, sufficient for most of the ^{17}N neutron activity to decay. Consequently, delayed neutron activity of ^{137}I is responsible for most of the background counts developed by the BF_3 detector. Iodine-137 background, plus a small background of ^{87}Br activity, will result from normal surface contamination in the core. A prompt and significant increase of ^{137}I activity would result from a release of gaseous fission products in the event of a small breach of the fuel cladding. Conventional counting arrangements, including pulse amplifier and discriminating and pulse-shaping circuitry, develop the pulse information to the output log count-rate form. The log count rate is displayed locally at the cladding failure detector cabinet in the auxiliary control room and on radiation recorder 1000 in the main control room. A contact in the local recorder, designated IC-89, actuates annunciator point C-13 when the count rate is approximately twice equilibrium background.

The total delay from core exit to the system 253 radiation detectors is about 68 seconds, sufficient for most of the

water activation beta and gamma background to decay. This permits the system to identify increases in beta and gamma activity resulting from escape of fission products from the fuel elements into the coolant. A "Linear-Log Radiation Monitor" (Q-2353) monitors this activity at the cladding failure detection cabinet in the auxiliary control room providing local indication. High radiation, approximately twice background, or downscale failure of the monitor instrument is annunciated on point 4E-22.

5. Reactor vessel inlet filter pressure drop.

   Pneumatic system 103 provides local indication on PdI-103 of differential pressure across the reactor vessel inlet filter.

6. Reactor vessel pressure drop.

   Pneumatic system 106 monitors total pressure drop across the reactor vessel and inlet filter. A recording of this quantity is provided on PdR-106 in the control room; and the system actuates the high and low vessel differential pressure annunciator points, 1E-21 and -22.

7. N^{16} sampling system.

   System 141 is intended to monitor for flux unbalance ("tilt") in the reactor, via differences in N^{16} activity in the coolant water from different core outlet points. The system samples water from four probes in quadrature, each at a point below the fuel annulus and on a radius that bisects a shim-safety control plate. The probes are sequentially valved into a common header, from which the sampled water is passed through

a collimator and discharged to the letdown system. A scintillation detector measures the collimated gamma radiation. The information is processed by suitable amplification, pulse shaping, pulse selection, and integrating circuitry in the N^{16} monitoring cabinet in the auxiliary control room. Final output of the system is the display on a multi-point recorder in the control room. The recorder automatically controls the sampling probe valving on a 30-second cycle; printout is at the end of the cycle in order to allow for line purging. A selector switch on the recorder permits the system to hold on one probe. A pneumatic system, consisting of a flow transmitter and local indicator, monitors flow in the sample line N^{16} recorder. The line from each probe is equipped with a manual block valve, a manual metering valve to adjust flow, and a pneumatic block valve which closes when two safety system failed fuel element detectors request scram. Controls for the manual valves are on the wall of the subpile room.

8. Heat exchanger performance.

Two thermocouples, No. 107-A and -B are mounted together on the main piping ahead of the heat exchanger branches, to measure the common exchanger inlet temperature. Thermocouples TE-136, -137, -138, and -139 are located, respectively, in the primary discharge lines of exchangers 1A, 1B, 1C, and 1D. All of the foregoing are connected to points of a selector switch on the control room console and may be read individually on TI-1040.

9. Main circulating pumps.

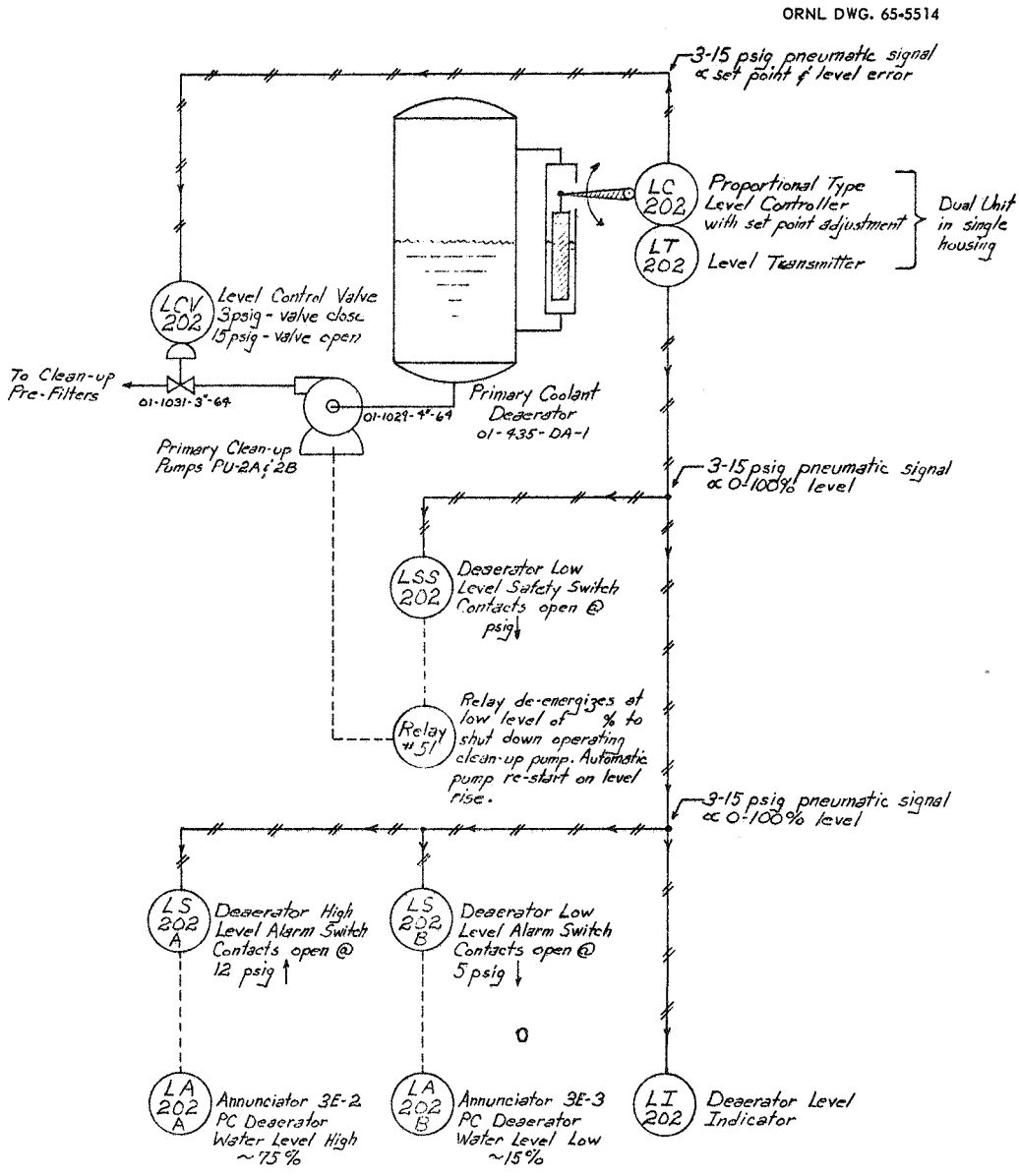
Local pressure indicating instruments are installed in the inlet and outlet of each pump. Instrumentation is provided for the pump motor loads, vibration, and temperatures, as described in Section 6, "Circulating Pumps." The pump gland system flow is monitored as described below under "Primary Coolant System - Auxiliary."

10. Primary cleanup and pressurization.

The quantity of water diverted from the primary loop into the deaerator vessel of the cleanup and pressurization system is controlled by the letdown and block valves as described under (1) above. Additional instrumentation is as follows:

a. Deaerator level.

Level controller 202 in pneumatic system 202 (Figure 3.20) senses level in the deaerator vessel and actuates (a) level indicator 202 in the control room; (b) high- and low-level annunciation switches for points 3E-2 and -3; (c) a switch that shuts down the primary cleanup system pumps on low level; and (d) control valve LCV-202, which regulates the rate of withdrawal of water from the deaerator by the cleanup system pumps. On extreme high, or flooding level, the direct-acting level switch of system 204 initiates annunciation on point 3E-1 and closure of the steam supply valve for the jet ejectors. Setpoint adjustment only is available to level controller 202.



Instrument	Location
LC-202	Adjacent Primary Deaerator
LT-202	Adjacent Primary Deaerator
LSS-202	Outside Cell 104
LS-202-A	Auxiliary Control Room
LS-202-B	Auxiliary Control Room
LI-202	Main Control Room
LA-202-A	Main Control Room
LA-202-B	Main Control Room
LCV-202	Cell 104
Relay #51	Motor Control Center "B"

Fig. 3.20. Primary Coolant Deaerator Level Control System 202.

b. Deaerator loss of vacuum.

Pneumatic system 201 senses pressure (vacuum) in the deaerator vessel, indicating same on PI-201 in the control room. A loss of vacuum annunciation switch is also actuated by the system when the vessel pressure exceeds -20 in. Hg, alarming on point 3E-4.

c. Local deaerator monitors.

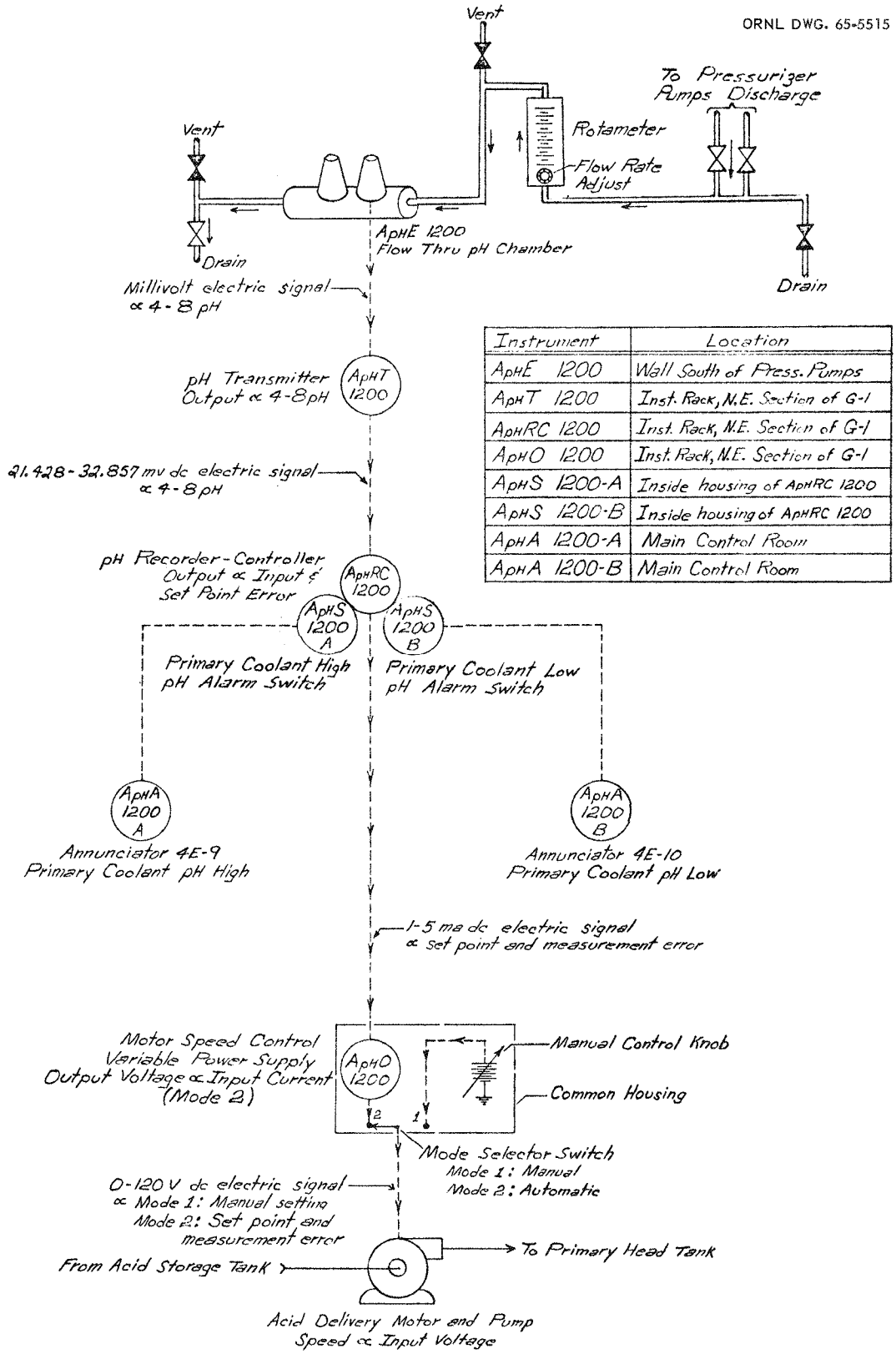
Local indicating instruments monitor pre- and after-condenser primary pressures (vacuum) and primary discharge temperatures, ejector steam supply pressure, deaerator inlet and outlet water temperature.

d. Primary cleanup system pumps.

Local indicators for the inlet and outlet pressure of each pump.

e. Primary loop pH and conductivity.

System 203 measures pH and conductivity of a sample stream in the cleanup system pumps discharge header. The sample is discharged to the ILW system. Conductivity is indicated on one point of conductivity recorder CR-1020, and pH on one point of pH recorder ApH-1010, all in the control room. The pH of the primary coolant water is maintained at 5.0 by controlling the pH of the water in the primary water head tank (Figure 3.21). Transmitter ApHT-1200 senses the pH of a sample stream of water taken from the pressurizer pump discharge line and actuates local recorder-controller ApHRC-1200. The milliamp dc output signal from the



Instrument	Location
ApHE 1200	Wall South of Press. Pumps
ApHT 1200	Inst. Rack, N.E. Section of G-1
ApHRC 1200	Inst. Rack, N.E. Section of G-1
ApHO 1200	Inst. Rack, N.E. Section of G-1
ApHS 1200-A	Inside housing of ApHRC 1200
ApHS 1200-B	Inside housing of ApHRC 1200
ApHA 1200-A	Main Control Room
ApHA 1200-B	Main Control Room

Fig. 3.21. Primary Coolant pH Control System 1200.

controller is then converted by operator ApHRC-1200 to a 0-120 volt dc range to control the speed of the pump delivering the acid solution to the primary water head tank, in order to hold the pH of the system at the desired value. Excessive deviations above or below setpoint actuate limit switches in the recorder section of ApHRC-1200 for high or low pH annunciation in the control room on points 4E-9 and 4E-10. Operator ApHO-1200 is furnished with a mode switch and a manual control knob which may be used to manually control the pH (i.e., acid pump speed) of the primary system.

f. Primary cleanup system filters.

Local indicators are provided for the pressure in the filter inlet and outlet common headers for use in determining pressure drop across filters. A flow glass in the common vent header exhibits a rise of liquid level on failure of filter vent ball float traps.

g. Primary cleanup system demineralizers.

Flow glasses are provided in the vent line of each demineralizer vessel, for use in locating leaking ball float traps. Two local pressure indicators are installed, one in the interconnection piping of each anion/cation pair. Local pressure indicators are also provided at the inlet and outlet of the demineralizer recycle pump. Rotameter flow indicators measure the transfer flow of caustic and acid solutions from their day tanks to the demineralizer system during regeneration operations.

g. Primary cleanup system demineralizers

Flow glasses are provided in the vent line of each demineralizer vessel, for use in locating leaking ball float traps. Two local pressure indicators are installed, one in the interconnection piping of each anion/cation pair. Externally mounted differential pressure indicators are also provided for each of the demineralizer columns. Local pressure indicators are also provided at the inlet and outlet of the demineralizer recycle pump. Rotameter flow indicators measure the transfer flow of caustic and acid solutions from their day tanks to the demineralizer system during regeneration operations.

h. Demineralizer after-filter

Pressure indicators and a differential pressure gauge are installed locally at the after-filter inlet and outlet to monitor for clogging.

i. Demineralizer effluent contamination

System 127 samples the primary demineralizer effluent beyond the after-filter and measures pH and conductivity. These quantities are indicated locally and recorded in the control room on multi-point recorders CR-1020 (conductivity) and ApHR-1010 (pH). In addition, CA-217A annunciates locally and in the control room on 4E-8 and CE-291 diverts the after-after filter exit flow to PWD in the event the demineralizer discharges very poor quality water into the primary head tank. R

j. Primary water head tank level

Pneumatic system 214 (Fig. 3.23) senses the level in the primary water head tank and transmits a signal which actuates (a) a switch that initiates low-level annunciation

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on point 4E-11, (b) level indicator LI-214 in the control room, (c) a switch that initiates pressurizer pump shutdown on low level, and (d) the level controller LC-214 which positions the demineralized water makeup valve. The loading station has indicators for set point and level measurement pressure.

Pneumatic system 214A provides a backup for system 214 by sensing the level in the primary water head tank and transmitting a signal which actuates (a) a switch that initiates low-level annunciation on point 4E-12, (b) local level indication, and (c) a switch that initiates pressurizer pump shutdown on low level.

Pneumatic system 215 senses flow in the demineralized water makeup line to the primary head tank and provides separate local indication and remote recording of this flow in the control room. A switch in this system ini- R
tiates annunciator 4E-16 at a makeup rate of 15 gpm.

k. Pressurizer pump performance

Local pressure-indicating instruments are provided to read the inlet and outlet pressure of each of the main pressurizer pumps PU-4A and -4B and the emergency primary feed pump, PU-11. Instrumentation is provided for the pump motor loads as described in Section 6, "Pressurizer Pumps." Systems 176, 177, 178, and 179 regulate the speed of the pressurizer pumps and indicate the speed in the control

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h. Demineralizer after-filter.

Pressure indicators are installed locally at the after-filter inlet and outlet to monitor for clogging.

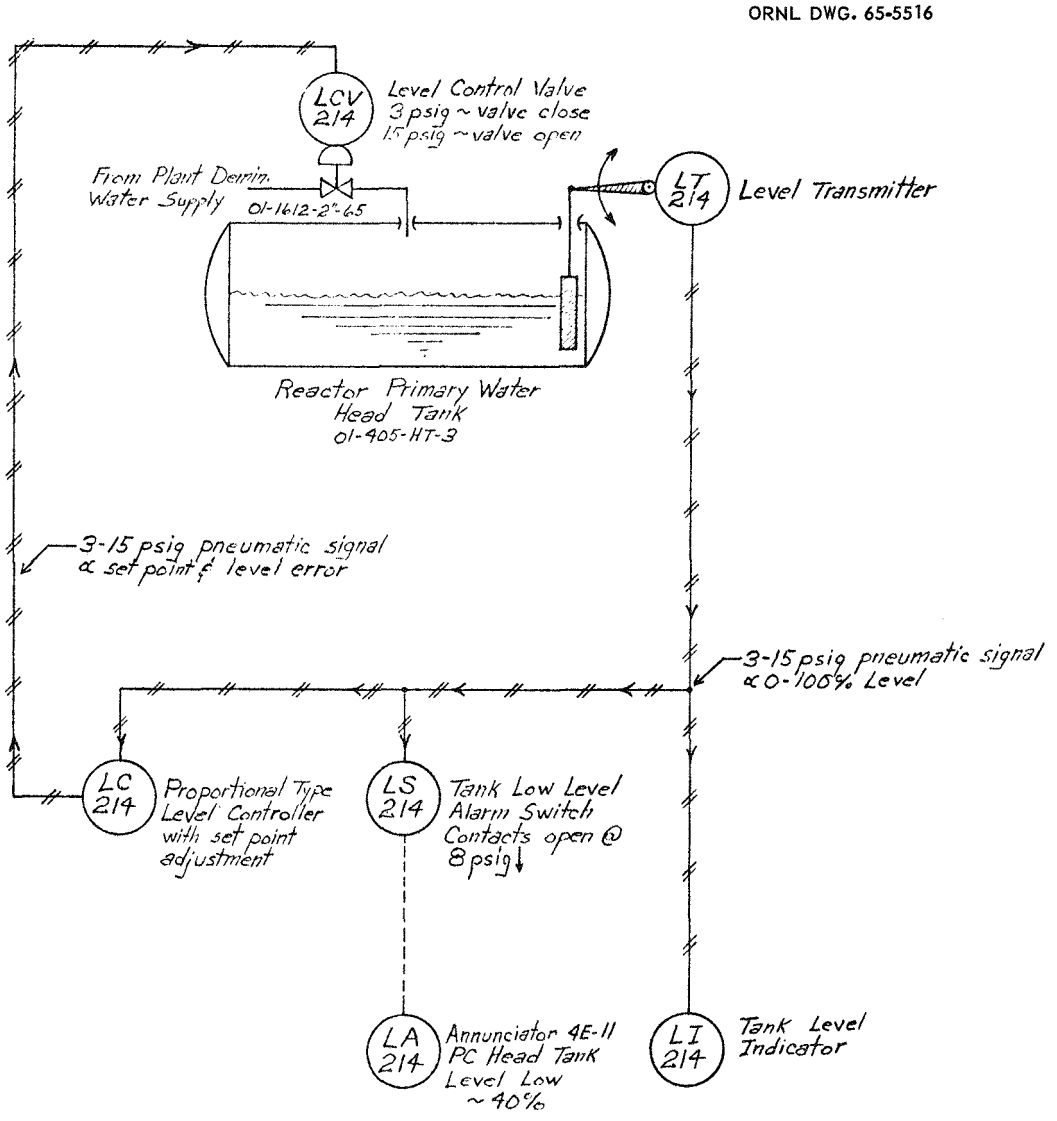
i. Demineralizer effluent contamination.

System 217 samples the primary demineralizer effluent beyond the after-filter and measures pH and conductivity. These quantities are indicated locally and recorded in the control room on multi-point recorders CR-1020 (conductivity) and ApHR-1010 (pH).

j. Primary water head tank level. Pneumatic system 214 (Figure 3.22) senses the level in the primary water head tank and transmits a signal which actuates (a) level indicator LI-214 in the control room, (b) a switch that initiates low-level annunciation on point 4E-11, and (c) the level controller LC-214 which positions the tank inlet valve from the demineralized water supply pumps (makeup). The controller and its manual loading station for setpoint adjustment are in the auxiliary control room. The loading station has indicators for setpoint and level measurement pressures. Pneumatic system 215 senses flow in the makeup line from the demineralized water supply pumps to the primary head tank and provides separate local indication and recording of this flow.

k. Pressurizer pump performance.

Local pressure indicating instruments are provided to read the inlet and outlet pressure of each of the main pressurizer pumps PU-4A and -4B and the emergency primary



Instrument	Location
LT-214	Atop PC Water Head Tank
LC-214	Auxiliary Control Room
LS-214	Auxillary Control Room
LI-214	Main Control Room
LA-214	Main Control Room
LCV-214	Vicinity PC Water Head Tank

Fig. 3.22. Reactor Primary Water Head Tank Level Control System 214.

feed pump, PU-11. Instrumentation is provided for the pump motor loads as described in Section 6, "Pressurizer Pumps." Systems 176, 177, 178, and 179 regulate the speed of the pressurizer pumps and indicate the speed in the control room. The systems attempt to regulate the pump speeds at any value set into the controller by the control room adjustment by varying automatically the electric current supplied to the magnetic clutch. The current will vary with pump torque requirement. Water cooling of the magnetic clutch is initiated by the opening of a solenoid valve simultaneously with motor startup. Flow is subsequently regulated to effect a clutch temperature of 135°F by means of a control valve responsive to a gas bulb temperature detector in the clutch housing. The pump motor is shut down automatically by a temperature switch when the housing temperature exceeds 165°F or by a pressure switch when the water supply to the control valve falls below 7.5 psi. The low-pressure condition can result from failure of the solenoid valve to open initially, or to remain open, while the pump motor is energized.

1. Primary loop input.

   The temperature of the water discharged by the main pressurizer pumps is monitored by a thermocouple, whose output may be read on TI-1040 at the console. The pressure of the water ahead of the check valve separating the loop and the pressurizer pump discharge piping is indicated locally.

Pneumatic system 216 senses total flow from the low-pressure system to the primary loop, the shim plate seals, and the normal primary coolant pump seal supply. The flow signal is recorded in the control room on FR-216. It is used to actuate a switch on low flow that starts the emergency pressurizer pump when the emergency pump is in "automatic" control mode.

m. Primary cleanup system radiation detection. Water samples are withdrawn from the inlet line to the primary cleanup system filters, from the discharge line of the after filter, and from nine intermediate points in the primary cleanup system. Along with three sample lines from the pool's coolant system, these are discharged into a sink designated sample station No. 1. Radiation system 250 senses high radiation in the sink, actuates a local alarm and control room annunciation on point 4E-13, and initiates closure of solenoid valves in seven of the sample lines. A second radiation system, No. 213, monitors the primary cleanup system outlet at a point downstream from the after-filter. The detector RE-213 senses any gross low-level activity and actuates (a) local indicator RI-213 and (b) one point on the multi-point recorder RR-1000 in the control room. The linear-log radiation electrometer, ORNL type Q-2353, incorporates a relay which actuates an annunciator point in the control room on either high radiation or downscale failure.

n. Miscellaneous.

A local indicator, PI-235, is provided to read pressure in the direct letdown line (01-1012-2). The indicator is for use when both valves of the line are closed off and the primary loop is pressurized; appearance of a pressure reading signifies undesirable leakage of a line isolation valve. A local rotameter, FI-228, measures the flow of demineralized water from pumps PU-18A and -18B to the primary cleanup system filters during back-flush operations.

System 248 includes control valve HCV-248A, whose purpose it is to create a restriction in the line between the pressurizer pumps and the primary loop. Local indicator-controller HIC-248 normally regulates the control valve position so as to produce a constant pressure drop, which is the source of water flow to the loop circulating pump seals and to the hot water test injection system. Operation of any of the temperature test initiating pushbuttons energizes a solenoid valve, HCV-248B, which allows instrument air to bypass HIC-248 and drive HCV-248A toward closed position. This increases the pressure drop, effectively raising the pressure available to drive water through the test injectors. A local pressure indicator, PI-249, displays the pressure downstream of the valve restriction.

11. Primary coolant system - auxiliary.

a. Main circulating pump bearing seals.

The flow of water from the high-pressure loop or emergency pressurizer pump to each main circulating pump seal is monitored by the following local instrumentation: (a) inlet pressure indicator in supply line from high-pressure loop only, (b) inlet flow indicator, (c) pressure indicator for outlet of first seal stage, (d) pressure indicator for outlet of second seal stage, (e) flow indicator for seal outlet, and (f) pressure indicator for seal outlet. At the same points as (a) and (f) above are switches to provide inlet flow and low and high outlet pressure actuation of the "pump seal" annunciator point for each pump, 2E-1 through -4. Item (e) above also incorporates a switch that was originally intended to initiate actuation of two pneumatic valves, each in parallel with a manual bypass valve around a seal stage. This system is not to be used initially, however. The low-flow switch is connected to actuate the "pump seal" annunciator point, along with the other switches mentioned above.

b. Safety system temperature test hot water injector supply.

The steam flow to the heat exchanger is controlled by a system in which the exchanger outlet water temperature is sensed by TE-1101, the information is fed by TT-1101 to indicator-controller TIC-1102, which positions pneumatic control valve TCV-1124A in the steam line. Valve

HCV-1124B is in parallel with TCV-1124A, and opens to admit additional steam whenever the command is given to inject hot water. In automatic mode, TIC-1102 regulates steam flow so as to maintain a constant water outlet temperature from the heat exchanger secondary; both the water temperature and controller output pressure to the steam valve are indicated. The setpoint for automatic regulation is adjusted by a control on the face of the instrument and displayed on an index scale. Manual mode may be selected whereby the operator may position the steam valve according to a separate manual control index on the lower part of the instrument. Local pressure indicator PI-1123 measures the steam pressure ahead of the exchanger inlet valves.

The hot water supply to the injectors is monitored as follows:

(1) TIC-1102 in the control room indicates exchanger water outlet temperature.

(2) PI-1120 indicates local exchanger outlet pressure.

(3) TE-1104 is a thermocouple whose output is run to a selector switch supplying temperature indicator TI-1040 in the control room.

(4) FE-1105 measures total flow to the injectors; the associated pneumatic transmitter output actuates flow indicator FI-1107 in the control room.

c. Primary loop water storage.

A purge bubbler in system 429 senses the water level in the storage tank compartment No. 2 and pneumatically transmits an indication to LI-429 in the control room.

3.3d. Pool Coolant System

The instrumentation associated with the pool coolant system is such as to provide information and/or control of pool level and flow, temperature, and contamination of the coolant water circulating through the loop. The instruments, switches, valves, etc., may conveniently be grouped as individual systems according to their functions in overall loop control.

1. Loop flow.

Since the overflow to the drain scuppers is the source of water for the pool coolant pumps, the system as such is self-regulating and there is no need for a flow control valve. The desired flow distribution among the pools may be achieved by proper positioning of the motor-driven valves in each of the return lines to the pools.

All-pneumatic systems 425, 441, and 468 sense the coolant flow rate from the heat exchangers to the reactor, critical, and combined clean pools, respectively, and provide control room indication of these measurements.

2. Loop temperatures.

Since the secondary water to the pool heat exchangers is maintained at a constant temperature by the action of the cooling tower control system (310) as described in Section

3.3e, the pool water temperature is held at 90°F by regu-ting the flow of secondary coolant water to the heat exchanger.

Pneumatic system 330 measures the common exit temperature on the primary side of the heat exchangers, indicates it locally, and actuates control valve TCV-330 in the secondary coolant line to the heat exchangers to automatically maintain the desired pool water temperature. Temperature controller TIC-330 is provided with setpoint adjustment only. Thermocouple 424 monitors the common inlet temperature to the pools. Thermocouples 430, 452, 459, and 455 monitor the exit temperature of the critical pool, the two clean pools, and reactor pool, respectively. All of the foregoing are connected to points on a selector switch at the console in the control room and may be read individually on TI-1040.

3. Pool level.

Float switches 422, 457, 458, and 463, located in the drain scuppers of the reactor, critical, and the two clean pools, respectively, monitor the water level and provide both high- and low-level annunciation in the control room. The annunciator points are 3E-9 and -10, -21 and -22, -13 and -14, and -17 and -18. Should a high level occur in either of the two clean pools, the pool demineralizer pumps will automatically be stopped. A high level in the reactor pool or critical pool will stop the pool coolant pumps.

These high-level shutdowns require a resetting of the pump control circuits before the affected pump can be placed back on the line, if the high-level condition persists for longer than sixty seconds. This reset action is accomplished by placing the appropriate pump control switch (SS9, 10, 11, 12) momentarily in the "off-reset" position.

4. Pool surge tank level.

The water level in the pool surge tank is automatically maintained at 50% full capacity by the all-pneumatic system 401 (Figure 3.23). The controller LCT-401 senses the level in the tank and actuates (1) level indicator LI-401 in the control room, (2) a low-level annunciator switch for alarm on point 3E-16, (3) a switch that shuts down the pool coolant pumps on low level (pump reset required), and (4) control valve LCV-401 which regulates the flow of demineralized makeup water to the tank. Setpoint adjustment only is available to level controller LCT-401.

Pneumatic system 407 senses the flow in the demineralized water makeup line and provides separate local indication and recording of this flow rate.

5. Loop pH and conductivity.

System 217B measures the pH and conductivity of a sample stream between the surge tank and the pool coolant pumps. These quantities are indicated locally and recorded in the control room on multi-point recorders ApHR-1010 and CR-1020.

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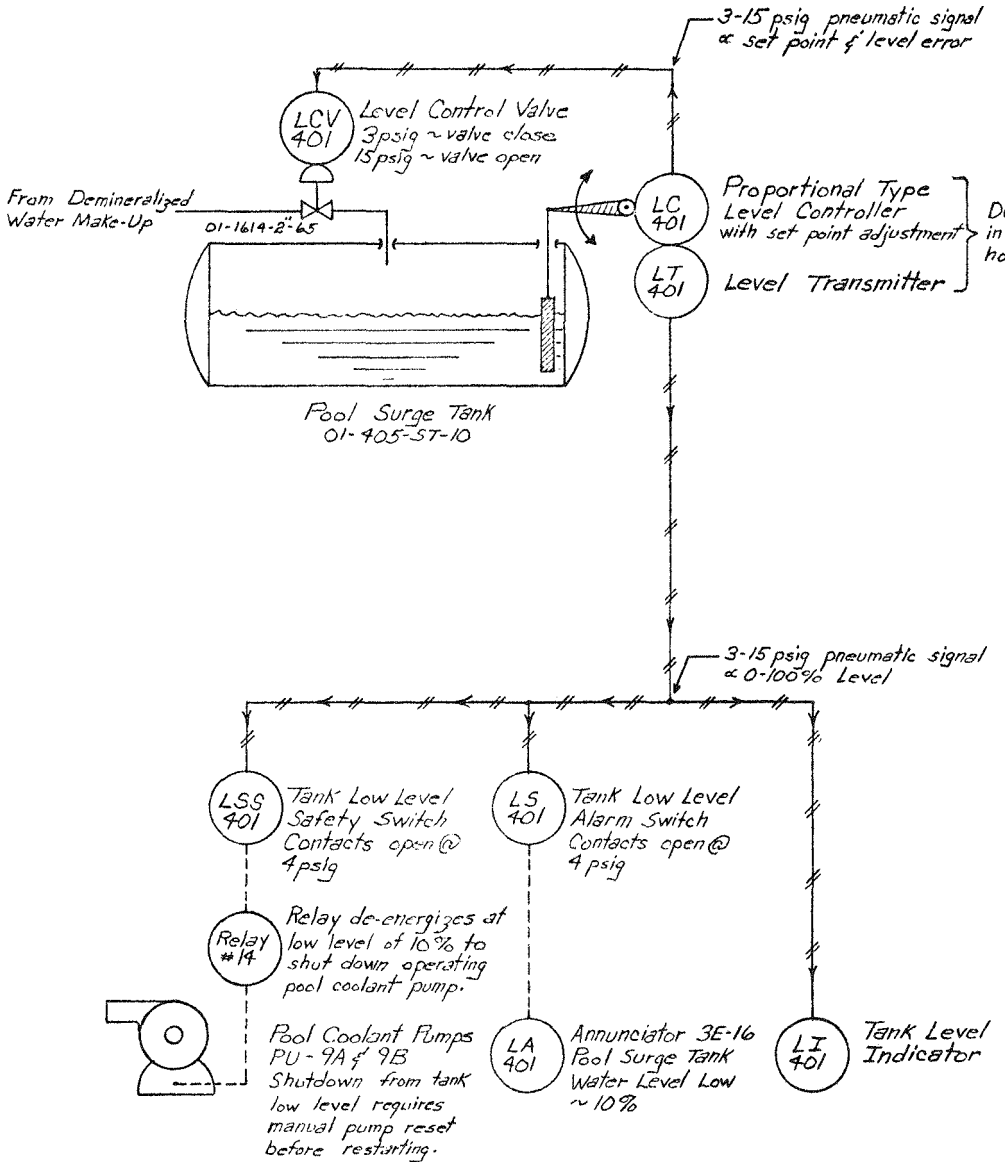


Instrument	Location
LC-401	Atop Pool Surge Tank
LT-401	Atop Pool Surge Tank
LI-401	Main Control Room
LSS-401	Auxiliary Control Room
LS-401	Auxiliary Control Room
LA-401	Main Control Room
LCV-401	Above Pool Surge Tank
Relay #14	Auxiliary Control Room

Fig. 3.23. Pool Surge Tank Level Control System 401.

6. Coolant pumps.

   Local pressure-indicating instruments are installed in the inlet and outlet of each pump to aid in the startup operations as described in Section 6.3d of the procedures.

7. Pool filter.

   Local pressure indicators are installed in the inlet and exit filter piping for use in detecting the pressure drop across the filter. The filter exit pressure indicator also serves as the common inlet pressure to the heat exchangers. A flow glass in the filter OHOG vent line is provided to aid in the air-bleeding operations as described in Section 6.3d of the procedures.

8. Heat exchanger performance.

   Local temperature indicators are mounted in the common primary inlet and each primary outlet of the heat exchangers. In addition, thermocouple 432 monitors the combined primary outlet temperature; it is connected to a point on the console temperature point selector switch in the control room and may be read on TI-1040.

   Local pressure indicators are provided to monitor the combined inlet and outlet primary pressures of the heat exchangers.

9. Pool loop water radiation.

   Loop water is monitored for radiation by detector RE-423 which is strapped to the common pool exit piping. This measurement is indicated locally on RI-423 and recorded on multi-point recorder RR-1000 in the control room; high activity is annunciated on point 4E-17.

10. Pool water storage.

Purge bubbler system 428 senses the water level in the storage tank compartment No. 1 and pneumatically transmits an indication to LI-428 in the control room.

11. Pool coolant cleanup.

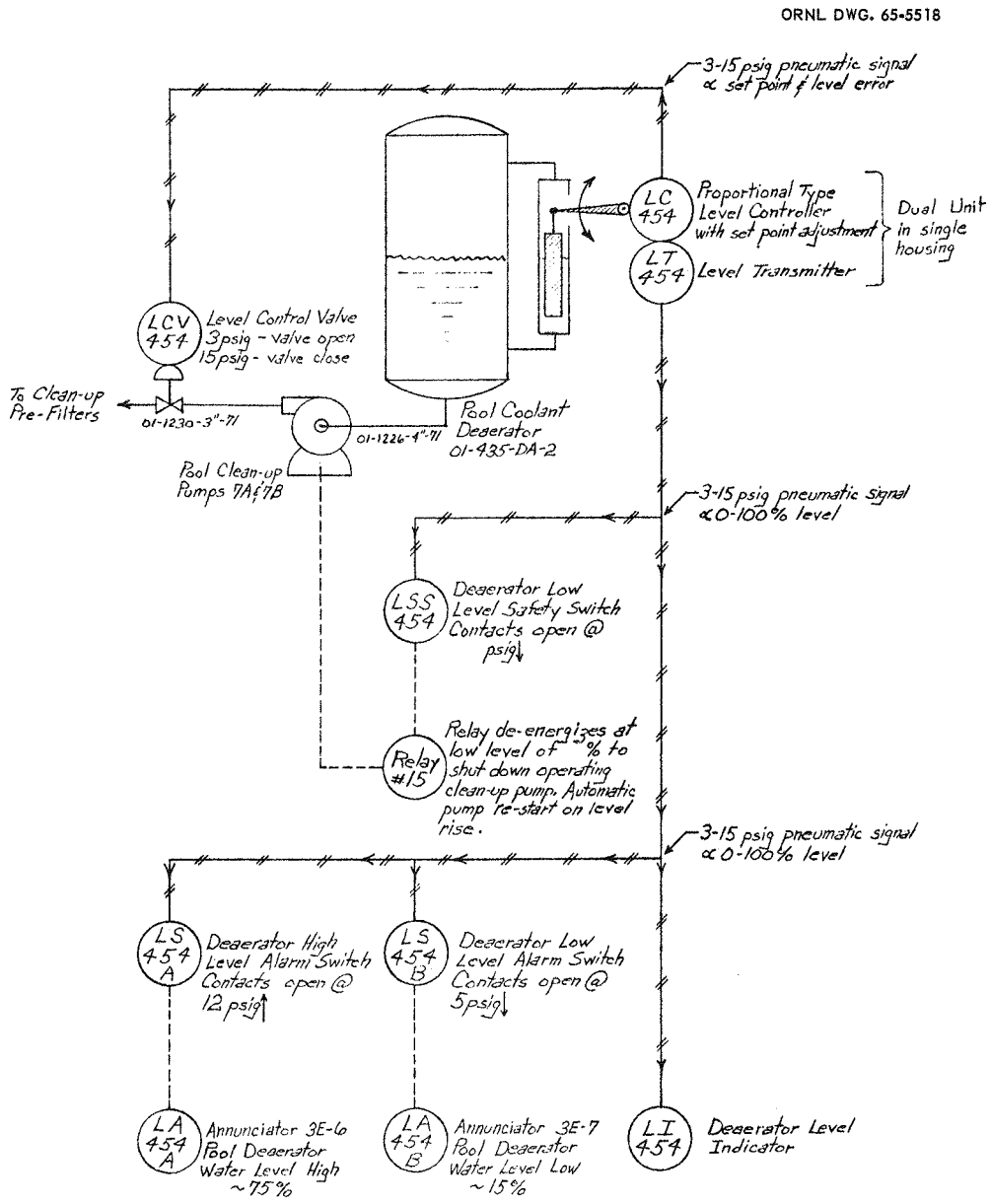
The quantity of water sucked through the defective fuel element storage tanks and into the deaerator vessel of the cleanup system is manually regulated by flow control valve FCV-469. Pneumatic system 460 provides a local indication of FI-460 of the flow rate of water into the cleanup system. Additional instrumentation is as follows:

a. Pool cleanup system radiation detection.

Radiation system 427 senses the amount of contamination in the water leaving the defective fuel element storage tanks. The detector RE-427, which is located in the line to the deaerator, actuates (a) local indicator RE-427, (b) one point on the multi-point recorder RR-1000 in the control room, and (c) a high activity alarm switch for control room annunciation on point 4E-18.

b. Deaerator level.

(See Figure 3.24.) Level controller LCT-454 senses the water level in the deaerator vessel and pneumatically actuates (a) level indicator LI-454 in the control room, (b) high- and low-level annunciator switches for points 3E-6 and -7, (c) a switch that shuts down the pool



Instrument	Location
LC-454	Adjacent Pool Deaerator
LT-454	Adjacent Pool Deaerator
LSS-454	Auxiliary Control Room
LS-454-A	Auxiliary Control Room
LS-454-B	Auxiliary Control Room
LI-454	Main Control Room
LA-454-A	Main Control Room
LA-454-B	Main Control Room
LCV-454	Cell 108
Relay #15	Auxiliary Control Room

Fig. 3.24. Pool Coolant Deaerator Level Control System 454.

demineralizer pumps (automatic restart on level rise), and (d) control valve LCV-454 which regulates the rate of withdrawal of water from the deaerator by the demineralizer pumps. Setpoint adjustment only is available to level controller LCT-454.

On extreme high, or flooding level, the direct acting level switch of system 476 initiates annunciation on point 3E-5 and closure of the steam supply valve LSV-476 for the ejectors.

c. Deaerator loss of vacuum.

Pneumatic system 400 senses the absolute pressure (vacuum) in the deaerator. An indication of this quantity is provided on PI-400 in the control room. A loss of vacuum annunciation switch is actuated by this system when the vessel pressure exceeds -20 in. Hg, to alarm on point 3E-8.

d. Local deaerator monitors.

Local indicating instruments monitor pre- and after-condenser primary pressures (vacuum) and primary discharge temperatures, ejector steam supply pressure, deaerator inlet and outlet water temperatures.

e. Pool demineralizer pumps.

Local pressure indicators are provided in the inlet and outlet of each pump.

f. Pool cleanup pre-filter.

Pressure gauges are installed in the inlet and exit filter piping for use in detecting the pressure drop across the filter.

A flow glass in the filter OHOG vent line is provided to aid in the air bleeding operations as described in Section 6.4d of the procedures.

g. Pool cleanup system demineralizers.

Pressure gauges are installed in the cation unit inlet, in the interconnecting piping of the cation/anion pair, in the anion unit outlet, and in the inlet and outlet of the demineralizer recycle pump.

Flow glasses are provided in the OHOG vent lines from the cation and anion units for use in system venting.

Rotameter flow indicators measure the transfer flow of caustic and acid solutions from their day tanks to the demineralizer system during the regeneration operations.

h. Pool cleanup after-filter.

Pressure gauges are installed in the inlet and exit filter piping for use in detecting the pressure drop across the filter.

A flow glass in the filter OHOG vent line is provided for use in system venting as described in Section 6.4d of the procedures.

i. Cleanup return flow.

System 426 senses the flow rate of water returning from the cleanup system to the pool coolant loop. This quantity is indicated locally on FI-426.

j. Cleanup system performance.

Water samples are withdrawn from the cation inlet, cation exit (anion inlet), and anion exit piping. These are

discharged into a sink, designated sample station No. 1, for manual checking of pH, conductivity, and radioactivity. Radiation system 250, described in Section 3.3c, senses high radiation in the sink and actuates both local and control room alarms. Unlike the primary cleanup system, the pool cleanup sampling lines are not provided with valves which automatically close on a high radiation alarm.

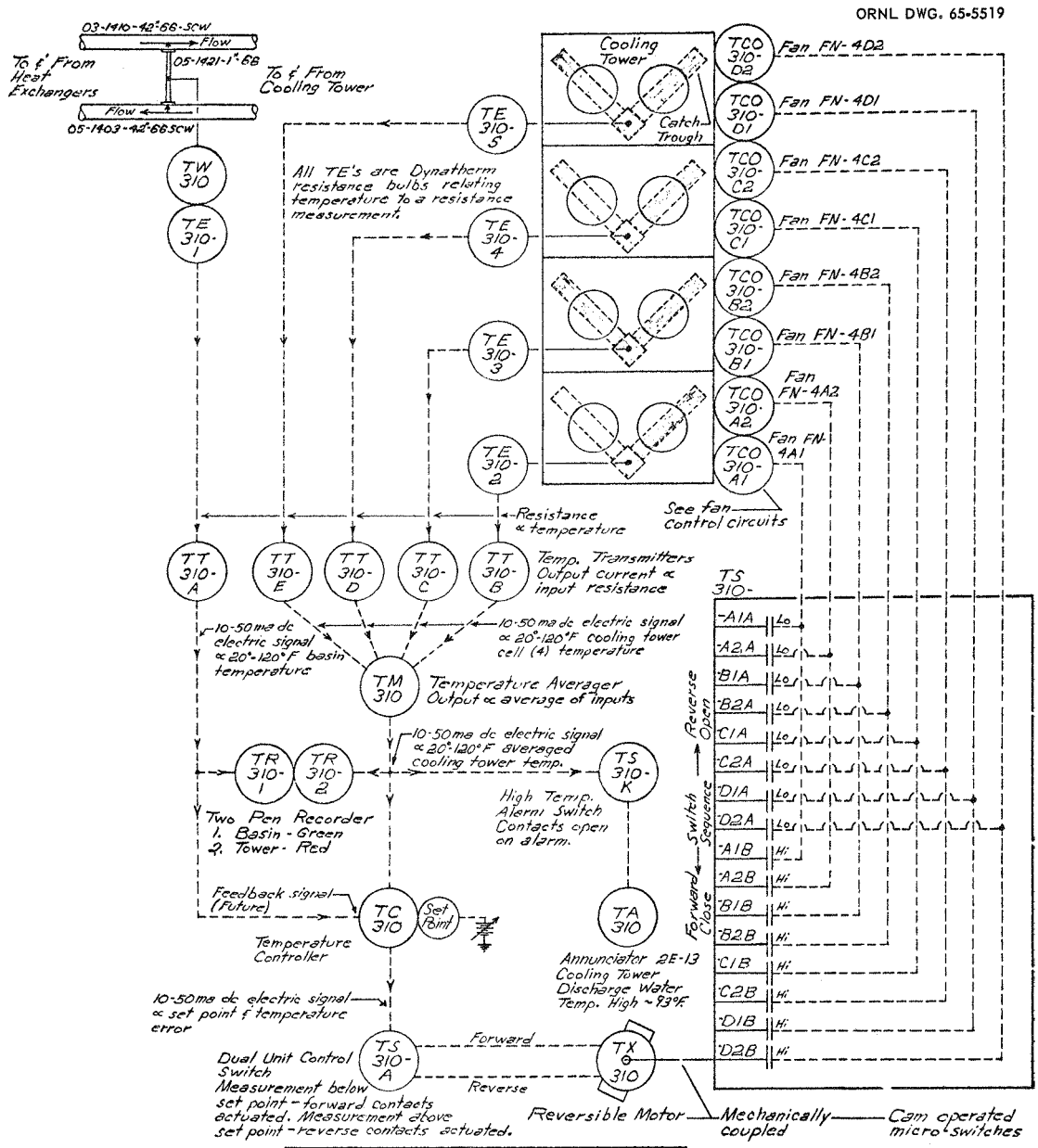
3.3e. Secondary Coolant System

The instrumentation for the secondary coolant system provides information and/or automatic control of temperature, flow, pH, and contamination of the coolant water circulating through the loop.

1. Secondary temperature control.

   All-electric system 310 is designed to maintain a constant secondary inlet temperature to the primary loop and pool coolant heat exchangers by automatic control of the cooling tower fans.

   System 310 (Figure 3.25) measures the temperature at the basin level of each of the four cooling tower cells, averages the temperatures, and records the average on TR-310 in the control room. Controller TC-310 in the cooling tower equipment building compares the average with an adjustable setpoint. Deviations above or below setpoint actuate limit switches in the controller which cause a motor-driven camshaft to rotate in a forward or reverse direction. Cams on the shaft actuate



Instrument	Location
TE 310-1	Area N.E. Secondary Aux. Pump
TE 310-2,3,4,5	Cooling Tower Basin
TT 310-A,B,C,D,E	Cooling Tower Equipment Building
TM 310	Cooling Tower Equipment Building
TR 310-1,2	Main Control Room
TC 310	Cooling Tower Equipment Building
TS 310-A	Cooling Tower Equipment Building
TX 310	Cooling Tower Equipment Building
TS 310-K	Cooling Tower Equipment Building
TA 310	Main Control Room

Fig. 3.25. Secondary Coolant Temperature Control System 310.

switches that sequentially control the cooling tower fans to optimize the rate and balance of evaporative cooling. There are 16 cam-operated switches in all. Eight of these operate in sequence first, to turn on the fans at low speed. The reminder transfer the fans to high speed.

The interval between successive operations of the fan control switches (i.e., the motor-cam speed) is long enough so that the effect of the change in speed of one fan is sensed by the controller before the next change in speed is requested, but short enough to allow the system to respond effectively to changes in reactor power.

Control of each fan may be removed from the automatic system by a control room mode selector switch, allowing the fan to be controlled manually from its pushbutton station on the control room process panel board. Additional information concerning manual operation and descriptions of cooling tower fire and fan-vibration sensing devices is found in Section 6.3c. High temperature actuates switch TS-310K to annunciate on point 2E-13.

2. Primary loop heat exchanger secondary flow.

The temperature of the primary coolant water leaving the primary loop heat exchangers is controlled at 120°F by manual regulation of secondary coolant flow to these exchangers. Manually operated loading station HIC-377, located in the control room, provides (1) a 0-20 psig pneumatic signal for positioning throttling valve FCV-377 in the secondary inlet common header line to the heat exchangers and (2) an indication of this output signal pressure.

Valve position is electrically transmitted to indicator ZI-377 in the control room by a potentiometer-type transmitter directly coupled to the valve disc shaft.

System 300 senses the secondary flow rate to the primary loop heat exchangers and electrically transmits an indication of this quantity to FI-300 in the control room.

3. Pool heat exchanger secondary flow.

System 330 maintains a constant pool inlet temperature of 90°F by automatically regulating the flow of secondary coolant water to the pool heat exchangers. A description of this system is found in Section 3.3d of this manual.

System 306 senses the secondary return flow rate from the pool heat exchangers and indicates it locally on FI-306.

4. Primary loop heat exchanger performance.

Pneumatic system 302 senses the pressure drop across the common secondary inlet and outlet of the heat exchangers and provides an indication of this quantity on PdI-302 in the control room. In addition, locally indicating pressure gauges are installed in the secondary inlet and outlet of each exchanger for use in determining the pressure drop across individual units.

Thermocouple 343 monitors the common inlet secondary coolant temperature to the heat exchangers. Thermocouples 352, 353, 354, and 355 are located, respectively, in the secondary discharge lines of exchangers 1A, 1B, 1C, and 1D. All of the above are connected to points on the selector switch on the console in the control room to be read individually on TI-1040.

Thermometer wells only are provided in the secondary common inlet and outlet piping to facilitate testing of the heat exchangers.

5. Pool heat exchanger performance.

   Locally mounted differential pressure indicators are installed across the secondary side of each pool heat exchanger to sense the coolant inlet and outlet pressure drop.

   Temperature indicators are installed locally in the secondary common inlet, in each outlet, and in the common outlet piping.

6. Pool and primary loop deaerator monitors.

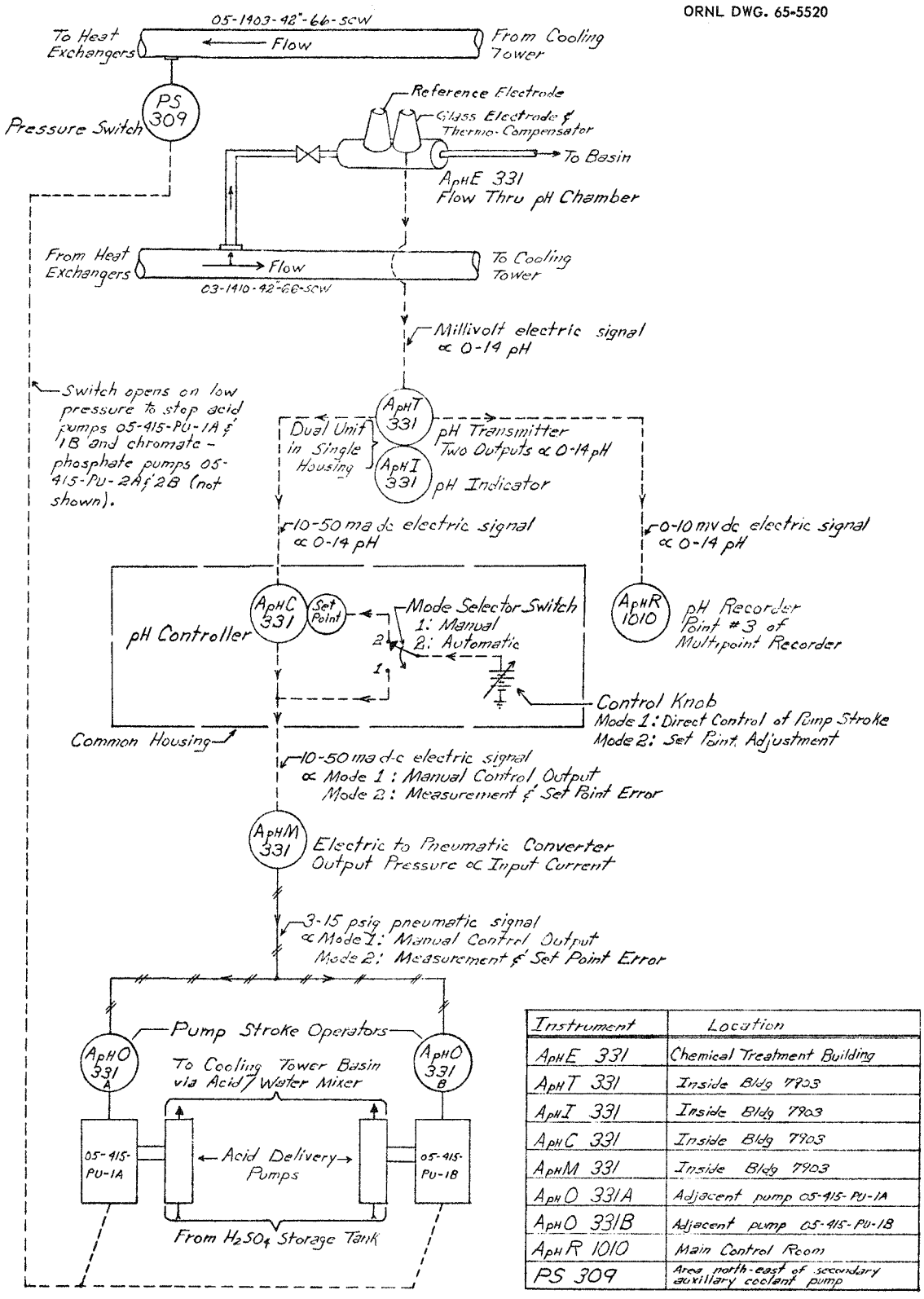
   Locally indicating instuments monitor pre- and after-condenser inlet pressure and temperature and after-condenser exit temperature of the secondary coolant water to the units.

7. Secondary pressure.

   System 309 senses the pressure in the cooling tower pump discharge header and indicates this quantity on PI-309 in the control room. Direct-acting pressure switch PS-309 actuates on low secondary coolant pressure to shut down the acid and chromate-phosphate delivery pumps (see following section).

8. Secondary pH control.

   The pH of the secondary coolant water is maintained at 6.6 by system 331 (Figure 3.26). Transmitter ApHT-331 senses the pH of a sample stream of water taken from the cooling tower return water manifold and actuates (1) local indicator ApHI-331, (2) one point on multi-point recorder ApHR-1010 in the control room, and (3) controller ApHC-331. The dc current



Instrument	Location
ApHE 331	Chemical Treatment Building
ApHT 331	Inside Bldg 7903
ApHI 331	Inside Bldg 7903
ApHC 331	Inside Bldg 7903
ApHM 331	Inside Bldg 7903
ApHO 331A	Adjacent pump 05-415-PU-1A
ApHO 331B	Adjacent pump 05-415-PU-1B
ApHR 1010	Main Control Room
PS 309	Area north-east of secondary auxiliary coolant pump

Fig. 3.26. Secondary Coolant pH Control System 331.

output from controller ApHC-331 is transformed into a pneumatic signal by modifier ApHM-331, and the pneumatic signal regulates the stroke of each of the pumps delivering the acid solution to the secondary system.

Controller ApHC-331 is furnished with setpoint adjustment, output indication, deviation indication, a transfer or mode switch, and a manual control adjustment whereby the operator may directly regulate the acid addition to the system.

To prevent local concentration of chemicals during periods of low secondary flow, such as when the reactor is shut down or at reduced power, pressure switch PS-309, located in the cooling tower pump discharge manifold, automatically shuts down the acid delivery pumps on low secondary coolant pressure. The chromate-phosphate delivery pumps are similarly controlled by this switch. When the pressure is sufficient to permit operation, the pumps may be restarted manually by the local "start" switch.

A second pH system (334) senses the pH of the secondary coolant water to the pool heat exchangers and actuates (1) local indicator ApHI-334, (2) two annunciator switches for high and low pH alarm on points 4E-5 and -6, and (3) one point on multi-point recorder ApHR-1010 in the control room. In addition to the alarm functions, this system serves as a check on the operation of acid-addition-control system 331.

9. Cooling tower basin level.

The water in the cooling tower basin is maintained at a predetermined level by a mechanically coupled ball float and

control valve unit. The ball float controller LC-335, located in the basin, operates control valve LCV-335 in the makeup water line. This valve, which opens on falling level, allows makeup water to flow into the basin to offset evaporation and blowdown losses.

A second ball float, also located in the basin, is integrally mounted with level switch LS-332 for basin low level annunciation in the control room, point 2E-14.

10. Secondary makeup flow.

Pneumatic system 336 senses the flow rate of makeup water to the secondary system and actuates (1) flow indicator FI-336 in the cooling tower equipment building and (2) the ratio controller FM-325 of the basin blowdown system described below.

11. Basin blowdown.

All pneumatic systems 325 and 336 (Figure 3.27) control the secondary coolant system blowdown flow, usually at a rate proportional to system makeup. The proportionality is adjustable to accommodate seasonal variations in evaporation losses at the cooling tower.

Flow indicator-controller FIC-325 receives blowdown flow rate information from FE/FT-325, compares this information with a setpoint signal and actuates control valve FCV-325 to regulate blowdown flow. When FIC-325 is in the "cascade" mode the controller setpoint is established by a makeup flow signal originating in FE/FT-336. The flow signal is modified in FM-325 to achieve the desired proportionality between flows,

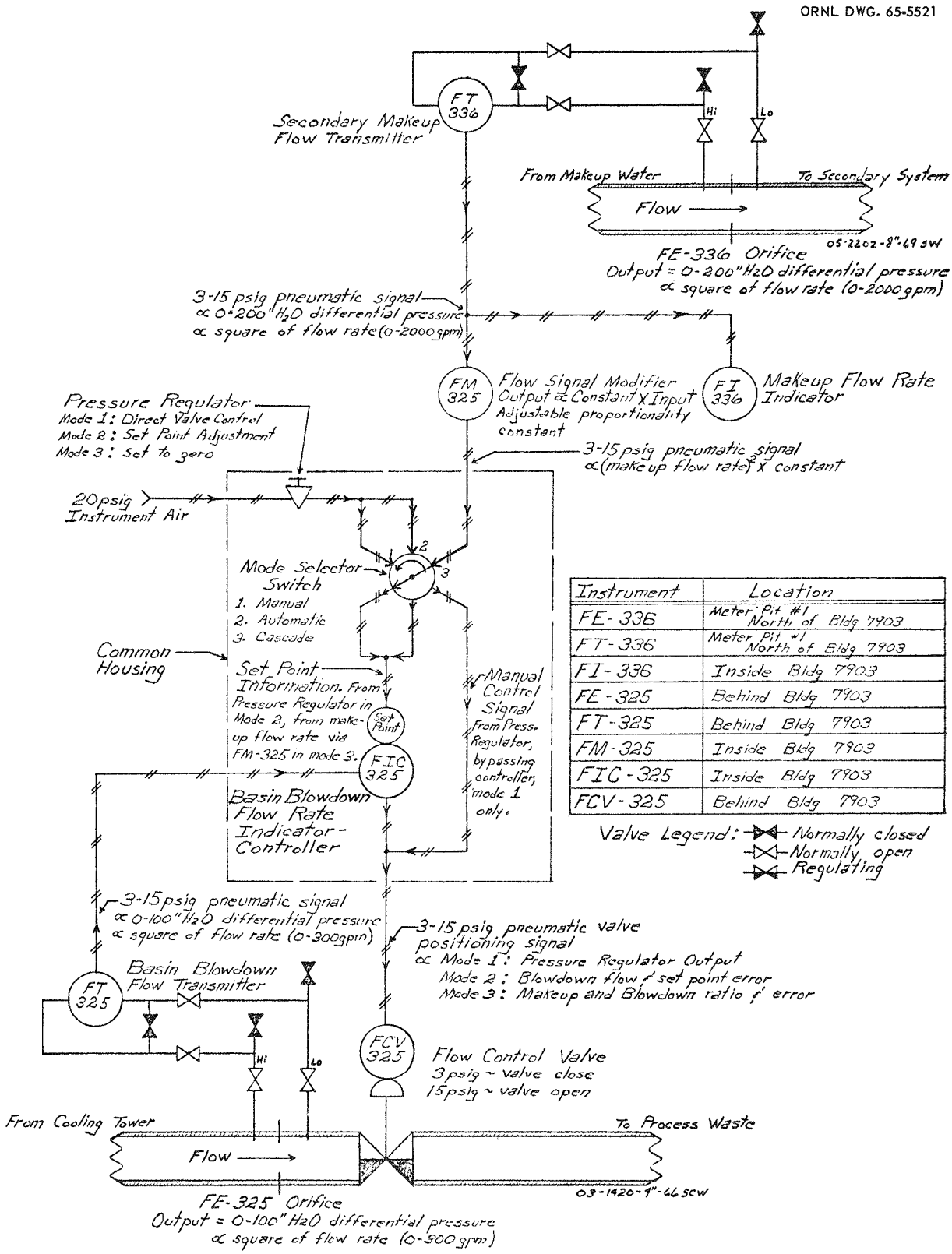


Fig. 3.27. Basin Blowdown Control System 325.

for which there is an adjustment provided on FM-325. Controller FIC-325 may alternatively be operated in the "automatic" mode, whereby it will control the blowdown flow about a manually adjustable setpoint, completely independent of the makeup flow or in the "manual" mode, whereby the valve may be positioned by direct manual control from the controller. To facilitate operation in any of the three modes, indicator-controller FIC-325 is furnished with blowdown flow rate indication, setpoint indication, a mode selector switch, and a pressure regulator for positioning setpoint on automatic control or for positioning the control valve directly on manual control. A "Reg-valve" switch on the controller permits the output pressure to the valve to be read out instead of the setpoint.

12. Secondary coolant radiation monitoring.

Radiation system 326 is intended to monitor for gross low-level beta-gamma activity in the secondary coolant and to provide an early indication of primary-to-secondary leaks in the heat exchangers of the primary and pool coolant loops. The detector, RE-326, is located in the inlet distribution header to the cooling tower and actuates (1) local indicator RI-326 and (2) one point on multi-point recorder RR-1000 in the control room.

Radiation system 702 is located on the cooling tower blowdown line and is described in Section 3.3j. The blowdown line originates at the cooling tower distribution header and, therefore, system 702 provides backup information for the secondary coolant monitor 326.

13. Cooling tower pumps.

Local pressure-indicating instruments are installed in the discharge piping of each main pump and in the outlet of the auxiliary pump.

14. Secondary coolant system - miscellaneous.

a. The levels of the solutions in the acid and chromate-phosphate supply tanks are indicated locally.

b. The flow of process water to the sulfuric acid mixer is locally indicated on FI-320.

c. The temperature of the water entering the cooling tower distribution header is indicated locally on TI-337.

3.3f. Process Water Supply and Demineralizer Chemical Supplies

1. Potable/process water air gap tank.

Parallel systems 383 and 384 maintain a positive air gap separation of at least one foot between the potable water inlet line and the surface of the process water stored in the tank. Controllers LC-383 and LC-384 sense the water level in the tank and actuate control valves LCV-383 and LCV-384 in the tank potable water supply line. Low level annunciation is provided by level switch LS-387, for alarm on point 4E-7. Pneumatic system 658 senses the potable water inlet pressure and indicates this quantity on PI-658 in the control room. A flow totalizer is installed locally in the inlet potable water piping to the tank.

2. Process water pumps.

Locally indicating pressure instruments are installed in the inlet and outlet of each pump. Direct-acting pressure switch

PS-370, located in the common outlet, actuates on low pump discharge pressure and automatically starts the standby process water pump provided it is in the "standby" mode. Once started, the standby pump must be stopped manually by either its local "stop" pushbutton or its control room selector switch (SS16, SS16).

3. Plant demineralizer performance.

Locally indicating instruments monitor the demineralizer inlet pressure, inlet flow rate, outlet pressure, and total outlet flow. System 374 senses the conductivity of a sample stream of water from the demineralizer exit and actuates local indicator CI-374 and switch CS-374 for high conductivity annunciation in the control room on point 4E-3. Rotameter flow indicators are installed in the caustic, acid, and rinse water supply lines for use during the regeneration and rinsing operations. A flow glass is provided in the vent line of the demineralizer vessel to aid in system venting.

4. Demineralized water supply tank level.

Pneumatic system 605 (Figure 3.28) senses the water level in the supply tank and transmits a signal which actuates (1) local indicator LI-605, (2) two switches for low- and high-level annunciation in the control room on points 4E-1 and -2, and (3) control valve LCV-605 in the makeup water line from the plant demineralizer. Setpoint adjustment is available to level controller LCT-605.

5. Plant demineralized water supply pumps.

Locally indicating pressure instruments are provided to monitor the inlet and outlet pressures of each pump.

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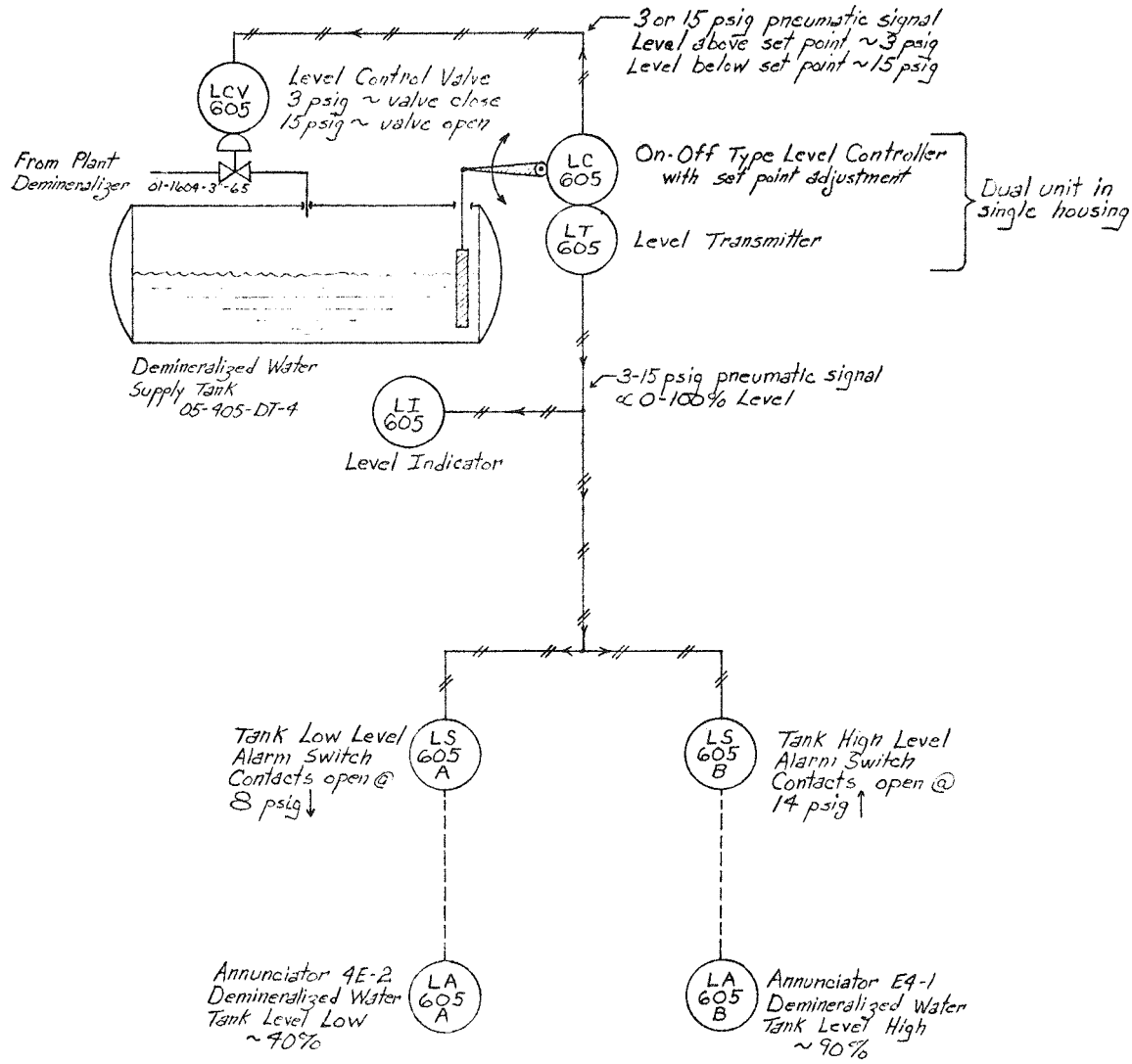


Instrument	Location
LC-605	Atop Demin. Water Supply Tank
LT-605	Atop Demin. Water Supply Tank
LI-605	East side Demin. Water Supply Tank
LS-605A	Auxiliary Control Room
LS-605B	Auxiliary Control Room
LA-605A	Main Control Room
LA-605B	Main Control Room
LCV-605	Vicinity Plant Demineralizer

Fig. 3.28. Plant Demineralized Water Supply Tank Level Control System 605.

