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FUNDAMENTALS IN THE OPERATION OF
NUCLEAR TEST REACTORS

Vol. 5 ADVANCED TEST REACTOR DESIGN AND OPERATION

RELEASED FOR ANNOUNCEMENT

IN NUCLEAR SCIENCE ABSTRACTS

PHILLIPS
PETROLEUM
COMPANY

ATOMIC ENERGY DIVISION

NATIONAL REACTOR TESTING STATION
US ATOMIC ENERGY COMMISSION

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FUNDAMENTALS IN THE OPERATION OF NUCLEAR TEST REACTORS

Vol. 1 Reactor Science and Technology	IDO-16871-1
Vol. 2 Materials Testing Reactor Design and Operation	IDO-16871-2
Vol. 3 Engineering Test Reactor Design and Operation	IDO-16871-3
Vol. 4 Engineering and Design Considerations for In-pile Tests .	IDO-16871-4
Vol. 5 Advanced Test Reactor Design and Operation	IDO-16871-5

This manual and course of study have been prepared under the direction of the MTR-ETR Operations Training and Qualifications Committee appointed in 1959 by R. L. Doan, Manager, Atomic Energy Division, Phillips Petroleum Company:

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Volume 5 is being issued to supply training material for operators of the Advanced Test Reactor, which will be completed in 1966.

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Vol. 5 ADVANCED TEST REACTOR DESIGN AND OPERATION

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VOLUME 5

ADVANCED TEST REACTOR DESIGN AND OPERATION

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CHAPTER I

DESCRIPTION OF THE ADVANCED TEST REACTOR

A. CONCEPTS AND DESIGN CRITERIA

1. Introduction

The Advanced Test Reactor (ATR) is the third in a family of test reactors built by the U. S. Atomic Energy Commission at its National Reactor Testing Station. Its predecessors, the Materials Testing Reactor and the Engineering Test Reactor, are described in FONTR Volumes 2 and 3.

2. Early History

The Atomic Energy Commission, as early as 1956, was interested in advanced test reactors capable of producing fluxes of approximately 1.5×10^{15} thermal neutrons/cm²-sec in experimental positions. Internuclear Co., in March 1958, published a report describing a reactor complex capable of meeting these requirements. This concept used the flux trap principle and suggested seven separate reactors to provide seven experimental positions. This approach was later modified by Internuclear and a two reactor system was suggested.

3. Final Concept

In August 1959, Phillips Petroleum Company was requested by IDAEC to prepare and submit a conceptual design for an Advanced Test Reactor which would provide additional experimental loop irradiation space for the AEC-DRD testing program. The flux requirements in these facilities are listed in Table 1-I.

A two or three reactor approach to the design was taken in the early stages of concept work. As study work progressed, effort was exerted to simplify the system, with consideration being given at one point to two or more independently critical cores in a single pressure vessel. An ingenious four lobe, serpentine fuel core arrangement finally evolved which met all DRD (Division of Reactor Development) program requirements and this was the design concept upon which ATR was constructed.

The design criteria used in development of the final design concept were:

(a) ATR will be a four lobe, multi-flux trap reactor.

(b) The reactor will be capable of operating with controllable power distribution between lobes.

TABLE 1-I

ATR FUEL REQUIREMENTS
(Average Midplane Fluxes)

Test	Fast	Thermal	Fast/Thermal
Type	n/cm ² sec x 10 ⁻¹⁵	n/cm ² sec x 10 ⁻¹⁵	Ratio
1	1.5	0.48	3:1
2	1.0	0.32	3:1
3	1.0	1.0	1:0

(c) Control shall be accomplished in such a manner as to preserve at least a cosine distribution of flux throughout each cycle of operation.

(d) The reactor shall be a generalized test reactor, but must meet Navy Reactor requirements as defined.

(e) The location is assumed to be northwest of the MTR-ETR complex.

The ATR criteria document design summary is given in Table 1-II.

1. Buildings

The overall reactor building covers an area of approximately 200 feet by 200 feet. The substructure extends approximately 60 feet below grade under this area; the superstructure height varies in accordance with functional requirements. In general, the building above grade is of steel frame construction with exterior walls of insulated aluminum fiber glass sandwich panels supported on steel girts with a reinforced masonry base wall 3 feet 4 inches high around the building perimeter. A minor amount of exterior wall is of pumice block construction.

Roof construction consists of steel

B. GENERAL DESCRIPTION OF FACILITIES

TABLE 1-II

ATR DESIGN SUMMARY

Reactor Configuration	Four-Lobe
Length of Reactor Core (ft)	4
Power Level -- nominal (MW)	250
Fuel Region Volume (liters)	262
Fuel Loading (kg U-235)	33
Estimated Operating Cycle (days)	> 17
Power Density (MW/liter)	
Maximum	2.5
Average	0.954
Vertical Power Distribution (maximum to average)	1.40
Radial Power Distribution (maximum to average)	1.87
Fuel Annulus Metal-to-Water Ratio	0.75 to 0.80
Primary Cooling Water	
Flow Rate (gpm)	30,000
Velocity in Fuel Channels (ft/sec)	44
Inlet Temperature (°F)	130
Inlet Pressure (psig)	300
Reactor Δt (°F)	57
Core Pressure Drop (psi)	92

plate decking covered with a vapor barrier, insulation, and built up roofing. Roof sections are sloped and provided with internal drains.

Buildings are designed in accordance with Uniform Building Code requirements for Zone 2 seismic probability and for wind loads between 30 and 40 pounds per square foot, depending upon elevation.

2. Foundations and Substructure

Building substructure is of heavily reinforced concrete construction either resting directly on dense subsurface lava or on concrete piers extending to the lava strata. Wherever possible, concrete shielding walls are used to meet parts of the building structural requirements. Other shielding and partition walls may be of concrete block construction, with some of the shielding walls utilizing high density blocks.

3. Arrangement

The building is divided into two basic types of areas, gastight and non-gastight. Within this basic division further subdivision has been made.

a. Ground Floor -- Reactor Area (Gastight)

The reactor "room" is 88 feet (N-S) by 100 feet (E-W) and occupies the south central portion of the building (see Figure 1-1). It has a floor-to-ceiling height of approximately 57 feet 6 inches and houses the reactor, which straddles the N-S center line of the area and is adjacent to the north wall. This area has been kept as clean and unencumbered as possible to facilitate decontamination and washdown. It is served by two vertical truck doors on the south, a horizontal truck door on the north, several personnel doors, elevators, and a stair well.

b. Ground Floor -- Utility Area (Non-Gastight)

The utility area is 68 feet (N-S) by 105 feet (E-W) and occupies the north-

east portion of the building. It houses the process control room and miscellaneous offices, heating and ventilating equipment and diesel-electric generators. It is served by a vertical truck door to the north and is separated from other areas by fire doors.

c. Ground Floor -- Storage and Laydown Area (Non-Gastight)

The storage and laydown area is 63 feet (N-S) by 95 feet (E-W) and occupies the northwest portion of the building. It contains a tool room and much of its floor area consists of shielding hatch covers which permit access to primary pumps, heat exchangers, and other equipment located at lower elevations. The roof area over the heat exchangers consists of removable panels to permit removal of heat exchangers, if required. The area is served by a vertical truck door to the north and is separated from other areas by fire doors.

d. Ground Floor -- Storage Canal Area (Non-Gastight)

The storage canal area is 44 feet (N-S) by 200 feet (E-W) and is located between the reactor room on the south and the utility area and storage and laydown area on the north. It houses the main storage canal and miscellaneous heating ventilation equipment to the east. It is served by vertical truck doors on the east and west ends to permit straight through truck movement.

e. Ground Floor -- Southeast Area

This area is occupied by the reactor control room, an instrument repair room, the data processing equipment room, two offices, the health physics shift office and issue room, and a mens' shower and locker room. It is 50 feet (E-W) by 88 feet (N-S). It is divided into gastight and non-gastight areas by the east entrance corridor, with areas north of the corridor except for office 101, being of gastight construction.

