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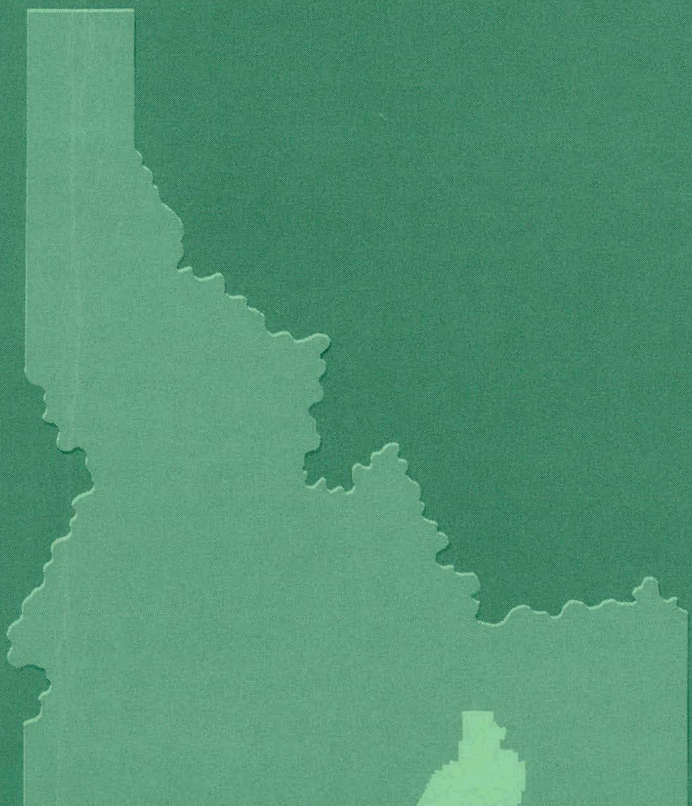
SPERT II REACTOR FACILITY

C. R. Montgomery



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SPERT II REACTOR FACILITY

by

C. R. Montgomery

PHILLIPS
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Atomic Energy Division
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SPERT II FACILITY REPORT

ABSTRACT

The Special Power Excursion Reactor Test II (Spert II) reactor is a pressurized-water nuclear research reactor which has been constructed to provide a facility for conducting reactor kinetic behavior and safety investigations. The facility incorporates sufficient flexibility to permit studies on a variety of cores using a variety of reflectors, especially heavy water. It is designed for operations up to pressures of 375 psig and temperatures of 400°F with flow rates up to 20,000 gpm This report describes the engineering features of the reactor and supporting process equipment as constructed at the National Reactor Testing Station.

SPERT II REACTOR FACILITY

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SPERT II FACILITY REPORT

I. INTRODUCTION

The Special Power Excursion Reactor Test (Spert) project, operated by Phillips Petroleum Co., was established as part of the U. S. Atomic Energy Commission's reactor safety program in 1954, and is directed toward experimental and theoretical investigations of the kinetic behavior and safety of nuclear reactors. A review of the overall Spert program and the kinetics and safety program in general is discussed in other reports [1, 2]. The Spert II reactor facility described herein has been constructed as a part of this safety program to fulfill the need for an intermediate pressure facility in which to conduct reactor behavior and safety studies under widely varying nuclear and operating parameters.

General objectives of the facility design were: (a) to provide a facility in which reactor power excursion tests could be performed and experimental information gathered on the kinetic behavior of the reactor; (b) to incorporate in the design a complete reactor and coolant system that could be equally adaptable as a light- or heavy-water system to permit investigation and evaluation of both systems and combinations of both systems in one facility; (c) to incorporate sufficient flexibility in the reactor to permit studies on a variety of cores using a variety of reflectors; and (d) to incorporate in the reactor sufficient volume to permit studies of the effects of neutron lifetime and variable plate spacing.

Power operation was not an objective in the design of the facility. The majority of the experimental studies are to be conducted from low initial reactor powers, and involve a relatively small total energy release.

The major components of the facility include a reactor vessel; a pressurizing vessel; one primary coolant loop, including pumps; a D_2O storage tank and cleanup facility; and a heat exchanger for cooling the coolant-moderator after shutdown. The reactor vessel and primary coolant system are designed for operation at pressures up to 375 psig and temperatures up to 400°F. Coolant system flow rates up to 20,000 gpm are available for either upflow or downflow through the core. Auxiliary equipment necessary for operation of a reactor of this type also has been included.

The major plant equipment is operable from controls located in both the reactor building and control center. The reactor is remotely operable only from the controls located in a control center building approximately 1/2 mile from the reactor. No external shielding is provided for the reactor.

The design of the Spert II reactor facility represents the recommendations of the Spert Advisory Panel, the Spert staff, and the suggestions of many other laboratories interested in the reactor-kinetics program. The conceptual design of the facility was prepared by Phillips Petroleum Co. Engineering design and inspection were completed by the Stearns-Roger Manufacturing Co. under an architect-engineer contract with the USAEC. The reactor control system, reactor core structure, control rods, control rod drives, and fuel were designed and procured by Phillips. Construction was accomplished by a lump sum contract with Paul Hardeman, Inc. as the prime contractor. Construction was completed and the facility accepted for operation by Phillips in February 1960.

This report describes the final design of the Spert II reactor facility as of March 1963. All previous publications [3, 4, 5], on this facility have either been based on preliminary design information or have presented only limited information. The present report should provide Spert personnel, as well as other engineers and scientists actively engaged in reactor kinetics programs, with a convenient reference on the plant as built.

II. PLANT SITE AND BUILDINGS

1. SPERT SITE

The Spert site is located within the boundaries of the National Reactor Testing Station approximately 50 miles west of Idaho Falls, Idaho. The location of the site with respect to other NRTS installations is shown in Figure 1.

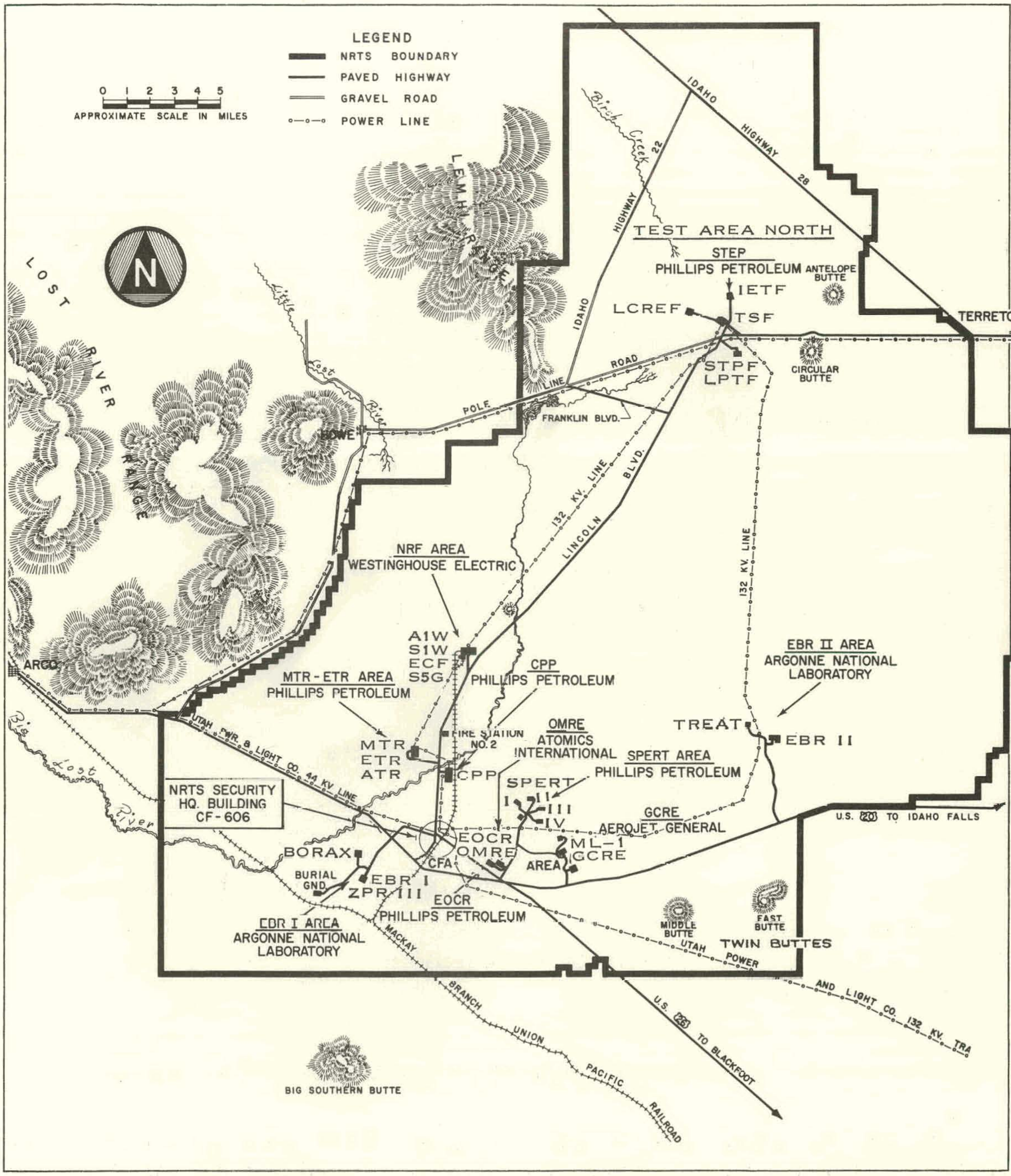


Fig. 1 Map of National Reactor Testing Station.

A general plan of the Spert site is shown in Figure 2. The nucleus of Spert operations is the Control Center. The reactor areas have been arranged in a semicircle of approximately 1/2-mile radius from the Control Center and at least 1/2 mile from each other. Spert II is approximately northwest of the Control Center. The other reactor areas are spaced at approximately 60° increments clockwise to give four reactor sites in the 180° arc.

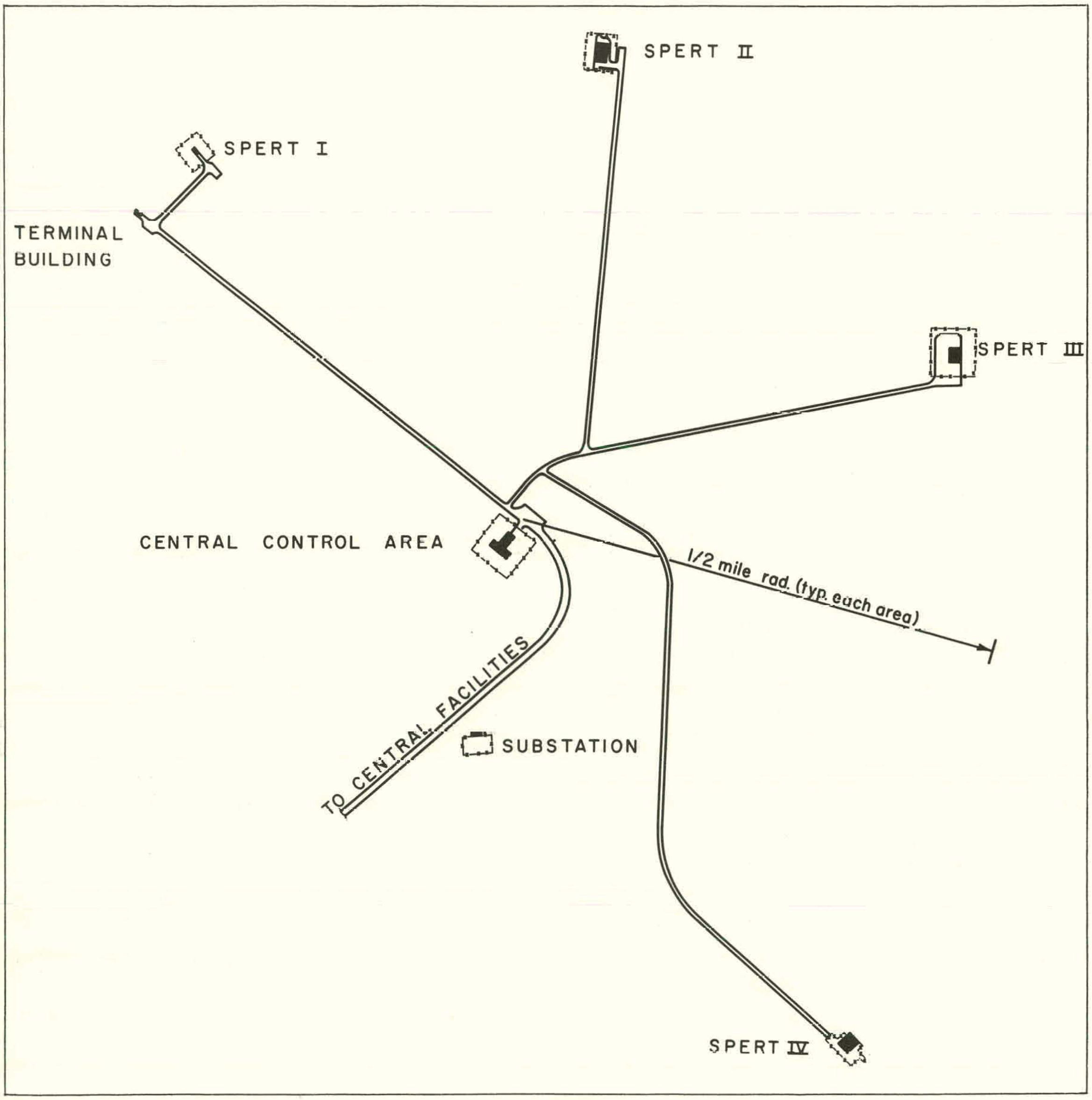


Fig. 2 Plan of Spert site.

2. CONTROL CENTER AREA

The Control Center area forms the center of the Spert operations. Within the 250- x 250-ft fenced area are the Control Center building and the raw water storage and distribution equipment for the Spert site. The Control Center building houses offices and laboratories, a darkroom, instrument and mechanical work areas, and the reactor controls and instrumentation for all the Spert reactors.

Water for the Spert site is supplied from two wells located near the Control Center area. Electrical power is supplied to the Control Center area and reactor areas from 13.8 kv feeders from the Spert substation. Power to the substation is obtained from the 132-kv NRTS distribution loop.

3. SPERT II AREA

The Spert II reactor building is located approximately 1/2 mile north of the Control Center. A general layout of the area is shown in Figure 3.

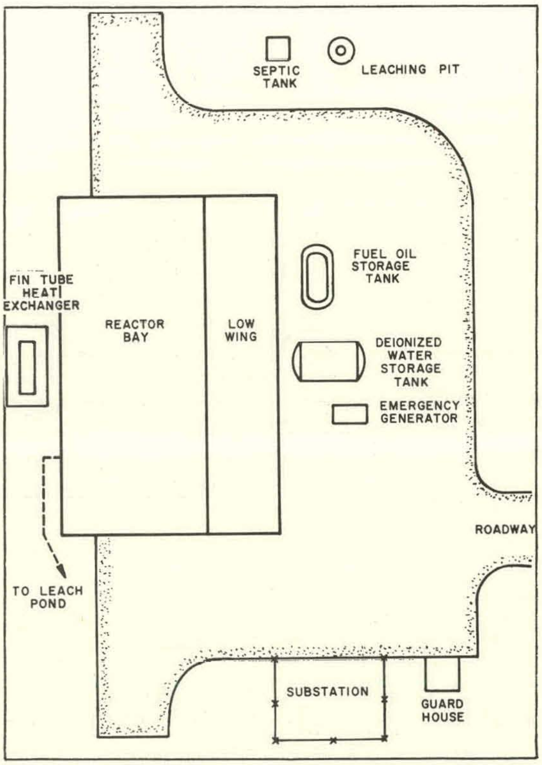


Fig. 3 Spert II area.

A substation located south of the main reactor building provides electrical power for the area. The substation consists of a 1500-KVA, 3-phase, 13.8-kv, 2400-v transformer system which provides power for the two primary coolant pumps, and a 500-KVA, 3-phase, 13.8-kv, 480-v transformer system for all other power requirements.

Potable water is pumped from the Control Center area through a 4-in. pipeline, and is supplied to the building at about 68 psig pressure.

A septic tank and a leaching pit, northeast of the reactor building, are used for disposal of sanitary waste. A fenced leaching pond, south of the reactor building, is provided for the disposal of nonradioactive liquid waste and/or radioactive liquid waste whose activity level is within AEC disposal tolerances.

Additional equipment in the area include a fin-tube air cooled, heat exchanger, a 12,000-gal deionized water storage tank, a 2000-gal fuel oil storage tank, a 15-KVA emergency generator, and a small guardhouse.

4. SPERT II REACTOR BUILDING

4.1 General

The reactor building consists of a main structure, housing the reactor and coolant systems; and a wing structure, housing electrical switchgear, process controls, instrumentation, and auxiliary equipment. A reactor building plan and section are shown in Figures 4 and 5, respectively.

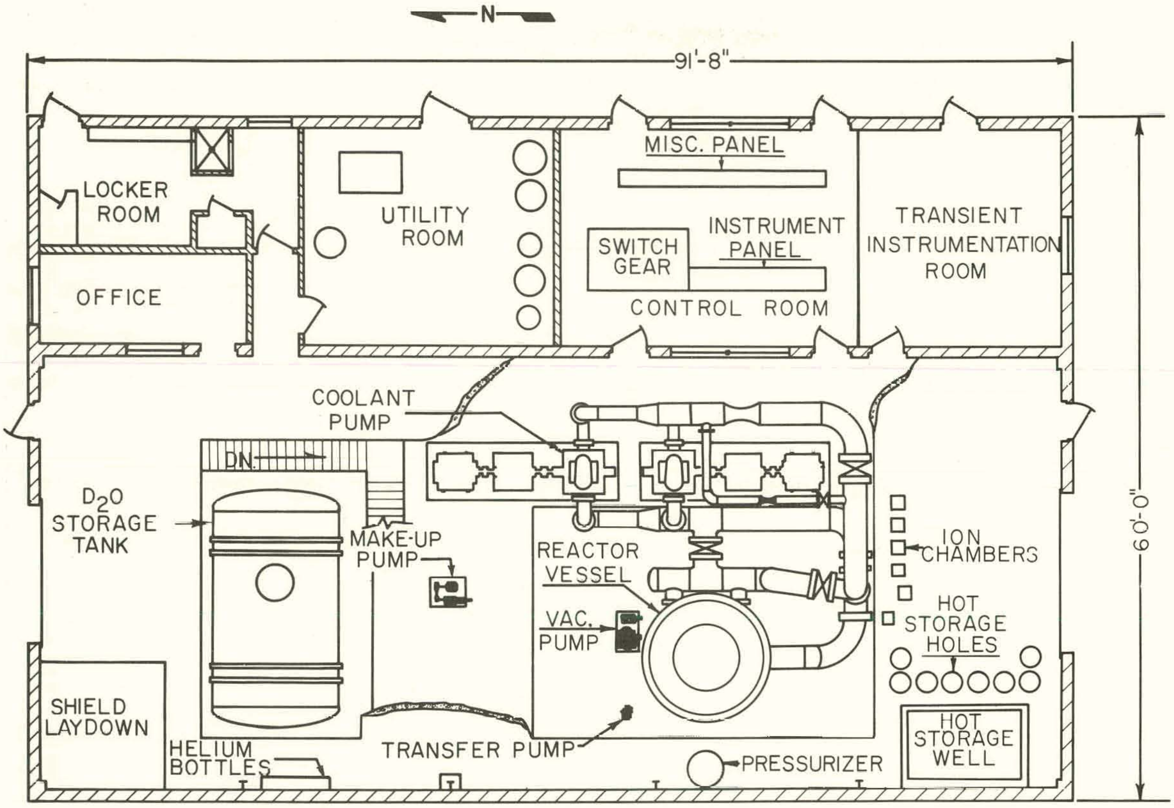


Fig. 4 Spert II reactor building plan.

4.2 Main Reactor Building

The main reactor building is a 40- x 90- x 30-ft-high, structural steel pumice-block structure. A 10-ton bridge and trolley overhead crane serves the 40- x 90-ft building area. A basement consisting of three levels is provided under this section of the building. Stairways at each end of the building provide basement access. The primary coolant pumps and piping, makeup pump, transfer pump, air compressor and receivers, D_2O storage tank, and auxiliary equipment for the D_2O system are located in the basement area. The reactor vessel, located in front of the process control room near the west building wall, extends into the basement. The area surrounding the vessel, on the main floor, is covered with removable steel grating for access to the basement levels. Two additional levels, covered with steel grating, are provided in the basement for access to the vessel shell. An 11- x 11-ft opening in the northwest corner of the floor provides access to basement storage space. A stainless-steel-lined fuel storage canal, 6 x 10 x 16 ft deep, is located in the floor at the southwest corner of the building. Additional fuel storage facilities include eight 6-in.-diam dry-storage holes. Each hole is 16 ft deep and is provided with a 10-in.-thick lead cover. Seven 6-in.-diam carbon-steel pipes buried in the floor provide locations for ionization chambers.

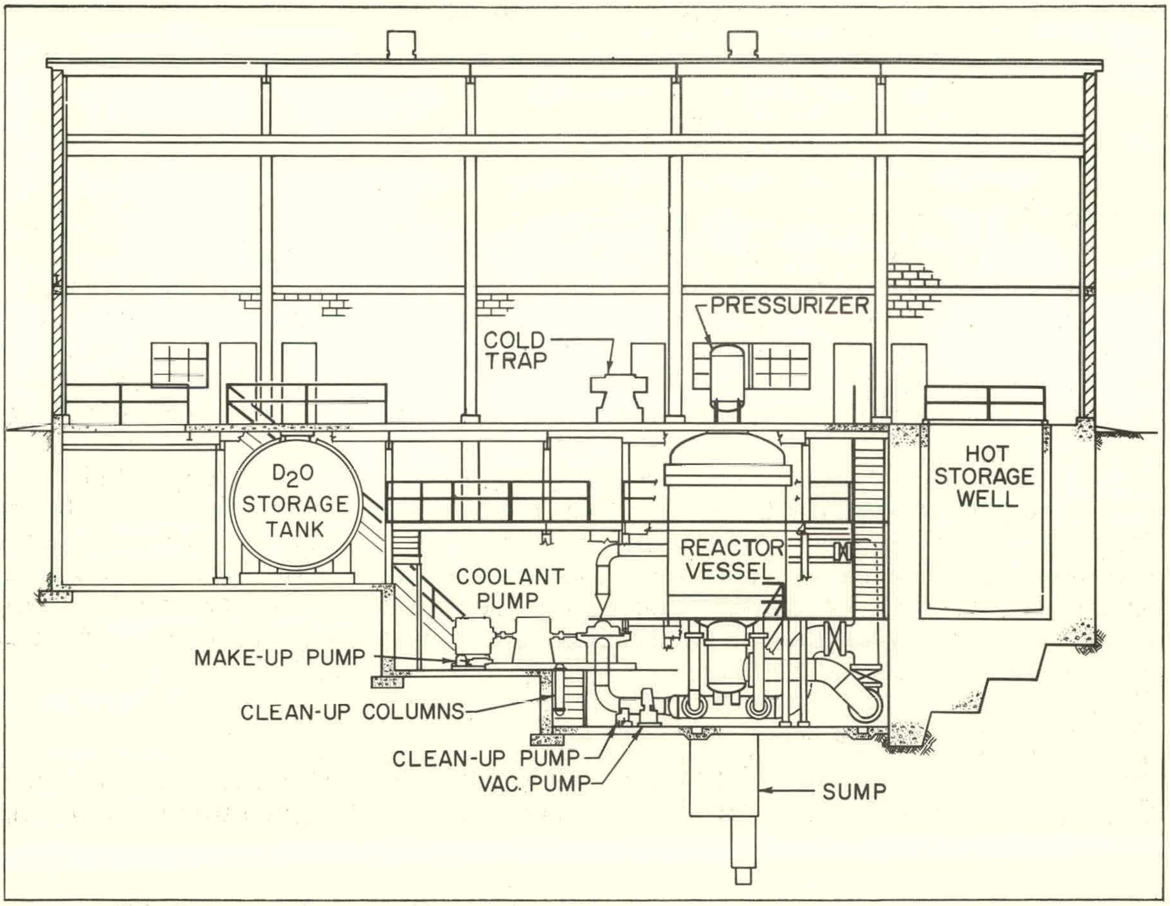


Fig. 5 Spert II reactor building section.

4.3 Wing Building

On the east side of the main building is a 20- x 90- x 12-ft-high wing building. At the north end of the wing is the office and locker room. The utility room contains the water-treatment equipment and building heating plant. Adjacent to this is the control room, which contains the process controls and instrumentation, switchgear associated with the process equipment and control system, and power distribution panels and transformers. The transient instrumentation room contains the power supplies and amplifiers to receive signals from detectors in the reactor and convert these signals to suitable form for transmission to the Control Center area.

III. REACTOR COMPONENTS

1. REACTOR VESSEL

1.1 Design Philosophy

The reactor vessel contains the nuclear components which will be used for various experimental reactor safety tests. These tests will be used to evaluate the effects of varying the operational parameters (flow, temperature, and pressure) on the kinetic behavior of the nuclear core. Incidental to, and as a direct consequence of these tests, the vessel will be subjected to stresses induced by shock loading, gamma-heat generation, thermal cycling, and pressure cycling.

The Spert II facility is located in a remote and sparsely populated area. Personnel are to operate the facility remotely, at infrequent intervals, and only for short periods of time. The total lifetime measured in days is extremely short and there was no apparent justification for a design philosophy which recognizes uniformly proportioned design taking into account stress concentration, cyclic loads, thermal stresses due to internal heat generation, and other conditions not covered by a code.

1.2 Design Conditions

The vessel was fabricated in accordance with the ASME Boiler and Pressure Vessel Code, 1956 Edition, Section VIII. The vessel is designed for the following conditions:

Design pressure	375 psig internal, 15 psia external
Design temperature	400°F
Minimum weld joint efficiency	95%
Radiography (includes all pressure strength welds)	100%
Minimum shop hydrostatic test pressure	655 psig
Minimum field hydrostatic test pressure	562 psig at 400°F
ASME Code inspection and stamping	required

1.3 General Description

The pressure vessel is illustrated in Figure 6. It consists of an access head, a full-opening hemispherical head, a rolled plate shell, a bottom head, and a 42-in.-diam well which is attached to the bottom head. The nominal inside diameter is 120 in., the overall length is 24 ft 6 in., and the dry weight is approximately 35 tons. Pressure parts, except for nozzle connections 6 in. and smaller are fabricated from carbon steel. All surfaces in contact with reactor water are either clad with stainless steel type 304L or with weld metal deposited from type 308L electrodes.

1.31 Access Head. The access head serves to mount the control rod drives and to maintain proper alignment between the core and the control rods. The head, along with the control rod drives, is removable to permit easy and frequent access to the core.

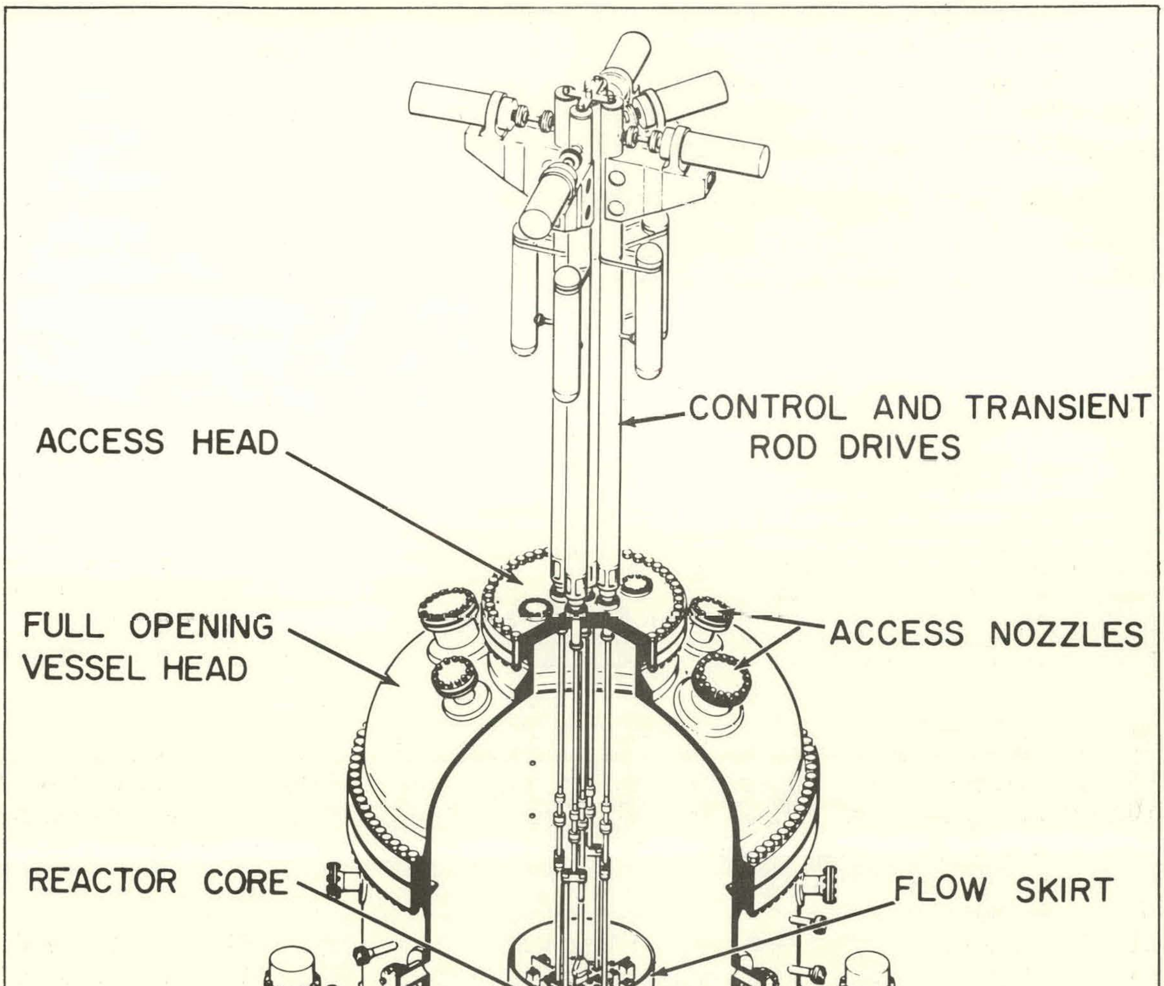


Fig. 6 Reactor vessel pictorial.

The head is fabricated from stainless steel plate, type 304L, and is 56-3/4 in. OD x 4-3/4 in. thick, and is held in place, against a sealing gasket, by forty-eight 1-1/4-in.-diam alloy cap screws. The cap screws are screwed into hex nuts tack-welded to the underside of a companion flange and nozzle (42 in. ID), which is a part of the hemispherical top head.

Five 3-in. control rod drive ports, and four 6-in. core access ports are machined into the plate. The control rod drives are bolted to the 3-in. ports and a seal is effected by stainless steel spiral-wound teflon filled gaskets.

1.32 Top Head Assembly. The top head assembly consists of a hemispherical plate forging and a ring forging. Plate material of the head is ASTM-A212, grade B, FBQ backing with 7% type 304L cladding; nominal thickness is 1-1/2 in. The ring forging is fabricated from ASTM-A181, grade II carbon steel, clad with a 1/8-in.-thick, type 304L stainless steel liner, plug-welded to the forging.

Welded into the head and extending upward is a 41-in.-diam nozzle and flange, which serve as support for the access head. The nozzle neck and flange are forged from ASTM-A181, grade II carbon steel. Both are clad with a 1/8-in.-thick type 304L, stainless steel liner. The liner is plug-welded to the neck and flange.

Additional attachments to the head consist of six 6-in., and two 10-in. flanged access nozzles. The 6-in. nozzles and flanges are stainless steel, type 304L. The 10-in. nozzles and flanges are forged from ASTM-A181 grade II carbon steel. The nozzle assemblies are clad with 1/8-in.-thick stainless steel liners, which are plug-welded to the nozzle assembly.

1.33 Shell. The vessel shell consists of a ring forging, ASTM-A181, grade II, and an integrally clad rolled plate shell. Plate material is ASTM-A212, grade B, FBQ backing with 7% type 304L cladding. The nominal thickness of the shell is 1-1/2 in.

Flanged nozzles for the removal of instrumentation leads are provided at several elevations around the vessel shell. The nozzles vary in size from 1 to 6 in., are equally spaced around the shell, and are fabricated from type 304L stainless steel.

In the lower half of the shell, eight flanged 2-1/2-in. nozzles are provided for the attachment of four 100-kw side arm immersion heaters.

Two thermocouples, located above and below the core, penetrate the vessel shell for measuring the temperature of the primary coolant in the vessel.

1.34 Bottom Head Assembly. The head consists of a hemispherical forging, ASTM-A212, grade B, FBQ backing with 7% type 304L cladding. The head is welded to the shell and has a nominal thickness of 1-1/2 in. Four 12-in. flanged nozzles, equally spaced, penetrate the head for the introduction or removal of coolant from the vessel. The nozzle necks are fabricated from ASTM-A212, grade B, FBQ backing with 8% type 304L cladding; the flanges are carbon steel, clad with 1/8-in.-thick, type 304L stainless steel liners plug-welded to the flanges.

Welded into the head and extending downward is a 42-in.-diam well, which consists of an integrally clad rolled-plate shell and forged head. Plate material is ASTM-A212, grade B, FBQ backing with 15% type 304L cladding. Nominal thickness of the shell and head is 3/4 in. The well also contains a 24-in. flanged coolant nozzle, and four 8-in. flanged nozzles for mounting four 50-kw immersion heaters.

1.35 Vessel Internals. The core structure and core are supported from the bottom of the vessel by a flanged nozzle. The nozzle assembly is welded into the bottom head and extends upward inside the vessel approximately 30 in. Both the nozzle and the flange are fabricated from type 304L stainless steel.

Eight, equally spaced, stainless steel brackets are welded to the bottom head to provide support for solid reflector pieces to investigate the effects of various types of reflectors on reactor behavior.

Provisions also have been incorporated in the vessel design for the use of water as a moderator, and heavy water as a reflector, or vice versa. Separation of the two liquids can be accomplished by the use of a metal diaphragm extending from the top of the core flow skirt to the vessel shell. Welded to the inside of the shell bolting flange is a stainless steel support ring. The support ring is provided with a round body ring gasket groove and 100 equally spaced tapped holes. The diaphragm can be bolted to the top of the core flow skirt and the support ring; the seal will be effected by the round body ring gaskets.

Four 100-kw and four 50-kw immersion heaters are provided to supply heat to the reactor vessel coolant-moderator. The 100-kw heaters are controlled by "on - off" selector switches; the 50-kw heaters are controlled through saturable core reactors by means of a temperature controller. Each heater consists of a number of tubular hairpin heating elements, heliarc-welded into a stainless steel blind flange. The heaters operate on 480-v, 3-phase, ac power with an element watt density of 20 watts per square inch.

1.4 Closures

Closure of the access head is effected by a stainless steel spiral-wound teflon-filled gasket. The gasket is compressed by 48 equally spaced cap screws, nominally 1-1/4-in. diam, on a 54-1/4-in. bolt circle diam. The cap screws are stressed to 20,000 psi by compressing the gasket to a predetermined thickness. Uniform compression is maintained by measuring the gap between the closure flanges as the bolts are tightened.

Closure of the full opening hemispherical head is effected by two concentric round body ring gaskets between the head flange and the vessel bolting flange. Two types of gaskets are used: for low-temperature tests (less than 200°F) both the inner and outer gaskets are Garlock Compound No. 9478 having a 1/2-in. cross section; for high-temperature tests the inner gasket is tubular stainless steel having a 1/4-in. section with 0.020-in. wall and an outer gasket of Garlock Compound No. 9478. The gaskets are compressed by 100 equally spaced cap screws, nominally 1-7/8-in. diam, on a 131-in. bolt circle diam. The cap screws are stressed to 20,000 psi by applying 2000 ft-lb or torque. Any leakage across the inner gasket is collected in an annulus between the two gaskets. Two 1/8-in. vents, 180° apart, from this annulus are brought out between the bolts for monitoring the intergasket leakage. Gas from an external source can be admitted to the intergasket annulus to verify the intergrity of each gasket.

1.5 Vessel Support

The pressure vessel is supported on a circular skirt welded to the bottom head, just below the circumferential weld between the shell and the bottom head. Mounting at this point allows both upward and downward thermal expansion of the vessel. The skirt is supported by an I-beam framework at an elevation approximately 10 ft above the floor of the reactor pit.

1.6 Vessel Geometry - Profiles

The specified permissible shell out of roundness was ± 1/4 in. on the diam. The actual concentricity achieved in fabrication was ± 1/8 in. The concentricity between the rod drive support flange, about a centerline projected through the vessel, and the core support flange was specified as 1/16 in. The actual concentricity achieved was 1/64 in. The face to face dimension between these flanges was held to 1/16 in. and the faces are parallel within 0.006 in.

The core support flange, rod drive support flange, and shell bolting flange are doweled to assure proper alignment.

1.7 Welds

Total radiographic inspection was required on all closure welds of the completed vessel. Techniques and procedures used were in accordance with ASTM E99-55T, class 2 definition. Nozzle connections penetrating the upper and lower heads posed particularly difficult radiographic problems because of the heavy metal sections encountered. Magnetic particle inspection was required for all carbon steel welds, and fluorescent penetrant inspection was required for all stainless welds.

Forged and rolled components of the vessel were stress relieved, before assembly, by heating to 1100 to 1150°F; holding 1 hr per in. of thickness and furnace cooled.

1.8 Pressure Tests

The specifications for the reactor vessel required a final hydrostatic test of 563 psig at 400°F after erection in the field. The shop hydrostatic test pressure was therefore adjusted to give an equivalent pressure, cold, based on those materials most sensitive to pressure and temperature. The most sensitive material was the type 304L stainless steel used in the nozzle design. The basis for calculating the equivalent pressure of these nozzles was ASME Boiler Code Case 1122-6.

The shop hydrostatic test was conducted, with the vessel in the horizontal position, at 655 psig at 70°F and held for 8 hr. Critical sections of the vessel were whitewashed to prove the strength of the design. Mercury plumb bobs were attached to the face of the rod drive support flange and to the face of a 3-in. nozzle in the bottom of the vessel to measure elongation during the test. A scribed line identified the start of the test, and a final scribed line was made at the 655-psig holding pressure. Elongation at the top of the vessel was 3/32 in., and 1/8 in. at the bottom of the vessel. The shell girth before the test was 32 ft 7-7/16 in.; at the 655-psig holding pressure it measured 32 ft 7-3/4 in.

A final measurement made after the pressure was dropped showed no permanent set in the shell. None of the whitewashed areas showed signs of distress and it was concluded that the design met ASME code requirements for the strength. The hydrostatic test was witnessed by a Hartford Insurance Co. inspector.

1.9 Cleaning Procedure

The interior surface finish of the vessel was specified to be 125 microinches or better in order to eliminate crevices or pockets wherein residue or radioactive material could lodge. All grinding, polishing, and buffing required to obtain such a finish was done in such a manner so as to prevent contamination of the stainless steel surfaces.

All interior wetted surfaces were cleaned of oil, grease, and other foreign materials. The surfaces were first cleaned with a detergent solution (150 lb of trisodium phosphate to 500 gal of 140°F water) to remove oil, grease, and other lubricants. The surfaces were then pickled with a 125°F solution of 10% by volume nitric acid (70%) and 2% by volume of hydrofluoric acid (60%). After draining and rinsing, a ferroxyl test was made for the detection of metallic iron on the stainless steel surfaces, especially at the welds. The vessel was then dried, and all openings sealed for shipping.

The reactor vessel and primary piping system were given a final cleaning after assembly and testing in the field. A detergent solution (10 lb of Altrex detergent to 160 gal of 140°F water) was circulated through the complete system for 2 hr at 20,000 gpm with the primary coolant pumps. The detergent solution was then removed, and the system filled with clean deionized water. The deionized water was heated to 140°F and circulated through the system for 2 hr. The system was then drained and vacuum-dried.

2. CORE SUPPORT STRUCTURE

The core support structure consists of a support skirt, a lower grid, and a cross assembly. The function of the core structure is to support and position fuel assemblies, control rods, and the transient rod. The assembly is shown in Figure 7. A plan view of support structure with flow skirt attached and control rods installed is shown in Figure 8.

2.1 Support Skirt

The support skirt consists of a slotted cylinder flanged at both ends. The slotted cylinder is 41-1/2-in. in diam and 21-in. high. The 21-in. height positions the active core relative to the limits of travel of the control rods. The slots provide for thermal circulation of the primary coolant under no flow conditions. The lower flange bolts to the reactor vessel core support flange to secure the assembly in the vessel. A machined surface on the top of this flange provides a bolting surface for the flow skirt. All parts are fabricated from suitable stainless steel.

2.2 Lower Grid

The lower grid consists of a grid ring and 4 grid quadrant assemblies which serve as supports for the fuel assemblies. The grid ring, which is 40-3/4-in.

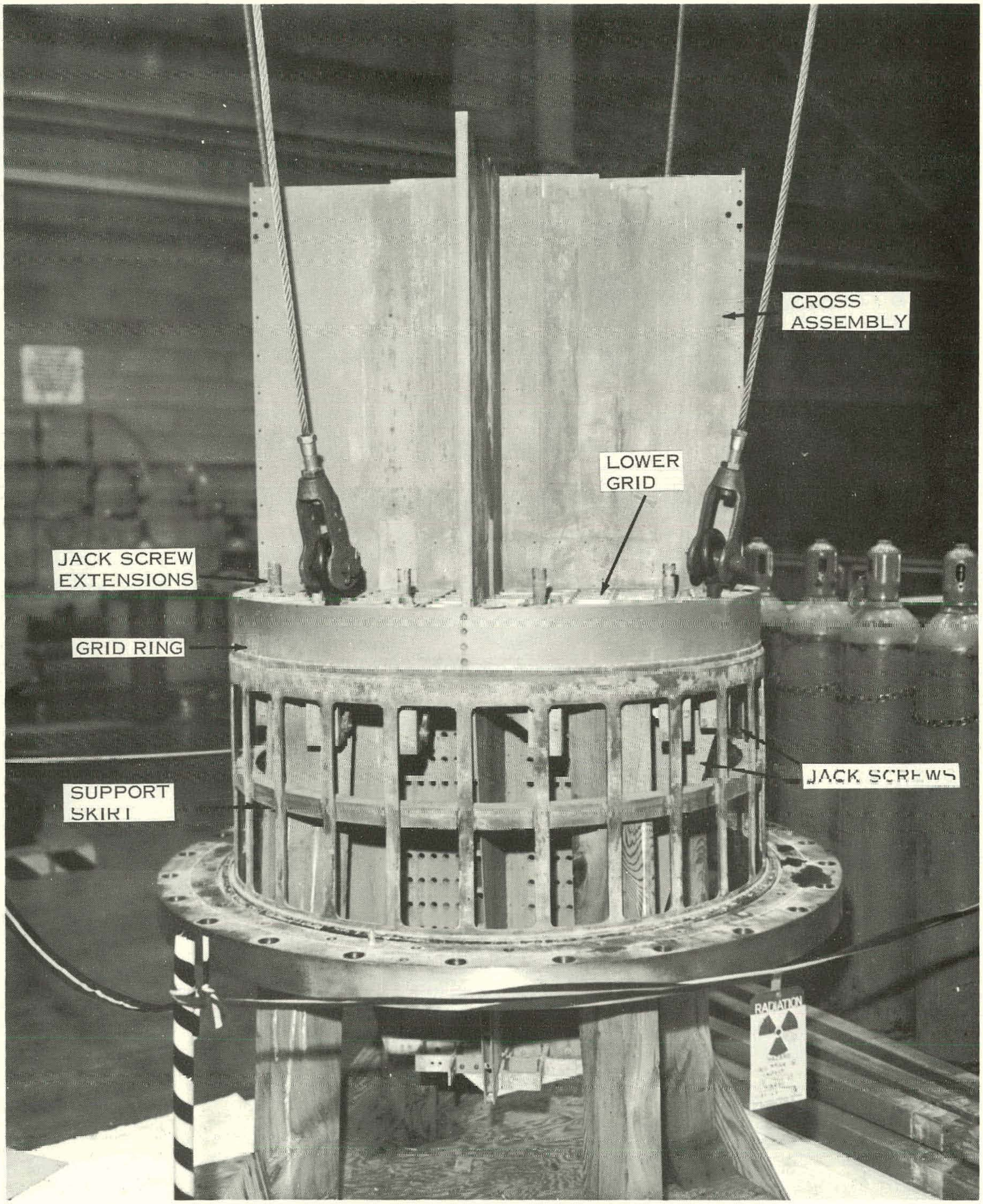


Fig. 7 Core structure.

in diam x 4 in. thick, bolts to the support skirt and is machined to contain the grid quadrants and the cross assembly. The grid quadrant assembly is an egg-crate-type structure with twenty-four 3- x 3-in. cells which fit the fuel assembly end boxes. The four quadrant assemblies provide 96 grid positions. Each assembly is fastened to the grid ring and cross with twenty-two 10-24 NC

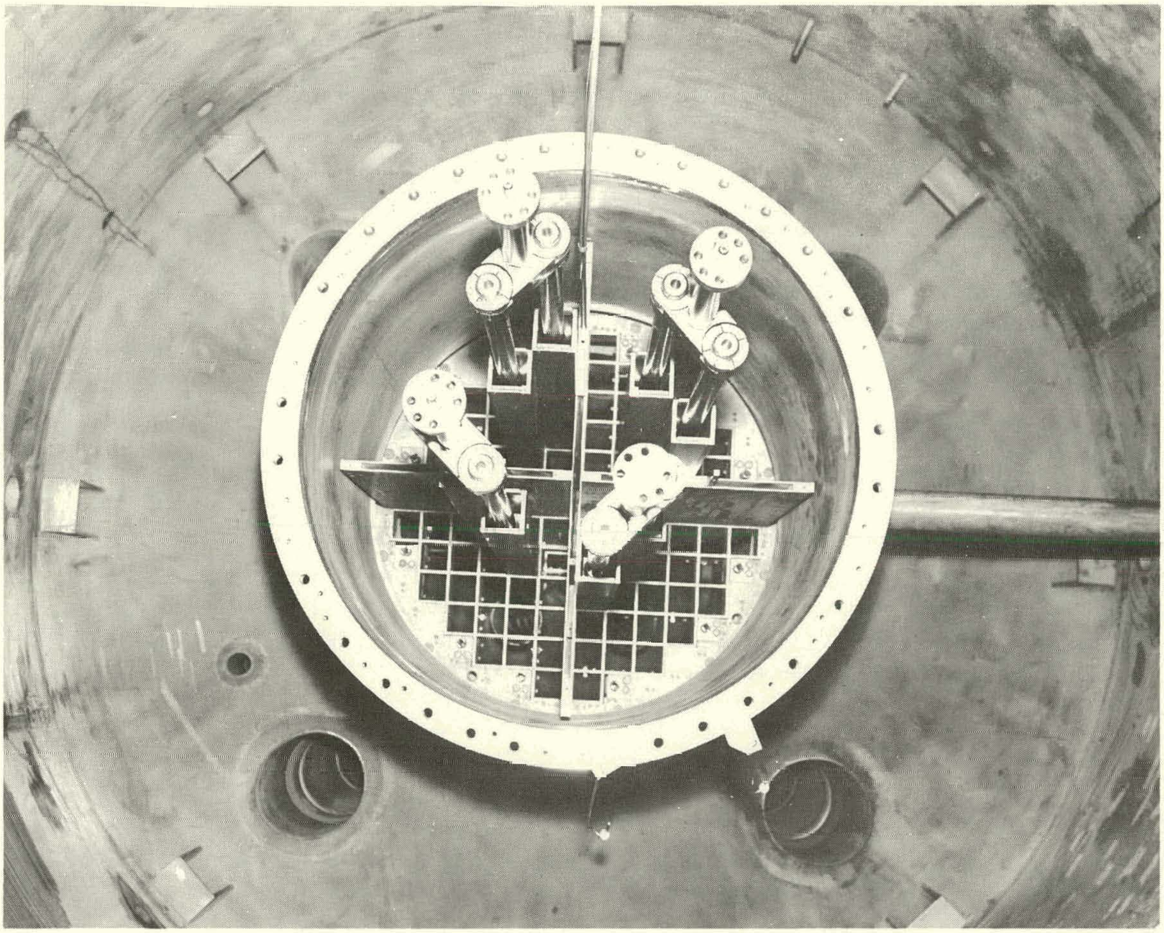


Fig. 8 Plan view of core structure with control rods.

stainless steel cap screws. Both the grid ring and quadrant assemblies are fabricated of 6061-T6 aluminum.