6. Caustic storage tank temperature.

   System 444 senses the temperature of the sodium hydroxide solution in the tank and directly actuates control valve TCV-444 in the steam supply line to the heater unit. Solution temperature is indicated locally on TI-444.

7. Caustic day tank temperature.

   System 445 senses the temperature of the caustic solution in the day tank and directly actuates local indicator TI-445 and control valve TCV-445 in the steam supply line to the tank heating unit.

8. Caustic and acid pumps. Locally indicating pressure instruments are installed in the inlet and outlet of each pumps.

9. Miscellaneous instrumentation.

   a. Local rotameter flow indicators measure the flow of process/demineralized water to the primary, pools, and plant demineralizers during rinsing operations.

   b. Pneumatic system 227 senses the process water supply pressure and actuates indicator PI-227 in the control room.

   c. Locally mounted sight glasses provide indication of the levels of the solutions in the caustic storage tank, caustic day tank, acid storage tank, and acid day tank.

   d. Local rotameter flow indicators measure the transfer flow of caustic and acid solutions from their day tanks to the primary, pools, and plant demineralizers during regeneration operations.

3.3g. Special Building Hot Exhaust and Hot Off-Gas Systems

The Special Building Hot Exhaust System (SBHE) is described in Section 7, and the Closed and Open Hot Off-Gas Systems (CHOG and OHOG) are described in Section 9. The associated instrumentation is discussed in further detail below and shown in Figure 3.29.

Special Building Hot Exhaust System Instrumentation.--Four pitot tubes (systems 903 and 913 west and systems 904 and 914 east) measure the air flow in the two main branches of the SBHE system. The pressure transmitter associated with each pitot tube produces a pneumatic signal, related to flow, which is used to actuate (1) a flow indicator in the fan shed, (2) a flow indicator in the control room, (3) a switch for low-flow annunciation in the control room on points FG-10 and -11, (4) a switch to trip relay R-102 which automatically starts the standby fan and annunciates this action in the control room, and (5) a switch to trip relay R-101 which shuts down air-conditioning units 2, 5, 10, and 14. No coincidence circuits are used, and any one of the four systems can initiate any of the foregoing control actions independently. Upon resumption of normal air flow, the air-conditioning units will restart automatically; however, the standby fan must be manually shut down.

To determine the effectiveness of the SBHE system, the differential pressures between three points in zone 3 and the outside atmosphere are monitored and displayed in the control room. These points are: the reactor bay (PdI-900), the beam room (PdI-901), and the experiment room (PdI-902). Readings for the reactor bay of less than 0.10 in. H_2O are annunciated in the control room on point FG-12.

Additional information concerning switch setpoints and fan control circuits is contained in Section 7.5c.

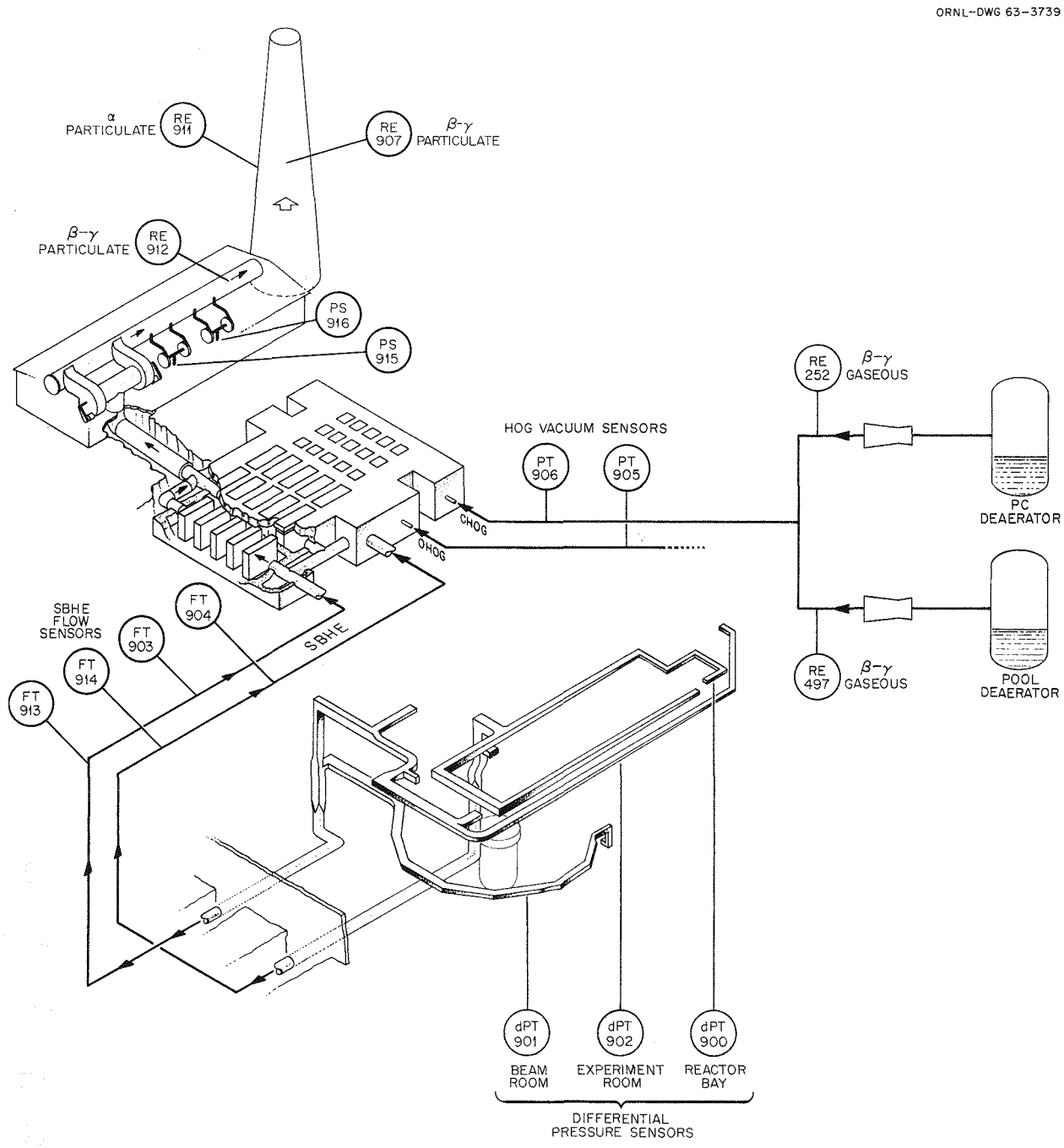


Fig. 3.29. Gaseous-Waste Monitoring System.

Closed Hot Off-Gas System Instrumentation.--Pneumatic system 905 is designed to detect loss of vacuum in the CHOG duct from either filter plugging or fan failure. Transmitter PT-905 senses the vacuum in the duct upstream of the filters and actuates indicator PI-905 in the control room and switch PS-905-1 for loss of vacuum annunciation on point FG-14. To aid in distinguishing between the two possible causes of alarm, pneumatic system 915 located downstream of the filters, monitors for loss of vacuum due to fan failure. Pressure transmitter PT-915 senses the vacuum in the fan inlet and actuates indicator PI-915 at the fan shed and pressure switch PS-915-1 which, on low vacuum, trips relay R-103 to start automatically the standby fan and annunciate this action in the control room. Once started, the standby fan must be manually shut down.

Additional information concerning switch setpoints and fan control circuits is contained in Section 9.4f.

Open Hot Off-Gas System Instrumentation.--The instrumentation for this system is identical to that of the CHOG system described above. Instrument application numbers 906 and 916 correspond to 905 and 915 above, respectively, and relay R-104 corresponds to relay R-103. Loss of vacuum is annunciated on point FG-16.

3.3h. Instrument Air System

1. Main compressor performance.

   The flow rate of coolant water from each air compressor after-cooler and the operating temperature of each after-cooler are indicated locally. Temperature switches TS-652 and TS-653, located in the discharge line of each air compressor

unit, open on high air temperature (>90°F) and actuate a common control room annunciator, point HI-1.

2. Air system performance.

The pressure in air reciever AR-6 is indicated locally on PI-623. Should the pressure in the receiver drop below 53 psig, pressure switch PS-624 actuates to start the standby air compressor and annunciate this condition in the control room on point HI-2. Once started, the standby compressor will continue to run until manually shut down by its local "stop" switch. Receiver pressure exceeding 70 psig causes pressure switch PS-628 to actuate which signals the unloader valves in each main compressor outlet to open. These valves will automatically close when the pressure in the receiver falls to 60 psig.

A rotameter flow indicator, FI-626, is installed in the main distribution header to monitor the total flow rate of instrument air from the main compressors.

System 627 senses the moisture content in a continuous sampling of the instrument air and provides a local indication of this quantity on AmI-627.

3. Reactor servo system heat-power instrument air supply monitoring.

System 625 senses the pressure in the heat power instrument air header and indicates this quantity on PI-625 in the control room. Should the pressure in the header drop to 48 psig, two-pole pressure switch PSS-651 actuates; pole A provides control room annunciation, and pole B starts the

emergency air compressor C-3. Once started, the compressor will continue to run until manually shut down. Whenever the pressure in the header exceeds 70 psig, pressure switch PS-617 actuates and causes an unloader valve to open in the emergency air compressor discharge line. The valve will automatically close when the pressure in the header falls to 60 psig.

The instrument air pressure in receivers 7-A, 7-B, and 7-C is indicated locally. Pressure switches PSS-654, PSS-655, and PSS-656 sense loss of air pressure (<30 psig) to the pneumatic instruments of servo channels A, B, and C, respectively, and actuate individual annunciators in the control room.

3.3i. Gaseous Waste Monitoring

Instrumentation is provided to measure the overall gaseous and entrained particulate radioactivity discharged from the HFIR-TRU-TUFCDF complex by the HFIR area stack. Additional monitoring instrumentation, ventilation system sampling, and access facilities serve to identify the origins of stack activity within the reactor building.

Stack Monitoring.--The sensors of three radiation channels are installed at the 50-ft level in the stack. These channels employ two probes to sample the stack gas; in each case, the sample is drawn through a paper-tape filter by means of a vacuum pump and ultimately discharged back to the stack. After passing through the tape filter, the sample gas stream from one of the probes is passed through a replaceable cartridge charcoal filter to trap iodine. The vacuum pump

and tape advance mechanisms are essentially the same as those used in the ORNL constant air monitors. With one of the paper-tape filter assemblies is a G-M tube; this constitutes the sensor for system 907, which is intended to detect the total of beta and gamma radiation from entrained gases and accumulated particles on the tape filters. The other tape filter is monitored for alpha radiation by means of a scintillation counter, the sensor of system 911. Multiple G-M tubes surround the charcoal trap, providing for sensitive detection of beta and gamma from accumulated iodine; these G-M tubes constitute the sensor for the iodine detection system. A separate system, complete with stack probe and vacuum pump, draws a continuous stack gas sample through a conveniently removable filter cartridge with paper and charcoal elements; the elements are to be analyzed in the laboratory for iodine and particulate accumulations. An anemometer is also provided to measure total flow in the stack.

The count-rate meters for the three stack radiation channels are installed in the auxiliary control room and include the calibration controls and output indicating instruments. Mounted on each count-rate meter is its high radiation warning lamp and count-rate meter instrument failure lamp. The vacuum and tape-break sensors are in the stack installations, each of which also includes a manual tape advance control and a timer with its on/off control to permit automatic periodic tape advance. Remote manual tape advance controls and the tape drive trouble indicators are located at the Laboratory Facilities Department monitoring center at Building 3105.

The output indications from the three count-rate meters are recorded on miniature recorders in the control room and are telemetered

to Building 3105. High radiation on any of the stack monitors, or on the duct monitor descirbed below, is annunciated in the control room on point HI-6. The anemometer output signal is displayed only in Building 3105.

The radiation instruments reset automatically when the alarm-initiating condition is removed. The local instrument failure lamp represents simply a low reading in the count-rate meter and does not respond to tape break or loss of vacuum; it must be reset manually at the CRM.

Duct Monitoring.--All three main ventilation systems of the reactor building discharge into a common duct which leads to the stack entrance. Since this duct serves only the reactor building, concurrent radioactivity increases in the duct and in the stack indicate the reactor building as the radiation origin. Channel 912 measures the activity of a continuous gas sample which is withdrawn from the duct far enough beyond all of the blower discharge points to ensure mixing of the three ventilation system effluents. The channel employs a sampling probe, vacuum pump, and paper-tape filter, and its shielded G-M tube sensor responds to beta and gamma in both sample gas and accumulated particles at the filter. The instrumentation, controls, readouts, and alarms are in all respects identical to that of channel 907, the above described stack monitor system, and the high radiation alarm is annunciated on the common point, HI-6, with the stack monitors.

Reactor Off-Gas Monitoring.--The primary coolant and pool cleanup system deaerators are intended to remove dissolved gas contaminants from the recirculating water. The deaerators are vented to the CHOG system, and each of the vent lines is monitored for beta and gamma

activity. Radiation channels 252 and 497 serve the primary coolant and pool system, respectively. Each channel consists of a probe with two G-M tubes, and a locally installed electrometer. High radiation and instrument failure actuate the same annunciator point in the control room for each radiation channel.

The electrometer, ORNL Type Q-2353, includes an indicating instrument and selector switch, which enables the operator to read low level radiation on a 0-10 mr/hr linear scale, high radiation on a 0-100,000 mr/hr log scale, low level alarm setpoint (instrument failure) on the linear scale, and high radiation level alarm setpoint on the linear scale. Screwdriver adjustment points are provided for the low and high level alarm points, as well as for zeroing the instrument. "Power On" and "Alarm" lamps are also on the electrometer panel, the latter being de-energized for either high radiation or instrument failure.

Local Sampling and Measurement.--Access hatches and handholes are provided at the ventilation systems filters, to enable measurement of accumulated radioactive contamination by portable instruments. Taps are installed on the various ventilation system ducts for withdrawal of samples for laboratory analysis.

3.3j. Liquid Waste Systems Instrumentation

The three sources of liquid waste from the HFIR are: (a) intermediate level waste system, (b) process waste drain system, and (c) secondary cooling system blowdown. The ILW is presumed to be contaminated and is collected in the ILW tank. From there it is pumped to the ORNL waste system or the holding ponds. The main instrumentation of the ILW system monitors the collection tank level; radioactivity

is determined in the laboratory from samples. The PWD effluent may occasionally contain significant amounts of radioactivity. This effluent normally is discharged to holding pond No. 1; it is continuously monitored for flow rate and radioactivity, and samples are collected automatically for laboratory analysis. When activity exceeds limits, the PWD flow is automatically diverted to holding pond No. 2. The secondary coolant blowdown normally is not contaminated by radioactive materials, and is discharged directly to Melton Branch. The effluent is monitored in the same manner as for the PWD. High radioactivity causes the blowdown flow automatically to be diverted to holding pond No. 1.

ILW System.--All-electric system 704 measures level in the ILW storage tank, and records the information on LR-704 in the control room. The same information actuates switch LSS-704, which stops pumps PU-4A and PU-4B on low level; the pumps are otherwise manually controlled. Timers IQ-706 A and B provide local readouts of total running time of the pumps.

Local pressure indicators are provided for the ILW pumps common inlet and individual discharges.

PWD System.--Systems 707 and 703 function together as follows to monitor PWD flow and radiation level, and to collect a PWD sample continuously proportional to flow:

1. FIC-707 measures PWD flow rate in terms of level backed up by the weir in monitor station No. 2 (manhole). A bubbler device is used for the measurement, which provides a pneumatic pressure output to FIC-707 proportional to the water level. Flow rate is recorded, and totalized flow is indicated

locally; flow rate is also retransmitted pneumatically and recorded in the control room.

2. A submersible pump in the No. 2 monitor station supplies a recirculating loop sampling system. The pump discharge normally passes through a three-way solenoid valve to the sampling system; a timer in the "pump controller" unit automatically interrupts the pump operation for 15 seconds once every eight hours, and, by means of the solenoid valve, (a) isolates the sampling system from the pump discharge and (b) admits instrument air to the pump discharge line to backflush the line and pump.

3. Beyond the solenoid valve, the sample line branches. One branch carries a continuous stream past the radiation detector RE-703 and discharges it back to the main PWD stream, and the other branch leads to the inlet of the sampling pump. The latter is a positive displacement "finger" pump which normally operates for a short interval every 30 seconds, and discharges into the sample collection vessel. The duration of the operating period varies from 0 to 15 seconds, proportional to the main PWD flow rate. The operating period duration is regulated by the same "pump controller" unit referred to above, using flow rate information from FIC-707.

4. Radiation monitoring system 703 detects beta and gamma in the continuous sample stream by means of a G-M tube probe. Count-rate meter RRC-703, in the auxiliary control room, measures the radiation level; the CRM includes the necessary calibration adjustments, an indicating meter and a miniature

recorder to display radiation level, and pilot and alarm lights. Radiation level information is retransmitted from the CRM to the multi-point radiation recorder RR-1000 in the control room. Relay contacts in the CRM initiate the following: (a) intermediate-high radiation level or instrument "downscale" failure (e.g., power failure) are annunciated together on point FG-3 in the control room, (b) the same conditions also cause motor-operated valve FCV-703A to close and valve FCV-703B to open, diverting PWD flow to holding pond No. 2, and (c) high-high radiation level is annunciated separately on point FG-2 in the control room, alerting the operator to conditions that might require manually-controlled diversion of the PWD stream to the ILW tank. The CRM relay contacts reset automatically a few seconds after the condition causing the alarm has cleared.

System 710 controls and monitors the level in the PWD sump. When level switch LSS-710 senses rising level (actually, change in pressure of a purge bubbler element) in the sump, it actuates a solenoid valve which, in turn, pneumatically causes steam valve LCV-710A to open and operate both steam-jet ejector pumps. Level switch LS-710 actuates annunciator point FG-4 in the control room on high water level in the sump.

Local pressure indicators PI-715 and -716 measure steam pressure at the ejector pumps.

Secondary Cooling System Blowdown.--Systems 708 and 702 which are almost identical, respectively, with the above-described systems 707 and 703, monitor the cooling tower blowdown stream at monitor station

No. 1 (manhole). The intermediate-high radiation level relay contacts in count-rate meter RRC-702 actuate control room annunciator point FG-1, and cause motor-operated valves FCV-702A and B to operate and divert blowdown flow to holding pond No. 1. However, there is no high-high radiation level annunciation.

4. STORAGE, REFUELING AND POOL WORK

4.1. Fuel Storage

4.1a. References

Drawings:

1546-01-M-5011 Isometric of the Pool Area

1546-01-M-5015 Fuel Element Seats for Clean Pools

1546-01-M-5016 Interpool Transfer Platforms for Fuel Elements

4.1b. Introduction

Fuel storage is the temporary retention of fissionable material outside of the reactor core. This fissionable material is normally in the form of standard HFIR fuel elements; however, fissionable material belonging to research groups may also be stored at the HFIR.

The methods of handling fissionable materials outside the reactor core must be approved by the ORNL Criticality Review Committee. Design of fuel storage racks and fuel transfer casks must also be approved by this Committee.

4.1c. Storage and Inspection of New Elements

Unirradiated fuel elements are stored in a steel-caged area in the southeast corner of the reactor building on the first floor. Provision is made for storage of up to 24 new elements on portable wooden skids. A guard rail around each element prevents damage and keeps the elements a safe distance from each other.

Each fuel assembly is inspected for dimensional tolerances just prior to installation in the reactor to assure that the two elements mate properly with each other and with other reactor components.

4.1d. Storage of Irradiated Elements

When irradiated fuel elements are removed from the reactor they must be stored on specially shielded racks in the reactor pool for at least 24 hours. They are then transferred to racks in the clean pools for further fission product decay prior to shipment to a reprocessing plant.

There are storage racks for 31 elements in the pools (Figure 4.1). Twenty-seven of these racks (Figure 2.17) are located in the clean pools and are used for general purpose fuel storage while the remaining four racks, located in the reactor pool, are used for special purposes.

Clean Pools.--The 27 long-term storage racks are located along the north wall of the clean pools. These three-place racks (Figure 4.2) are located on 2-1/2-ft centers and support irradiated elements 2 ft above the pool bottom. The racks position the elements 7 1/2 ft from the south pool wall and 3 1/2 ft from the north pool wall.

Each of the storage racks is equipped with a hollow stainless steel centering post and an outer sleeve. In the centering post and outer sleeve 0.058-in-thick cadmium foil is sandwiched between layers of stainless steel. This acts as an absorber of thermal neutrons. The outer sleeve is surrounded by a 30-in. square aluminum frame which has a hinged, grating-type cover to protect the element.

Ample cooling for the element is provided by natural convection through the grating on which the element sits and through the grating-type cover. Decay heat is removed by the pool coolant system.

Reactor Pool.--Two storage racks, located east of the reactor vessel, are used for short-term storage. As previous mentioned,

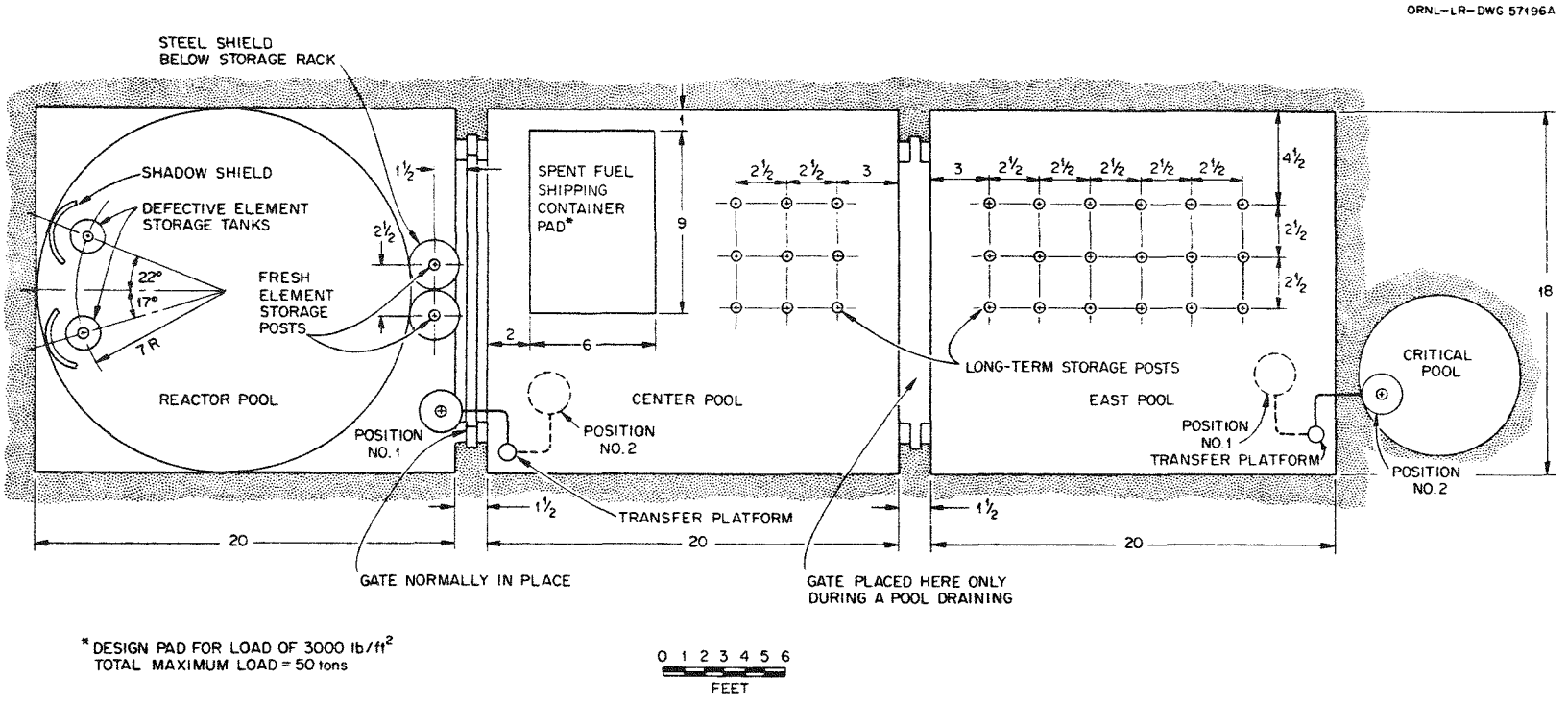


Fig. 4.1. Fuel Element In-Pool Storage.

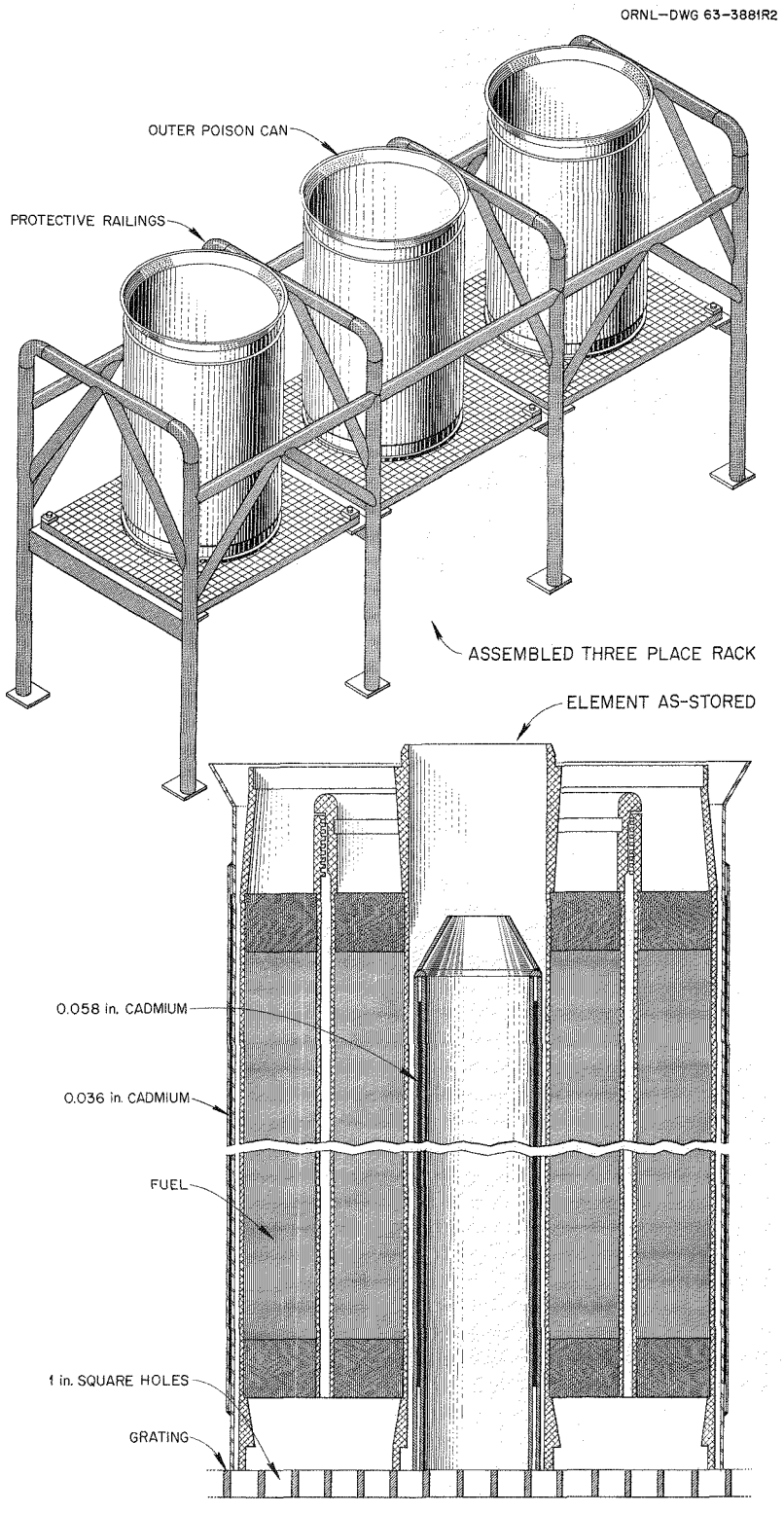


Fig. 4.2. Irradiated Fuel Storage Racks.

freshly irradiated elements are stored on these racks for a minimum of 24 hours before being transferred to the clean pools. These two racks are similar to those in the clean pools. Located beneath the racks is a 3-in.-thick steel shadow shield to protect the pool floor concrete from excessive heating.

Two defective fuel element storage racks, located west of the reactor vessel, also utilize a 3-in.-thick steel shadow shield to protect the pool wall concrete from overheating. When a defective element is placed in these racks, it will remain there until the emission of radioactive contamination has stopped or sufficient decay time has elapsed for shipment to the fuel reprocessing plant.

Up to 200 gpm of pool water flows through the defective fuel element storage rack and into the pool cleanup system. Therefore, pool contamination occurs only while transferring the element from the reactor vessel to the storage rack. In the event of a failure of the pool cleanup loop, a heat exchanger, located in the reactor pool (Figure 4.3) will provide up to 300 kw of cooling using natural convection flow of pool water.

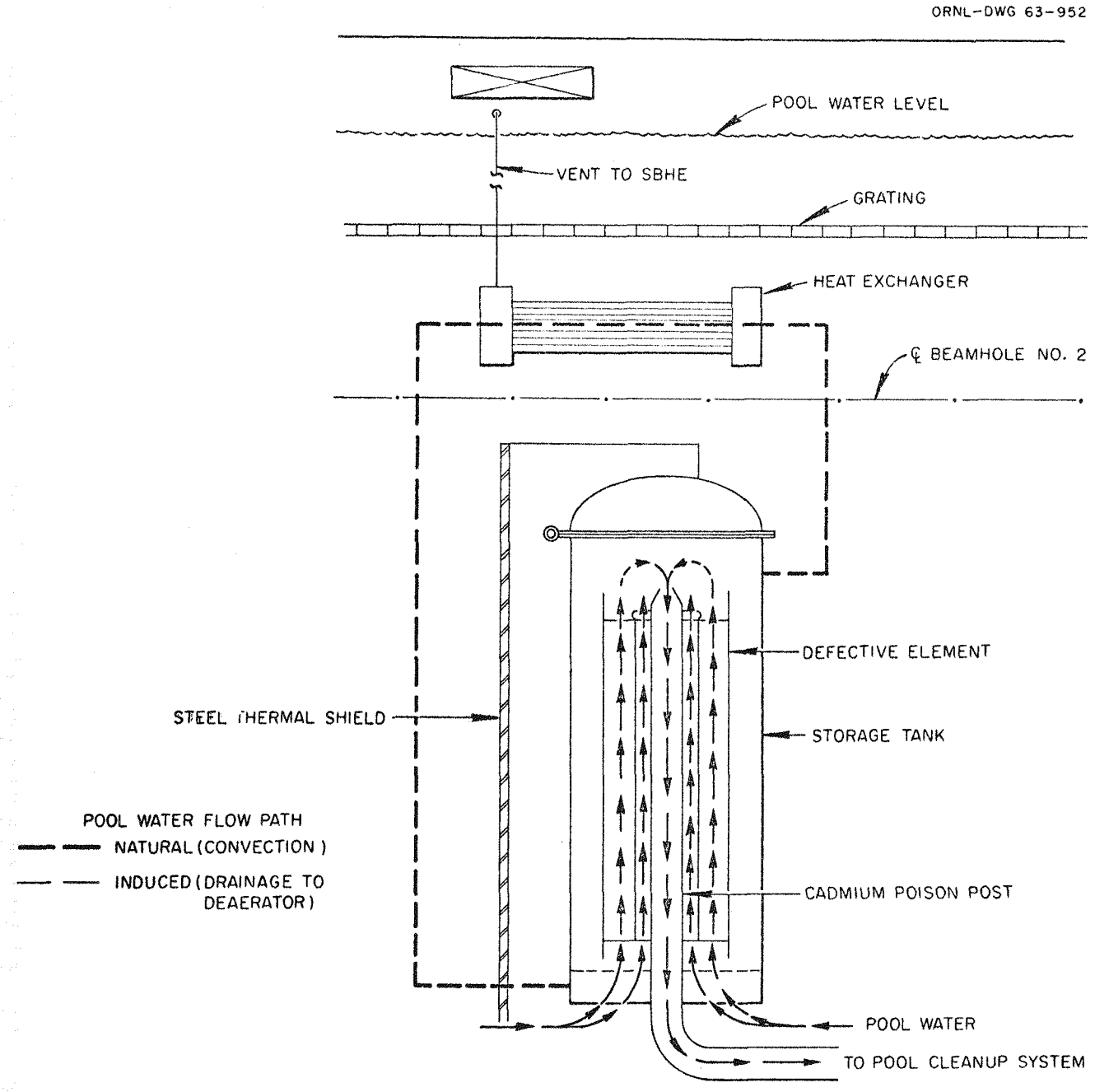


Fig. 4.3. HFIR Defective Element Storage.

5. RESEARCH

5.1. Californium-252 Production

5.1a. References

Drawings:

E-49750-E-49752 HFIR Target Holder

M-A70582N Prototype - HFIR Target Element Assembly

5.1b. Introduction

The prime purpose of the HFIR is to establish an unperturbed thermal flux of $\sim 5 \times 10^{15}$ n/cm^2-sec for the purpose of producing milligram quantities of Californium-252 annually. The central region of the core, called the "island" has the highest thermal neutron flux and constitutes the flux trap. It is approximately five inches in diameter and contains the Pu^{242} target material in the form of a bundle of target rods. (See Figure 5.1,)

5.1c. Target

The target assembly is shown in Figure 2.5. It consists of thirty-one 3/8-inch O.D. rods spaced in a triangular pattern. The rods are fabricated from a mixture of PuO_2 and aluminum powder which is pelletized (See Figure 2.6). The pellets are then packed in aluminum tubes, capped, and the tubes collapsed onto the pellets to provide good heat transfer. The targets are centered inside 5/8-inch cylindrical shrouds, thereby providing each rod with its own cooling channel.

A minimum design flow rate of approximately 630 gpm is maintained through the target assembly while 200 gpm flows between the target assembly and the inner fuel element. This corresponds to a coolant velocity

ORNL-LR-DWG 50304

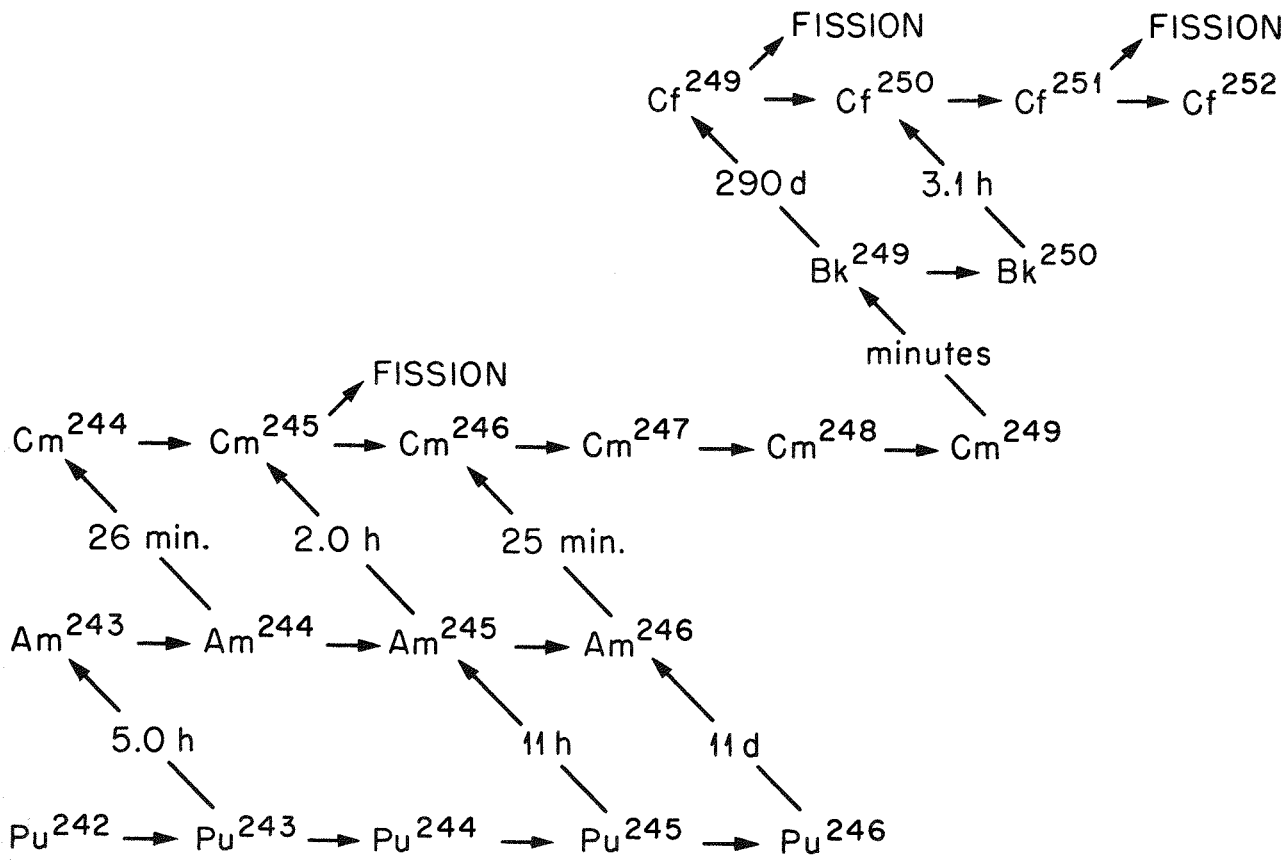


Figure 5.1 **Reaction Paths in the Production of Cf^{252} from Pu^{242}.**

of 40 ft/sec in the target region and is more than that required for the removal of the approximately 900 kw of heat generated by the target.

Fission product gases, consisting mostly of xenon, helium and krypton, build up in the target rods during the irradiation period. The target rods are designed with voids on either end to contain these gases and have sufficient strength to resist 1000 psi external pressure and the internal pressure resulting from the fission gas build up.

5.1d. Approval of Targets

It is the responsibility of the Reactor Supervisor and of the assigned Technical Assistance staff member to inspect and approve all Plutonium-242 and/or Curium recycle targets before insertion into the reactor.

Since each new Plutonium-242 target may be of a different concentration and have different amounts of impurities, it is necessary to evaluate the physical properties (i.e. heat production etc.,) of that target and to determine the overall effects upon the reactor. This evaluation, in general, is done by the Chemical Technology Division personnel along with the Operations Division Technical Assistance staff. Dimensional tolerances and structural rigidity of the target are checked prior to insertion.

5.2. Hydraulic Rabbit Facility

Provisions were made in the design of the reactor pressure vessel and the pools separation gates for the installation of several hydraulic rabbit tube facilities. The pressure vessel head is equipped with twenty-one flanged nozzles and a target hole plug, any of which can be used for the installation of a hydraulic tube.

Sleeves through the abutments alongside the pool gates have been provided to allow installation of the various lines associated with the hydraulic rabbit tubes. Three sleeves are provided through both the north and south abutments between each of the pools. They are as follows:

4-in. sleeves at elevation 841 ft 0 in.,

6-in. sleeves at elevation 840 ft 0 in., and

6-in. sleeves at elevation 839 ft 0 in.

A hydraulic tube will occupy the central target position and penetrate the vessel through the center of the target hole plug assembly. This rabbit tube utilizes the pressure drop across the target region for insertion and cooling of the rabbits; and utilizes the pressure drop across the orifice plate below the target region for removal of rabbits to the loading station. An auxiliary pump is provided for establishing water flow through the rabbit tube during periods of low or no flow conditions in the primary coolant system.

The loading and control station for the rabbit tube is located against the north wall of the clean pool. Rabbits of 1/2-in. diameter and up to 2 1/2-in. length can be inserted into the facility.

5.3. Engineering Facilities

5.3a. References

Drawings:

43-501-013 HFIR Pressure Vessel

43-501-056 Reactor Vessel Assembly

5.3b. Description

Provision is made for the future installation of up to four engineering facilities to accommodate experiments which require a relatively low neutron flux (See Figure 5.2). These facilities consist of 4-inch OD tubes which enter the pressure vessel at elevation 825 ft and extend downward, at an angle of 41° with the vertical plane, to the outer periphery of the beryllium reflector. The upper ends of the tubes terminate at the outer face of the pool wall in the experiment room.

A variety of service connections are provided near the point where each of the facilities penetrates the pool wall. These include instrument air, normal and normal-emergency electric power, process water, pool water, CHOG and OHOG outlets, and both process waste and ILW drains.

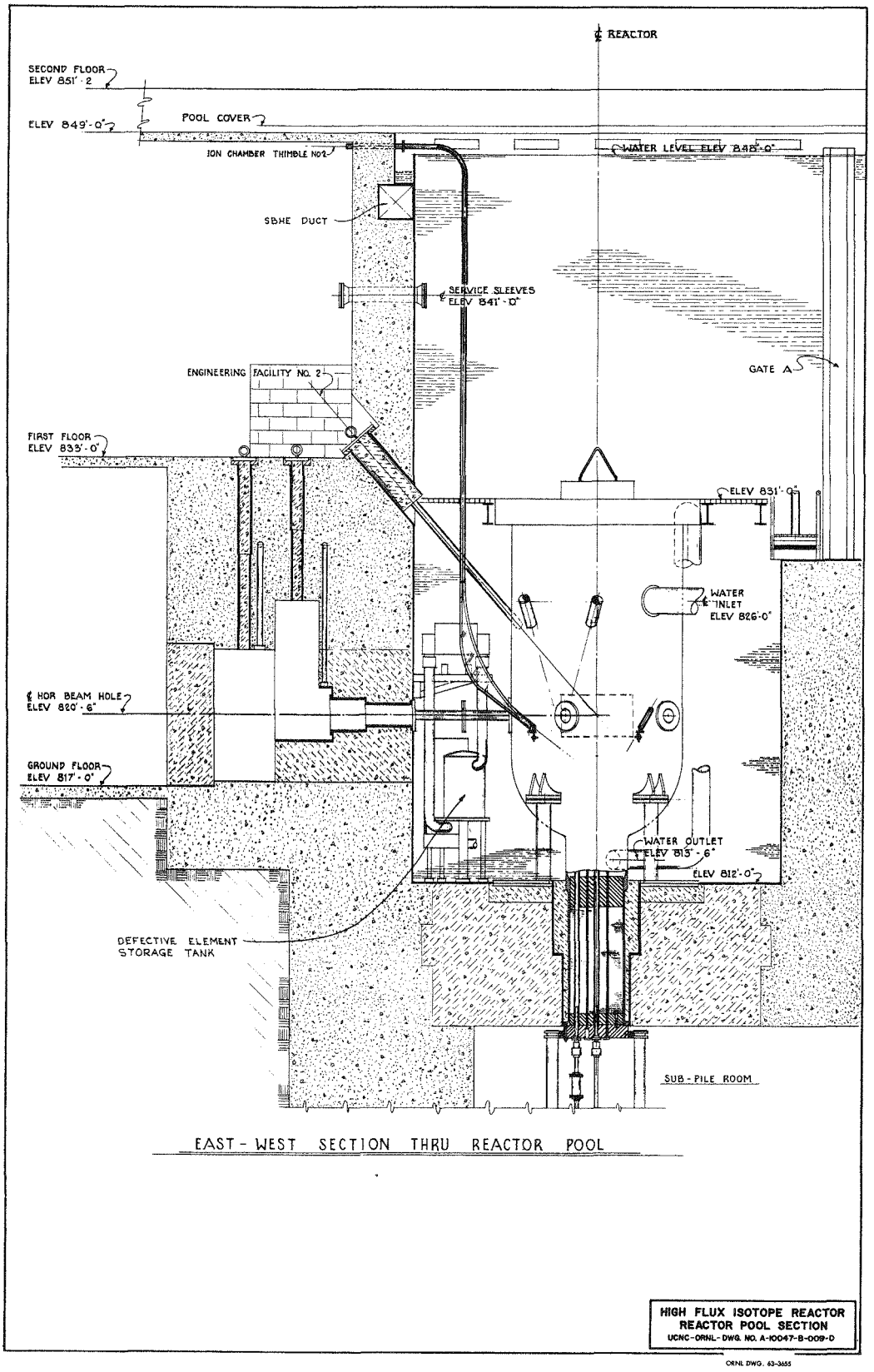


Figure 5.2 **Reactor Pool, East-West Section.**

5.4. Horizontal Beam Tubes

5.4a. References

Drawing:

E-42018 Permanent Reflector, Horizontal Beam Tube Liners Installation

5.4b. Description

The reactor is provided with three nominally 4-inch I.D. horizontal beam tube experiment facilities which extend outward from the reactor core at the midplane (elevation 820 ft 6 in.; see Figure 5.3). One beam tube, HB-2, extends radially from the reactor center line with its inner end penetrating the permanent reflector. Another tube, HB-3, extends tangentially from the core, offset approximately 10-1/2 inches from the reactor center line. It also penetrates the permanent reflector. The remaining tube is aligned on a tangential line approximately 15-1/8 inches from the reactor center line with both ends extending outward from the reactor. It is arranged to allow the installation of either two individual facilities or a single through tube. The two ends of this tube are designated HB-1 and HB-4.

Each of the tubes is made of aluminum and is sealed to, and supported by, the reactor pressure vessel by means of a system of clamped and bolted flanged joints. From the flanged connection at the pressure vessel, each tube continues through the reactor pool and pool wall and terminates in a recess located in a large cavity in the reactor pool wall, where it is fastened to the outside of the pool wall by a bolted flanged joint. This joint is sealed to a continuation of the pool liner by means of a double-bellows, flexible joint.

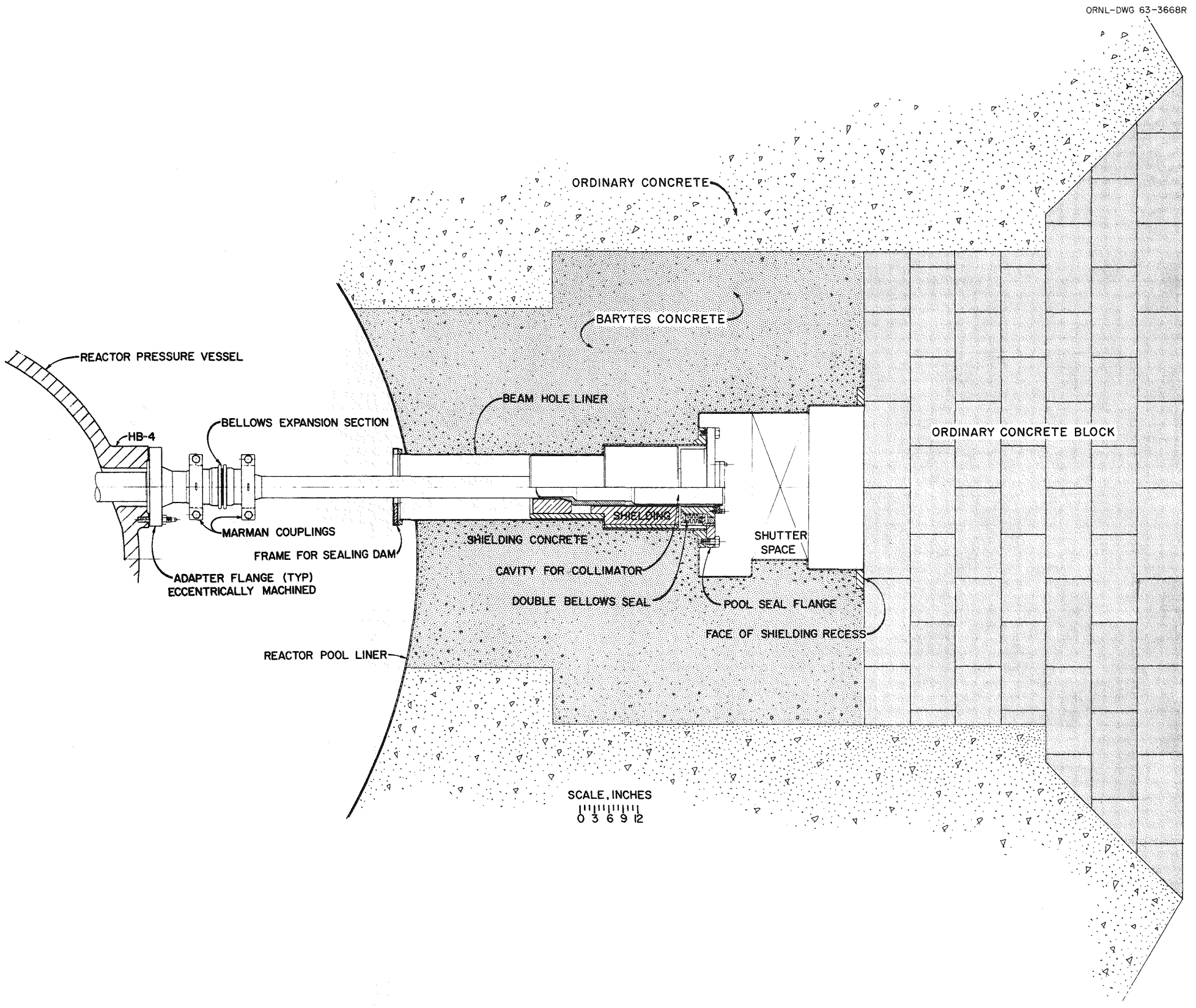


Fig. 5.3. Horizontal Beam Tube.

The recess inside the cavity is provided with a 2-1/2-inch SBHE vent, a 1 1/2-inch drain. stainless steel pipe sleeves, conduit sleeves, and 110-volt-duplex instrument and normal power receptacles. These services are brought out to valve stations and to quick-disconnect couplings at the shield face beside the beam port. Other services at each beam port include 60 psig air, demineralized water, reactor pool water (supply and return), process drain, and an OHOG vent line. Additional electrical outlets are also provided.

At the reactor end, each of the beam tubes is force-convection cooled by water flowing through 24 parallel milled grooves cut longitudinally into, and equally spaced around, the periphery of the tubes. Defined flow passages are formed by covering the tube with a close fitting jacket. Reactor primary coolant water is forced through the coolant jacket by the pressure drop across the reactor core. Water from the primary cleanup system is used to cool the inside of the beam tubes.

5.5. Vertical Experiment Facilities

5.5a. References

Drawings:

E-42017	Permanent and Semi-Permanent Reflector Assembly
42-501-060	HFIR Pressure Vessel Top Head

5.5b. Description

The permanent reflector is penetrated by 22 vertical holes which extend completely through the beryllium. The vertical holes are lined with 6061 aluminum. Sixteen of these holes have an inside diameter of 1.584 in. They are located concentric with the core and are on two circles of radii 15.306 in. and 17.344 in., respectively. The other six holes have a 2.834 in. inside diameter and are located in a concentric circle of radius 18.216 in. In addition to these 22 vertical holes, 16 similar 1/2-inch I.D. vertical holes are located in the removable beryllium.

The vertical facilities in the permanent beryllium are located beneath the upper plenum cover. Access to these facilities is by means of special penetrations through the plenum cover. The vertical facilities in the removable beryllium are reached by removing the inner shroud during fuel replacement.

5.6. Handling of New Research Experiments

The following procedures are for the handling of new research experiments from the time of initial contact by the reasearch personnel with Operations personnel until the termination of the experiment operation.

5.6a. Preliminary Contact of Operations by Research

Research personnel may initially contact anyone in the Reactor Operations Department. When this occurs, the research man shall be directed to the official liaison between Operations and research. In some cases discussions may be desirable with the Superintendent of the Reactor Operations Department.

5.6b. Preliminary Review and Space Assignment

The official liaison will handle the space assignments and will obtain any technical aid from the Operations Technical Assistance Department and the I & C Division on the experiment design after all space assignments and other initial decisions have been made by Reactor Operations Department through the liaison.

5.6c. Assignment of the Experiment to Technical Personnel

After all preliminaries have been completed, the handling of the experiment will be turned over to an Operations technical man selected by the Superintendent of Operations Division. The duty of this person is to see that initial requirements in the design and installation of the experiment are met by the researcher. He will also see that any necessary changes or developments in design and installation have the approval of the Reactor Operations Department. He will see that the initial

requirements in the design and installation of the experiment are met by the researcher. He will also see that any necessary changes or developments in design and installation have the approval of the Operations Division. He will require that the research personnel complete, at the earliest possible date, a questionnaire for experiment review and submit it to the liaison for obtaining the necessary approvals. This questionnaire may be of a rudimentary nature to establish the operability of the experiment and to be reviewed only by Operations Division personnel. If this is done, a more detailed questionnaire must be prepared later, for safety approval by the Operations Division and, in most cases, by the Experiment Review Committee, before the experiment can be installed. If research personnel so desire, the detailed questionnaire may be completed at this time and may also serve as the operability questionnaire; however, the operability review should generally be done before the experiment is completely designed.

5.6d. Operability Review by Operations Division

The operability review should be made in the early stages of design. This may involve only a meeting with Operations Division personnel to review the following items:

1. Operational feasibility and compatibility with other experiments and with reactor operations.
2. Adequacy of equipment design from the standpoint of installation into, and removal from the reactor.
3. Provisions for neutralizing the equipment, in case of failure, so that reactor operation can continue.

5.6e. Final Review by Operations and the Technical Group

When the liaison is satisfied with the review questionnaire, it will be turned over to the head of the Operations Technical Assistance Department for final approval by Operations Division. If the experiment does not meet the approval of Operations Division, the questionnaire and comments will be given back to the liaison for revision by the research personnel. The liaison may contact the research personnel directly or have the Operations Technical man assigned to the experiment to do this. In some instances, for the purpose of clarification, it may be desirable to arrange a meeting between research personnel, Operations Technical Assistance Department Head, and other Operations personnel before approval is given.

5.6f. Review by I & C Division and the Experiment Review Committee

When Operations Division's requirements for the overall experiment are met, a request will be directed, by the liaison or Operations Technical Assistance Department Head, to the I & C Division for a final review of safeguard instrumentation. When the final review is satisfactory, written approval for the experiment will be given to the liaison for Operations Division by the Operations Technical Assistance Department Head. At the same time the Operations Technical Assistance Department Head will request that the experiment be reviewed by the Experiment Review Committee if it is considered sufficiently complex, hazardous, or different from already approved experiments; otherwise, the experiment will be considered approved for operation in a reactor. Those experiments requiring review by the Experiment Review Committee will be considered ready for operation only after they are reviewed and approved by the Committee.

5.6g. Installation and Inspection of the As-Built Experiment

1. All aspects of the installation of the experiment, including the scheduling of the time of installation, will be handled by the Operations Division technical man assigned to the experiment. After the installation is complete, a final inspection should be made by the liaison, with the aid of the Operations Technical Assistance Dept. and other personnel the liaison may request, in order to know that the "as-built" equipment meets the required specifications. Also, the specimens to be irradiated should be inspected, by the same personnel, if possible, before irradiation in the system. One of these inspecting personnel should be the reactor supervisor of the reactor into which the experiment is installed.
2. After the experiment is installed, the responsibility for liaison between Operations Division and research becomes the responsibility of the reactor supervisor who may at any time request assistance from the Operations Technical Assistance Department, Operations Technical man assigned to the experiment, or the official liaison.
3. Reinsertion of specimens in an approved facility will be under the direction of the reactor supervisor. He should notify the liaison and Operations Technical Assistance personnel to allow their inspection of the specimen and to obtain their approval for its insertion.
4. Reinsertion arrangements for an experiment facility which has been removed should be directed by the liaison in the same

manner as for a new experiment which has already been approved by the Operations Technical Assistance Department Head and the Experiment Review Committee.

5. Approval for changes, either in the method of operation or the physical makeup of an experiment, should be obtained by the liaison from the Operations Technical Assistance Department Head.

5.6h. Termination of Experiment

Termination of an experiment will be reported to the laison by the reactor supervisor. The liaison will take steps to place the Experiment Information File in the "inactive" files and notify the appropriate personnel that a facility has been vacated and may be offered for use to other research groups.

5.6i. Disposal of Used Experimental Equipment

Disposal of the used equipment from any experiment will be handled by the reactor supervisor and the research personnel involved. Storage of any equipment in the Operations area should be approved by the reactor supervisor.

5.6j. Experiment Operational Records

1. A brochure for each experiment is started when initial contact is made with the research personnel concerning any experiment. This brochure may be loose-leaf notebook in which copies of all correspondence, records or meetings, commitments, etc., are filed. It is not necessary to file all blueprints in the brochure since they are too bulky; however, schematics and layout

prints may be of value. A file is started and maintained by the liaison at the time the planning for any experiment is begun. It should contain duplicates of the material in the brochure plus all other literature and prints too detailed and bulky for the brochure.

2. The brochure should be in the possession of the Operations Division person who is in charge of the experiment at the time and should aid in defining when any other person's direct responsibility ends. The routing of the brochure is somewhat as follows:

   a. The liaison starts the brochure and inserts copies of correspondence, minutes of meetings, and memoranda stating decisions which occur during the initial phase.

   b. The technical man assigned to the experiment receives it from the liaison when he is placed in charge of the experiment.

   c. The Department Head in the Operations Technical Assistance Dept. receives it when it goes to him for approval. He returns it to the liaison after approval.

   d. After Operations Division and Experiment Review Committee approval is obtained, the brochure goes back to the technical man who is following the experiment.

   e. When the experiment is ready for the final inspection before operation, the brochure goes back to the liaison who will place it, after final inspection, in the file of "Operating Experiments" along with other literature related to the experiment. The reactor supervisor will add any

operating information which may be considered important as the experiment progresses.

f. When the experiment is finished, the liaison will place all of the literature concerning that experiment in an "inactive" or "completed" file. It is seldom necessary to keep all of the literature unless the experiment is likely to be repeated soon. During this time, the brochure will have accumulated a full record of the experiment handling and operation. Each person who has the brochure will be responsible for recording any pertinent data so that the next person will have a complete record when he receives it.

5.7. Experiment Pre-Operational Checks

Prior to reactor startup, all new experiment installations must be thoroughly checked to insure that the materials, workmanship, and components meet the safety requirements for the experiment and that all pre-installation requirements such as pressure and leak testing, weld x-rays, etc., have been met. In addition, it is necessary to check each safety monitor to establish that it will perform the necessary corrective action as stipulated in the experiment approval. This initial pre-start check is made by both the Reactor Operations Department engineer following the experiment and the reactor supervisor. Subsequent startup checks are generally done as a part of the reactor startup checks.

5.8. Coverage of Experiments by Operations Division Personnel

In order to ensure that unmanned research experiments are covered efficiently, safely, and expediently by Operations Division personnel, it is essential that all personnel be properly informed and that operational changes be relayed from one shift to the next. The following procedure summarizes the coverage of research experiments and the general steps to be taken in the event of difficulties:

A notebook is provided for all written instruction. In addition to the usual information supplied by the experiment sponsor, the "Experiment Information Sheet" will be filled out by the research coordinator or someone delegated by him to summarize the experimenter's instructions. These instructions must be up to date at all times and reviewed each week. If special instructions are made by an experimenter on the 4-12 or 12-8 shifts, the shift engineer will put them in the proper notebook position and leave a notice in the log book that additional instructions or changes in instructions have been received. Otherwise, all instructions from the experimenter must be presented to the reactor supervisor for review before being put into the notebook. When an experiment facility is not in use, the instructions will be removed from the notebook and filed by the research supervisor or someone delegated by him. The shift engineer is to check all instructions at the beginning of each shift for any changes. He should then give these instructions to all operators concerned.

6. COOLING SYSTEMS

6.1. Introduction

The cooling requirements for power operation of the HFIR are satisfied by two separate cooling systems. One of these, the reactor cooling system, is designed to remove virtually all of the energy from the core. This system uses demineralized water as the primary coolant which is pumped through the reactor tank at a design flow rate of 15,000 gpm. The primary coolant then passes through the tube side of three of the four primary heat exchangers where it gives up its heat to the secondary coolant which is circulated through the shell side of the heat exchangers. The secondary coolant (treated process water) is then circulated through a conventional induced-draft cooling tower which dissipates the heat to the atmosphere.

It is estimated[5] that approximately 0.3 Mw of reactor heat will be transferred to the reactor pool by conduction from heated surfaces and as the result of absorbed radiation. To accommodate this and up to 0.5 Mw of heat released by stored spent fuel elements, a second cooling system, the pool cooling system, permits circulation of 1000 gpm of pool water through the shell sides of two heat exchangers. The same secondary coolant system is used as in the case of the reactor cooling system.

Because of the heat generated by the fission product inventory in the core, it is necessary to provide cooling to the core for some time following shutdown. Under normal circumstances this is handled by the primary circulation pumps. In the event of a failure of power to the main pump motors, adequate coolant flow is maintained by battery-powered

[5] N. Hilvety, L. A. Haack, and J. R. McWherter, HFIR Pool Criteria, ORNL CF-61-3-82

d.c. motors attached to the shafts of the main coolant pumps. Any one of these motors can provide coolant flow sufficient to prevent damage due to afterheat. This d.c.-powered circulation system can also be used for operation at 10 Mw during a normal-power outage.

Each of the water systems has associated with it various components for the purpose of demineralizing, deaerating, and measuring the flow. Most of these components are located in the water wing of the building.

6.2. The Primary Coolant System

The primary reactor coolant is demineralized light water which is maintained at a pH of 5.0 ± 0.1 to minimize corrosion of the aluminum-clad fuel element. The system is designed to operate at a maximum reactor inlet pressure of 1000 psi; however, it is anticipated that the normal operating condition will be with an inlet pressure of 600 psi.

As illustrated in Figure 6.1., the primary coolant enters the pressure vessel through two 16-in. inlet lines located near the top. It passes, by parallel flow paths, through the fuel elements, control rods, target, and reflector and leaves the pressure vessel through an 18-in.-diameter line at the bottom of the vessel. The design inlet temperature is 120°F and the inlet pressure is 600 psi. At 100 Mw operation with 15,000 gpm flow the design exit temperature and pressure are 167°F and 525 psi, respectively.

Upon leaving the pressure vessel, the exit line passes through the pipe tunnel where it branches into four parallel headers leading the hot water to the four heat-exchanger cells. The 120°F water from each heat exchanger enters the associated main circulating pump. Flows from the circulating pumps recombine in the pipe tunnel and return to the reactor pool where the water passes through a filter before entering the reactor vessel. Sensing devices for measuring temperature and pressure, as well as the main venturi for measuring flow, are located in the return line within the pipe tunnel. The location of these devices is shown in Figure 6.2.

A 200-gpm bypass flow is taken from the main coolant flow stream at the heat exchanger exits. This bypass flow is sent to the primary coolant

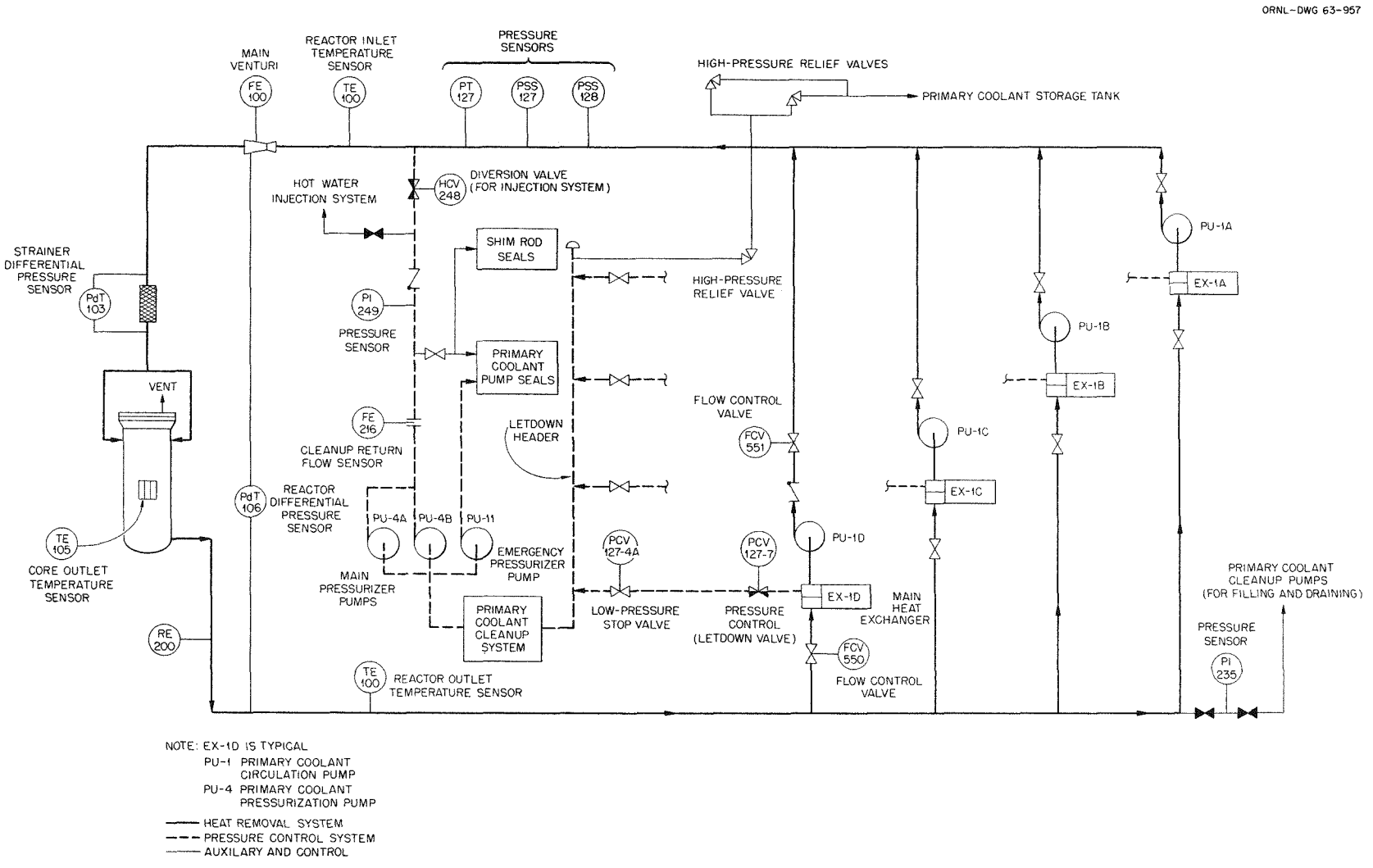


Fig. 6.1. Primary Coolant System.

