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OPERATING MANUAL FOR THE HIGH FLUX ISOTOPE REACTOR

Compiled by

High Flux Isotope Reactor Staff

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OPERATING MANUAL FOR THE HIGH FLUX ISOTOPE REACTOR

Volume I. Description of the Facility

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-s for the purpose of producing milligram quantities of ^{252}Cf 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 ^{235}U 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 acheived.

The reactor core, which is shown schematically in Fig. 2.1, consists of four concentric regions each approximately 61-cm (2-ft) long. The central region, often called the "island," has the highest flux and constitutes the flux trap. It is approximately 12.7 cm (5 in.) in diameter and will contain the curium target in the form of a bundle of rods. The fuel region, located immediately outside the island, has an

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[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, October 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.

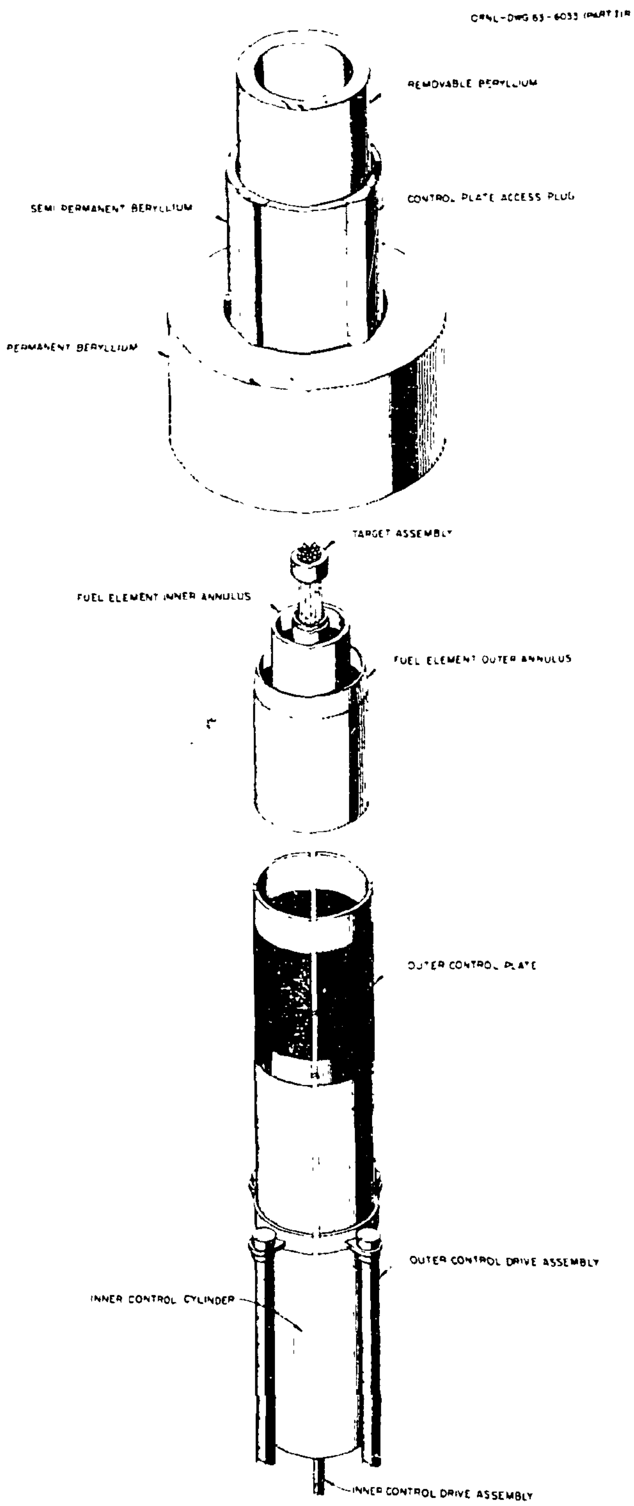

Fig. 2.1. Exploded view of core.

inside diameter of approximately 12.7 cm (5 in.) and an outside diameter of approximately 43.5 cm (17 1/8 in.). It consists of two cylindrical fuel elements containing 9.4 kg of ^{235}B in vertical curved 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 ^{10}B.

The fuel region is surrounded by a concentric ring of beryllium reflector approximately 30.5-cm (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 a 2.44-m-diam (8-ft) pressure vessel. It is cooled by demineralized water which, under minimum design conditions, is pumped through the system at the rate of 56,775 l/min (15,000 gpm). This corresponds to a velocity of 12.8 m/s (42 ft/s) through the fuel region and 12.2 m/s (40 ft/s) through the target array. The pressure vessel is located in a pool of water 5.5 m (18 ft) in diameter and 11 m (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 12.6-m (41 1/2-ft) long, 6.1-m (20-ft) deep, and 5.5-m (18-ft) wide. The general arrangement of the reactor components is shown in Figs. 2.2, 2.3, and 2.4.

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.

2.2.1 Target assembly

The target assembly, shown in Fig. 2.5, is located in the island and contains the curium target material. It consists of 31, 0.95-cm-OD (3/8-in.) rods, spaced in a triangular pattern. The rods are fabricated from a mixture of curium oxide 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 1.6-cm-diam (5/8-in.) tubes, thereby providing each rod

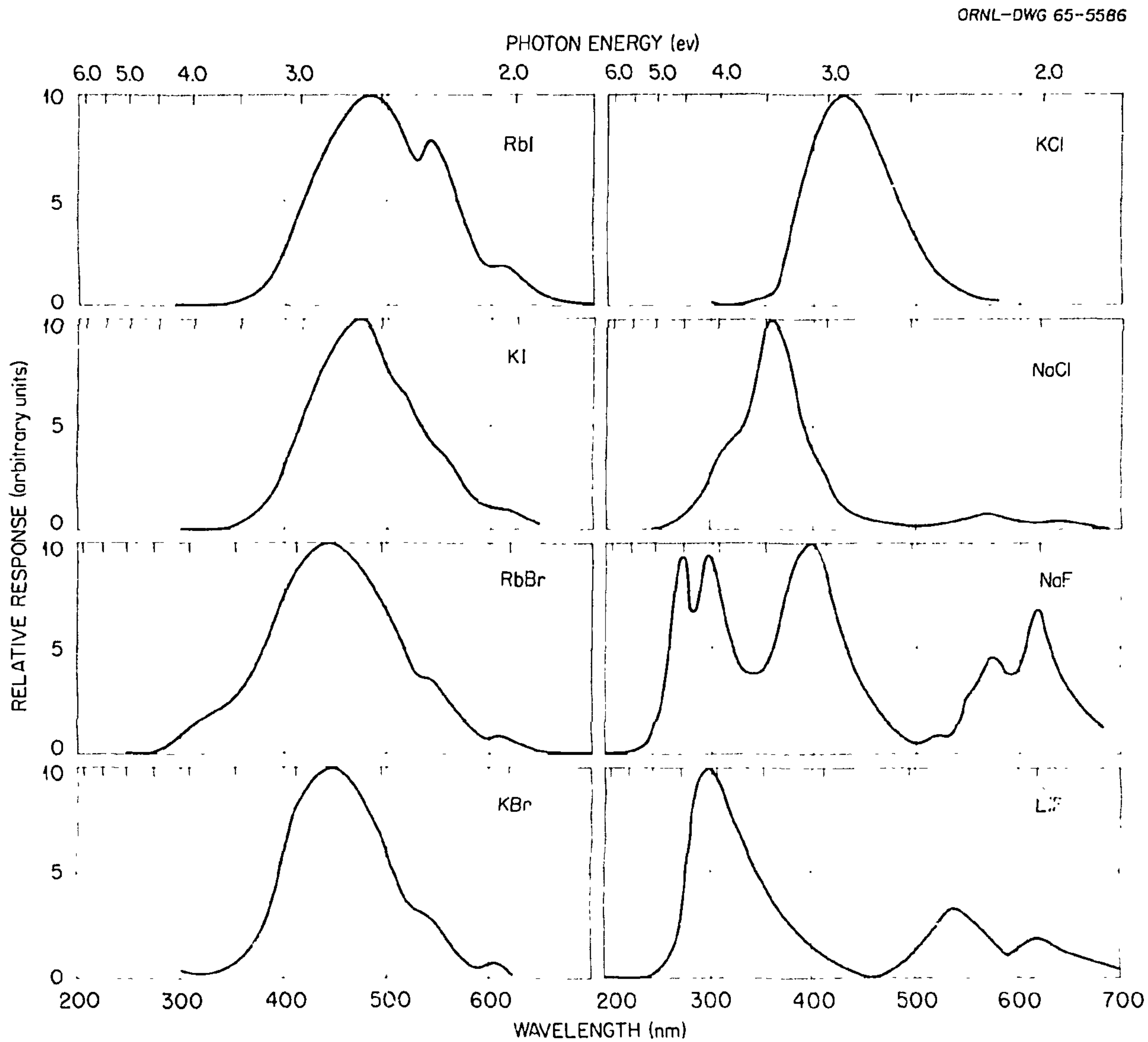

Fig. 2.2. Vertical section of reactor vessel and core.

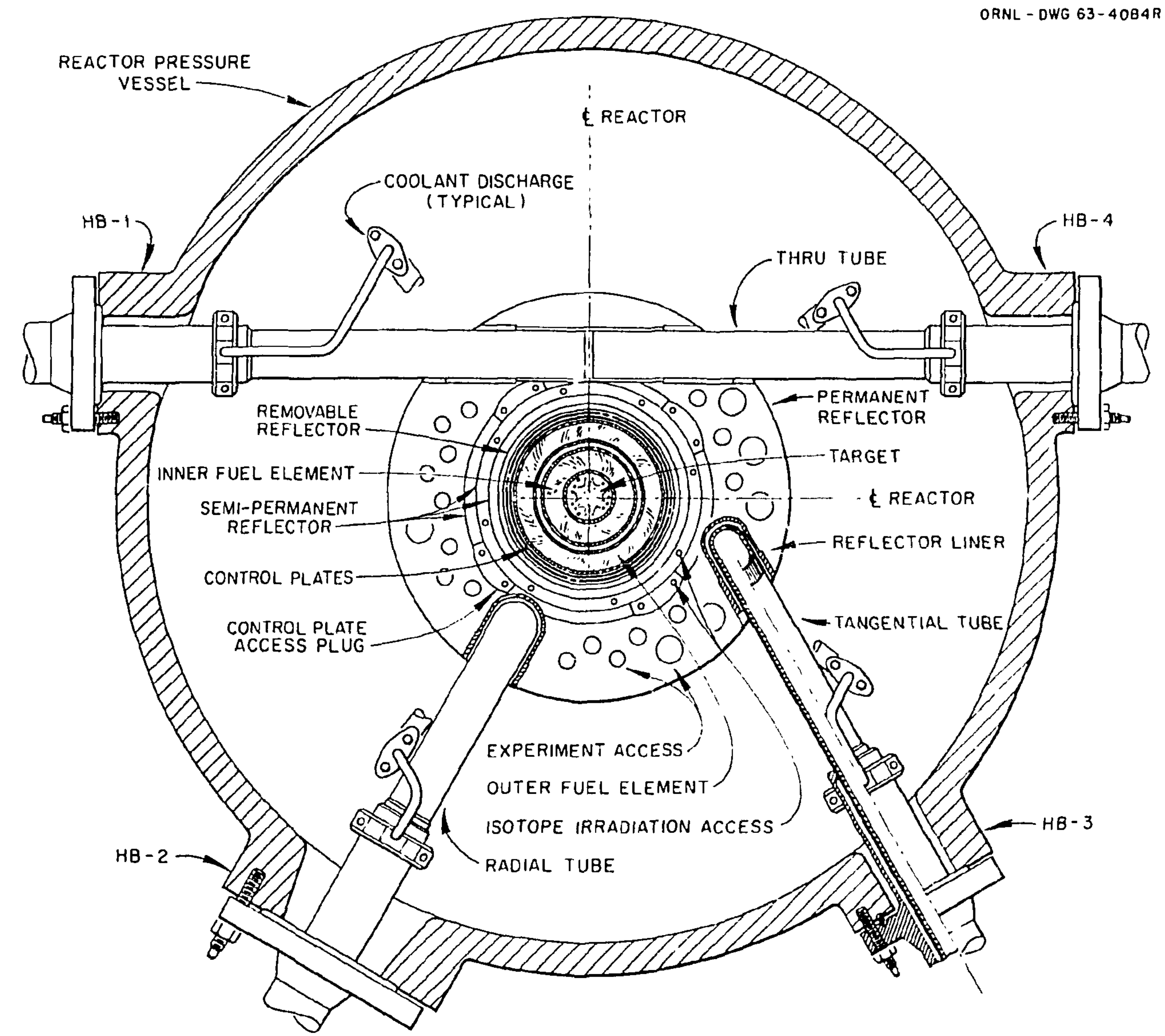

Fig. 2.3. Plan view of reactor core.

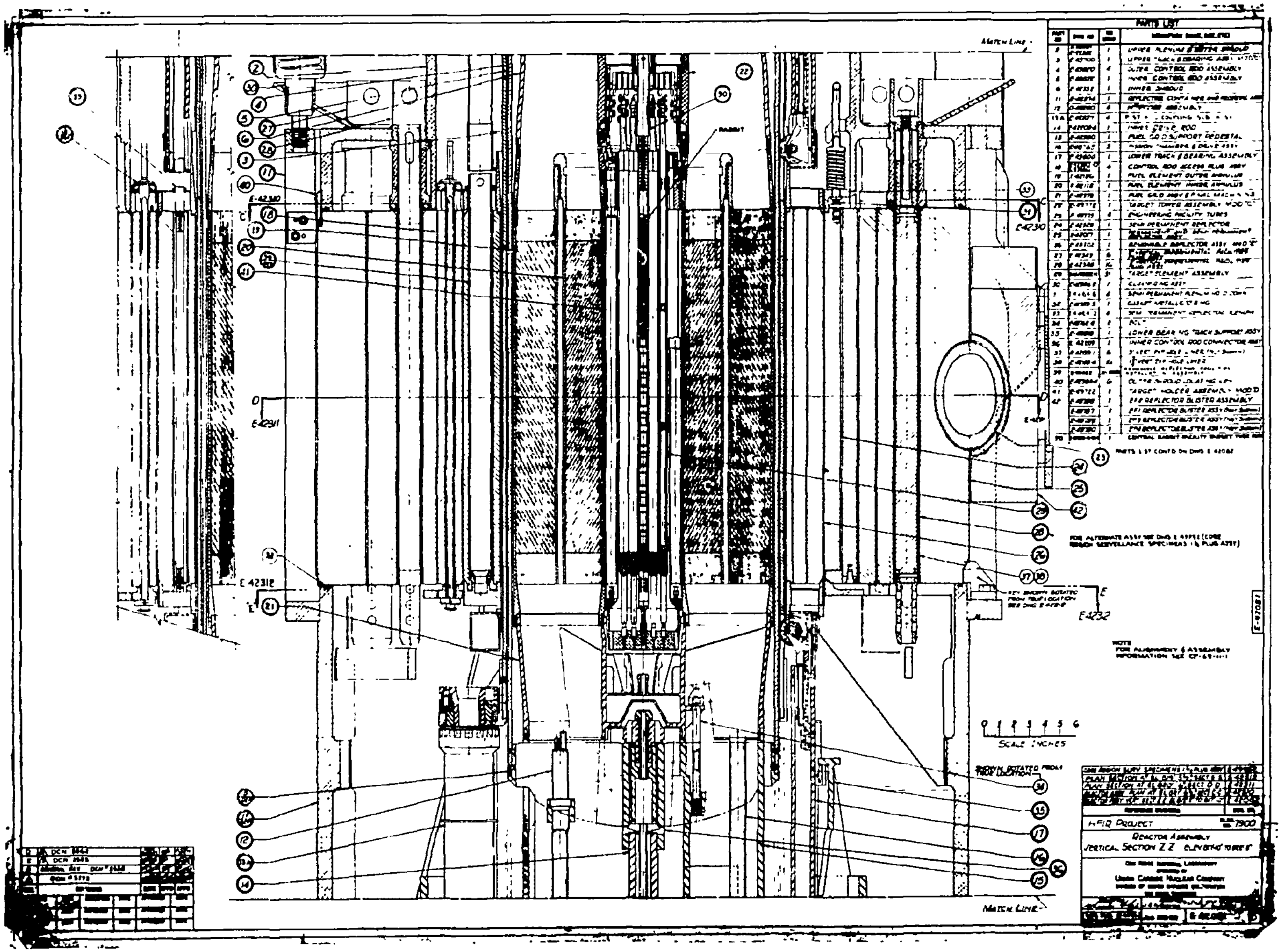

Fig. 2.4. Reflector - elevation.

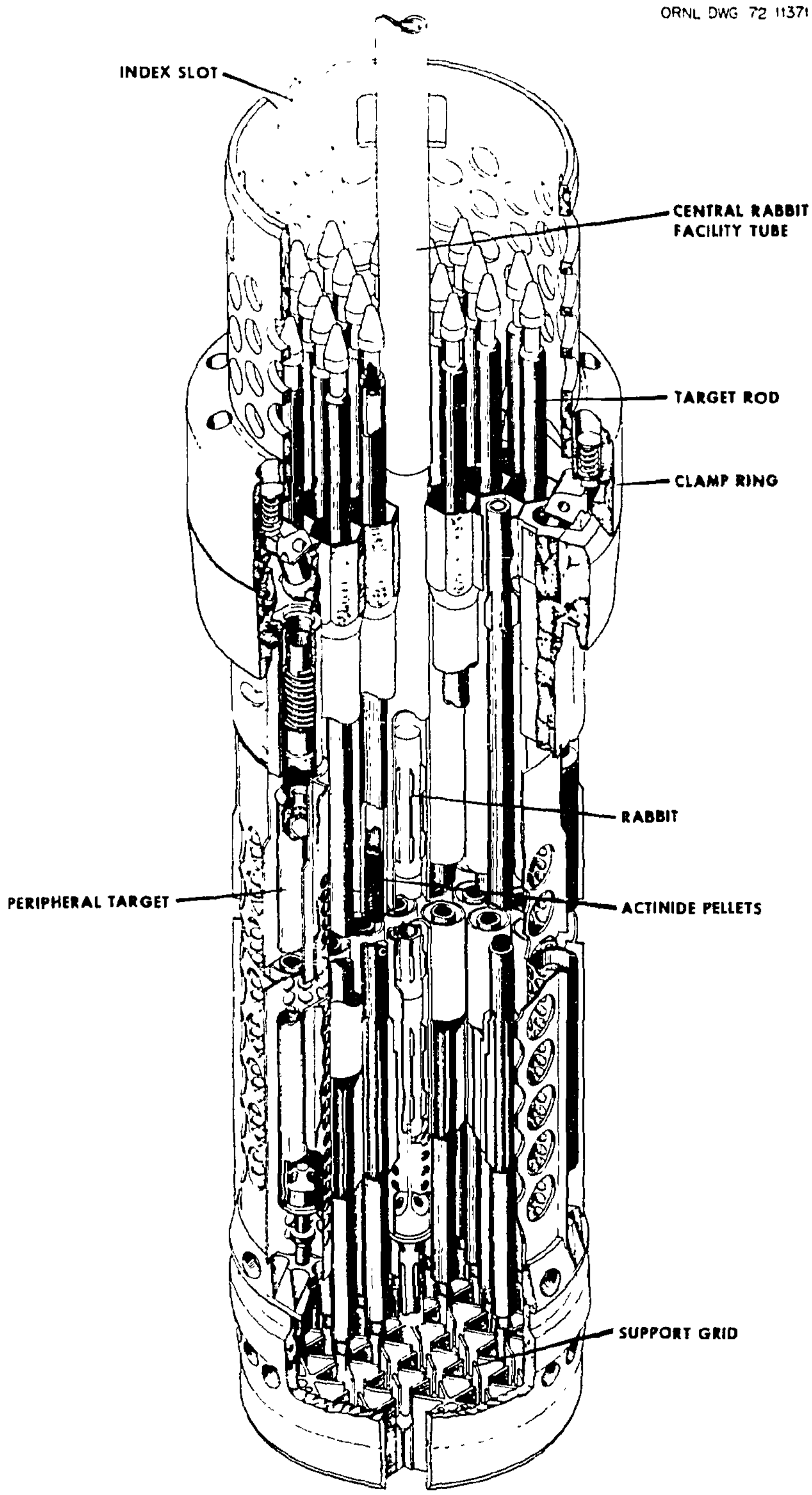

Fig. 2.5. Target holder assembly.

providing each rod with its own cooling channel of about 0.3 cm (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 Fig. 2.6.

A minimum design flow rate of approximately 2385 l/min (630 gpm) is maintained through the target assembly while 757 l/min (200 gpm) flows between the target assembly and the inner fuel element. This corresponds to a coolant velocity of 12.2 m/s (40 ft/s) 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 3.15×10^6 W/m^2 (1×10^6 Btu/ft^2-h); however, peaks are expected due to buildup and burnup of various isotopes. With low conductivity pellets [65.3 W/m^2-K (11.5 Btu/ft-h-°F)] and a 0.1-mil air gap between pellet and rod wall, the internal temperature is not expected to exceed 538°C (1000°F).

Calculations indicate that approximately 100 cc (STP) of gas containing Xe, He, and Kr will be produced during an 18-month irradiation of a curium target rod containing 10 g curium oxide. 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 0.025 cm (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.

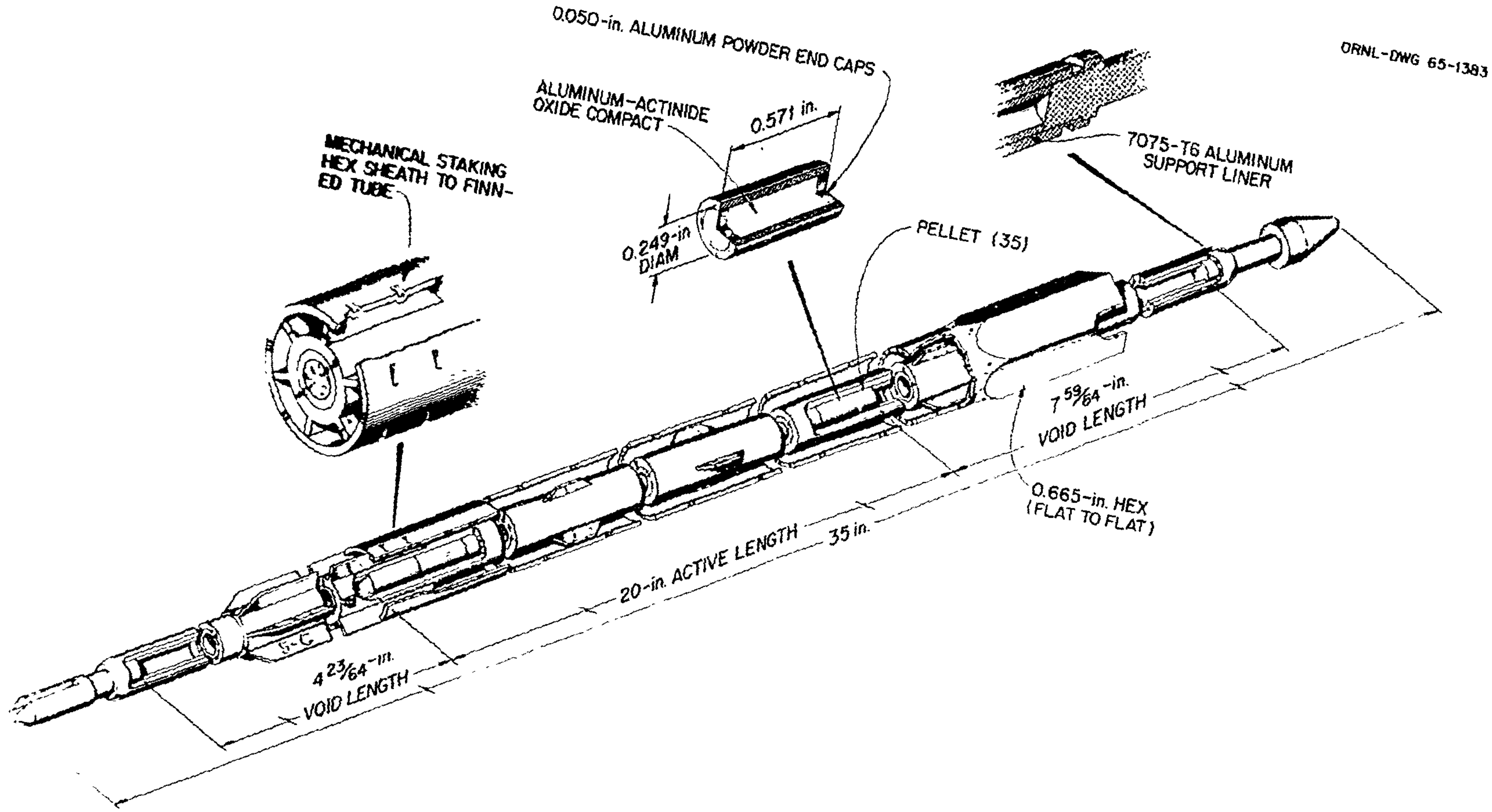

Fig. 2.6. Target rod.

2.2.2 HFIR fuel elements

The fuel region of the HFIR, shown in Fig. 2.7, is composed of two concentric cylindrical fuel elements containing ertical, curved plates extending in the radial direction. The inner element which contains 171 plates is initially loaded with 2.6 kg of ^{235}B and 2.80 g of ^{10}B burnable poison. The inner diameter is 12.87 cm (5.067 in.) and the outer diameter is 26.9 cm (10.590 in.). The outer element contains 369 plates and initially contains 6.8 kg of ^{235}U but no burnable poison. Its inner diameter is 28.6 cm (11.250 in.) and outer diameter is 43.5 cm (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% ^{235}U is used as fuel. Initially each inner annulus plate contains 15.18 g $\pm$ 1.0% ^{235}U. In addition, each inner annulus plate initially contains 0.0164 g $\pm$ 11.0% of ^{10}B. The finished plates are 0.127-cm (0.050-in.) thick and 61-cm (24-in.) long with a nominal active length of 50.8 cm (20 in.). The maximum thickness of the fuel bearing cermet is 0.07 cm (0.030 in.) so the minimum cladding thickness is 0.025 cm (0.010 in.). The plates are curved in the form of an involute to preserve a constant cooling channel width of 0.127 cm (0.050 in.) between plates. Before bending, the inner plates are approximately 9.6-cm (3.8-in.) wide and the outer plates are approximately 8.9-cm (3.5-in.) wide. The fuel cores are centered to provide adequate edge cladding. Both inner and outer plates are fastened between the 73.6-cm (29-in.) long cylindrical aluminum side plates by welding.

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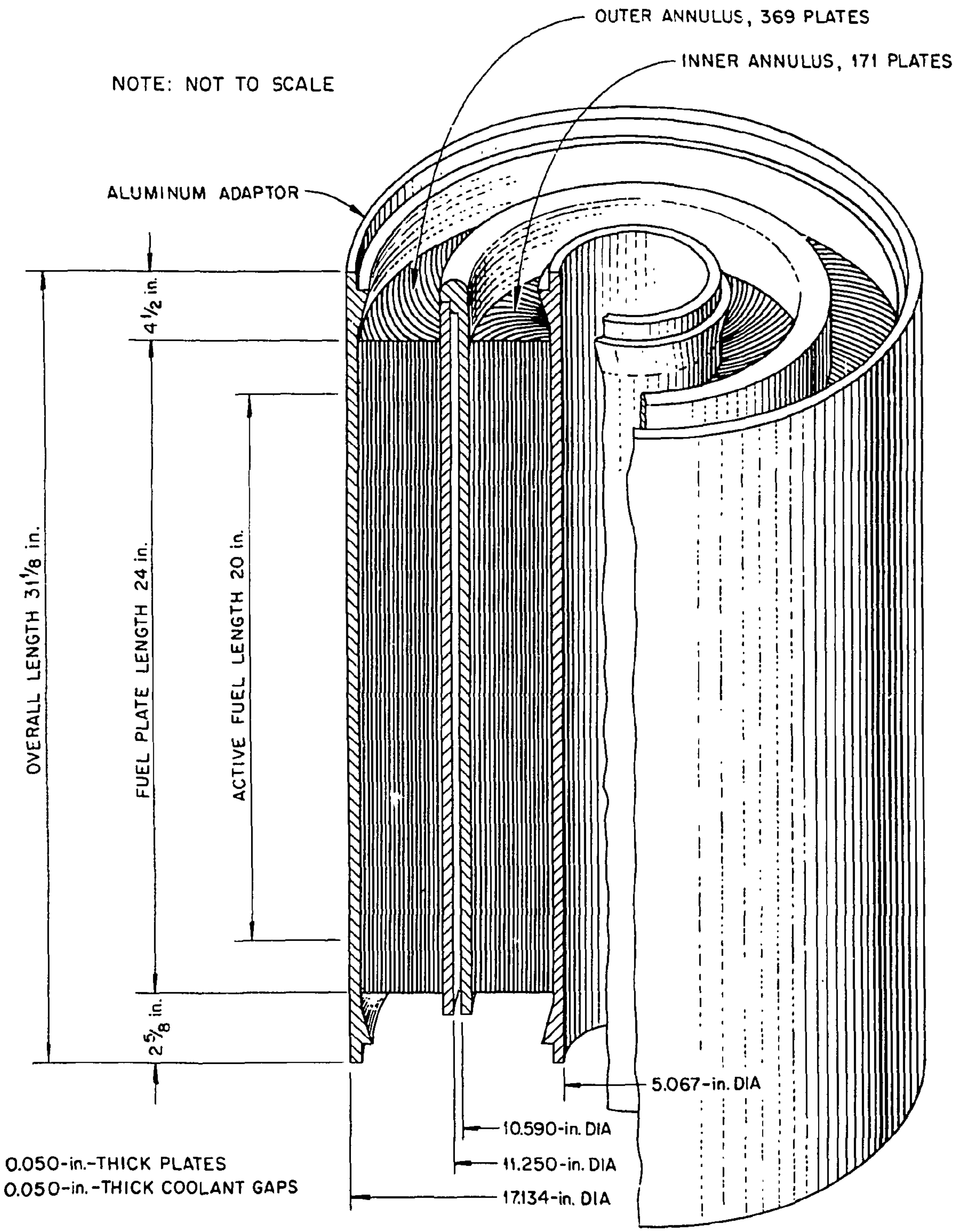

Fig. 2.7. Fuel element.

To minimize the radial peak-to-average power density ratio, the fuel loading in each plate is varied along the arc of the involute curve. The boron-10, included in the inner plates in the form of ^4BC, 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 Figs. 2.8 and 2.9.

Each fuel core is expected to have a lifetime, at 100 MW, of approximately 23 days. Under minimum design conditions, coolant flow through the fuel is 4164 l/min (11,000 gpm) which corresponds to a velocity of 12.8 m/s (42 ft/s) at a core pressure drop of 620 kPa (90 psi). At 100 MW total heat power the average heat flux is 25 x 109 W/m^2 (8 x 10^5 Btu/ft^2-h), and the calculated maximum hot spot heat flux is 6.6 x 10^{10} W/m^2 (2.1 x 10^6 Btu/ft^2-h). The power level calculated for incipient boiling under typical conditions - 4.5 MPa (650 psi) inlet pressure, 15.3 m/s (51 ft/s) flow, 49°C (120°F) inlet temperature - is approximately 133 MW. Present operating inlet pressure is 5.2 MPa (750 psi).

2.2.3 Beryllium reflector

The fuel region is radially reflected by a 30.5-cm (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 9.5-cm (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 20.95-cm (8.25-in.) thick beryllium annulus with axially directed circular coolant channels. Three of the four inner

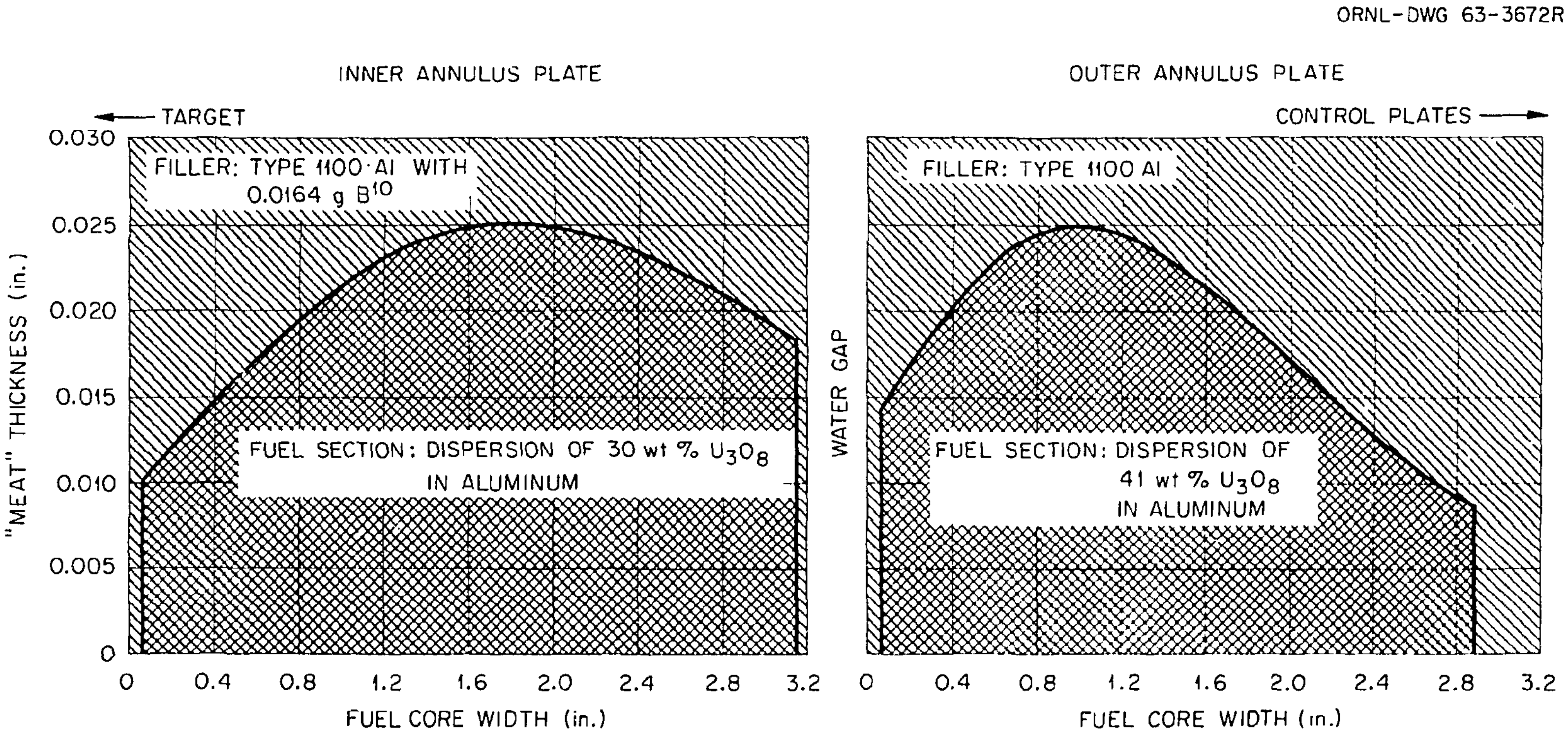

Fig. 2.8. Cross section of fuel plate before bending.

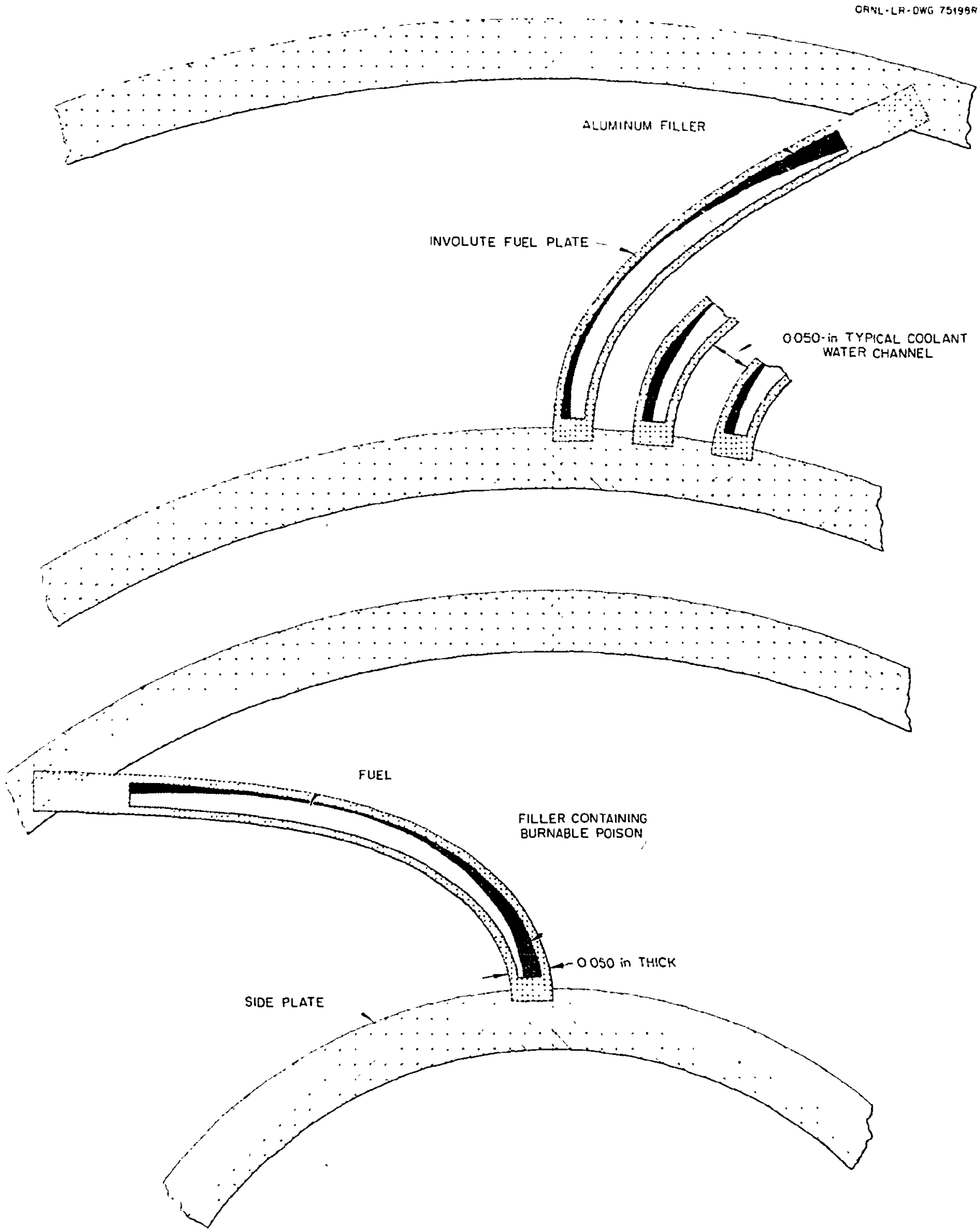

Fig. 2.9. Fuel and burnable-poison distribution in the as-built element.

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 reflector," is removed only when necessary because of radiation damage. Although the thick outer annulus, called the "permanent reflector," may be removed, it is done very infrequently. To facilitate access to the control drives, four small pieces of the "semipermanent 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 0.159-cm (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 0.069 cm (0.027 in.). Aluminum rivets located at the top and bottom of each annulus are used to ensure a minimum coolant channel width. A 0.159-cm (1/16-in.) thick water gap between the removable and semipermanent reflectors facilitates removal and replacement of the removable reflector, furnishes cooling, and provides for expansion of the removable reflector. Four 1.27-cm-diam (1/2-in.) and four 3.5-cm-diam (1 3/8-in.) 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 0.318-cm-diam (1/8-in.) 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 4.01-cm-diam (1.58-in.) and 6 vertical 7.19-cm-diam (2.83-in.) experimental facilities similar to those in the removable reflector. Two of the 10.2-cm (4-in.) beam tubes penetrate the permanent reflector and terminate in the semipermanent beryllium. One 10.2-cm-diam (4-in.) 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.

2.2.4 HFIR control plates

The control plates are located in a 2.2-cm (0.869-in.) thick annular region between the outer fuel element and the removable beryllium. The control plates consist of two 0.635-cm (0.250-in.) concentric cylinders which move in the 2.2-cm (0.869-in.) gap between the fuel and reflector regions. The nominal water velocity through this gap is 4.88 m/s (16 ft/s). 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 Fig. 2.10.

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 incease 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

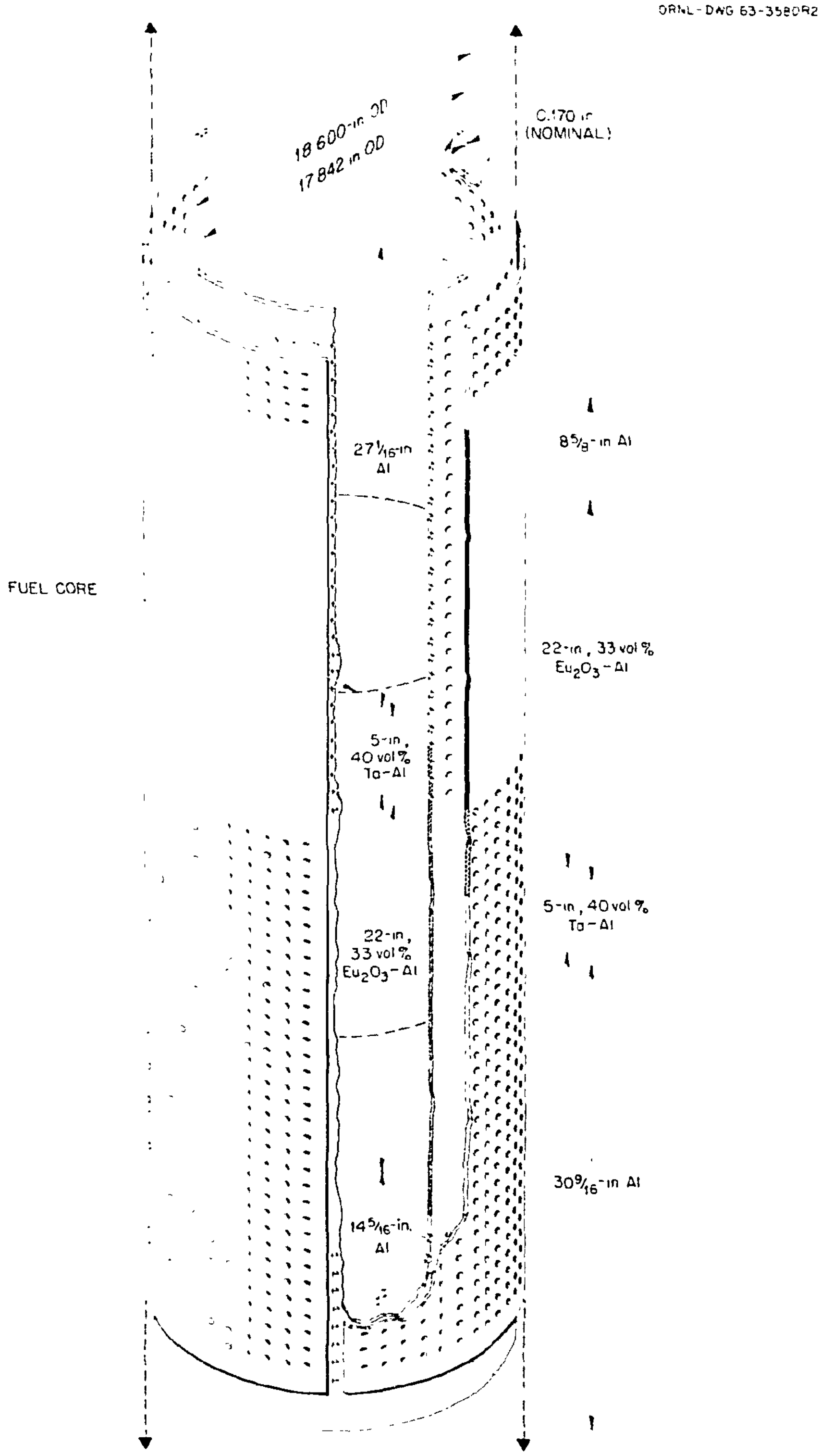

Fig. 2.10. Control plates.

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 normal operation criticality is achieved by driving the inner cylinder down and the outer quadrants up in unison. As shown in Fig. 2.11, 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 0.476 cm (3/16 in.), and is clad with 0.08-cm (1/32-in.) thick aluminum. The gray regions are 12.7-cm (20-in.) long and are of solid aluminum. In order to balance the hydraulic forces, a large number of 0.635-cm (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 22.66 cm (8.921 in.) and an inner radius of 22 cm (8.671 in.) The overall length is 173.7 cm (68 3/8 in.). The lower end of the black region is 36.35 cm (14 5/16 in.) above the lower end of the plate and the upper end of the white region is 68.7 cm (27 1/16 in.) below the upper end of the rod. The outer control plates have an outer radius of 23.6 cm (9.300 in.) and inner radius of 23 cm (9.050 in.). The overall width of each is 34.4 cm

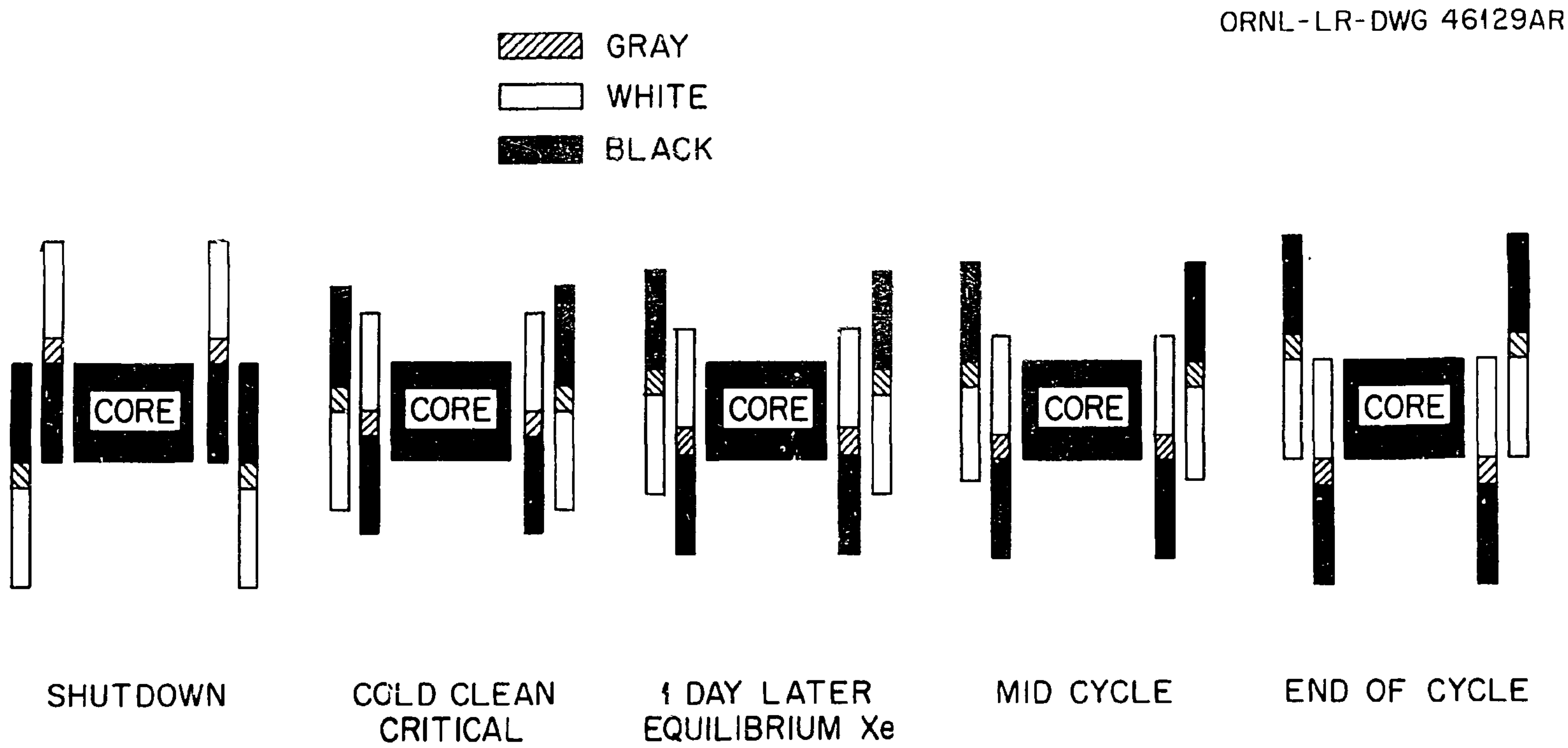

Fig. 2.11. Control plate positions during a cycle.

(13 9/16 in.) and the overall length is 168.1 cm (66 3/1· The upper end of the black region is 16.8 cm (6 5/8 in.) below the upper end of the plate and the lower end of the white region is 26.8 cm (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 bearings. Four bearings are attached to each outer control plate, two at each end, and run in stationary tracks which extend above and below the core. The other two 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 Fig. 2.12. 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 106.7 cm (3 1/2 ft) in diameter by 76.2 cm (2 1/2 ft) high. It is bolted to the edge of the support assembly.

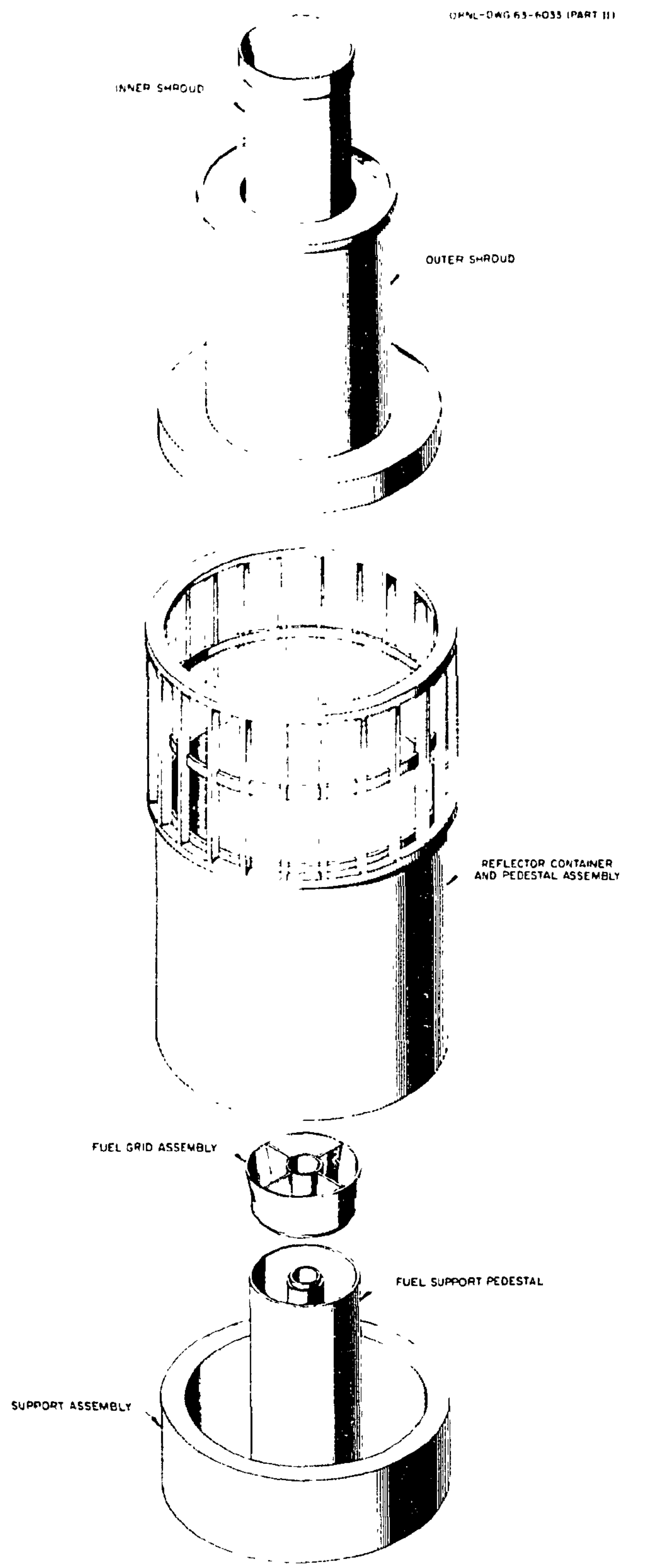

Fig. 2.12. Core and reflector support.

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 it located inside and concentric with the reflector pedestal and is bolted to the center of the support assembly. This pedestal is approximately 31.1 cm (1 ft, 3 in.) in diameter and 91.4 cm (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 91.4-cm (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 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 861.8 kPa (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 0.09 cm (0.036 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

2.4.1 General description

The HFIR core is contained in a 238.7-cm-ID (94-in.) 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 213-cm (7-ft) thick pool floor. The carbon steel vessel wall is 7.3-cm (2 7/8-in.) thick. A minimum cladding thickness of 0.318 cm (1/8 in.) is provided on the inside with a minimum of 0.254 cm (0.1 in.) on the outside. The general arrangement is shown in Fig. 2.13.

The flat upper head of the vessel is made of 35.6-cm (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 76.2-cm-diam (30-in.) 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 30.5-cm-diam (12-in.) target access plug with a sheer block type closure and an elastomer O-ring piston seal.

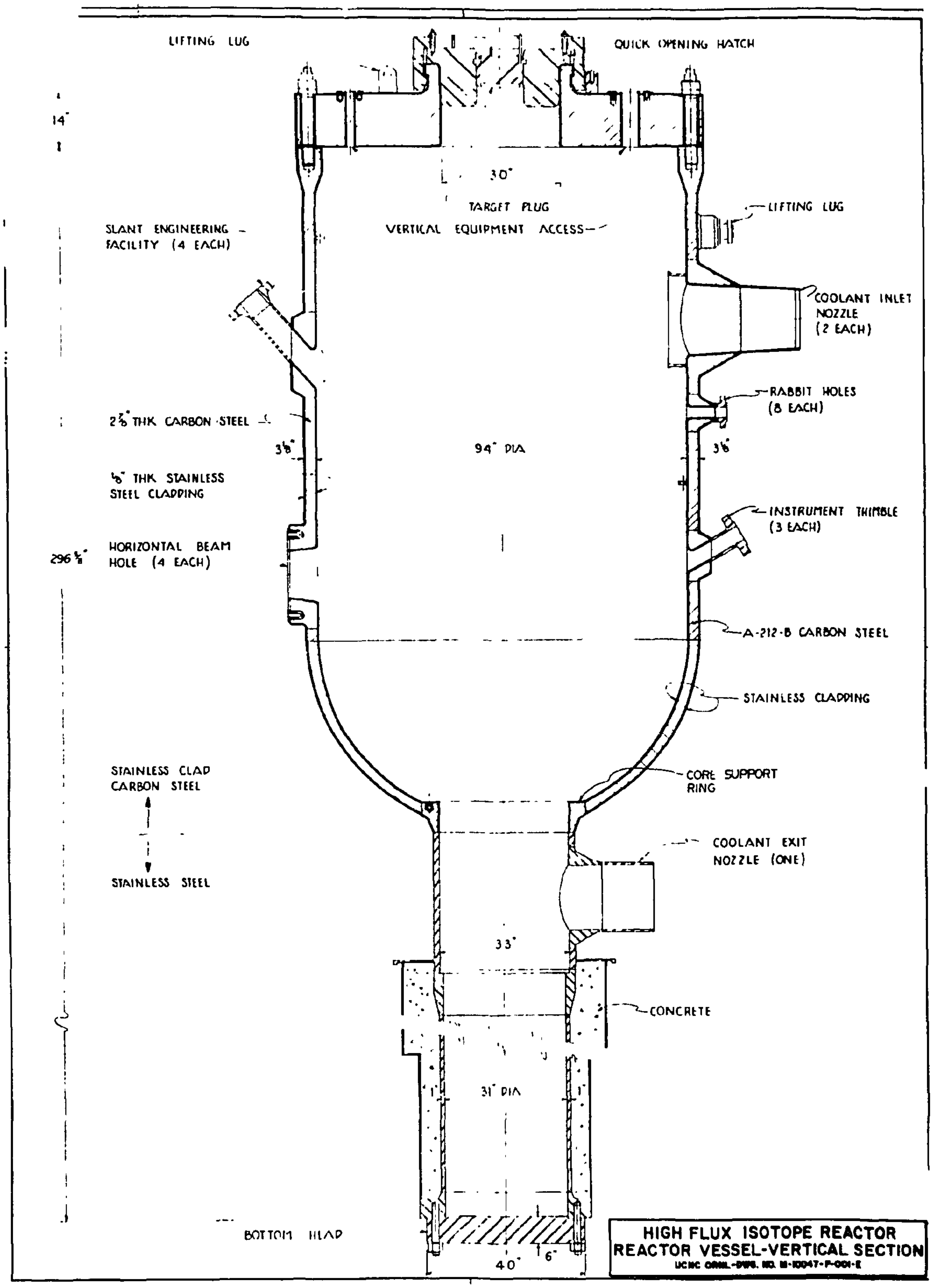

Fig. 2.13. Reactor pressure vessel.

The lower head for the control rod access extension is a 16.5-cm (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 Figs. 2.14 and 2.15.

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.

2.4.2 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	49 - 75°C	93°C	24°C
	(120-167°F)	(200°F)	(75°F)
Pressure	5.2 MPa	6.9 MPa	10.7 MPa
	(750 psig)	(1000 psig)	(1550 psig)

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," December 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.

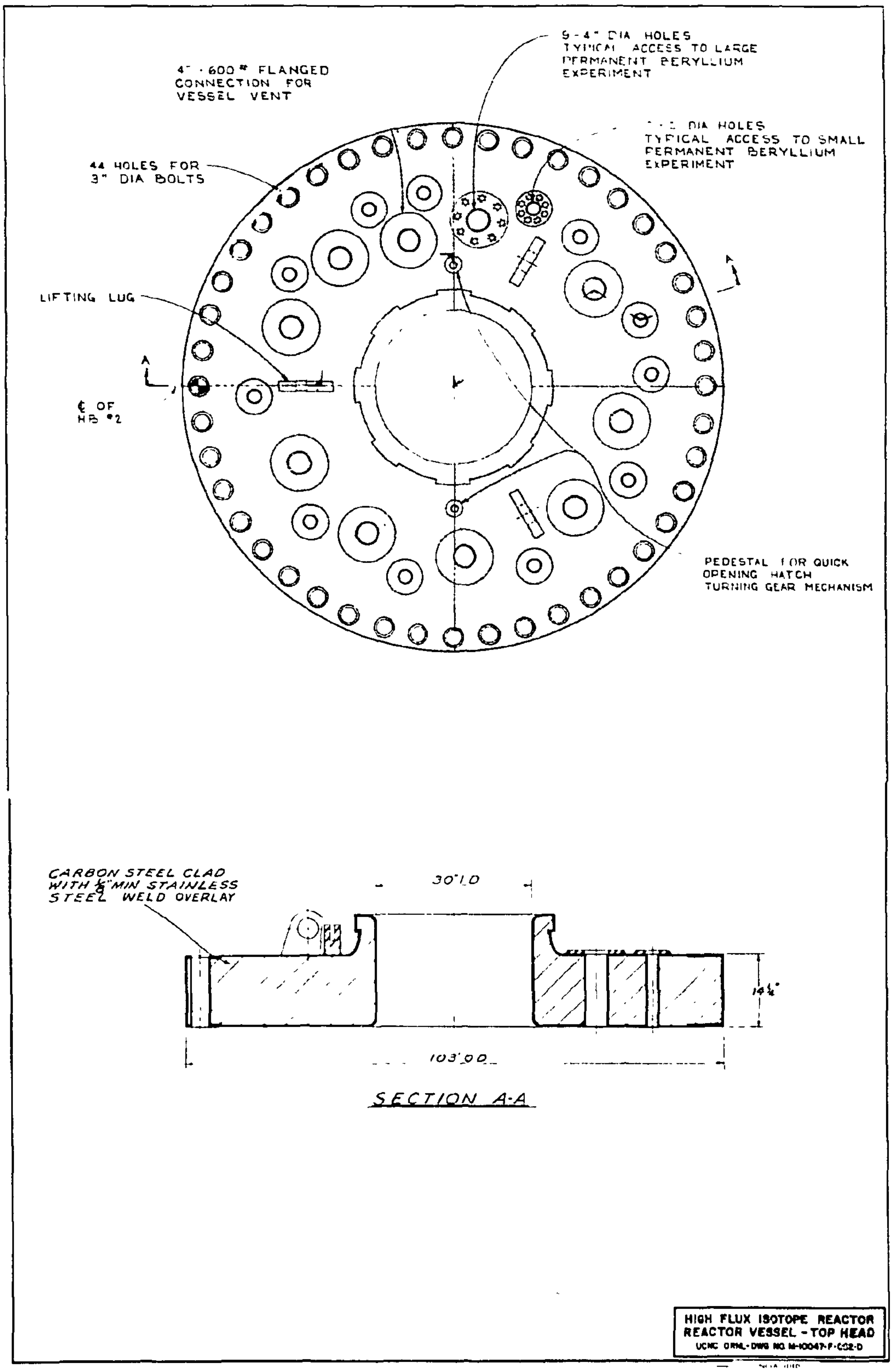

Fig. 2.14. Reactor vessel top head

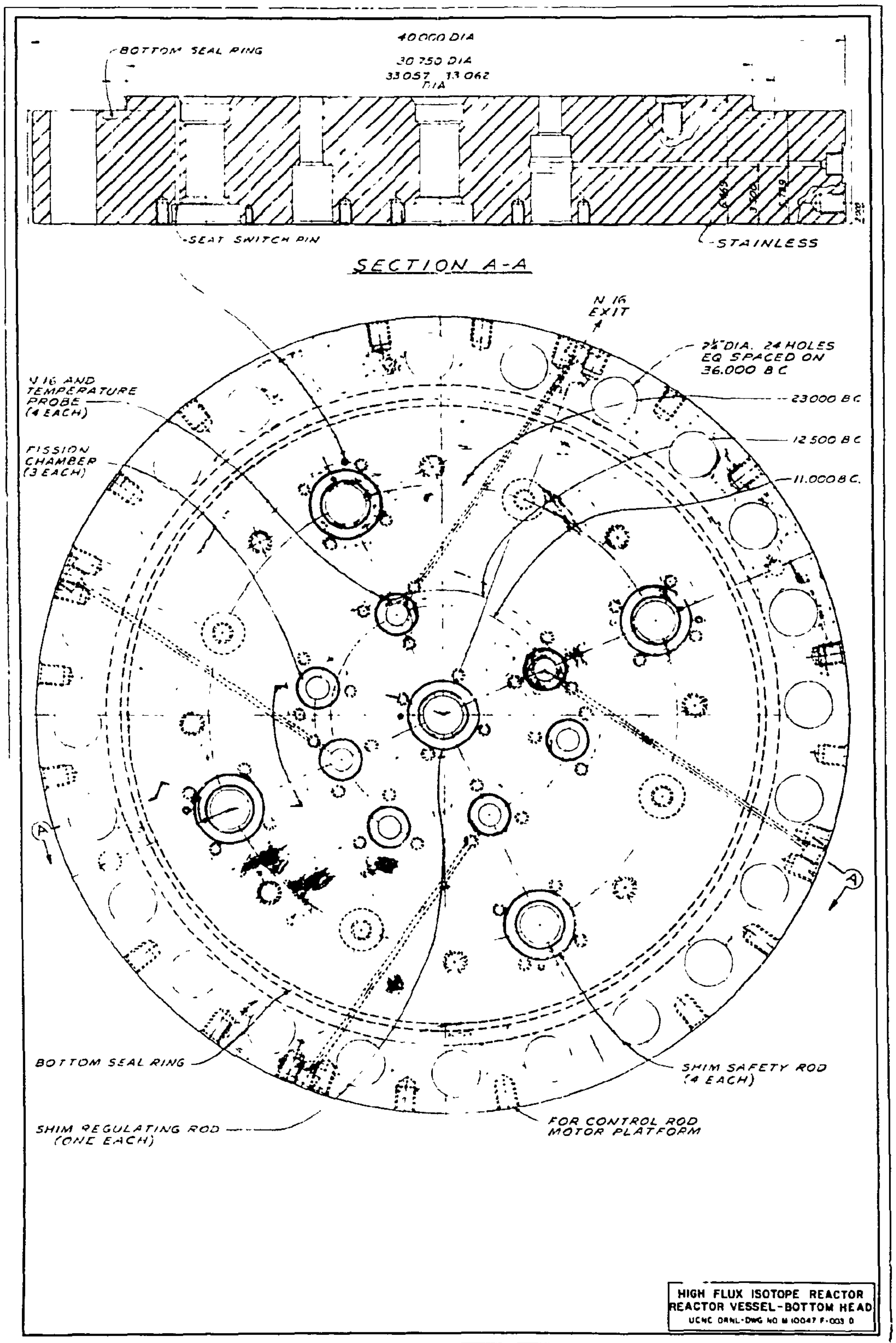

Fig. 2.15. Reactor vessel bottom head

Table 2.1. Reactor pressure vessel

Nomenclature	Number	Size
Cooling water inlet	2	40.6-cm-OD (16-in.) pipe
Cooling water exit	1	45.7-cm-OD (18-in.) pipe
Slant engineering facility penetration	4	15.2-cm (6-in.) 272 kg (600 #) RJ flange
Ion chamber penetration	3	10.2-cm (4-in.) 272 kg (600 #) RJ flange
Rabbit hole penetration	8	7.6-cm (3-in.) 272 kg (600 #) RJ flange
Radial horizontal beam tube penetration	1	35.6-cm (14-in.) 272 kg (600 #) RJ flange
Tangential horizontal beam tube penetration	3	20.3-cm (8-in.) 272 kg (600 #) RJ flange
Vertical experimental penetration*	12	5.1-cm (2-in.) 272 kg (600 #) RJ flange
Vertical experimental penetration*	9	10.2-cm (4-in.) 272 kg (600 #) RJ flange
Vessel vent*	1	76.2-cm (30-in.) flange
Bottom head	1	
N-16 water exit**	4	0.635-cm-diam (1/4-in.)
Quadrant thermocouple**	4	0.318-cm-diam (1/8-in.)
Control rod shafts**	5	4.9-cm-diam (1.938-in.)
Top head	1	261.6-cm-OD (103-in.)
Quick-opening hatch*	1	76.2-cm-diam (30-in.)
Top plug*	1	30.5-cm-diam (12-in.)
Fission chamber penetrations**	3	1.9-cm-diam (3/4-in.)

*Top head.

**Bottom head.

The vessel was inspected in accordance with the requirements of the basic Code and Nuclear Code Case 1273N. Additional inspections performed included 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 10.7 MPa (1550 psig) and supplementary tests at 6.9 MPa (1000 psig) following 17 cycles from atmospheric pressure to 6.9 MPa (1000 psig) were performed. Measurements were made of the top head bolt tensile stress under preload and at 10.7 and 6.9 MPa (1550 and 1000 psig).

After being put into operation, the vessel has been inspected periodically for physical deterioration. Tests are also 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 -12.2°C (+10°F) after 20 years. The operating procedures require that the vessel temperature be maintained above 11°C (70°F) whenever the stress level is more than 34.5 MPa (5000 psi). This stress level is developed at a vessel pressure of approximately 1.4 MPa (approximately 200 psig).

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

2.5 HFIR Pools

2.5.1 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 Fig. 2.16):

1. a 10.97-m (36-ft) deep reactor pool, the lower portion of which is a 5.5-m-diam (18-ft) by 4.88-m (16-ft) deep cylinder, the upper portion is a 5.5-m (18-ft) wide by 6.1-m (20-ft) long rectangle;
2. two 6.1-m (20-ft) deep clean pools, each of which is 5.5-m (18-ft) wide by 6.3-m (20 3/4-ft) long; and
3. a 7.6-m (25-ft) deep by 2.4-m-diam (8-ft) critical pool for future use.

The reactor pool contains the reactor vessel and two defective fuel element storage tanks. The clean pools contain the long-term spent fuel storage facilities. The critical pool was 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 0.635-cm (1/4-in.) thick. The lining on the pool floors and the walls of the cylindrical section of the reactor pool is 0.95-cm (3/8-in.) thick. The reactor and clean pools are separated by removable aluminum gates which allow the transfer of spent fuel elements between pools. A concrete wall, with a transfer hatch, separates the clean pool and the critical facility pool.

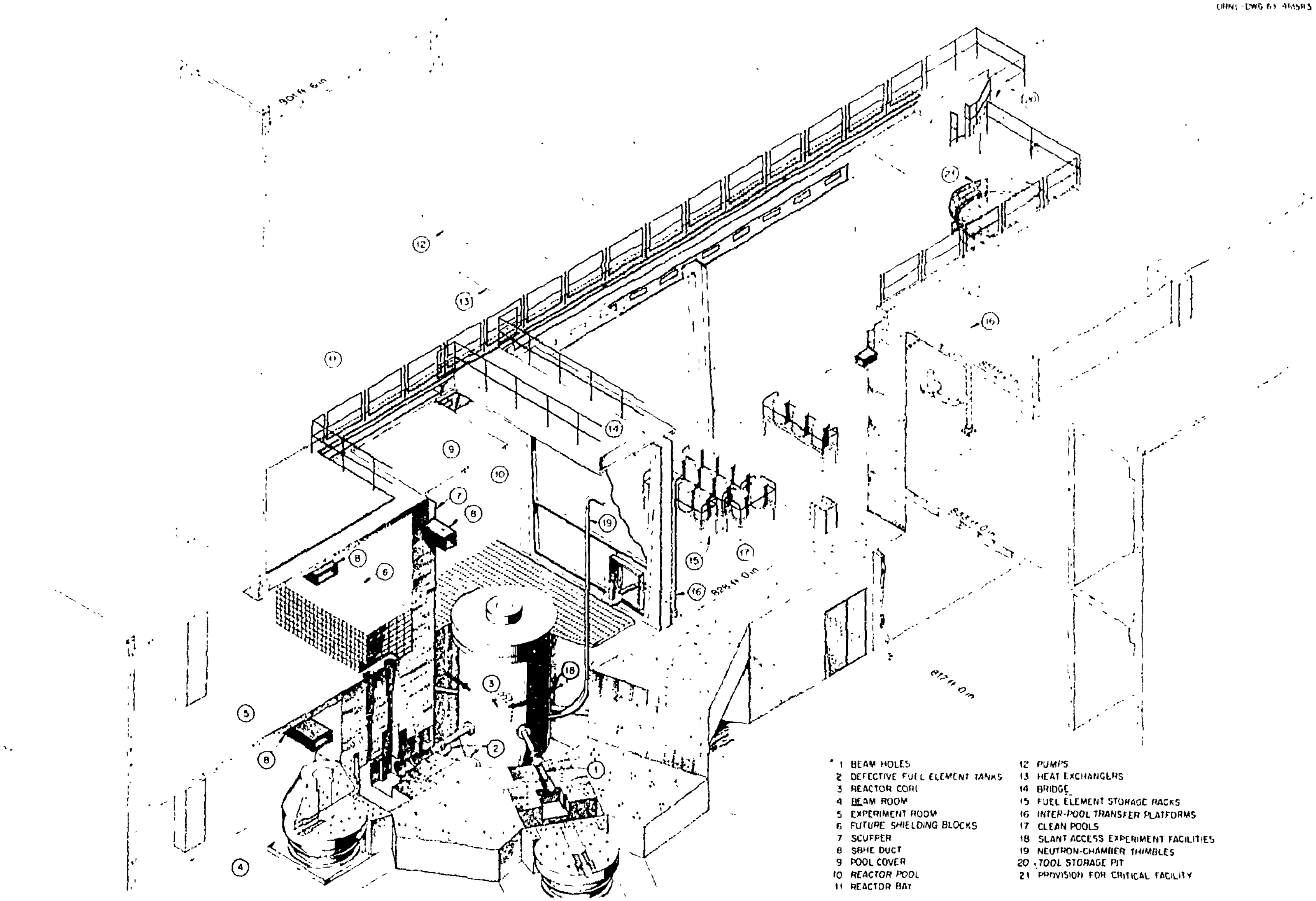

Fig. 2.16. Isometric of pools and experimental facilities.

The walls of the cylindrical section of the reactor pool are of ordinary concrete 3.66-m (12-ft) thick. Four beam tube access holes penetrate the reactor pool wall at elevation 250 m (820 ft, 6 in.); and, in these regions, the wall is of high density concrete 2.28-m (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 253.9 m (833 ft)] are of ordinary concrete 91-cm (3-ft) thick. Concrete block, supported by the 3.66-m (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 2.13-m (7-ft) thick.

The south wall of the clean pool is constructed of ordinary concrete 1.52-m (5-ft) thick, and the north wall, which also serves as the south wall of the heat exchanger cells, is 1.22-m (4-ft) thick ordinary concrete. The walls of the critical pool are also of ordinary concrete a minimum of 1.83-m (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 91-cm (3-ft) thick under the clean pool and 60.1-cm (2-ft) thick under the critical pool. The pool floor above the stairwell to the subpile room is of 55.8-cm (1-ft, 10-in.) thick high density concrete backed up by 35.6 cm (14-in.) of steel armor plate.