Jack-screw-operated fuel assembly hold-down mechanisms are provided to lock the fuel assemblies to the grids. The jack screws are attached to the grid ring, and by means of mechanical linkage, are connected to horizontal hold-down bar under the grids. Hangers installed on the bottom of the grids support and guide the hold-down bars. Rotation of the jack screw causes horizontal movement of the hold-down bar. Rollers installed on the bar may thus be positioned over lugs provided on the fuel assembly end box locking the fuel assembly to the grid. Four hold-down mechanisms are installed in each quadrant providing hold-down for all grid positions. All components of the hold-down mechanism are fabricated from stainless steel. Short jack screw extensions above the grid ring permit the locking and unlocking of the hold-down mechanisms from the top of the reactor vessel.

2.3 Cross Assembly

The core is divided into four symmetrical quadrants by a 3/4-in.-thick cross of aluminum and water, which positions and guides the transient rod blade. The cross has an overall length of 70 in; 39-in. extend above the lower grid and

27-in. extend below the grid. It consists of aluminum side plates and spacers which separate the side plates. The plates are riveted to the spacers to form an integral assembly, which is bolted to the grid ring. The side plates below the lower grid are perforated to allow circulation of water between the plates.

3. FLOW SKIRT

An aluminum flow skirt (Figure 9) directs the flow to coolant through the core and separates the core from the balance of the vessel to a height of about 16 in. above the top of the cross. The skirt has a nominal diam of 42 in., is 1/2 in. thick, and is fabricated from 6061-T6 aluminum. The lower flange bolts to the top side of the support skirt flange and is gasketed to prevent cross leakage.

A second flow skirt is provided for the use of water as a moderator, and heavy water as a reflector, or vice versa. This skirt is provided with a bolting flange on the top, and extends above the top of the cross to a height of 63 in. Separation of the two liquids is accomplished by the use of a metal diaphragm extending from the flow skirt flange to the vessel shell. The diaphragm is bolted to the flow skirt and to a support flange welded to the vessel shell. The seal is effected by round body ring gaskets installed in the bolting flanges.

4. CORE COMPONENTS

The core components consist of the fuel assemblies, control rods, transient rod, and core filler pieces.

4.1 Fuel Assemblies

The Spert II facility, being a basic research facility, is not limited to a specific type of fuel assembly. Instead the type of assembly used is dictated by the needs of the experimental program. To date, two types have been used in the core. These are designated as Spert type B and Spert type BD. The type B assembly was used for exploratory static tests with water-moderated cores [6, 7]. Following these tests, the reactor system was converted for heavy-water operation and a program of investigation was undertaken on heavy-water-moderated cores using type BD assemblies [1]. Both are highly enriched, uranium-aluminum, plate-type assemblies.

4.11 Type B Assembly. The initial core in Spert II was designated as type B. Figure 10 shows the general construction of the type B assembly. The assembly consists of a stainless steel end box with locking lugs; an aluminum end box extension; two aluminum side plates with four fixed fuel plates; and four stiffener plates, which serve as a lifting bail. The end box and end box extension are fixed to the side plates with rivets. The stiffener plates are brazed to the side plates. The side plates are grooved to accommodate 20 removable fuel plates which are held in the assembly by the end box and a plate under the stiffner plates. The use of removable fuel plates permits the construction of 4-, 8-, 12-, or 24-plate assemblies with uniform plate spacing. The physical data of these assemblies are given in Table I.

Fig. 9 Flow skirt.

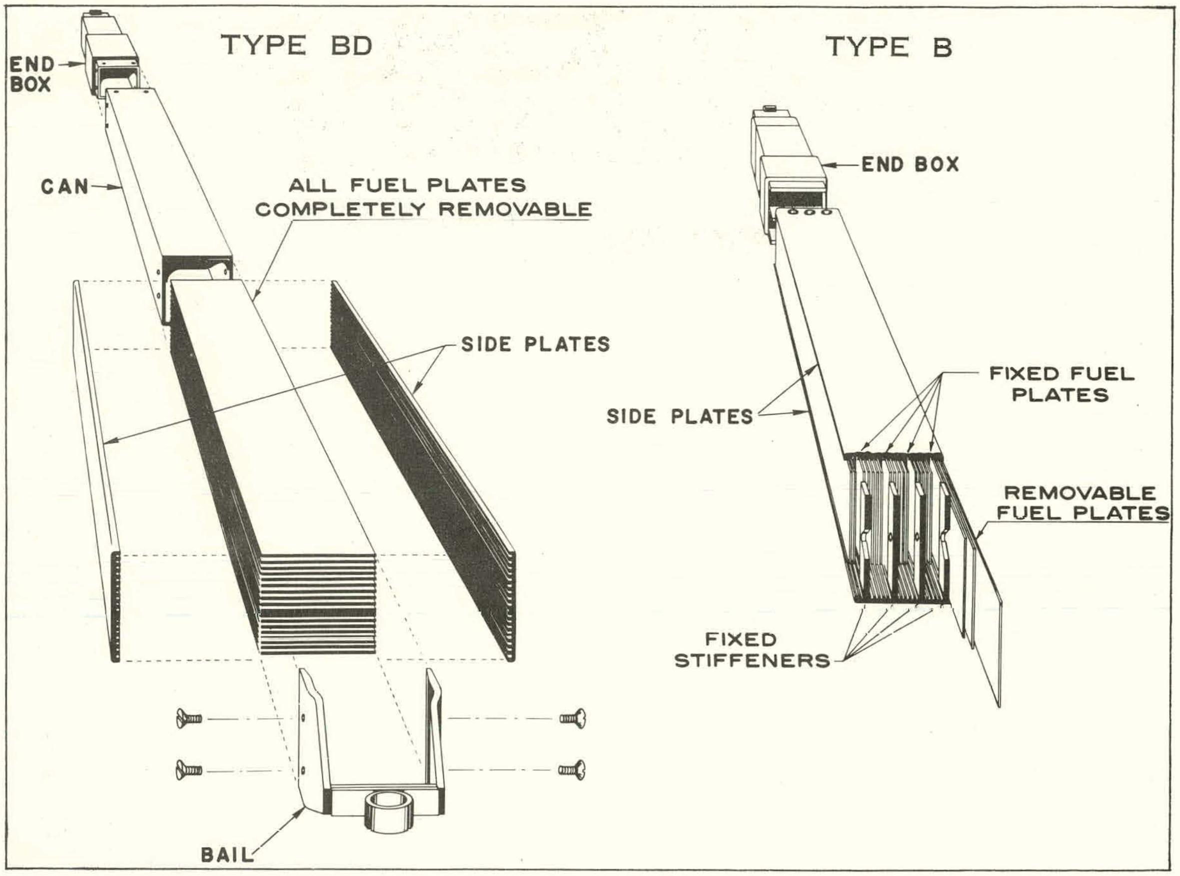


Fig. 10 Fuel assemblies.

4.12 Type BD Assembly. The "BD" assembly is shown in Figure 10. Basically, the assembly consists of an aluminum end box with locking lugs; an aluminum can 3-in square x 0.060-in. wall x 27-5/8 in. long; two grooved side plates; 22 removable fuel plates; and a lifting bail. The lifting bail and end box perform the secondary function of holding the plates in the assembly. Complete disassembly of the fuel assembly is accomplished by removing 12 machine screws. Removal of four machine screws releases the lifting bail and fuel plates. All components of the assembly, except fuel plates, were fabricated in the NRTS shops. The end boxes are machined from aluminum castings; side plates are machined from 6061-T6 aluminum; cans are fabricated from commercial, square, 6061-T6 aluminum tubing; and bails are fabricated from 6061-T6 aluminum. The bails, cans, and end boxes are jig-drilled to permit interchange between assemblies.

The fuel in each plate consists of 7g of U-235 alloyed with aluminum melting stock to produce a core 0.020-in. thick, 2.45 in. wide, and 24 in. long. The core is clad with 6061 aluminum to produce a fuel plate 0.060 in. thick, 2.704 in. wide, and 25-1/8 in. long. The spacing between plates is nominally 0.065 in. However, this spacing may be readily changed by removal of plates or by fabrication of new side plates having a different number of grooves. Physical data of the 22-plate assembly are given in Table II.

TABLE I

PHYSICAL DATA OF TYPE B FUEL ASSEMBLIES

Description	24-Plate	16-Plate	12-Plate	8-Plate
Enrichment (wt% U-235)	≈93.5	≈93.5	≈93.5	≈93.5
Fuel Plates				
Meat thickness (in.)	0.020	0.020	0.020	0.020
Clad thickness (in.)	0.020	0.020	0.020	0.020
Meat length (in.)	——	24.0	(nominal)	——
Meat width (in.)	2.505	2.505	2.505	2.505
Fuel	U-235	U-235	U-235	U-235
Meat composition (wt%)				
U-235	13.09	13.09	13.09	13.09
U	14.0	14.0	14.0	14.0
Al type 1100	85.98	85.98	85.98	85.98
Cladding material	Al type 6061	Al type 6061	Al type 6061	Al type 6061
Overall length (in.)	25.125	25.125	25.125	25.125
Overall width (in.)	2.704	2.704	2.704	2.704
Overall thickness (in.)	0.060	0.060	0.060	0.060
U-235/plate (g)	7.0	7.0	7.0	7.0
Fuel Assemblies				
Overall length (in.)	38.125	38.125	38.125	38.125
Overall width (in.)	2.960	2.960	2.960	2.960
Overall thickness (in.)	2.960	2.960	2.960	2.960
Number of fuel plates	24	16	12	8
Plate spacing (in.)	0.065	0.065	0.190	0.314
Avg U-235 content/assem (g)	168	112	84	56
Flow area (3 x 3 cell)/assem (in.^{2})	4.20	5.52	6.16	6.82
Heat transfer area/assem (in.^{2})	2826	1923	1441	961
Metal-water ratio (3 x 3 cell)	1.14	0.63	0.46	0.32

4.2 Control Rods

The type control rod used for reactor control is established by the type fuel assembly used in the core or by the core configuration. Two types have been fabricated for use in the facility. One is of the fuel-poison type, the other is a simple poison type. Two rods are provided in each quadrant of the core. The two rods are joined by a yoke and driven by a single-drive mechanism.

4.21 Fuel-Poison Rods. The fuel poison rod is shown in Figure 11, and consists of a lower end box, a fuel section, and a poison section.

The poison section is fabricated from a hollow stainless steel tube 2-1/4 in. square with cadmium and stainless steel laminated on the outer surfaces. The cadimum-stainless laminate is built up by first undercutting a 35-in.-long section of the tube. This reduced section is then metal-sprayed with 0.020-in. of cadmium

TABLE II

PHYSICAL DATA OF TYPE BD FUEL ASSEMBLIES

Description	FA
Enrichment (wt% U-235)	≈93.5
Fuel Plates	
Meat thickness (in.)	0.020
Clad thickness (in.)	0.020
Meat length (in.)	24.0 (nominal)
Meat width (in.)	2.485
Fuel	U-235
Meat composition (wt%)	
Al type 1100	85.98
U-235	13.09
U	14.0
Cladding material	Al type 6061
Overall length (in.)	25.125
Overall width (in.)	2.704
Overall thickness (in.)	0.060
U-235/plate (g)	7.0
Fuel Assemblies	
Overall length (in.)	41
Overall width (in.)	2.996
Overall thickness (in.)	2.996
Number of fuel plates	22
Plate spacing (in.)	0.065
Side plate material	Al type 6061
Avg U-235 content/assem (g)	154
Flow area (inside)/assem (in.^{2})	4.136
Heat transfer area/assem (in.^{2})	2591
Flow area (3 x 3 cell)/assem (in.^{2})	4.160
Metal/water ratio (3 x 3 cell)	1.164

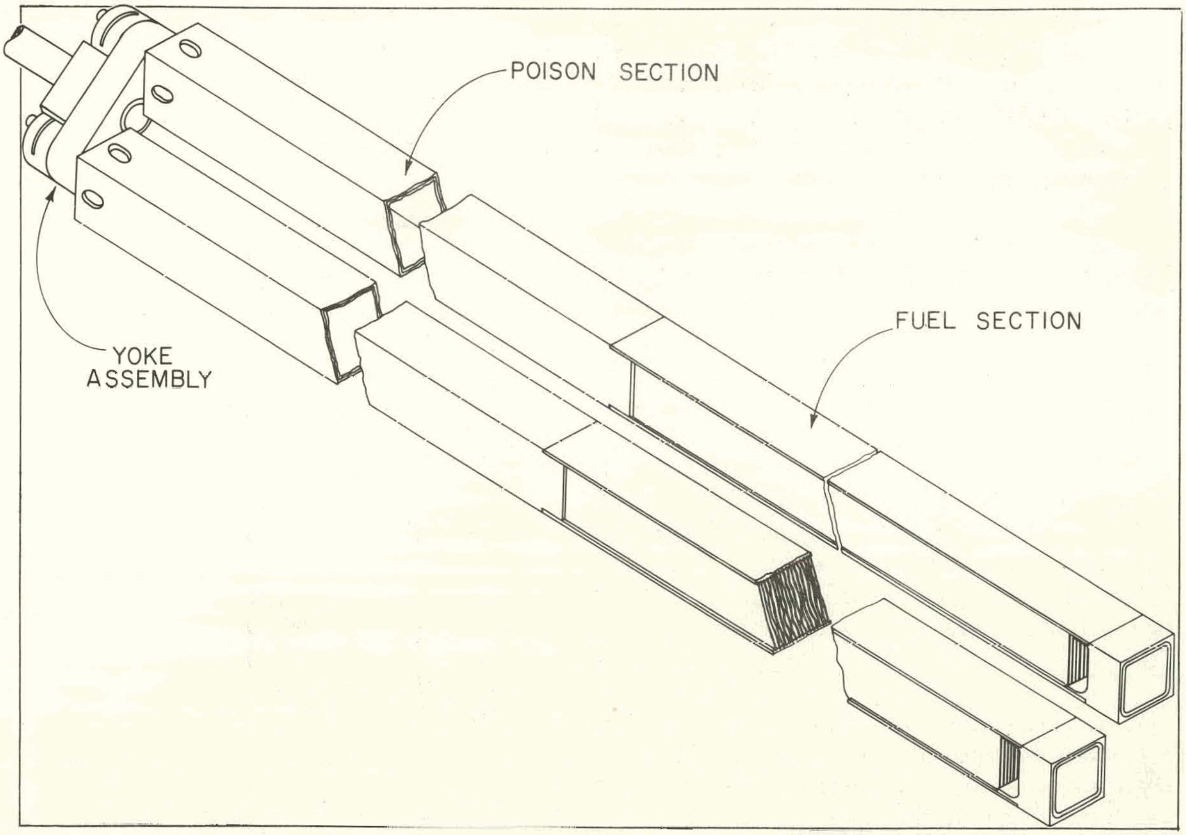


Fig. 11 Fuel-poison control rod with yoke.

which is then sprayed with 0.040 in. of stainless. The sprayed section is then machined to produce smooth surfaces having the same outside dimensions as the tube.

The fuel section consists of two aluminum side plates and fuel plates which are brazed to the side plates. The fuel plates are 0.060 in. thick, 2-3/8 in. wide, and 25-1/8 in. long which match the length of the 7-g fuel plates. Each plate contains 4.7 g of U-235 which provides a fuel density equal to that of the 7-g fuel plates. Four stainless steel flux-suppressor plates, containing 1.34 wt% boron-10, are provided between the end of the poison box and the top of the fuel plates.

The lower end box functions to position and guide the rods in guide tubes which are connected to the top and bottom of the support grids.

The rod componets are assembled into an integral unit in the following manner: The end box is riveted to the fuel section, the fuel section is riveted to the bottom of the poison section, and a stem is welded to the top of the poison tube. The integral unit is connected to the yoke by a threaded coupling; the yoke is connected to the drive mechanism by a bolted coupling.

Three sets of eight rods are provided which differ only by the number of plates in the fuel section. One set has 5 plates, one set 8 plates, and one set 17 plates. This arrangement provides control rods which are, within limits, compatible with the plate loading in the fuel assemblies.

4.22 Poison Rods. The poison control rod (Figure 12) was designed for use with the heavy-water-moderated, 22-plate, "BD" assembly core. The rod consists of a poison section and an aluminum follower section.

The poison section is fabricated from a 1-1/2-in.-OD stainless steel tube with a 28-in.-long cadmium-stainless steel laminate on the outside of the tube. The laminate is built up in the same manner as that of the fuel-poison rods.

The follower is fabricated from a 1-1/2-in.-OD 6061-T6 aluminum tube with a spherical cap attached to the lower end. Both the poison tube and follower are provided with orifices to permit the flow of coolant through the rod.

A 3-in.-square aluminum tube, attached to the top of the support grid, equipped with two roller assemblies guides and positions the rod in the core.

4.3 Transient Rod

The transient rod used in Spert II depends upon the fuel assemblies used, or on the core configuration. In general, however, the rods differ only in the width of the blade.

The transient rod (Figure 13) is a blade-type rod with poison in the lower section and aluminum in the upper section. The blade is constructed of 1100 aluminum tubing which is flattened around a 0.020-in.-thick aluminum filler sheet and 0.020-in.-thick cadmium poison sheet to produce an overall thickness of 5/16 in. After flattening, rivets are installed to maintain the integrity of the sandwich; following this, the ends of the blade are welded shut. The lower end of the poison section is provided with a stainless steel protector plate riveted to the blade. The diameter of the tube establishes the width of the blade; therefore, blades of different widths can be fabricated by selecting the proper tube diameter. A stainless steel yoke

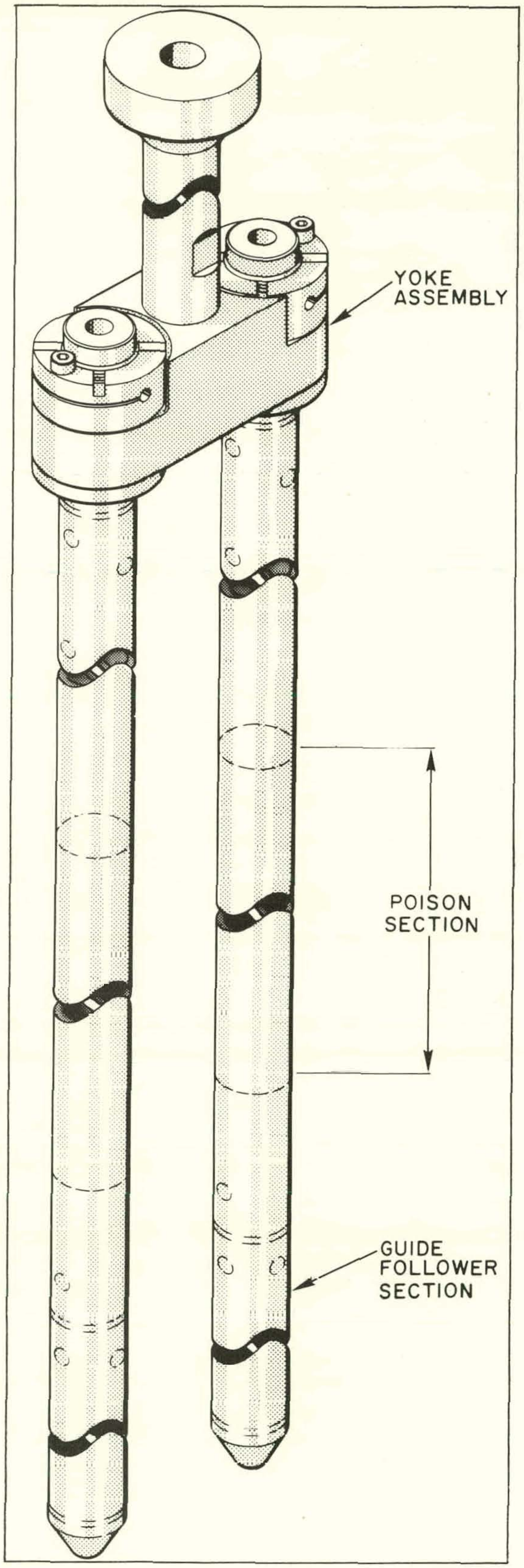


Fig. 12 Poison control rod with yoke.

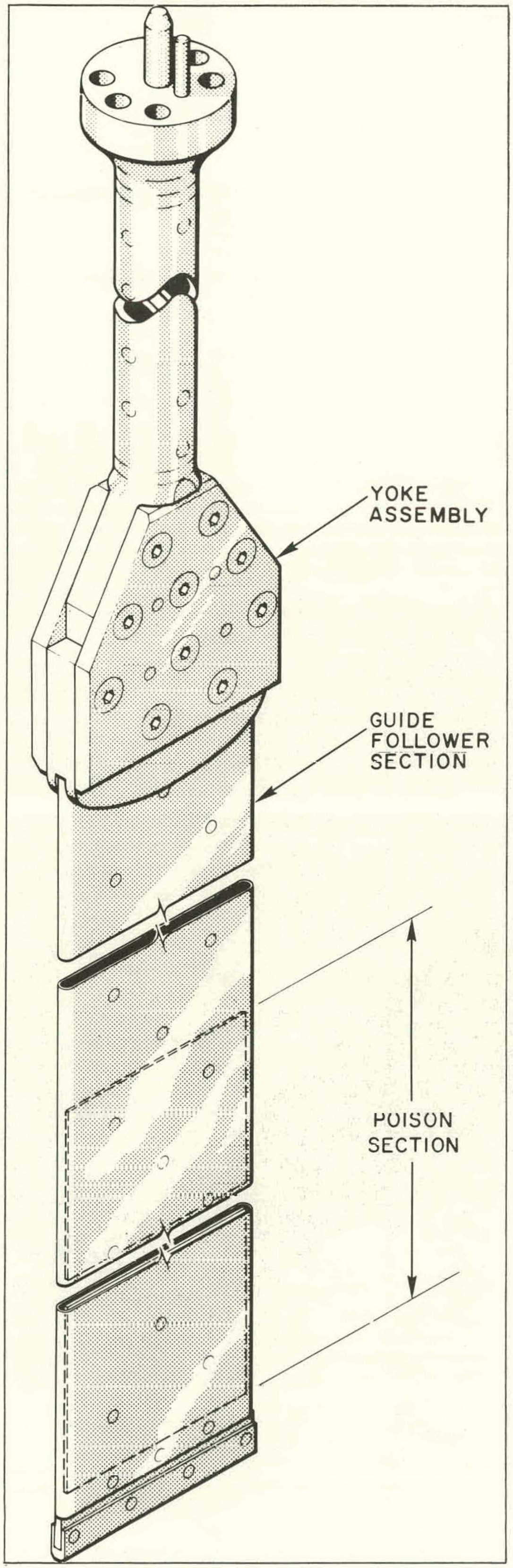


Fig. 13 Transient rod.

assembly is bolted to the blade to complete the assembly.

4.4 Core Filler Pieces

Experimental considerations necessitated a core structure in which the number of fuel assemblies could be varied to meet the versatile operating conditions dictated by the experimental program. Dummy assemblies, of the same overall dimensions as the type B fuel assembly, are used to fill the grid positions unoccupied by fuel assemblies in order to equalize the flow through the core. These assemblies are designated as type 1-F assembly.

The 1-F assembly (Figure 14) is constructed of 1/8-in. aluminum plate welded into a hollow box shape with an end box welded to the bottom and a cap welded to the top. Locking lugs on the end box permit the assembly to be locked to the grid. The cap on the top is orificed with a 3/16-in.-diam hole to restrict coolant flow. A stainless steel eye bolt threaded into the cap permits assembly handling.

Due to the square geometry of the fuel assemblies it is possible only to approximate the cylindrical geometry of the flow skirt in assembling a core. Filler pieces, designated as type 2-F, 3-F, 4-F, and 5-F, are provided to complete the cylindrical geometry of each core quadrant to maintain hydraulic balance in the core.

The filler pieces (Figure 15) are constructed of 3/16-in. aluminum plate welded to the size and shape required. The filler pieces are positioned on the grid ring by dowel pins and connected by bolts. Jack screw extensions are provided to permit locking and unlocking of the lower grid.

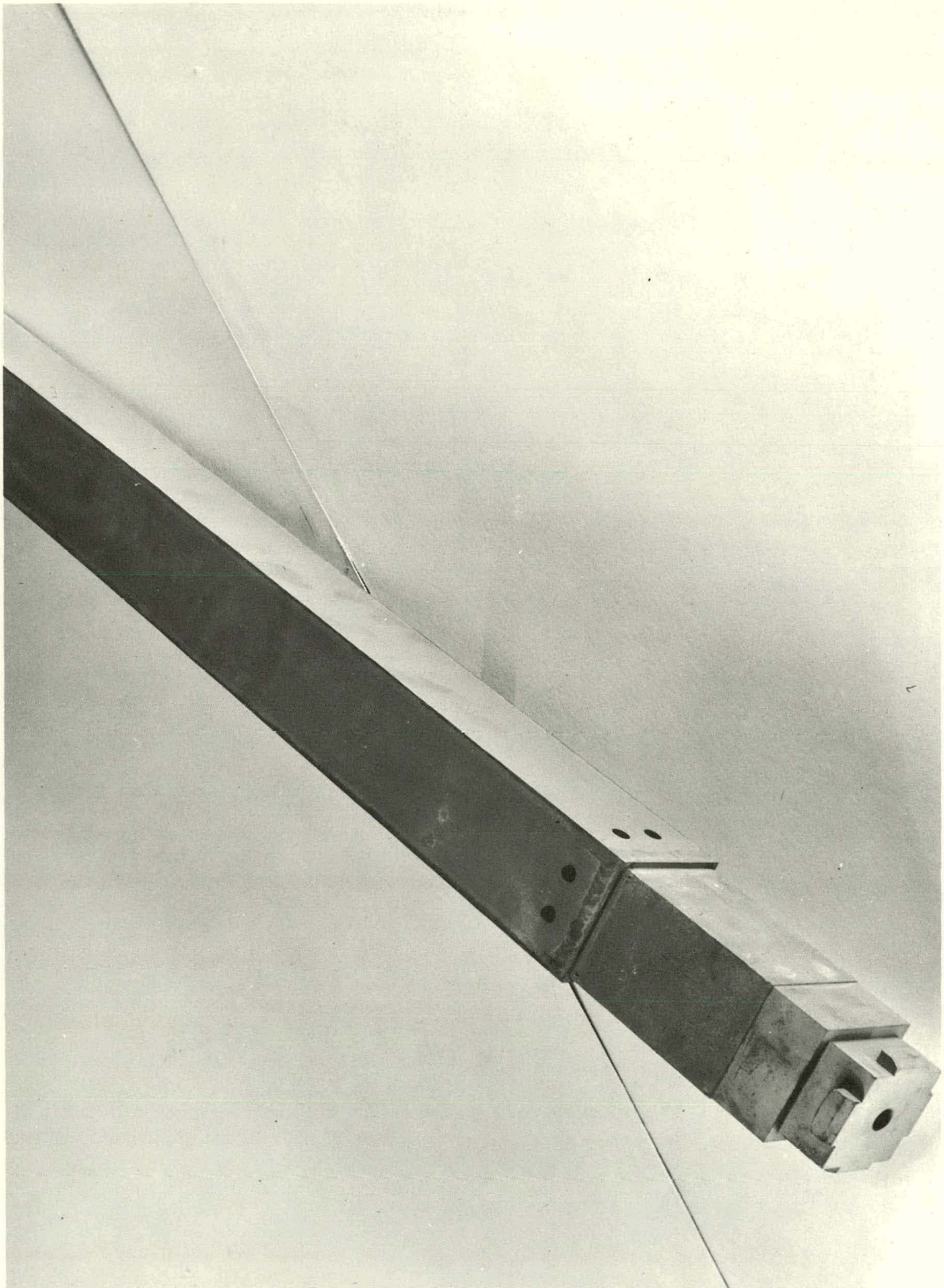


Fig. 14 Type 1-F assembly.

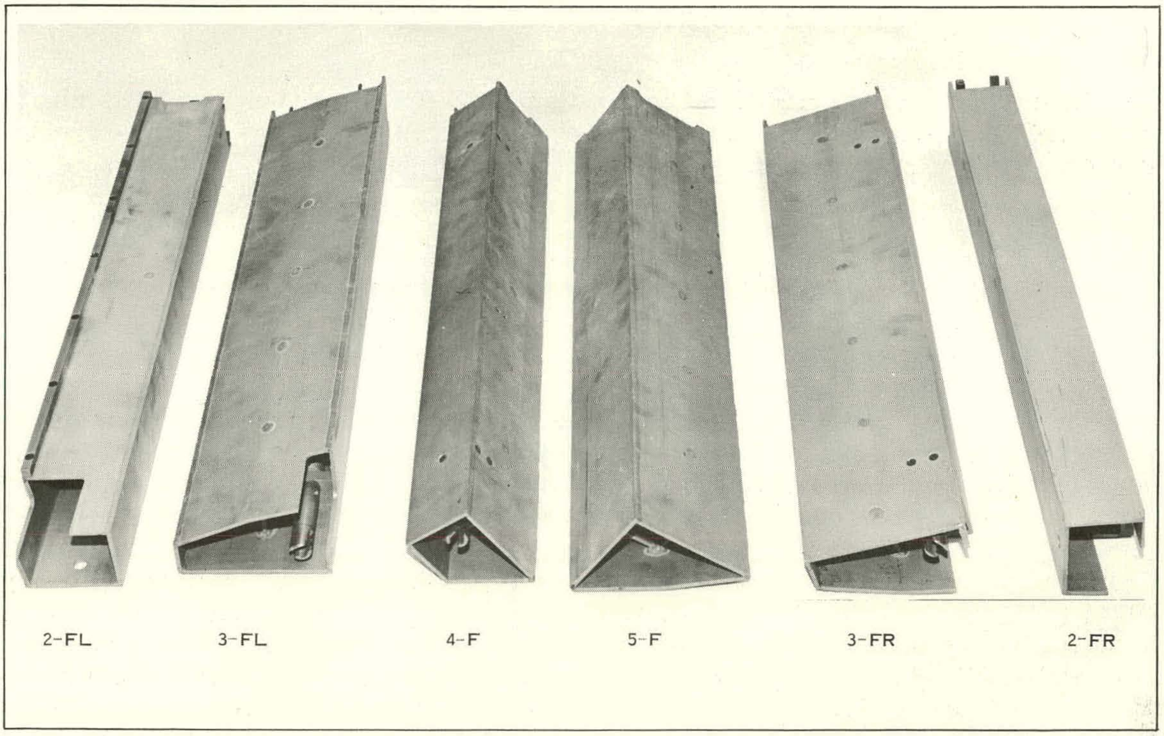


Fig. 15 Type 2-, 3-, 4-, and 5-F filler pieces.

IV. COOLANT AND PRESSURIZATION SYSTEMS

A schematic flow diagram of the coolant and pressurization system is shown in Figure 16. The principal components are the primary coolant system, a pressurizer vessel with helium-pressurizing system, and a heavy-water system.

1. PRIMARY COOLANT SYSTEM

1.1 General Description

The primary coolant system is designed for use with either water or heavy water and, as required by the experimental program, provides for the alternate use of these coolants. The small differences between viscosities, densities, and vapor pressures of heavy water and water do not require different types of vessels, pumps, valves, or other equipment for use in the circulation of the two liquids in a facility such as Spert II. The inherent danger of contaminating heavy water with residual water necessitated that the piping, fittings, valves, and pumps be installed to minimize liquid holdup in the system. The system is installed to assure maximum drainage with drain lines provided from all low points or pockets where liquid might be trapped. Where feasible, valves are located in vertical piping runs; valves in horizontal piping runs are provided with drain lines in the bodies.

The system consists of 8-, 12-, 14-, 16-, and 24-in. stainless steel piping; flanges and expansion joints; two flow tubes; two flow control valves; four spectacle line blinds incorporated in a crossover in the piping to permit the circulation of coolant either upward or downward through the core; drain and vent valves for draining and venting various components of the system; two primary coolant pumps; and a makeup pump.

For upward flow through the core, coolant enters the 42-in.-diam well at the bottom of the reactor vessel through the 24-in. piping, then flows upward past the 50-kw immersion heaters and through the core. The coolant then reverses itself, flowing downward and out of the vessel through the four 12-in. nozzles in the bottom head. The flow from the nozzles is then combined in headers and continues on to the two 10,000-gpm primary pumps which are installed in parallel. From the pumps, the coolant flows through one of the two flow tubes and flow control valves, through the spectacle line blinds and back to the reactor vessel. For downward flow through the core, the spectacle line blinds in the crossover piping are rearranged to direct the coolant from the primary pumps to the four 12-in. nozzles in the bottom head of the vessel, through the core, out the 24-in. nozzle, and back to the primary pumps.

The primary coolant system is filled with either light or heavy water by gravity fill from the storage tanks or with a 75-gpm transfer pump. Makeup water to the full system is supplied by a 5-gpm makeup pump.

Flanged pipe spools are provided at the coolant nozzles of the reactor vessel. If desired these spool pieces can be removed and the vessel nozzles blinded to permit non-flow nuclear tests in the facility.

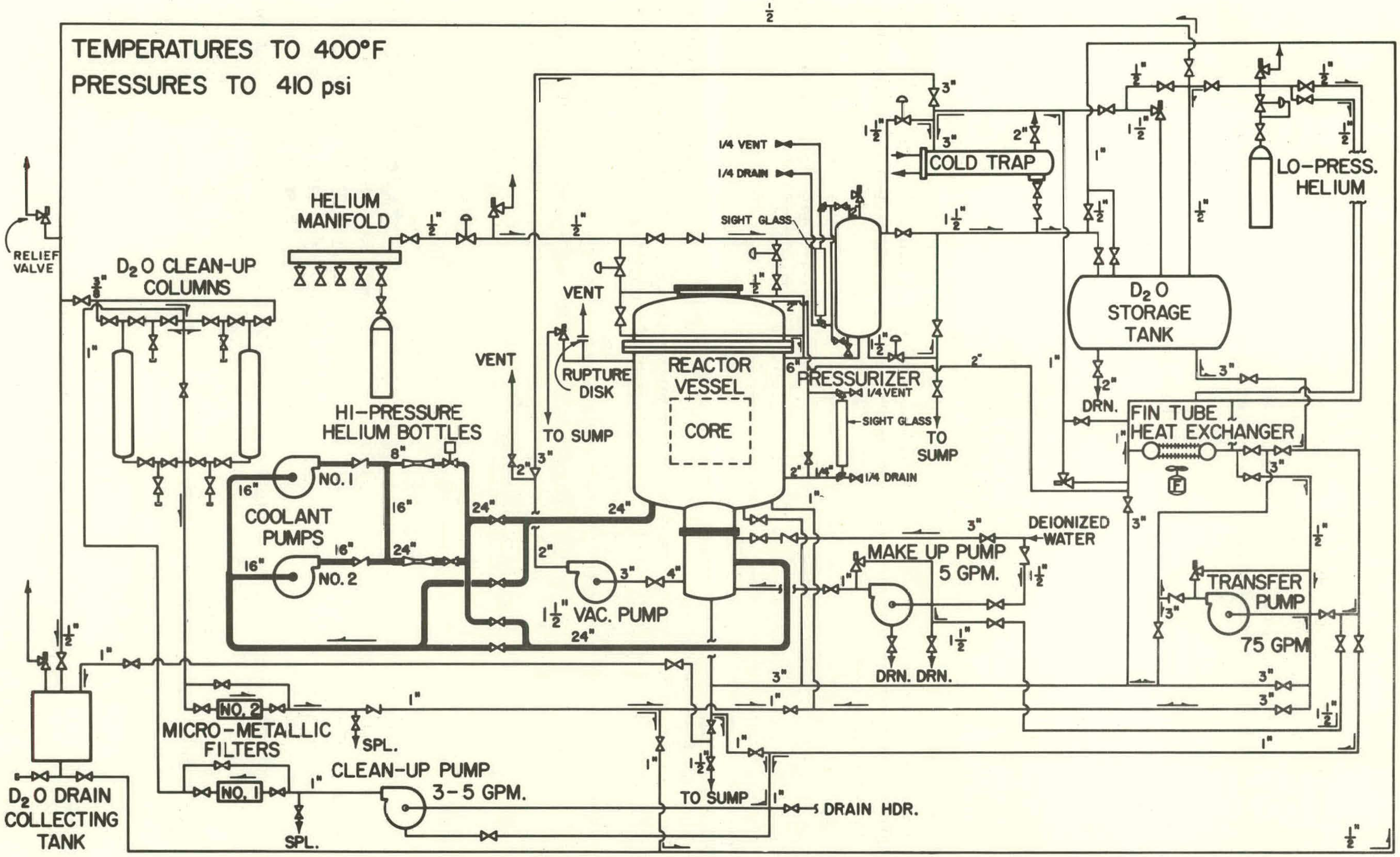


Fig. 16 Spert II process flow diagram.

1.2 Piping

The primary piping is stainless steel, type 304L, schedule 40 S in sizes up through 12 in., and schedule 40 in sizes over 12 in. The 12-in. and smaller piping is seamless, manufactured in accordance with ASTM specification A312-55T. The 14-in. and larger piping is butt-welded, and was shop-fabricated in suitable lengths to keep the number of field welds to a minimum. All completed welds were 100% radiographed, and each length of pipe was hydrostatically tested at 750 psig. Tensile tests at room temperature were made on the plate prior to fabrication. Typical physical properties were as follows.

Tensile Strength	Yield Point	Elongation
79,900	33,000	60%

Field welding of the stainless steel piping was done by the inert-gas shielded-arc method. High-purity welding grade Argon was used as the inert gas shield and purge. Preheating and/or annealing of the piping for welding was not required. The use of consumable inserts was optional. Repair of weld defects was done mechanically by grinding. All welds in the 6-in. and larger piping subject to system design conditions were 100% radiographed in accordance with ASTM specification E99-55T, class 2.

Fittings are stainless steel, type 304L, either seamless or butt-welded, manufactured in accordance with ASTM specification A312-55T.

1.3 Flanges

Flanges are welding neck stainless steel, type 304L, faced and drilled to 300-lb ASA standard suitable for use with flexitallic gaskets. Flanges are bored to match the pipe. The 14-in. and larger flanges were fabricated from plate, and welded using the submerged-arc process.

All flanged joints are made up with alloy steel bolt-studs and nuts conforming to ASTM A-19, B-7, and ASTM A-194 standards, respectively. Gaskets are Flexitallic, style CG, stainless steel with teflon filler.

1.4 Expansion Joints

There are four 16-in. and four 12-in. expansion joints in the primary piping. The joints are of the self-equalizing type to prevent internal pressure and expansion thrusts from acting against the piping and equipment. The piping is suitably anchored and guided. The joints were manufactured by the Magnilastic Division of Cook Electric Co., Chicago, Ill. The 16-in. weld end joints are installed in the vertical suction and discharge piping of the two primary pumps as shown in Figure 17. The stainless steel bellows are provided with carbon steel equalizing rings and tie rods. The 12-in. joints are installed in the piping headers under the reactor vessel. One end is flanged to the 12-in. coolant nozzles of the reactor vessel, the other is welded into the piping.

1.5 Flow Tubes

Primary coolant flow is measured by either of two flow-measuring tubes, installed in parallel, downstream of the primary pumps. A 24-in.-diam tube is used for measuring flow rates between 2000 and 20,000 gpm. An 8-in.-diam tube measures flow rates between 200 and 2000 gpm. The tubes are Gentile type D,

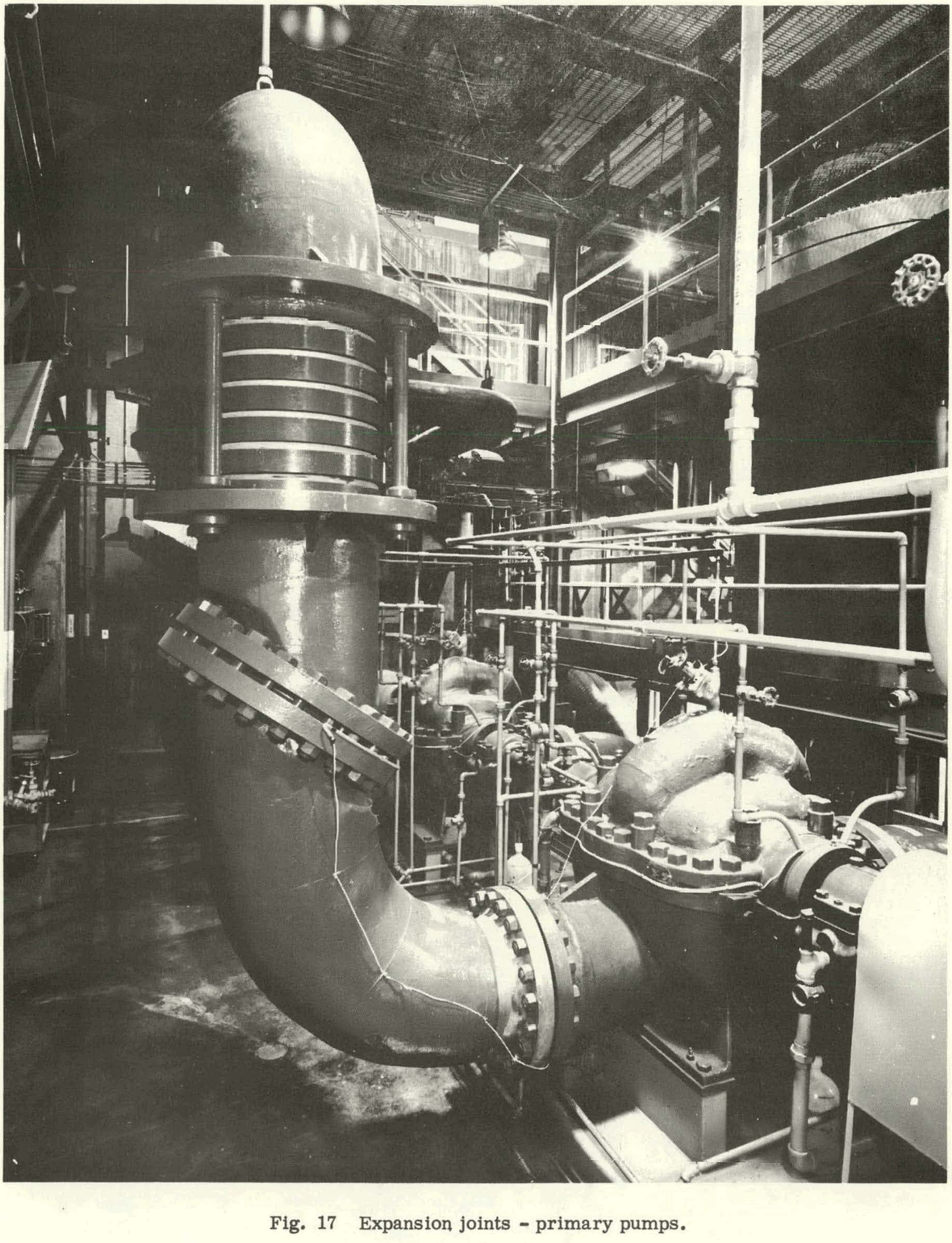


Fig. 17 Expansion joints - primary pumps.

manufactured by the Foster Engineering Co., Union, N. J. The tubes are welding end type, equipped with internal piezometer rings, drilled and tapped for instrument and drain connections.

The tubes were calibrated under conditions simulating their positions in the primary piping with the instrumentation used for recording the flow rates. Calibrations were made for inches of water differential vs flow in gpm at temperatures of 60, 200, 300, and 400°F, respectively. The overall accuracy of the flow tubes and associated instrumentation, including the flow recorders, is ± 1-1/2% over the calibrated range.

1.6 Flow Control Valves and Check Valves

1.61 Twenty-Four-Inch Gate Valve. A 24-in. manually operated, rising-stem, wedge disc gate valve is installed in the 24-in. piping downstream of the 24-in. flow tube. This valve is used as a combination block and flow control valve. The valve is closed when the 8-in. flow tube is in service, and is throttled to control flow rate when operating in the range of 2000 to 4000 gpm.

The valve (Figure 18) is fabricated from welded steel plate. The exterior is carbon steel; trim and all wetted surfaces are stainless steel. All welds were radiographed and the valve was hydro-tested in the shop at 750 psig. The stuffing box is extra deep, to minimize stem leakage, and is packed with chevron-type Teflon packing. The chamber pocket under the wedge disc is provided with a 1/2-in. drain connection.

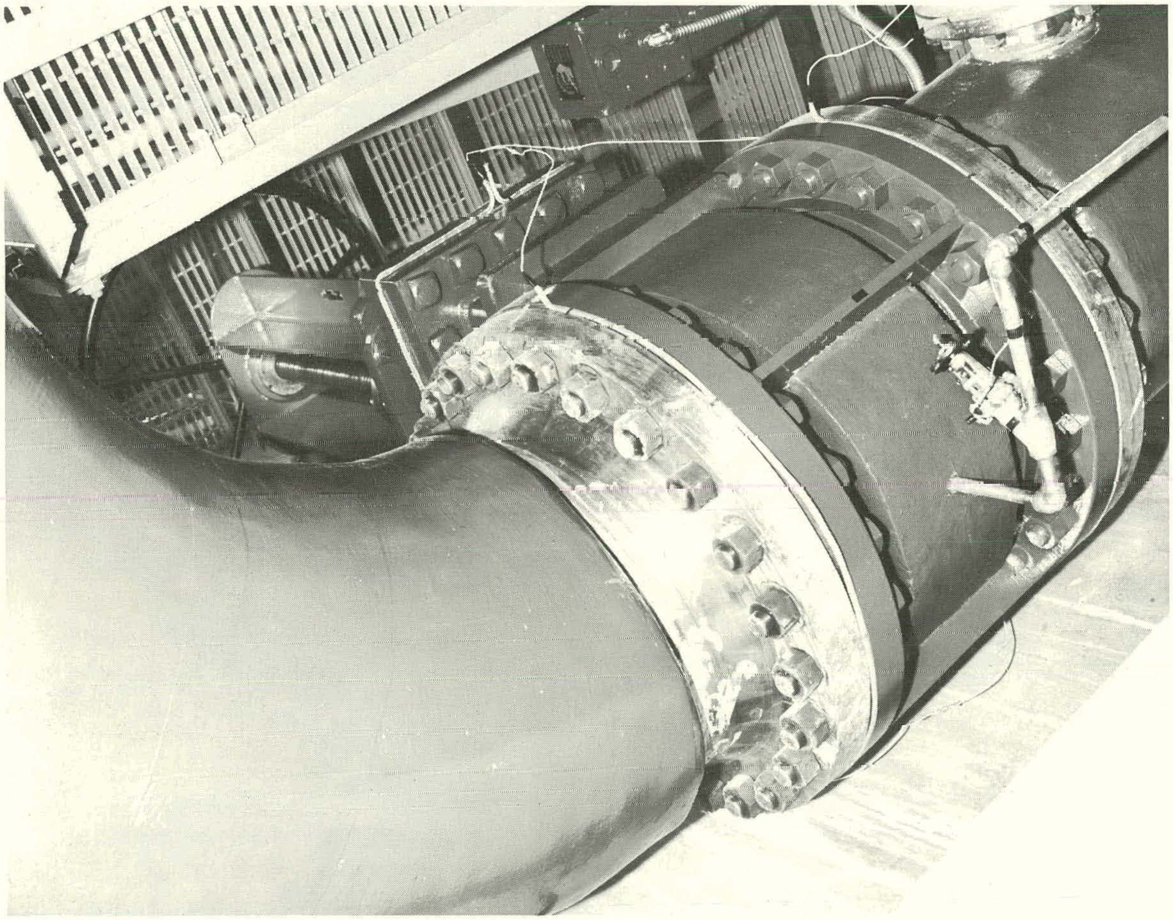


Fig. 18 Gate valve (24 in.).

This type of construction represents a considerable dollar savings over a conventional cast stainless steel valve. Performance of the valve has been satisfactory. The valve was fabricated by Fabri-Valve Co. of America, Portland, Ore.

1.62 Eight-Inch Valve. An 8-in. motor operated valve is installed downstream of the 8-in. flow tube and is used as a combination block and flow control valve. The valve is closed when the 24-in. flow tube is in service and is throttled to control flow rate when operating below 1000 gpm.