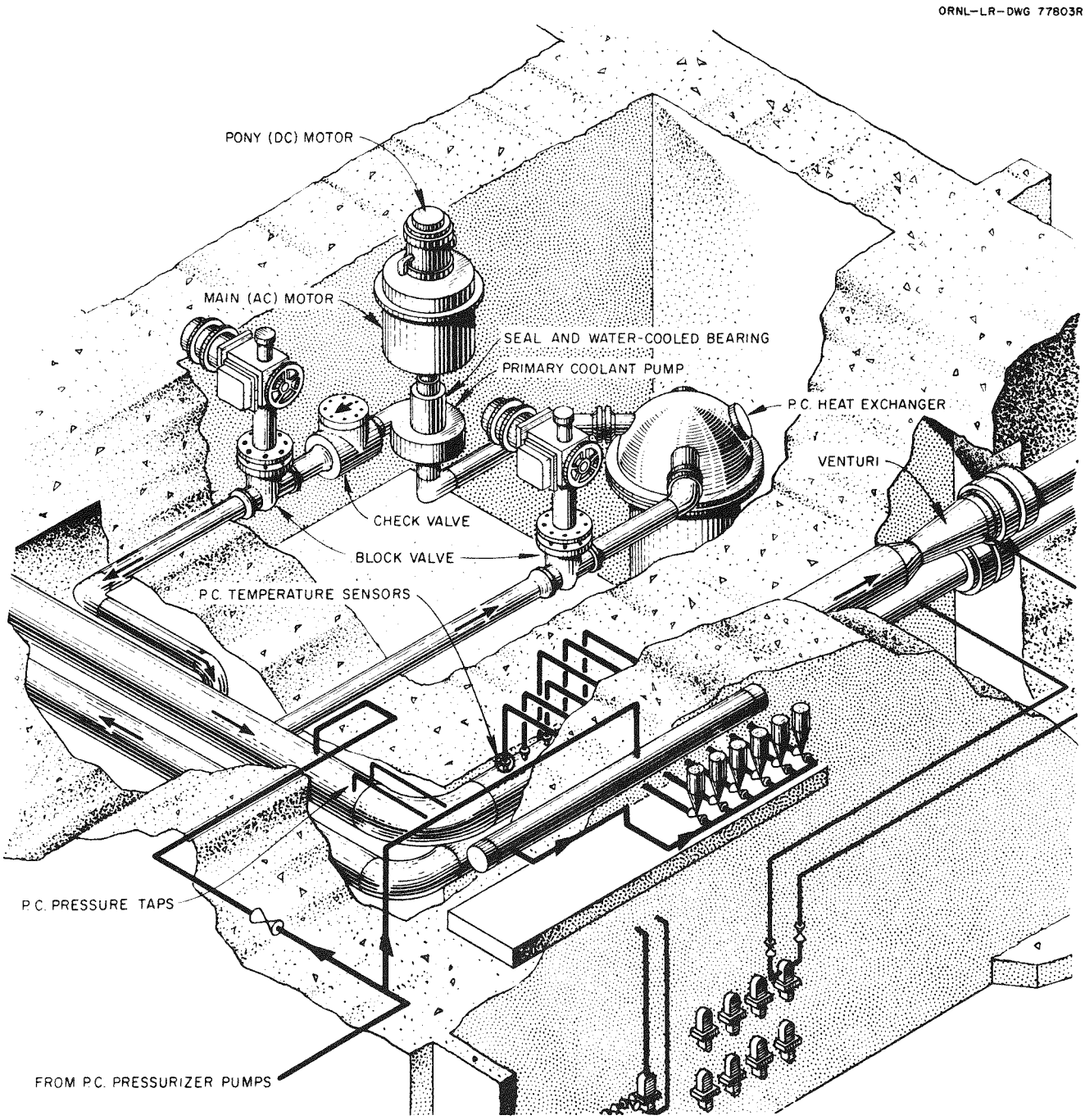


Fig. 6.2. Pipe Tunnel and Heat Exchanger Cell.

cleanup system which consists of a deaerator, filters, and demineralizer. Primary coolant pressure is maintained by pressure-controlled letdown valves located in these bypass lines at the heat exchanger exit. The 200-gpm return flow of clean water passes through the primary coolant pressurizer pump and returns to the main system in the pipe tunnel just upstream of the monitoring devices. This return flow is adjusted manually by varying the pressurizer pump speed with a magnetic coupling. The high pressure portion of the system is provided with two relief valves: one set at 975 psi, and one set at 1025 psi. Both discharge to the primary coolant storage tank.

It is convenient to divide the primary coolant system into two subsystems. The primary coolant high-pressure system, which has a capacity of approximately 13,800 gal, contains the reactor pressure vessel, high-pressure piping, primary heat exchangers, pressurizer pumps, and main cooling pumps. The primary coolant low-pressure system, which as a capacity of approximately 7,000 gal, contains the cleanup system deaerator, filters, and demineralizers. The systems are separated by the letdown valves and the pressurizer pumps.

6.2a. Primary Coolant High Pressure System

Reactor Vessel.--The reactor vessel, described in detail in another section, is designed to operate at internal pressures up to 1000 psi at temperatures below 200°F. It is fabricated of 2 7/8-in.-thick carbon steel with 1/10-in.-thick weld-overlaid stainless steel on the outside and 1/8-in.-thick stainless steel cladding on the inside. The vessel head is 14 in. thick, also of stainless steel clad carbon steel. Drive components for

control rods and fission chambers enter through a bottom flange. Various oblique, vertical, and horizontal openings are provided for experiment installation. The top head includes a central quick-opening hatch through which fuel elements, targets, reflector pieces, and control rods can be moved. In addition, there are numerous flanged openings in the top head to permit access to the vertical experiment positions in the beryllium.

High Pressure Piping and Filter.-- High pressure stainless steel piping connects the reactor vessel with the heat exchangers and pumps. Water enters the top of the reactor vessel through two diametrically opposed 16-in. lines. The outlet from the reactor vessel is a single 18-in. line which runs from the bottom of the tank through the pool liner and biological shield to the pipe tunnel. From this point, the header continues in the tunnel to feed the four individually compartmented heat exchanger-pump combinations. A 10-in. inlet line branches from the main header to the tube side of each heat exchanger. From the heat exchanger outlet, the line continues to the main circulation pump and returns to a 20-in. return header in the pipe tunnel. This 20-in. return header runs parallel to the outlet header in the pipe tunnel and continues into the reactor pool. Here it passes through the inlet filter, which contains a wire mesh basket with a maximum opening of 23 mills, before branching into the two 16-in. reactor inlet lines and entering the reactor vessel. The general arrangement is shown in Figures 6.3., 6.4., and 6.5.

Heat Exchangers.-- The primary heat exchangers are of the shell and U-tube type, mounted vertically, and designed to permit tube-bundle removal. Each heat exchanger, together with its associated circulation pump and letdown valve, is located in an individually shielded compartment.

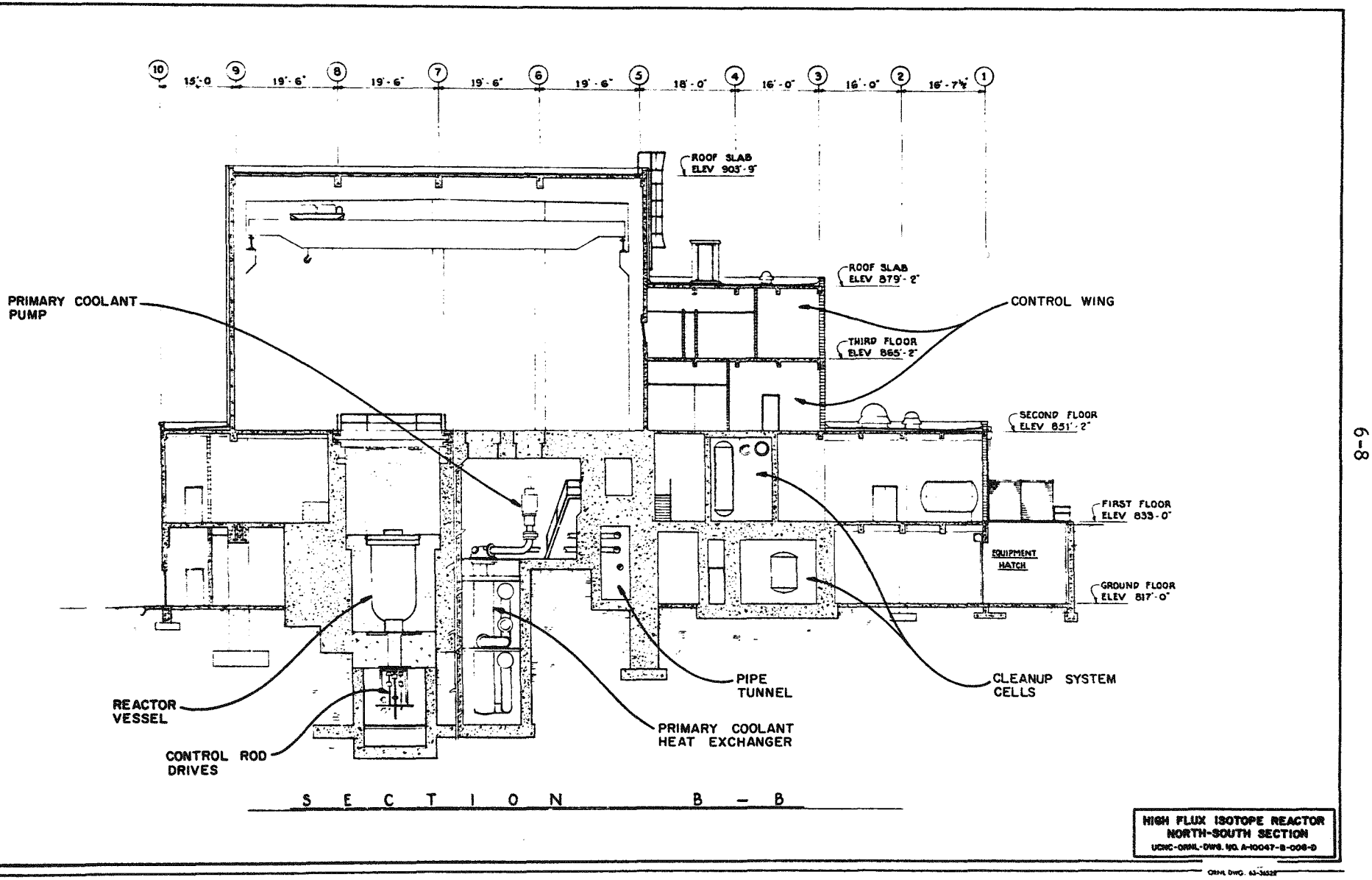
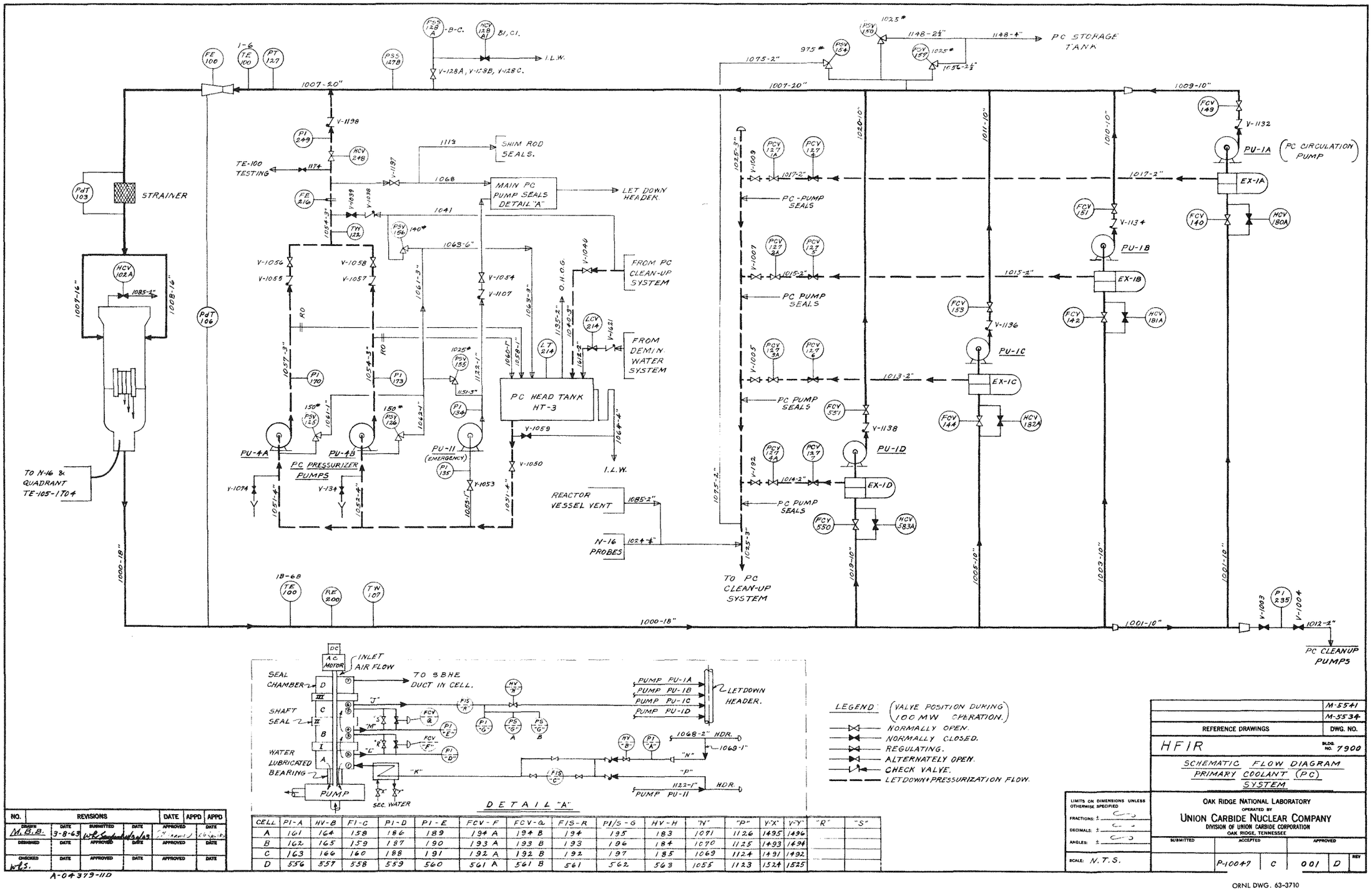


Fig. 6.3. Primary Coolant System Components.



CELL	PI-A	HV-B	FI-C	PI-D	PI-E	FCV-F	FCV-G	FIS-R	PI/S-G	HV-H	"N"	"P"	Y-X	Y-Y	"R"	"S"
A	161	164	158	186	189	194 A	194 B	194	195	183	1071	1126	1495	1496		
B	162	165	159	187	190	193 A	193 B	193	196	184	1070	1125	1493	1494		
C	163	166	160	188	191	192 A	192 B	192	197	185	1069	1124	1491	1492		
D	556	557	558	559	560	561 A	561 B	561	562	563	1055	1123	1524	1525		

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CHECKED W.L.S.	DATE	APPROVED	DATE	APPROVED	DATE

A-04379-11D

	M-5541
	M-5534
REFERENCE DRAWINGS	DWG. NO.
HFIR	BLDG. NO. 7900

SCHEMATIC FLOW DIAGRAM PRIMARY COOLANT (PC) SYSTEM

LIMITS ON DIMENSIONS UNLESS OTHERWISE SPECIFIED
FRACTIONS: ±
DECIMALS: ±
ANGLES: ±
SCALE: N.T.S.

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE NUCLEAR COMPANY
DIVISION OF UNION CARBIDE CORPORATION
OAK RIDGE, TENNESSEE

SUBMITTED	ACCEPTED	APPROVED		
	P-10047	C	001	D

REV

ORNL DWG. 63-3710

Fig. 6.4. Primary Coolant - Schematic Flow Diagram.

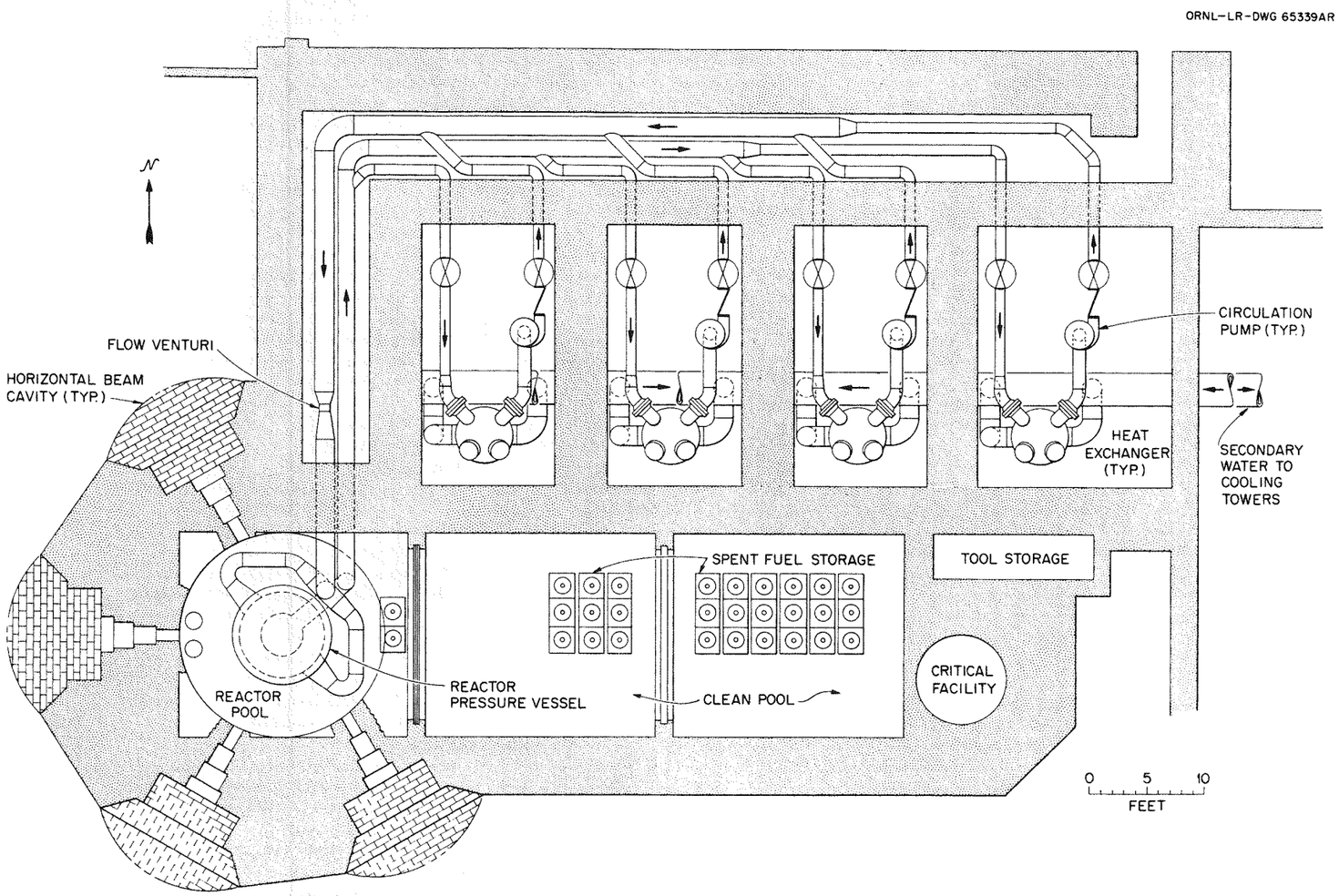


Fig. 6.5. Reactor Shield, Heat Exchanger Cells, and Pool Structures - Horizontal Section.

Each heat exchanger is designed to transfer ~117 million Btu/hr (34-1/3 Mw) from the primary cooling loop to the secondary cooling loop. Thus, only three heat exchanger-pump combinations are required for full power operation. The nominal design flow rates are 5000 gpm at 167°F in the primary system and 7000 gpm at 85°F in the secondary system.

The heat exchangers are ~34 ft long and contain 1190 U-tubes, each 5/8 in. in diameter. The tube side is designed to operate at up to 1000 psi at 200°F, and the shell side is designed for 150 psi at the same temperature: The tube bundles can be removed by the reactor bay crane through normally plugged and shielded hatches in the top of the heat exchanger cell (reactor bay floor). The heat exchanger support channel is at the 826-ft level with the remainder of the heat exchanger extending into the pit to the 796-ft elevation. All primary coolant system valves are located in the heat exchanger cells. Each heat exchanger-pump combination can be isolated from the system by motorized valves on the heat-exchanger inlet and pump discharge lines. Personnel may enter the cell containing the isolated unit while the reactor is at power. Access to the cells is from the first floor of the water wing.

Circulating Pumps.-- The vertical centrifugal primary coolant pumps, Figure 6.6., take their suction from the individual heat exchangers. Each pump is located in the same cell as its associated heat exchanger. The hatches in the reactor bay floor permit pump removal by the reactor bay crane. Each main pump, PU-1A, 1B, 1C, 1D, will deliver at least 5000 gpm against a 365-ft head of water when three pumps are operated in parallel. They are driven by 2300 volt, ac, 600 hp squirrel cage induction motors coupled to the pump shaft.

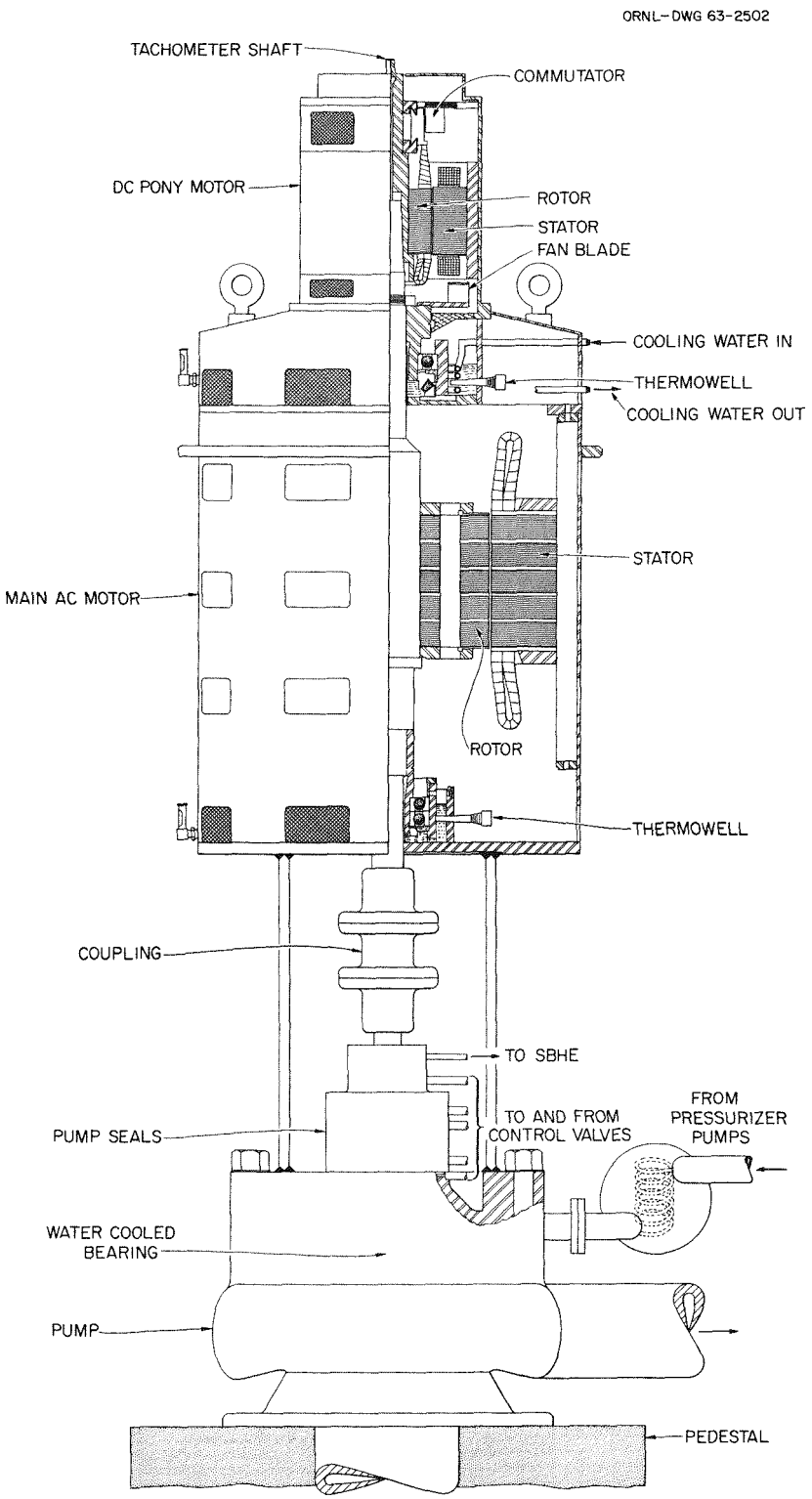


Fig. 6.6. Primary Coolant Pump Motors.

Directly coupled to each ac motor shaft is an auxiliary 3 hp, series wound, dc motor called a "pony motor". These motors are supplied with 120-v power from a failure-free system (see Section 10.8) and each one is capable of supplying at least 1300 gpm to the reactor. Shaft seals for the pumps are limited leakage mechanical type. Curves showing the pump characteristics are given in Figure 6.7.

In normal operation both the main ac motor and the pony motor are energized and supply torque to the pump rotor. Because only three main pumps are normally required at full power, a selector switch in the control room is provided to permit selection of the spare ac motor which is not to be included in the automatic startup sequence. The corresponding pony motor must be locked out by means of a manual circuit breaker. The main pump motor "Start-Stop" pushbuttons and running lights are located in the control room and a "Stop" pushbutton is located in each of the pump cells. The main pump motors are automatically stopped by any one of the following conditions:

1. Overload (relay must be hand reset to start).
2. Ground fault (relay must be hand reset to start).
3. Opening of the door to the 2400-volt motor starter.
4. Excessive vibration.
5. Low pressure in the primary loop.
6. Loss of normal 2.4-kv power.

Whenever a main circulating pump is on the line, the associated pony motor should be energized. The pony motor may be shut down only by opening a safety switch located in the battery room. An ammeter in the metering cabinet indicates current supplied to, or taken from, the battery bank.

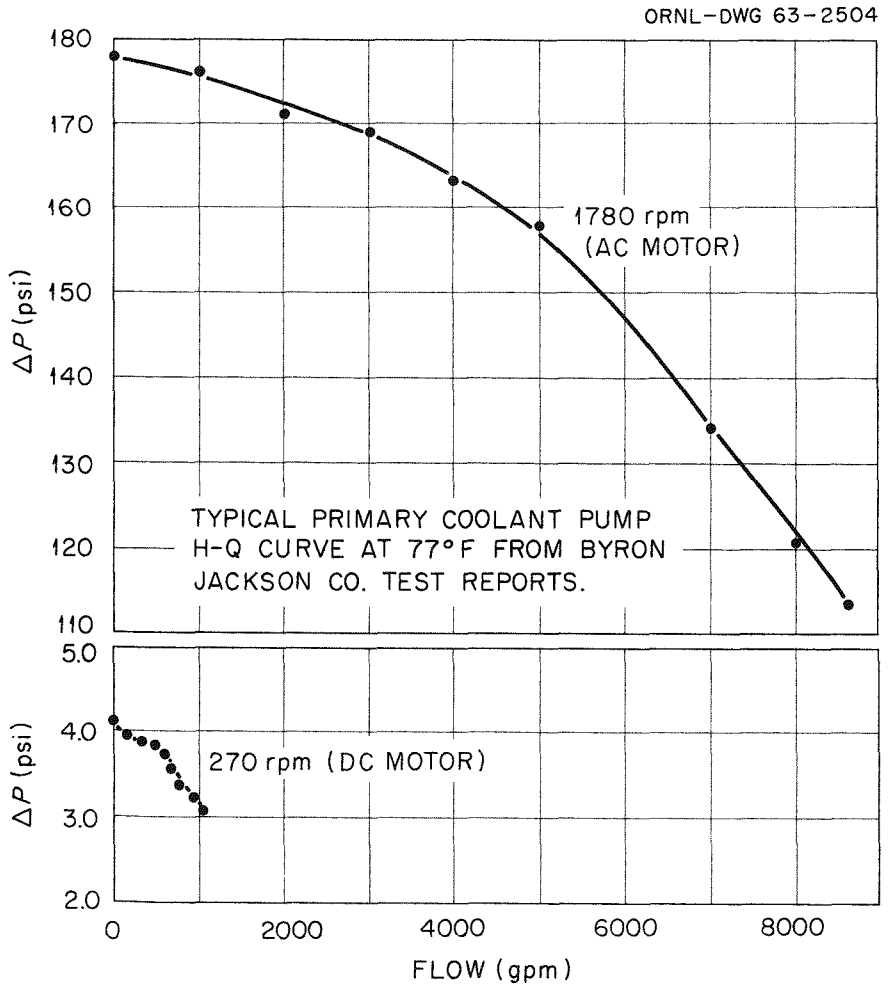


Fig. 6.7. Characteristic Curves for Primary Coolant Pumps.

The d-c pony motor also has a shunt field which permits a test at full load current with the main motor in operation. The test pushbutton which energizes the shunt field is located in the control room, as is the ammeter indicating the test current. The test circuit is shown in Figure 6.8. The test is prevented on loss of ac power to the motor.

Alarms are received in the control room should any of the following abnormal conditions exist at the primary coolant pumps:

1. Winding temperature higher than normal.
2. Winding temperature approaching insulation damage point.
3. Excessive vibration.
4. High motor-bearing temperature.
5. Charger failure or d c ground in battery charger.
6. Abnormally high current to the pony motor series field.
7. Abnormally low current to the pony motor series field.
8. Abnormal water flow to the mechanical seals.

Pressurizer Pumps.-- The two main pressurizer pumps, PU-4A and B, are 9-stage horizontal centrifugal pumps. A variable speed drive enables each pump to deliver up to 300 gpm at pressures up to 1000 psi. The characteristics of these pumps are shown in Figure 6.9. A small 6-1/2-gpm positive displacement pump, operated by the normal-emergency power supply, maintains primary loop pressure and circulating pump seal injection water flow during a failure of the normal power. The pressurizer pumps are located on the ground floor of the water wing. They take water from the primary water head tank (see Section 6.2b.) and discharge into the high pressure system between the main circulation pumps and the inlet to the reactor vessel.

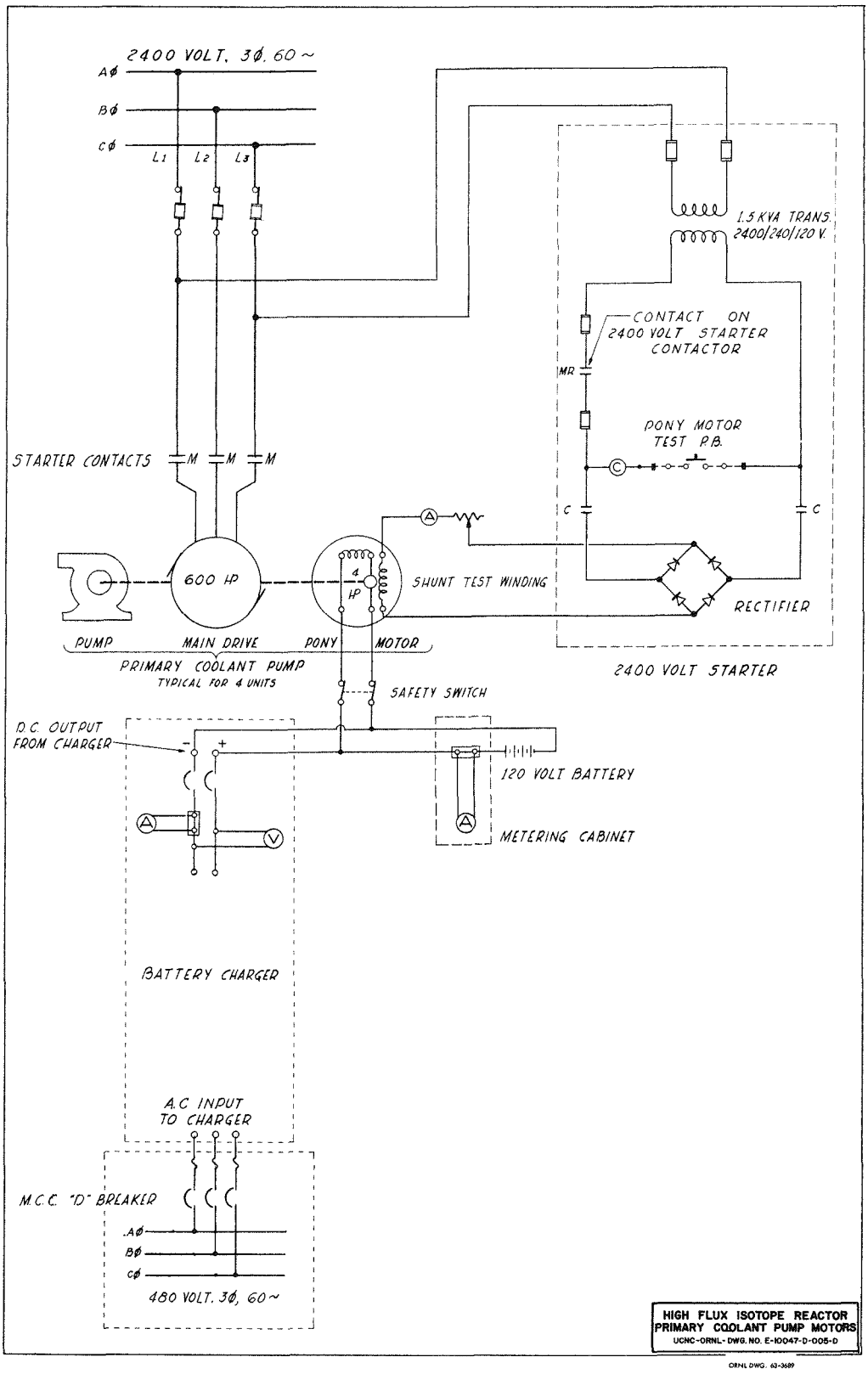


Fig. 6.8. Primary Coolant Pump Motor Test Circuits.

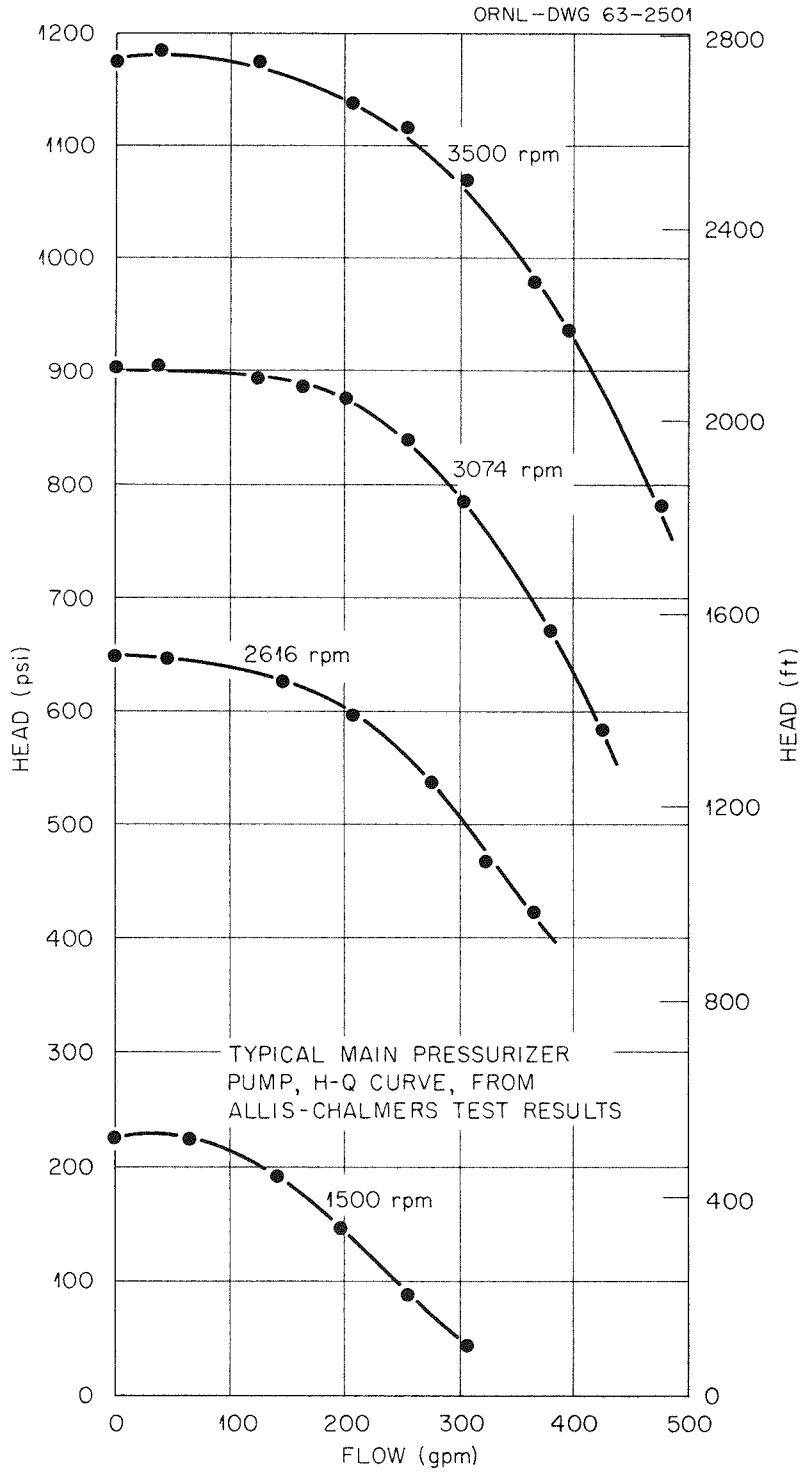


Fig. 6.9. Characteristic Curves for Main Pressurizer Pump.

The flow rate of water bypassed into the low pressure cleanup system is determined by the speed of the pressurizer pumps. The set point of the pressure-controlled letdown valves controls the pressure in the primary system. The pressurizer pump variable speed unit consists of a 2300-volt, 300-hp squirrel-cage induction motor and an "eddy current" coupling. A selector switch in the control room permits the selection of a pressurizer pump to be started in the "automatic-sequence" mode. Each pump has a spring return "Stop-Neutral-Start" selector switch, a "Stand-by" pushbutton, and a running light in the control room. In normal operation one pump is running while the other is in stand-by. The stand-by pump will automatically start upon an abnormal reduction of primary coolant system pressure. The pressurizer pumps are automatically stopped by the following conditions:

1. Overload (relay must be hand reset to start).
2. Ground fault (relay must be hand reset to start).
3. Opening of the door to the 2400-volt motor starter.
4. Low coolant flow to the variable speed coupling unit.
5. Loss of voltage.

The eddy-current coupling variable speed drive units are automatically started and stopped whenever the corresponding drive motor is started and stopped. Each unit is provided with a manually operated potentiometer and a speed indicator; both are located in the control room.

The emergency pressurizer pump has a locally mounted "Run-Off-Auto" switch to permit selection of the mode of operation. In the automatic mode the pump is automatically started by either a low-flow sensing element in the discharge line of the main pressurizer pumps or by an auxiliary con-

tact in normal-emergency switchge ar unit No. 1 during a failure of normal power. The pump, once started, will continue to run until manually stopped. Running lights for the pump are located at the local "Run-Off-Auto" switch and at a "Remote Control-Off" selector switch in the control room. The "Remote Control-Off" switch permits the pumps to be shut down from the control room. When either the "Remote Control-Off" switch or the "Run-Off-Auto" switch is in the "Off" position, an alarm is sounded in the control room.

6.2b. Primary Coolant Low Pressure System

The low pressure portion of the primary cooling system is the primary cleanup system and is separated from the high pressure cooling loop by the letdown valves and the pressurizer pumps. This system contains the following equipment: deaerator, pumps, prefilters, demineralizers, after filters, and primary coolant head tank with interconnecting piping. The flow schematic is shown in Figures 6.10. and 6.11., with the arrangement of this equipment, which is located in the water wing, shown in Figure 6.12.

Description of Flow in Low Pressure System.-- Primary coolant discharged through the letdown valves is sent through the primary coolant cleanup system before being returned to the high pressure system by the pressurizer pumps. The maximum design flow rate through the cleanup system is 200 gpm. The flow rate is controlled by varying the pressurizer pump speed. The flow from the letdown valves is joined by small flows of primary coolant from the N^{16} monitoring system, the primary circulation pump seals, and the reactor tank top vent (to remove trapped gases). The composite of these flows passes through a 48-ft section of 12-in.-diameter

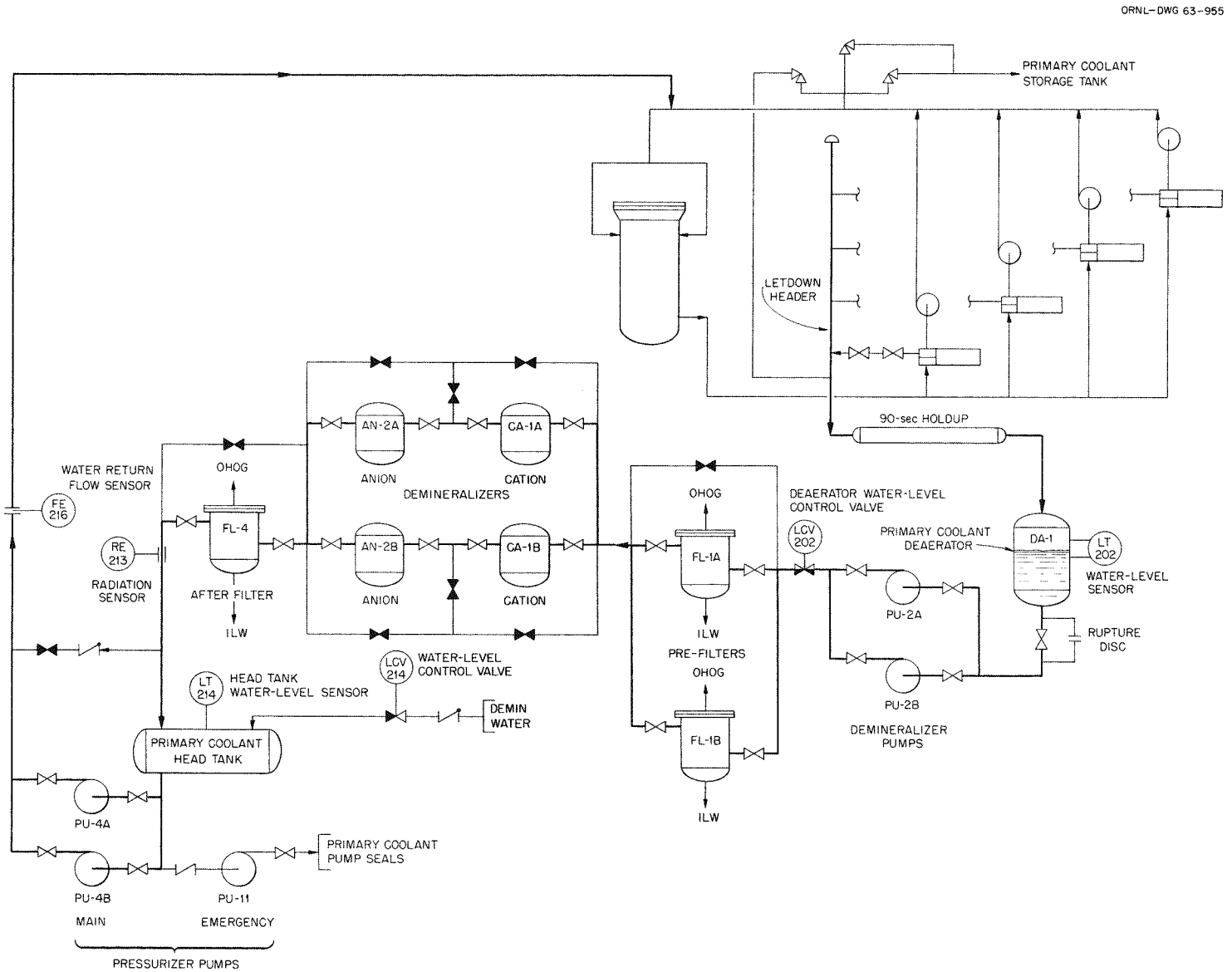
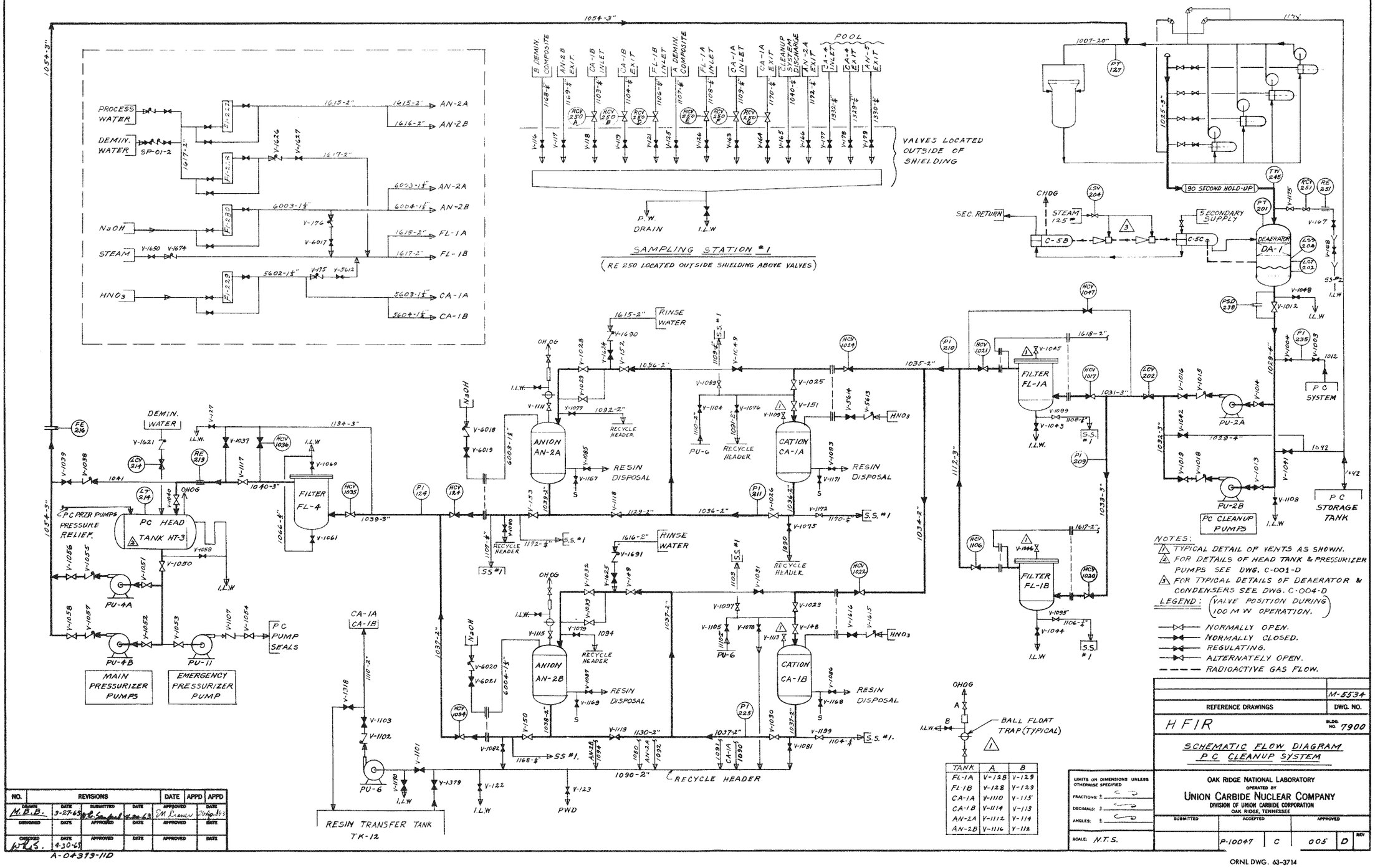


Fig. 6.10. Primary Coolant Cleanup System.



TANK	A	B
FL-1A	V-128	V-129
FL-1B	V-128	V-129
CA-1A	V-1110	V-115
CA-1B	V-1114	V-113
AN-2A	V-1112	V-114
AN-2B	V-1116	V-112

NO.	REVISIONS	DATE	APPD	APPD
DRAWN M.B.B.	DATE 3-27-63 SUBMITTED	DATE APPROVED	DATE	DATE
DESIGNED	DATE APPROVED	DATE APPROVED	DATE	DATE
CHECKED W.L.S.	DATE 4-30-63 APPROVED	DATE APPROVED	DATE	DATE

Fig. 6.11. Primary Coolant Cleanup - Schematic Flow Diagram.

ORNL-LR-DWG 77796R

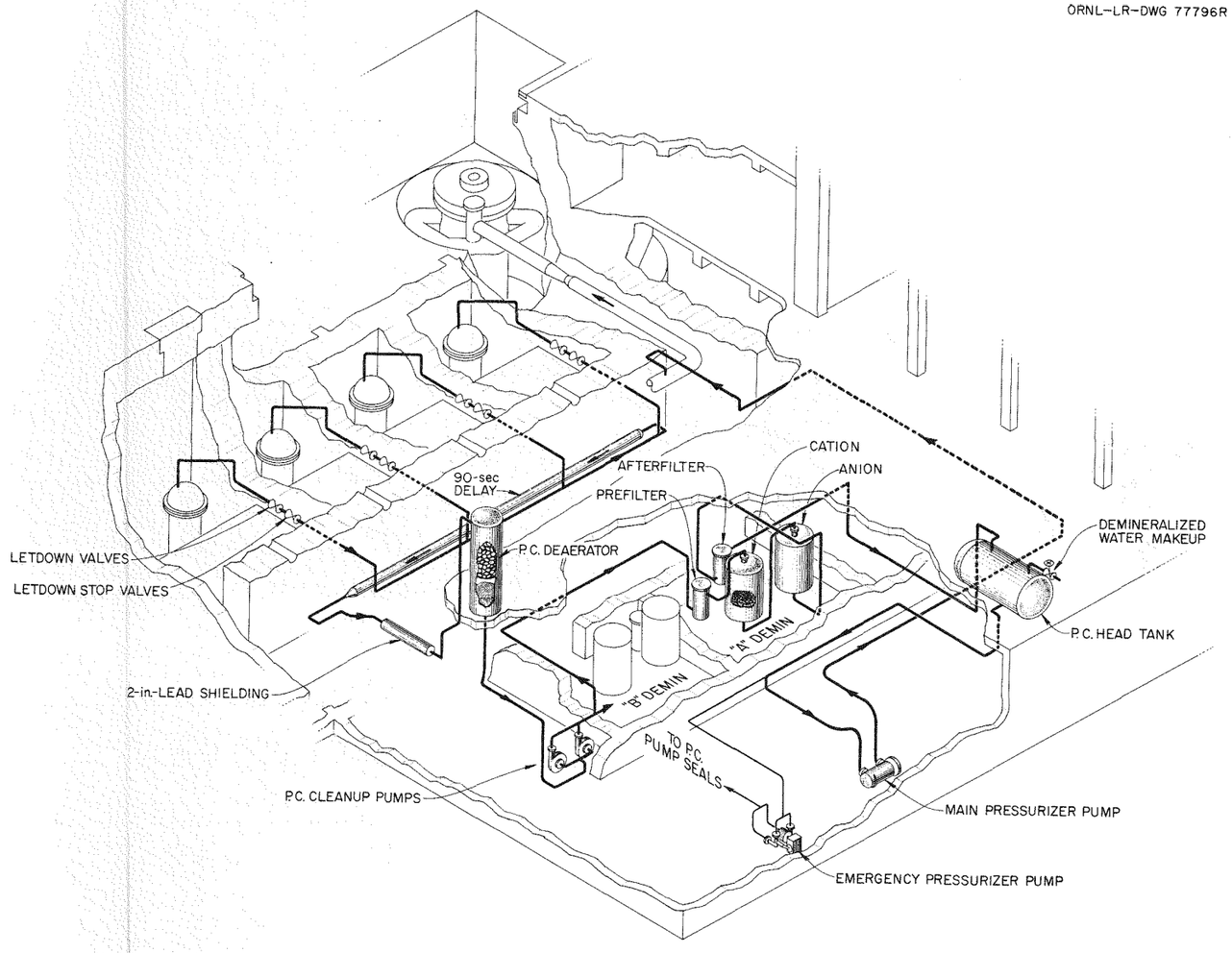


Fig. 6.12. Primary Coolant Cleanup Equipment Arrangement.

pipe located in the pipe tunnel. At a flow of 200 gpm this provides ~90 sec for the decay of N^{16} before the water leaves the pipe tunnel. From the N^{16} decay line, the water enters the primary coolant deaerator. Here most of the dissolved gases are removed and sent to the closed hot off-gas system. The deaerator also serves as a surge tank to handle changes in the letdown flow rate.

One of two 200-gpm centrifugal pumps, PU-2A and B, pumps water from the deaerator through the remainder of the cleanup system to the primary coolant head tank. A flow control valve throttles the flow from these cleanup pumps to maintain a constant level in the deaerator. The cleanup flow passes through one of the two prefilters into one of the two demineralizer systems. These systems are identical; each consists of a cation bed followed by an anion bed. The common discharge line from the demineralizers passes through the after-filter before discharging into the primary coolant head tank. The after-filter located in the exit line from the demineralizers prevents the resin fines from escaping.

A level control valve supplies plant demineralized water to the primary coolant head tank during primary coolant cooldown or as required by leakage. The primary coolant head tank provides the suction head for the pressurizer pumps.

Deaerator.-- The primary coolant deaerator, also shown in Figure 6.12., is designed to reduce the concentration of dissolved gases in the primary cooling water. During normal operation these include A, O_2, H_2, CO_2, and traces of fission gases. In the event of a fuel element meltdown or leak, the gaseous fission products are removed from the water and discharged into the closed hot off-gas system. The deaerator, with its associated

steam jets and condensers, is located on the first floor of the water wing. This equipment is enclosed in a cell shielded by 3 ft of high density concrete or its equivalent. Inlet and exit primary water lines and off-gas lines are also shielded.

Primary water enters the deaerator tank from the N^{16} decay line located in the pipe tunnel. The activity in this line is monitored by a radiation detector which sounds an alarm in the control room if high activity is detected. As the water enters the deaerator it falls through a bed of Raschig rings and is collected in the bottom of the tank. The primary cleanup pumps, PU-2A or B, take their suction from the bottom of the deaerator vessel. A pneumatic level sensor transmits a deaerator vessel liquid level signal to the main control room and to the flow control valve located on the discharge side of the cleanup pumps. The pH is monitored by a cell which receives a sample from the common discharge of these pumps and returns it to the ILW system. Water conductivity is also monitored at this point. Both conductivity and pH are recorded in the control room.

A vacuum is maintained in the deaerator tank by a steam-jet ejector system which consists of a precondenser, high-vacuum ejector, low-vacuum ejector and an after-condenser. The evolved gases are discharged to the closed hot off-gas system. The condensers are cooled by secondary coolant. Condensate from both pre- and after-condensers is returned directly to the deaerator tank. A deaerator overflow line is provided which discharges into the intermediate level waste system.

Filters and Demineralizers.-- The primary coolant filters and demineralizers are designed to remove particulate and dissolved material from

the primary coolant. During normal operation the prefilters prevent particulate material from reaching the demineralizers. The after-filter removes demineralizer-resin fines from the water before it is returned to the high pressure system. The demineralizer resins remove dissolved contaminants from the water. In the event of a fuel meltdown, particulate and dissolved fission products in the water will be removed by the filters and demineralizers. The prefilters, demineralizer units, and after-filter, shown in Figure 6.13., are located in a pair of shielded cells on the ground floor of the water wing.

Each of the two prefilters has a nominal flow capacity of 200 gpm and consists of 28 porous tubes, 2-3/4 in. in diameter by 19-1/2 in. long, made of sintered stainless steel. Water flows from the outside to the inside of the tubes through 20-micron pore openings. These filter elements can withstand a pressure drop of 150 psi. Additional shielding is provided by 3 in. of lead around the filter shell. Both prefilters are vented to the open hot off-gas system through ball float traps. Each unit can be operated from outside the shielded cells.

The demineralizer system consists of two units in parallel, each with a design flow rate of 100 gpm. Each unit consists of a cation bed and an anion bed in series. Each cation bed contains 35 cu ft of cation resin in a vessel 4 ft in diameter by 6 ft high. Each anion bed contains 60 cu ft of anion resin in a similar vessel 5 ft in diameter by 6 ft high. Under normal operating conditions, one unit is in service. Some of the cation effluent is bypassed around the anion bed to aid in maintaining a system pH of 5.0 ±0.1. Additional local shielding is provided by 3 in.

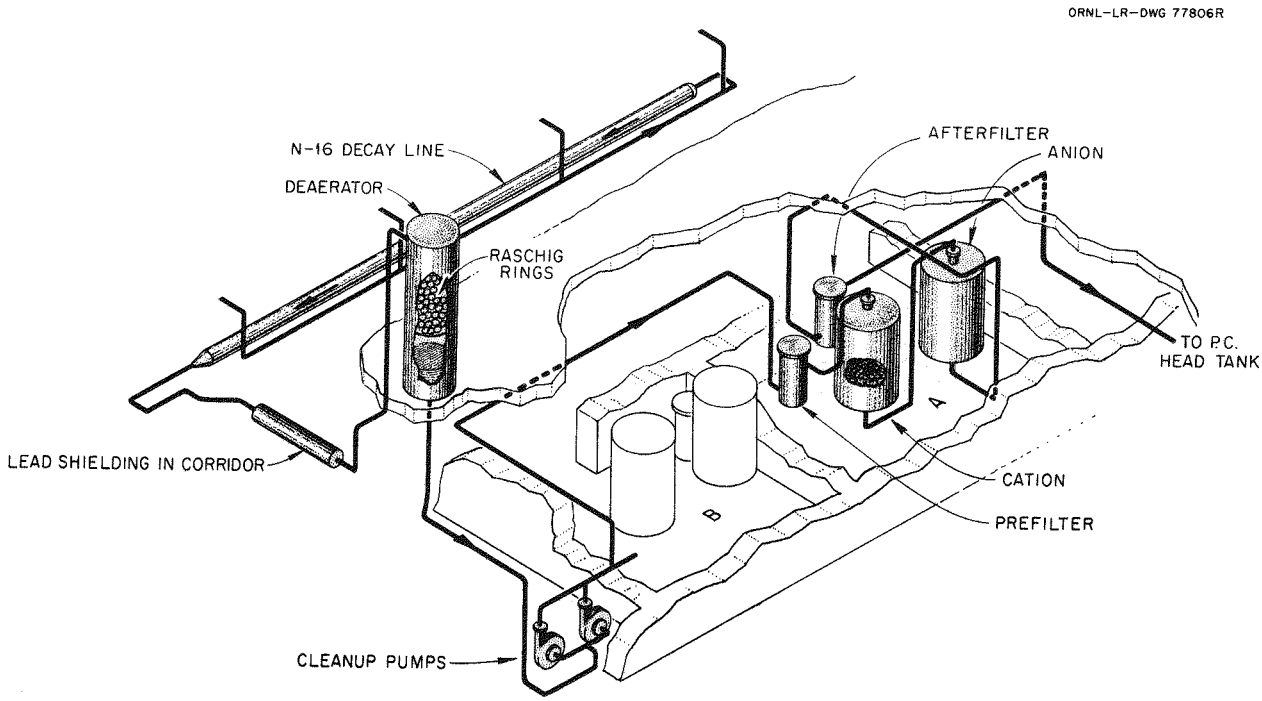


Fig. 6.13. Primary Coolant Cleanup System Details.

of lead surrounding the cation tanks. The anion tanks are not directly shielded.

The after-filter is designed for a 200-gpm flow rate. The filter element is 100 mesh stainless steel screen which has a mean pore opening of 120 microns. The filter element can withstand a maximum pressure differential of 150 psi, the TDH of the cleanup pumps. Pressure drop across a clean filter is 1.5 psi at 200 gpm flow. The after-filter can be operated, bypassed, and cleaned from outside the shielded cell.

From the after-filter the clean water is sent to the primary coolant head tank which is located on the first floor of the water wing. It is a 2500 gal horizontally mounted stainless steel tank 6-ft-6 in. in diameter by 11-ft-8 in. long.

6.2c. Primary Coolant Makeup, Fill, and Drain Systems

During routine operation at pressure, makeup water to replace that lost by leakage from the system is furnished by the plant demineralized water pumps, PU-18A and B. This is automatically supplied to the primary coolant head tank through a water level control valve.

Several lines are available to permit filling, draining and flushing the system at low pressure. A shielded 20,000-gal primary coolant storage tank is located underground at the northeast corner of the building. Water from the primary coolant system can be sent directly to this tank or can be routed through the primary coolant demineralizers by means of a 2-in. line which bypasses the pressure letdown valves and deaerator. A 3-in. line connects the discharge of the primary coolant after-filter to the discharge line of the pressurizer pumps, thus permitting the primary coolant cleanup pumps to send water to the primary

coolant system. Thus, it is not necessary to use the large pressurizer pumps to circulate primary coolant through the filters and demineralizers while the reactor is depressurized. A schematic diagram of the fill-and-drain lines is shown in Figure 6.14.

The roof top of the underground water storage tank is at grade level. Its walls, floor and roof are of 14-in. thick concrete. The inside is lined with plastic sheets bonded together to form a watertight shell. A 4-in. line exits from the bottom of the storage tank, enters the east side of the water wing, and leads to the primary coolant cleanup pumps. The transfer line can be valved into either the suction or discharge of either or both of these pumps to transfer water to and from the underground storage tank.

The storage tank is vented to the SBHE system.

6.2d. pH Control System

An automatic pH control system maintains the primary coolant at a pH of 5.0 ±0.1. The pH of the pressurizer pump discharge flow, which is injected into the primary system, is controlled by an automatic addition of 5% HNO_3 to the primary head tank. The 5% acid is mixed in the acid day tank and pumped into the head tank by a small (50 cc per hour) chemical feed pump. The pH of pressurizer pump effluent water will be adjusted as required to maintain the primary coolant system at a pH of 5.0.

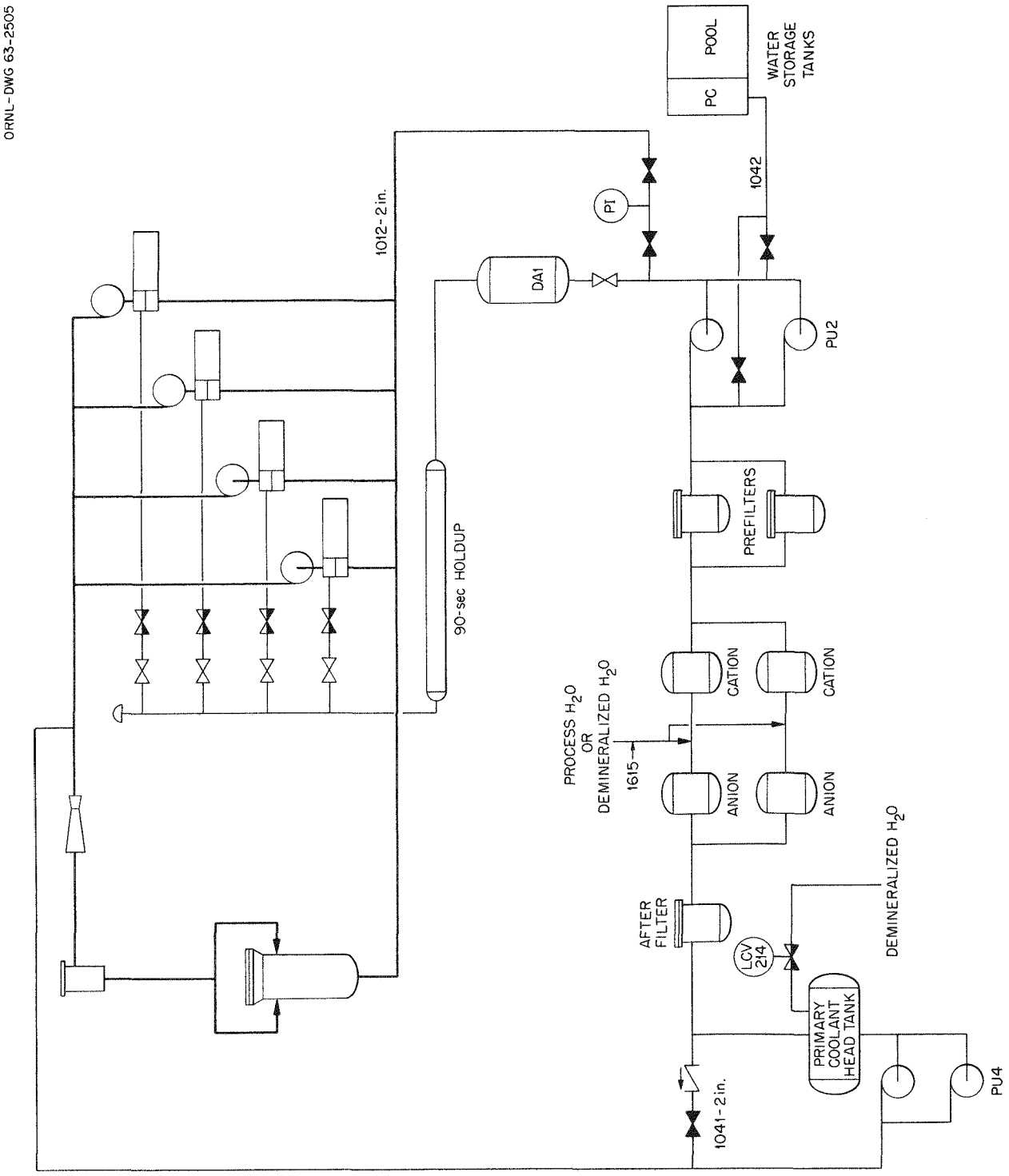


Fig. 6.14. Primary Coolant Makeup, Fill, and Drain Systems.

6.3. Secondary Coolant System

6.3a. Introduction

Heat from the HFIR complex is dissipated to the atmosphere by a conventional induced-draft cooling tower. The secondary coolant pumps circulate water through the cooling tower and the various heat exchangers thus removing heat from the different systems. Of the nominal 26,000 gpm circulated in the system, ~21,000 gpm passes through the primary coolant heat exchangers, ~3200 gpm through the auxiliaries in the water wing, and ~1800 gpm goes to the adjacent Transuranium Processing Facility (TRU). The secondary coolant system is shown in Figues 6.15., and 6.16.

6.3b. Cooling Tower

The cooling tower is a four-cell induced-draft tower located southeast of the reactor building. It is designed to transfer 380 million Btu/hr by cooling 26,000 gpm of 115°F water to 85°F at an ambient wet bulb temperature of 77°F. Of this total heat transferred, 350 million Btu/hr is supplied by the primary coolant, 10 million by the pool coolant, 8 million by the air-conditioning system, 3 million by other loads, and 4 million is reserved for future operations. The cooling tower is composed of four individual cells mounted as one unit over a concrete basin approximately 120 ft long by 54 ft wide. The basin is divided into four separate compartments, each with a capacity of 100,000 gal. This 400,000-gal storage capacity is sufficient for ~8 hours of full power operation without makeup water. Each compartment can be drained and cleaned individually while the rest of the tower is operating. Potable water is supplied to the tower basin through a float valve to make up for evaporation, drift loss, and blowdown.

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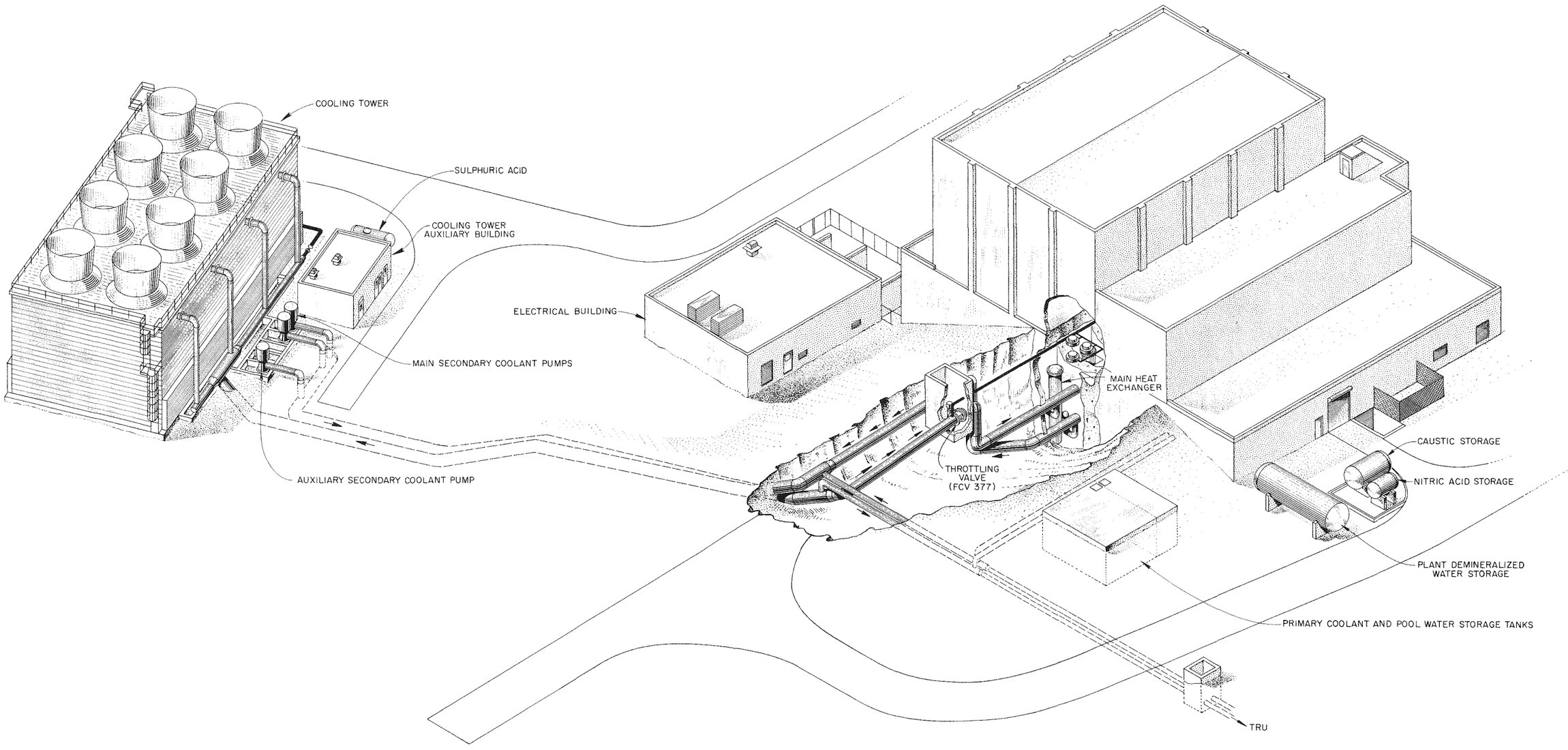
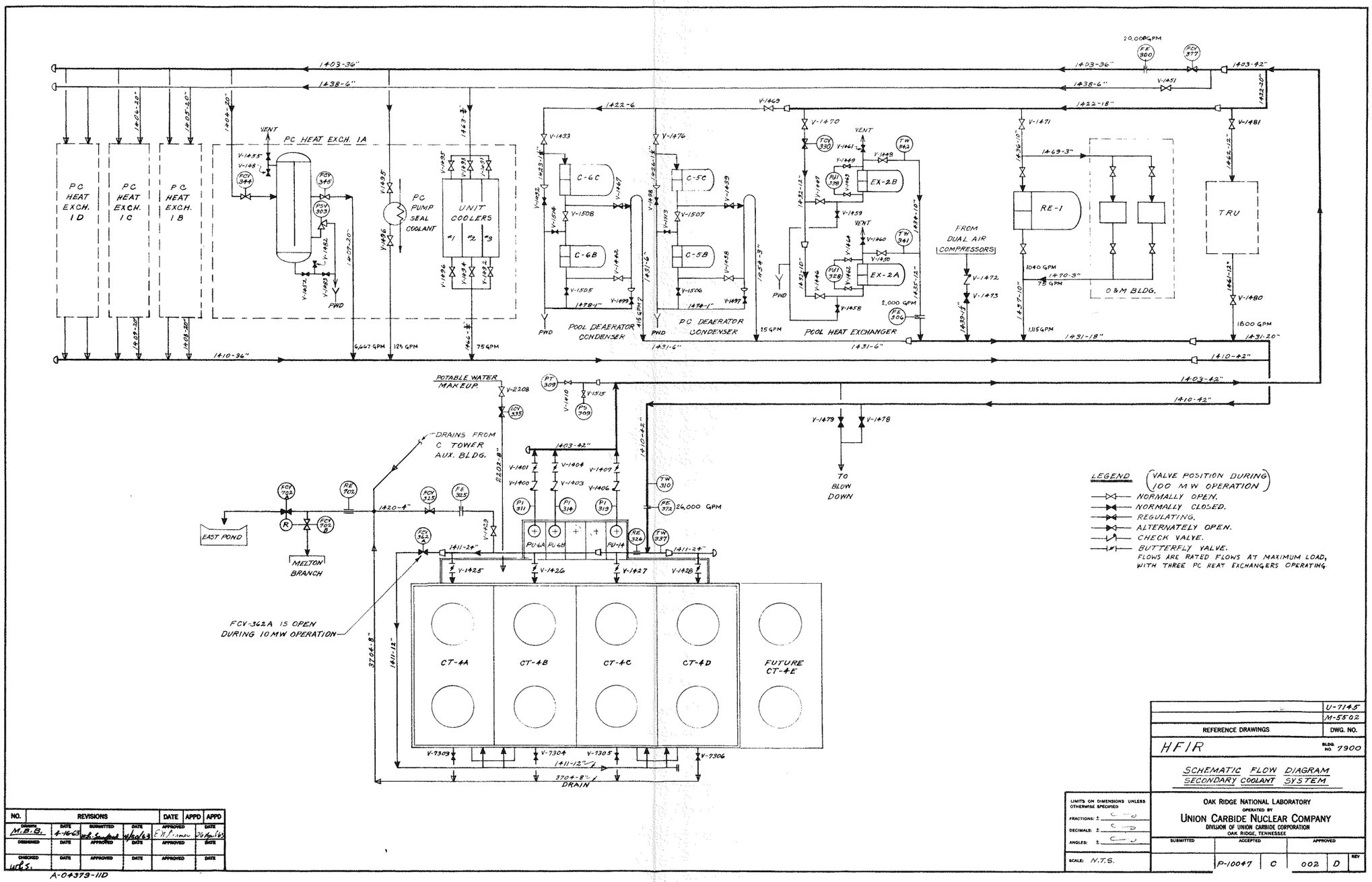


Fig. 6.15. Secondary Coolant Equipment Arrangement.