This area is separated from the

P P Co C-7474

Fig. 1-1 First floor plan.

reactor room by a masonry block wall which is penetrated by several sealed windows to permit viewing the reactor from the control room.

f. Mezzanine -- East Area (Non-Gas-tight)

The mezzanine floor over the areas described immediately above is divided into several offices. Each office on the west side of the mezzanine has a sealed window to permit observation of the reactor and reactor room.

g. Ground Floor -- Mezzanine Southwest Area (Non-Gastight)

This area is 88 feet (N-S) by 50 feet (E-W). The ground floor is occupied by the ATR critical facility, a counting room, and a laboratory. The mezzanine houses offices and heating and ventilating equipment.

h. First Basement (Gastight) See Figure 1-2

The first basement, 19 feet below the first floor, is divided into three main areas. Switchgear, MG sets, and battery banks occupy the NE corner. The NW corner houses reactor process equipment. The remaining area (south of the canal) contains the reactor and experiment cubicles and associated equipment.

i. Second Basement (Gastight) See Figure 1-3

The second basement, 38 feet below the first floor, also is comprised of three main areas. The NE corner houses miscellaneous services equipment. The NW corner houses reactor process equipment, and the south area contains the reactor and its access rooms together with experiment cubicles and associated equipment.

4. Gastight Design

Certain areas in the ATR building, as defined in the preceding section, have

been designed to be "gastight". Low leakage is probably a better term. This feature was made a part of the design with the objective of containing, under controlled conditions, any releases of airborne or gaseous radioactivity from the reactor.

The areas have been created by application of special construction techniques such as seal welding, gasketing, and caulking, and by use of special inflatable seals on sliding doors. The relationship of the ventilation system to this design will be described in a later section.

5. Canals

The main canal in the storage canal area is 156 feet long (E-W), 8 feet wide, and 20 feet deep. It is connected to the reactor working canal to the south, which in turn contains the transfer device which allows underwater movement of radioactive materials from the reactor to the storage canal. Another extension at the west end permits underwater movement of radioactive material into and out of the critical facility canal which is 10 feet wide and extends approximately 50 feet to the south.

All the canal sections are lined with stainless steel sheet and provision is made for insertion of inflatable seal bulkheads in several locations to isolate canal sections.

6. Cranes

Cranes, hoists, and monorails have been provided in all areas where reoccurring hoisting needs could be foreseen. The more important of these are:

(a) Reactor Room Crane, 40 ton, capacity with 10 ton auxiliary hoist. Bridge in NS direction. Lifting ability over the entire reactor room area except for clearances around the perimeter of the room.

(b) Reactor Handling Crane, 2 ton capacity: This crane serves the reactor.

Fig. 1-2 First basement floor plan.

Fig. 1-3 Second basement floor plan.

The bridge is in the EW direction and travel is limited.

(c) Storage Canal Crane, 30 ton capacity: Bridge is in NS direction. Lifting ability over the entire storage canal area except as restricted along north and south walls by ventilating ducts.

(d) Critical Facility Crane, 15 ton capacity: Bridge in EW direction. Complete coverage of area except for normal clearance required.

(e) Utilities Area Crane, 5 ton capacity: Bridge in NS direction. Complete coverage of diesel area except for normal clearance required.

(f) Reactor Jib Crane, 2 ton capacity: Located over the reactor working canal.

7. Outside Facilities

The main exhaust stack, of concrete construction and 250 feet high, is located north and west of the reactor building. It is connected to the main exhaust fans by underground concrete ducting.

The cooling tower and the cooling tower pumphouse are located north of the reactor building, and the main transformers are outside and east of the utilities area.

C. REACTOR VESSEL

The reactor vessel is a single diameter Type 304L stainless steel cylinder with elliptical heads and top- and bottom-head closure plates (see Figure 1-4).

Its important characteristics are given in Table 1-III.

The vessel is a pressurized container for the reactor internals and operating core and provides a part of the cooling water flow path. The top- and bottom-head closure plates have penetrations to accommodate nine in-pile loop pressure

tubes. The bottom-head closure plate has additional penetrations for neck shim and regulating rod drive housings and the center flux trap baffle.

The top head has five large elliptical ports which provide access to the core and internals under normal conditions. Removal of the top head as a unit takes place only under unusual conditions.

In addition to the closure plate penetrations and the access ports, the vessel has numerous other penetrations and nozzles for control and safety rod drives, cooling water, instruments, experiment leads, etc. Table 1-IV summarizes all these penetrations.

D. REACTOR INTERNALS

1. Inlet Flow Baffle

The inlet flow baffle is a 2-inch-thick vertical 304 SS cylindrical shell approximately 10 feet in diameter and 10 feet high. It has a flanged bottom conical transition section which bolts to the flange of the core support tank (see Figure 1-5).

This baffle directs most of the cooling water from the two 24-inch inlets on the bottom head up through the annulus formed by the baffle and the vessel wall and into the upper portion of the vessel over the core. The upper portion of the baffle constitutes the inner thermal shield.

An additional outer thermal shield of 2.5-inch-thick SS is located between the flow baffle and the vessel wall. This outer shield is required for reduction of gamma heat to concrete shielding outside the vessel and is not specifically needed to protect the vessel itself. It is supported from the vessel wall on 12 brackets.

2. Core Support Assembly

The core support assembly is a stacked group of four cylindrical tank sections. As its name implies, it supports

Fig. 1-4 ATR vessel elevation.

and contains the reactor core within the pressure vessel (see Figure 1-6). Its overall height is 14.5 feet and its inside diameter is 50.625 inches.

a. Core Support Tank

The lowest tank in the assembly is called the core support tank (see Figure 1-5). It is 61.5 inches high and its lower flange bolts to the bottom-head closure plate. This tank, of 304 SS, is primarily a structural member supporting other components including the conical section of the inlet flow baffle, nozzles for the bearings which support the horizontal drive shafts for the safety rod drive assemblies, and the flow distribution tank (the next highest of the four tanks).