The valve is a cast stainless steel, flanged globe valve manufactured by Pacific Valves Inc., Long Beach, Calif., and is equipped with a single-seated V-port plug and stellited seat. The stem is equipped with a stainless steel bellows and extra deep stuffing box packed with chevron-type Teflon packing.

The electric motor operator is a "Tork-Master" geared unit equipped with a manual handwheel and a position indicator. Upper and lower limit switches prevent over-run on electric operation.

1.63 Check Valves. A 16-in. check valve is installed in the vertical discharge piping of each primary pump to prevent recirculation of coolant during one pump operation.

The valves are welding-end, tilting-disc type fabricated from welded steel plate by Fabri-Valve Co. of America. All wetted surfaces are stainless steel type 304L. Discs are drilled with a weep hole to allow drainage of liquid trapped above the disc when in the closed position.

1.7 Spectacle Line Blinds

There are four spectacle line blinds installed in the crossover piping of the primary system to control the flow direction through the core. These blinds in effect function as block valves, and were selected for the dollar savings which could be realized from their use.

The blinds are fabricated from stainless steel plate; one end is a solid circular disk, the other is a ring. Blinds are inserted between companion weld-neck flanges in the piping as shown in Figure 19, and depending upon which end is inserted, the flow is either blocked or permitted to pass through. By rearranging the blinds coolant flow is either directed upward or downward through the core.

1.8 Drain and Vent Valves

Vent valves and piping are provided from the primary piping, flow tubes, valves, and pumps. The vented gas, air, etc. pass to the pressurizer vessel. Drain valves and piping are provided from valves, piping, and pumps. In general, drains from the high parts of the primary piping are drained to the lower piping. The lower piping is in turn drained to the 42-in.-diam well in the bottom of the reactor vessel, which is the low point of the system.

Drain and vent valves are Powell "Belloseal", 300-lb Y-pattern, type 304L stainless steel with socket weld ends. "Belloseal" valves were selected to minimize valve stem leakage.

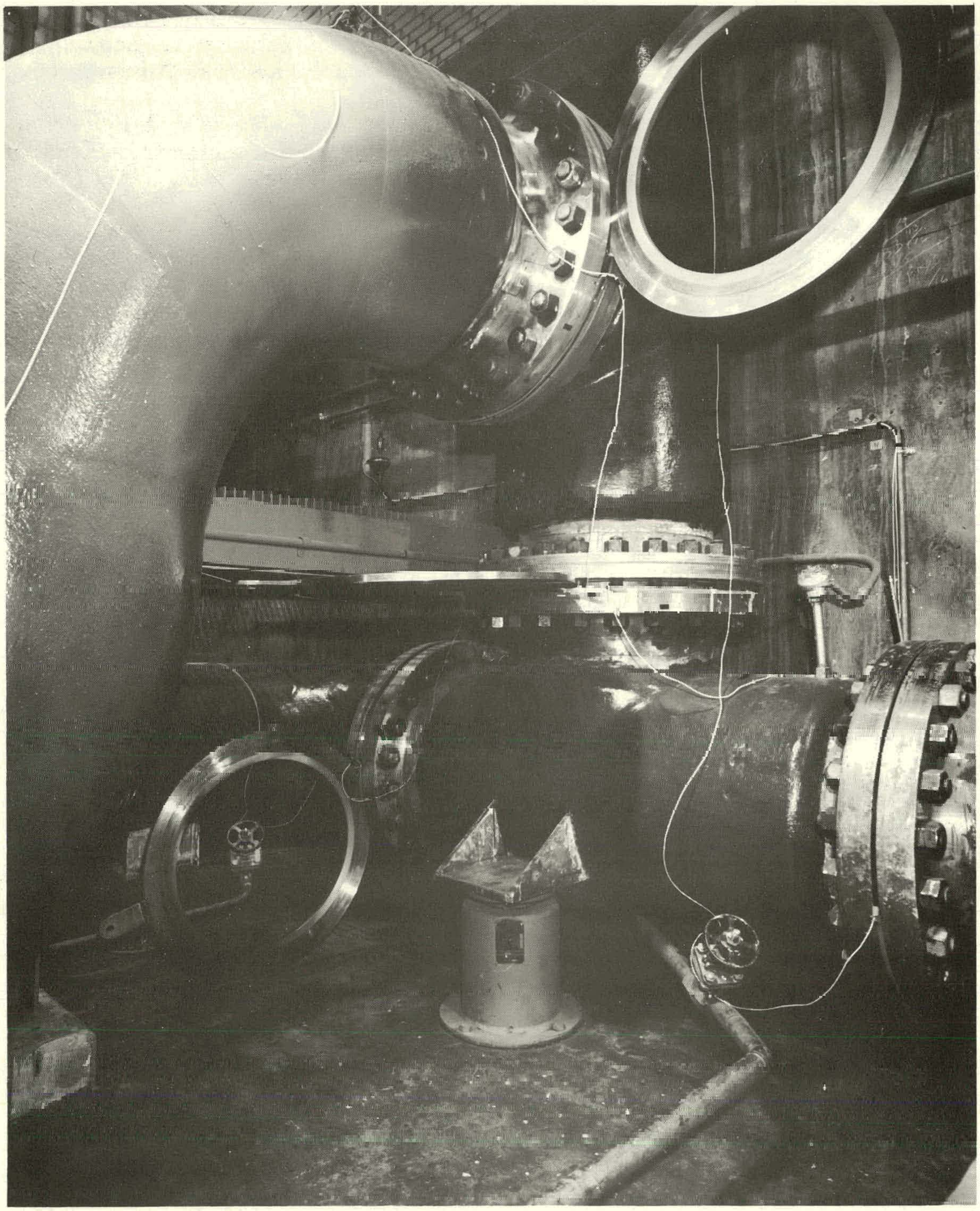


Fig. 19 Spectacle line blinds.

1.9 Insulation

The equipment and piping in the primary system are insulated to minimize heat losses during temperature operations.

The primary piping is insulated with 2-in. of Foamglass. Preformed blocks, with sufficient bands to hold securely in place, were used on all pipe and fittings. One layer of rosin-sized paper was then applied and canvas was applied over the paper using lagging cement, and then painting was done as required. Flanges and bolting were not insulated, to permit early detection of leakage and easy access for tightening.

1.10 Primary Coolant Pumps

The primary coolant pumps are of standard commercially available design and were selected to minimize facility costs, and to demonstrate the feasibility of using such a design in a nuclear test facility such as Spert II. A unique feature of this installation is the fluid coupling of the pumps to the drivers. This feature permits a wide range of pump speeds, which in turn, permits a wide range of flow rates from a minimum of 2000 to a maximum of 20,000 gpm. The pump fluid drive unit, and driver are mounted on an integral base plate as shown in Figure 20.

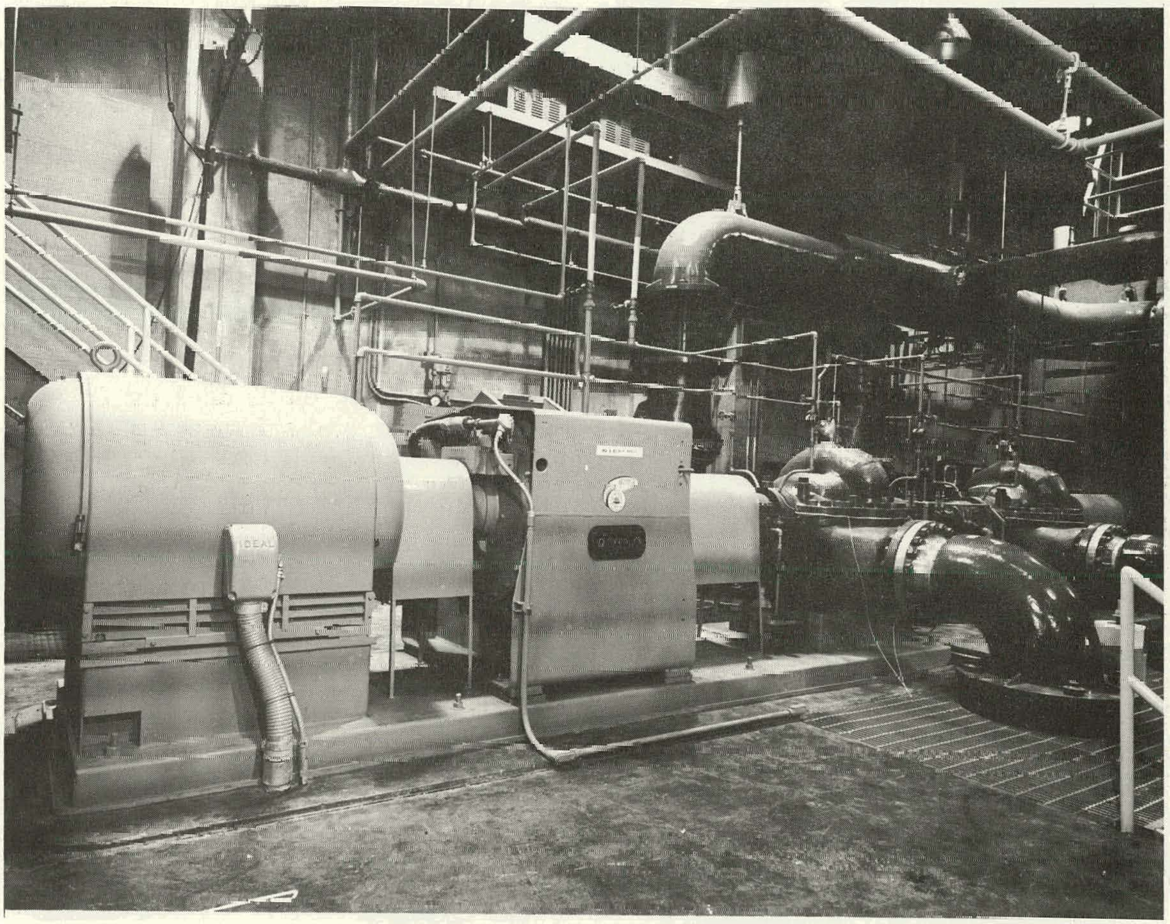


Fig. 20 Primary coolant pump installation.

The pumps were manufactured by Allis Chalmers Mfg. Co., and are 16 x 14, type SGP, single stage, centrifugal type, horizontal split case, flanged side suction and discharge with a maximum capacity of 10,000 gpm each at a net differential head of 175 ft of water. The hydraulic characteristics are shown in Figure 21.

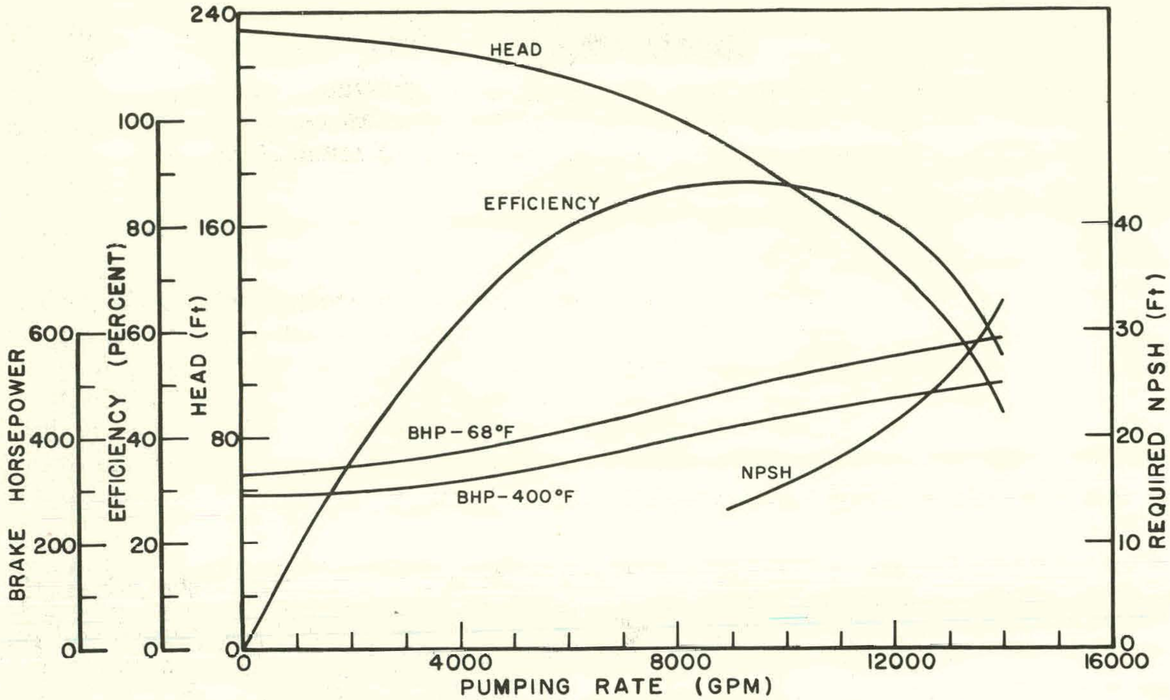


Fig. 21 Hydraulic characteristics of primary pumps.

The pump cases are constructed of nodular cast iron plated with "Kanigen" plating on the wetted surfaces. The "Kanigen" process, patented by the General American Transportation Corp., Chicago, Ill., is a method for depositing a uniform, hard, corrosion-resistant nickel-phosphorous plate on iron from a chemical bath. The as-plated coating is non-crystalline and exhibits the characteristics of a super-cooled liquid of virtually zero porosity with a hardness of approximately 49 Rockwell C. Approximately 0.005 in. of plate was applied to the wetted surfaces of the cases. Iron-free tests were required on the plating before acceptance. Some difficulties were encountered in obtaining iron-free tests due to severe porosity in some areas of the castings. These areas were repaired by grinding and satisfactorily re-plated. The impellers and shaft sleeves are 18-8 stainless steel. Shafts are 12-14 chrome steel equipped with double-row ball bearings at each end. Bearings are lubricated by gear-driven lube oil pumps mounted on the outboard end of the pump shaft. Impeller and casing wear rings are stellited for wear resistance. Figure 22 is a view of the pump internals.

The pumps are equipped with "John Crane", type-9B, Chemlon mechanical shaft seals manufactured by the Crane Packing Co., Morton Grove, Ill. Seal housings are jacketed for water cooling and provided with leak-off connections.

The seal faces are of necessity cooled and lubricated by the pumped fluid. However, since heavy water was to be the pumped fluid, it was mandatory that the seal design include provisions to minimize leakage across the faces. Seal faces consist of a rotating carbon ring and a stationary seat of Cranamic No. 4 (a tungsten carbide material). Seat and shaft sleeve seals are "0" rings made of Viton-A. A short labyrinth is provided, on the liquid side of the seal, for pressure breakdown before the fluid reaches the seal faces. The cooling water

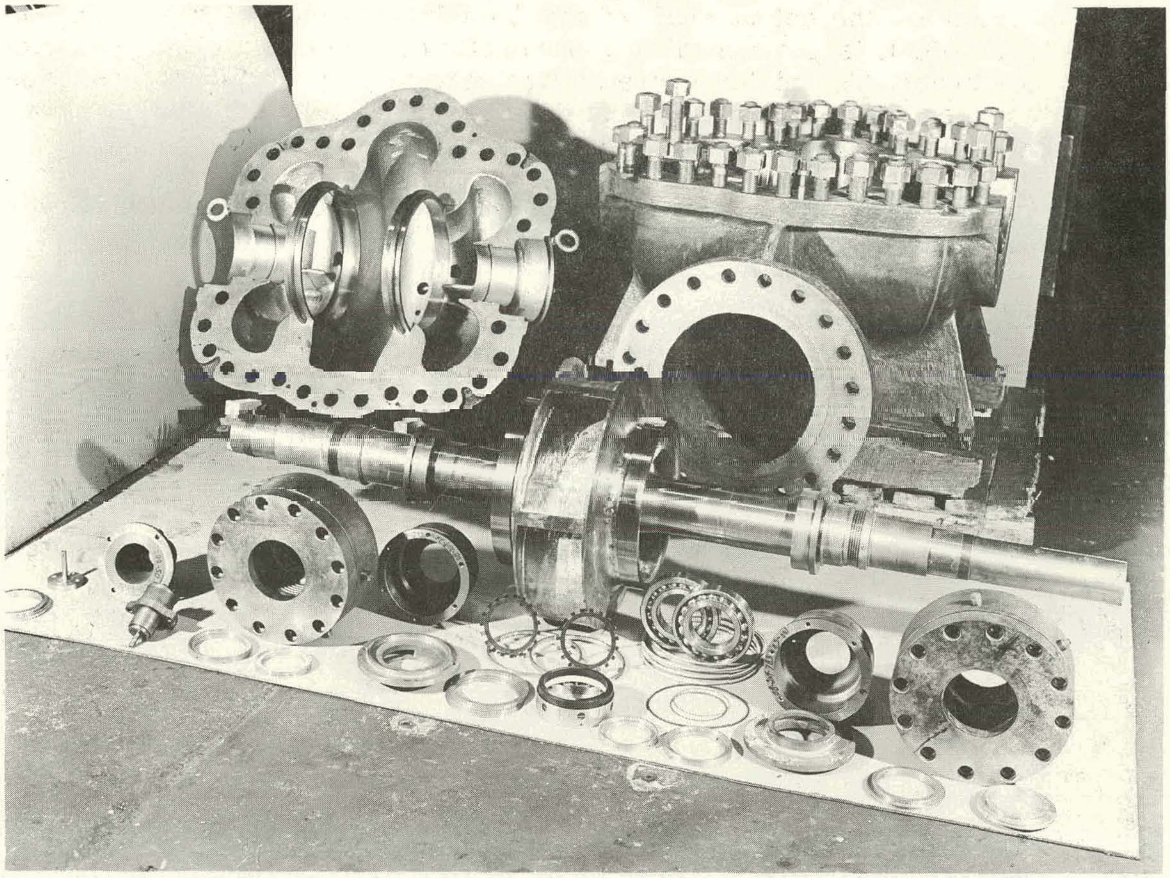


Fig. 22 Primary coolant pump internals.

arrangement around the seals keeps the leakage below the flash point of the liquid. Temperature of the liquid, at maximum operating conditions, is 160 to 180°F; leakage is less than 180 cc/hr per seal. Heavy water leakage is collected locally at the pumps or piped to a collection tank from the leak-off connection in the seal housings. Light water leakage is piped to the floor drain.

The pumps are driven by variable-speed fluid drives which provide smooth stepless speed control between 227 and 1135 rpm. They are size 270, type Vs, class 2, GYROL units, manufactured by American Blower Corp., Detroit, Mich.

A welded-steel, oil-tight housing encloses the rotating elements of the drives and provides a reservoir for oil. The rotating elements are cast aluminum enclosed in steel inner and outer casings. An oil circulating pump, mounted on the input shaft, delivers the necessary oil for the fluid circuit, cooling, and bearing lubrications. The input shaft, impeller, and casings rotate together at motor speed; the output shaft and runner rotate together at output speed. Power is smoothly transmitted from the impeller to the runner by a vortex of oil. The sensible heat due to inefficiency is removed from the oil in an externally mounted water-cooled exchanger. Thermocouples are provided to monitor the oil temperatures.

The speed of the output shaft of the fluid drive is controlled by a speed-control arm, which is positioned by a pneumatic piston operator equipped with a pilot positioner. The piston operator was manufactured by Johnson Service Co., Milwaukee, Wis. The piston operators are controlled, from either of two instrument panels, by a manual speed-selecting device.

The fluid drives are driven by 2300-v, 3-phase, 60-cycle, squirrel cage induction motors which deliver 600 hp to the input shaft of the drives.

1.11 Makeup Pump

A makeup pump (Figure 23) provides makeup to the primary system to compensate for blowdown, volume shrinkage, and leakage. It is automatically

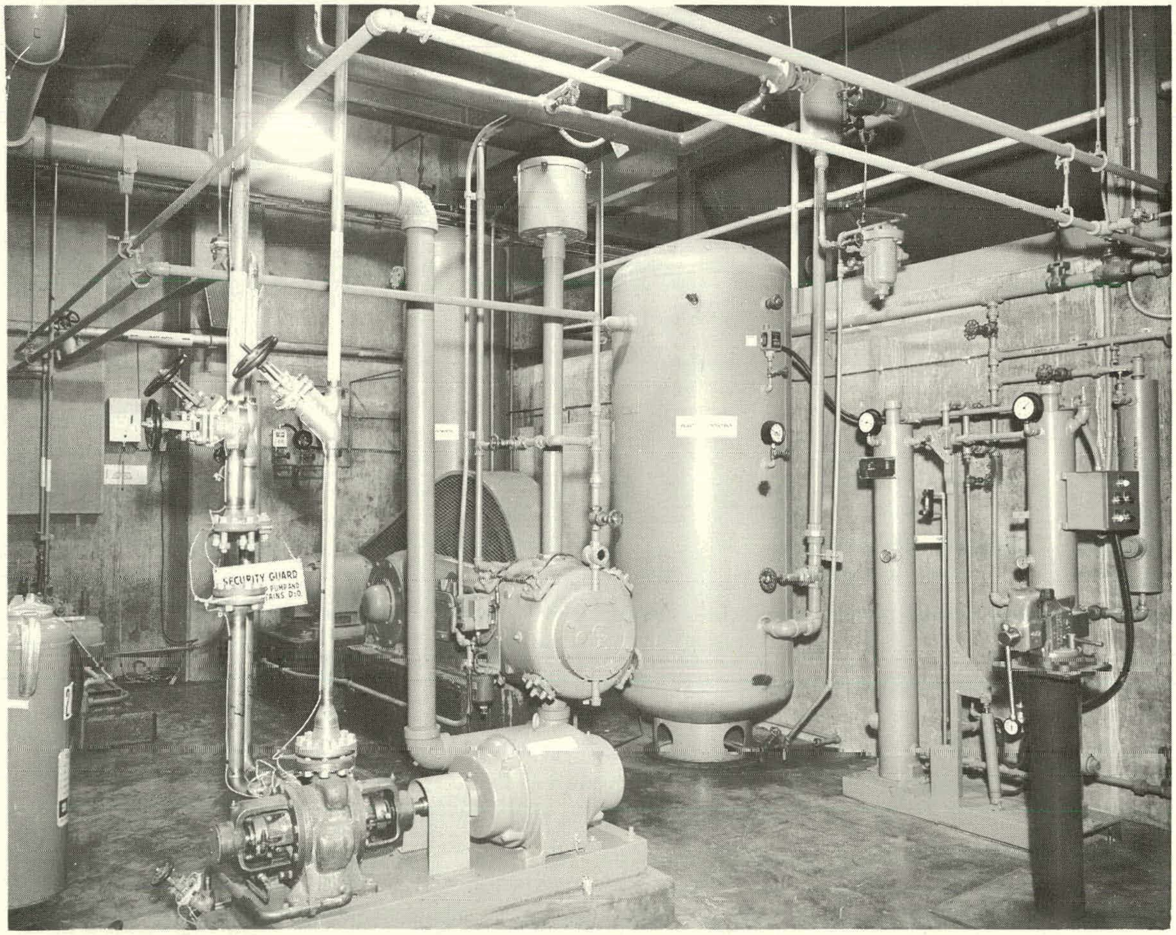


Fig. 23 Makeup pump installation.

controlled by the pressurizer liquid level controller, or may be manually controlled from the reactor building or control center. The suction piping is arranged to permit pumping from either the deionized-water storage tank or the heavy-water storage vessel. Discharge from the pump is directed to the bottom of the reactor vessel.

The pump is a two-stage, center-mounted turbine type, designed for a capacity of 5 gpm against a TDH of 900 ft of water. Hydraulic characteristics are shown in Figure 24. All wetted parts are constructed of suitable stainless

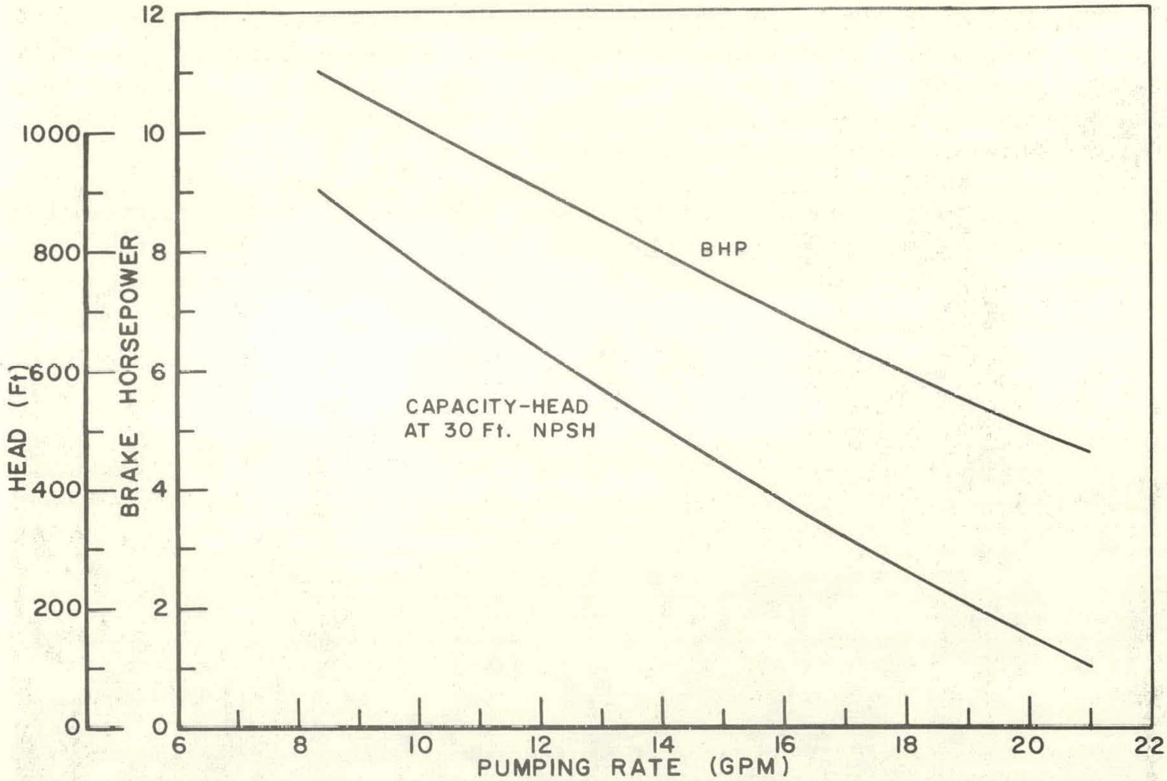


Fig. 24 Hydraulic characteristics of makeup pump.

steel. The shaft is equipped with two John Crane, type 9B mechanical seals, similar in design to those provided for the primary coolant pumps. The suction and discharge flanges are faced and drilled to the 600-lb ASA standard, suitable for use with style CG flexitallic gaskets. The pump is driven by a 10-hp, 440-v, 3-phase, 60-cycle splash-proof electric motor.

2. PRESSURIZATION SYSTEM

2.1 General Description

Pressure for the primary coolant system is provided by a pressurizer system. This system consists of a pressurizer vessel and a high-pressure helium system (Figure 25). Pressure is maintained on the primary system to prevent boiling of the coolant at elevated temperatures to provide adequate NPSH for the primary pumps, or to satisfy the requirements of the experimental program. Normally, pressurized operations are conducted with a liquid-full primary system, and a liquid level in the pressurizer vessel. Helium is introduced in the top of the pressurizer and pressure is transmitted to the primary system through a 6-in. liquid leg which interconnects the pressurizer and the reactor vessel. Pressure control is maintained by a pressure recorder-controller. The addition of makeup water to the primary system, or blowdown of excess water is controlled by a liquid-level controller which maintains a constant liquid volume in the system.

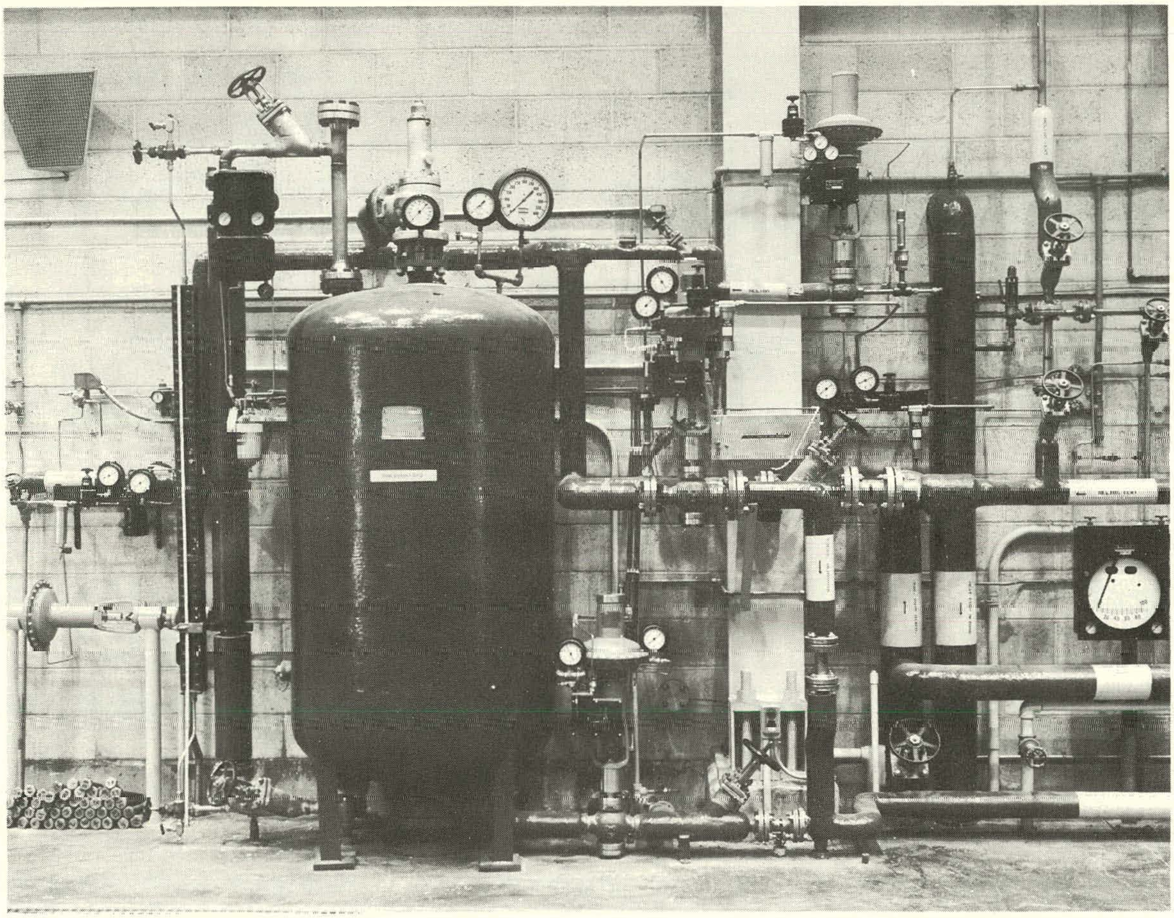


Fig. 25 Pressurizer installation.

2.2 Pressurizer Vessel

The pressurizer vessel was designed and fabricated in accordance with Section VIII, ASME Pressure Vessel Code, 1956 Edition for a pressure of 375 psig at 400°F. The vessel is 3 ft ID x 6 ft overall and of all-welded construction fabricated from ASTM-A285, grade C FBQ barking with 10% type 304L stainless steel cladding. Nozzle attachments to the vessel are stainless steel, type 304L seamless pipe. Flanges are weld-neck faced and drilled to 300-lb ASA standard suitable for use with flexitallic gaskets.

A 6-in. flanged nozzle at the bottom center of the vessel is provided for the liquid-leg connection to the reactor vessel. Pressure to the primary system is transmitted through this leg. Conversely, pressure transients and volume changes generated in the core during nuclear tests are transmitted to the pressurizer through this leg. A 1-1/2-in. flanged nozzle at the bottom right of the vessel connects the liquid blowdown piping. A 1-1/2-in. flanged nozzle in the top of the vessel connects the high-pressure helium piping for system pressurization. This same nozzle is used for venting helium to depressurize the system. A 3-in. flanged nozzle, top center of the vessel, mounts a rupture disc assembly and a safety relief valve. These components provide pressure relief for the primary system. The rupture disc is provided to prevent leakage of helium through the relief valve, and is sized to rupture at 400 ± 5 psig. The relief valve is set to relieve at 400 psig.

Two 2-in. flanged nozzles, top and bottom of the vessel, connect a displacement-type liquid-level controller which has a range of 0 to 84 in. A sight glass adjacent to the displacer provides a visual indication of level. The level controller automatically maintains a constant level in the pressurizer by stop-start operation of the makeup pump, or actuates a diaphragm control valve in the liquid blowdown piping to reduce the system volume. If the liquid blowdown is heavy water, it is directed to the heavy-water storage tank. If the blowdown is water, it is directed to the building sump. The diaphragm control valve is a single-seated globe type with stainless steel seat and stellited plug. All wetted surfaces arc stainless steel. The stem is bellows sealed. The valve is positioned by a Moore valve positioner, manufactured by Moore Products Co., Philadelphia, Pa.

2.3 Helium System

High-pressure helium is used to pressurize the primary system, and was selected as the pressurizing medium to provide an inert atmosphere for contact with heavy water. In addition, it affords a convenient, safe, and relatively inexpensive pressurizing medium.

Helium is supplied to the pressurizer from a high-pressure manifold through suitable piping and valves. Nine standard helium bottles are connected, in parallel, to the manifold. A pressure-regulating valve on the manifold reduces the pressure to 425 psig. A safety relief valve set to relieve at 450 psig is installed on the piping to the pressurizer.

2.4 Pressure Control

Control of primary system pressure is accomplished through a recorder and two controllers located at the control center, or two manual pressure-selecting devices at the reactor building. The controllers and manual selectors are electrically operated devices which, through transducers in the reactor building, actuate pneumatic diaphragm control valves in the helium piping.

The first controller with its associated control valve functions to pressurize the system. The second controller with its associated control valve functions to de-pressurize the system. Both controllers incorporate proportional, reset, and rate modes of automatic control or manual control. A more complete description of the pressure controls is contained in Section V, 2.

The diaphragm control valves are single-seated glove type with stellited plugs and stainless steel seats with teflon inserts. Initially the seats provided were stainless steel; however, considerable difficulty was experienced with helium leakage across the seats. The stems are sealed with bellow seals. The valves are positioned by Moore valve positioners.

3. HEAVY-WATER SYSTEM

The dollar value of heavy water and the importance of maintaining its isotopic purity for experimental reasons requires careful equipment design and handling techniques to prevent loss or degradation. Heavy water will exchange in the vapor phase with water, and in the liquid phase by exchange between vapor and liquid phases. Considerable care must, therefore, be exercised in storing, transferring, or circulating heavy water as this exchange will occur equally well in all parts of the sytem. In a test reactor which requires frequent changes in core types and their configurations, entry of water into the heavy-water system will occur. In general, the amount of water that enters the system will be a function of plant design and the care exercised by operating personnel.

3.1 General Description

The heavy-water system is comprised of a number of small systems which include a storage vessel, a transfer system, a cleanup system, and a recovery system. In general these systems were designed for use with heavy water only; however, portions of the transfer system are used with water. The primary considerations in the design of any system for handling heavy water are given to preventing loss of material from the system, or contamination with water and/or water vapor from the normally humid atmospheric air. All the piping and equipment designs are such to assure maximum integrity of the system and minimum holdup of liquid. Wherever it is possible for water to flow or be pumped into the heavy-water system, removable spool pieces are provided in the piping. The systems are isolated by removing the spool pieces provided and installing blind flanges.

3.2 Piping and Valves

All piping and fittings are seamless schedule 10S stainless steel, type 304L. The piping is sloped to drain to low points of the systems and is installed without pockets wherein liquid would be trapped. Fittings 1/2 to 2 in. are socket-welding type; 2 in. and larger are butt-welding type. Flanges 1/2 to 2 in. are socket-welding type; 2 in and larger are butt-welding type. Flanges are faced and drilled to the 300-lb ASA standard where subjected to primary system pressure; otherwise they are faced and drilled to the 150-lb ASA standard. Gaskets are flexitallic, style CG with teflon filler where permanently installed, and teflon ring type for removable spool pieces.

All block valves are stainless steel, welding-end type, equipped with bellows seals and stuffing boxes to minimize stem leakage, and where feasible, are located in vertical piping runs to minimize liquid holdup. Valves are "Belloseal" streamline "Y" pattern manufactured by the Powell Valve Co.

3.3 Storage Tank

Storage of the heavy-water inventory is provided in a horizontal cylindrical pressure vessel which is maintained with a helium atmosphere (2 to 5 psig) to prevent diffusion of atmospheric air into the vessel. The vessel was designed for a pressure of 40 psi at 100°F in accordance with Section VIII of the ASME Pressure Vessel Code, 1956 Edition. The diameter of the vessel is 137 in., length is 22 ft, and capacity is 14,500 gal. The shell and heads are fabricated of carbon steel plate clad with 0.075-in. of stainless steel; nominal thickness is 3/8 in.

In general, nozzle attachments were restricted to the top of the vessel to minimize losses in the event of flange leaks. Two 1-1/2-in. flanged nozzles connect the liquid and pressure blowdown from the pressurizer vessel. A 1-in. nozzle connects the liquid transfer piping from the drain collecting tank. A 2-in. nozzle connects a safety relief valve which is relieved to the cold trap for recovery of heavy-water vapors. Additional nozzle connections in the top of the vessel include a 24-in. flanged manway, a helium pressurizing line, and a makeup connection.

A 3-in. welded nozzle with a block valve, bottom center of the shell, is provided for the transfer of material to and from the vessel. Additional connections to the bottom of the vessel include a thermocouple, an indicating thermometer, and a conductivity cell.

Heavy water is an accountable material and the vessel incorporates devices for making accurate measurements of the liquid level for this purpose. Two devices are provided for liquid-level determinations: a sight glass and a mercury manometer with a helium bubble tube. The sight glass has a range of 0 to 120 in. and covers the lower 120 in. of vessel. This device is a manometer which was modified to provide direct liquid level readings in 0.1-in. increments. The glass column has a pressure rating of 150 psi. The shutoff valves, which connect the glass to the top and bottom of the vessel, are equipped with ball-checks which close if the glass should break. The manometer and bubbler tube cover the top 50 in. of the vessel.

3.4 Transfer System

Heavy water is transferred from the storage vessel to the primary system or vice versa by means of a transfer pump. Incorporated as a part of the transfer system in an outdoor forced-draft fin-tube heat exchanger. A suitable piping manifold is provided for selecting pump use.

The transfer pump is a Chempump Model CH-5-1 1/2S, sealless centrifugal type with a capacity of 75 gpm against a TDH of 120 ft of water or 150 gpm against a TDH of 80 ft of water. NPSH requirements are adequately met by pressurizing the primary system with helium. The case was designed for a pressure of 565 psig at 400°F. Pump casing, impeller, rotor and stator liners, and shaft are stainless steel; shaft bearings are Graphitar. The pump is driven by a 5-hp, 440-v, 3-phase, 60-cycle totally enclosed electric motor. The pumped fluid provides for both lubrication and cooling of the pump and motor.

An outdoor forced-draft, fin-tube heat exchanger (Figure 26) is provided for the cooling of heavy water. Following elevated temperature operations, the heavy water is cooled below the boiling point before the system is depressurized. Additional cooling is required if the reactor vessel is to be opened for core service work, or if cleanup operations are to be initiated. The transfer pump is used for the circulation of water through the exchanger. The piping at the transfer pump is arranged to permit the circulation of water through the reactor vessel to prevent stratification. A precaution taken is that circulation of water through the exchanger is never attempted when the outside air temperature is below 40°F. Since heavy water freezes at approximately 39°F it is possible to cause direct damage to equipment, with the subsequent loss of heavy water.

The exchanger is a 4-pass air-cooled unit manufactured by Smithco Engineering, Inc., Tulsa, Okla. It was designed for a pressure of 400 psi at

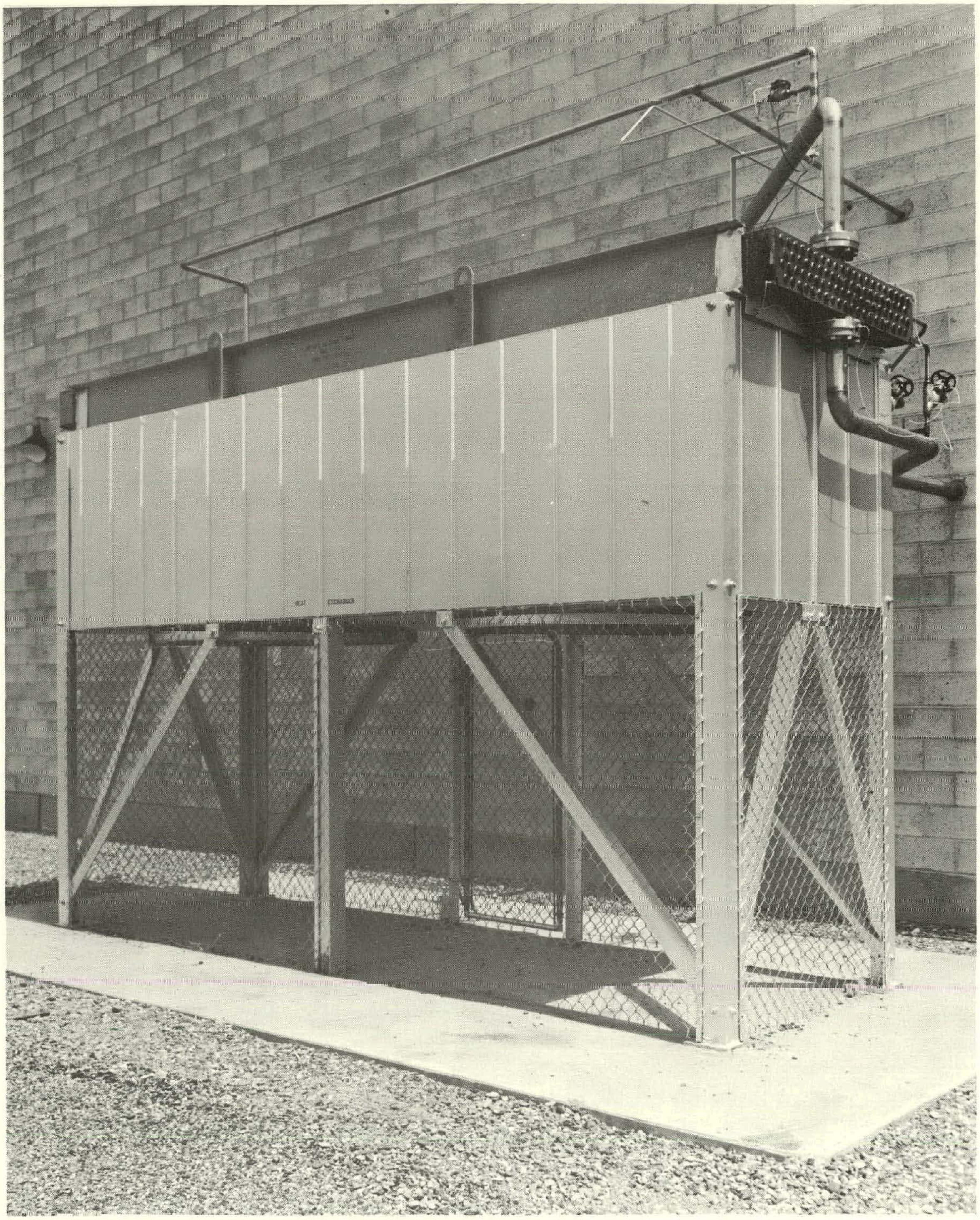


Fig. 26 Fin-tube heat exchanger installation.

400°F at a flow rate of 150 gpm. Design heat removal capacity is 2,880,000 Btu/hr (average) with 168,500 lbs/hr air rate at an average air temperature of 80°F. This heat removal capacity is sufficient to cool 12,500 gal of water from 400 to 100°F in approximately 12 hr. The tubes are stainless steel, type 304L with aluminum solder-bonded fins, rolled and seal-welded into inlet and outlet headers. Tubes are sloped to permit drainage, and outside drain lines are provided to drain the headers. Helium piping is installed to each header to permit purging and venting of the exchanger.

Two 54-in.-diam adjustable pitch fans, mounted under the tube bank, provide air circulation. Each fan is driven by a 3.4-hp, totally enclosed electric motor. Start and stop switches for the fan motors are located on the reactor building instrument panel.

Instrumentation for the exchanger includes an indicating flowmeter, thermocouples for recording inlet and outlet water temperatures through the exchanger, and the necessary pressure gages.

3.5 Cleanup System

A high ionic and particulate quality is desired in heavy water since impurities absorb neutrons, produce radioactivity in the material, and, if high enough in concentration, accelerate the decomposition of heavy water to deuterium and oxygen gases in the presence of radiation. Heavy-water quality is maintained by a cleanup system consisting of a 5-gpm canned motor pump, two filters, and two mixed-bed ion exchange columns. Water from the storage vessel or the primary system can be circulated through the system and returned as desired.

The cleanup system (Figure 27) is designed for a flow rate of 5 gpm, and 150-psi pressure at 100°F. The flow is from the pump discharge through a 35-micron stainless steel pre-filter, the ion exchange columns, a 35-micron after filter, and back to the system. A remote-reading flowmeter, two recording conductivity cells, two indicating pH cells, and a sampling station provide operating information and indication of abnormal bed conditions.

The ion exchange columns are manifolded to permit either individual or series flow, and are equipped with valves to permit removal from the piping when the bed is exhausted. Each column contains 1 ft^3 of mixed resin. The optimum proportion of the two resins depend upon the quantity of ionic impurities in the water. The bed used is the Rohm and Haas Monobed-1 which is a mixture of amberlite anion resin IRA-400, and cation resin IR-120. The volume ratio of the bed is 1.5 parts anion to 1 part cation resin. This bed has a relatively large capacity and is stable to 140°F. The pH of the heavy water inventory is maintained at 5.0 to 5.5 (neutral pH for heavy water is ≈ 7.3), and the conductivity at ≈ 1.0 micromho.

The cleanup pump is a Chempump Model CFH-1 1/2-3/4S, sealless centrifugal type, rated at 5 gpm for a TDH of 125 ft of water. Pump casing impeller, rotor and stator liners, and shaft are stainless steel; shaft bearings are Graphitar. The pumped fluid provides for both lubrication and cooling of the pump and motor.

Two filters are installed in the cleanup piping. The pre-filter is provided for the removal of particulate material from the cleanup stream. The after filter removes resin fines from the column effluent. The filter elements are fabricated of sintered stainless steel with an average pore size of 35 microns. The conductivity and pH instrumentation provide operating information on cleanup efficiency.

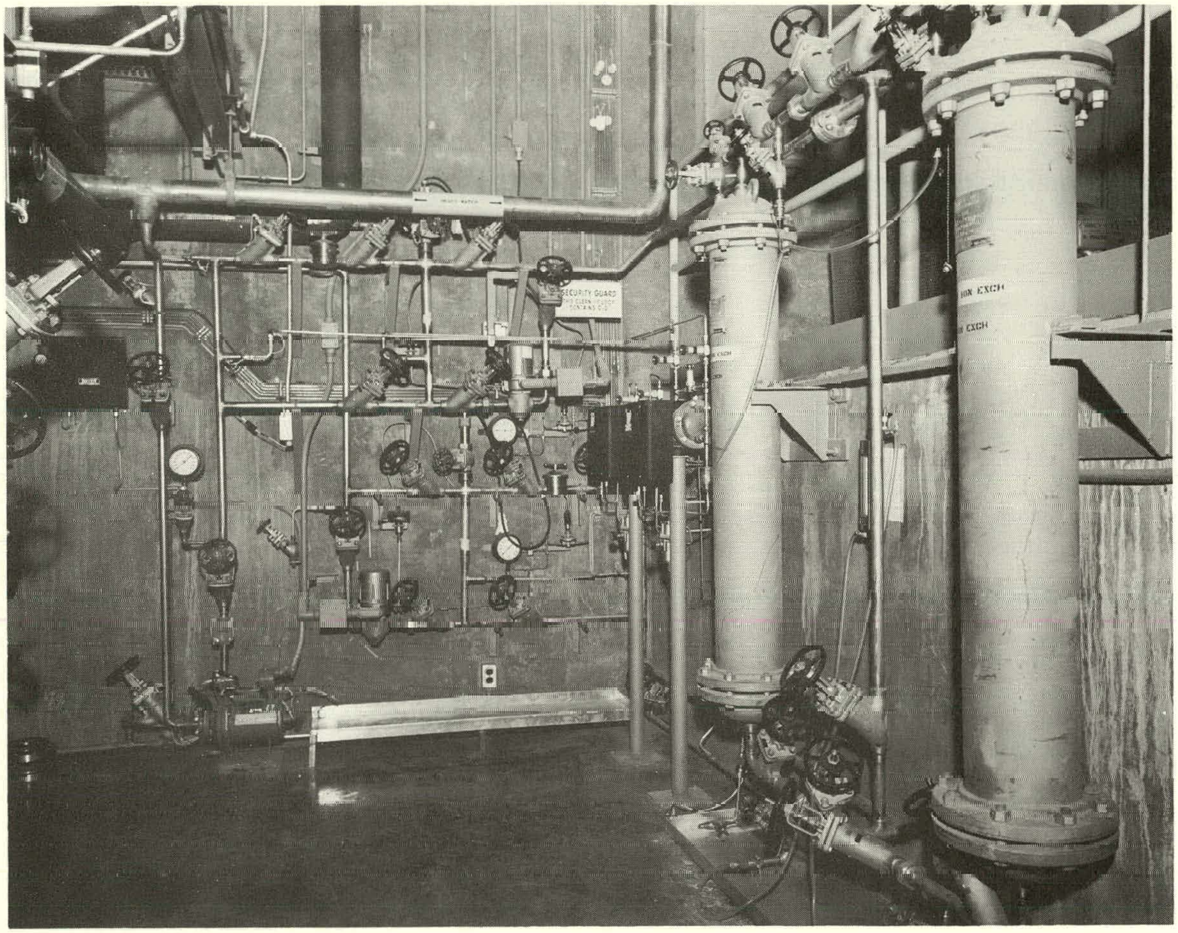


Fig. 27 Heavy-water cleanup system.