NO.	REVISIONS	DATE	APPD	APPD
DRAWN M.B.B.	DATE 4-16-63 SUBMITTED W.E.S. [illegible] DATE 4/26/63	APPROVED [illegible] DATE 5-11-63		APPROVED [illegible] DATE 5/24/63
DESIGNED	DATE APPROVED DATE	APPROVED		APPROVED DATE
CHECKED W.E.S.	DATE APPROVED DATE	APPROVED		APPROVED DATE

A-04379-IID

	U-7145
	M-5502
REFERENCE DRAWINGS	DWG. NO.
HFIR	BLDG. NO. 7900

SCHEMATIC FLOW DIAGRAM SECONDARY COOLANT SYSTEM

LIMITS ON DIMENSIONS UNLESS OTHERWISE SPECIFIED
FRACTIONS: ± [illegible]
DECIMALS: ± [illegible]
ANGLES: ± [illegible]
SCALE: N.T.S.

OAK RIDGE NATIONAL LABORATORY
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OAK RIDGE, TENNESSEE

SUBMITTED	ACCEPTED	APPROVED		
	P-10047	C	002	D

REV

ORNL DWG. 63-3711

Fig. 6.16. Secondary Coolant - Schematic Flow Diagram.

6.3c. Cooling Tower Fans

Each cell is equipped with two 50-hp two speed fans which can be reversed for de-icing the tower. Operation of the cooling tower fans is controlled by a "Run-Off-Auto" mode switch on the control room process panel board. When in the run mode, each fan is controlled by a three-unit pushbutton station located in the control room. This station provides alternatively for:

1. Fast speed-forward direction.
2. Slow speed-forward direction.
3. Slow speed-reverse direction.

A time-delay relay provides for automatic deceleration when transferring from fast to slow speed or reverse or from reverse to forward. Mechanical interlocks permit only one starter coil to be energized at a time. Indicating lights designating the different speeds are located on the process panel in the control room.

In the automatic mode, the fan speed is controlled by a temperature controller through eight dual switches. Each of these switches operates two time-delay relays, one for fast forward speed, the other for slow forward speed. Each relay controls the two fans, as a unit, in one of the tower cells. The time-delay relays are adjustable and perform the following functions:

1. The provision of different time settings for the relays allows the fan load to be added to the motor control center in a stepped sequence. This limits the voltage drop to permissible levels when voltage is restored under maximum

cooling requirements following a power outage.

2. By adjustment of the time delay, the number of starts, stops, and speed changes can be limited, thus preventing motor overheating due to cycling.
3. The relays permit the use of low voltage switches to operate the high voltage fan starters.

In the automatic mode, the fans will automatically restart after a power failure. A typical response to an automatic startup is shown in Figure 6.17. In the run mode, the fans must be restarted manually following a power failure. All the fans are automatically shut down by a fire alarm from the cooling tower. A vibration switch near each fan shuts down only the affected fan. These devices must be manually reset before the fans can be restarted.

6.3d. Water Treatment

The blowdown and chemical treatment of the secondary coolant system is designed to inhibit corrosion, scale formation, and microbiological growth. The water in the secondary cooling loop is chemically treated as follows:

1. Automatically regulated addition of H_2SO_4 to control pH.
2. Automatic addition of phosphate or chromate chemicals to inhibit corrosion.
3. Manual addition of nonoxidizing biocides to control algae.

The acid-injection system consists of a 5000-gal H_2SO_4 storage tank, two proportionating chemical feed pumps, an acid-water mixer, and an instrumentation system which measures pH and controls the pumps. Phosphate-chromate treating equipment consists of a dissolving tank and a pair of

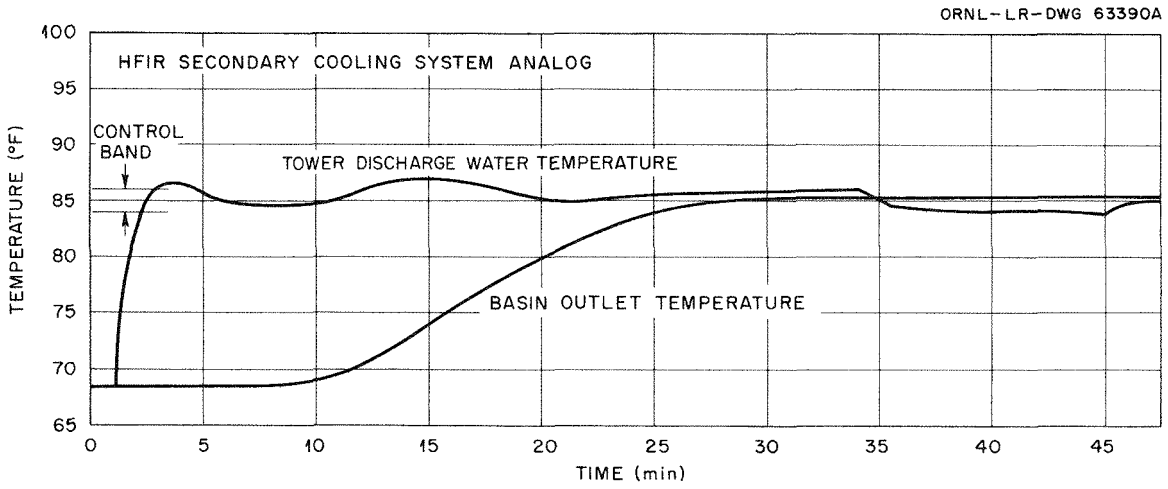

Fig. 6.17. Typical Secondary Coolant Temperature Response Following Startup.

manually adjustable proportionating feed pumps.

6.3e. Secondary Coolant Pumps

The two main secondary coolant pumps, PU-6A and B, are vertically mounted centrifugals which have a combined capacity of 26,000 gpm. The characteristics of these pumps are shown in Figure 6.18. A smaller third pump, PU-14, has a capacity of 6000 gpm. It provides shutdown and emergency water circulation. These pumps are mounted in a separate pump basin along the north side of the cooling tower. The pump basin is fed by a flume which collects water from the individual tower basins. A chemical treatment distribution header above the pump basin mixes the chemicals with the basin water.

During periods when the reactor is shut down, the cooling demand is greatly reduced. The 6000-gpm pump is then put into service and the main pumps are stopped. This pump maintains cooling for the auxiliary systems. It also provides 3000 gpm emergency flow during a normal-power outage when a second winding receives power from the auxiliary diesel motor-generator set.

A selector switch in the control room permits choice of a main secondary pump to be excluded from the automatic startup sequence. This is in anticipation of the installation of a third main pump to serve as a spare. A spring return "Start-Neutral-Stop" switch for each pump is located in the control room. The pumps are automatically stopped by the following conditions:

1. Overload (relay must be hand set to start).
2. Ground fault (relay must be hand set to start).
3. Opening of 2400-volt motor starter door.

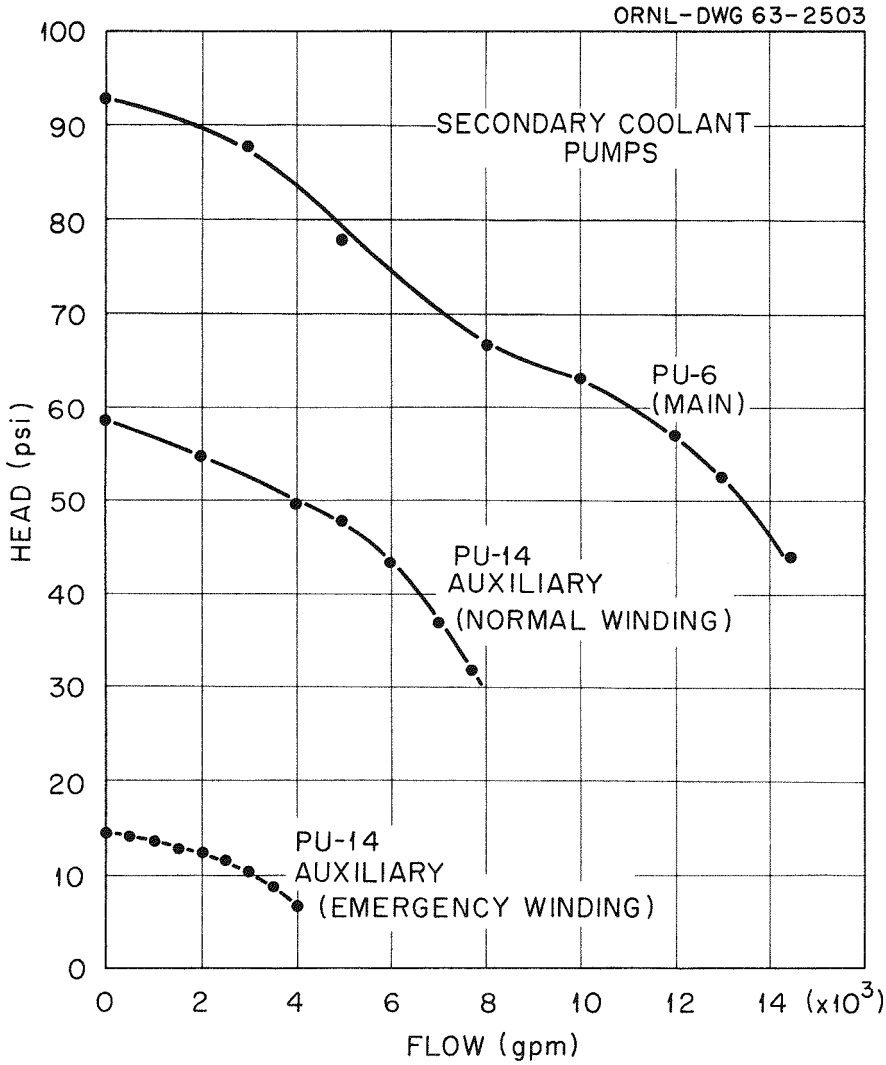

Fig. 6.18. Characteristic Curves for Secondary Coolant Pumps.

4. Loss of voltage.

The auxiliary 6000-gpm circulation pump, PU-14, is driven by a two-winding motor. The high-speed winding provides sufficient secondary coolant flow, 6000 gpm, to handle the normal requirements at the site when the reactor is not operating at power. The slow-speed winding, supplied from the normal-emergency power system, provides sufficient cooling, 3000-gpm, to permit the reactor to operate at 10 Mw during a normal-power outage because other heat sources are inoperative. A spring return "Stop-Neutral-Start" switch for the high-speed winding and a running light are located in the control room. Electrical and mechanical interlocks between the high- and low-speed starters permit only one to be energized at a time. A "Run-Off-Auto" mode switch and a running light are located in the control room. This permits selection of the mode of operation for the slow-speed winding and indicates the mode chosen. An alarm is sounded in the control room when the switch is placed in the "Off" position.

In the automatic mode, the slow-speed winding is energized upon loss of normal power by a contact in normal-emergency transfer switch No. 1. The contact is closed when the transfer switch is in the emergency position, i.e., the diesel generator is supplying power to the No. 1 normal-emergency circuit.

The pump will continue to run, after normal-power has been restored, until manually shut off. The slow-speed starter is interlocked with a solenoid valve so that return flow is routed through a bypass directly to the tower basin when this winding is energized.

The secondary coolant pumps discharge water into a 42-in. pipe which runs underground to the east side of the reactor building where it divides

into a 36-in. and an 18-in. line (see Figure 6.15.). The 36-in. line carries approximately 21,000 gpm of cooling water to the primary coolant heat exchangers. The 18-in. line supplies the pool heat exchangers, air conditioning units, other auxiliary equipment, and the TRU facility. Return water lines to the cooling tower run parallel to the supply headers. Remotely operated motor-driven control valves on the inlet and exit of each primary heat exchanger throttle the flow to the individual heat exchangers and permit them to be isolated for cleaning and repair. An automatic flow control valve regulates the flow of secondary coolant to the heat exchangers as required to maintain a constant primary water temperature of 120°F.

6.4. Pool Water System

The reactor pressure vessel is located in a cylindrical pool 18 ft in diameter and 36 ft deep which contains approximately 80,000 gal of water. Connected to this pool is a rectangular storage pool, 41-1/2 ft long, 20 ft deep, and 18 ft wide, which contains approximately 114,000 gal of water. A smaller cylindrical pool 8 ft in diameter and 25 ft deep is located at the east end of the rectangular pool. This is provided to accommodate a future critical assembly. The critical assembly pool contains approximately 10,000 gal of water.

The reactor pool is separated from the rectangular pools by a removable gate. The rectangular pool, called the clean pool, is divided into two 20-ft sections by means of a second removable gate. All of the pools are lined with stainless steel to prevent leakage, to permit decontamination, and to help maintain the water purity. The general arrangement is shown in Figure 6.19.

The pool water requires circulation and heat removal to dispose of up to 0.8 Mw of heat absorbed from the reactor core, hot primary coolant components, and stored spent fuel elements. Moreover, to reduce corrosion and to maintain a low contamination level, it is necessary to circulate a fraction of the pool water through a cleanup system.

6.4a. Pool Coolant System

All pools are provided with overflow scuppers at the 848-ft level. Pool water overflowing into these scuppers flows by gravity into the pool surge tank as shown in Figures 6.20., 6.21., and 6.22. The pool surge tank maintains a positive suction head on the two pool-coolant pumps, Pu-9A

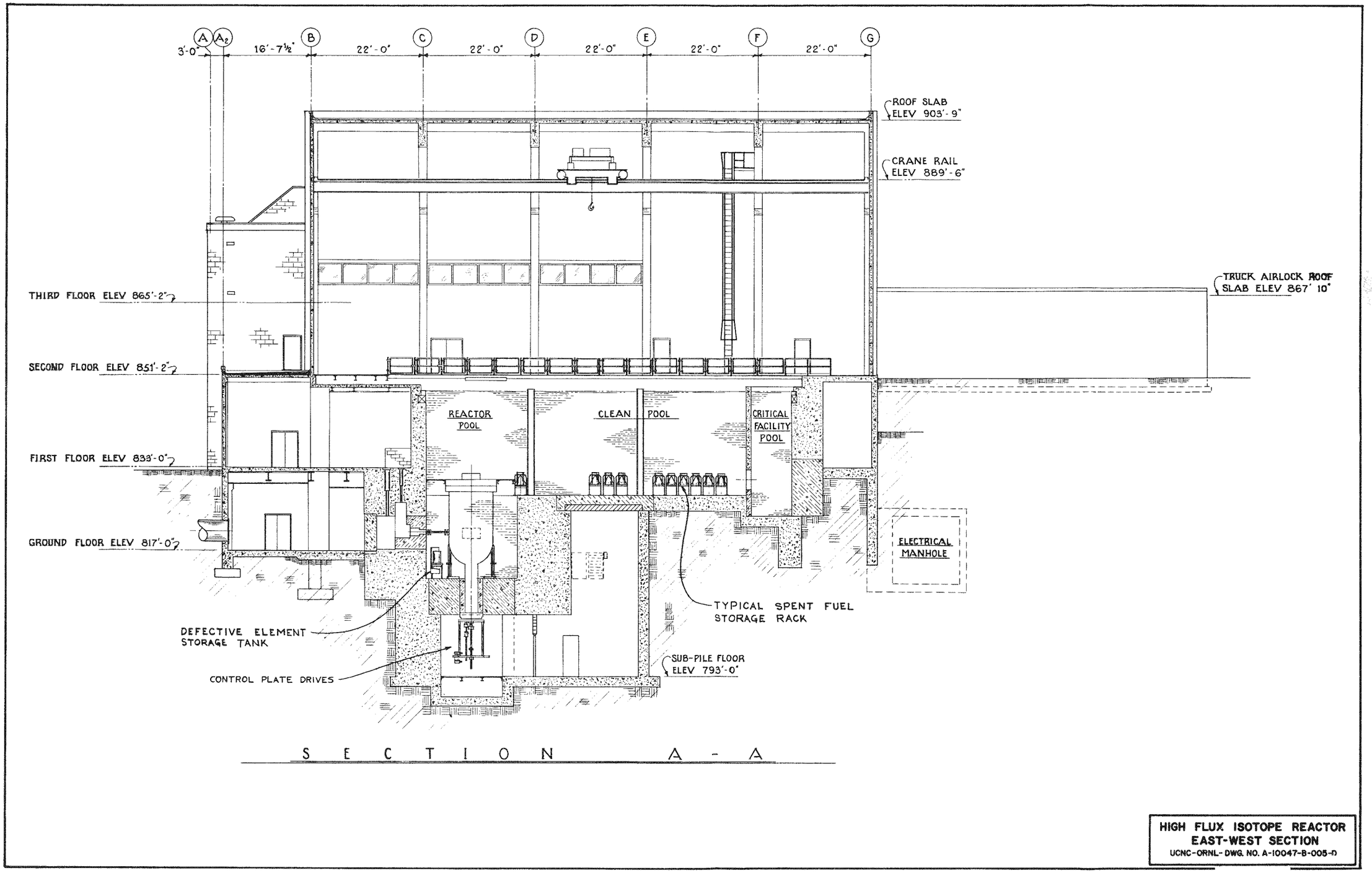

Fig. 6.19. East-West Section.

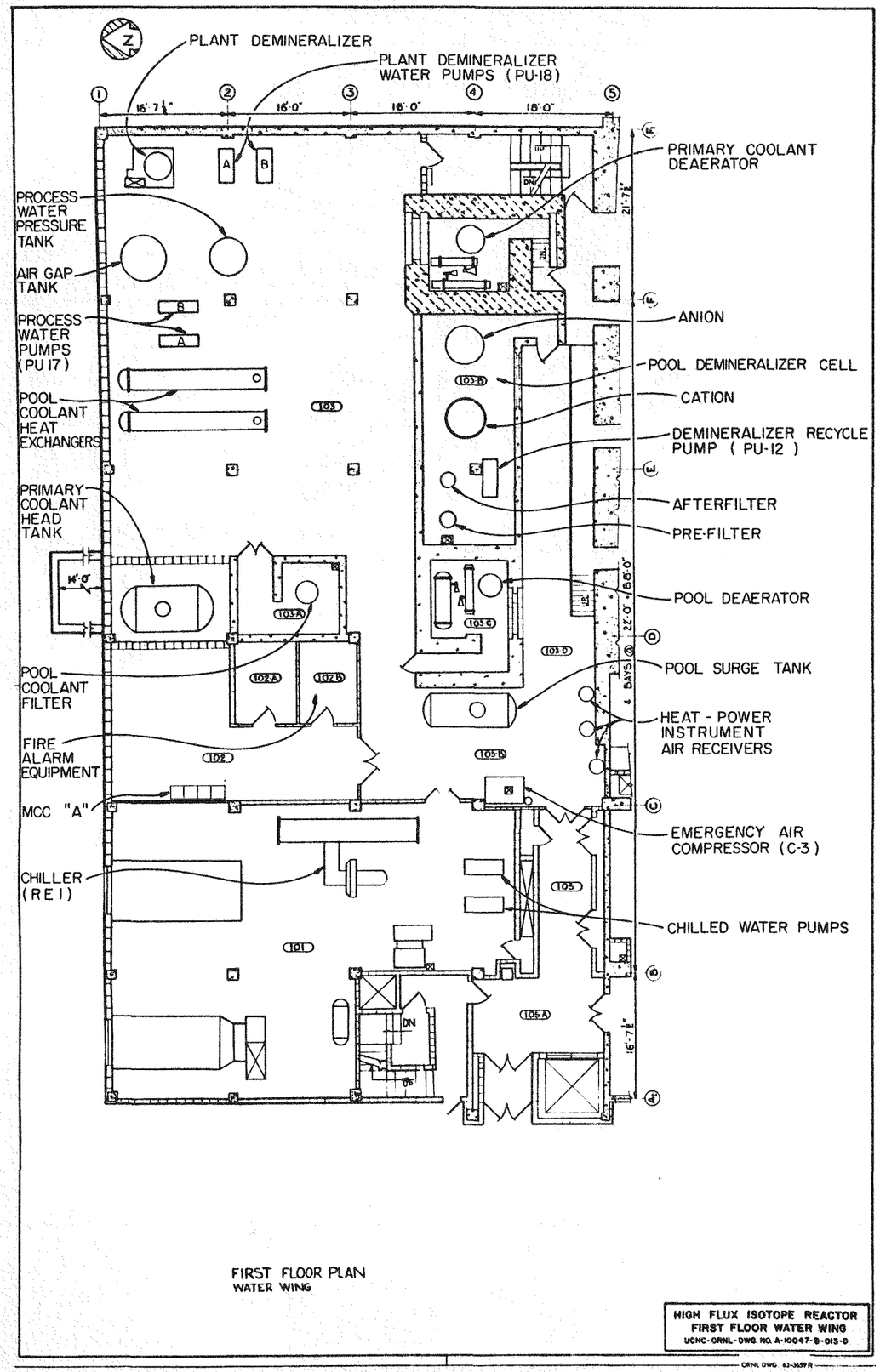
PLANT DEMINERALIZER
PLANT DEMINERALIZER WATER PUMPS (PU-18)
PRIMARY COOLANT DEAERATOR
PROCESS WATER PRESSURE TANK
AIR GAP TANK
PROCESS WATER PUMPS (PU 17)
ANION
POOL DEMINERALIZER CELL
CATION
POOL COOLANT HEAT EXCHANGERS
DEMINERALIZER RECYCLE PUMP (PU-12)
PRIMARY COOLANT HEAD TANK
AFTERFILTER
PRE-FILTER
POOL DEAERATOR
POOL COOLANT FILTER
POOL SURGE TANK
HEAT - POWER INSTRUMENT AIR RECEIVERS
FIRE ALARM EQUIPMENT
MCC "A"
EMERGENCY AIR COMPRESSOR (C-3)
CHILLER (RE I)
CHILLED WATER PUMPS
FIRST FLOOR PLAN
WATER WING
HIGH FLUX ISOTOPE REACTOR
FIRST FLOOR WATER WING
UCNC-ORNL-DWG. NO. A-10047-B-013-0
ORNL DWG. 62-3659R

Fig. 6.20.

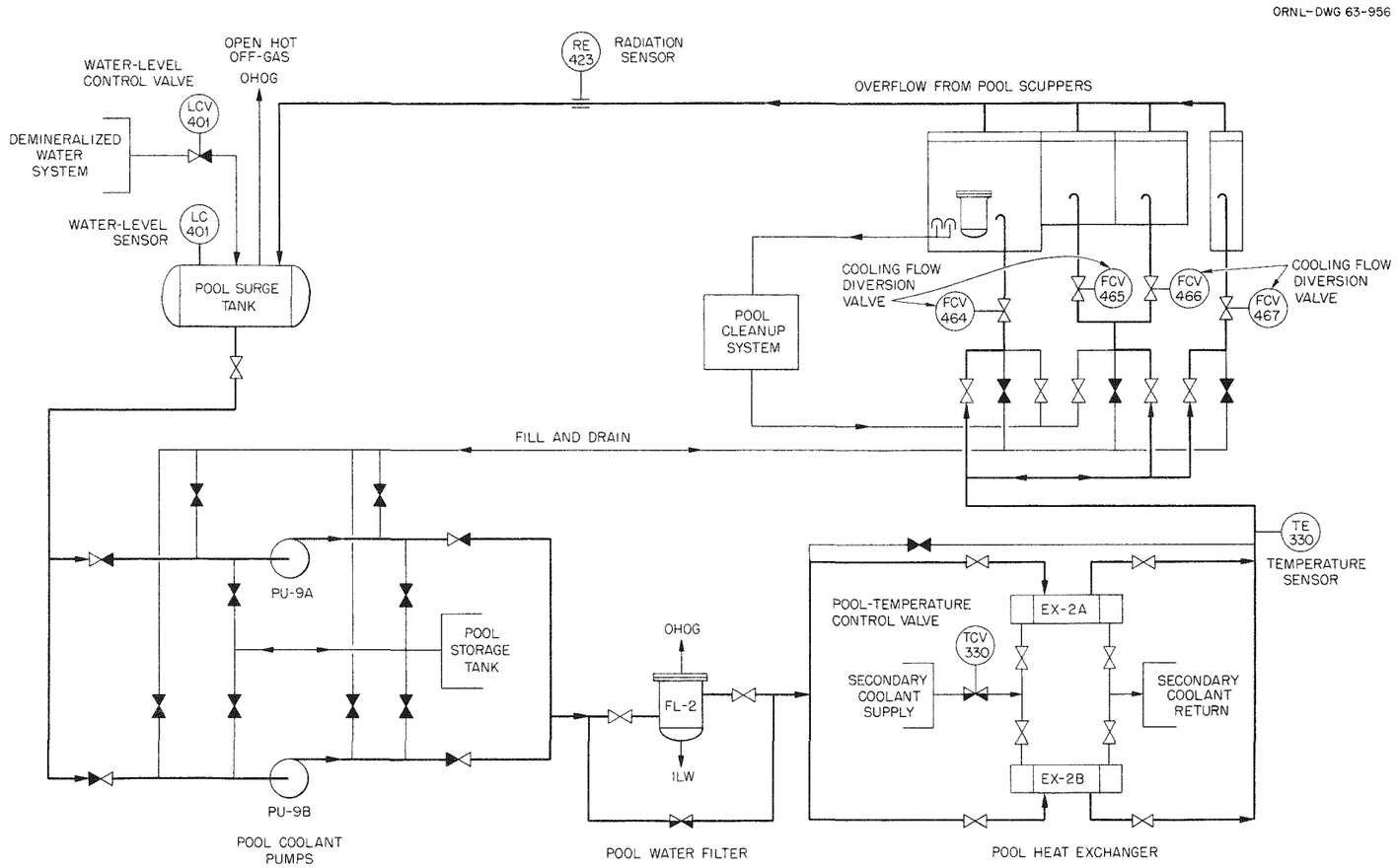

Fig. 6.21. Pool Coolant System.

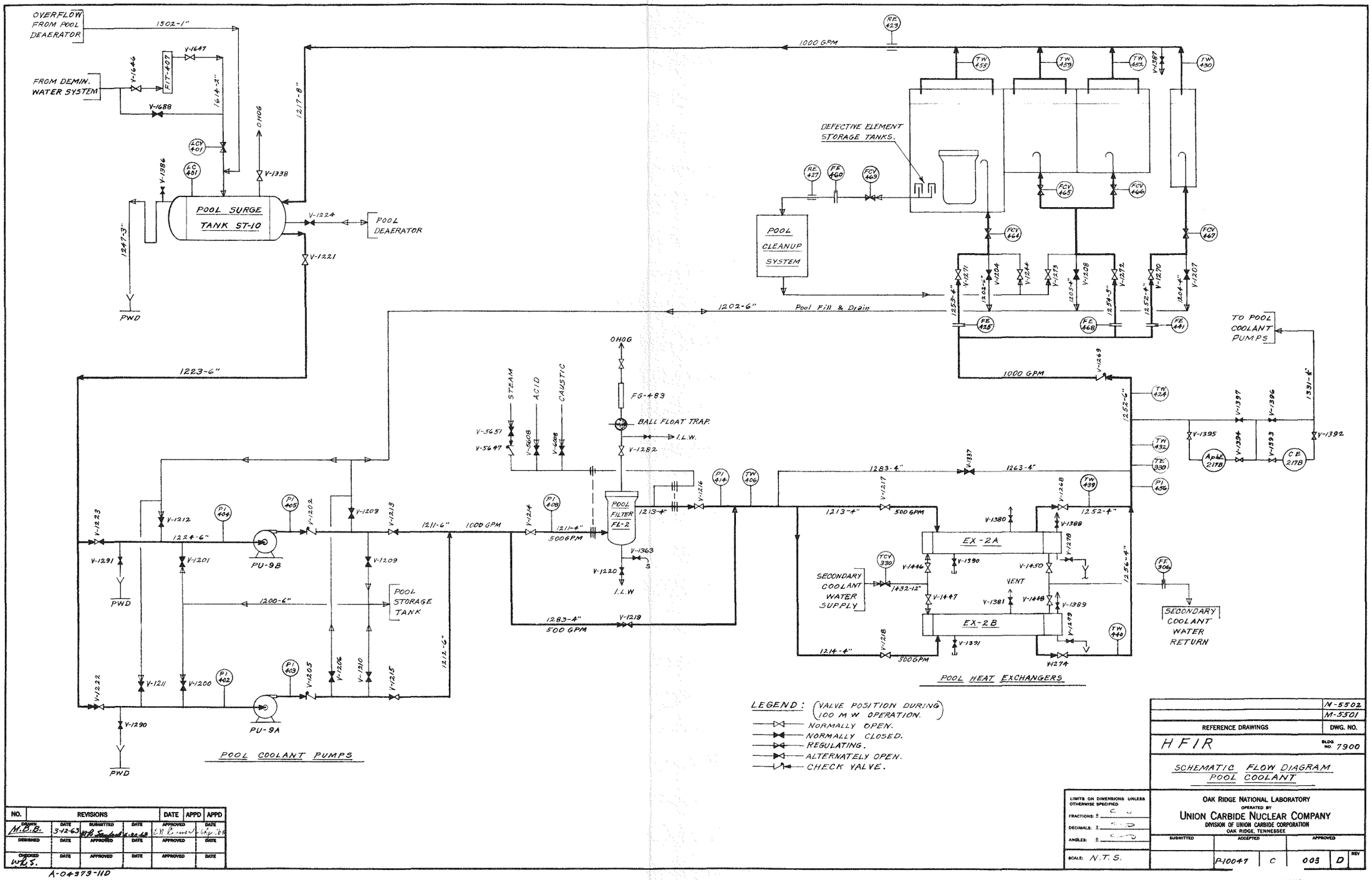

Fig. 6.22. Pool Coolant - Schematic Flow Diagram.

and B, which are rated at 1000 gpm each. Up to 500 gpm of the 1000 gpm total pool coolant water flow leaving the pumps goes through the pool filter; the remainder is bypassed around the filter. The water then enters the shell side of the pool heat exchangers. Either exchanger can handle up to 1000 gpm. Secondary coolant entering the tube side of the heat exchangers is automatically regulated by a valve to maintain the pool water leaving the exchangers at a preset temperature.

From the heat exchangers the cooled water may be diverted to the various pools as required by the heat load distribution. Various temperature sensors, located in the overflow lines from the pool scuppers, indicate the temperature distribution in the pools.

There is no need for a flow control valve in this system as it is self-regulating. The system is balanced manually to achieve the desired flow distribution between the pools by adjusting the valves in the return lines to the pools. A level control valve supplies plant demineralized water to the surge tank as makeup for evaporation and leakage.

The pool coolant pumps also serve as pool water transfer pumps. They can transfer water both to and from the pool water underground storage tank.

The general arrangement of the pool cooling equipment is shown in Figure 6.23.

Pool Overflow.-- The reactor pool overflow of approximately 500 gpm flows by gravity through two lines to the 8-in.-diameter common pool overflow collection line. Approximately 400 gpm from the clean pool and 100 gpm from the critical pool also flow into this line. The collection line dips below the level of the pool surge tank before entering it, thus providing a water seal for the scupper drains.

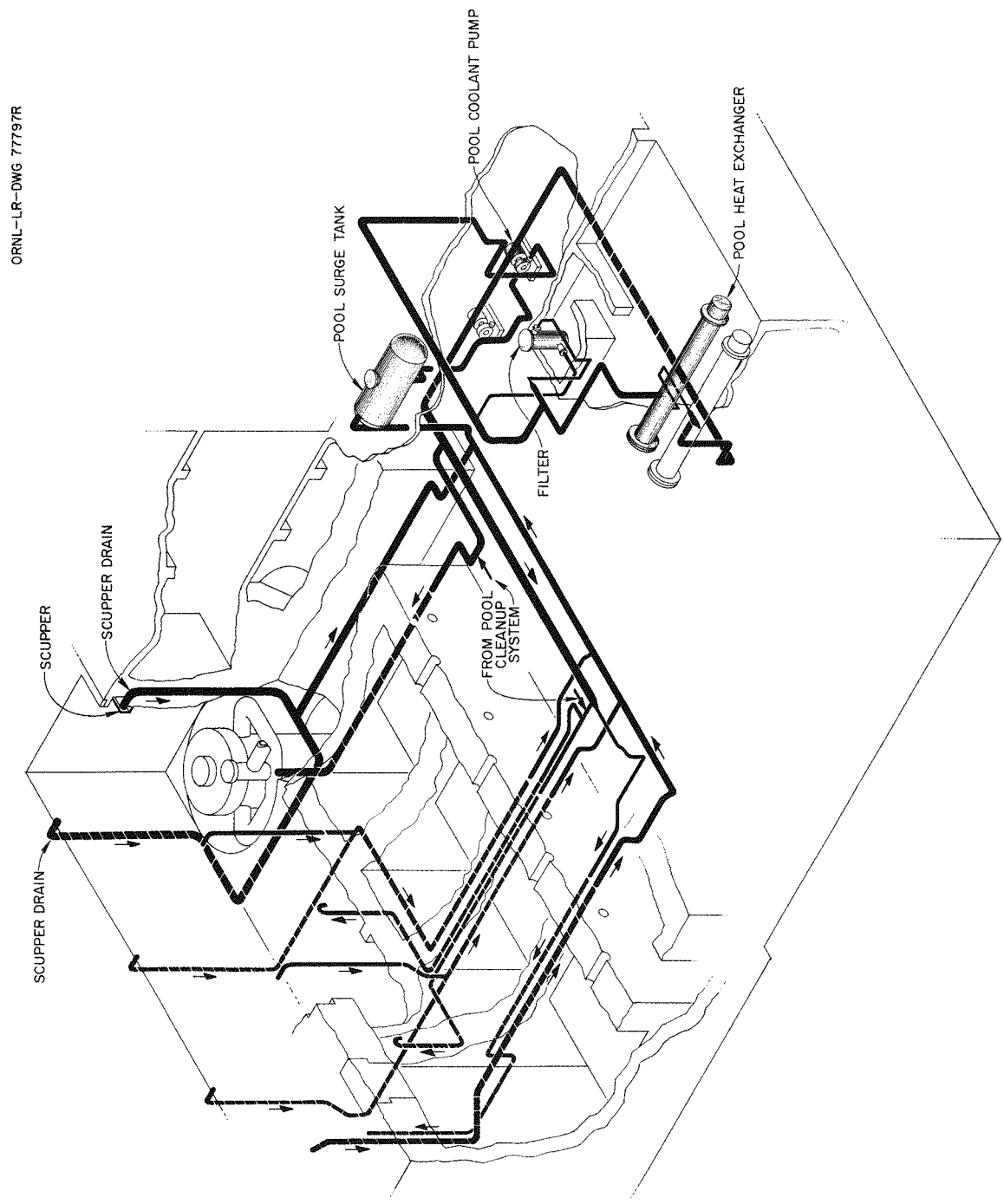

Fig. 6.23. Pool Coolant Equipment Arrangement.

The temperature of the water overflowing from each pool is monitored by thermocouples and is displayed in the control room. A float switch in each pool monitors the water level. An alarm is received in the control room if an abnormally high or low level is detected. The pool coolant pumps are automatically shut off if a high water level is detected in the reactor or critical pool. A radiation monitor is located in the common collection line. The water activity level is recorded in the control room. An alarm is also received in the control room if a high radiation level is detected by this instrument.

Pool Surge Tank.-- The pool surge tank which collects the overflow from the pools has a capacity of 1250 gal. It is located on the first floor in the water wing at the west end of the pool demineralizer cells. A water level sensor transmits the water level indication to the control room. If a low water level is detected in the surge tank, an alarm is received in the control room and the pool coolant pumps are automatically stopped. The level sensor also controls an automatic makeup valve which permits demineralized water to flow into the tank in order to maintain a minimum level. Any overflow runs to the process waste drain. The overflow line is equipped with a 6-ft leg to provide a water seal. Other lines connected to the surge tank are:

1. A vent to the open hot off-gas system.
2. An overflow line from the pool deaerator.
3. A normally unused crosstie to the pool coolant cleanup deaerator.
4. A line to the suction of the pool coolant pumps.

Pool Coolant Pumps.-- The pool coolant pumps, PU-9A and B, each have

a rated capacity of 1000 gpm. They are located on the ground floor of the water wing outside the pool demineralizer pump cell. An "On-Off-Reset" selector switch and running light for each pump are located on the process panel in the control room. A "Stop-Reset" button is located at each pump. The pumps are stopped automatically by a high water level in the reactor or critical pools and by a low level in the surge tank. When a pump is shut down by a level switch, it will restart automatically if the abnormal level condition clears within 60 seconds. Otherwise the pump must be manually restarted. The pumps are connected to the normal-power system and will automatically restart when power is applied following a normal-power failure. Pressure gauges are mounted on the inlet and exit of each pump. The pool coolant pumps normally take their suction from the pool surge tank and discharge into the heat exchangers either through or around the pool water filter. They can, however, also be used for various filling and draining operations.

Pool Coolant Filter.--The pool coolant filter has a nominal flow capacity of 500 gpm. It consists of 47 porous tubes, 2-3/4 in. in diameter by 29-1/4 in. long, made of sintered stainless steel. Water flows from outside to inside through pore openings having a mean diameter of 20 microns. It is located in a shielded cell on the first floor of the water wing. A bypass around the filter carries the coolant flow in excess of 500 gpm. The filter can be cleaned with acid, caustic, or steam by countercurrent flow. A vent at the top of the filter is connected to the open hot off-gas system through a ball float trap.

Heat Exchangers.--Each of the pool heat exchangers, EX-2A and B, is designed to remove 6 million Btu/hr (1.5 Mw) from the system. They each have 540 fixed tubes 5/8 in. in diameter. In normal operation each

exchanger will operate with a flow of 500 gpm of pool water but can accommodate 1000 gpm. Pool water makes two passes on the shell side of each exchanger and the secondary cooling water makes two pases in the tubes. Normally the secondary water flow to each exchanger is approximately 1600 gpm. The temperature of the water in the common pool water exit line from the heat exchangers is monitored by a thermocouple and is displayed in the control room. A temperature control sensing element is also located in the common exit line. This element controls the flow of secondary coolant to the exchangers in order to maintain the exit temperature constant. Each exchanger is equipped with a manually operated shell vent to the atmosphere and a shell drain to process waste. A bypass line which permits pool water to be routed around the heat exchangers rejoins the exit line ahead of the temperature sensing elements.

The headers to the reactor and clean pools branch off the common heat exchanger exit which continues to the critical pool. Each header is equipped with a flow measuring orifice which permits display in the control room of the return flow to each pool. These headers returning to each pool contain remotely operated valves which permit throttling of the flow from the control room.

6.4b. Pool Cleanup System

In order to maintain high purity water, it is necessary to pass approximately 200 gpm of pool water through the pool cleanup system which consists of a deaerator, prefilter, demineralizer, and after-filter in series. The task of cleaning the pool water is made more complex by the possibility that one or more defective and leaking fuel elements will be stored in the reactor pool. The system, shown schematically in Figures

6.24. and 6.25., is designed to handle this situation but will function equally well if no defective element is present. The general arrangement of the equipment is shown in Figure 6.26.

Pool water flows through the defective fuel element storage tanks, into the pool deaerator. From here it is forced through the pool cleanup system and returns to the pools in common with the pool coolant flow. As indicated in Figure 6.27., the normal flow path of the pool water is into the bottom of the defective element tanks, up through the element, and out the bottom through a hollow cadmium-lined post to the pool cleanup system. Should the cleanup system flow be interrupted, cooling is provided by natural circulation through a small heat exchanger immersed in the pool.

Approximately 200 gpm of pool water flows from the defective element storage tanks into the deaerator. The flow is adjusted by a remotely operated valve and a flow indicator in the control room. The deaerator removes the dissolved gases and provides surge capacity for the system. From the deaerator, water flows to the pool cleanup pumps, PU-7A and B. The discharge from these pumps is automatically regulated by a valve to maintain a constant level in the deaerator. Water leaving these pumps passes through a prefilter, cation and anion beds, and an after-filter before returning to the reactor and clean pools. There is only a single set of pool demineralizers. The pool volume is sufficiently large so that water conditions will not change to any great extent during the time required for regeneration. During regeneration the demineralizers can be bypassed without affecting the operation of the deaerator and filters. A radiation detection device located in the line to the deaerator provides an indication in the control room of the amount of contamination in the water leaving the defective element storage tanks.

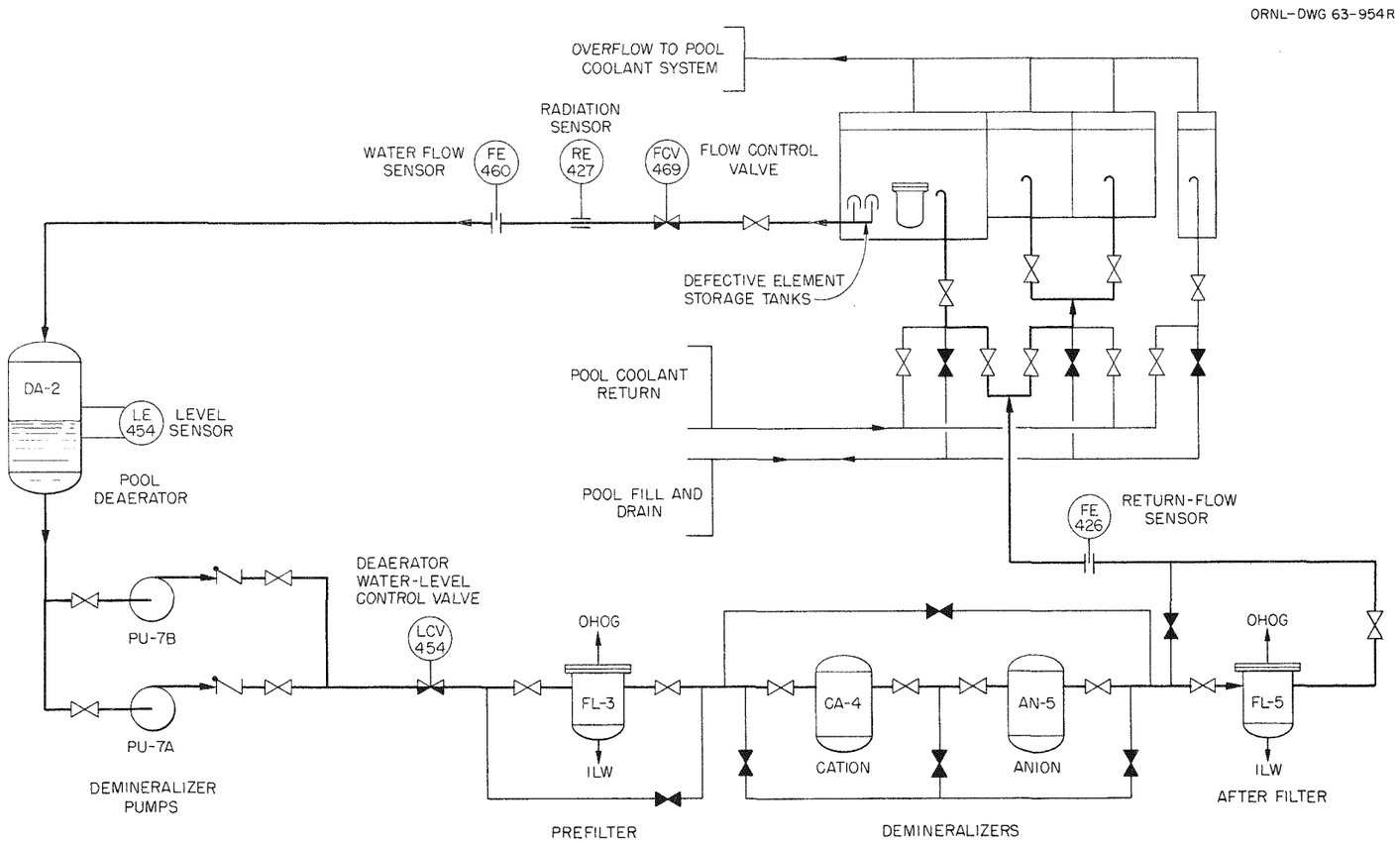

Fig. 6.24. Pool Cleanup System.

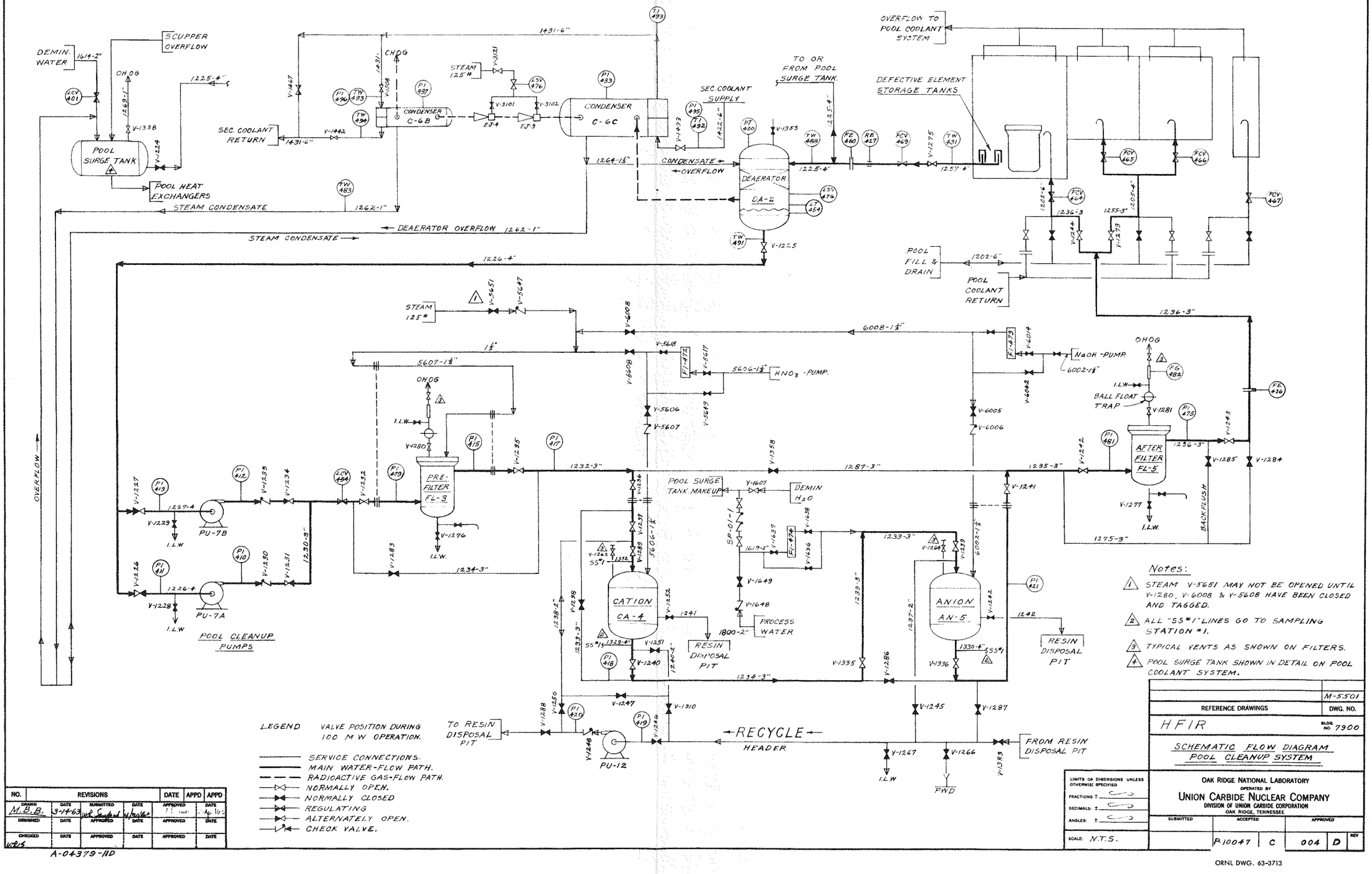

Fig. 6.25. Pool Cleanup--Schematic Flow Diagram

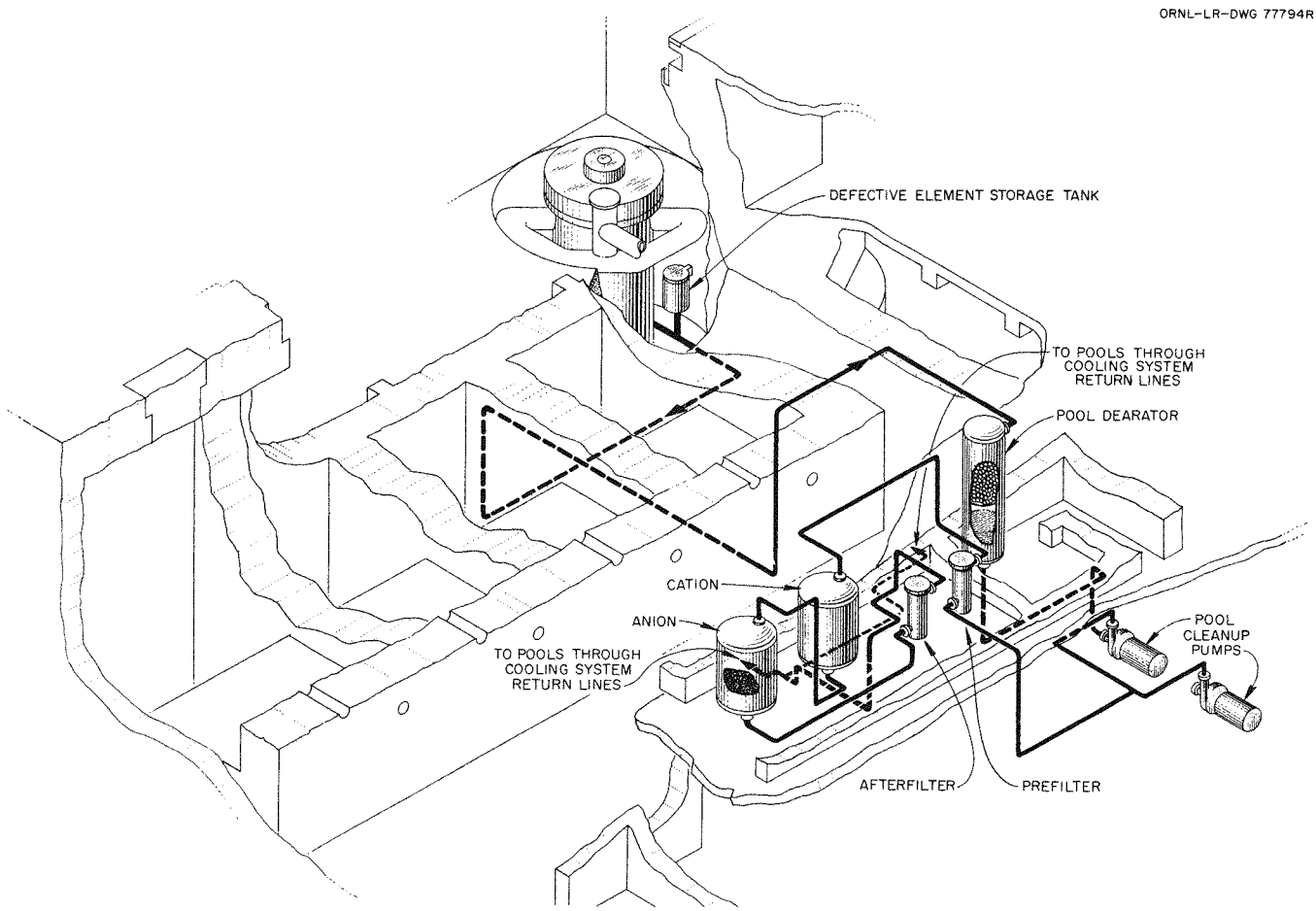

Fig. 6.26. Pool Cleanup Equipment Arrangement.

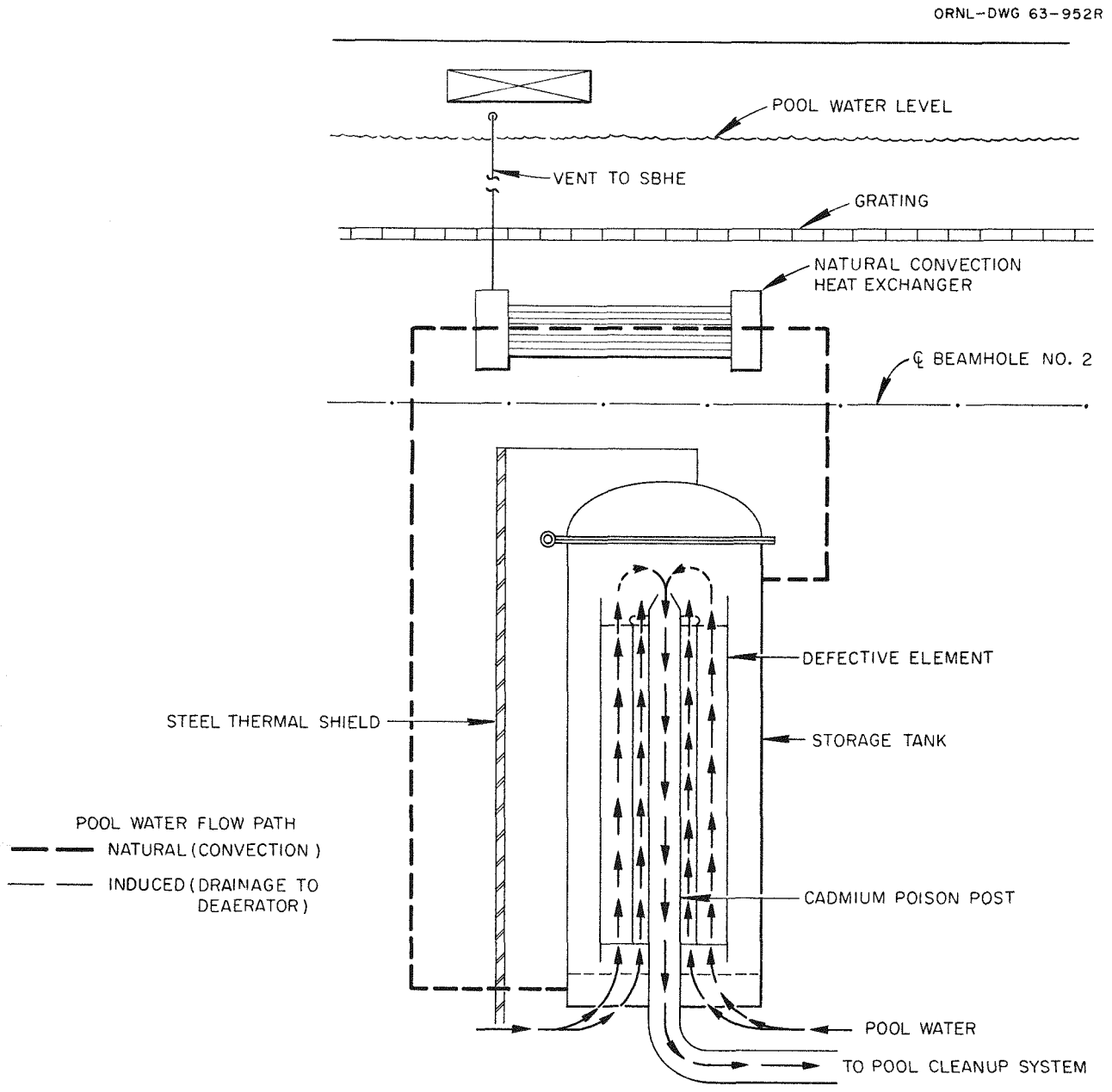

Fig. 6.27. Defective Element Storage Tank.

Deaerator.--The pool deaerator, shown in Figure 6.28., is designed to remove essentially all of the dissolved gases from the pool water at a flow of 200 gpm. Together with its associated condensers and steam ejectors, it is located in a 1-ft-thick normal concrete-shielded cell on the first floor of the water wing. Water enters the top of the deaerator tank and passes down through a bed of Raschig rings. The high vacuum maintained by the steam ejectors removes dissolved gases from the water. Gases from the deaerator pass through a precondenser, a high-vacuum ejector, a low-vacuum ejector, and an after-condenser before entering to the closed hot off-gas system. Condensate from the condensers is returned to the deaerators. A level sensor detects the water level in the deaerator and transmits a signal to a flow control valve on the discharge of the pool demineralizer pumps to hold the level constant. The demineralizer pumps are automatically shut down if a low-level setpoint is reached and are automatically restarted when the low-level switch is cleared. The deaerator level signal is also displayed in the control room. A separate level safety switch on the deaerator transmits an alarm to the control room if a high level is detected and closes a block valve in the steam supply line to the ejectors to prevent discharging water into the CHOG system. Each condenser is equipped with pressure gauges to aid in adjusting the vacuum. A pressure sensor transmits the deaerator vacuum to an indicator in the control room and sounds an alarm if high pressure is detected.

Pool Demineralizer Pumps.--Water from the deaerator enters the suction of the demineralizer pumps, PU-7A and B, and is discharged to the pool demineralizer prefilter. These pumps are located in a shielded cell

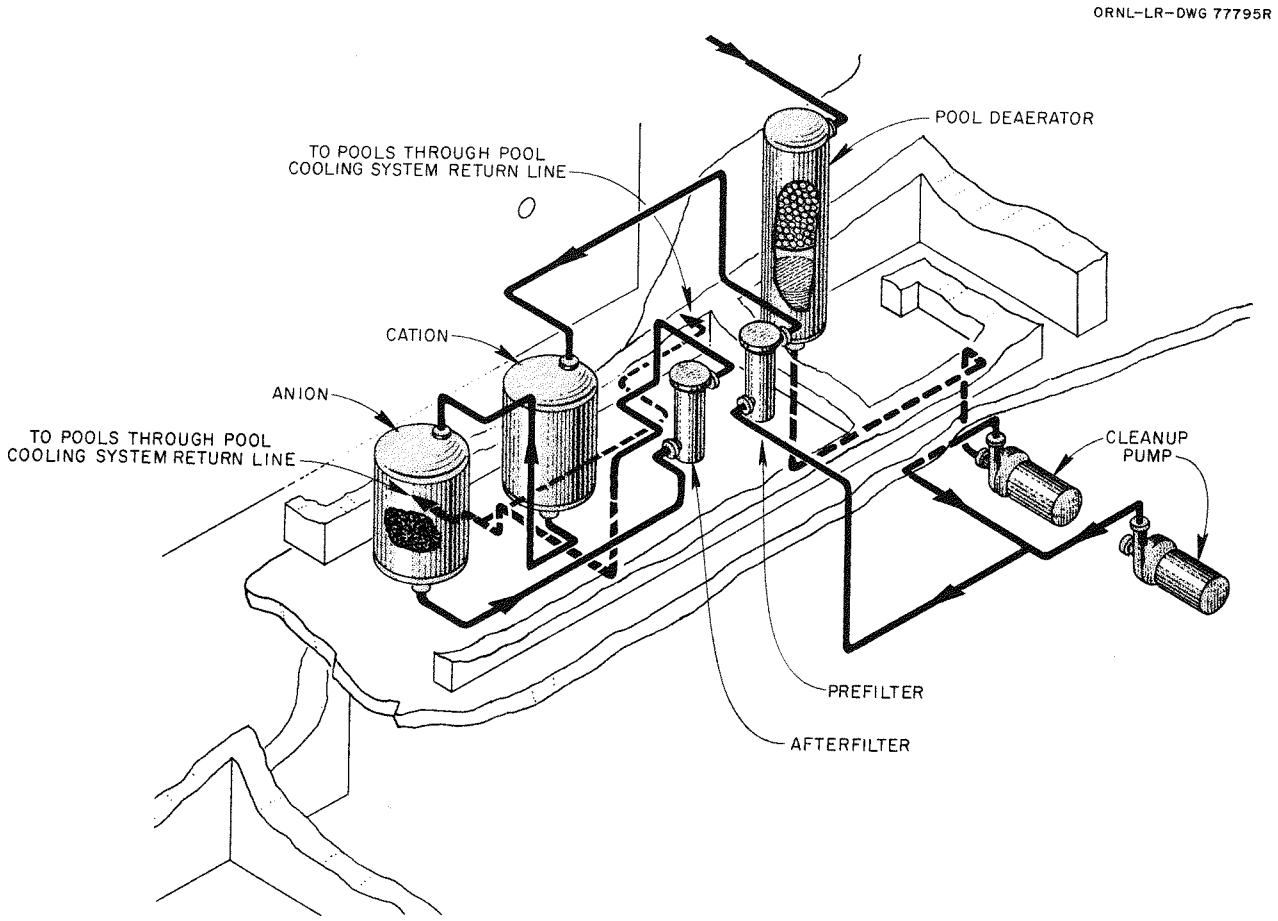

Fig. 6.28. Pool Cleanup System Details.

on the ground floor of the water wing. Each pump has a capacity of 200 gpm. The pumps discharge into a common line containing the deaerator level-control valve. Compound pressure gauges are located on the suction side of each pump and normal gauges are located on the discharge side. An "On-Off-Reset" selector switch and a running light for each pump motor is located on the process panel in the control room. A "Stop-Reset" button is located at each pump. High water level in the clean pool will shut down the pumps, but they restart automatically if the high-level condition clears within 60 seconds. Otherwise, they must be restarted manually. A low level in the pool deaerator will also stop the pumps; but, in this case, a restoration of the level starts the pumps.

Either, or both, pumps may be operated at one time. The motors are connected to the normal-power system and will restart automatically when power is restored following an outage.

Pool Cleanup Filters and Demineralizers.--The pool demineralizer pre-filter has a rated flow capacity of 200 gpm with a 2.5 psi pressure drop. It is similar to the other pre-filters and contains 28 porous sintered stainless steel filtering tubes with a mean pore size of 20 microns. Water flows from the outside of the tubes to the center. The filter is located on the first floor of the water wing in the same shielded cell as the pool demineralizers. It is covered with a 2-in.-thick lead shield and is vented through a ball float trap to the open hot off-gas system. The filter, which is also equipped with a bypass, can be cleaned by backwashing with acid, caustic, or steam. Pressure gauges are located on both the inlet and outlet.

After passing through the prefilter, water enters the pool demineralizers, shown in Figure 6.26., which consist of separate cation and anion beds. They are located on the first floor of the water wing in a shielded cell. The cation column contains 50 cu ft of cation resin and is surrounded by 2 in. of supplementary lead shielding. The anion column contains 50 cu ft of anion resin, but has no supplementary shielding. Water enters the top of the cation column, passes through it, and into the top of the anion column. From the bottom of the anion bed the water flows to the after-filter. Both demineralizer columns are vented to the open hot off-gas system through ball float traps. Appropriate acid, caustic, and backwash lines are provided. A demineralizer recycle pump, PU-12, is available for recycling water during regeneration. Sample taps are located on the inlet and outlet of each column. The sample lines run outside the cell to a sampling sink.

From the demineralizers the water flows to the pool demineralizer after-filter. This filter has a rated flow capacity of 200 gpm with a 2.5 psi pressure drop when clean. The filtering media is 100-mesh stainless steel screen. It is located on the first floor of the water wing in the same shielded cell as the pool demineralizers. Pressure gauges are located on the inlet and exit lines. The filter is vented to the open hot off-gas system through a ball float trap. It can be backwashed to the intermediate level waste system using water from the pool demineralizers. Water leaving the after-filter can be returned to any pool through lines common with those returning water from the pool cooling system.

6.4c. Pool Fill and Drain Systems

Each section of the clean pool has one 3-in. line entering below the surface of the water; the critical pool has a single 4-in. line entering below the surface. These lines terminate at the ~835-ft level, i.e., ~7 ft above the pool floor. The reactor pool contains two lines which enter below the surface. One is the normal 6-in. return from the pool coolant system which terminates at the 828 ft 6 in. level at a water depth of 16 ft 6 in., i.e., 8 ft above the core centerline. These lines also serve as fill and drain lines for the pools. The second line in the reactor pool is the 4-in. feed line to the pool deaerator from the defective element storage tanks. This is located at the 817 ft 6 in. level, 3 ft below the core centerline.

A 55,000-gal underground pool water storage tank has been provided to receive pool water when it is necessary to drain the pools. This is a concrete vessel lined with plastic and is located outside the east wall of the water wing. The top of the 14-in.-thick concrete shield is flush with the finished grade at this point. A second section of this tank provides the 20,000-gal primary coolant storage mentioned in Section 6.2c. Both sections of the tank are vented by the SBHE system and the overflow is connected to the process waste system.

The fill and drain lines from the individual pools run to a common fill and drain header located in a pipe tunnel on the ground floor. By an appropriate system of valving, this header can be routed into the suction or discharge of either of the pool coolant pumps (PU-9A and B). Similarly, the line from the underground storage tank can be connected to either side of these pumps to fulfill any fill or drain requirement.

6.5. Emergency Cooling Requirements

It is possible to distinguish three types of emergency cooling requirements which arise from the following causes:

1. Failure of a component, a pump for example, in the cooling systems.
2. Loss of the normal 13.8-kv electrical supply.
3. Reactor shutdown due to some cause such as multiple component failure, human error, or a combination of these events.

The occurrence of a component failure, as in case 1, is highly probable. However, this event has been anticipated. Except in the case of a main secondary coolant pump, all vital components have standby counterparts which are available to assume the load. Such a situation would result in, at most, the necessity for a small reduction in power.

In case 2 where the normal 13.8-kv electrical supply is interrupted, presumably for only a short time, the system can still operate at 10 Mw. However, the auxiliary power systems must operate normally and no vital mechanical components can fail concurrently.

Because of the short life and cost of the HFIR fuel and the rate of growth of xenon and samarium following shutdown, it is desirable to keep the reactor at as high a power as possible even during abnormal conditions. For this reason, certain of the emergency systems have been designed to permit short term operation at 10 Mw even though the normal power has been interrupted. The design features incorporated to permit 10-Mw operation during this condition are as follows:

1. Two diesel motor generator sets share the burden of supplying emergency power to the system. Certain crucial items are

included in duplicate with one unit on each diesel; others are connected to the power source through a failure-free battery system which supplies power for sufficient time even though the diesel systems do not operate.