TABLE 1-III

REACTOR VESSEL CHARACTERISTICS

Outside Diameter	12 ft
Height, overall	35 ft
Material	304SS
Thickness	2 in. to 5 in.
Volume	3250 ft ³
Design Pressure	390 psig
Operating Pressure	355 psig inlet
Design Temperature	240°F
Operating Temperature	125°F inlet
Weight, empty	100 tons

TABLE 1-IV

REACTOR VESSEL NOZZLES AND PENETRATIONS

<u>NOZZLES</u>				
<u>Quantity</u>	<u>Nominal ID (inches)</u>	<u>Purpose</u>	<u>Location in Vessel</u>	
2	23	Coolant inlet	Bottom head, 12 ft below the core	
4	15	Coolant outlet	Shell course, 3.5 ft above the core	
8	6	Safety drive line	Shell course, 9.5 ft below the core	
8	3	Outer shim drive line	Shell course, 1 ft above the core	
4	2	Neck shim drive line	Bottom closure plate	
4	2	Demineralized water inlet	Bottom closure plate	
1	8	Upper overflow	Shell course, 14.5 ft above the core	
1	8	Lower overflow	Shell course, 10 ft above the core	
12	5	Instrument thimbles	Shell course, 13 ft above the core	
<u>PENETRATIONS</u>				
<u>Quantity</u>	<u>Nominal ID (inches)</u>	<u>Purpose</u>	<u>Method of Closure</u>	<u>Location in Vessel</u>
5	20 x 40 elliptical	Refueling port	Bolted cover with gasket	Top head
5	9-3/4	Air purge port	Bolted cover with gasket	In-refueling port cover
9	6	Pressure tube penetration	Packing gland	Top closure plate
9	5-1/2	Pressure tube penetration	Packing gland	Bottom closure plate
4	12	Loop piping	Bolted cover with gasket	Shell course, 14 ft above the core
9	10	Loop piping	Bolted cover with gasket	Shell course, 13 ft above the core
16	3	Capsule instrument leads	Bolted cover with gasket	Shell course, 12 ft above the core
1	16	Drop tube port	Internal cap with gasket	Blister, 1/2 ft above the core

Fig. 1-5 Reactor vessel assembly.

Fig. 1-6 Internal tank assembly.

It contains eight vertical 6-inch-ID sleeves for support and containment of safety rods, and eight 7/8-inch-ID sleeves for N₁₆ monitor tubes. Other openings penetrate the top and bottom flanges to accommodate emergency fire-water inlets and outlets and neck shim drive housings. Figure 1-7 is a view of the upper three quarters of the core support tank.

Fig. 1-7 Core support tank.

b. Flow Distribution Tank

The next tank in the series is called the flow distribution tank (see Figure 1-6). It is 39.5 inches high and is bolted to the top of the core support tank. This tank, also of 304 SS, is a critical component in the alignment of the entire core assembly. It is open at the top but closed at the bottom by the core support plate. This core support plate locates and supports major core components including safety rod guide tubes and flux trap baffles, the center flux trap baffle, and the neck shim rod housing.

The upper portion of the flow distribution tank is divided by four vertical baffles which split total reactor core flow from the four quadrants and direct flow to each of the four internal outlet pipes. A plenum in the lower one foot of the tank collects flow from the flux trap baffles and most of the aluminum capsule facilities and distributes it equally to the four quadrants.

c. Reflector Support Tank

This component can hardly be called a tank since it is only one foot high (see Figure 1-6). It is, however, of extreme importance in locating the beryllium control cylinders and locating and supporting reflector filler blocks. Its lower flange bolts to the flow distribution tank and its upper flange, in addition to bolting to the highest tank in the assembly, projects inwardly to form a flat ring support assembly. This section is fabricated from an aluminum casting and is of a very complex design, as shown by Figure 1-8, a photograph of the top of this

Fig. 1-8 Reflector support tank.

tank. Penetrations receive funnel shaped alignment cups for the reflector blocks and the outer cylinders, as well as providing positioning bushings for capsule cans that will be placed in reflector irradiation facilities.

d. Core-Reflector Tank

The last, or highest, tank in the stack of four is made of aluminum and is 58.25 inches high and open at top and bottom (Figure 1-6). It bolts to the reflector support tank and contains the fuel-reflector core assembly. It helps in support of the beryllium reflector blocks by means of a small internal bottom flange. Its top supports the gear box beams for the cylinder drives. The top of this tank

projects 4 inches above the top of the fuel core to keep the core covered with the water at all times.

4. Outlet Flow Pipes

Four 16-inch-OD SS outlet flow pipes connect the four quadrants of the flow distribution tank to the reactor vessel outlet nozzles (Figure 1-5). Each flow pipe is equipped with a sliding piston ring type expansion point. One inch equalizing lines run from the top of each flow pipe to a location just under the vessel head, serving as siphon breakers.

5. Reactor Core Assembly

a. General Description

The core is the heart of the ATR. In its 4-foot-high by 50-9/16-inch-diameter volume is contained the fuel, beryllium reflector, safety rods, neck shim and regulating rods, outer cylinder shims, and the sections of in-pile pressure tubes occupied by loop experiments. It is built up of carefully fitted parts and its geometry is set by the neck shim rod housing, the flux trap baffles, and the core-reflector tank (see Figure 1-9 which is schematic and not intended to reflect construction accurately).

b. Neck Shim Housing

The neck shim housing (Figure 1-10) is a modified cruciform shape fabricated from an aluminum extrusion. It acts as the center structural member of the core and has been machined and located with a very high degree of precision. In conjunction with the eight flux trap baffles and the beryllium reflector pieces, it defines the dimensions of the serpentine fuel annulus.

It rests upon the core support plate, engaging a stub tube which projects upward from the upper surface of the core support plate. The four inner flux trap baffles which are located by support stubs from the core support plate are keyed and locked to the ends of the arms of the neck shim cruciform.

In addition to its support and locating function, the neck shim housing is drilled (six holes per arm) to accommodate neck shim and regulating rods. It accommodates the center flux trap baffle, and it is also drilled to receive small radiation surveillance specimens.

c. Center Flux Trap Baffle

The center flux trap baffle is a long, aluminum tube which passes through the center of the neck shim housing, the core support plate, and the reactor bottom head. It is supported from the bottom head by tabs projecting from the surface of the baffle tube and is keyed to the neck shim housing at the top. The upper, in-core, section has a heavy wall which is drilled to receive filler pieces, and a portion of the nitrogen sixteen sample assemblies.

d. Inner and Outer Flux Trap Baffles

These eight vertical tubes, 5-7/8-inch OD by 5-1/4-inch ID, support and locate the fuel elements and provide the boundary for the flux traps in which are installed the in-pile experiment pressure tubes and, in specified locations, the safety rods. They are seated inside support tubes mounted on the core support plate and extend upward to a point approximately 17 inches above the core active fuel region. The outer baffles receive their top support from the outer shim cylinder gear box support beams; the inner baffles are keyed and locked to the neck shim housing. All eight baffles are slotted at the top and near the bottom to receive and support the fuel elements (Figure 1-9).

e. Beryllium Reflector

The reactor core is completed by 16 movable beryllium control cylinders (see Section E-2), 8 fixed beryllium core reflector blocks, and the fuel elements. The fixed reflector blocks are supported at the bottom by the reflector support tank and positioned laterally at the top by the outer shim cylinder gear box support beams by means of alignment cups. (Figures 1-11

Fig. 1-9 Core-reflector assembly

Fig. 1-10 Neck shim housing.

Fig. 1-11 Reflector blocks.

and 1-12 show construction of individual blocks and their assembly in the tank.)