3.6 Recovery System

The dollar value of heavy water requires that equipment be provided for recovery. However, the equipment provided should be commensurate with the value of the material recovered. The recovery system at Spert II, while not elaborate, is adequate for this facility. The recovery system consists of vacuum pump, a cold trap, and a D_2O drain collecting tank.

3.61 Vacuum Pump. For experimental purposes, it is necessary to alternately use water and heavy water in the reactor vessel, primary coolant system, and transfer system. The possibility of degrading the heavy water necessitated that equipment be provided for thoroughly drying these systems to remove residual water and/or water vapor. In addition, this equipment also provides for the recovery of residual heavy water and vapor. To accomplish the above objectives these systems are dried with a vacuum pump. Vacuum drying utilizes the principle of reduced saturation temperatures at reduced pressures. The latent heat of vaporization is supplied to the liquid from the metal walls of the system. If possible, drying is initiated with the system at an elevated temperature to reduce the time required to dry the various systems.

The vacuum pump is a model KDHBO and was manufactured by the Kinney Manufacturing Div. of the New York Brake Co. It is a single-stage, duplex unit with a free air capacity of 131 cfm at 535 rpm and an ultimate pressure of 10 microns. The pump is water cooled and is equipped with an oil separator and a gas ballast valve. The oil separator removes entrained droplets of oil from the discharge gases by centrifugal action. The gas ballast valve admits atmospheric air to the pump on the compression stroke which dilutes the compressed vapors and helps to prevent condensation in the pump and oil. This valve is in the off position when pumping heavy-water vapors.

The pump discharge is directed to the atmosphere when carrying water vapor or to the cold trap when carrying heavy-water vapor.

The system volume is approximately 1600 ft^3, and the pump is capable of reducing system pressure to 0.1-in. of mercury in 40 hr. The dryness of the system is determined by observing system pressure and temperature, and by monitoring the pump discharge with a dew point device.

3.62 Cold Trap. The cold trap is a water-cooled heat exchanger which is used to cool the vacuum pump discharge and gases vented from the various systems for partial recovery of heavy-water vapors. The gases are cooled to 70°F to condense most of the vapor. The condensate drains to the D_2O drain-collecting tank. The cooled gases pass to a centrifugal-type separator to remove entrained droplets, and then to the atmospheric vent. The atmospheric vent is equipped with a check valve to prevent air infiltration, and a temperature alarm which warns of excessive temperatures. The cooling water passes through helical coils in the shell of the trap, and the gases pass through the shell side.

The cold trap was manufactured by Graham Manufacturing Co., Inc., Los Angeles, Calif. The separator was manufactured by Air Systems Co., Los Angeles, Calif. All wetted surfaces of both the trap and separator are fabricated of suitable stainless steel.

3.63 Heavy Water Drain Collecting Tank. The various drains from the mechanical equipment and piping are directed by gravity to the collecting tank, which is located below the reactor vessel. In addition, leakage from pumps seals and control rod drive seals are piped to this tank for collection. The collected material is periodically transferred to the storage vessel. The transfer is made by applying helium pressure to liquid surface and forcing the material to the storage vessel.

The tank is fabricated from 12-in. schedule 10S stainless steel pipe and has a capacity of 16 gal. It is designed for a pressure of 150 psig at 200°F. The tank is equipped with a pressure gage, a sight glass, a solenoid vent valve, and the necessary nozzles and valves for drains inlet, helium inlet, and discharge piping to the storage vessel.

3.7 Low-Pressure Helium System

Low-pressure helium is used to purge the various systems of atmospheric air, and to provide an inert atmosphere in contact with heavy water.

This system consists of a single helium cylinder which is connected to suitable piping and valves for distribution to the various systems. The cylinder is connected to a pressure-regulating valve which reduces the pressure to 20 psig or less. A safety relief valve set to relieve at 50 psig protects the piping and equipment on the downstream side of the regulation. Either fully charged cylinders, or partially depleted cylinders from the high-pressure manifold are used for the helium supply.

3.8 Leak Detection

A matter of vital importance in any facility designed for use with heavy water is the loss of material through leakage from the various systems. For static conditions (ie, no pressure or temperature) visual inspection of the various systems probably would suffice. However, the possibility of leakage with the subsequent loss of large quantities of material is increased when the systems are pressurized, and further increased when the reactor building is evacuated for nuclear operations. To guard against this eventuality, the piping systems are kept under constant surveillance by leak detectors which monitor potential sources of leakage such as flanged joints, valve bonnets and stems, pressure connections, etc.

An eight-channel detector, centrally located in the reactor building, monitors the piping systems. Figure 28 shows the detector circuit for a single channel, and its associated sensing probe. The probe consists of a copper conductor insulated with a cotton sleeve which is fastened to piping, valves, flanges, etc, as shown in Figure 29. In general the probes are located on the underside of the piping in order to detect dropwise leakage. In the event of a leak, water absorbed by the cotton sleeving provides a conductive path between the normally insulated copper conductor and the metal piping which triggers an electronic relay in the detector circuit. This relay actuates alarms in both the reactor building and control center. The eight-channel detector is equipped with indicating lights for visual indication of leak locations to operating personnel.

In those cases where the metal surfaces are painted or insulated, the sensing probes are modified by placing a loosely braided copper sleeve over the cotton sleeving. This arrangement provides a return ground for the detector circuit which is independent of the metal piping. Experience has shown that a single drop of water on the sensing probe will actuate the alarm.

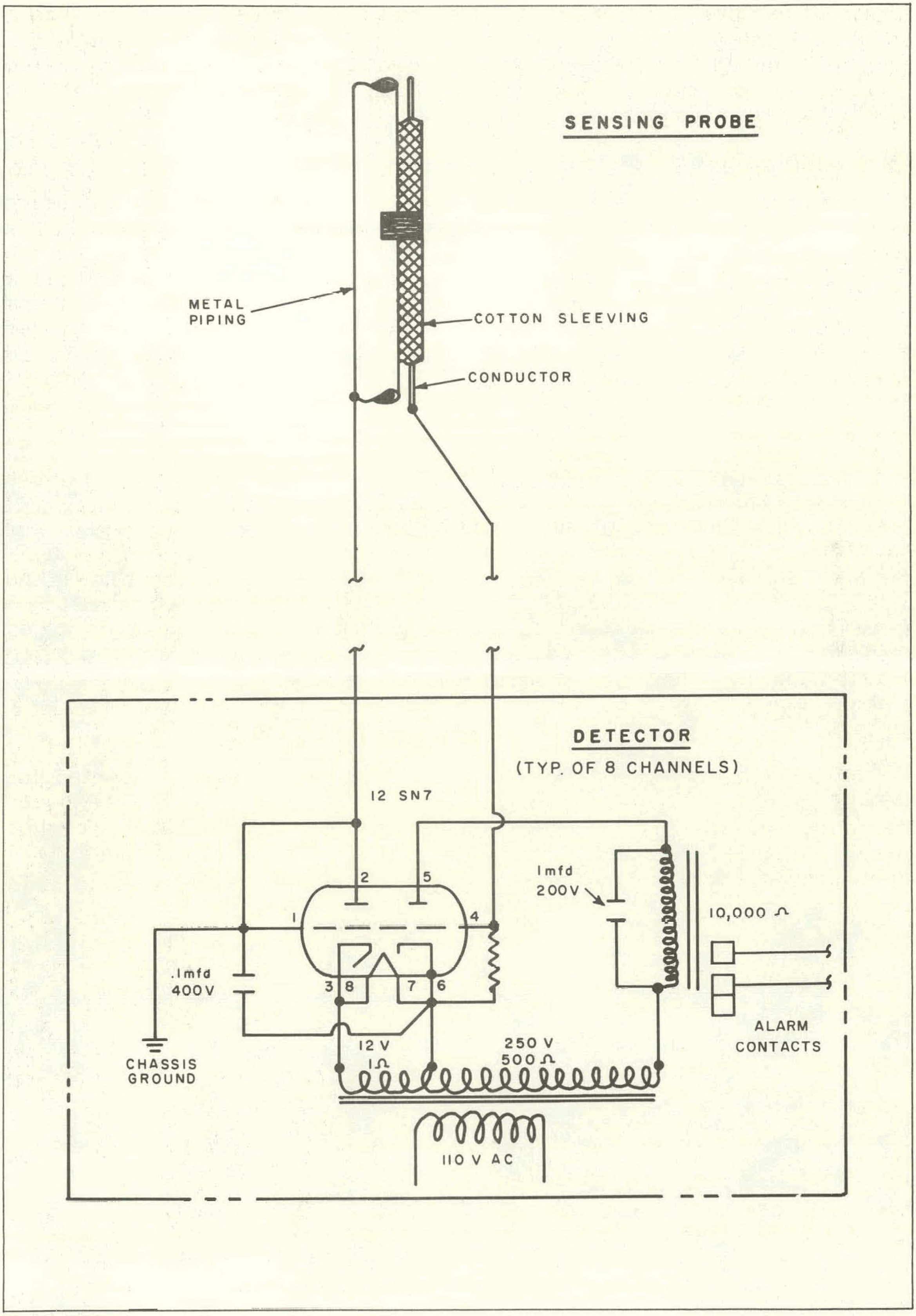


Fig. 28 Leak detector circuit.

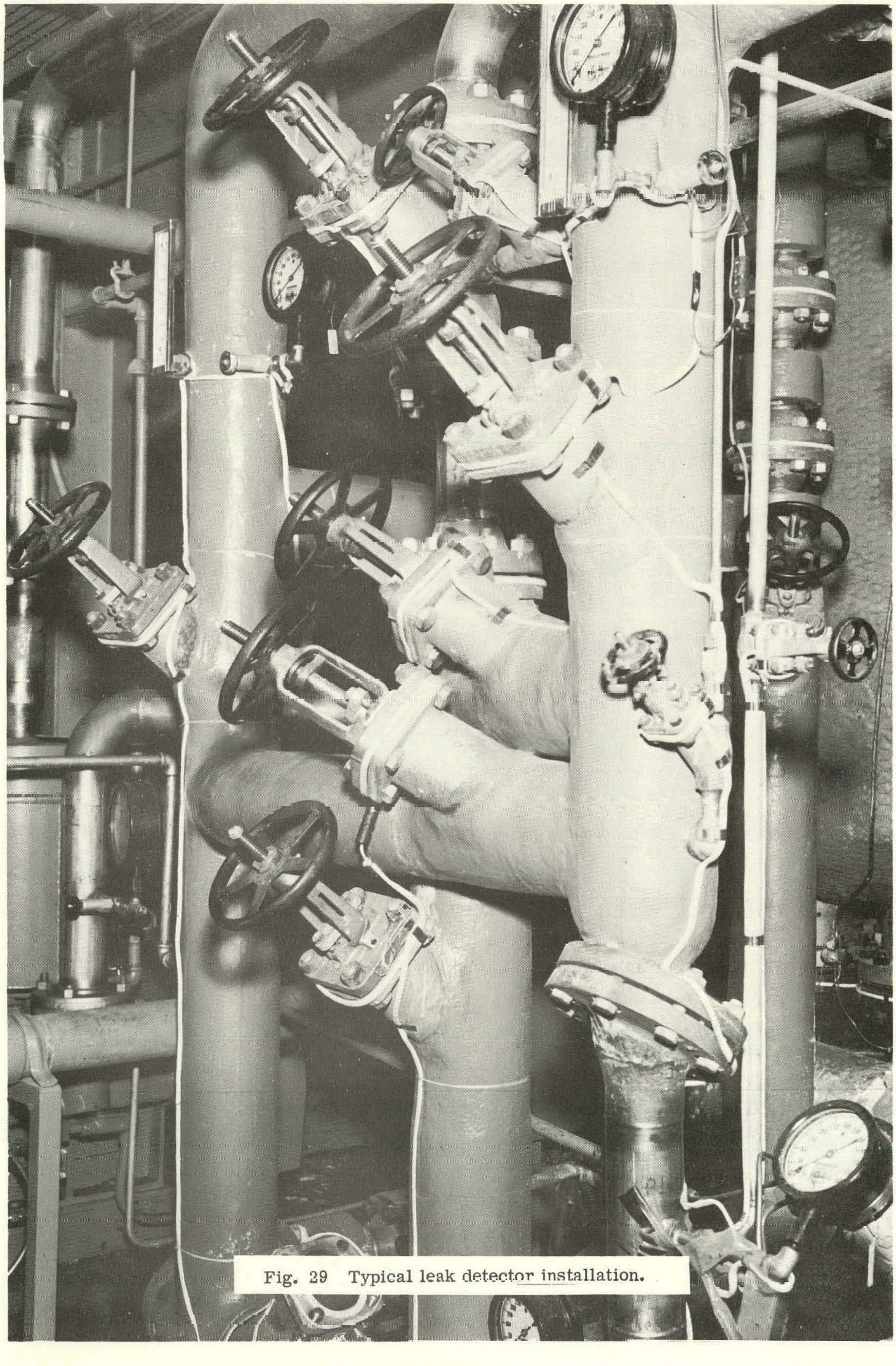


Fig. 29 Typical leak detector installation.

V. PLANT INSTRUMENTATION

1. GENERAL DESCRIPTION

A wide variety of industrial-type instrumentation is used for sensing and controlling plant parameters. These include pressure, temperature, flow, liquid level, conductivity, and pH instrumentation.

The plant instrumentation is designed primarily for operation at the reactor building. However, key parameters of the primary system (ie, pressure, temperature, level, and flow) can be remotely controlled from the control center 1/2 mile away. Because of the distance, electrical transmission is required for transmission of signals to the control center. The signals are transmitted over multi-conductor cables, laid on the ground between the two areas. Pneumatic instruments at the reactor building are equipped with transducers to convert pneumatic signals to electrical signals for transmission to the control center. A simplified block diagram of the instrumentation is shown in Figures 30, 31, and 32.

Key plant parameters are monitored on two alarm panels, one at the reactor building and one at the control center. These panels advise operating personnel of abnormal conditions during plant operations.

2. PRESSURE

The reactor vessel pressure is measured by a strain-gage-type pressure transducer with an output of 0 to 20 mv for a range of 0 to 400 psig. The pressure is indicated on the process panel at the reactor building and recorded at the control center on a strip chart recorder. The indicating instrument at the reactor building is equipped with a front setting alarm, normally set 20 psi above operating pressure.

The reactor inlet and outlet pressures are measured by strain-gage-type transducers. The pressures are recorded on dual-pen strip chart recorders at both the reactor building and the control center.

Control of the primary system pressure is accomplished through a recorder and two controllers located at the control center, or two manual pressure-selecting devices at the reactor building. The controllers and manual selectors are electrically operated devices which, through transducers in the reactor building, actuate penumatic diaphragm control valves in the helium piping.

The first controller with its associated control valve functions to pressurize the system. The second controller with its associated control valve functions to depressurize the systems. Both controllers incorporate proportional, reset, and rate modes of automatic or manual control. Output signals from the controllers are modulated in proportion to the differential existing between system pressure and control pressure. However, a 5-psi differential must exist between

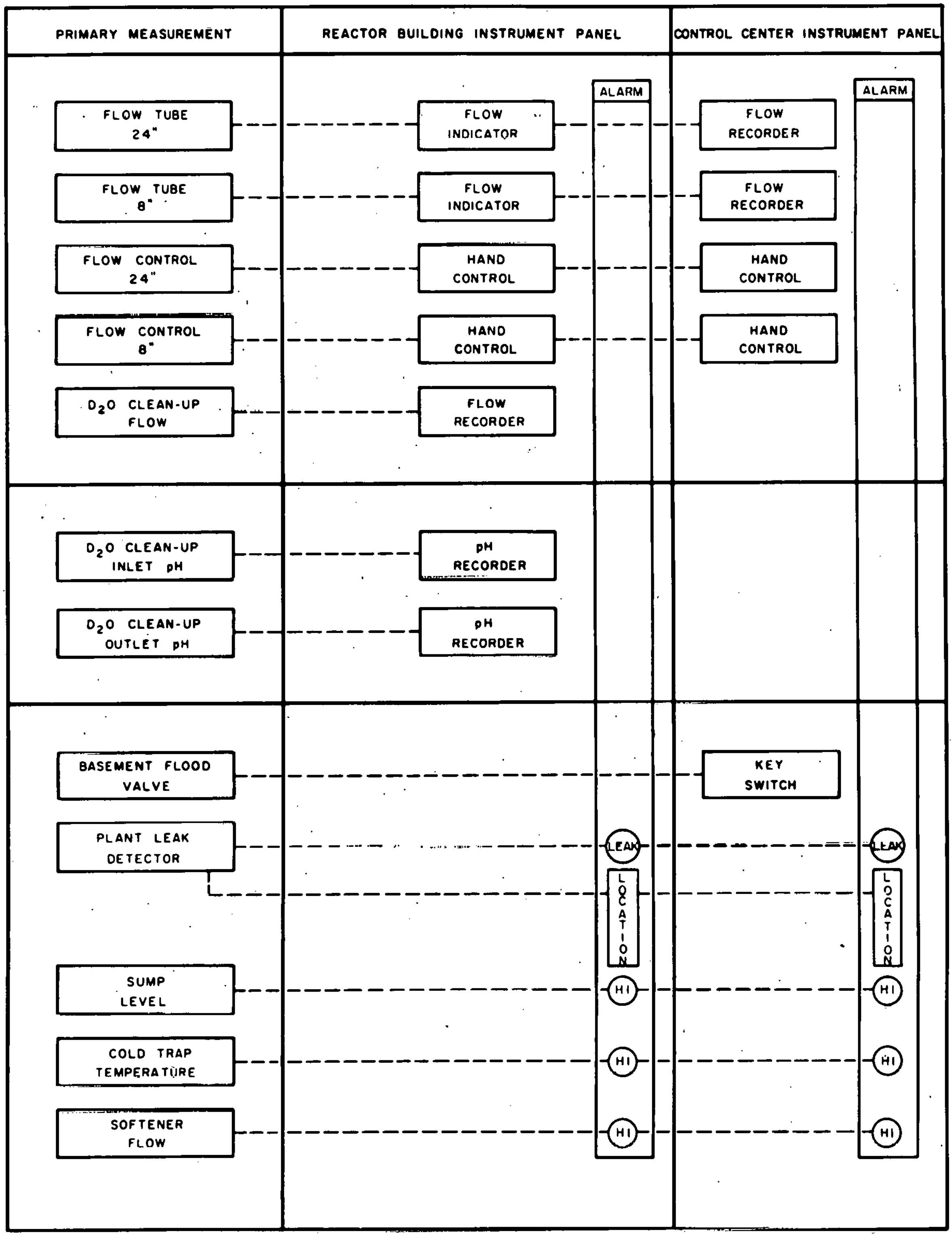


Fig. 30 Simplified block diagram of flow pH and miscellaneous instrumentation.

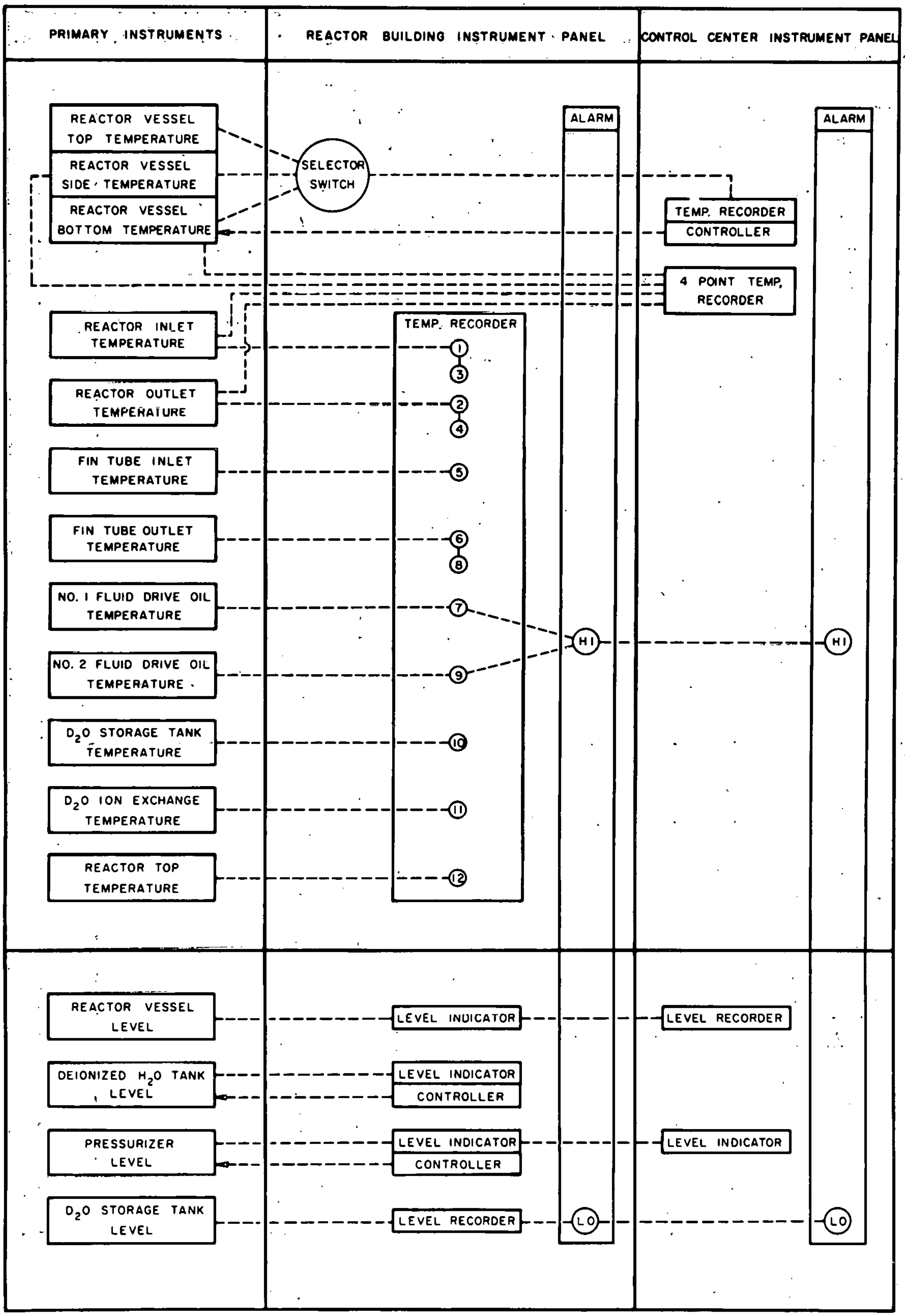


Fig. 31 Simplified block diagram of temperature and level instrumentation.

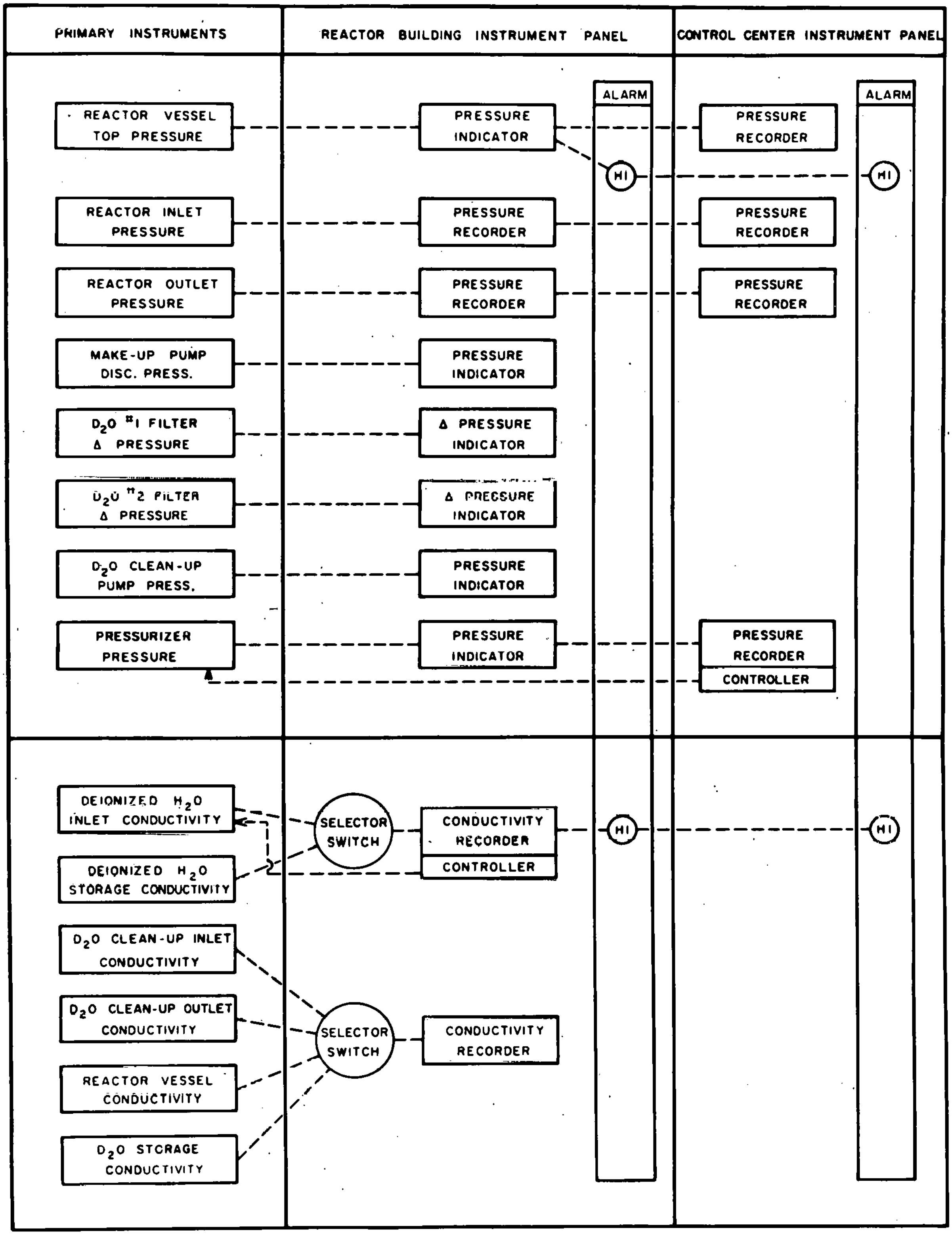


Fig. 32 Simplified block diagram of pressure and conductivity instrumentation.

system pressure and control pressure before the second controller acts to depressurize the system. This arrangement prevents simultaneous opening of both valves.

The recorder is equipped with a snap-action upper limit safety switch. If the system pressure increases to 25 psi above the control set point, and the increase is faster than the operation of the second controller, the safety switch actuates an auxiliary control relay at the reactor building. This relay in turn admits full air pressure to the diaphragm control valve to depressurize the system.

Manual control of system pressure is provided by hand-indicating-control switches (HIC). These switches are variable potentiometers which actuate the diaphragm control valves. System pressure is selected by observing the action of the pressure indicators as the control switches are operated. System pressure control is transferred between control stations by positioning a manual selector switch.

The makeup pump and transfer pump discharge pressures are indicated at the reactor building by pneumatic pressure transmitters which have a range of 0 to 400 psig.

The heavy-water cleanup pump discharge pressure system consists of a pneumatic differential pressure transmitter and indicator with a range of 0 to 100 psig.

Two pneumatic differential pressure loops are provided for measuring the pressure drop across the two micro-metallic filters in the cleanup system. The pressure is indicated on the control panel at the reactor building by a 0- to 20-psig pressure gage.

Pressure gages for local pressure readings are provided at 13 locations in the plant. These include the drain-collecting tank, heavy-water storage tank, inlet and outlet of the transfer pump, fin-tube heat exchanger, pressurizer, softener, vacuum pump, and air systems.

3. TEMPERATURE

Ten double-element thermocouples, in thermowells, are provided for measuring temperatures in the primary system. The thermocouples are iron-constantan, type "J" with a temperature range of 0 to 500°F.

The temperature in the reactor vessel is measured and controlled by one of three thermocouples located in the top, side, and bottom of the vessel. Selection of the control thermocouple is accomplished by positioning a selector switch located on the reactor building instrument panel. A recorder-controller, located at the control center, in conjunction with immersion heaters in the reactor vessel provides system temperature control. The controller incorporates proportional, reset, and rate modes of automatic control or manual control. The controller controls 600 kw of electrical heaters which are arranged in banks of 200 kw each. The first two banks of heaters (400 kw) are step-controlled by the recorder set point; the third bank (200 kw) is controlled by a magnetic amplifier and three 37.5-kva saturable core reactors which modulate power to the heaters. This arrangement provides smooth temperature control proportional to deviation from the system control point.

A 12-point temperature recorder located at the reactor building records various temperatures of the primary coolant system. A four-point recorder at the control center records reactor inlet and outlet temperatures, and reactor vessel side and bottom temperatures.

Those temperature signals which are transmitted to the control center are connected to a reference junction which is maintained at 150°F. Those temperature signals which are transmitted to instruments at the reactor building are direct connected, so that in the event of a reference junction failure, the temperature records at the reactor building will still be accurate.

4. FLOW

The primary coolant system flow is variable over the range of 200 to 20,000 gpm. In order to obtain a high degree of accuracy in measuring flow, an 8-in. and a 24-in. flow loop, installed in parallel, are provided to measure flow rates of 200 to 2000 gpm and 2000 to 20,000 gpm, respectively. Each loop consists of a flow tube, a differential pressure transmitter, a resistance-bulb-type temperature detector and servo mechanism, a square root extractor, a flow indicator, and a flow recorder.

The recorder for the 2000- to 20,000-gpm range is an extended range model which records flow rate in three steps. The first full-scale range is 1900 to 8900 gpm, the second covers the range 8000 to 15,000 gpm, and the third 14,000 to 21,000 gpm.

The flow rate in the primary system is primarily controlled by varying the pump speeds by means of the variable-speed fluid drive units. Additional flow control is obtained by a 24-in. manual flow-control valve or an 8-in. motor-operated flow-control valve. Variable potentiometer controllers are provided at both the reactor building and control center for speed control of the fluid drive units.

5. LEVEL

Liquid level in the reactor vessel is measured by a displacer-type level device with an electronic transmitter which has a range of 0 to 120 in. The level transmitter is temperature-compensated and transmits a signal to an indicator at the reactor building and to a recorder at the control center. A selector switch at the reactor building provides a density correction to the level signal when using heavy water. A sight glass with a range of 0 to 120 in. is installed on the reactor vessel as a backup liquid level instrument.

Level in the pressurizer vessel is measured by a displacer-type level device with a pneumatic transmitter which incorporates proportional band and reset adjustments. The output air from the transmitter goes to the valve positioner on the blowdown valve and to an electro-pneumatic transducer. This transducer drives level indicators at both the reactor building and the control center. The level indicator at the reactor building is equipped with a microswitch which starts the makeup pump with a decrease in level.

A 100-in. displacer level device and pneumatic transmitter serves the deionized water storage tank. The level signal is transmitted to a pneumatic level indicator at the reactor building. Two pressure switches are actuated by the level signal. One turns on the heaters in the storage tank if the level drops to within 6 in. of them. The other closes a solenoid shutoff valve in demineralizer effluent line when the tank is full.

6. MISCELLANEOUS

Conductivity of deionized water is measured at the outlet of the demineralizer and the storage tank. The conductivity of the effluent water is continuously recorded and controlled by a recorder-controller which is equipped with a set point and an alarm switch. The controller closes a solenoid valve in the effluent line on high conductivity. The conductivity of the water in the storage tank may be spot-checked by positioning a selector switch.

The instrumentation provided for measuring conductivity of heavy water consists of four cells, a recorder, and a selector switch. The four cells are located in the inlet and outlet of the cleanup system, bottom of the reactor vessel, and the heavy-water storage vessel. The conductivity of these four stations is recorded, one at a time, on a single-point recorder which has a range of 0 to 10 micromhos. The choice of which point is recorded is accomplished by a selector switch at the reactor building.

Instrumentation for measuring pH is provided in the heavy-water cleanup system only. Two separate and complete systems are provided in the inlet and outlet of the cleanup piping. Each system consists of a pH cell, mounted in a pressurized flow chamber, an amplifier, and a recorder. The ranges of these systems are 2 to 12 pH.

7. PANEL ALARM

Alarm panels with eight channels each are provided at the reactor building and control center. The alarm functions are duplicated at each location and can be acknowledged from either location.

VI. CONTROL AND TRANSIENT ROD DRIVES

1. INTRODUCTION

Reactor start-up and control is accomplished using eight control rods. These are yoked together in pairs which are positioned by four electric motor positioning air-scram drives located on the reactor vessel access head. A transient rod, centrally located in the core, is used to rapidly introduce reactivity in the reactor, thereby initiating power excursions. This rod is positioned by a fifth drive unit.

1.1 Design Philosophy

The active core length selected for the initial operation of the facility was 24 in. However, future testing of other cores of undetermined length was planned. At the time, the maximum expected active core length was 42 in. The decision was made to incorporate provisions for testing 42-in. cores, provided this did not compromise the design for 24-in. drives. Subsequent detailed design was able to incorporate this feature into the drives. However, in order to keep all of the drives essentially mechanically interchangeable, certain limitations were placed on the transient rod drive.

While it was not a design parameter, it was understood from the beginning that the primary function of this facility was to perform reactor behavior and safety experiments, and that the control-rod-drive design was to be accomplished with the minimum development work possible using the maximum "off-the-shelf" commercial hardware. Exotic design and radical departure from proven systems was to be avoided if possible.

1.2 Design-Safety Criteria

Design-safety criteria were established to provide as nearly as possible a drive system that would fail-safe, both from a mechanical and from a control circuit standpoint, under any foreseeable condition that might arise even during a major disaster in the reactor building. The following is a tabulation of the various safety criteria:

(1) After full insertion of the rods, it shall not be possible to raise the rods through any means except by deliberate operator action.

(2) Under no conditions of rod position or mechanical equipment condition (ie, loss of motor brakes, power, air, gears, or couplings, either singly or in a series of multiple failures) shall the control rods raise without an intentional act of the reactor console operator.

(3) In the event of loss of external driving forces, sufficient energy must be contained in the drive units to effect a scram.

(4) Adequate mechanical and/or control devices must be incorporated in the drives to prevent mechanical damage or hazardous reactor operation due to over-travel of the rods in either direction or any other operator-controlled function.

(5) The transient rod drive must not permit an inadvertent scram of the transient rod.

(6) Positive indication of control rod position must be provided. While it is desirable to know the position of the control rod itself at all times, the mechanical and electrical problems attendant to such a system of indication due to the emergency scram feature and the reactor vessel environment indicated that considerable expense and delay for development would be required. As an alternate, it was deemed acceptable to use secondary indication of the control and transient rod positions during all times of controlled movement by indicating the position of the controlling portion of the drive units in mechanical contact with the control and transient rod parts. During emergency scrams, the mechanical contact would be broken, thus resulting in no indication of control rod position until contact was reestablished.

1.3 Mechanical Design Criteria

In keeping with the original philosophy of designing a reliable drive unit in the shortest possible time and without unduly delaying the overall project, the drive unit design provided for external mounting in a vertical position on the reactor vessel access head. Vessel design, recognized as one of the more difficult and time-consuming facets of the overall project, was to proceed concurrently with the design of the drive units. Any other method of providing drive units would have delayed the vessel and/or vessel support design until firm space commitments for the drive units were established. Further, the accessibility of the drive units for maintenance and handling increased the advantage of a top-head drive system, especially since the reactor was to be installed below floor level and utilized no personnel shielding around the reactor vessel.

The requirement for sufficient self-contained stored energy to accomplish an emergency scram indicated a need for a stored-energy system capable of being triggered remotely and giving up sufficient energy to effect a scram within the allotted time. In addition, the release of stored energy to effect a scram required reliable operation at all times with the added feature of rapid operation under varying conditions of reactor environment. It was necessary from both the operational viewpoint and from the mechanical stress viewpoint to keep the control and transient rod accelerations essentially the same for all conditions of reactor environment. The use of external drives thus dictated the design of a remotely controlled variable stored energy source. Since stored energy is required at zero reactor pressure, a system related to, but independent of, the reactor primary system was required. A compressed-air-driven piston proved to be the most economical and most available source of motive power.

The requirement for fail-safe speed control, precise control rod mechanical positioning, and the self-locking feature to prevent accidental withdrawal of the control rods due to electrical or mechanical failures dictated the choice of an ac electric-motor-driven lead screw with self-locking Acme threads.

The design of the reactor core established the control rod drive locations on a radius of 7.23 in. with the transient rod drive located in the center. The drives were then designed to contain the majority of the components within a

6.5-in. diam. Miscellaneous connections, minor equipment devices, and the drive motors were so arranged as to prevent interference among the drives when installed on the vessel head.

The following is a tabulation of the criteria for design and operation of the rod drives for the control rods and the transient rod:

(1) Controlled rod movement travel:

a. control rod — 44 in.

b. transient rod — 44 in.

(2) Accuracy of controlled rod-position indication:

a. control rod — ± 0.01 in.

b. transient rod — ± 0.01 in.

(3) Speed of controlled movement:

a. control rods - 3 speeds approximately 19.9 in./min, 13.2 in./min, 6.5 in./min

b. transient rod - 3 speeds approximately 19.9 in./min, 13.2 in./min, 6.5 in./min

(4) Emergency insertion (scram) times as measured from initiation of scram signal to insertion through full travel to seat:

a. control rod — 0.4 to 0.7 sec

b. transient rod — 0.3 sec

(5) All rod drives must be operable and meet all other design criteria through the full operating range of the reactor system which include operation from 0 through 375 psig, 75 through 400°F, and no flow through 20,000 gpm upflow, and all possible variations and combinations of these process variables.

(6) "Bounce" of control rods and transient rod after scramming could not be permitted.

(7) Leakage of coolant through any seals or connections for the drive units must be limited to a maximum of 5 lb/hr for each drive unit.

(8) Control rods are to be run individually if desired or "synchronized" in gang operation to maintain relative positions within 0.01 in.

2. DESCRIPTION OF DRIVE UNIT

2.1 General Description

The drive unit (Figures 33 and 34) may be visualized as a vertical column 6.5 in. in diameter and 14 ft 8 in. long. A 4-in.-diam pneumatic piston is connected

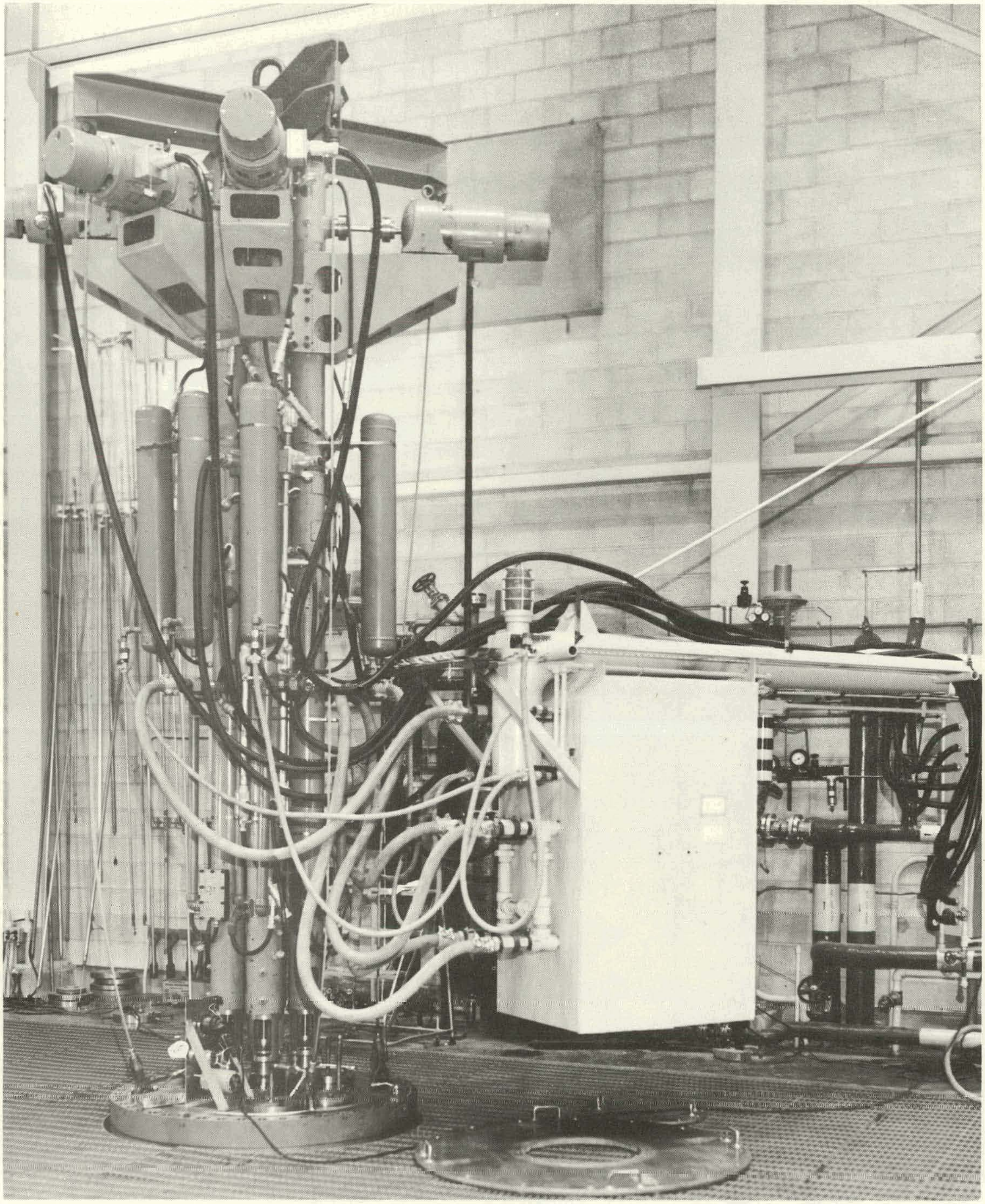


Fig. 33 Drive unit installation.

to the upper end of the drive rod. Rapid control rod scrams or rod insertions are obtained by exhausting compressed air below the piston, and allowing compressed air above the piston to drive the rods into the core.

Slow rod travel is obtained by running the drive motors in either direction. The motors are geared to an Acme screw-nut combination in the drive-screw

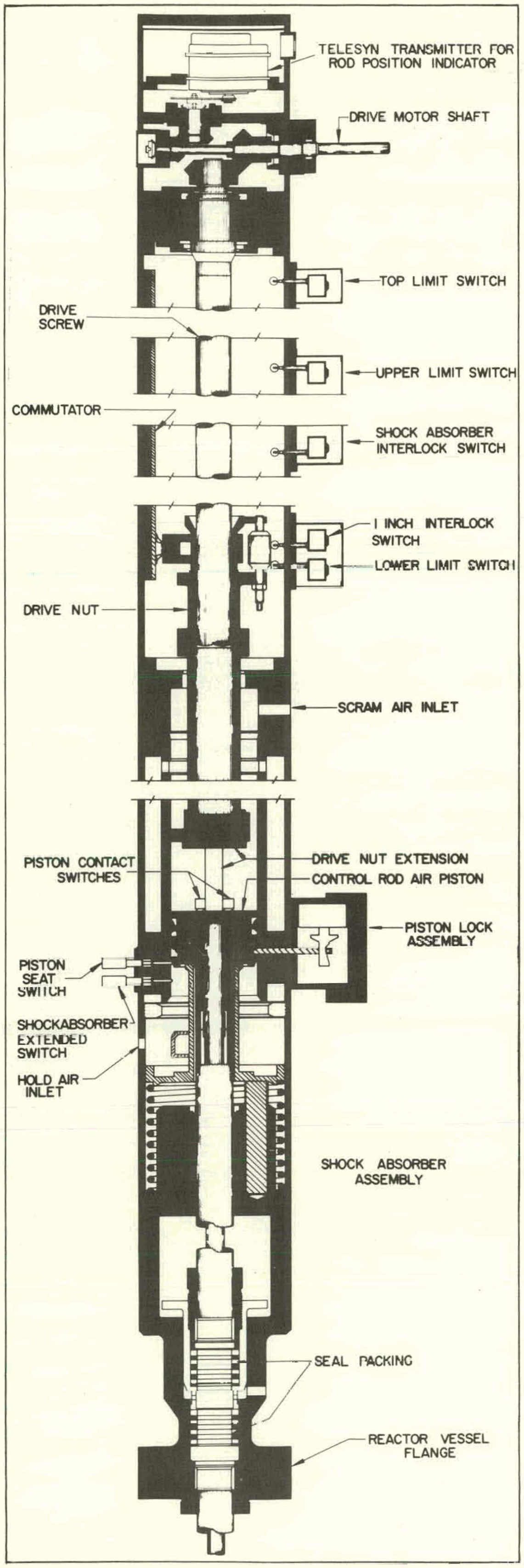


Fig. 34 Drive unit assembly.

section located above the air cylinder. Air pressures on the piston maintain a positive upward force on an extension connected to the Acme nut. The nut extension enters the air cylinder from the drive screw section. Directly below the air cylinder section is the shock absorber which absorbs the energy of the control rods during scrams.

The drive rod seal for retaining the reactor coolant is located below the shock absorber. Detailed descriptions of the drive components are presented in Section 2.2, beginning at the top of the drive unit. Differences between the control and transient rod drives will be discussed at the point where specific differences occur.

2.2 Detailed Description

2.21 Drive Motor. Under normal operating conditions, with the air pressure controls functioning properly, the drive motors are only required to have sufficient power input to overcome the drive-system friction, the net upward force on the piston to maintain contact, and the force to produce acceleration and overcome system inertia. However, as a safety requirement in case of air-system failure or in the case of operational convenience for the transient rod drive, the drive motors are sized to provide adequate power to drive the rods into the reactor under any and all conditions of reactor environment. Accordingly, each drive unit is powered by a 480-v, 3-phase, drip-proof, 3-speed, squirrel-cage induction-gear motor with a rating of 1 hp at 1780 rpm, 2/3 hp at 1180 rpm, and 1/3 hp at 580 rpm. An integral gear reduction of 25.6:1 reduces the output speeds to 69.5 rpm, 46.2 rpm, and 22.65 rpm, respectively. This results in drive-rod speeds of 19.9 in./min, 13.2 in./min, and 6.5 in./min, respectively. Each motor is equipped with a spring-set, magnetic-release disc brake.