Three 7.6-cm-diam (3-in.) pipe sleeves through the north wall of the clean pool, at elevation 255 m (837 ft), furnish access to three of the heat exchanger cells. In addition to the experiment facilities, six 15.2-cm-diam (6-in.) pipe sleeves at elevation 256.3 cm (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 258.5 m (848 ft) which is 96.5 cm (3 ft, 2 in.) below the reactor bay floor. These scuppers are 25.4-cm (10-in.) wide and 48.3-cm (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.

2.5.2 Pool cover and personnel bridges

The personnel bridge spans the pool from north to south; see Fig. 2.17. It is a 1.83-m (6-ft) wide, 6.1-m (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 0.05 m/s (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 5-10 cm (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.

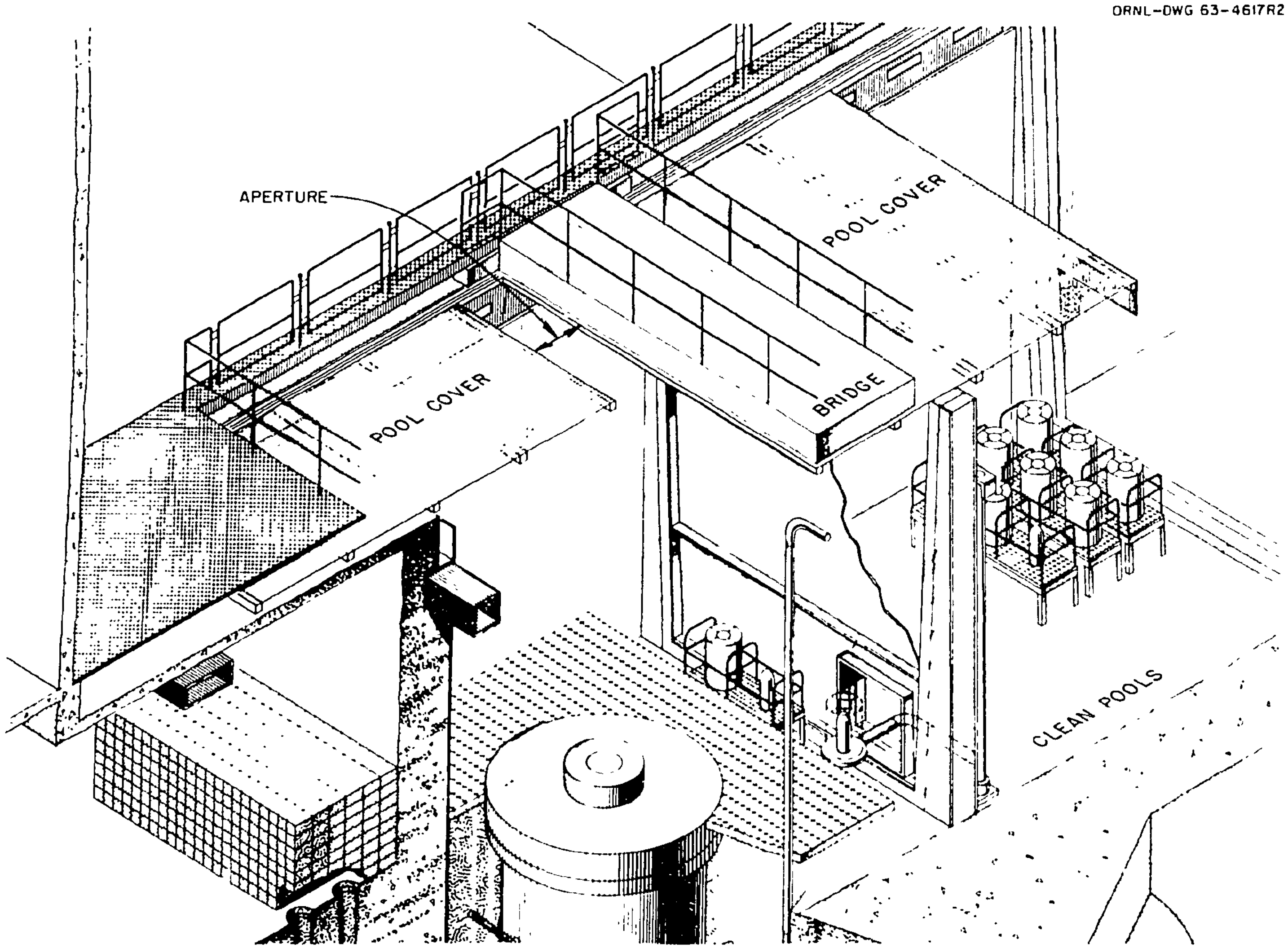

Fig. 2.17. Pool cover and personnel bridge.

To provide additional containment and protection, the reactor pool is covered by a cover fabricated from 1.3-cm (1/2-in.) thick Plexiglas panels supported by aluminum beams. There are two covers each 6-m (19-ft, 7-in.) wide and 3.17-m (10-ft, 5-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 nominally 91.5 cm (3 ft) in width but is adjustable to provide adequate air velocity. The cover itself is carried on a wheel and track arrangement. Four long pins operated from the bridge, two on the east and two 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.

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 centralized in the control room (Fig. 3.1).

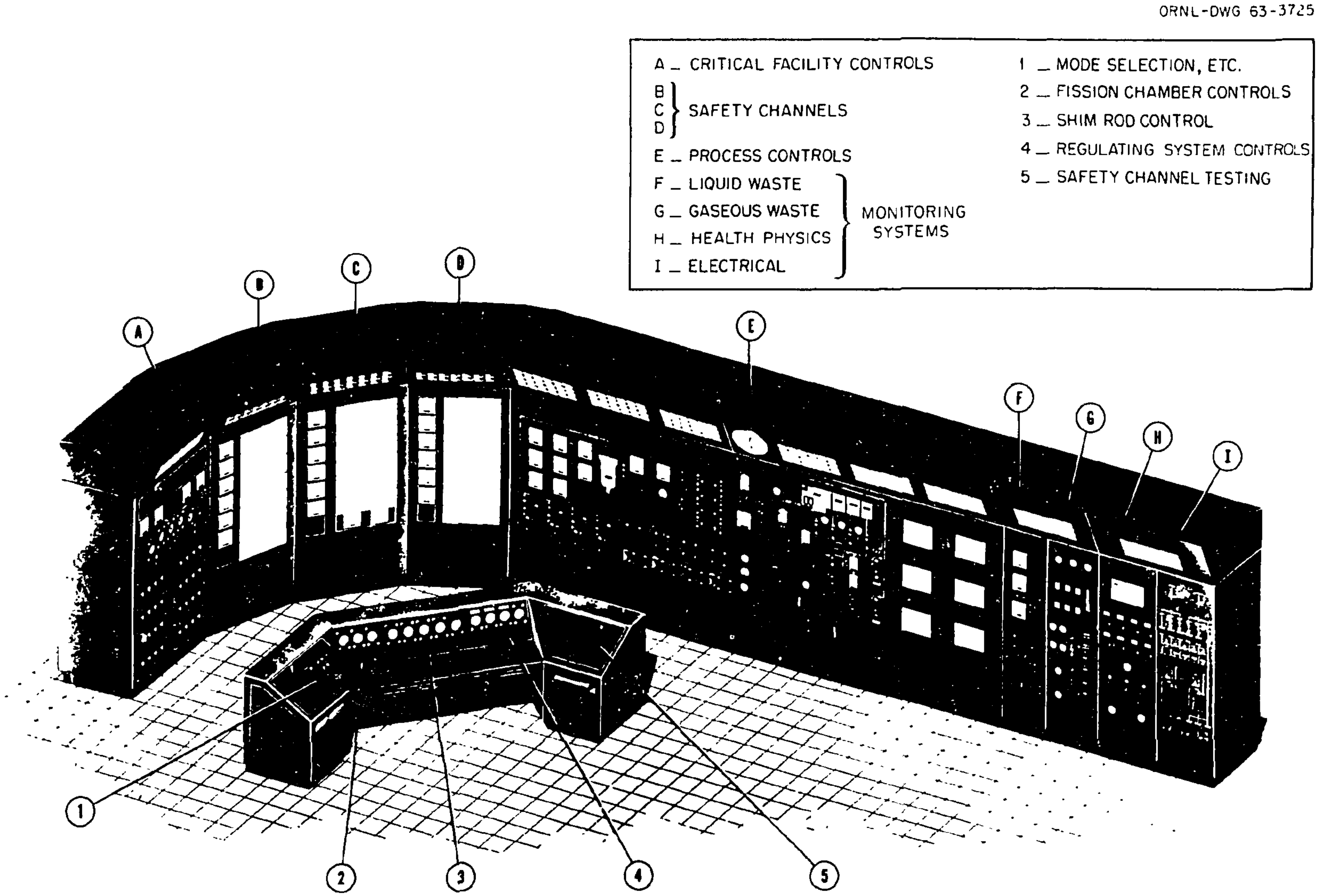

Fig. 3.1. Control room.

3.2 Reactor Instrumentation and Controls

3.2.1 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 11-1-2G	Elementary diagram shim rod drives
RC 11-1-2H, -2P	Elementary diagram contact tabulation, Sheet 1 (2)
1546-01-E-2130	Elemlentary 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

3.2.2 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 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, Run - servo controlled progression to and operation at power levels between 10 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 to 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 prevent core damage. The scram criteria are: (a) excessive rate of power increase, in Mode 1; (b) excessive core power; (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. There are three independent 64-V batteries, each of which supplies 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 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 deenergize 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.

3.2.3 Shim plates, drives, and drive-motor controls

The control elements consist of two vertical concentric cyliners, 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 Nos. 1 through 4. The inner element is a cylinder, which 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 68.6 cm (27 in.) 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 (Fig. 3.2). 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 (Fig. 3.3). 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 approximately 15 cm (6 in.) per minute. The lead screws for the quadrant plates also can be driven in the insert direction by air motors, at plate speeds of 127 cm (approximately 50 in.) 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 duscussed with the servo system.

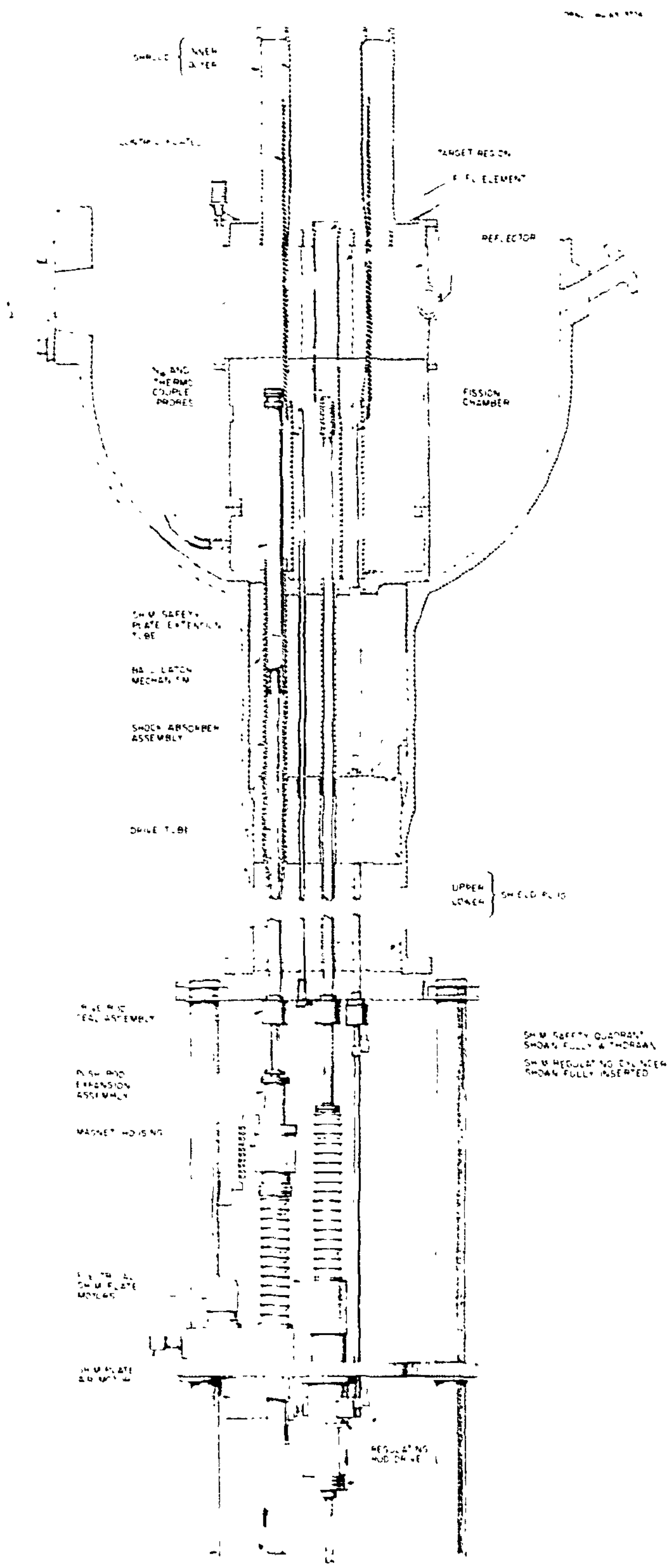

Fig. 3.2. Control plate drives.

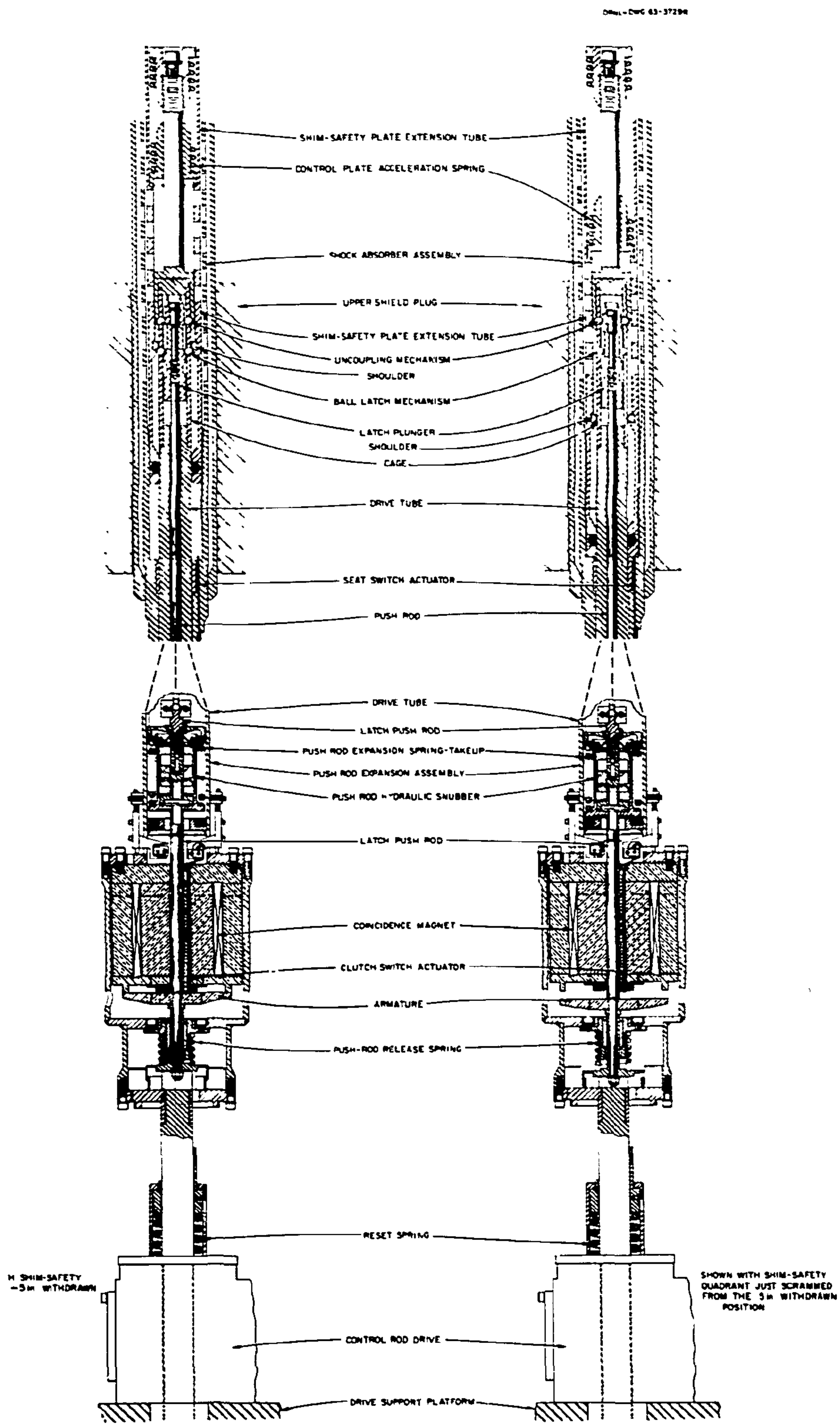

Fig. 3.3. Scram plate magnet and latch mechanism.

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.

3.2.4 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 Fig. 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 change. Insert requests, whether "normal" or origniated 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, each withdrawal is initiated with operater permission and thereafter is automatically controlled. The manual controls serve also for trimming operations to adjust and balance the plate positions.

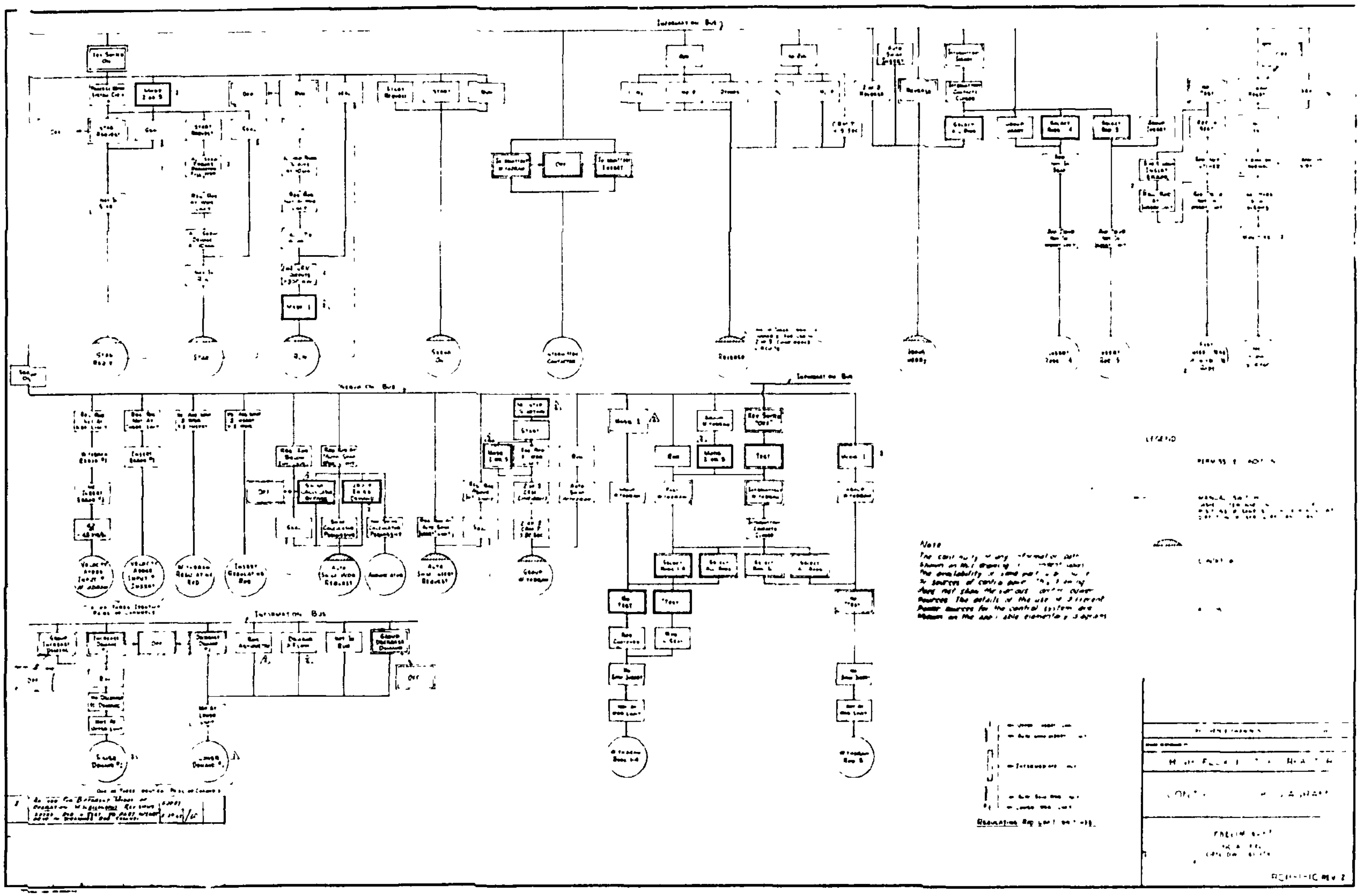

Fig. 3.4. Block diagram of control system.

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 restrictions governing reactor operation, appropriate to the "mode." "Mode 1" position is for intended automatic startup to 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. 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.

b. 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.

c. When the permissives in (b) above are all satisfied, provided the control system is not in "Run" condition, 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, or (b) key switch is turned off.

d. Effecting "Start" condition initiates automatic group withdrawal of all plates via their shim drives.

e. Group withdrawal proceeds continuously, subject to restrictions from the count-rate and servo systems. At least two count-rate channels must signal "Confidence." "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. All three count-rate meters must signal periods greater than 30 seconds.

f. 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 3.2.5).

g. 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 5 MW, (b) regulating drive of No. 5 cylinder is not at its with-draw 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 cause it to drop out: (a) key switch turned "Off;" (b) mode switch turned to "Mode 2" or "Mode 3;" (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 5 MW.

3. Control of power above 10 MW

   a. Power demand instructions are manually set into the servo system (see "Servo System" description, Section 3.2.5).

   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 the shim computer bypass switch is placed in "Bypass." This switch is spring-return to "Off," and 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 will proceed, subject to temporary interruption by (a) 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, (c) plate actuate switch "pulled" to block withdrawal, or (d) any one count rate period shorter than 30 seconds. 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 until the "Auto Shim Withdraw" condition is cleared. The conditions of servo system requesting withdraw and no per mission granted via the bypass switch is annunciated.

4. Shim computer 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.")

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 and "Air Motor Insert" affects the four shim-safety plates, while the other positions affect either individual drives or the group as selected by the shim rod drive selector switch (S-8), Insert requests may be made regardless of whether the handle is "pushed in" or "pulled out," and take precedence over automatic shim withdrawal request. 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 with-draw 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, plates 1 through 4, or the entire group of five plates, to be actuated by switch S-7 described above. This switch has no effect when "Fast Insert" or "Air Motor 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. Insert requests, by rotary position of handle, are effected without restriction. Withdraw requests are effective subject to the following permissives, which are also among those imposed for Mode 1 automatic startup: (a) all count rate periods greater than 30 seconds; (b) at least two count-rate channels must signal "Confidence;" "Confidence" signifies that the count-rate meter is switched to "Use" mode and measured counts are at a rate greater than 10 per second and less than 50,000 per second; and (c) 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 and "Air Motor Insert" request affects all four shim-safety plates. 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, plates 1 through 4, 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" or "Air Motor 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 and locks the demand at 10 MW. This feature is a comparison network which recognizes (a) any quadrant plate is withdrawn more than 3.05 cm (1.2 in.) further than any other quadrant plate, or (b) the withdrawal distance of the shim-regulating cylinder is more than 6.1 cm (2.4 in.) 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 all five 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 mentioned 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 counting 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 a scram or a latch release of a single plate, the drive(s) are 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 safety channels have flux/flow ratios in excess of 1.1 and continues as long as this condition holds. Operation of the air motors is blocked as a group by the raise test switch (S-9) during test operations of or maintenance on shim-safety plate drives. The air motors are individually turned off by actuation of the shim drive clutch switches. Circuit design prevents the air and electric drive of any plate from opposing each other.

Reactor control system readous and manual controls. Reactor control system readouts and manual controls are given in Table 3.1.

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 using the raise-test switch.

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 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 restricted in either direction only by their travel limit switches; test withdrawal is prohibited unless the plate is seated and the seat switch made up.

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, shim drives 1-4, 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

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., Annunciator Procedures
	B) Reverse: No. 2 Channel	Ann. Panel C Point 3	
	C) Reverse: No. 3 Channel	Ann. Panel D Point 3	
	D) Shim request, no permit	Ann. Panel C Point 1	
	E) Plate Asymmetry	Ann. Panel C Point 10	
	F) ac control bus power off	Ann. Panel C Point 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."

3.2.5 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 affected 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 safety 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 Figs. 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. This condition terminates at 10 MW. 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 except asymmetry terminate when their initiating cause is removed, or when the demand potentiometers reach their 10 MW (minimum) settings.

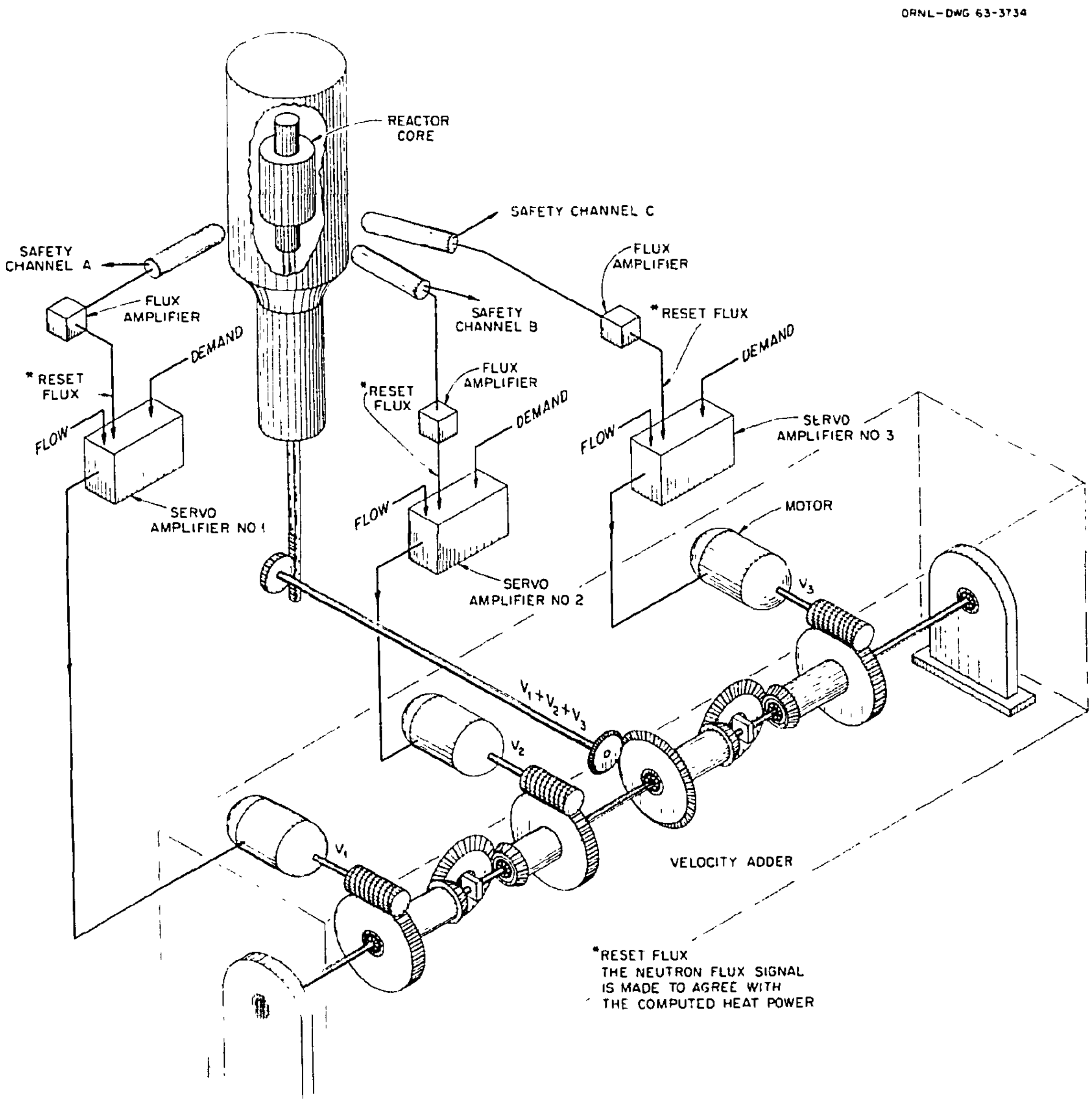

Fig. 3.[illegible] Multiple channel regulating system.

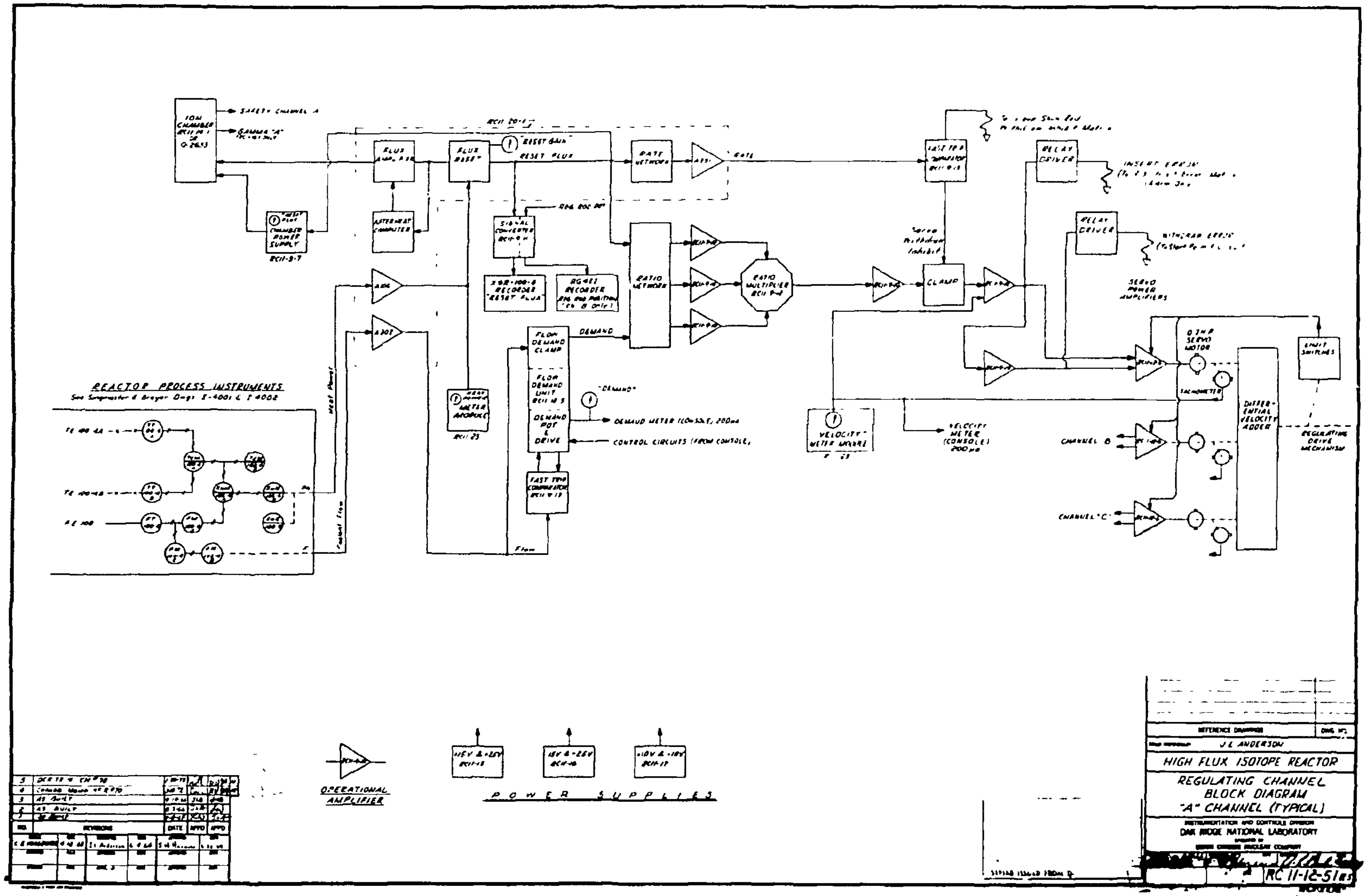

Fig. 3.6. Block diagram of regulating channel A.

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 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 (Fig. 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

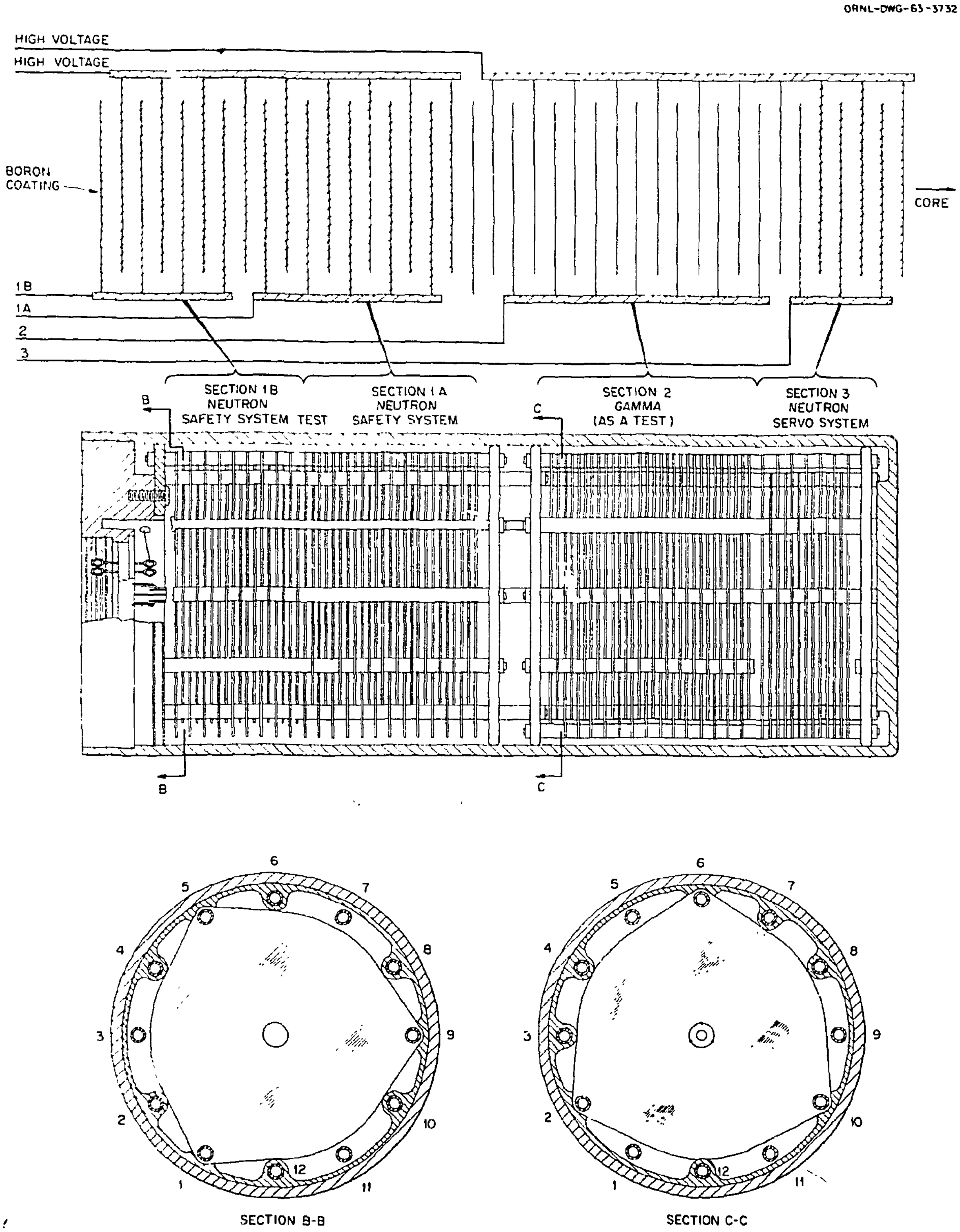

Fig. 3.7. Multisection ionization chamber.

"conditioners," 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 conditioner 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 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 an electronic device to change the flux signal amplification factor. In Mode 1, the device 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 Fig. 3.8. Each of these systems derives primary coolant flow information from a separate differential pressure measurement across the commen 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 pneumetically, 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 two 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 38 cm (15 in.) 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

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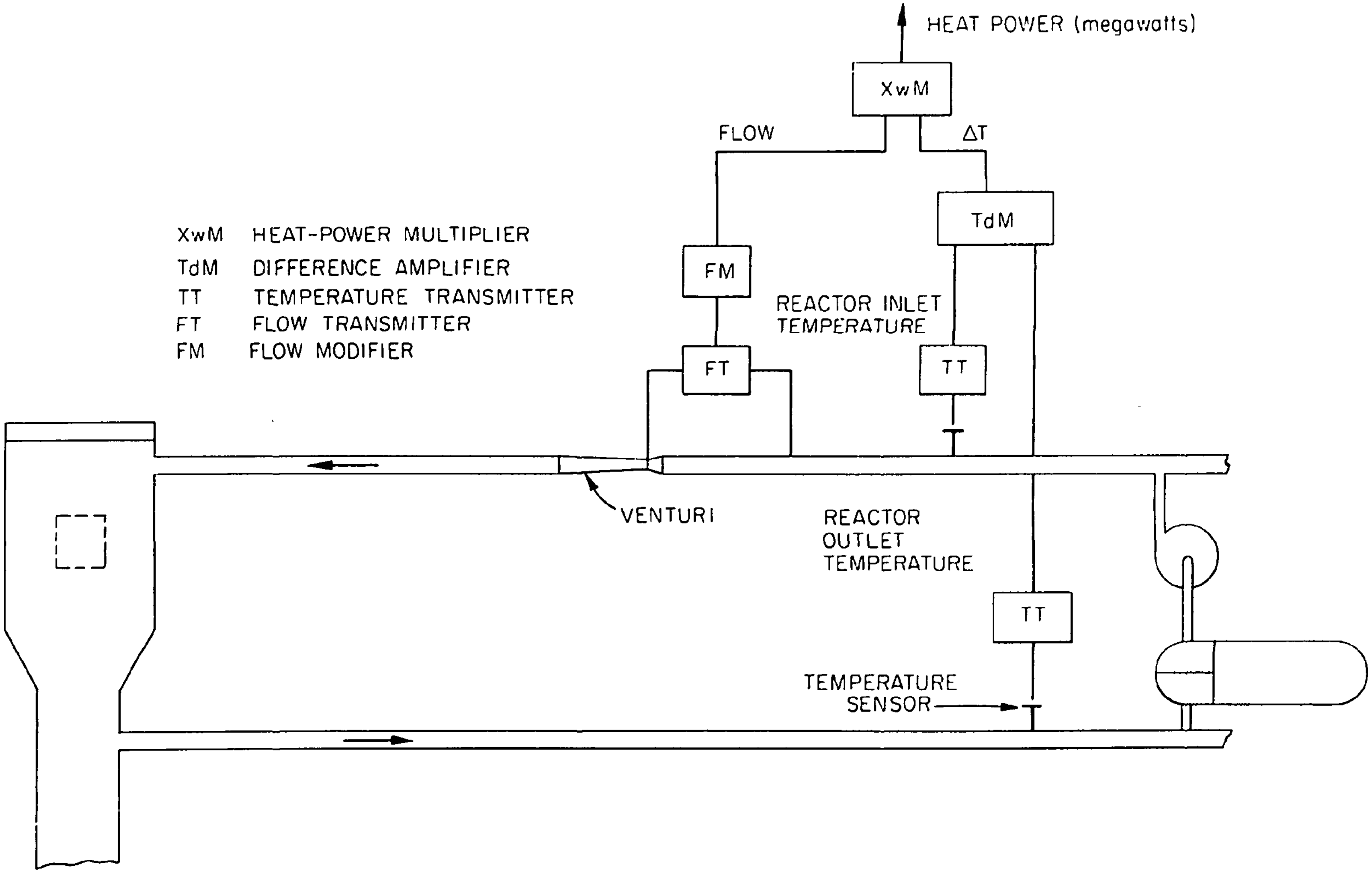

Fig. 3.8. Typical heat-power computer block diagram.

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.

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 MW 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 1 in. 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 1/2 in. from its fully inserted limit, or shim insertion when the drive has inserted to within 1/10 in. of its fully inserted limit.

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

The error signals in the servo channels are used in a control scheme, described under "control system." Maximum withdraw error in all three channels is required for the control system to enter "start" conditions.

Table 3.2 lists servo system readouts and manual controls.

Table 3.2. Servo system readouts and manual controls

Item	Description	Location	Remarks
1	Recorder: 2 pen: XØR 100-4 XWR 100-4	Panel B	XØR reads "Reset Flux" scaled in percent of 100 MW *(same for all modes)*
	Recorder: 2 pen: XØR 100-5 XWR 100-5	Panel C	XWR reads "Heat Power" scaled in percent of 100 MW
	Recorder: 2 pen: XØR 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 °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 percent of 100 MW (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 percent of 100 MW (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 1.33, 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 signals (2) Inhibit all plate withdrawals when reactor power increase rate exceeds 5 MW/s	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 the application. Test switch (E) is intended to provide a quick test of the comparator ability to develop the "trip" output signal

Table 3.2. (Continued)

Item	Description	Location	Remarks
9	Recorder: 1 pen: RG 422	Panel C	Reads position of platform drive of No. 5 (cylindrical) control plate
10	Recorder: 1 pen: XØR-100-7-ΔK	Panel C	Not in use
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 (three instruments: one 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 (three pairs of lamps; one 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 Fig. 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.

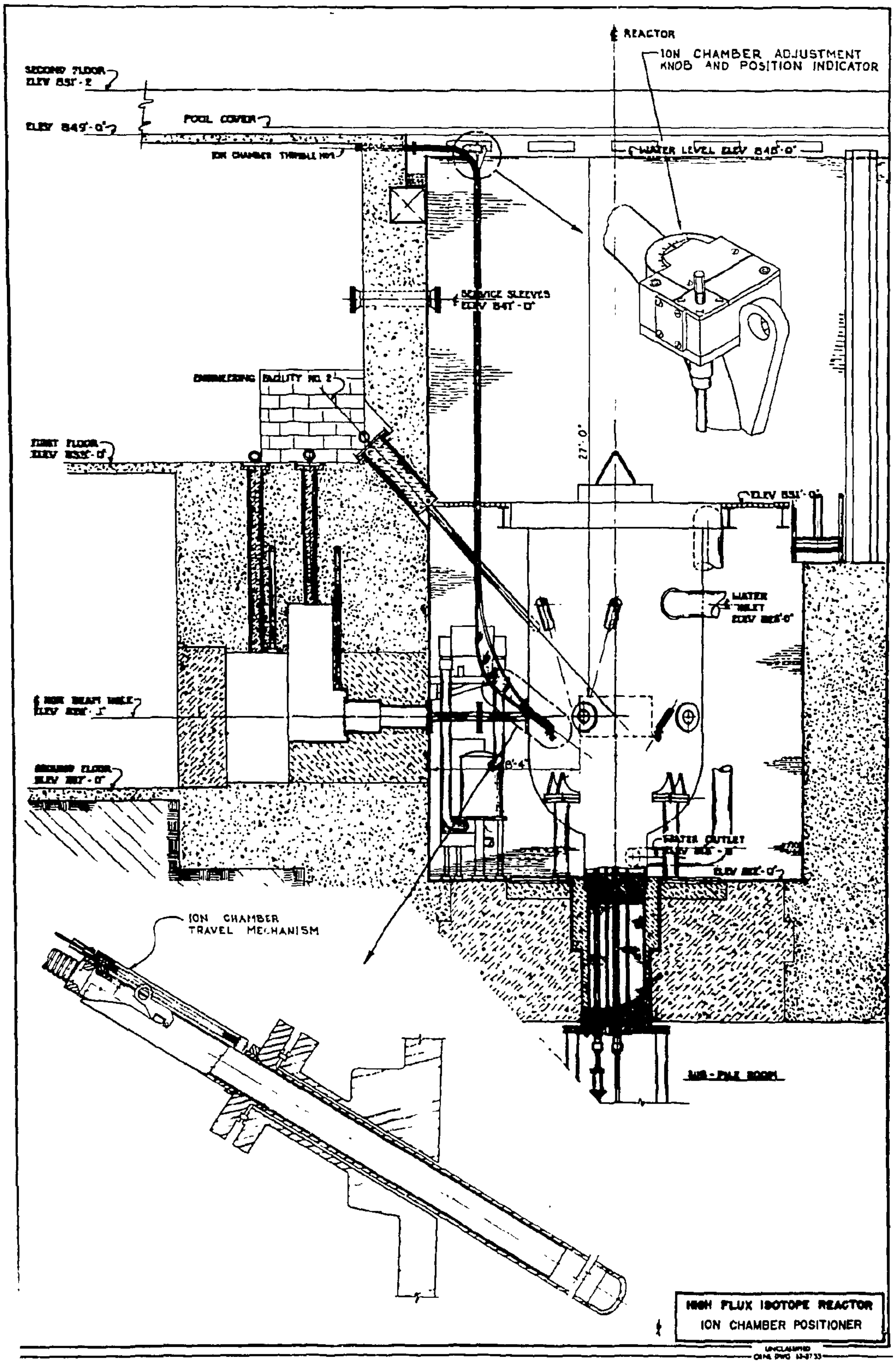

Fig. 3.9. Ion chamber positioning mechanism.

3.2.6 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 are to prohibit shim plate withdrawal when the power increase period is shorter than 30 s and to initiate reverse at reactor power levels below 10 MW when the period becomes less than 5 s. 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 Fig. 3.10. Table 3.3 lists system readouts and manual controls.

The fission chambers for each channel are located with their 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 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.

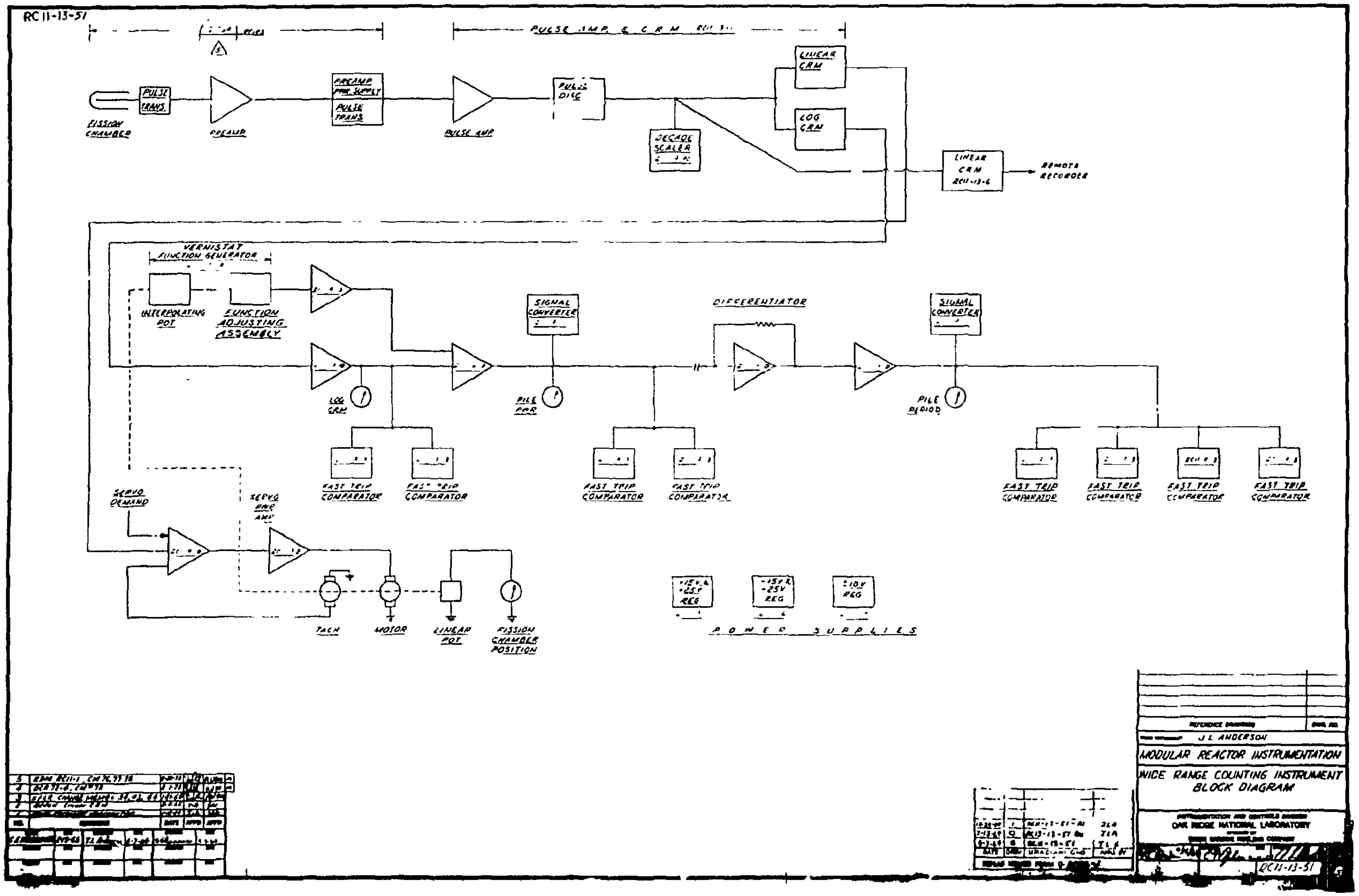

Fig. 3.10. Wide range counting instrument block diagram,

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 percent of 100 MW (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 RTR 100-3	Panel D	
3	Power indicating instrument	1 each, Panels B, C, D	Reads reactor power, scaled in percent of 100 MW (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 positioning indicating instrument	1 each, Panels B, C, D	Reads chamber position to scale of 1 to 7 ft 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" pushbuttons (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" pushbutton (J) "Trigger Level" adjustment (K) "Operate-Test" switch (L) Clock set-operate switch	1 group each, 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 s. 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 section, 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" permit-sag) (4) Period less than 100 s, 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 30 s, positive (no withdraw permit in "Start") (6) Period less than 5 s, positive (reverse, in "Start")	
11	Linear count-rate meter module: (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-s period, CR Channel A	Ann. Panel B, Point 6	See Volume 2, Section 2.4, "Annunciator Procedures"
	(B) 5-s period, CR Channel B	Ann. Panel C, Point 6	
	(C) 5-s 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	

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 s," required for shim rod withdrawal at all times, and (c) "Period less than 5 s," which initiates reverse in start condition. The actual control actions just mentioned are effected only in response to combinations of individual requests for conditions (a) and (c) and individual request of condition (b), 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 s 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" pushbuttons, "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- or a 10,000-cps oscillator is substituted for the chamber preamp pulse signal; alternatively, a circuit is completed whereby a simulated 5-s 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 signal 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 summarized in Table 3.3.

3.2.7 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 amplifers 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 (Fig. 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

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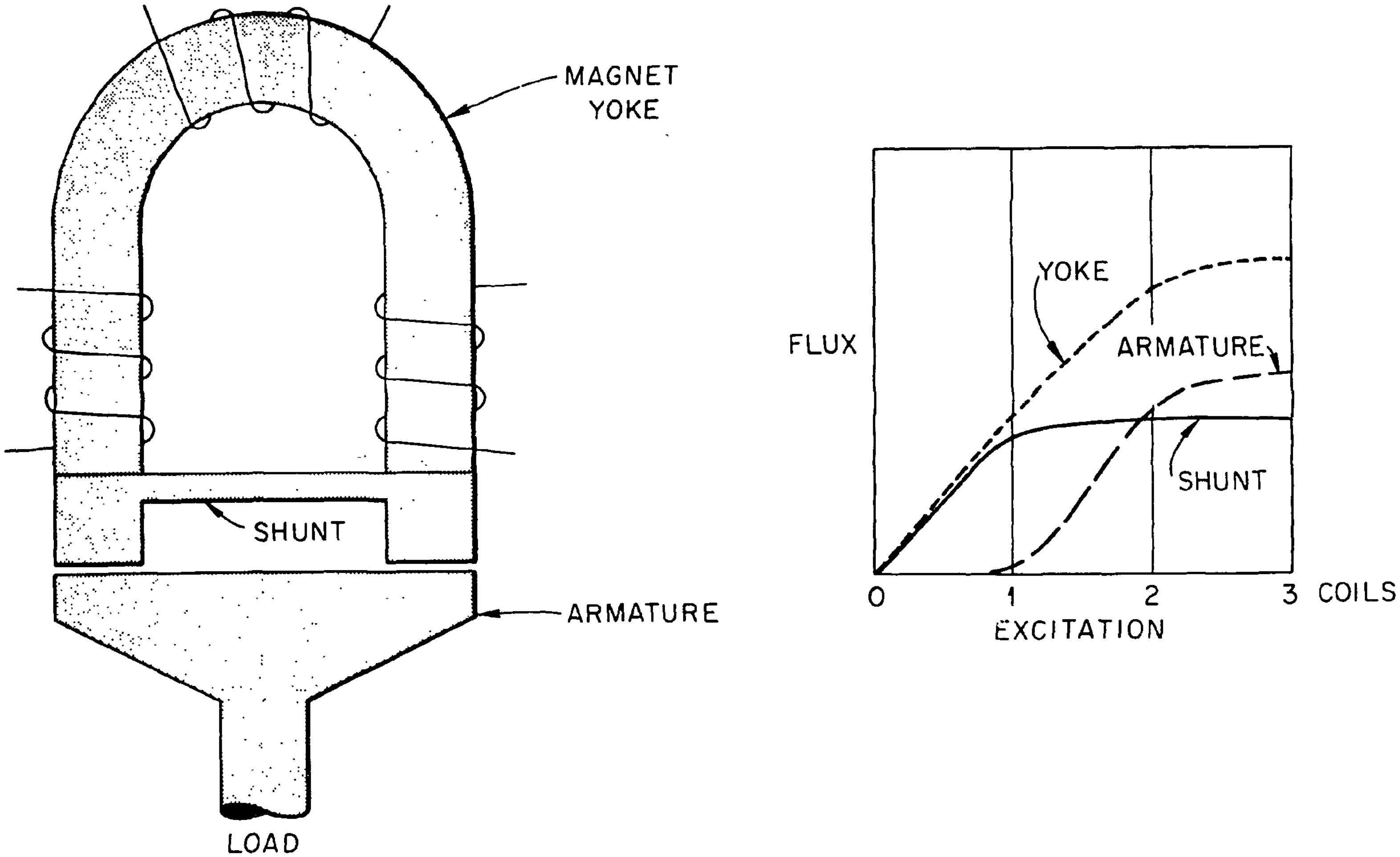

Fig. 3.11. Coincidence magnet.

is prohibited when scram is in effect. The safety system functions are shown in Fig. 3.12. Table 3.4 lists system readouts and manual controls.

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 Fig. 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.

Seven comparator elements in each channel are specially connected to initiate fast scram request. In this application, each comparator develops a dc output signal of -10 V when the monitored condition is "normal." When the condition changes to beyond tolerance, the comparator output changes instantly to 0 V dc. 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.

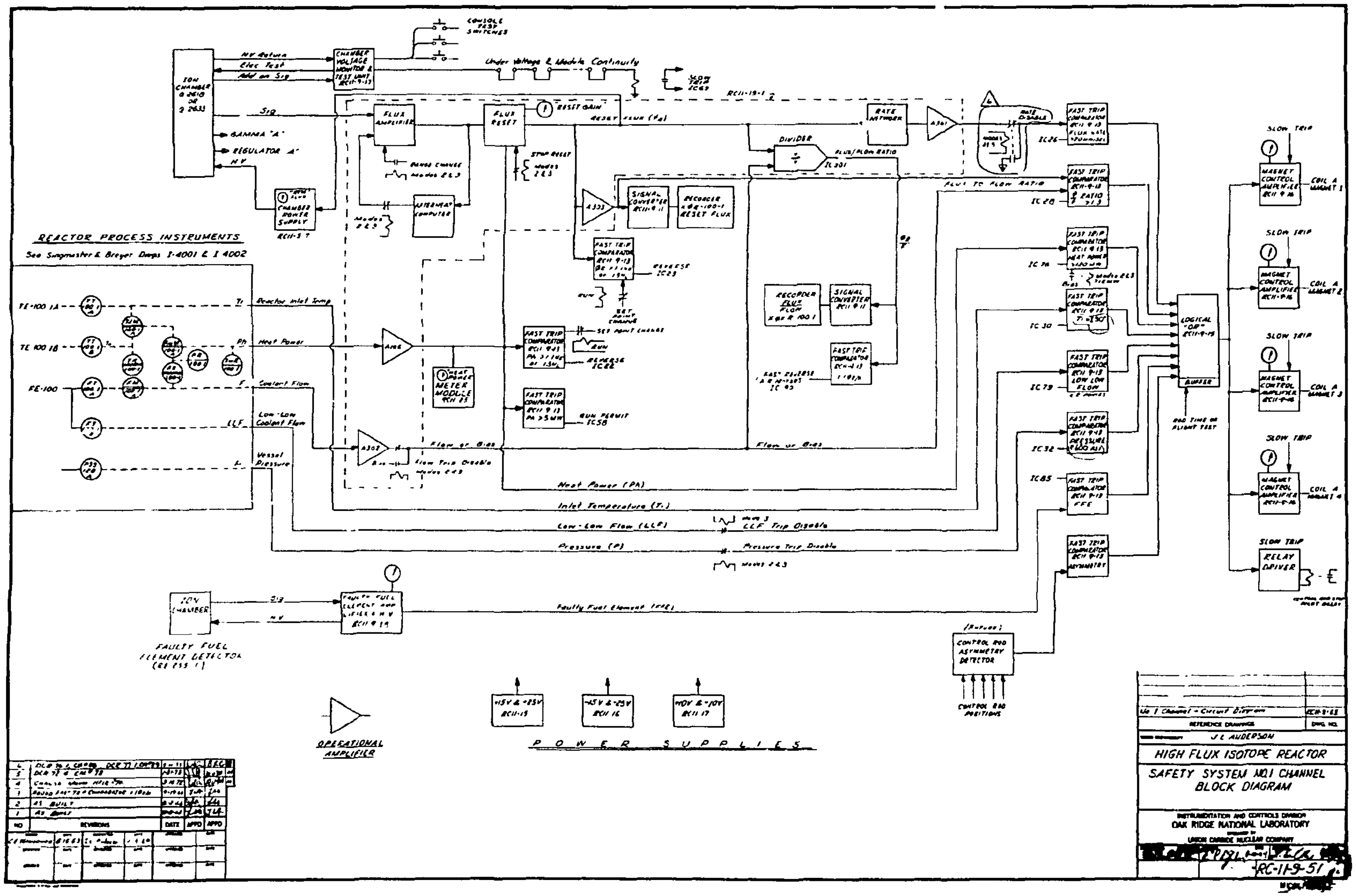

Fig. 3.12. Block diagram of safety channel No. 1.

Table 3.4. Safety system readouts and manual controls

Item	Description	Location	Remarks
1	Recorder: 2 Pen: XØR 100-1 XWR 100-1	Panel B	XØR reads "Reset Flux" scaled in % of reactor rated power for the operating Modes 2 and 3, reading is acutally un-corrected flux)
	Recorder: 2 Pen: XØR 100-2 XWR 100-2	Panel C	XWR reads "Heat Power" scaled in % of 100 MW
	Recorder: 2 Pen: XØR 100-3 XWR 100-3	Panel D	
2	Recorder: 2 Pen: FR 100-1 X(Ø/F)R 101-1	 Panel B Panel B	FR reads "Flow" of primary coolant in % of 1.26 m^3/s (20,000 gpm) X(Ø/F)R reads flux/flow ratio in Mode 1 only; Modes 2 and 3 it reads flux to scale of fraction of rated power for the mode
	Recorder: 2 Pen: FR 100-2 X(Ø/F)R 100-2	 Panel C Panel C	
	Recorder: 2 Pen: FR 100-3 X(Ø/F) 100-3		
3	Recorder: 1 Pen: TR 100-1A	Panel B	TR records reactor inlet temperature of primary coolant, in °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 °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 to (near) 0. "Magnet Current" adjustment sets running current to magnet. The four magnet amplifiers of each channel each supply one of the three magnet coils 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 MW (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, XØR)
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 1.33, 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

Table 3.4. (Continued)

Item	Description	Location	Remarks
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" push-button (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
10	Failed fuel element detector module: Meter Indicating Radiation in Coolant Discharge from Reactor	1 each Panels B, C, D*	Reads beta and gamma radiation from water in core discharge line

Table 3.4. (Continued)

Item	Description	Location	Remarks
11	Fast trip comparator module--scram request; (A) "Normal" indicating lamp (B) "Trip" indicating lamp (C) Trip "latch" indicating lamp (D) Latch "reset" push-button (E) "Trip" test, screw-driver actuated switch (F) Pressure: 3 push-buttons (G) Failed fuel element detector: 6 push-buttons (H) Low-low-flow: 6 push-buttons (I) Mode indicating lamps: 9 (J) Failed fuel element detector position indicating lamps: 6	8 each, Panels B, C, D* Rate, flux/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," "O_R: N_F and N_L," "P_H 5 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 5 MW" unit, trip condition obtains when heat power is less than 5 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 (F) Flux/flow: 3 pushbuttons	Right-hand panel of console: Items A through G arranged by columns according to functions A 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. 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) Function selector switch (B) "Initiate test" pushbutton (C) Channel selector switches (3)	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), (F), (G), and (I), which stop automatically when their

Table 3.4. (Continued)

Item	Description	Location	Remarks
	(D) Digital timer readout--"Rod No. 1" response time (E) Digital timer readout--"Rod No. 2" response time (F) Digital timer readout--"Rod No. 3" response time (G) Digital timer readout--"Rod No. 4" response time (H) Digital timer reset pushbutton (3) (I) PDP 11/60 (J) Transfer switch		respective measurement cycles are completed. The timers monitor the function selected by switch (A), and are reset manually by switches (H). The computer monitors all three parameters of any or all plates that are scrammed. Switch (J) selects either the timers or the computer for response time measurements
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

Table 3.4. (Continued)

Item	Description	Location	Remarks
22	†Plate clutch lamps (4)	Cosole	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
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., Flux/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	

Table 3.4. (Continued)

Item	Description	Location	Remarks
	Low pressure trip -		
	Chanel A	Ann. panel B Point 14	
	Chanel B	Ann. panel C Point 14	
	Chanel 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	
	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		
	1.5 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	

Table 3.4. (Continued)

Item	Description	Location	Remarks
	(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 idicated safety functions; control functions are described under "Reactor Control System."

Auxiliary control action. Four 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; (3) permit for control system to enter and remain in "Run" condition when heat power is above 5 MW; and (4) air motor insert based on reset flux/flow ratio. The control actions are effected 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 let down block valves, (b) the vessel vent valve, and (c) a block valve in the sampling line for fuel cladding failure 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 in "Mode 1--Start," at 15 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 "Test," 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-V 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").

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 1, 2, and 3, 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 (see Fig. 3.13). The computer

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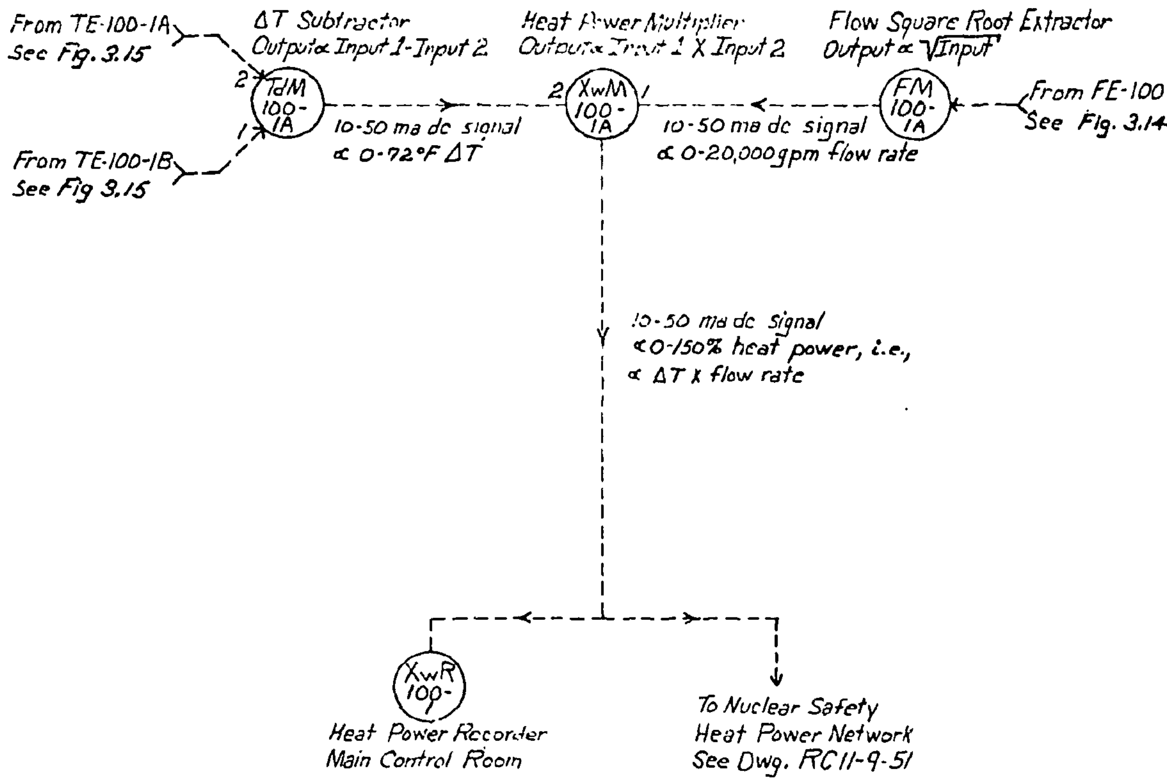

Instrument	Location
FT-100-1A	Inst. Monitoring Platform
EM-100-1	Auxiliary Control Room
FM-100-1A	Auxiliary Control Room
FX-100-1	Auxiliary Control Room
FR-100-1	Main Control Room
TE-100-1A	G-10 Pipe Tunnel
TE-100-1B	G-10 Pipe Tunnel
TT-100-1A	Inst. Monitoring Platform
TT-100-1B	Inst. Monitoring Platform
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. 3.13. Process safety reactor heat power instrumentation.

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 3.2.5. 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 preset 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.

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 1, 2, and 3, 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 54.4°C (130°F).

5. Low-low flow

On loss of the main ac power supply, the primary coolant pumps continue to be driven by dc "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 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 6,435 l/m (1,700 gpm).

6. Primary coolant loop low pressure

The primary coolant system pressurization pumps are intended to maintain the loop pressure at 5.2 MPa (750 psig) in Mode 1 operation, substantially above the 2.07-MPa (300-psi) level at which boiling might begin in the core at full power. Direct acting pressure switches of process sytems 128-A, -B, and -C signal the tirp comparators in safety channels 1, 2, and 3, respectively, to request scram when the loop pressure decreases below 4.13 MPa (600 psig). 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 120% of the steady-state background level 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) loss of 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 reactor power of 40%, and will depend on control system status (i.e., Modes 1, 2, 3, and start/run), reactor 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 ramp

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 NF per second. The ramps are initiated by the "Current-Ramp" 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 ramp 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 Ramp," 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 the low range flow sensor 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.

6. Pressure switch test

The pressure switches that signal loss of primary coolant pressurization for each safety channel area each connected via small diameter tubing to an individual tap in the reactor outlet line. There is normally no flow in the connecting tube, and the entire loop pressure is transmitted directly to the switch presssure 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 2.07 MPa (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 1/2-in. 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 and "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.

8. Flux/flow ratio test

This test, provided in Mode 1 only, reduces the pressure at the main flow dp cell and produces a channel scram request on the flux/flow trip element. Channel repsonses include immediate decreases in heat power and flow indications and an increase in flux/flow indication and subsequent scram request. The 1.1 flux/flow element, which gives an air motor insert request, is also tripped.

Shim-safety plate drop and time-of-flight tests are facilitated by use of the HFIR on-line computer, electronic digital timers, and response switches. Normally the time measurements are made by the computer with the digital timers reserved for back-up use. 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 the timing process by the computer (or the digital timers if they have been selected). If two or three channels are selected, the magnet 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." The computer has the capability of monitoring all three parameters of all four plates simultaneously. However, only four digital timers are provided, one for each plate. A manual selector switch determines which parameter is to be monitored. The digital timers then are stopped by the selected "Response" limit switches. Type-out of measured times by the computer is provided in the main control room. All other controls and digital 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.

3.3. Process Instrumentation

3.3.1 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
D-49137	Hot Water Injection System Flow Diagram
RC11-8-2	Instrument Air, One Line Diagram
RC11-10-9	Instrument Application Diagram, SBHE, OHOG, and CHOG Systems

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

3.3.2 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 contiuous 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 regualtors at various locations, each of which reduces pressure to 138 kPa (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-V 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 penumatic "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, penumatic 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 penumatic 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 penumatic 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/250-V/120-V transformer, No. 7. They are automatically switched 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, C1-B, and C1-C via air receiver 6A and 6B which stores a substantial reserve supply. The compressors are fed form different power supplies, one with backup from No. 1 diesel-generator and another 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.

3.3.3 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 (Fig. 3.14) actuates (a) the loop high pressure annunciator switch, (b) a switch that 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 control valves, one at each heat exchanger outlet, which regulate the flow of water into the loop cleanup system.

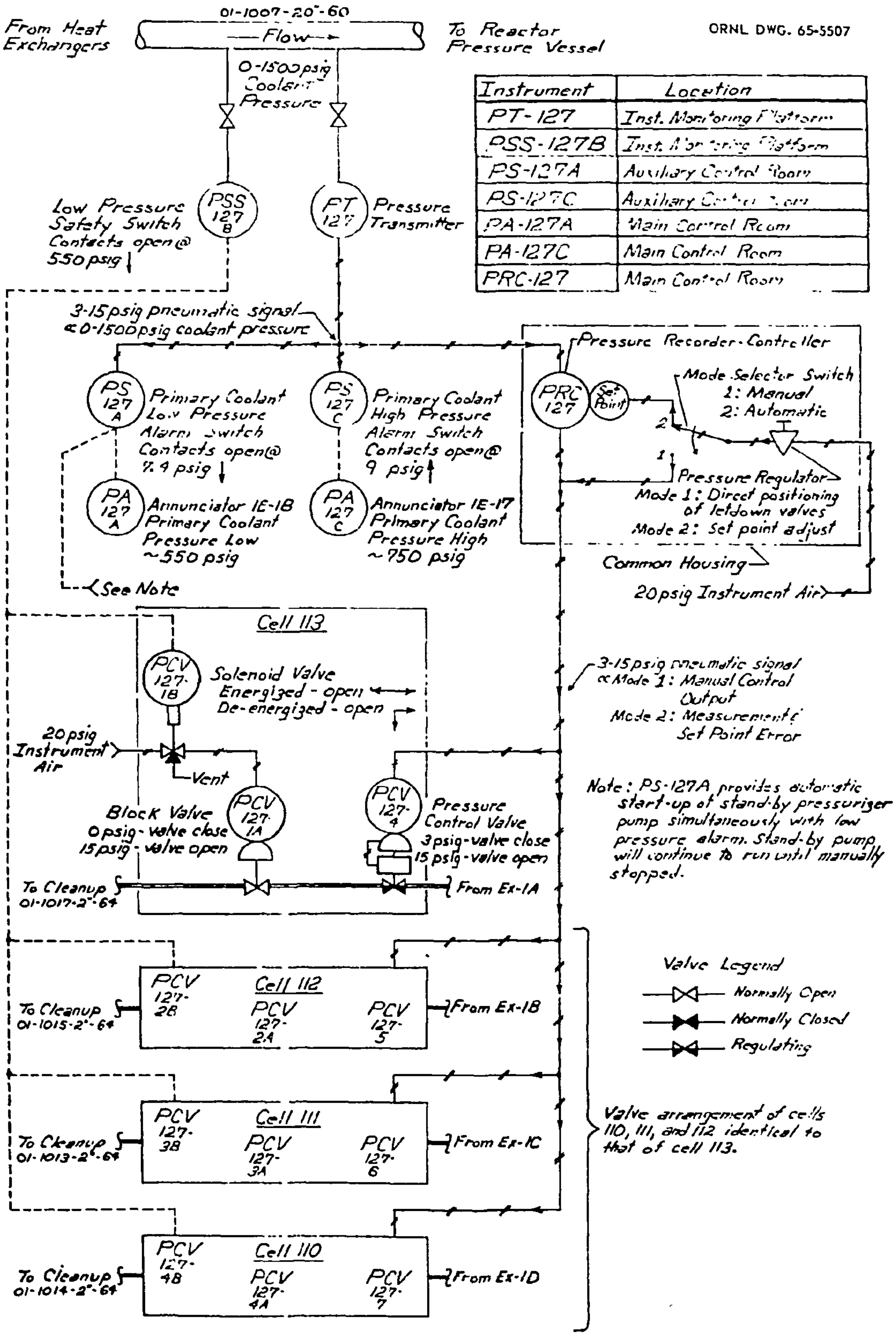

Fig. 3.14. Primary coolant pressure control system 127.