6. Gearbox Support Beams

Although designed primarily to support portions of the outer cylinder drive mechanisms, the gearbox support beams have other functions important to the ATR core assembly. They provide support for the outer flux trap baffles through a latch mechanism and, therefore, are an important element in core alignment. These support beams are illustrated in Figure 1-13 which shows the support clips for the flux trap baffles.

7. Fuel Elements

The ATR serpentine fuel annulus requires a circular sector fuel element. Each element consists of 19 parallel curved fuel plates attached to two side plates to form a 45 degree sector of a right circular cylinder (see Figures 1-14 and 1-15). Forty of these elements complete the core loadings.

Each fuel plate has an active fueled

length of 48 inches. Plate thickness is varied at the two outermost plates to withstand large pressure differentials at these two locations. Side plates are slotted at intervals to reduce lateral pressure differentials.

The element end fittings are designed for supporting and positioning the fuel element on the flux trap baffles. The upper fittings also provide a lifting bail to permit handling into and out of the core.

E. CONTROL AND SAFETY RODS AND DRIVE SYSTEMS

1. General

The ATR is equipped with three separate systems of movable control: the safety rods and drives, the neck shim rods and drives (including two rods and drives used for fine servo control), and the outer shim cylinders and drives. Nuclear characteristics of the control rods are given elsewhere; this section pertains to the

Fig. 1-12 Reflector blocks.

mechanics of their design, installation, and operation.

2. Outer Cylinder Shims and Drives

The outer shim control element is a beryllium cylinder 7-1/4 inches in diameter and 46-13/16 inches long which has hafnium poison plate sections covering 120° of its surface (see Figure 1-16). Sixteen such cylinders, arranged in eight pairs, are fitted into the fixed beryllium reflector blocks described in Section D-5-e of this chapter. The operating characteristics of these elements and drives are shown in Table 1-V.

The hafnium in the cylinder is in the form of six replaceable inserts and the drum is drilled with multiple vertical holes to allow flow of cooling water. Details of the fabrication and assembly of this cylinder are shown in Figures 1-17, -18, and -19.

Each drum has aluminum end plates and an aluminum shaft through its center. The upper end plate is bolted to a connector column at the bottom of the internal drive gearbox. The lower end "floats" but will drop into a smooth bearing surface should the upper connection fail. The construction prevents the drum from

Fig. 1-13 Support beams.

turning in a more reactive direction in the event of connector failure.

Each pair of cylinders is driven by one outer shim drive mechanism consisting of an internal worm gearbox, a horizontal drive shaft, a shaft housing assembly, and an external motor drive assembly. The horizontal shafts are equipped with water flushed mechanical seals (see Figure 1-20).

The drive mechanisms were designed, developed, and prototype tested by the Bendix Corporation. For additional details, the Bendix Design Manual and Report, and drawings on file at the ATR should be consulted.

3. Neck Shim and Regulating Rods and Drives

Both the neck shims and the regulating rods are fluted hafnium rods drilled with a center hole for passage of cooling water. They are 0.384 inch in their largest diameter and approximately 48 inches long and 54 inches long, respectively. All the neck shims have aluminum follower sections and the regulating rods have Iconel drive rod extensions (see Figure 1-21).

Of the 24 locations in the neck shim housing, 22 are used for shim rods and 2 by regulating rods. It is possible

Fig. 1-14 Fuel element details.

Fig. 1-15 Fuel element assembly and details.

to convert 2 additional rods to regulating rod service if necessary. All of the neck shim housing holes are provided with liners (aluminum). The neck shim rods operate within aluminum guide tubes and the regulating rods have similar Iconel guide tubes. These guide tubes pass through the reactor bottom head and extend into the neck shim rod access room, which contains the drive motors and mechanisms, and which is also the lowest point in the ATR building.

The 20 neck shim rods are driven by Teleflex cables which are, in essence, flexible jack screws driven by a small electric motor through a worm gear. These drive cables do not rotate, but exert a push-pull motion within guide tubes which prevent them from buckling in compression (see Figure 1-22).

The regulating rods are connected to their drive motor by a straight through, rigid Iconel drive rod. These rods operate through a labyrinth seal at the reactor bottom head, whereas the shim

rod cable guide tube and worm gear housing are under direct reactor operating pressure. The drive motor for the regulating rods is larger than those supplied for the neck shims and is under servo control.

The general characteristics of the neck shims and regulating rods and drives are listed in Table 1-VI.

The drive mechanisms were designed, developed, and prototype tested by the United Shoe Machinery Company. For additional details the USM Design Manual and Report, and drawings on file at the ATR should be consulted.

4. Safety Rods and Drives

The ATR safety rod is a vertically moving tubular assembly which operates within the annulus formed by the outer surface of the loop pressure tube insulation can and the inner surface of the flux trap baffle (see Figure 1-23). The assembly is comprised of an aluminum guide tube, 7 feet long, which is the structural member which guides and supports the:

(a) Poison inserts, which are four, 80° sections of hafnium 36 inches long and 1/4 inch thick and are latched to the upper section of the guide tube.

(b) Flux trap fillers, which are aluminum inserts (other material may be used) installed in guide tube slots directly below the poison inserts.

(c) Flux wire assemblies, which are inserted in small holes in the guide tube walls and which serve as lock pins in the poison plate latching assembly.

Connected to the bottom of the guide tube is a drive tube assembly driven by a rack and pinion linkage to an electric motor drive located outside the reactor vessel. A hydraulic snubber is provided below the rack tube to decelerate the safety rod assembly as it

Fig. 1-16 Outer cylinder shim.

TABLE 1-V

OUTER CYLINDER SHIM CONTROL
ELEMENT AND DRIVE CHARACTERISTICS

Beryllium Drum Diameter	7-1/4 in.
Beryllium Drum Length	46-13/16 in.
Hafnium Length	46 in.
Total Available Travel	160°
Rate of Travel -- degrees/min	20°/min
Time for Full Withdrawal	8 min

Fig. 1-17 Outer cylinder shim details.

Fig. 1-18 Outer cylinder shim details.

Fig. 1-19 Outer cylinder shim details.

Fig. 1-20 Outer shim control drive mechanism.

Fig. 1-21 Neck shim rod.

nears the end of its travel following a scram.

Five safety rods and drives are provided in five different flux trap locations.

The safety rod drive is comprised of a drive motor; gearbox; electro-magnetic clutch; accelerating spring assembly, which is coupled to the horizontal drive shaft through a ball screw assembly; the horizontal drive shaft, which passes through a nozzle in the vessel wall equipped with a mechanical face seal and which is supported internally by a water cooled bearing supported in the core support tank; and the rack and pinion gear set (Figure 1-24).

The general characteristics of the safety rods and drives are listed in Table 1-VII.

The drive mechanisms were designed, developed, and prototype tested by American Machine and Foundry. For additional details, the AMF Design Manual and Report, and drawings on file at the ATR, should be consulted.

F. INSTRUMENT THIMBLES AND CHAMBER DRIVES

Immediately outside the core-reflector tank are located twelve instrument thimbles (Figure 1-25). These thimbles are curved sections of 5-inch-ID stainless steel pipe closed at the bottom end and penetrating the reactor vessel wall at their upper end. The upper end terminates in the vessel nozzle trench at which point the drive mechanisms are installed.