2. In order to prevent a scram during the switching transient caused by a 13.8-kv feeder transfer or a normal-power failure, failure-free battery systems supply power continuously to vital instrumentation. A flux-to-flow ratio computer initiates an automatic reduction in the reactor power to match the primary coolant flow and prevent flux-to-flow ratio or high-temperature scrams.

3. An emergency pressurizer pump and emergency windings for the auxiliary secondary coolant pump, both supplied by a diesel, have been provided.

4. As described in Section 6.2a, each of the primary coolant pumps is equipped with a 3-hp dc pony motor supplied from a battery system. These motors are energized at all times during operation and take over the load upon failure of the main motors. The flows developed by the pony motors are as follows:

Number of Pumps Operating	1	2	3
Flow (gpm)	1600	2100	2400

The sequence of automatic operations in the cooling system following a 13.8-kv power outage is as follows:

1. The primary pumps coast down and, due to the pony motors, flow stabilizes at 2400 gpm after one minute. Simultaneously, the

servo control system reduces the reactor power in an orderly fashion to ~10 Mw, the letdown block valves close, the pressurizer pumps coast down, and the secondary coolant pumps coast down.

2. Approximately 30 sec after the power failure, diesel power is available to run the emergency pressurizer pump and the emergency winding of the auxiliary secondary pump, to open the cooling tower bypass valve, and to maintain charge on the various battery systems.

Following the loss of the 2400-v bus the same sequence is followed except that the diesels need not be started. In this case, the 13.8-kv system would supply power to the normal-emergency system, and the normal winding of the auxiliary pump.

The third type of emergency cooling requirement, case 3, is that in which either because of multiple component failure, power failure, or some combination of events, it is necessary to shut the reactor down. In this case, only afterheat need be considered.

The heat generation rate as a function of time after shutdown due to 15-day operation of the HFIR core at 100 Mw is given in Figure 6.29. The heat generation drops from 100 Mw to 7 Mw virtually instantaneously at shutdown. Below this power, one pony motor is adequate to supply cooling; however, the coastdown of the main pumps augments the flow. Forced convection, supplied by the pony motors, is required for approximately one hour. The batteries, even without recharging, can supply power for a minimum of two hours. At the end of one hour, the heat generation rate has dropped to less than 1.3 Mw and natural convection cooling in an open pool or in the reactor is adequate.

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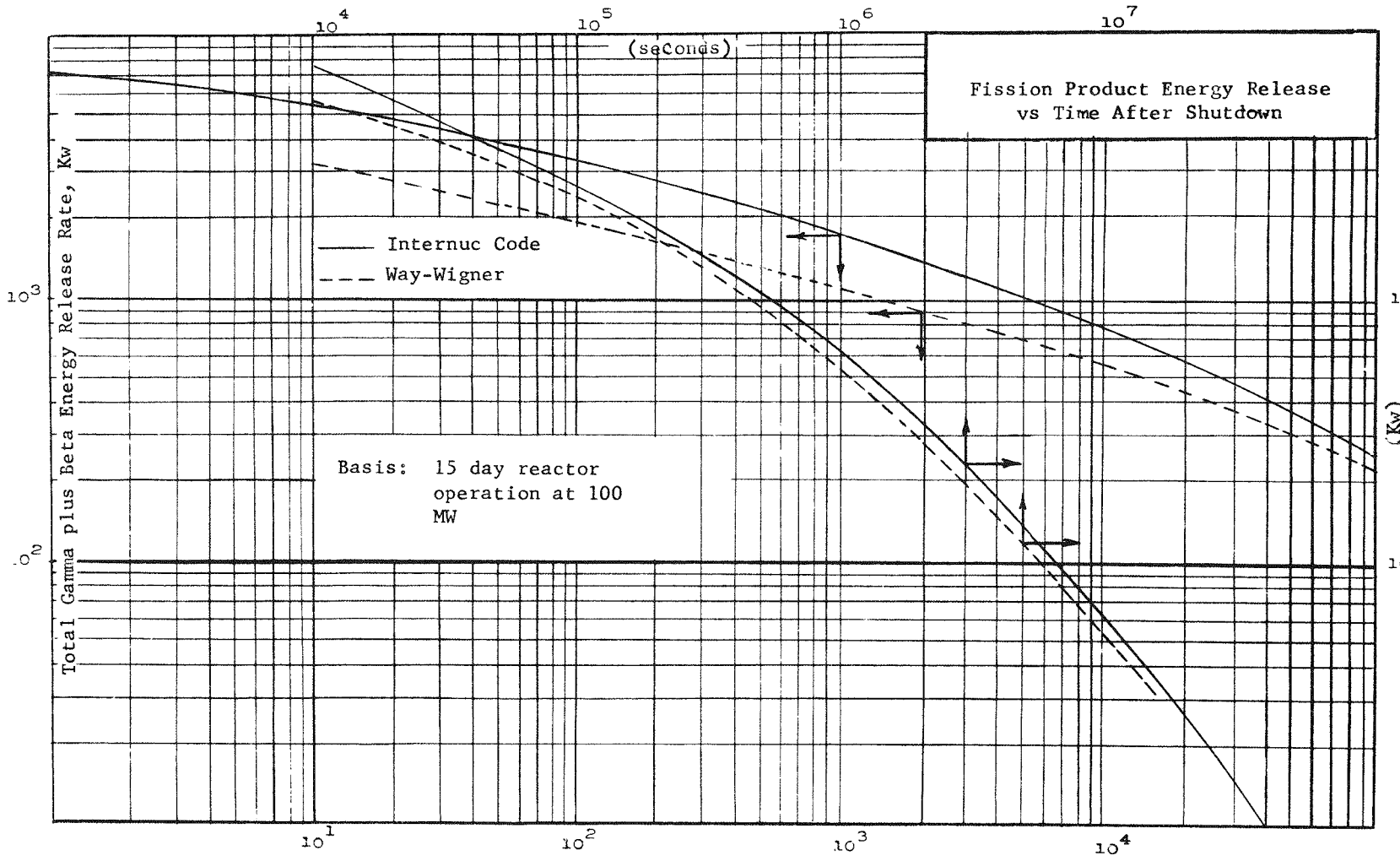

Fig. 6.29. Fission Product Energy Release vs Time After Shutdown.

7. CONTAINMENT, VENTILATION, AND AIR CONDITIONING

7.1. Introduction

The air and gas handling facilities at the HFIR have been specifically designed to minimize the spread of contamination within and without the building in the event of an accidental release of activity, and to provide maximum convenience and safety during normal operation. Two separate systems are provided for the disposal of gaseous waste; the Special Building Hot Exhaust (SBHE) which provides dynamic containment in the event of an abnormal release of activity, and the Hot Off-Gas* systems (HOG) which handle the routine disposal of gaseous activity from the various system components. Certain areas, such as the control rooms and offices, which contain no significant sources of radioactive material are isolated from the other portions of the building and are served by a separate air-conditioning system.

The SBHE system is designed to provide a constant flow of air through those portions of the building which contain components capable of releasing significant quantities of activity to the environment. These include the primary heat exchanger cells and pipe tunnel, the reactor bay, the primary coolant deaerator and demineralizer cells, and the primary coolant cleanup pump cells. Certain other areas are also served by the SBHE system because of the configuration of the building and convenience in locating the equipment. These areas which are physically separated from those above by doors, include the beam room, experiment room, and the cells containing the pool cleanup equipment. By maintaining appropriate

*The HOG systems are discussed in Section 9.2.

pressure gradients, air flows from the clean areas of the building into the areas served by the SBHE system. The air is then transported through ducts to appropriate filtering equipment, and is finally discharged to the atmosphere at the top of a 250-ft stack.

7.2. General Containment Philosophy

Briefly, the general concept of dynamic containment consists of maintaining a positive inward leakage of air into the contained region by exhausting air from that region. The air exhausted from the contained region is then decontaminated by passing it through suitable cleanup equipment and is deliberately discharged to the atmosphere in a manner designed to eliminate excessive environmental pollution.

In the case of the HFIR, this concept has been expanded so that, not only is the building as a whole contained in this manner, but also various areas of the building are protected from contamination originating in other areas. For convenience, the movement of air will be described in terms of pressure differentials; however, it should be understood that the important parameters are the direction and flow of the air and not the measured pressure differentials which may or may not be a true indication of them. Moreover, it must be realized that leakage--controlled leakage-- of air from outside the building and from the various regions in the building is absolutely necessary if the system is to work properly.

For containment purposes the building is divided into four major ventilation-control areas or zones as follows:

Zone 1: This area is kept at a slight positive pressure (~0.1 in. H_2O) with respect to the ambient atmospheric pressure. It is located on the second and third floors of the control and water wing and includes the control rooms, offices, and other facilities which are normally occupied and which contain no significant potential sources of activity.

Zone 2: This is a generally clean area but operates at a slightly negative pressure (-0.1 in. H_2O). It includes the process equipment rooms on the ground and second floor of the water wing.

Zone 3: This includes all of the area inside the main reactor building, with the exception of the primary heat exchanger cells and pipe tunnel. It also includes those portions of the water wing which contain the primary and pool cleanup cells. It is directly connected to the SBHE system and is maintained at $\sim$ -0.3 in. H_2O.

Zone 4: This includes the primary heat exchanger cells and the main pipe tunnel. It too is connected directly to the SBHE system and is kept at $\sim$ -0.4 in. H_2O.

These various zones are shown graphically in Figures 7.1, 7.2, 7.3, and 7.4. Two rooms in the southeast corner of the ground floor, G-12 and G-13, contain electrical equipment and batteries and require cooling by exhaust fans. They are not considered to be within the contained area.

Zone 1 is self-contained from a ventilation and exhaust standpoint. It is equipped with a large air-conditioning unit which maintains the slight positive pressure with respect to the outside atmosphere.

The negative pressure in Zone 3 is maintained by the operation of various individual supply dampers. A manually-operated volume control damper, located in the SBHE exhaust duct, is periodically adjusted to maintain a fixed volume of exhaust air. The volume of intake air (controlled inward leakage), which enters through the fresh air intakes

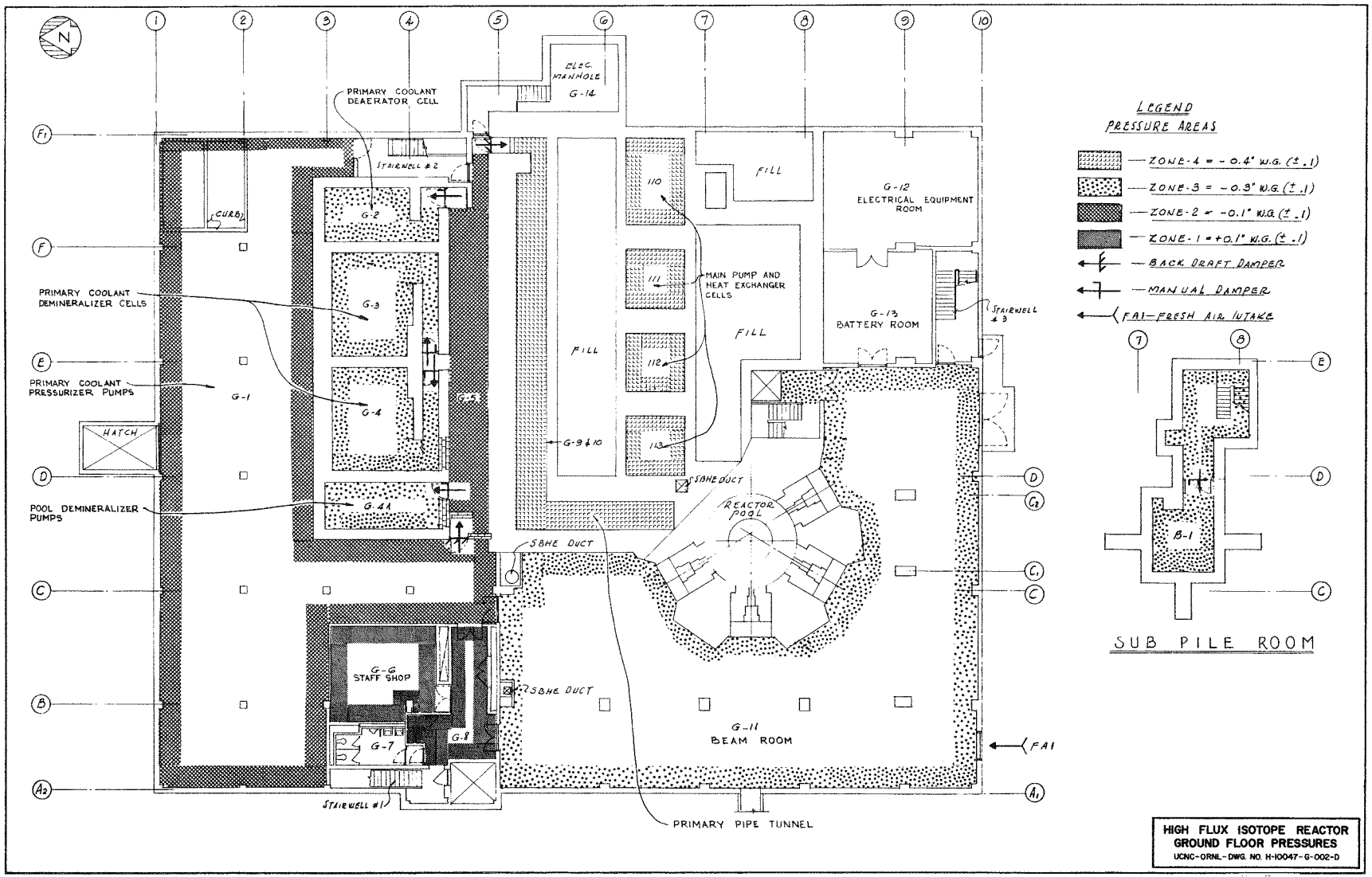

Fig. 7.1. Ground-Floor Pressures.

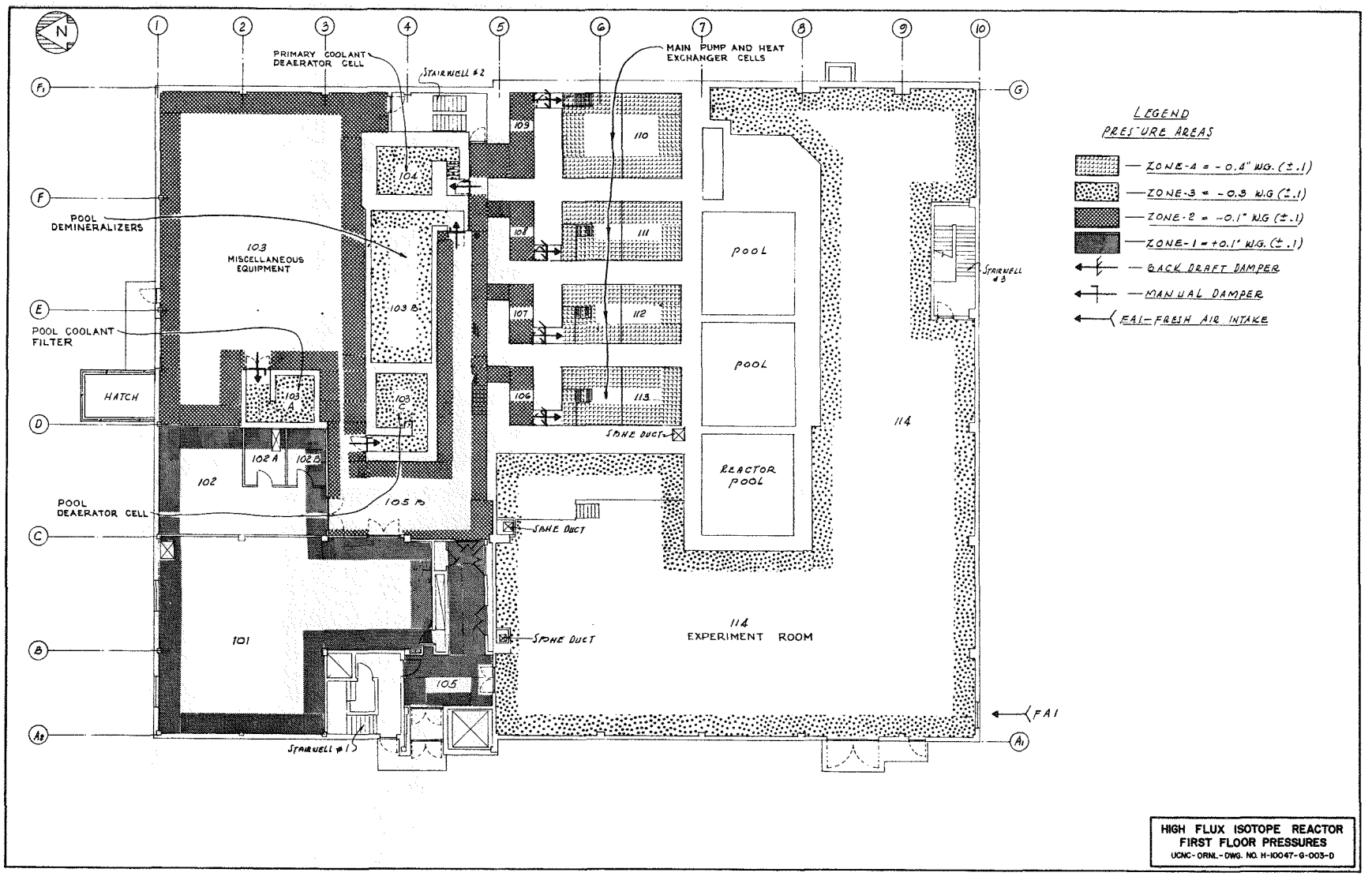

Fig. 7.2. First-Floor Pressures.

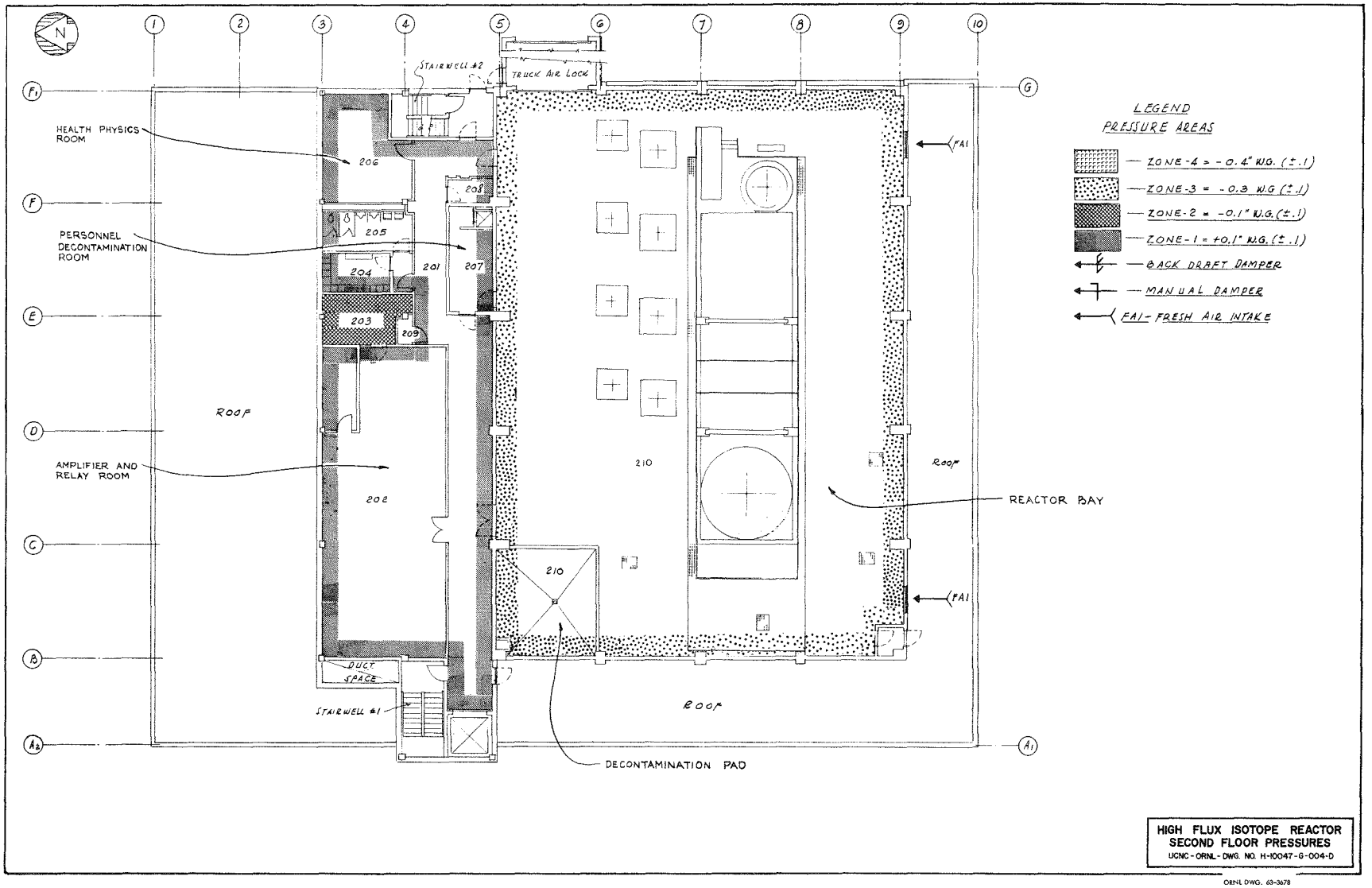

Fig. 7.3. Second-Floor Pressures.

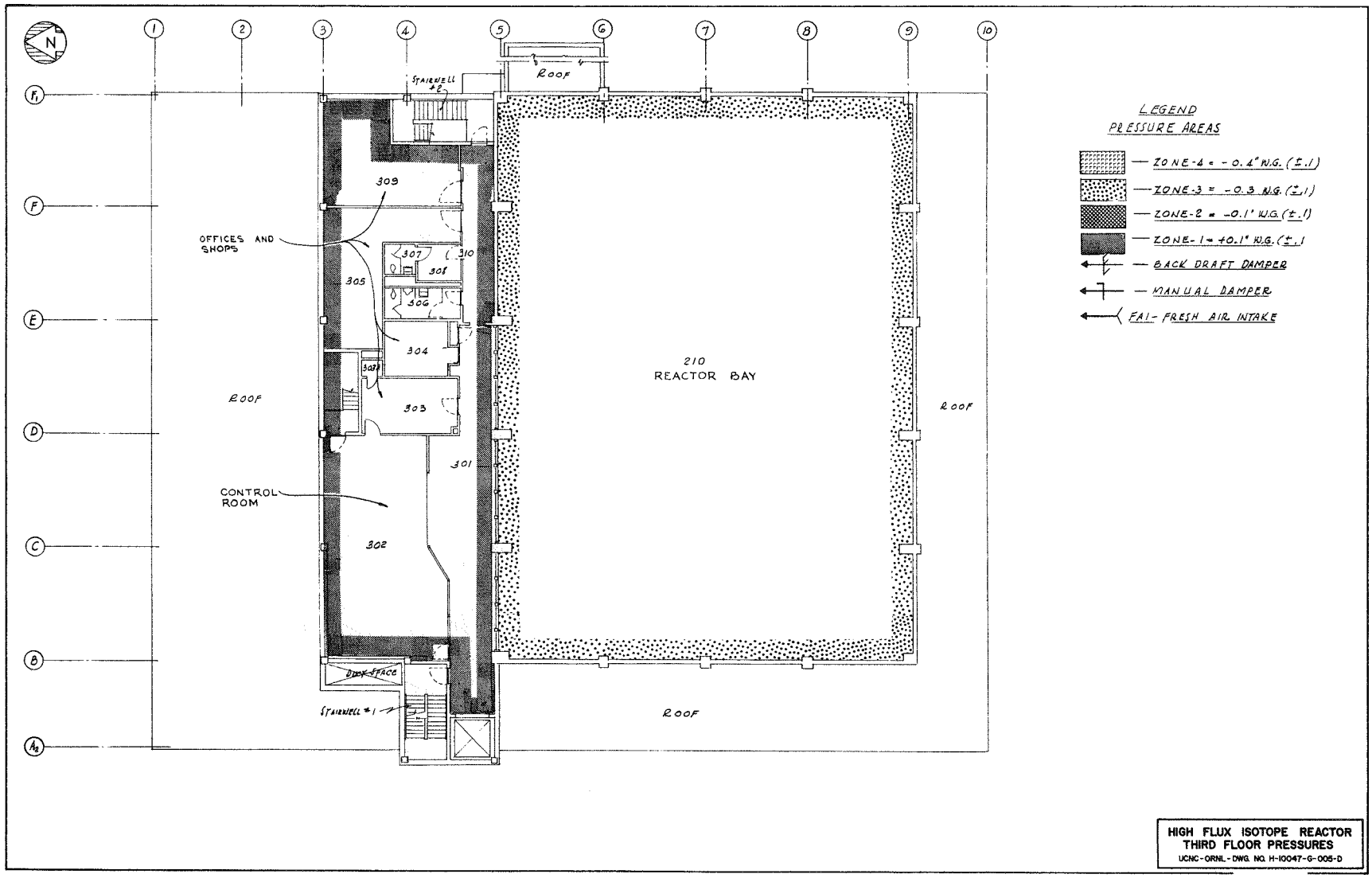

Fig. 7.4. Third-Floor Pressures.

on the various air-conditioning units, is controlled by pressure-regulated dampers in order to maintain the required negative pressure in the area. The fresh air intake regulators are pneumatically controlled and are not affected by an electric power outage. Duplication of equipment and automatic switching protect against SBHE exhaust fan failure. Should both exhaust fans fail, interlocks shut the supply dampers and de-energize the supply fans to prevent pressurization of the building. By proper regulation of air flow, Zones 2 and 4 are kept at the appropriate pressures with respect to Zone 3. The only Zone 3 areas normally occupied are the reactor bay, beam room, and experiment room. Of these, the reactor bay is the most likely location for an activity release and the containment philosophy is most rigidly applied here. All personnel and vehicle passages from the reactor bay which are used during reactor operation are provided with air locks. It should be noted, however, that one of the advantages of dynamic containment is that it will provide protection even if there is a large opening in the building.

Containment for individual experiments in the experiment and beam rooms will be provided as needed when the experiments are installed. Blanked-off SBHE connections are available for this purpose. Although these rooms are in Zone 3, their inclusion is primarily for convenience because of their locations rather than because of a real containment requirement. Various system conditions are remotely indicated at the reactor control room. The pressure difference between the reactor bay and outside the building is indicated in the control room as are also the pressure differences between the beam room and outside and the experiment room and outside.

7.3. Air-Conditioning Systems

The control and water wing of the reactor building is air-conditioned by a single, package-type, multizone air-conditioning unit, designated AC-15. The unit is sized for ~11,865 cfm. It consists of a fresh air intake louver, replaceable air filters, heating coil, chilled water cooling coils, slow-speed centrifugal fan, and hot and cold deck dampers. Pneumatic controls are used to automatically regulate the zone temperatures and, in room 203, the humidity. Up to 9,270 cfm is recirculated and the areas served are maintained at a slight positive pressure with respect to the reactor bay. The conditioned air supply is conveyed throughout the area by ducts to a system of diffusers which provide even distribution. The AC-15 unit is located in room 101 at the northwest corner of the first floor of the water wing.

The Zone 3 areas--reactor bay, beam room, and experiment room--utilize small packaged air-conditioning units and require a minimum of distribution duct work. The reactor bay conditioning is handled by six, floor-mounted, individual package units. Two of these draw fresh air from outside the building through intake louvers and washable filters; the other four merely recirculate air. The four recirculating units are equipped with individual filter chambers containing banks of prefilters and absolute filters. Access doors are provided through which, after spraying with a particle-confining coating and, if necessary, bagging, the filters can be removed. The filter chambers are of painted carbon steel sheet metal with all joints sealed airtight. No special shielding is required. Pressure-differential gauges are mounted on the chambers to indicate the condition of the filters. These units are sized to handle

38,400 cfm of which ~26,400 cfm is recirculated. The remaining 12,000 cfm is removed by the SBHE system.

Air conditioning in the experiment and beam rooms is handled in a similar fashion by packaged units. The experiment room units are sized to handle a total of 32,400 cfm with 26,400 cfm being recirculated. The beam room units handle 19,200 cfm with a recirculation of 13,200 cfm. The SBHE system exhausts ~12,000 cfm from these areas.

Chilled water at 40°F is supplied to the various air-conditioning units by a large chilled-water unit which has a capacity of 4×10^6 Btu/hr. The heat collected is dumped to the secondary coolant system through the chiller located in room 101. Low pressure (15 psi) steam for the air-conditioning units is obtained by pressure reduction from the 125-psi steam supply. Work areas, where special heating is required, are supplied with unit heaters employing heating-coil-fan combinations. Semi-isolated stairwells, vestibules, offices, etc., are provided with steam-heated fin-tube radiators.

7.4. Ventilation Systems

Although maintained at a positive pressure with respect to the main reactor building and the shielded portions of the water wing, portions of Zone 2, including the electrical, mechanical, and process equipment rooms, are ventilated by a system which uses 100% outside air supply. The main ventilation unit, designated FN-1 (this FN-1 is not to be confused with the FN-1 of the SBHE system or the FN-1 of the cooling towers), is of the built-up type, consisting of fresh air intake louvers, replaceable filters, preheat coils, reheat coils, and centrifugal fan. Exhaust fans FN-2, 3, and 4 exhaust ~18,500 cfm directly to the atmosphere from the water wing. The ventilation system for the electrical equipment and battery rooms G-12 and G-13 is a packaged heating and ventilating unit consisting of a fresh air intake louver, replaceable filter, heating coil, and a slow-speed fan. Approximately 5,000 cfm of air is exhausted from these rooms directly to the atmosphere by exhaust fan FN-5. These rooms which were originally intended to house lead-acid batteries, since replaced by nickel-cadmium batteries, are considered to be outside the containment. A diagram showing the air flows described is given in Figure 7.5.

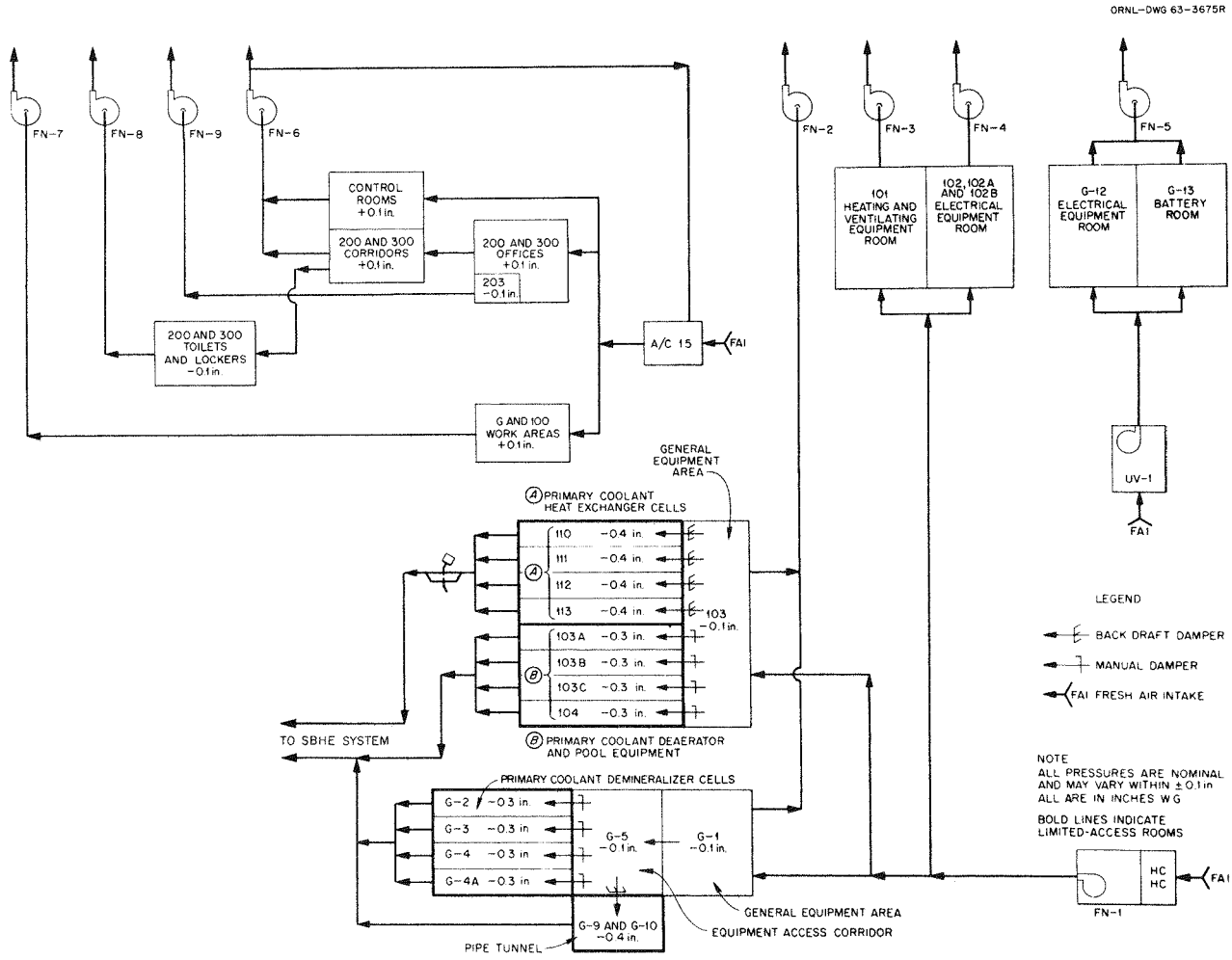

Fig. 7.5. Airflow Diagram.

7.5. Special Building Hot Exhaust System (SBHE)

7.5a. Description

The SBHE system is a maximum reliability system which provides secondary containment to control the release to the atmosphere of airborne activity from either the primary coolant system or from fuel and other components stored in the reactor pool. It also provides secondary protection for the experiment and beam rooms.

The system has two main branches, both of which, after passing through a filter system designed to remove both particulate matter and vapors, ultimately discharge into the 250-ft reactor stack.

One of these branches serves the various sections of the reactor pool and the primary coolant heat exchanger cells. The other branch exhausts air from the beam room, experiment room, pipe tunnel, and the shielded equipment rooms which house the cleanup equipment in the water wing. The arrangement of the SBHE ducts is shown in Figure 7.6.

The ducts for the reactor bay system originate in the pool walls and are provided with inlet registers immediately above the pool scuppers. Air is drawn into these registers from the reactor bay through an aperture in the reactor pool cover. The duct is sized and damper-controlled to remove a minimum of 5,000 cfm of air from under the pool cover. This corresponds to a minimum velocity of 100 ft/min flow from the reactor bay through the 50-ft^2 aperture. The movable reactor pool cover is so arranged that during fuel handling manipulations in the reactor pool, the aperture will move with the bridge and thus leave the pool covered. The remainder of the peripheral duct draws ~6,000 cfm of reactor bay air over the surface of the clean pools and the critical pool. The defective fuel element

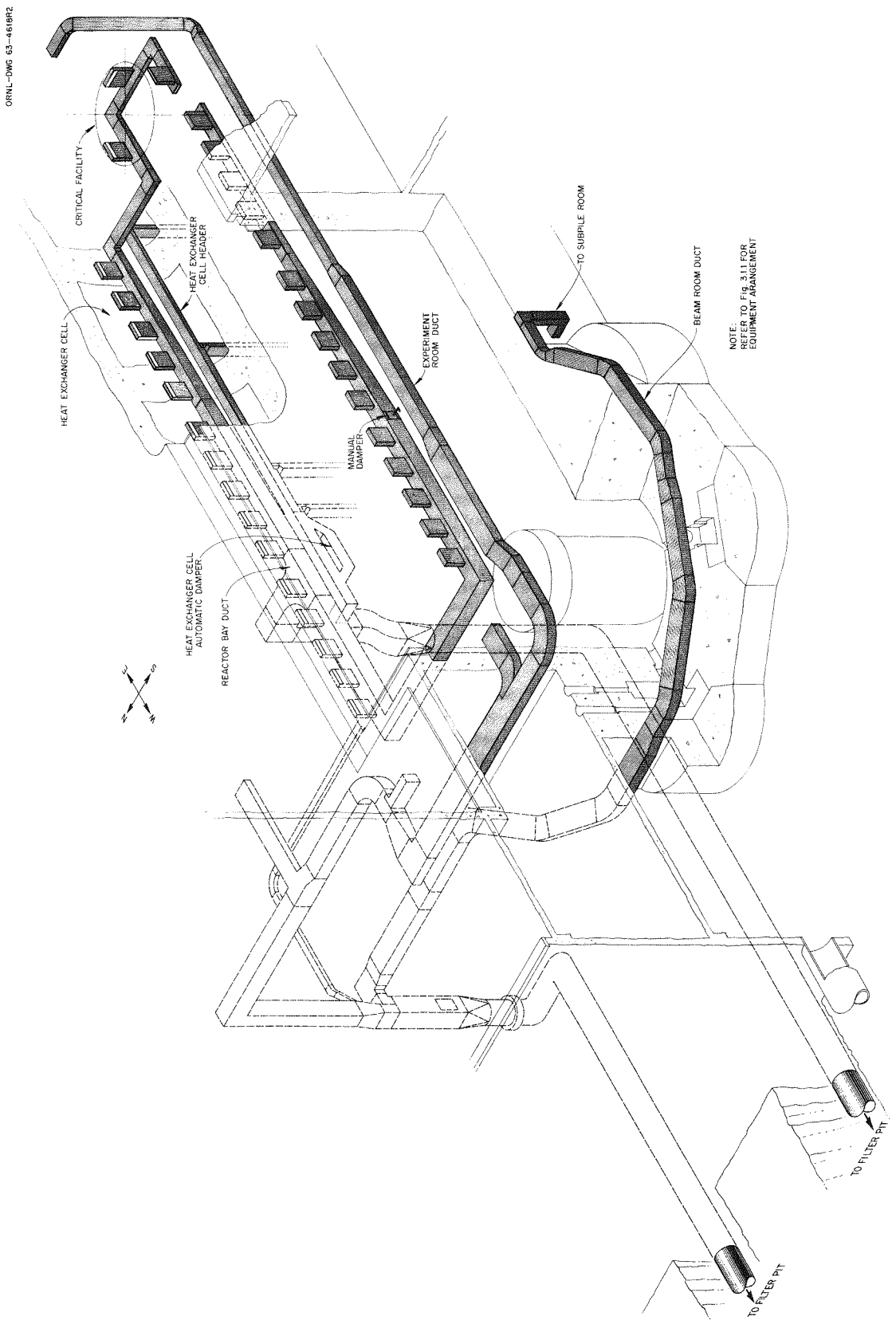

Fig. 7.6. Isometric of SBHE Ducts in Reactor Building.

storage tanks are continuously vented into the poolside SBHE duct above pool water level. Air flow through the south portion of the duct serving the clean pools may be adjusted with a manually-controlled damper. In the header from the heat exchanger cells, automatic damper PD-4 controls cell ventilation whenever cell doors are opened or access plugs are removed. In this fashion, a flow of air from the bay and into the cells is assured during maintenance operations.

A branch of the poolside SBHE header serves to exhaust 1,000 cfm directly from the northwest corner of the bay adjacent to the decontamination pad. Another branch serves the four primary heat exchanger cells with a total flow of 2,300 cfm. The main reactor bay branch is run within the pool structure below the beam room to the west side of the building and then north to the SBHE section of the filter pit.

The second main branch of the SBHE system, which is not shielded, also runs under the beam room floor to the west side of the building and then north to the filter pit. It serves the experiment room, beam room, and the shielded equipment areas. Approximately 6,000 cfm is drawn from the beam room including 500 cfm originating in the subpile room. An additional 6,000 cfm is exhausted from the experiment room, and 2,300 cfm originates from the equipment cells.

All ducts embedded in concrete, the pool peripheral exhaust duct and inlets, the exhaust from the pump and exchanger cells, and the ducting embedded in the pool structure are type 304 stainless steel, welded by radiographically qualified procedure and welders to the specifications established particularly for this system. Shop or field welds made for construction were inspected both visually and by dye penetrant test.

All welds were made by the Heliarc welding process. All embedded ductwork was pressure tested to assure airtightness before it was encased in concrete. Exposed ductwork, made of galvanized sheet iron in accordance with standard sheet metal duct construction, is painted with a protective coating throughout. All joints are sealed airtight.

Ductwork laid underneath soil bearing floor slabs or buried in earth outside of the reactor building structure is constructed of 3,300-lb and 5,000-lb transite pipe, joined with applications of gastight sealing compounds, and coated with 2-ply tar and felt to prevent water seepage into the ducts. A chevron-type baffle moisture eliminator is located at the inlet to each filter compartment to remove entrained water from the air, especially in the duct system which drains air from over the pool, thus protecting the charcoal filters. All exposed ducting is installed to fit tightly against the wall surfaces with the minimum amount of horizontal surface to permit ease of decontamination.

7.5b. Filters and Exhaust Equipment

Air from the SBHE is led from the various headers to an underground filter pit which contains both absolute and charcoal filters for the purpose of decontamination. After passing through the filters, it is monitored and forced up a 250-ft stack so that any residual activity is dissipated by diffusion and decay.

The filter pit is an outdoor, below grade, waterproofed, concrete structure designed to withstand pressure differences between +0.5 psi and -4.75 psi.

The SBHE section of the filter pit contains three filter compartments in parallel. One compartment serves each branch of the system. The

third compartment serves as a standby which can be put into service on either branch without necessitating a plant shutdown. A diagram of the system is shown in Figure 7.7. At grade level, the SBHE section is shielded with 2 ft of concrete with stepped shield plugs over each filter bank (Figure 7.8).

Each filter compartment contains an assembly of: (1) a 3 x 4 bank of 12 pre-filters, (2) a 3 x 4 bank of 12 Figerglas-asbestos absolute filters, (3) a silver coated copper mesh screen, (4) two 3 x 4 banks of 12 charcoal absorption units in series, and (5) a 3 x 4 bank of Fiberglas-asbestos absolute filters. The filter system is designed to be 99.97% effective in removing particulate matter of greater than 0.3 micron size and to remove greater than 99.99% of the iodine.

The filter pit is designed for a filter removal method in which the filters are withdrawn into lead shielding casks. After removal of a concrete shield plug, the casks are placed over the opening; and the wedging devices which seal the filter to the filter frames are removed remotely, permitting withdrawal. Full air flow during filter changes is maintained by using externally-operated manual dampers to divert the flow to the standby compartment.

The filter frames are corrosion-protected carbon steel. Drainage and condensate from the filter pit are collected in a sump which is drained by gravity to the process-waste disposal system. Condensate in the exhaust ducts is drained directly to the process waste.

Two 28,600-cfm exhaust fans driven by 75 hp squirrel cage induction motors convey the air from the SBHE filters to the stack. These are of carbon steel construction but with scrolls and wheels painted with

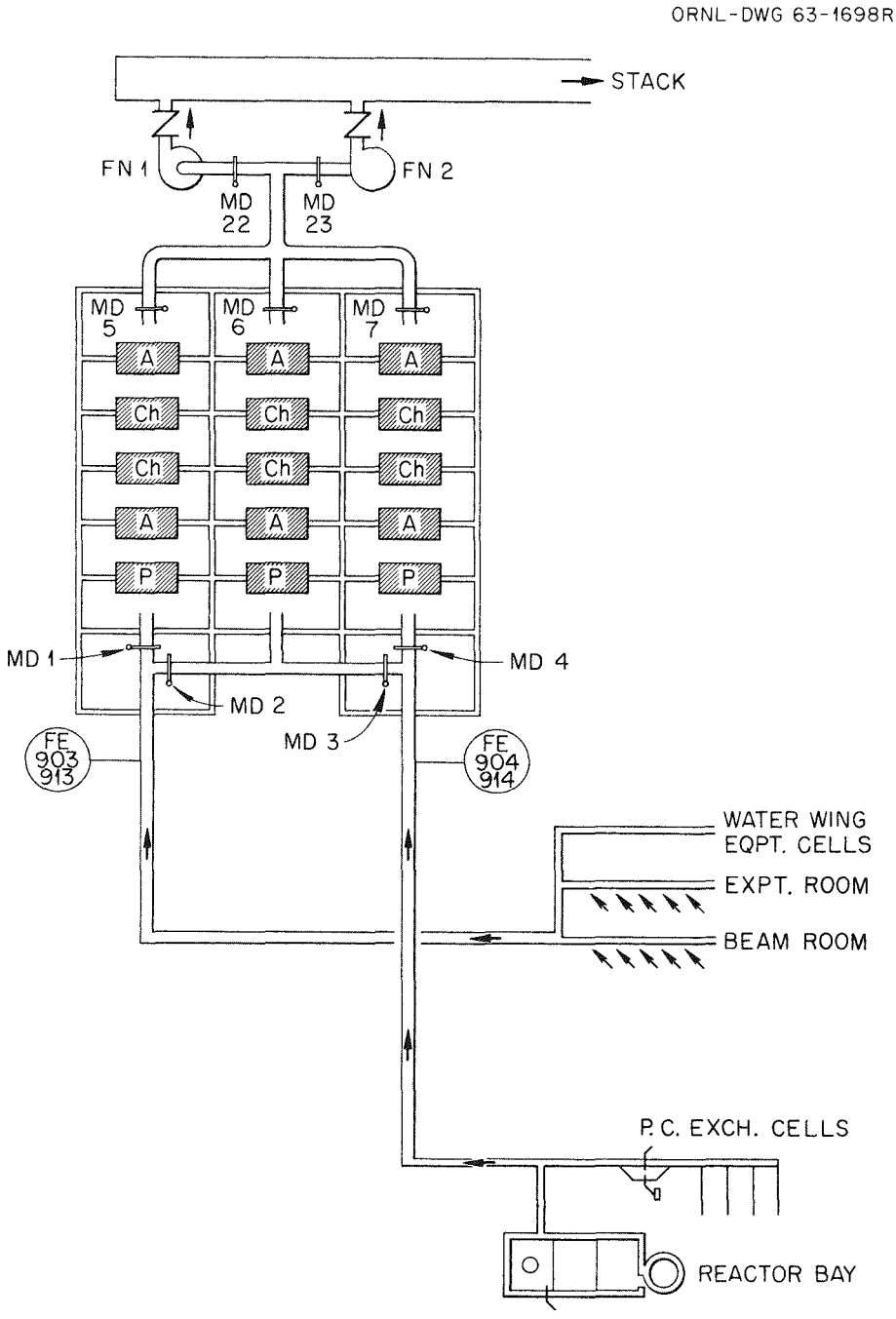

Fig. 7.7. Special Building Hot Exhaust System.

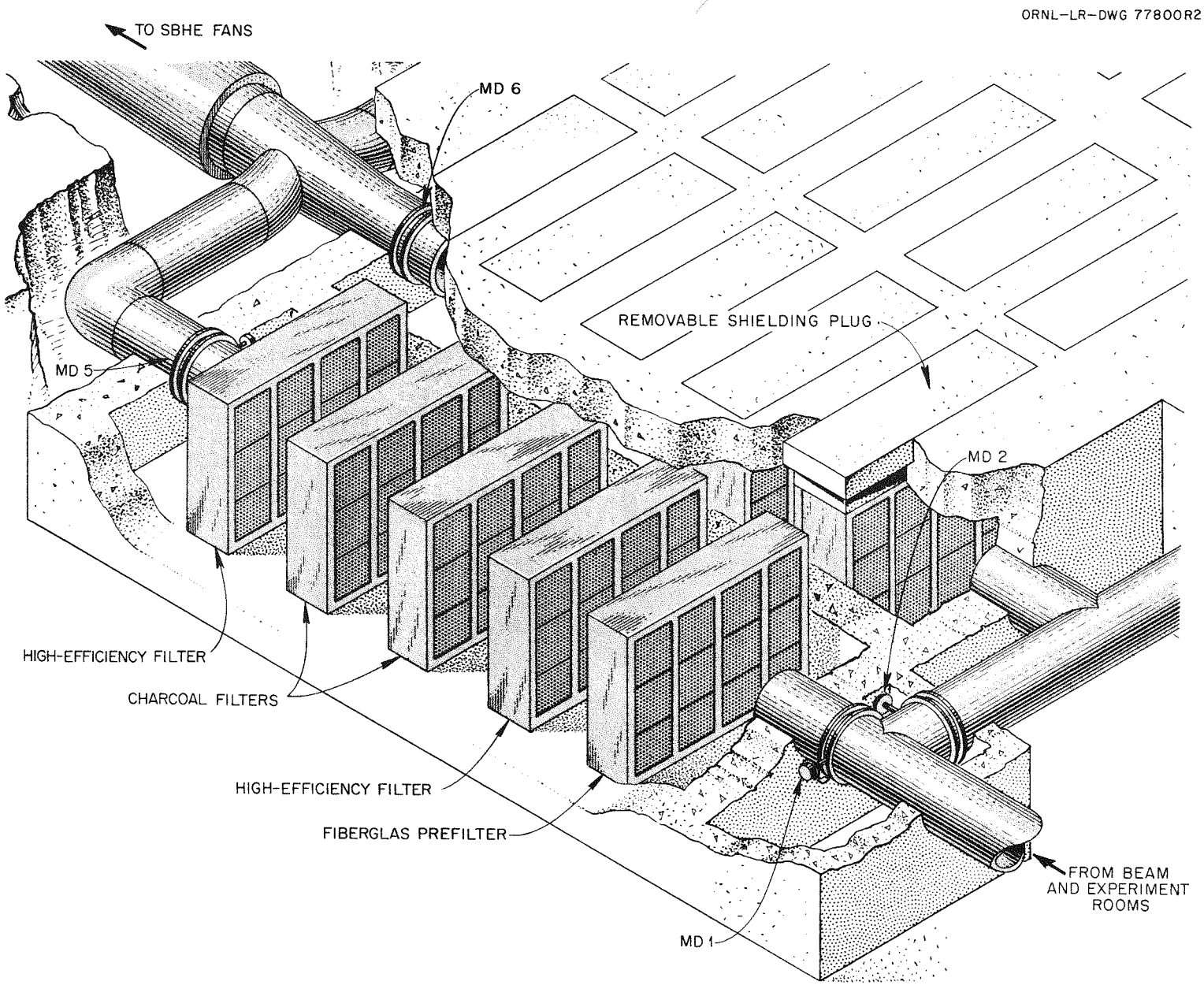

Fig. 7.8. SBHE Filter Pits.

corrosion-resisting paint. Normally only one fan is operated with the other in standby condition. The single duct from the SBHE section of the filter pit is split at the fans to permit switch over from one to the other. Each fan is fed from a different generator in the normal-emergency power system to provide reliability during a normal power outage. The automatic change over from the operating fan to the standby fan is actuated by air flow switches which detect malfunction of the operating unit. Once started, the fan must be shut down manually.

7.5c. SBHE Instrumentation and Control

Because of the necessity that the exhaust systems retain a high degree of reliability even under abnormal conditions, considerable effort has been expended to provide adequate instrumentation and control and to ensure the availability of a continuing source of power to drive the fan motors. The normal and emergency power supplies are described in some detail in Section 10.8; and, in the following descriptions, some familiarity with these systems is assumed.

Fan Controls.--Each of the SBHE exhaust fans, FN-1 and 2,* is provided with an "On-Off-Standby" selector switch which is located at the local panel board in the fan shed. In normal operation, one fan is operating with the switch in the "On" position and the other is in "standby." The fan selected as preferred will be alternated periodically. Indicating lights on the panel board in the control room, operated by motor contacts and the standby switch, provide information concerning

*Fans in separated areas of the HFIR complex are numbered FN-1, 2, 3, etc. Do not confuse air-conditioning fan numbers, etc., with those in this section.

the condition of the fans. The color code is as follows:

Fan not running - white light.

Fan running - amber light.

Fan in standby - blue light.

Note that in some cases two lights may be lit simultaneously. For example, if FN-1 is the preferred fan and is running, only its amber light is on. For FN-2, the panel board switch is on "standby" and both the white and the blue lights are on.

Flow Monitors.--Four pitot tubes, two in each branch, are provided to monitor the flow through the SBHE system. The flow indicators are located on the gaseous waste system panel in the control room. The air flow through the reactor bay system (east branch) is monitored by sensors FI-904B and 914B while sensors FI-903B and 913B handle the beam and experiment rooms (west branch). A diagram showing the SBHE control system is shown in Figure 7.9.

Pressure Controls.--Pressure transmitters at the pitot locations in the main branches of the SBHE system upstream of the filter pit actuate switches to provide two-stage alarm and control action. The method of operation is as follows. A drop in air flow to ~85% of normal in either branch will cause the pressure switch in that duct to open and actuate a visual and audible alarm in the control room. A loss of air flow to ~80% of normal in either duct will cause one or more of four pressure switches, two in each branch, to open, trip a relay (R-102) which starts the standby fan and simultaneously sounds an alarm in the control room. A further decrease of flow to ~75% of normal will cause one or more of four other

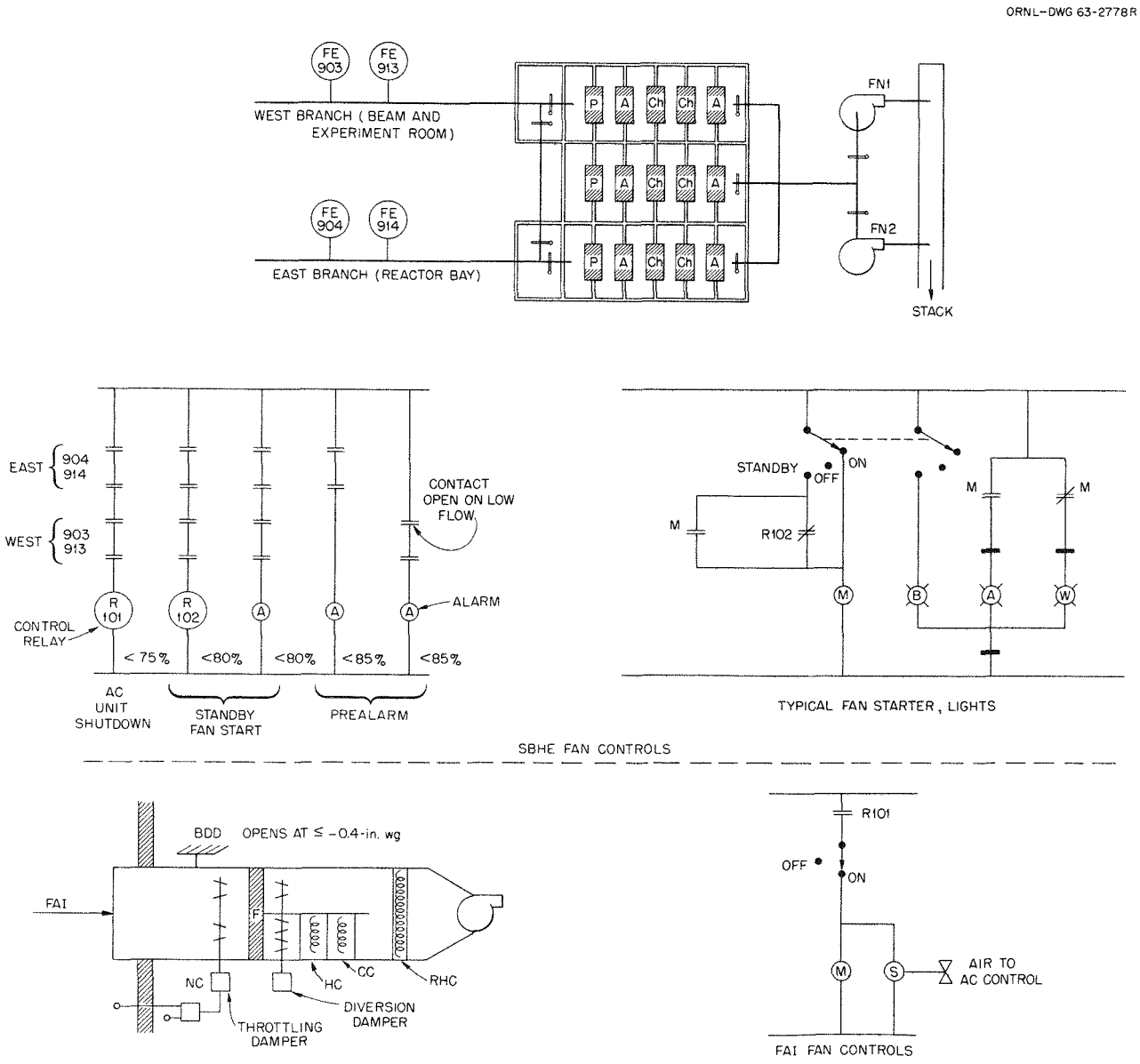

Fig. 7.9. SBHE Fan and FAI Controls.

pressure switches, two in each branch, to open and trip another relay (R-101) which shuts down air-conditioning units AC-2, 5, 10, and 14. These are the fresh air intakes for the three containment areas. When normal flow is restored, the air-conditioning units will restart automatically. These control circuits are designed so that a loss in control power or the opening of a relay coil will simulate a loss of air flow. A gravity relief damper on the fans will start opening at -0.4 H_2O to provide protection against a false damper closure signal when the fans are running normally. No coincidence features are used in these pressure switch devices. Any one of the switches can cause an alarm, standby fan startup, or air-conditioning unit shutdown. The operating conditions and functions of these pressure switches are listed in Table 7.1.

Fan FN-1 is connected to normal-emergency power system No. 2 via motor-control center "H" and fan FN-2 to normal-emergency power system No. 1 via motor-control center "G." The timing sequence for the operation of these two feeders, subsequent to diesel generator startup in the event of a failure of normal power, is that motor control center "H" will be energized ~10 sec prior to motor control center "G." This permits TRU and HFIR stack fans to receive top priority on generators No. 1 and 2, respectively. The circuits are so arranged that, assuming both diesels start simultaneously following a power outage, the following operation is obtained.

Table 7.1. SBHE Pressure Switch Tabulation

Switch No.	Duct Location	Normal Pressure*	Setpoint Pressure*	Type of Action
PS-1	West	0.60	0.45 (85% flow)	Alarm.
PS-2	East	0.60	0.45 (85% flow)	Alarm.
PS-6A and 6B	East	0.60	0.40 (80% flow)	Starts standby fan and alarms.
PS-6C and 6D	West	0.60	0.40 (80% flow)	Starts standby fan and alarms.
PS-5A and 5B	East	0.60	0.35 (75% flow)	Shuts down AC units 2, 5, 10, and 14
PS-5C and 5D	West	0.60	0.35 (75% flow)	Shuts down AC units 2, 5, 10, and 14

*Indicates velocity head in inches of H_2O.

Fan No.	Switch Position	Operation Obtained
FN-1	On	FN-1 only runs
FN-2	Standby	FN-1 only runs
FN-1	Standby	FN-1 and 2 run
FN-2	On	FN-1 and 2 run

NOTE: If the velocity pressure in the duct is not greater than 0.4 in. H_2O by the end of the 10-sec delay on the No. 1 normal-emergency system, FN-2 will also start.

A continuous display of the differential pressure between the Zone 3 containment areas and the outside atmosphere is given at the gaseous-waste-system panel board. This is obtained from three pressure gauges which monitor the experiment room, beam room, and the reactor bay. The characteristics of these instruments are given in Table 7.2.

Table 7.2. Differential Pressure Gauge Tabulation

Gauge No.	Area Monitored	Normal Inches H_2O	Setpoint Inches H_2O	Type of Action
PdI-900	Reactor bay	0.30	0.10	Alarm
PdI-901	Beam room	0.30	None	None
PdI-902	Experiment bay	0.30	None	None

The nominal differential is -0.3 in. H_2O. Because neither the beam room nor the experiment room are provided with air locks, it is expected that the differential pressure in these rooms will fluctuate to a greater extent than that in the reactor bay. Modulating dampers are provided in the fresh air intakes to minimize the fluctuations. The reactor bay is provided

with air-lock entrances for both personnel and motorized equipment. These are not true locks such as those found in "static" containment systems, but are merely small antichambers which serve a similar purpose. A visual and audible alarm is given in the control room should the differential pressure in the reactor bay decrease below -0.10 in. H_2O.

8. EMERGENCY SYSTEMS

8.1. Diesel Electric Generation and Distribution Systems

8.1a. References

Drawings:

1546-01-E-2007 One Line Diagram, Normal-Emergency System No. 1

1546-01-E-2008 One Line Diagram, Normal-Emergency System No. 2

1546-01-E-2124 Elementary Control Diagram, Diesel Generator No. 2 Air Compressor

1546-05-U-7021 Flow Diagram, Diesel Generators and Fuel Distribution

Singmaster & Breyer Specifications:

107 Electrical Work, Diesel Generators and Normal-Emergency Switchgear

8.1b. Introduction

Emergency ac electric power is supplied to the HFIR by two 350 kw, 480-volt, 3-phase, 60-cycle, diesel-engine-driven generators located in the electrical building. Power is supplied by the generators to two sets of normal-emergency switchgear which distribute the emergency power to the equipment required for 10% full-power reactor operation. In normal operation both sets of normal-emergency switchgear are energized by the normal-power system; the diesel generators are not running.

In the event of a sustained normal-power failure or a 30% drop in source voltage for a duration of two seconds, auxiliary contacts in the automatic transfer switches: (a) energize the diesel engine startup circuits to crank the engines; (b) trip all of the ciruit breakers in

the normal-emergency switchgear; and (c) apply a trip impulse to the diesel test-loading circuit breakers.

8.1c. Normal-Emergency System No. 1

Diesel Engine.-- The diesel engine (Caterpillar Tractor Co. Model No. D-379) is rated to provide 350 kw of generator output continuously and 400 kw for 2 hours. The unit is turbo-charged, has eight cylinders, operates on a 4-stroke cycle, and uses No. 2 fuel oil. The engine is water cooled and has an integrally mounted radiator and fan. It is electrically started by two 32-volt dc motors and has a thermostatically controlled jacket water heater which maintains the cooling water at 90°F.

Starting Battery.-- Starting power is obtained from a 32-volt 24-cell nickel-cadmium storage battery which is installed in the No. 1 diesel-generator room of the electrical building. The battery has an 8-hour discharge rate of 270 ampere hours and is sized to provide the proper breakaway and rolling currents for the diesel engine. The battery will supply 2100 amperes for 5 seconds or 1050 amperes for 90 seconds.

Battery Charger.-- The battery charger for the starting battery is rated 14 amperes continuous at 32-volt dc. The charger floats the battery at 33.6 volts continuously and has an adjustable 24-hour timer which permits the battery to be given a freshening charge at 1.50 volts per cell (36 volts total). After the freshening time period has elapsed, the charger automatically returns to the floating voltage of 33.6 volts. In the event of battery charger failure or a dc ground, an annunciator on the "HI" panel in the main control room will alarm.

Charger instrumentation and equipment includes a voltmeter and an ammeter for monitoring the output voltage and current, an "On-Off" push-button, an "ac Power On" indicating light, and rheostats for adjusting the floating and freshening voltages. The charger has a built-in current limiting circuit which limits the current to its rated value under all conditions of operation.

Generator.-- The generator is a General Electric package-type unit integrally mounted with the diesel engine and is rated at 350 kw, 0.8 power factor continuously, or 385 kw for two hours without destructive overheating. The generator is self-excited and includes a rotating exciter.

Controls and Instrumentation.-- The mode of operation is selected by the "Engine Test-Automatic-Stop-Hand Crank" control switch located on the diesel-generator control panel.

1. In the "Automatic" position, the diesel generator starts automatically upon a failure of the normal-power system.
2. The "Engine Test" position is used for starting the diesel generator for test purposes--either to run it unloaded or with a test load. Operation in this position allows automatic transfer from the normal to the emergency system in the event of a normal-power failure while a test run is being made.
3. In the "Stop" and "Hand Crank" positions, the electric starting controls are inoperative. NOTE: The switch should never be left in these positions during reactor operation.

The following instrumentation is provided locally on the engine:

1. Lubricating oil-pressure gauge.

2. Cooling water temperature gauge.

3. Fuel pressure gauge.

4. Service meter.

5. Lubricating oil-level gauge.

Abnormal engine operating conditions are indicated locally by a buzzer and indicating lights and remotely in the main control room by an annunciator on panel "HI." Conditions which cause actuation of the annunciator are:

1. High cooling-water temperature (209°F).

2. Low lubricating oil pressure (below normal but not serious enough to require immediate engine shutdown) (<18psi).

3. Low fuel oil pressure (<12 psi).

4. Engine overspeed. This condition shuts the engine down and requires resetting of the overspeed relay and rack solenoid. Should this fail, a mechanical overspeed device set at a slightly higher speed will shut down the engine.

5. Very low lubricating oil pressure. This shuts the engine down and requires resetting of the rack solenoid to restart the engine (≤8 psi).

6 Overcranking. When this alarm occurs, the engine has completed the three 15-second cranking cycles and has not started.

7. Rack solenoid in the "Stop" position.

The following generator instrumentation and controls are provided locally on the diesel-generator control panel:

1. Voltmeter and associated switch which permits reading the three phase-to-phase output voltages.

2. Wattmeter which displays the power output.

3. Ammeter and associated switch to permit reading the output current for each phase.

4. Frequency meter which indicates the line frequency.

5. Running time integrator which maintains a record of operating time.

6. A voltage regulator control switch to permit selecting the mode of voltage regulator control. In the "Auto" position, the voltage is controlled automatically at a pre-selected value. This pre-selected value may be adjusted with the "Voltage Adjust Rheostat" mounted on the right-hand side of the panel. In the "Manual" position the voltage is controlled by a rheostat located at the center of the panel. The "Test" mode is used for testing the voltage regulator output during maintenance.

7. Main generator breaker. NOTE: This breaker must always be in the closed position during reactor operation.

8. Test loading circuit breaker. This breaker is used to test load the diesel generator using the building lighting system as the load. An interlock permits testing only one generator at a time.

Normal-Emergency Switchgear.-- Normal-emergency switchgear consists of the automatic transfer switch, six circuit breakers with 125-volt dc control power, a sequence-closing timer, and a multipole auxiliary relay. The following controls and instrumentation are provided locally:

1. Two red, automatic transfer switch position-indicating lights--one marked "Normal" and the other marked "Emergency".

2. A circuit breaker control switch and red and green position-

indicating lights for each feeder breaker. (When the red light is on, the breaker is closed; when the green light is on, the breaker is open.)

3. A white light to indicate that power is available for operating the timer when required.

4. A key operated "Test" switch to simulate a normal-power failure. When placed in the "Test" position, the diesel generator starts and automatic transfer occurs. This will only be done when the reactor is shut down.

Control Room Instrumentation.--The general condition of the normal-emergency system is indicated on panel "I" in the control room by the following instrumentation:

1. Three red lights which indicate that the diesel-generator is running.

2. Red and green position-indicating lights for the generator main breakers.

3. Two main automatic transfer switch position-indicating lights.

4. Two diesel test-loading transfer switch position-indicating lights (one for each normal-emergency system).

In addition to these lights, annunciators are provided in the main control room for:

1. Diesel-generator No. 1, misoperation.

2. Diesel-generator No. 1, battery charger failure.

3. Low fuel-oil level in the day tanks.

8.1d. Normal-Emergency System No. 2

The No. 2 normal-emergency system is identical to the No. 1 system, with the following exceptions: The diesel engine has an air motor

starting system instead of an electrical system. This unit is supplied with an air motor and drive, a pressure regulator, vapor arrestor, and noise muffler. The pressure regulator reduces the inlet pressure from a maximum of 250 psi to 90-100 psi of regulated pressure for the air motor. Supply air is obtained from an air receiver and air compressor located adjacent to the diesel-generator.

Air Receiver.-- The air receiver has sufficient capacity to permit five starts of approximately 5-sec duration each. Pressure switch PS-639 operates to start the air compressor when the pressure in the air receiver drops to 215 psi and to cut it off when the pressure reaches 250 psi. In the event the pressure drops to 175 psi, pressure switch PS-645 actuates an annunciator on panel "HI" in the main control room to indicate low starting air pressure.

Air Compressor.-- The air compressor is controlled by a "Run-Off-Automatic" selector switch. In the "Run" position the compressor operates continuously. In the "Automatic" position the compressor is controlled by pressure switch PS-639 as described above.

An overcranking alarm is actuated after the cranking cycle has run for 75 seconds without the engine starting.

8.1e. Fuel-Oil Storage and Distribution

Fuel-oil storage and distribution equipment consists of:

1. FOT-1, a 4000-gal capacity storage tank, located underground just south of the electrical building.
2. FOT-2 and 3, two 60-gal capacity fuel-oil day tanks, one located in each diesel-generator room.
3. PU-1 and 2, two fuel-oil transfer pumps, one located in each diesel-generator room.

Storage Tank.-- The underground storage tank is equipped with a 2-in. level-gauge opening, a 1-1/2-in. vent line with flame arrestor, a 1-1/2-in. fill line, and a level switch, LS-647, for low-level annunciation.

Three 1-1/2-in. lines enter the tank. One is a common overflow line from the two day tanks; the other two lines feed the fuel-oil transfer pumps. These two lines extend to the bottom of the storage tank and are equipped with strainers and foot valves to prevent the transfer pumps from losing their primes.

Day Tanks FOT-2 and FOT-3.-- The 60-gal capacity fuel-oil day tanks are provided with overflow lines which drain by gravity through a common header back to the underground storage tank. The day tanks are mounted at sufficient elevation to feed fuel oil to their respective diesel engines by gravity. Oil is recycled from the diesel engines back to the day tanks by the diesel-engine fuel pumps. Each day tank has sufficient capacity for two hours' diesel-generator operation.

A spring-loaded valve is located in the fuel-oil supply line from the day tank to the diesel engine. This valve is held open by mechanically attached fusible links which are located above the day tank, above the transfer pump, and above the diesel engine. In case of fire the links will open, allowing the valve to close and shut down the diesel engine.