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. Each letdown control valve and its two associated block valves are caused to close individually when the discharge valve of their associated primary circulating pump is closed. This automatic action results from operation of a limit switch (ZS149-3, 151-3, 153-3, 551-3) on the discharge valve, and consequent action of solenoid valves to relieve the pneumatic pressure in the letdown control valve operator and the block valves operators. In series with each of the four letdown control valves are the two above-mentioned block valves. All eight of these block valves are controlled as a group and assume completely open or completely closed positions on command of switch matrices. When control switch HS-127 on Panel E is in the "Normal" position, either of two conditions will cause block valve closure: (1) opening of direct-acting pressure switch PSS-127B in response to loop pressure below 4.65 MPa (675 psi); or (2) high radiation trip condition in the faulty fuel element detectors of two safety channels. "Block" position of HS-127 causes the valves to close independently of other signals, and "Unblock" causes the valves to open and remain so. The latter control feature permits water from the primary loop to be transferred to the cleanup system regardless of loop pressure or contamination conditions. 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 PSS-127A is actuated at pressures below 4.8 MPa (700 psi) to initiate an alarm on annunciator point IE-18 and to request start of the "Standby" pressurizer pump. Switch PSS-127C initiates an alarm at pressures above 5.5 MPa (800 psi) on annunciator point IE-17. Systems 128A, B, and C are primarily independent pressure switches operating directly from loop pressure. Each switch has two poles, one actuating the "Low Pressure" trip comparator to produce scram request in one safety channel during Mode 1 operation, and the other producing 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 presssure 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. These hand valves may be used to test operation of the pressure switches in the event the regular test system did not function.

The same switching matrices that control the letdown block valves also control a block valve in the sample stream for the fission product detection systems 200 and 253 (see Item 4 below); this valve assumes the same position as the letdown block valves. The matrices also exert partial control on the reactor vessel vent valve, per Item 12 below.

System 104 senses primary system inlet water pressure and transmits this signal to the main control room for digital pressure indication.

All of the block valves also close when two (out of three) safety system failed fuel element detectors recognize high radiation.

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 (Figs. 3.15 and 3.16). 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

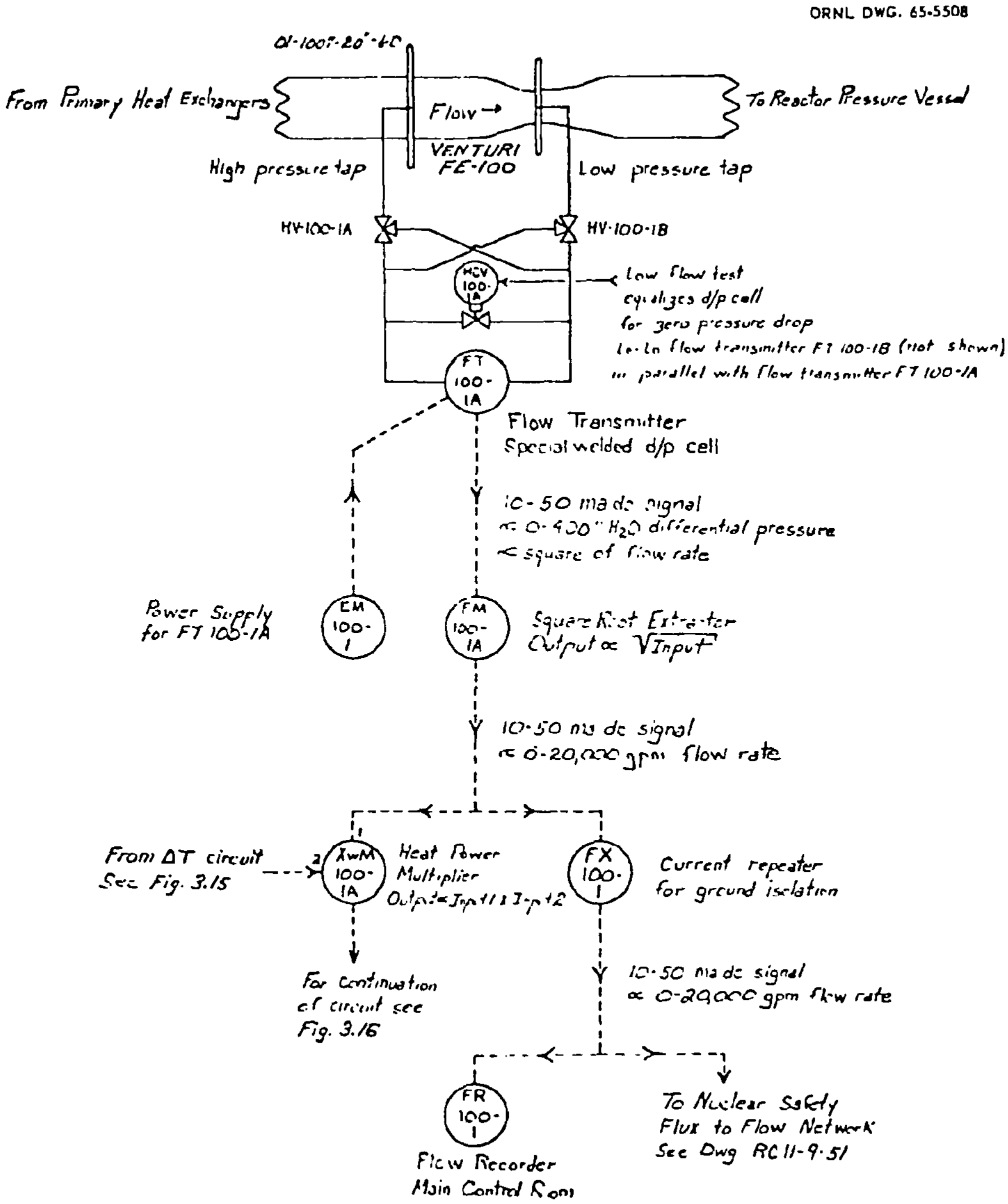

Fig. 3.15. Process safety primary flow instrumentation.

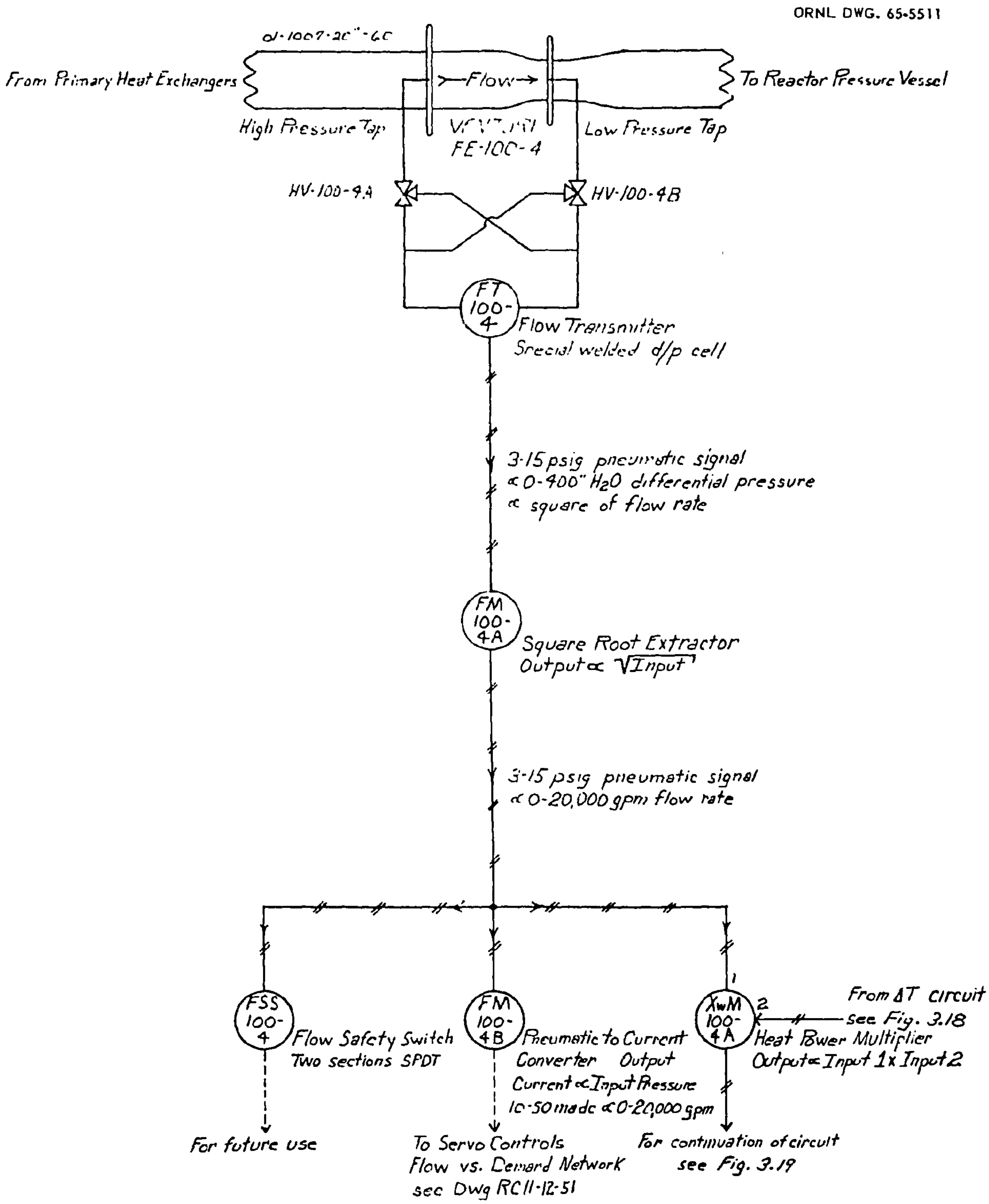

Fig. 3.16. Process servo primary flow instrumentation.

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 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 (see Fig. 3.17). 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 auto-matically 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.

3. Loop temperatures

Control of the primary loop temperature is effected either by manual or automatic control of the heat exchanger's secondary water flow, and indirectly by automatic control of the

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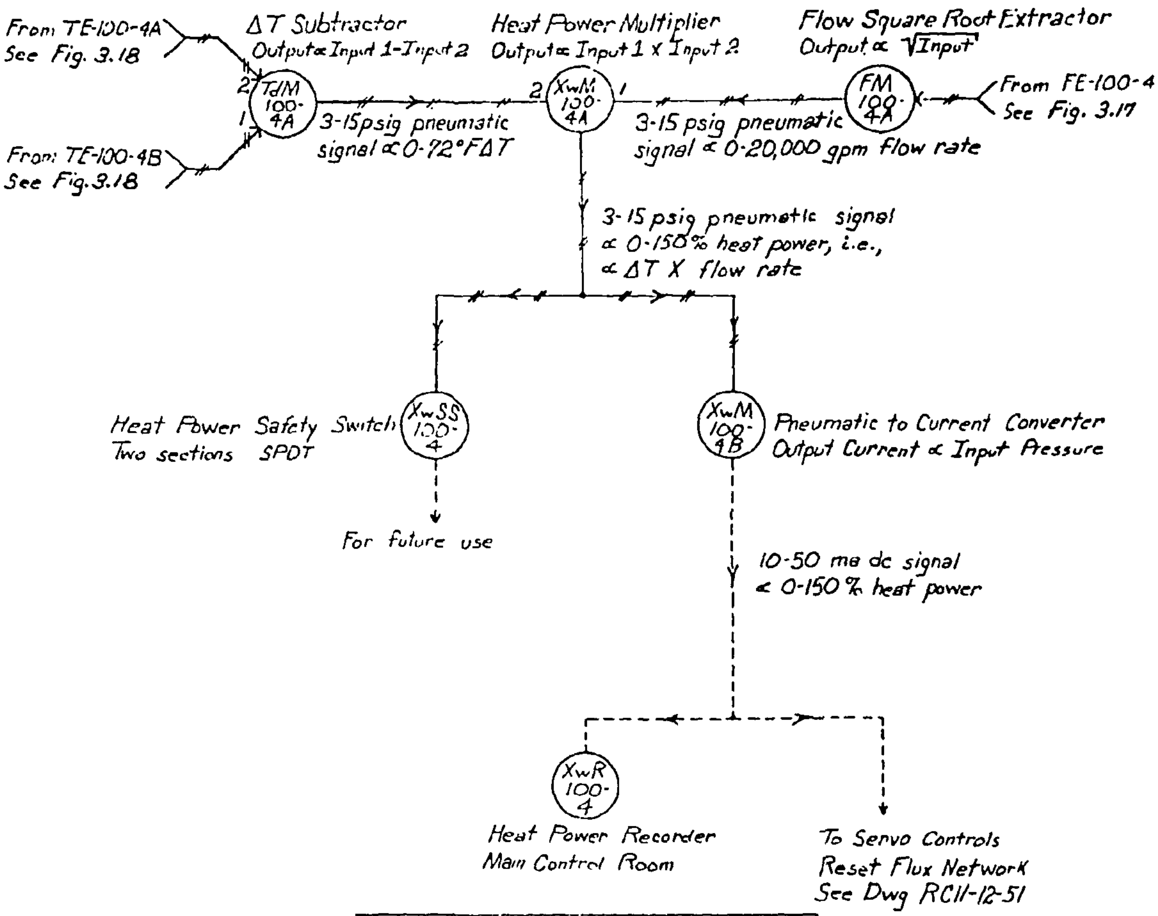

Instrument	Location
FT-100-4	Inst. Monitoring Platform
FM-100-4A	Auxiliary Control Room
FM-100-4B	Auxiliary Control Room
FSS 100-4	Auxiliary Control Room
TE-100-4A	G-10 Pipe Tunnel
TE-100-4B	G-10 Pipe Tunnel
TT-100-4A	Inst. Monitoring Platform
TT-100-4B	Inst. Monitoring Platform
TSS-100-4A	Auxiliary 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. 3.17. Process servo heat power instrumentation.

secondary loop cooling tower discharge water temperature. The primary loop temperature instrumentation provides information to the operator and to the reactor control and safety system (Figs. 3.18 and 3.19). Each of the 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 form 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 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.

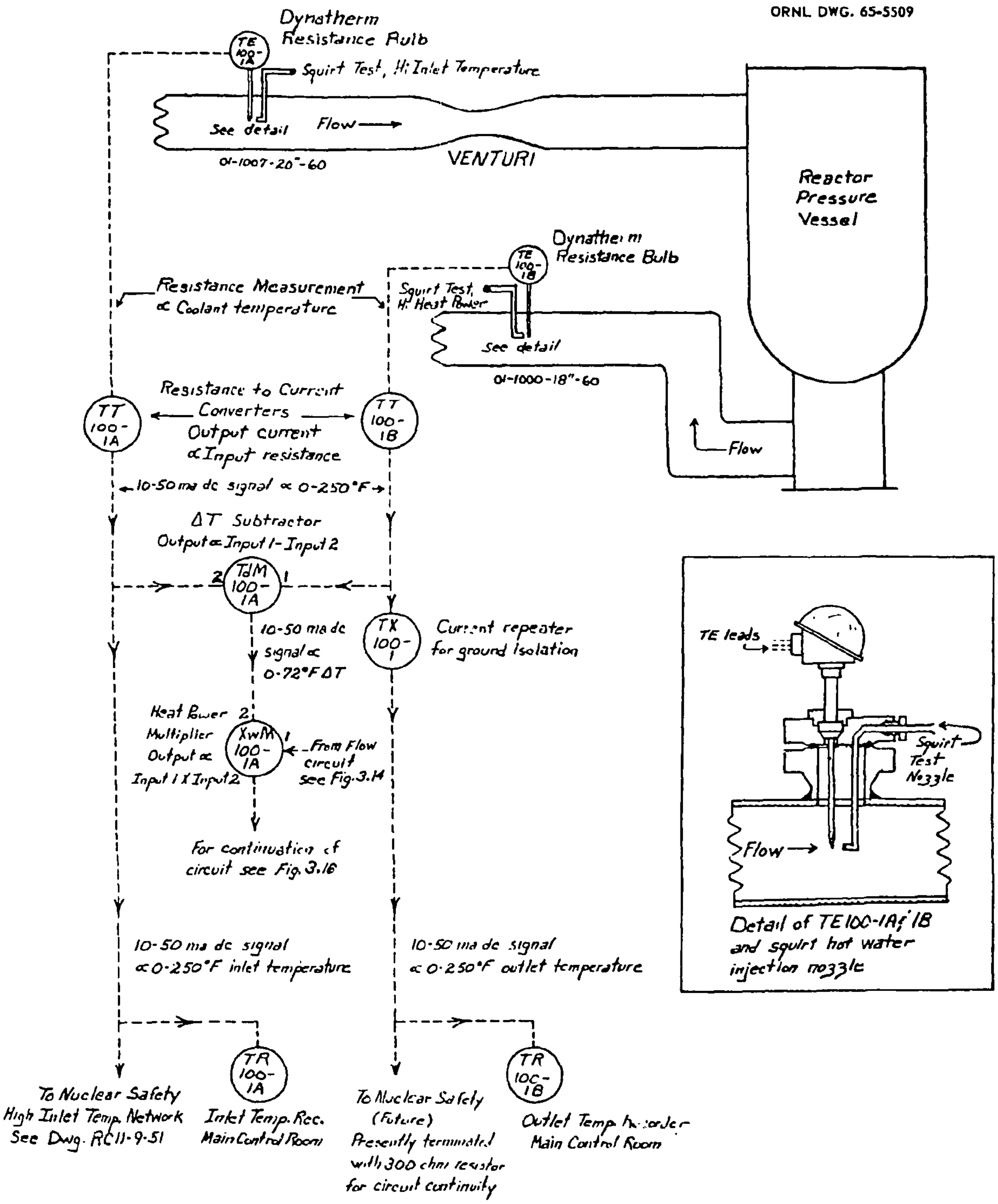

Fig. 3.18. Process safety primary inlet and outlet coolant temperatures and core ΔT instrumentation.

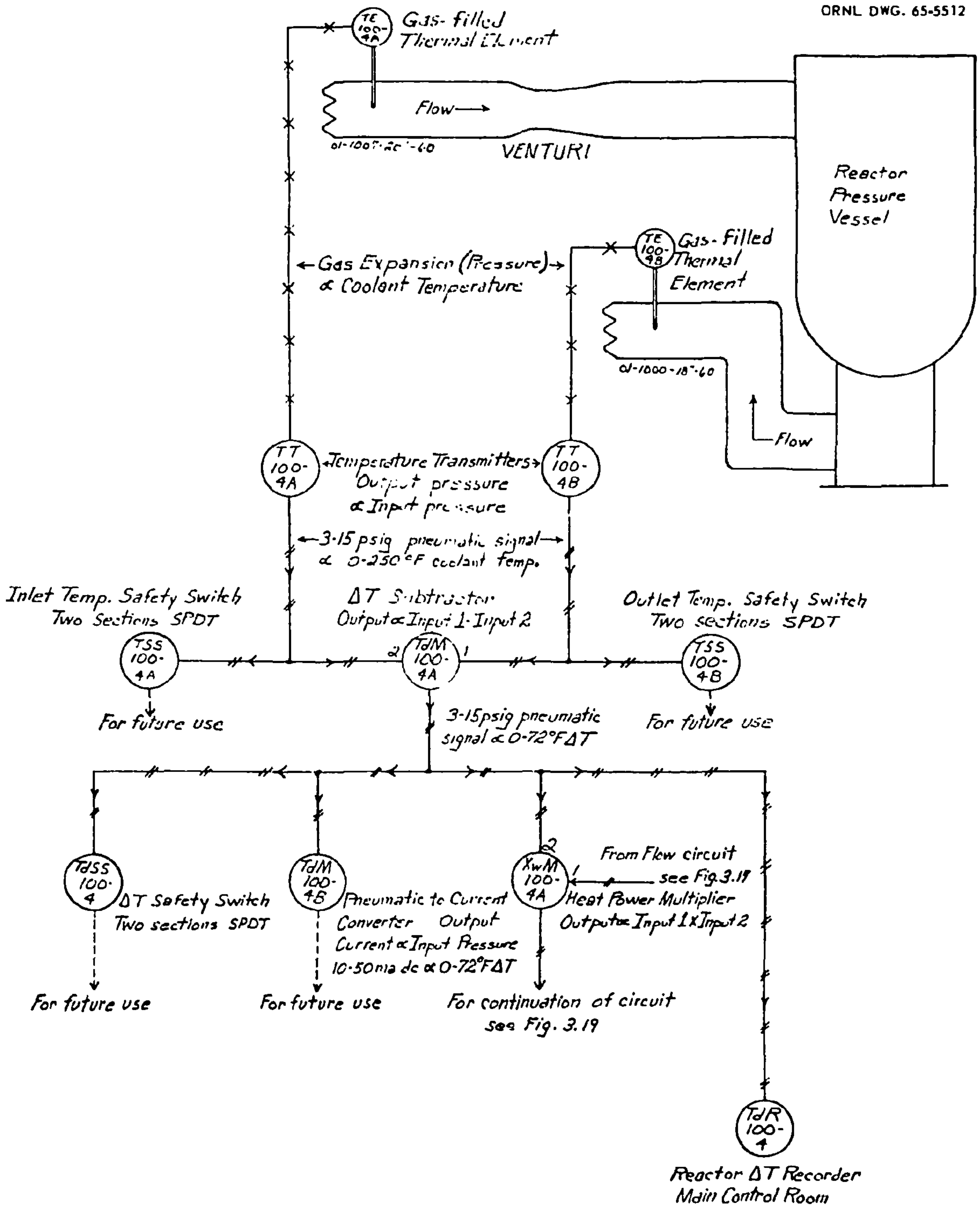

Fig. 3.19. Process servo primary inlet and outlet temperatures and core ΔT instrumentation.

Additional temperature instrumentation in the primary loop is described below in association with the particular equipment monitored. The instrumentation necessary to control the primary coolant at the desired temperature may be grouped into two subsystems. The first subsystem, consisting of the 25.4-cm (10-in.) secondary coolant system valve (TCV-377A) and its associated instrumentation (see Fig. 3.20) is the actual temperature control system, maintaining a constant reactor inlet temperature at the desired operating power. The inlet temperatures as measured by the three servo heat power systems are fed to three independent controllers, and their outputs are fed through a pneumatic relay matrix. This relay matrix rejects the highest and lowest error signals and passes the median signal, positioning the 25.4-cm (10-in.) valve to maintain the desired temperature.

Since the 25.4-cm (10-in.) valve has a limited range of temperature control, a second subsystem is necessary to keep the 25.4 cm (10-in.) valve within its control capabilities at various power levels. This second subsystem is comprised of the 91.4-cm (36-in.) secondary coolant system valve (TCV-377) and its manually controlled positioner HIC-377.

4. Radioactivity due to fuel element cladding failures

In addition to the core outlet gross activity monitors associated with the safety system (see Section 3.2.7), 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

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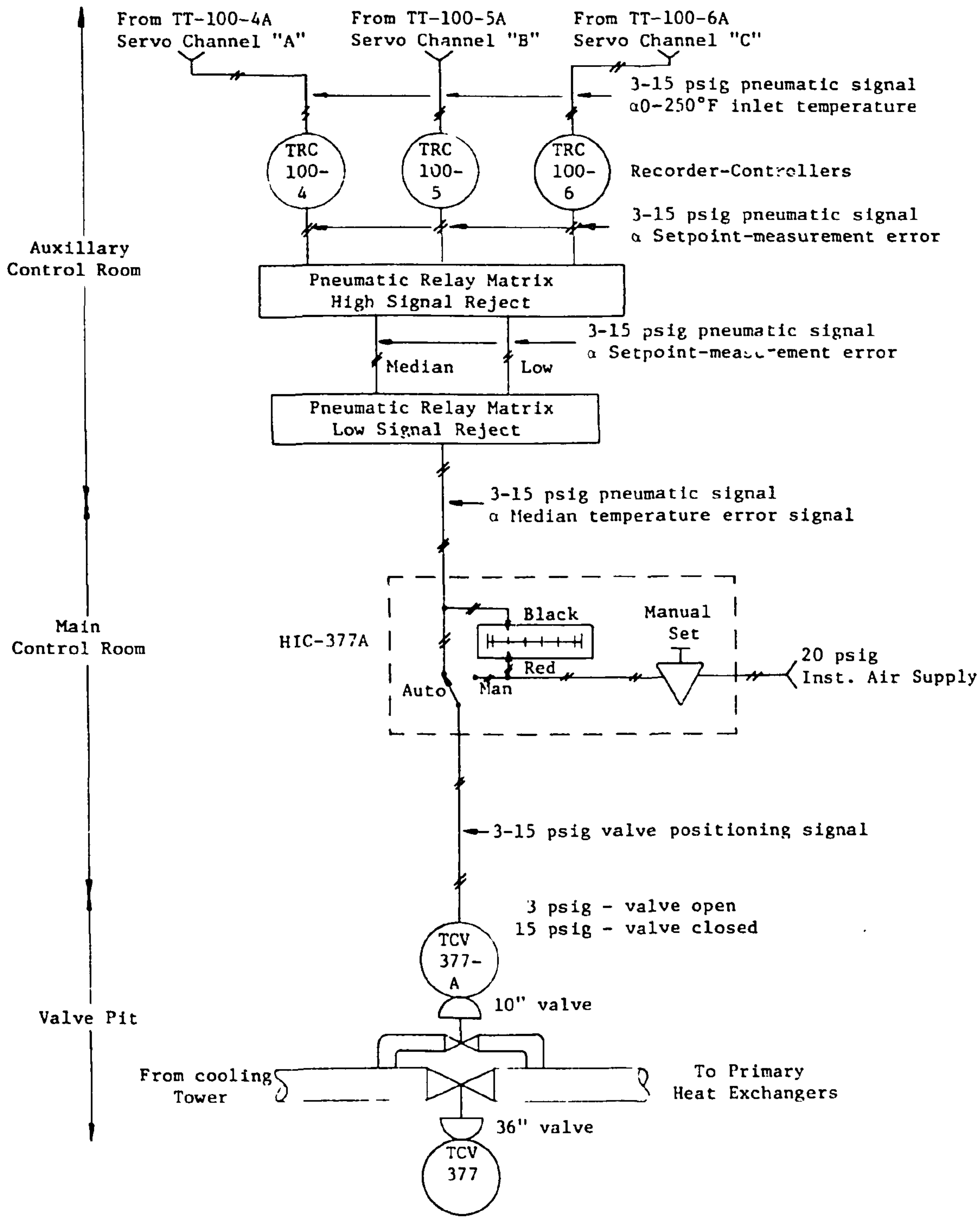

Fig. 3.20. Reactor primary temperature TCV-377A valve control system.

indicated locally by pneumatic instruments including a flow transducer, an indicator controller, and a control valve. A pneumatically operated block valve in the sample line is controlled by the same switching matrix that controls the main letdown block valves (see "Loop Pressurization"). Thus, sample flow is shut off (a) when HS-127 on panel E is in "Block" position, or (b) when HS-127 is in "Normal" position and either low pressure or high radioactive contamination conditions exist. 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, which is 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 indicated and recorded locally at the cladding failure detector cabinet in the auxiliary control room. A fast trip comparator 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, which is 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 and provides local indication. High radiation, approximately twice background, or downscale failure of the monitor instrument is annunciated on point 4E-22. Activity level is recorded in the control room on multipoint recorder RR-1000.

Hand valves HV-274 and -275 isolate the radiation detectors when required.

5. Reactor vessel inlet strainer pressure drop

Pneumatic system 103 provides indication on PdR-103 of differential pressure across the reactor vessel inlet strainer and annunciation for high ΔP on IE-23.

6. Reactor vessel pressure drop

Pneumatic system 106 monitors total pressure drop across the reactor vessel and inlet strainer. 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. 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.

8. 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."

9. 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 (Fig. 3.21) 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

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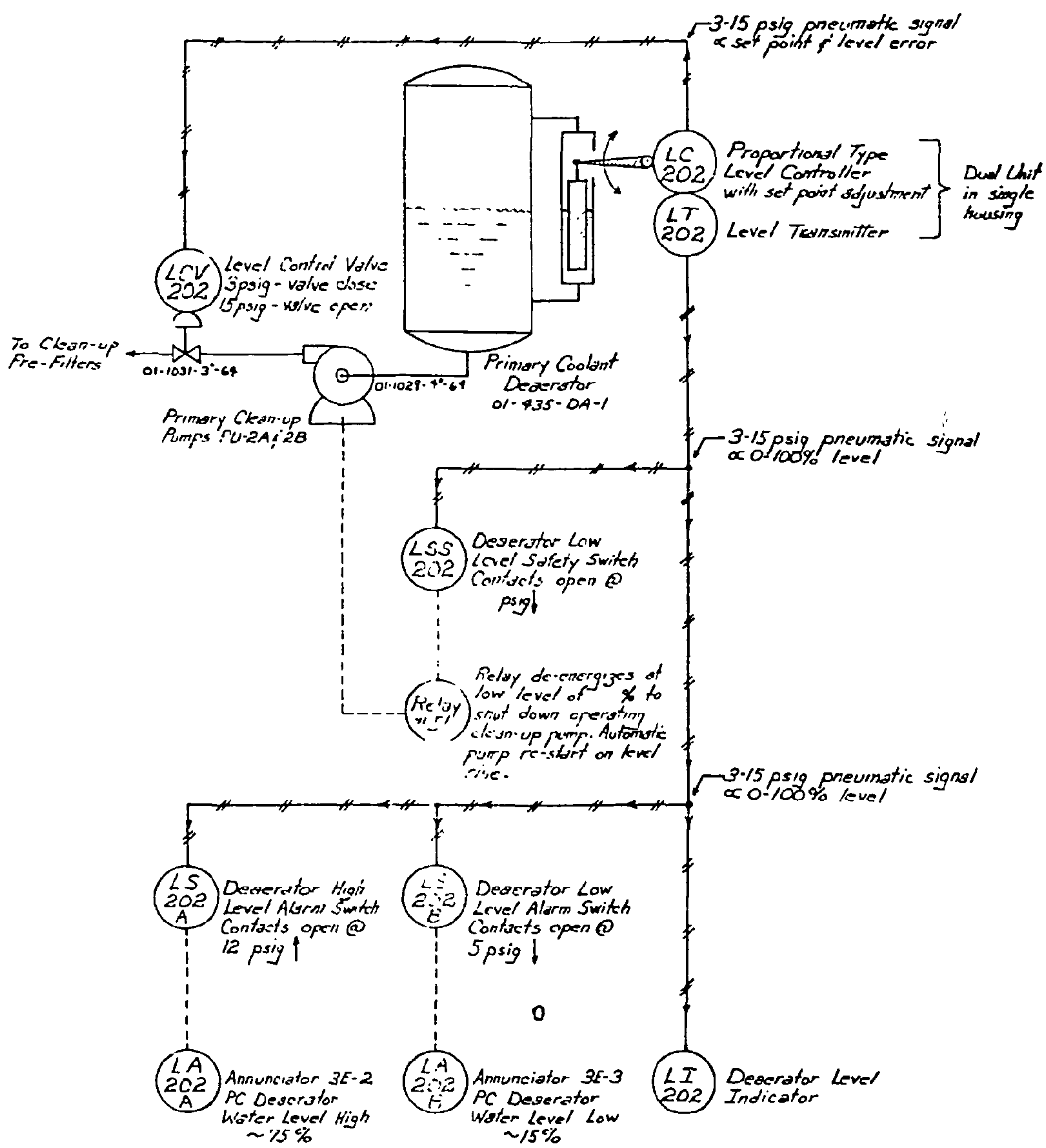


Instrument	Location
LC-202	Adjacent Primary Deaerator
LT-202	Adjacent Primary Deaerator
LSS-202	Outside Cell 104
LS-202-A	Auxiliary Control Room
LS-202-B	Auxiliary Control Room
LI-202	Main Control Room
LA-202-A	Main Control Room
LA-202-B	Main Control Room
LCV-202	Cell 104
Relay #51	Motor Control Center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

Fig. 3.21. Primary coolant deaerator level control system 202.

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. Upon high off-gas temperature indication by TE-476, TS-476 actuates annunciator 3E-12 and closes the steam supply valve for the jet ejectors.

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 -67.5 kPa (-20 in. Hg) gauge 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

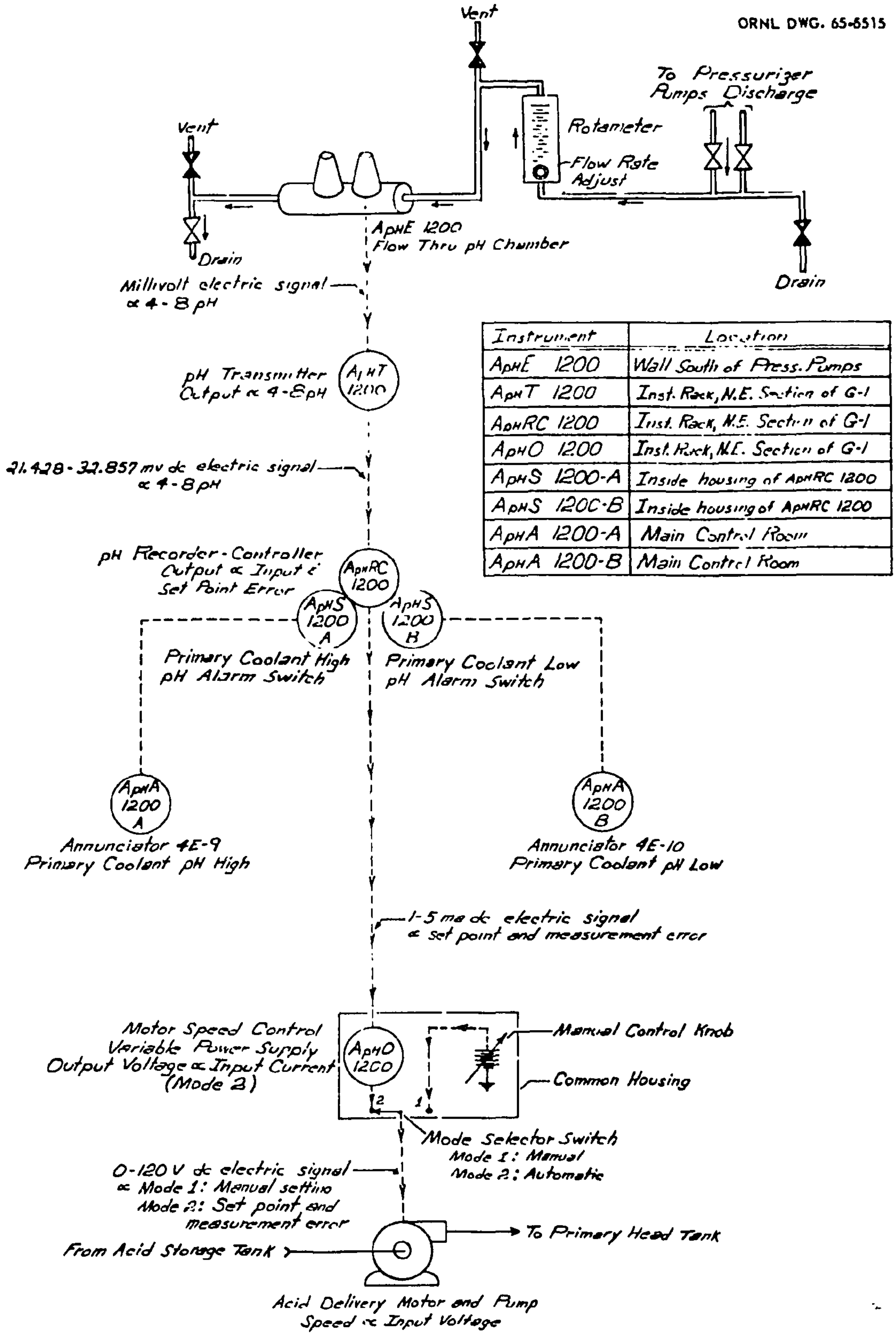
Local indicators for the inlet and outlet pressure of each pump.

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 (Fig. 3.22). 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 controller is then converted by operator ApHRC-1200 to a 0-120 V 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. Externally mounted differential pressure indicators are also provided for the prefilters. A flow glass in the common vent header exhibits a rise of liquid level on failure of filter vent ball float traps.



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. 3.22. Primary coolant pH control system 1200.

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 afterfilter

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

i. Demineralizer effluent contamination

System 127 samples the primary demineralizer effluent beyond the afterfilter 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 CS-217A closes the demineralizer outlet valve to shut the system down in the event the demineralizer is discharging poor quality water into the primary head tank.

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 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 setpoint 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.

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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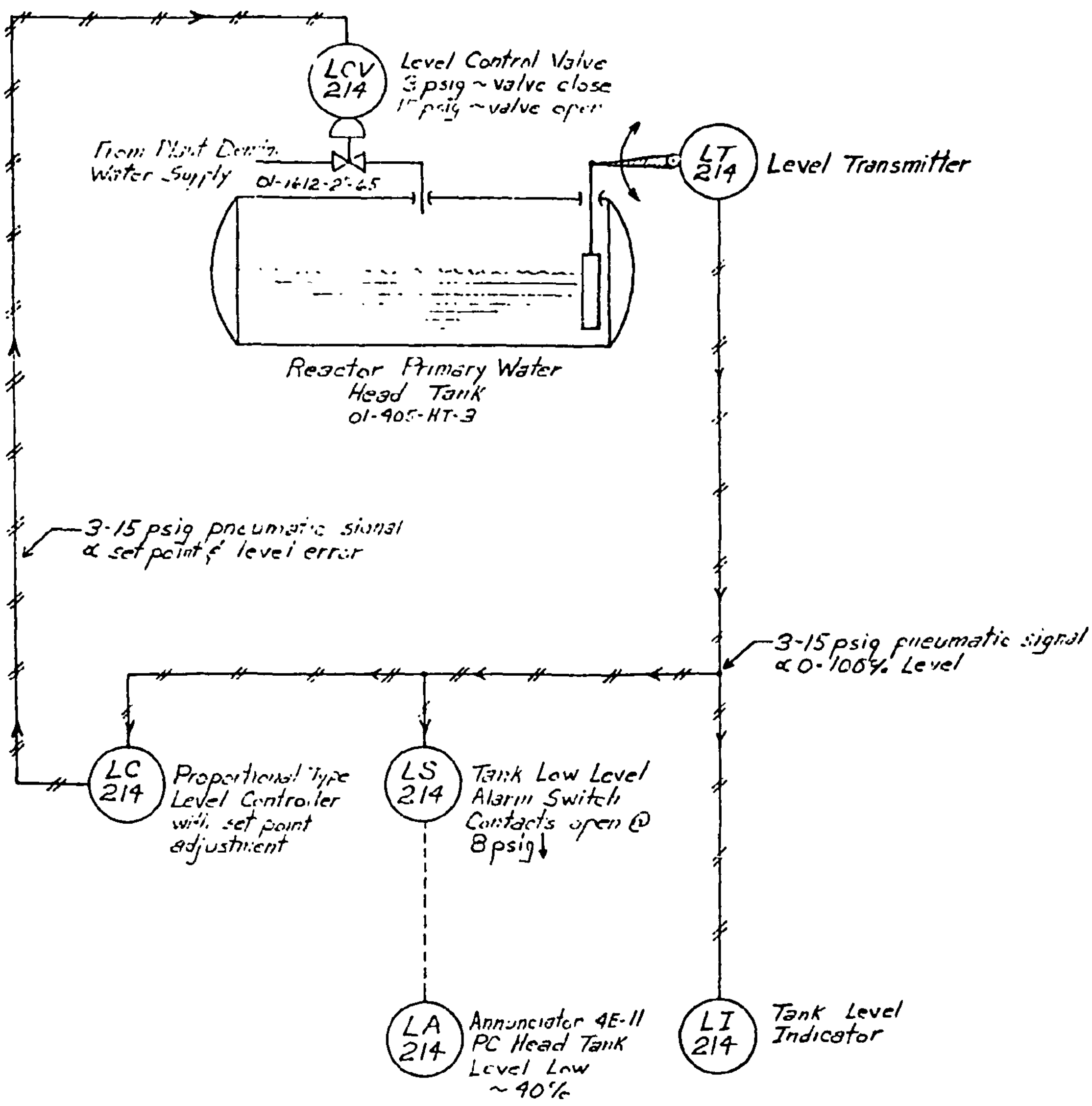

Instrument	Location
LT-214	Atop PC Water Head Tank
LC-214	Auxiliary Control Room
LS-214	Auxiliary Control Room
LI-214	Main Control Room
LA-214	Main Control Room
LCV-214	Vicinity PC Water Head Tank

Fig. 3.23. Reactor primary water head tank level control system 214.

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 57.2°C (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 73.8°C (165°F) or by a pressure switch when the water supply to the control valve falls below 52 kPa (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. The pump motor is also shut down upon loss of pump suction pressure, high discharge water temperature, and high discharge pressure 5.9 MPa (850 psig).

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 drive rod 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. Flow recorder FR-216 also records a signal from flow element FE-258 which is located between the demineralizers and the primary head tank.

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 afterfilter, 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 and actuates a local alarm and control room annunication on point 4E-13. A second radiation system, No. 213, monitors the primary cleanup system outlet at a point downstream from the first afterfilter. 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 backflush 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.

10. 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.

b. Safety system temperature test hot water injector supply

The steam flow to the heat exchanger is controlled by HCV-1124 located in the steam line to the heat exchanger. Valve HCV-1124 opens to admit steam whenever the command is given to inject hot water. 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) PI-1120 indicates local exchanger outlet pressure.

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

(3) FE-1105 measures total flow to the injectors; the associated penumatic transmitter output actuates flow indicator FI-1107 at the control panel.

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.

11. Reactor vessel venting

Venting of the reactor vessel is controlled by pneumatically-operated vent valve HCV-102-A. "Vent" and "Block" positions of master switch HS-102 on panel E directly command the vent valve to open or close, respectvely. "Normal" position of HS-102 places the vent valve under the control of the same switching matrix that controls the main letdown block valves. Thus, when HS-102 is in the "Normal" position, the vent valve will close when (a) HS-127 on panel E is in "Block" position or (b) when HS-127 is in "Normal" position and either low pressure or high radioactive contamination conditions exist.

3.3.4 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 function 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 3.3.5, the pool water temperature is held at 35°C (95°F) by regulating the flow of secondary coolant water to the heat exhanger. 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 exchnagers 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 at the sides 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 60 s. 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 by the all-pneumatic system 401 (Fig. 3.24). 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.

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

5. Loop conductivity

System 217B measures the conductivity of the pool cleanup system outlet downstream of the afterfilter. This quantity is indicated locally and recorded in the control room on a multipoint recorder, CR-1020.

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 6.3.4 of the procedures.

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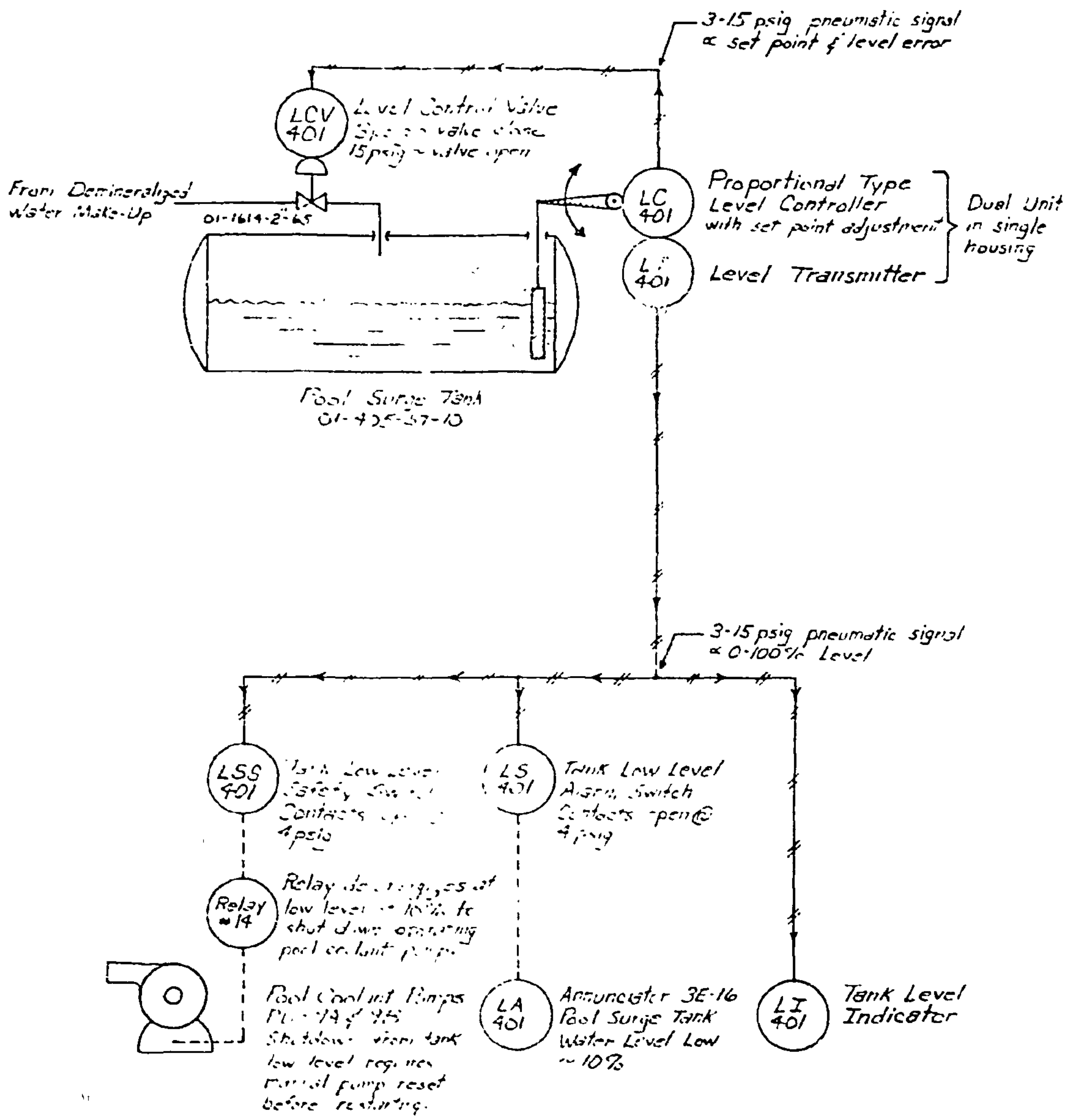


Instrument	Location
LC-401	Atop Pool Surge Tank
LT-401	Atop Pool Surge Tank
LI-401	Main Control Room
LSS-401	Auxiliary Control Room
LS-401	Auxiliary Control Room
LA-401	Main Control Room
LCV-401	Above Pool Surge Tank
Relay #14	Auxiliary Control Room

Fig. 3.24. Pool surge tank level control system 401.

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 6.3.4 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 multipoint 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 local and control room indication of the flow rate of water into the cleanup system. Additional instrumentaiton is as follows:

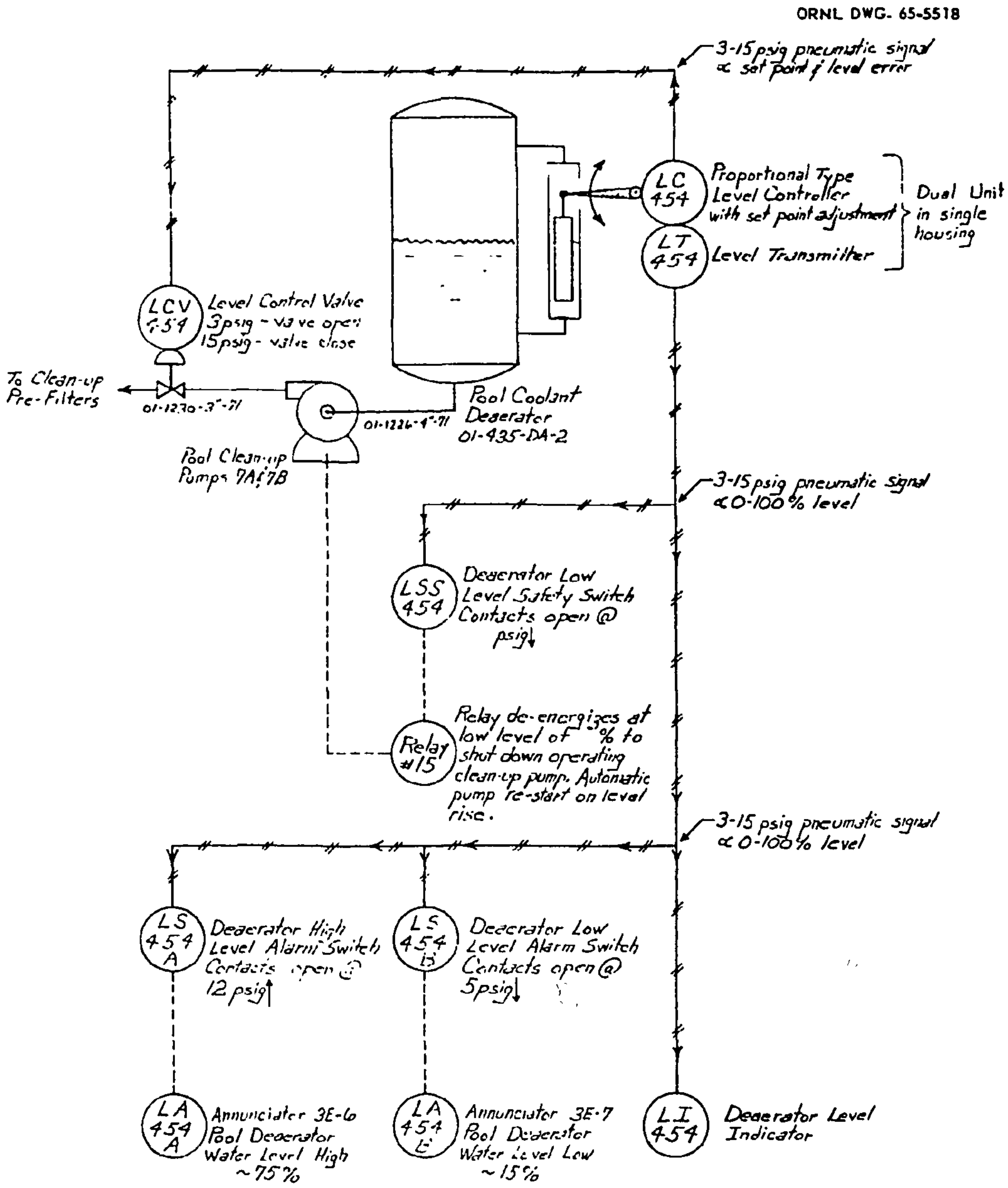
a. Pool cleanup system radiation detection

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

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 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 (see Fig. 3.25).

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



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 105
Relay #15	Auxiliary Control Room

Fig. 3.25. Pool coolant deaerator level control system 454.

ejectors. This same steam supply valve is closed upon high HOG temperature at the discharge of the deaerator condensers.

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 -67.5 kPa (-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 6.4.4 of the procedure.

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 6.4.4 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 3.3.3, senses high radiation in the sink and actuates both local and control room alarms.

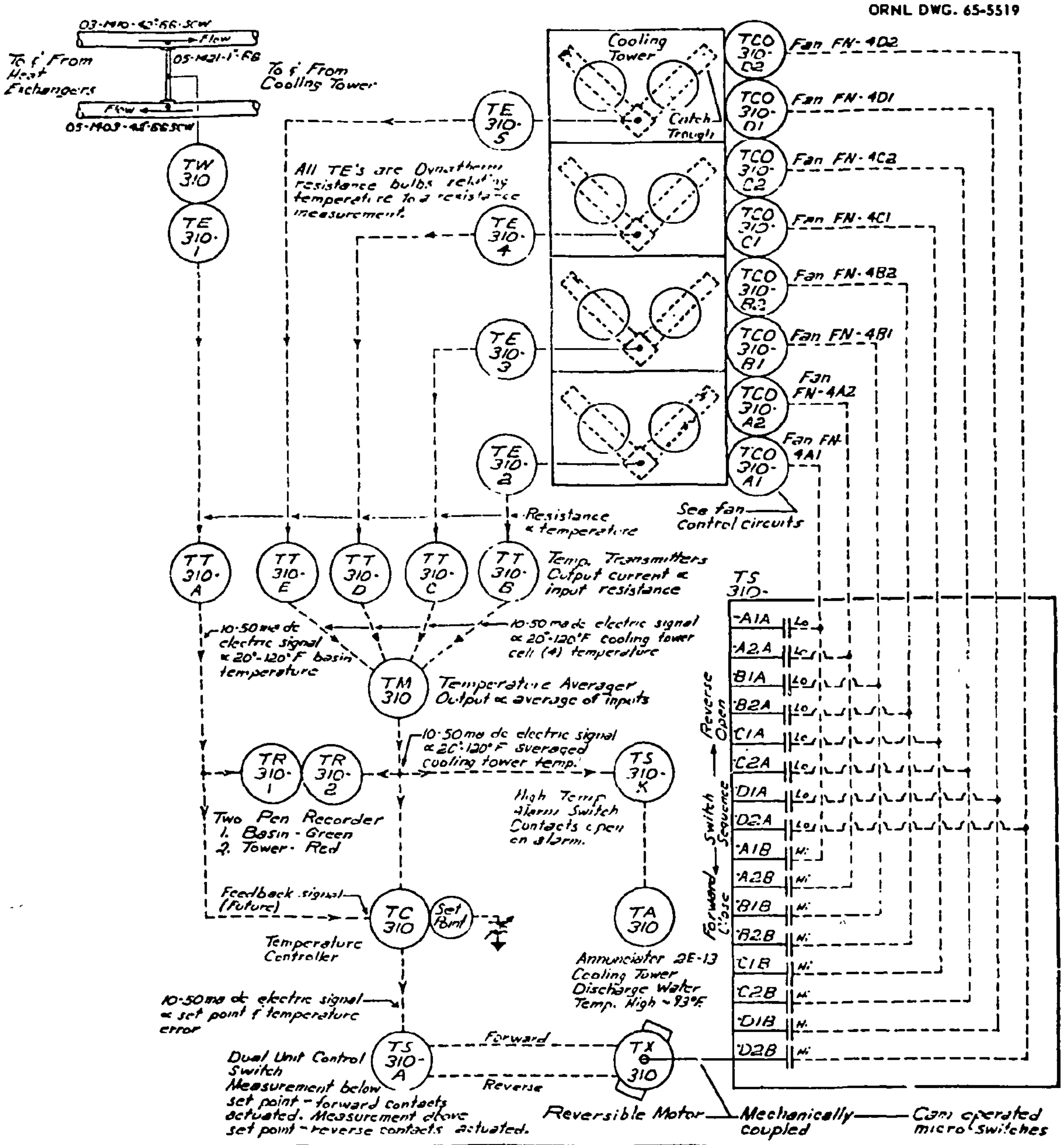
3.3.5 Secondary coolant system

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 (Fig. 3.26) 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 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 remainder 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.



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. 3.26. Secondary coolant temperature control system 310.

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 6.3.3. 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 49°C (120°F) by manual and automatic regulation of secondary coolant flow to these exchangers. Manually operated loading station HIC-377, located in the control room, provides (1) a 0-138 kPa (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. FCV-377A, a 25.4-cm (10-in.) bypass around FCV-377, is designed to provide fine control of the secondary coolant flow. FCV-377A can be operated either manually by HIC-377A or automatically by signal from the servo TRC-100-4, -5, and -6.

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 at 35°C (95°F) by automatically regulating the flow of secondary coolant water to the pool heat exchangers. A description of this system is found in Section 3.3.4 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 instruments 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 delivery pumps (see following section).

8. Secondary pH control

The pH of the secondary coolant water is maintained at a pre-selected value by system 331 (Fig. 3.27). 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 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. When the pressure is sufficient to permit operation, the pumps may

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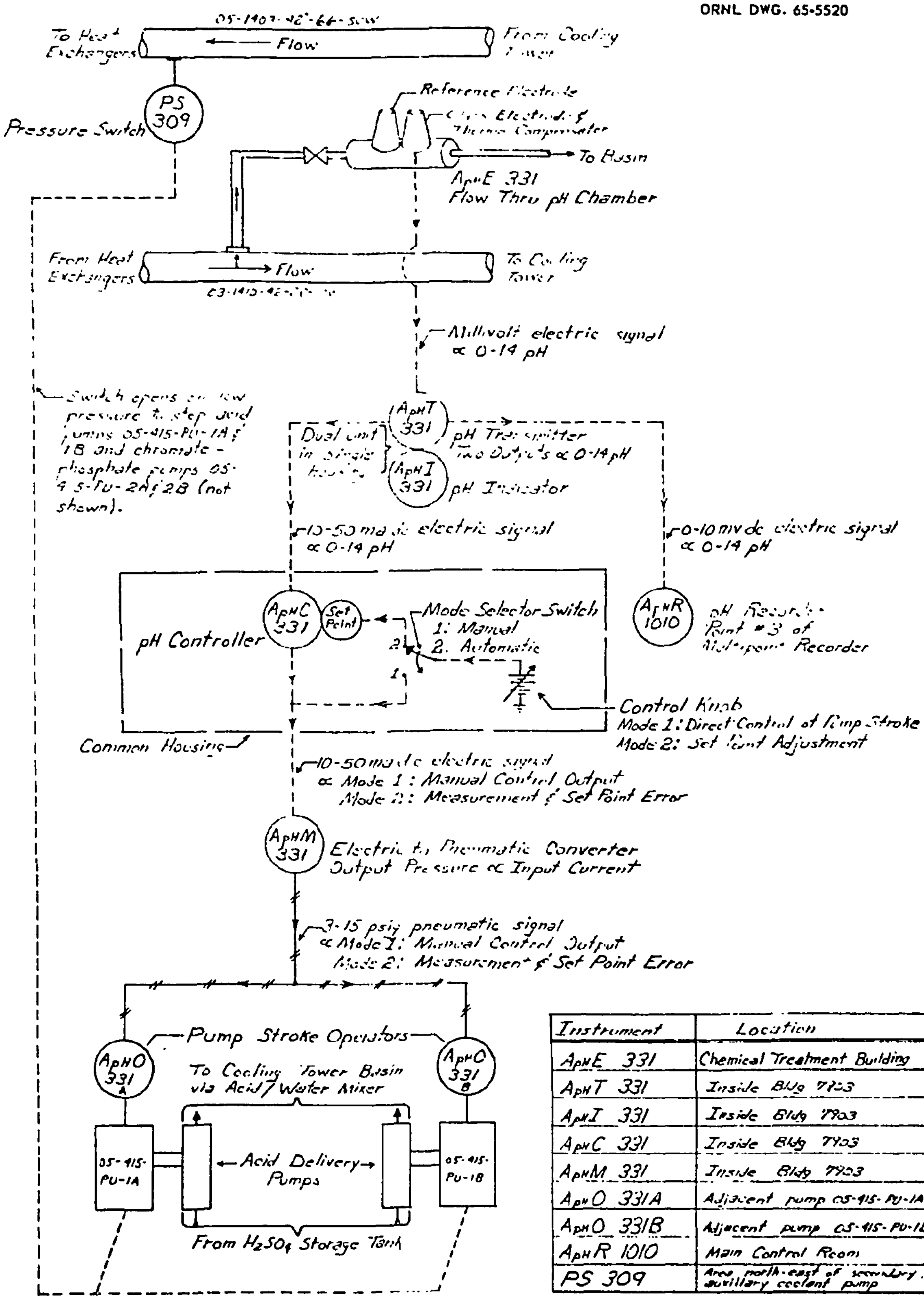

Instrument	Location
ApHE 331	Chemical Treatment Building
ApHT 331	Inside Bldg 7903
ApHI 331	Inside Bldg 7903
ApHC 331	Inside Bldg 7903
ApHM 331	Inside Bldg 7903
ApHO 331A	Adjacent pump 05-415-PU-1A
ApHO 331B	Adjacent pump 05-415-PU-1B
ApHR 1010	Main Control Room
PS 309	Area north-east of secondary auxiliary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

Fig. 3.27. Secondary coolant pH control system 331.

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 multipoint 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 pneumatic bubbler system which 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 ball float, 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 (Fig. 3.28) 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.

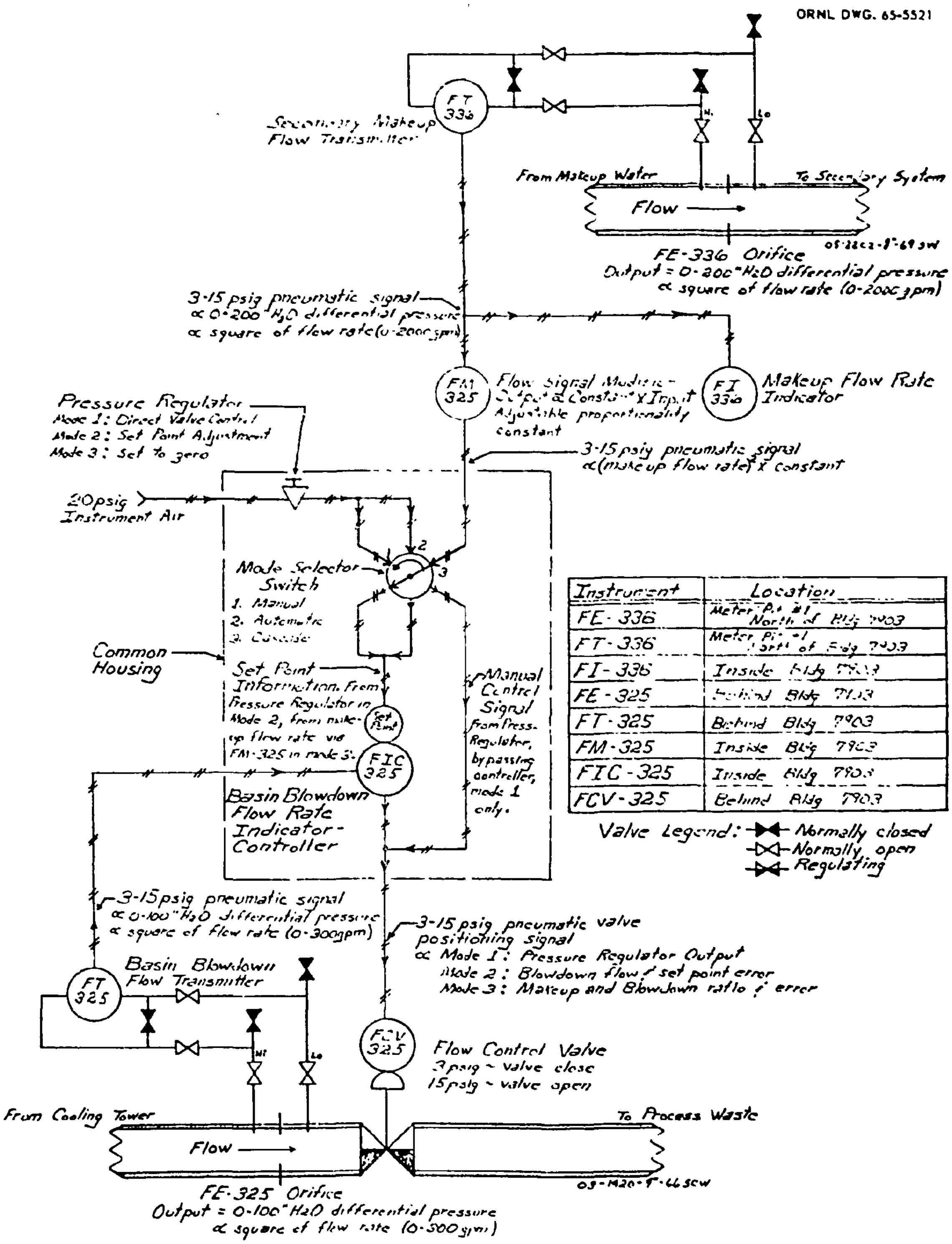

Fig. 3.28. Basin blowdown control system 325.

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

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

    c. The level in the acid storage tank is monitored by a pneumatic bubbler system and is indicated in the chemical treatment room.

3.3.6 <u>Process water supply and demineralizer chemical supplies</u>

1. Potable/process water backflow preventers

   Two parallel backflow preventers separate the potable water system from the process water system. Pressure indicating system 227 indicates the pressure of the process water system locally and remotely in the control room. Pressure indicating system 658 indicates the pressure of the potable water system locally and remotely in the control room.

2. 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.

3. Demineralized water supply tank level

Pneumatic system 605 (Fig. 3.29) 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.

4. Plant demineralized water supply pumps

Locally indicating pressure instruments are provided to monitor the inlet and outlet pressures of each pump. System 614 initiates pressure signals to local and remote indicating instruments and actuates annunciator 4E-4 upon low pressure in the demineralized water system.

5. 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.

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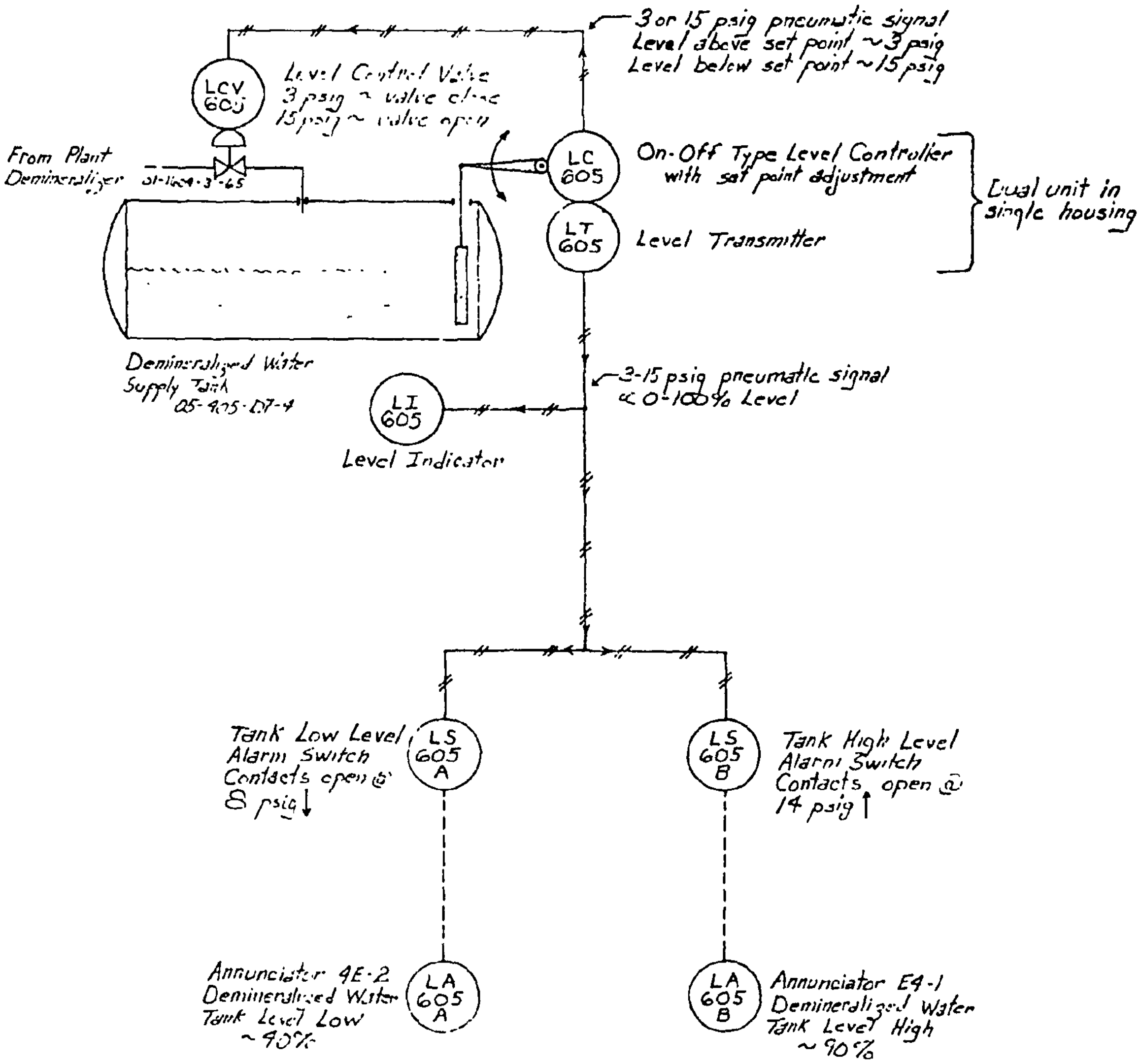

Instrument	Location
LC-605	Atop Demin. Water Supply Tank
LT-605	Atop Demin. Water Supply Tank
LI-605	East side Demin. Water Supply Tank
LS-605A	Auxiliary Control Room
LS-605B	Auxiliary Control Room
LA-605A	Main Control Room
LA-605B	Main Control Room
LCV-605	Vicinity Plant Demineralizer

Fig. 3.29. Plant demineralized water supply tank level control system 605.

6. 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.

7. Caustic and acid pumps

   Locally indicating pressure instruments are installed in the inlet and outlet of each pump.

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

3.3.7 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 Fig. 3.30.

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,

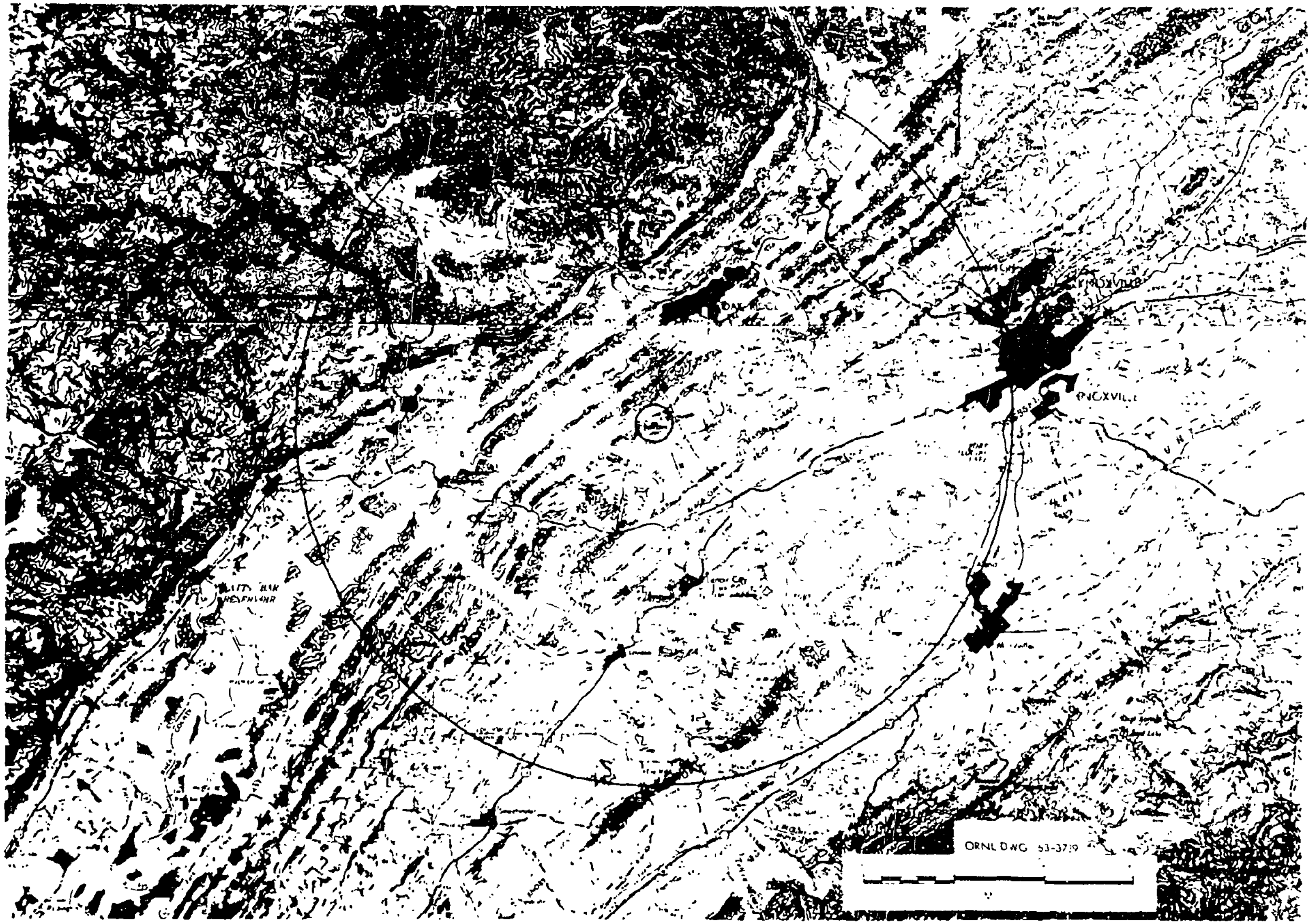

Fig. 3.30. Gaseous-waste monitoring system.

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 0.25 cm (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 7.5.3.

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 9.4.6.

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.

3.3.8. 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 switch TS-653, located in the common discharge line of the air compressors opens on high air temperature 43°C (>110°F) and actuates a common control room annunciator, point HI-1.

2. Air system performance

   The pressure in air receiver AR-6 is indicated locally on PI-623. Should the pressure in the receiver drop below 365 kPa (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 or its control switch in the control room. Receiver pressure exceeding 483 kPa (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 413 kPa (60 psig).