Ten thimbles extend to the bottom of the reflector support tank and are clamped to the wall of this tank. Two thimbles are shorter, ending about 1-1/2 feet above the core and are clamped to adjoining thimbles. One of these two short thimbles accommodates the control system galvanometer ion chamber, the other

NOTES

- 1 FOR INSTALLATION INSTRUCTIONS SEE ATR NECK CONTROL ROD DRIVE MECHANISM TECHNICAL MANUAL
- 2 FOR PLAN VIEW SEE REF DWG NO 6
- 3 THE INFORMATION PRESENTED ON THIS DRAWING FORMS A PART OF SPECIFICATION NO M 161 OF CONTRACT NO AT(10 1)1075

Fig. 1-22 Neck shim rod drive.

TABLE 1-VI
NECK SHIM AND REGULATING ROD CONTROL
ELEMENT AND DRIVE CHARACTERISTICS

	Neck Shim	Regulating Rod
Hafnium Rod Length	48 in.	54 in.
Hafnium Rod Diameter (flutes)	0.384 in.	0.384 in.
Length of Travel	48 in.	48 in.
Direction of Travel for Withdrawal	Up	Down
Rate of Travel	6 in./min	50 ft/sec
Drive HP	1/20	1.0
Time for Full Withdrawal	8 min	---

is a spare. The ten long thimbles contain ion chambers for the neutron level, start level, servo, and Log-N Period channels.

All of the thimbles are equipped for dry gas purging and contain a stainless steel and polyethylene shield plug to prevent radiation streaming.

The ion chambers are mounted on wheeled carriages which are moved into and out of the thimbles by means of an aluminum support -- coaxial transmission cable fabricated as a unit. This cable is wound onto drums in the nozzle trench as chambers are raised. Drums for the fission chamber cables are motor driven, and provision has been made to convert all drums to motor drives.

G. EXPERIMENTAL FACILITIES

1. Pressure Tube Facilities

ATR was designed primarily to accommodate dynamic or loop-type experiments in high flux positions. Details of design, fabrication, and operation of loop experiments will be found in Volume 4

FONTR. This section pertains only to provisions made to receive the in-tank or in-pile hardware.

Each of the nine flux trap positions (Figure 1-26) is designed to receive an in-pile pressure tube. The alignment of penetrations in the top- and bottom-head closure plates and the centers of the circles circumscribed by the flux trap baffles have been set with a high degree of precision. Pressure tubes as installed in these nine locations will penetrate both heads through O-ring or Packed seals. Inlet and outlet lines are located in the subpile room. In five of the nine locations the in-pile tubes will be surrounded by safety rods assemblies. In in-pile tube locations where safety rods are not installed, a dummy flux trap filler must be installed to restrict water flow. In flux traps containing neither in-pile tubes nor safety rods, a dummy in-pile tube as well as a dummy flux trap filler is installed.

In addition to the high flux lobe positions other facilities which might be used for loop experiments have been provided by penetrations in the beryllium reflector blocks. Four 5-inch-diameter and sixteen 3.25-inch-diameter holes of

Fig. 1-23 Safety rod assembly.

Fig. 1-24 Safety rod drive mechanism.

TABLE 1-VII

SAFETY ROD AND
DRIVE CHARACTERISTICS

Hafnium Poison Section Length	36 in.
Follower Length (Flux Trap Filler)	48 in.
Total Travel	36 in.
Withdrawal Rate -- 4 rods	4.5 in./min
Withdrawal Rate -- 1 rod	9 in./min
Direction of Travel for Withdrawal	Up
Time for Full Withdrawal -- 4 rods	8 min
Time for Full Withdrawal -- 1 rod	4 min
Scram Insertion Rate	138 msec [a]

[a] For first twelve inches of travel.

this nature have been provided (Figure 1-26).

2. Capsule Facilities

The penetrations in the beryllium reflector described above, although potentially usable for specially designed loop experiments, were provided primarily for irradiation of capsule type experiments, either instrumented or uninstrumented. When not in use the holes will be plugged with removable beryllium filler pieces.

Additional irradiation facilities are provided outside the core reflector tank by means of capsule irradiation "tanks" attached to the outside of the core reflector tank. The north tank is comprised of a 2 x 5 array of irradiation positions; the south tank is a 4 x 5 array. These positions are occupied by aluminum filler pieces drilled to accommodate capsules of various sizes. The construction of these "tanks" is shown in Figures 1-27 and -28.

H. VESSEL ACCESSORIES

1. Drop Tube

Radioactive material, including spent fuel, is discharged from the reactor vessel

through a penetration in the wall to the working canal through a drop tube. The vessel penetration is 16 inches in diameter and is located in a "blister" which provides the approach angle necessary to discharge relatively large items such as fuel elements (see Figure 1-4). During operation this penetration is closed with the drop tube cover. The cover utilizes a double O-ring seal and is held in place by cam-lock lugs designed to be easily unlatched with remote handling tools. A special internal rack is provided to store the cover when the drop tube is in use.

A discharge mechanism in the working canal, which is an aluminum tube pivoted at its lower end, mates at its upper end with the vessel drop tube penetration. This tube receives inserts at its upper end which contain material being discharged. The tube, after loading, is pivoted with a hydraulic piston to a vertical position in the canal for removal of the discharged material.

2. Internal Fuel Storage Racks

Two fuel storage racks, each with a 12 element capacity, are located inside the reactor vessel for interim storage of fuel elements (see Figure 1-26). The racks will accommodate either fresh or irradiated fuel during an operating cycle. Coolant flow through the fuel is by natural thermal circulation since the rackframes are stainless steel plate boxes, open at the top end only. A poison insert consisting of an aluminum clad cadmium plate must be inserted in each fuel basket before fuel may be stored.

3. Protective Covers

A horizontal plane in the annulus between the core-reflector tank and the reactor vessel is covered by stainless steel expanded metal screen and segmented aluminum cover plates to keep foreign objects inadvertently dropped from sinking to the bottom and being lost. The aluminum plate covers are provided with six hinged six-inch "flow hats" to permit limited water flow and access below

Fig. 1-25 Instrument thimble locations.

① BERYLLIUM REFLECTOR BLOCK	⑭ FUEL STORAGE RACK
② PRESSURE TUBE ASSEMBLY	⑮ CORE-REFLECTOR TANK
③ FUEL ELEMENT	⑯ OUTER SHIM CONTROL CYLINDER
④ OUTER SHIM DRIVE SHAFT	⑰ INLET FLOW BAFFLE ASSEMBLY
⑤ REACTOR VESSEL	⑱ N 16 SAMPLE TUBE
⑥ THERMAL SHIELD	⑲ GEAR BOX SUPPORT BEAM
⑦ INSTRUMENT THIMBLE	⑳ OUTER CAPSULE IRRADIATION FACILITY
⑧ NECK SHIM ROD HOUSING	㉑ SAFETY ROD
⑨ INNER CAPSULE IRRADIATION FACILITY	㉒ DROP TUBE
⑩ PRESSURE TUBE LOCATOR TIES	㉓ REFUELING PORT RP 1
⑪ OUTER SHIM GEAR BOX	㉔ REFUELING PORT RP 2
⑫ OUTLET FLOW PIPE	㉕ REFUELING PORT RP-3
⑬ OUTER FLUX TRAP BAFFLE
HOLD DOWN LATCH	㉖ REFUELING PORT RP 4
	㉗ REFUELING PORT RP 5

Fig. 1-26 Vessel internals plan.