Level switches LS-648 on FOT-2, and LS-649 on FOT-3 actuate a common annunciator on panel "HI" in the main control room upon low fuel-oil level (40% full). Level indicators LI-634 and LI-636 indicate locally the level inside FOT-2 and FOT-3, respectively.

Transfer Pumps PU-1 and PU-2.-- Fuel oil is delivered by truck to the underground storage tank and is then pumped, as required, by the transfer pumps to the two day tanks. Each of the pumps is controlled by a "Run-Off-Automatic" selector switch. In the "Automatic" position, PU-1 is controlled by level switch LS-633, located on FOT-2; PU-2 is controlled by level switch LS-635, located on FOT-3. The pumps are started when the fuel-oil level inside the day tanks drops to 50% full and are stopped when the level reaches 100% full. The pumps run continuously when the selector switch is in the "Run" position.

In the event one fuel-oil transfer pump becomes inoperative, the other may be used to pump fuel to both day tanks. In this case manual control of the pump is necessary.

8.2. Battery-Powered Pony Motors

8.2a. References

Drawings:

1546-01-E-2007 One Line Diagrams, Fail-Free System

1546-01-E-2113 Operating Description

1546-01-E-2120 Elementary Control Diagrams, Primary Coolant Pumps

ORNL Specification No.:

500-E-2 - Primary Coolant Pumps

8.2b. Description of System Operation

Forced circulation of primary coolant water is provided during normal-power outages in order to ensure against damage to the reactor due to afterheat production. This forced circulation is accomplished by dc pony motors coupled directly to the ac motor shafts of the main primary coolant pumps. The pony motors are rated at 3 hp, 31.0 amperes full load current. One pony-motor pump delivers 1600 gpm, two deliver 2100 gpm, and three deliver 2400 gpm.

Each pony motor is supplied from a 125-volt dc battery in parallel with a battery charger. Under normal conditions, the battery charger supplies the pony motor and floats the battery at constant voltage. Upon a normal-power outage or battery charger failure, the battery supplies the pony motor. The batteries, battery chargers, and the pony motor metering cabinets are all located in the battery room (G-13) on the ground floor of the reactor building.

A pony motor is mounted on top of each of the four primary coolant pump ac motors. During normal operation both motors are energized,

and the pony motor contributes only a small amount of torque to the pump. De-energizing the main ac motor, as during a normal-power outage, resulting in the slowing down of the pump until the pony motor torque is sufficient to drive the pump at a reduced speed (270 rpm). No manual or automatic operation is necessary for the transfer of load from the main ac motor to the dc pony motor.

Test Circuit.--Each pony motor has a 108-volt dc shunt "test" field which permits full load current to be drawn by the motor during normal operation of the reactor. The "test" field current is applied by a pushbutton on panel "E" in the main control room and is supplied by a silicon diode rectifier. The motor current may be observed on an indicator located adjacent to each test button. An associated ammeter and a rheostat for adjustment are located in the 2400-volt motor starter.

Batteries.--Each battery is rated at 125 volts and contains 92 nickel-cadmium alkaline pocket plate cells in sealed plastic containers. Each battery is capable of supplying approximately 50 amperes for a two-hour period without use of the charger. This rating enables the battery to drive the pony motor for at least two hours during a normal-power outage even if the diesel-generator does not start.

Battery Chargers.--Each battery charger is rated at 480-volt, 3-phase, 60-cycle input with 129-volt, 50-ampere dc output. Each has an automatic voltage-control circuit that maintains a floating voltage of 129 volts from 0-100% load. A current limiting device prevents over-current under all operating conditions.

The chargers are supplied from normal-emergency system No. 1 through motor control center "D" which is located in the electrical equipment room (G-12) on the ground floor of the reactor building. Motor control

center "D" is energized by the No. 1 diesel-generator 20 seconds after the generator assumes the load. This allows pony motor operation for as long as the diesel-generator runs in addition to the two hours of operation from the batteries.

The following equipment is located on the front panel of each battery charger:

1. An ac power disconnect switch.
2. An "On-Off" start switch.
3. A pilot light to indicate that the unit is in operation.
4. A dc voltmeter to indicate the output voltage.
5. A dc ammeter to indicate the output current.
6. A variable transformer control for adjusting the floating voltage (1.40 volts per cell or 129 volts total).
7. A variable transformer control for adjusting the freshening voltage (1.50 volts per cell or 138 volts total).
8. A 0-24 hour adjustable timer for the freshening charge (the charger automatically returns to the floating charge rate at the end of the timer cycle).

A dc output circuit breaker is located behind the front panel of the charger to ensure against inadvertent opening. A common annunciator on panel "HI" in the main control room annunciates a charge failure or dc ground at any of the four battery chargers.

Pony-Motor Metering Cabinet.-- On the front panel of the metering cabinet is a zero center ammeter which indicates charge or discharge current of the battery.

A shunt, between the pony-motor metering cabinet and the pony motor, is connected to a voltage-to-current converter. This voltage-to-current converter transmits a signal to the pony-motor current ammeter (one for each pony motor) on panel "E" in the main control room and to a dual alarm switch in the auxiliary control room which actuates annunciators on panel "IE" for high (35 amps) and low (3 amps) pony-motor current.

8.3. Instrument Batteries

8.3a. References

Drawings:

1546-01-E-2007 - One Line Diagrams, Normal-Emergency Bus, MCC "J"

1546-01-E-2009 - One Line Diagram - Instrument Power

1546-01-E-2024 - Panel Schedule, Reactor Building

1546-01-E-2026 - One Line Diagram, P-31, P-32, and P-33

Singmaster & Breyer Specifications:

107 - Electrical Work, Batteries, and Battery Chargers

8.3b. Introduction

The instrument power system supplies power for all process and nuclear instrumentation at the HFIR. The system is supplied by a feeder from the normal-power system through 13.8 kv -- 120/240 volt electrostatically-shielded transformers; but in the event of a normal-power failure, the instrumentation load is automatically transferred to the normal-emergency system. Two sub-systems are provided -- one for reactor operation and the other for experiment use.

The normal-emergency power system usually operates from the emergency diesel-generators during a normal-power outage; but since its operation depends upon the automatic starting of the diesel generators, it is not considered to have maximum reliability. For those applications where loss of normal ac power could cause hazard to personnel or major equipment, ultra-reliable power systems are provided which are not dependent upon the successful startup of the diesel-generators. Two such applications are:

1. The power supplies for the four primary coolant pump emergency

motors (pony motors) which remove the heat produced in the reactor after shutdown. This system is referred to as the "fail-free" system (see section 8.2. in this procedure).

2. The power supplies for the three reactor safety systems and regulating channels.

In general, each of these power supplies consists of a nickel-cadmium storage battery in parallel with a battery charger which is supplied from the normal-emergency system.

8.3c. Direct Current Instrument Power (32/64 volts)

Each of the three 32/64 volt dc power systems supplies a nuclear safety and control channel. The systems are kept separate from each other wherever feasible. Each of the systems consists of a storage battery, two battery chargers, monitoring equipment, and a power panel.

Batteries.-- Each battery consists of a center-tapped bank of 48 nickel-cadmium cells. The center tap is grounded, making the voltage of the three terminals -32 volts, zero, and +32 volts. The battery is sized to provide 40 amperes of current for a two-hour period without charger operation.

Battery Chargers.-- Each battery bank is supplied by two battery chargers to ensure adequate charging to each half of the bank regardless of the current drain from each half. The charger is rated to produce 50 amperes continuously at 32 volts dc. The charger floats the 24-cell battery section at 1.40 volts per cell (33.6 volts total). It has an adjustable 24-hour timer which permits the battery to be given a freshening voltage of 1.50 volts per cell. After the pre-selected freshening time period has elapsed, the charger automatically returns to the

floating voltage. In the event of a failure of any one of the six battery chargers in the instrument power system, a single common annunciator on panel "HI" in the main control room will alarm.

Battery charger instrumentation and control equipment is similar to that of the pony motor battery chargers (see section 8.2 in this procedure).

Distribution.-- Each of the batteries supplies a power distribution panel located in the main control room. These panels are P-31, safety system No. 1; P-32, safety system No. 2; and P-33, safety system No. 3. The panels contain both 32-volt and 64-volt circuit breakers. A fused safety switch is tapped off ahead of each panel to provide power to the three reactor servo systems.

120 Volt Non-interruptive Power.-- The heat-power calculators require a 120-volt a.c power supply which is not subject to interruption. To provide this service, three 32-volt d.c input 118-volt a.c output inverters are provided -- one for each safety system channel. The inverters are supplied 32-volt d.c power from panels P-31, P-32, and P-33 and are located in the process relay cabinet in the auxiliary control room. The inverters utilize solid state circuitry and will provide 250-volt-amperes continuously at 118 volts, 60 cycles per second. A "Power-On" indicating light is provided in the cabinet for each inverter.

125-Volt d.c. Power.-- The switchgear battery, located in the electrical building (see section 8.1 in this procedure), supplies 125-volt d.c power for reactor instrumentation and control through distribution panel P-29 in the main control room. This panel supplies power to

the four shim-safety-plate seat relays, to the regulating plate insert- and withdraw-limit relays, and to the fast insert shim-safety rod drive relays and solenoids.

8.4. Auxiliary Pressurizer Pump

8.4a. References

Drawings:

1546-01-E-2118 Elementary Control Diagrams, Primary Feed Pump

Singmaster & Breyer Specifications:

41 Primary Feed Pump

8.4b. Introduction

The auxiliary pressurizer pump, PU-11, is a duplex-plunger-operated, positive displacement type pump and is operated from the normal-emergency system No. 1. It is used to maintain primary coolant system pressure and to supply primary pump seal-water flow during failures of the normal-power system. The pump delivers 400 gph and will keep the system pressurized if leakage does not exceed this amount.

8.4c. Controls

The pump is provided with a "Run-Automatic-Off" switch, locally mounted to permit selecting the mode of operation. In the automatic mode, the pump is started by low flow in the main pressurizer pump effluent line, which is sensed by flow element FE-216, and by an auxiliary contact on the automatic transfer switch of normal-emergency system No. 1 switchgear. Power for the pump comes from MCC "E" and is delayed 30 sec after the diesel assumes the load. The pump continues to run after normal power has been restored.

Running lights are provided at the "Run-Automatic-Off" switch and at the "Remote Control-Off" selector switch which is mounted on the process panelboard in the control room. The "Remote Control-Off" selector switch enables the pump to be shut down from the control room.

An annunciator, "PU-11 Off", on panel "IE" in the main control room will annunciate when the "Remote Control-Off" selector switch and/or the "Run-Automatic-Off" switch are in the "Off" position.

8.5. Auxiliary Secondary Coolant Pump

8.5a. References

Drawings:

1546-01-E-2118 Elementary Control Diagrams, Process Water Equipment

1546-01-I-4007 Instrument Application Diagram, Secondary Coolant Loop

Singmaster & Breyer Specifications:

50 Cooling Tower Vertical Centrifugal Pumps

8.5b. Introduction

The auxiliary secondary coolant pump is driven by a two-winding, two-speed, 440 volt, 3-phase, 60-cycle motor. The two windings are completely independent of each other and are brought out to separate junction boxes located on opposite sides of the motor. Each of the two windings serves a different purpose. The high-speed winding (1200 rpm) is used for normal operation of the pump to provide secondary coolant flow when the reactor is shutdown and the main secondary coolant pumps are out of service. The slow-speed winding (600 rpm) is used to provide the emergency coolant flow required to keep the reactor at 10% of full power during a normal-power outage.

8.5c. Controls

The pump is provided with a "Run-Automatic-Off" switch for the low-speed winding and an "On-Neutral-Off" switch for the high-speed winding. The two switches are located on control room panel board E3. An interlock in the control circuitry prevents energizing both windings simultaneously.

The high-speed winding is supplied from MCC "N" and is inoperative during a normal-power outage. The low-speed winding is supplied by normal-emergency system No. 1 through MCC "J." In the event of a power outage a delay of 20 seconds exists before the diesel assumes this load. A time-delay relay keeps the pump running after return to the normal-power system. This feature provides secondary coolant flow during the time interval between return to normal power and the manual starting of the main secondary coolant pumps.

The pump starter is interlocked with valve FCV-362A so that the static head of the cooling tower is bypassed whenever the low-speed winding is energized. FCV-362A is located in a 12-in. line which bypasses the vertical risers and allows circulation through the basin only.

A running light, located on the process panelboard, indicates when the low-speed winding is energized. An annunciator on panel "2E" in the main control room is actuated when the selector switch, SS-1, is in the "Off" position.

8.6. Fire-Protection Systems

8.6a. References

Drawings:

1546-01-E-2079-2083 Fire Alarm Interconnection Diagrams

1546-01-E-2084 Fire Alarm Block Diagram

Singmaster & Breyer Specifications:

70 Fire Protection

107 Electrical, Fire-Alarm System

8.6b. Introduction

Fire protection at the HFIR includes the following:

1. Underground fire water piping (see Potable Water System).
2. Sprinklers.
3. Standpipes, hose cabinets, and portable extinguishers.
4. Fire-alarm signaling systems (including electrical controls, alarms, and heat detectors).

There are three basically identical fire-protection systems. Each has a sprinkler system and a fire-alarm system which consists of a control panel, a zone panel, and a master box. A fourth master box monitors troubles in the three alarm systems.

8.6c. Cooling-Tower Area

Master box No. 1 (ORNL Code 843), located outside the cooling tower equipment building, serves the cooling tower, the cooling tower equipment building, and the electrical building. To prevent freezing of the water lines, a dry-pipe sprinkler system protects the cooling tower and the cooling tower equipment building. Due to the large quantity of electrical gear, the electrical building has no sprinkler system.

The lines supplying the dry-pipe sprinkler heads in the cooling tower and the cooling tower equipment building are pressurized with 40 psi air from an air compressor located in the equipment building. Upon excessive temperature (165°F in the cooling tower equipment building and 212°F in the cooling tower) sprinkler heads will open causing a loss of air pressure in the lines. The loss of air pressure, in turn, allows water to fill the line and supply the sprinkler heads. At the same time the fire alarm is actuated by a flow switch.

A manual fire alarm box is located in the cooling tower equipment building. Actuation of the fire alarm either manually or automatically by the water-flow switch will cause the cooling-tower fans to shut down.

Electrical building fire-protection equipment includes heat detectors and manual alarm boxes to initiate a fire alarm, and portable fire extinguishers.

8.6d. Reactor Building

Master box No. 2 (ORNL Code 842), located outside the west side of the reactor building, serves the reactor building and the reactor building pre-action sprinkler system. Upon high temperature or a high rate of rise in temperature at the heat-sensing devices, which are strategically located throughout the building, the sprinkler system is filled with water by an automatic water-control valve. This valve is located in the stairwell on the west side of the building at ground floor level.

Sprinkler heads open upon reaching 165°F. Fire alarms are initiated by excessive temperature at the heat-sensing devices, by actuating a manual alarm, or by water flow at the automatic water-control valve. A trouble bell is actuated by high or low air pressure in the pre-action system, by low water pressure in the supply line, and by the supply-

water valve being closed. An annunciator on panel "HI" in the main control room is actuated by the heat detector devices manual boxes and the water flow switch in the sprinkler system.

Air pressure of 1-1/2 to 2 psi is kept in the pre-action sprinkler lines by an air compressor which is located near the pre-action valve in the stairwell. Either low or high air pressure causes a trouble alarm.

Hose cabinets and portable fire extinguishers are located strategically throughout the reactor building. Water supply for the fire hoses comes from the fire water loop which encircles the building.

8.6e. Office and Maintenance Building

The office and maintenance building is served by master box No. 3 (ORNL Code 841), which is located just east of the building. The fire alarm is actuated by manual fire-alarm boxes and by the water-flow switch located in the supply line to the wet-pipe sprinkler system. Sprinkler heads open upon reaching a temperature of 160°F.

The following is a list of zones covered and actions produced by the fire protection system:

Alarm Code 843 - Cooling Tower, Cooling Tower Equipment Building, and Electrical Building (Master Box No. 1)

Zone	Location	Actuating Device or Condition	Action*
1	Cooling tower and cooling tower equipment building	Heat detectors and water-flow switch	Alarm and fan shutdown
2	Electrical building	Heat detector	Alarm
3	Dry-pipe system supervision (trouble)	High or low air pressure, low water pressure, and water valve closed	Trouble bell

*Zones 1 and 2 cause pipes to be filled with water.

4 Spare

Alarm Code 842 - Reactor Building 7900 (Master Box No. 2)

Zone	Location	Actuating Device or Condition	Action*
1	Ground floor	Heat detector	Alarm and shut-down of UV-1 and FN-5
2	First floor	Heat detector	Alarm
3	Second floor	Heat detector	Alarm
4	Third floor	Heat detector	Alarm
5	Water flow	Water-flow switch	Alarm
6	Pre-action supervision (trouble)	High or low air pressure, low water pressure, and water valve closed	Trouble bell

*Zones 1 through 5 cause: (a) annunciator HI-12 "Fire Alarm", (b) AC-15 and FN-1 shutdown, and (c) pipes to be filled with water.

Alarm Code 841 - O & M Building (Master Box No. 3)

Zone	Location	Actuating Device or Condition	Action
1	Entire building	Manual fire-alarm box or water-flow switch	Alarm
2	Wet-pipe system supervision (trouble)	Low water pressure or water valve closed	Trouble bell

Alarm Code 8422 - Trouble Alarm for Area (Master Box No. 4)

Zone	Location	Action
1	Master Box No. 1	Fire alarm and trouble bell
2	Master Box No. 2	Fire alarm and trouble bell
3	Master Box No. 3	Fire alarm and trouble bell

8.6f. Power Supply

The HFIR fire protection system is powered by d-c voltage supplied by a bank of nickel-cadmium cells in parallel with a battery charger. This equipment is located in the fire alarm equipment room (102B). In case of a failure of normal power, the battery (24 volts) is capable of supplying sufficient current to the system for a period of 12 hours. The battery charger is similar to those of the instrument-power system.

8.7. Emergency Services

8.7a. Introduction

When an emergency occurs, it is the responsibility of the person discovering the emergency to take immediate action to protect personnel and property and to bring the emergency under control. This applies to fire, radiation incidents, explosions, personnel injury, or any other emergency. It should be accomplished by one or more of the following:

1. Control the emergency singlehandedly, if possible.
2. Telephone 3-6358 (Emergency Control Center) for help.
3. Pull the nearest fire alarm.
4. Call the local emergency supervisor.
5. Call a local emergency squad member or anyone nearby.
6. Sound the building evacuation alarm, if necessary.
7. Meet and orient the emergency service unit.

When a call is received by the Emergency Control Center at 3-6358 the dispatcher immediately notifies the Laboratory Shift Supervisor and dispatches the emergency service units needed (fire, guard, etc.).

8.7b. Fire Department

The Fire Department contains two sections: a fire-fighting section and a building-inspection section. The fire-fighting group is available at all times. The building-inspection group is available on the regular 8-4:30 shift, Monday through Friday.

The inspection group makes periodic inspections of the HFIR complex and reports fire hazards to the HFIR supervisor. Reactor Operations personnel can aid in fire prevention by reporting fire hazards to either the shift supervisor or to the Fire Department Inspection Group.

A fire may be reported to the Fire Department by telephone (call 3-6358) stating the location, name of the caller, badge number, and the type of fire, or by actuating the nearest fire alarm box. In either case the person should remain in the area and direct Fire Department personnel to the fire.

Immediately after a fire extinguisher is used, a call should be made to the fire captain on duty, reporting the use of the fire extinguisher and the nature of the emergency. This will ensure that the fire extinguisher will be refilled and placed back in service for future emergencies.

Personnel of the Fire Department are equipped and trained to administer first aid. The pnealator and inhalator are taken on all emergency calls.

Fire-Fighting Rules

a. Put out a small fire if you are sure you can, then notify the Fire Department.

b. Report all other fires to the Fire Department at once and, if necessary, sound the evacuation horn.

c. Direct the Fire Department personnel to the scene of the fire.

8.7c. Guard Department

The Guard Department headquarters is located in Building 2500 in the main X10 area of ORNL. The main function is plant security; however, many other services are performed by the department personnel. Plant employees can aid the guards in the performance of their duties by properly wearing the picture film badge and observing plant rules. The badge should be worn on the left side, shirt pocket area.

The Guard Department works in conjunction with the Fire Department on fire alarms. Both departments have identical alarm code systems. Upon receiving a fire alarm by phone or fire alarm box, the Fire Department dispatcher will accompany the fire trucks to the emergency and the Guard Department dispatcher will operate the alarm code system until the fire dispatcher's return. Designated guards on all shifts are trained auxiliary firemen. These men also have training in first aid.

Permits for the operation of plant vehicles are issued by the day-shift guard captain. Permits for operating vehicles up to a 3/4-ton truck will be issued upon presentation of a state permit, a completed application form signed by the applicant and his supervisor, and certification of an eye examination from the Health Division. For operation of vehicles larger than the 3/4-ton truck, completion of a driver's test given by the Guard Department is required.

The plant ambulance is operated by guards. In an incident where ambulance service is needed, a telephone call should be made to the Emergency Control Center, phone 3-6358. The ambulance driver will stop at the medical dispensary, and a nurse and/or doctor will accompany the driver to the emergency.

8.7d. Medical Dispensary

The Health Division's main dispensary is located in Wing 5 of Building 4500 in the X-10 area of ORNL. The division is staffed with doctors and nurses. Field offices are located in Buildings 2418, 7009, and 4500. The field offices, with one nurse on duty at each office, are open Monday through Friday on the day shift. The main dispensary is always open. However, only one nurse is on duty on the 4-12 shift, on

holidays, and on weekends. Only limited services are available on the 12-8 shift.

Services of the dispensary can be received at any time; however, an appointment must be made for a doctor's services except in case of an emergency. In case of an injury, regardless of how slight, the employee must report to the dispensary for treatment.

8.7e. Maintenance

The operation of the HFIR complex requires considerable maintenance. To obtain the services of the Maintenance Department, a work order bearing the department number, the job-order number, and a brief description of the repair work needed is sent to the maintenance engineer. If the job is an emergency, arrangements can be made for immediate repairs.

For emergency maintenance on night shifts or weekends, the Laboratory Shift Supervisor (phone 3-6606) should be notified of the situation; and he will make the necessary arrangements for obtaining the appropriate personnel.

9. WASTE SYSTEMS

9.1. Sanitary Waste Disposal System

9.1a. References

Drawings:

1546-01-U-7112 Yard Piping

1546-01-U-7114 Yard Piping

1546-01-U-7115 Yard Piping

1546-01-U-7310 Sewage Treatment Plant

1546-01-U-7124 Sanitary Sewer Details

Singmaster & Breyer Specifications:

76 Sanitary Sewer System

90 Sewage Treatment Plant Equipment

9.1b. Introduction

The sanitary sewage disposal system collects, treats, and disposes of wastes from drains in the reactor building and the office and maintenance building. Sanitary waste drainage from the buildings empties into manhole SA-1, located approximately 130 ft south of the reactor building, before draining into the sewage disposal unit as shown in drawing 1546-01-U-7114. Clean-out accesses are provided at each intersection of the drain lines.

9.1c. Description of the Sewage Treatment Plant

As the raw sewage flows into the plant, it passes through a comminuter which cuts the solids into small particles so that treatment can more easily be effected. After the coarse solids are eliminated, the sewage flows to the aerator tank where it is mixed with air and settled solids which have

been returned from the clarifier. Air is added in such a manner as to create an overturning, circulatory motion in the liquid contents. A further function of this air is to saturate the mixed contents with oxygen which is required for the oxidation of the sewage. The sewage then overflows from the aerator tank into the clarifier tank.

Solids and liquids are separated in the clarifier tank by a settling process. The liquid overflows through the effluent trough into the chlorine contact tank where it is disinfected with a chlorine solution before being discharged into Melton Branch.

The activated sludge from the separation consists of fluffy particles which have settled to the bottom of the clarifier tank. The sludge is removed from the clarifier by an air lift arrangement and returned to the aerator tank where it aids in decomposing the incoming raw sewage. In the event sludge accumulation occurs in the clarifier tank, it can be transferred, by the sludge recirculation pump through bypass piping, to a sludge storage hopper located on the extreme south end of the disposal unit.

Chlorine gas from a cylinder is added to the overflow effluent from the clarifier tanks prior to discharge over a V-notch weir plate into the chlorine contact chamber. The capacity of the chlorine contact chamber provides a 15-min retention period to the effluent before it is discharged into Melton Branch via manhole S-2.

9.2. Process Waste System

9.2a. References

Drawings:

1546-05-U-7114 Yard Piping

1546-05-U-7115 Yard Piping

1546-05-U-7126 Valve Boxes and Monitor Boxes - Details

1546-05-U-7128 Porcess Waste and ILW - Details

1546-05-U-7130 Process Waste Sump

1546-05-U-7145 Flow Diagram, Process Waste and ILW

1546-05-U-7306 Process Waste Basins

Singmaster & Breyer Specifications: Section 75 Process Waste

9.2b. Introduction

The process waste system receives liquid wastes of low-level radioactivity, that is, wastes other than sanitary, storm drainage, and those wastes having an appreciable amount of radioactivity. Process wastes are frequently free of contamination; however, these wastes originate from sources such as equipment drains, experiment drains, and floor drains in the reactor building, filter pit, and cooling tower areas which either contain or may contain, because of leaks, spills, etc., low levels of radioactivity.

9.2c. Collection System

1. Floor drains.

   Each drain is provided with a trap, sediment bucket, and clean-out. Floor drains in the reactor bay, experiment room, beam room, and process-equipment rooms of the reactor building generally are

located at the columns. In other areas, such as the heating and ventilating and electrical rooms, shielded-compartment areas, and pipe tunnels, the floor drains are not necessarily at the columns but are conveniently located with regard to the potential source of waste. A special sump in the bottom of the elevator pit is drained to the system by steam jets.

2. Experiment drains.

   a. Experiment station.

      Individual drain connections are located at each of the pool experiment stations. When an experiment is set up, a temporary connection is made between the experiment and the process-waste drain located at floor level.

   b. Beam room.

      A drain connection is located near the shielding wall at each beam port and in the floor nearby but not directly in front of the beam cavity. Inside the cavity, piping is available for a temporary connection to the process-waste system.

3. Process waste sump.

This 1000-gal sump pit collects wastes from the subpile room, primary heat-exchanger shell drains, heat-exchanger-cell floor drains, and the SBHE drip drains because they are located below the elevation at which the main header leaves the building. It also collects any overflow from the ILW storage tank. The sump is emptied by two steam jets which are automatically operated by level switches to keep the liquid level in the sump between the elevations of 785 ft and 788 ft. Each jet is designed to

discharge 100 gpm against a head of 30 ft. The jetted waste is delivered to the process waste main header which leaves the reactor building on the west side.

Process wastes from all sources in the reactor-building area are collected in common headers which discharge into a process waste main header located at the southwest corner of the reactor building under the floor of the beam room. The process waste main header leaves the building on the west side to enter the process waste disposal system. Wastes from the cooling tower area are collected in a common header and are discharged at the west end of the cooling tower.

9.2d. Disposal System

Since there are two flow patterns of process waste, one from the reactor building and one from the cooling tower area, they will be discussed separately (see Figure 9.1).

1. Reactor building area.

   The normal flow of process waste from this area is through valve box No. 3 to valve box No. 2 and on to retention pond No. 1.

   Valve box No. 3 contains:

   a. Monitor box No. 2, which is composed of a weir for flow measurement, a proportional sampler which collects samples for laboratory analysis, a radiation detector, and recording and controlling instrumentation.

   b. Valve FCV-700 (to the ILW storage tank--normally closed)

   c. Valve FCV-701 (to valve box No. 2--normally open).

   Flow control valves 700 and 701 may be operated either manually or remotely from the control room.

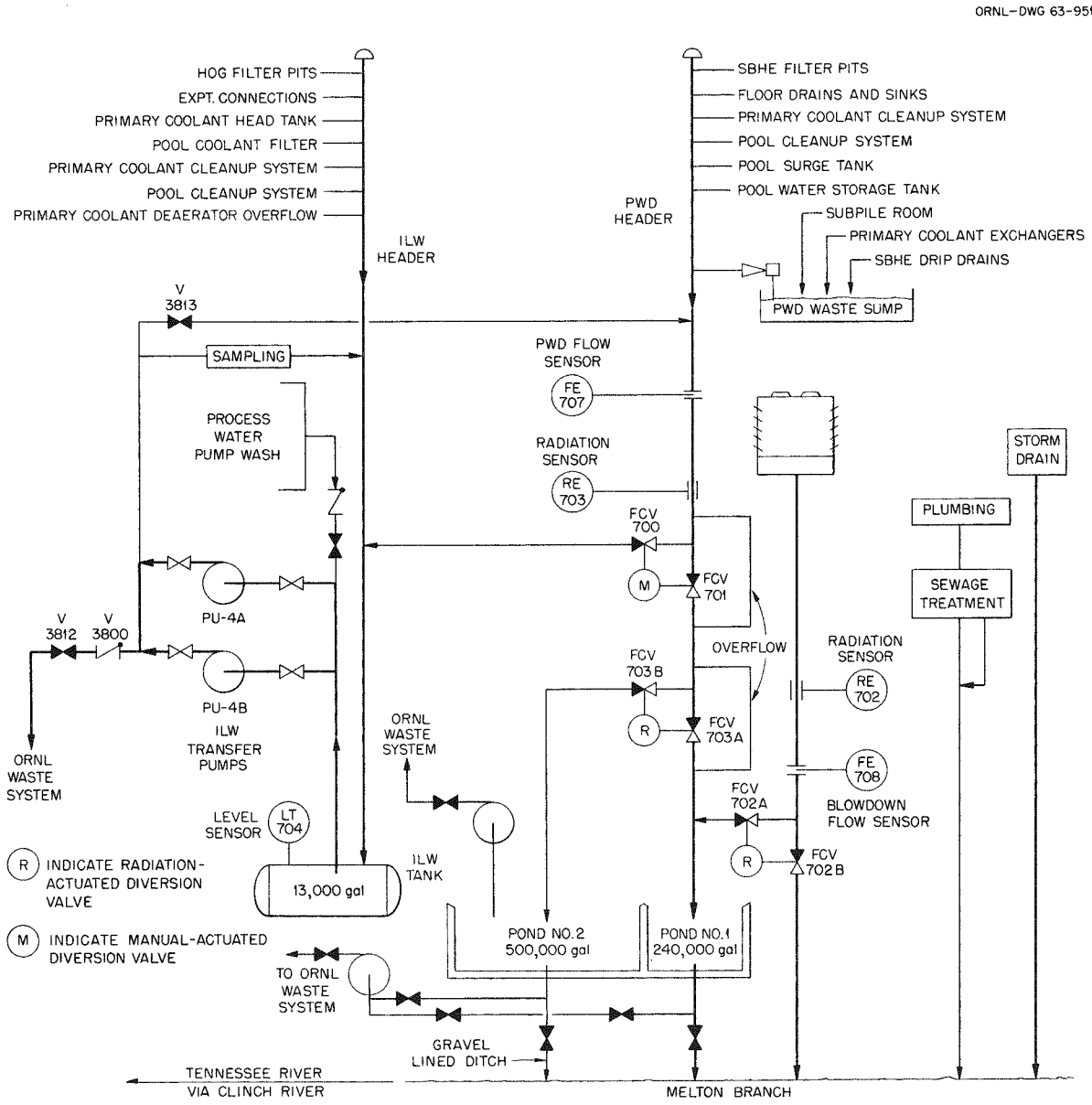

Fig. 9.1. Liquid Waste System.

Valve box No. 2 contains motor driven, automatically operated diversion valves FCV-703A (normally open to pond No. 1) and FCV-703B (normally closed to pond No. 2). Normal operation is automatic, but they may be operated manually if necessary.

2. Cooling tower area .

The normal flow of blowdown from the cooling tower is through valve box No. 1 and on to manhole S-2 where it mixes with storm drain and sanitary disposal system effluent before being discharged to Melton Branch. Valve box No. 1 contains flow control valves FCV-702A (to pond No. 1--normally closed) and FCV-702B (to Melton Branch--normally open). Also located in valve box No. 1 is monitor box No. 1 which is similar to the previously discussed monitor box No. 2

3. The monitoring system .

a. Monitor box No. 2 .

A radioactivity monitor samples the waste and initiates a signal which is recorded both locally and remotely in the control room. It is this signal that causes the controller to operate the diversion valves in valve box No. 2 to change the flow from pond No. 1 to pond No. 2. The recorder has two activity-level switches which act in the following order:

(1) Activity below the low-level switch setting: The flow is normally through FCV-701 in valve box No. 3 and FCV-703A in valve box No. 2 to retention pond No. 1.

(2) Activity above the low-level switch setting and below the high-level switch setting: The controller automatically closes FCV-703A and opens FCV-703B, in valve

box No. 2, diverting the flow to retention pond No. 2. The change is also annunciated in the control room

(3) Activity above the high-level switch setting: The higher reading is annunciated in the control room and the operator manually closes FCV-701 to the retention ponds and opens FCV-700 to the ILW storage tank.

b. Monitor box No. 1.

A radioactivity monitor samples the waste and initiates a signal which is recorded both locally and in the control room. This recorder has only one activity level switch which operates the controller as follows:

(1) Activity below the level switch setting: The flow is normal through FCV-702B to Melton Branch.

(2) Activity above the level switch setting: The controller automatically closes FCV-702B and opens FCV-702A which diverts the flow to retention pond No. 1. This action is annunciated in the control room.

4. Retention ponds.

These ponds, located about 250 ft south of the reactor building, allow low-level wastes to be retained long enough for natural decay and settling.

a. Pond No. 1.

This pond provides storage for 240,000 gal of liquid waste; a volume estimated to be adequate to give a minimum retention period of 12 hours under normal conditions. Normally, all process wastes from the reactor-building area enter this

pond. There is no special treatment; decontamination is by decay and settling.

Influent waste enters the pond with an upward flow through a 24-in.-diameter vitrified clay pipe that pierces the north bank at elevation 798.5 ft. The pipe extends upward from the bank to the elevation 799.5 ft which is 2-1/2 ft above the pond bottom and 4-1/2 ft below the maximum high-water level. The upward flow of the influent waste tends to eliminate short-circuiting of the flow through the pond.

On the opposite side of the pond, the effluent leaves through a flexible 8-in.-diameter, 12-ft-long rubber suction hose. This hose is coupled to an 8-in. pipe which runs under the south embankment, at elevation 796.9 ft, to valves which are used to regulate the flow. The influent end of the hose is raised or lowered by a winch and cable mechanism thus controlling the pond level with the height of this end of the hose. The hose may be lowered into a special sump at elevation 796.5 ft should it become advisable to drain the pond completely.

After leaving the pond, the effluent flows to manhole S-1 where it combines with waste from the storm and sanitary sewer systems before being discharged to Melton Branch.

b. Pond No. 2.

Retention pond No. 2 is used to impound waste of a higher activity level than that normally discharged into pond No. 1 but of lower activity level than that normally processed by

the ILW system. As discussed previously, when the activity of the waste through monitor station No. 2 is above the first setpoint but below the second setpoint, the waste is automatically diverted to pond No. 2. The 500,000-gal storage capacity of this pond also makes it capable of impounding extreme flows such as might result from the sprinkler system and/or fire-fighting equipment in contaminated areas.

Influent wastes enter at the northeast corner of the pond through a system identical to that in pond No. 1, and the effluent leaves at the southwest corner of the pond through a flexible suction hose system also identical to that in pond No. 1. However, in this case, the effluent stream does not mix with wastes from the storm and sanitary system but is discharged to a rip-rap lined drainage ditch south of the embankment.

c. Laboratory-wide waste collection system.

Both retention ponds can be pumped into the laboratory-wide waste collection system. The discharge from each pond can be valved into pumps which return the liquid to the main ORNL area for treatment. All retention pond elluent which contains radioactivity above the background level is returned to the laboratory-wide waste collection system.

9.3 Intermediate Level Waste System

9.3a. References

Drawings:

1546-05-U-7145 Flow Diagram, Process Waste and ILW

1546-05-U-7304 ILW Tank Piping and Foundation Details

1546-05-U-7128 Process Waste and ILW Details

Singmaster & Breyer Specifications:

61 Intermediate Level Waste

92 ILW Pumps

9.3b Introduction

Intermediate level wastes are liquid wastes which contain activity levels between 5.7×10^3 d/m-ml and 5.7×10^9 d/m-ml of beta and gamma activity. The intermediate level waste may have a pH from 1 to 14, dissolved solids up to 150 ppm, and suspended solids up to 1% by weight. It is the purpose of the system to collect and store the waste so that any acidity can be neutralized; suspended solids may be kept in suspension by recirculation, and activity levels can be determined before final disposal is effected.

Intermediate level wastes result from demineralizer backwash and regeneration effluents, decontamination fluids, sampling streams of experimental coolant, etc., in the reactor building as well as drainage from the compartmented areas of the filter pits.

9.3c. Collection

Wastes are collected at points of origin by closed piping connections. Collection mains are vented to the OHOG system through the filter pit sump.

1. Experimental drains.

   a. Drain connections are located at the service stations at the pool structure on the experimental area level, and at the shield surface on the beam room level. These connections are merely drain pipes extended from the main system to the experimental area. The drains are sealed until they are needed; at which time, the sealed end is cut off and the drain from the experiment is welded into the system to give positive containment.

   b. A floor connection is located on each side of the reactor pool in the reactor bay.

2. Equipment drains.

   a. Primary coolant-loop drains.

   b. Spent resin disposal drains.

   c. Demineralizer and filter equipment drains.

   d. Decontamination area drains.

3. Hot off-gas drains.

   Wastes originating in the hot off-gas systems are drained to a special sump in the filter pits. This sump also acts as a connecting link by which the ILW system is vented to the OHOG system.

9.3d. Normal Flow Patterns

The wastes move by gravity flow from collection points to the main ILW drain headers. The headers are shielded, where they cross open areas, with the equivalent of 2 in. of lead. The main header leaves the reactor building at the southwest corner at elevation 810.11 ft and proceeds west about 200 ft to a buried storage tank which will be discussed later. The

system is designed to accommodate a maximum flow of 300 gpm; however, flow rates should seldom, if ever, reach this maximum.

In addition to this primary flow, waste may be diverted to the ILW system from the PWD system. This diversion is effected by remotely closing FCV-701 and opening FCV-700 should the activity level of the process waste warrant this change (see Figure 9.1).

9.3e. Waste Storage and Accessory Equipment

The ILW storage tank and the transfer pumps will normally be operated by Laboratory Waste Collection personnel but, since they are part of the HFIR complex, will be described here.

1. The ILW storage tank.

   The 13,000-gal, 8-ft-diameter, stainless steel tank is supported by a concrete pad and buried. Its bottom elevation is 798 ft, top elevation is 806 ft, while the grade elevation is 825 ft. The liquid level is measured by a level indicator with an electronic readout in the control room. The tank is emptied periodically after its contents have been sampled and checked for activity level and pH.

2. Transfer pumps (PU-4A and 4B).

   The pumps are vertical centrifugal, self-priming, stainless steel pumps, piped in parallel and rated at 60 gpm each against a head of 115 ft. The pumps and associated piping are located in a concrete pump pit just north of the buried storage tank. The pump suction elevation is 812.5 ft, 10.6 ft above the center line of the storage tank.

   The top of the pit is concrete, 2 ft thick to give adequate shielding to the operator. Two access ports, each 4 ft 9 in.

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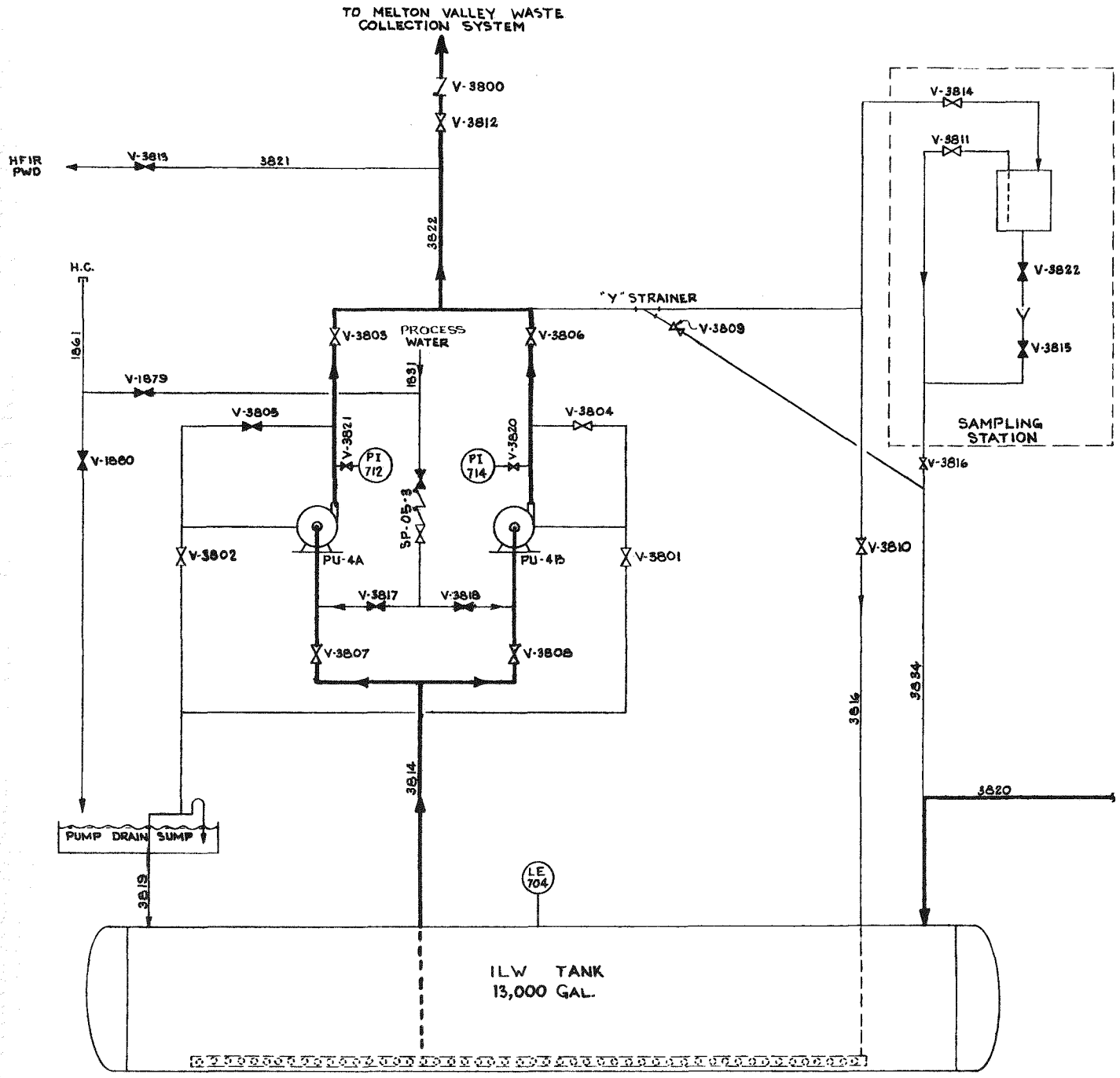

Fig. 9.2. Schematic Flow Diagram ILW Tank and Pumping Station.

by 3 ft are located in the top shield. These openings are closed by stepped concrete plugs.

The pumps have a two-fold purpose. Their main function is to transfer wastes from the storage tank to either the Laboratory disposal system or the HFIR process waste system. Their secondary function is to recirculate the stored wastes to prevent suspended solids from settling, and to provide a method of sampling the waste.

3. Sampling system.

On the discharge side of each pump, piping is provided to carry part of the waste above the pit cover to a sampling station. Drainage from the sampling station is back to the storage tank. Samples are taken periodically and are analyzed for pH and gross beta-gamma activity.

If the pH analysis shows that the waste is acidic, it is neutralized by adding caustic to the system from the caustic day tank.

The results of the gross beta-gamma analysis help to determine the final disposition of the waste, that is, whether to the HFIR process waste system or to the Laboratory ILW system.

9.4. Hot Off-Gas Systems

9.4a. References

Drawings:

1546-01-H&V-3001	Air Flow Diagrams
1546-01-H&V-3028	Building-Control Diagram
RC11-10-9	Instrument Application Diagrams
RC11-10-11	Gaseous Waste Monitoring

Singmaster & Breyer Specifications:

59 Charcoal Bed Filters

62 Open and Closed Hot Off-Gas Systems

9.4b. Introduction

The HOG systems collect and decontaminate the gaseous effluent from the various process vessels, lines, and other equipment. They also serve local areas into which highly concentrated radioactive gases may be discharged, either inadvertently or as a result of normal operation. The gases are decontaminated by absolute filters and charcoal absorbers and are then routed through the SBHE filters and vented to the atmosphere through the 250-ft stack. Two systems are provided: one, the closed hot off-gas system (CHOG), to handle components from which the gases escape under pressure; and the other, the open hot off-gas system (OHOG), to handle unpressurized equipment (see Figure 9.3). Both systems are constructed of Type 304L stainless steel, schedule-10 pipe throughtout, except where heavier gauge pipe was required for embedment. Embedded pipe was pressure tested before concrete was poured to assure an air-tight system.

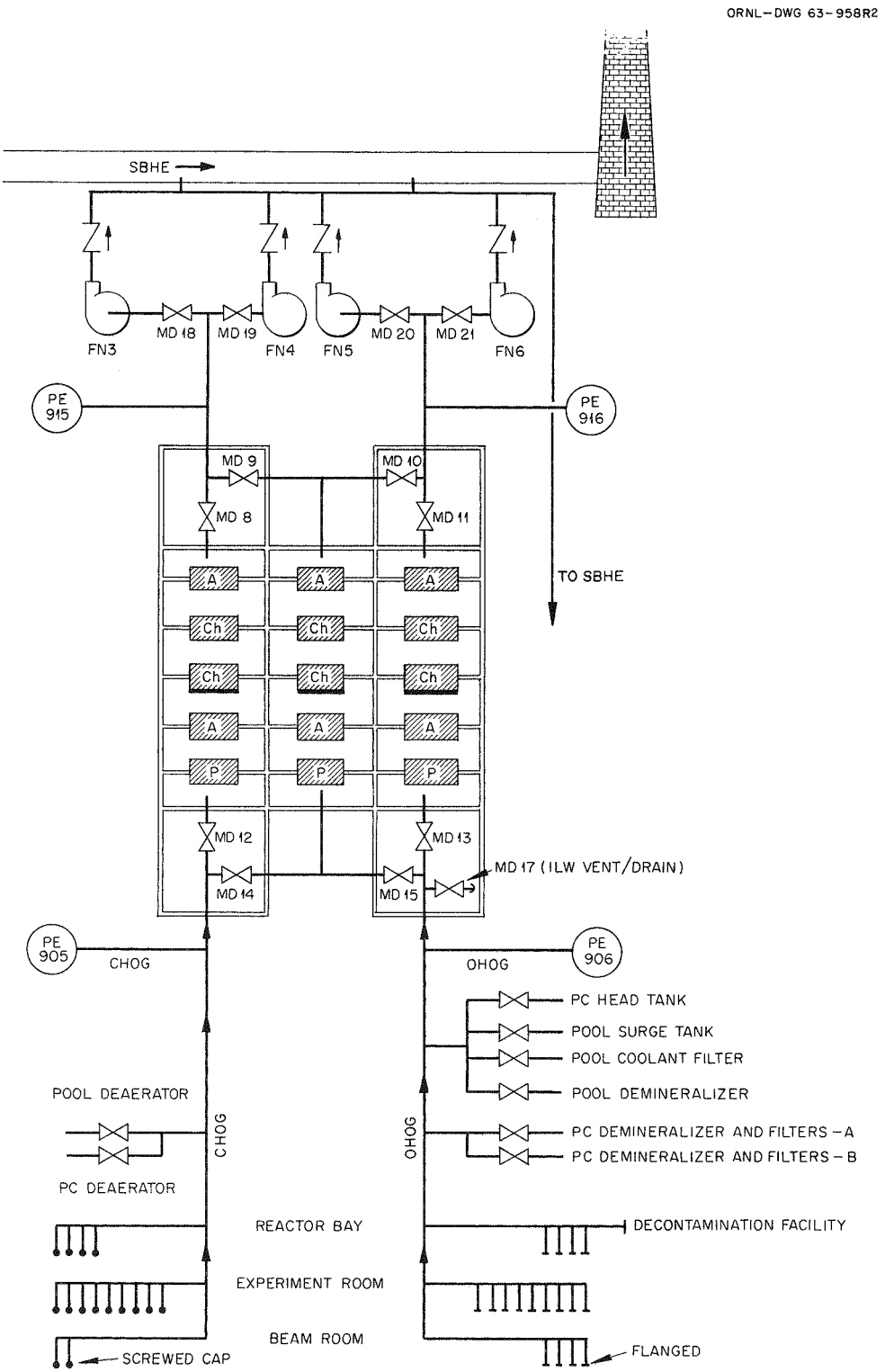

Fig. 9.3. Hot Off-Gas System.

9.4c. The Closed Hot Off-Gas System (CHOG)

The CHOG system services those components which may become pressurized. It is connected to the primary coolant and pool coolant deaerators. Stations designed for future connections to the CHOG system are located both in the experiment room on the shield wall at each beam-tube access and high on the shield wall to permit connection to pool experiments through sleeves in the pool structure.

The CHOG ducts which originate at the collection points run to a common header and thence to the HOG section of the filter pit. Those ducts located in occupied areas are shielded with the equivalent of 1 in. of lead. The system is sized to handle up to 500 cfm with minimum inlet pressures of -30 in. H_2O when any 4 of the functional connections are in use. The design pressure of the piping upstream of the filters is 100 psig.

9.4d. The Open Hot Off-Gas System (OHOG)

The OHOG system services those connections which cannot be pressurized. In addition to handling those components which are open to the building and certain valve stations, it also vents the intermediate level waste system. The following components are served directly by the OHOG system:

1. Primary coolant demineralizers and filters.
2. Primary coolant head tank.
3. Pool coolant demineralizers and filters.
4. Pool coolant filter.
5. Pool surge tank.

In addition, valve stations permitting future access to the OHOG system are provided in the following locations:

1. On the experiment room floor at the shield wall adjacent to each beam-hole access.
2. In the experiment room high on the shield wall to permit connection to pool experiments through sleeves in the pool structure.
3. At each of the beam hole ports in the beam room.
4. In the floor of the reactor bay--two flush connections, one north and one south near the pool rim.
5. On the wall of the reactor bay adjacent to the decontamination pad.

Ductwork for the OHOG system runs, separately from the CHOG duct, directly to the filter pit. Similarly, in occupied areas it is shielded with the equivalent of 1 in. of lead.

Like the CHOG system, the OHOG system is sized to collect up to 500 cfm with inlet pressures of -30 in. H_2O when 4 of the functional connections are in use.

9.4e. HOG Fans and Filters

The filters for the CHOG and OHOG systems are located in a section of the filter pit which is separated from the SBHE filters by a concrete wall. The HOG section is shielded with 4 ft of concrete with stepped plugs over each cell. To facilitate decontamination, the inside of the pit is painted with a protective coating which prevents radioactive material from soaking into the concrete. The general arrangement is shown in Figure 9.4 and Figure 9.5. Three filter compartments are used: one for the CHOG system, one for the OHOG system, and a common stand-by for use during filter changes. The filter sequence used in each compartment consists of a Fiberglas prefilter, a Fiberglas-asbestos absolute

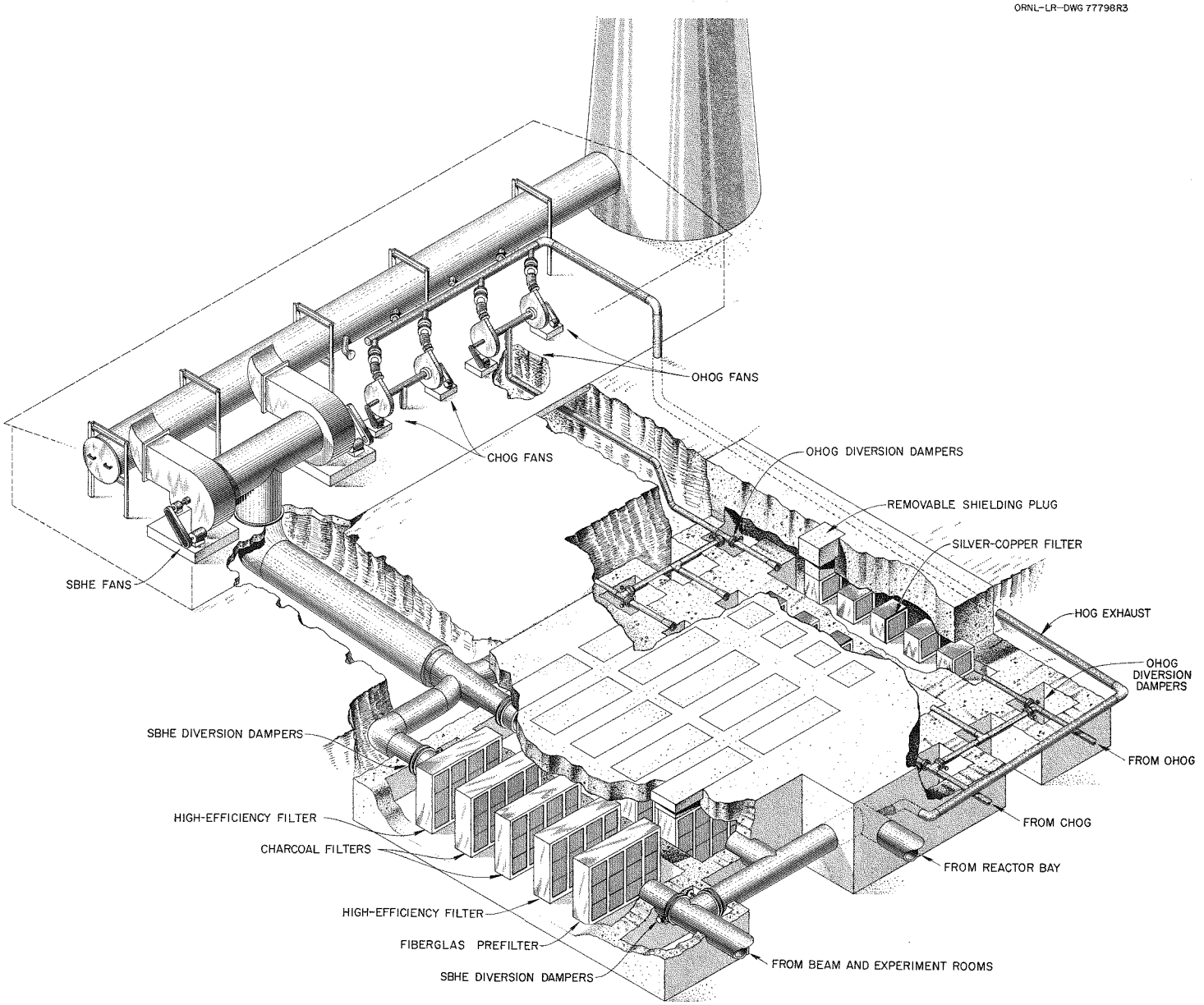

Fig. 9.4. Filter Pit and Fan Shed.

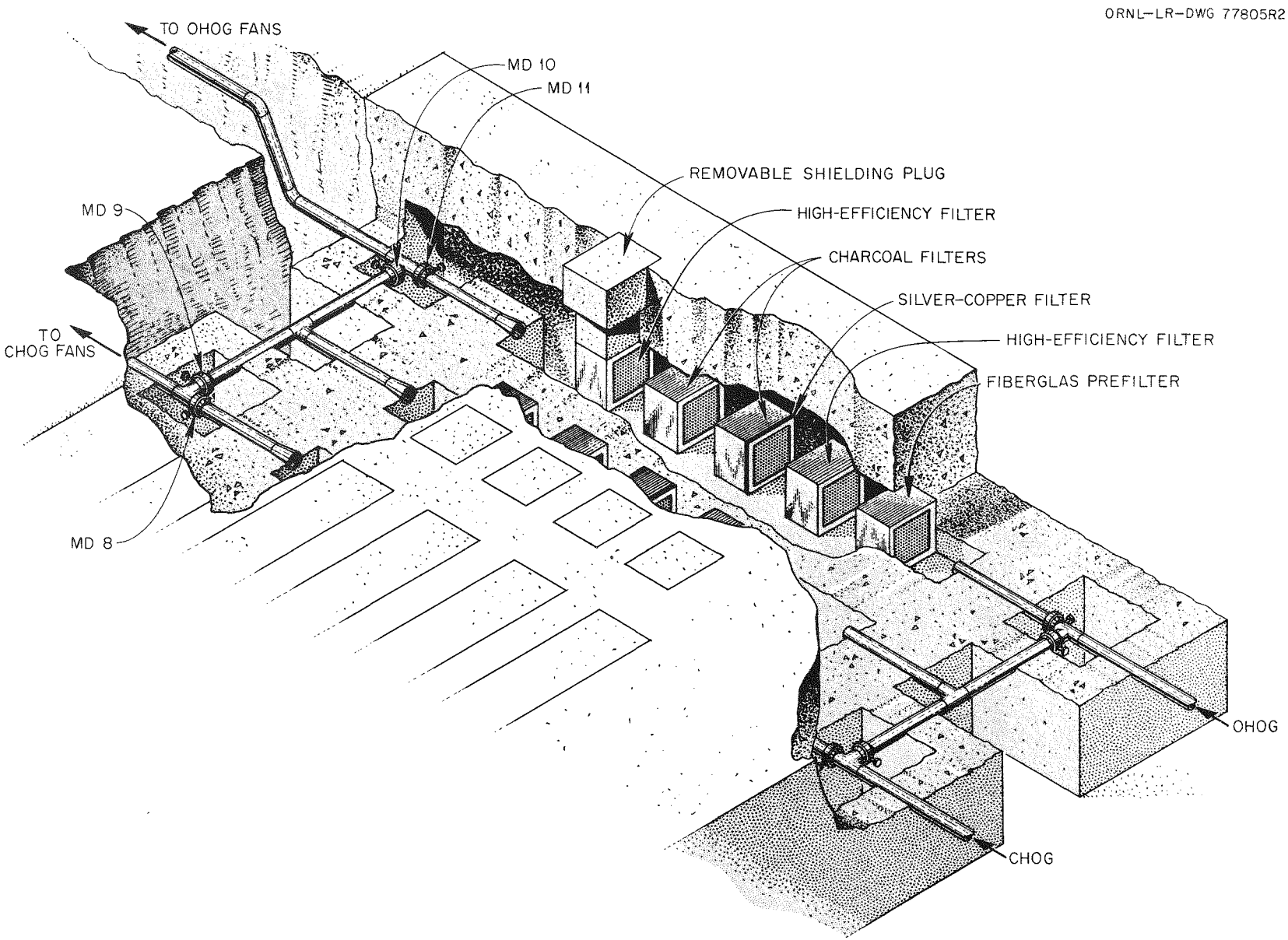

Fig. 9.5. HOG Filter Pit.

filter, a silver-coated copper mesh screen, two charcoal absorbers in series, and a final absolute filter. All exposed metal is stainless steel.

Change over to the standby cell is accomplished by means of externally operated manual dampers, allowing the filters to be changed without interrupting plant operation, in a manner similar to that described for the SBHE system. Air from the HOG systems enters the filter pit through two ducts, one for each system. These may be suitably dampered to permit full flow during a filter change.

Each system is equipped with two fans, one of which is normally operating while the other is in standby. The outlet ducts from the filters are split and suitably dampered to permit automatic fan change over. Four identical 500-cfm exhaust fans, driven by 7-1/2-hp squirrel cage induction motors, are provided for this service. One fan from each system is connected to normal-emergency power system No. 1 and the other is connected to normal-emergency power system No. 2. Pressure controllers are used to detect malfunctions of the normally operating fan and to start the standby fan. The system switch over is actuated automatically; but a fan, once started, must be manually shut down. Gravity dampers prevent back flow through the inoperative unit. Various system parameters are displayed in the control room.

9.4f. HOG Instrumentation and Control

The instrumentation for the HOG system is quite similar to that utilized by the SBHE (Section 7.1); however, static vacuum is monitored instead of flow. The fans are controlled exactly like those in the SBHE; the CHOG instruments and controls are identical to the OHOG instruments and controls.

The CHOG fans FN-3 and 4 and OHOG fans FN-5 and 6 are each provided with an "on-off-standby" switch on the panel board in the fan shed. Normally, one fan is running while the other is on standby. Indicating lights on the panel board in the control room indicate the condition of each fan. The color code is identical with that for the SBHE fans.

Electropneumatic pressure transmitters in each duct transmit a signal for display in the control room and provide alarm and standby fan startup signals. A drop in the vacuum of either system, on the upstream side of the filters (from -48 in. H_2O to -43 in. H_2O), will cause an alarm in the control room. The loss of vacuum may be due to either fan failure or filter plugging. Should it be due to fan failure, a pressure switch located in the fan inlet downstream of the filters will be affected by the vacuum loss and actuate a relay starting the standby fan. An alarm is also given in the control room. The fan vacuum is displayed at the fan shed and the "fan-running" lights will indicate, at the control room, which of the two conditions has occurred. The pressure switches in the HOG systems are listed in Table 9.2.

Table 9.1. HOG Pressure Switch Tabulation

Switch	Duct	Normal Vacuum (in. H_2O)	Setpoint	Action
PS-905-1	CHOG, inlet to filter	-48	-43	Alarm
PS-915-1	CHOG, inlet to fan	-54	-41	Alarm, fan start
PS-906-1	OHOG, inlet to filter	-48	-43	Alarm
PS-916-1	OHOG, inlet to fan	-54	-41	Alarm, fan start

No other systems are affected by these low-vacuum alarm and fan-start signals. Just as in the SBHE system, the switches and relays are designed to "fail safe" as a result of loss of control power or relay circuit.

Fans FN-3 and FN-5, CHOG and OHOG respectively, are connected to normal-emergency power system No. 2 via motor control center "H", and CHOG fan FN-4 and OHOG fan FN-6 are connected to normal-emergency power system No. 1 via motor control center "G". As in the case of the SBHE fans, the starting sequence of these motor-control centers is such that "G" is energized ~10 sec after the normal-emergency switchgear switches to the No. 1 diesel-generator, while "H" is energized as soon as the switchgear for the No. 2 system switches to the No. 2 diesel-generator. The expected operation of the CHOG fans following a power outage is given below.

Table 9.2. HOG Fan Operation

Mode	Fan No.	Switch Position	Operation Obtained
1	FN-3	On	FN-3 only runs
1	FN-4	Standby	FN-3 only runs
2	FN-3	Standby	Both FN-3 and FN-4 run
2	FN-4	On	Both FN-3 and FN-4 run

NOTE: If in Mode 1 the vacuum in the CHOG duct does not reach the 41-in. H_2O setpoint before the 10-sec delay is completed, FN-4 will also start.

A similar arrangement holds for FN-5 and FN-6 in OHOG system. A diagram of the HOG control system is given in Figure 9.6.

9.4g. Stack and Stack Monitoring

The HFIR stack is a free-standing, reinforced-concrete stack lined with acid-resistant brick. The connecting breeching to the exhaust fans

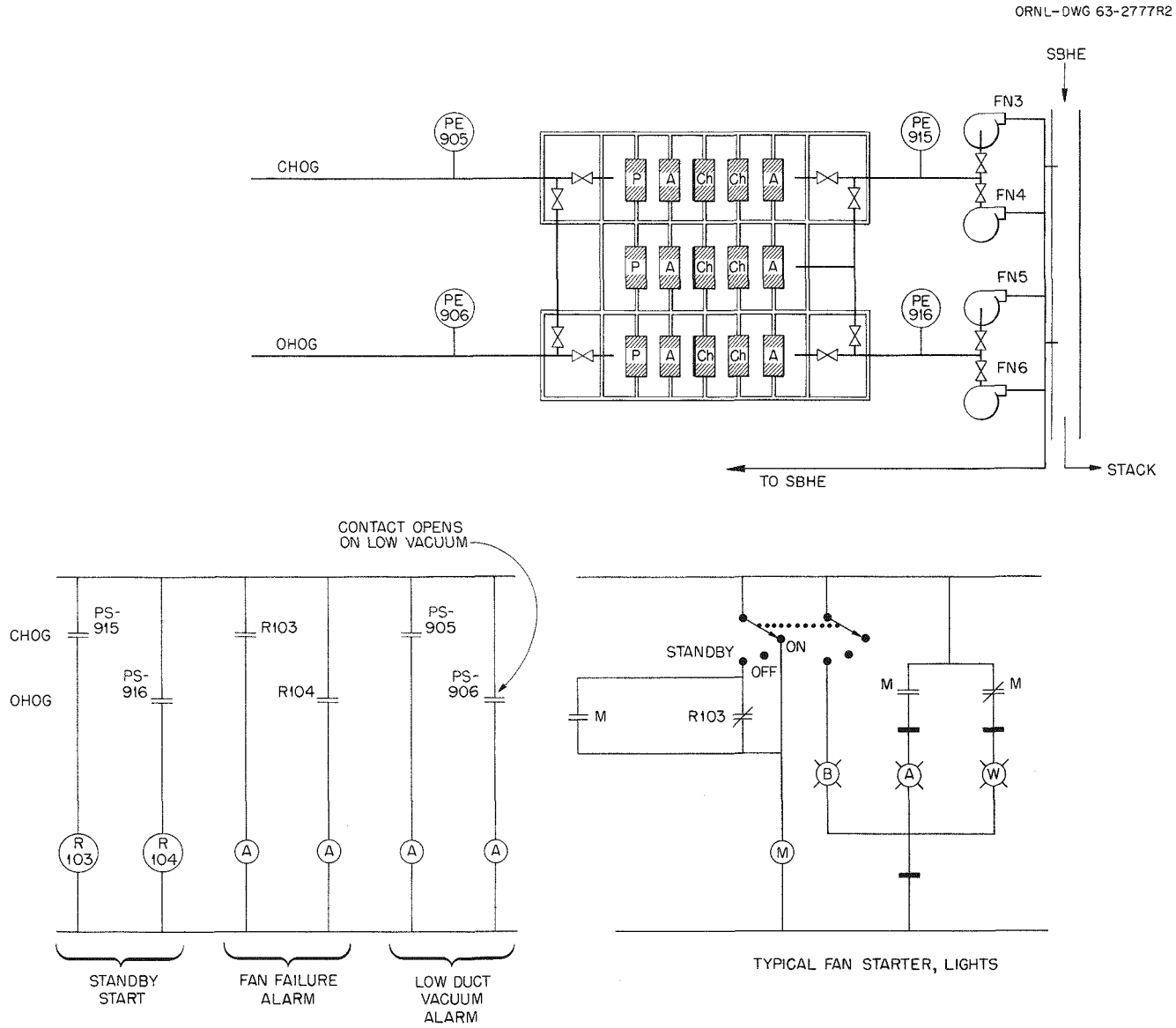

Fig. 9.6. HOG Fan Controls.

is constructed of carbon steel plate, and painted with corrosion-resistant paint. The stack is 250 ft in height with its discharge orifice at elevation 1085 ft. The inside diameter of the discharge orifice is 5 ft. The inside diameter at the entrance is 10 ft 9 in.

The stack provides for HFIR exhaust of 30,000 cfm and has an additional capacity of 30,000 cfm to handle future requirements. At full design load, the stack discharges 60,000 cfm at 130°F. Under these conditions, the discharge velocity is ~3,050 ft/min. With only the ~30,000 cfm HFIR load, the discharge velocity is 1,525 ft/min. Provisions are made for sampling gas and measuring flow in the main ducts and in the stack itself. Radioactivity monitors, to indicate continuously the amount of activity discharged to the atmosphere, include both β-γ and α particulate monitors on the stack and a β-γ particulate monitor in the HFIR duct.

An open shed-type structure near the base of the stack provides weather protection for the fans, and a small enclosure in this shed houses the instrumentation.

9.5. Solid Waste Disposal

Standard ORNL practice is followed in the disposal of solid waste. Nonradioactive solid waste is placed into dumpsters (10 ft x 5 ft x 5 ft covered metal containers). The dumpsters are then removed by special trucks. The waste is incinerated.

Low-level radioactive wastes are placed in special yellow-painted dumpsters, generally after being sealed in plastic bags. They are then removed by truck to the ORNL burial ground. Wastes producing radiation of less than 3 mr/hr at the surface may be temporarily stored at the work site in yellow-painted cans.

Special procedures are used to remove highly radioactive solid waste. In some cases trucks with shielded cabs are used. For very high levels of radiation, it may be necessary to cut up the radioactive component under water and remove the pieces in lead casks. In the case of the used SBHE and HOG filters, special shields are provided. The filters can be drawn into these shields which are then removed by truck. In all cases, final disposal is accomplished by burial using existing ORNL equipment and facilities.

10. ON SITE UTILITIES

10.1. Potable Water System

10.1a. References

Drawings:

1546-05-U-7112, -U-7113, -U-7114, -U-7115 Yard Piping Plans

1546-05-U-7141 Flow Diagram, Fire and Potable Water

Singmaster and Breyer Specification: 69 Potable Water

10.1b. Introduction

The primary source of potable water to the reactor site is a 16-in. main line that enters the area at a point east of the reactor building. This line will deliver 2800 gpm. It supplies potable water to a fire loop which encircles the reactor building area and from which all other systems are fed (Figure 10.1). The main line is fed from two 1.5 million gallon capacity reservoirs located atop a hill to the north and east of the reactor site. Elevation of the reservoirs is sufficient to give the HFIR facility, after allowing for pressure losses in the line, a potable water pressure of approximately 50 psi.