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

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 sense 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 296 kPa (43 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 482 kPa (70 psig), pressure switch PS-617 actuates and causes an unloader valve to open in the emergency air compresor discharge line. The valve will automatically close when the pressure in the header falls to 413 kPa (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 220kPa (<32 psig) to the pneumatic instruments of servo channels A, B, and C, respectively, and actuate individual annunciators in the control room.

3.3.9 Gaseous waste monitoring

Instrumentation is provided to measure the overall gaseous and entrained particulate radioactivity discharged from the HFIR-TRU-TRUF 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 15.24-m (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 described 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 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/h 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.

3.3.10 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 tanks. 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 total flow is indicated locally; flow rate is also retransmitted penumatically 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 s once every 8 h, 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 s, and discharges into the sample collection vessel. The duration of the operating

period varies from 0 to 15 s, 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 activity 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 multipoint 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) very 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 presure 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 very high radiation level annunciation.

4. STORAGE, REFUELING AND POOL WORK

4.1. Fuel Storage

4.1.1. 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

4.1.2. 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.

4.1.3. Storage and inspection of new elements

New fuel elements are not normally stored at the HFIR but are requested and shipped to the HFIR as needed. The new elements are scheduled to arrive, as nearly as possible, just prior to their insertion into the reactor.

Each fuel assembly is inspected for cleanliness and structural damage just prior to installation in the reactor.

4.1.4. Storage of irradiated elements

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

There are storage racks for 20 elements in the pools (Fig. 4.1). Eighteen of these racks (Fig. 2.16) are located in the clean pools and are used for general purpose fuel storage while the remaining two racks, located in the reactor pool, are used for special purposes.

Clean pools. The 18 long-term storage racks are located along the center of the clean pools. These four-place racks (Fig. 4.2) are located on 53-cm (21-in.) centers and support irradiated elements 61 cm (2 ft) above the pool bottom.

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 0.147-cm-thick (0.058-in.) cadmium foil is sandwiched between layers of stainless steel. This acts as an absorber of thermal neutrons. The outer sleeve is surrounded by a 76-cm (30-in.) x 53-cm (21-in.) aluminum frame.

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.

Two storage racks, located at the south side of the west clean pool, are used for short-term storage. As previously mentioned, freshly irradiated elements are stored on these racks for a minimum of 24 hours before being transferred to other storage racks. These two racks are similar to others located in the clean pools. Located beneath the racks is a 7.6-cm-thick (3-in.) 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 7.6-cm-thick (3-in.) 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.

ORNL-DWG. 82-16874

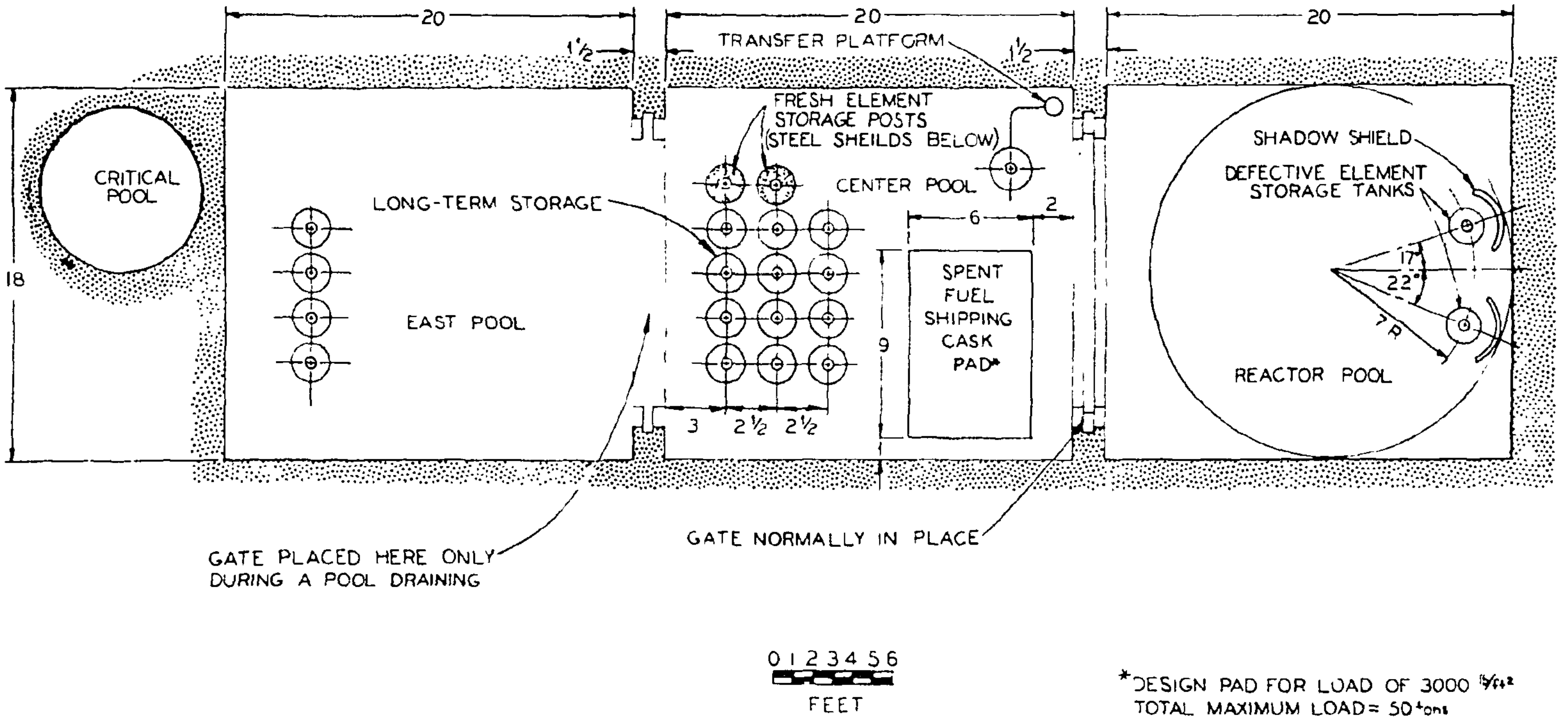

Fig. 4.1. Fuel element in-pool storage.

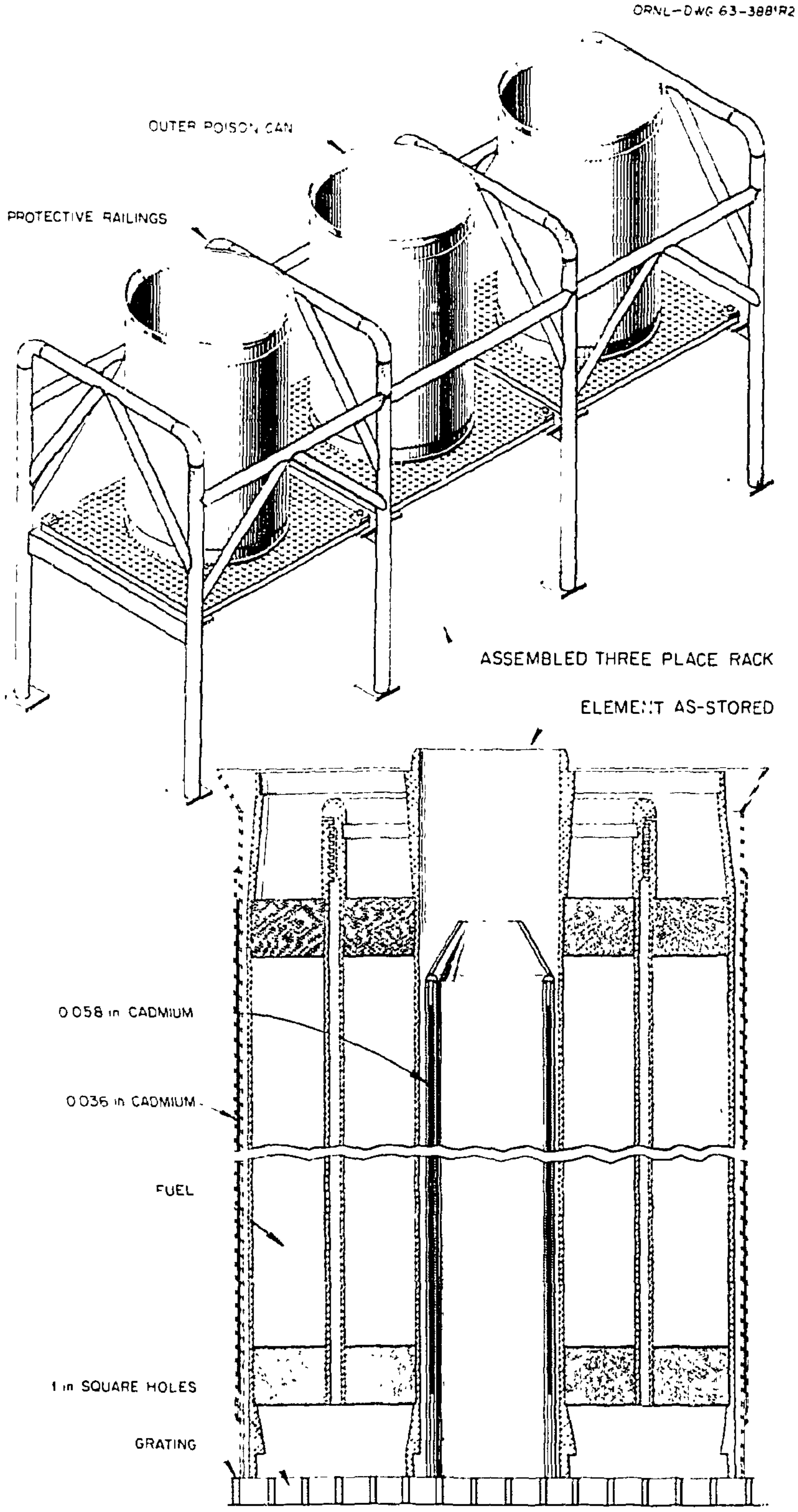

Fig. 4.2. Irradiated fuel storage racks.

Up to 757 l/min (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 (Fig. 4.3) will provide up to 300 kW of cooling using natural convection flow of pool water.

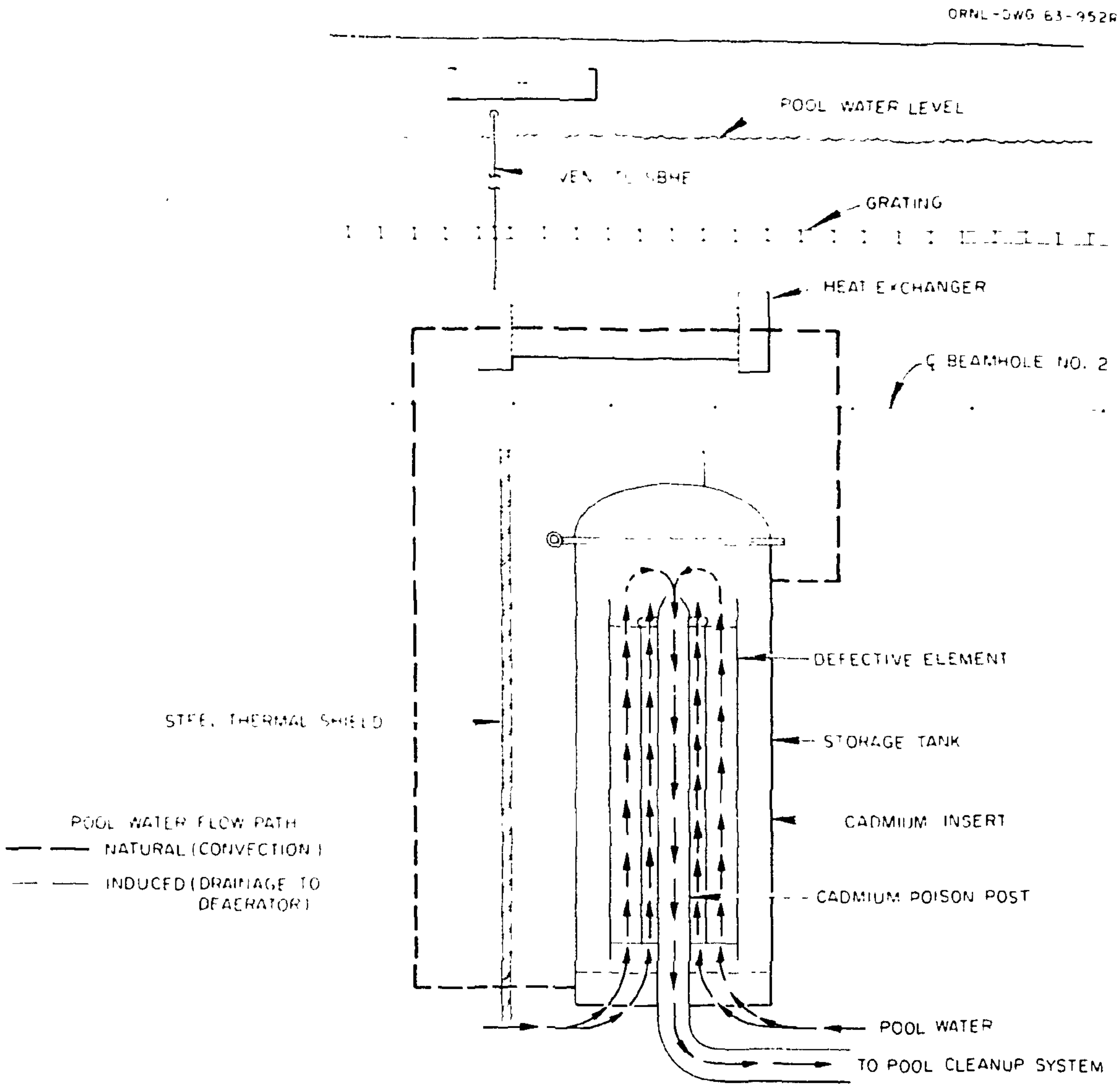

Fig. 4.3. *HFIR defective element storage.*

5. RESEARCH

5.1. Californium-252 Production

5.1.1. References

Drawings:

E-49750-E-49752	HFIR Target Holder
M-A70582N	Prototype - HFIR Target Element Assembly

5.1.2. Introduction

The prime purpose of the HFIR is to establish an unperturbed thermal flux of approximately 5×10^{15} n/cm^2-s 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 5 in. in diameter and contains the Curium target material in the form of a bundle of target rods (see Fig. 5.1).

5.1.3 Target

The target assembly is shown in Fig. 2.5. It consists of 31 0.95-cm-OD (3/8-in.) rods spaced in a triangular pattern. The rods are fabricated from a mixture of curium oxide and aluminum powder which is pelletized (see Fig. 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 1.59-cm (5/8-in.) cylindrical shrouds, thereby providing each rod with its own cooling channel.

A minimum design flow rate of approximately 2385 l/min (630 gpm) is maintained through the target assembly while 757 l/min (200 gpm) flows between the target assembly and the inner fuel element. This corresponds to a coolant velocity of 12.2 m/s (40 ft/s) in the target region and is

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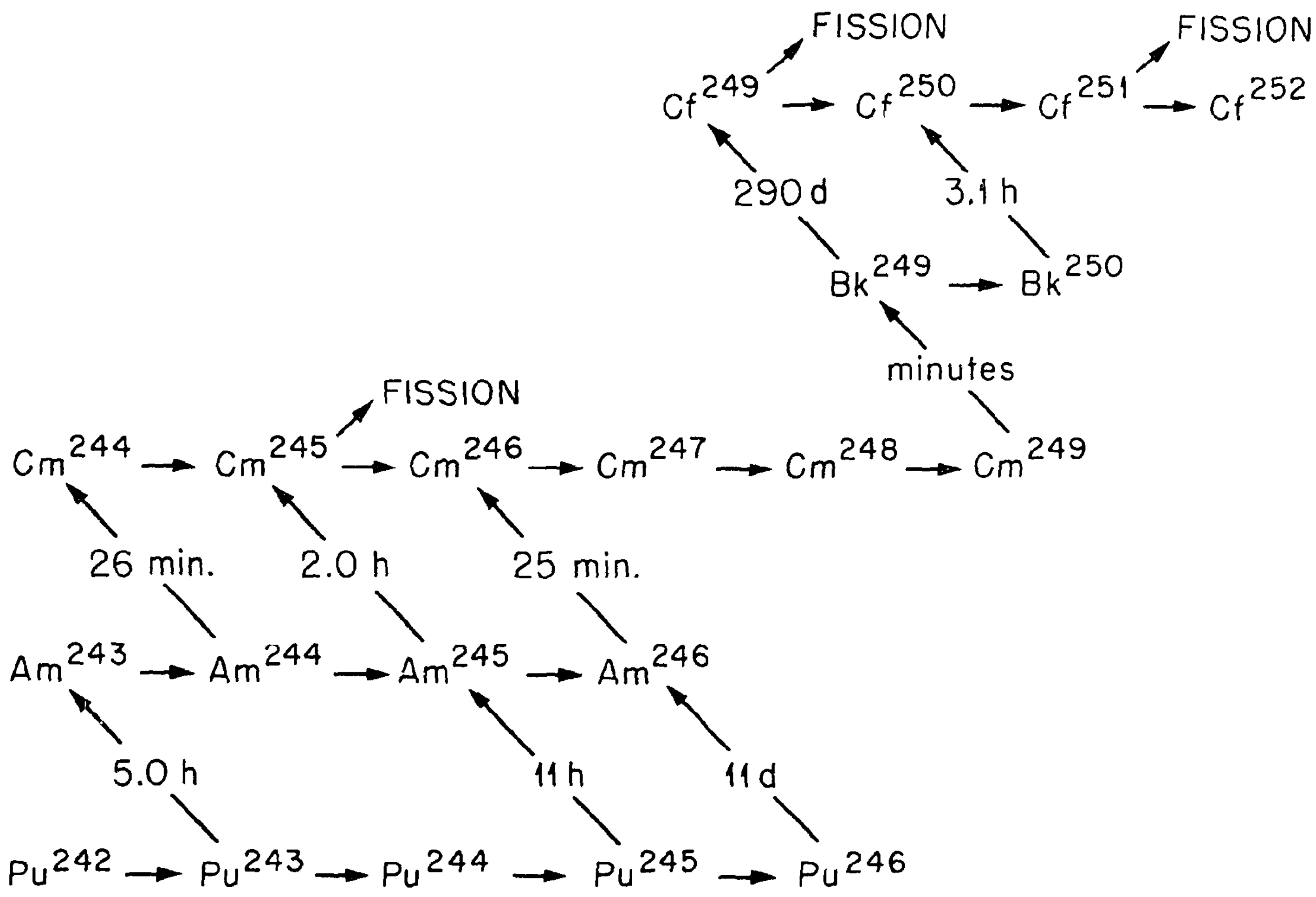

Fig. 5.1. Reactor paths in the production of ^{252}Cf from ^{242}Pu.

and is more than that required for the removal of the approximately 900 kW of heat generated by the target.

Fission product gasses, 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 6.9-MPa (1000-psi) external pressure and the internal pressure resulting from the fission gas buildup.

5.1.4 Approval of targets

It is the responsibility of the Reactor Supervisor and of the assigned Technical Assistance staff member to inspect and approve all curium recycle targets before insertion into the reactor.

Since each new curium 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

5.2.1 Introduction

The HFIR central rabbit facility consists of the necessary piping, valving, and instrumentation to hydraulically move rabbits between the reactor core and the rabbit loading station. The piping forms a closed loop so that no water is removed from the reactor primary water system during the transfer of rabbits. The differential pressures that exist in the primary system are the driving forces which move the rabbits. Instrumentation is provided for automatic ejection of the rabbits from the core region upon a flow decrease through the primary system, upon a flow decrease through the rabbit tube, or upon an instrument air failure.

5.2.2 Description of the facility

Rabbits placed in the loading station are moved into the reactor core by water flow from the high pressure side of the core (see Fig. 5.2). This water provides the normal cooling flow 15.1 l/min (4.0 gpm minimum) for the in-core rabbits. By proper manipulation of the valving, water from just below the in-core rabbit tube is used to drive the rabbits out of the core and return them to the loading station.

The loading station, located on the north wall of the east clean pool, is connected to the reactor vessel by piping which runs along the north walls of the east, center, and reactor pools. High pressure water is obtained from the vessel via RH-1 nozzle. A return to the low-pressure side of the core is provided through a connection on the reactor vessel outlet water line located just below the reactor pool grating. The valving manifold and underwater instrumentation are located near the loading station. The entire facility, excluding the instrument panel, is beneath at least 8 ft of pool water. The instrument panel is located near the loading station at the northeast corner of the east pool.

A concentric pipe assembly is employed as the rabbit transport system. The inner pipe carries the rabbits, while the surrounding pipe is utilized for returning primary water to a lower pressure point in the system. This concentric piping arrangement is necessary in the core region because of space limitations; the rabbit tube actually occupies

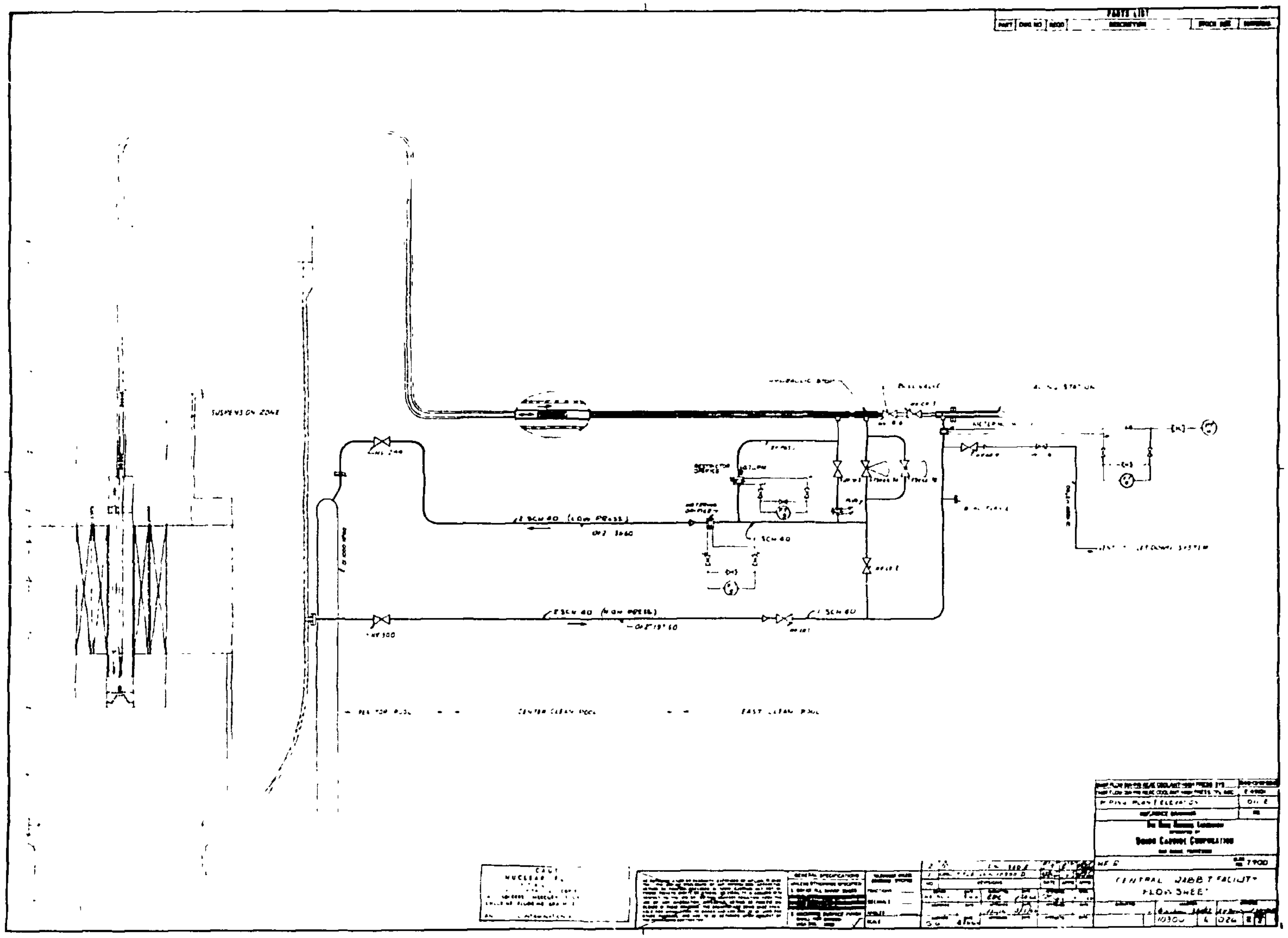

Fig. 5.2. Central rabbit facility flow sheet.

the position of the center target rod in the target bundle. All piping is 304 stainless steel except that part extending into the vessel; this portion is 6061 aluminum. The tube extending into the vessel is replaceable and must be removed before the quick-opening hatch can be removed.

Figure 5.3 gives the dimensions and shape of the rabbits. This design specifies a capsule made from the extruded target tubes. The fins are utilized to space the rabbit away from the tube wall, thus insuring adequate cooling to all the rabbit surface. Nine rabbits of the length shown provide a symmetrical facility loading.

Hydraulic stops are provided just above the core and just before the loading station. At these two locations, the water velocities in the central tube can be reduced to zero and the rabbits suspended or stopped. This is done to prevent the rabbits from slamming into the stops at the ends of the tubes and damaging the rabbits and/or the tubes. These hydraulic stops are created by allowing water flow from opposite directions to pass from the inner tube to the annulus between it and the outer connentric tube at the region where the stop is located. By proper valve operation, the two opposing flow streams can be directed through the outer annulus to the low pressure point in the system through holes located in the inner tube.

The normal flow discharge from the in-core rabbit tube is just above the fuel grid orifice plate. About 65% of the core differential pressure for the target flow takes place across this orifice plate, thus providing the necessary stepwise pressure drops in the primary system for using a closed loop to move the rabbits. Pressure drops through the system for normal, three-pump operation are shown in Fig. 5.4. A total

O.R.N.L. DWG. 67-6775

PARTS LIST			
ITEM No.	DWG. No. SK-WGC-	QTY.	NAME
2	661003-2	1	BODY CASING
3	-3	2	END PLUG
4	-4	1	SPECIMEN

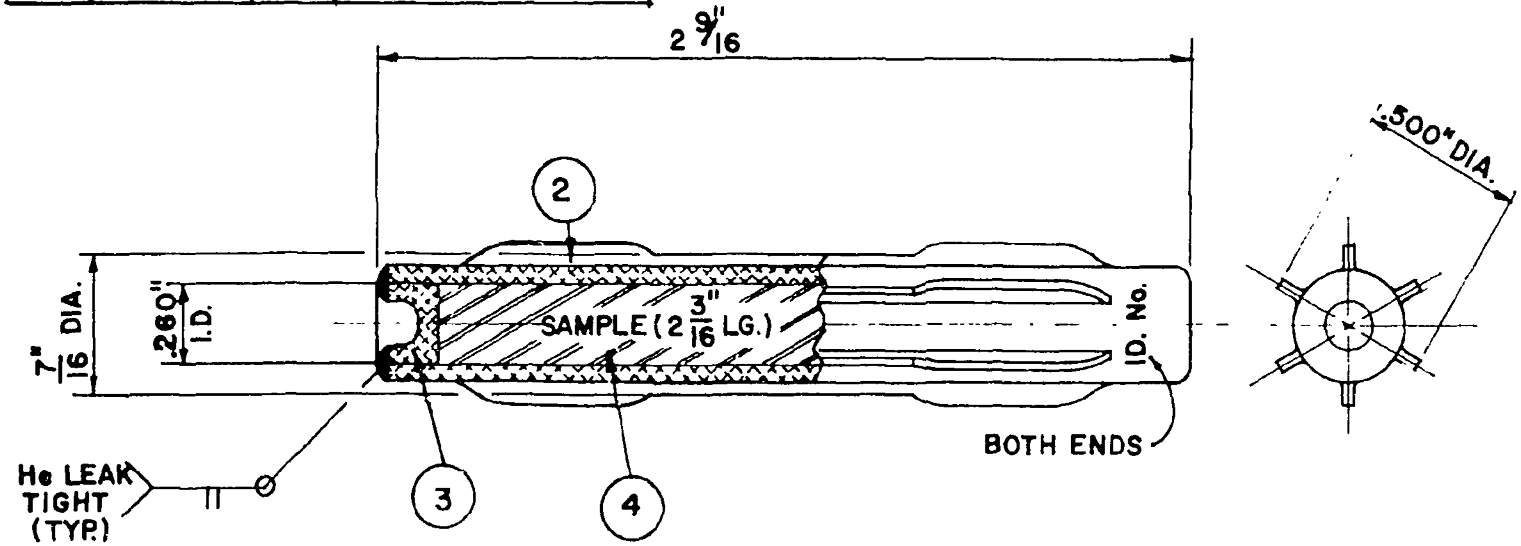

Fig. 5.3. HFIR rabbit assembly.

O.R.N.L. DWG. 67-6774

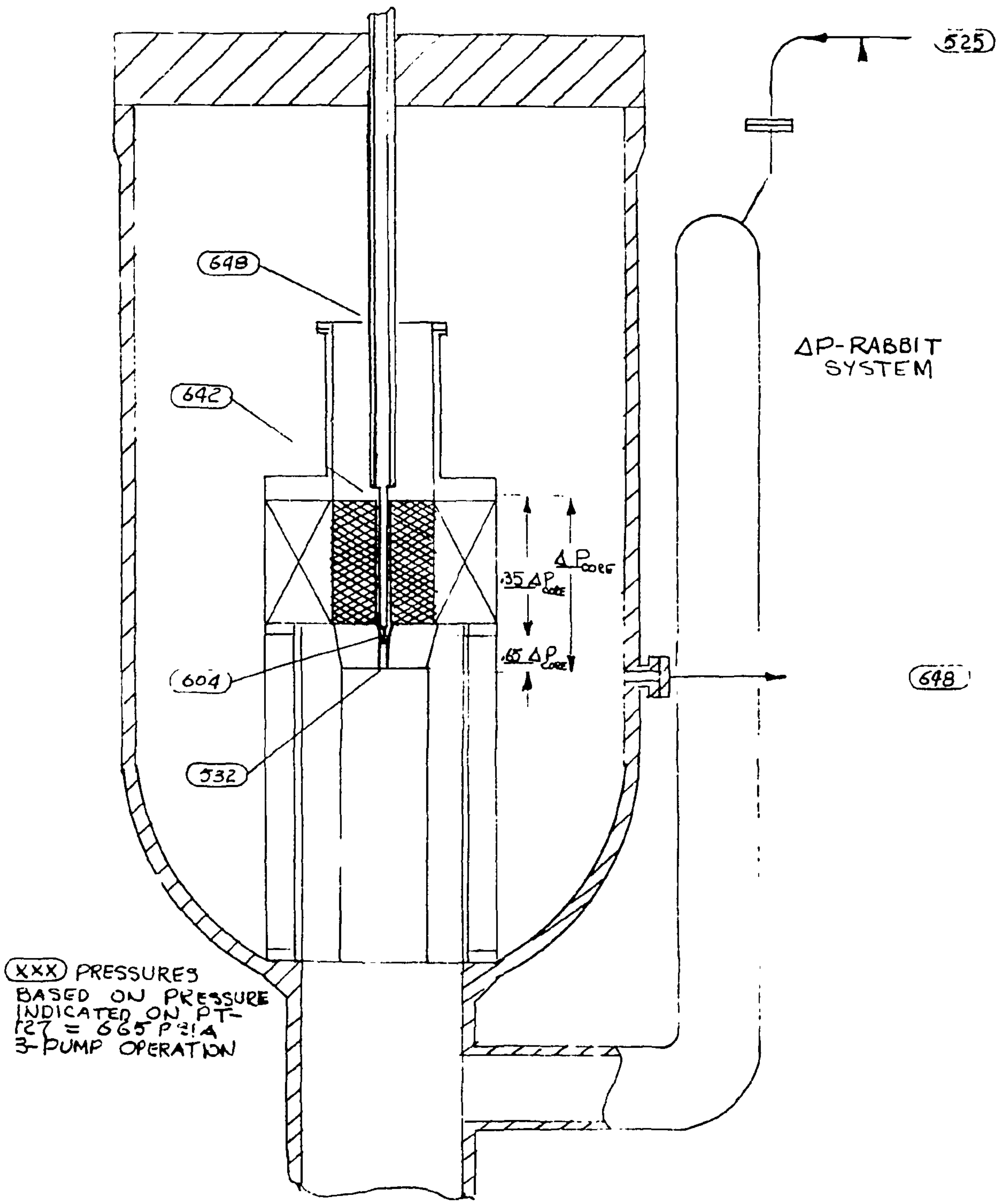

Fig. 5.4. Operating pressures in hydraulic rabbit facility.

ΔP of approximately 0.3 MPa (44 psi) is available for inserting the rabbits into the core and for normal in-core cooling. Approximately 0.54 MPa (79 psi) differential pressure is available for ejection of the rabbits from the core.

Instrumentation. The instrumentation is provided to monitor the flows through the system. An orifice with a flow recorder is provided to measure the flow rate in the central tube. A restrictor orifice is provided to allow some water to flow past the rabbits, although in the reverse direction, in the event of a mis-valving operation. This orifice is in an unrestricted flow path from the in-pile rabbit tube to the system low-pressure point. If the normal cooling flow is inadvertently stopped, approximately 2.65 l/min (0.7 gpm) water flow would automatically be initiated from the bottom of the tube to the system low-pressure point. This also provides water flow past the bottom rabbits when they are suspended or stopped above the core.

A delta-flow instrument is utilized to indicate the actual flow past the rabbits. This instrument subtracts the flow in the line to the system low-pressure point from that flowing through the main rabbit tube. This difference represents the actual flow past the rabbits. A decrease in this flow past a given set point is utilized to automatically eject the rabbits.

A pressure readout is provided so that the pressure in that portion of the system containing the loading station, when isolated from the loop, will be known before the station is opened. When the loading station is isolated for opening, the isolated portion of the loop is bled to the letdown system to prevent primary water from escaping into the clean pool.

Two solenoid-controlled, air-to-close-pneumatic valves mounted in parallel are used for normal and emergency ejection of rabbits from the core. The operation of either valve causes rabbit ejection. The solenoids to these valves are instrumented so that when the reactor primary water flow rate drops below 56,775 l/min (15,000 gpm), the valves will open. The actuating signals are taken directly from the three Venturi dP cells in the reactor servo-control-flow-sensing system and cause rabbit ejection from a two of three coincidence relay matrix. Approximately 0.4 s is required for the valves to open.

Heat transfer. For the normal coolant flow of 15.1 l/min (4 gpm) through the rabbit tube, the incipient boiling heat flux is 2.77×10^{10} W/m^2 (2,400,000 Btu/h-ft^2). The corresponding values when flow is limited to that through the restrictor orifice are 4.7×10^9 and 5.2×10^{10} W/m^2 (150,000 and 1,650,000 Btu/h-ft^2).

In the extreme case of zero flow through the facility with the reactor continuing to operate at 100 MW, heat would be transferred by natural convection from the rabbit to the facility wall and eventually to the coolant in the target region. The incipient boiling heat flux for this situation has been calculated at about 1.58×10^9 W/m^2 (50,000 Btu/h-ft^2).

5.2.3 HFIR-TRU hydraulic rabbit transfer facility

The HFIR-to-TRU hydraulic rabbit tube is used to transfer irradiated rabbits directly to the TRU hot cells using pool water and a centrifugal pump as the driving force. The loading station is located in the east clean pool 2.74 m (9 ft) below the surface of normal water level. The tube exits at the east end of the east clean pool, is lead shielded where it passes through the fuel vault and runs underground until it enters the TRU building hot cells. The underground portion of the tube is at sufficient depth to eliminate any radiation hazard during rabbit transfer.

This facility is used mainly to transfer irradiated rabbits which have short-lived isotopes that would decay excessively if they were transferred by the usual method.

5.3 Engineering Facilities

5.3.1 References

Drawings:

43-501-013	HFIR Pressure Vessel
43-501-056	Reactor Vessel Assembly

5.3.2 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 Fig. 5.5). These facilities consist of 10.2-cm-OD (4-in.) tubes which enter the pressure vessel at elevation 251.5 m (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.

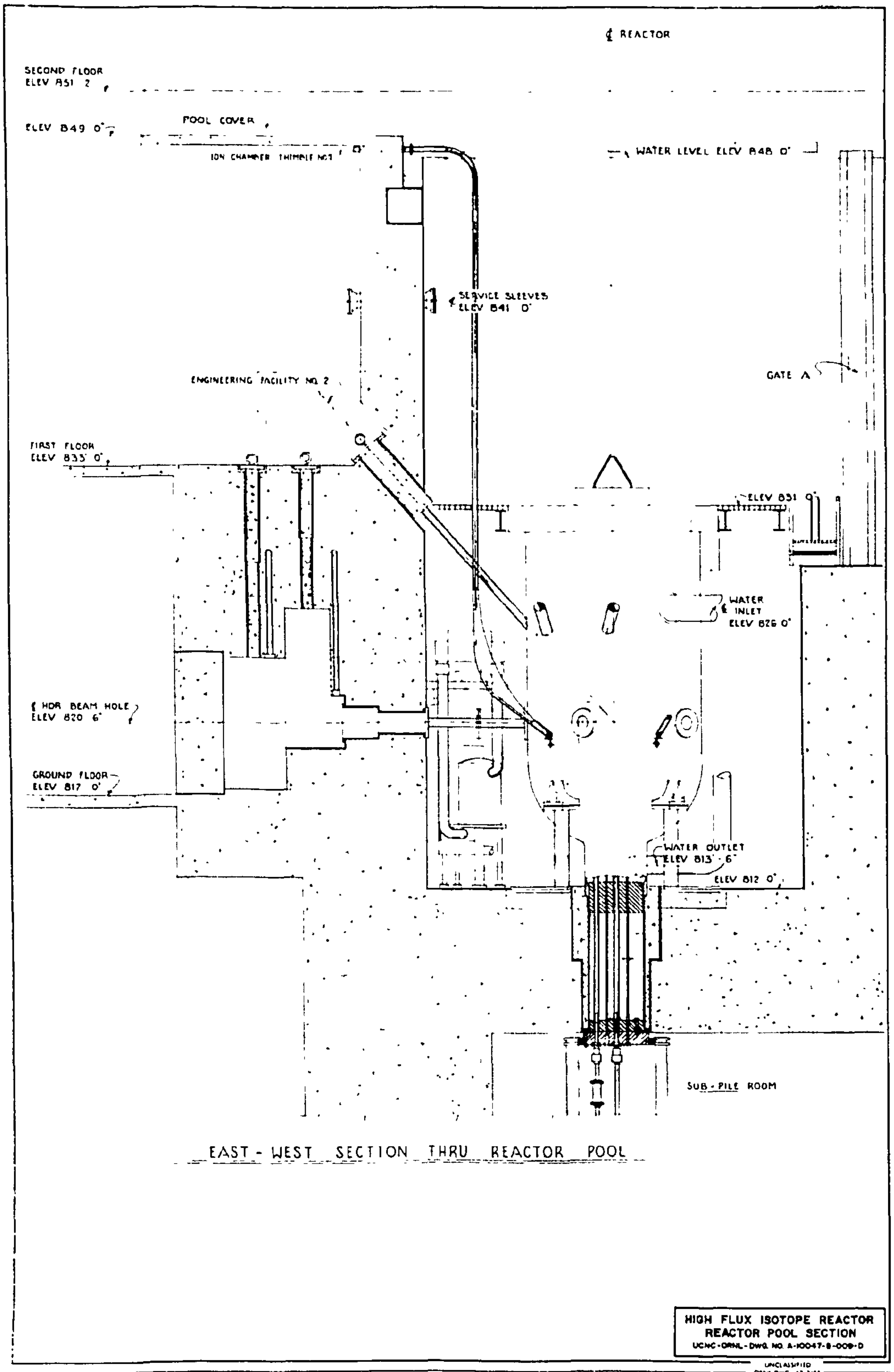

Fig. 5.5. Reactor pool, east-west section.

5.4 Horizontal Beam Tubes

5.4.1 References

Drawing:

E-42018 Permanent Reflector, Horizontal Beam Tube Liners Installation

5.4.2 Description

The reactor is provided with three nominally 10.2-cm-ID (4-in.) horizontal beam tube experiment facilities which extend outward from the reactor core at the midplane [elevation 250 m (820 ft 6 in.); see Fig. 5.6]. 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 26.7 cm (10 1/2 in.) from the reactor center line. It also penetrates the permanent reflector. The remaining tube is aligned on a tangential line approximately 38.4 cm (15 1/8 in.) 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.

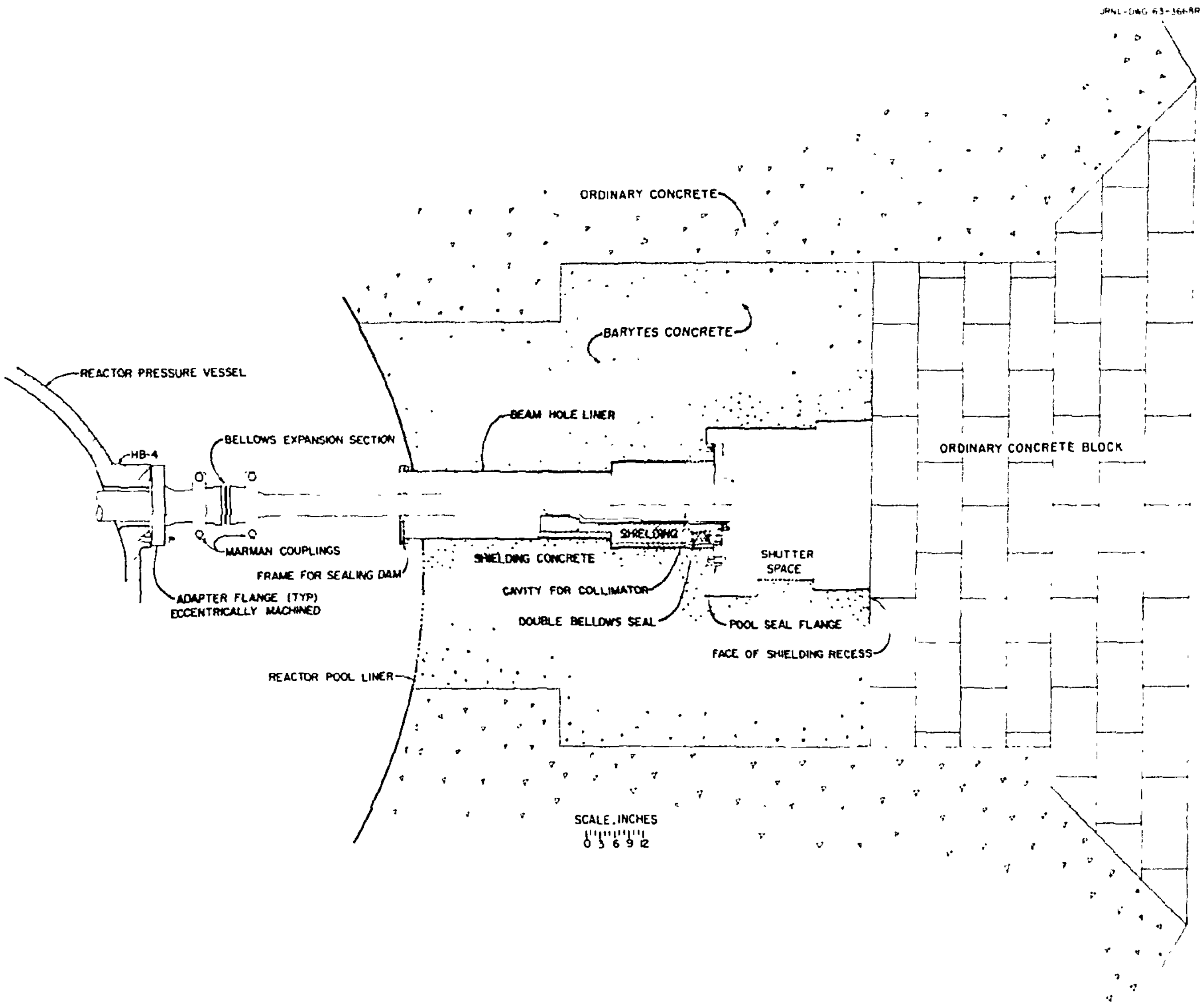

Fig. 5.6. Horizontal beam tube.

The recess inside the cavity is provided with a 6.35-cm (2 1/2-in.) SBHE vent, a 3.8-cm (1 1/2-in.) drain, stainless steel pipe sleeves, conduit sleeves, and 110-V 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 414 kPa (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 pool cleanup system is used to cool the inside of the beam tubes.

5.5 Vertical Experiment Facilities

5.5.1 References

Drawings:

E-42017	Permanent and Semi-Permanent Reflector Assembly
E-49702	Removable Reflector Model "C" Assembly
42-501-060	HFIR Pressure Vessel Top Head

5.5.2 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 4.02 cm (1.584 in.). They are located concentric with the core and are on two circles of radii 39.3 and 44 cm (15.438 and 17.344 in.), respectively. The other six holes have a 7.2-cm-ID (2.834-in.) and are located in a concentric circle of radius 46.3 cm (18.219 in.). In addition to these 22 vertical holes, four similar 3.6-cm (1.400-in.) and four 1.27-cm-ID (0.5-in.) vertical holes are located in the removable beryllium and eight 1.27-cm-ID (0.5-in.) vertical holes are in the semipermanent 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 research personnel with Operations personnel until the termination of the experiment operation.

5.6.1 Preliminary contact of operations by research

Research personnel may initially contact anyone in the Reactor Operations Section. When this occurs, the research man shall be directed to the Reactor Experiments Coordinator. In some cases, discussions may be desirable with the Reactor Operations Section Head.

5.6.2 Preliminary review and space assignment

The Reactor Experiments Coordinator will handle the space assignments and will obtain any technical aid from the operations Technical Support Group and the I&C Division on the experiment design after all space assignments and other initial decisions have been made by Reactor Operations Section through the Reactor Experiments Coordinator.

5.6.3 Assignment of the experiment to technical personnel

After all preliminaries have been completed, the handling of the experiment may be turned over to an Operations technical man selected by the Operations Technical Section Head if technical support is not being supplied by another ORNL 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 Section. He will see that the initial requirements in the design and installation of the experiment are met by the researcher. He will require that the research personnel complete, at the earliest possible date, an experiment information form for experiment review and submit it to the Reactor Experiments Coordinator to obtain the necessary safety and operability approvals from the Operations Division and, in most cases, from the Reactor Experiment Review Committee, before the experiment can be installed.

5.6.4 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; and
3. provisions for neutralizing the equipment, in case of failure, so that reactor operation can continue.

5.6.5 Review by the Experiment Review Committee

When Operation Division's requirements for the overall experiment are met, written approval for the experiment will be given by the Reactor Experiments Coordinator who will request that the experiment be reviewed by the Reactor 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 Reactor Experiment Review Committee will be considered ready for operation only after they are reviewed and approved by the Committee.

5.6.6 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 or by the appropriate technical group from another division. After the installation is complete, a final inspection should be made by the Reactor Supervisor in order to know that the "as-built" equipment meets the required specifications. Also, the specimens to be irradiated should be inspected, if possible, before irradiation in the system.
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 Section or the Reactor Experiment Coordinator.
3. Reinsertion of specimens in an approved facility will be under the direction of the Reactor Supervisor.

4. Reinsertion arrangements for an experiment facility which has been removed should be directed by the Reactor Experiment Coordinator in the same manner as for a new experiment which has already been approved by the Reactor Experiments Coordina-
5. Changes, either in the method of operation or the physical makeup of an experiment, should be approved by the Reactor Supervisor and the Reactor Experiments Coordinator.

5.6.8 Termination of experiment

Termination of an experiment will be reported to the Reactor Experiments Coordinator by the Reactor Supervisor. The Coordinator 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.

5.6.9 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.

5.7 Experiment Preoperational Checks

Prior to reactor startup, all new experiment installations must be thoroughly chcked to ensure that the materials, workmanship, and components meet the safety requirements for the experiment and that all preinstallation 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 prestart check is made by both the Reactor Experiments Coordinator 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 experimenter 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 Foreman 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 Reactor Supervisor or someone delegated by him. The Shift Foreman 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 56,775 l/min (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.

Approximately 0.4 MW of reactor heat is 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 dc 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 dc-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 $\pm$ 0.1 to minimize corrosion of the aluminum-clad fuel element. The system is designed to operate at a maximum reactor inlet pressure of 6.9 MPa (1000 psi); however, the normal operating condition is with an inlet pressure of 5.2 MPa (750 psig).

As illustrated in Fig. 6.1, the primary coolant enters the pressure vessel through two 40.6-cm (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 45.7-cm-diam (18-in.) line at the bottom of the vessel. The design inlet temperature is 49°C (120°F) and the inlet pressure is 4.3 MPa (600 psi). At 100 MW operation with 56,775 l/min (15,000 gpm) flow the design exit temperature and pressure are 75°C (167°F) and 3.6 MPa (525 psi), respectively.

Upon leaving the pressure vessel, the exit line passes through the pipe tunnel where it branches into three of four parallel headers leading the hot water to three of four heat-exchanger cells. The 49°C (120°F) water from each heat exchanger enters the associated main circulating pump. Flows from the circulating pumps recombine in the pipe

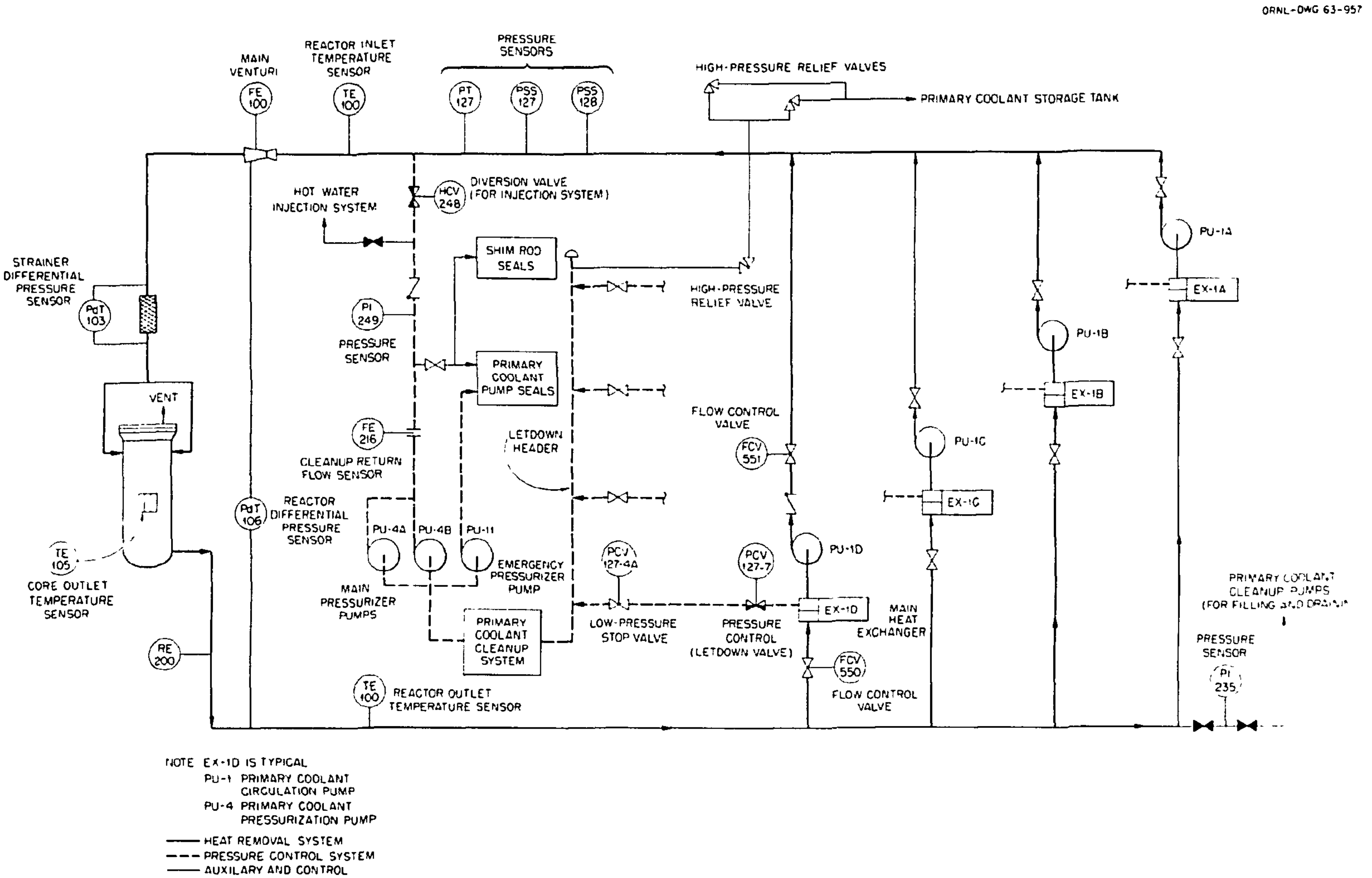

Fig. 6.1. Primary coolant system.

tunnel and return to the reactor pool where the water passes through a strainer 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 Fig. 6.2.

A 577-l/min (150-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 cleanup system which consists of a deaerator, filters, and deminalizer. Primary coolant pressure is maintained by pressure-controlled letdown valves located in these bypass lines at the heat exchanger exit. The 577-l/min (150-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 6.7 MPa (975 psi) and one set at 7.1 MPa (1025 psi). Both valves 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 52,233 l (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 has a capacity of approximately 26.5 m^3 (7000 gal), contains the cleanup system deaerator, filters, and demineralizers. The systems are separated by the letdown valves and the pressurizer pumps.

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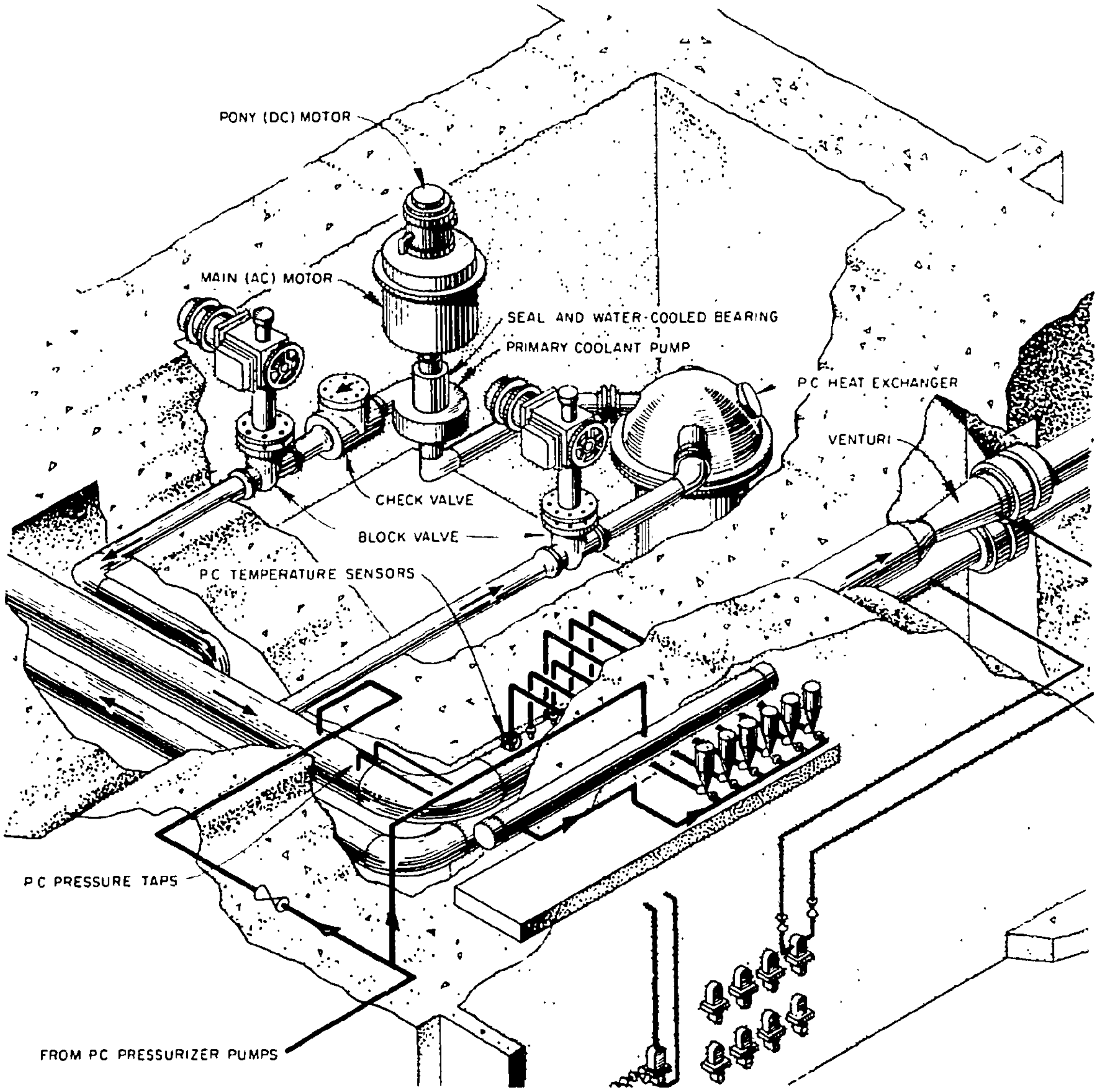

Fig. 6.2. Pipe tunnel and heat exchanger cell.

6.2.1 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 6.9 MPa (1000 psi) at temperatures below 93.3°C (200°F). It is fabricated of 7.3-cm-thick (2-7/8-in.) carbon steel with 0.25-cm-thick (1/10-in.) weld-overlaid stainless steel on the outside and 0.317-cm-thick (1/8-in.) stainless steel cladding on the inside. The vessel head is 35.6 cm (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 40.6-cm (16-in.) lines. The outlet from the reactor vessel is a single 45.7-cm (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 25.4-cm (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 50.8-cm (20-in.) return header in the pipe tunnel. This 50.8-cm (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 0.09 cm (36 mils), before branching into the two 40.6-cm (16-in.) reactor inlet lines and entering the reactor vessel. The general arrangement is shown in Figs. 6.3, 6.4, and 6.5.

Heat exchanger. 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. Each heat exchanger is designed to transfer 34.3 MW (approximately 117 million Btu/hr) 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 11,925 l/m (5000 gpm) at 75°C (167°F) in the primary system and 26,495 l/m (7000 gpm) at 29.4°C (85°F) in the secondary system.

The heat exchangers are approximately 10.4 m (approximately 34 ft) long and contain 1,190 U-tubes, each 1.59 cm (5/8 in.) in diameter. The tube side is designed to operate at up to 6.9 MPa (1,000 psi) at 93.3°C (200°F), and the shell side is designed for 1.03 MPa (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 251.7-m (826-ft) level with the remainder of the heat exchanger extending into the pit to the 242.6-m (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.

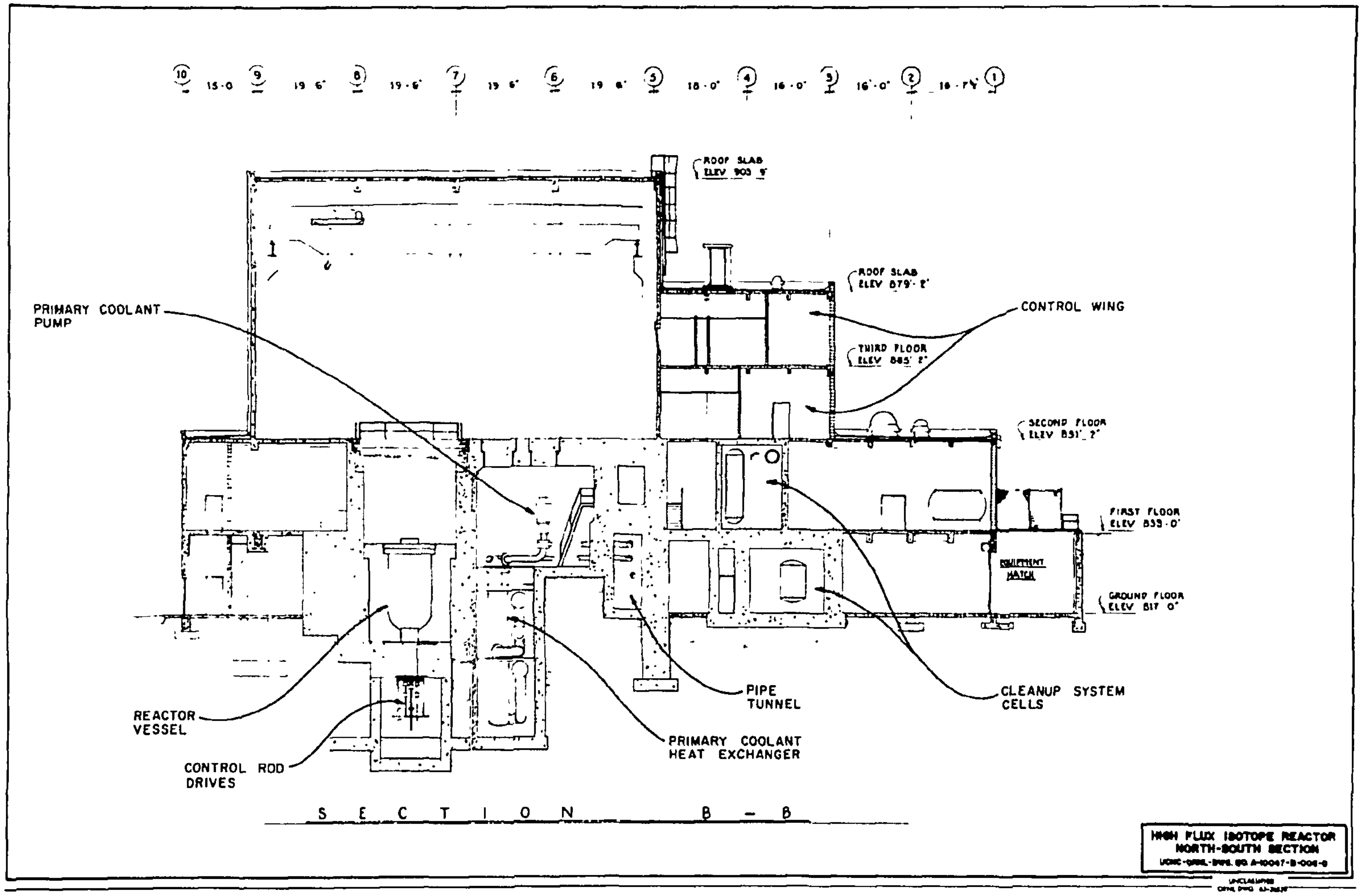

Fig. 6.3. Primary coolant system components.

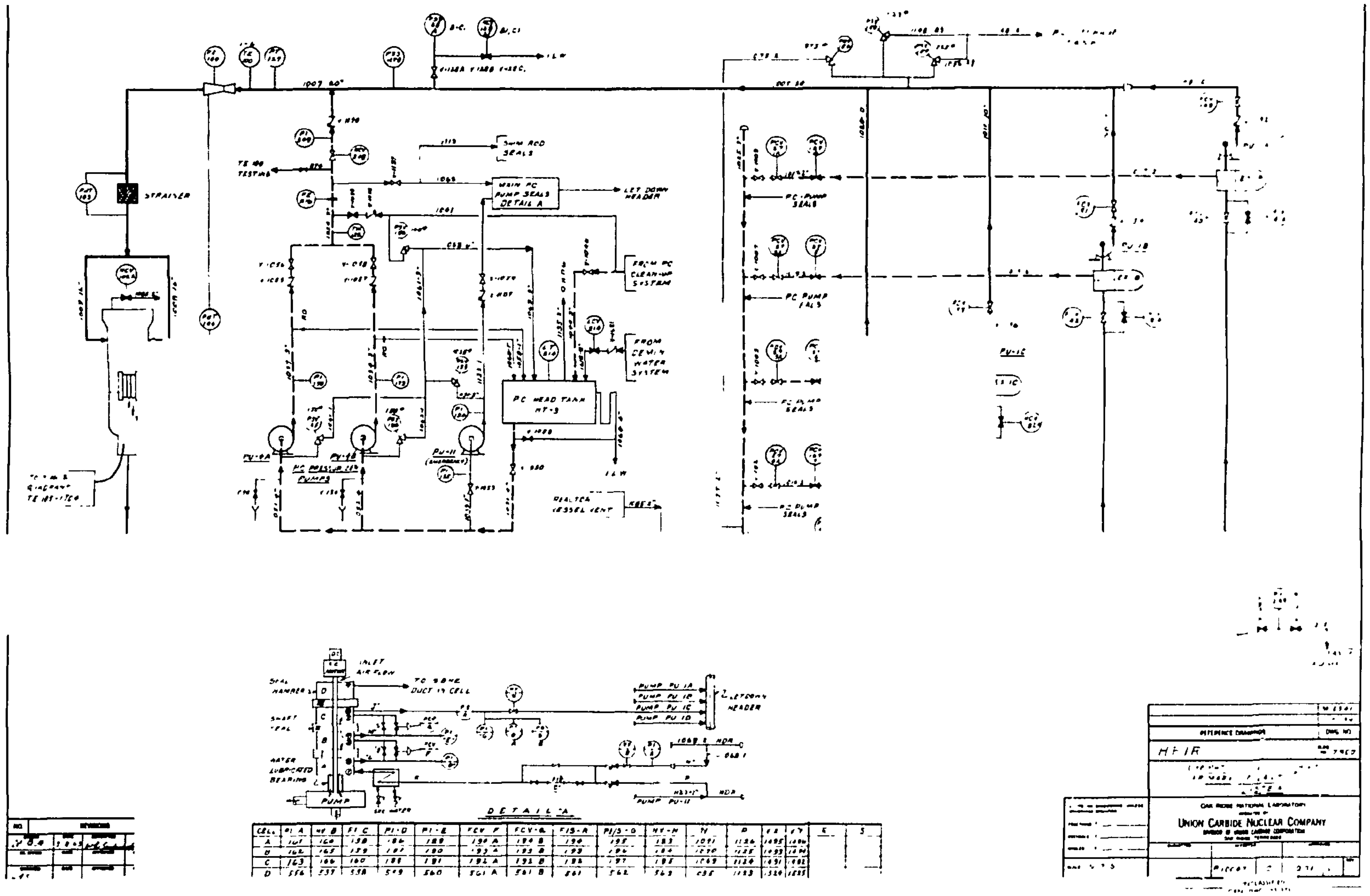

Fig. 6.4. Primary coolant-schematic flow diagram.

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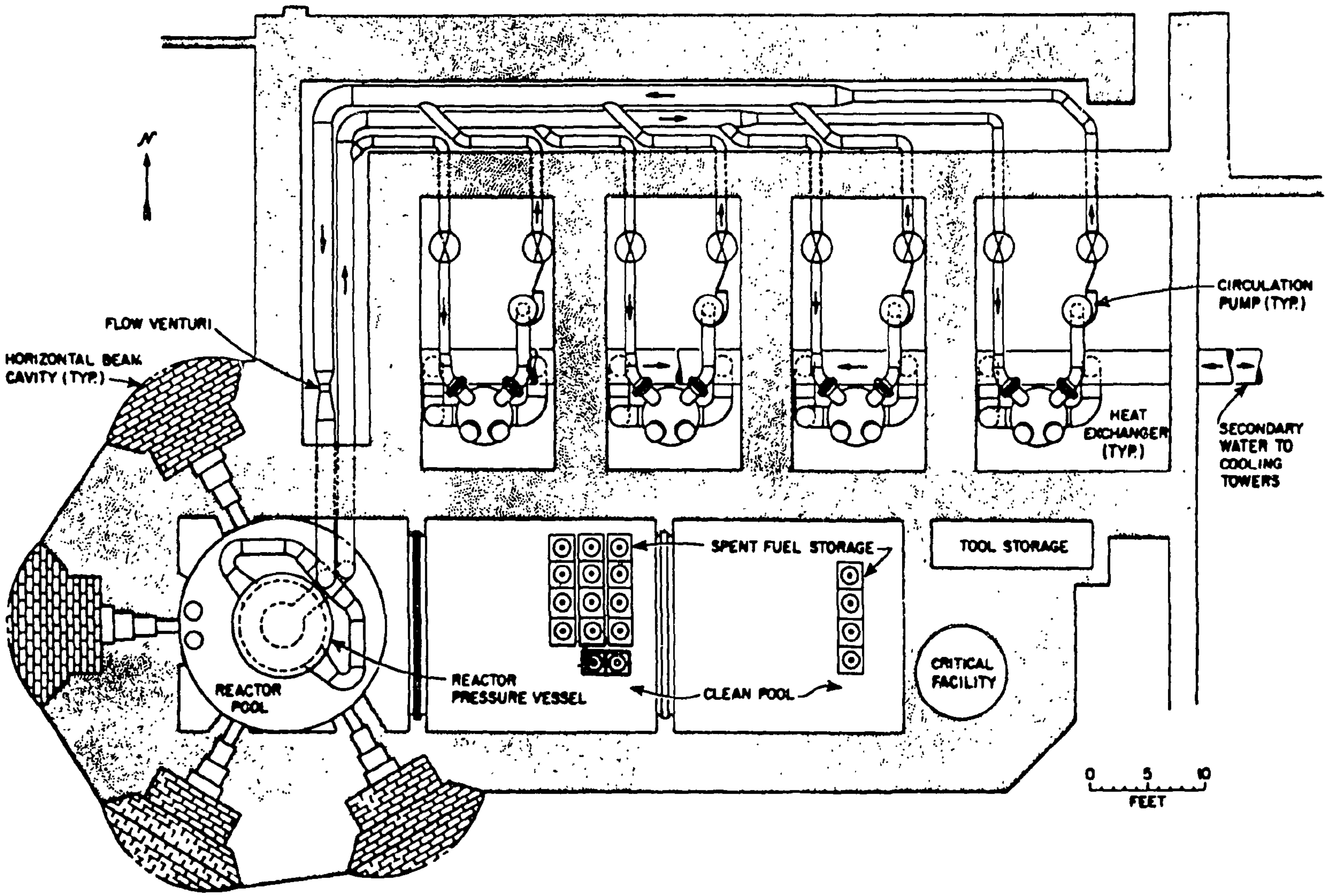

Fig. 6.5. Reactor shield, heat exchanger cells, and pool structures - horizontal section.

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, Fig. 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, and -1D, will deliver at least 18,925 l/m (5,000 gpm) against a 111-m (365-ft) head of water when three pumps are operated in parallel. They are driven by 2300 V, ac, 600 hp squirrel cage induction motors coupled to the pump shaft.

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 4921 l/m (1300 gpm) to the reactor. Shaft seals for the pumps are limited leakage mechanical type. Curves showing the pump characteristics are given in Fig. 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:

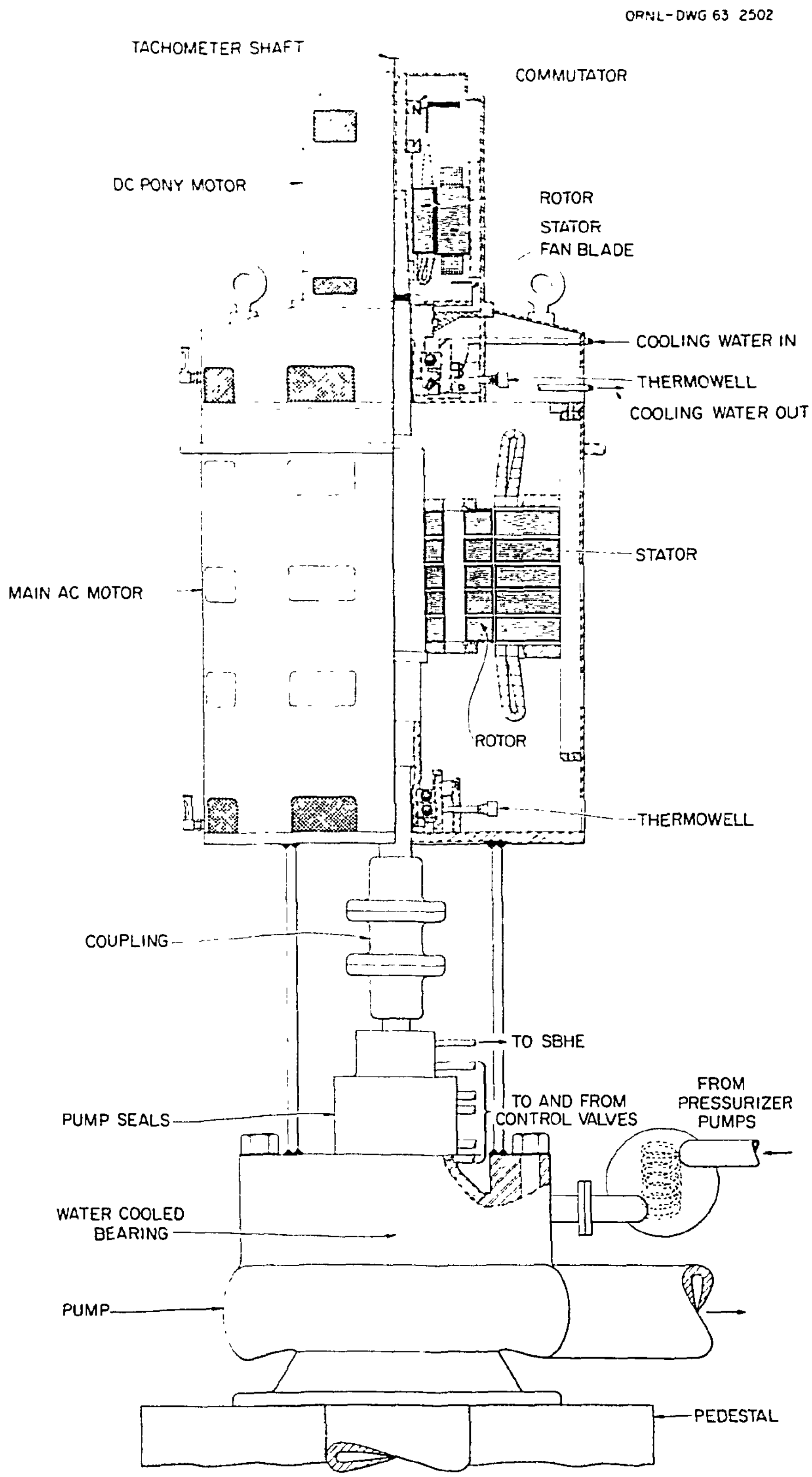

Fig. 6.6. Primary coolant pump motors.