Fig. 1-27 South capsule facility.

Fig. 1-28 North capsule facility.

without removing entire cover plate sections.

4. Internal Support Bars

Twenty-three vertical slotted 4- x

4-inch "T" bars are welded to the vessel wall to provide anchor points for clamps which will be required to support pressure tubes and lead experiments (see Figure 1-4).

CHAPTER II

REACTOR CONTROL COMPONENTS AND INSTRUMENTATION

A. CONTROL PHILOSOPHY

Control methods and philosophy adopted for the design of the ATR instrumentation are based on providing a high-integrity system capable of controlling the facility in a safe manner for all required modes of operation. The several unique design features of the ATR to improve experiment performance also influence the instrumentation design. These features include the following:

- (1) Flux trapping to peak the thermal flux in the experiment area and also isolate the experiment from thermal flux variation (burnup) in the fuel region
- (2) Undisturbed axial flux distribution caused by control rod motion during a cycle
- (3) Lobe power shift and control capability during a cycle
- (4) Large fraction of core neutrons obtained from the reflector.

The ATR control system can be naturally divided into two parts: (a) nuclear instrumentation and (b) process instrumentation. Each part is independent except for reactivity feedback effects of coolant temperature and reactor kinetics.

The controlled parameters are monitored by multiple instrumentation channels or by backup devices which have a known relationship to each other. All corrective and safety actions can be initiated by any single parameter since coincident circuitry is not used in the ATR.

The control system also provides graded corrective actions to reduce the frequency of scram action.

The normal operating range of the reactor is approximately 10 decades above source strength; therefore, it is not practical for one instrument to adequately cover the entire span. To meet this situation, the neutron flux range is divided into three parts: the source or start-up range, the intermediate or Log N period range, and the neutron level or power range. Each range covers a specific portion of the entire neutron flux span with positive overlapping of at least one decade between successive ranges.

B. REACTOR CONTROL COMPONENTS

1. Control Rods

Because the ATR reactor must have the capability of shifting flux levels within its core, it has been designed to contain a much greater variety of control rods than other test reactors. There are facilities for 48 control mechanisms: 8 safety rods, 24 neck shim rods, and 16 outer cylinders. Each of these control mechanisms are capable of being remotely positioned within the core.

a. Safety Rods

Each safety rod is a vertically moving tubular assembly which surrounds one of the experiment in-pile tubes in an inner or outer lobe position.

Provision is made for installing safety rods and drives in any of the flux trap positions except the center position. However, the physical dimensions of the in-pile portion of certain loop experiments, eg, the gas-cooled loop, prevent installation or operation of safety rods in all flux trap positions. A minimum of five operating safety rods must be installed and available to provide the reactor safety

scram requirements. These five positions are the SE, S, SW, NW, and N lobes for the initial start-up.

An aluminum guide tube seven (7) feet long supports the vertical components. Four (4), 80-degree segments of curved hafnium plates 1/4 inch thick and 36 inches long serve as poison inserts and are located immediately above the flux trap fillers near the top of the guide tube. Four aluminum flux trap filler inserts of variable sizes are installed in the guide tube slots below the poison inserts to provide a wide range of aluminum-to-water ratios in the flux trap annulus. Four flux wire assemblies inserted in four (4) small holes in the guide tube wall serve as lock pins in the hafnium insert latch arms. A rack tube mounted at the bottom of the guide tube engages a horizontal drive shaft pinion gear.

During reactor operation, 33 inches of the poison insert will be above the core allowing the flux trap filler to fill all but the upper 3 inches of the flux trap. By having three inches of poison in the core at all times, the initial poison effect upon a scram is greatly increased.

The safety rod assembly is driven from below the core by the rack tube and horizontal pinion shaft which extends through the side wall of the reactor to an external drive package. The drive package consists of a gear motor, scram spring assembly, and electromagnetic clutch assembly. The gear motor is the only component that is not mounted on the horizontal drive shaft and is the only component that does not move when the rod is scrambled.

A ball nut and helical spring assembly is coupled directly to the drive shaft to provide an energy supply for scram assistance. The spring has an initial static load of 1600 pounds with the rod in the full-in position. The spring is compressed by the drive shaft and ball nut to 2000 pounds during the last 12 inches of withdrawal. The resulting

torque is always in the direction of rod insertion.

The electromagnetic clutch discs are mechanically secured to the horizontal drive shaft, and the magnet armature is fastened to the gear motor and gear motor gear wheels. When the electromagnet is energized, the discs and armature are held together so that the gear motor is coupled to the horizontal drive shaft. On a scram signal, the horizontal drive shaft is uncoupled from the drive motor by the electromagnetic clutch, and the safety rod assembly is driven into the core by the combined forces of gravity, the scram spring (first 12 inches), and downward coolant flow. A hydraulic snubber section is provided below the rack tube to decelerate the safety rod assembly during the final 24 inches of its travel.

Normal rod withdrawal rate is 4.5 inches per minute; one of the rods, designated a fast recovery scram rod, has a double-speed drive (9 inches per minute) and is located in the south flux trap position.

Continuous position indication is provided by a position transmitter coupled directly to the drive shaft. Electric limit switches are used for full-up and full-down indication and control interlocks. A positive mechanical stop in the safety rod drive package prevents accidental upward overtravel. Engagement of the mechanical stop actuates a torque-limiter device on the gear motor thus stopping power to the motor. In the event of failure of both the limit switches and torque-limiter device, protection is provided by slippage of the electromagnetic clutch. An independent backup indication of the full-in rod position is provided by a hermetically sealed, proximity-type indicator (seat switch) located in the snubber section of the safety rod assembly. A dormant spare proximity switch is provided in each snubber section.

b. Neck Shim Control Rods

There are four groups of neck control rods. Each group contains six

cylindrical hafnium rods arranged in a row, radiating outwards from the core center line forming a pattern with a cruciform cross section. In each group the fourth rod outward from the core center line is a regulating control rod; the remaining five rods are shim control rods.

The neck shim control rods are composed of a fluted hafnium poison section, 48 inches long by 7/16 inches diameter; an aluminum follower, 48 inches long by 5/16 inches diameter; and a flexible drive cable, which acts as a gear rack by virtue of an outer helical wire wrap. The cables are engaged by drive wheels or pinions having special teeth hobbled to fit the cable and are driven by constant speed motors at a rate of 6 in./min. Each drive assembly is equipped with a lower and upper limit switch which opens a contact in the reactor control circuit to stop the drive motor at 0 and 48 inches of withdrawal, respectively, and a decittrak position indicator which sends a position signal to a digital display readout at the reactor control console. Neck shim rod withdrawal is accomplished by driving the rod upward out of the core.

The neck regulating control rods are composed of a fluted hafnium poison, 54 inches long by 7/16 inch in diameter, and a rigid drive rod or rack. The pinion drive gear can either be driven by a constant speed gear motor (regulating rod shim drive) or a variable speed motor, using an amplidyne generator (regulating rod servo drive). Normally two will be driven by regulating rod shim drives and two by regulating rod servo drives. The constant speed motors drive at a rate of 6 in./min. The variable-speed servo motor drive at a rate of 5 in./sec to 50 in./sec with an acceleration rate of 5 to 45 in./sec in 0.4 sec.