A second 16-in. main line enters the area from the west and may be valved into the fire loop as an auxiliary source of potable water whenever needed. This auxiliary line is also capable of delivering a flow of 2800 gpm. Under normal conditions it is not used but is kept for emergency use only. The source of this supply is the reservoir which is located just north of the ORNL X-10 area.

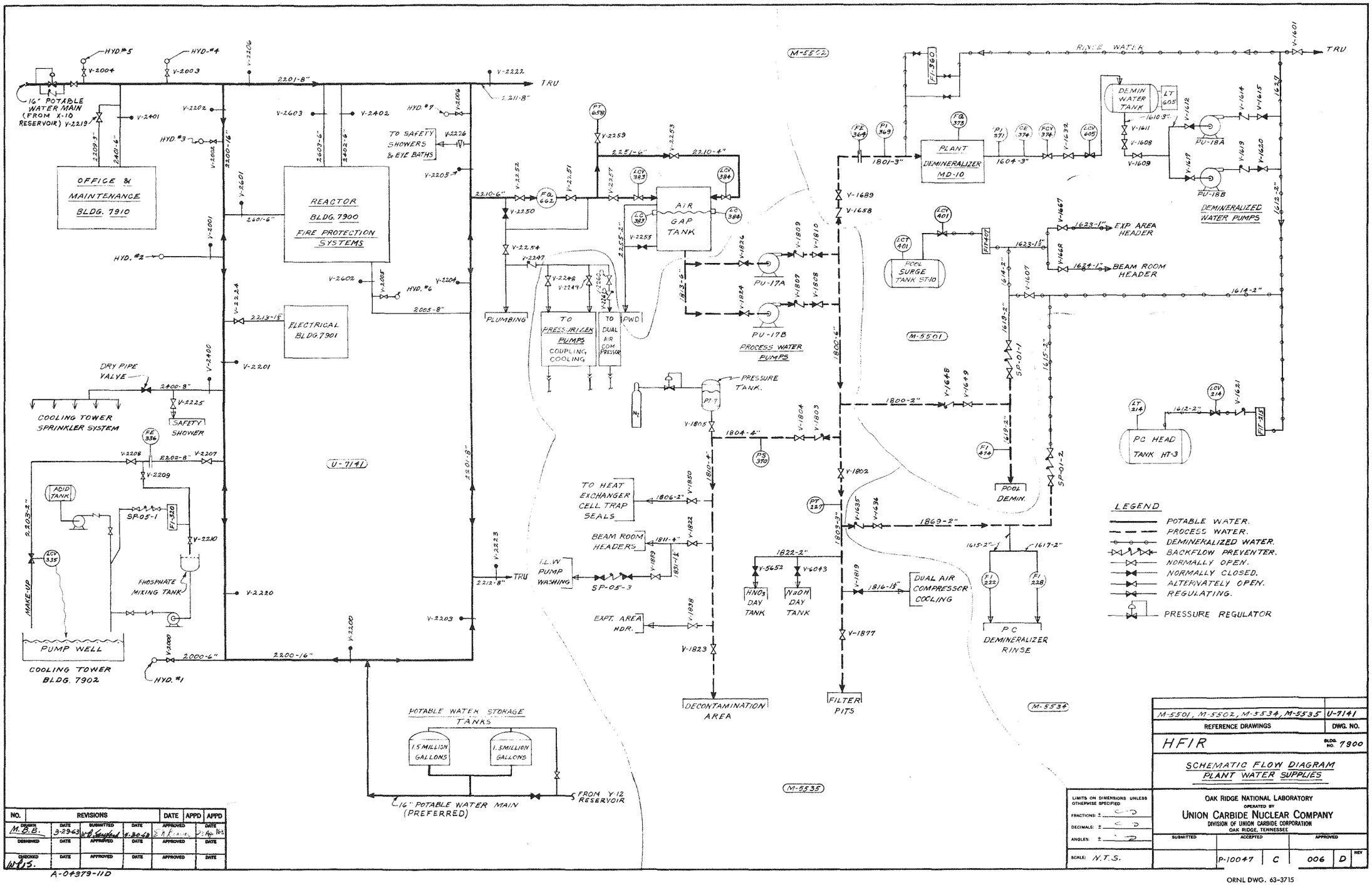

Fig. 10.1. Plant Water Supply - Schematic Flow Diagram.

10.1c. Description of the System

Seven strategically located fire hydrants are supplied potable water by the fire loop which encircles the reactor building. Six of the seven hydrants are fed by 6-in. lines that serve each hydrant exclusively. The seventh fire hydrant is fed by an 8-in. line which also supplies water to two standpipes on the east side of the reactor building.

Two other 6-in. standpipe water lines and one 6-in. sprinkler water line enter the reactor building from the fire water loop. These standpipe water lines supply fire hoses at various locations inside the building. Sprinkler water, as well as all other potable water used in the office and maintenance building, is taken from the same fire loop.

Post indicator valves in the fire loop are located so that any part or all of the system can be isolated from the 16-in. main lines.

10.1d. Potable Water Metering

Potable water usage is metered in three places and measured at a fourth:

1. Flow to the office and maintenance building is metered by FQ-660 in the utility room of that building. Maximum flow is 140 gpm. Of this, 13.75 gpm is the maximum potable hot water need.
2. Flow to the electrical building is metered by FQ-661 in the diesel-generator battery room. Maximum use is 20 gpm with no hot water provided.
3. Potable water to the reactor building is metered by FQ-662 in Room 103 of the water wing before the water reaches the air-gap tank. Maximum use is 800 gpm of which 4.5 gpm is for hot water and 700 gpm is for makeup to the process water system.

4. The potable water system supplies makeup to the process water system in the cooling tower area (i.e., secondary coolant water makeup and process water in the cooling tower equipment building). Flow through this 8-in. line is measured at meter pit No. 1 by flow element FE-336 which indicates volume by measuring the differential pressure across an orifice. This flow element is used to determine the required blowdown rate of the secondary coolant system.

10.1e. Uses of Potable Water

In addition to supplying fire hydrants and standpipes, potable water is used to supply:

1. Domestic sinks, drinking fountains, rest rooms, and personnel showers in the office and maintenance building. These facilities are fed through a 3-in. line which enters the utility room on the east side of the building after branching off the 16-in. main which enters the area from the west.
2. Secondary coolant water makeup (process water), the cooling tower sprinkling system, the chemical mixing and dispensing system, the safety shower and eye bath facility near the sulfuric acid storage tank, and a domestic sink in the cooling tower equipment building. These systems are fed by an 8-in. line which branches off the fire loop just east of the fuel oil storage tank and enters the cooling tower area just west of the secondary coolant water pumps. From this line a 2-in. branch enters the cooling tower equipment building. The 8-in. line continues out of the ground and enters the flume where it discharges makeup water to the secondary cooling water system.

3. An acid-proof sink and a safety shower in the battery room of the electrical building. These facilities are fed by a 1 1/2-in. line which branches off the fire loop just west of the fuel oil storage tank and enters the building under the battery room.
4. A safety shower and eye bath near the acid and caustic storage tanks on the north side of the reactor building. A 1-in. line branches off the 8-in. portion of the fire loop just a few feet northwest of the nitric acid storage tank to supply the facility.
5. The air-gap tank (process water makeup) in the reactor building, a safety shower and eye bath near the nitric acid and caustic day tanks, cooling for instrument air compressors C-1A, C-1B, and C-3, cooling for the pressurizer pumps' magnetic couplings, and domestic sinks, rest rooms, personnel showers, and drinking fountains in the reactor building. These are all fed by a 6-in. line which branches off the north side of the fire loop and enters the reactor building in the northeast corner of the water wing.

10.2. Process Water System

10.2a. References

Drawings:

1546-05-U-7114 Yard Piping

1546-05-U-7141 Flow Diagram, Fire and Potable Water

1546-05-U-7147 Flow Diagram, Chemical Treatment

1546-05-M-5535 Flow Diagram, Process Water System

1546-05-I-4007 Instrument Application, Process Water System

Singmaster and Breyer Specifications:

68 Process Water

113 Process Water Pumps

114 Process Water Pressure Tank

10.2b. Introduction

The process water system is separated from the potable water system by backflow preventers or by air breaks. Since potable water is used for human consumption, there must be assurance that there can be no backflow or mixing of potentially contaminated process water in the potable water system. This separation is accomplished by an air break at the cooling tower basin, an air-gap tank in the reactor building, and backflow preventers elsewhere.

10.2c. Description of the System

Reactor Building Area.-- Potable water for the reactor building is taken from the fire loop on the north side of the building and is metered by flow totalizer FQ-662 before branching in one direction to the domestic water system and in the other direction to the air-gap tank of the process water system.

1. The air-gap tank AG-5.

   This 1000-gallon tank is located in Room 103 of the water wing of the reactor building and is used to isolate the two water systems. Potable water enters the top of the tank through two parallel lines. Level control valves LCV-383 and LCV-384, one in each line, keep the water level such that the minimum air break is one foot. A low-level control switch, LS-387, provides protection for the process water pumps in case of inadequate potable water supply. This switch shuts the pumps down upon low level (15%) in the tank and actuates an annunciator in the main control room. Overflow protection, in case the level-control valves should fail, is provided by a line which drains to the process waste system. The tank is vented to the building atmosphere.

2. Process water pumps.

   Since water in the air-gap tank is at atmospheric pressure, it must be pressurized before use. This is accomplished by one of the two 500 gpm centrifugal booster pumps, PU-17A and 17B. One pump is in operation while the other is on standby. Each pump has a "start - stop - standby" selector switch, a white running light, a momentary contact standby switch, and a blue standby monitoring light. In the "standby" position, pressure switch PS-370 will automatically start the standby pump should the process water pressure drop to 35 psi. The pressure element is located in the process water header at the common pump discharge. The pump will

continue to run until manually shut down. No annunciator is provided for low water pressure.

The pumps are supplied electric power from normal-emergency system No. 1 through motor-control center "E," and, in the event of a normal-power outage, the operating pump will restart 30 seconds after the normal-emergency switchgear transfers the load to the emergency diesel-generator.

3. Pressure tank PT-7.

This tank, located in Room 103 near the air-gap tank, is kept filled by the process water pumps. Water level inside the tank is indicated by level-indicator LI-650. The tank "floats" on the line as a means of sustaining pressure in the process water system during the time delay (approximately 40 seconds) in change over from normal to emergency power in the event of a normal-power outage.

Cooling Tower Area.--Makeup water to the secondary coolant water system is supplied by a branch line off the potable water fire loop. Flow of makeup water to the cooling tower pump flume is controlled by level-control valve LCV-335. The effluent end of the makeup water line is at an elevation of 816 ft while the basin water level is kept at 815 ft. This leaves an air gap of one foot between the potable makeup water and the process water in the basin.

A 2-in. line branches off the cooling tower makeup line and enters the cooling tower equipment building near the west end to supply water to the chemical mixing and dispensing system as well as to the safety shower and eye-bath facility. Two kinds of chemical solutions are mixed here and added to the secondary coolant water system. The first, a chromate-phosphate solution, inhibits corrosion and scale formation. The second, a sulfuric acid solution, controls the pH of the water.

1. Chromate-phosphate solution tank.

   This 300-gallon tank is vented to the atmosphere and seves as an air gap between the potable and process water systems. Separation between the two systems is attained by manually adding potable water through the fill line at the top of the mixing tank. This allows a minimum air gap of 6 in. between the two systems. Mixing is done once each day, and the solution is drawn off continuously and fed to the secondary coolant system at the rate of about 10 gallons per hour.

2. Sulfuric-acid mixer.

   This solution is mixed continuously by acid mixer AM-1 and is fed into the secondary coolant system. A backflow preventer, SP-05-1, is located in the potable water inlet line to make the separation between the two water systems. The flow of approximately 50 gpm through the mixer is metered by a tee-orifice flow element, FE-320, and is controlled by a manually-operated valve.

ILW Pumping Pit Area.-- Process water from the reactor building area is used at the ILW pumping pit to flush the pumps and the pump pit and to fill the sump at the bottom of the pit. A backflow preventer, SP-05-3, is

utilized in the process water line to prevent the contaminated water of the ILW system from entering the process water line.

10.3. Plant Demineralized Water System

10.3a. References

Drawings:

1546-01-M-5534 Flow Diagram, Demineralized Water Supply

1546-01-M-5502 Flow Diagram, Plant Demineralizer

1546-01-M-5501 Flow Diagram, Demineralized Water

Singmaster and Breyer Specifications:

51 Plant Demineralizer Equipment

55 Plant Demineralized Water Storage Tank

65 Plant Demineralized Water System

10.3b. Description of System

Demineralized water is required at the HFIR complex for various applications. Some of these are: (1) makeup water to the pool coolant system, (2) makeup water to the primary coolant system, and (3) regeneration of process demineralizers. To ensure an adequate supply for these various uses, demineralized water is made from process water at a relatively slow rate (10 to 90 gpm) and is stored in an aluminum storage tank. Two demineralized-water pumps draw water from this tank and pressurize the building demineralized water header. The various systems which utilize demineralized water draw from this header as required.

10.3c. Description of Equipment

Plant Demineralizer.-- The plant demineralizer is a package monobed unit which includes its own 64-scfm blower, for mixing the resin, and

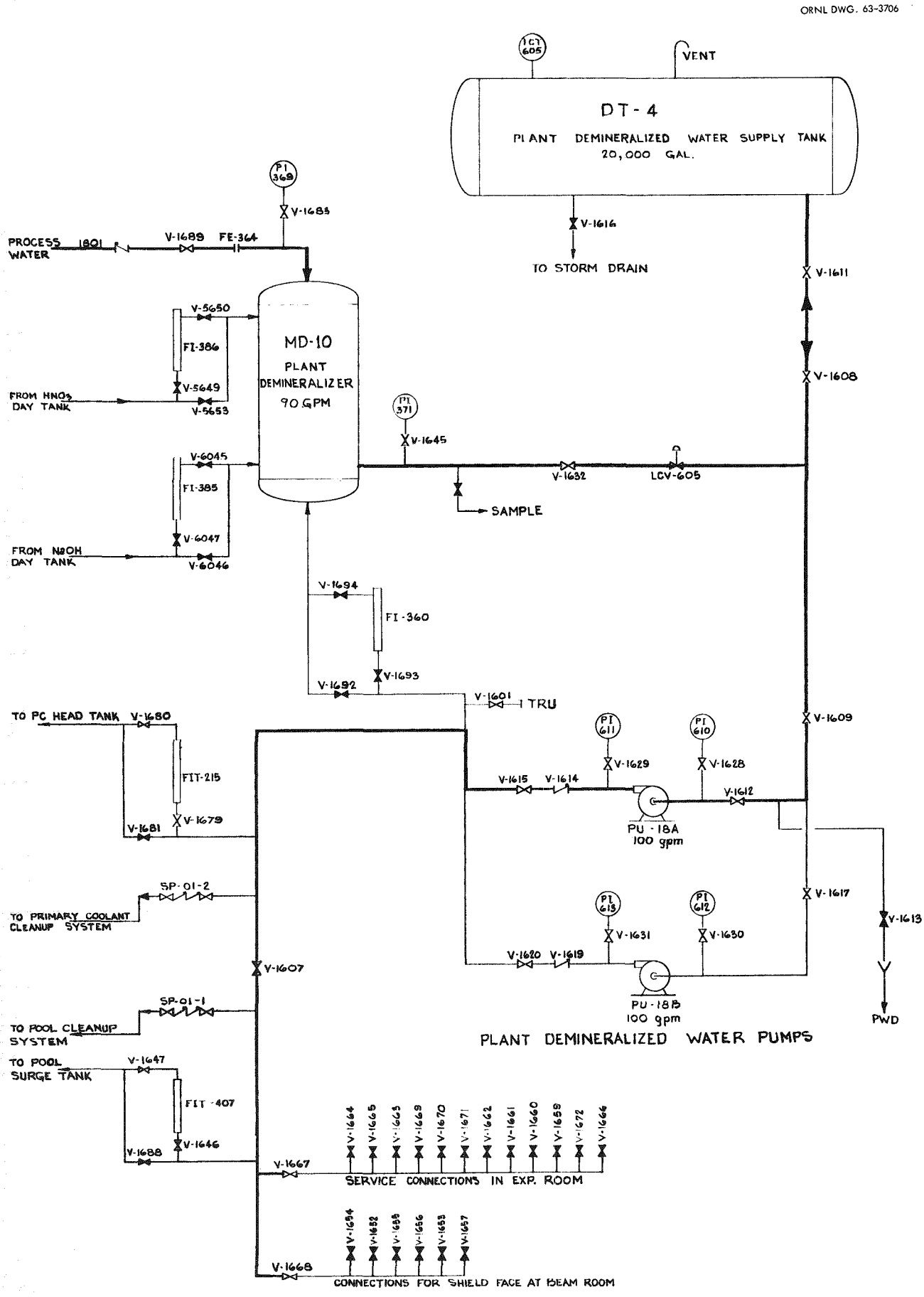

Fig. 10.2. Plant Demineralized Water System.

control instrumentation for semiautomatic operation. The ion exchange vessel is fabricated of carbon steel, lined with an 0.080-in. thick coating of unplasticized polyvinyl chloride. It contains 13 ft^3 of Rohm and Haas IR 120 cation resin and 25 ft^3 of IRA 402 anion resin. This volume of resin was designed to demineralize 45,000 gallons of process water between regenerations and produce effluent water with a resistivity of 1.5×10^6 ohm-cm. The flow rate can be varied between 10 and 90 gpm with no appreciable change in effluent water quality. The unit shuts itself down automatically when effluent water quality drops below a preset level, and annunciates the shutdown in the control room. Regeneration is manually initiated with a pushbutton and proceeds automatically to completion. Return of the unit "on stream" after regeneration is also manually initiated.

Demineralized-water Storage Tank.-- Demineralized water produced by the monobed unit is stored in a 20,000-gallon aluminum water-storage tank, DT-4, located above ground just outside the northeast corner of the reactor building. A level signal is transmitted from this tank to an indicator on the process panel board in the control room. High- and low-level alarms are annunciated in the control room. A single 2-in. line carries the effluent of the monobed unit to both the storage tank and the demineralized water pumps. Therefore, the storage tank "floats" on the line receiving water when more is being produced by the demineralizer than is required by the system and supplying water to the pumps when more is being demanded by the system than is being produced. A flow-control valve on the outlet of the monobed unit is controlled by a level transmitter at the storage tank. This mode of control tends to hold the

water level in the storage tank constant and to vary the flow through the demineralizer as the system demand changes.

Demineralized Water Pumps.-- The two pumps, 01-415-PU-18A and 18B, which pressurize the building demineralized-water system are centrifugal type with their wetted parts made of stainless steel. They will pump 100 gpm each against a 90-ft head with a maximum shut-off pressure of 49 psig. Power is supplied by 5 hp, 3500 rpm, 440 v, 3 phase motors. A spring return "start-neutral-stop" selector switch and a running light for each motor is located on the process panel in the control room. A "stop" button is located at each pump. Either or both pumps can be run continuously. The motors are connected to the normal-power supply and must be restarted manually after a power outage.

10.4. Chilled Water System

10.4a. References

Drawings:

1546-01-H&V-3003 Steam and Water Flow Diagrams

1546-01-H&V-3010 Mechanical Equipment

Singmaster and Breyer Specifications:

72 Hot and Chilled Water Distribution

100 Heating, Ventilating, and Air Conditioning

10.4b. Introduction

The chilled water system refrigerates and distributes a maximum of 833 gpm of 40° chilled water to the reactor building air conditioning system. The system consists of a packaged chilled water unit with 386 tons capacity, two chilled water pumps, a chemical feeder, an expansion tank and associated plumbing.

10.4c. Chiller Unit

The packaged chiller unit consists of the following components:

1. Motor-compressor assembly, a two-stage centrifugal compressor driven by a 367-hp motor. Located in the compressor base is a 12-gal oil reservoir with a submerged 1/2-hp motor and gear pump, oil heater, water type cooler, pressure regulator, shutdown switch, bearing thermometer, reservoir thermometer, oil pressure guage, oil level sight-glass and oil filter. A portion of the vaporized refrigerant is taken from the main stream at the economizer unit and sent through the electrically insulated motor

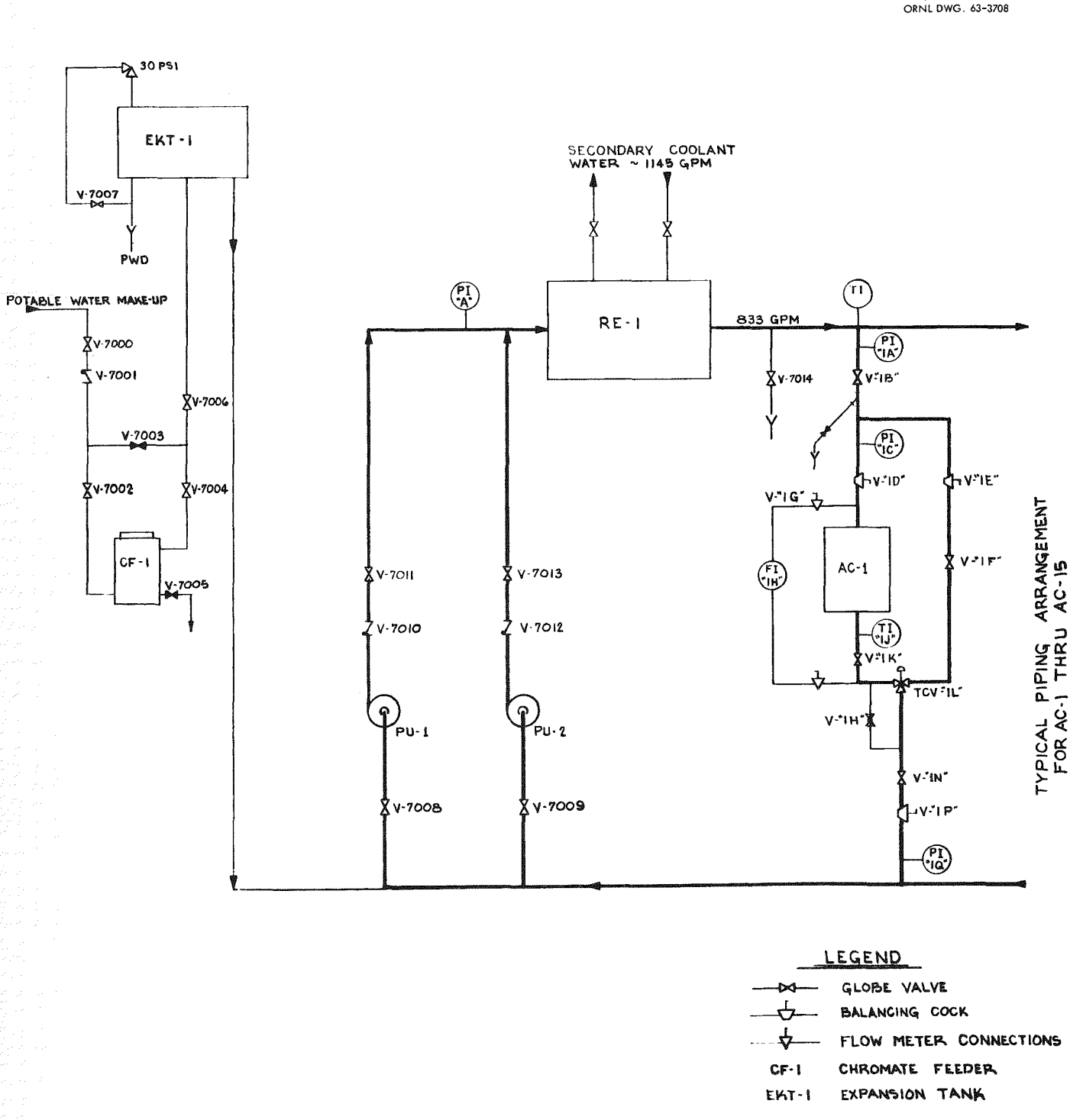

Fig. 10.3. Schematic Flow Diagram - Chilled Water System.

windings to supply cooling for the motor. Low bearing-lubrication-oil pressure or high bearing and motor winding temperature causes the unit to shut itself down.

2. Condenser.

Refrigerant vapor is compressed and sent to the condenser where, in its heated state, it comes into contact with the condenser coolant water tubes (secondary coolant water). The cooling water absorbs the excess heat and removes it to the secondary coolant tower. After the vapor is cooled, it condenses into liquid and flows by gravity into the economizer.

3. Economizer.

The liquid refrigerant from the condenser enters the economizer chamber and flows through two float valves en route to the cooler. Between the float valves there is a gas passage connection through the motor windings to the suction of the second stage impeller of the compressor. The greater portion of the liquid refrigerant flows to the cooler where it vaporizes due to the lower pressure.

4. Cooler.

The cooler unit consists of a shell and tube heat exchanger where the water being chilled makes two passes through the tubes before being circulated throughout the air conditioning system. Freon gas, after condensing into a liquid in the condenser, flows into the cooler and covers the tubes containing the chilled water. Here, the freon expands and absorbs heat from the water. After the freon changes from liquid to the gaseous state, it is compressed by the compressor and sent to the condenser as a vapor.

5. Control system.

The chiller compressor motor is controlled by a single local momentary "start-stop" pushbutton with green and red lights to indicate when the motor is running or stopped. The chiller is automatically shut down by the following safety features: (red lights on the local console indicate the cause of the shutdown.)

a. Condenser pressure high.

b. Bearing or motor winding temperature high.

c. Refrigerant temperature low.

d. Loss of chilled water flow, oil pump not running, or loss of condenser water flow.

e. Oil pressure low.

f. Chilled water temperature low.

If the chiller is stopped by a safety action, other than low chilled water temperature, the start button must be pushed to restart the motor. If the chiller stops because of low chilled water temperature, it will automatically restart as soon as the temperature increases above the cut-out setpoint. A timer is also provided which limits the number of motor starts to approximately three per hour.

A fixed resistor is connected to the current transformer circuit to provide a signal voltage for overcurrent protection for the motor. This output signal voltage is applied to a separate control circuit which prevents motor overcurrent by decreasing the compressor loading.

The chiller must be restarted manually with the local "start-stop" control switch after an outage of normal power.

10.4d. Chilled Water Pumps, PU-1 and PU-2

The 833-gpm capacity chilled water pumps are the horizontal, split case, centrifugal type. They are controlled by a local selector switch marked "PU-1-off-PU-2". Normally, only one pump is in operation while the other is in standby. When either pump is selected, the control circuit is energized and the pump will start upon demand for chilled water. The pump motors are connected to the normal-power system through motor control center "A" and will restart automatically after a power outage, if required by the chilled water thermostat. Energizing the pump motor control circuit also actuates an electro-pneumatic relay, to permit control air to operate the various pneumatic-control-system components.

10.4e. Chemical Feeder

A chemical feeder is provided in the chilled water makeup line so that a corrosion inhibitor may be added to the system.

10.4f. Expansion Tank

The expansion tank is provided with a pressure safety valve which is to operate at 30 psi. In the event the system becomes pressurized greater than this amount, the valve opens and allows the excess water to drain into the process waste system. The tank is located overhead, above the chilled water pumps.

10.5. Acid and Caustic

10.5a. References

Drawings:

1546-05-U-7147 Flow Diagram, Chemical Treatment

1546-01-M-5501 Engineering Flow Diagram

Singmaster and Breyer Specifications:

45 Nitric Acid Storage Tank and Day Tank

47 Caustic Storage Tank and Day Tank

52 Acid Pump

53 Caustic Pump

78 Nitric Acid Storage and Distribution

91 Caustic Storage and Distribution

10.5b. Nitric Acid Storage and Distribution

Nitric acid of 66% concentration is received by truck and stored in a 1500-gallon stainless steel tank (AT-7) located above ground on the north side of the reactor building. Vent and overflow line, 5614, drains into a limestone-filled drain to the process waste disposal system. The tank can be drained and flushed out to the process waste system through line 5615. Acid level inside the tank is indicated by sightglass LI-462.

The concentrated acid flows by gravity through line 5600 to the 1200-gallon nitric acid day tank (AT-4) located on the ground floor of the reactor building. Here, process water from line 1828 is mixed with the concentrated acid to dilute it to a 5% solution. Pump PU-15 is used both to mix the solution (through line 5605) and to pump the solution to the primary demineralizer and filter system, the plant demineralizer, and the pool coolant demineralizer and filter system.

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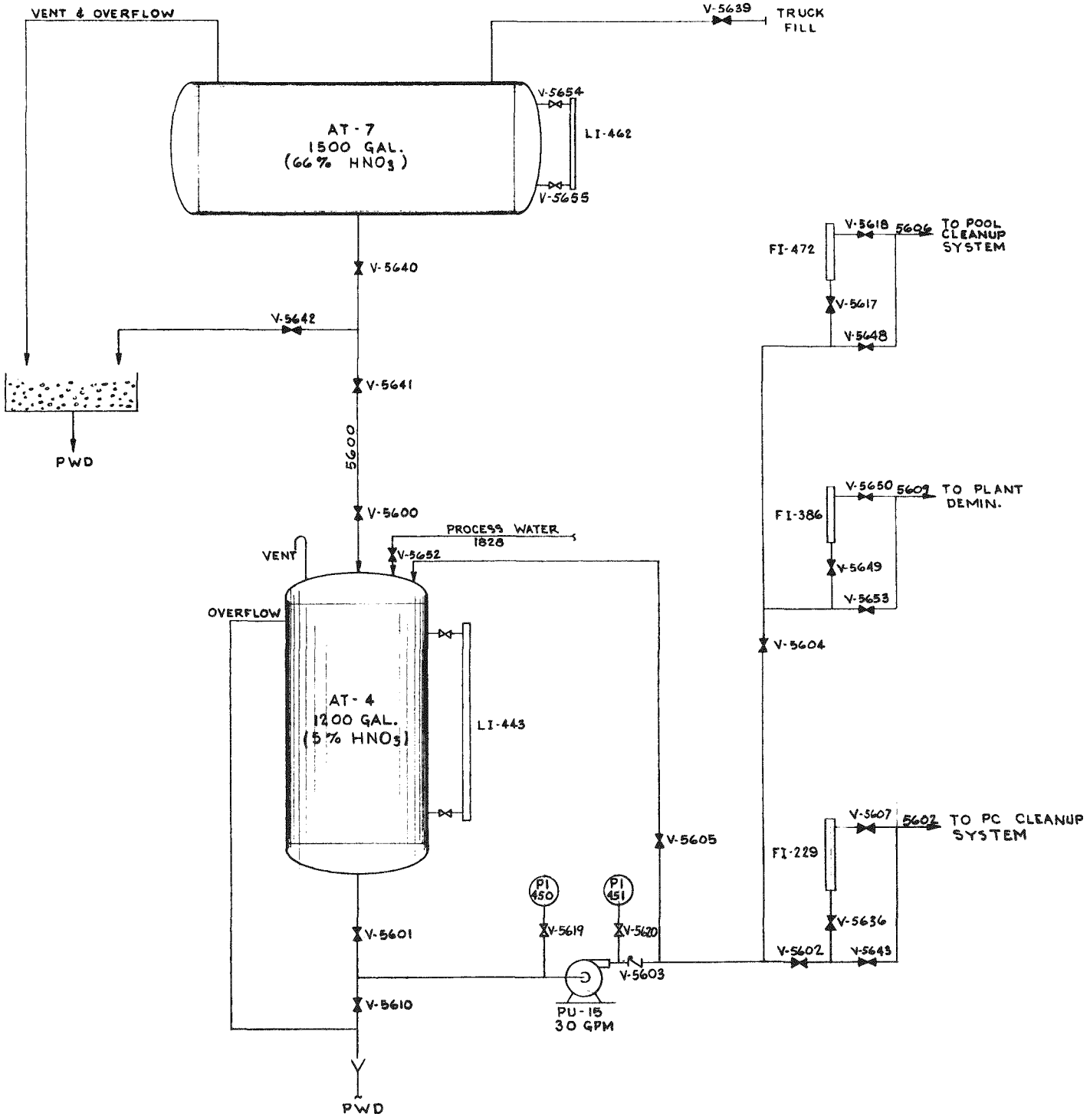

Fig. 10.4. Nitric Acid System.

10.5c. Caustic Storage and Distribution

Concentrated caustic (50%) is received by truck and stored in a 5000-gallon tank (CAT-8) located above ground on the north side of the reactor building. The tank is insulated and steam heated to prevent the caustic from solidifying. Temperature control valve TCV-444 controls the temperature of the tank at 130°F. All lines associated with the tank have steam tracing and connections for steam clean out. An overflow and vent line 6014 opens into a limestone filled drain to the process waste system. Line 5615 allows the tank to be drained and steamed out into the process waste system. Caustic level inside the tank is indicated by sightglass LI-461.

Line 6000 allows caustic to flow by gravity from the storage tank into the caustic day tank (CAT-5) located on the ground floor of the reactor building. Process water from line 01-1829 is mixed with the concentrated caustic in the day tank to dilute it to a 5% solution. Pump PU-16 is used both to mix and circulate the 5% solution in the day tank and to transfer the solution to the pool demineralizer and cleanup filter system, the primary coolant demineralizer and cleanup filter systems, the plant demineralizer, and the ILW receiving tank. The day tank is also steam heated and kept at a constant temperature by temperature control valve TCV-445. Venting is to the atmosphere. Sightglass LI-442 indicates the caustic level inside the tank. An overflow line empties into the process waste system.

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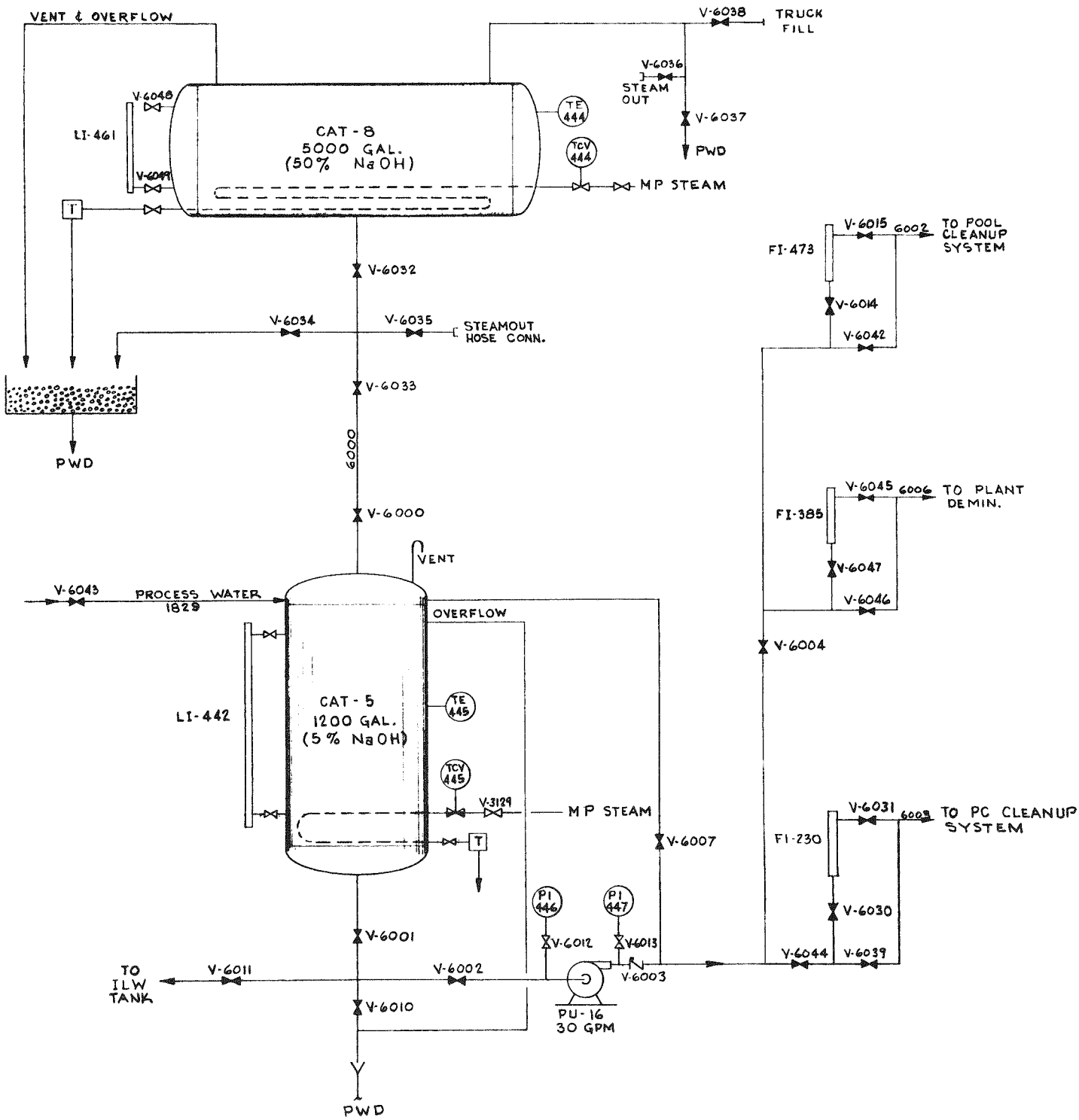

Fig. 10.5. Caustic System.

10.5d. Sulfuric Acid Storage and Distribution

Concentrated sulfuric acid (93%) is received by truck and stored in a 5000-gallon stainless steel tank (AT-1) located above ground near the cooling tower equipment building.

The acid is used to maintain the secondary coolant water pH at a constant value. It flows from the storage tank by gravity through line 5802 to the two parallel acid metering pumps, PU-1A and -1B. Normally, only one metering pump is in operation while the other is on standby. From here it is sent to acid mixer, AM-1, where it is diluted with process water from line 2208. Backflow preventer SP-05-1 prevents acid from entering the potable water system. After dilution, the acid flows into the cooling tower basin through line 7100.

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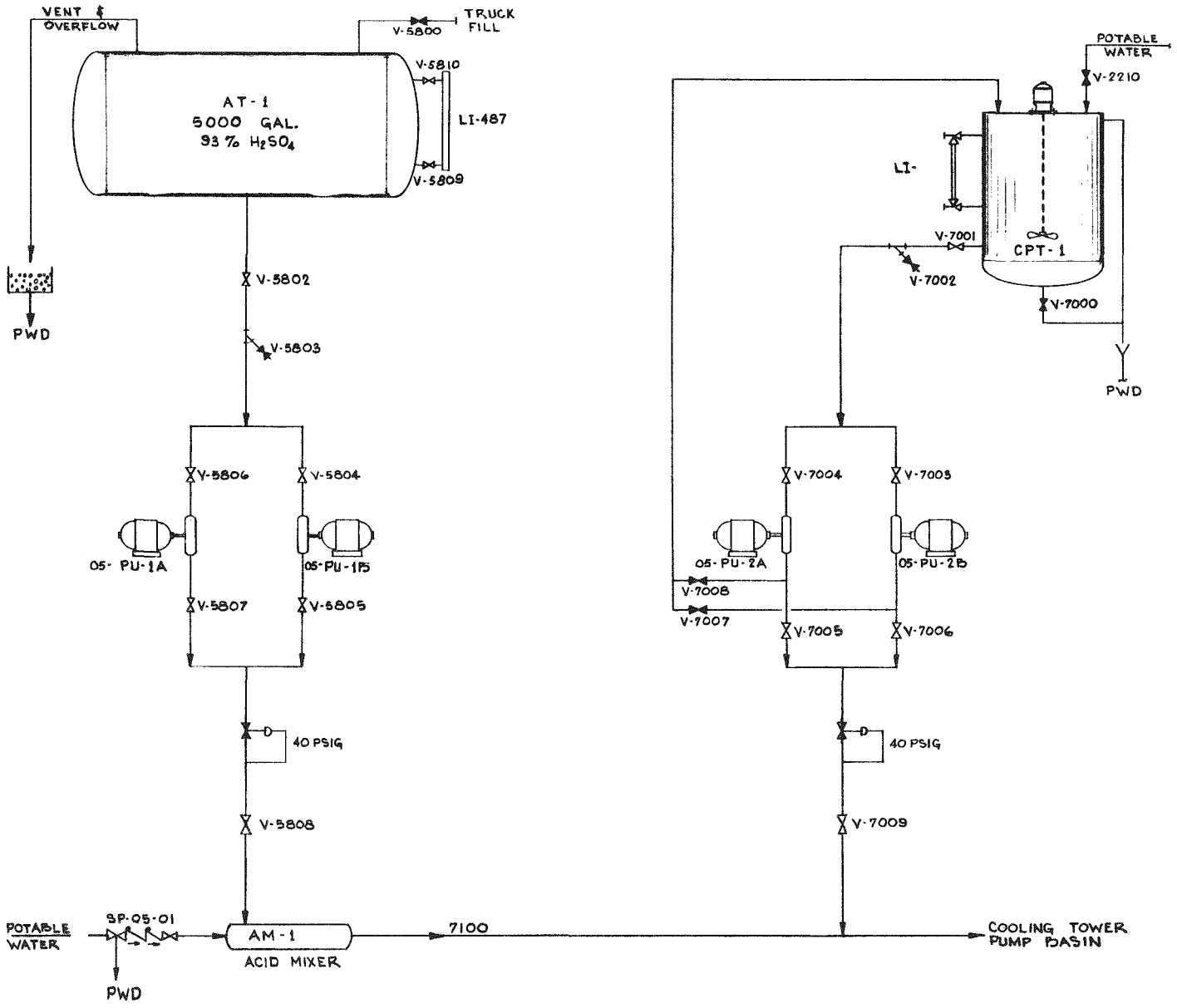

Fig. 10.6. Secondary Coolant Chemical Treatment.

10.6. Steam

10.6a. References

Drawings:

1546-05-U-7101, -7102	Utility Plans
1546-05-U-7140	Steam Flow Diagram
1546-01-H&V-3017	Steam Service Piping
1546-02-H&V-3042	Office and Maintenance Building Steam Flow Diagram
1546-01-H&V-3003	Reactor Building Steam Flow Diagram

Singmaster and Breyer Specifications:

73 Steam Distribution and Steam Tracing System.

10.6b. Introduction

Steam is furnished to the HFIR facility from the ORNL steam plant. A 6-inch high-pressure steam line, 250 psig, enters the area from the north and continues along the east fence to a point east of the reactor building. Here, a 4-inch line, controlled by valve V-3004, goes west to the north side of the reactor building. It enters Room G-1 in the reactor building at the ~827' level. In room G-1, the pressure is reduced and the steam is metered before being distributed throughout the area. The flow pattern through this section is as follows:

1. Steam enters the pressure reducing station where the pressure is lowered to 125 psig by pressure control valve PCV-1. Any condensate is bypassed to a flash tank and the storm drain.
2. Downstream from the reducing station the steam is metered by a stainless steel diaphragm-type meter, R-1. After being

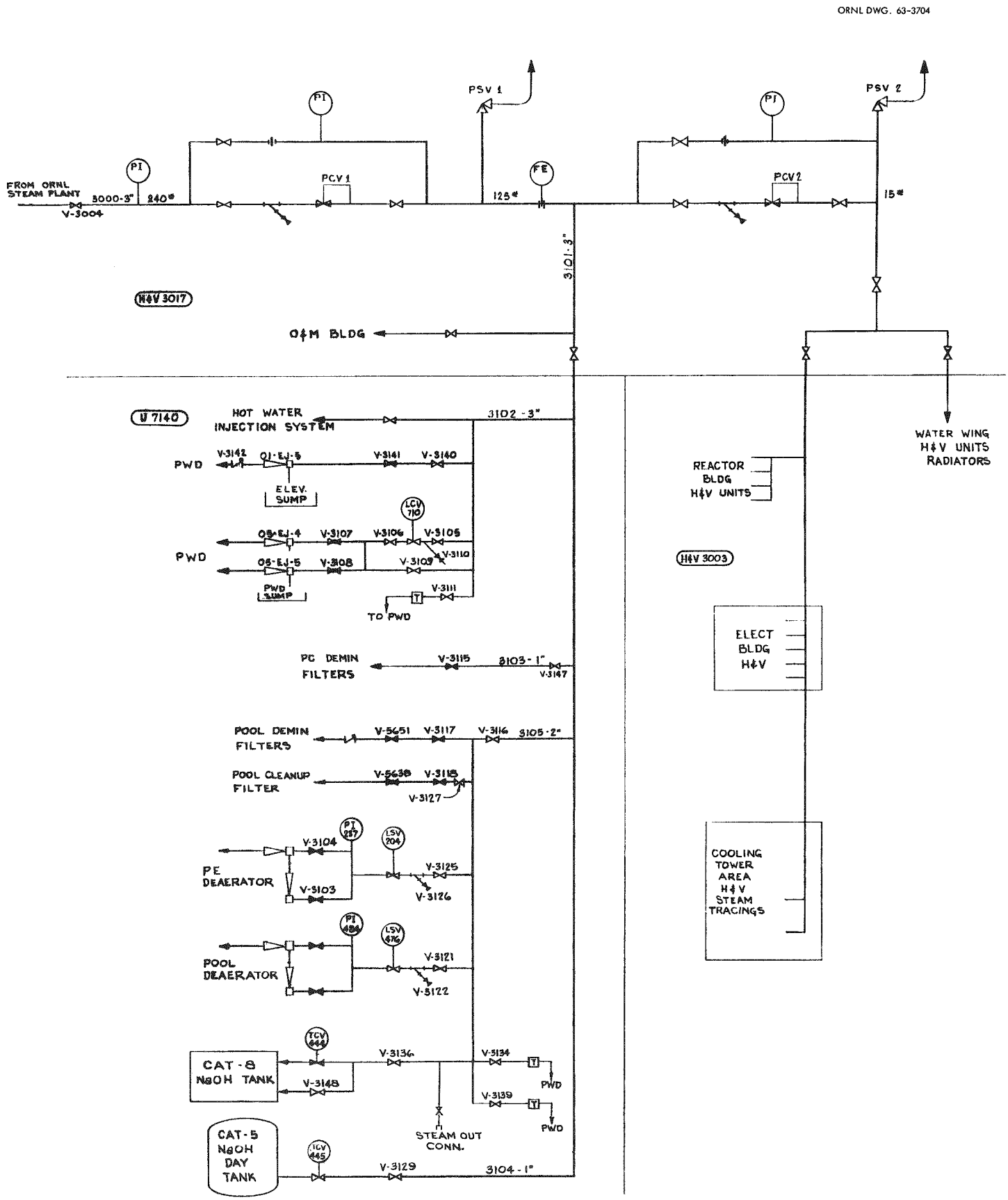

Fig. 10.7. Steam Distribution System.

metered the 125 psig steam is channeled into two systems, the process steam system and the plant steam heating system.

10.6c. Process Steam System

The 3-inch process steam main furnishes a maximum of 4000 lb/hr of 125 psig steam to the process equipment as follows:

1. A 3-in. line which can supply a maximum of 3100 lb/hr to the elevator sump pit ejector and the process waste drainage sump ejectors. The elevator sump pit is emptied by manually valving steam to ejector EJ-5. Process waste is jetted from the process waste sump by ejectors EJ-4 and EJ-5 which are piped in parallel. They are activated by level control valve LCV-710A when the level of waste in the sump reaches an elevation of 788 ft.
2. A 2-in. line which can supply a maximum of 650 lb/hr of 125 psig steam to the following equipment:
   a. 250 lb/hr to the pool deaerator high and low vacuum ejectors, EJ-3 and EJ-4 respectively. The two ejectors can be automatically cut off by LSV-476 (see Section 6.4b).
   b. Pool cleanup filters intermittent use.
   c. Pool demineralizer filter, intermittent use.
   d. The primary deaerator high vacuum and low vacuum ejectors, EJ-1 and EJ-2, respectively, use 250 lb/hr. These ejectors can be automatically cut off by LSV-204.
   e. The caustic storage tank, CAT-8, is heated by steam to keep the caustic from solidifying. The tank also has a steam-out connection and steam tracing lines for freeze protection to its instrumentation.

3. Steam is supplied to the primary cleanup system filters through a 1-in. line for intermittent use.
4. A maximum of 100 lb/hr of steam is supplied to the caustic day tank, CAT-5. The temperature of the caustic is controlled by TCV-445.

10.6d. Plant Steam Heating System

Steam for the heating systems is sent in two directions, to the office and maintenance building which uses a maximum of 1400 lb/hr, and to the reactor building, electrical building, and the cooling tower equipment building which, combined, use a maximum of 7100 lb/hr.

Reactor Building and Adjacent Areas.-- In room G-1, just downstream from the metering equipment, the 125-psig steam is reduced to 15 psig, by PCV-2, for the heating system. In the reactor building, 6590 lb/hr is available for heating and ventilating and 160 lb/hr is used by the domestic hot water heaters.

Leaving the reactor building at the southeast corner, a 2-1/2-in. line supplies a maximum of 350 lb/hr to the electrical building where 250 lb/hr is used for space heating and 100 lb/hr is sent on to the cooling tower equipment building for use in space heating and steam tracing.

Office and Maintenance Building.-- From room G-1 in the reactor building a line furnishes a maximum of 1400 lb/hr of 125-psig steam to the office and maintenance building. This line enters the building via a pit below the northeast corner of the utility room. In the utility room, the 125 psig steam pressure is reduced to 15 psig by two pressure reducers installed in series. The 15-psig steam is then used directly by the domestic hot water heater and indirectly by the building heating and ventilating system.

10.7. Instrument Air System

10.7a. References

Drawings:

1546-05-U-7146 Instrument Air Flow Diagram

1546-01-M-5505 Piping Drawings

1546-01-M-5513 Piping Drawings

RC11-8-2 Air Flow Diagrams

Singmaster and Breyer Specifications:

54 Equipment for the Compressed Air System

79 Instrument Air Distribution System

10.7b. Introduction

Compressed air for instruments is produced at the HFIR facility rather than being supplied from existing ORNL facilities. There are two compressor stations; the normal air compressor station which supplies 60- to 70-psig air to all instruments in the area, and the emergency air compressor station which supplies 60-psig air to the three surge air receivers in the safety instrumentation systems. The normal-air compressor station has two compressors, one in operation and the other in standby. The nominal capacity of each compressor is 100 scfm. The normal air compressors draw building air through their inlet filters, compress it, and then discharge it through their aftercoolers and moisture separators into the air receiver. The air receiver supplies air through prefilters, the air dryer, and after-filters to the air distribution system and the surge air receivers (see Figure 10.8.) The air compressors, aftercoolers, moisture prefilters, air dryer, and after-filter are located as a packaged assembly on the ground floor near the north wall in Room G-1.

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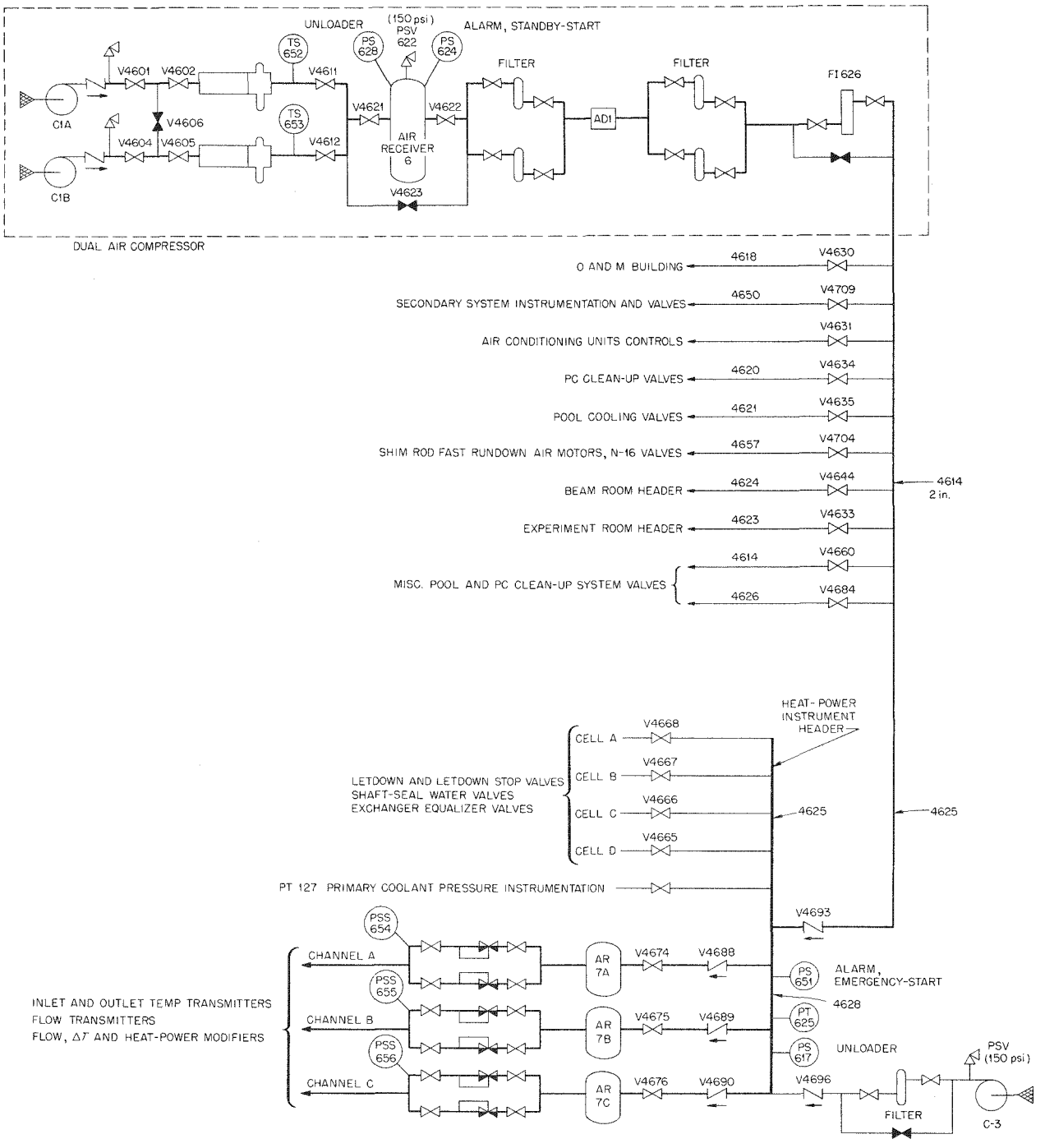

Fig. 10.8. Instrument Air System.

The emergency-air compressor station has only one compressor with a nominal rated capacity of 20 scfm. This compressor and the surge air receivers are located on the first floor near the south wall of the water treatment wing of the reactor building.

10.7c. Control System

The operating compressor runs continously, either at full load or at no load. It is automatically loaded when the air receiver pressure drops to 60 psig and unloaded when the pressure reaches 70 psig. Solenoid valves 1-SV and 2-SV and the loading and unloading valves for compressors C-1B and C-1A, respectively, are operated by pressure switch PS-628 which is located on the air receiver.

The standby compressor starts automatically when the pressure in the air receiver drops to 53 psig and remains loaded until the air pressure reaches 70 psig. Simultaneously, an alarm is annunciated on panel "HI" in the reactor control room. Both the alarm and the standby compressor start relay are actuated by pressure switch PS-624.

Selector switch, SS-13, located on the instrument air system panel in the reactor control room, is used to select the operating compressor. Lights indicate which compressor is running. The compressor not selected is automatically on standby.

10.7d. Emergency Operation

Air compressor C-1A is operated from the No. 1 normal-emergency power distribution system through MCC "E". In the event of a failure of normal power, the compressor will restart 30 seconds after the No. 1 diesel-generator assumes the load.

Air compressor C-1B is operated from the No. 2 normal-emergency power distribution system through the 225-amp west bus duct in the experiment room. In the event of a failure of normal power, the compressor will restart 30 seconds after the No. 2 diesel-generator assumes the load.

A failure of the cooling water supply to the operating compressor and its aftercooler is detected by a high temperature alarm set at 90°F. This alarm is actuated by TS-652 on compressor C-1A and TS-653 on compressor C-1B and is annunciated on panel "HI" in the main control room.

Low lubricating oil pressure in an operating compressor automatically shuts down that compressor.

If the air pressure at the surge air receivers which supply air to the safety channel instrumentation drops to 48 psig, the emergency air compressor, C-3, will start. This compressor is loaded at 60 psig and unloaded at 70 psig by solenoid valve 3-SV. This solenoid valve is operated by pressure switch PS-617, which is located on the discharge header of the compressor. The compressor continues to run until manually de-energized by pushing the local "stop" button. Pressure switches PS-654, 655, and 666 actuate alarms on panels B, C, and D, respectively, in the main control room, should the pressure in the three surge air receivers drop to 32 psig.

10.7e. Normal Air Compressor Package

The capacity of each of the two compressors is 100 scfm at 60 psig of air at ambient temperature. The compressors are vertically mounted, water cooled, reciprocating, oil-free type with teflon rings.

Each of the two aftercoolers, AC-1A and 1B, cools 100 scfm at 60 psig to within 15°F of the cooling water temperature. Cooling water from the potable water system flows through the aftercoolers and then to the compressor cooling jacket before discharging into the storm drain system. The cooling water flow rate is approximately 2.5 gpm, which is sufficient to cool the compressed air to < 110°F.

Air receiver, AR-6, is sized to receive 90 cubic feet of air at 100 psig. Discharge of air from the receiver is through parallel filters and into an air dryer, either AD-1 or -2. The air dryers are divided into two sections (one section dries air while the desiccant in the other is being regenerated). See Figure 10.9. Capacity of each dryer is 200 scfm, of which the net output is 150 scfm. Fifty scfm of dry air is used to regenerate the desiccant in the standby compartment. Recycle time for the automatic regeneration is three minutes.

10.7f. Emergency Air Compressor (C-3)

The emergency air compressor supplies the three surge air receivers with air in case of failure of the normal air compressors. This system consists of one 20-scfm compressor, three 13.5-ft^3 surge air receivers and one air filter. A check valve prevents back flow to other sections of the instrument air distribution system.

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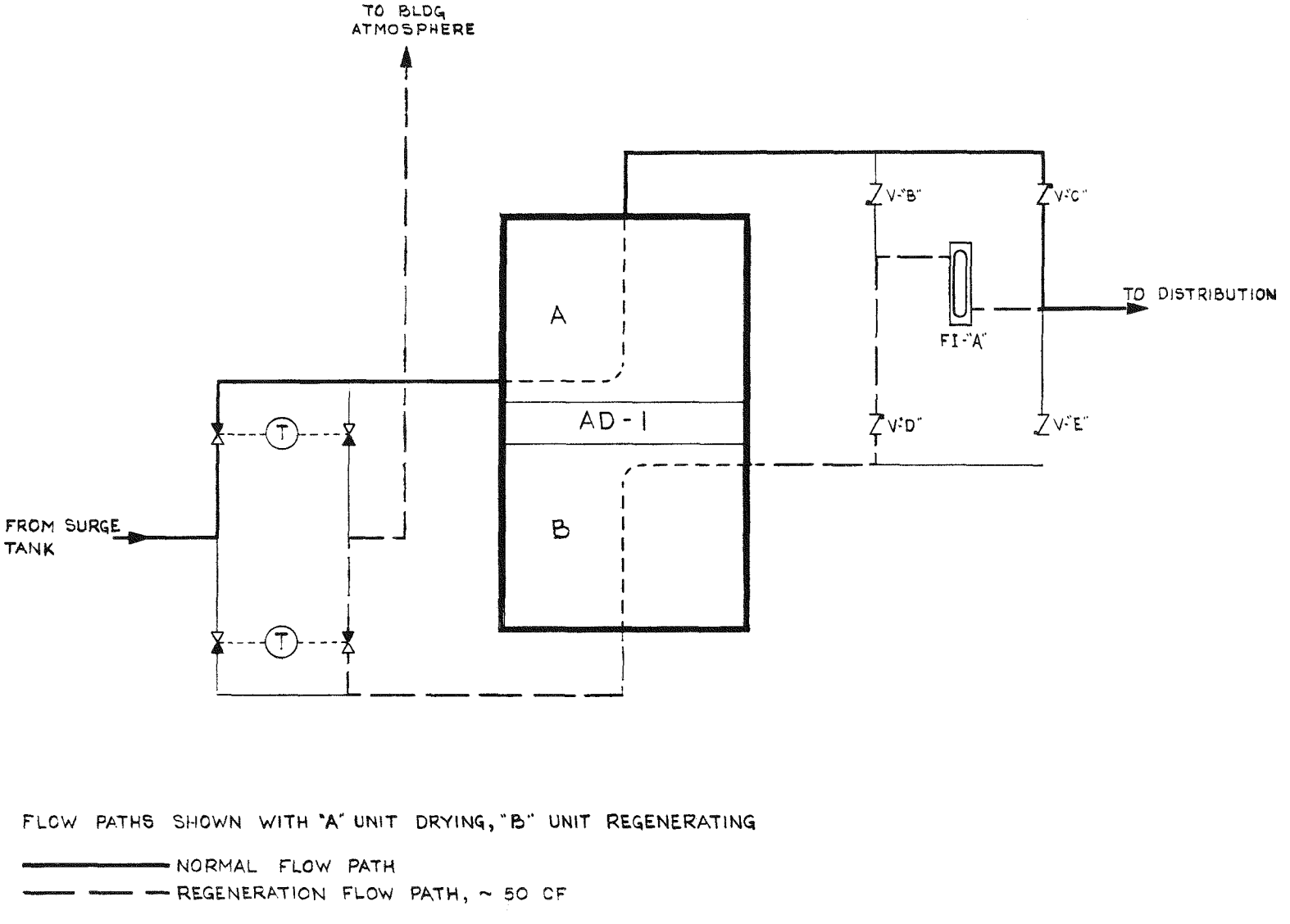

Fig. 10.9. Simplified Flow Diagram - Air Dryer.

10.8. Electrical System

10.8a. References

Drawings:

1546-05-E-2001	Electrical Key Plans
1546-04-E-2002	Normal Power--13.8-kv 2.4-kv Distribution
1546-01-E-2003	480-v Normal Power--Substation No. 1, Reactor Building
1546-01-E-2004	480-v Normal Power--Substation No. 2, Reactor Building
1546-04-E-2005	480-v Normal Power--Substation No. 3, Electrical Building
1546-04-E-2006	480-v Normal Power--Substation No. 4, Electrical Building
1546-04-E-2007	Normal-Emergency System No. 1 and Fail-Free System
1546-04-E-2008	Normal-Emergency System No. 2
1546-01-E-2009	Instrument Power

10.8b. Description of Systems

All electrical loads with the HFIR complex are served by one, or more, of four power systems as determined by the nature and importance of the load. These four power systems are:

1. Normal system.
2. Normal-emergency system.
3. Fail-free system.
4. Instrument-power system.

To ensure a high degree of service reliability the HFIR is supplied by two 13.8-kv, 3-phase, 60-cycle aerial feeders from the main ORNL 154-13.8-kv substation. One feeder is the preferred supply circuit, the

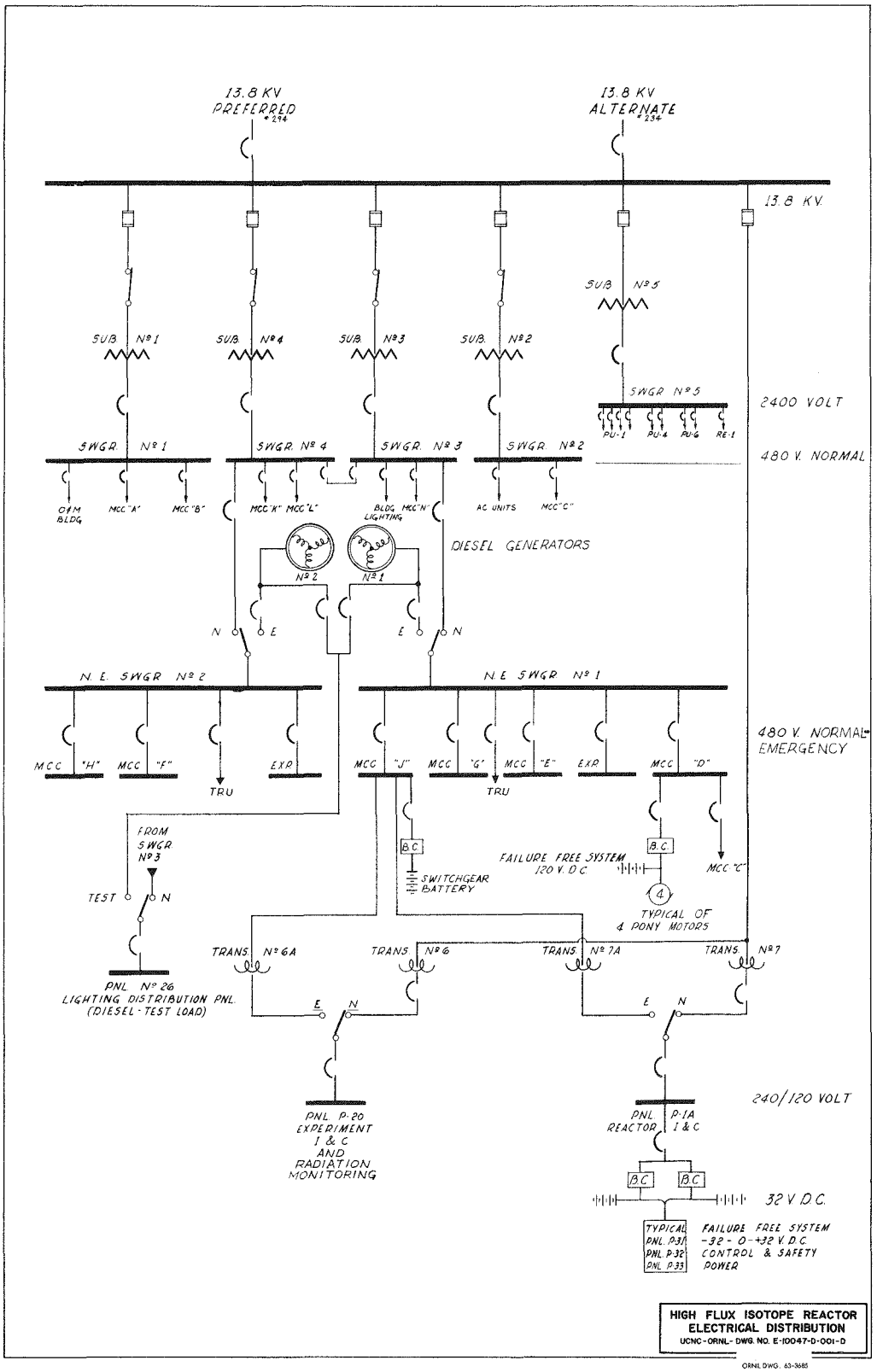

Fig. 10.10. Electrical Distribution.

second feeder is an emergency alternate. These two feeders supply the normal-power system. An automatic switching station transfers the load from the preferred to the alternate feeder in case of power interruption on the preferred feeder. In the event of a normal-power failure, i.e., a failure in both distribution circuits to the HFIR, the loads served by the normal-power system are dropped or transferred to the normal-emergency system.

The normal-emergency system serves essential loads in the event of a normal-power system failure. During such a failure, these essential loads are automatically transferred to standby diesel-generator units.

An ultra-reliable system, designated as the fail-free system, is provided for certain critical loads which, if they were to be dropped, might cause serious hazard to personnel or result in serious damage to equipment. This system includes storage batteries and battery chargers in parallel with the normal-emergency supply circuit to provide power should the diesels fail to start.

Separate circuits designated as instrument-power systems are used to supply the reactor and experiment instrumentation. These systems serve sensitive electronic circuits and are kept free of voltage and frequency disturbances. Power is supplied by the normal supply system through transformers with electrostatically shielded secondary windings. Precautions have been taken to ensure adequate electromagnetic shielding of the entire instrument-power system.

10.8c. Description of Equipment

Normal-Power System.--

1. 13.8-kv switching station.

The HFIR is supplied by two 13.8-kv feeders, one a normal supply and the other an emergency alternate. Both feeders are brought to a 13.8-kv switching station in the HFIR electrical building. This station consists of an indoor, completely enclosed, metal-clad assembly which contains:

a. Two 13.8-kv drawout, electrically operated, air circuit breakers, one for each incoming line, with associated relaying, metering, and control equipment. The breakers are rated at 1200 amperes continuously, 500-MVA interrupting capacity, 95-kv basic impulse level. The breakers have dc trip coils. Each breaker is provided with an ammeter and ammeter switch, voltmeter and voltmenter switch and suitable relays. Relays include 2-phase overcurrent relays and a ground relay. A single watt-hour meter with a demand attachment is provided to measure the HFIR load.

b. Control equipment for the automatic transfer scheme.

c. Six, 600-ampere, manually operated, fused interrupter switches. Five of the interrupter switches serve load center substations. One interrupter switch serves the instrument-power transformers. The switches are operable from outside the switch cubicle and are provided with quick-make, quick-break mechanisms, so designed that the speed of opening or closing is independent of the operating motion. The switches are capable of closing against a full short circuit and have a basic impulse level of 95-kv.

d. Provisions for future addition of two fused-interrupter switches.