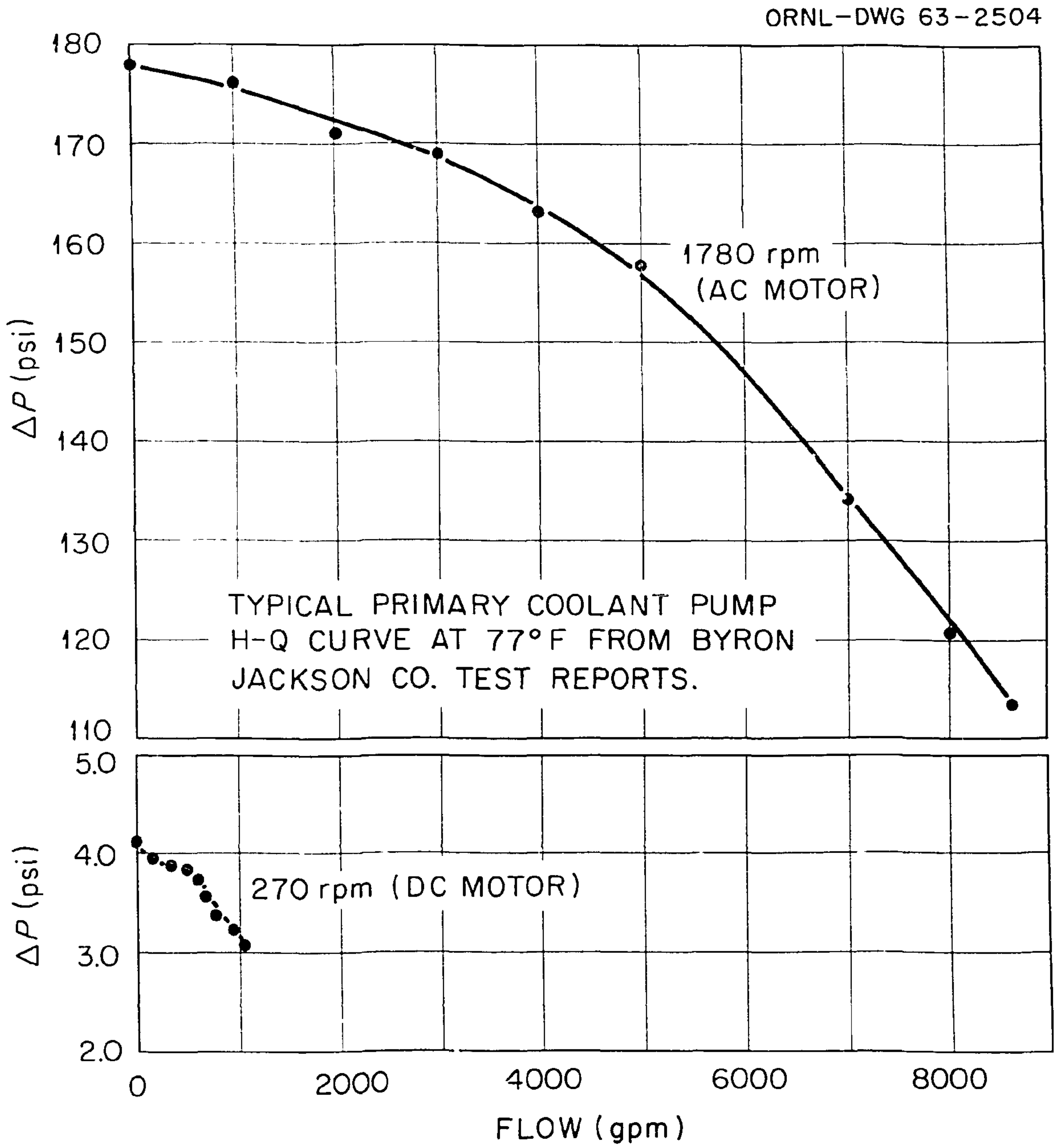

Fig. 6.7. Characteristic curves for primary coolant pumps.

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-V motor starter,
4. excessive vibration,
5. low pressure in the primary loop, or
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. The dc 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 Fig. 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 dc ground in battery charger,
6. abnormally high current to the pony motor series field,
7. abnormally low current to the pony motor series field, and
8. abnormal water flow or pressure to the mechanical seals.

Pressurizer pumps. The two main pressurizer pumps, PU-4A and -4B, are 9-stage horizontal centrifugal pumps. A variable speed drive

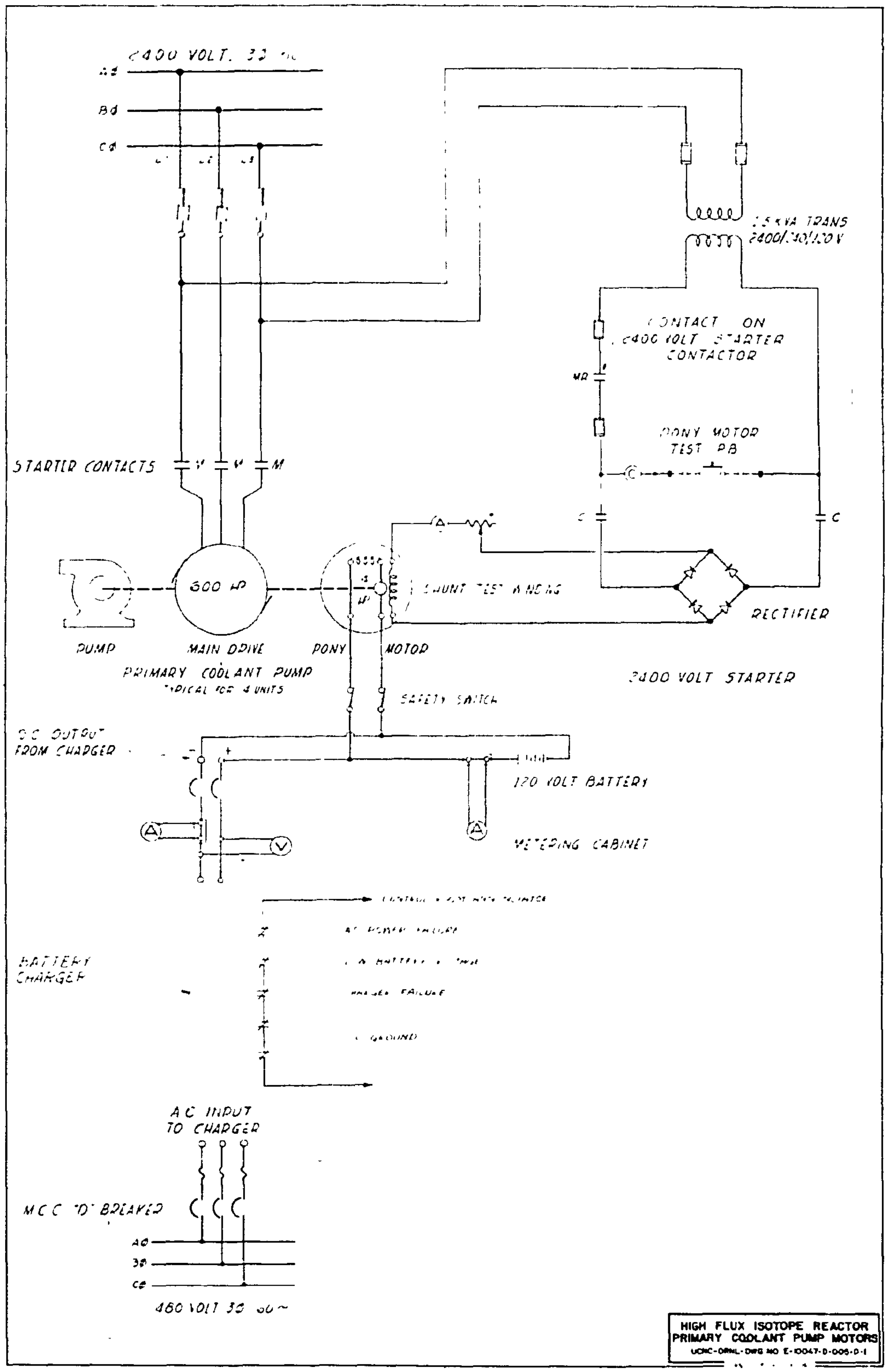

Fig. 6.8. Primary coolant pump motor test circuits.

enables each pump to deliver up to 1136 l/m (300 gpm) at pressures up to 6.9 MPa (1000 psi). The characteristics of these pumps are shown in Fig. 6.9. A small 33-gpm single-stage vertical centrifugal 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 6.2.2) and discharge into the high pressure system between the main circulation pumps and the inlet to the reactor vessel.

The flow rate of water bypassed into the low pressure cleanup system is determined by the speed of the pressurizer pumps. The setpoint of the pressure-controlled letdown valves controls the pressure in the primary system. The pressurizer pump variable speed unit consists of a 2300-V, 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 "Standby" push-button, and a running light in the control room. In normal operation one pump is running while the other is in standby. The standby 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-V motor starter,
4. low coolant pressure 51.7 kPa (7.5 psig) to the variable speed coupling unit,
5. loss of voltage,

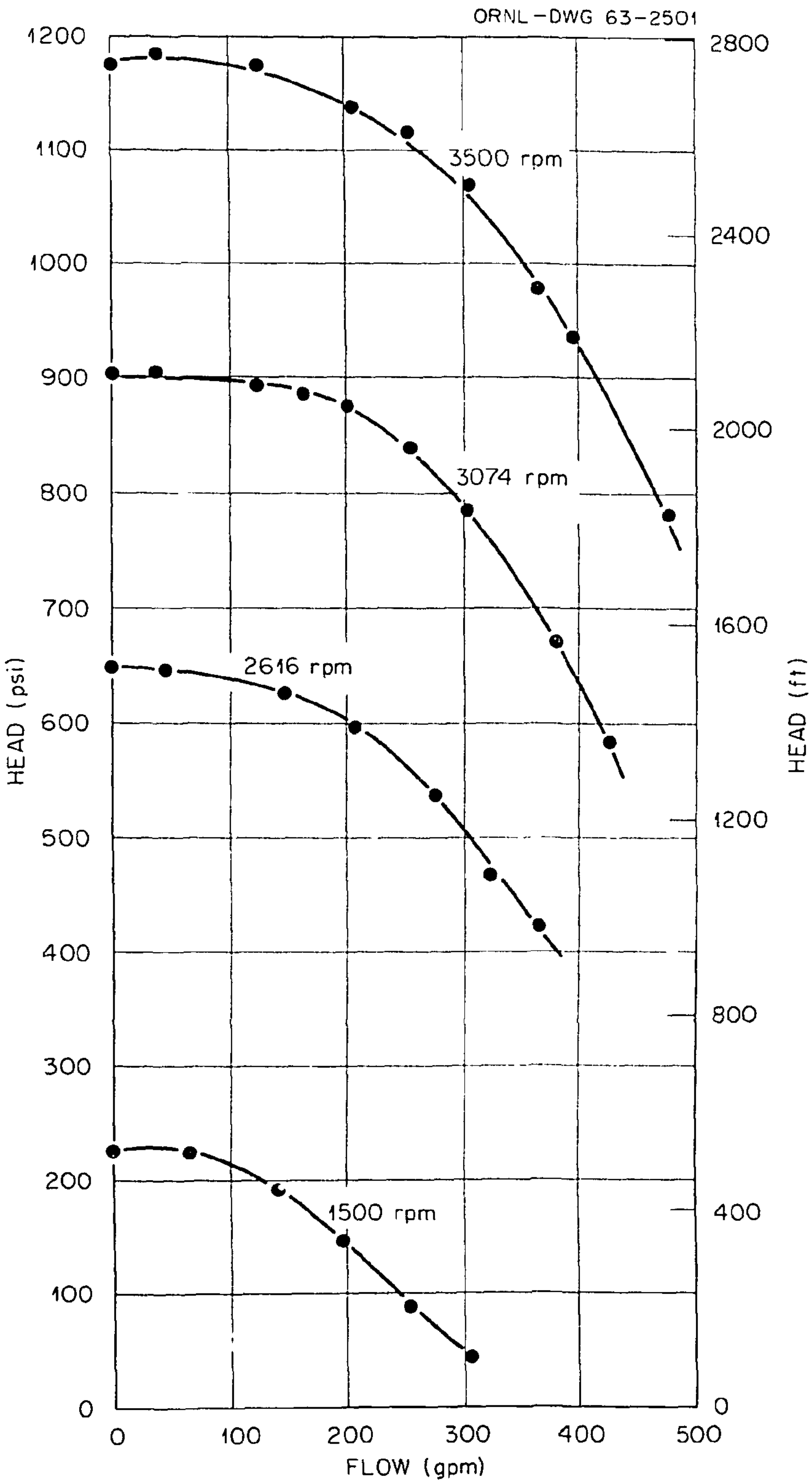

Fig. 6.9. Characteristic curves for main pressure pump.

6. low suction head pressure (after a 5-s time delay), and
7. high discharge temperature 65.5°C (150°F) and pressure 5.86 MPa (850 psig).

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 contact in normal-emergency switchgear 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.

6.2.2 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 equiment: deaerator, pumps, prefilters, demineralizers, afterfilters, and primary coolant head tank with interconnecting piping. The flow schematic is shown in Figs. 6.10 and 6.11, with the arrangement of this equipment, which is located in the water wing, shown in Fig. 6.12.

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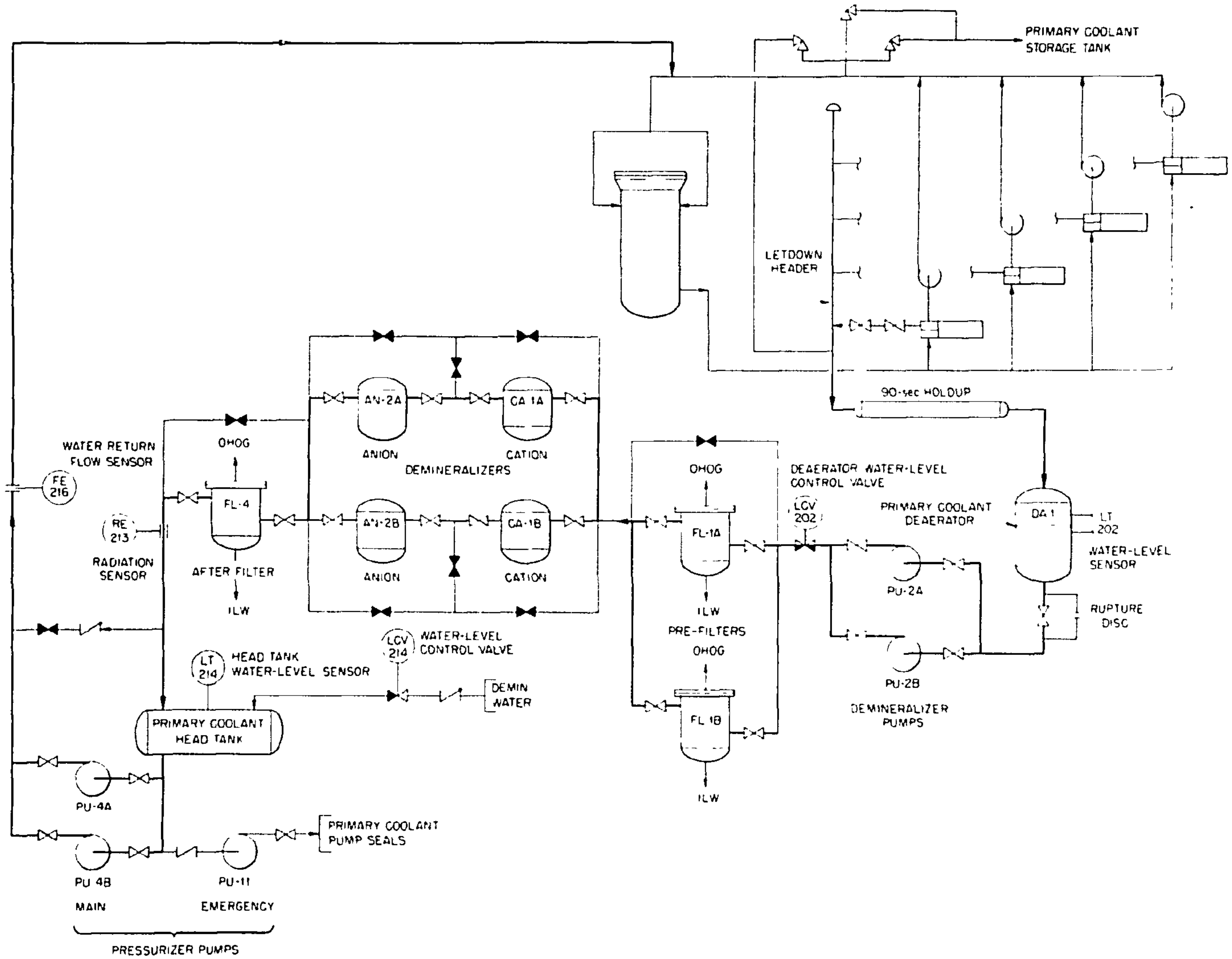

Fig. 6.10. Primary coolant cleanup system.

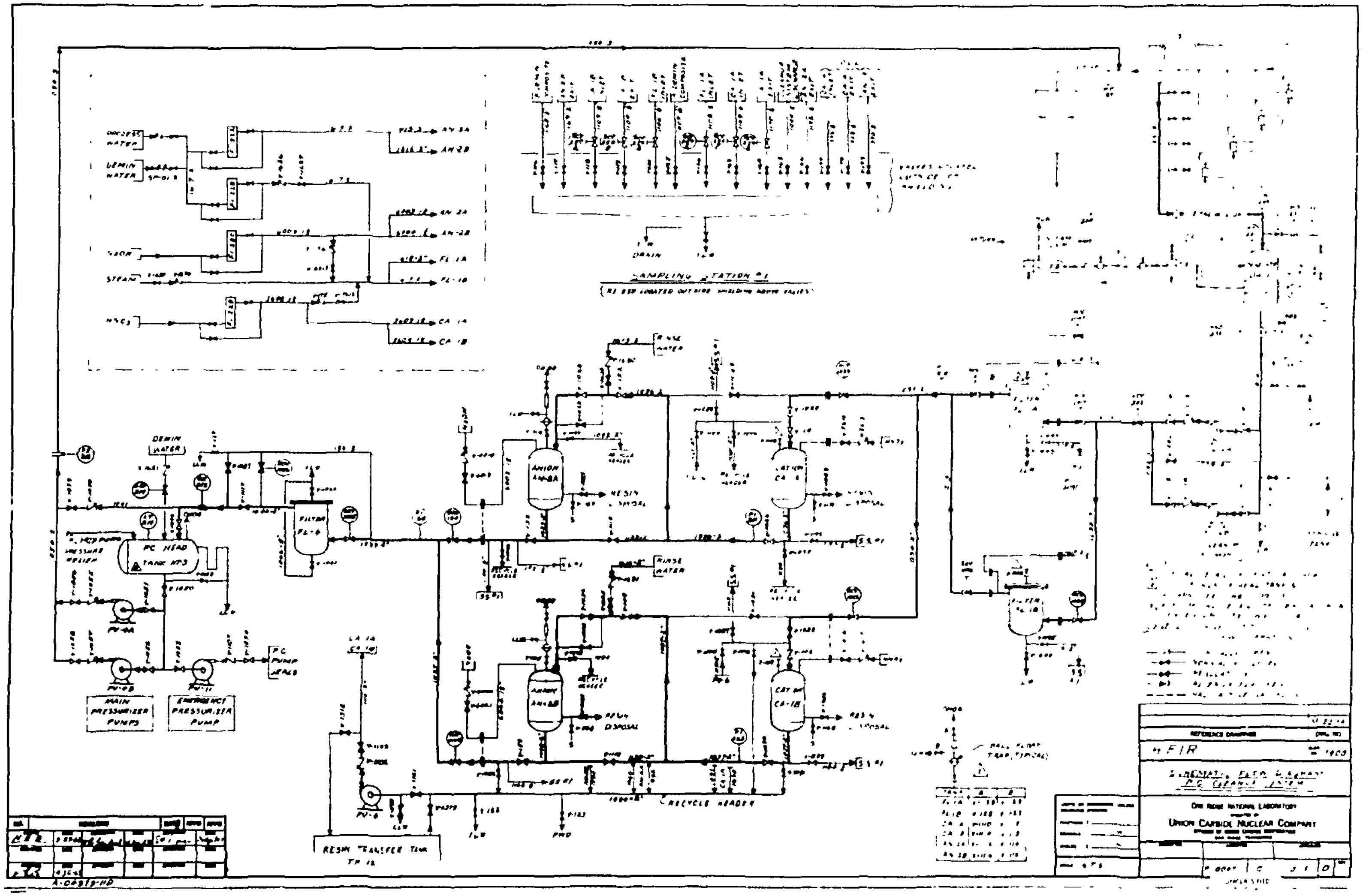

Fig. 6.11. Primary coolant cleanup - schematic flow diagram.

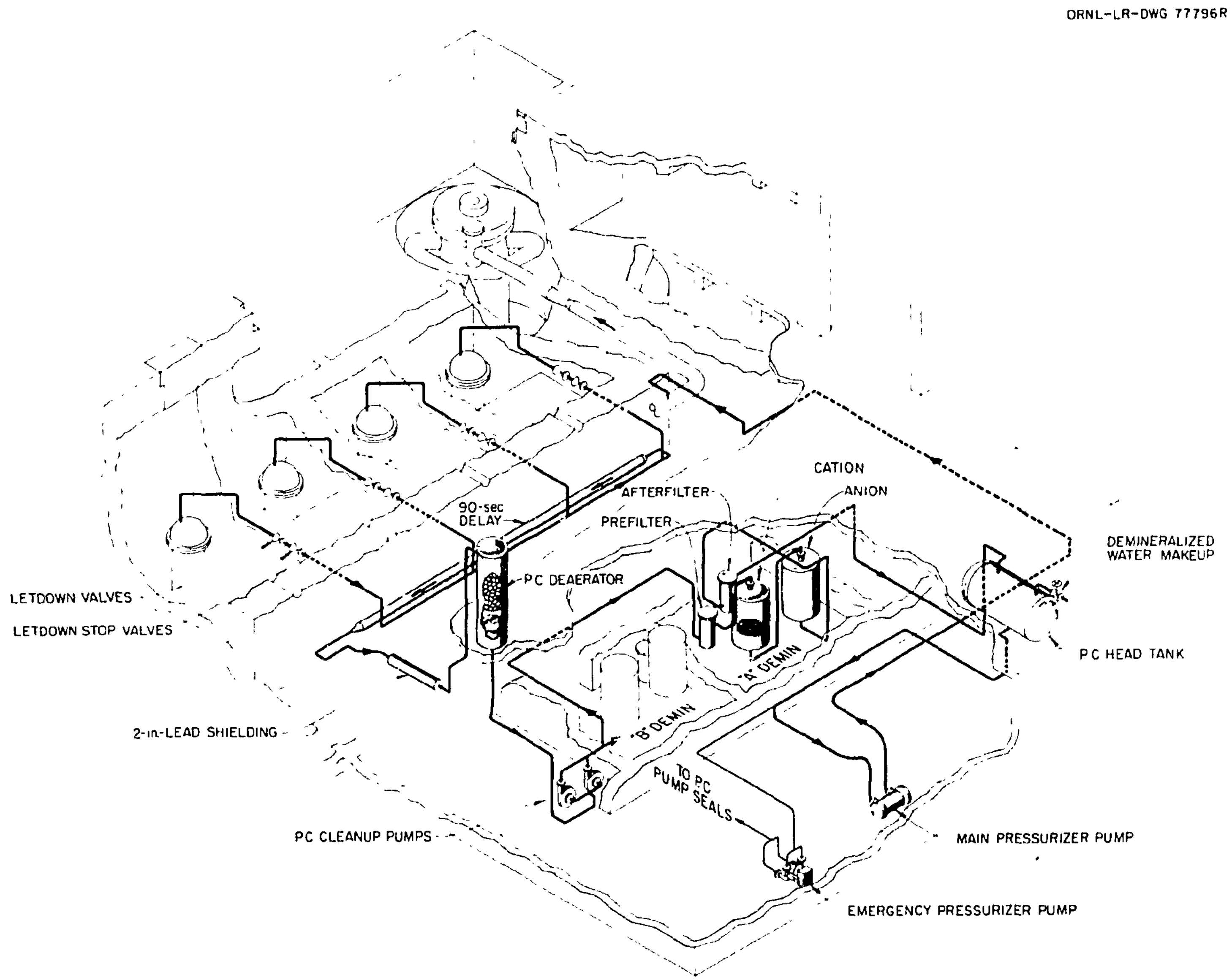

Fig. 6.12. Primary coolant cleanup equipment arrangement.

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 757 l/m (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 primary circulation pump seals and the reactor tank top vent (to remove trapped gases). The composite of these flows passes through a 14.6-m (48-ft) section of 30.5-cm-diam (12-in.) pipe located in the pipe tunnel. At a flow of 757 l/m (200 gpm), this provides approximately 90 s 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 757 l/m (200-gpm) centrifugal pumps, PU-2A and -2B, 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 two afterfilters before discharging into the primary coolant head tank. The afterfilters located in the exit line from the demineralizers prevent 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 pump.

Deaerator. The primary coolant deaerator, also shown in Fig. 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 91.4 cm (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. 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 aftercondenser. The evolved gases are discharged to the closed hot off-gas system. The condensers are cooled by secondary coolant. Condensate from both pre- and aftercondensers 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 afterfilters remove demineralizer-resin fines from the water before it is returned to the high pressure system. The demineralier 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 afterfilter, shown in Fig. 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 757 l/m (200 gpm) and consists of 28 porous tubes, 7.0 cm (2 3/4 in.) in diameter by 49.5 cm (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 1.03 MPa (150 psi). Additional shielding is provided by 7.6 cm (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 378 l/m (100 gpm). Each unit consists of a cation bed and an anion bed in series. Each cation bed contains 0.99 m^3 (35 ft^3) of cation resin in a vessel 1.2 m (4 ft) in diameter by 1.8 m (6 ft) high. Each anion bed contains 1.7 m^3 (60 ft^3) of anion resin in a similar vessel 1.52 m (5 ft) in diameter by 1.8 m (6 ft)

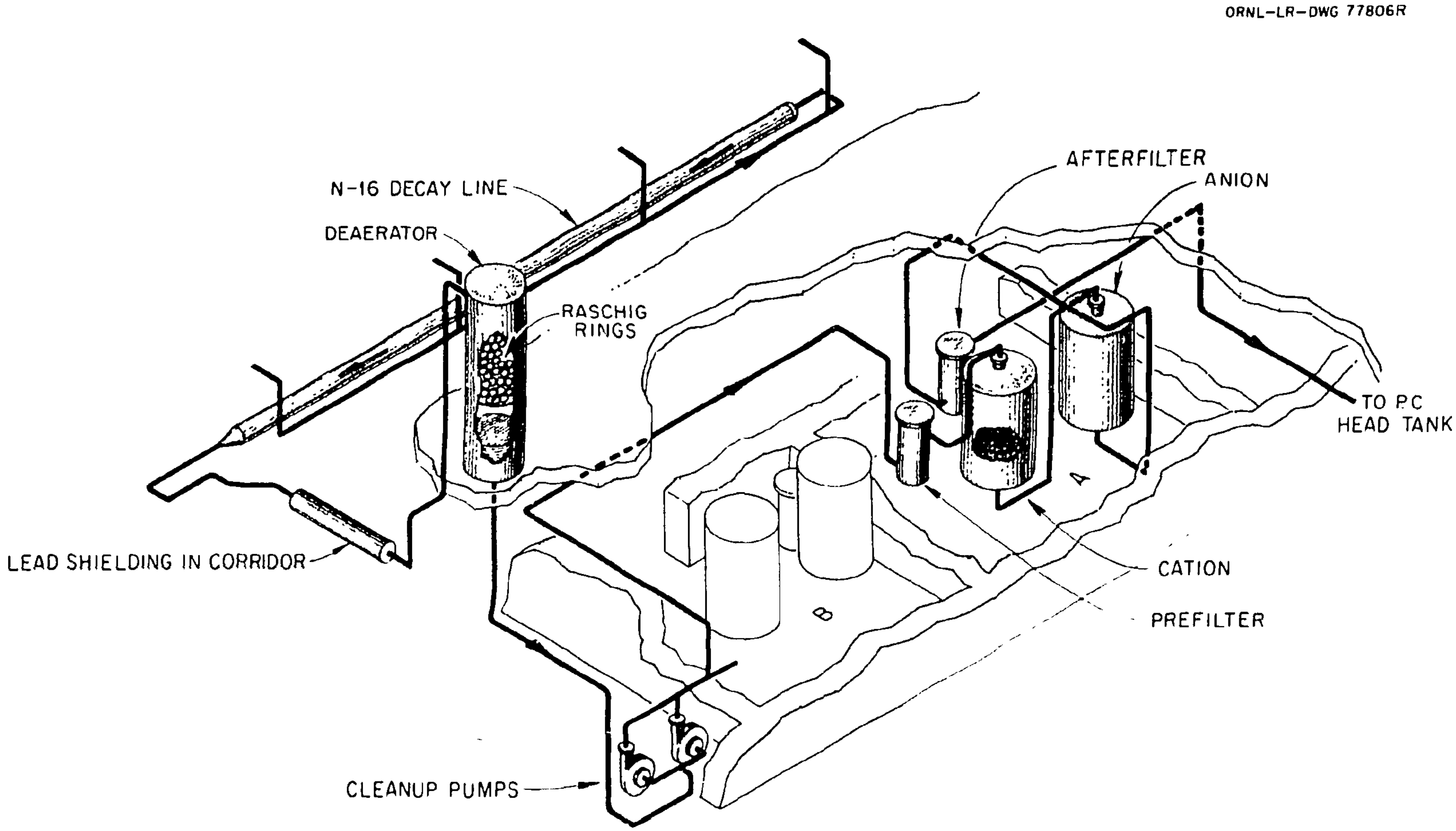

Fig. 6.13. Primary coolant cleanup system details.

high. Under normal operating conditions, one unit is in service. Some of the cation effluent may be bypassed around the anion bed to aid in maintaining a system pH of 5.0 $\pm$ 0.1. Additional local shielding is provided by 7.6 cm (3 in.) of lead surrounding the cation tanks. The anion tanks are not directly shielded.

The afterfilters, located in series, are designed for a 757-l/m (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 presure differential of 1.0 MPa (150 psi), the TDH of the cleanup pumps. Pressure drop across a clean filter is 0.01 MPa (1.5 psi) at 757 l/m (200 gpm) flow. The first afterfilter can be operated and cleaned from outside the shielded cell. Neither can be bypassed.

From the afterfilters 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 9463-l (2500-gal) horizontally mounted stainless steel tank 2.0 m (6 ft, 6 in.) in diameter by 3.56 m (11 ft, 8 in.) long.

6.2.3 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 -18B. 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 75,700-l (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 5.1-cm (2-in.) line which bypasses the pressure letdown valves and deaerator. A 7.6-cm (3-in.) line connects the discharge of the primary coolant afterfilter 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 Fig. 6.14.

The roof top of the underground water storage tank is at grade level. Its walls, floor, and roof are of 35.6-cm-thick (14-in.) concrete. The inside is lined with plastic sheets bonded together to form a watertight shell. A 10.2-cm (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.

6.2.4 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 is adjusted as required to maintain the primary coolant system at a pH of 5.0.

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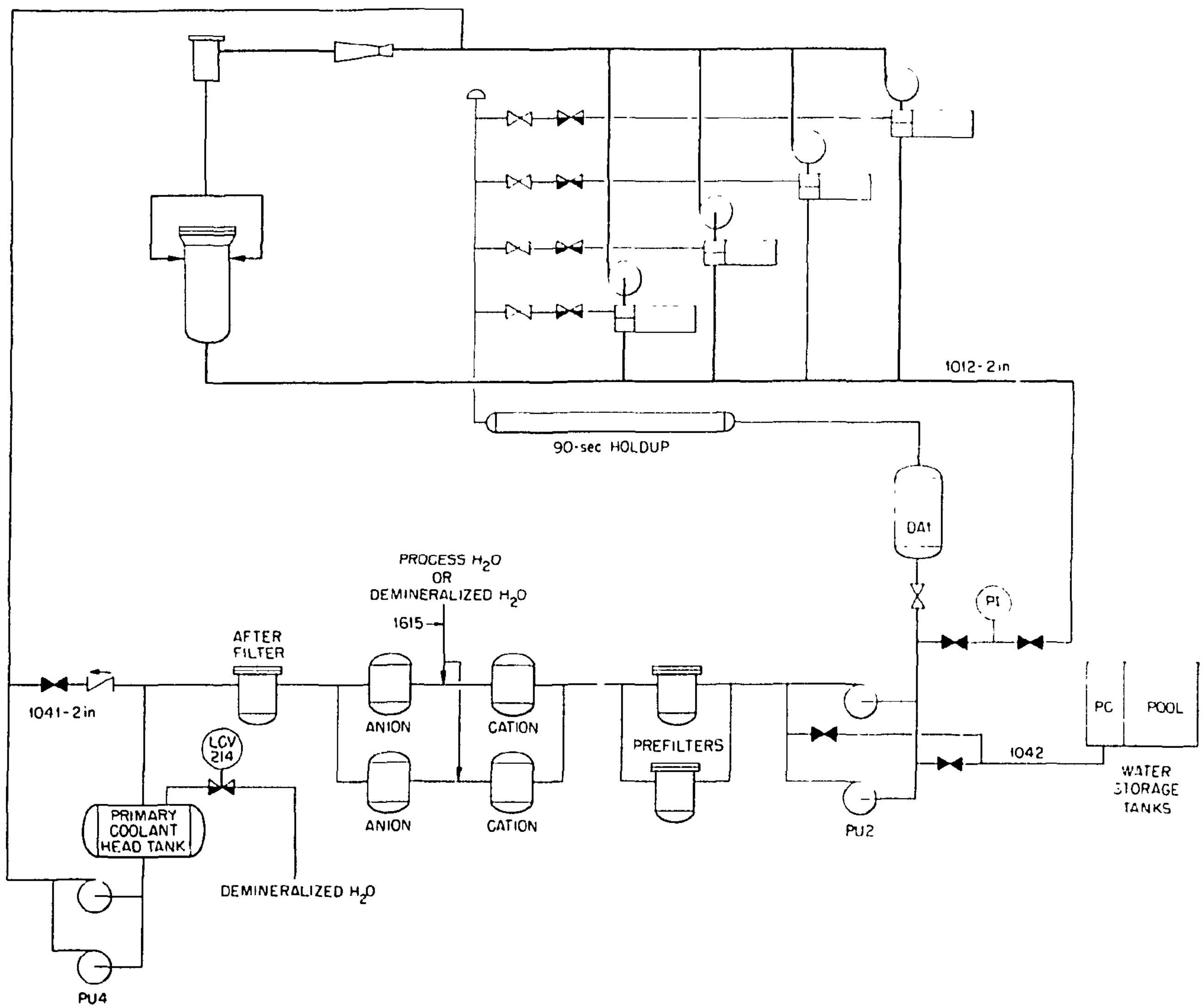

Fig. 6.14. Primary coolant makeup, fill, and drain systems.

6.3 Secondary Coolant System

6.3.1 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 98,410 l/m (26,000 gpm) circulated in the system, a maximum 73,808 l/m (19,500 gpm) passes through the three primary coolant heat exchangers, 12,112 l/m (approximately 3200 gpm) through the auxiliaries in the water wing, and 6813 l/m (approximately 1800 gpm) goes to the adjacent Transuranium Processing Facility (TRU). The secondary coolant system is shown in Figs. 6.15 and 6.16.

6.3.2 Cooling tower

The cooling tower is a four-cell induced-draft tower located southeast of the reactor building. It is designed to transfer 111 MW (380 million Btu/h) by cooling 98410 l/m (26,000 gpm) of 46°C (115°F) water to 29°C (85°F) at an ambient wet bulb temperature of 25°C (77°F). Of this total heat transfered, 102.5 MW (350 million Btu/h) is supplied by the primary coolant, 2.9 MW (10 million) by the pool coolant, 2.3 MW (8 million) by the air-conditioning system, 0.88 MW (3 million) by other loads, and 1.2 MW (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 36.6 m (120 ft) long by 16 m (54 ft) wide. The basin is divided into four separate compartments, each with a capacity of 378,500 l (100,000 gal). 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 level control valve to make up for evaporation, drift loss, and blowdown.

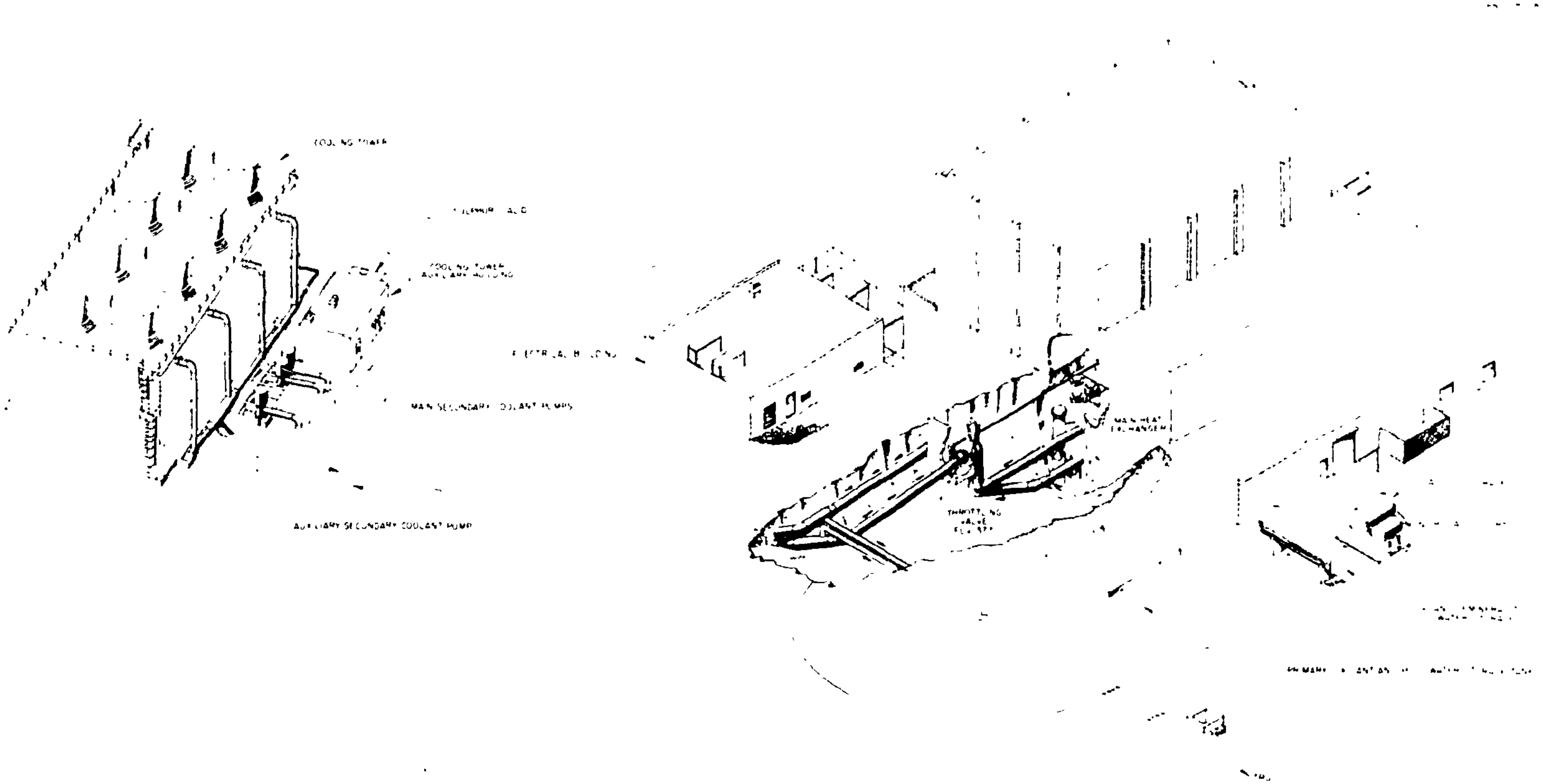

Fig. 6.15. Secondary coolant equipment arrangement.

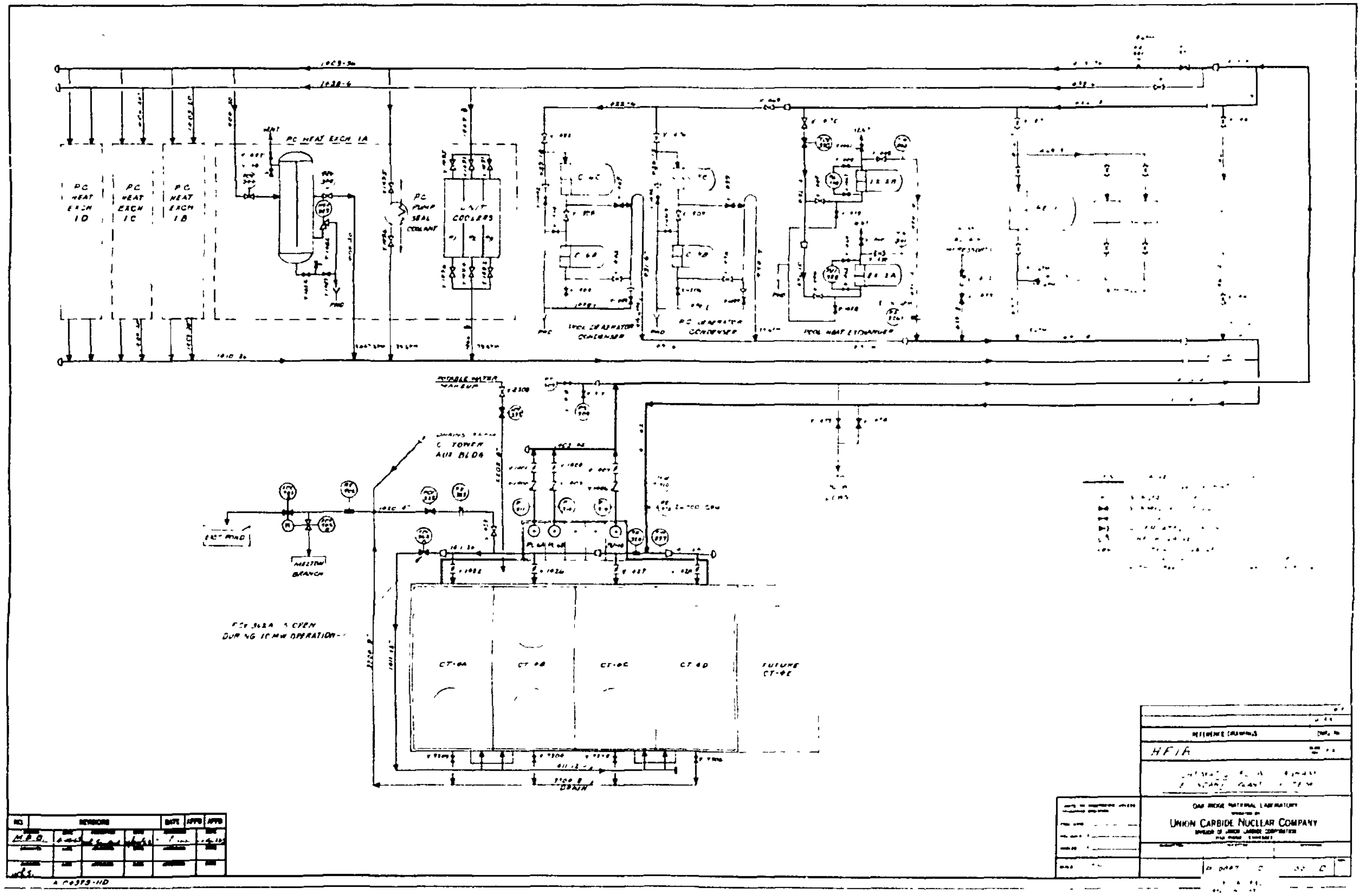

Fig. 6.16. Secondary coolant - schematic flow diagram.

6.3.3 Cooling tower fans

Each cell is equipped with two 50-hp two speed fans which can be reversed for deicing 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 alternately for:

1. fast speed-forward direction,
2. slow speed-forward direction, and
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. The time-delay relays are adjustable and perform the following functions:

1. The provision of different time settings for the relays allows the 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. 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 Fig. 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 but can be restarted if there is no fire. A vibration switch near each fan shuts down only the affected fan. These devices must be manually reset before the fans can be restarted.

6.3.4 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 chemicals to inhibit corrosion, and
3. manual addition of nonoxidizing biocides to control algae.

The acid-injection system consists of an 18,925-l (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 treating equipment consists of a supply tank and a manually adjustable proportionating feed pump.

6.3.5 Secondary coolant pumps

The three main secondary coolant pumps, PU-6A, -6B, and -6C are vertically mounted centrifugals, any two of which have a combined capacity of 98,410 l/m (26,000 gpm). The characteristics of these pumps are shown in Fig. 6.18. A smaller fourth pump, PU-14, has a capacity of

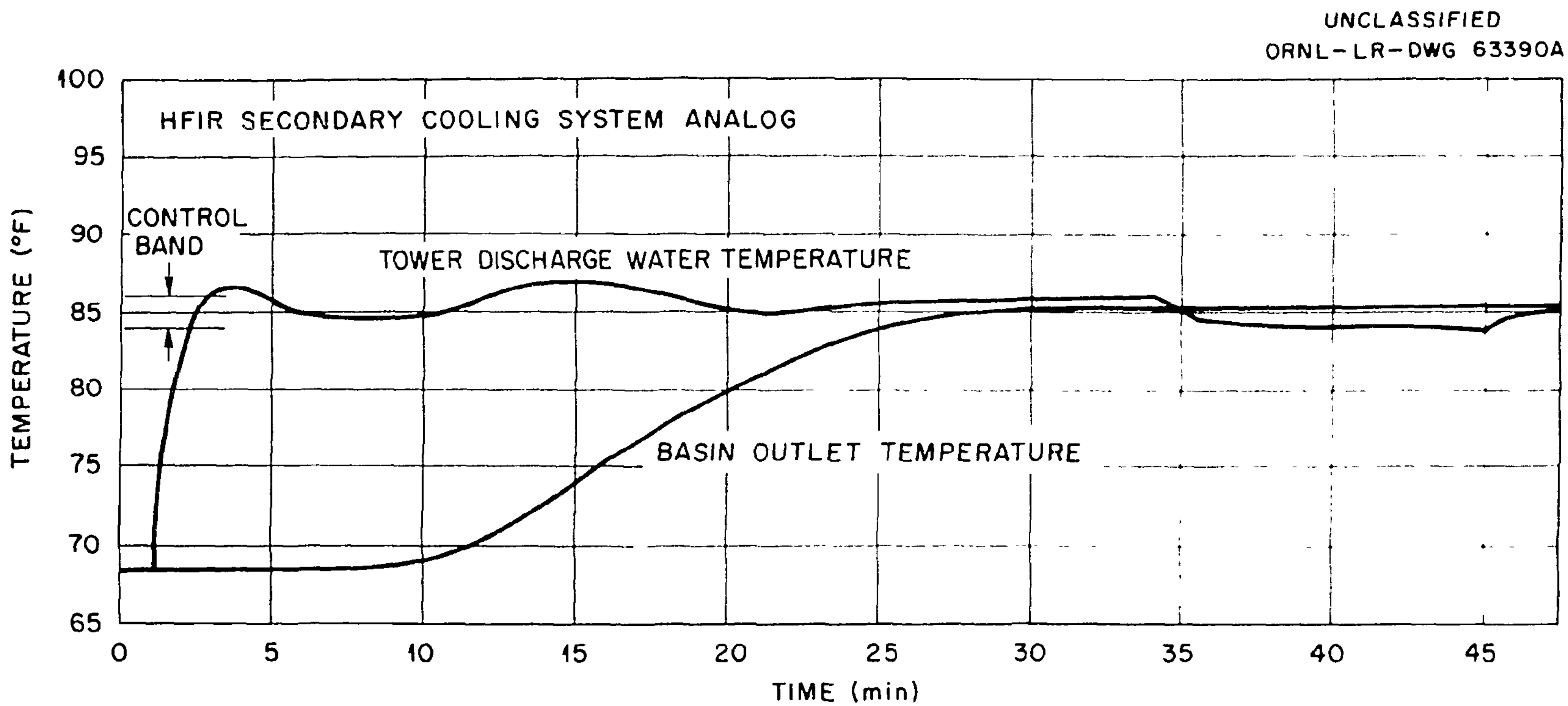

Fig. 6.17. Typical secondary coolant temperature response following startup.

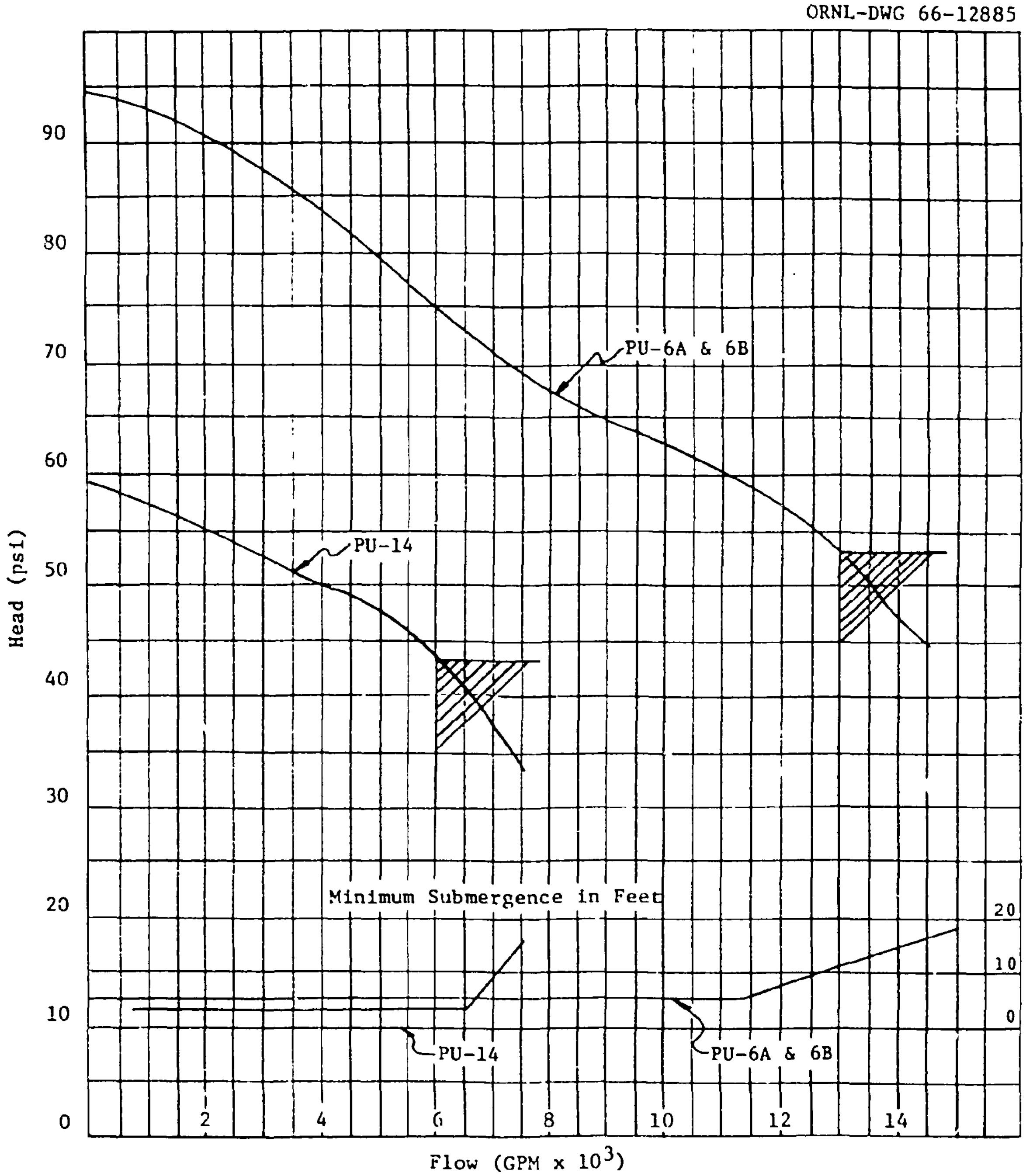

Fig. 6.18. Characteristic curves for secondary coolant pumps.

22,710 l/m (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 shutdown, the cooling demand is greatly reduced. The 22,710-l/m (6000-gpm) pump may then be put into service and the main pumps stopped. This pump maintains cooling for the auxiliary systems. It also provides 11,355-l/m (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. 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-V motor starter door, and
4. loss of voltage.

The auxiliary 22,710-l/m (6000-gpm) circulation pump, PU-14, is driven by a two-winding motor. The high-speed winding provides sufficient secondary coolant flow, 22,710-l/m (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, 11,355-l/m (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 mechanial 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 106.7-cm (42-in.) pipe which runs underground to the east side of the reactor building where it divides into a 91.4- and a 45.7-cm (36- and 18-in.) line (see Fig. 6.15). The 91.4-cm (36-in.) line carries a maximum of 22,710 l/m (6000 gpm) of cooling water to each of the primary coolant heat exchangers. The 45.7-cm (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 49°C (120°F).

6.4 Pool Water System

The reactor pressure vessel is located in a cylindrical pool 5.5 m (18 ft) in diameter and 11 m (36 ft) deep which contains approximately 302,800 l (80,000 gal) of water. Connected to this pool is a rectangular storage pool, 12.6 m (41-1/2 ft) long, 6.1 m (20 ft) deep, and 5.5 m (18 ft) wide, which contains approximately 431,490 l (114,000 gal) of water. A smaller cylindrical pool 2.44 m (8 ft) in diameter and 7.62 m (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 37,850 l (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 6.1-m (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 Fig. 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.

6.4.1 Pool coolant system

All pools are provided with overflow scuppers at the 258.5-m (848-ft) level. Pool water overflowing into these scuppers flows by gravity into

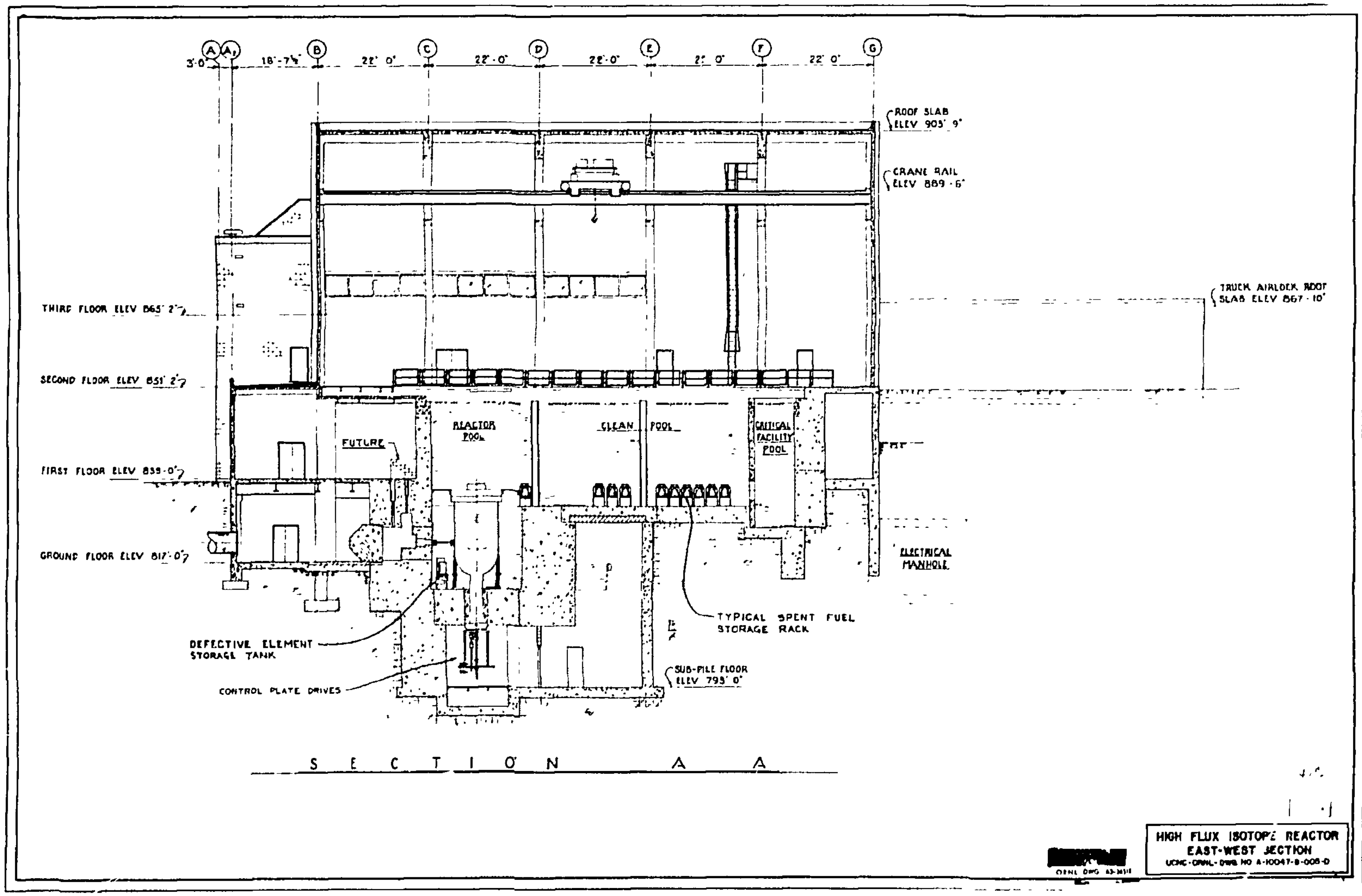

Fig. 6.19. East-west section.

the pool surge tank as shown in Figs. 6.20, 6.21, and 6.22. The pool surge tank maintains a positive suction head on the two pool-coolant pumps, PU-9A and B, which are rated at 3785 l/m (1000 gpm) each. Up to 1892 l/m (500 gpm) of the 3785 l/m (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 3785 l/m (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 Fig. 6.23.

Pool overflow. The reactor pool overflow of approximately 1893 l/m (500 gpm) flows by gravity through two lines to the 20.3-cm-diam (8-in.) common pool overflow collection line. Approximately 1514 l/m (400 gpm) from the clean pool and 379 l/m (100 gpm) from the critical pool also

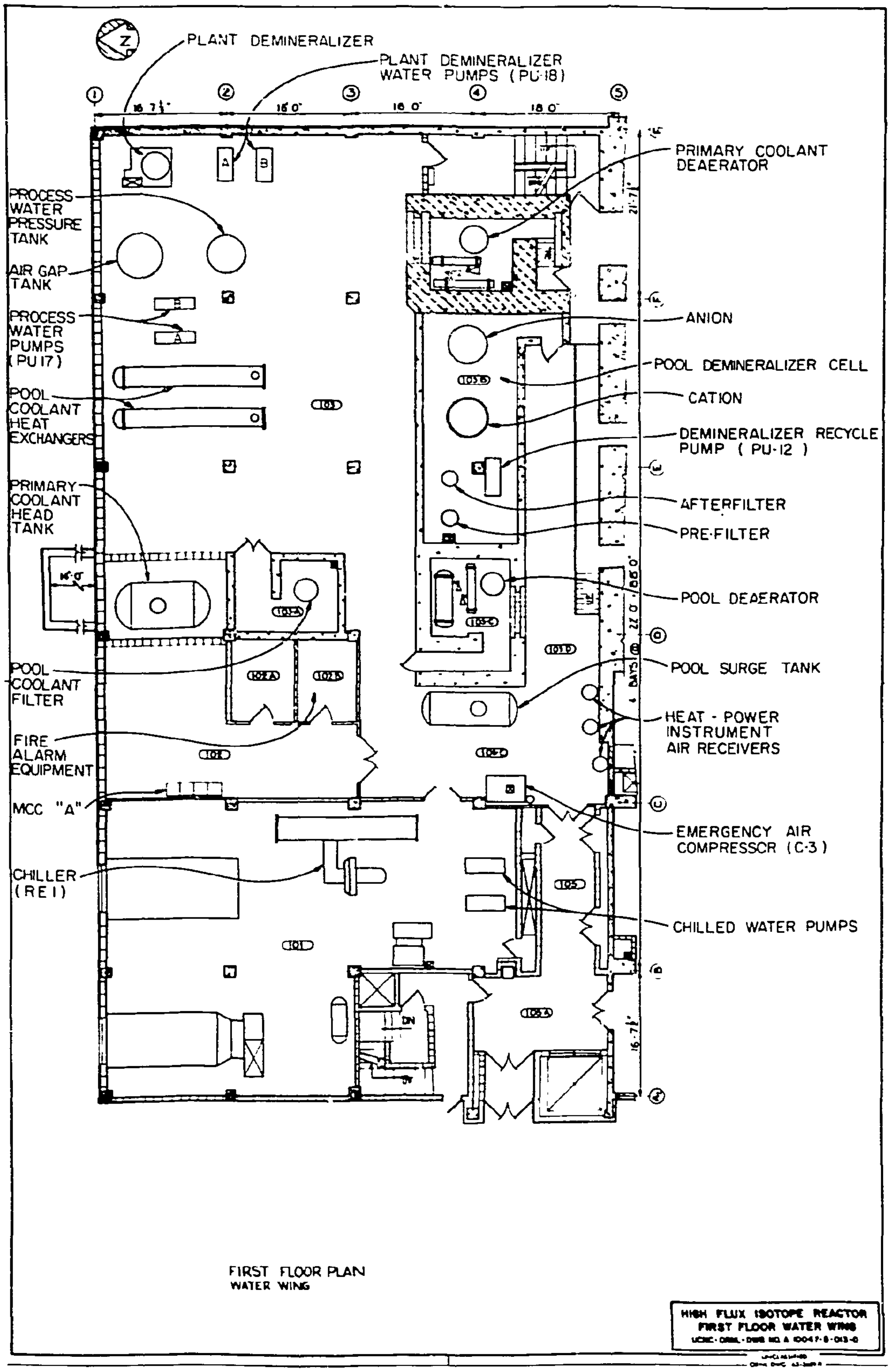

Fig. 6.20. First floor plan - water wing.

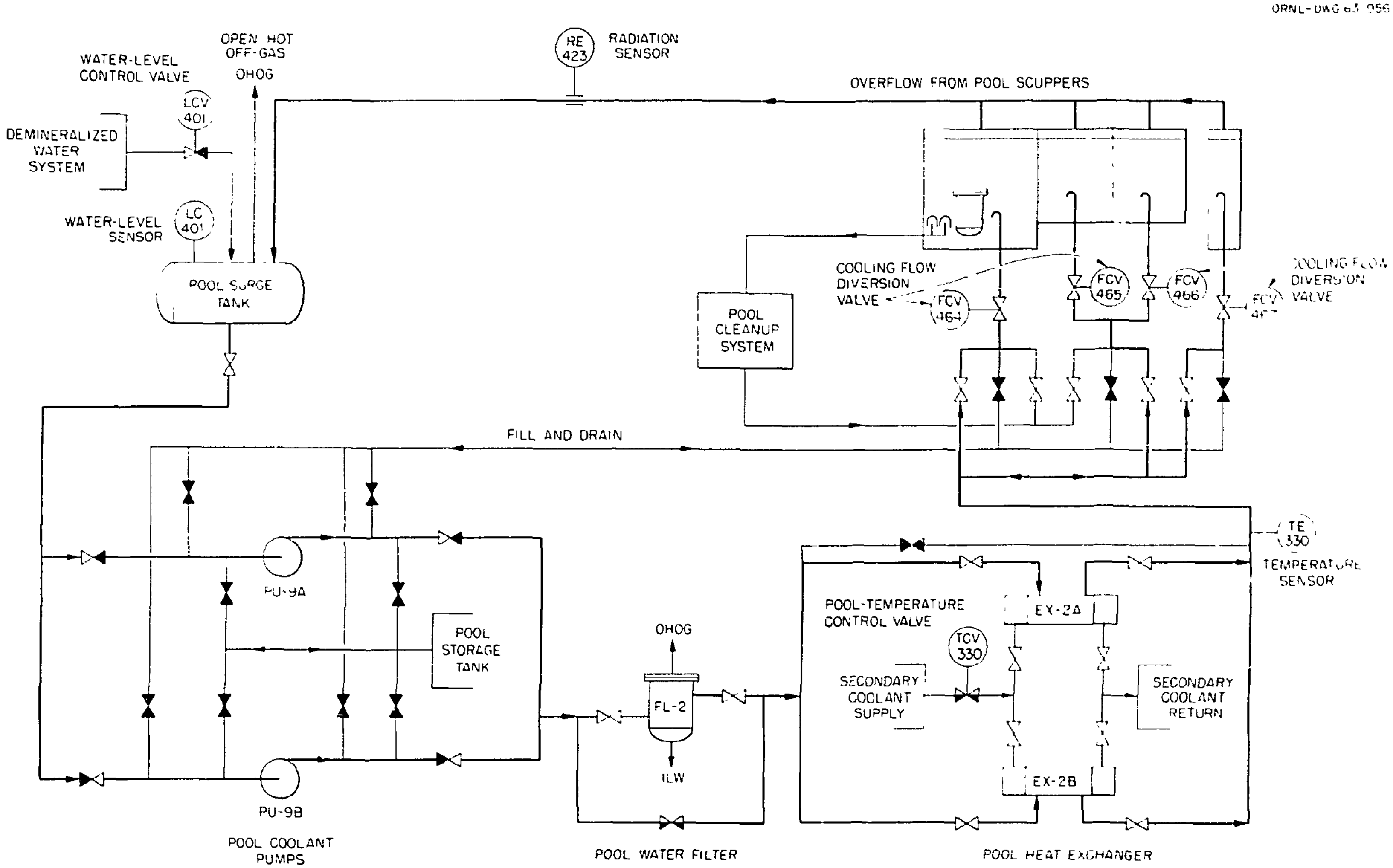

Fig. 6.21. Pool coolant system.

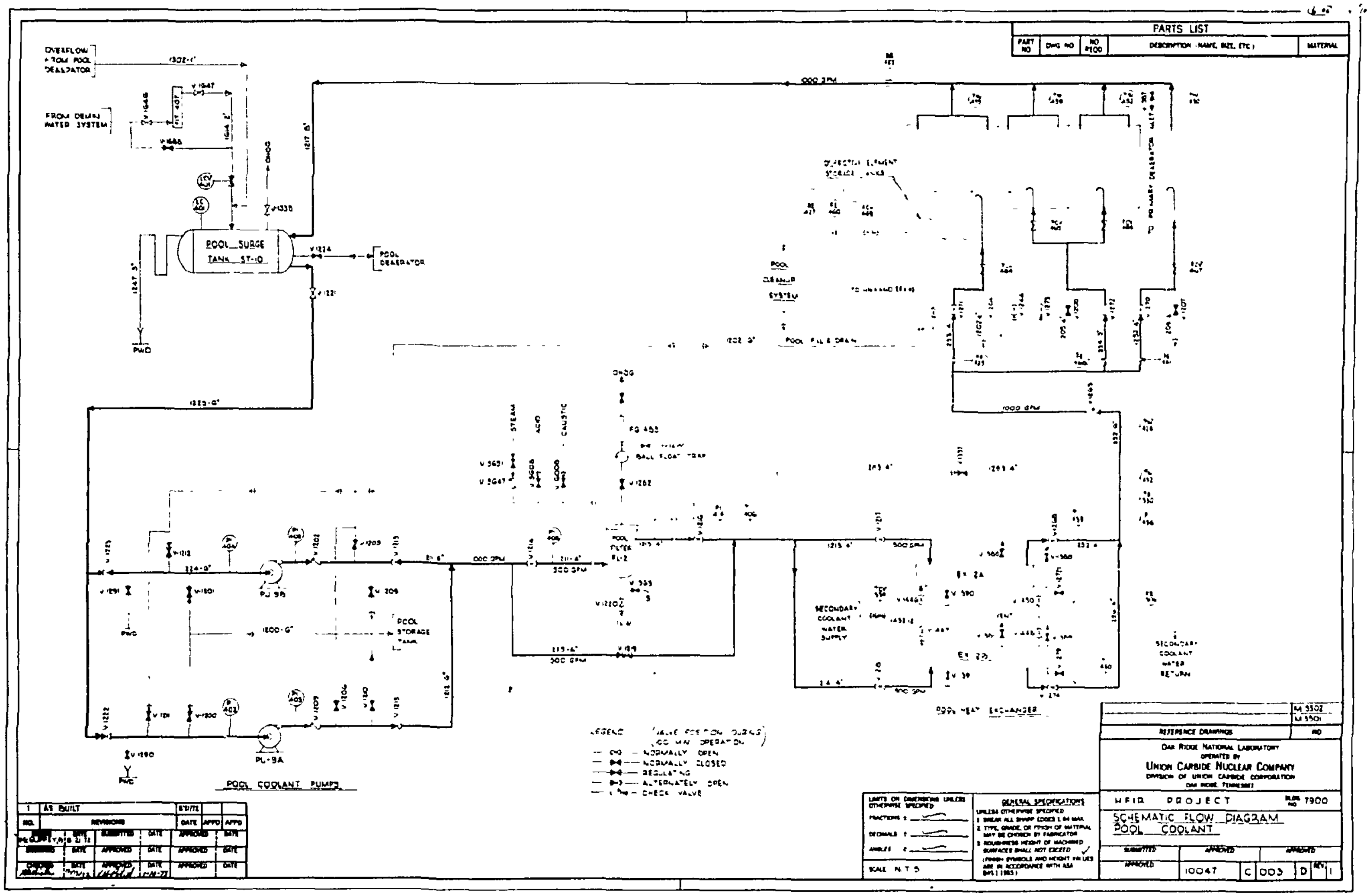

Fig. 6.22. Pool coolant - schematic flow diagram.

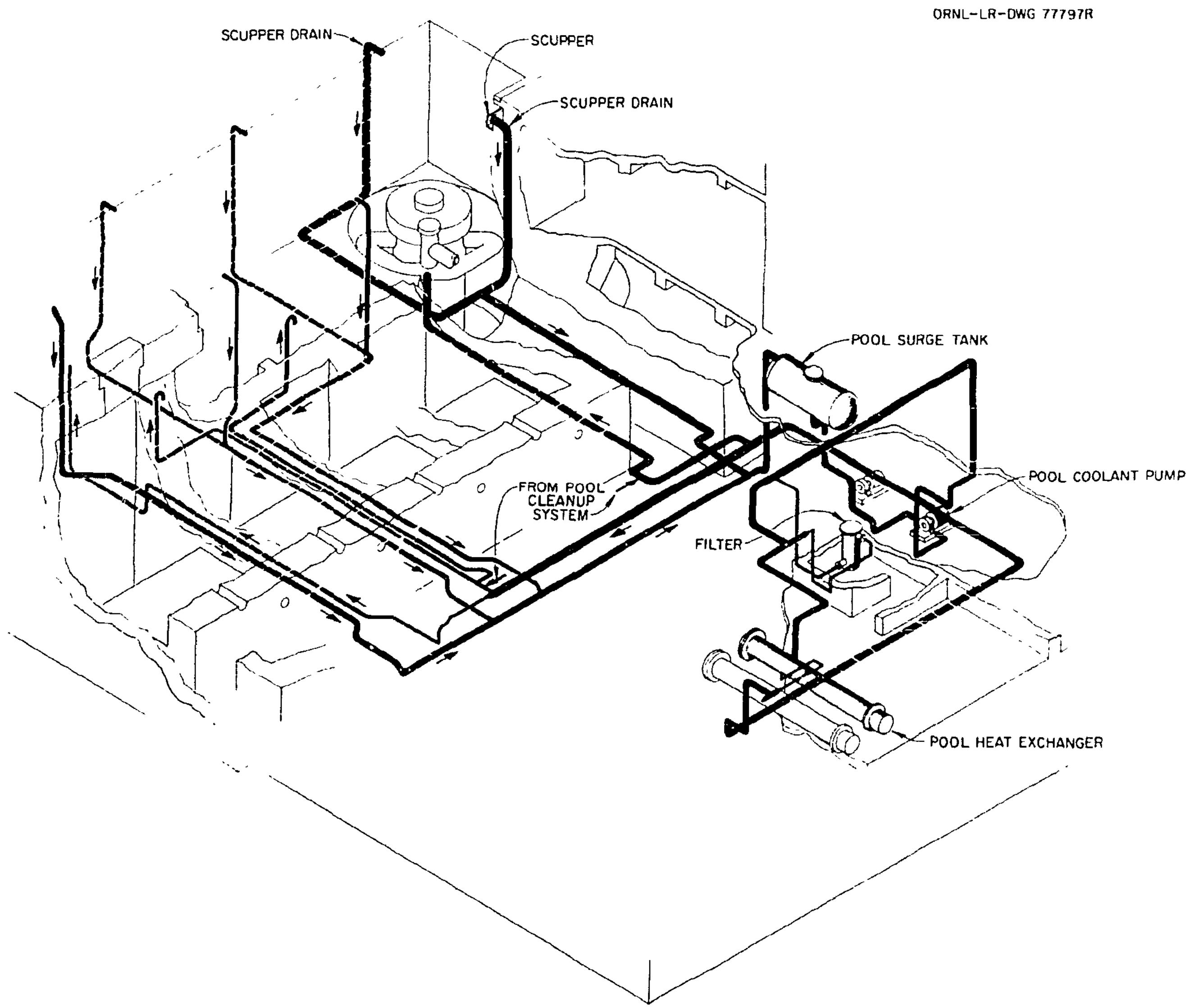

Fig. 6.23. Pool coolant equipment arrangement.