2.22 Drive Gear Box. The gear box (Figure 35) contains a pair of 1:1 right-angle bevel gears which transmit power

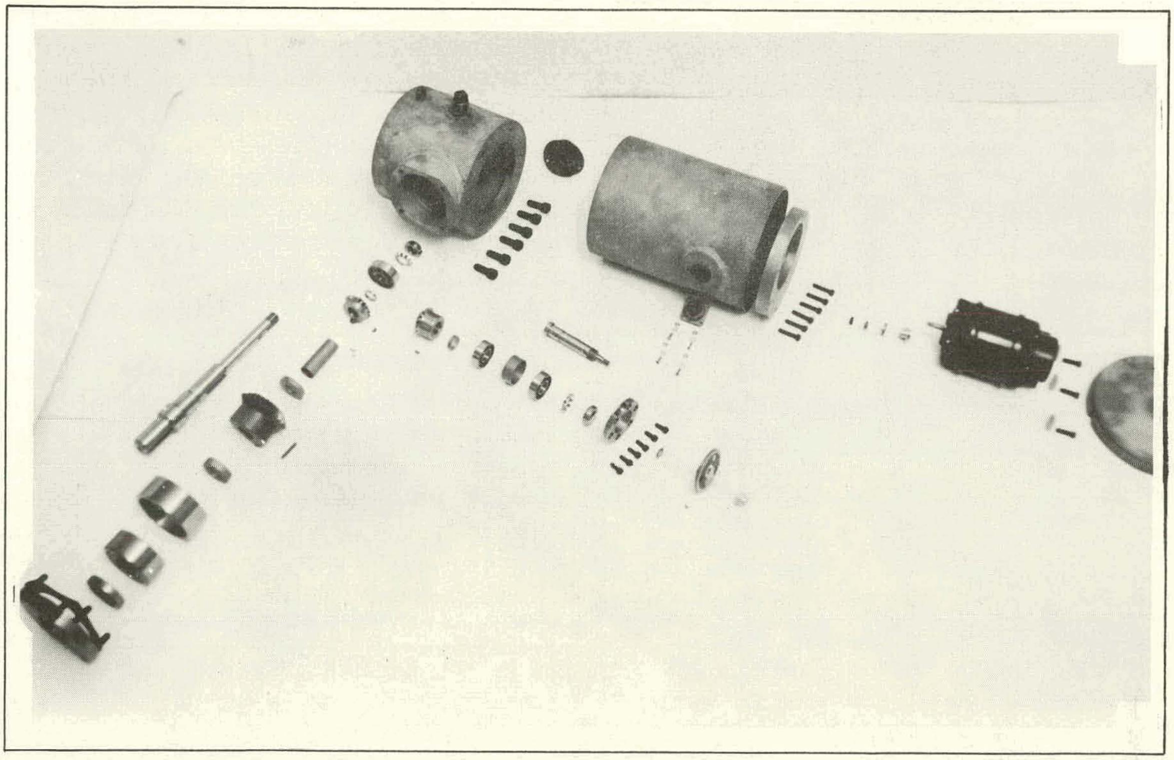


Fig. 35 Gear box section.

from the gear motor to the drive screw. It also contains a telesyn generator geared to the lead screw in such a ratio that one revolution of the telesyn is equivalent to 0.1 in. of rod movement. The telesyn generator drives a slave-telesyn-digital counter combination located on the control console. This counter indicates control or transient rod positions in the core when the air piston is in contact with the drive screw-nut extension.

2.23 Drive Screw Section. Converting rotary motion of the gear motor to linear motion for rod position is the function of the Acme screw and nut located in the drive-screw section (Figure 36). The screw is so constrained as to produce only rotary motion and the nut is so constrained as to produce only linear motion. The acme thread is used to provide a self-locking screw-nut combination.

Thus, under no conditions of rod position or mechanical equipment condition (loss of motor brakes, power, air, gears, or couplings) will the control rods raise without an intentional act of the reactor-console operator. This screw has a 1-1/4-in. diameter with 3.5 threads per inch. The total rod travel possible is approximately 46 in. The nut is constrained from rotating by a pair of rollers which travel in guides mounted inside the drive screw section walls. Attached to the nut is the nut extension which extends downward through an air seal into the air-cylinder section. During motor-driven rod positioning, the air piston is held in contact with the lower end of this extension by air pressure under the piston. During air scrams, contact is broken at this point. Contact is electrically indicated by a pair of snap action switches. This contact switch feature is common to both the control and transient rods.

In the case of the transient rod, a 28-v solenoid-operated latch is mounted on this extension to prevent the accidental release of this rod. The latch contains

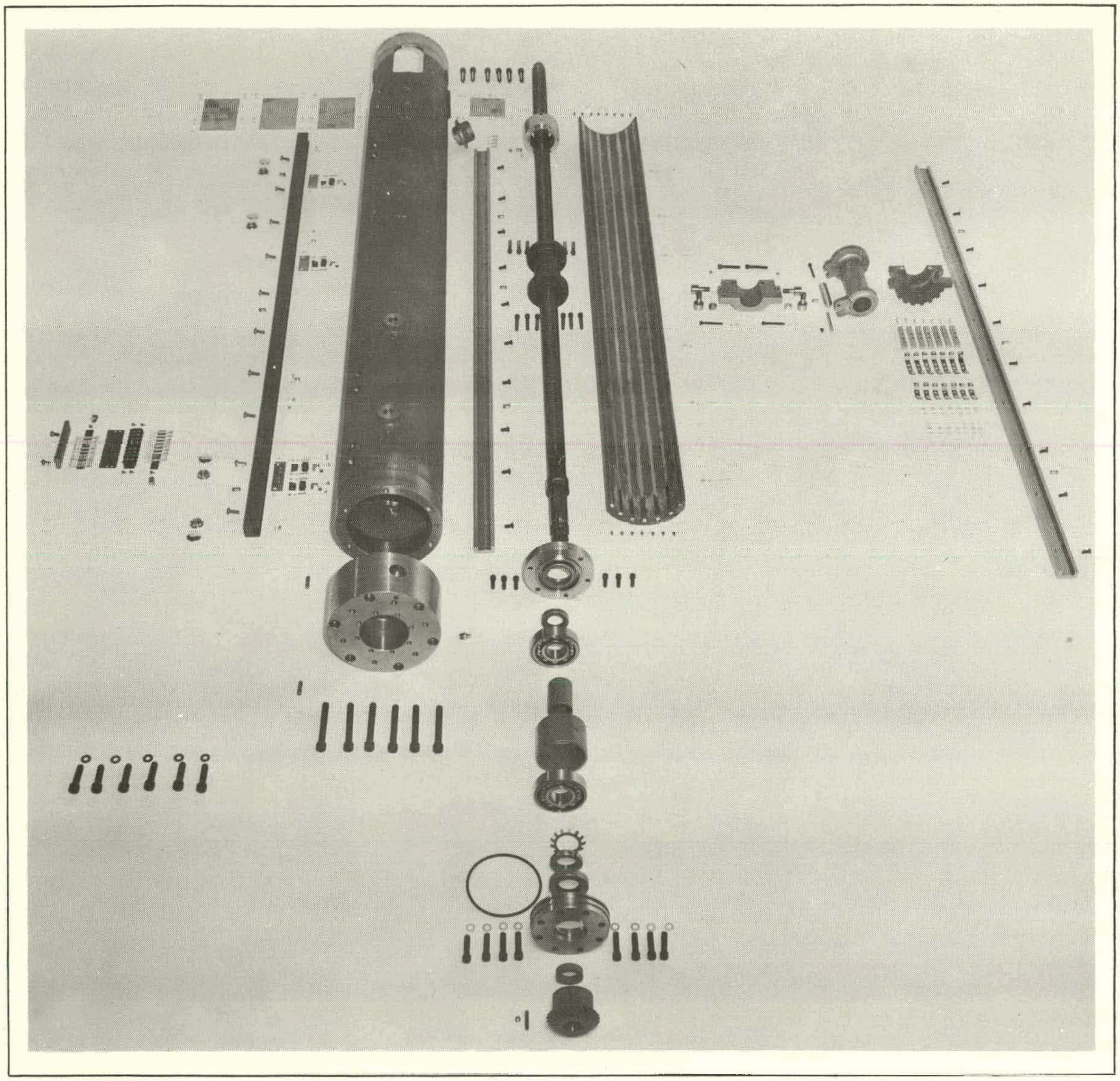


Fig. 36 Drive screw section.

a set of pivoted "fingers" which act as shear pins between the top of the piston and the Acme nut extension forming a mechanical linkage between these parts. Because of the relatively small force exerted by the solenoid, these fingers can only be retracted from the latch plate when there is no load on the latch. This is the normal condition when air pressures are correctly balanced. If there is a load on the latch, an abnormal operating condition exists which must be corrected before the transient rod can be dropped. Miniature snap action switches indicate the position of the latch fingers as either "locked" or "unlocked".

In order to bring electric power to the latch, latch switches, and contact switches, a stationary, segmented commutator is provided in the drive-screw section. The commutator consists of 7 segments; leads are brought to it inside the nut extension. Double wiper contacts are mounted on an assembly which is bolted to the Acme nut. Leads from the commutator segments are gathered at a multi-contact connector attached externally to the drive-screw section wall.

Control rod safety-interlock control is accomplished by five snap-action switches mounted parallel to the commutator on the outside of the drive unit housing which are actuated by a projection (torpedo) on the wiper assembly. These switches are: (a) top-limit switch at a 45-in. position from the physical bottom; (b) the control rod upper-limit switch at 36 in.; (c) an interlock at 6-1/2 in.; (d) an auto-stop switch at approximately 1 in.; and (e) the lower-limit switch located about 1/8 in. above the physical bottom of the drives.

It should be noted that the reference to physical bottom of the drive units is a reference to bottoming of the shock absorbers. Physically these switches are mounted in a position to accomplish the desired function at the desired relative location and are not actually mounted at the specified distances from the reference point. All of these switch indications are primary indications of the position of the nut extension.

The interlock switch works in conjunction with a shock-extended switch in the air cylinder section and prevents withdrawal of the rods beyond the 6-in. position in the event that the shock absorber does not come up to the extended position on withdrawal. The auto-stop switch prevents the insertion of the rods below 1-in. by the motor at speeds other than slow.

Transient rod safety and interlock switches are identical to the control rod switches except that the upper limit switch in the transient rod drive is located at the 45-in. position and serves as both upper and top limit.

2.24 Air Cylinder Section. Located directly below the drive screw section is the air cylinder section. The control rod air cylinder section is shown in Figure 37 and the transient rod air cylinder section is shown in Figure 38. This section contains a 4-in.-diam air piston which is connected to the drive rod. During rod operations, compressed air at approximately 150 psi is maintained above the piston and air at 250 psi is maintained below the piston. The 250-psi air pressure below the piston provides sufficient force to maintain contact between the piston and the nut extension as the rods are withdrawn. Rod scram is effected by rapid exhausting of the lower air. The resultant unbalanced force on the piston acts to drive the rods into the core.

A snap action switch, externally mounted at the lower end of the air cylinder, and actuated by the air piston, informs the operator when the piston has been driven to its seat position. Following rod scram, and before the nut extension again makes contact with the air piston to hold it in place, if the top air were to be lost it is possible for system pressure to drive the rods back out of the core. To preclude this possibility, a piston lock assembly is provided at the lower end of the air cylinder to lock the air piston in its seat position. The piston lock consists of a spring-loaded latch bar, similar in design to the common door latch, which protrudes into the cylinder through a hole in the cylinder wall. The latch is housed in a pressure-tight lock box assembly which is externally mounted on the cylinder. The piston passing the latch causes it to retract until it snaps into a groove provided in the piston. This groove is so located that the latch will not engage the piston until it is approximately 1/8 in. from mechanical bottom. A solenoid, provided in the lock box assembly, is used to mechanically retract the latch to permit withdrawal of the rods. However, as long as there is pressure on the latch bar, either from the system or air under the piston, without the opposing force of the nut extension,

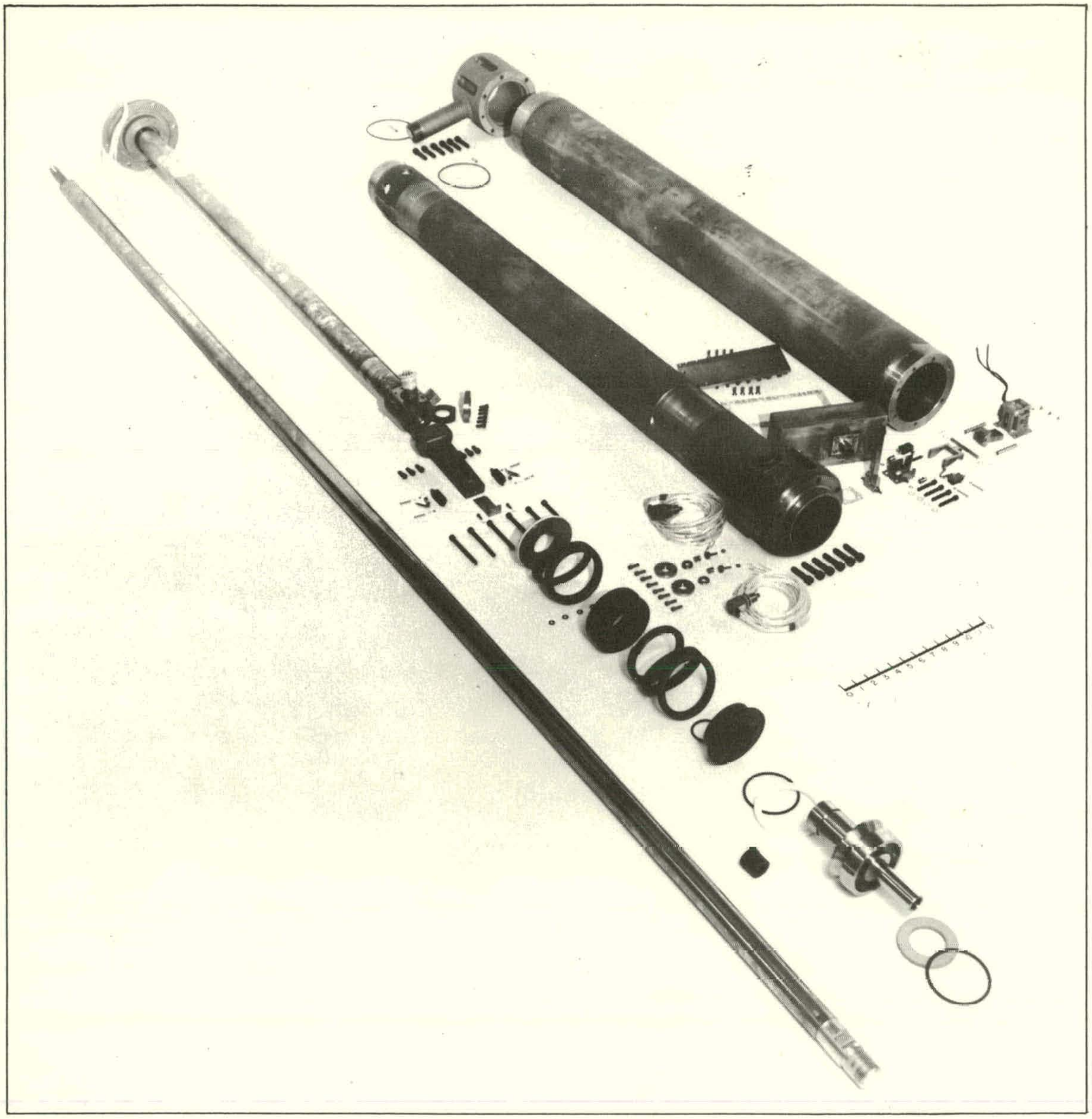


Fig. 37 Control rod air cylinder section.

the solenoid will not retract the latch bar. Miniature snap action switches in the lock box indicate latch bar position as either locked or unlocked.

2.25 Shock Absorber. Due to the kinetic energy developed in the scramming of the rods, a shock absorber assembly (Figures 39 and 40) was designed to apply a relatively constant decelerating force to the rods over a total travel of 6 in. This assembly is mounted directly below the air-cylinder section and is actuated by the air piston coming in contact with the shock absorber mechanism.

The shock absorber consists of six 1-in.-diam bronze pistons joined together on a ring and arranged radially around the drive rod. These pistons operate in a fluid-filled housing containing a cylinder block with six cylinders. Each cylinder has six orifice holes equally spaced along its length, which are

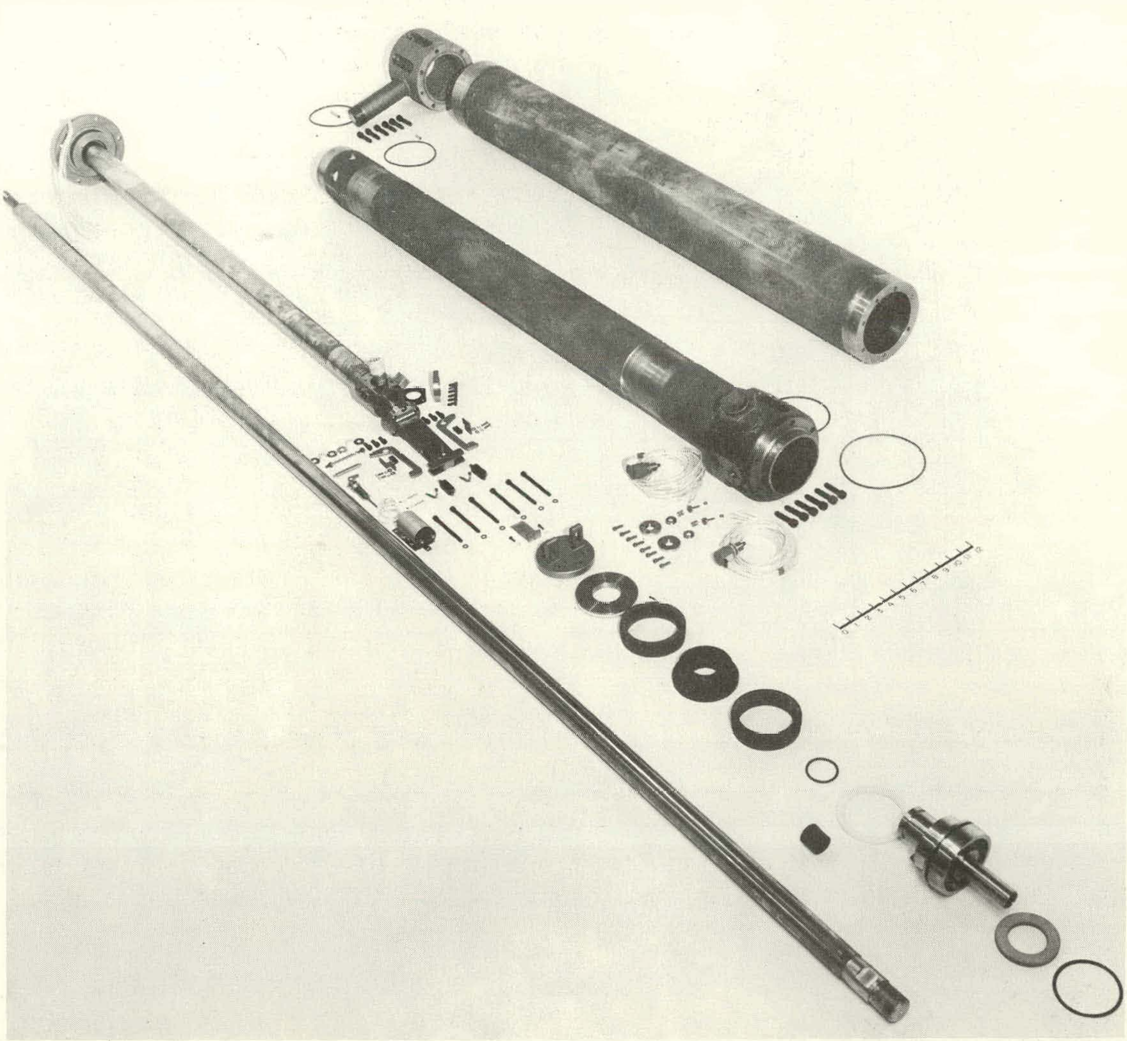


Fig. 38 Transient rod air cylinder section.

connected to a fluid reservoir. This allows a nearly constant decelerating force to be applied to the rod throughout the 6-in. stroke. A coil spring returns the piston group to the extended position on rod withdrawal. To prevent bounce, the coil spring is designed to lift only the moving parts of the shock absorber and will not lift the control rods. An externally mounted switch, similar to the piston seat switch, is actuated when the piston group reaches the extended position. This switch is interlocked with the interlock switch discussed in the drive-screw section.

Silicone fluid consisting of two parts 350-centipose viscosity and one part 1000-centipose viscosity is used for the shock absorbing fluid. This fluid has the combination of a relatively high flash point and relatively stable viscosity over the operating range of 100 to 200°F. Although the lubricity of the silicone fluid is not fully satisfactory, this fluid is adequate for this service and is commercially available.

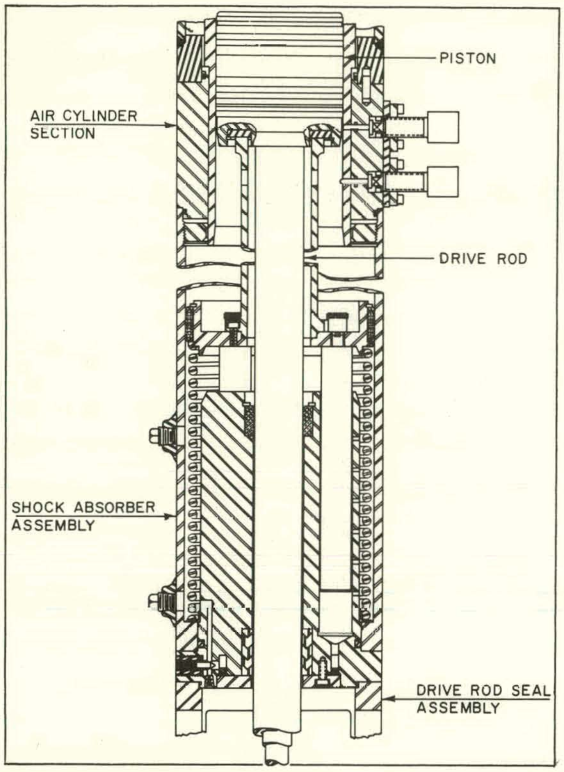


Fig. 39 Shock absorber assembly.

2.26 Drive Rod Seal. The drive-rod seal assembly (Figures 41 and 42) bolts to the reactor vessel access head and isolates the drive units from the reactor vessel environment. The seal housing is constructed of stainless steel to resist corrosion of the reactor water and is equipped with four large openings at the upper end to permit cooling of the drive rod and adjustment of the packing glands.

The seal packing consists of two sets of standard commercial teflon-filled-asbestos, chevron-type packing. Each set consists of five rings 1-1/2 in. ID x 2-1/4 in. OD with a stack height of 1-1/2 in. The lower set of packings retains the vessel pressure under normal conditions with the top set acting as an emergency backup in case the lower set fails. A leak-off connection between the two sets of packing permits drainage of any leakage through the lower packing.

The success or failure of the seal unit is based upon the characteristics of the drive rod. The rod is fabricated from a mild-steel tube of 1-1/2-in. diam with 1/4-in. wall thickness. Applied externally, is a 0.030-in. coating of nickel-

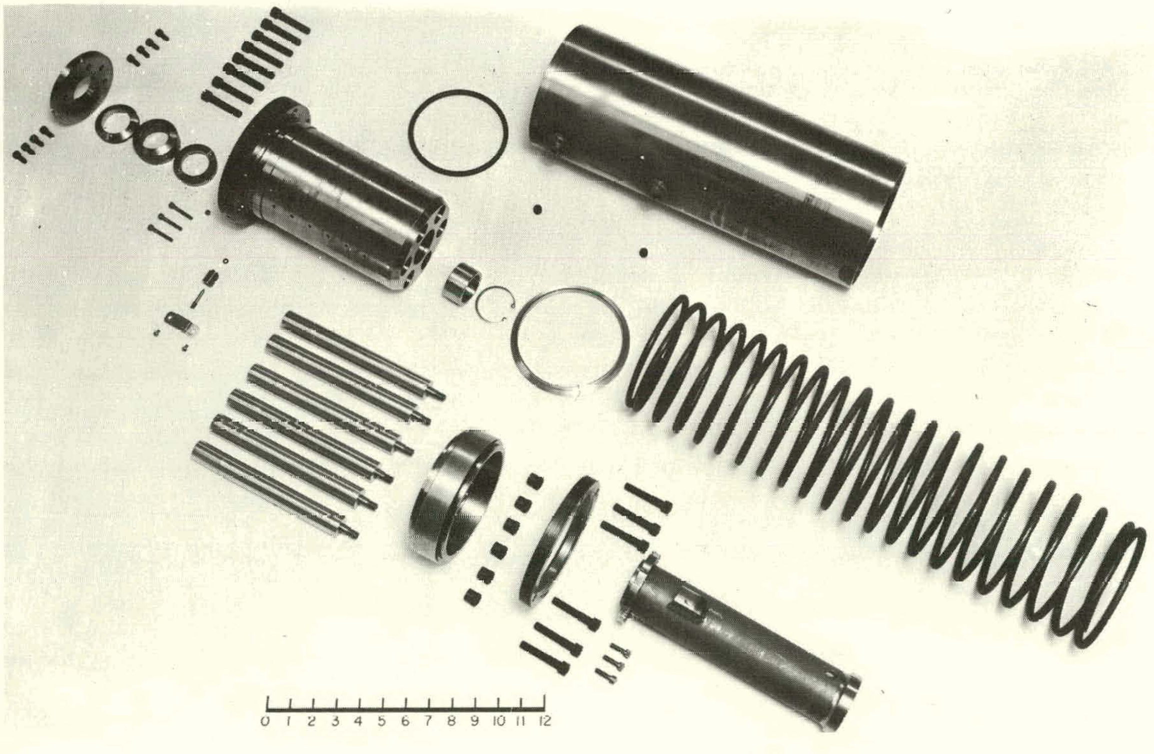


Fig. 40 Parts - shock absorber unit.

chromium-boron alloy. This coating is ground to an 8-microinch finish and has a hardness of 60 Rockwell "C".

Rather than subject the hard-faced tube to the stresses generated during rod scrams, these stresses are transmitted from the piston to the control rods or transient rod through a 4130-alloy steel rod provided inside the drive-rod tube. This rod is prestressed so that the outer tube is in compression at all times and does not contribute to the support of the rods in the reactor core.

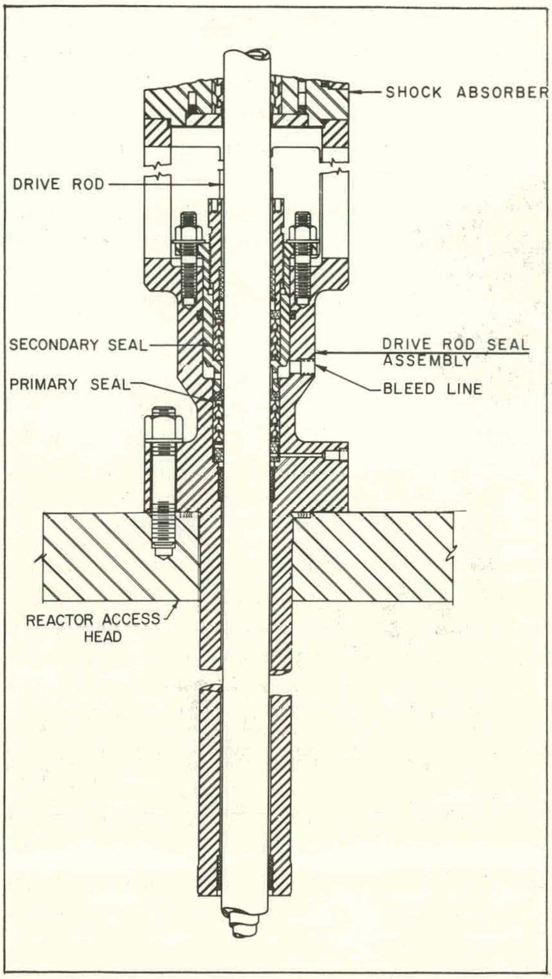


Fig. 41 Drive rod seal assembly.

3. CONTROL AND TRANSIENT ROD OPERATION

3.1 General

For all practical purposes, the operation of the control rod and transient rod drive units is identical, except that the piston latch bar has been omitted from the transient rod inasmuch as no reactor hazard exists in the event that a malfunction permitting the transient rod to rise occurs.

In order to present the operation of the drive units in a logical sequence, the following conditions are pre-supposed to exist:

(1) Emergency power generator is running.

(2) The air system is fully charged and ready to operate.

(3) The control rods are at seat position and locked (seat and lock switches energized). The nut extension is in contact with the piston (contact switches energized).

(4) Transient rod latch is closed (transient rod latch switch energized).

3.2 Rod Withdrawal

In normal sequence, the following operations occur for withdrawal of control rods:

(1) Air is introduced above the piston through a solenoid valve in the air system.

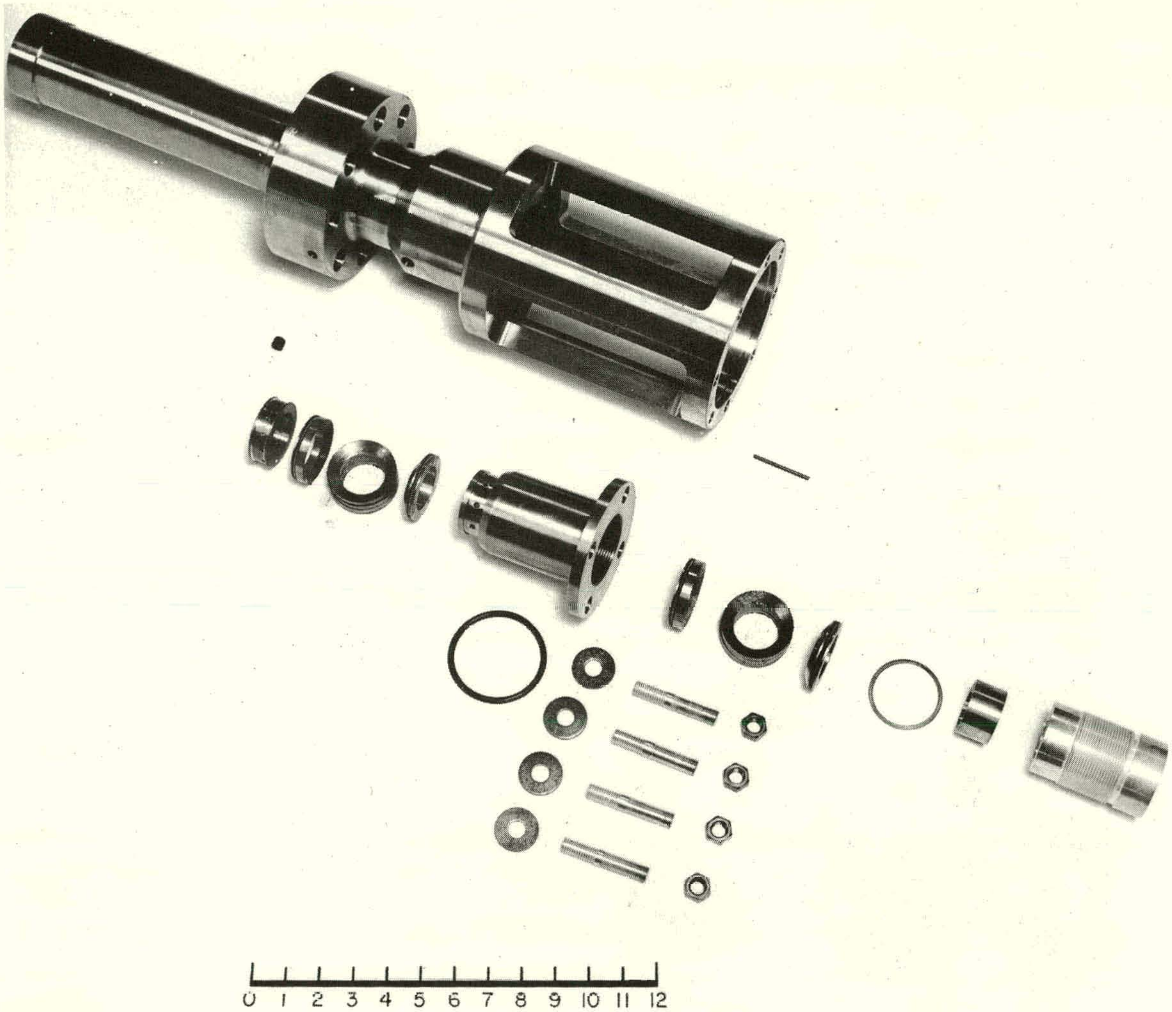


Fig. 42 Parts - seal assembly.

(2) Air is introduced below the piston through a solenoid valve in the air system.

(3) To withdraw the control rods, the piston latch is unlocked and the nut extension is moved up by motor power.

(4) The piston latch is released to be in position for operation at any time.

(5) Assuming a signal has been received by the interlock switch from the shock absorber extend switch signifying that the shock absorber has extended, withdrawal may continue to the desired height as indicated by the digital counter on the console.

3.3 Rod Insertion

Normal insertion is as follows:

(1) Fast-speed insertion, by motor power, to the down-auto-stop position approximately 1 in. above lower limit. Slow-speed insertion, by motor power, to lower limit position. The seat switch, contact switches, lower limit switch, and piston-locked switch indicate that the rods are fully inserted, that the piston is locked down, and the drives are at lower limit.

3.4 Rod Scram

Scram insertion is as follows:

(1) Air scram of the rods to seat position; scram is effected by air pressure above the piston with simultaneous exhausting of the air under the piston through two pilot-operated exhaust valves in the air system. Loss of contact between the nut extension and piston initiates automatic fast run-down of the drives to the down-auto-stop position; then slow-speed run-down to lower limit. The seat switch, contact switches, lower limit switch, and piston-locked switch indicate that the rods are fully inserted, that the piston is locked down, and the drives are at lower limit. Following reset of the scram circuit, the drives are ready for rod withdrawal as outlined above.

4. SAFETY FEATURES

Table III lists some of the most probable drive system failures or malfunctions which could occur and the safety features incorporated into the drive system to counteract these failures.

TABLE III

DRIVE SYSTEM FAILURES AND SAFETY DEVICES

Failure	Corrective Action
Loss of commercial power	Automatic air scram Automatic switching to emergency power Automatic fast rundown of drives by emergency power
Loss of emergency power	Automatic fast rundown with commercial power
Loss of all power	Automatic air scram
Loss of piston contact	Automatic air scram
Loss of air above piston	Automatic fast rundown by motor power
Loss of all electric power, coincident with loss of all air	Acme self-locking screw prevents further rod movement and maintains status quo. Motor brake backs up self-locking Acme screw.
Failure of shock absorber to extend	Interlock prevents withdrawal of rods more than 6-1/8 in. above seat position.
Failure of drive rod seal	Second set of seals becomes operative.
Breakage of mechanical-drive parts above Acme screw (motor couplings, broken gears, etc)	Self-locking Acme screw prevents further rise of rods. Manual air scram possible
Failure of operator to observe upper end lower limits of rod travel	Upper and lower limit switches de-energize drive motor contactors.
Failure to obtain contact on all pistons	Permission to withdraw rods is automatically denied. All contact switches must be energized to obtain motor power.
Attempt by operator to unlock piston with no piston contact, and no top air	Friction between the latch and piston will prevent unlock of latch.
Attempt by operator to insert rods at fast speed to lower limit	Down-auto-stop switch prevents rod insertion to lower limit position except at slow speed.
Various faults in control wiring	Continuity circuits are provided and an alarm sounds at console.
Loss of air in air reservoir or low reservoir pressure	Automatic fast rundown to down-auto-stop position Warning light on console indicates low pressure and reactor should not be run until the situation is corrected.

VII. CONTROL SYSTEM DESIGN

1. INTRODUCTION

This section of the report is devoted to a discussion of the various components of the Spert II reactor control system with particular emphasis on the functional operation of the items discussed. In order to establish a framework for such a descriptive discussion, consideration is first given to the various requirements which the control system must fulfill.

From a general viewpoint, the primary design requirements for the control system are that no hazard to personnel shall arise from control system operation and that risks to reactor equipment shall be minimized. The control system must provide proper manipulation of the control units and must furnish information on operations performed. It also must indicate equipment failures or improper operation, and be designed in such a manner that any component failure which constitutes loss of control will automatically shut down the system.

1.1 Design Philosophy

The control system design reflects the philosophy of operation of the Spert reactors. The purpose of Spert II is to provide a facility in which experimental programs can be carried out to develop information on the kinetics of various cores and on the inherent physical mechanisms which affect the neutronic behavior, and thus the safety, of these reactors. The experiments which will be performed include transient power excursions initiated by reactivity perturbations. First, a poison "transient" rod may be ejected from the core, thus adding reactivity as a step function. Secondly, the control rods or transient rod may be moved with a time-dependent motion, thus adding reactivity as a ramp function. This may be accomplished by either moving the transient rod or the control rods out of the core.

The philosophy of operation of the Spert reactors provides that no nuclear operation of the facilities be conducted with any personnel within approximately one-third mile of the reactor. Thus, the control system design provides for operation of the facility from the control center building, which is approximately one-half mile from the reactor.

The variety of tests to be performed and the short test-time interval for most of the experiments performed led to the selection of a simple control system in which operation is strictly manual with no servo or feedback loops in the control system. Because of the short time scale for the tests, the individual functions required during a transient test, such as starting data recording and photographic equipment, ejecting the transient rod, and scramming control rods, are programmed on a sequence timer and the test is initiated by starting the timer. The reactor operator is always under the direct surveillance of at least one other qualified reactor operator who provides backup and, together with all other persons in the control room, has the authority and responsibility to scram the reactor in the event of any unanticipated situation.

Because the action of conventional power level or period scram circuits would in many instances not only compromise the acquisition of information for which the experiment is conducted, but also the development of proper operator attitude, such circuits are not included in the control system design. Provision is made, however, for the inclusion of special scram circuits for specific experiments where operator fatigue might become a factor and where the action of the scram circuits would not interfere with the purpose of the experiment. The type of tests performed in the Spert reactors requires that the operator be cognizant of the safety implications of each individual act in the performance of a test. This attitude must carry over beyond the test to all activities such as fuel manipulations and changes in the reactor core, components, and control systems as necessitated by the experimental programs. The development of this attitude can be severely inhibited if an individual believes that he can error and have his error automatically compensated by an automatic scram circuit. A reliance on protective devices which frequently would have to be bypassed, or for which set points must be specified and adjusted prior to each test, actually would result in a less-safe operation. The required attention span of the operator is very brief for most of the experiments performed, thus feedback control and safety scram circuits to obviate operator inattention or fatigue are not required.

2. DESCRIPTION OF CONTROL SYSTEM

This section of the report describes the motors used to drive the control and transient rods, the power sources for the motors, the motor-speed selectors, the inhibitions placed on the power source, the various switches that are located on the control and transient rods, the inhibitions placed on the movement of the control and transient rods, the circuitry used for running a transient, the shutdown circuits, the timer circuit, the control rod position indicator, the control rod air system, the alarm system, and the control console.

2.1 Drive Motors and Power Requirements

The basic power requirement of the control system is for the five drive motors. These are 480-v, 3-phase, 60-cycle, 3-speed, squirrel cage induction motors equipped with magnetic brakes. The motors have two stator windings and taps for 4-, 6-, or 12-pole operation. This provides synchronous speeds of 1800, 1200, and 600 rpm. Slip at rated load is 20 rpm. The current ratings of each motor are 2.2, 2.3, and 1.3 amp for high, medium, and low speeds, respectively. Breakdown torque at high speed is 430% of rate torque, so that the maximum power requirement per motor, assuming 75% efficiency, is 4.3 kw. The power system must be able to provide 73 kva for starting and 18 kw for maximum power load for four motors. Voltage must be maintained at 60% of normal in order to carry the magnetic relays and contractors of the control system. Commercial 480-v 3-phase power is supplied to the control system through a 100-amp branch air circuit breaker, which is supplied through a 600-amp feeder circuit breaker from a 750-kva transformer bank. Emergency power is provided by a gasoline-engine-driven generator which is paralleled to the 100-amp branch air circuit breaker through an automatic transfer switch. The generator rated at 15 kw at 80% power factor is powered by a four-cylinder L-head 35-hp Continental engine. It is of the rotating armature, self-excited type with inherently self-regulated voltage from saturated field design. Overload capacity is ample for the 18-kw power load requirement and voltage regulation is satisfactory during motor starting current surges.

2.2. Motor Power

Power from the branch circuit breaker and from the standby generator is brought to two manually operated disconnect switches. A phase-sequence and undervoltage relay is connected to the load side of each disconnect switch through potential transformers (Figure 43). The control system proper is

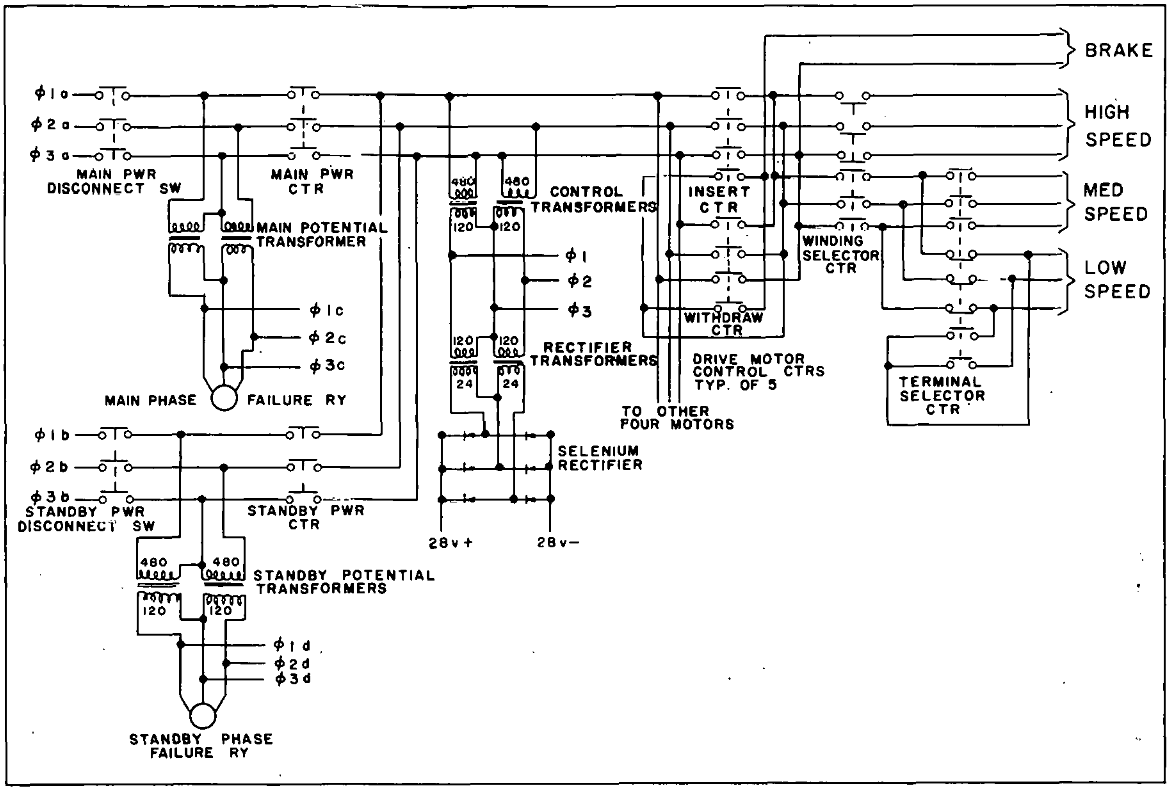


Fig. 43 Drive motor power system.

connected to one or the other of these power sources through a pair of magnetic contactors which are mechanically interlocked to prevent simultaneous operation. Power for the drive motors is taken directly from these control power contactors through a group of contactors which provide three speeds forward and reverse for each of the five motors. The speed control contactors select from the nine leads of each motor the three which are appropriate for a desired speed. These contactors are not required to make or break live circuits; speeds are selected only with the motors stopped. Mechanically interlocked contactor pairs are used for starting, stopping, and reversing the motors, and for releasing the magnetic brakes. Each motor circuit is kept independent of the others, insofar as possible, in order to minimize the occurrence of malfunctions capable of interfering with insertion of more than one control rod.

A pair of 3-kva transformers connected open-delta, 3-phase to the main contactors, is used to provide 120-v power for all control relays and contactor coils. A second pair of transformers rated at 0.5 kva each and connected open-delta, provides 28-v dc from a 3-phase full-wave bridge selenium rectifier. This 28-v dc operates the indicating lights and the transient rod latch solenoid.

2.3 Motor Speed Selector

The motor speed selector system is used to select the control rod rate of travel. Through different winding combinations, it is possible to obtain fast, medium, or slow speeds.

Each drive motor has nine leads brought out from two windings. One of the windings is an ordinary Y-connected 4-pole winding. The other winding has six leads which can be connected to give either 6 or 12 poles. In addition, each motor is equipped with a spring-set, magnetically released disc brake, the windings of which must be energized continuously with 480 v single phase during motor operation.

Each of the five drive motors has independent circuitry beyond the insert and withdraw relays in the control system. The transient rod drive controls are completely independent. By means of selector switches, the control rod drives are ganged to operate in unison. That is, as many control rod drives as are selected operate as one drive and no drive can be operated in any other way. Thus, three pushbuttons on the console suffice to select fast, medium, or slow speed for the rod drives.

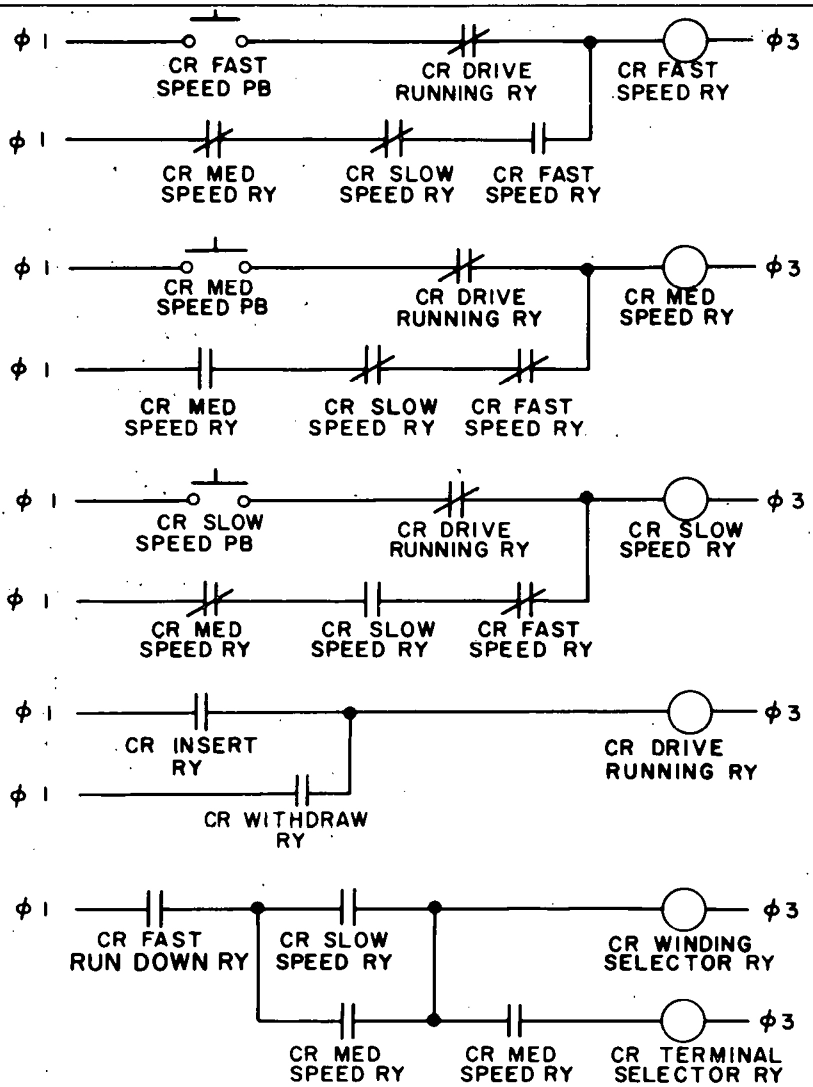
The motor speed selector relay system is shown in Figure 44. In order to select fast speed, the Control Rod Fast Speed pushbutton is depressed. This will pick up the Control Rod Fast Speed relay provided that the Control Rod Drive Running relay is de-energized, which indicates that the control rods are not being moved. This interlock is used so that speeds cannot be changed while the control rods are moving, thus allowing smaller contacts to be used on the terminal and winding contactors. Once the Control Rod Fast Speed relay is picked up, it is locked in by a shunting circuit, provided that the medium or slow speed relays are not picked up.