The HFIR load is normally carried by the "preferred" 13.8-kv feeder circuit. In the event of a sustained undervoltage or a loss of voltage on the preferred feeder, the load is automatically transferred to the alternate feeder after a delay of ~2 seconds, if voltage is available on it. If voltage is lost on both feeders, no transfer takes place. Return to the preferred feeder, after a transfer to the alternate feeder, is a manual operation. A dead-bus transfer is effected by operation of the circuit breaker control switches. A live-bus transfer, in which both breakers are momentarily closed, can be effected with the live bus transfer switch. This three-position switch is marked "Transfer from HFIR Circuit No. 3--Normal--Transfer from Circuit No. 3 to HFIR Circuit" and is spring loaded to return to "Normal." When held in the "Transfer from Circuit No. 3 to HFIR Circuit" position the preferred breaker will close (paralleling both circuits momentarily) and is followed by an immediate trip out of the alternate breaker. Operation in the other position is similar except that the circuits are reversed. A two-position selector switch marked "HFIR Circuit--Circuit No. 3" is mounted on the electrical control panel. This switch permits either of the two feeders to be selected as the preferred feeder. The preceding description is for the selector switch in the "HFIR Circuit" position. In the "Circuit No. 3" position, automatic transfer takes place from circuit No. 3 to the HFIR circuit for undervoltage on Circuit No. 3. Interlocks are provided to prevent any circuit transfer when undervoltage is accompanied by

overcurrent. This prevents a transfer due to undervoltage caused by a fault within the HFIR.

2. 13.8-kv distribution.

Power from the 13.8-kv switchgear is supplied to seven transformers. One of the transformers supplies 2400-volt power, four supply 460-volt power, and two supply 120/240-volt instrument power. Three of the 13.8-kv--460-v transformers and the 13.8-kv--2400-v transformer are located outside the west wall of the electrical building. The other 13.8-kv--460-v transformer is located outside the north wall of the main reactor building. Instrument transformers are located inside the electrical building. The outside transformers are mounted on concrete pads which include a curb for oil containment. Fire walls are installed between adjacent units where required. Connections between the 13.8-kv switchgear and the transformers are made with 3-conductor, paper insulated, lead covered, neoprene jacketed cables, run in underground concrete encased conduit.

a. 13.8-kv--460-v unit,

A complete voltage reduction unit consists of an oil-filled transformer suitable for outdoor service with an integral oil-filled disconnect switch, a 460-v indoor metal clad switchgear lineup, and a metal enclosed bus duct between the transformer and switchgear. The transformers are rated at 13,800-v wye--460-v delta, 1000 kva, 55°C rise, self-cooled, with provision for the addition of fans which can increase the rating to 1250 kva, 3 phase, 60 cycles. The

transformers have 13.8-kv pot-heads for underground, paper-insulated, lead-covered cable entrance. The 460-v switchgear consists of manually operated main and feeder breakers in three vertical stacks. Power distribution is 460-v delta ungrounded, with ground detection monitoring lights. Switchgear instrumentation consists of a voltmeter and an ammeter with their respective switches.

b. 13.8-kv--2400-v unit.

The unit consists of an oil-filled transformer for outdoor use and an indoor lineup of high-voltage, fused, motor starters, a main transformer-secondary breaker, and a feeder breaker. The transformer is rated at 13,800-v delta--2400-v delta, 5,000-kva self-cooled, 6667-kva forced air cooled, 3 phase, 60 cycles. The 2400-v ungrounded delta system is converted into a resistance grounded system by a zig-zag grounding transformer and grounding resistor. The zig-zag transformer is connected to the spare 2400-v feeder breaker in the lineup. A 2400-v resistance grounded system has the following advantages over an ungrounded or solidly grounded system:

(1) Freedom from transient overvoltages which occur on ungrounded system.

(2) Simple relaying of ground faults.

(3) A reduction in damage from fault current in any single phase-to-ground fault. This is essential because the 2400-v system serves all the large, expensive motors.

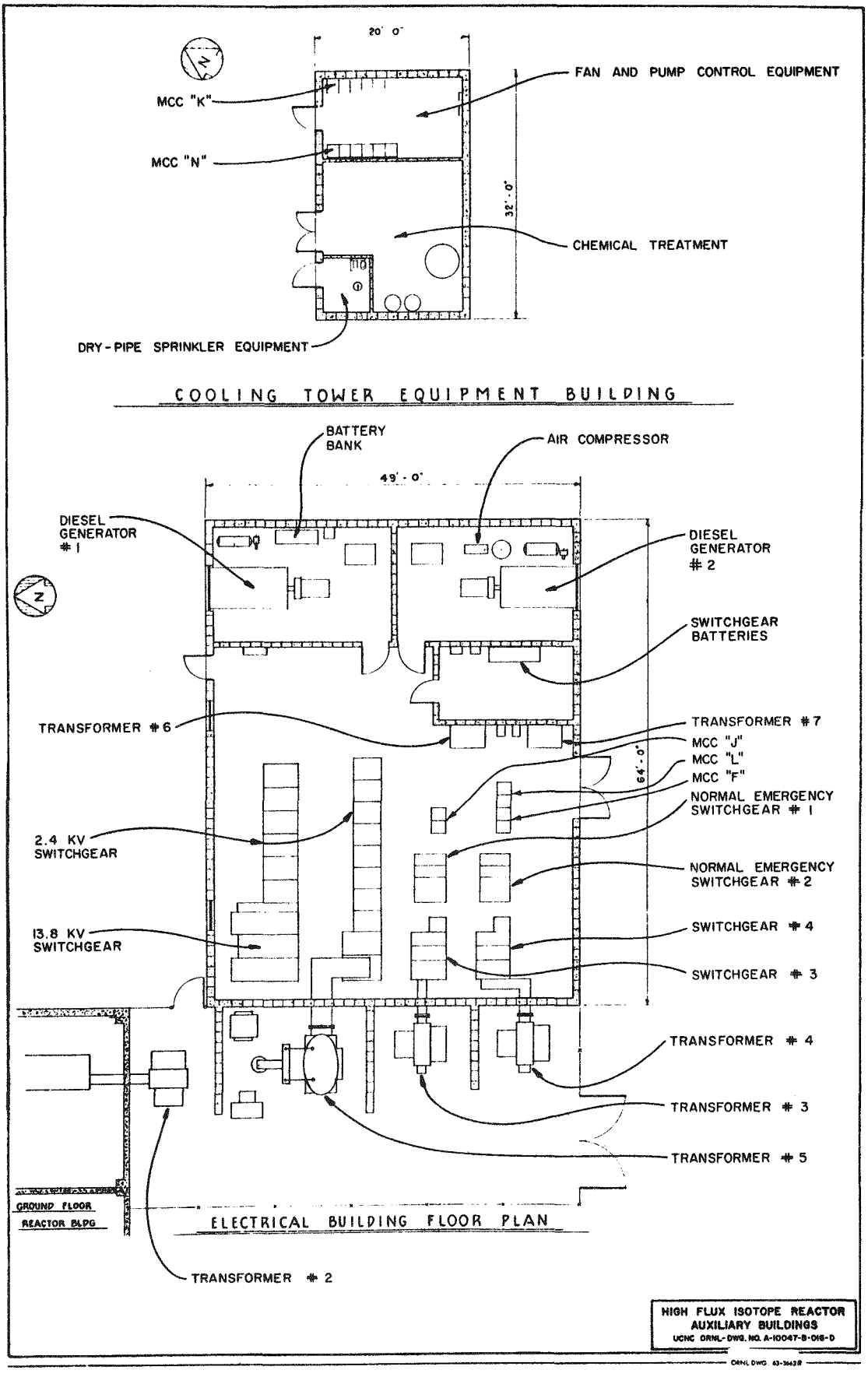

Fig. 10.11. Electrical Equipment

3. Electrical building (Figure 10.11).

A separate electrical building, located just southeast of the main reactor building, houses the 13.8-kv switchgear, the 2400-v switchgear, the 460-v switchgear, the two diesel-generators and the normal-emergency switchgear. This centralization of major electrical components simplifies operation and maintenance.

Normal-Emergency Power System.--Power for essential equipment and emergency lighting can be provided by either the normal-power supply or the emergency diesel-generators. The switchgear, generators, and associated equipment required to effect transfers between the two power sources are called the normal-emergency power system. Two independent diesel-generators increase the reliability of the emergency-power supply. Power supply to critical equipment, which already has an installed spare, is split between the two generators to protect against failure of one of the diesels to start. All normal-emergency circuits are supplied from the normal-emergency switchgear located in the electrical building. This switchgear is normally supplied by a 460-v feeder from a load center transformer, but, in the event of a supply failure, the load is automatically transferred to the diesel-generators.

1. Sequence of operation (Figures 10.12 and 10.13).

In normal operation both normal-emergency switchgear No. 1 and No. 2 are energized from the HFIR primary feeder. The diesel-generators are not running, but their main breakers are closed. In the event of a sustained normal-power supply failure of approximately two seconds duration, auxiliary contacts in the automatic transfer switches start the diesels as follows:

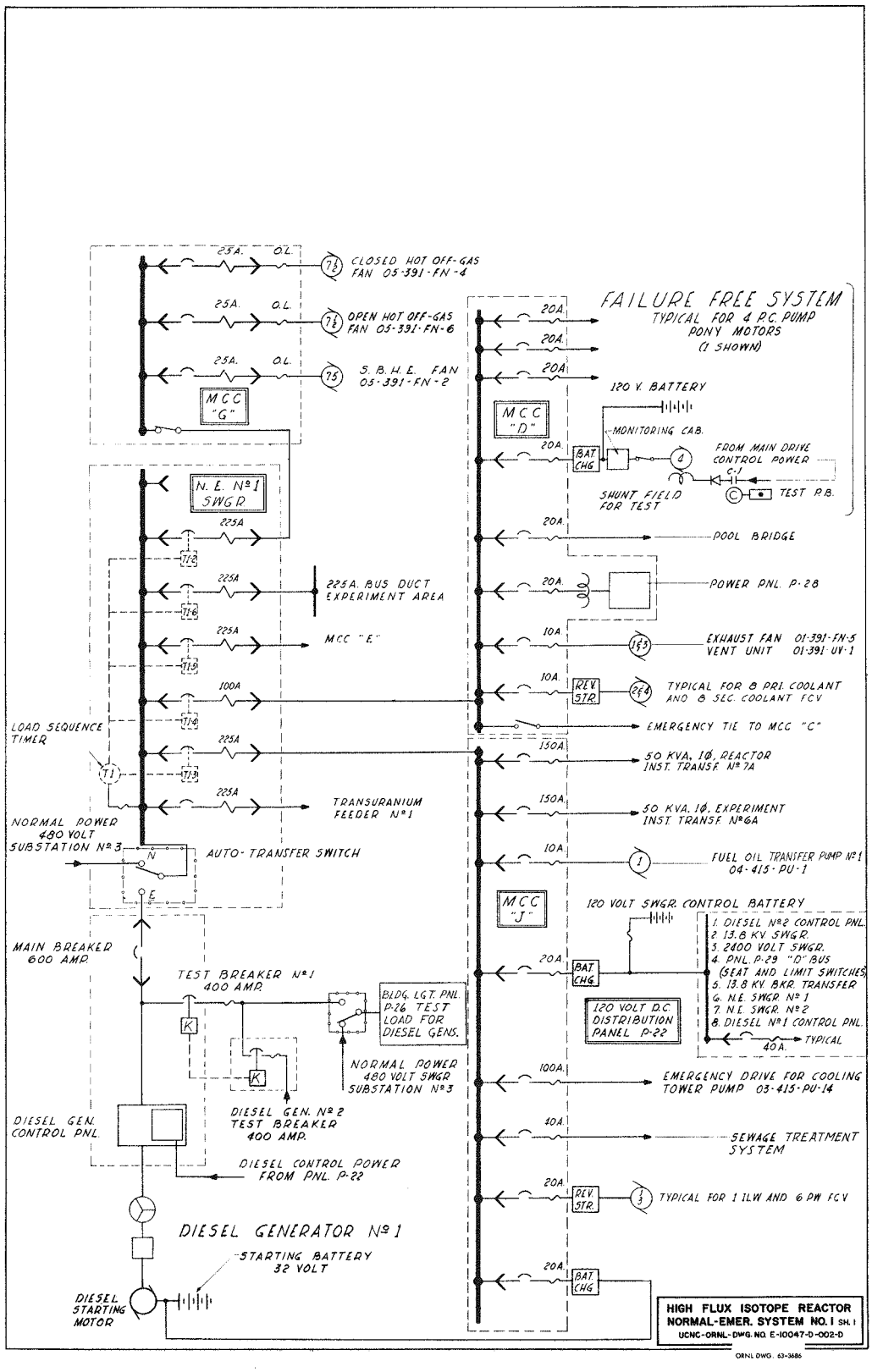

Fig. 10.12. Normal-Emergency System No. 1.

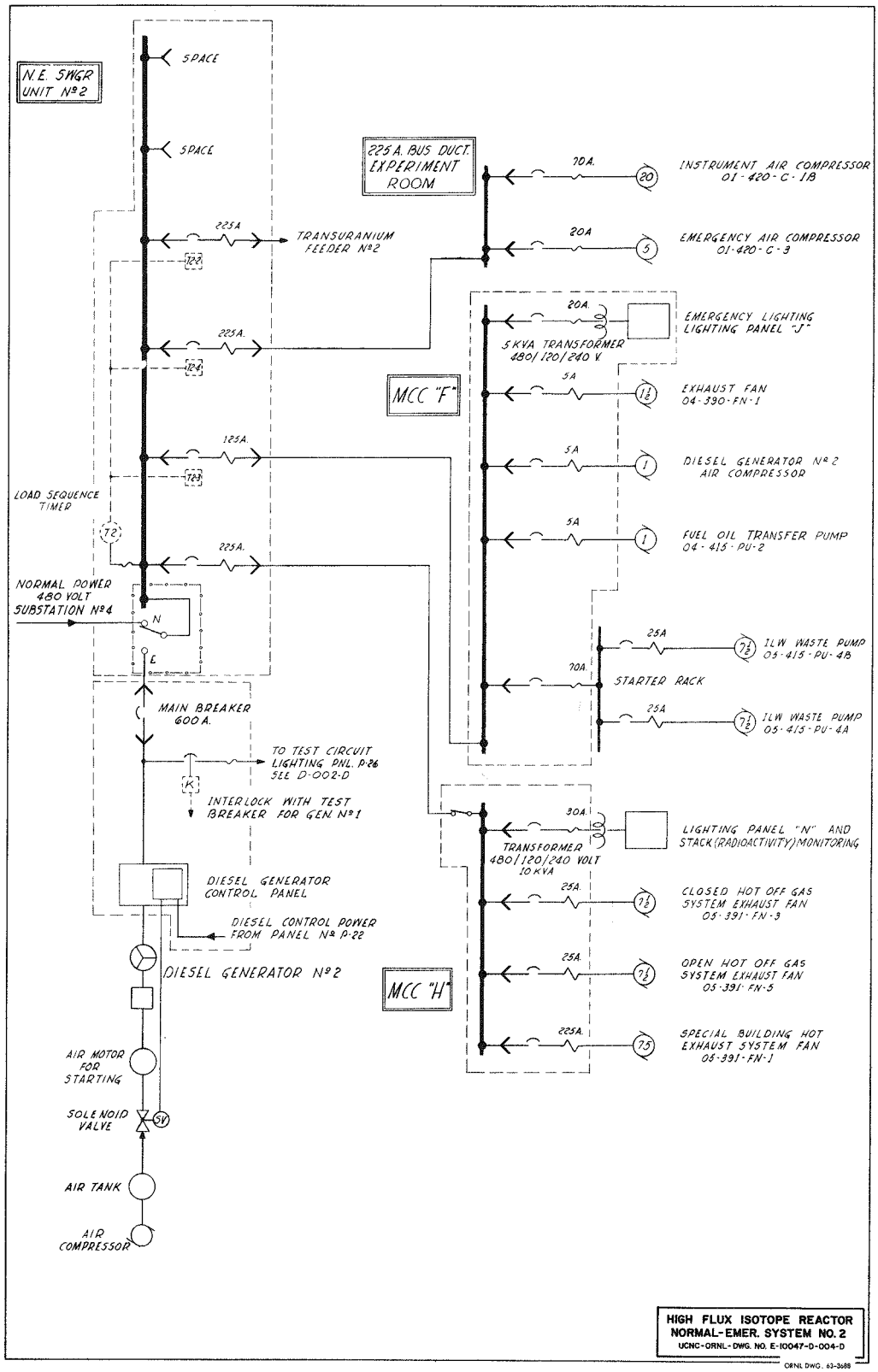

Fig. 10.13. Normal-Emergency System No. 2.

a. The normal-emergency system No. 1 will:

(1) Energize the diesel engine startup relay to crank the engine.

(2) Trip all of the circuit breakers in the normal-emergency switchgear No. 1.

(3) Apply a trip impulse to the diesel test loading circuit breaker.

(4) Crank the diesel in the following cranking cycle--"crank for 15 seconds--wait 15 seconds--crank for 15 seconds--wait 15 seconds--crank for 15 seconds--stop".

b. The normal-emergency system No. 2 will:

(1) De-energize the solenoid coils to open the valves suppling air to the air motor. Two paralleled valves are provided so that opening either one will permit sufficient air flow to start the diesel.

(2) Trip all circuit breakers in normal-emergency switchgear No. 2, except the feeder breaker to MCC "H".

(3) Apply a trip impulse to the diesel test loading circuit breaker.

(4) Allow compressed air to flow from the reservoir to the air motor until either the supply of air has been exhausted or the diesel starts.

When the diesel-generator is delivering approximately 90% of its rated voltage, the automatic transfer switch transfers to the emergency position, thereby transferring the first block of load

onto the diesel-generator. Two auxiliary contacts which close when the transfer switch is in the emergency position are located in switchgear No. 1 for starting the auxiliary pressurizer pump motor, PU-11, and the slow speed winding of the auxiliary secondary water pump motor, PU-14. A timer in each normal-emergency switchgear controls the closing of the remaining 460-v breakers. The breakers close in sequence so that the load is added to the generator in suitable increments.

A test load, which consists of the reactor building lighting system, can be added to the diesel-generators. This loads the generators to approximately 30% of their rated load for maintenance and test purposes without interrupting the normal-emergency distribution system. The test circuit is designed so that either of the generators can be connected to the reactor building lighting load. In the event of a normal-power failure during the testing operation, the test load is automatically disconnected from the generator. Interlocks permit the test load to be connected to only one generator at a time.

2. Diesel-generator units.

   a. Diesel engines.

      The diesel engines are four cycle, turbo-charged, aftercooled, and designed for operation on No. 2 fuel oil. Each engine is capable of driving its generator with 350-kw generator output continuously and 400-kw generator output on an intermittent basis for a period of two hours. Engine cooling is provided by a water cooled radiator, circulating system, and fan. A

jacket water heater and thermostat maintain cooling water temperature at 90°F when the unit is not in service. Two methods of starting the engines are employed to add starting reliability. The starting and fuel oil supply systems are as follows:

(1) Unit No. 1.

Diesel-engine No. 1 is supplied with two 32-v dc starting motors, one on each side of the diesel. An electrically operated contactor to carry the high dc breakaway current is mounted near each motor. The motors are suitable for operation over a range from 20-v to 36-v dc. A 24-cell nickel cadmium battery system supplies power for the starting motors. A constant voltage battery charger, with silicon rectifying elements, keeps the batteries fully charged.

(2) Unit No. 2,

Diesel-engine No. 2 is equipped with an air-motor starter, complete with a drive assembly, silencer, pressure regulator, and vapor arrestor. The air motor is designed for operation over a range of 90 to 150 psi. The pressure regulator reduces the inlet pressure from a maximum of 250 psi to 90-100 psi at the air-motor inlet. An air receiver is provided with sufficient capacity for five air starts of approximately five seconds duration each. The air receiver is provided with a drain cock, a pressure gauge, and pressure switches for automatically starting and stopping the air compressor.

The air compressor charges the air receiver tank. The compressor will pressurize the air receiver to 250 psi within 30 minutes, starting with atmospheric pressure in the air receiver. A safety valve is set at 300 psi to protect the pressure system.

(3) Fuel oil storage.

The fuel oil supply system for the emergency diesel generators includes a 4000-gal fuel oil storage tank, individual 60-gal day tanks for each unit and associated pumps and piping required for oil transfers. The 4000-gal supply tank is located underground immediately south of the electrical building. Oil is pumped from the supply tank to the day tanks by either of two 60 gph pumps located at the day tanks in the electrical building. Fuel oil feeds from the day tanks to the diesel engines by gravity. The transfer pumps are powered by the normal-emergency system. They are automatically started and stopped by level controls on the day tanks. The pumps, day tanks and diesels are interconnected with piping to provide a positive supply of fuel oil to both engines in the event of failure of one pump.

b. Generators.

The generators are each rated at 350 kw, 0.8 power factor, 437 kva, 6 pole, 1200 rpm, 60 cycle, 3 phase wye with the midpoint of the wye ungrounded. They are capable of supplying 110% of their rated load for two hours without injurious

ORNL DWG. 63-3709

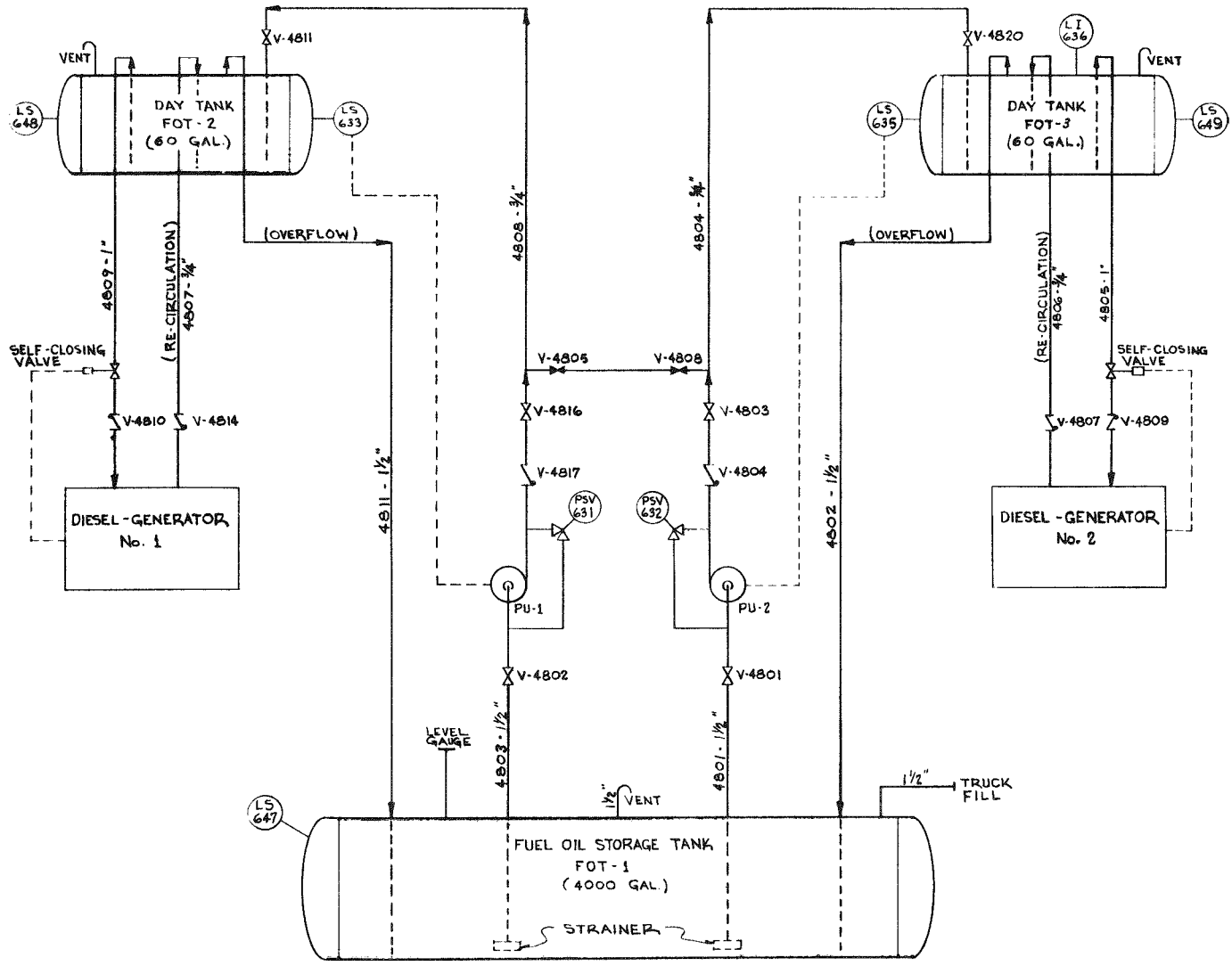

Fig. 10.14. Schematic Flow Diagram-Fuel Oil Storage & Distribution.

overheating. Each generator unit contains an integrally mounted static exciter, regulator, and control panel which provide a steady state voltage regulation of ± 2% of the rated voltage. The excitation system consists of a static exciter and static voltage regulator mounted on the generator. The excitation system self-excites the alternator from the output of the generator via a saturable core reactor and full wave rectifier circuit. Voltage regulation is obtained by sensing the three phase output voltages, comparing them with a constant reference voltage and then applying the error signal to the saturable reactor to correct the generator output voltage. A current forcing circuit forces the field in order to minimize voltage dips on low power factor load swings. Generator field rectifiers are the low loss silicon type.

3. Automatic-transfer switches.

The automatic transfer switches are 3 pole, rated 480 v, 600 amperes, mechanically held for operation on 3-phase, 3-wire, 60-cycle normal and emergency sources. Load circuits are transferred to the diesel-generators when any phase voltage of the normal power source drops below 70% of normal for a sustained period of approximately two seconds. Load transfer does not occur until the emergency generator is producing at least 90% of its rated voltage (a frequency relay is used to control the load transfer). Upon restoration of the normal-power supply for approximately one minute, the transfer switch returns the load to the normal source. The transfer switches are the double throw

type operated by a single coil mechanism momentarily energized. Each switch is interlocked mechanically and electrically. Operating current for transfer is obtained from the same source as that to which the load is to be transferred. Switch design and construction does not permit a neutral position even if the transfer coil fails. The switch is positively locked mechanically in either position. Each transfer switch is provided with the following accessories and devices:

a. A key operated test switch, to simulate a normal source voltage failure, mounted on the front panel of the transfer switch.

b. Two red indicating lights on the front panel to indicate the position of the transfer switch (normal position--emergency position). The lights are operated by auxiliary contacts which operate in synchronism with the main power contacts of the transfer switch.

c. Eight auxiliary contacts for starting the diesel engines and tripping the test and normal-emergency circuit breakers on loss of normal power. Contacts close after a two second delay period.

d. Two auxiliary contacts for starting emergency pumps when the automatic transfer switch is in the emergency position.

4. Automatic transfer switch for diesel-generator test loading circuit. The test loading automatic transfer switch is 3 pole, 600 v, 300 ampere, mechanically held for operation on 3-phase, 3-wire, 480-v, 60-cycle normal and emergency sources. The

diesel-generator is connected to the "normal" terminals of the switch via its test breaker and the normal-power supply to the "emergency" terminals. In normal operation the diesel-generator test breaker is open and the transfer switch is in its "emergency" position. When it is desired to load the diesel, the generator is put into operation and the test breaker closed, thereby energizing the "normal" terminals of the transfer switch and causing it to throw over. The switch transfers its load from normal to emergency and from emergency to normal upon a loss of voltage (single phase detection only) without time delay. The transfer switch is a double throw switch operated by a momentarily energized single coil mechanism. The switch is interlocked mechanically and electrically. Operating current for transfer is obtained from the same source as that to which the load is being transferred. The transfer switch is provided with the following accessories:

a. Test switch to simulate a normal voltage failure.

b. Two red indicating lights on the front panel to indicate the position of the transfer switch (Normal position--Emergency position).

Fail-free Systems.--An ultra-reliable uninterrupted power supply is required for certain critical loads in the HFIR complex. Continuous power is required to these circuits to protect the reactor and personnel from harm. Uninterrupted power supplies are provided by battery banks which are continuously charged by the normal-emergency power system. The batteries provide limited, but adequate, power for safely shutting the

reactor down in the event of a complete failure of the normal and normal-emergency supply systems. The fail-free systems are:

1. Pony-motor drive system.

   A positive coolant flow must be maintained through the reactor core for one hour after shutdown to remove afterheat. The function of the pony motors is to provide sufficient coolant flow to remove this afterheat in the event of a normal-power failure (the circulating pump main drive motors are too large to be supplied by the normal-emergency system). Emergency coolant flow is obtained by the dc pony motors which are directly coupled to the main pump drive motors. The pony motors are energized whenever the reactor is in operation. Each pony motor is supplied from a battery bank and battery charger in parallel. Each battery bank provides 125-v (nominal) power from 92-cell, nickel cadmium alkaline pocket plate type batteries. Battery chargers are constant voltage type with silicon diodes rated to supply 50 amperes continuously at 129-v dc. They are sized to carry the full load current of the dc motors plus sufficient capacity to completely recharge the storage batteries in approximately 12 hours. The pony-motor batteries, battery chargers, and metering equipment are located in battery room G-13 on the 817-ft level of the reactor building.

2. Instrument dc system.

   The shielded transformer for general reactor instrumentation loads also supplies three separate dc instrument buses. Each instrument bus is also supplied by two 32-v battery banks in

series with a center tap to form a 3-wire, 32/64-v system with individual battery chargers serving each bank. The batteries act to smooth the voltage during transient disturbances on the ac line. Three sets of batteries are provided to be consistent with the "two out of three coincidence" circuit philosophy. The battery bank for each bus is a 64-v (nominal) center tapped, 48-cell, nickel cadmium alkaline pocket plate type. Each of the six battery chargers is a constant voltage type with silicon diodes rated to supply 50 amperes continuously at 32-v ac.

3. Switchgear, ac system.

An independent power supply system is required at the electrical building to operate the normal-emergency and 13.8-kv switchgear closing and tripping breakers, diesel-generator No. 2 control circuits and certain reactor control circuits during a normal-power failure. These transfer switches and control circuits must function during a normal-power failure, so they are powered by a battery bank which is floated on the line by a battery charger. The battery bank supplies 125-volts (nominal) from 92 nickel cadmium alkaline pocket plate cells in sealed plastic containers. The battery charger is a constant voltage type with silicon diodes which can supply 12 amperes continuously at 129-v.

Instrument-Power System.--Instrument power is obtained from the 13.8-kv switching station through a fused interruptor switch. The 13.8-kv feeder supplies two 13.8-kv–120/240-v single phase transformers. One transformer supplies the nuclear reactor instrumentation loads and plate control drive mechanisms. The second transformer supplies instrument

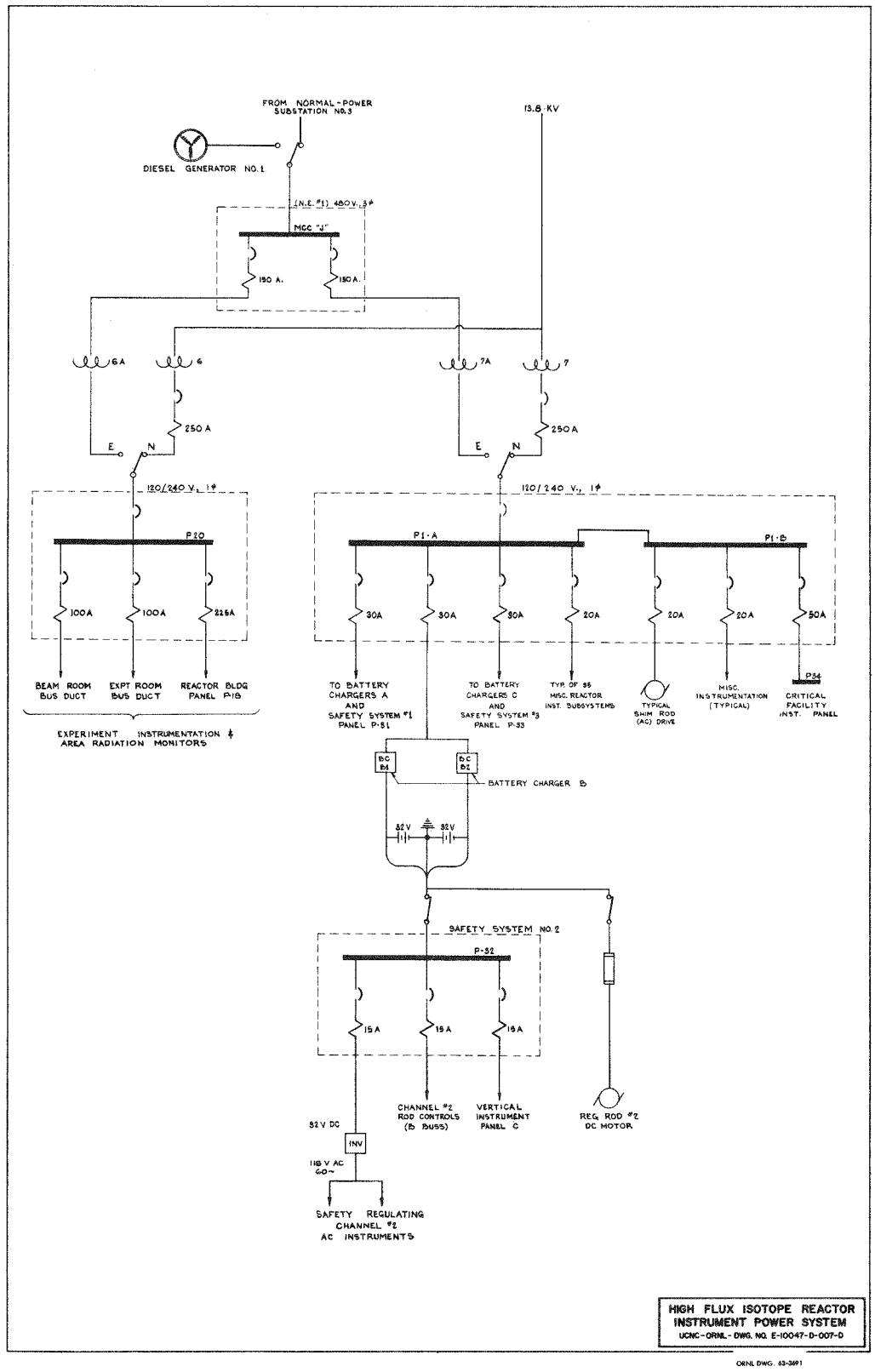

Fig. 10.15. Instrument Power System.

power for experiment loads. In the event of a 13.8-kv or instrument-power transformer failure, the instrument-power load is automatically transferred to the normal-emergency bus by automatic transfer switches and feeds through auxiliary 460--120/240-v transformers. Return to the instrument power transformer is automatic upon restoration of normal power for a period of one minute.

1. Instrument-power transformers.

   The main instrument power transformers are each rated at 50 kva, 13.8 kv--12/240 v, single phase, 60 cycles. Transformer secondary windings are electrostatically shielded from the primary by means of a copper shield. They are filled with non-flammable liquid and have 95-kv basic impulse level with two 2-1/2% full capacity taps above and below normal on the primary winding. Auxiliary instrument power transformers are rated at 50 kva, 460--120/240 v, single phase, 60 cycles. The standby transformers are of standard non-shielded design.

2. Automatic transfer switches.

   The automatic transfer switches are 3 pole, 600 v, 300 amperes, mechanically held for operation on single phase, 3-wire, 120/240-v, 60-cycle normal and emergency sources. Load circuits are transferred to the emergency source when phase voltage of the normal source drops below 70% for a sustained period of approximately two seconds. Upon restoration of normal source voltage for approximately one minute, the transfer switch automatically returns the load to the normal source. The transfer switch is a double throw switch operated by a momentarily energized single

coil mechanism. The switch is interlocked mechanically and electrically. Operating current for transfer is obtained from the same source as that to which the load is being transferred. Each transfer switch is provided with the following accessories.

a. A test switch to simulate normal source voltage failure.

b. Two red indicating lights mounted on the front panel to indicate transfer switch position (normal position--emergency position). The lights are operated by auxiliary contacts which operate in synchronism with the main power contacts of the transfer switch and are supplied from its load side.

10.8d. Normal-Power Outage

The HFIR is designed to operate at a reduced reactor power level during a normal-power failure. Two 13.8-kv aerial feeders supply normal power to the HFIR complex. A failure in one feeder between the ORNL 13.8-kv switching station and the HFIR does not constitute a power failure since automatic transfer switches are capable of transferring the load to the remaining circuit. Therefore, a normal-power outage must occur at or beyond the ORNL switching station to affect the HFIR. If such a failure occurs while the reactor is at power, the various systems respond as follows:

Reactor Control System.-- The reactor servo control system tries to maintain a constant flux to flow ratio. During steady state operation, the value of this ratio is a function of the power level requested by the operator. If the main circulating pumps stop, as will be the case during a power failure, the primary coolant flowwill be reduced to approximately 10% of its normal value. This 10% flow will be maintained by battery

driven pony motors. As the primary coolant flow coasts down from 100% to 10%, the servo control system will reduce reactor power to maintain a constant flux to flow ratio. Therefore, if the reactor were originally at full power or 100 Mw, the power would be automatically reduced to 10 Mw following a normal-power outage. All reactor control circuits, shim-plate magnets, and other instruments operate on battery supplied dc power so they are not affected immediately by an ac power outage. Operation of the four outer shim plates and inner shim cylinder main drive depends upon ac motors so if the power outage persists more than a few minutes and the No. 1 diesel generator does not start, the reactor will be shut down by xenon poisoning when the regulating cylinder reaches the end of its servo controlled stroke.

Primary Coolant Loop.-- The primary circulating pump motors operate on 2400-v ac. They will stop during a normal-power outage. Small battery driven pony motors are connected to the shafts of the primary motors. Pony motors are energized and are trying to turn the circulating pumps whenever the reactor is at power. When the ac motors stop, the pump speed decreases until the pony motors are able to carry the load. At this reduced speed the pumping rate is reduced to about 10% of the full speed value. The battery supplied pony motors are able to maintain this pumping rate for several hours. When the No. 1 diesel-generator starts, the pony motors will operate indefinitely because the battery chargers are supplied with this emergency power.

Pressure must be maintained in the primary coolant loop. Loss of ac power stops the main pressurizer pumps; and, even though analog studies of the response of the pressure regulators and letdown valves

indicate that the valves will close fast enough to prevent loss of pressure on a power failure, leakage from the high pressure system could be a problem. When the No. 1 diesel-generator starts, power is supplied to a 400-gph auxiliary pressurizer pump. This pump helps to maintain system pressure, provided leaks do not exceed the capacity of the pump. If primary coolant loop pressure falls below 325 psi, the reactor will scram.

Secondary Coolant Loop.-- The large cooling tower circulating pump motors and fan motors will stop upon loss of ac power. Cooling water will be supplied to the primary heat exchangers when the No. 1 diesel-generator starts. When this emergency generator starts, it will supply power to the emergency secondary water pump circulating approximately 3000 gpm (about 10% of the normal rate) through the secondary coolant system. However, the water is drawn from the front and returned to the back side of the tower basin. It is not passed over the tower and is not cooled. The large tower basin reservoir holds about 400,000 gallons of cool water, enough for sustained reactor operation at 10 Mw.

Emergency-Power Supply.-- There are two independent emergency diesel-generators which should start upon loss of normal-power to the HFIR complex. These two generators feed two separate emergency distribution systems. The No. 1 diesel-generator supplies all the critical loads. A few systems which have duplicate components, such as the stack exhaust fans and instrument air compressors, are supplied from both diesel generators. Operation of the reactor during a normal-power failure is dependent upon the No. 1 diesel-generator starting. The No. 2 diesel-generator provides back-up power for the building containment.

Building Exhaust System.--Three exhaust fans are normally operating at the fan shed when the reactor is at power. These are one SBHE blower, one OHOG blower, and one CHOG blower. These three fans have identical standby units which start automatically upon failure of the operating unit. The normal-emergency power distribution systems are arranged so that one group of these fans is supplied by diesel-generator No. 1 during a normal-power outage and the other group is supplied by diesel-generator No. 2. This ensures building ventilation and off-gas during an ac failure if either diesel-generator starts.

Primary Cleanup System.--Since the main pressurizer pumps do not operate during a normal-power outage, a large volume of high pressure water will not be letdown to the cleanup loop. The cleanup loop circulation pumps are also inoperative, therefore, the loop is automatically shut down. The deaerator vessel provides sufficient volume to store possible valve leakage and other minor sources of primary water until normal power is restored.

Pool Coolant and Cleanup Systems.--Neither the pool coolant pumps nor the pool cleanup loop pumps are supplied with emergency power. Therefore, both of these loops are inoperative during a normal-power failure. It should be noted that the pool water temperature will increase during this period. If the power outage persists for as long as three days, it may be necessary to institute purge and fill operations since the pool water temperature might approach 180-200°F. The maximum temperature reached after a coolant circulation failure is dependent upon the inventory of spent fuel elements stored in the pool, but under the worst conditions should not exceed 200°F.

Instrument-Air System.--Instrument air is essential for reactor operation. Various critical components, such as computers in the reactor control system, air operated flow control valves, and transmitters for building containment monitors depend on instrument air. Therefore, there are three instrument air compressors to ensure a continuous supply. The two main compressors are on different emergency power circuits so that instrument air will be available if either diesel-generator starts. A small emergency air compressor is also connected to the No. 2 diesel-generator. This will supply a minimum amount of air if the main compressors become inoperable.

Potable and Process Water.--Potable water is furnished to the HFIR area from an elevated reservoir. Therefore, its supply is independent of electrical power for a limited period of time. The reservoir, which holds approximately 3,000,000 gallons, is large enough to permit operation at low power for an extended time.

Process water is supplied to the area from the potable water system through an air gap vessel. However, process water pumps are required to pressurize the system after the air-gap vessel. These pumps are connected to the No. 1 emergency system which is supplied with power by the No. 1 diesel-generator.

Sewage Treatment Plant.--The various blowers, pumps, and comminutor of the sewage treatment plant are supplied with power by the No. 1 normal-emergency system. Operation during a normal-power outage is dependent upon operation of the No. 1 diesel-generator.

10.9 Communications Systems

10.9a. References

Drawings:

1546-05-E-2085 - Block Diagram, Intercom System

Singmaster and Breyer Specifications:

107 Electrical Work, Intercome System

10.9b. Intercom System

The intercom system provides a convenient method of communication between persons in different areas of the HFIR site. The system consists of master stations, staff stations, and all required amplifiers, power supplies, and connecting wires.

Master Stations.--The master units are designed to selectively originate calls to other master or staff stations by depressing the proper buttons. The circuits are designed so that it is possible to hold a conference between masters. A master is capable of conferring with more than one staff station simultaneously since each is provided with built-in extra power for this purpose. Each master station is provided with a cradle phone which, when removed from its rest, automatically disconnects the loudspeaker within the master station and directs all incoming and outgoing voices through the phone only. (The loudspeaker for master station No. 1 is mounted separately on the reactor console.) Electrical power is supplied from normal-emergency system No. 1.

A two-position switch marked "Master #1-Master #2" is mounted on the reactor console. In the "Master #1" position, all incoming calls from staff stations go to master station No. 1. In the "Master #2" position, calls from the staff stations are transferred to master station No. 2.

Master stations are located in the main control room (No. 1), in the supervisor's office (No. 2), and in the office and maintenance building (No. 3).

Staff Station.--The staff stations are designed to reply to all master stations in the system but are capable of originating calls to master station No. 1 only (except when the "Master #1-Master #2" switch is in the "Master #2" position). Each staff station has a volume control and a "Talk--Listen" button. Certain staff stations, which are located in noisy areas, are equipped with cradle phones to make listening easier.

Number	Locations of Staff Stations
4	Auxiliary control room (column C-4)
5	Reactor bay (column C-7)
6	Reactor bay (column E-5)
7	Reactor bay (column F-8)
8	Reactor bay (column D-8)
9*	Experiment area (column D-9)
10*	Experiment area (column B-7)
11*	First floor pipe corridor (room 103-D)
12*	First floor water wing (column E-3)
13*	Beam room (column C-9)

*Indicates cradle phone.

Locations of Staff Stations

Number	
14*	Beam room (column B-6)
15*	Ground floor water wing (column E-2)
16*	Ground floor pipe corridor (room G-5)
17	Subpile room
18	Electrical equipment building
19	Cooling tower equipment building (chemical treatment room)
20	Fan shed

*Indicates cradle phone.

10.9c. Sound-Powered Telephone System

The sound-powered phone system consists of two, 2-conductor cables (circuit A and circuit B), plug-in jacks, and telephones. The system is provided for emergency communication and for use in high-noise areas or infrequent-usage areas not appropriate for the intercom system.

Locations of Sound-Powered Phone Jacks

Main control room	column B-4
Main control room	column C-3
Main control room	at reactor console
Auxiliary control room	column B-4
Auxiliary control room	column C-4
Auxiliary control room	column D-9
Auxiliary control room	column C-3
Reactor bay	column C-7

Reactor bay	column E-5
Reactor bay	column F-8
Reactor bay	column D-8
Experiment area	column F-8
Experiment area	column D-9
Experiment area	column B-7
Experiment area	monitoring platform (2 locations)
Heat-exchanger cells	one in each of four cells
First floor water wing	column D-4
First floor water wing	column E-3
Electrical equipment room (room 102)	column D-2
H & V equipment room	column B-3
Cooling tower equipment building	chemical treatment room
Cooling tower equipment building	electrical equipment room
Electrical building	main room
Electrical equipment room (room G-12)	column G-9
Subpile room	
Beam room	column C-9
Beam room	column B-6
Ground floor water wing	column B-2
Ground floor water wing	column E-2
Staff shop	column B-3
Fan shed	
Ground floor pipe corridor	

10.9d. Dial Phones

Dial phones are provided in the offices and at such experiment stations as may be needed. The control-room phone has an unlisted number to keep the phone free of unnecessary calls. On night shifts and weekends, calls to the HFIR offices are transferred to the reactor control room.

10.9e. Public-Address System

Public-address system microphones are located in the main control room, in the supervisor's office, and in the office and maintenance building. Public-address system speakers are located in each of the major areas inside the buildings in addition to several outside the buildings which adequately cover the immediate HFIR area.

Two amplifiers are used for the system--one is on standby; the other is in operation. The two amplifiers are supplied power from separate normal-emergency systems.

Locations of Public-Address Speakers

Area Location	Number of Speakers
Subpile room	1
Ground floor	11
First floor	20
Second floor	14
Third floor	7
Fan shed and stack	2
Outside northeast corner of reactor building	1
Outside west side of reactor building	1
Outside south side of reactor building	1
Electrical building	1

Area Location	Number of Speakers
Cooling tower	2
Cooling tower equipment building	1
Outside north side of office and maintenance building	1

11. RADIATION SAFETY AND CONTROL

11.1. Introduction

It is the policy of the Operations Division, Reactor Operations Department to:

1. Carry out all operations with the lowest reasonable personnel exposure to radiation and contamination. In no case shall internal and external exposures exceed the recommendations of the Federal Research Council and the National Committee on Radiation Protection.
2. Perform all work in such a manner that losses resulting from contamination are minimized. Such losses may include research, development, and production time; facility and/or equipment abandonment; and the cost of cleaning up contamination.
3. Maintain environmental contamination of a level as low as is consistent with sound operating practice.

11.2. Responsibilities

Since, according to Laboratory policy, the primary responsibility for radiation safety rests on the Division supervision, Health Physics functions must be regarded as purely advisory. Though Health Physics personnel are alert to radiation hazards and do report them, they do not assume the primary responsibility which is assigned to the Divisions. Only the Division is assumed to be familiar enough with its own operations to evaluate the hazards involved; however, Health Physics personnel's advice on radiation and contamination control is sought when deemed necessary. It is therefore the responsibility of supervision to:

1. See that all areas are surveyed for radiation as required.
2. Establish appropriate boundaries and portals for zoned areas.
3. Assist Health Physics in the posting of zone signs with up-to-date instructions.
4. Provide suitable clothing change stations for personnel working in contamination zones, with provision for storage of personal effects if needed.
5. Provide a supply of required contamination zone clothing and equipment.
6. Establish eating places as required and in accordance with Health Physics specifications.

Health Physics provides personnel monitoring, building and area surveys, exposure and survey records, consultation, and other services as required.

11.3. Exposure Limits

The permissible occupational dose for an individual is that dose, accumulated over a long period of time or resulting from a single exposure, which carries a negligible probability of severe somatic or genetic injuries.

11.3a. Maximum Permissible Dose--Normal Conditions

The values indicated in the following tables are maximum values and only in exceptional cases should the accumulated RBE dose be permitted to exceed 10 percent of the values given.

Table 11.1. Maximum Permissible Dose (MPD) in Rems

Organ	MPD in any 13 week period (rems/13 wks)	MPD per year	MPD Age Proration total (N = present age)
Total body, head and trunk, lens of eyes, gonads, or blood forming organs	3	12	5(N-18)
Skin of whole body, thyroid	8	30	30(N-18)
Hands and forearms, feet and ankles	20	75	75(N-18)
Bone	$30/4n^*$	$30/n^*$	$(30/n)(N-18)^*$
Other single organs	4	15	15(N-18)

*This n is referred to as the "relative damage factor". It is one for radium isotopes and for gamma radiation, otherwise it is set equal to five for all radionuclides in bone.

Table 11.2. Weekly Maximum Exposure Limits Recommendations

Organ	Weekly Maximum Recommended Limit* (External)
Total body, head and trunk, lens of eyes, gonads or blood-forming organs	100 mrems
Skin of the whole body	600 mrems
Hands and forearms, feet and ankles	1,500 mrems

*Laboratory-wide standards.

The reactor Operations Department limits are 50 mrems/week on whole body doses, to fully insure compliance with Laboratory standards with the other limits correspondingly cut in half.

Table 11.3. Approval Required for Exposure to High Dose Rates

Dose Rate Range (rem/hr)	Special Approvals Required		
	Area Division Director	Health Physics Division Director	Deputy Laboratory Director
5-20	X		
20-50	X	X	
Over 50	X	X	X

In addition, when planned doses exceed the weekly limits, the following approvals are required:

Authorized Dose Accumulation (Total Body)	Special Approvals Required
> 60 mrem per single day to non-operating personnel, and/or >300 mrem per single week to operating personnel.	Division Director in charge of individual
> 1 rem per single exposure	Division Director in charge of individual and Deputy Laboratory Director.

11.3b. Maximum Permissible Dose--Emergency Conditions

The emergency conditions which justify the maximum permissible dose are:

1. When another person's life may be saved.
2. When large-scale releases of radioactive material (dust, gas or liquid) that may endanger other peoples' lives or health may be averted.
3. When considerable damage to a facility may be averted.

It is obvious that, if sufficient time exists, the Health Physicist should be consulted and an acceptable technique for a planned dose should be followed.

The Laboratory acceptable emergency dose to persons regularly sustaining measurable exposures is 10 rem. For all others it is 25 rem.

11.4. Zoning Requirements

11.4a. Radiation Zone

A radiation zone is an area where control measures are established to prevent or minimize external radiation exposure.

Table 11.4. Regulations for Posting and Establishing Radiation Zones

Dose-Rate Range (Rems/hr)	Immediate Action	Follow-up Action
2.5 mrem/hr to 5.75 mrem/hr	Post low-level tag if the accumulated daily dose to personnel may be 20 mrem	Periodic review
6 mrem/hr to 1 rem/hr	Post warning signs or tags	Rope off the area if the accumulated weekly dose may be 1 rem.
1 rem/hr to 3 rem/hr	Post warning signs or tags Rope off area	Erect a barricade which provides absolute exclusion of personnel if the accumulated weekly dose in the area may be 12 rems. Lock or block the entrance.
>3 rem/hr	Post a guard until a temporary barricade has been erected. Lock and/or block entries.	

11.4b. Contamination Zone

A contamination zone is an area where control measures are established to prevent or minimize internal radiation exposure and the spread of the radioactive contaminant.

A contamination zone should be established when one or more of the following values is exceeded.

Type of Radiation	Air Contamination (μc/cc)	Direct Reading Surface Contamination	Transferrable Surface Contamination (d/m/100 cm^2)
Alpha*	2×10^{-12}	300d/m/100 cm^2	30
Beta-Gamma	3×10^{-10}	0.25 mrad/hr	1000

*The alpha surface contamination levels are maximum values and are derived primarily to serve as a guide where the contamination involves a small area such as a single room or cell. When the contamination is extensive and involves radionuclides such as plutonium or some other long lived emitter of comparable toxicity, the alpha levels permitted should average no more than 1/10 of the above values.

11.4c. Regulated Zone

A regulated zone is an area where operations are restricted in order to control contamination. This zone may contain radiation zones, contamination zones, or both, ranging in size from a small spot to a large area.

11.4d. General Entry Requirements

Radiation Zones.-- Operating personnel doing routine jobs should always carry their film badges, pocket pencil meters and personal radiation monitors. Other items such as Health Physics surveys, monitoring instruments and direct-reading dosimeters may be required.

Contamination Zones.-- In addition to film badges, pocket pencil meters and personal radiation monitors, operating personnel should wear "C" clothing (coveralls or lab coats), gloves and shoe covers. Other items which may be necessary are:

cap,

assault mask, for air contamination,

survey instruments,

paper towels or smear papers,

direct-reading dosimeters,

Health Physics survey,

Constant Air Monitor.

In situations where gross contamination is known or may be expected, two pairs of coveralls should be worn; the outer pair should be removed immediately upon leaving the "C" zone to prevent spreading the contamination. In all cases, persons and equipment leaving a "C" zone must be monitored at the exit of the zone for contamination to prevent the spread of radioactive materials into places where people normally take no protective precautions.

Regulated Zone.--Persons entering the regulated zone from a contamination zone must be monitored for contamination.

11.5. Radiation Work Permits

The Radiation Work Permit (Example 11.1) is used in situations where personnel may be exposed to radiation or contamination in excess of certain limits. Operating personnel assigned to a particular process may not need a Radiation Work Permit for routine work where there are posted regulations. The Radiation Work Permit is required as follows:

1. For non-operating personnel.
2. Where specified by other procedures or special situations.
3. When an individual may receive greater than 20 mrems, whole body dose.
4. When radiation fields exceed 5 rems per hour.
5. When air contamination exceeds the maximum permissible concentration.

The Radiation Work Permit specifies the precautions and monitoring required, and provides a record of the necessary approvals and doses accumulated in doing the work. The Radiation Work Permit form is completed only by a qualified Health Physicist after a survey is made. The permit must be signed by the Health Physicist making the survey, by the craft foreman in charge of the job and by a member of the Reactor Operations supervision, usually the shift supervisor. Radiation Work Permits expire at the end of eight hours but may be extended for an additional eight hours by the Health Physicist.

RADIATION WORK PERMIT (RWP)

DATE AND TIME FROM ____ AM PM TO ____ AM PM | EXTENDED BY ____ TO ____ AM PM | WORK PERMIT NO. R 19001

LOCATION & JOB DESCRIPTION

RADIATION SURVEY DATA (To be filled in by Health Physics)

LOC. CODE	SPECIFIC LOCATION AND DISTANCE FROM SOURCE	TYPE OF RADIATION	mrem/hr.	WORKING TIME FOR ____ mrem	CONTAMINATION TYPE	CONTAMINATION MEASUREMENT	RADIATION SURVEY BY	RADIATION SURVEY DATE AND TIME
A								
B								
C								
D								

INSTRUCTIONS*

HEALTH PHYSICS MONITORING REQUIRED: ☐ START OF JOB ☐ INTERMITTENT ☐ CONTINUOUS ☐ END OF JOB

☐ CONTACT HP FOR SURVEY BEFORE STARTING WORK IN A NEW LOCATION	☐	☐ PROVIDE ASSISTANCE FOR REMOVAL OF PROTECTIVE CLOTHING	☐
☐ TAPE COVERALLS TO GLOVES AND FOOTWEAR	☐	☐ MONITOR BREATHING ZONE	☐
☐ CHECK TOOLS AT END OF JOB	☐	☐ NASAL SMEAR REQUIRED	☐
☐ CHECK PERSONNEL AT END OF JOB	☐	☐ BIOASSAY SAMPLE REQUIRED	☐
☐ TIMEKEEPING REQUIRED	☐	☐ DO NOT WORK ALONE - STANDBY OBSERVER REQUIRED	☐

REMARKS

PROTECTIVE EQUIPMENT AND MONITORING INSTRUMENTS

☐ CAP	☐	☐ COVERALLS (1 PR.)	☐	☐ SHOE COVERS	☐	☐ POCKET METERS	☐
☐ CANVAS HOOD	☐	☐ COVERALLS (2 PR.)	☐	☐ C-ZONE SHOES	☐	☐ DOSIMETER	☐
☐ SAFETY GLASSES	☐	GLOVES: ☐ CANVAS	☐	☐ RUBBERS	☐	☐ FILM RING	☐
☐ EYE SHIELD	☐	☐ LEATHER	☐	☐ RUBBER BOOTS	☐	☐ DOSE-RATE ALARM	☐
☐ HALF MASK	☐	☐ SURGEON'S	☐	☐ PLASTIC BOOTEES	☐	☐ DOSE ALARM	☐
☐ ASSAULT MASK	☐	☐ PLASTIC	☐	☐ LAB COAT	☐	☐ CUTIE PIE	☐
☐ CHEMOX MASK	☐	☐ RUBBERIZED CANVAS	☐	☐ SPECIAL FILM METER	☐	☐ GMS METER	☐
☐ AIR-LINE HOOD	☐	☐ HOUSEHOLD RUBBER	☐				
☐ AIR-LINE SUIT	☐						

REGULAR APPROVALS	SPECIAL APPROVALS
HEALTH PHYSICS CERTIFICATION	DIVISION DIRECTOR
SUPERVISION	H.P. DIVISION DIRECTOR
SUPERVISION	DEPUTY LAB DIRECTOR

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*Only items checked (√) apply.

(OVER)

Example 11.1.

11.6. Hazards Work Permit

A Hazards Work Permit (Example 11.2) is required where service personnel are exposed to environmental hazards arising out of work in an area, or on equipment, or with materials of which they do not have complete knowledge, and over which they do not exercise complete control. Situations requiring permits, but not limited to these are:

1. Any welding or burning operation.
2. Where ignition of flammable gases or liquids is possible.
3. Where release of toxic, corrosive, or highly reactive chemicals is possible.
4. Work to be performed in the presence of mechanical or physical hazards such as moving machinery, dangerous heights, high pressures, etc.
5. Any change in status of equipment, facilities, or system which would create additional hazards or eliminate any safeguards against hazards.

Hazards Work Permit forms must be completed by the craft foreman and signed by that foreman and by a member of the Reactor Operations Department supervision.

HAZARDS WORK PERMIT

ISSUED TO: FOREMAN OR REPRESENTATIVE				BADGE NUMBER		DEPARTMENT		PHONE NUMBER
FROM	SHIFT	DATE	TIME	TO	SHIFT	DATE	TIME	WORK ORDER NO.
LOCATION OF WORK	BUILDING NUMBER			FLOOR			ROOM NUMBER	

DESCRIPTION OF WORK

PRECAUTIONS TO BE TAKEN IN PREPARATION FOR WORK

GENERAL PREPARATION	YES	NOT APP'D	FIRE PREVENTION	YES	NOT APP'D
VALVES CLOSED AND TAGGED VALVE NUMBERS			TEST FOR FLAMMABLE VAPORS		
EQUIPMENT DRAINED AND CLEANED			IGNITION SOURCES REMOVED		
PIPELINES BLANKED			WELDING AND BURNING REQUIRED		
MOVING MACHINERY GUARDED			INSTRUCTIONS ON REVERSE SIDE COMPLIED WITH		
AREA ROPED OFF			WELDER'S NAME		
SPECIFY VESSELS VENTED			FIRE WATCHER'S NAME		
OTHER			OBSERVERS		

HEALTH			ELECTRICAL		
TEST FOR TOXIC MATERIAL			NON-ELECTRICAL PERSONNEL EXPOSED TO		
SPECIAL VENTILATION REQUIRED			ELECTRICAL HAZARDS*		
PROTECTIVE EQUIPMENT REQUIRED			CIRCUITS DEENERGIZED, TAGGED, LOCKED OUT		
☐ RESPIRATOR ☐ GLOVES ☐ EYE PROTECTION ☐ GAS MASK ☐ CLOTHING			SPECIFY		

OTHER PRECAUTIONS

I have personally inspected the work site and certify that the area is cleared for work and that conditions are safe for the work indicated.

SUPERVISOR REQUESTING WORK	PHONE NUMBER	ELECTRICAL DEPARTMENT FOREMAN*	PHONE NUMBER

PERMIT TERMINATION

WORK COMPLETED	PERMIT TERMINATED		WELDING AND BURNING	
	DATE	TIME	TIME STARTED	TIME FINISHED

SUPERVISOR REQUESTING WORK	MAINTENANCE FOREMAN

COMPLIANCE WITH C-5 (ON REVERSE SIDE)
CHECKED BY:

Distribution: Original given to Maintenance Foreman for display at work site. Duplicate retained by issuing supervisor. Upon termination of the permit, duplicate is completed and maintained for division file. The original is completed by the Maintenance Foreman and forwarded to the Safety Department (to the Fire Department when welding and burning has been performed).

* Approval of Electrical Department Foreman is required when personnel other than electricians will be exposed to electrical hazards.

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(SEE REVERSE SIDE FOR INSTRUCTIONS)

Example 11.2.

11.7. Health Physics Instrumentation

Each member of the operating group of the Reactor Operations Department should be able to monitor for each type of radiation and radioactive contamination using all the common instruments.

The following tables list the more commonly used instruments at ORNL and the pertinent data about each.

Table 11.5. Personnel Monitoring Instruments (Portable)

Instrument	Detector	Radiation Detected	Range	Application	Remarks
1. Film meter (badge)	Film, Au, In, S, silver phosphate glass, and chemical dosimeter.	γ, β N_f, N_{th}	0.1-10,000 rad	Permanent record of dose of each type of mixed radiation. Au and In activated by neutrons from criticality accident.	Film-density dependence on photon energy circumvented by filters. Orientation of film during exposure a problem.
2. Pocket Chamber (indirect reading) Victoreen Type	Ionization chamber (air)	γ	to 100 ± 5 mr, to 200 ± 10 mr	Measurement of day-to-day gamma exposure.	Relatively energy independent for γ. Read by minometer.
3. Pocket Chamber (Direct reading)	Ionization chamber (air)	γ N_{th} (when coated with boron enriched in B^{10})	to 200 mr; available with higher ranges	Visual check on gamma and, when modified, thermal neutron exposure.	Position of electrometer fiber read through magnifying lens.
4. Personal Radiation Monitor	G-M tube	γ, x high-level β	Maximum audible warning at 0.5 r/hr; flashing light becomes continuous at 10 r/hr	Visible (light) and audible warning of radiation field	Signal frequency proportional to radiation intensity. Available in higher rate ranges.

Table 11.6. Portable Survey Instruments
(Battery or Electrostatically Powered)

Instrument	Detector	Radiation Detected	Range (Nominal)	Application	Remarks
1. Cutie Pie	Ionization Chamber (air)	γ, x High-energy β	5 to 10,000 mrad/hr	Dose-rate meter for γ and x (0.008 to 2 Mev) within 10%. With ORNL chamber measures with at least 50% efficiency the externally hazardous betas.	Most widely used instrument for these measurements. A "soft-shell" instrument (ORNL chamber) is made by cutting away sections from the detector housing and replacing them with a thin film. Adjusted to "zero" position through grid bias potentiometer.
2. Geiger-Mueller Survey Meter (Thyac and Nuclear 2610)	G-M tube	$\beta > 0.2$ Mev, γ	Three scales: x1, x10, x100 x1 may be 600-800 counts/min full scale.	Detection instrument for $\beta > 0.2$ Mev and γ. Rate meter and audible pulse. Indicates approximate γ dose rates between 0.05 and 20 mr/hr.	Energy dependent. Should be used with earphones for faster response. Sliding shield for β-γ discrimination. Some models saturate above 50-100 mr/hr and will not indicate higher dose rates. Commercial instruments insensitive to low β energies, unless equipped with thin window counter.
3. Alpha Proportional Counter	Proportional counter (gas)	α	May detect as little as 50 d/min α in presence of	Analysis of mixed γ, β, and α radiation; discriminates between and β-γ.	More stable than air proportional counter. Reading not dependent on section of probe face receiv-

Table 11.6. (continued)

Instrument	Detector	Radiation Detected	Range (Nominal)	Application	Remarks
(gas) (PAC-3G)			1 rad/hr γ; range to 500,000 d/min.		ing radiation, as with scintillation counter. Grade or type of gas used should not be changed without recalibration.
4. Thermal Neutron Proportional Counter (Q-2004)	BF_3 enriched in B^{10}. Proportional counter, gas	N_{th}	20 to 20,000 N_t/cm^2 sec	Can disciminate against intense γ radiation (measure 200 N_{th}/cm^2 sec in field of 10 rad/hr γ).	Employs β^{10}+ N Li^7 + reaction.
5. Fast Neutron Proportional Counter (Rudolph)	Proportional Counter gas	N_f	0.1 to 100 mrad/hr	Measure first-collision tissue dose of N_f from 0.2 to 14 Mev. Discrimination a problem in γ fields above 2 r/hr.	Tissue-equivalent walls and gas.

Table 11.7. Area Monitoring Instruments

Instrument	Detector	Radiation Detected	Range	Application	Remarks
1. Continuous Beta-Gamma Air Monitor (Particulate)	G-M tube (shielded)	β, γ	Includes MPC level	Continuous recording of β-γ particulate radiation. Amber light and bell alarms for preset level.	Count-rate and strip-chart recorder incorporated. Does not distinguish between β and γ.
2. Monitron	Ionization chamber	γ if chamber is coated with carbon only, γ and N_{th} if coated with B^{10}-enriched boron.	To 125 mr/hr	Dose-rate meter for γ background monitoring-measures only the relative intensities of N_{th}. Required Ac power input. Several ion chambers can be placed 150 ft or more from control unit.	Zero setting should be checked daily. Should be operated only on high-sensitivity setting unless users are warned of low-sensitivity setting. Where background permits, alarm should sound at 7.5 mr/hr. Calibrated with Ra source.
3. Threshold Detector Unit	Series of foil detectors.	N_{th}, N_f.	High-intensity neutron flux.	Provides data which, when analyzed with special counting equipment, gives the dosage of high-intensity neutron bursts.	Should supplement, but never be substituted for, alarm-type instruments which warn of dose rate, but which do not measure dose.

Table 11.8. Personnel and Area Contamination Monitoring Instruments (Fixed)

Instrument >	Detector	Radiation Detected	Range	Application	Remarks
1. Hand and Foot Monitor	Halogen quenched G-M tube	β, γ	Low-level	Simultaneous detection of β and γ contamination of hands and shoes. Will not detect α.	Most models have auxiliary probe for monitoring clothing.
2. "Stack" Monitors for Gaseous Effluents	Combinations of monitors listed above for gaseous and particulate activity.	Depends upon detectors chosen.		Rough estimate of the radioactivity of effluent from a multi-use stack.	Requires complicated and expensive sampling, collecting, detecting, counting, and data-interpreting equipment.

12. SERVICES TO TRANSURANIUM LABORATORY

The proximity of the trans-uranium processing facility to the HFIR site makes it advantageous to commingle certain utilities. Since the HFIR was constructed first, most of the utility services were constructed as part of this facility with provisions made to supply TRU when required. Actually, the HFIR is the major user of most of these utilities and the portion supplied to TRU is but a small part of the total system.

The various services furnished TRU are:

Secondary Coolant Water.

The TRU facility is supplied with secondary cooling water from the HFIR secondary coolant system. Twelve-inch headers branch from the underground secondary supply-and-return lines east of the reactor building. These twelve-inch headers continue north, passing the east side of the underground water storage tank, and terminate in a pit on the north side of the air lock access road. The HFIR portion of these lines ends in the pit with block valves, V-1480 on the return line and V-1481 on the supply line. The TRU facility ties into the HFIR secondary coolant system at this point.

Demineralized Water.

TRU is supplied demineralized water from the HFIR plant demineralized water system. A two-inch line, 01-1627-2"-69, branches from the discharge header of the plant demineralized water supply pumps, runs out the north wall of the reactor building, and continues underground in a northerly direction toward the TRU facility. A valve, V-1601, located near the demineralized water pumps in the reactor building, controls the demineralized water supply to the TRU facility.

Exhaust Stack.

The HFIR stack was designed to exhaust 60,000 scfm. Since the HFIR exhaust requirements are only about 30,000 scfm, another 30,000 scfm of capacity is available. Most, if not all, of this excess capacity will be utilized by the TRU facility. The HFIR exhaust stream enters the base of the stack on the west side. An opening for the TRU facility exhaust stream is available on the north side of the stack.

Hot-Waste Collection (ILW).

The HFIR and TRU facilities maintain essentially independent waste collection systems. However, due to its location and elevation, condensate from a portion of the TRU exhaust duct is drained into the HFIR ILW systems. This tie line runs underground from the TRU exhaust duct, passes on the east side of the HFIR exhaust stack, and connects to the line which drains the stack into the filter pit sump. A block valve is located underground in the tie line at a point southeast of the stack area instrumentation cubicle.

Emergency Electrical Power.

Emergency electrical power (available during a normal-power outage) is supplied to TRU from the HFIR diesel-generators. A separate circuit to TRU is run from each normal-emergency system. On normal-emergency system No. 1, the breaker feeding TRU is not tripped out by the automatic transfer switch. Thus, TRU receives power from the No. 1 normal-emergency system as soon after normal-power outage as the switchgear transfers the load to the diesel. On normal-emergency system No. 2, the breaker feeding TRU is tripped out by the automatic transfer switch and it is not reclosed until 10 seconds after the switchgear transfers the load to the

diesel. This arrangement allows the TRU stack fans to receive priority on the No. 1 normal-emergency system and the HFIR stack fans to receive priority on the No. 2 normal-emergency system.

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