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.

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.

<u>Pool surge tank</u>. The pool surge tank which collects the overflow from the pools has a capacity of 4731 l (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 1.83-m (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 fr[illegible] deaerator
3. a normally [illegible] crosstie to the pool coolant cleanup deaerator, and
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 3785 l/m (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 s. 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. Presssure 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 1893 l/m (500 gpm). It consists of 47 porous tubes, 7 cm (2-3/4 in.) in diameter by 74 cm (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 1893 l/m (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 1.5 MW (6 million Btu/h) from the system. They each have 540 fixed tubes 1.6 cm (5/8 in.) in diameter. In normal operation each exchanger will operate with a flow of 1893 l/m (500 gpm) of pool water but can accommodate 3785 l/m (1000 gpm). Pool water makes two passes on the shell side of each exchanger and the secondary cooling water makes two passes in the tubes. Normally the secondary water flow to each exchanger is approximately 6056 l/m (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.

6.4.2 Pool cleanup system

In order to maintain high purity water, it is necessary to pass approximately 757 l/m (200 gpm) of pool water through the pool cleanup system which consists of a deaerator, prefilter, demineralizer, and afterfilter 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 Figs. 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 Fig. 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 Fig. 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 757 l/m (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 afterfilter 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.

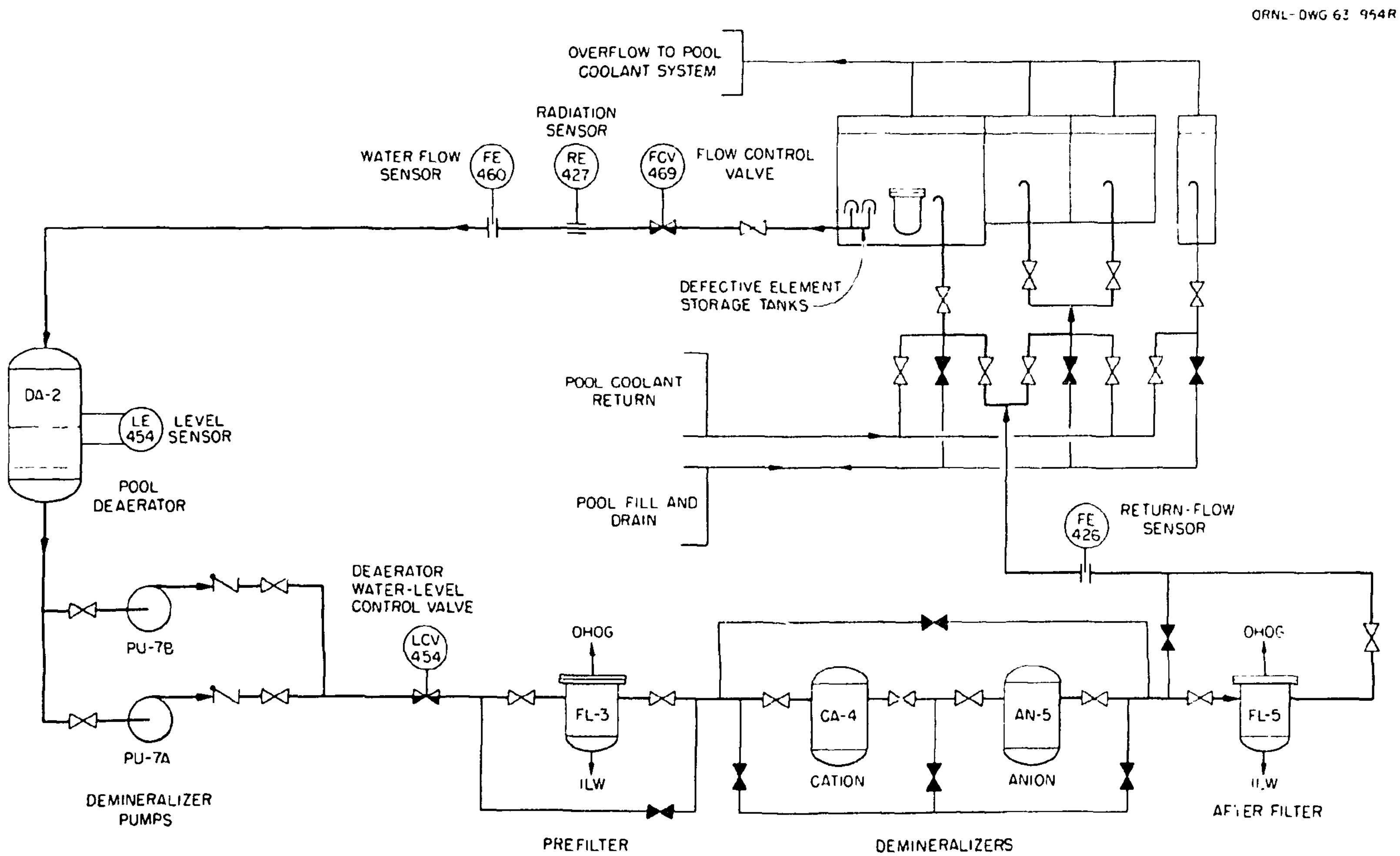

Fig. 6.24. Pool cleanup system.

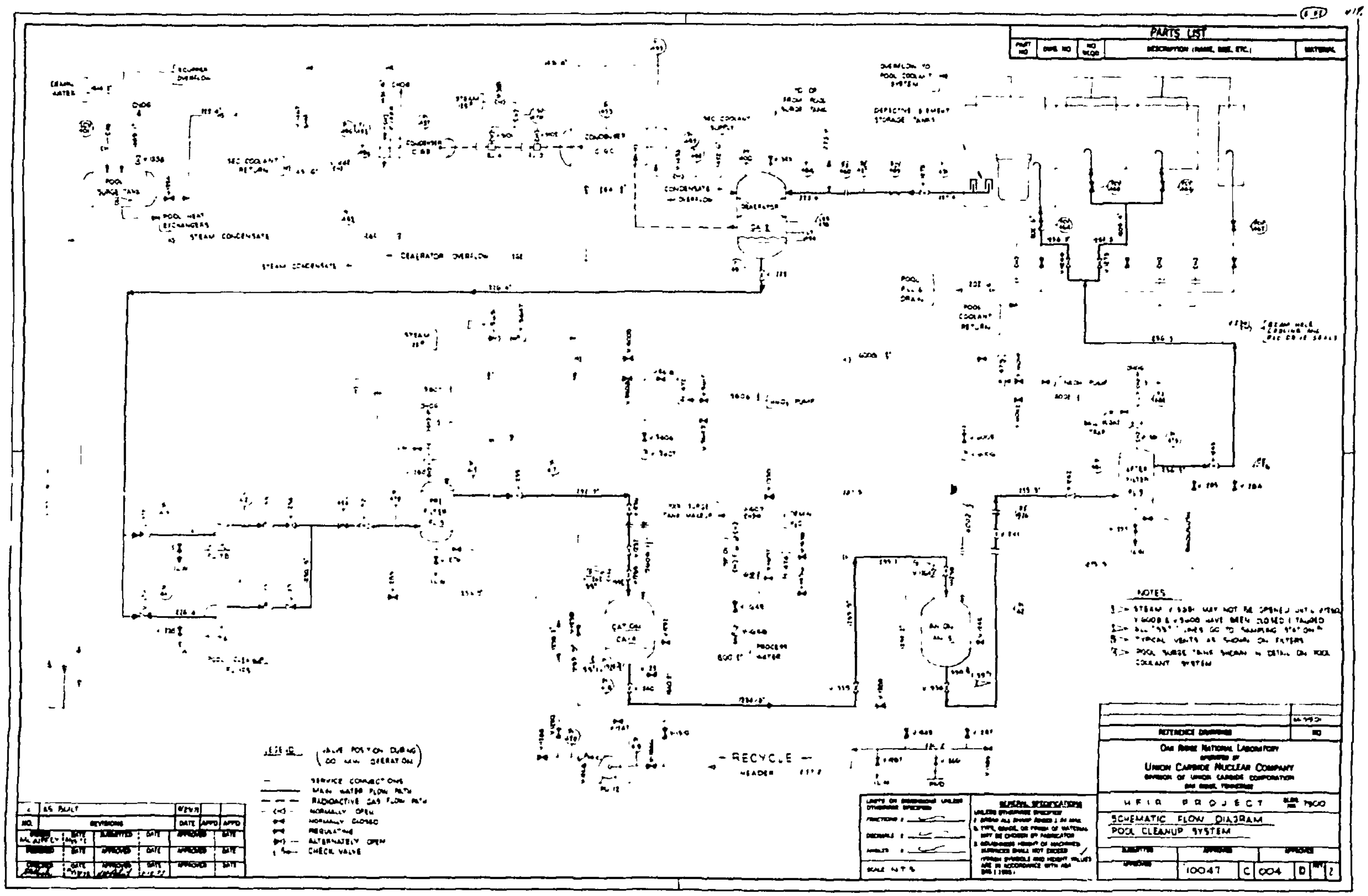

Fig. 6.25. Pool cleanup - schematic flow diagram.

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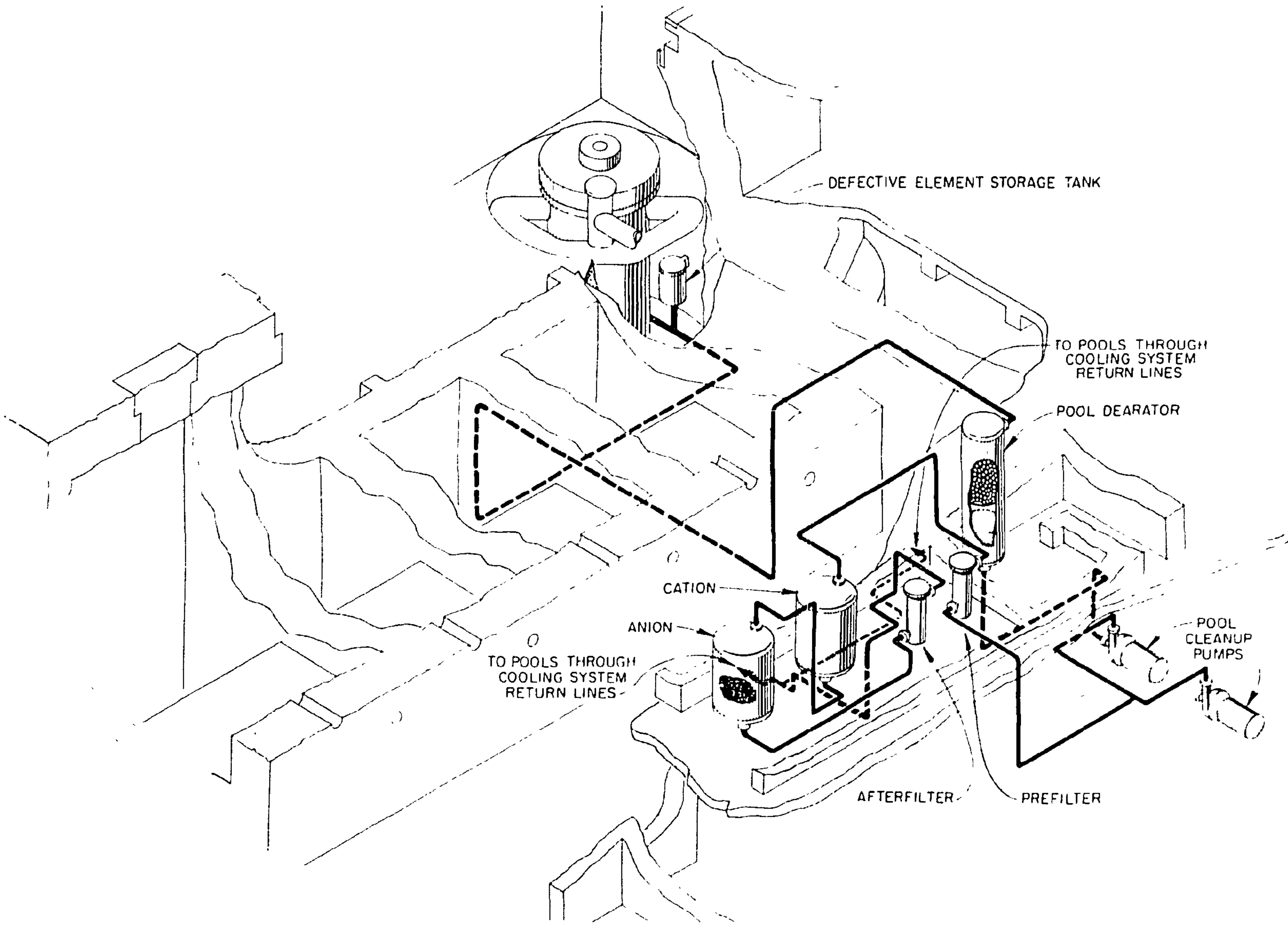

Fig. 6.26. Pool cleanup equipment arrangement.

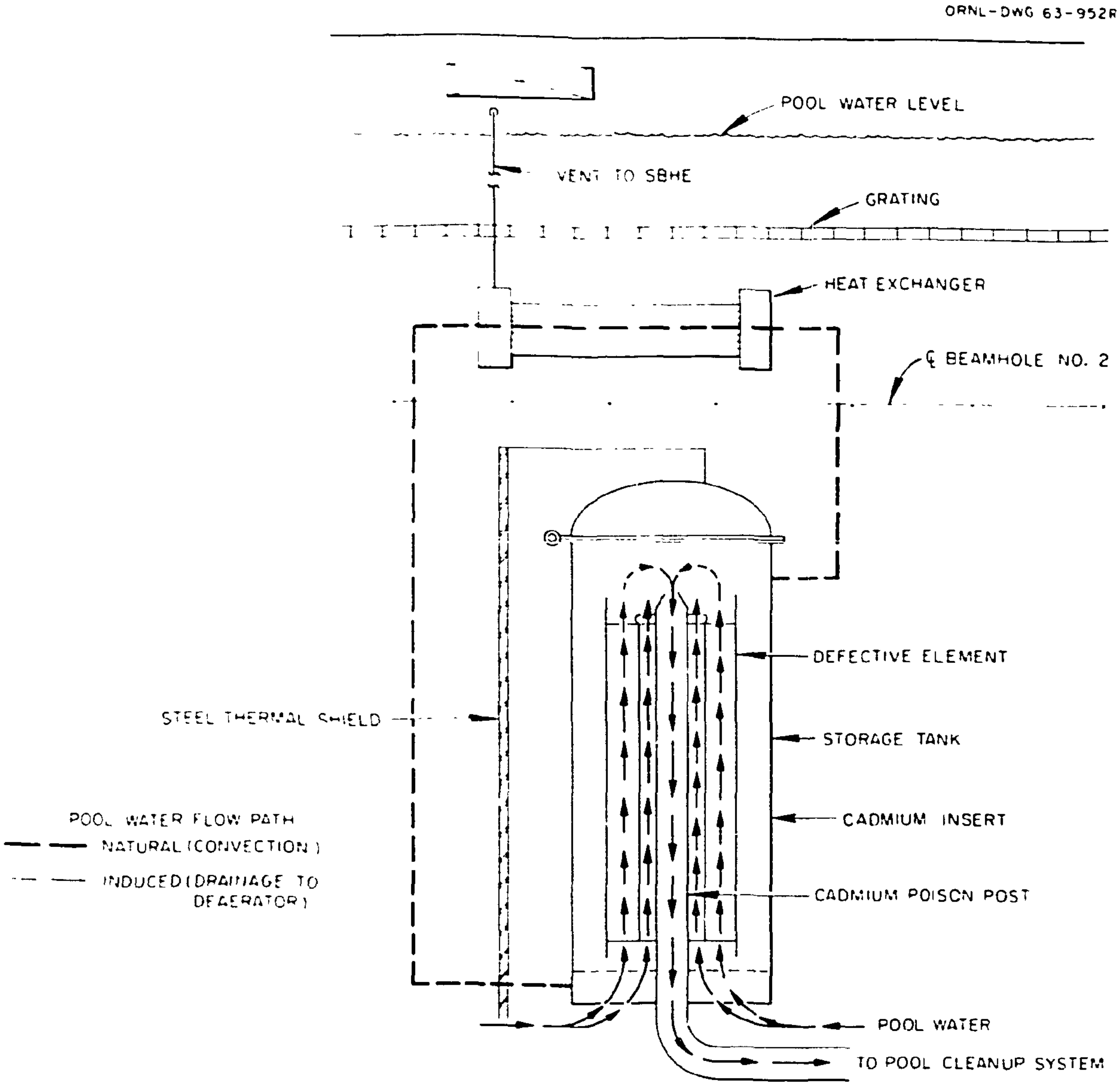

Fig. 6.27. Defective element storage tank.

Deaerator. The pool deaerator, shown in Fig. 6.28, is designed to remove essentially all of the dissolved gases from the pool water at a flow of 757 l/m (200 gpm). Together with its associated condensers and steam ejectors, it is located in a 30.5-cm-thick (1-ft) 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 on the ground floor of the water wing. Each pump has a capacity of

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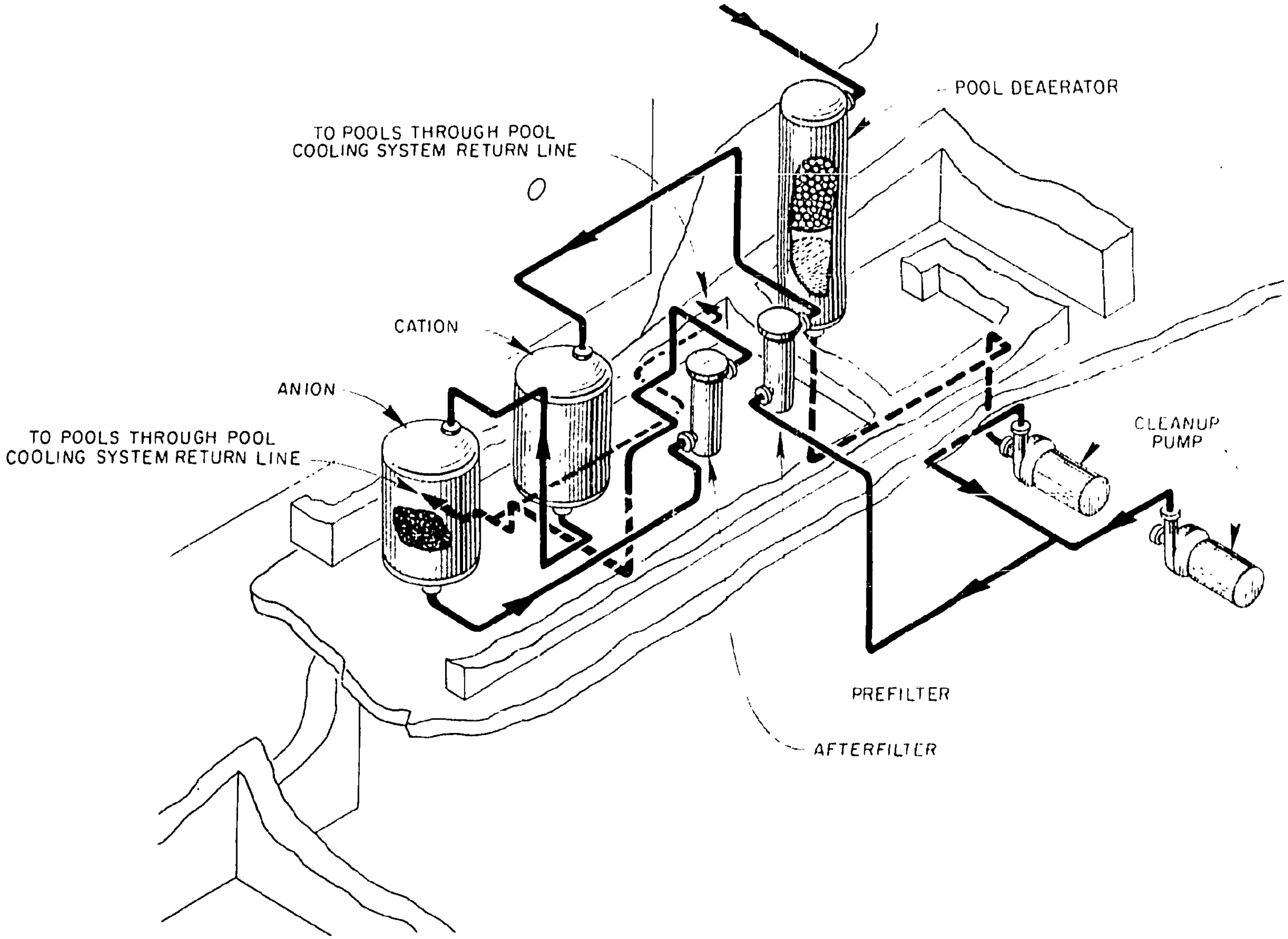

Fig. 6.28. Pool cleanup system details.

75 l/m (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 s. 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 prefilter has a rated flow capacity of 757 l/m (200 gpm) with a 17.2 kPa (2.5 psi) pressure drop. It is similar to the other prefilters 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 5.1-cm-thick (2-in.) 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 Fig. 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 4.6 m^3 (50 ft^3) of cation resin and is surrounded by 5.1 cm (2 in.) of supplementary lead shielding. The anion column contains 4.6 m^3 (50 ft^3) 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 afterfilter. 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 afterfilter. This filter has a rated flow capacity of 757 l/m (200 gpm) with a 17.2 kPa (2.5 psi) pressure drop when clean. The filtering media is 100-mesh stainles 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 afterfilter can be returned to any pool through lines common with those returning water from the pool cooling system.

6.4.3 Pool fill and drain systems

Each section of the clean pool has one 7.6-cm (3-in.) line entering below the surface of the water; the critical pool has a single 10.2-cm (4-in.) line entering below the surface. These lines terminate at the

254.5-m (approximately 835-ft) level, i.e., 2.1 m (approximately 7 ft) above the pool floor. The reactor pool contains two lines which enter below the surface. One is the normal 15.2-cm (6-in.) return from the pool coolant system which terminates at the 251.9-m (828-ft, 6-in.) level at a water depth of 5.03 m (16 ft, 6 in.), i.e., 2.44 m (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 10.2-cm (4-in.) feed line to the pool deaerator from the defective element storage tanks. This is located at the 249.2-m (817-ft, 6-in.) level, 91.4 cm (3 ft) below the core centerline.

A 208,175-l (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 35.6-cm-thick (14-in.) concrete shield is flush with the finished grade at this point. A second section of this tank provides the 75,700-l (20,000-gal) primary coolant storage mentioned in Section 6.2.3. 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; or
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. 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 temporary 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 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 flow-demand clamp 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 presurizer pump and emergency windings for the auxiliary secondary coolant pump, both supplied by a diesel, have been provided.
4. As described in Section 6.2.1, each of the primary coolant pumps is equipped with a 3-hp dc pony motor supplied from a battery system. At least two of 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			
(l/m)	6056	7949	9084
(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 9084 l/m (2400 gpm) after 1 min. Simultaneously, the servo control system reduces the reactor power in an orderly fashion to approximately 10 MW, the pressure control valves throttle, the pressurizer pumps coast down, and the secondary coolant pumps coast down.

2. Approximately 30 s 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 Fig. 6.29. The heat generation drops from 100 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 1 h. The batteries, even without recharging, can supply power for a minimum of 2 h. At the end of 1 h, 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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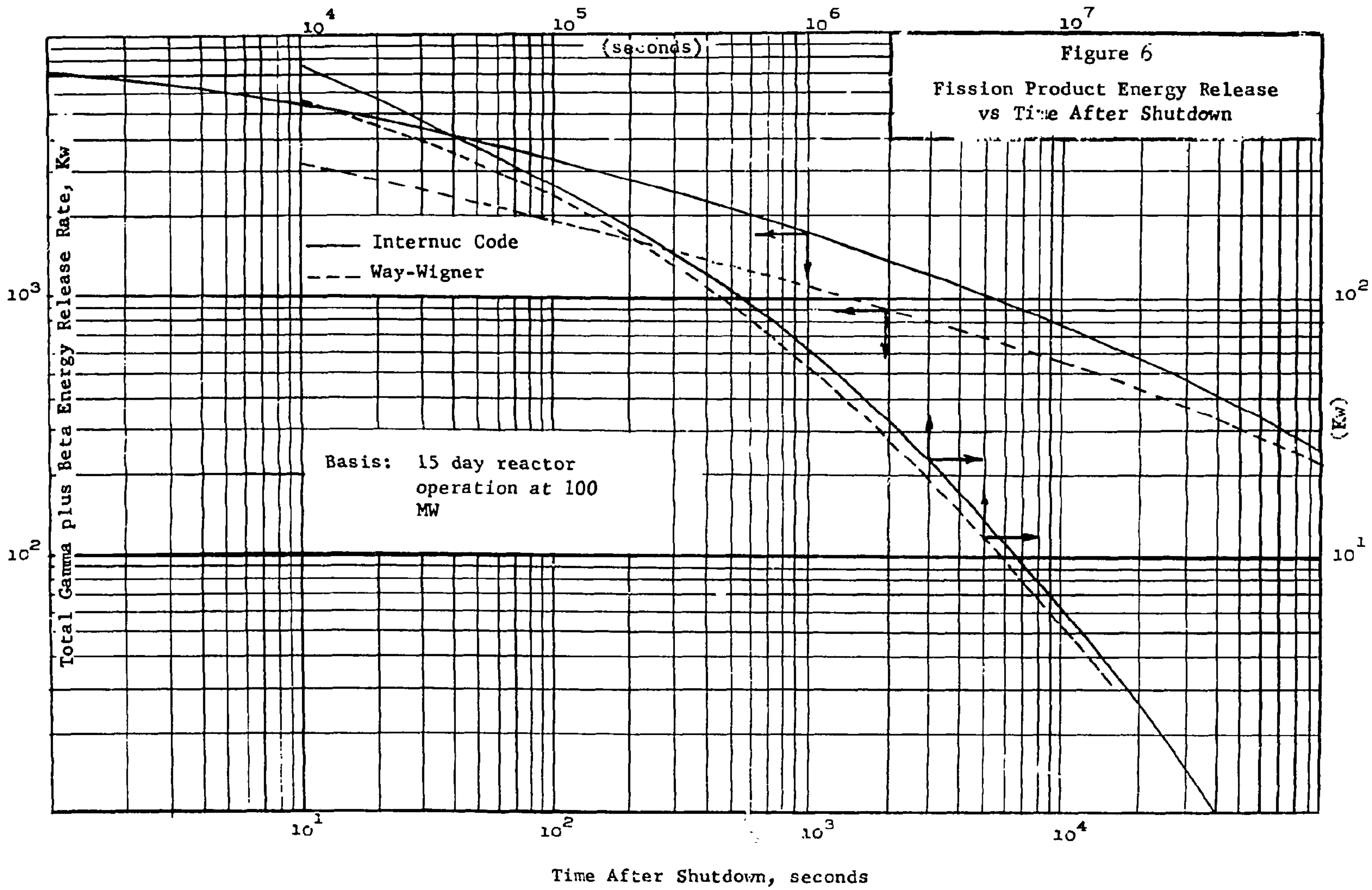

Fig. 6.29. Fission product energy release vs time after shutdown.

6.6 Hot Water Injection System

6.6.1 References

Drawings:

I-43930	Flow Diagram
P-43953	Piping Layout
P-10047 EF 013	Flow Diagram

6.6.2 Introduction

The hot water injection system provides a means of checking the operability of the primary coolant system resistance wire temperature sensors and their function as part of the reactor safety system. Hot water is sprayed onto the inlet temperature sensors to test the response of the high heat power trip.

6.6.3 Description of the system

Water from the primary pressurizer pumps is heated by condensing 125 psig steam in a tube-and-shell heat exchanger. This water is taken from the primary system makeup line just upstream of HCV-248. The heated water is forced through a nozzle at a rate of approximately 15 l/m (4 gpm) and sprayed against the sensitive portion of the resistance wire temperature sensor. The pressure differential which sprays the water into the primary system is created by the pressurizer pump head, and the increased pressure drop across HCV-248 during operation of the system.

When a test button on the console in the control room is pushed, (see Sections 3.3.3-11.2) an air-operated valve in the individual spray nozzle line of the channel being tested is opened (see Fig. 6.30). At the same time HCV-248 is throttled, creating the differential pressure, and temperature control valve TCV-1124A is opened to allow steam into the heat exchanger to heat the water.

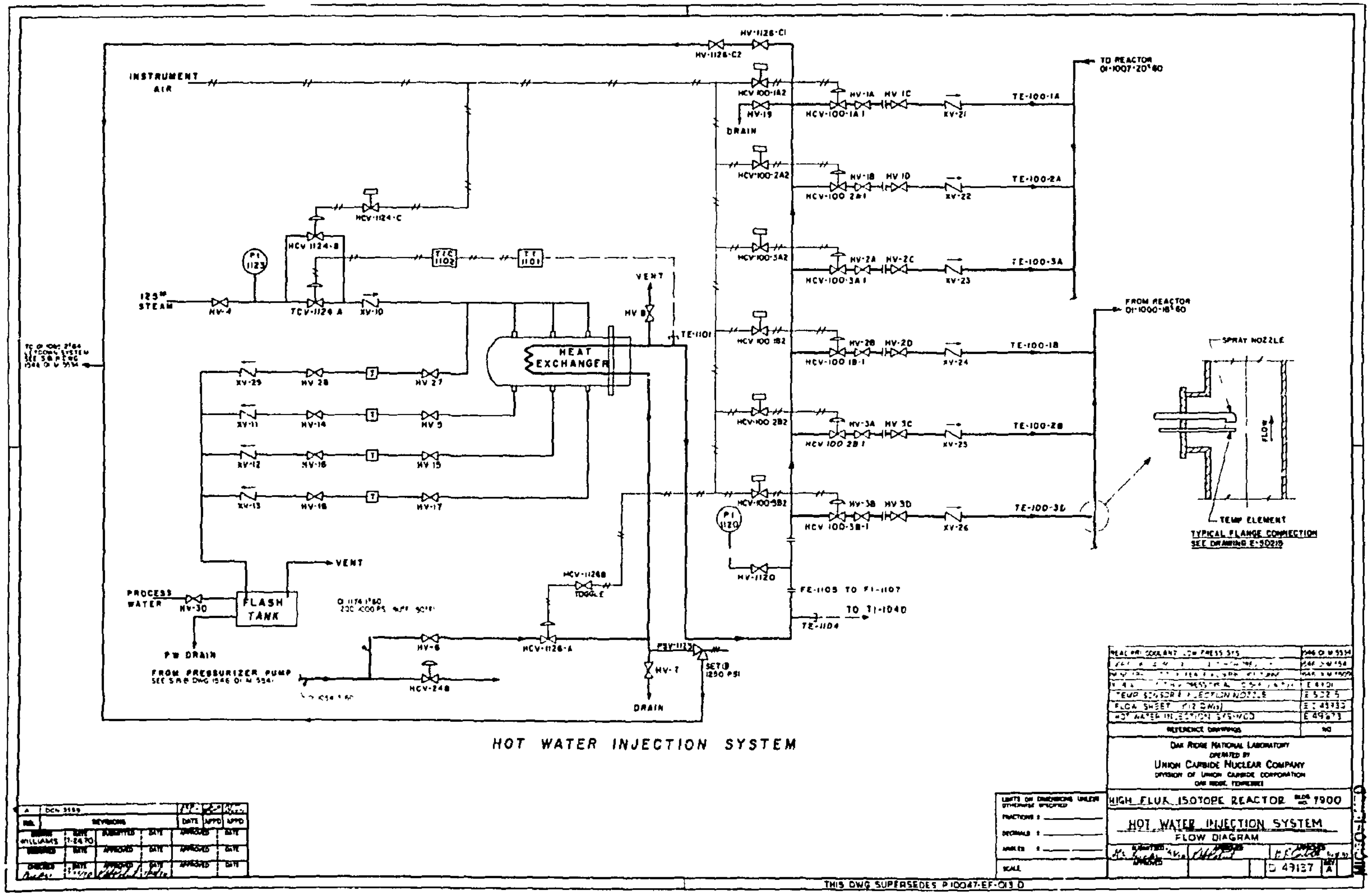

Fig. 6.30. Hot water injection system.

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 acitvity, 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 pressure gradients, air flows from the clean areas of the building into the areas served by the SBHE system. The air is then

*The HOG systems are discussed in Section 9.2.

transported through ducts to appropriate filtering equipment, and is finally discharged to theatmosphere at the top of a 76.2-m (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 approximately -24.9 Pa (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 [-24.9 Pa (-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 approximately -74.6 Pa (-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 approximately -100 Pa (-0.4 in.) H_2O.

These various zones are shown graphically in Figs. 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 on the various air-conditioning units, is controlled by pressure-regulated

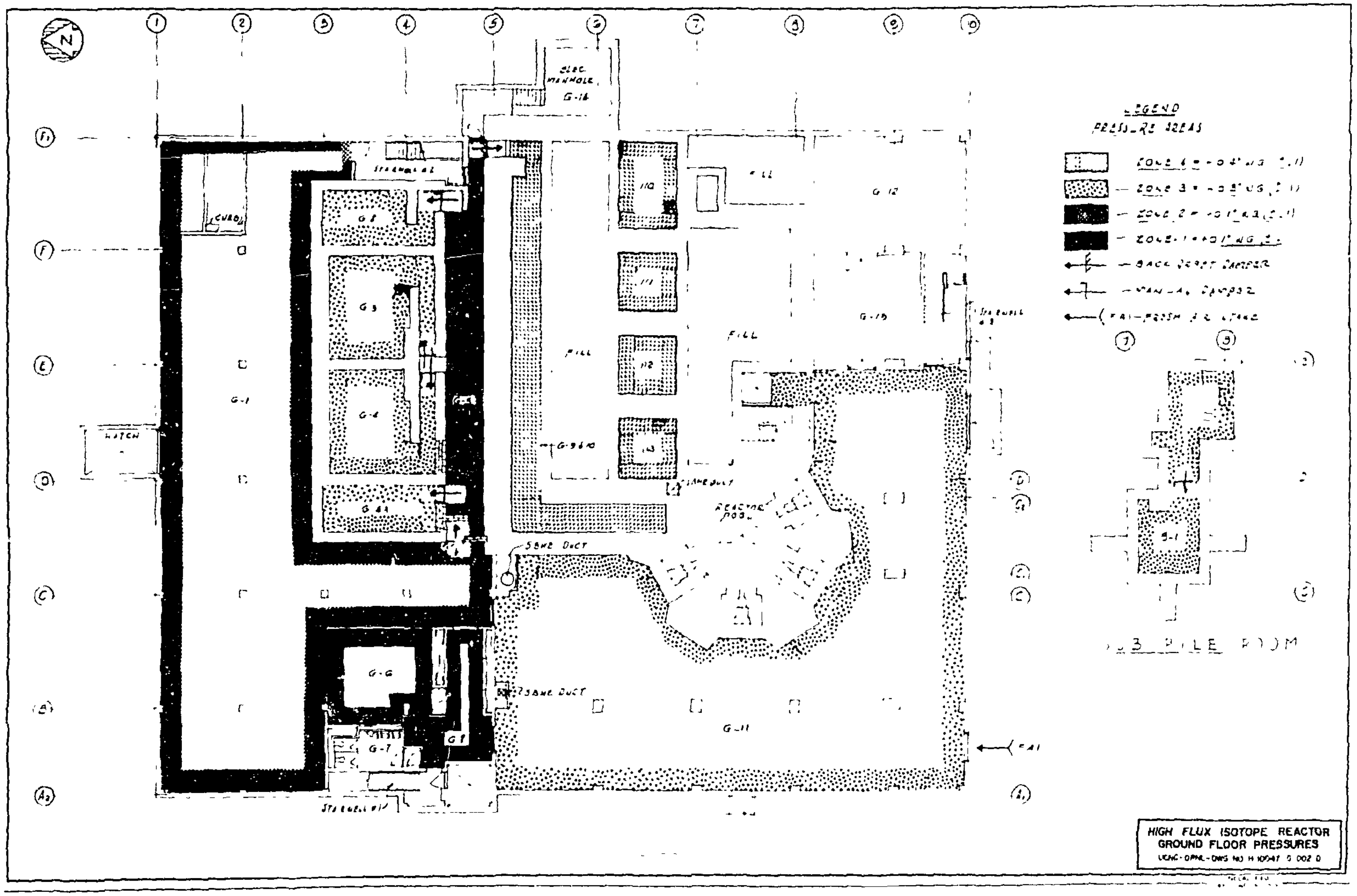

Fig. 7.1. Ground-floor pressures.

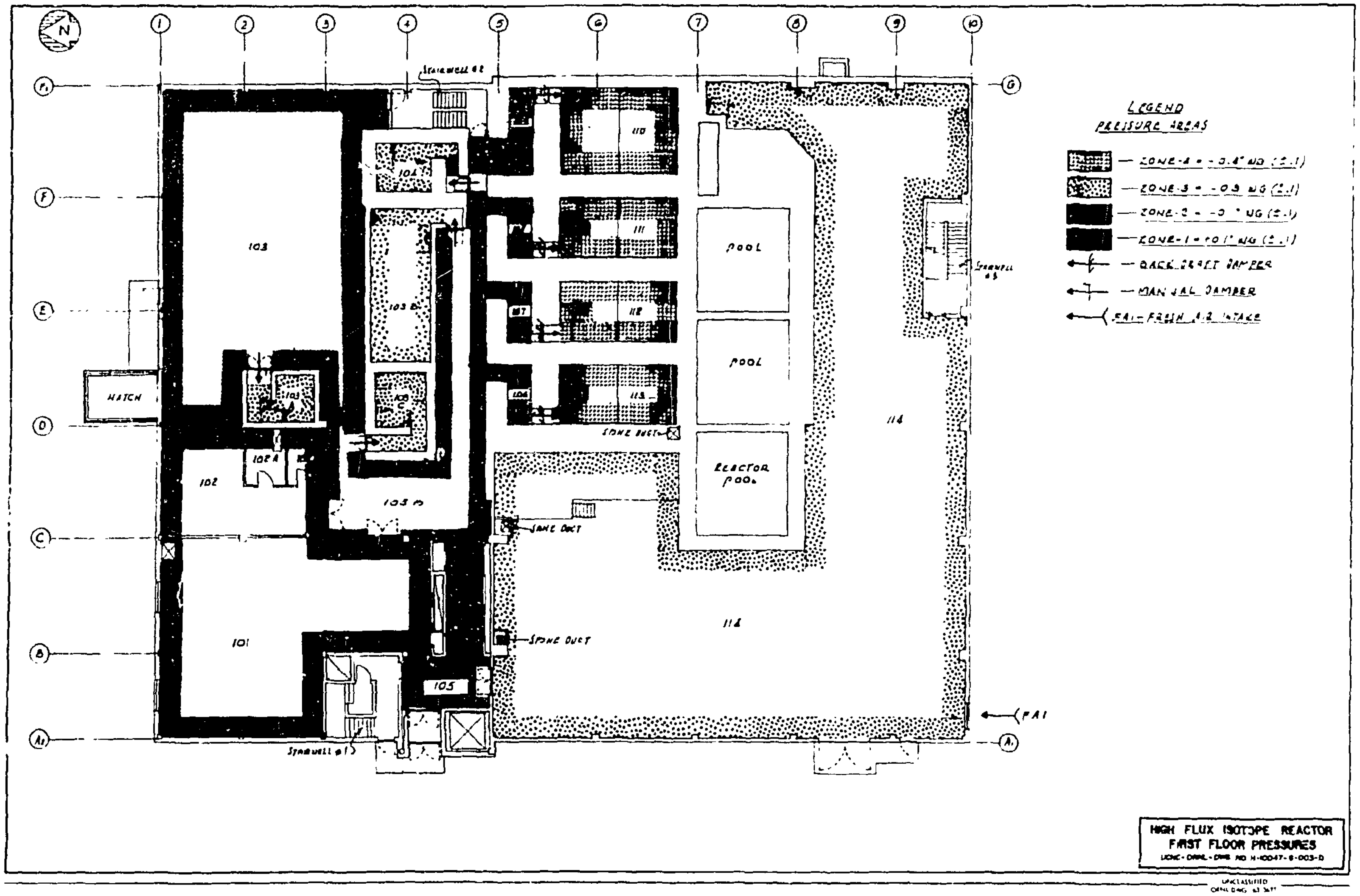

Fig. 7.2. First-floor pressures.

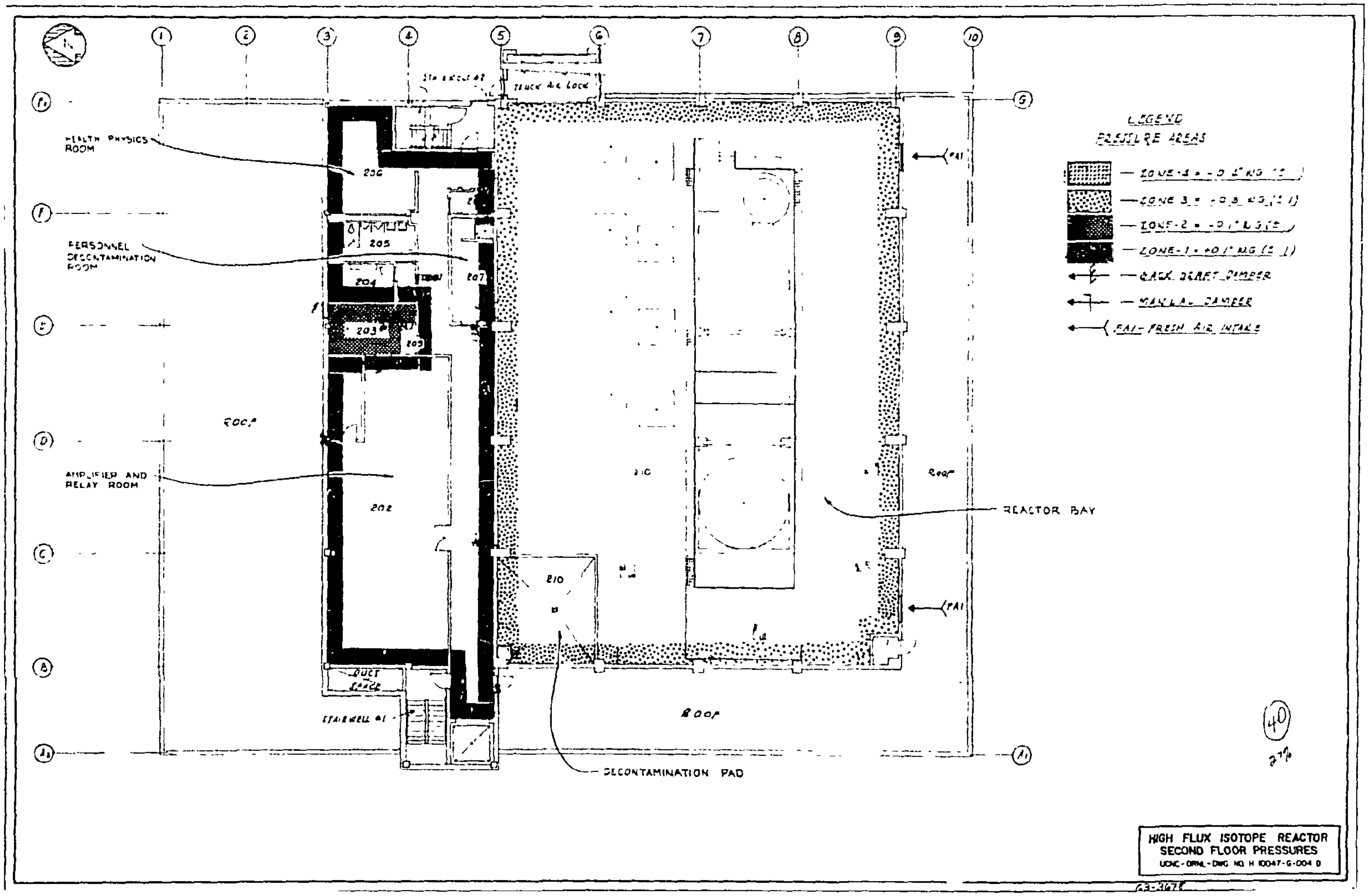

Fig. 7.3. Second-floor pressures.

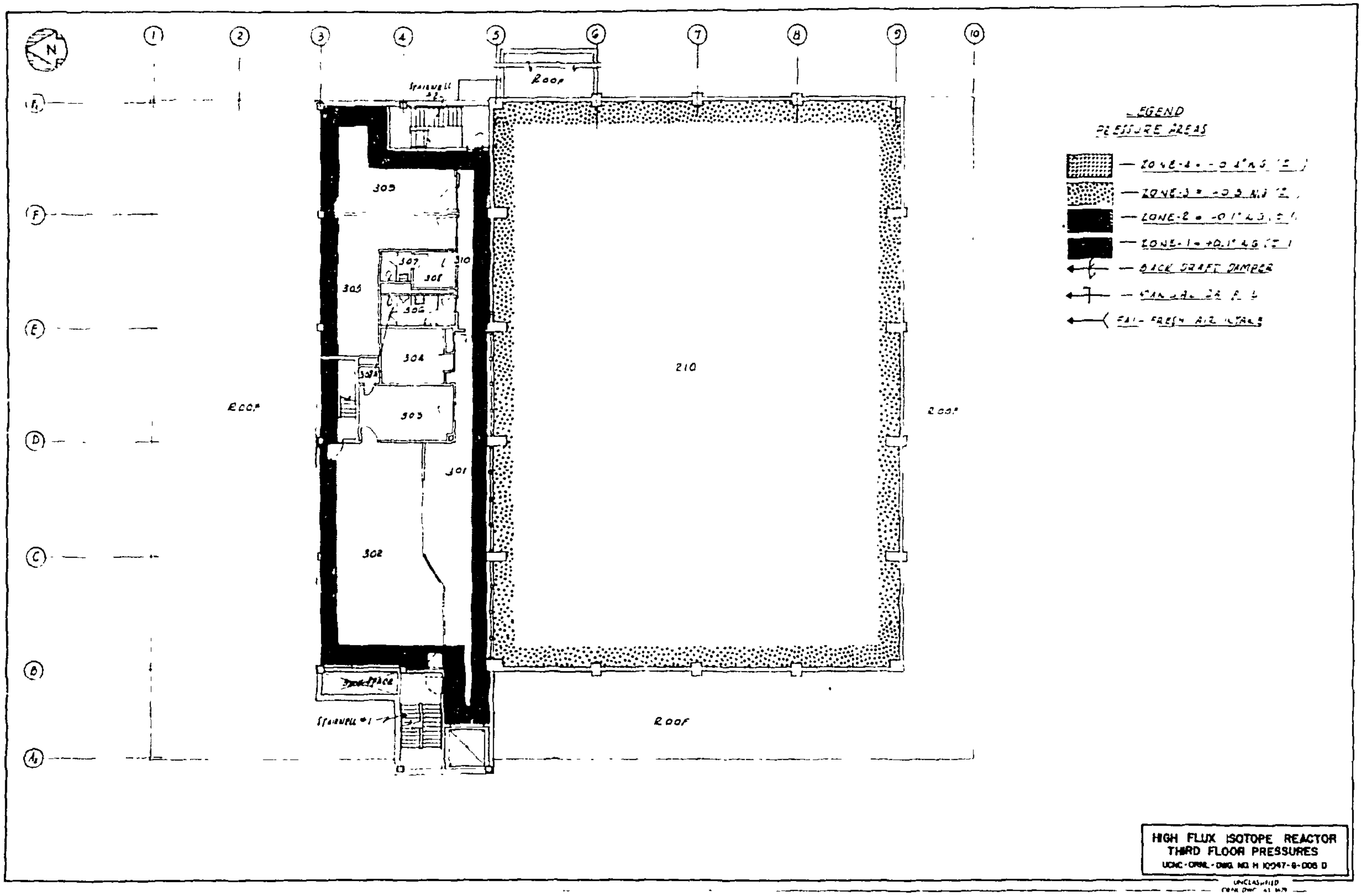

Fig. 7.4. Third-floor pressures.

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 all three 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 approximately 336 m^3/min (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 262.5 m^3/min (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. Presure-differential gauges are mounted on the chambers to indicate the condition of the filters. These units are sized to handle 1,087.5 m^3/min (38,400 cfm) of which approximately 747.6 m^3/min (26,400 cfm) is recirculated. The remaining 340 m^3/min (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 917.5 m^3/min (32,400 cfm) with 747.6 m^3/min (26,400 cfm) being recirculated. The beam room units handle 544 m^3/min (19,200 cfm) with a recirculation of 374 m^3/min (13,200 cfm). The SBHE system exhausts approximately 340 m^3/min (12,000 cfm) from these areas.

Chilled water at 4.4°C (40°F) is supplied to the various air-conditioning units by a large chilled-water unit which has a capacity of 1.2 x 10^6W (4 x 10^6 Btu/h). The heat collected is dumped to the secondary coolant system through the chiller located in room 101. Low pressure 103-kPa (15-psi) steam for the air-conditioning units is obtained by pressure reduction from the 862-kPa (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 approximately 524 m^3/min (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 141.6 m^3/min (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 showing the air flows described is given in Fig. 7.5.

7.5 Special Building Hot Exhaust System (SBHE)

7.5.1 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 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 76.2-m (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, the underground water storage tanks, and the shielded equipment rooms which house the cleanup equipment in the water wing. The arrangement of the SBHE ducts is shown in Fig. 7.6.

The inlet registers to the ducts for the reactor bay system are in the pool walls immediately above the pool scuppers. Air is drawn into these registers from the reactor bay. The duct is sized and damper-controlled to remove a minimum of 141.6 m^3/min (5,000 cfm) of air from under the pool cover. This corresponds to a minimum velocity of 0.51-m/s

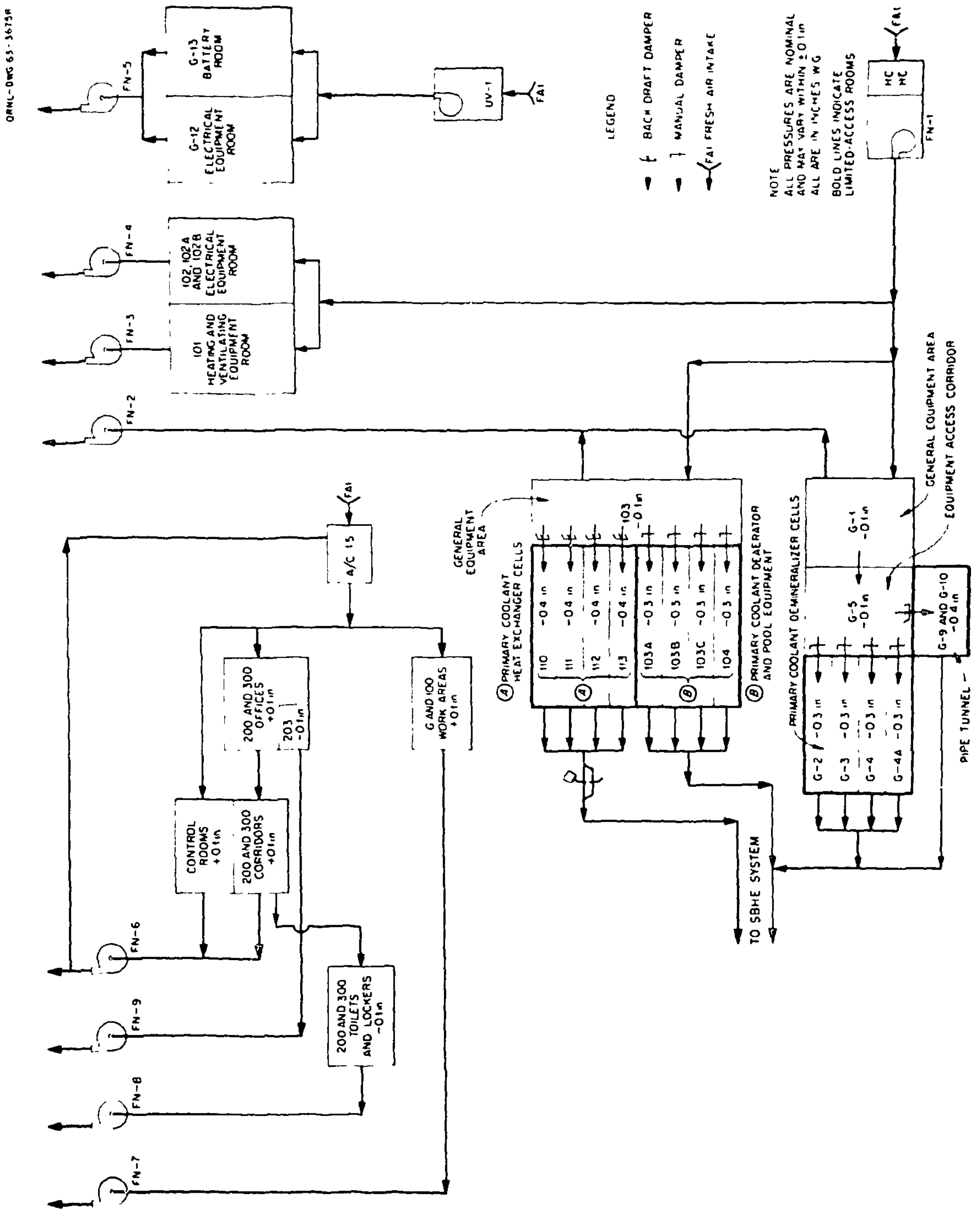

Fig. 7.5. Airflow diagram.

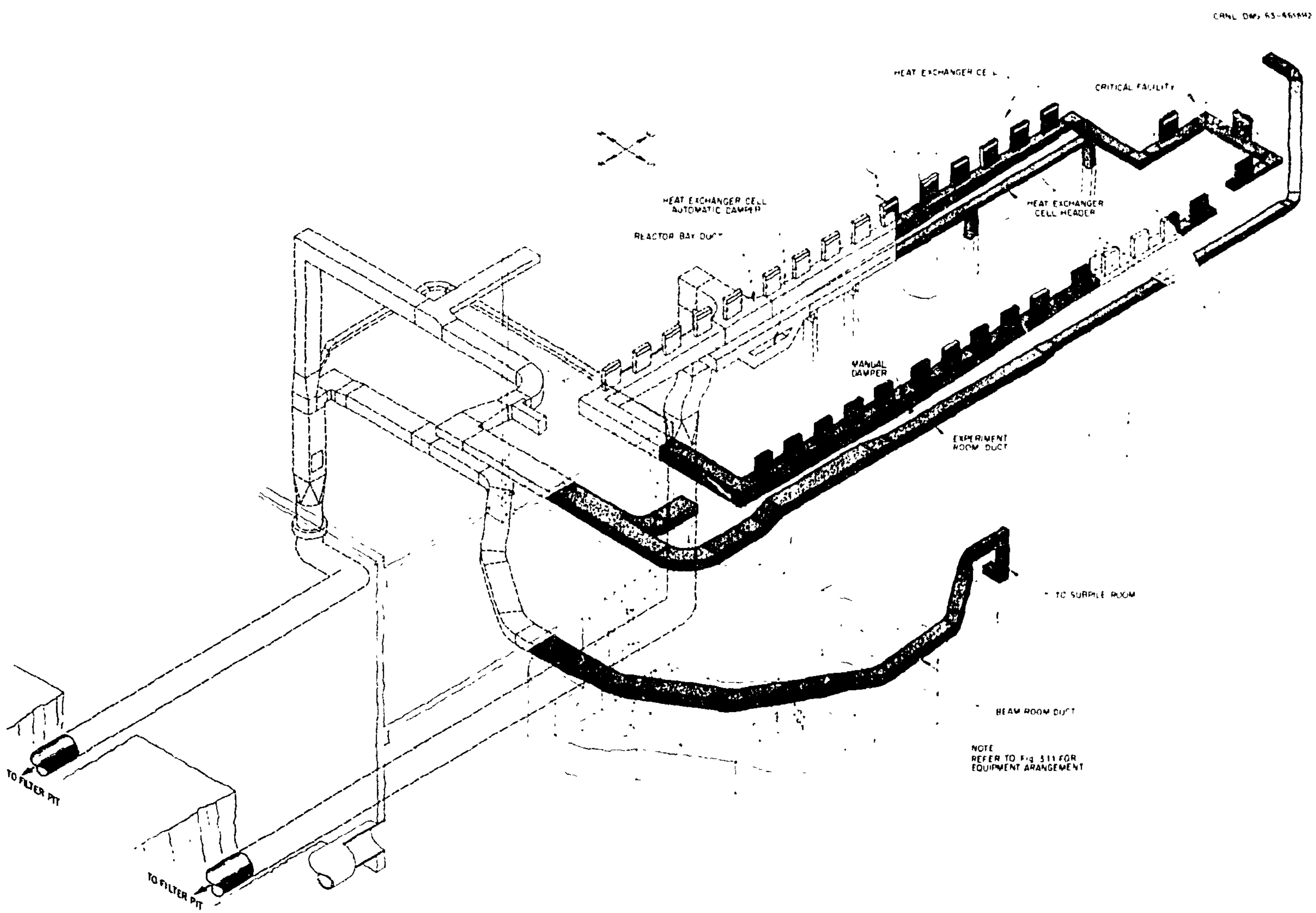

Fig. 7.6. Isometric of SBHE ducts in reactor building.

(100-ft/min) flow from the reactor bay through the 4.6 m^2 (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 approximately 170 m^3/min (6,000 cfm) of reactor bay air over the surface of the clean pools and the critical pool. The defective fuel element 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 28.3 m^3/min (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 65 m^3/min (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, as well as the underground storage tanks. Approximately 170 m^3/min (6,000 cfm) is drawn from the beam room including 283 m^3/min (1,000 cfm) originating in the subpile room. An additional 170 m^3/min (6,000 cfm) is exhausted from the experiment room, and 65 m^3/min (2,300 cfm) originates from the equipment cells.

All ducts embedded in concrete are type 304 stainless steel. All embedded ductwork was pressure tested to assure airtightness before it was encased in concrete. Exposed ductwork made of galvanized sheet iron is painted with a protective coating. All joints are sealed airtight.

Ductwork buried in earth outside of the reactor building structure is constructed of transite pipe, joined with gas-tight sealing compounds, and coated with 2-ply tar and felt. A chevron-type baffle is located at the inlet to each filter compartment to remove entrained water from the air. All exposed ducting is installed to fit tightly against the wall surfaces with the minimum amount of horizontal surface for ease of decontamination.

7.5.2 Filters and exhaust equipment

Air from the SBHE is routed from the various headers to an underground filter pit which contains both absolute and charcoal filters. After passing through the filters, it is monitored and forced up a 76.2-m (250-ft) stack so that any residual activity is dispersed by diffusion.

The filter pit is an outdoor, below grade, waterproofed, concrete structure designed to withstand pressure differences 3.45 kPa (0.5 psi) above and 32.7 kPa (4.75 psi) below atmospheric.

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 Fig. 7.7. At grade level, the SBHE section is shielded with 61 cm (2 ft) of concrete with stepped shield plugs over each filter bank (Fig. 7.8).

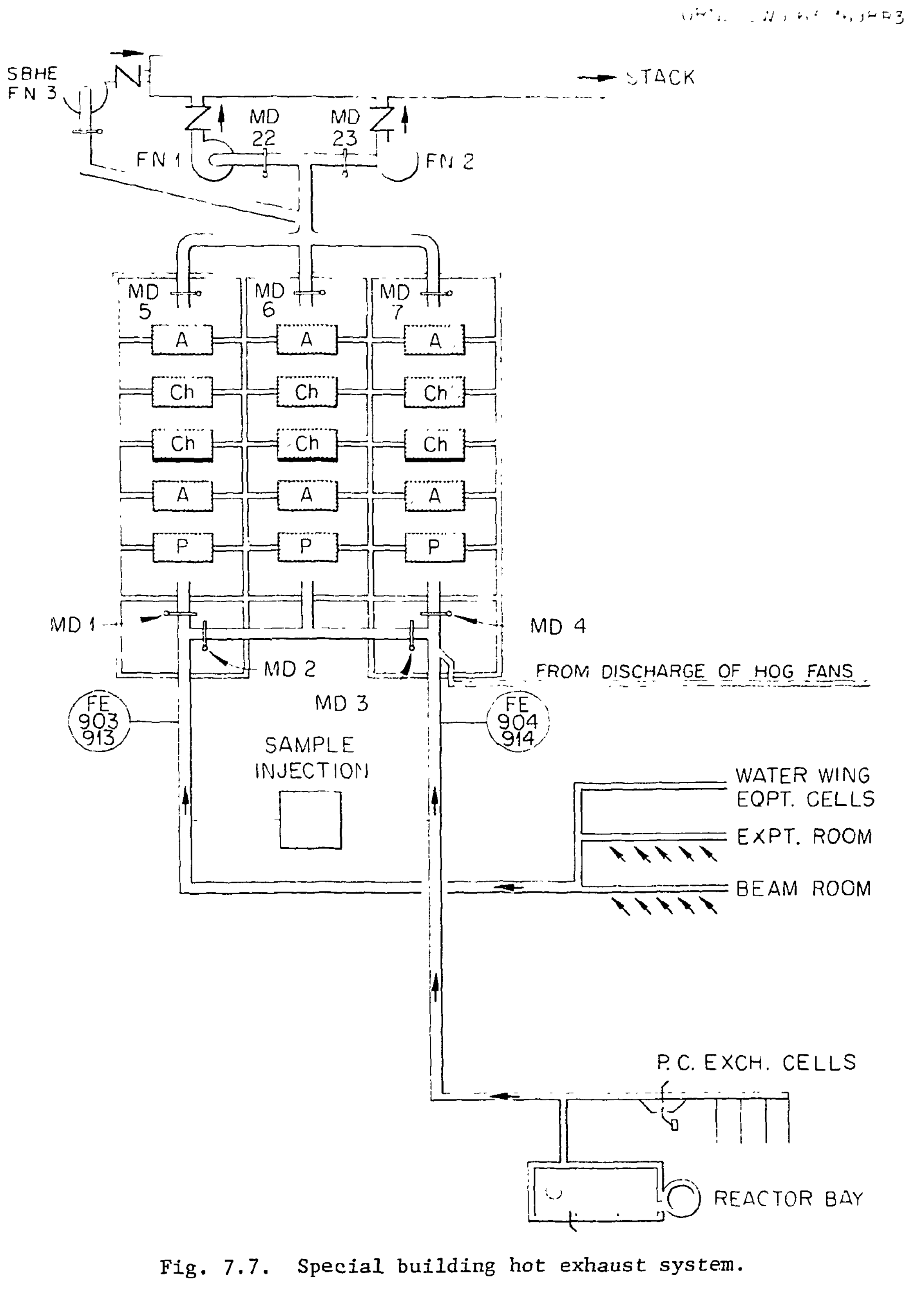

Fig. 7.7. Special building hot exhaust system.

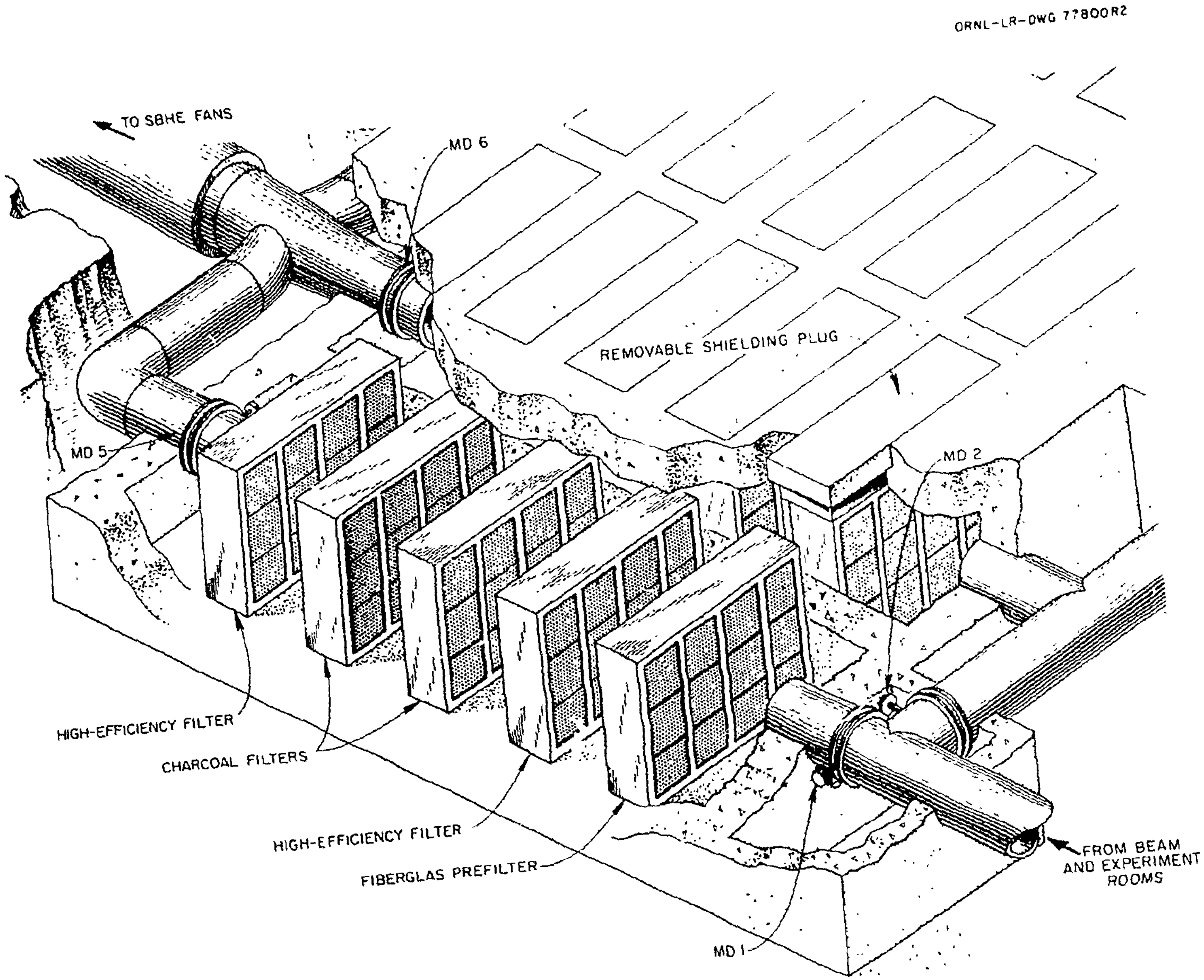

Fig. 7.8. SBHE filter pits.

Each filter compartment contains an assembly of: (1) a 3 x 4 bank of 12 prefilters; (2) a 3 x 4 bank of 12 fiberglass-aluminum 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 fiberglass-aluminum 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 99.00% 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 except in the case of the charcoal filters which are constructed of stainless steel. Drainage and condensate from the filter pit are collected in a sump which is drained by gravity to the process-waste disposal system.

A 950-m^3 (33,550-cfm) exhaust fan driven by a 100-hp squirrel cage induction motor and two 810-m^3/min (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 corrosion-resisting paint. Normally only one fan is operated with the other two in standby condition. The single duct from the SBHE section of the filter pit divides at the fans. Each of the two standby fans is fed from a different generator in the normal-emergency power system to provide reliability during a normal power outage. The automatic changeover 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.

7.5.3 SBHE instrumentation and control

Because the exhaust systems must 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 two standby SBHE 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, both fan control switches are in "standby." Indicating lights on the panel board in the control room, operated by motor contacts and the standby switch, provide information concerning 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 a fan is in standby and is not running, both the white light and the blue light are on.

The third SBHE fan is provided with an "On-Off" selector switch, which is located at the local panel board in the fan shed. This fan is normally operated continuously except during periods of maintenance. During these maintenance periods, either fan FN-1 or -2 is selected to operate while the other is in standby.

Indicating lights on the panel board in the control room provide information concerning the condition of the fan.

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 Fig. 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 approximately 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 approximately 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-120) which starts the standby fan and simultaneously sounds an alarm in the control room. A further decrease of flow to approximately 75% of normal will cause one or more of four other 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 -99.5 Pa (-0.4 in. H_2O) to provide protection against 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,

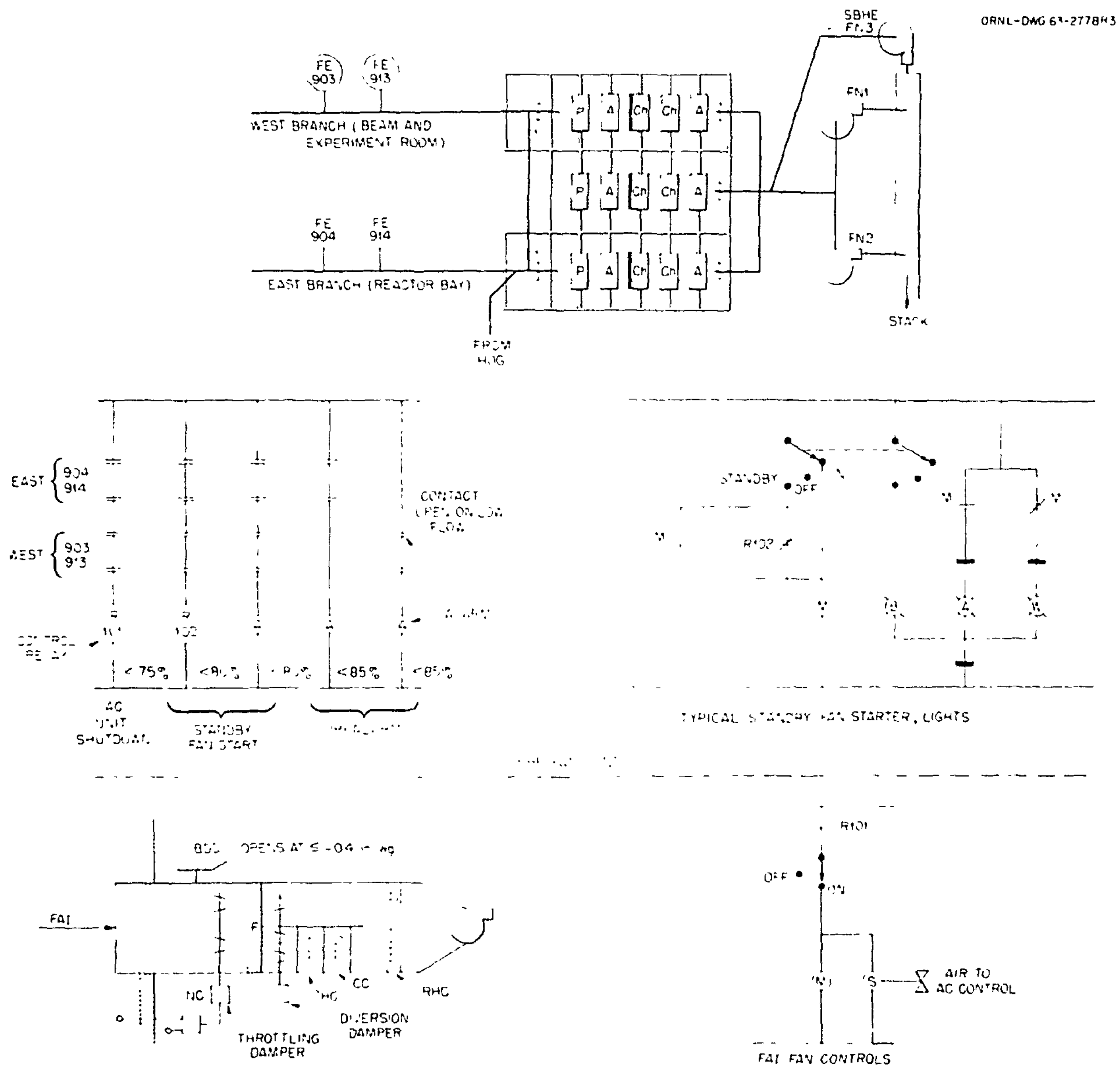

Fig. 7.9. SBHE fan and FAI controls.

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." Both motor control centers "G" and "H" are energized immediately upon diesel-generator startup and transfer of the "Normal-Emergency" switches to the "Emergency" position. The circuits are arranged so that, assuming both diesels start simultaneously following a power outage, both standby fans FN-1 and FN-2 start at the same time. (The third SBHE fan is operated from the normal power system and has no standby-start feature.)