Each regulating rod drive assembly is equipped with a position indicator and with switch contacts at the following withdrawal positions: 0, 6, 8, 12, 16, 42, and 48 inches for use in servo operation.

The position indicators on the regulating rods with shim drives are identical to those on neck shim rods described above. The regulating rods with servo drives have standard synchro-type position indicators which send a position signal to a dial indicator at the reactor control console.

Regulating rod withdrawal is accomplished by driving the rod downward out of the core.

c. Outer Shim Control Cylinder

There are 16 outer shim control cylinders driven by eight drive motors. The cylinders are located in the Be blocks around the periphery of the fuel annulus.

The outer shim control assembly is made up of a drive motor, drive and coupling shaft, worm gear box assembly, gear box support beam, Be cylinder, hafnium absorber, and Be aligning cup. The drive motor drives a pair of cylinders through one drive and coupling shaft. The drive motor has an output of 2.19 rpm. The worm gear box assembly reduces the 2.19 rpm output of the motor to the cylinder rotation of 0.055 rpm (20° rotation per minute).

Through the worm gears, which are mounted in and supported by the gear box support beam, the output of one coupling shaft is transferred to a pair of outer shim control cylinders.

The control cylinder is a 7-1/4-inch-diameter Be cylinder with a 138° milled slot. In the slot fit six hafnium plates and two aluminum retainers which hold the hafnium plates to the cylinder. A column connector is attached to the top of the cylinder. The column connector is the means by which the cylinder is attached to the worm gear assembly. To the bottom of the cylinder is attached the stop collar weldment. The stop collar weldment fits into the Be aligning cup and aids in the alignment of the cylinder. The Be aligning cup fits into the reflector support tank and aids in the aligning of the cylinder.

Each cylinder is provided with an internal mechanical stop. These stops are 186° apart. The stop is made when the tang of the column connector mates with the cutout of the aligning cup of the gear box support beam. There is also on each cylinder an "in-limit" flow switch. When the drum is rotated to the "in-limit", a series of holes mate up allowing gland seal water to flow.

Each pair of cylinders have mechanical stops on the drive shaft and electrical limit contacts on the drive shaft. Nominal travel is 160°.

The position of each pair of cylinders is read out on a digital display on the reactor control console to 0.1 degree.

There are also switches provided on the reactor control console for individual as well as group movement of the control cylinders, both "in" and "out".

2. Servo System

The ATR servo system is a closed-loop system designed to automatically control the reactor power between N_L and N_F . It accomplishes this by changing the regulating rod position to compensate for reactivity changes in the reactor.

The servo channel consists of a compensated ion chamber, a motor-operated rheostat (MOR), a preamplifier, a servo amplifier, a drive motor, a feedback tachometer, and a regulating rod. See Figure 2-1. A positive voltage is applied to the compensated ion chamber and an equal negative voltage to the MOR. The output of the compensated ion chamber will be a positive current proportional to reactor power, and the output of the MOR, a negative current proportional to the desired power level. The resultant current to the servo preamplifier (servo error) will be the difference of the two and carry the polarity of the larger. The preamplifier is used to eliminate outside noise signals from reaching the servo amplifier. The servo amplifier provides a field current, proportional to the servo error, to the amplidyne, which is an ac motor, dc generator set. The dc output of the amplidyne drives a dc servo motor which, in turn, drives the regulating rod with a velocity and direction proportional to the amplidyne output. A tachometer connected to the servo motor drive shaft provides a feedback signal to the servo amplifier to produce stability in regulating rod movement.

There are two identical servo systems, one of which is used for

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Fig. 2-1 Power level servo system.

reactor control; the other is used for a standby.

3. Reactor Control Console

The reactor control console contains all the controls necessary for the operation of the nuclear portion of the reactor. Its components, their titles, locations, and functions are described below. See Figure 2-2 for a schematic of the console.

a. Indicator Lights and Control Switches

(1) Reactor Procedure Panel

This panel is located on the left control panel, lower right. The panel provides an indication of the various steps that the operator must take to start-up the reactor.

(2) Rod Position Indicating Lights

(a) Green Light: This light is energized to indicate that the "lower limit" (or "in-limit") switch is actuated.

(b) Amber Light: This light is energized to indicate the rod is selected for group or individual movement.

(c) Red Light: This light is energized to indicate the "upper limit" (or "out-limit") switch is actuated.

(d) Second Green Light on Safety Rods: This light is energized when the rod "seat" is actuated.

(3) Fission Chamber Lights

(a) Amber Light: There are three amber lights for each fission chamber. Each light is energized at one of the three positions of the chamber: "in", "intermediate", and "out".

(b) White Light: This light is energized when either of the fission chambers is moving.

(4) Rod Selector and Movement Switches

(a) Safety Rod Switches

1. Safety Rod Selector S-3: This switch is a nine-position switch. One position is "group" and the other eight are for each safety rod position. This switch is used to select a rod for individual movement or rods for group movement. The switch is located on the left console, center.

2. Safety Rod Group Selector, S-4 through S-11: This is a two-position switch: "select" and "not select" and is used to select a rod for group movement. These switches are located on the left console, center.

3. Safety Rod Motion S-12: This switch is a three-position switch: "withdraw", "off", and "insert". The switch is spring return to the "off" position and is used to move the rods individually or grouped. The switch is located on the left console, left.

(b) Outer Shim Control Cylinder Switches:

1. Outer Shim Group Selector, S-13 through S-20: These switches are four-position switches: "off", "preferred insert", "group", and "preferred withdraw". One switch is provided for each pair of cylinders and is used to select the cylinders for a type of motion. The switches are located on the right console, top.

2. Outer Shim Individual and Group Selector S-21: This switch is a nine-position switch: "group" and eight individual positions. The switch is used to select a pair of cylinders for individual movement or cylinders for group movement. This switch is located on the right console, top left.

3. Outer Shim Motion S-22: This is a three-position switch: "insert", "off", and "withdraw". The switch is spring return to the "off" position and is used to move the cylinders individually