If the Control Rod Slow Speed relay is picked up, the Control Rod Winding Selector relay will be energized if the Control Fast Rundown relay is energized, indicating there is no signal for a fast insertion of the rods. The Control Rod Winding Selector and Control Rod Terminal Selector relays will be energized if the Control Rod Medium Speed relay is picked up. These relays actuate the same named contactors.

2.4 Power Control

Operation of the main and standby control power contactors is initiated manually by means of the power keyswitch on the reactor control console, as shown schematically in Figure 45. The power control system will preferentially feed commercial power to the circuit. Interlocks are provided to prevent energizing the system if commercial power voltage is low or phase sequence is wrong, if any plug-disconnect in the system is not properly engaged, or if a relay rack door is open. However, once the control system is in operation, these latter two interlocks are designed not to kill control power in the event of a mishap.

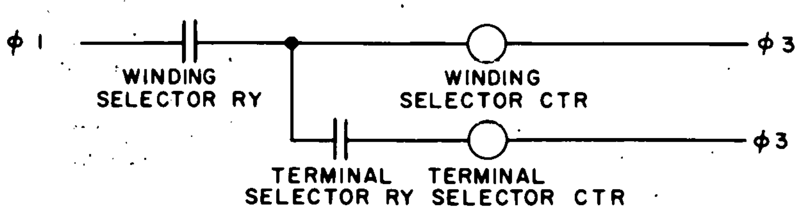
Commercial power of proper voltage and phase sequence at the main potential transformer actuates the Main Phase Failure relay and thereby admits power to the Main Power Keyswitch and the Main Power OK relay. The relay rack Door Interlock relay will be de-energized if all the relay rack doors are closed.



CONTROL ROD SPEED CONTROL RELAY CIRCUITS

THE ABOVE GROUP OF CONTROL ROD SPEED CONTROL CIRCUITS IS USED FOR 4 CONTROL ROD DRIVES.

THE CONTROL ROD DRIVES MAY BE SWITCHED ON OR OFF INDIVIDUALLY BY THE OPERATOR, BUT THOSE THAT ARE RUNNING ALL RUN AT THE SAME SPEED AND DIRECTION. A SIMILAR GROUP OF SPEED CONTROL CIRCUITS (NOT SHOWN) IS USED FOR THE TRANSIENT ROD DRIVE.



SPEED CONTROL CONTACTOR CIRCUITS TYPICAL OF 5

Fig. 44 Motor speed selector system.

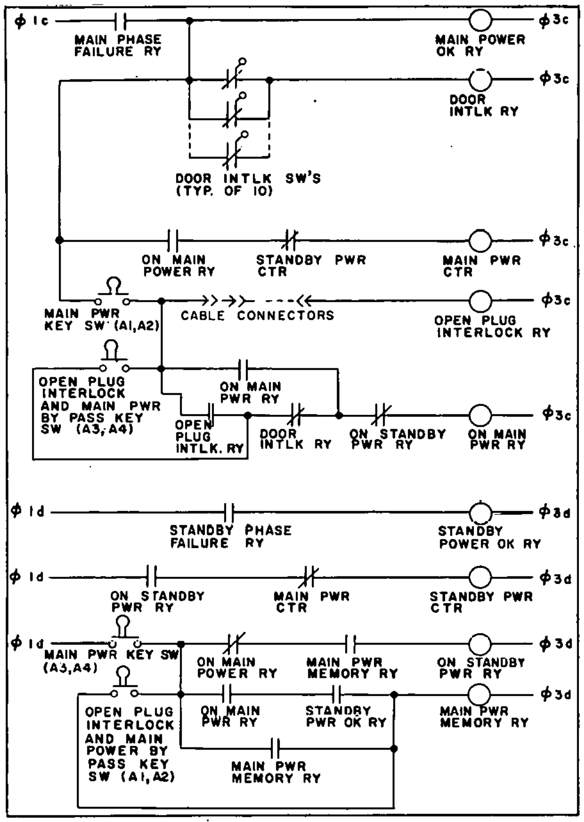


Fig. 45 Power control system.

If all cable connections are made properly, the Open Plug Interlock relay will be energized.

With the relay rack doors closed and control cable connectors all properly engaged and the On Standby Power de-energized, closing the Main Power Keyswitch picks up the On Main Power relay, which then picks up the Main Power Contactor, thus energizing the control system. Once the On Main Power relay is picked up, a pair of its contacts bypasses the Door Interlock and Open Plug Interlock so that a mishap will not kill main power. Initially, the Main Power Memory relay prevents the On Standby Power relay from picking up with the On Main Power relay. Once the On Main Power relay is safely picked up, a pair of its normally closed contacts prevents the On Standby Power relay from being picked up and a pair of its normally open contacts picks up the Main Power Memory relay provided that the Standby Power OK relay is energized, thus indicating proper standby voltage (90% of normal voltage) and phase sequence. The Main Power Memory relay, through a holding circuit, remains picked up, ready to pick up the On Standby Power relay which in turn energizes the Standby Power Contactor the moment the On Main Power relay drops out on main power failure.

No provision is made for automatic return to main power on termination of the main power outage, but, if standby power should fail, main power will be picked up.

The Open Plug Interlock and Main Power Bypass keyswitch provides a means of picking up main power despite an open cable connector, or, if main power is not available, a means of bypassing the preference for main power in order to pick up standby power in emergency circumstances.

2.5 Control Rod Control Switches

Mechanically actuated switches are provided in the control system to indicate rod positions and air pressures, and to energize indicating lights. Only the location of the switches will be given; the purpose will be described in the next section. The pistons of the four control rods and the transient rod each actuate a Seat switch when the rods are fully inserted into the core and a Contact switch when in contact with the Acme nut extension of the rod drives. An actuator on each shock absorber assembly actuates a Shock Extended switch when the shock absorbers are fully extended.

The Acme nut of each drive actuates switches on the drive housing at the following positions:

Lower limit (Low Limit switch)

One inch above lower limit (Down-Auto-Stop switch)

Six inches above lower limit (Up-Auto-Stop-switch)

45-in. above lower limit (Top Limit switch)

In addition, the four control rod drives have Upper Limit switches located nine inches below the Top Limit switch which correspond to top of the active core. The transient rod drive has no switch at the core Upper Limit position; its Upper Limit position corresponds to the control rod drive Top Limit. The transient rod drive is equipped with a mechanical latch which couples the Acme nut extension to the air piston, to prevent premature dropping of the rod. Two switches are mounted on the latch; one is actuated when the latch is open and the other when closed (Transient Rod Locked and Transient Rod Unlocked switches). The control rod drives have mechanical latches which lock the control rods in the down position (Control Rod Locked and Control Unlocked switches). Five air-pressure switches are included in the system which, when actuated by air pressure, close relays in the Main Air OK, Scram Air OK, Control Rod Hold Air On, Fire Air On, and Transient Rod Hold Air On circuits. Each drive motor is equipped with a thermal switch which opens when the temperature of the motor becomes dangerously high and sounds an alarm on the console. The jib crane, which carries the electrical cable and compressed air hose connectors for the rod drives, swings to two positions: one for operating the drives on the reactor, the other for operating the drives in dry dock. Two switches, Reactor Position and Dry Dock Position, are mounted at the base of the jib crane to indicate its position.

As a general rule, the normally open contacts in all of the above switches operate relays in the relay rack which actuate console indicator lights and control system interlocks.

As exceptions to the general rule, the Motor Overheat switch relay operating contacts are normally closed, as are the jib crane position switches. The Up-Auto-Stop switches do not operate relays or indicating lights; their sole function is to provide normally closed contacts for use directly as interlocks with the Shock Extended relays in the rod withdrawal circuits to prevent any rod being withdrawn above an unextended shock absorber. The Down-Auto-Stop and Top Limit switches operate relays but there are no corresponding console indicator lights. The air pressure switches also operate relays with no indicator lights, but annunciators are connected to the Scram Air OK and Main Air OK relays.

2.6 Control and Transient Rod Relay System

2.61 Miscellaneous Relays. Except for automatic shutdown in certain hazardous situations, the control of the Spert II reactor is entirely manual. In order to prevent damage to the control rod drive system or to the reactor core, certain interlocks have been designed into the system. These interlocks are described below.

Figure 46 shows the wiring of the Up-Auto-Stop switches and relays. When the control rods are first withdrawn, the Up-Auto-Stop switches allow the control rods to be withdrawn approximately 6 in. above Lower Limit. If the shock absorbers do not extend, indicating that they are not ready to decelerate a control rod, the Control Rod Shock Extend relays will not be picked up and further control rod withdrawal will be prevented. However, if the Control Rod Shock Extend relays are energized, the Control Rod Up-Auto-Stop Series relay is energized and control rod withdrawal may be continued.

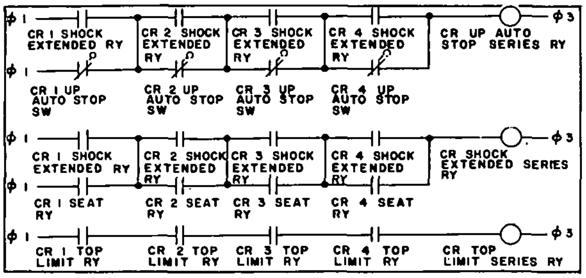


Fig. 46 Miscellaneous relays.

The Control Rod Shock Extend Series relays is picked up if each individual Control Rod Shock Extend relay is energized or if the control rod is down (ie, Control Rod Seat relay is energized). The Control Rod Top Limit Series relay circuit is typical of four others not shown: Control Rod Contact Series, Control Rod Seat Series, Control Rod Lower Limit Series, and Control Rod Piston Locked Series. The function of each series relay will be described later.

2.62 Control Rod Relays. Primary control of the drive motors is by the control rod Insert-Withdraw switch on the control console. This is a pistol grip switch which has a spring return from withdraw to off position. The insert position is maintained by a detent until manually returned to off. Also, the control rods may be withdrawn by a timer-operated "ramp" circuit which is intended for ramp-type power excursions. Fast Rundown circuits provide automatic insertion of the Acme screw after the control rods have been scrammed or the transient rod fired.

For manual or ramp operation, any desired number of the control rod drives may be operated in unison through the use of the drive selector switches on the console and corresponding relays in the starting contactor circuits.

No interlocks restrict the operation of the Control Rod Insert relay. However, the Control Rod Withdraw relay has several restrictions (Figure 47). In order to energize the Control Rod Withdraw relay the following conditions have to be met. The Transient Rod Locked relay has to be energized, indicating that the transient rod is locked to the Acme screw. The Transient Rod Contact relay is energized indicating contact of the transient rod and Acme screw. The Fire Air On relay and the Transient Rod Arming relay are de-energized, thus indicating that the transient rod does not have air to the top side of the piston and the transient rod is not in position to fire. If a ramp transient were being run, a Timer Section relay would be used in conjunction with the Control Rod Ramp relay in order to withdraw the control rods for a given time element. This section bypasses the Control Rod Insert-Withdraw Switch, Transient Rod Locked relay, Transient Rod Contact relay, and Fire Air - On relay. To complete the energizing of the Control Rod Withdraw relay circuit, the Standby Power OK relay, Scram Air OK relay, Control Rod Contact Series relay, and Control Rod Up-Auto-Stop Series relay must be energized. The Scram Air OK relay indicates that the scram air pressure is within the prescribed limits, the Control Rod Contact Series relay signifies all the control rods are in contact with the Acme screws, and the Control Rod Up-Auto-Stop Series relay indicates that the shock absorbers are extended and are ready to decelerate the control rods. The last four relays can be bypassed by energizing the Upper Limit Bypass relay by means of the Upper Limit

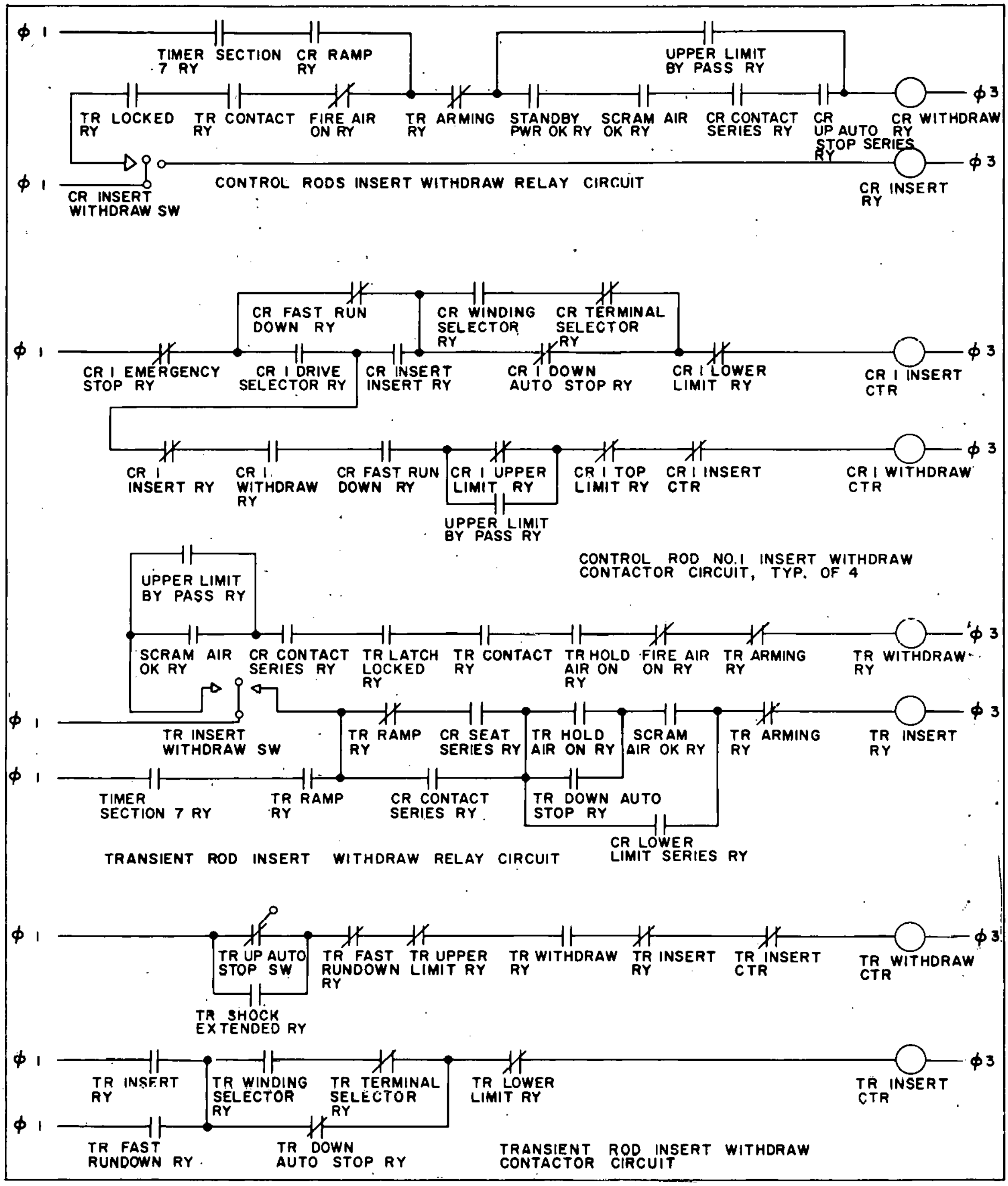


Fig. 47 Control and transient rod relay system.

Bypass keyswitch. This bypassing procedure is for dry dock operation or connecting or disconnecting the rods only. It is not used for reactor operation.

In order to energize the Control Rod Withdraw contactors the following conditions must be fulfilled. The Control Rod Drive Selector relay, Control Rod Withdraw relay, and Control Rod Fast Rundown relay are energized while the Control Rod Insert relay, Control Rod Upper Limit relay, (which can be bypassed by the Upper Limit Bypass relay), Control Rod Top Limit relay, and the Control Rod Insert contactor must be de-energized.

The Control Rod Insert contactors are energized if the Control Rod Drives Selector relay and Control Rod Insert relay are energized and the Control Rod Down-Auto-Stop relay and Control Rod Lower Limit relay are de-energized. A Control Rod Fast Rundown signal bypasses the first two relays. The Down-Auto-Stop relay prevents insertion at high or medium speed beyond one inch above lower limit. It may be bypassed by selecting slow speed which energizes the Control Rod Winding Selector relay and Control Rod Terminal Selector relays, thus allowing the control rods to be fully inserted.

If the Control Rod Emergency Stop relay is picked up through actuation of the Control Rod Emergency Stop toggle switch, neither the Control Rod Insert contactor or the Control Rod Withdraw contactor can be energized.

2.63 Transient Rod Relays. Since insertion of the transient rod removes poison, thus adding reactivity to the core, it has many inhibitions in its insertion. Also, in order to insure that the transient rod is not prematurely dropped, there are certain interlocks in its withdrawal. In order to withdraw the transient rod, the following conditions must be fulfilled. The Transient Rod Insert-Withdraw switch is moved to the withdraw position. The Scram Air OK relay, indicating there is sufficient air to scram the control rods, is energized. This interlock may be bypassed for testing the transient rod by closing the Upper Limit Bypass keyswitch which energizes the Upper Limit Bypass relay. The Control Rod Contact Series relay and the Transient Rod Locked relay must be energized. The latter signifies that the transient rod is locked to the Acme screw drive. The Transient Rod Contact relay, indicating contact of the piston and the Acme screw, must be energized. Also, the Transient Rod Hold Air On relay must be energized, thus indicating that there is air on the bottom side of the piston. The Fire Air On relay must be de-energized indicating that there is no air on the top side of the transient rod piston. Also, the Transient Rod Arming relay must be de-energized, thus indicating the transient rod is latched and not ready to be fired. If all of these conditions are fulfilled, the Transient Rod Withdraw relay may be energized.

In order to energize the Transient Rod Withdraw contactors, for the actual movement of the rod, the following conditions must be fulfilled. The Transient Rod Up-Auto-Stop switch is energized in order to allow withdrawal of the transient rod from lower limit. At shock extend position, this switch is de-energized and if the shock absorber is extended the Transient Rod Shock Extend relay will be energized.

If the shock absorber does extend, the transient rod withdrawal may be continued if the following conditions are satisfied: the Transient Rod Fast Run Down relay is de-energized; the Transient Rod Upper Limit relay is de-energized, indicating that the rod is not at upper limit; the Transient Rod Withdraw relay is energized; and the Transient Rod Insert relay and contactors are de-energized. Meeting the above conditions will permit energizing the Transient Rod Withdraw Contactor which will cause the withdrawal of the transient rod.

In order to insert the transient rod, the following conditions have to be met. The Transient Rod Insert-Withdraw switch is in the insert position. The Control Rod Contact Series relay must be energized (indicating control rods are in contact with the Acme screw). The Transient Rod Hold Air On relay and the Scram Air OK relay are energized indicating that the transient rod piston will be held up against the Acme screw and that the control rods are able to be scrammed. The Transient Rod Arming relay must be de-energized, thus indicating that transient rod piston is locked to the Acme screw and cannot be fired. The Transient Rod Insert relay will then be energized and the Transient Rod Insert contactors will be picked up. The transient rod may be inserted for ramp transients through the timer section 7 relay and the Transient Rod Ramp relay. These relays bypass the Transient Rod Insert-Withdraw switch. Once the Transient Rod Insert relay is picked up, the Transient Rod Insert contactors are energized and the transient rod is inserted. The transient rod may be inserted at high or medium speed to one inch above lower limit. At this point, the Transient Rod Down-Auto-Stop relay is energized prohibiting further insertion of the transient rod. The transient rod may be inserted to lower limit by selecting slow speed. This energizes the Transient Rod Winding Selector relay and de-energizes the Transient Rod Terminal Selector relay which allows the Transient Rod Down-Auto-Stop interlock to be bypassed and permits the Transient Rod Insert contactors to be picked up. Insertion at slow speed is continued to lower limit at which point the Transient Rod Lower Limit relay is picked up thus prohibiting further insertion.

Step changes in reactivity are obtained by firing the transient rod from the core. After this type of transient the piston would be at lower limit while the Acme screw would be at the transient rod position before the rod was fired. Automatic rundown circuits return the Acme screw to the piston. Once the transient rod has been fired, the Transient Rod Fast Rundown relay is energized by means of the Transient Rod Contact relay contactors. This relay parallels the Transient Rod Insert relay contactors in the Transient Rod Insert contactor schematic and insures Acme screw return to the down-auto-stop position. At this position, the Transient Rod Fast Rundown relay is de-energized by means of a pair of normally closed contacts of the Transient Rod Down-Auto-Stop relay. In order to insert the transient rod to lower limit, slow speed has to be selected, and the Transient Rod Insert relay has to be picked up. However, the Control Rod Contact Series relay, due to scramming the control rods, and the Transient Rod Hold Air On relay, due to firing the transient rod, are no longer energized. Therefore, the Transient Rod Down-Auto-Stop relay parallels the Transient Rod Hold Air On relay and permits energizing the insert relay after the fast rundown has brought the Acme screw down to the down-auto-stop position. The Control Rod Seat Series relay bypasses the Control Rod Contact Series relay and permits transient rod insertion after the control rods have been scrammed. The Transient Rod Ramp relay contacts are in series with the Control Rod Seat Series relay to prohibit further transient rod insertion during a transient rod ramp transient if, for some reason, the control rods have been scrammed.

2.7 Transient Relay Systems

Many relays were mentioned in the previous section with little or no description of purpose. These will be described below. After the transient rod and control rods have been withdrawn to the desired position, the transient rod is armed. This is accomplished by moving the Transient Rod Arming and Unlock switch to the arming position (Figure 48). The Transient Rod Arming relay will be picked up if the following conditions are met. The Standby Power OK relay is energized, the Control Rod Fast Rundown relay is energized indicating that there is no signal for a fast rundown or a scram, and the Scram Air OK relay,

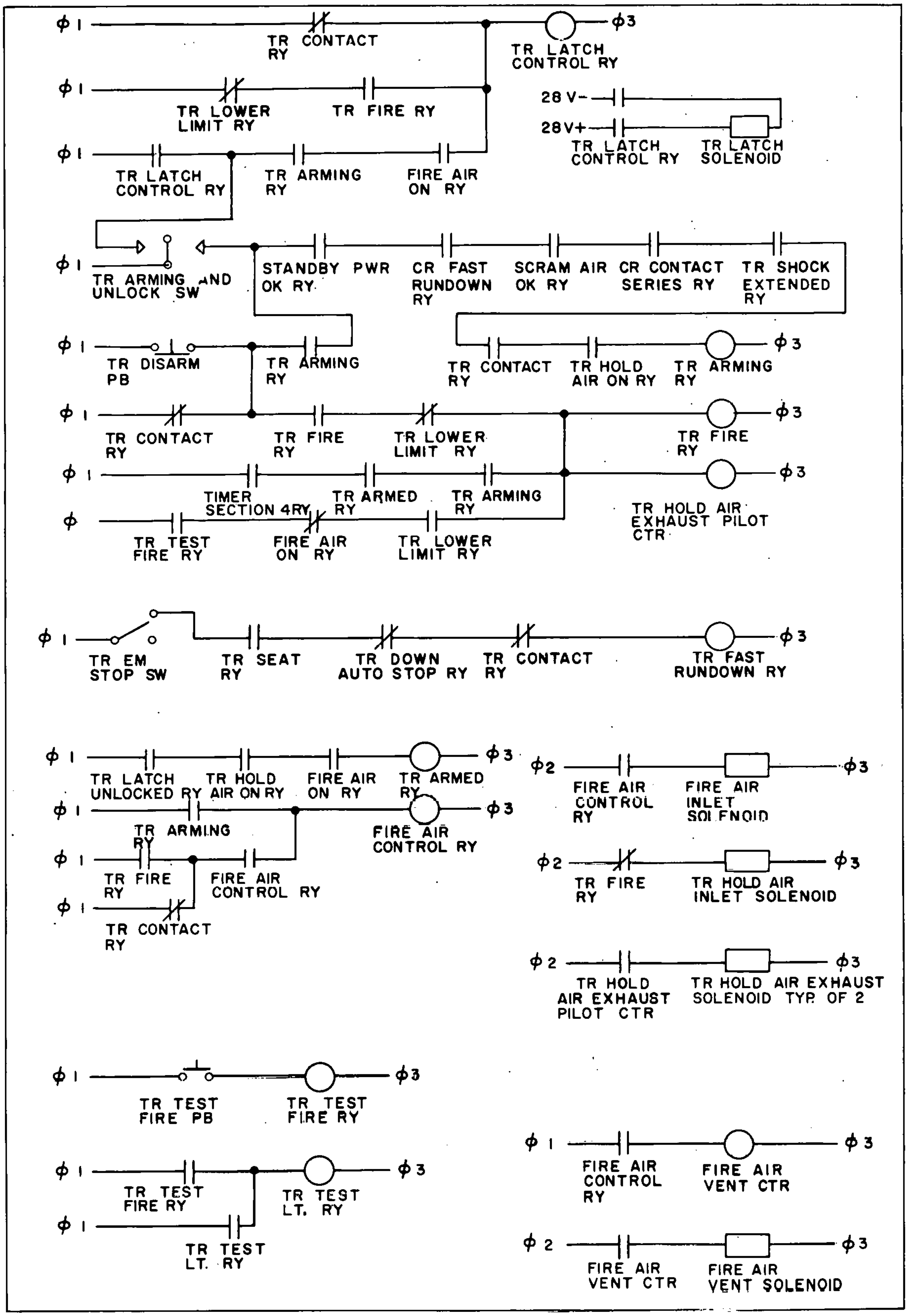


Fig. 48 Transient relay system.

Control Rod Contact Series relay, Transient Rod Shock Extend relay, Transient Rod Contact relay, and the Transient Rod Hold Air On relay are also energized. These conditions will cause the Transient Rod Arming relay to be picked up. Once this relay is picked up, the circuit is locked in. The relay may be de-energized by pushing the Transient Rod Disarm push button. Once the relay has been picked up, the Fire Air Control relay is energized thereby energizing the Fire Air Vent contactors which closes the Fire Air Vent Solenoid, and also opens the Fire Air Inlet Solenoid admitting air to the top side of the transient rod. If the fire air pressure is sufficiently high, a pressure switch will close and the Fire Air On relay will be picked up.

By moving the Transient Rod Arming and Unlock switch to the unlock position, the Transient Rod Latch Control relay may be energized, thus unlocking the latch which holds the Acme screw to the transient rod piston. Once the relay is made, it is locked in. The contactors on this relay will energize the Transient Rod Latch solenoid, thus unlocking the piston and Acme screw. The latch movement will actuate the Transient Rod Latch Unlocked switch which will energize its relay. The Transient Rod Armed relay will then be energized if the Transient Rod Hold Air On, Transient Rod Latch Unlocked, and Fire Air On relays are energized. The transient may then be initiated by starting the timer. When timer section 4 relay is energized, the Transient Rod Fire relay and Transient Rod Hold Air Exhaust Pilot contactor are energized provided that the Transient Rod Arming and Transient Rod Armed relays are energized. This will close the inlet solenoid valves for the hold air, and open the exhaust solenoid valves, thus allowing the transient rod to be ejected from the core.

Once the Transient Rod Fire relay has been energized it is locked in until the transient rod makes contact with the Acme screw or the transient rod drive reaches lower limit. This insures that the solenoid valves are not reset before contact has been restored between the piston and Acme screw. This is necessary since resetting the valves prematurely would drive the piston up against the Acme screw which, in all probability, would damage the screw. The Fire Air Control relay is also locked in by the Transient Rod Fire relay or the Transient Rod Contact relay. This maintains the fire air on top of the piston. Once the transient rod has been fired and is seated (Transient Seat relay energized), the Acme screw will be inserted by the energizing of the Transient Rod Fast Rundown relay. The motion will be stopped by opening the Transient Rod Emergency Stop switch and energizing the Transient Rod Down-Auto-Stop switch when the drive reaches one inch above lower limit, or when the transient rod Acme screw comes in contact with the piston thus energizing the Transient Rod Contact relay. In order to insure that the transient rod latch is not sheared off when it comes into contact with the piston, there are two parallel interlocks that keep the Transient Rod Latch Control relay energized after the transient rod has been fired. One contact comes from the Transient Rod Contact relay which closes when the transient rod is fired. The other interlock contains contacts from the Transient Rod Lower Limit relay which is closed until the transient rod drive reaches the lower limit switch. In series with this interlock is the Transient Rod Fire relay. Both relays are essentially the same source of information since transient rod contact will drop out the Transient Rod Fire relay. These relays allow the latch to be recoupled with the piston after the Acme screw drive has made contact.

In order to check out the solenoid valves on the transient rod air system, the Transient Rod Test Fire push button is pushed before the transient rod has been withdrawn. This picks up the Transient Rod Test Fire relay which then picks up the Transient Rod Test Light relay. This relay is then locked in. The Transient Rod Test Fire relay also picks up the Transient Rod Fire relay, and the Transient Rod Hold Air Exhaust Pilot contactors provided that the fire air is not on (Fire Air On relay de-energized) and the transient rod has not been raised (Transient Rod Lower Limit relay energized). This will close the Transient Rod Hold Air Inlet solenoid and open the Transient Rod Hold Air Exhaust solenoid.

2.8 Scram, Ramp, and Rundown Circuits

The scram circuits for the reactor control system are shown in Figure 49. In order to be in the fail-safe position, the scram relays are energized at all times; any interruption of power will de-energize the relays and initiate a scram. A scram also may be initiated by depressing the Console Scram push button or one of three Reactor Building Scram push buttons located at strategic locations in the reactor building. Once the relays have been de-energized, they remain locked out by two pairs of normally open contacts wired in series. The Scram relay may be re-energized by pushing the normally open Scram Reset push button provided that the Control Rod Top Limit Series relay is energized. The Control Rod Lower Limit Series relay prevents resetting the scram before the Acme screws are at lower limit. If the scram were reset prematurely, the

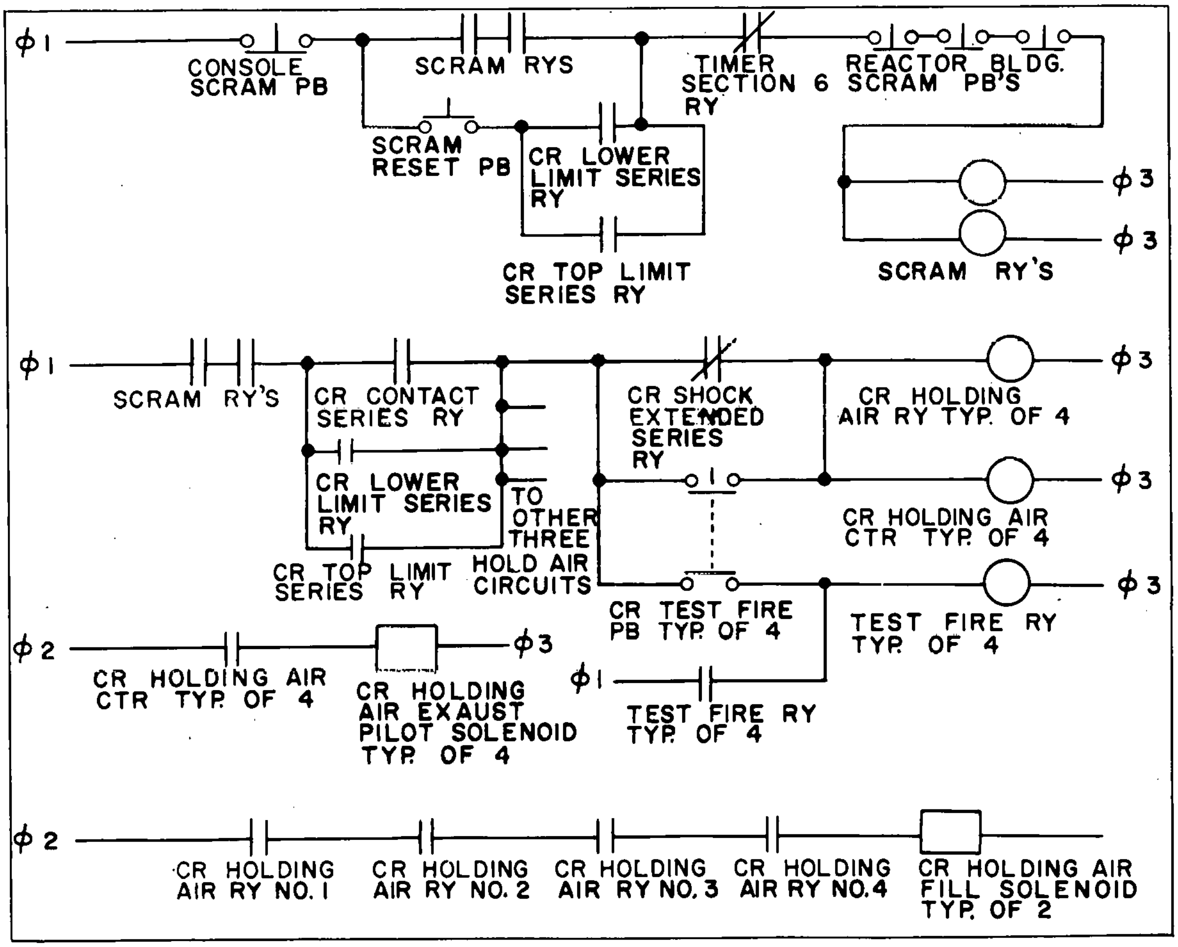


Fig. 49 Scram circuits.

pistons would be driven up against the Acme screw with possible damage to the screw.

Scramming the control rods vents the hold air from the bottom of the control rods. This is accomplished as follows: de-energizing the Scram relays will de-energize the Control Rod Holding Air relay and Control Rod Holding Air contactor, thus closing the hold-air inlet valves and opening the hold-air vent valves provided that the Control Rod Contact Series relay, Control Rod Lower Limit Series relay, or the Control Rod Top Limit Series relay is energized. In order to test the solenoid valves, a Control Rod Test Fire push button is provided on the console for each of the control rods. Pushing the button will drop out the Control Rod Hold Air relay and the Control Rod Hold Air contractors provided the Scram, Control Rod Contact Series, Control Rod Lower Limit, and Control Rod Top Limit Series relays are energized. The Test Fire relay is locked in once it is energized. The Control Rod Hold Air contactors actuate the Control Rod Hold Air Exhaust Pilot solenoid which vents the air from the bottom side of the control rods. The Control Rod Hold Air relay for each control rod actuates the Control Rod Air Fill solenoid valves.

The ramp and rundown circuits are shown in Figure 50. Ramp transients are run as well as step transients. The ramp transients are of two types.

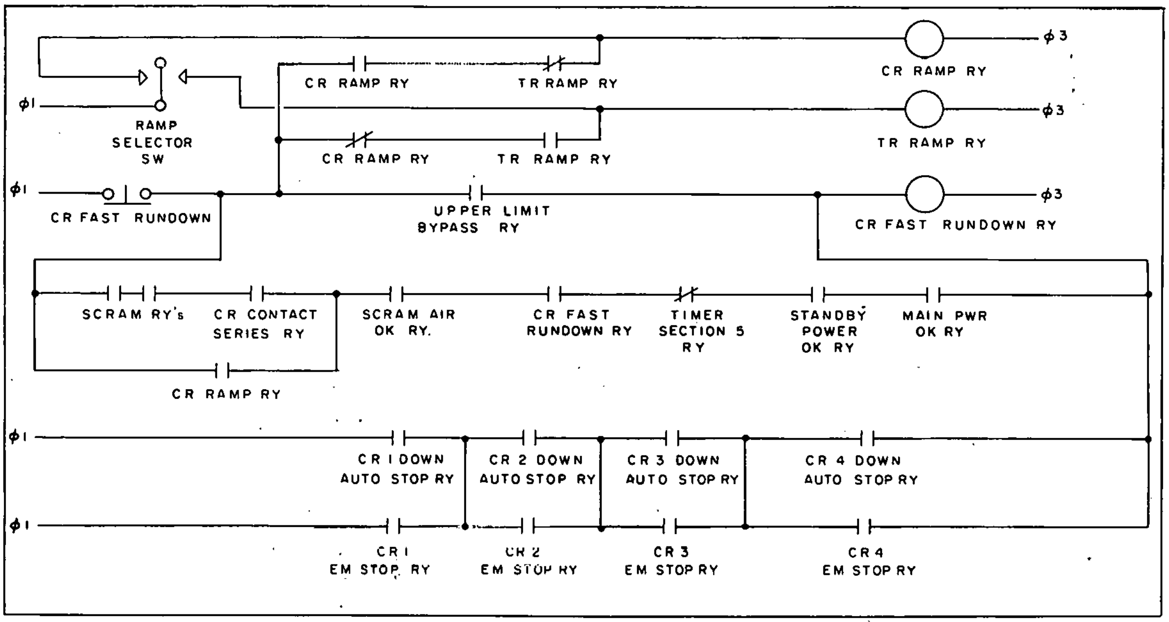


Fig. 50 Ramp and rundown circuits.

The first is the control rod ramp in which the control rods are withdrawn at a constant speed thereby adding reactivity at a time-dependent rate. The second is the transient rod ramp in which the transient rod is inserted at a constant speed, thereby removing poison and increasing the reactivity. The type of ramp is selected on the Ramp Selector switch. Turning it to Control Rod position will energize the Control Rod Ramp relay. The function of this relay in conjunction with the timer relay for the control rod withdraw has already been described in the control rod movement section. Once the Control Rod Ramp relay has been picked up it is locked in by a pair of normally open contacts. It may be de-energized by pushing the Control Rod Fast Rundown push button.

The control rod fast rundown circuitry is also shown in Figure 50. When the Control Rod Fast Rundown relay drops out, it energizes the Control Rod Insert contactors, thereby driving in the control rods. The Control Rod Fast Rundown relay is initially picked up while the control rods are fully inserted by means of the Control Rod Down-Auto-Stop relays which would be energized. Once the relay is energized it is locked in, provided the Scram relays and the Control Rod Contact Series relay are energized. These two conditions may be bypassed when the Control Rod Ramp relay is energized. This bypass is used to prevent motor starting disturbance from interfering with data recording during a control rod ramp transient. In this case, the fast rundown is programmed by the timer section 5 relay. The following conditions are also necessary: Scram Air OK relay energized, Standby Power OK relay energized, and Main Power OK relay energized. A fast rundown is called for when the timer section 5 relay is energized or if the Control Rod Fast Rundown push button is pushed. The timer section 5 relay is used for a fast rundown at the termination of a control rod ramp transient. The fast rundown may be stopped if all the Control Rod Emergency Stop relays are energized.

2.9 Sequence Timer Circuits

The control system is provided with two Multiflex timers, manufactured by Eagle Signal Corp., for sequence programming of experiments. Two similar units are provided; one has a range of 0 to 30 sec, the other 0 to 300 sec. Precise timing is available for sequences up to 30 sec. Sequences requiring greater than 30 sec can be programmed but with less precision. Timer settings can be made with an accuracy of 0.25% of full scale.

The basic timer circuit is shown in Figure 51. The 30-sec timer or the 300-sec timer is selected by a selector switch and started by a keyswitch which energizes a clutch solenoid to start the timer. A stop push button de-energizes the clutch solenoid and resets the timer to its original position. Section 1 timer contacts are used as a holding circuit, enabling a momentary switch to be used for starting so that the timer does not automatically repeat its cycle after resetting.

The reactor control system is not operated by the timer directly, but by seven timer-controlled relays at the control console and seven identical relays in the reactor building relay rack. These relays are designated console timer section 1, relay rack timer section 1, console timer section 2, etc, and are controlled by correspondingly numbered contact pairs of the timers. Timer relays 2 through 7 are shown at the top of Figure 30. The selector switch switches the 30- or 300-sec timers contacts to the console timer section and relay rack timer section relays, thus energizing the relays when the switches close. Contacts of the Transient Rod Fire relay and relay rack timer section 7 relay are used to bypass to timer stop button during programmed transient power excursions. Timer section 7 relay is permanently assigned to control ramp transients, and the Transient Rod Fire relay controls step transients.

2.10 Control Console

The control console is built up from eight standard prefabricated 22-in. metal sections and two 45° "pie" sections. The two pie sections are inserted

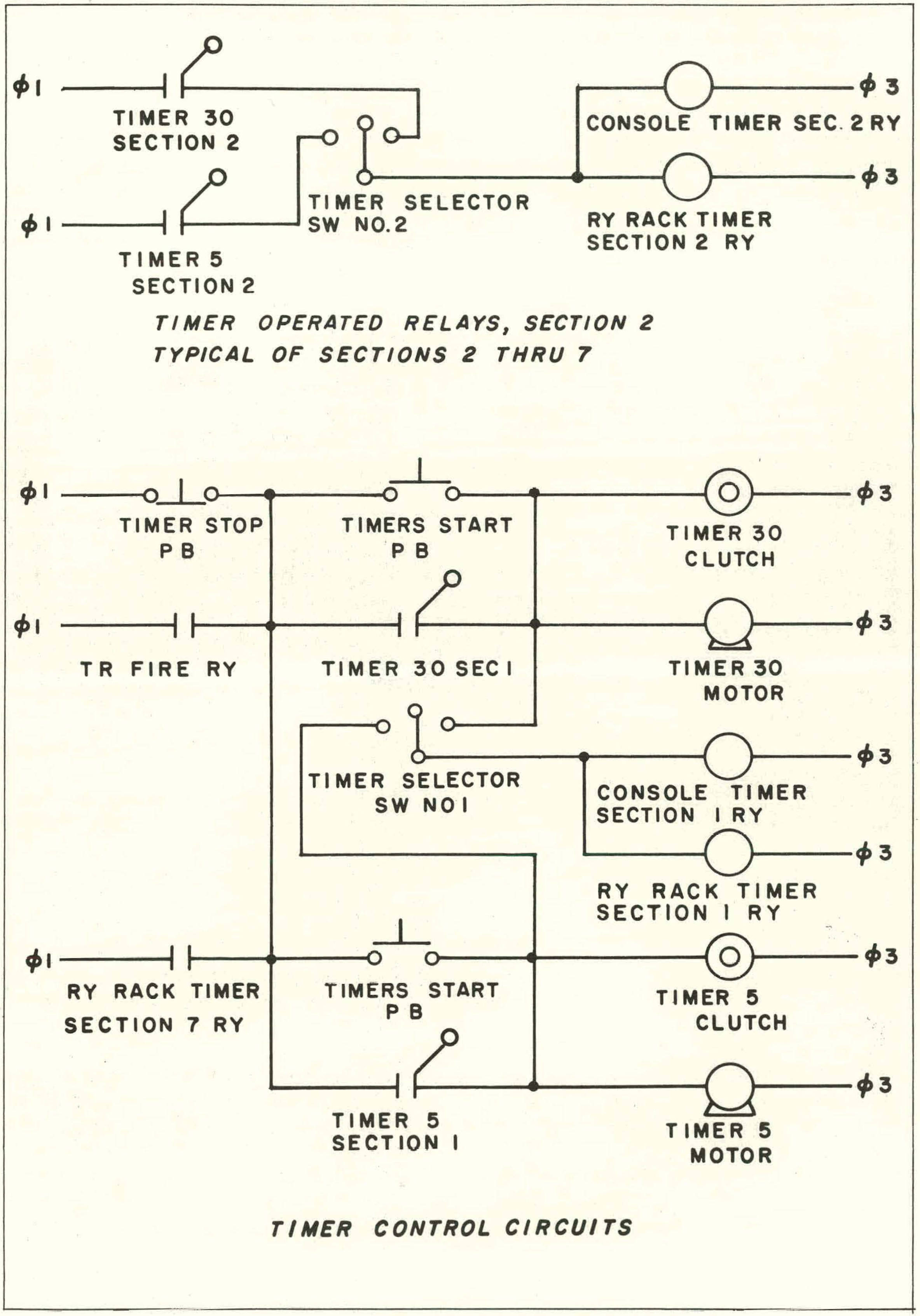


Fig. 51 Sequence timer circuits.

between the fifth and sixth, and the sixth and seventh rectangular sections, so that the overall appearance is roughly that of a quadrant of a circle. The operator is seated in front of the sixth section. Figure 52 is a photograph of the complete **reactor control console.**

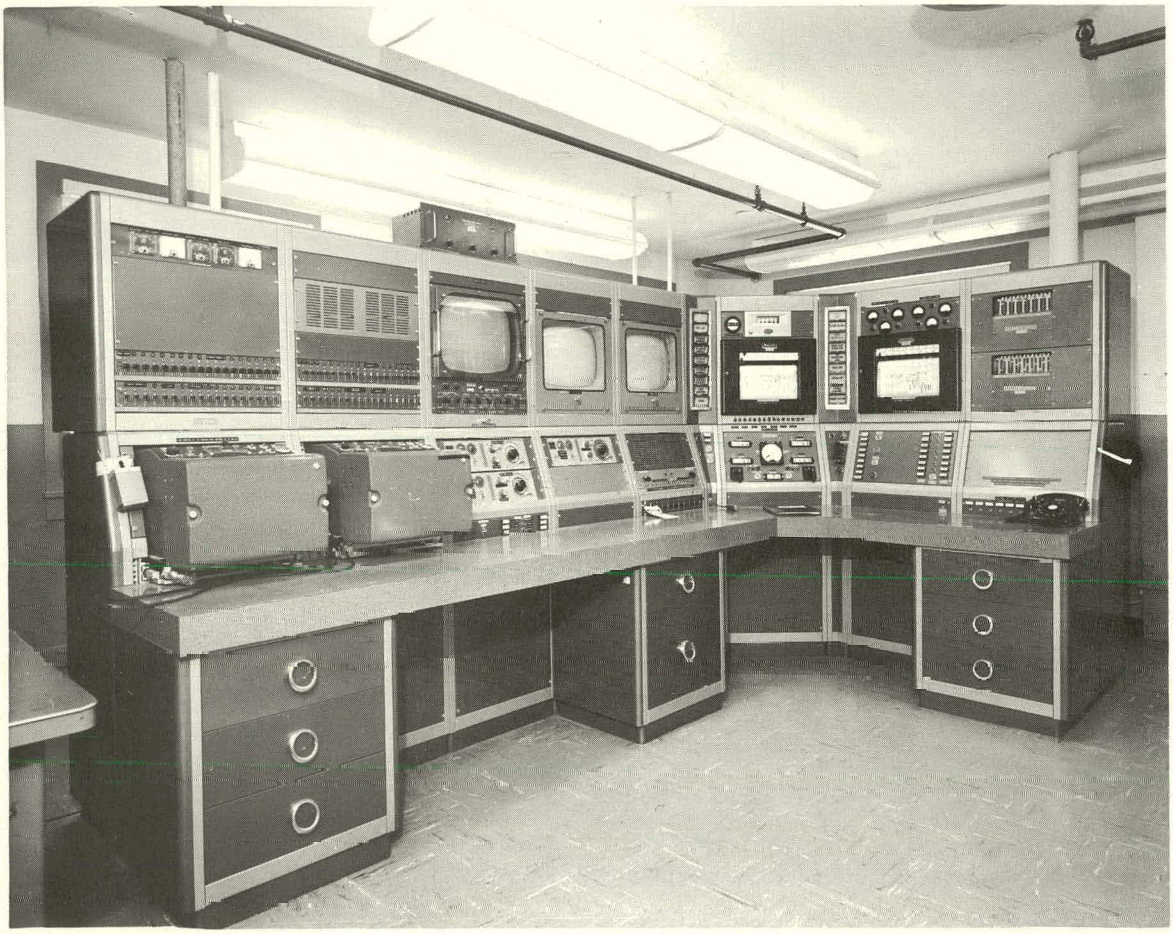


Fig. 52 Control console.

The five rectangular sections at the operator's left contain recording oscillographs, nuclear instrumentation, television monitors, and intercom controls.

The left-hand pie section of the console contains nine annunciator unit windows, the manual Horn push button, the Annunciator Reset button, Clear light, the Console Power On light, the Main Power keyswitch and the Open Plug Interlock and Main Power Bypass ketswitches. The Clear light is operated by a series of contacts from the Control Rod Contact Series, Control Rod Piston Locked Series, and the Transient Rod Lower Limit relays. Lighting of the Clear light indicates that all rods are locked in the fully inserted position.

The sixth panel before which the operator is seated contains the linear power recorder, the count rate meter, and the basic rod drive control switches and indicating lights. The lower portion of this panel contains the Control Rod

Insert-Withdraw switch, Control Rod Speed Selector button switches, Control Rod Drive Selector switches, drive position indicators, and the drive position indicating lights; ie, Contact light, Lower Limit light and Upper Limit light for each control rod. Corresponding transient rod equipment is at bottom center. The speed control push buttons are illuminated to indicate speed selection. Test-fire push buttons for each of the hold-air exhaust valves are at top center above the count rate meter. This section also contains the Upper Limit Bypass and Control Rod Piston Unlock switches.