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 7.1. SBHE pressure switch tabulation

Switch No.	Duct location	Normal flow m^3/min (scfm)	Setpoint flow m^3/min (scfm)	Type of action
FS-903B-1 and FS-913B-1	West	204 (8,500)	205 (7,225)	Alarm
FS-904B-1 and FS-914B-1	East	240 (8,500)	205 (7,225)	Alarm
FS-904A-1 and FS-914A-1	Eact	240 (8,500)	193 (6,800)	Starts standby fan and alarms
FS-903A-1 and FS-913A-1	West	240 (8,500)	193 (6,800)	Starts standby fan and alarms
FS-904A-2 and FS-914A-2	East	240 (8,500)	181 (6,375)	Shuts down AC units 2, 5, 10, and 14
FS-903A-2 and FS-913A-2	West	240 (8,500)	181 (6,375)	Shuts down AC units 2, 5, 10, and 14

Table 7.2. Differential pressure gauge tabulation

Gauge No.	Area monitored	Normal Pa (in. H_2O)	Setpoint Pa (in. H_2O)	Type of action
PdI-900	Reactor bay	74.6 (0.30)	24.9 (0.10)	Alarm
PdI-901	Beam room	74.6 (0.30)	None	None
PdI-902	Experiment bay	74.6 (0.30)	None	None

The nominal differential is -74.6 Pa (-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 -24.9 Pa (-0.10 in. H_2O).

8. EMERGENCY SYSTEMS

8.1 Diesel Electric Generation and Distribution Systems

8.1.1 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

8.1.2 Introduction

Emergency ac electric power is supplied to the HFIR by two 350-kW, 480-V, 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 circuit breakers in the normal-emergency switchgear; and (c) apply a trip impulse to the diesel test-loading circuit breakers.

8.1.3 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 two 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-V dc motors and has a thermostatically controlled jacket water heater which maintains the cooling water at 32°C (90°F).

Starting battery. Starting power is obtained from a 32-V 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-h discharge rate of 9.7×10^5C (270 A-h) and is sized to provide the proper breakaway and rolling currents for the diesel engine. The battery will supply 2100 A for 5 s or 1050 A for 90 s.

Battery charger. The battery charger for the starting battery is rated 14 A continuous at 32-V dc. The charger floats the battery at 33.6 V continuously and has an adjustable 24-h timer which permits the battery to be given a freshening charge at 1.50 V per cell (36-V total). After the freshening time period has elapsed, the charger automatically returns to the floating voltage of 33.6 V. 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, and
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 98°C (209°F);
2. low lubricating oil presure (below normal but not serious enough to require immediate engine shutdown) [<124 kPa (18 psig)];
3. low fuel oil pressure [<82.7 kPa (12 psig)];
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 ressetting of the rack solenoid to restart the engine, <55 kPa (8 psig).];
6. overcranking (When this alarm occurs, the engine has completed the three 15-s cranking cycles and has not started.); and
7. rack solenoid in the "Stop" position.

The following generator instrumentaiton 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 voltage,
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.]; and

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-V 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 cricuit 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; and
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, and

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; and

3. low fuel-oil level in the day tanks or underground storage tank.

8.1.4 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 1.7 MPa (250 psig) to 0.62-0.69 MPa (90-100 psig) 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-s duration each. Pressure switch PS-639 operates to start the air compressor when the pressure in the air receiver drops to 1.5 MPa (215 psig) and to cut it off when the pressure reaches 1.5 MPa (250 psig). In the event the pressure drops to 0.69 MPa (100 psig), 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 s without the engine starting.

8.1.5 Fuel-oil storage and distribution

Fuel-oil storage and distribution equipment consists of:

1. FOT-1, a 15,140-1 (4,000-gal) capacity storage tank, located underground just south of the electrical building;
2. FOT-2 and -3, two 227-1 (60-gal) capacity fuel-oil day tanks, one located in each diesel-generator room; and
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 5.1-cm (2-in.) level-gauge opening, a 3.8-cm (1 1/2-in.) vent line with flame arrestor, a 3.8-cm (1 1/2-in.) fill line, and a level switch, LS-647, for low-level annunciation.

Three 3.8-cm (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 227-1 (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, LS-649 on FOT-3, and LS-647 on the storage tank actuate a common annunciator on panel "HI" in the main control room upon low fuel-oil level. 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 approximately 90% full and are stopped when the level reaches approximately 95% full. The pumps run continuously when the seletor 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

8.2.1 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

8.2.2 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 A full load current. One pony-motor pump delivers 6056 l/min (1600 gpm), two deliver 7949 l/min (2100 gpm), and three deliver 9084 l/min (2400 gpm).

Each pony motor is supplied from a 125-V 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, results 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-V 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-V motor starter.

Batteries. Each battery is rated at 125 V and contains 92 nickel-cadmium alkaline pocket plate cells in sealed plastic containers. Each battery is capable of supplying approximately 50 A 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-V, 3-phase, 6-cycle input with 129-V, 50-A dc output. Each has an automatic voltage-control circuit that maintains a floating voltage of 129 V 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 s 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. Provision has been made to supply power from the No. 2 diesel-generator in the event No. 1 diesel fails to start.

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 V per cell or 129 V total),
7. a variable transformer control for adjusting the freshening voltage (1.50 V per cell or 138 V total), and
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

8.3.1 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

8.3.2 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 the normal-power system through 13.8-kV, 120/240-V 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.

8.3.3 Direct current instrument power (32/64 V)

Each of the three 32/64-V 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 V, zero, and +32 V. The battery is sized to provide 40 A 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 A continuously at 32 V dc. The charger floats the 24-cell battery section at 1.40 V per cell (33.6 V total). It has an adjustable 24-h timer which permits the battery to be given a freshening voltage of 1.50 V 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- and 64-V circuit breakers. A fused safety switch is tapped off ahead of each panel to provide power to the three reactor servo systems.

120 V non-interruptive power. The heat-power calculators require a 120-V ac power supply which is not subject to interruption. To provide this service, three 32-V dc input 118-V ac output inverters are provided--one for each safety system channel. The inverters are supplied 32-V dc 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 VA continuously at 118 V, 60 cycles per second. A "Power-On" indicating light is provided in the cabinet for each inverter.

125-V dc power. The switchgear battery, located in the electrical building (see Section 8.1 in this procedure), supplies 125-V dc 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

8.4.1 References

Drawing:

1546-01-E-2118 Elementary Control Diagrams, Primary Feed Pump

8.4.2 Introduction

The auxiliary pressurizer pump, PU-11, is a high speed, centrifugal-type pump and is operated from 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. It can also be used during reactor operation when both main pressurizer pumps are inoperative. The pump delivers 114 l/min (30 gpm) at 4.8 MPa (700 psig) and will keep the system pressurized if leakage does not exceed this amount.

8.4.3 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 s after the diesel assumes the load. The pump contiues 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 panel board 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

8.5.1 References

Drawings:

1546-01-E-2118	Elementary Control Diagrams, Process Water Equipment
1546-01-I-4007	Instrument Application Diagram, Secondary Coolant Loop

Singmaster & Breyer Specificatiosn:

50	Cooling Tower Vertical Centrifugal Pumps

8.5.2 Introduction

The auxiliary secondary coolant pump is driven by a two-winding, two-speed, 400 V, 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.

8.5.3 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 s 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 30.5 cm (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

8.6.1 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

8.6.2 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; and
4. fire-alarm signaling systems (including electricl 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.

8.6.3 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 276 kPa (40 psig) air from the instrument air system. Upon excessive temperature [74°C (165°F) in the cooling tower equipment building and 100°C (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. Provision has been made to allow the cooling-towc fan shut-down feature to be bypassed in the event of a false fire alarm.

Electrical building fire-protection equipment includes heat detectors and manual alarm boxes to initiate a fire alarm and portable fire extinguishers.

8.6.4 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 74°C (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 10.3 to 13.8 kPa (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.

8.6.5 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 71°C (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
4	Spare		

*Zones 1 and 2 cause pipes to be filled with water.

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 super-vision (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

8.6.6 Power supply

The HFIR fire protection system is powered by dc 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 V) 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

8.7.1 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 911 (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 911 the dispatcher immediately notifies the Laboratory Shift Supervisor and dispatches the emergency service units needed (fire, guard, etc.).

8.7.2 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 time. 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 911) 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.

8.7.3 Guard Department

The Guard Department headquarters is located in Building 2500 in the main X-10 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 680-kg (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 680-kg (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 911. The ambulance driver will stop at the medical dispensary, and a nurse and/or doctor will accompany the driver to the emergency.

8.7.4 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. The main dispensary is open between 7:00 a.m. and 6:00 p.m. Monday through Friday, but only one nurse is on duty before 8:00 a.m. and after 4:30 p.m.

Only limited services are available on holidays, weekends and off-shifts, but a doctor is on call at all times.

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.

8.7.5 Maintenance

The operation of the HFIR complex requires considerable maintenance. To obtain the services of the Plant and Equipment Division, a work order bearing the department number, the job-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 4-6606) should be notified of the situation; and he will make the necessary arrangements for obtaining the appropriate personnel.

8.8 Radiation and Contamination Alarm and Evacuation Systems

8.8.1 Introduction

The facility radiation and contamination systems are used to provide Health Physics monitoring information, local alarms when abnormal conditions occur, and remote alarms on a central monitoring panel located in the main control room. Nine monitrons continuously monitor for gamma radioactivity. Five of these monitrons are used in the facility radiation alarm system (see Table 8.1). Nine constant air monitors continuously sample the air in the building for beta-gamma particulate activity. Six of these constant air monitors are used in the facility contamination alarm system.

Table 8.1 Radiation and air contamination monitors installed in Building 7900

Location	Monitor number
Facility radiation monitors	
Subpile room	1
Beam room*	2
Experiment room*	3
Room 103*	4
Pool top, northwest	5
Reactor bay, southeast*	6
Pool top, southeast	7
Reactor bay, northwest*	8
Third level	9
Facility contamination alarm monitors	
Subpile room	11
Beam room†	12
Room G-5†	13
Room G-1	14
Experiment room†	15
Room 103†	16
Reactor bay, southeast†	17
Reactor bay, northwest†	18
Third level	19

*The monitrons in these locations are connected to the facility radiation alarm system.

†All constant air monitors in these locations are connected to the facility contamination alarm system.

Operating personnel are first given warning when a "caution level" of 7.5 mr/h or 1,000 cpm is detected by a monitron or constant air monitor, respectively, and again when a "high level" of 23 mr/h or 4,000 cpm is detected.

The building evacuation system is actuated automatically when two or more monitrons or two or more air monitors in the alarm systems detect "high-level" conditions.

8.8.2 Description of systems

Monitrons. Each of the nine monitrons, which are located strategically throughout the building, is an independent unit and operates as follows:

1. An alarm circuit operates a bell and a red light on the instrument when the radiation level exceeds 7.5 mr/h. At the same time a yellow light on an indicator module on the main control panel is made to burn brightly. The alarm is automatically reset when the radiation level decreases below 7.5 mr/h.
2. If a radiation level of 23 mr/h is detected a signal is sent to the control room to cause the red "High-Level" light to burn brightly on the indicator module. The local bell continues to ring since it was actuated at 7.5 mr/h. No provision is made for a local "high-level" alarm.

Constant air monitors. Each of the nine constant air monitors is also an independent unit and operates as follows:

1. When the "caution" setpoint (1,000 cpm) is reached, an amber light comes on and a buzzer is energized. There is no switch to silence the buzzer.
2. When the "high-level" setpoint (4,000 cpm) is reached, a red light comes on and a bell rings. The bell can be silenced by a

toggle switch; and when this is done, amber neon indicator light, located near the toggle switch, comes on.

3. A timer automatically advances the filter tape once every 24 hours. A local pushbutton allows the operator to advance the tape at any time. If the tape breaks, a neon indicator is lighted and the caution light flashes and buzzer sounds intermittently.
4. If a tape breaks at the same time the caution alarm sounds, the tape-break neon light, the caution light, and the buzzer will be on continuously. A test pushbutton permits checking the alarm panel by simulatneously simulating tape-break and high-level alarm signals.

Indicator module. When the instrument connected to an indicator module is operating normally, all lamps on that module are dim (see Table 8.2). When the module receives a signal that the instrument is operating abnormally or that the caution-level or the high-level alarm setpoints have been exceeded, the lamps burn at full intensity--white for an inoperative instrument, yellow for caution level, and red for high level. A signal from the module actuates annunciator "HI-5" on the control panel. The white lamp will remain bright until the condition causing the alarm is corrected, at which time the lamp will become dim.

The red and amber lights will remain bright, even after the condition causing the alarm is corrected, until they are manually reset by means of the pushbutton on the indicator module. Annunciator "HI-5" can then be cleared. If the pushbutton is depressed to reset the indicator module when the condition causing an alarm has not been corrected, the lamps will momentarily dim while the button is depressed and then will become bright and the annunciator will sound again when the reset button is released.

Table 8.2 Central control panel alarm indications for monitrons and air monitors

Instrument alarm condition	Lamp instensities		
	Red	Amber	White
Normal operation	Dim	Dim	Dim
Caution level*	Dim	Bright	Dim
High level**	Bright	Bright	Dim
Instrument trouble or out of service	Dim	Dim	Bright
Instrument removed†	Bright	Bright	Bright

*Caution level for air monitor is 1,000 counts/min and for monitron is 7.5 mr/h.

**High level for air monitor is 4,000 counts/min and for monitron is 23 mr/h.

†Lamp intensities exist until a maintenance connection is made giving "Out of Service" indication.

Coincidence module. When two or more monitron indicator modules or two or more air-monitor indicator modules receive high-level signals, the associated coincidence module will actuate the building warning and evacuation equipment and will transmit a signal to the Emergency Control Center. A red lamp on the affected coincidence module will indicate which set of instruments has detected an abnormal condition.

When the indicator modules showing an abnormal condition are reset manually, the coincidence module will also be reset.

Buzzer module. The buzzer module gives audible notice that an indicator module has received one of three input signals. The buzzer module, which serves all indicator modules, is reset by a pushbutton at the front of the module. After being reset, the module will cause the annunciator to sound again whenever an input signal is received by one of the indicator modules. For example, a change from a normal condition to a "Caution-Alarm Level" will start the annunciator. After it is reset, a change to "High-Alarm Level" or to "Inoperative Instrument" will start the annunciator again.

Air horn and beacon lights. When a coincidence module has been energized by two or more monitrons or air monitors, five air horns are actuated by nitrogen gas bottles (one for each horn) to notify the building occupants to leave the building. The horns will sound for about four minutes once they are actuated. Two nitrogen cylinders are attached to each horn but only one should have its valve open. The other cylinder is used as a spare.

Normal nitrogen cylinder pressure is greater than 10.3 Mpa (1,500 psig). Line pressure is between 0.55 and 0.83 kPa (80 and 120 psig). Abnormal pressures are indicated by red lamps (labeled "Horn Trouble") on the central control panel, one lamp for each horn. The dim lamp indicates normal presssures, and a bright lamp indicates abnormal pressures.

Five beacon lights are installed on the outside of the building to warn personnel that the building has been evacuated. The magenta-colored lights are turned on when the evacuation system is acutated and remain on until the coincidence module has returned to a normal condition.

Control switches. The key-operated switch, labeled "Evacuation Alarm," on the central panel board can be used to disconnect the air horns and beacons during maintenance or abnormal operating periods. Since the Emergency Control Center receives an alarm signal when the switch is turned to the "Disable" position, the Emergency Control Center should be notified before the switch is moved to this position.

A large, red pushbutton is located on the right-hand module and is labeled "Manual Evacuate." This pushbutton actuates the evaucation air horns and beacons and sends an alarm signal to the Emergency Control Center, regardless of the position of the "Normal-Disable" switch.

A pushbutton on the reactor console can be pressed to temporarily silence the evacuation horns if it becomes necessary to make announcements while the horns are sounding. The horns are shut off only as long as the pushbutton is depressed.

8.9 Poison Injection System

8.9.1 References

Drawings:

E-50161	Flow Sheet
E-50157	Piping Arrangement

8.9.2 Introduction

A poison injection system, utilizing cadmium nitrate, has been provided as an emergency backup for the normal reactor control system. Although it is not anticipated that the poison injection system will ever be required, it must always be in standby while the reactor is operating in Mode 1.

It has been postualted that the most likely time the poison injection system will be needed, if ever, is during restart of the reactor subsequent to operating at high power levels. It is during this period that the rate of change in reactivity is the greatest due to the burnup of xenon.

There are several methods of shutting down the reactor by use of the shim plates. These methods are:

1. scram of the shim-safety plates;
2. reverse of the shim-safety plates and the shim-regualting cylinder;
3. insertion of the shim-safety plates with the air motors;
4. insertion of the No. 5 shim-regulating cylinder, using the portable air motor, located in the subpile room; and
5. insertion of the shim-safety plates manually, using the hand crank.

In all the above methods, it is necessary that the shim plates be movable. It has been postulated that conditions might exist such that it would be impossible to insert any of the shim plates. If these conditions should exist concurrent with a time when the reactivity of the reactor is increasing, such as by burnup of xenon on restart of the reactor, a method of shutting down the reactor without use of the shim plates would be required; therefore, a poison injection system has been provided.

Use of the poison injection system will be limited to conditions when it is impossible to maintain control of the reactor by manipulation of the shim plates by any of the methods previously listed or because there is not sufficient time to try them. It is not planned to ever inject the poison into the reactor system unless it is really needed to shut down the reactor. Water will be used when flow tests are required to check the system.

The most efficient use of the poison injection system during "xenon chase" could be made only by calculating, at the time of restart of the reactor, the various parameters applicable to that particular restart. Some of these parameters are the power level prior to shutdown, time operated, time shut down, and time required to put poison injection system into operation after observing that the shim plates are inoperative. Therefore, a programmed restart procedure is provided to eliminate making "on-the-spot" calculations during restart of the reactor and to simplify the restart procedure.

At any time during the cycle, if the reactor should shut down from 100-MW operation, the power level may be raised immediately to 100 MW if the down time does not exceed 10 min. If the down time exceeds 10 min, the procedure for restart of the reactor after shutdown from 100-MW operation is given in the following table.

Programmed restart of the HFIR after 100-MW operation

Time operated at 100 MW	Power escalation on restart		
	1st step		2nd step
Days	MW	Hours	MW
<1	42	1 3/4	100
1 to 8	70	1 1/2	100
8 to 13	90	2/3	100
>13	100	--	--

If it should be observed that the control plates continue to come out at the first-step power level, the power level should be increased to the "break-even" power level and held there for the duration indicated in the first step.

The above data are taken from Fig. 8.1 which shows allowable power levels and the waiting time required at those power levels upon restart. Figure 8.2 is a similar graph showing the first 24 hours of the cycle on an expanded scale.

8.9.3 Description of the system (see Fig. 8.3)

Cadmium nitrate in solution (44 wt %) with water is stored in a 379-l (100-gal) tank located at the head of the stairwell leading from the main control room. The poison solution is discharged by gravity flow from the bottom of the tank through 5.1-cm (2-in.) piping to the suction of the pressurizer pumps.

Three air-operated ball-type valves are used to inject the poison solution into the pressurizer pump suction line. A 5.1-cm (2-in.) test and drain line tees into the injection line between two valves and

ORNL-DWG. 82-16875

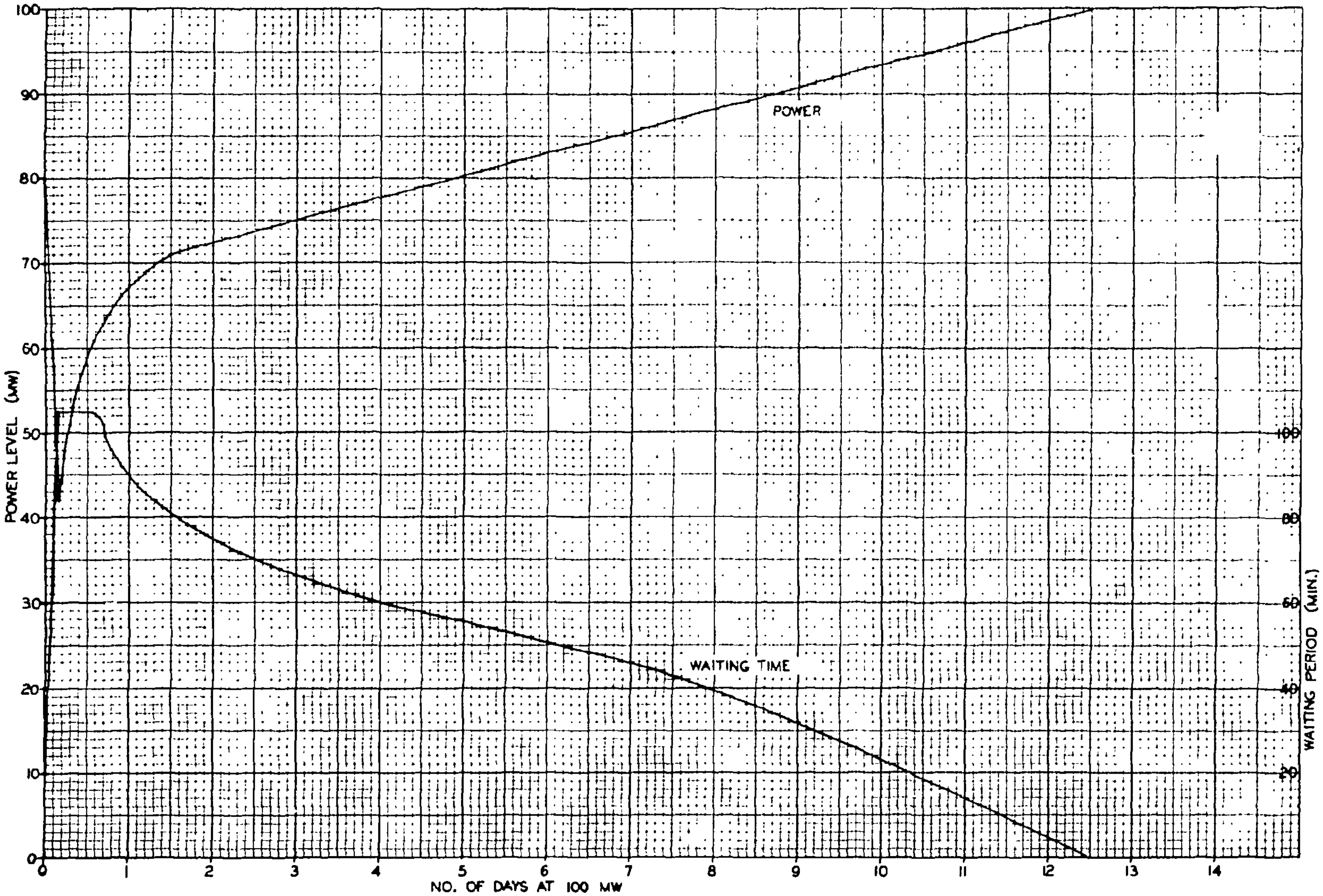

Fig. 8.1. Waiting time and permissible power levels, zero to 14 days.

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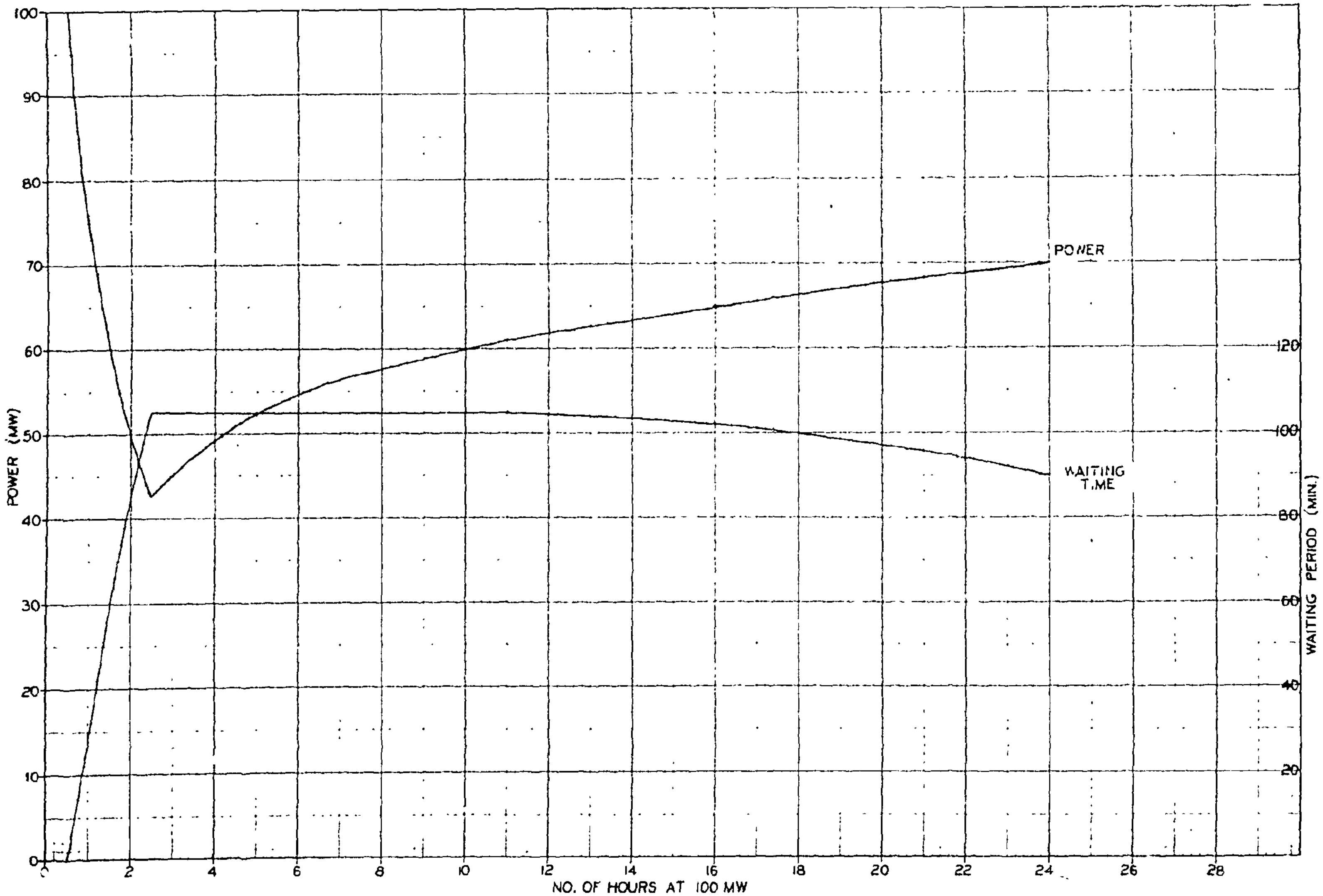

Fig. 8.2. Waiting time and permissible power levels, zero to 24 hours.

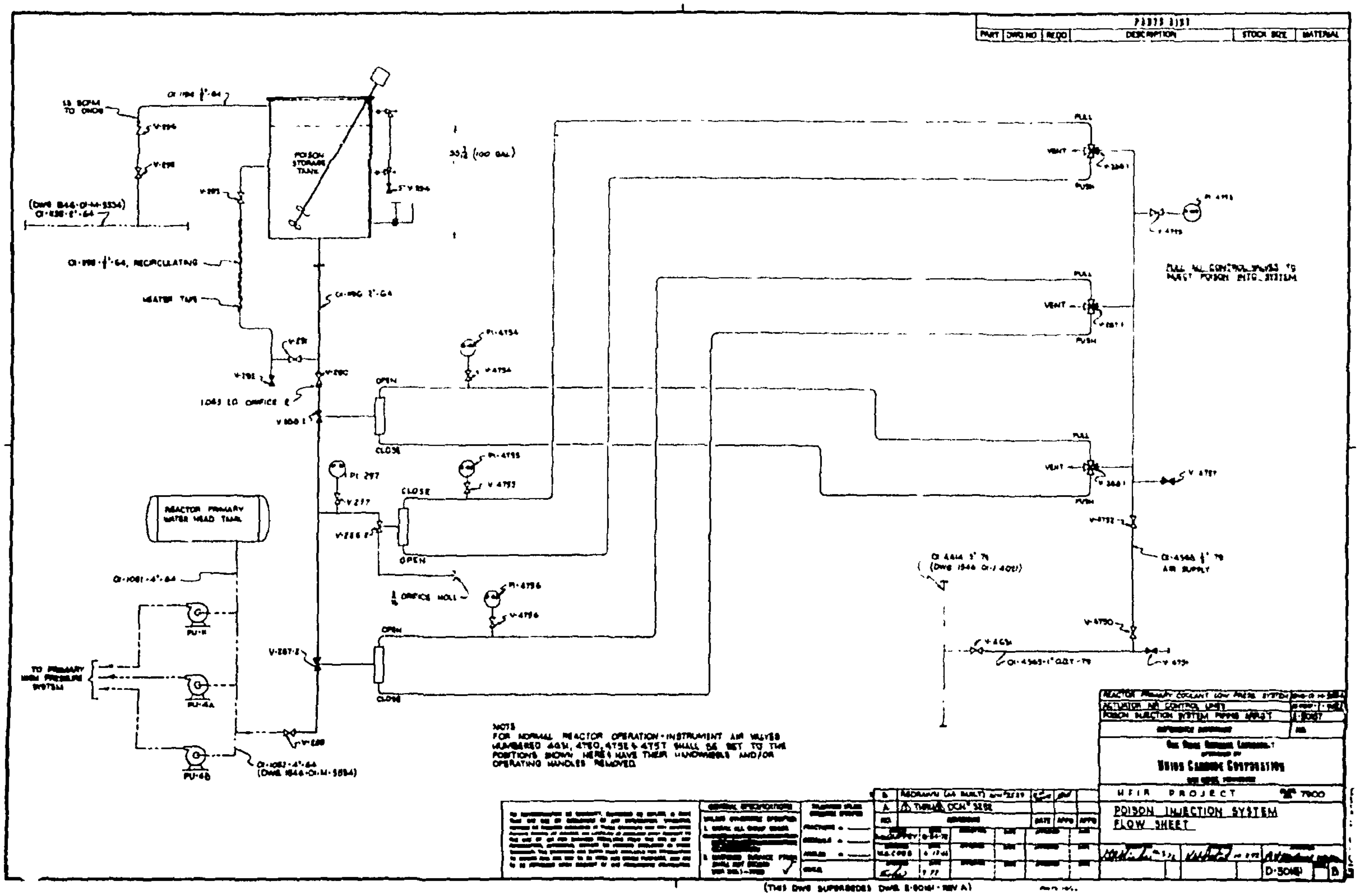

Fig. 8.3. Poison injection system.

discharges through the third valve to a floor drain. The valve discharging to the floor drain is normally open while the other two are normally closed. A leak to the floor drain probably would indicate one of the injection valves is leaking.

These three valves have individual operators, and they can be manually operated locally. The valves are designed, however, to be operated remotely from the main control room. Recessed in the control panel behind a small door are three actuating knobs. These three knobs must be pulled in the outward direction to supply air to valve operators and thus inject the poison. This operation opens the normally closed injection valves and closes the normally open test and drain valve. Should the test and drain valve fail to close, essentially all poison will be injected, since this line has a pipe cap over its end with only a small hole in it to the floor drain.

An orifice is located in the 5.1-cm (2-in.) injection line near the storage tank. This orifice is sized to permit a flow rate of approximately 3.8 l/s (1 gps) which results in poison injection over a period of approximately 100 s. Since the primary system coolant cycle time is less than 50 s, this assures even distribution of poison throughout the system.

A sight glass liquid level indicator is located on the storage tank so that the operator who actuates the system may observe that the solution is being injected.

A 1.3-cm (1/2-in.) recirculating line which is wrapped with electrical resistance heater tape tees off the injection line at ground floor level and returns to the top of the storage tank. The solution is recirculated through this line at approximately 0.4 l/min (0.1 gpm) by thermal convection to keep the cadmium nitrate from precipating.

Since cadmium nitrate is toxic, the storage tank is vented to the open hot off-gas system.

Periodic checks are made to assure that the storage tank remains full and that the solution remains at its proper concentration.

Hand operated gate valves are located both upstream and downstream of the three injection valves so that the system may be tested periodically during reactor shutdown without injecting the poison. These valves are locked open with a chain and padlock while the reactor is operating.

9. WASTE SYSTEMS

9.1 Sanitary Water Disposal System

9.1.1 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

9.1.2 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 building empties into manhole SA-1, located approximately 39.6 m (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.

9.1.3 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.

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.

9.2 Process Waste System

9.2.1 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	Process 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

9.2.2 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.

9.2.3 Collection system

1. Floor drains

   Each drain is provided with a trap, sediment bucket, and cleanout. 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 3785-l (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 239 and 240 m (785 and 788 ft). Each jet is designed to discharge 379 l/min (100 gpm) against a head of 9.14 m (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.

9.2.4 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 Fig. 9.1).

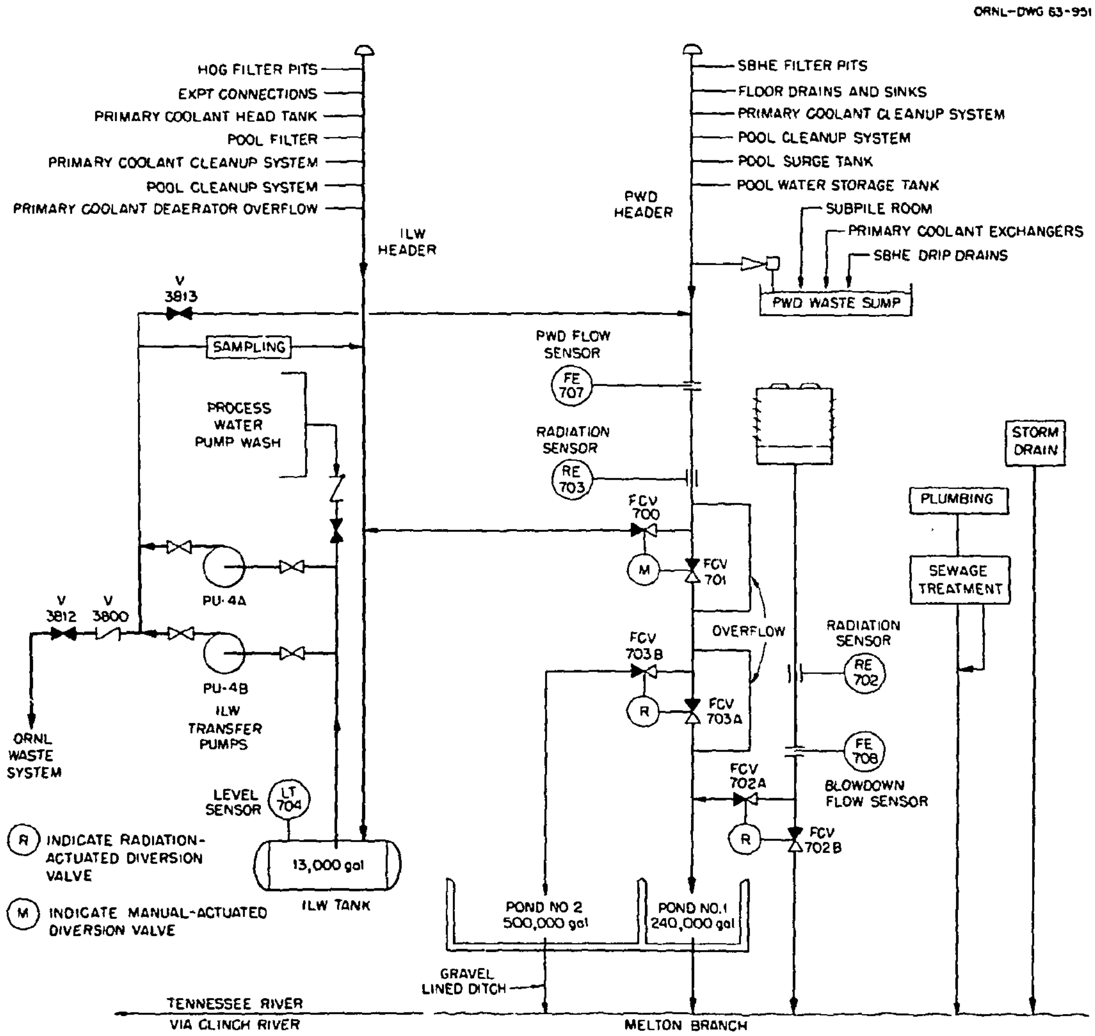

Fig. 9.1. Liquid waste system.

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.

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 form 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 radoactivity 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 76 m (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 908,400 1 (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 form the reactor-building area enter this pond. There is treatment for pH neutrality; decontamiantion is by decay and settling.

Influent waste enters the pond with an upward flow through a 61-cm-diam (24-in.) vitrified clay pipe that pierces the north bank at elevation 243.4 m (798.5 ft). The pipe extends upward from the bank to the elevation 243.7 m (799.5 ft) which is 76 cm (2 1/2 ft) above the pond bottom and 137 cm (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 20.3-cm-diam (8-in.), 3.66-m-long (12-ft) rubber suction hose. This hose is coupled to an 20.3-cm (8-in.) pipe which runs under the south embankment, at elevation 24.9 m (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 242.8 m (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 1,890,000-l (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 effluent which contains radioactivity above the background level is returned to the laboratory-wide waste collection system.

9.3 Intermediate Level Waste System

9.3.1 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

9.3.2 Introduction

Intermediate level wastes are liquid wastes which contain activity levels between 5.7 x 10^3 d/m-ml and 5.7 x 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.

9.3.3 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. Decontamiantion 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.

9.3.4 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 5.1 cm (2 in.) of lead. The main header leaves the reactor building at the southwest corner at elevation 246.9 m (810.11 ft) and proceeds west about 61 m (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 Fig. 9.1).

9.3.5 Waste storage and accessory equipment (see Fig. 9.2)

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.

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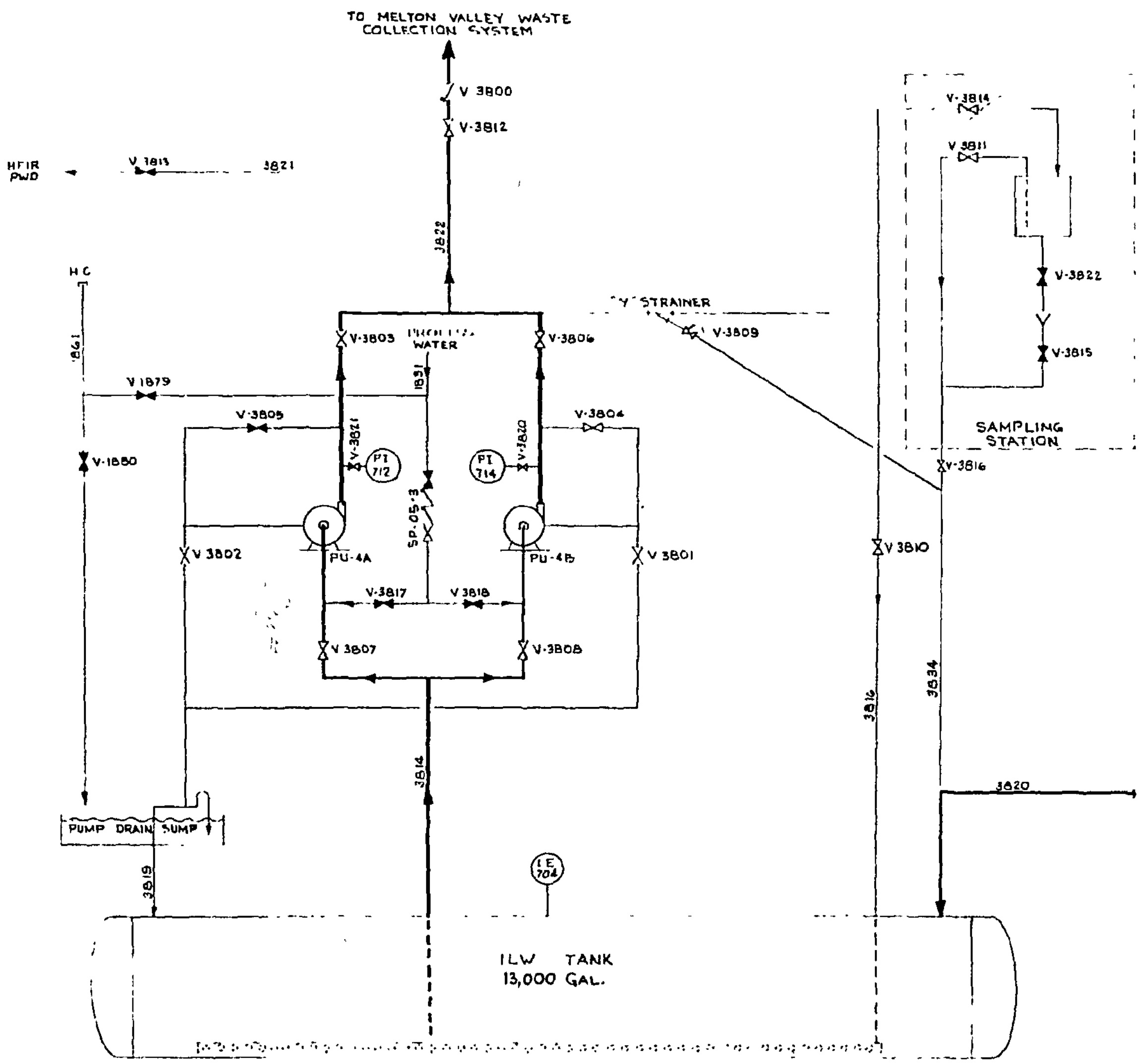

Fig. 9.2. Schematic flow diagram - ILW tank and pumping station.

1. The ILW storage tank

The 49,205-l (13,000-gal), 2.44-m-diam (8-ft), stainless steel tank is supported by a concrete pad and buried. Its bottom elevation is 243.2 m (798 ft), the top elevation is 245.7 m (806 ft), while the grade elevation is 251.5 m (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, stainless steel pumps, piped in parallel and rated at 227 l/min (60 gpm) each against a head of 35.1 m (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 247.6 m (812.5 ft), 3.23 m (10.6 ft) above the center line of the storage tank.

The top of the pit is concrete, 61-cm-thick (2-ft) to give adequate shielding to the operator. Two access ports, each 1.45 m (4 ft 9 in.) by 91.4 cm (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 tranfer 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

9.4.1 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 [illegible] Hot Off-Gas Systems

9.4.2 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 76.2-m (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 Fig. 9.3). Both systems are constructed of Type 304L stainless steel, schedule-10 pipe throughout, except where heavier gauge pipe was required for embedment. Embedded pipe was pressure tested before concrete was poured to assure an air-tight system.

9.4.3 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 2.54 cm (1 in.) of lead. The system is sized to handle up to 14 m^3/min (500 cfm) with minimum inlet pressures of -7.5 kPa (-30 in. H_2O) when any four of the functional connections are in use. The design pressure of the piping upstream of the filters is 0.7 MPa (100 psig).

9.4.4 The open hot off-gas system (OHOG)

The OHOG system services those connections which cannot be presssurized. In addition to handling those components which are open to the building

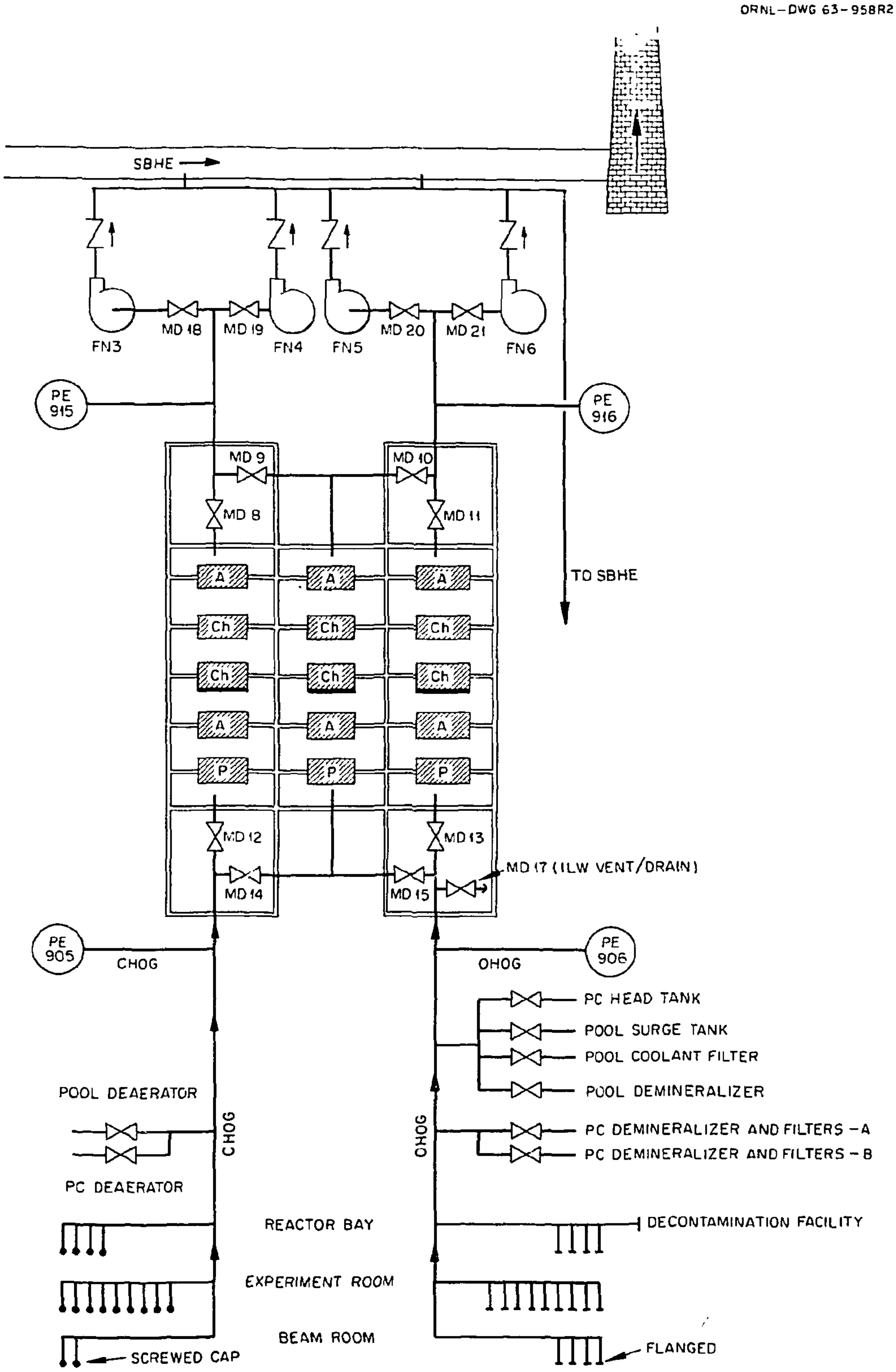

Fig. 9.3. Hot off-gas system.

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, and
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, and
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 2.54 cm (1 in.) of lead.

Like the CHOG system, the OHOG system is sized to collect up to 14 m^3/min (500 cfm) with inlet pressures of -7.5 kPa (-30 in. H_2O) when four of the functional connections are in use.

9.4.5 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 1.2 m (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 Figs. 9.4 and 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 fiberglass prefilter, a fiberglass-asbestos absolute filter, a silver-coated copper mesh screen, two charcoal absorbers in series, and a final absolute filter. All exposed metal is stainless steel.

Changeover 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 14-m^3/min (500-cfm) exhaust fans, driven by 7.5-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 switchover 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.

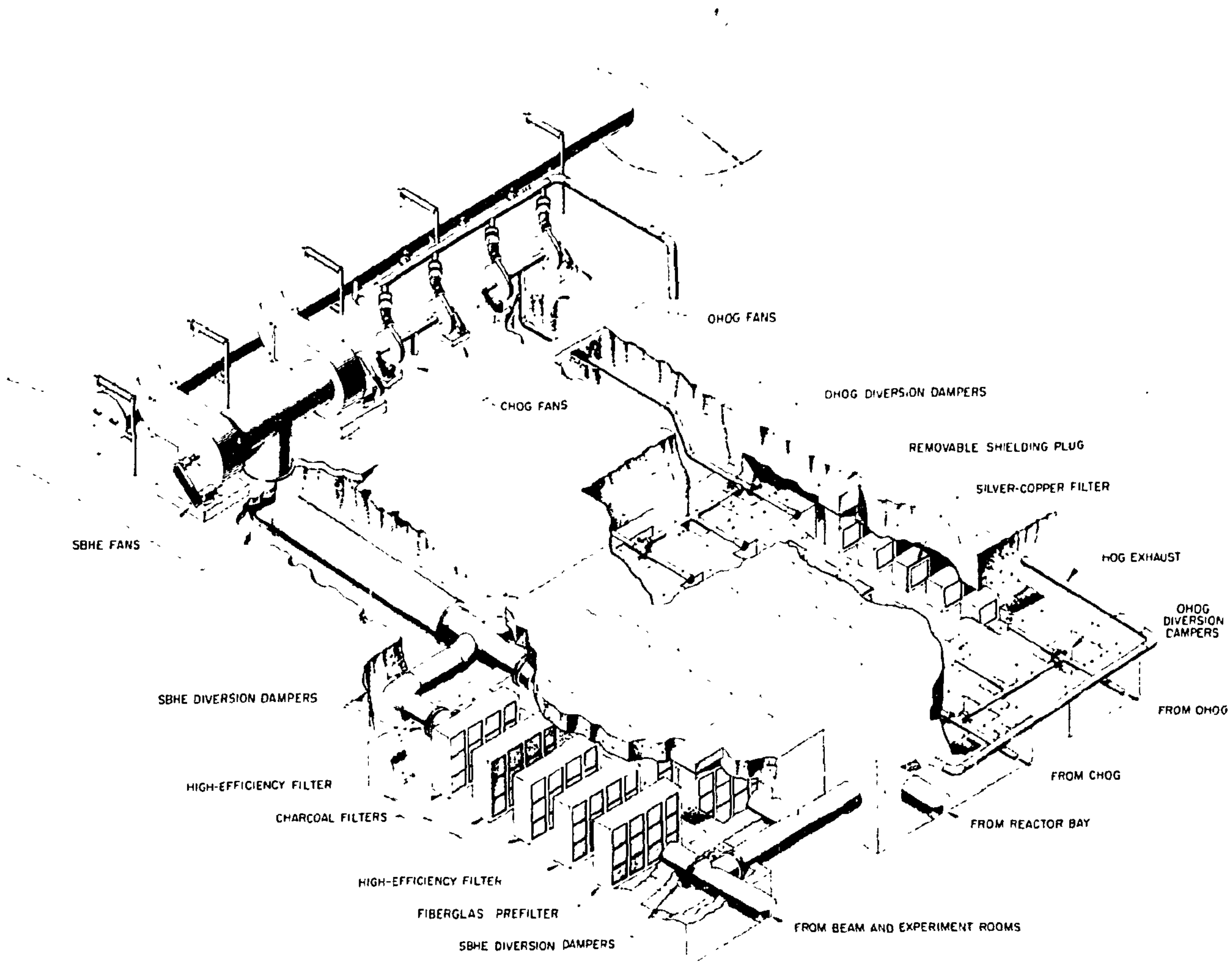

Fig. 9.4. Filter pit and fan shed.

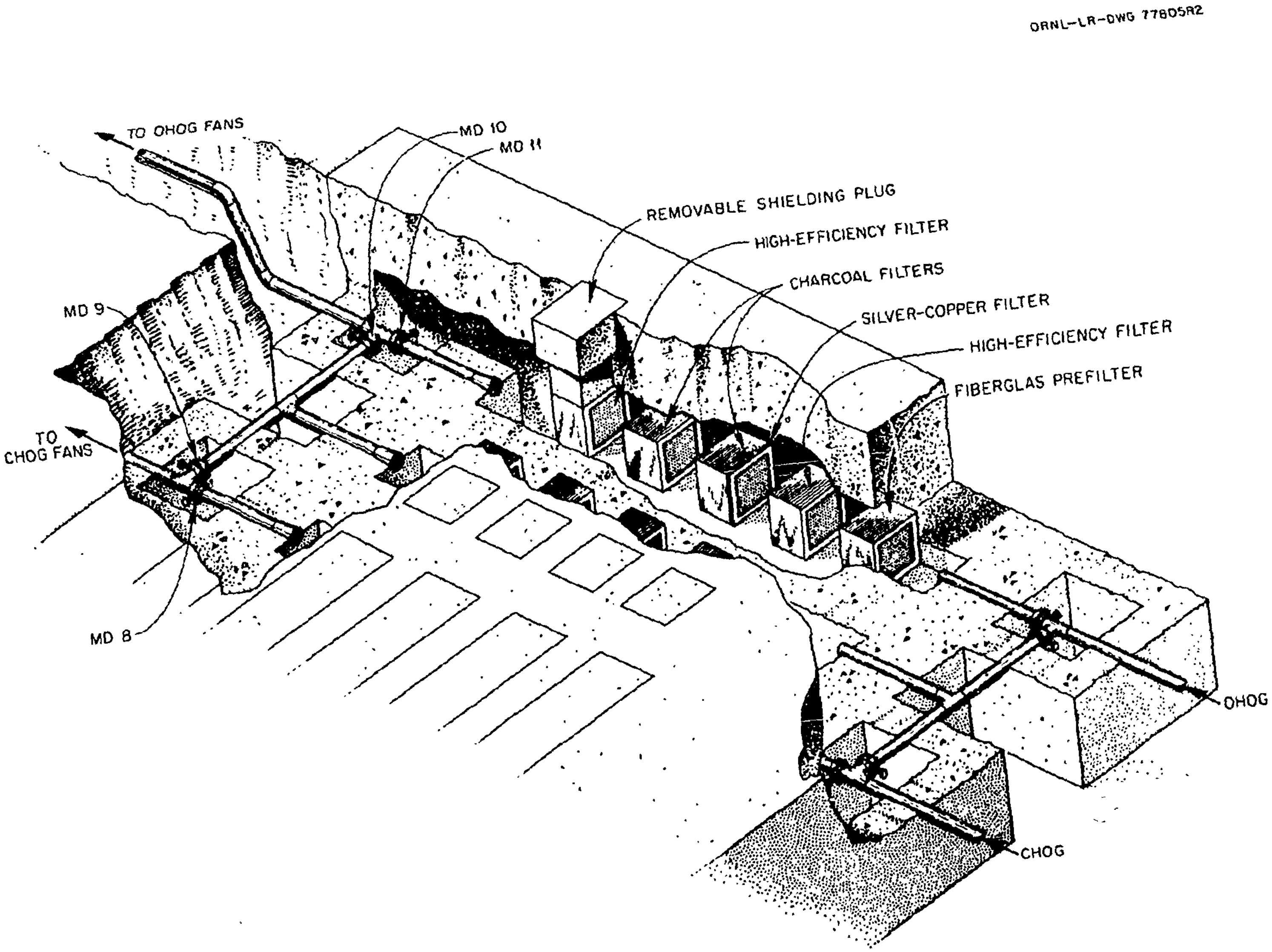

Fig. 9.5. HOG filter pit.

9.4.6 HOG instrumentation and control (see Fig. 9.6)

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 [-11.9 kPa (-48 in. H_2O) to -10.7 kPa (-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 9.1.

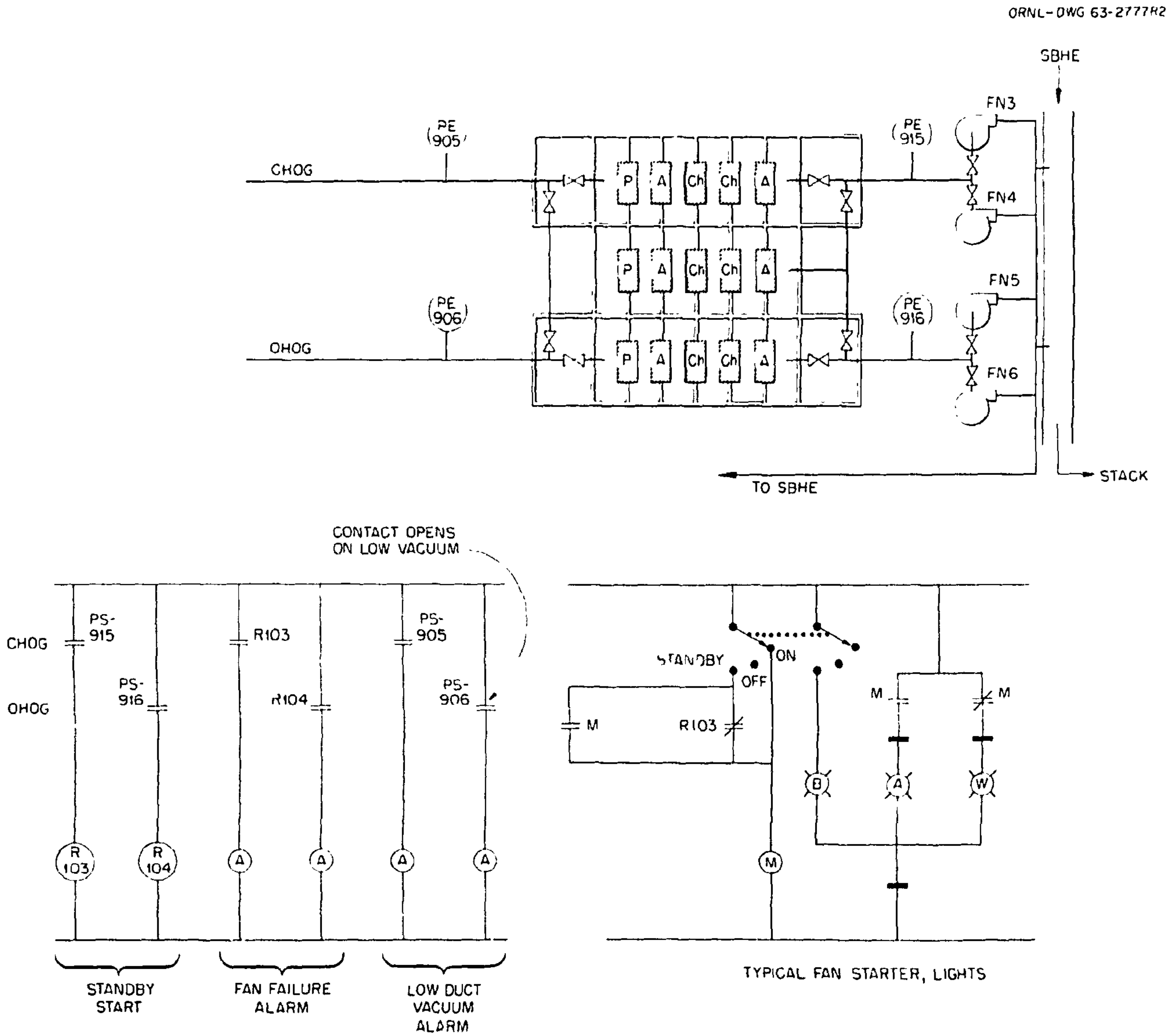

Fig. 9.6. HOG fan controls.

Table 9.1 HOG pressure switch tabulation

Switch	Duct	Normal vacuum kPa (in. H_2O)	Setpoint kPa (in. H_2O)	Action
PS-905-1	CHOG, inlet to filter	-11.9 (-48)	-10.7 (-43)	Alarm
PS-914-1	CHOG, inlet to fan	-13.4 (-54)	-10.2 (-41)	Alarm, fan start
PS-906-1	OHOG, inlet to filter	-11.9 (-48)	-10.7 (-43)	Alarm
PS-916-1	OHOG, inlet to fan	-13.4 (-54)	-10.2 (-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 -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 is the case of the SBHE fans, the starting sequence of these motor-control centers is such that both "G" and "H" are energized immediately after the normal-emergency switchgear switches to the emergency position upon startup of the diesel-generators.

9.4.7 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 is constructed of carbon steel plate, and painted with corrosion-resistant paint. The stack is 76.2 m (250 ft) in height with its discharge orifice at elevation 330.1 m (1085 ft). The inside diameter of the discharge orifice is 1.5 m (5 ft). The inside diameter at the entrance is 3.3 m (10 ft, 9 in.).

The stack provides for HFIR exhaust of 850 m^3/min (30,000 cfm) and has an additional capacity of 850 m^3/min (30,000 cfm) to handle future requirements. At full design load, the stack discharges 1,700 m^3/min (60,000 cfm) at 54°C (130°F). Under these conditions, the discharge velocity is approximately 15.5 m/s (3,050 ft/min). With only approximately 850 m^3/min (30,000 cfm) HFIR load, the discharge velocity is 7.7 m/s (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 beta-gamma and alpha particulate monitors, a high level activity monitor, an inert gas activity monitor, and an iodine activity monitor on the stack. A beta-gamma particulate monitor is also located 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 [3 m x 1.5 m x 1.5 m

(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/h 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

10.1.1 References

Darawings:

1546-05-U-7112, -7113, -7114, and -7115	Yard Piping Plans
1546-05-U-7141	Flow Diagram, Fire and Potable Water

Singmaster and Breyer Specification:

69 Potable Water

10.1.2 Introduction

The primary source of potable water to the reactor site is a 40.6-cm (16-in.) main line that enters the area at a point east of the reactor building. This line will deliver 10,598 l/min (2,800 gpm). It supplies potable water to a fire loop which encircles the reactor building area and from which all other systems are fed (Fig. 10.1). The main line is fed from two 5675 m^3 (1.5 million gal) 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 620 kPa (90 psi).

A second 40.6-cm (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 10,598 l/min (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.

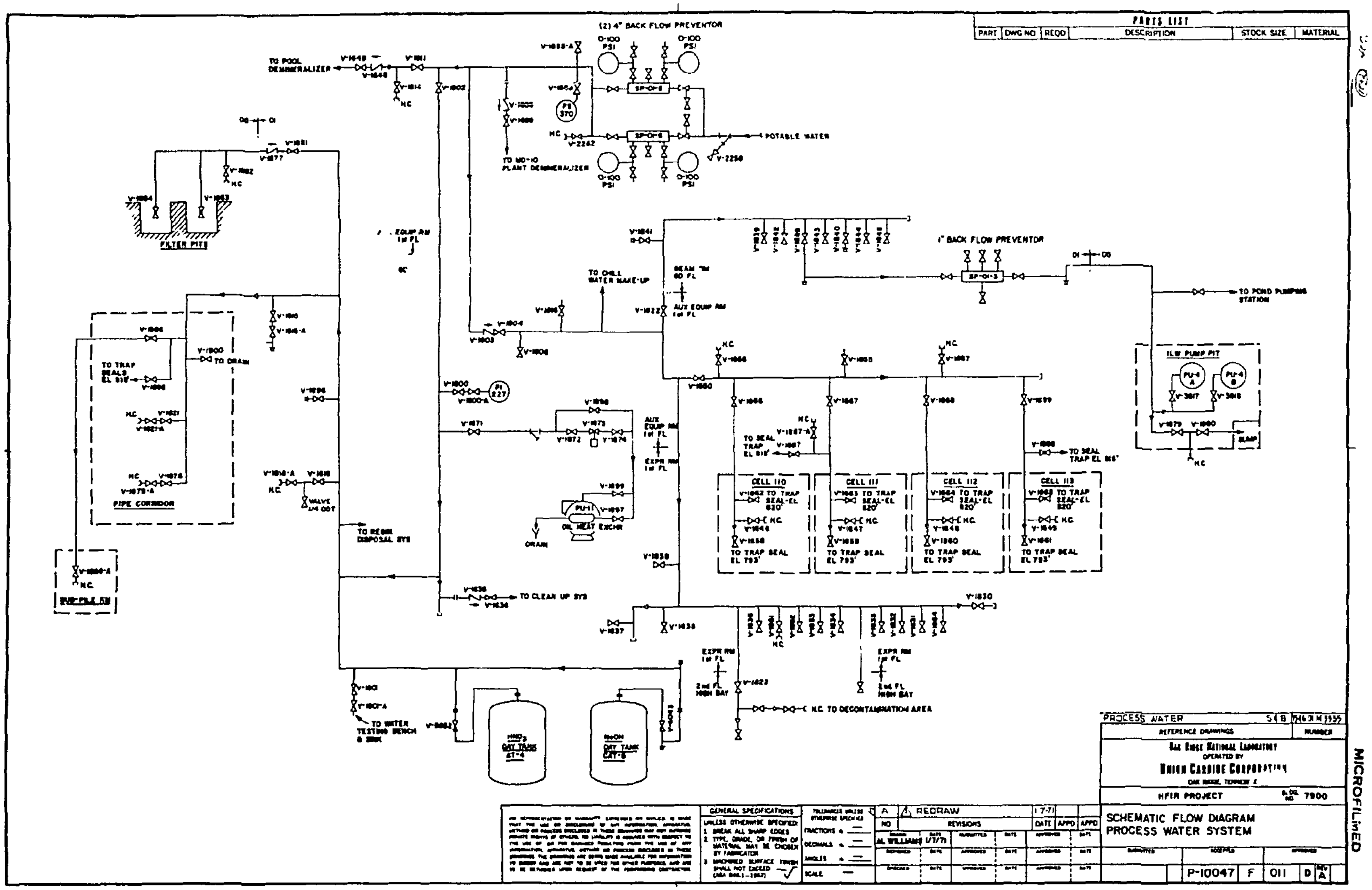

Fig. 10.1. Process water system - schematic flow diagram.

10.1.3 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 15.2-cm (6-in.) lines that serve each hydrant exclusively. The seventh fire hydrant is fed by an 20.3-cm (8-in.) line which also supplies water to two standpipes on the east side of the reactor building.

Two other 15.2-cm (6-in.) standpipe water lines and one 15.2-cm (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 40.6-cm (16-in.) main lines.

10.1.4 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 530 l/min (140 gpm). Of this, 52 l/min (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 76 l/min (20 gpm) with no hot water provided.
3. Potable water flow to the reactor building is not metered but enters the building in room 103 of the first floor water wing. Maximum designed usage is 3028 l/min (800 gpm).

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 20.3-cm (8-in.) line is measured at meter pit No. 1 by flow element FE-336 whch 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.

10.1.5 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 7.6-cm (3-in.) line which enters the utility room on the east side of the building after branching off the 40.6-cm (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 20.3-cm (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 5.1-cm (2-in.) branch enters the cooling tower equipment building. The 20.3-cm (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 3.8-cm (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 2.54-cm (1-in.) line branches off the 20.3-cm (8-in.) portion of the fire loop just a few feet northwest of the nitric acid storage tank to supply the facility.
5. Process water makeup in the reactor building, a safety shower and eye bath near the nitric acid and caustic day tanks, emergency cooling for instrument air compressors C-1A, C-1B, and C-1C, 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 15.2-cm (6-in.) line which branches off the north side of the fire loop and enters the reactor building in the north-east corner of the water wing.

10.2 Process Water System

10.2.1 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 Specification:

68 Process Water

10.2.2 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 and backflow preventers elsewhere.

10.2.3 Descriptioon 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 branches in one direction to the domestic water system and in the other direction to the backflow preventers of the process water system.

Two parallel backflow preventers, SP-01-5 and SP-01-6, are used to separate the reactor building process water system from the potable water system. These backflow preventers are sized so that either is capable of supplying the process water needs of the building. This allows them to be removed from service, one at a time for testing, without interrupting building service.

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 248.7 m (816 ft) while the basin water level is kept at 248.4 m (815 ft). This leaves an air gap of 30.5 cm (1 ft) between the process water in the basin.

A 5.1-cm (1-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.

1. 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 189 l/min (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

10.3.1 References

Drawings:

1546-01-M-5334	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

10.3.2 Description of system (Fig. 10.2)

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 38 to 341 l/min (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.

10.3.3 Description of equipment

Plant demineralizer. The plant demineralizer is a package monobed unit which includes its own 1.8-m^3/min (64-scfm) blower, for mixing the resin, and control instrumentation for semiautomatic operation. The ion exchange vessel is fabricated of carbon steel, lined with an 0.2-cm (0.080-in.) thick coating of unplasticized polyvinyl chloride. It contains 0.37 m^3 (13 ft^3) of Rohm and Haas IR 120 cation resin and 0.7 m^3 (25 ft^3) of IRA 402 anion resin. This volume of resin was designed to demineralize 170,000 l (45,000 gal) of process water between regenerations and produce effluent water with a resistivity of 1.5 x 10^6 ohm-cm. The flow rate can be varied between 38 and 340 l/m (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.

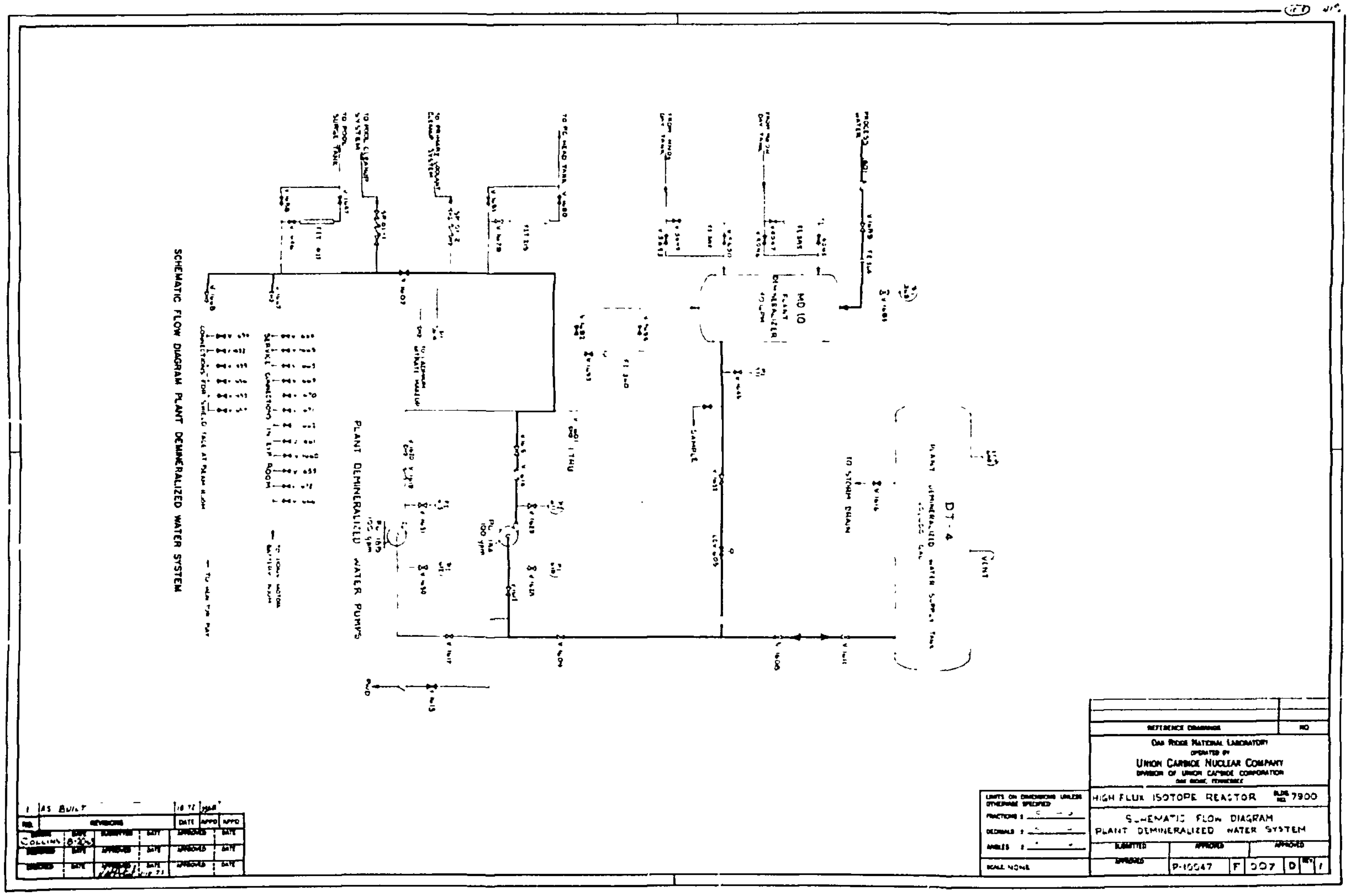

Fig. 10.2. Plant demineralized water system.

Demineralized-water storage tank. Demineralized water produced by the monobed unit is stored in a 75,700-l (20,000-gal) 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 5.1-cm (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 380 l/m (100 gpm) each against a 27.5-m (90-ft) head with a maximum shut-off pressure of 338 kPa (49 psig). Power is supplied by 3.7-kW (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. Annunciator 4E-4 alarms on low demineralized water pressure.

10.4 Chilled Water System

10.4.1 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

10.4.2 Introduction (Fig. 10.3)

The chilled water system refrigerates and distributes a maximum of 3153 l/m (833 gpm) of 4.5°C (40°F) chilled water to the reactor building air conditioning system. The system consists of a packaged chilled water unit with 136 kW (386 tons) cooling capacity, two chilled water pumps, a chemical feeder, an expansion tank, and associated plumbing.

10.4.3 Chiller unit

The package chiller unit consists of the following components:

1. Motor-compressor assembly, a two-stage centrifugal compressor driven by a 274-kW (367-hp) motor.

   Located in the compressor base is a 45-l (12-gal) oil reservoir with a submerged 376-W (1/2-hp) motor and gear pump, oil heater, water type cooler, pressure regulator, shutdown switch, bearing thermometer, reservoir thermometer, oil pressure gauge, 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 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.