The right-hand pie section contains nine more annunciator unit windows and the Scram, Scram Reset, Control Rod Fast Rundown, and Control Rod Emergency Stop switches. The scram switch is a large red mushroom head push button; the Scram Reset switch is a green flush-mounted push button; the Control Rod Fast Rundown switch is a red push button which protrudes 1/2 inch. The Control Rod Emergency Stop switches are toggle switches, protected from inadvertent operation by hinged guards.

Section 7, to the right of the operator, contains, at the top, main and standby power monitors, including line-to-line voltage meters and ground detector lights. Immediately below is the logarithmic power recorder. Below this is the panel which contains the selector switches, key switches, and indicating lights for initiating a reactor transient. On the left side of the panel are the lights which indicate Transient Rod Hold Air On, Transient Rod Shock Extended, Transient Rod Fire Air On, Transient Rod Latch Locked, Transient Rod Latch Unlocked, Transient Rod Armed, Transient Rod Disarmed, Transient Rod Fired, and Transient Rod Fast Rundown. Next are the Transient Rod Arming and Unlock keyswitches, the Timers Start keyswitch, and the Timers Stop push button switch. At the right is the Timer Selector switch with indicating lights for each section of the timer. Below these is the Ramp Selector keyswitch with lights to indicate control rod and transient rod ramp excursions.

Section 8 contains the timer mechanisms and toggle switches for operating auxiliary control relays.

2.11 Rod Position

Telesyn self-synchronous motion-transmitting systems are geared to the Acme screws of the transient rod drive and the four control rod drives. These drive Veeder-Root digital counters, on the control console, to indicate rod drive positions in hundreths of inches.

2.12 Alarm and Warning System

Warning lights and horns incorporated in the control system indicate reactor start-up and dangerous situations. A schematic diagram of the system is shown in Figure 53.

To notify personnel in the reactor area of reactor start-up, two warning horns and eight flashing red lights are provided in the area. One horn is located inside the building and one outside. Six red lights are located on the exterior of the building and two inside the building. With the jib crane in the reactor position, turning on main power will energize the Reactor On relay. Movement of the rods will de-energize the CR Seat Series relay which will energize the Warning Flasher relay to flash the warning lights. When the Reactor On relay is energized, a Horn relay also is energized which sounds the horns. The horns

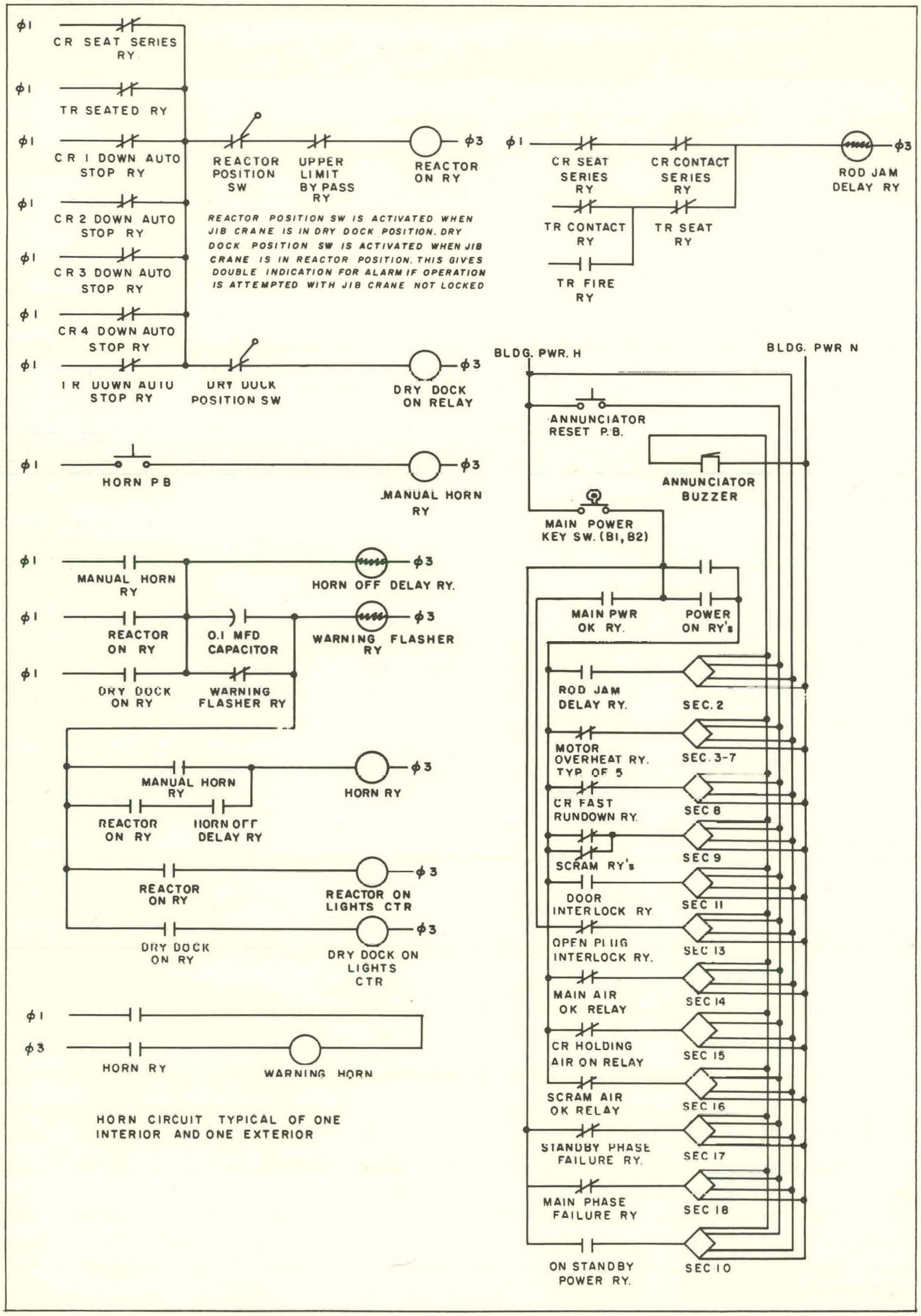


Fig. 53 Alarm circuits.

will sound intermittently for approximately 30 sec at which time a Horn Off Delay relay is picked up to silence the horns. The horns also may be sounded by pushing the Horn bush button on the console. If the jib crane is in the dry dock position yellow flashing lights, one on the jib crane and two in the dry dock area, warn of control rod drive operation.

The Rod Jam Delay relay circuitry is shown in Figure 53. The purpose of the relay is to indicate when a rod jam has occurred. When a control rod has been scrammed, the Control Rod Contact Series relay will be de-energized, thus closing the contacts in rod jam circuit. Normally, the control rods will drop into place, thus opening the Control Rod Seat Series relay contacts in the rod jam circuit. However, if the Control Rod Seat Series relay is not energized within 2 sec after the Control Rod Contact Series relay has been de-energized, the Rod Jam Delay relay will be picked up, thus indicating that a rod jam has occurred. The circuitry for the transient rod is essentially the same, except that a normally open pair of contacts from the Transient Rod Fire relay parallel a pair of normally closed contacts of the Transient Rod Contact relay.

An 18-channel annunciator panel on the control console provides alarm signals for certain abnormal conditions in the control system. The window of each channel contains three lamps (red, white, and green) series-connected to line voltage. Normally, the bulbs operate on reduced voltage which gives a dim light to indicate no bulbs are burned out. When an alarm occurs, all contacts close, applying full voltage to all bulbs and activating the annunciator buzzer. Pressing the Alarm Reset push button silences the buzzer and leaves only the red bulbs lighted. Clearing of the alarm condition lights the green bulb. Pressing the reset button again returns the unit to normal.

Alarm circuits included on the annunciator panel are shown in Figure 53. Power for the annunciator is obtained through a set of contents on the Main Power keyswitch. The Open Plug Interlock, Door Interlock, Standby Power Failure, and Main Power Failure alarm circuits are powered from the keyswitch. All other alarm circuits are not powered unless the Main Power OK and Power On relays are energized.

The following abnormal conditions will actuate an alarm:

Rod Jam Delay - Indicates that the rod has not dropped to seat position after scram.

Motor Overheat - (5) Indicates thermal overload switch on one of the drive motors has tripped.

Control Rod Fast Rundown - Indicates control rod drives are in fast rundown.

Scram - Indicates a control rod scram has occurred.

Door Interlock - Relay rack doors are not closed.

Open Plug Interlock - All connections to the drive system are not complete.

Main Air OK - Indicates there is insufficient air pressure in the control rod air receiver.

Control Rod Hold Air On - Indicates there is insufficient air pressure on the bottom side of the air pistons.

Scram Air OK - Indicates air pressure on the top side of the air pistons is outside normal limits, either too high, or too low.

Standby Phase Failure - Standby voltage is not high enough or the phase sequencing is not correct.

Main Phase Failure - Commercial voltage is not high enough or the phase sequencing is not correct.

On Standby Power - Indicates that the control system has transferred to standby power due to main power failure.

2.13 Rod Drive Air System

The control rod air system supplies compressed air to the transient rod and the control rods to scram the rods or to initiate transient power excursions. Compressed air at 600 psi is supplied from a 36-ft^3 air receiver, or from an 8-ft^3 surge tank at 300 psi, and is divided into three types: (a) hold air; (b) control rod scram air, and (c) transient rod fire air. The three types of air are distributed to the rods from valves located in the valve box mounted on the end of the jib crane. Figure 54 shows the jib crane valve box and air connections to the rod drives. A schematic flow diagram of this air system is shown in Figure 55. The compressor and auxiliaries are described in Section VIII, 2 of this report.

2.13.1 Hold Air. Hold air (bottom side of the air pistons) for all the drives is supplied from the 600-psi receiver through a pressure regulator in the valve box which is set at 250 psi. The hold-air inlet nozzles on each of the control rod drives are connected by flexible hoses to a common manifold located on the valve box. Air is admitted to this manifold by two normally closed solenoid valves connected in series. Hold air is exhausted from the manifold, on a scram, through four pilot-air-operated, normally open, exhaust valves. Each of the four exhaust valves has a three-way air pilot solenoid valve which admits pilot air to the exhaust valve when energized, thus closing the valve, and vents pilot air when de-energized, thus opening the valve.

Each hold-air relay and contactor is controlled by a separate circuit from the console so that the operation of each exhaust valve may be individually checked by the console operator using four Test-Fire push buttons. The push buttons are shunted by the Control Rod Shock Extended Series relay, which allows the exhaust valves to be tested either with the rods at the lower limit position or the shock extended position.

Control Rod Contact, Lower Limit, and Top Limit Series relays prevent power from the scram circuit being applied to the hold air circuits when the air pistons are separated from the drive screw nut extensions, as mechanical damage would be likely from slamming the pistons against the nut extensions. The Control Rod Lower Limit Series relay is necessary to admit hold air to

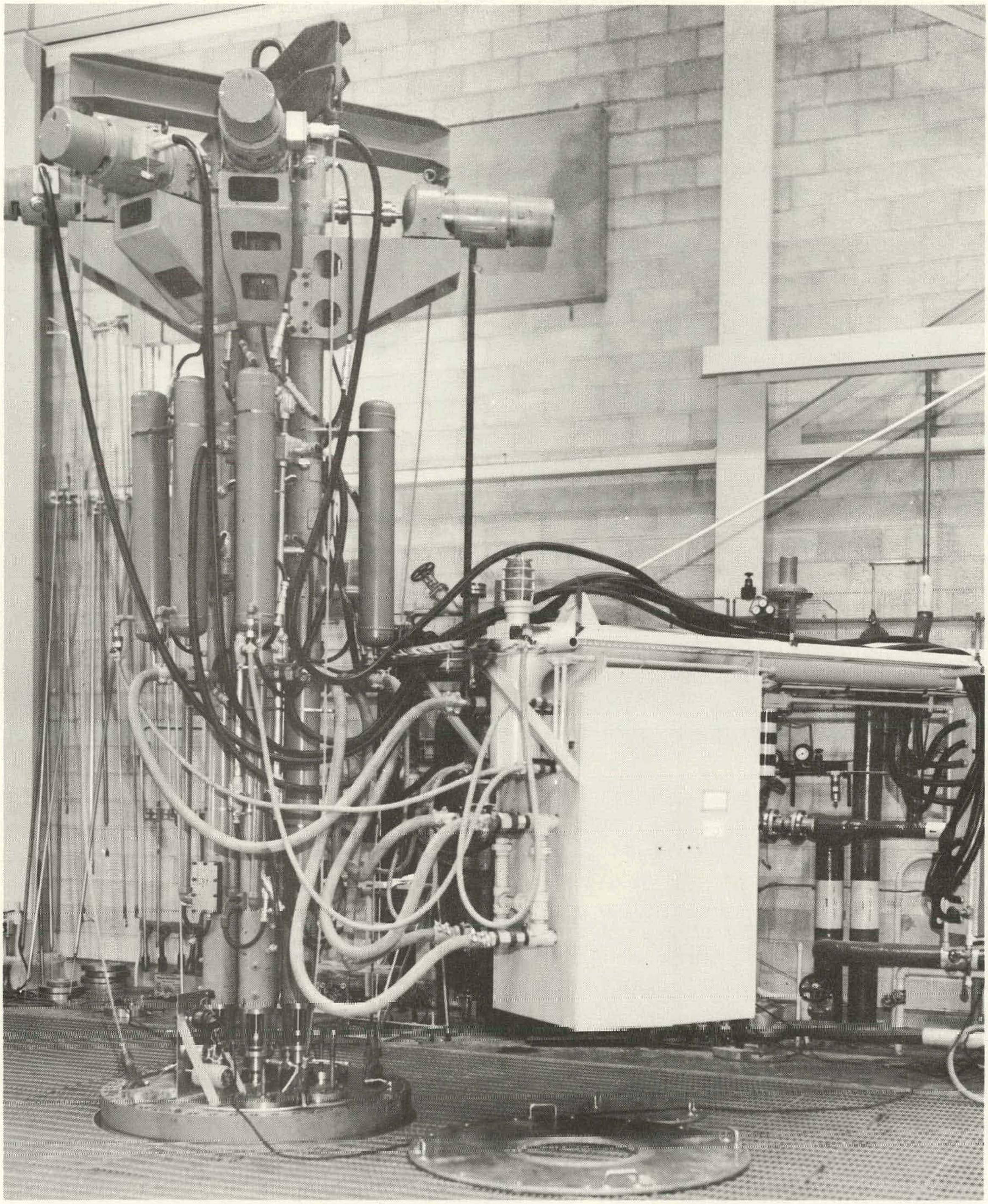


Fig. 54 Control rod air valve box and jib crane.

the drives. The Control Rod Contact Series relay then maintains hold air after the drives have been withdrawn from lower limit.

The transient rod hold-air exhaust valve is a pilot-operated valve identical to those used on the control rod hold air, but its three-way air-pilot solenoid

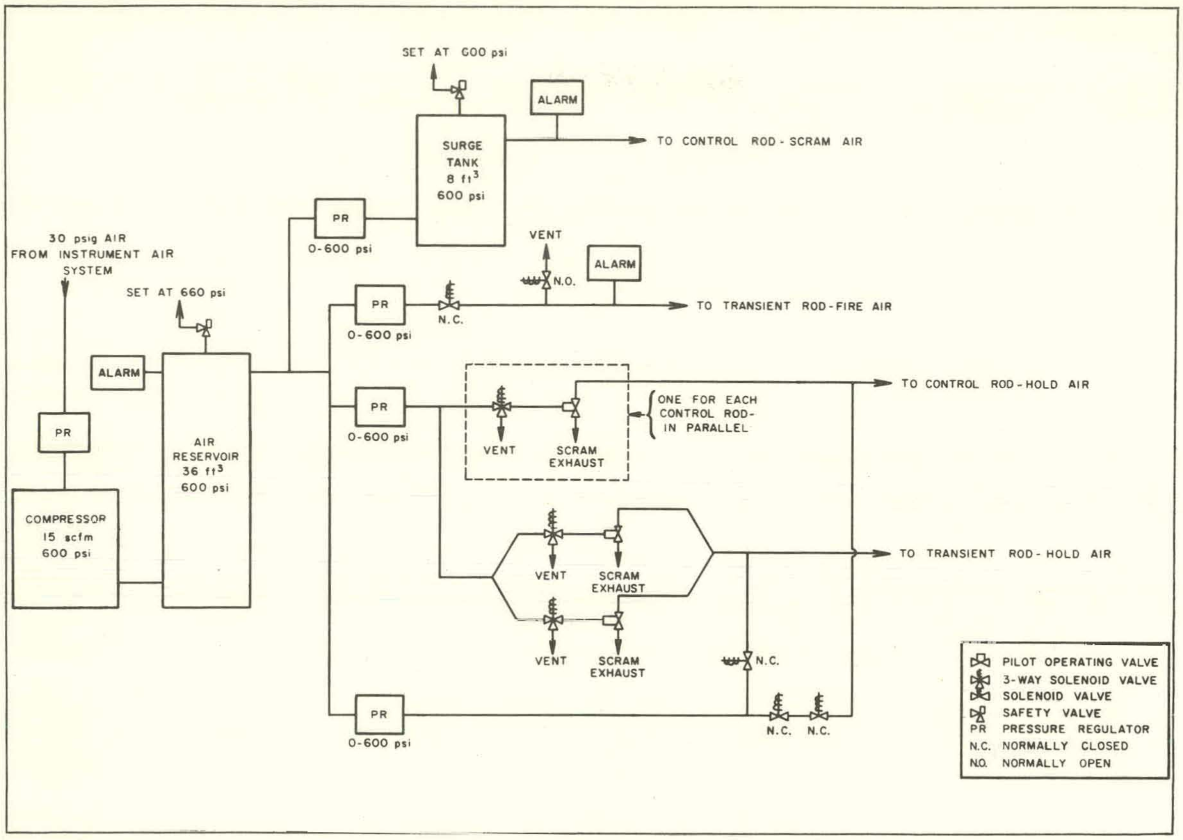


Fig. 55 Schematic flow diagram of control rod air system.

valve is normally open, admitting pilot air to hold the exhaust valve closed when de-energized. To exhaust transient rod hold-air the pilot air is released by energizing the pilot valve which exhausts hold air from the transient rod drive.

2.13.2 Control Rod Scram Air. Top air for the control rods is used to scram the control rods, on a signal from the scram circuits. Air is supplied from the 8 ft^3 surge tank, at a pressure of 150 psi, through flexible connectors from the valve box to 0.44-ft^3 reservoirs on each drive. The reservoirs are in turn connected to the air cylinders of the drives. The air reservoirs provide a surge tank at the drives to reduce the magnitude of the pressure rise which accompanies rod withdrawal, and also provide a reserve air supply in case of failure of the air system.

A pressure switch located in the line between the surge tank and scram air manifold provides a signal to the Scram Air On relay in the control system. A minimum pressure of 100 psi is required to scram the rods against a system pressure of 375 psi. Low pressure, less than 100 psi, or high pressure, greater than 160 psi, will sound the annunciator alarm on the console.

2.13.3 Transient Rod Fire Air. Top air on the transient rod is used to initiate step transient power excursions. Air is supplied from the 600-psi air receiver through a pressure regulator in the valve box which is set at 125 psi. Located downstream of the regulator are the solenoid-operated fill and vent valves which fill or vent air from the air cylinders. A pressure switch provides a signal to the Fire Air On relay in the control system.

VIII. AUXILIARY EQUIPMENT

1. WATER TREATMENT SYSTEM

1.1 Introduction

Water for the Spert site is supplied by two deep-well pumps, one at the control center designated as No. 1 well pump and one near the control center designated as No. 2 well pump. The No. 1 well pump is a 20-stage, 10-in. submersible type with a capacity of 400 gpm at a 500-ft head. The No. 2 well pump is a 15-stage, 10-in. line shaft type with a capacity of 550 gpm at a 545-ft head.

Either or both pumps operate intermittently, on storage tank level controls, to supply two interconnected storage tanks having a total capacity of 75,000 gal.

Water is distributed within the Spert area by two 400-gpm, parallel-connected, booster pumps, which, in conjunction with a pressure control valve, maintain a 70-psig pressure in the distribution system. Under normal conditions, only one booster pump is in service; however, if required the second pump can be put into service. Well water is used at Spert II for equipment cooling, utility purposes, and water treatment supply which is deionized. Table IV is a typical analysis of the well water.

The water-treating equipment for Spert II consists of a softener and a mixed-bed deionizer with associated piping, controls, and alarms.

TABLE IV

CHEMICAL ANALYSIS OF SPERT WELL WATER

Analysis	ppm
Ca	39
Mg	14
Fe	0.04
Mn	0.1
Na	8.8
K	2.7
B	0.05
SiO_2	26
NO_3	1.2
HCO_3	158
Cl	16
SO_4	19
F	0.1
Hardness as $CaCO_3$	155
Dissolved solids	205
Specific conductance at 25°C	332μ
Turbidity	low
pH	8.2

The well water for chemical treatment flows first into the softener. The softened water then flows through the mixed bed deionizer, from which it flows to the deionized-water storage tank. From the storage tank, the deionized water is gravitated into the reactor vessel and primary system piping. All wetted surfaces in the deionized-water system are stainless steel or an inert organic material so as not to contribute minerals or ions to the treated water.

1.2 Softener

A zeolite softener, using a styrene resin and operating on the sodium cycle, is installed in the system to remove water hardness thereby permitting regeneration of the demineralizer with sulfuric acid. The interconnecting line between the softener and the demineralizer has a totalizing flowmeter with alarm to determine bed life of the unit. Table V is a summary of engineering and operating data for the softener.

TABLE V

ENGINEERING AND OPERATING DATA FOR SOFTENER

Shell height (in.)	72
Shell OD (in.)	30
Design pressure (psi)	100
Resin:	
Type	Sodium Zeolite
Ft^3 of resin	13
Regenerant	NaCl
Lb salt/regeneration	150
Resin Rating:	
Kilograms/ft^3	26
Lb salt/ft^3	11.7
Capacity per unit (g)	330,000
Gal/regeneration	35,800
Maximum flow rate (gpm)	35

1.3 Deionizer

The deionizer is a single-column mixed-bed unit of conventional design with a maximum flow rate of 35 gpm and a minimum capacity of 10,000 gal of deionized water. The water produced has a specific conductance of 2 micromhos/cm or less and a maximum silica content of 1.0 ppm.

Deionized-water flow is measured by a totalizing meter equipped with an alarm which sounds when 10,000 gal of water have been treated. Breakthrough of the bed is determined by a conductivity cell located in the effluent piping. A conductivity recorder-controller, in conjunction with a solenoid valve in the softened-water line, automatically stops flow through the deionizer in the event of high conductivity.

The engineering and operating data of the deionizer unit are summarized in Table VI.

TABLE VI

ENGINEERING AND OPERATING DATA FOR DEMINERALIZER

Shell OD (in.)	30
Shell height (in.)	84
Design pressure (psi)	100
Cation Resin:	
Type	Rezes 5A
Ft^3	9
Regenerant	66° Baume H_2SO_4
Lb acid/regeneration	45
Anion Resin:	
Type	Rezex 42
Ft^3	14.5
Regenerant	Caustic Soda
Lb caustic/regeneration	72.5
Capacity per unit (g)	116,000
Gal/regeneration	10,000
Maximum flow rate (gpm)	35

1.4 Storage Tank

Deionized water is stored at ground level in a 14,000-gal horizontal storage tank located outside the reactor building. The tank is fabricated from carbon steel plate with a 3/16-in. neoprene lining and is externally insulated with 1-1/2 in. of fiberglass. Two 6-kw electric immersion heaters with thermostat control are provided in the tank to prevent freeze-up during cold weather. The tank piping and valves are wrapped with electrical heating cable, under the insulation, wherever freezing can occur.

The tank is equipped with a displacer type liquid level device which indicates level at the reactor building, and a high-low level alarm at both the reactor building and control center. Conductivity of the stored water is recorded at the reactor building.

2. COMPRESSED AIR SYSTEMS

Two compressed air systems are provided at the reactor building. A plant air system supplies air for pneumatic instruments, diaphragm control valves, and general plant use. A control rod air system supplies air for the control and transient rod drives.

2.1 Plant Air System

A flow diagram of the plant air system is shown in Figure 56. Air for this system is supplied by a single-stage, double-acting, water-cooled, oil-less

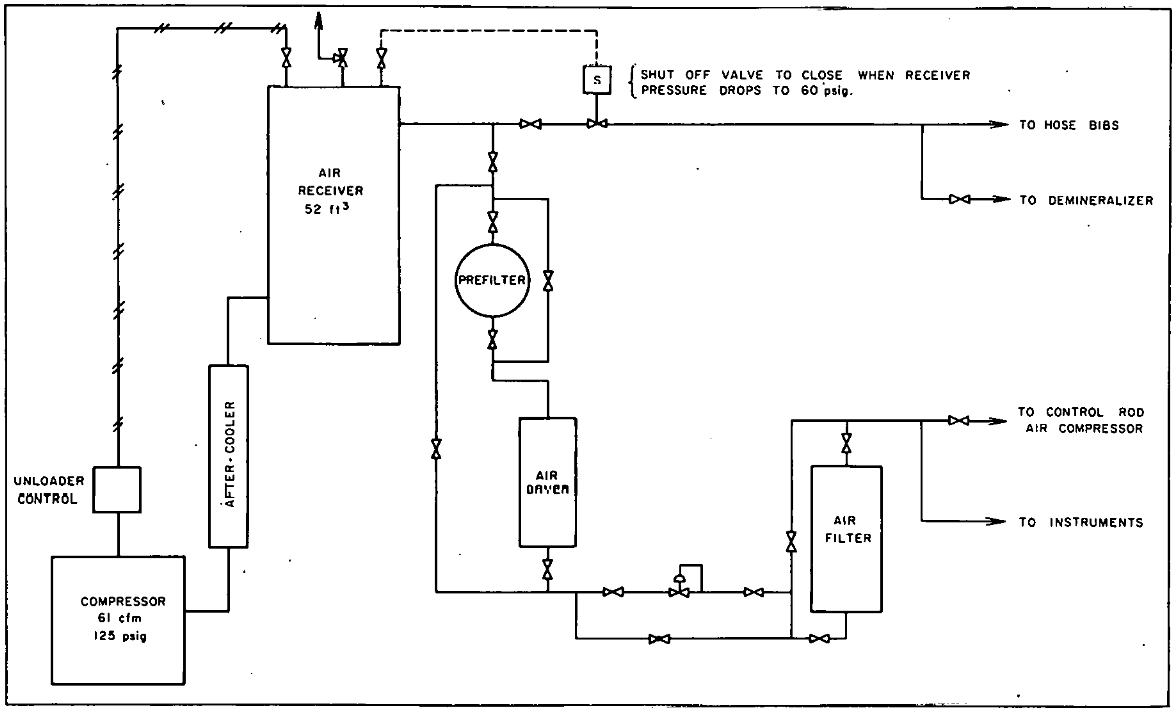


Fig. 56 Schematic flow diagram of plant air system.

compressor rated at 61.5 scfm with a discharge pressure of 125 psig. The compressor discharges through a water-cooled, pipe-line-type aftercooler to a 52-ft^3 air receiver. Pressure in the receiver is maintained by automatic stop-start operation of the compressor. Air from the receiver is divided into two branches, general use and instrument air.

General-use air is distributed throughout the building at 125 psi with outlets provided at all levels. To insure an adequate supply of instrument air, in the event of failure of the compressor, a solenoid-operated shutoff valve is provided in the general-use distribution line. This valve, which is activated by a pressure switch in the air receiver, closes when the receiver pressure drops to 60 psi.

Instrument air flows from the receiver, through a pre-filter which is filled with activated Bauxite ore, to a dryer. The dryer is an automatic dual-tower unit with electric reactivation on an 8-hr reversal cycle. Electric heaters, embedded in each tower, provide for reactivation of the beds. Each bed is capable of drying 125 lb/hr of 90°F saturated air on a continuous basis. Average dew point of the air leaving the dryer is less than -30°F. Air from the dryer passes through a pressure-reducing valve, where the pressure is reduced to 30 psi, then through a filter and then to the distribution piping.

2.2 Control Rod Air System

A flow diagram of the control rod air system is shown in Figure 57.

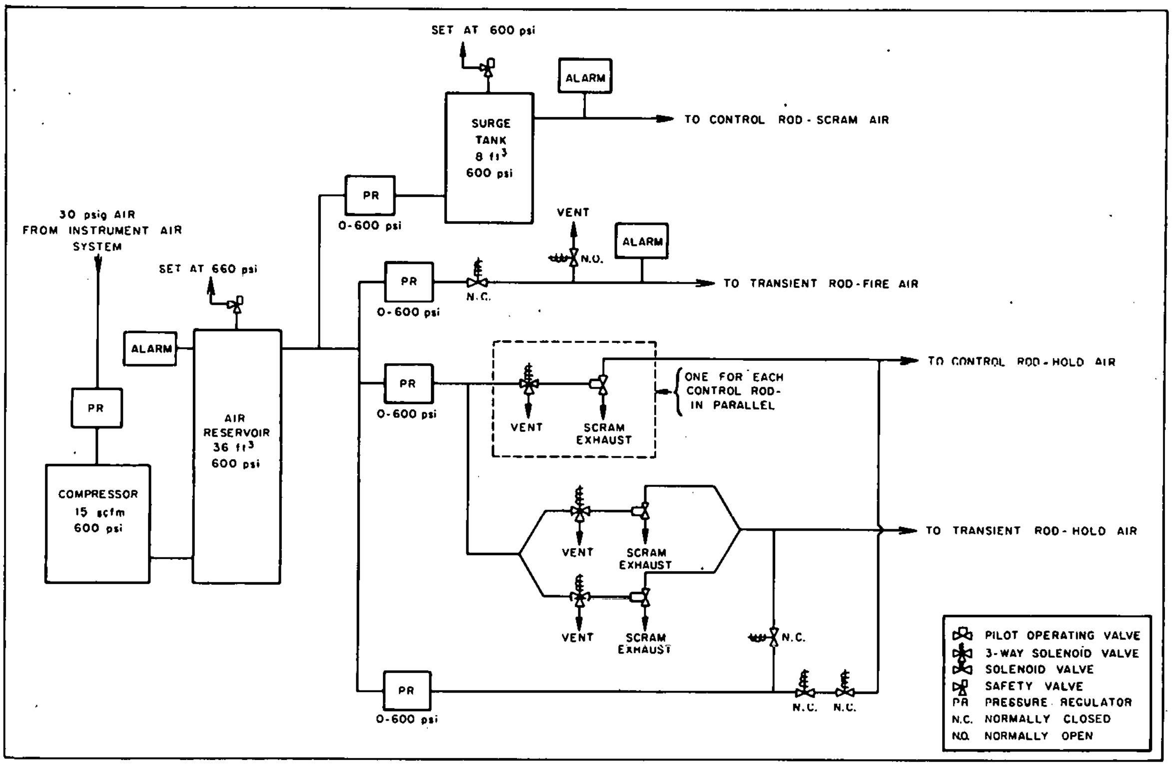


Fig. 57 Schematic flow diagram of control rod air system.

Compressed air for this system is supplied by a Worthington Corp., type V4A3, three-stage, four cylinder, air-cooled machine with intercoolers and aftercoolers, and second- and third-stage oil and moisture separators. The machine is rated at 15 scfm at a discharge pressure of 600 psig and a suction pressure of 2 psig. The compressor takes suction from the dry instrument air supply and discharges into a 36-ft^3 air receiver. Pressure in the receiver is maintained by automatic stop-start operation of the compressor. A pressure switch provides an alarm on the console annunciator panel on low receiver pressure.

Air from the receiver is distributed to three systems:

(1) Control rod scram air

(2) Transient rod fire air

(3) Hold air

These systems are described in detail in Section VII.

3. WASTE DISPOSAL

3.1 General

Under normal operating conditions the only radioactive waste to be handled is primary coolant water drained from the system to maintain water purity, or water drained for the maintenance of mechanical equipment. Any water activity will be due primarily to the presence of corrosion and/or erosion products. Normally the activity level will be low enough to permit discharge of water directly to a leaching pond which is located 300 ft south of the reactor building. Since Spert II is an experimental facility, it is conceivable that rupture and/or melting of fuel could occur during transient tests and thereby release substantial amounts of fission products into the water. However, the fission product inventory of the core is small when compared to conventional power reactors and consists almost entirely of short-life isotopes. In the event that the water activity should exceed prescribed limits for discharge to the leaching pond, it must be retained in the primary system long enough to permit decay to acceptable levels, or it must be pumped from the system and transferred to the Idaho Chemical Processing Plant for disposal.

When heavy water is used as the primary coolant, removal of any radioactive contamination is accomplished by circulating the water through the cleanup loop provided.

3.2 Reactor Building Sump

All building floor drains, equipment drains, and primary system drains are piped to a 3- x 3- x 6-ft-deep stainless-steel-lined sump located directly under the reactor vessel. A 75-gpm vertical sump pump transfers the waste water to the leaching pond. The pump is automatically controlled by a liquid-level device in the sump. Manual stop-start operation of the pump also is provided.

3.3 Waste Cooling Water

Waste cooling water is well water which is used for cooling mechanical equipment such as air compressors, pumps, etc. This water originates from the distribution water system and, after passing through the equipment, is discharged to the leaching pond.

3.4 Chemical Wastes

Chemical wastes are produced from regeneration of the water-treating equipment and are piped to the leaching pond for disposal. The piping is vitrified clay to withstand the corrosive action of the dilute acid and caustic.

3.5 Leaching Pond

A leaching pond located 300 ft south of the reactor building with an area of approximately 10,000 ft^2 is provided for disposal of waste water by allowing it to percolate through the ground until it reaches the water table. A percolation rate of 2 $gal/ft^2/day$ was determined by laboratory tests of ground cores obtained from the site. Although no activity is expected to accumulate in the pond, it is enclosed by a fence to prevent animals or unauthorized persons from entering the area.

4. HOT-STORAGE FACILITIES

Two facilities, dry-storage holes and a water-filled hot-storage well, are provided for the storage of radioactive fuel and equipment.

4.1 Dry-Storage Holes

Eight hot storage holes are embedded in the concrete floor at the southwest corner of the reactor building. The holes are 6-in.-diam, 16-ft-deep, schedule 40, carbon steel pipe, which are plugged with stepped lead covers 13 in. thick. Each hole is provided with a drain pipe which connects to the building sump. Fuel that is moderately radioactive and infrequently used is stored in these holes.

4.2 Hot-Storage Well

A concrete pit 6 x 10 x 10 ft deep, lined with stainless steel, is provided in the southwest corner of the building for storage of highly radioactive fuel. The well is filled with deionized water and provided with removable hand rails and covered with removable aluminum covers.

Cadmium-lined fuel storage racks are provided in the bottom of the well. Additional racks for storage of control rods and miscellaneous equipment are provided on the sides of the well. Deionized water, for radiation shielding, is supplied from the storage tank. A 2-in. drain line in the bottom of the well connects to the building sump.

5. HEATING AND VENTILATING SYSTEM

The reactor building is heated and ventilated by a hot-air furnace located in the utility room. The furnace is rated at 750,000-Btu/hr output on No. 2 fuel oil. Warm air from the furnace is distributed about the building through three ducts. One large duct supplies the reactor room, one small duct supplies the office and locker room, and another supplies the control room and transient instrumentation room. Registers are provided in each room for manual adjustment of the warm air volume. Three room thermostats control motor-operated dampers in the warm air ducts. The cold air return is from the reactor room to the furnace where it is mixed with fresh air for recirculation. Thermostatically controlled dampers adjust the fresh air intake.

The furnace is equipped with a selector switch which allows summer ventilation operation of the air fans. Additional ventilation is provided by two exhaust fans located in the roof of the reactor room. Each fan has a capacity of 8430 cfm. With both fans operating, a volume of air equal to the volume of the reactor room can be exhausted in approximately 7 min.

6. TRANSIENT INSTRUMENT ROOM AIR CONDITIONER

The sensible heat generated by instrumentation in the transient instrument room is removed by a water-cooled, 5-ton air conditioning unit which maintains a nearly constant room temperature to obtain maximum reliability of the instruments. The unit is located in the reactor room and is equipped with ducts for delivering cooled air to the instrument room, returning air from the instrument room and fresh air intake. Room temperature is controlled at 72°F by a reverse-acting thermostat located in the instrument room.

7. BUILDING CRANE

A 10-ton traveling bridge and trolley crane spans the high-bay area. The crane services the main floor area directly, and the levels below by removing the floor grating. The maximum vertical hook travel is 25 ft above the main floor, and 35 ft below the main floor. The crane capacity is sufficient for the removal and transport of the full-opening reactor vessel head and control rod drives. All motions of the crane are controlled from a pendant-type push button station suspended from the bridge. The push button station is equipped with momentary push buttons for run and jog of all motors in both directions. The bridge and trolley speeds are 10 ft/min; the hoist speed is 6 ft/min. The jog provision provides for approximately 1/8 in. of travel in all directions. The hoist is equipped with a "fail-safe" solenoid brake for full-load capacity.

8. DRY DOCK

A dry dock is provided in the reactor building for repairs, adjustments, routine maintenance, etc, to the rod drives.

The dry dock consists of a 4-ft-square hatchway in the operating floor of the reactor room. The perimeter of the hatchway is faced with 6- x 6-in. oak timbers to provide a surface for the access head laydown.

A platform under the hatchway provides a working area below the drives. The space directly below the drives is caged on four sides with chain link fencing. A padlocked access gate provides entry to the caged area. Amber flashing lights, located around the caged area, indicate rod drive operation.

The warning lights and cage-access gate are provided to protect personnel in the reactor area from possible injury during rod drive operation in the dry dock.

9. TELEVISION

A remotely controlled, closed-circuit television system is used to provide visual surveillance of the reactor building during nuclear operation. One camera provides coverage for the operating floor of the reactor building, and one provides coverage for the basement area. Both cameras are equipped with the following remote controls: (a) 350° pan and tilt, (b) automatic iris adjustment, (c) electrical focus adjustment, (d) target voltage adjustment, (e) beam voltage adjustment, (f) mechanical lens focus, and (g) zoom lens. Two monitors located in the control room console provide personnel with a view of the reactor and its associated equipment during nuclear operation.

10. INTERCOMMUNICATIONS SYSTEM

An intercommunications system is provided for voice communication between the reactor building and the control center control room. This system consists of five independent systems: transmission to the reactor building from the control console; transmission from the reactor building to the control console; transmission from the instrumentation calibration point in the control room, to the transient instrument room; transmission from the transient instrument room to the instrumentation calibration point; and telephone-headset communication both ways. There are 13 stations, at strategic locations in the reactor building, where messages may be received or transmitted. The 13 stations are divided into seven discrete groups which can be individually selected by selector switches located on the control console. In addition, all stations can be called simultaneously if the need arises.

A patch panel, located in the reactor building, is provided for inter-station communication in the reactor building. This feature permits independent two-way communications between two or more stations.

The telephone system is a plug-in headset type with outlets located at each of the 13 stations and in the control room. The patch panel also can be used for the telephone system.

11. RADIATION MONITORING SYSTEMS

There are two separate and distinct radiation monitoring systems provided in the reactor building. These consist of a constant air monitor and five remote area monitors.

11.1 Constant Air Monitor

The constant air monitor (CAM) is Nuclear Measurements Model AM-2A and consists of a detector, a count rate meter and a recorder, a compressor with interchangeable flow orifices, a filter holder with disposable filters, and alarm circuitry.

The detector measures both γ and β radiations collected on the filter and, by means of the count rate meters and recorders, the radiation level in the building is indicated and recorded at both the reactor building and the control room. The range of the meters and recorders is 50 to 50,000 counts per minute.

The alarm circuitry consists of an alert and alarm circuit. Alert conditions are signified by a flashing yellow light and a bell which rings continuously for 30 sec. Alarm conditions are signified by a flashing red light and a bell which rings intermittently.

11.2 Remote Area Monitors

The remote area monitoring system consists of a basic control unit and five detector units located in the reactor building.

The control unit is located in the guardhouse at the reactor area. It is equipped with a recorder, five indicating meters with calibration potentiometers, high-radiation set points and light, and reset control.

The five detectors are Tracerlab Inc. Model TA-6, γ sensitive only, with ranges of 0.1 to 100 r/hr. Each detector is enclosed in a waterproof housing which contains a 1-μc strontium-90 calibration source.

Five indicating meters, one for each detector, are provided on the control console at the control center.

11.3 Emergency Power Supply

A direct-connected engine and generator set is installed at the reactor building to maintain power to the area monitors in the event of commercial power failure.

The engine is a 4-cylinder, 4-cycle, propane-fueled unit with sufficient fuel supply for approximately 100 hr of operation. Engine starting is accomplished by battery cranking. The generator is self-excited, 5-kw, 115-v ac, single-phase, 3-wire, 60-cycle rotating-armature type.

An automatic transfer switch panel is provided to transfer system load to the generator on commercial power failure. The transfer panel includes the following:

(1) A close voltage differential relay set at 70% of normal line voltage.

(2) An inverted switch arrangement spring held in normal power position.

(3) A test switch to simulate commercial power failure.

(4) A disconnect switch to permit operation of the engine without interrupting normal power.

(5) A 1/2- to 3-sec time delay on engine starting.

(6) A 10-min time delay on switching back to commercial power when such power is restored.

(7) A fused 12-v trickle charger for maintaining engine starting batteries at full charge at all times.

IX. PLANT CASUALTY EVALUATION

1. INTRODUCTION

The experimental programs for the Spert II plant will include several types of tests with a variety of reactor cores. Some experiments will have a planned high probability of damage to the plant or equipment and, because of the exploratory nature of the program, there is an attendant non-negligible probability that this probing of reactor behavior may result in more extensive mechanical damage than anticipated. For both of these situations, the hazards report [5] has discussed the principal problems of protection of personnel engaged in the experiments and the protection of all other persons, including the public at large. The cases considered therein were treated in such a fashion that the results, which were found acceptable even under the extreme assumptions postulated, were independent of the particular form of the incident. That is, it was not an essential part of the argument that details of the postulated incidents be specified with regard to the consequence or likelihood of the failure of a particular component. While this maximum accident analysis covered the primary area of concern in hazards evaluation, it is also of importance to examine the possible consequences of various types of failures in the plant. Accordingly, this section discusses the consequences of failures in the principal plant systems. Since the presentation of the system failures encompasses the failures of individual components, these generally will not be singled out for further examination, but in a few special cases individual component failures will be discussed as a part of the respective system analysis.

2. SYSTEMS ANALYSIS

2.1 Compressed Air Systems

Plant systems which can affect plant safety are the air systems. The air systems provide high-pressure air for the control and transient rod drive units and low-pressure air for the pneumatic instrumentation and diaphragm control valves. The pneumatic instrumentation includes the speed controls for the two fluid-drive units which control the speed of the primary pumps, the pressurizer-vessel level transmitter, the deionized-water storage-tank level transmitter, and other pressure and flow transmitters which operate indicator and recorder instruments. The air-operated valves include the reactor vessel vent valve, the pressure control valve, the blowoff valve, and the blowdown valve. Two modes of gross system failure are of importance, loss of pressure and system overpressure. They are discussed below.

2.11 Loss of Air Pressure. If the high-pressure system should fail due to compressor failure, air line rupture, or other reasons, the "main air" and "scram air" annunciators on the control center reactor console will alarm. Subsequent low pressure also will initiate a fast rundown of the reactor control rods.

With the loss of low-pressure air to the pneumatic speed controllers of the fluid drive units, the drives will slow to their minimum speed of 227 rpm with a corresponding decrease in speed of the primary coolant pumps. The result of this decrease in pump speed will be a reduction of coolant flow through the reactor core. The consequences of this reduction of flow will be dependent upon the condition of the core under test at that time. The majority of the experimental studies will be conducted from low initial powers and will involve a relatively small total energy release; therefore, no hazard due to meltdown of fuel will exist from loss of flow.

The pressurizer level transmitter will actuate the blowdown valve to the closed position upon loss of air pressure to the transmitter. This air-operated valve also will close automatically on air failure. The closure of this valve will prevent the blowdown of water from the pressurizer.

The reactor vent valve, blowoff valve, blowdown valve, and pressure control valve are normally closed valves; therefore, the valves will close with loss of air pressure. The closure of these valves will result in the pressure and level of the system being fixed at constant values. Under these conditions, operation of the makeup pump, primary coolant pumps, or heaters in the reactor vessel will increase both the pressure and level.

2.12 System Overpressure. Air overpressure of significant magnitude to cause rupture of the air system will result in air pressure loss with the consequences noted above.

Air overpressure of significant magnitude to cause rupture of the pressure regulators so that line pressure is applied to the pneumatic instruments will cause the instruments to give maximum output signals. A maximum signal from the pressurizer level transmitter will actuate the blowdown valve to the open position. This, in turn, will discharge water from the pressurizer until the instrument is corrected or until the pressurizer is empty. An overpressure to the speed controllers of the fluid drive units will cause the positioners to move to their upper limit with a resulting increase in the speed of the primary coolant pumps. However, the upper limit of the positioners is adjustable and is adjusted to set the maximum allowable flow rate through the core.

2.13 Component Failure. The failure of individual components will lead to one of the two situations discussed above, and the possible effects of such occurrences as encompassed by the above general discussions are indicated by the following examples of the considered incidents:

(1) Compressor failure will result in low air pressure throughout the system and eventually to complete loss of the air supply.

(2) Rupture of valves, pipe, fittings, etc, will result in loss of the air system if the leakage is in excess of the capabilities of the compressors.

(3) Simultaneous loss of pressure control on the compressors and failure of all relief valves to function will result in overpressure and rupture which will be an air loss to the system.

2.2 Loss of Electric Power

A second system which must be analyzed from the standpoint and consequences of failure is the electric power distribution system. The two major distribution nets in this system include the 2400-v power feeder and the 480-v power feeder. The 2400-v power feeder serves the primary pumps, and the 480-v power feeder serves the control rod drives, reactor coolant heaters, and the rest of the electrical equipment at the reactor building. In order that the reactor may be safely shut down during commercial power failure, an emergency generator is provided to maintain control power for the rod drives.

2.21 Reactor Control Power. Commercial reactor control power failure may occur at the main substation, the Spert II substation, the 480-v load center, or at individual components in the control system. With failure of commercial power, the control system is automatically switched to emergency power. Switching from commercial to emergency power will initiate a control rod scram and fast rundown of the control rod drives. Upon restoration of commercial power, positive reactor operator action is required before the control system can be re-energized.

2.22 Building Power. Loss of building power will cause loss of the reactor instrumentation power supplies and amplifiers at which time operating procedures require that the reactor be scrammed immediately. Barring simultaneous loss of emergency power, the control panel on the console will provide the necessary information to the operator that the reactor is safely shutdown.

In the event there is a simultaneous failure of emergency power, a continuity check can be made at the control console to determine that the control rods are at seat position. Four pairs of wires from the control rod seat switches are brought to the control console. Continuity of these circuits indicates the seat switches are closed and the rods are at seat positions.

A battery-powered neutron pulse system, at the reactor building, provides the following information on neutron levels:

(1) Audible counts over the intercommunications system

(2) Log-count rate display at the reactor area

(3) Remote log-count rate display on the control console at the control center

This system is designed to operate approximately 3 hr on battery power.

Power for the area radiation monitoring systems is maintained by a 5-kw, engine-generator set which automatically starts on building power failure. An automatic transfer switch panel is provided to transfer line load to the generator.

Loss of building power will stop all auxiliary equipment and will automatically open some of the breakers which control electrical equipment. The following equipment will have to be manually started when power is restored to normal:

(1) 2400-v main feeder braker

(2) Reactor coolant pumps 1 and 2

(3) Piping system vacuum pump

(4) Vent fans 1 and 2

(5) Fin-tube heat exchanger fans

(6) Transfer pump

(7) D_2O cleanup pump

Power to the following equipment will be automatically restored when power to the reactor building is restored, provided that such equipment was in service at the time of power failure:

(1) Reactor coolant electric heaters

(2) Deionized water storage tank heaters and pipe heaters

(3) All lighting transformers

(4) All instrumentation transformers

(5) Transient instrument room air conditioner

(6) Both air compressors

(7) Eight-inch flow control valve

(8) Waste sump pump

(9) Makeup pump

Battery-powered emergency lights automatically provide sufficient illumination in all hazardous areas of the reactor building when power fails.