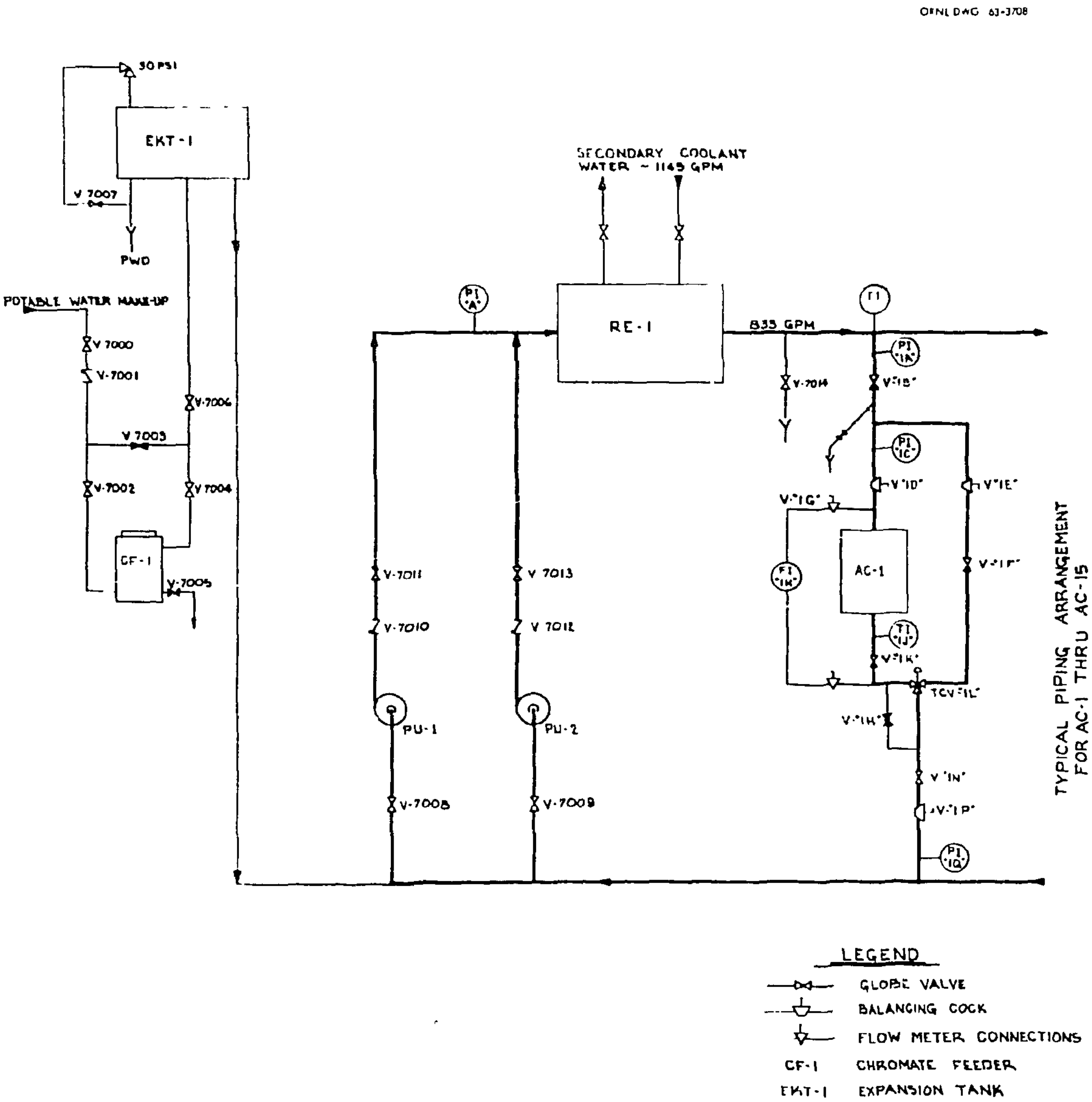

Fig. 10.3. Schematic flow diagram - chilled water system.

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; or

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.

10.4.4 Chilled water pumps, PU-1 and PU-2

The 3153-l/m (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.

10.4.5 Expansion tank

The expansion tank is provided with a pressure safety valve which is to operate at 207 kPa (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

10.5.1 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

10.5.2 Nitric acid storage and distribution (Fig. 10.4)

Nitric acid of 66% concentration is received by truck and stored in a 56,775-l (1,500-gal) 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 4542-l (1200-gal) 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.

10.5.3 Caustic storage and distribution

Concentrated caustic (50%) is received by truck and stored in a 7570-l (2000-gal) 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 54°C (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

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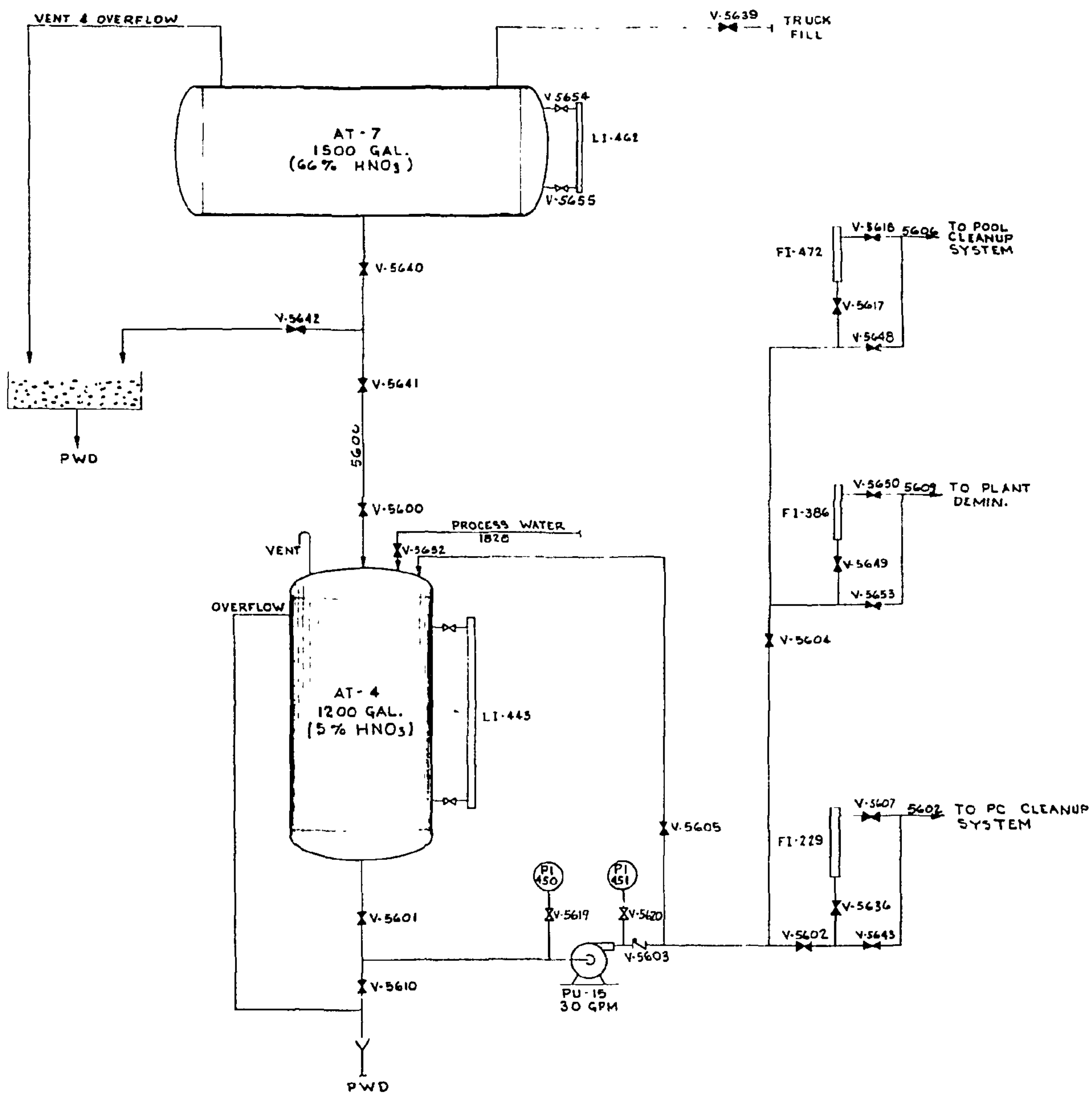

Fig. 10.4. Nitric acid system.

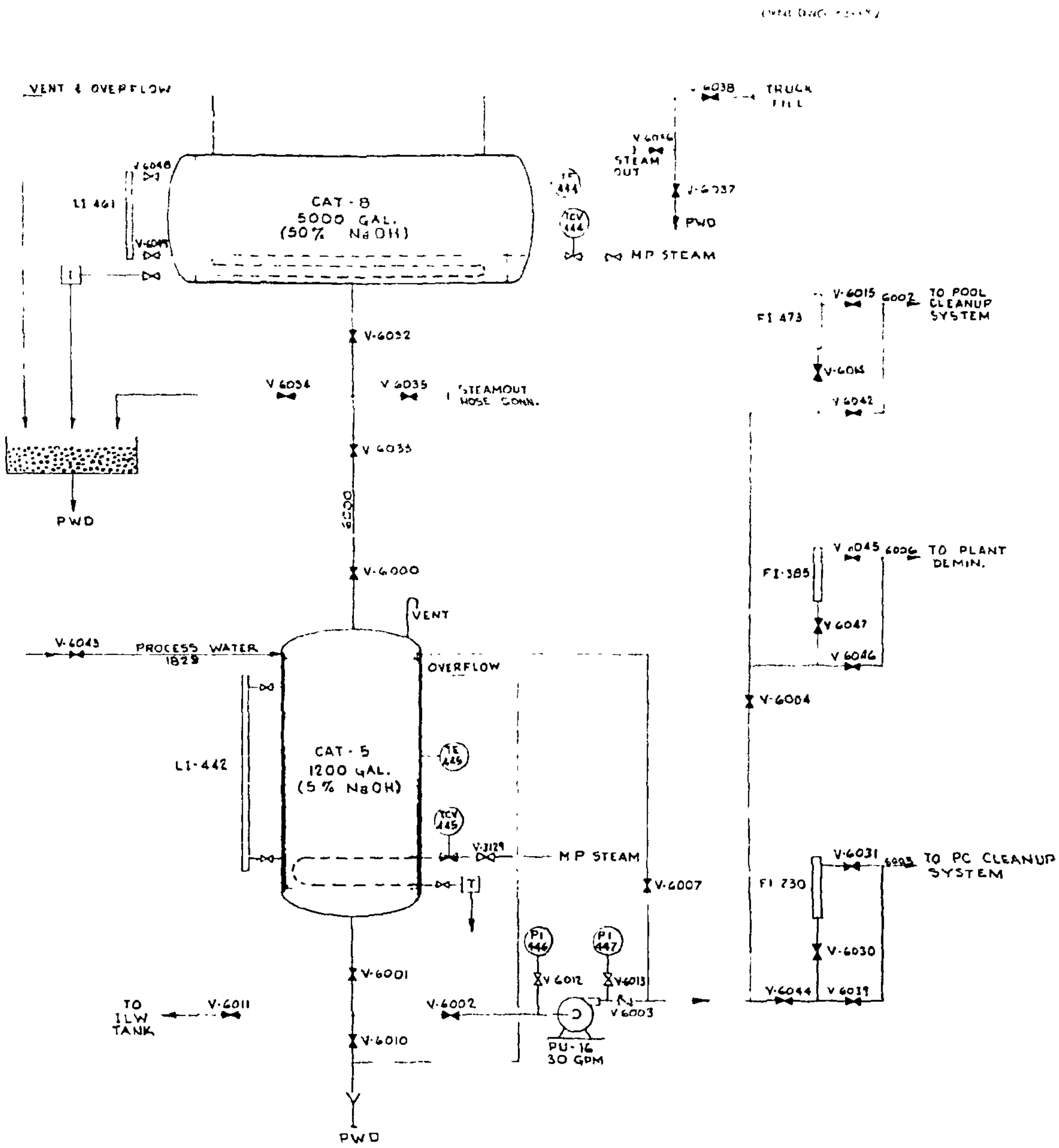

Fig. 10.5. Caustic system.

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.

10.5.4 Sulfuric acid storage and distribution (Fig. 10.6)

Concentrated sulfuric acid (93%) is received by truck and stored in a 18,925-l (5,000-gal) 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.

10.6 Steam

10.6.1 References

Drawings:

1546-05-U-7101, -7102	Utility Plans
1546-05-U-7140	Steam Flow Diagram

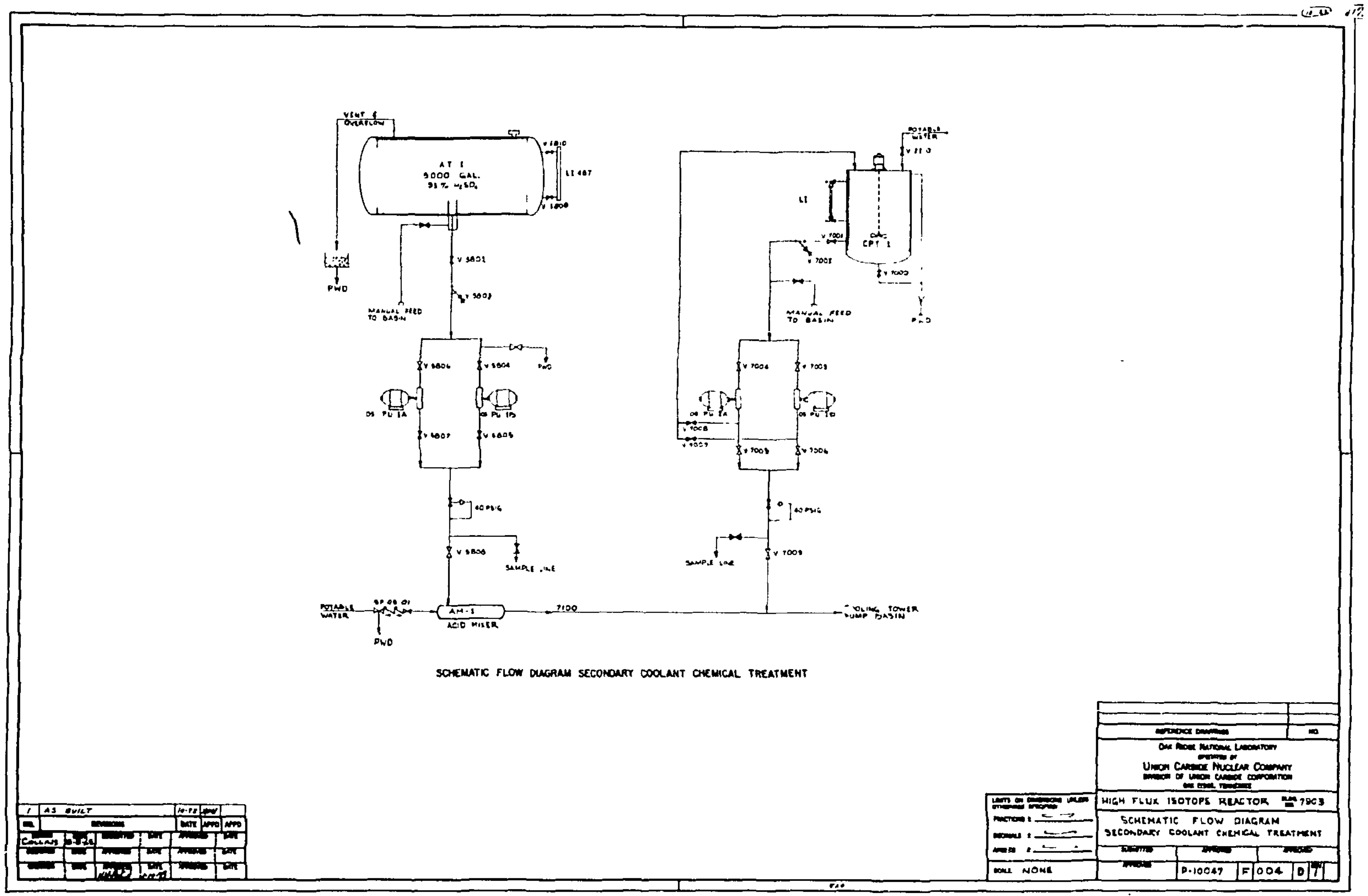

Fig. 10.6. Secondary coolant chemical treatment.

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

10.6.2 Introduction (Fig. 10.7)

Steam is furnished to the HFIR facility from the ORNL steam plant. A 15.25-cm (6-in.) high-pressure steam line, 1.724 MPa (250 psig), enters the area from the north and continues along the east fence to a point east of the reactor building. Here, a 10-cm (4-in.) 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 approximately the 252-m (827-ft) 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 862 kPa gage (125 psig) by two parallel pressure control valves. 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 metered the 862-kPa gage (125-psig) steam is channeled into two systems, the process steam system and the plant steam heating system.

10.6.3 Process steam system

The 7.6-cm (3-in.) process steam main furnishes a maximum of 1815 kg/h (4000 lb/h) of 862 kPa gage (125 psig) steam to the process equipment as follows:

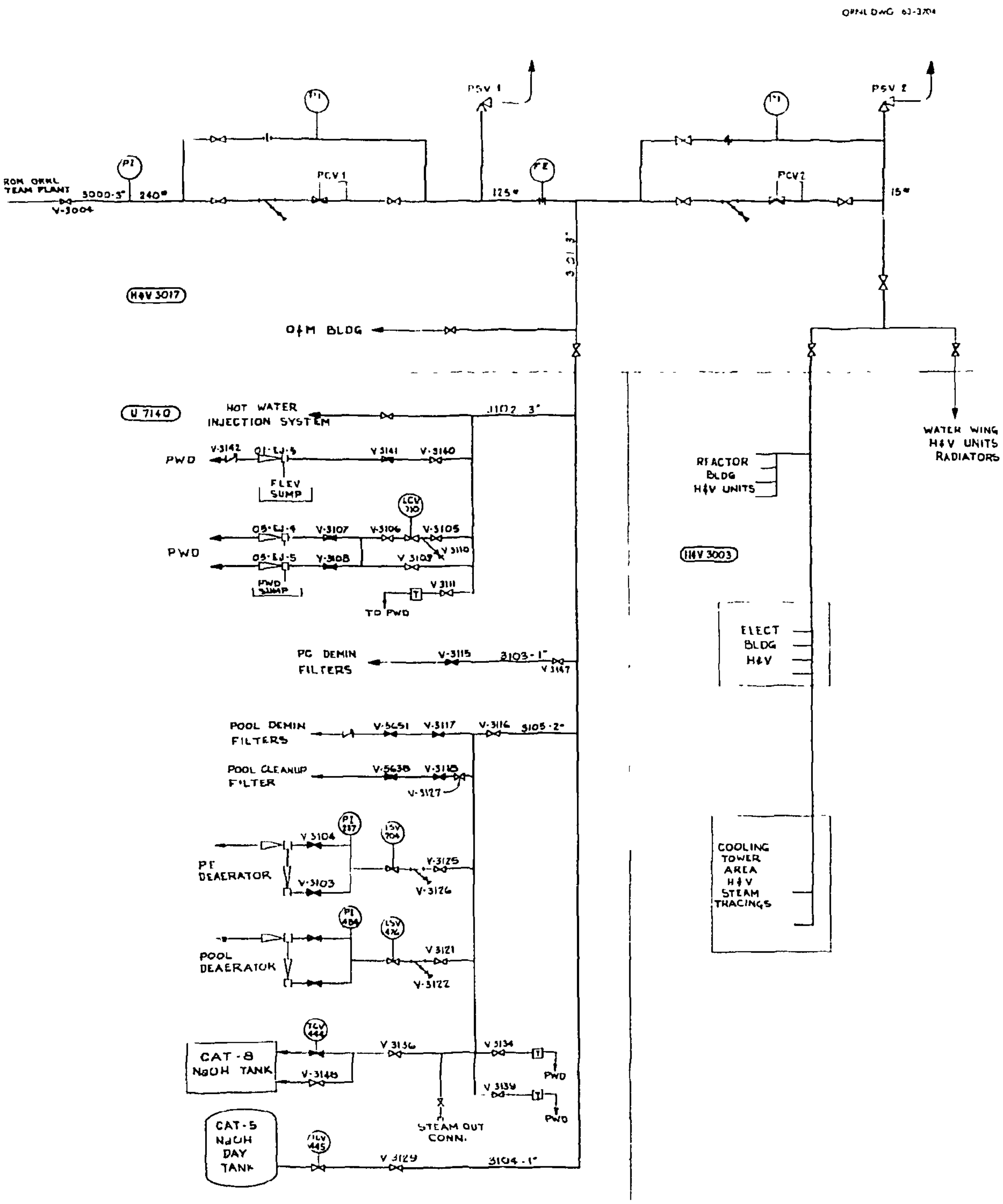

Fig. 10.7. Steam distribution system.

1. A 7.6-cm (3-in.) line which can supply a maximum of 1406 kg/h (3100 lb/h) 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 230 m (788 ft).
2. A 5.1-cm (2-in.) line which can supply a maximum of 295 kg/h (650 lb/h) of 862 kPa gage (125 psig) steam to the following equipment:
   a. 113 kg/h (250 lb/h) 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 6.4.2).
   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 113 kg/h (250 lb/h). These ejectors can be automatically cut off by LSV-204.
3. Steam is supplied to the primary cleanup system filters through a 2.5-cm (1-in.) line for intermittent use.
4. A maximum of 45 kg/h (100 lb/h) of steam is supplied to the caustic day tank, CAT-5. The temperature of the caustic is controlled by TCV-445.

10.6.4 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 635 kg/h (1400 lb/h), and to the reactor building, electrical building, and the cooling tower equipment building which, combined, use a maximum of 3220 kg/h (7100 lb/h).

Reactor building and adjacent areas. In room G-1 just downstream from the metering equipment, the 862-kPa gage (125-psig) steam is reduced to 103 kPa gage (15 psig) by two parallel reducing valves for the heating system. In the reactor building, 2989 kg/h (6590 lb/h) is available for heating and ventilating and 73 kg/h (160 lb/h) is used by the domestic hot water heaters.

Leaving the reactor building at the southeast corner, a 6.35-cm (2 1/2-in.) line supplies a maximum of 159 kg/h (350 lb/h) to the electrical building where 113 kg/h (250 lb/h) is used for space heating and 45 kg/h (100 lb/h) is sent on to the cooling tower equipment building for use in space heating and steam tracing.

The caustic storage tank, CAT-8, is heated by steam to keep the caustic from solidifying. The tank also has a steamout connection and steam tracing lines for freeze protection to its instrumentation.

Office and maintenance building. From room G-1 in the reactor building a line furnishes a maximum of 635 kg/h (1400 lb/h) of 862-kPa gage (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 862-kPa gage (125-psig) steam pressure is reduced to 103 kPa gage (15 psig) by two pressure reducers installed in series. The 103-kPa gage (15-psig) steam is then used indirectly by the building heating and ventilating system.

10.7 Instrument Air System

10.7.1 References

Drawings:

1546-05-U-7146	Instrument Air Flow Diagram
1546-01-M-5513	Piping Drawings
RC11-8-2	Air Flow Diagram
P-20977-EC-22, 006, 007	Piping Arrangement

Singmaster and Breyer Specifications 54 and 79

10.7.2 Introduction (Figs. 10.8 and 10.9)

Compressed air for instrument usage is produced by two 11.5-m^3/min (405-cfm) compressors and one 3.8-m^3/min (135-cfm) compressor, any one of which is sufficient for normal usage. A smaller emergency compressor can supply 0.6 m^3/min (20 cfm) to the pneumatically operated servo system in the event of failure of the normal system. The normal air system compressors draw building air through their inlet filters, compress it, and then discharge it through their aftercoolers and moisture separators into the two air receivers. The two parallel air receivers supply air through prefilters, air dryers, and afterfilters to the air distribution system.

The emergency air compressor is located on the first floor near the south wall of the water wing of the reactor building. Normal air system compressors are located on the ground floor at the west end of the water wing.

10.7.3 Control system

The operating compressor, usually C-1A, or C-1B, runs continuously either at full load or at no load. It is automatically loaded when the air receiver pressure drops to 414 kPa gage (60 psig) and unloaded when the air receiver pressure reaches 483 kPa gage (70 psig). This

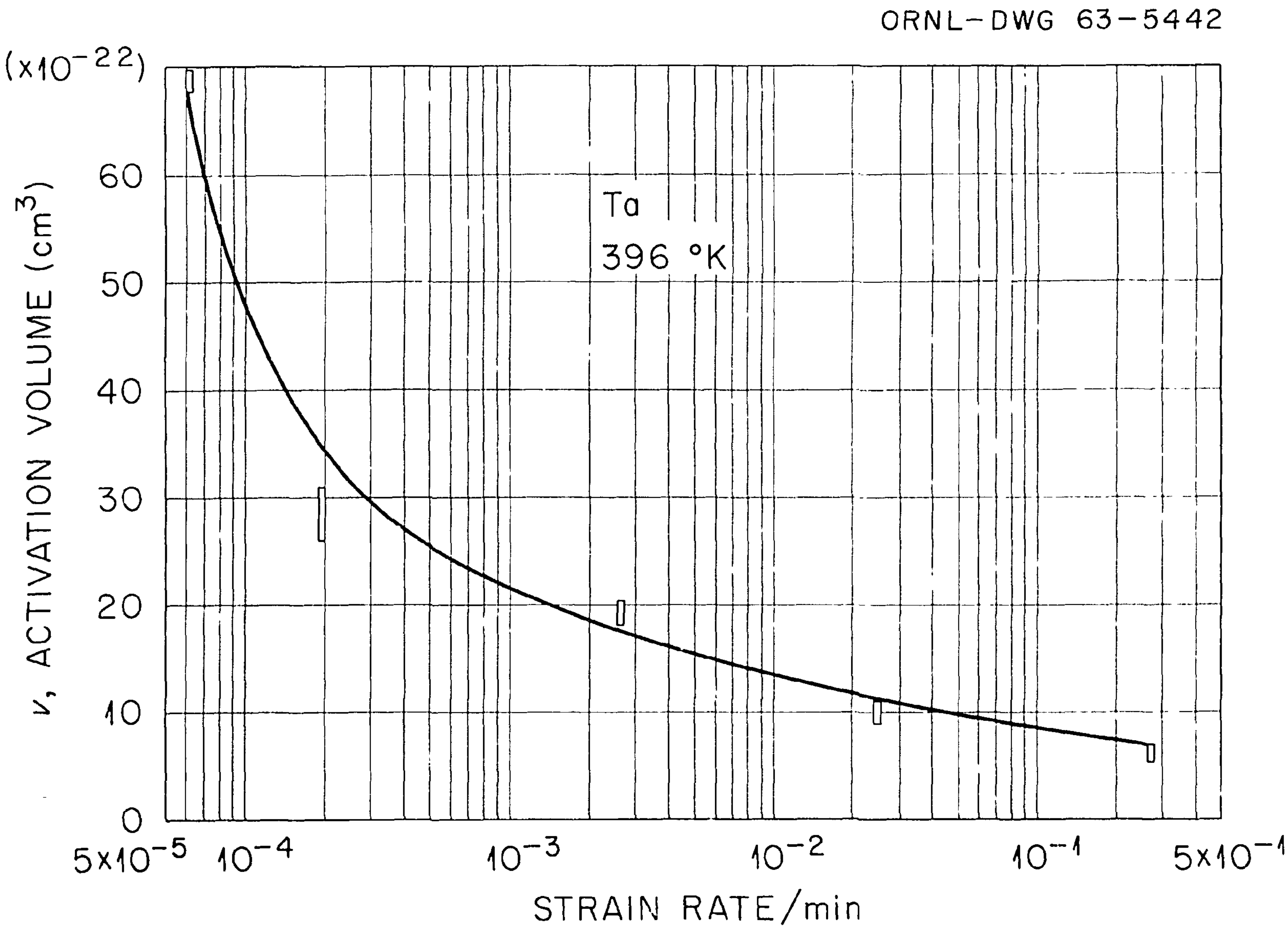

Fig. 10.8. Instrument air system.

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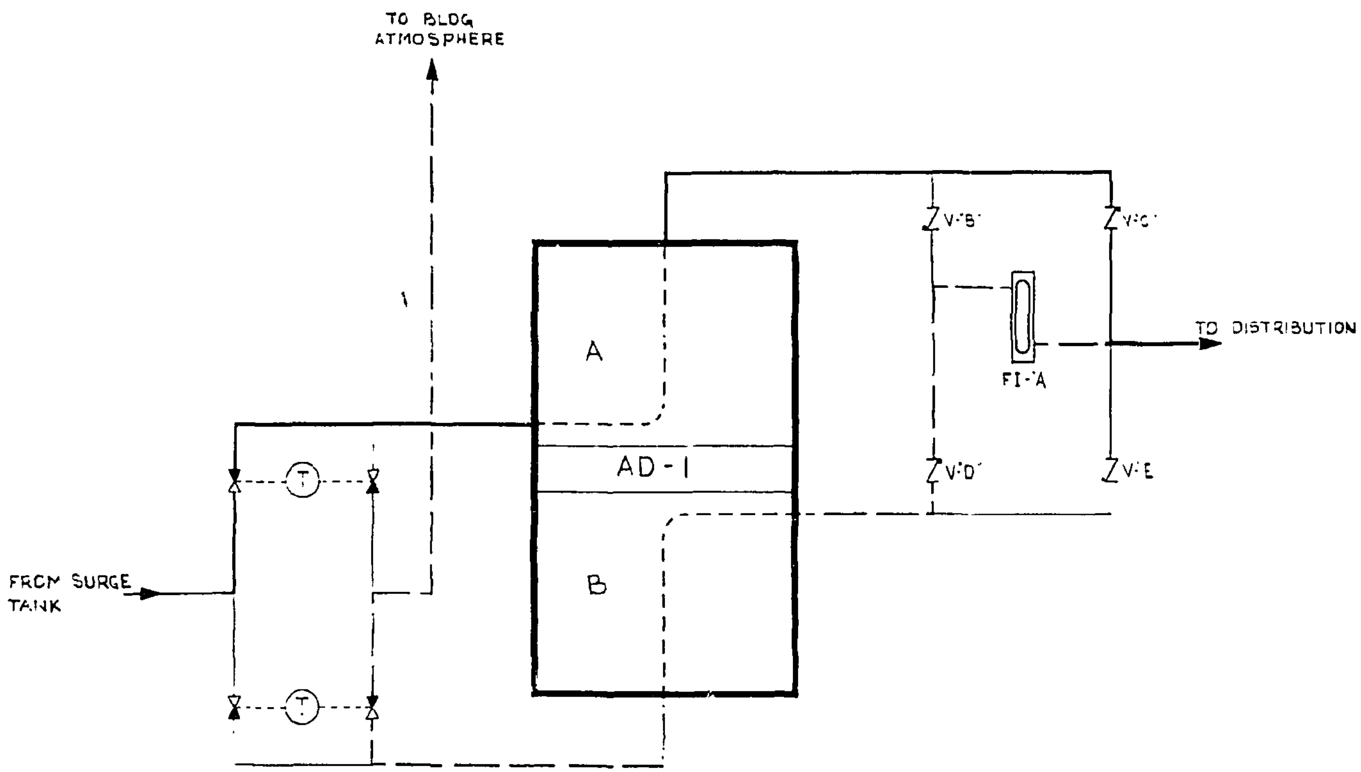

FLOW PATHS SHOWN WITH 'A' UNIT DRYING, 'B' UNIT REGENERATING

——— NORMAL FLOW PATH

— — — REGENERATION FLOW PATH, ~ 50 CF

Fig. 10.9. Simplified flow diagram - air dryer.

compressor is supplied power from the normal power system and will not run during a normal power outage. The compressor has, however, a standby-start feature whereby it starts automatically when the receiver pressure drops to 365 kPa gage (53 psig).

Other control features of C-1A compressor are as follows:

a. An oil-pressure switch which shuts down the compressor when the oil pump discharge pressure drops to 103 kPa gage (15 psig). A time-delay relay prevents operation of this feature when starting the compressor. This switch also operates the running light located in the main control room.

b. A water-flow switch which shuts down the compressor upon loss of cooling water flow to the compressor cylinder head. A time-delay relay also prevents operation of this feature when starting the compressor.

c. A compressor main-bearing-temperature switch shuts the compressor down when the bearing temperature reaches 71°C (160°F).

d. A temperature switch shuts the compressor down when the compressor output air temperature reaches 232°C (450°F).

e. Pressure switch PS-651a initiates an alarm in the control room and starts the standby compressor when the air receiver pressure drops to 365 kPa gage (53 psig).

f. A "Standby-Off-Start" selector switch is located in the main control room to select its operating mode. The local "Off-Auto" switch allows a local stop feature.

g. Indicating lights in the main control room indicate "off," "standby," and "running" conditions.

h. Two pressure indicators are located in the main control room to give "normal" and "emergency" air system pressure indications.

i. A temperature switch located in the main header downstream of the aftercoolers actuates an alarm in the main control room if the air temperature exceeds 43°C (110°F).

Air compressors C-1B and C-1C, usually on standby, operate in exactly the same manner as C-1A with the exception that C-1B is supplied power from the No. 2 Normal-Emergency System and C-1C is supplied power from the No. 1 Normal-Emergency System.

A moisture detector, AmI-627, located on the main distribution header, measures moisture content of the output air. It in effect measures the efficiency of the air dryers and moisture separators.

10.7.4 Emergency operation

Air compressor C-1A is operated from the normal power system through MCC "A." In the event of a failure of normal power, the compressor will stop and will not restart until normal power service is restored.

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 start 30 s after the No. 2 diesel generator assumes the load if the receiver air pressure has dropped to 365 kPa gage (53 psig).

Compressor C-1C 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 start 30 s after the No. 1 diesel generator assumes the load if the receiver air pressure has dropped to 365 kPa gage (53 psig).

If the air pressure at the three air receivers which supply the servo systems drops to 296 kPa (43 psig), the emergency air compressor

C-3 will start. This compressor loads at 414 kPa gage (60 psig) and unloads at 483 kPa gage (70 psig). It 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 start 30 s after the No. 2 diesel generator assumes the load if the servo system air pressure has dropped to 296 kPa gage (43 psig).

Pressure switches PS-654, -655, and -656 actuate alarms on panels B, C, and D, respectively, in the main control room should the pressure in the three servo systems air receivers drop to 221 kPa gage (32 psig).

10.8 Electrical System

10.8.1 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

10.8.2 Description of systems (Fig. 10.10)

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, and
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 second feeder is an emergency alternate. These two feeders supply the normal-power system. An automatic swtiching 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.

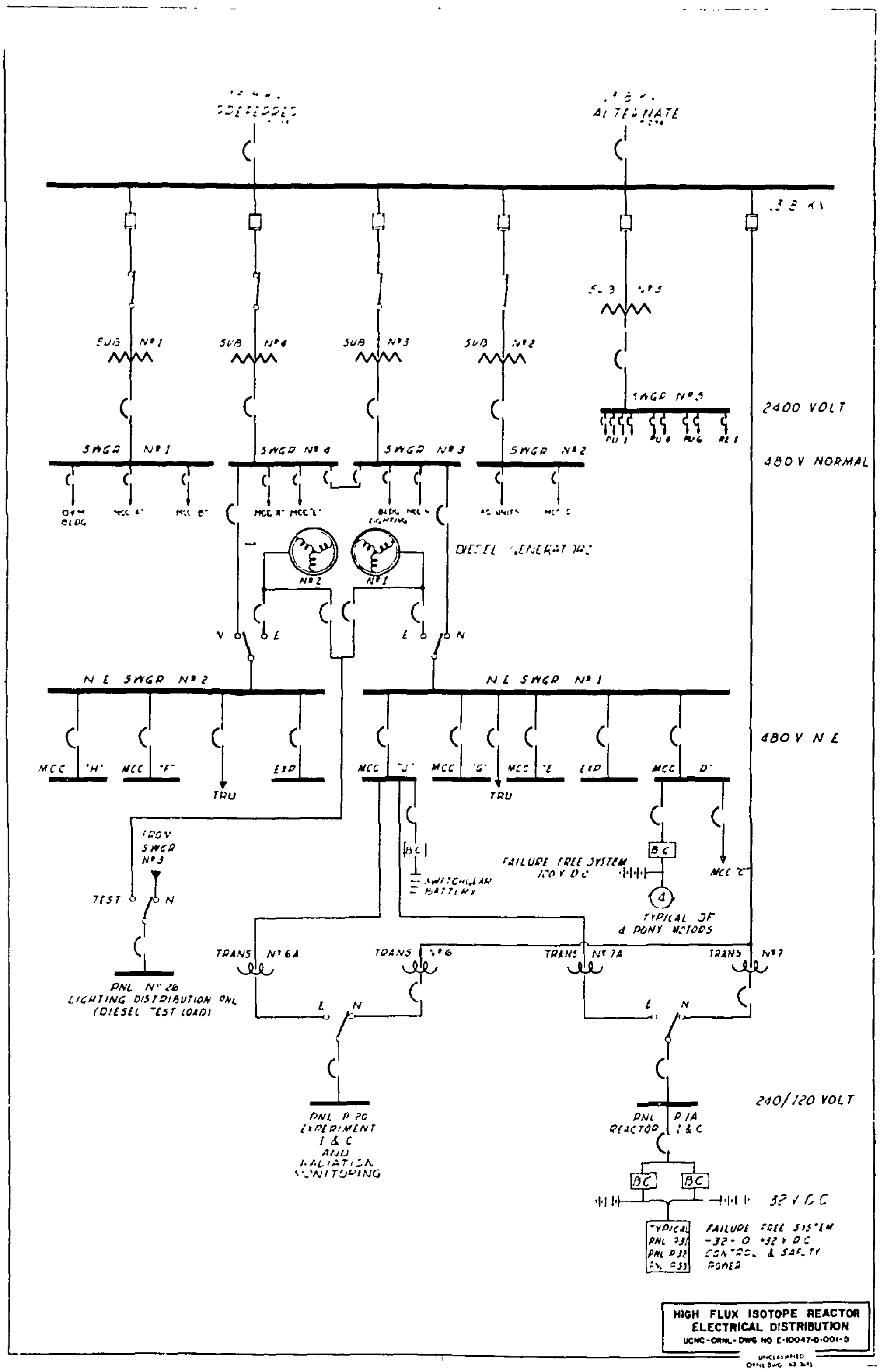

Fig. 10.10. Electrical distribution.

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.

10.8.3 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 A 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 voltmeter 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-A, 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 alterntate feeder after a delay of approximately 2 s, 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-V power, four supply 460-V power, and two supply 120/240-V instrument power. Three of the 13.8-kV--460-V tranformers 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 wye--2400-V delta, 5,000 kVA self-cooled, 6,667 kVA forced air cooled, 3 phase, 60 cycles. The 2,400-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:

(a) freedom from transient overvoltages which occur on ungrounded system,

(b) simple relaying of ground faults, and

(c) 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.

3. Electrical building (Fig. 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 swithgear, 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.

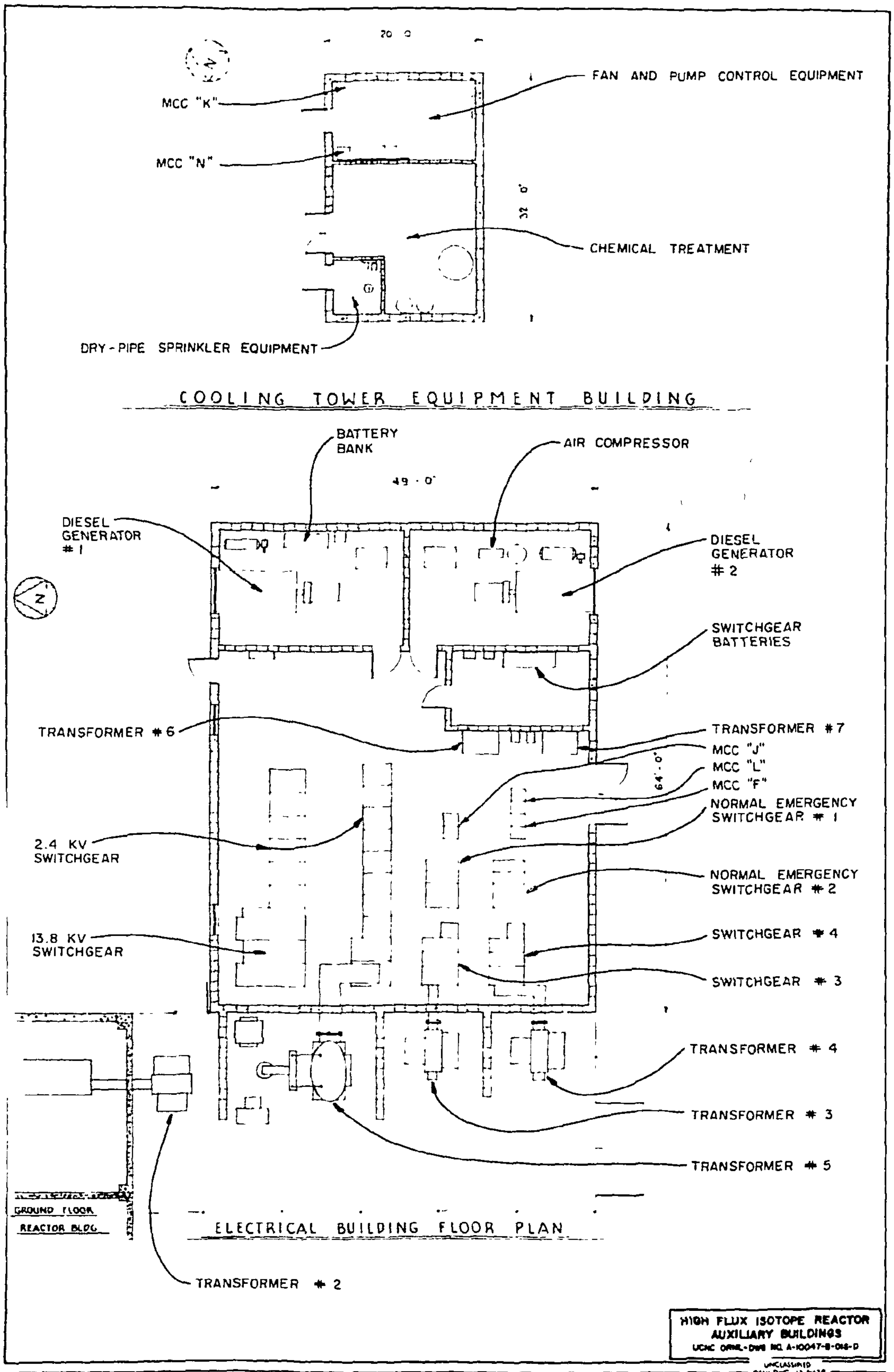

Fig. 10.11. Electrical equipment.

1. Sequence of operation (Figs. 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 2-s duration, auxiliary contacts in the automatic transfer switches start the diesels as follows:

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 except the feeder breaker to MCC "G,"
   (3) apply a trip impulse to the diesel test loading circuit breaker, and
   (4) crank the diesel in the following cranking cycle--"crank for 15 s--wait for 15 s--crank 15 s--wait for 15 s--crank for 15 s--stop."

b. The normal-emergency system No. 2 will:
   (1) de-energize the solenoid coils to open the valves supplying air to the air motor [Two parallel 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,"

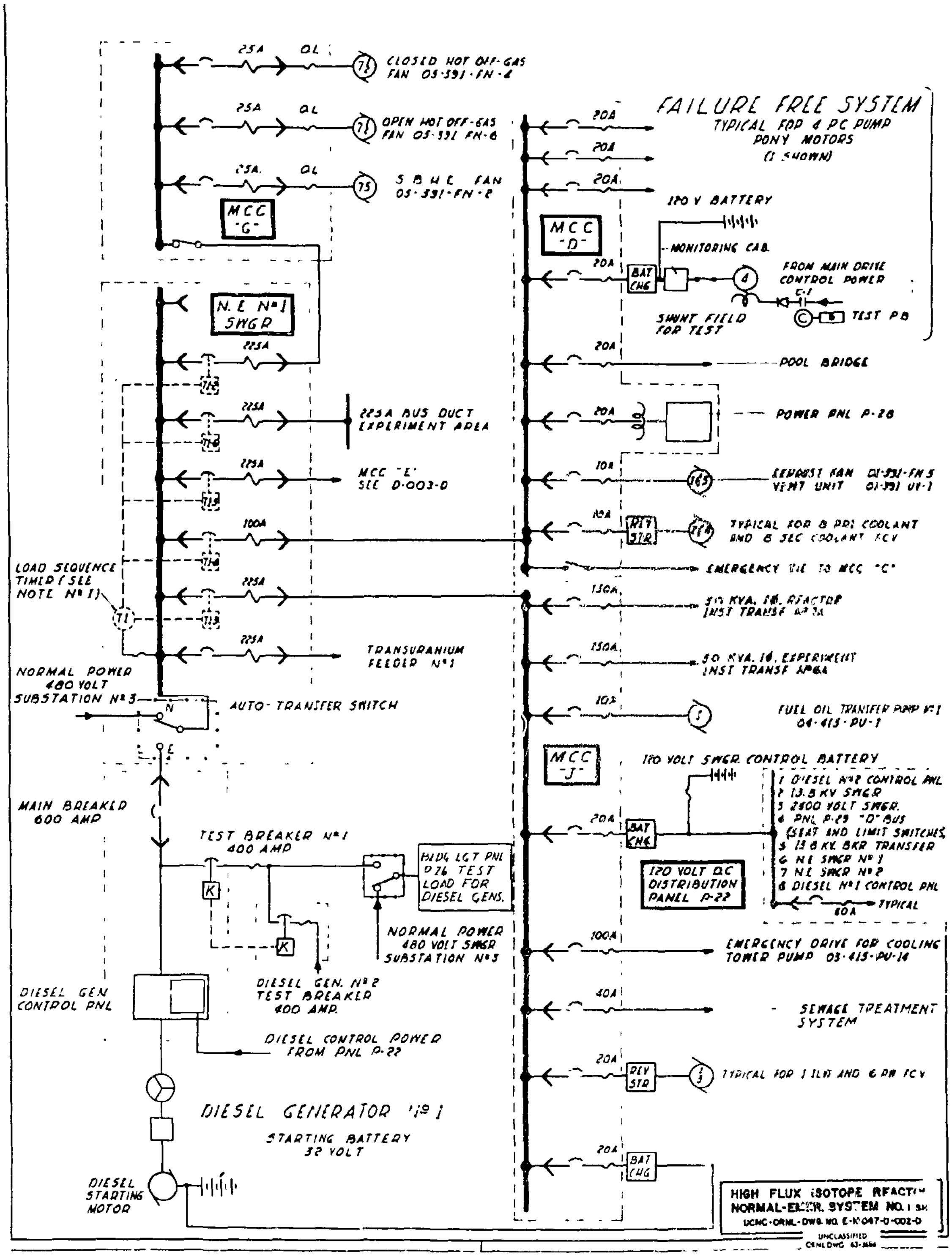

Fig. 10.12. Normal-emergency system No. 1.

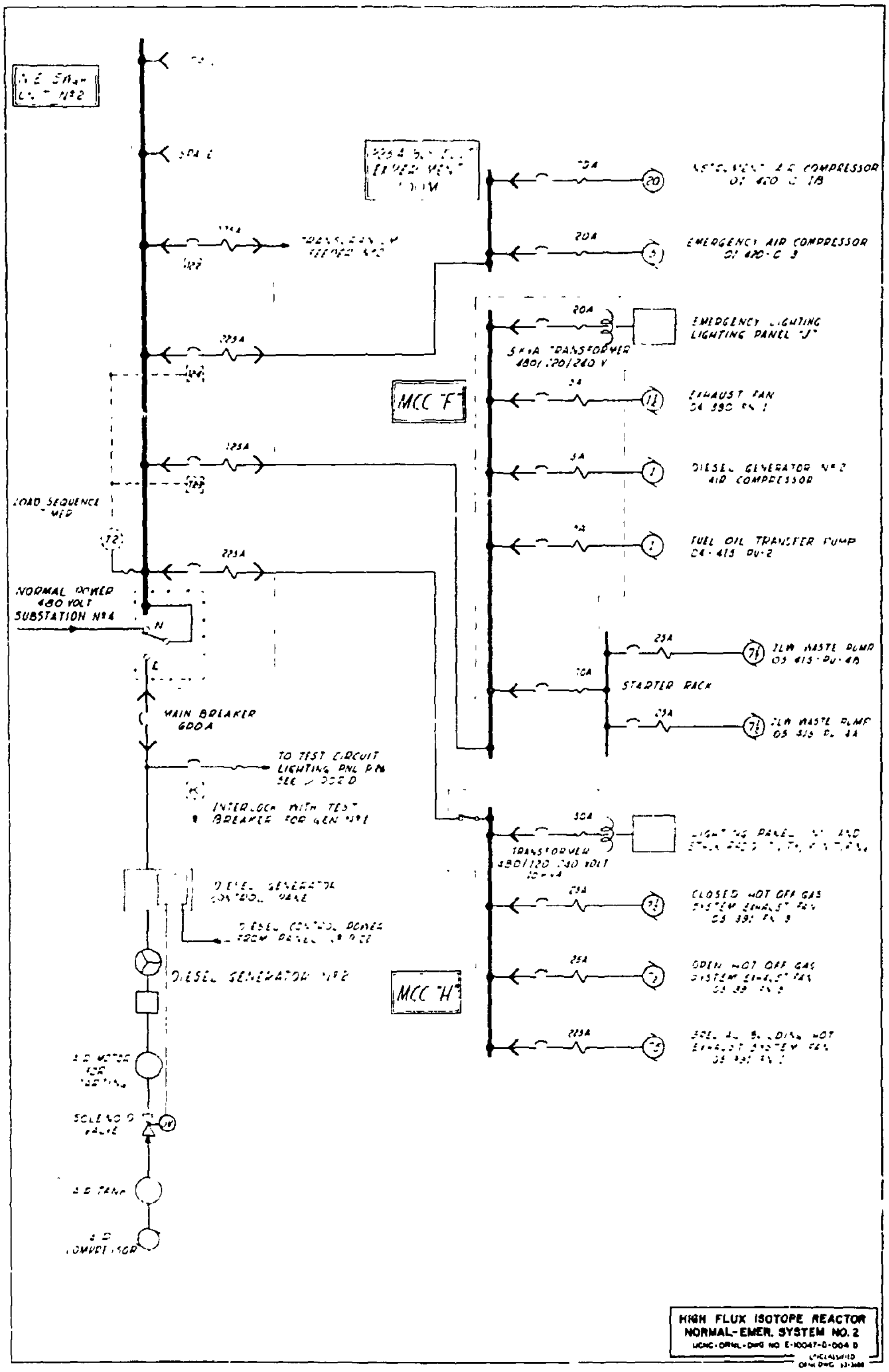

Fig. 10.13. Normal-emergency system No. 2.

(3) apply a trip impulse to the diesel test loading circuit breaker, and

(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 38°C (100°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- 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 621 kPa to 1.034 MPa (90 to 150 psi). The presure regulator reduces the inlet pressure from a maximum of 1.724 MPa (250 psi) to 0.621 to 1.034 MPa (90-100 psi) at the air-motor inlet. An air receiver is provided with sufficient capacity for five air starts of approximately 5-s 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 1.724 MPa (250 psi) within 30 min, starting with atmospheric pressure in the air receiver. A safety valve is set at 2.068 MPa (300 psi) to protect the pressure system.

(3) Fuel oil storage (Fig. 10.14)

The fuel oil supply system for the emergency diesel generators includes a 15,140-1 (4,000-gal) fuel oil storage tank, individual 227-1 (60-gal) day tank for each unit and associated pumps and piping required for oil transfers. The 14,140-1 (4,000-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 277-1/h (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

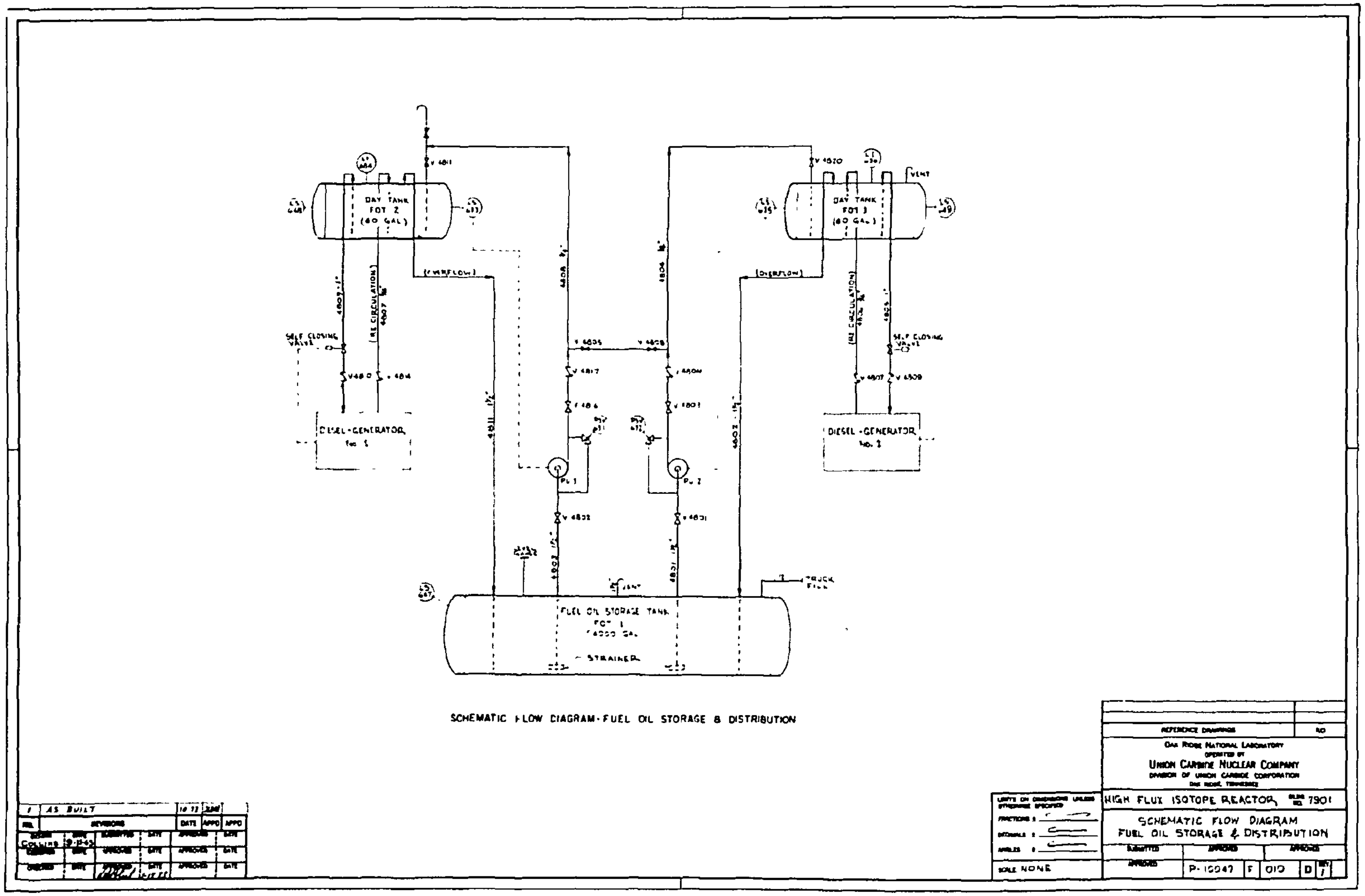

Fig. 10.14. Schematic flow diagram fuel oil storage and distribution.

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 overheating. Each generator unit contains an integrally mounted static exciter, regulator, and control panel which provide a steady-state voltage regulation of $\pm$ 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 A, mechanically held for operation on 3-phase, 3-wire, 6-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 2-s. 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 2-s 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 A, 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) wihtout 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, and

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 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 A 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 h. The pony-motor batteries, battery chargers, and metering equipment are located in battery room G-13 on the 249-M (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 A 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 V (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 A continuously at 129 V.

Instrument-power system (Fig. 10.15). 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 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--120/240 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 A, 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

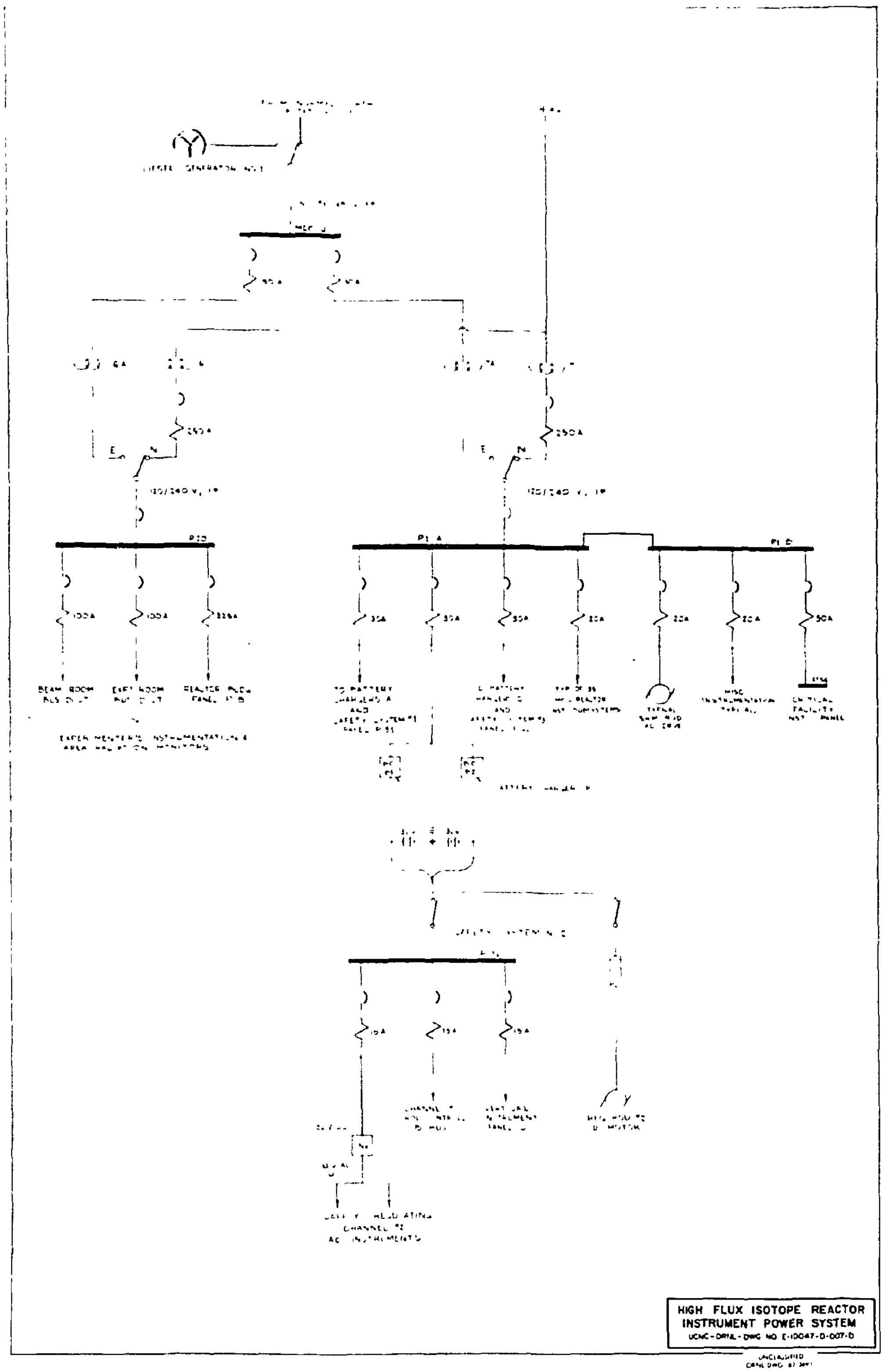

Fig. 10.15. Instrument power system.

period of 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; and

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.

10.8.4 Normal-power outage

The HFIR is designed to operate at a reduced 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 power level consistent with flow. During steady-state operation, the power level is requested by the operator. If the main circulating pumps stop, as will be the case during a power failure, the primary coolant flow will 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 the value allowed by the flow rate. 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. In the event No. 1 diesel-generator fails, the battery charger load may be manually connected to the No. 2 diesel-generator.

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 125 l/min (33 gpm) auxiliary pressurizer pump. This pump maintains system pressure, provided leaks do not exceed the capacity of the pump. If primary coolant loop pressure falls below 4.123 MPa (600 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 11,355 l/min (3,000 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 1,514,000 l (400,000 gal) 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 let down 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 82-93°C (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 93°C (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 four instrument air compressors to ensure a continuous supply. Two of the three 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.

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.

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 11.36×10^9 l (3,000,000 gal) is large enough to permit operation for an extended time.

Process water is supplied to the area from the potable water system through backflow preventers and is available as long as potable water is available.

10.9 Communications Systems

10.9.1 References

Drawings:

1546005-E-2085 Block Diagram, Intercom System

Singmaster and Breyer Specifications:

107 Electrical Work, Intercom System

10.9.2 Intercom system

The intercom system provides a convenient method of communication between persons in different areas of the HFIR site. The system consists of a master station, staff stations, and all required amplifiers, power supplies, and connecting wires.

Master stations. The master unit is designed to selectively originate calls to other staff stations by depressing the proper buttons. It may also receive a call from any staff station which has its talk button depressed regardless of the staff station selected on the master. One of two speakers may be selected by a toggle switch on the reactor console. One is contained in the master unit and the other is mounted on the console. Electrical power is supplied from normal-emergency system No. 1.

Staff station. The staff stations are designed to reply to the master staion but are capable of originating calls to the master station. Each staff station has a volume control and a "Talk-Listen" button. Certain staff stations, which are located in noisy areas, are surrounded by a sound barrier to make listening easier.

Number	Locations of staff stations
4	Auxiliary control room, west end
5	Reactor bay, poolside northwest
6	Reactor bay, north
7	Reactor bay, poolside east
8	Reactor bay, poolside southwest
9	Experiment area, southwest
10-1	Experiment area, monitoring platform
10-2	Experiment area, north

Number	Locations of staff stations
11	First floor, room 103-D
12	First floor, water wing
13	Beam room, south
14	Beam room, north
15	Ground floor, water wing
16	Ground floor, pipe corridor
17	Subpile room
18-1	Electrical building
18-2	Pony motor battery room
19-1	Cooling tower equipment building
19-2	Top of cooling tower
19-3	Water softener building
20	Fan shed
21-1	Counting room
21-2	Rod drive staff shop
22	Health Physics room
23	Truck air lock entrance
24	Auxiliary control room, east

10.9.3 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-5
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	

10.9.4 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 unneccessary calls. On night shifts and weekends, calls to the HFIR offices are transferred to the reactor control room.

10.9.5 Public-address system

Public-address system microphones are located in the main control room, 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
Cooling tower	2

Area location	Number of Speakers
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 Section to:

1. Carry out all operations with as low as reasonably achievable 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 contaminatin 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 reasonably achievable 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 and Industrial Safety functions must be regarded as purely advisory. Though Industrial Safety and Applied Health Physics personnel are alert to radiation hazards and do report them, they do not assume the primary responsibility which is assigned to the Division. Only the Division is assumed to be familiar enough with its own operations to evaluate the hazards involved; however, Industrial Safety and Applied 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 and Industrial Safety 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, and
6. establish eating places as required and in accordance with Health Physics and Industrial Safety specifications.

Health Physics and Industrial Safety 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.

11.3.1 Maximum permissible dose--normal conditions

The values indicated in the following tables (Tables 11.1, 11.2, and 11.3) are maximum values and only in exceptional cases should the accumulated RBE dose be permitted to exceed 10% of the values given.

Table 11.1. Maximum permissible dose (MPD) in rems

Organ	MPD per year	MPD age proration total (N = present age)
Total body, head and trunk, lens of eyes, gonads, or blood-forming organs	5	5(N-18)
Skin of whole body, thyroid	30	30(N-18)
Hands and forearms, feet and ankles	75	75(N-18)
Bone	30/n*	(30/n)(N-18)*
Other single organs	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

Organs	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	1500 mrems

*Laboratory-wide standards.

Table 11.3. Approval required for exposure to high dose rates

Dose rate range (rem/h)	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

The Reactor Operations Section limits are 50 mrem/week on whole body doses, to fully insure compliance with Laboratory standards with the other limits correspondingly cut in half.

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.

11.3.2 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, and
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

11.4.1 Radiation zone

A radiation zone is an area where control measures are established to prevent or minimize external radiation exposure (Table 11.4).

11.4.2 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 values shown in Table 11.5 is exceeded.

11.4.3 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.

Table 11.4. Regulations for posting and establishing radiation zones

Dose-rate range (rems/h)	Immediate action	Follow-up action
2.5 mrem/h to 5.75 mrem/h	Post low-level tag if the accumulated daily dose to personnel may be 20 mrem	Periodic review
6 mrem/h to 1 rem/h	Post warning signs or tags	Rope off the area if the accumulated weekly dose may be 1 rem
1 rem/h to 3 rem/h	Post warning signs or tags. Rope of 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/h	Post a guard until a temporary barricade has been erected. Lock and/or block entries	

Table 11.5. Regulations for posting and establishing contamination zones

Type of radiation	Air contamination (uc/cc)	Direct reading surface contamination	Transferrable surface contamination (d/m/100 cm^2)
Alpha*	2×10^{-12}	300 d/m/100 cm^2	30
Beta-Gamma	3×10^{-10}	0.25 mrad/h	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.

11.4.4 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, and
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 contamiantion 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 contamiation 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, and
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 Opertions 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.

11.6 Safety Work Permit

A Safety 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:

RADIATION WORK PERMIT (RWP)	DATE AND TIME FROM AM PM TO AM PM	EXTENDED BY TO AM PM	WORK PERMIT NO. R- 57086

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		RADIATION SURVEY	
					TYPE	MEASUREMENT	BY	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	

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		GLOVES: LEATHER		RUBBER BOOTS		DOSE-RATE ALARM	
HALF MASK		GLOVES: SURGEON'S		PLASTIC BOOTEES		DOSE ALARM	
ASSAULT MASK		GLOVES: PLASTIC		LAB COAT		CUTIE PIE	
CHEMOX MASK		GLOVES: RUBBERIZED CANVAS		SPECIAL FILM METER		GMS METER	
AIR-LINE HOOD		GLOVES: HOUSEHOLD RUBBER					
AIR-LINE SUIT							

REMARKS

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)

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Example 11.1. Radiation Work Permit

SAFETY WORK PERMIT

ISSUED TO: FOREMAN-IN-CHARGE	BADGE NO.	DEPARTMENT	PHONE	WORK ORDER NUMBER

GOOD FOR DATE AND TIME SPECIFIED

FROM: (DATE AND TIME)	TO: (DATE AND TIME)	BUILDING	ROOM

DESCRIPTION OF WORK

THE FOLLOWING PREPARATIONS HAVE BEEN COMPLETED IN CONNECTION WITH THIS WORK

GENERAL PREPARATION	Yes	Does Not Apply
1. Valves closed, tagged and locked		
2. Pipelines under pressure		
3. Pipelines drained and depressurized		
4. Pipelines blanked		
5. Pressure vessels checked and cleaned		
6. Pipelines and equipment purged		
7. Machinery and equipment safe for work to proceed		
8. Other (specify)		

PROTECTIVE EQUIPMENT	Yes	Does Not Apply
1. Protective Equipment Required		

CHECK OR SPECIFY EQUIPMENT REQUIRED

	TYPE OF CARTRIDGE OR CANISTER REQUIRED
HALF MASK	
FULL FACE MASK	
FRESH AIR MASK	

IMPERMEABLE SUITS   MONOGOGGLES

GLOVES   APRONS

OTHER (SPECIFY): ______

2. SPECIAL VENTILATION REQUIRED

3. OTHER

FIRE PREVENTION	Yes	Does Not Apply
1. Explosive atmosphere test required		
2. Nonsparking tools required		
3. Welding and or burning required		
IF WELDING AND/OR BURNING IS REQUIRED THE FOLLOWING PROVISIONS HAVE BEEN MET:		
4. Area personally inspected		
5. Surrounding floor area swept clean and wet down, if necessary		
6. All combustible materials removed to a safe location or protected with flame proof covers		
7. Ample fire protection equipment at hand: extinguishers, water pails, hose lines, etc.		
8. Monitor appointed		
9. Observer appointed, if necessary		

ELECTRICAL	Yes	Does Not Apply
1. Work is being done by nonelectrical personnel (Signature of Electrical Supervisor Required)		
2. Circuits have been de-energized		
3. Electrical tags and lock-outs		

INDUSTRIAL HYGIENE	Yes	Does Not Apply
1. Chemical stress (toxic or corrosive chemicals to be used or released)		
2. Physical stress (noise, heat, laser, ultra-violet or other physical agents)		
NOTE: If yes is checked in either 1 or 2, Ind. Hygiene must be contacted	Person Contacted	

I have personally inspected site and certify that the work area has been properly cleared for work and that conditions are safe for the work indicated. This Safety Work Permit is therefore approved for the class of work indicated. (Copy of Work Permit to be posted at work site.)

SUPERVISOR REQUESTING WORK ______ PHONE ______ FOREMAN-IN-CHARGE ______ PHONE ______

☐ WORK HAS NOT BEEN COMPLETED DUE TO: ☐ End of Shift ☐ Other Reasons (specify)   ☐ WORK HAS BEEN COMPLETED

This permit surrendered at ______ AM/PM   Signed ______ (FOREMAN-IN-CHARGE)   Badge ______

At Start of Work Original and copy to the Foreman-in-charge. On Completion of Work P & E, I & C, etc. will send the original and copy to the Division Safety Officer of the Foreman-in-charge's Division. Foreman-in-charge's Division Safety Officer will retain the original for his division file, forward the copy to the Industrial Hygiene Department, and prepare xerox copies for distribution to operating supervisor, Safety Department, and to the Fire Department when appropriate.

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Example 11.2. Safety Work Permit

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., and
5. any change in status of equipment, facilities, or system which would create additional hazards or eliminate any safeguards against hazards.

Safety Work Permit forms must be completed by the craft foreman and signed by that foreman and by a member of the Reactor Operations Section supervision.

11.7 Health Physics Instrumentation

Each member of the operating group of the Reactor Operations Section should be able to monitor for each type of radiation and radioactive contamination using all the common instruments.

The following tables (Tables 11.5, 11.6, 11.7, and 11.8) list the more commonly used instruments at ORNL and the pertinent data about each.

Table 11.6. 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 $\pm$ 5 mr, to 200 $\mp$ 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	Maximum audible warning at 0.5 r/h; flashing light becomes continuous at 10 r/h	Visible (light) and audible warning of radiation field	Signal frequency proportional to radiation intensity. Available in higher rate ranges

Table 11.7. 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/h	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	β > 0.2 MeV, γ	Three scales: x1, x10, x100 x1 may be 600-800 counts/min full scale	Detection instrument for β > 0.2 MeV and γ. Rate meter and audible pulse. Indicates <u>approximate</u> γ dose rates between 0.05 and 20 mr/h	Energy dependent. Should be used with earphones for faster response. Sliding shield for β-γ discrimination. Some models saturate above 50-100 mr/h and will not indicate higher dose rates. Commercial instruments insensitive to low β energies, unless equipped with thin window counter
3. Alpha Proportional Counter (gas) (PAC-3G)	Proportional counter, gas		May detect as little as 50 d/min α in presence of 1 rad/h γ; range to 500,000 d/min	Analysis of mixed γ, β, and α radiation; discriminates between α and β-γ	More stable than air proportional counter. Reading not dependent on section of probe face receiving radiation, as with scintillation counter. Grade or type of gas used should not be changed without recalibration

Table 11.7. (continued)

Instrument	Detector	Radiation detected	Range (nominal)	Application	Remarks
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 s	Can discriminate against intense γ radiation (measures 200 N_{th}/cm^2 s in field of 10 rad/h γ)	Employs B^{10} + N Li^7 + reaction
5. Fast Neutron Proportional Counter (Rudolph)	Proportional counter, gas	N_f	0.1 to 100 mrad/h	Measure first-collision tissue dose of N_f from 0.2 to 14 MeV. Discrimination a problem in γ fields above 2 r/h	Tissue-equivalent walls and gas

Table 11.8. Area monitoring instruments

Instrument	Detector	Radiation detected	Range (nominal)	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 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/h	Dose-rate meter for γ back-ground 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 set-ting unless users are warned of low-sensitivity setting. Where background permits, alarm should sound at 7.5 mr/h. 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 11.9. Personnel and area contamination monitoring instruments (fixed)

Instrument	Detector	Radiation detected	Range (nominal)	Application	Remarks
1. Hand and Foot Monitor	Halogen quenched G-M tube	β, γ	Low-level	Simultaneous detection of β and γ contamiantion 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 transuranium 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. Headers branch from the underground secondary supply-and-return lines east of the reactor building. These 30.5-cm (12-in.) 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 5.1-cm (2-in.) 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 1,700 m^3/min (60,000 scfm). Since the HFIR exhaust requirements are only about 850 m^3/min (30,000 scfm), another 850 m^3/min (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. Upon a normal power outage, the TRU feeder breaker in each system is tripped out and recloses 10 s after the normal emergency switchgear transfers the loads to the diesel-generators.

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