2.3 Loss of Primary System Water

Loss of water from the primary system must be considered in terms of possible damage to equipment, radiation hazard, and cost of moderator when using heavy water. The events which could lead to a loss of water are rupture of the reactor vessel, the pressurizer vessel, the primary coolant piping, or other piping connected to the primary coolant system; or malfunction of the primary system blowoff valve, blowdown valve, and pressure relief valves.

To minimize the possibility of these events occurring, operating limits of temperature and pressure have been set for the Spert II reactor. The limits are as follows:

(1) Routine non-transient plant operation will be permissible according to the following tabulation of maximum pressure vs temperature.

Temperature	Maximum Pressure	Limiting Factor
Ambient to 200°F	430 psig	Vessel Shell
250°F	420 psig	Flanges
300°F	400 psig	Flanges
350°F	380 psig	Flanges
400°F	360 psig	Flanges

(2) For transient operation, maximum pressure shall be permitted up to 10% over the permissible plant operating pressure on a routine basis.

(3) Total pressure during transient operation shall be permitted up to 500 psig provided the reasons for entering into this range are documented and approved by the branch manager prior to the test.

(4) Total pressure during transient operation extending into the range above 500 psig will be permitted only on a calculated-risk basis with prior documentation, approvals, and notification of intent to higher management prior to the tests.

If rupture occurs, under circumstances leading to the major loss of the water in the primary system, the sump pit will be completely flooded and the reactor pit will be flooded to a height of approximately 1.6 ft. This will flood and cause possible damage to the sump, cleanup, transfer, and vacuum pump motors.

Another problem presented by loss of coolant will be core exposure. This condition will exist if the lower portion of the reator vessel and primary piping ruptures with the subsequent loss of approximately 8000 gal of water. Loss of core moderator-coolant at room temperature poses no special hazard or probability of extensive damage to either the building or the plant equipment. However, it could entail special working conditions to effect repair and cleanup, depending on the water contamination, if any, and the condition of the specific core installed in the reactor. The problem of repair and cleanup could be increased when using heavy water as the moderator, if access near the reactor vessel is required immediately after reactor operation. This is due to the high radiation field resulting from photoneutron production in heavy water by fission product decay.

The greatest personnel hazard exists if the stored thermal energy in the coolant-moderator at 360 psig and 400°F is suddenly released by an extensive rupture of the reactor vessel or piping system. The thermodynamic properties of the water will cause it to flash to vapor, giving up part of its energy to the air and producing a rapid increase in pressure and temperature inside the reactor building. Calculations, using the method of Bergstrom and Chittenden [9], show that an instantaneous release of the stored thermal energy will increase the pressure and temperature in the building to a maximum of 58 psia and 264°F, respectively. The time required for the mechanisms of escape, vaporization, and expansion to occur, and the heat loss to the cold building surfaces, will lower the calculated peak pressure. However, the actual resultant pressure will, in all probability, collapse the building, presenting a hazard to any personnel in the building. The probability of an extensive primary system rupture described above is very slight since conventional design procedures were followed in the construction of the plant.

When operating with heavy water, the cost of the coolant must be considered in conjunction with the above discussed events.

3. CONTAMINATION OF PRIMARY SYSTEM WATER

Contamination of the primary water could occur by a break in the fuel plate cladding. The consequences of this will be dependent upon the condition of the core under test at that time. Since extended high-power operation is not possible, the fission product inventory in the reactor core will always be small in comparison to that contained in conventional power reactors. The fission product activity which might be released in an accident will consist almost exclusively of those short-lived products of the initiating incident.

The Spert II reactor water is discharged directly to a leaching pit located within a fenced area. In the event that the reactor water activity exceeds the limits for discharge to the ground, it must be held up in the reactor vessel until the radioactive isotopes decay to permissible levels, or it must be pumped from the vessel and transferred to the ICPP for disposal. If the reactor water does not exceed dumping limits, it can be transferred directly from the reactor vessel to the leaching pond.

When using heavy water, the radioactive isotopes can be removed by circulating the water through the ion-exchange columns of the D_2O cleanup loop. The contaminated ion-exchange columns can then be removed from the system for disposal.

4. PRESSURIZER

Rupture of the pressurizer vessel will result in a loss of system pressure. If this occurs when the system is at temperature, the coolant will boil. The pressure also will drop below the NPSH requirements of the primary pumps, causing them to cavitate.

Rupture of the pressurizer will result in loss of water with consequences described in Section VI, 2.3.

5. LOSS OF HEATING SYSTEM

In order to prevent freezing of the D_2O and possible rupture of the D_2O containers, it is necessary to keep the building temperature above 45°F in the event of a loss of the heating system. Since the heat loss from the building will be slow and auxiliary portable heaters are available from the Central Facilities Stores, no hazard or post-incident damage should occur as a result of the failure of the heating system. Explosion of the furnace probably will damage the softening and deionizing equipment located in the same room. Since this equipment is located in a wing building, damage to the main reactor building should not occur.

6. FIRES

The only major source of fire hazard is from malfunction of the electrical equipment or the furnace. Fire protection is furnished by local appropriate fire extinguishers and the AEC Fire Department located 6.6 mi away. An ADT alarm system is used to manually report fires in the Spert area. An automatic ADT alarm is actuated by a heat-sensing device in the main reactor building ceiling. Since the furnace is located in a separate room in the wing building and is separated from the main building by a non-combustible 12-in. pumice block wall, fires originating in the furnace room will be effectively delayed from spreading to the rest of the reactor building.

Protection from fire in the main building structure, which is erected of 12-in. pumice block with bare structural steel, is accomplished by limiting the storage of combustibles in the main reactor building by strict administrative control.

7. EARTHQUAKES

AEC design criteria for construction at the NRTS specifies that the NRTS is in zone 2 (moderate damage) in an anticipated damage zone scale ranging from 0 (resulting in no damage) to 3 (resulting in severe damage). Although minor damage is possible at the NRTS to zone 2 buildings, the August 1959 earthquake north of West Yellowstone, Montana, caused no known physical damage at the NRTS even though the intensity of this earthquake was rated as "VII" on the modified Mercallis scale.

Some disturbance of instrumentation might be expected and possible fluctuations in water levels are likely. However, none of these would result in any serious plant problems.

8. PLANT DRAWINGS

Reproducible copies of all drawings furnished by Stearns-Roger Mfg. Co. are kept in the Idaho Falls drafting section of Phillips Petroleum's division engineering branch. Prints of these drawings are available at both the control center and the reactor building.

Original drawings pertaining to Spert II (ie, control rod drives, core structure, control rods, fuel handling tools, etc) are retained at the Central Facilities offices of the Spert design section of Phillips' division engineering branch. Reproducibles of these originals also are retained at the MTR design and drafting section of division engineering to preclude loss of originals, should fire or other disaster endanger either the MTR or Central Facilities. Prints of all Phillips' drawings are available at both the control center and the reactor building.

Equipment drawings and vendor data are retained in a master file at the control center; working copies are kept at the reactor building.

X. REFERENCES

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2. W. E. Nyer, S. G. Forbes, Spert Program Review, IDO-16634 (October 19, 1960).

3. T. R. Wilson, The Spert-II Reactor Facility; Preliminary Design Report, IDO-16386 (October 1, 1957).

4. C. R. Montgomery et al, Summary of the Spert-I, -II, -III Reactor Facilities, IDO-16418 (November 1, 1957).

5. G. O. Bright, J. E. Grund, Spert II Hazards Summary Report, IDO-16491, (February 17, 1959).

6. T. R. Wilson, Ed., Spert Project Quarterly Technical Report, 1st Qtr 1960, IDO-16617, pp 7-13 (1961).

7. Frank Schroeder, Ed., Spert Project Quarterly Technical Report, 2nd Qtr 1960, IDO-16640, pp 13-19 (1961).

8. R. E. Heffner, T. R. Wilson, Spert III Reactor Facility, IDO-16721 (October 25, 1961).

9. R. N. Bergstrom, W. A. Chittenden, "Reactor-Containment Engineering - Our Experience to Date", Nucleonics, 17, No. 4, pp 86-93 (April 1959).

APPENDIX A

DESIGN DATA SUMMARY

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APPENDIX A

DESIGN DATA SUMMARY

A summary of the characteristics of the reactor and major plant equipment is tabulated in this section. The core information included here, such as core loading, core composition, core volume, heat-transfer area, is based on the two cores that have been used in the Spert II facility. It should be noted that this core information is not necessarily representative of that which will be used throughout the experimental program. The core loading for a particular series of experimental investigations is determined by experiment and will be dependent upon the particular reactor parameters under investigation.

1. GENERAL REACTOR DESIGN DATA

Type - pressurized-water experimental reactor

Function - experimental, reactor transient behavior and safety

Fuel - 93.5% enriched U-235, U-Al alloy, heterogeneous, plate type

Moderator - H_2O or D_2O (optional)

Coolant - H_2O or D_2O (optional)

Neutron Energy - thermal

Power - none, transient tests only.

Design Pressure - 375 psi

Design Temperature - 400°F

2. REACTOR COMPONENT DESIGN DATA

Reactor Vessel

Construction - Section VIII, ASME Code, 1956 Edition

Overall Length - 24 ft 6 in.

Inside Diameter - 10 ft

Shell Thickness - 1.5 in.

Head Thickness - 1.5 in.

Clad Thickness - 0.100 in. minimum

Materials:

Shell and heads - ASTM A-212, grade B

Clad - type 304L, stainless steel

Design Pressure:

Continuous service - 360 psig at 400°F

Max allowable working pressure - 410 psig at 400°F

Insulation - 2 in. of foamglass

Fuel Assemblies - (Type "B")

Type - rectangular, plate type, four fixed plates, aluminum except stainless steel lower end box extension.

Overall Dimensions - 3.00 x 3.00 x 38.125 in.

Number of Fuel Plates Element - 4, 8, 12, or 24 (optional)

Fuel Content/Element - 28, 56, 84, or 168 grams (optional)

Plate Spacing - 0.690, 0.314, 0.190, or 0.065 in. (optional)

Fuel Assemblies - (Type "BD")

Type - rectangular, plate type, aluminum

Overall Dimensions - 3.00 x 3.00 x 41 in.

Number of Fuel Plates/Element - variable

Fuel Content/Element - variable

Plate Spacing - variable

Fuel Plates

Type - rectangular, flat

Materials:

Cladding - 0.020 in. of 6061 aluminum alloy

Fuel - 93.5% U-Al alloy

Overall Dimensions - 0.060 x 2.704 x 25.125 in.

U-235/Plate - 7.0 g

Fuel Core Composition - 13 wt% U-235
86 wt% Al type 1100
14 wt% U

Control Rod - Fuel-Poison type)

Type - rectangular; upper section absorber material, lower section is a fuel subassembly

Number - 8

Absorber Section - 3/16-in.-thick hollow stainless steel tube metal with 0.040 in. cadmium and 0.040 in. stainless steel.

Fuel Section - 5-, 8-, or 17-plate assembly (optional)

Length of Absorber - 34-15/16 in.

Rod Travel - 44 in.

Withdrawal Rates - 6.5 in./min, 13.2 in./min, or 19.9 in./min

Scram Time - 0.4 to 0.7 sec (upper limit to seat)

Control Rod - (Poison type)

Type - tubular; upper section is stainless steel type 304L, middle section is an absorber material, lower section is aluminum.

Number - 8

Absorber Section - 0.315-in.-thick hollow stainless steel tube metal sprayed with 0.020 in. of cadmium and 0.040 in. of stainless steel.

Length of Absorber - 28 in.

Rod Travel - 44 in.

Withdrawal Rates - 6.5 in./min, 13.2 in./min, or 19.9 in./min

Scram Time - 0.4 to 0.7 sec (upper limit to seat)

Transient Rod - (Typical)

Type - blade; lower section absorber (Al-Cd-Al), upper section aluminum

Number - 1

Dimensions of Blade - 5/16 x 5 x 69-3/4 in.

Absorber - cadmium

Dimensions of Absorber - 0.020 x 4-3/4 x 28 in.

Travel - 44 in.

Withdrawal Rates - 6.5 in./min, 13.2 in./min, or 19.9 in./min

Average Release Time - 0.3 sec (upper limit to seat)

Control Rod Drives

Type - Acme nut and screw. Air pressure maintains rod in contact with screw and scram rods.

Number - 4

Motor Type - 480 v, 3θ, 3 speed, constant torque

Motor Rating - 1 hp

3. PRIMARY COOLANT SYSTEM DESIGN DATA

Primary Pumps

Type - horizontal, centrifugal, single stage

Number - 2

Capacity, each - 10,000 gpm

Head - 175 ft of H_2O

Motor:

Rating - 600 hp

Type - 2300 v, 131 amp, 3θ, 60 cycle

rpm - 1183

Material:

Pump Casing - nodular cast iron with "Kanigen" plating

Pump Impellers - 18-8 stainless steel

Shaft Sleeves - 18-8 stainless steel

Shaft - 12-14 chrome steel

Pressurizer Vessel

Construction - Section VII, ASME Code, 1956 Edition

Design Pressure - 375 psig

Design Temperature - 400°F

Outside Diameter - 3 ft

Overall Length - 6 ft

Shell Thickness - 5/8 in. plus 10% (minimum) cladding

Head Thickness - 1 in. plus 10% (minimum) cladding

Materials:

Shell and heads - ASTM A-285, grade C

Clad - type 304L stainless steel

Makeup Pump

Type - two stage, turbine

Number - 1

Capacity - 5 gpm (minimum)

Head - 900 ft of H_2O

Motor:

Rating - 10 hp

Type - 440 v, 3θ, 60 cycle

rpm - 3600

Material - type 304 stainless steel

Primary System Piping

Type - rolled plate, butt welded

Wall Thickness - schedule 40

Material - type 304L stainless steel

Insulation - 2 in. of foamglass

4. TRANSFER AND HEAVY-WATER SYSTEMS

Transfer Pump

Type - centrifugal, canned motor

Number - 1

Capacity - 75 gpm at 120 ft of H_2O
150 gpm at 80 ft of H_2O

Design Pressure - 375 psig

Design Temperature - 400°F

Motor:

Rating - 5 hp

Type - 440 v, 3θ, 60 cycle

rpm - 3450

Material - suitable stainless steel

Cleanup Pump

Type - centrifugal, canned motor

Number - 1

Capacity - 5 gpm at 125 ft of H_2O

Design Pressure - 300 psig

Design Temperature - 180°F

Motor:

Rating - 1-1/2 hp

Type - 440 v, 3θ, 60 cycle

rpm - 3450

Material - suitable stainless steel

D_2O Storage Tank

Capacity - 14,500 gal

Outside Diameter - 11 ft

Overall Length - 22 ft 3 in.

Design Pressure - 40 psi at 100°F

Shell Thickness - 0.375 in. plus clad

Clad Thickness - 0.75 in.

Material:

Shell and heads - carbon steel

Clad - type 304L stainless steel

Vacuum Pump

Type - single stage, duplex

Capacity - 131 cfm at 535 rpm

Rating - 10 microns of ultimate pressure

Motor:

Rating - 5 hp

Type - 440 v, 3θ, 60 cycles

rpm - 1800

Heat Exchanger

Type - finned tube

Number - 1

Number of Passes - 4

Flow Rate - 150 gpm

Design Pressure - 400 psi

Tube-Side Fluid - primary coolant

Shell-Side Fluid - forced air

Materials:

Tubes - type 304 stainless steel

Headers - type 304 stainless steel

Fins - aluminum

5. AUXILIARY EQUIPMENT

Water Treatment System

Softener:

Type - sodium zeolite

Capacity/cycle - 35,800 gal

Flow rate (max) - 35

Demineralizer:

Type - mixed bed

Anion resin - Rezex 42

Cation resin - Rezes 5A

Capacity cycle - 10,000 gal

Flow rate (max) - 35 gpm

Deionized Water Storage Tank:

Construction - carbon steel, neoprene-lined

Capacity - 14,000 gal

Sump Pump:

Type - enclosed impeller, vertical turbine

Number - 1

Capacity - 75 gpm

Head - 71 ft of H_2O

Motor:

Rating - 3 hp

Type - 440 v, 3θ, 60 cycle

rpm - 1740

<u>Plant Air Compressor</u>

Type - single stage

Rating - 61.5 scfm at 150 psig

Cooling - water

Motor:

Rating - 20 hp

Type - 440 v, 3θ, 60 cycle

rpm - 1160

<u>Control Rod Air Compressor</u>

Type - 3 stage, 4 cylinder

Rating - 15 scfm at 600 psig

Cooling - air

Motor:

Rating - 7.5 hp

Type - 440 v, 3θ, 60 cycle

rpm - 1160

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APPENDIX B

ENGINEERING CALCULATIONS

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APPENDIX B

ENGINEERING CALCULATIONS

1. HYDRAULICS

Hydraulic experiments and calculations have been performed on some of the core components of the Spert II facility. These include experiments on the type B and BD fuel assemblies and calculations on the type B fuel assembly, fuel-poison control rod, and 1-F filler pieces. A summary of the calculations and experimental data is presented in the following pages.

1.1 Type B Fuel Assembly

Hydraulic calculations have been made on the 24-, 12-, and 8-plate type B fuel assemblies for temperatures of 100, 200, 300, and 400°F and a pressure of 400 psi. The calculated relationships were obtained by using the Fanning friction formula for straight losses and the enlargement or contraction coefficients that are given in the handbooks for acceleration losses. In obtaining these relationships the following assumptions were made:

(1) There was no flow around the outside of the end box extension.

(2) The flow outside of the side plate section was neglected.

(3) The pressure loss in each channel of the fuel assembly was equal.

(4) The width of the fuel channel was the average width.

(5) The relative roughness of the fuel plates was 5×10^{-6} ft.

The results of the calculations are shown in Figure 58.

Experimental flow tests have been conducted on the 24-plate fuel assembly in order to obtain the overall pressure loss vs flow relationship and the channel pressure distribution. The data were obtained in a closed-loop hydraulic facility. The channel static pressure profile was obtained by inserting tubes in each channel with a hole perpendicular to the flow. The overall pressure drop vs flow relationship at 85°F is shown in Figure 58. The normalized channel pressure profile is shown in Figure 59 for a point located 3 in. from the bottom of the fuel plate. In the test, flow was from the bottom to the top of the fuel assembly. The channel static pressure profile is quite flat for the flow rates tested. The flat pressure profile probably is due to the ability of the plates to move slightly in their slots and thus adjust for any large pressure differentials. Because of the square end box, there is little nozzle effect. This would result in a more equal flow distribution at the plate section.

1.2 Type BD Assembly

Hydraulic tests have been conducted on the 22-plate type BD assembly in order to obtain the overall pressure drop vs flow relationship and to obtain the channel flow distribution.

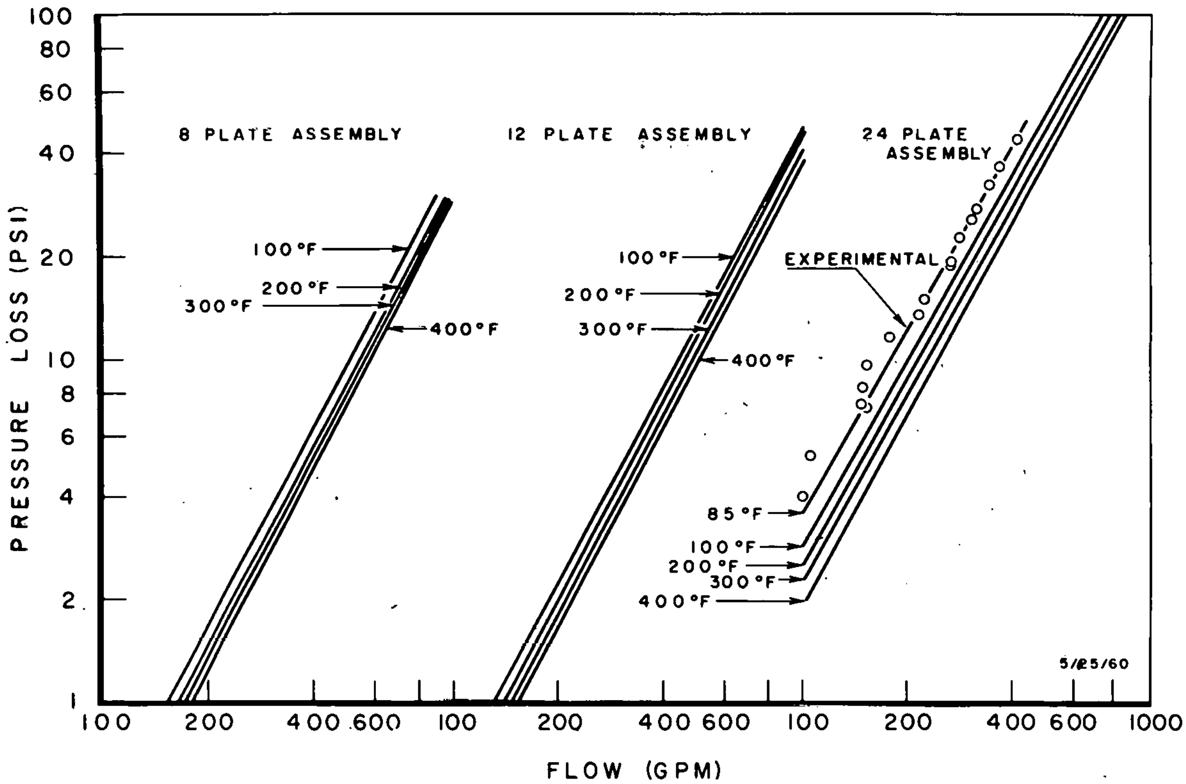

Fig. 58 Flow vs pressure drop - type B assembly.

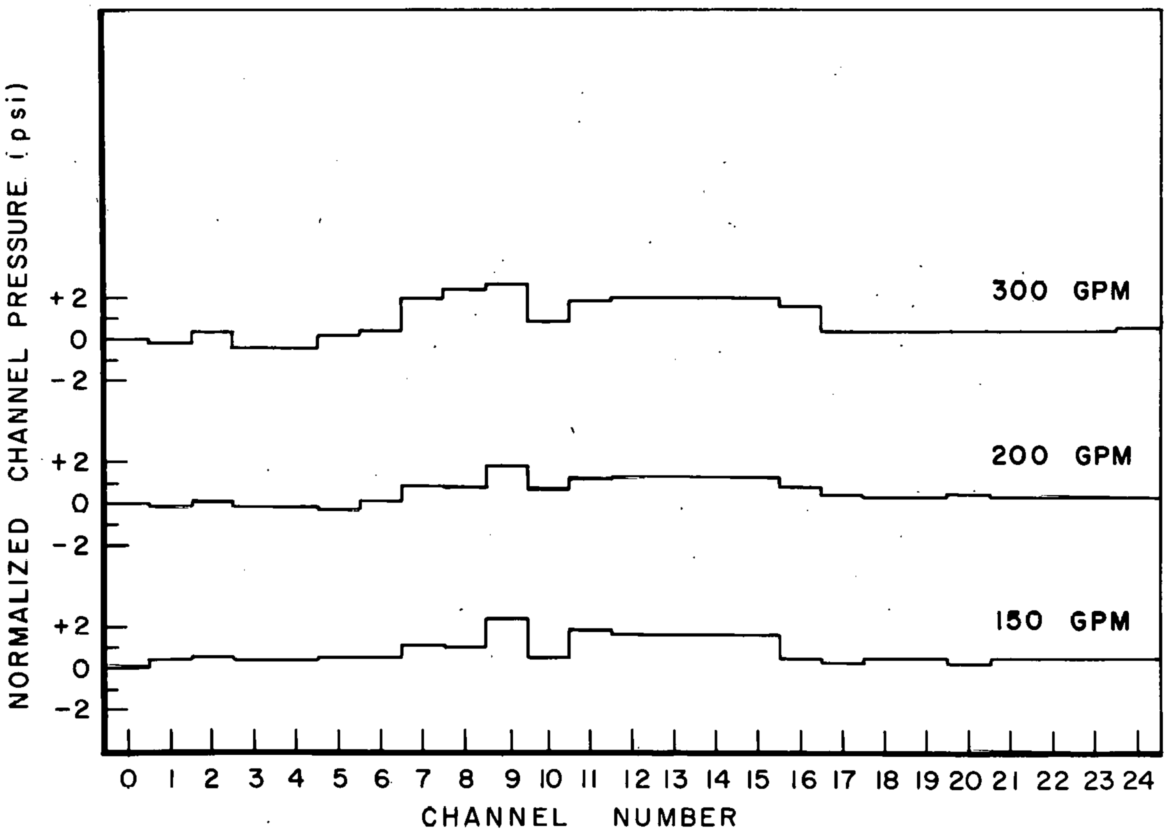

Fig. 59 Channel pressure profile - type B assembly.

The tests were conducted in a closed-loop hydraulic test facility. The channel flow distribution was obtained by measuring the frictional pressure loss at two points in a fuel channel and converting this to velocity by means of the Fanning correlation. In the conversion, it was assumed that the channel width was the average channel width.

The experimental overall pressure loss vs flow relationship is shown in Figure 60 for upflow and downflow at 85°F. The slightly different relationship probably is due to the enlargement and contraction losses for the two geometrics. The channel velocity profile is shown in Figures 61 and 62 for downflow and upflow, respectively. The average velocity in the outside channel is greater than the average velocity in the adjacent channel because the average outside channel width is larger than the average inner channel width (0.085-in. width compared to 0.065 in.), thus offering less resistance to flow.

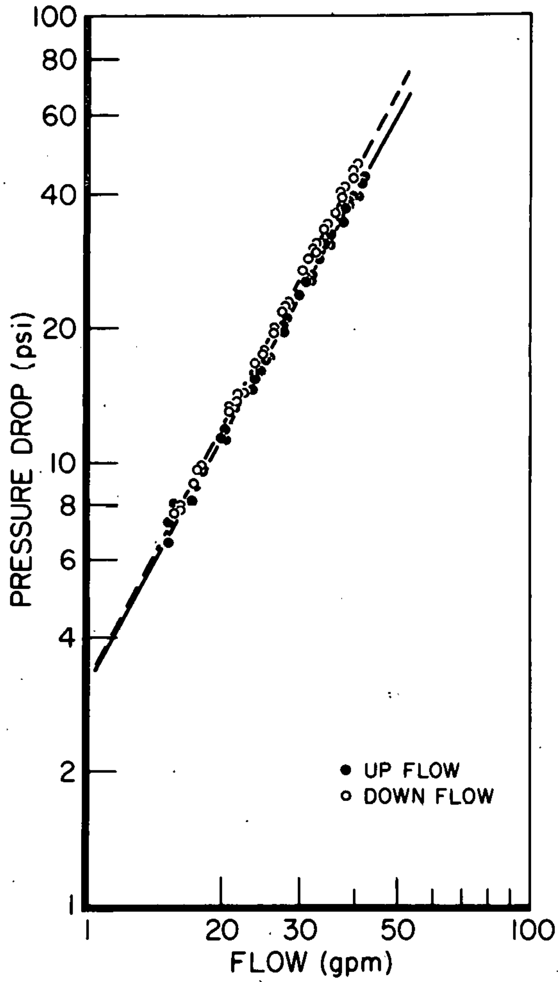

Fig. 60 Flow vs pressure drop - type BD assembly.

1.3 Control Rod

Calculated overall pressure drop vs flow relationships have been obtained for the 5-, 8-, and 17-plate control rods. In obtaining the relationships, the following assumptions were made:

(1) The straight section loss in the guide tube was neglected.

(2) The flow outside the side plate section was neglected.

(3) The pressure loss in each channel of the fuel plate section was equal.

(4) The relative roughness of the fuel plates was 5×10^{-6} ft.

The results of the calculations are shown in Figure 63 for temperatures of 100, 200, 300, and 400°F and a pressure of 400 psi.

1.4 Type 1-F Filler Piece

Hydraulic calculations have been made on the type 1-F filler piece, using the techniques previously outlined. The results of the calculation are shown in Figure 64 for temperatures of 100, 200, 300, and 400°F and a pressure of 400 psi.

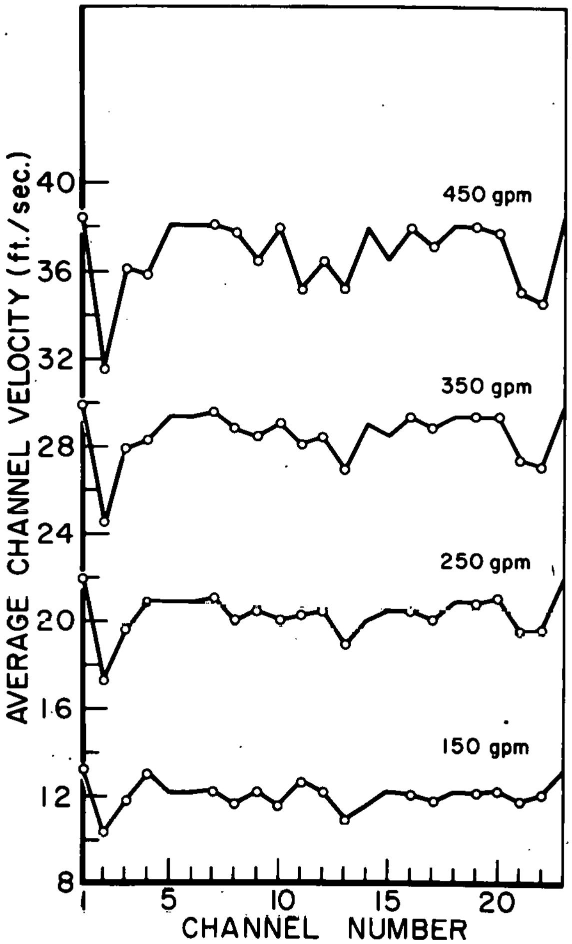

Fig. 61 Channel velocity profile - type BD assembly - downflow.

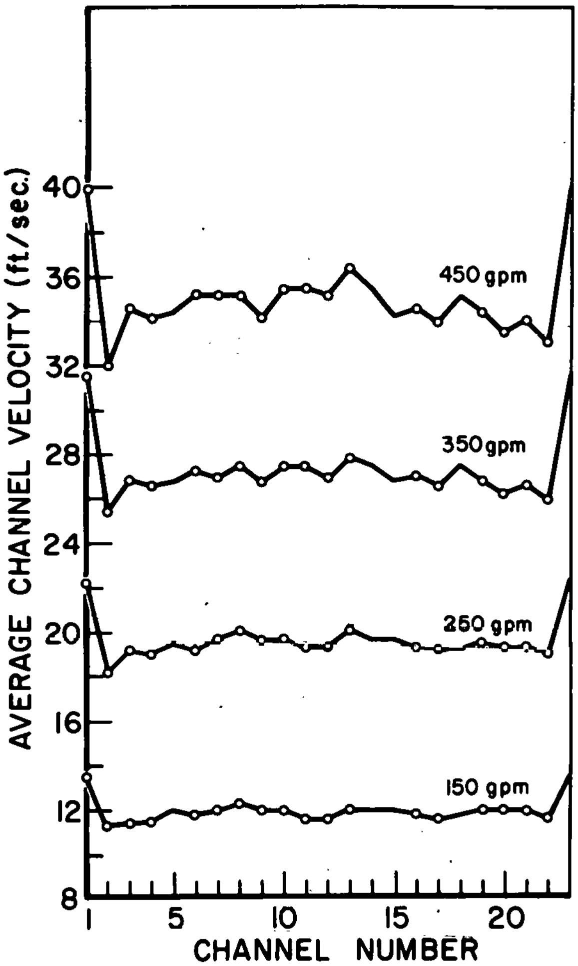

Fig. 62 Channel velocity profile - type BD assembly - upflow.

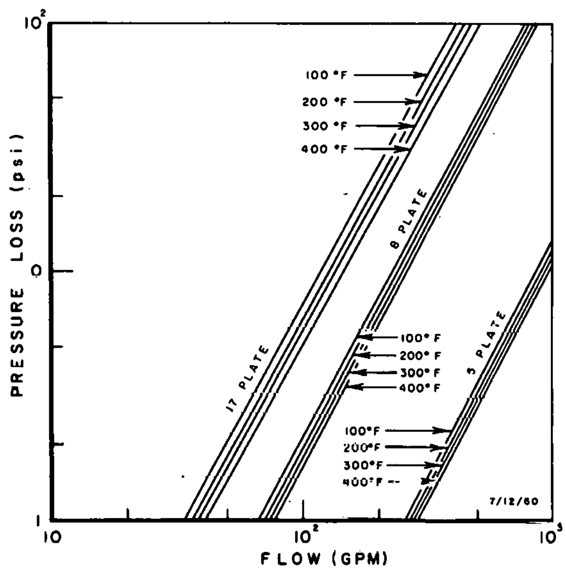

Fig. 63 Flow vs pressure drop - control rod fuel assembly.

2. HEAT TRANSFER

Heat transfer coefficients at various mass flow rates and temperatures have been calculated for the 4-, 8-, 12-, and 24-plate type B fuel assemblies. The calculations were made using the Dittus-Boetter equations. The results are shown in Figure 65.

3. HEATING AND COOLING RATES

Heating and cooling rates for the primary coolant were measured during the Spert II acceptance tests. The results are shown in Figure 66.

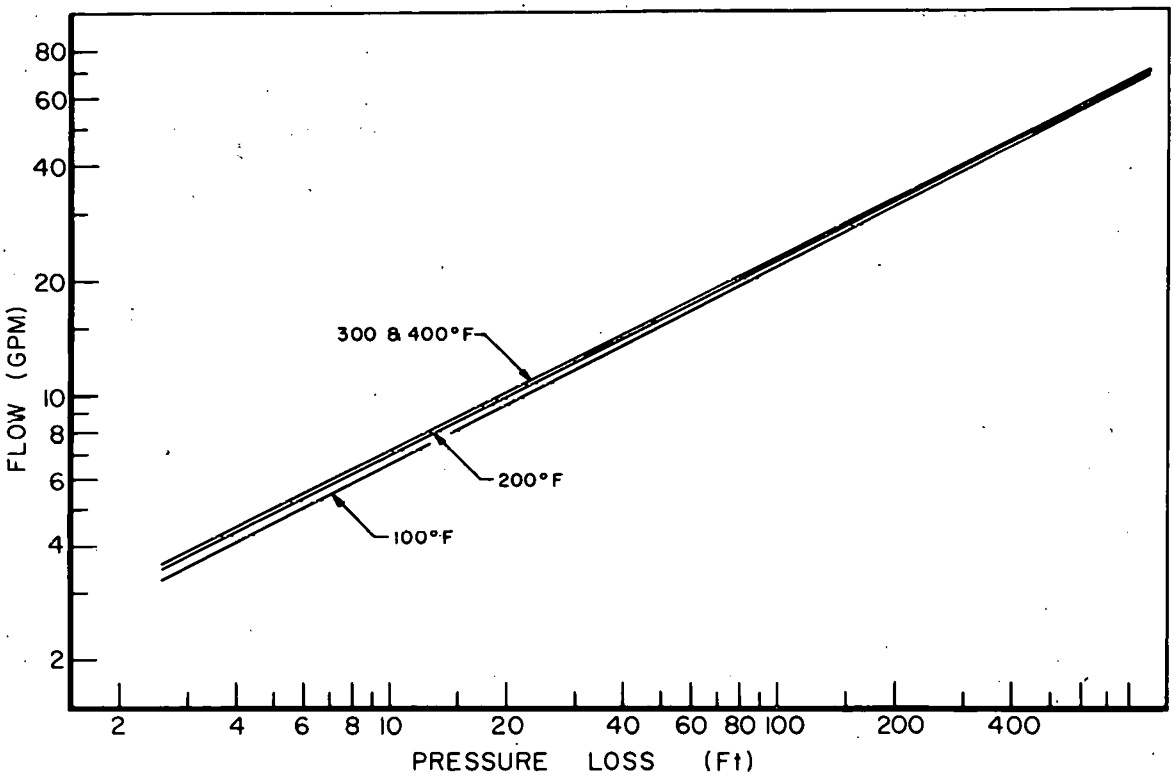

Fig. 64 Flow vs pressure drop - 1-F filler piece.

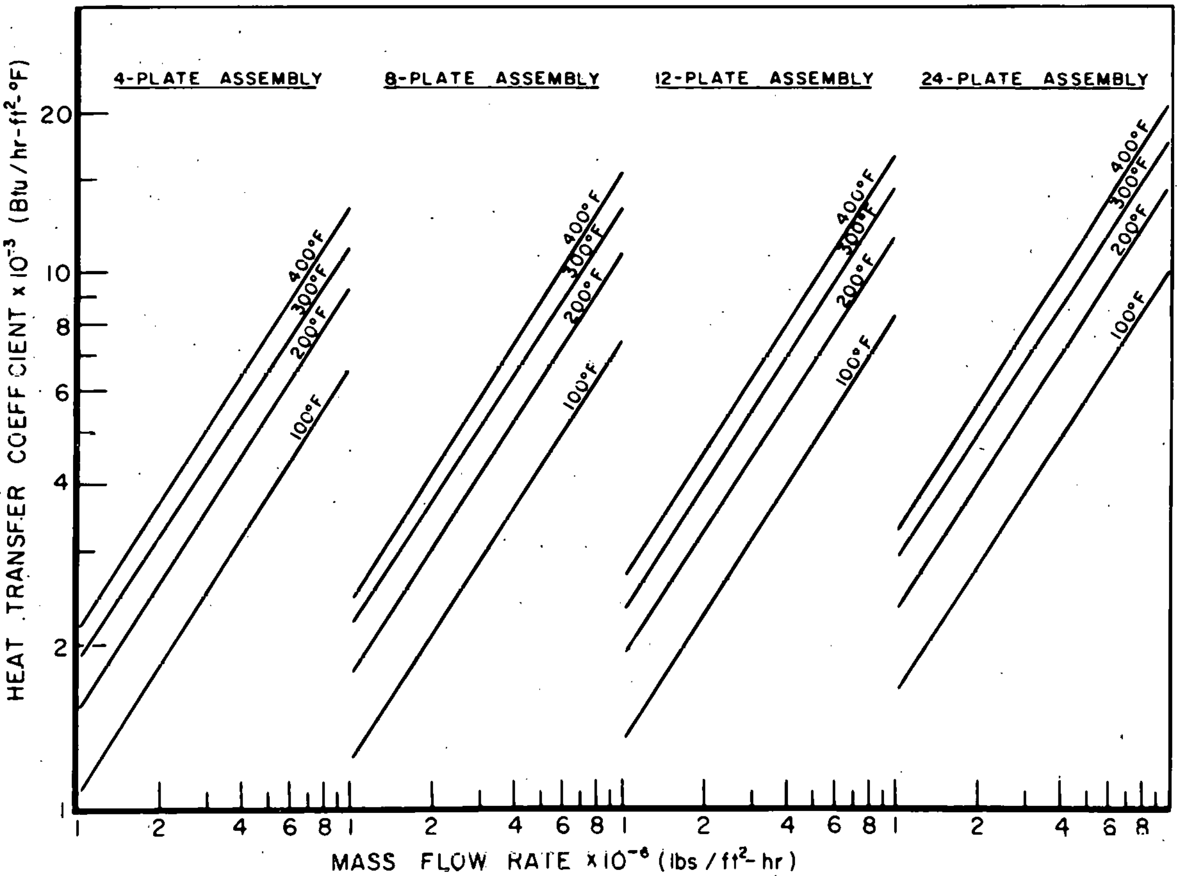

Fig. 65 Calculated heat transfer coefficients for type B core.

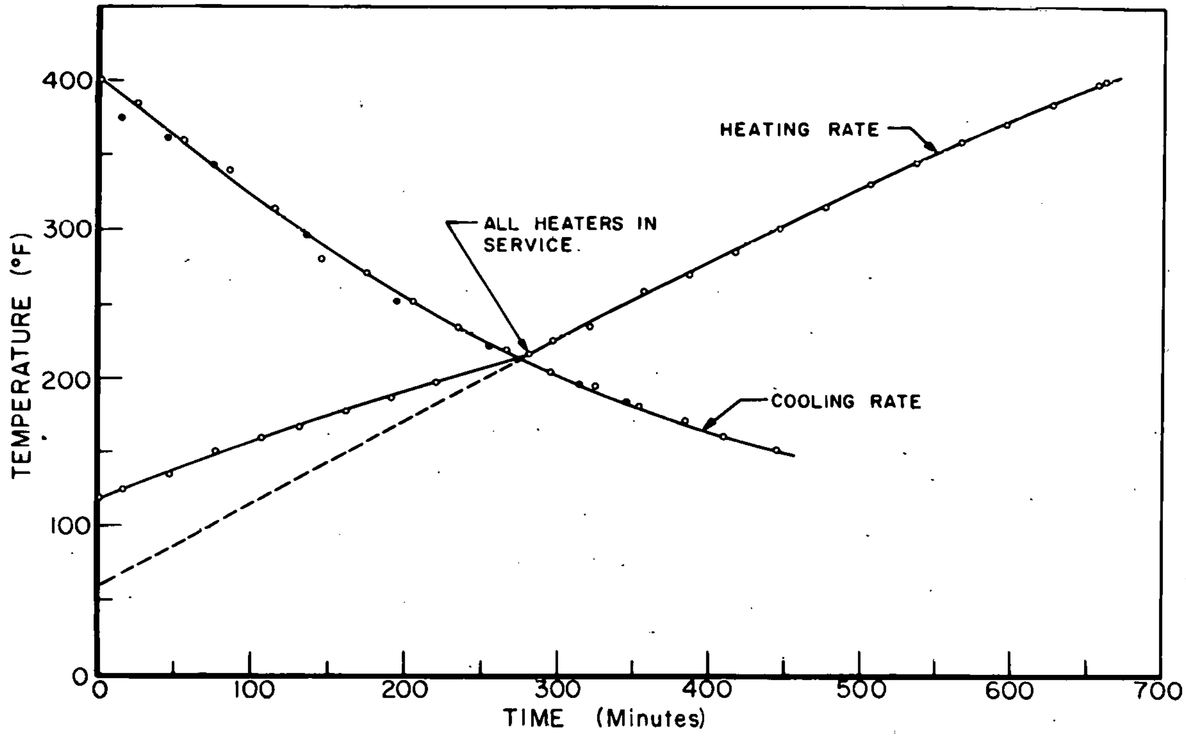

Fig. 66 Heating and cooling rates of primary system.

Eleven hours were required to heat the system from 118 to 400°F. The heating rates were as follows: 22°F per hour at 150°F, 18°F per hour at 200°F, 30°F per hour at 250°F, 31°F per hour at 300°F, 29°F per hour at 350°F, and 25°F per hour at 400°F. The heat rate was slower at the beginning than at end of the test because all of the heaters were not in service until the system reached a temperature of 218°F. Extrapolation of the steep portion of the heating curve (all heaters in service and each primary pump loaded to 105 amp.) indicates that the system could be heated from 60 to 400°F in 11 hr.

During these tests, the cooling loop was in service at all times. Some cooling occurred because of natural circulation through the heat exchanger; therefore, the heating rate probably could be increased by valving out the heat exchanger.

The system was cooled from 400 to 150°F in 7-1/2 hr. The cooling rates at various temperatures were as follows: 47°F per hour at 400°F, 47°F per hour at 350°F, 45°F per hour at 300°F, 39°F per hour at 250°F, 25°F per hour at 200°F, and 16°F per hour at 150°F. It will be noted that the cooling rates at 400, 350, and 300°F are approximately the same. This is due to the cooling rate being limited by the capacity of the makeup pump. In addition, the cooling rate is affected by the outside air conditions.

4. DESIGN CALCULATIONS

4.1 Lower Grid

Stress calculations were made on the following components of the core structure at various temperatures to obtain an allowable pressure drop across the lower grid assembly.

(1) Lower grid ring bolt stress

(2) Lattice screws shearing stress

(3) Lattice spacer bending stress

Spacer 1

Spacer 13

The allowable stresses used for the pressure drop calculations at the various temperatures were taken from the ASME Design Code. This code allows only 80% of the allowable stress to be used when making calculations involving screws, bolts, or rivets. The results of the calculations are shown in Table B-I.

The allowable ΔP calculations for the lattice spacers are ultraconservative; therefore, a higher core ΔP than calculated could actually be used. The limiting factor for the allowable ΔP appears to be the lattice and cross screws. The stress calculations for the screws are straight forward and determine the allowable ΔP for reactor operations at 15 psi.

TABLE B-I

ALLOWABLE CORE PRESSURE DROP

Temperature (-°F)	100	200	300	400
Grid Ring Bolts (Allowable ΔP-psi)	32	29	26	24
Lattice Screws (Allowable ΔP-psi)	20	18	16	15
Lattice Spacer 1 (Allowable ΔP-psi)				
1. [a]	105	99	79	44
2. [b]	35	33	26	15
Lattice Spacer 13 (Allowable ΔP-psi)				
1. [a]	107	101	81	45
2. [b]	35	33	27	15

[a] Assumed spacer ends fixed.
[b] Assumed spacer ends simply supported.

4.2 Control Rod Drives

The Spert II control rod drives are similar to the Spert III drives. The calculations for the Spert III drives were reported previously[8].

4.3 Flow Skirt

Calculations were made to determine the pressure required to damage the flow skirt in the Spert II reactor. The calculations were based on the ASME Unfired Vessel Design Code formula which is as follows:

$$P = \frac{SEt}{R + 0.6t}$$

where:

P = pressure

S = yield stress = 35,000 psi for 6061-T6-Al

E = weld efficiency = 80%

t = wall thickness = 0.5 in.

R = inside radius of skirt = 19.5 in.

The results indicate that the pressure required to damage the flow skirt is of the magnitude of 700 psi. Because of impact conditions, the actual pressure to cause yield could be a factor of 2 to 3 lower than the 700-psi limit.

4.4 Operating Pressure Limits

Pressure calculations were made on the following components of the primary system to determine the maximum operating pressure of the system as allowed by the ASA and ASME codes.

(1) Primary piping

(2) Vessel nozzles

(3) Reactor vessel

(4) Pressurizer

(5) Reactor well

(6) Reactor flanges

The results of these calculations are shown in Table B-II.

The maximum internal service pressure for piping and nozzles was derived by using the American Standard Code for Pressure Piping - ASA B31.1-1955 Section 1 - Power Piping.

The code formula is as follows:

$$P = \frac{2S\ (tm - C)}{D - 2y\ (tm - C)}$$

TABLE B-II

CALCULATED PRESSURE RESULTS

Primary Piping

Pipe Size (in.)	Schedule	Pressure (psi)
6	40	520
8	40	480
12	40	435
14	40	435
16	40	445
24	40	425

Vessel Nozzles

Size (in.)	Schedule	Pressure (psi)
1	160	2680
$1\frac{1}{4}$	160	1875
2	160	2000
$2\frac{1}{2}$	160	1850
3	160	1840
4	80	1000
6	80	920
8	Special	4535
10	Special	3920
12	Special	3000
24	Special	815

Reactor Vessel

Inside Diameter (in.)	Wall Thickness (in.)	Pressure (psi)
120	1.5	410

Pressurizer

Inside Diameter (in.)	Wall Thickness (in.)	Pressure (psi)
34.75	0.625	460

Reactor Well

Inside Diameter (in.)	Wall Thickness (in.)	Pressure (psi)
42	0.625	490

Reactor Flanges

Size Rating (lb)	Pressure (psi)
300	360

where:

P = Maximum internal service pressure in psi

S = Allowable stress for material in psi

tm = Minimum pipe wall thickness in inches

D = Outside diameter of pipe in inches

y = Temperature coefficient

C = Allowable for threadings, mechanical strength and/or corrosion in inches

The allowable material stress used in the pressure calculations was taken from Section VIII - ASME Code - 1959 Edition - Unfired Pressure Vessels for seamless piping and tubes.

The maximum internal service pressure for the vessel, pressurizer, and reactor well was derived by using the ASME Code for Unfired Pressure Vessels - Section VIII - 1956 Edition.

The code formula is as follows:

$$P = \frac{SEt}{R + 0.6\,t}$$

where:

P = Design pressure in psi

S = Allowable stress for material in psi

t = Minimum shell thickness in inches

E = Weld efficiency

R = Inside radius of shell in inches

No pressure calculations were made on the flanges but the flanges were checked against the American Standard Code for Steel Pipe Flanges and Flanged Fittings - ASA B16.5 - 1957 with the 1960 Addenda. The 1960 Addenda to the code gives pressure ratings for stainless steel 304L flanges. The code sets the pressure limit for SS304L - 300 lb flanges at 360 psi when operating at 400°F.

Of the components checked for operating pressure limits, the 300-lb vessel flanges appear to limit the maximum operating pressures to 360 psi at 400°F from code viewpoint.

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