INSTRUMENT SCHEDULE NAMEPLATE LEGEND AND ESCUTCHEON ENGRAVING

MARK NO	NO	DEVICE	SERVICE	NAMEPLATE LEGEND	ESCUTCHEON ENGRAVING	MARK NO	NO	DEVICE	SERVICE	NAMEPLATE LEGEND	ESCUTCHEON ENGRAVING	MARK NO	NO	DEVICE	SERVICE	NAMEPLATE LEGEND	ESCUTCHEON ENGRAVING
1		SYNCHRO	POSITION INDICATOR	SAFETY ROD SPS	NOT REQUIRED	46	5-18	4 POSITION SEL SW	PREF. INSERT GROUP PREF WITHDRAW	OUTER SHIM DRIVE CM 1 & 2 MODE SELECT	AS PER DWG 670-T-142	71	5-58	2 POSITION SEL SW	MOR SELECTION	MOR SERVO CHANNEL SELECTOR	AS PER DWG 670-T-144
2		SYNCHRO	POSITION INDICATOR	SAFETY ROD SRS	NOT REQUIRED	47	5-19	4 POSITION SEL SW	PREF. INSERT GROUP PREF WITHDRAW	OUTER SHIM DRIVE CM 3 & 4 MODE SELECT	AS PER DWG 670-T-142	72	5-60	3 POSITION SEL SW	INSERT - WITHDRAW	FISSION CHAMBER #1 INSERT - WITHDRAW	AS PER DWG 670-T-144
3		SYNCHRO	POSITION INDICATOR	SAFETY ROD SRS	NOT REQUIRED	48	5-20	4 POSITION SEL SW	PREF. INSERT GROUP PREF WITHDRAW	OUTER SHIM DRIVE CM 1 & 2 MODE SELECT	AS PER DWG 670-T-142	73	5-61	3 POSITION SEL SW	INSERT - WITHDRAW	FISSION CHAMBER #2 INSERT - WITHDRAW	AS PER DWG 670-T-144
4		SYNCHRO	POSITION INDICATOR	SAFETY ROD SRS	NOT REQUIRED	49	5-21	9 POSITION SEL SW	INDIVIDUAL SELECTION	OUTER SHIM DRIVE INDIVIDUAL SELECT	AS PER DWG 670-T-142	74	-	MILLIVOLTMETER	INDICATOR	SERVO ERROR #1	NOT REQUIRED
5		SYNCHRO	POSITION INDICATOR	SAFETY ROD SRS	NOT REQUIRED	50	5-22	3 POSITION SEL SW	INSERT WITHDRAW	GROUP INDIVIDUAL OUTER SHIM DRIVE INSERT - WITHDRAW	AS PER DWG 670-T-142	75	-	MILLIVOLTMETER	INDICATOR	SERVO ERROR #2	NOT REQUIRED
6		SYNCHRO	POSITION INDICATOR	SAFETY ROD SRS	NOT REQUIRED	51	5-23	4 POSITION SEL SW	INSERT WITHDRAW	OUTER SHIM DRIVE PREFERRED MOTION	AS PER DWG 670-T-142	76	-	PUSH BUTTON	REACTOR RUN	REACTOR LOCKOUT	OFF - ON
7		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-1	NOT REQUIRED	52	5-24	5 POSITION SEL SW	REGION SELECTION	NECK SHIM ROD REGION SELECT	AS PER DWG 670-T-142	77	5-2	PUSH BUTTON	REACTOR RUN	REACTOR LOCKOUT	OFF - ON
8		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-2	NOT REQUIRED	53	5-25	5 POSITION SEL SW	REGION SELECTION	NECK SHIM ROD REGION SELECT	AS PER DWG 670-T-142	78	-	PUSH BUTTON	REACTOR RUN	REACTOR LOCKOUT	OFF - ON
9		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-3	NOT REQUIRED	54	5-26	7 POSITION SEL SW	POSITION SELECTION	SSE NECK SHIM RODS INDIVIDUAL SELECTOR	AS PER DWG 670-T-142	79	-	PUSH BUTTON	REACTOR RUN	REACTOR LOCKOUT	OFF - ON
10		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-4	NOT REQUIRED	55	5-27	7 POSITION SEL SW	POSITION SELECTION	SSE NECK SHIM RODS INDIVIDUAL SELECTOR	AS PER DWG 670-T-142	80	-	PUSH BUTTON	REACTOR RUN	REACTOR LOCKOUT	OFF - ON
11		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-5	NOT REQUIRED	56	5-28	7 POSITION SEL SW	POSITION SELECTION	SSE NECK SHIM RODS INDIVIDUAL SELECTOR	AS PER DWG 670-T-142	81	-	PUSH BUTTON	REACTOR RUN	REACTOR LOCKOUT	OFF - ON
12		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-6	NOT REQUIRED	57	5-29	7 POSITION SEL SW	POSITION SELECTION	SSE NECK SHIM RODS INDIVIDUAL SELECTOR	AS PER DWG 670-T-142	82	-	PUSH BUTTON	REACTOR RUN	REACTOR LOCKOUT	OFF - ON
13		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-7	NOT REQUIRED	58	5-30	7 POSITION SEL SW	POSITION SELECTION	SSE NECK SHIM RODS INDIVIDUAL SELECTOR	AS PER DWG 670-T-142	83	5-1	PUSH BUTTON	REACTOR RUN	REACTOR LOCKOUT	OFF - ON
14		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-8	NOT REQUIRED	59	5-31	2 POSITION SEL SW	NOT SELECTED	#1 #2 #3 PAR #5 #6 SRS NECK SHIM RODS	AS PER DWG 670-T-142	84	-	PUSH BUTTON	REACTOR RUN	REACTOR LOCKOUT	OFF - ON
15		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-9	NOT REQUIRED	60	5-32	2 POSITION SEL SW	NOT SELECTED	#1 #2 #3 PAR #5 #6 SRS NECK SHIM RODS	AS PER DWG 670-T-142	85	-	PUSH BUTTON	REACTOR RUN	REACTOR LOCKOUT	OFF - ON
16		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-10	NOT REQUIRED	61	5-33	2 POSITION SEL SW	NOT SELECTED	#1 #2 #3 PAR #5 #6 SRS NECK SHIM RODS	AS PER DWG 670-T-142	86	-	PUSH BUTTON	REACTOR RUN	REACTOR LOCKOUT	OFF - ON
17		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-11	NOT REQUIRED	62	5-34	2 POSITION SEL SW	NOT SELECTED	#1 #2 #3 PAR #5 #6 SRS NECK SHIM RODS	AS PER DWG 670-T-142	87	-	PUSH BUTTON	REACTOR RUN	REACTOR LOCKOUT	OFF - ON
18		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-12	NOT REQUIRED	63	5-35	2 POSITION SEL SW	NOT SELECTED	#1 #2 #3 PAR #5 #6 SRS NECK SHIM RODS	AS PER DWG 670-T-142	88	-	PUSH BUTTON	REACTOR RUN	REACTOR LOCKOUT	OFF - ON
19		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-13	NOT REQUIRED	64	5-36	2 POSITION SEL SW	NOT SELECTED	#1 #2 #3 PAR #5 #6 SRS NECK SHIM RODS	AS PER DWG 670-T-142	89	-	PUSH BUTTON	REACTOR RUN	REACTOR LOCKOUT	OFF - ON
20		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-14	NOT REQUIRED	65	5-37	2 POSITION SEL SW	NOT SELECTED	#1 #2 #3 PAR #5 #6 SRS NECK SHIM RODS	AS PER DWG 670-T-142	90	-	PUSH BUTTON	REACTOR RUN	REACTOR LOCKOUT	OFF - ON
21		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-15	NOT REQUIRED	66	5-38	2 POSITION SEL SW	NOT SELECTED	#1 #2 #3 PAR #5 #6 SRS NECK SHIM RODS	AS PER DWG 670-T-142	91	-	PUSH BUTTON	REACTOR RUN	REACTOR LOCKOUT	OFF - ON
22		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-16	NOT REQUIRED	67	5-39	2 POSITION SEL SW	NOT SELECTED	#1 #2 #3 PAR #5 #6 SRS NECK SHIM RODS	AS PER DWG 670-T-142	92	-	PUSH BUTTON	REACTOR RUN	REACTOR LOCKOUT	OFF - ON
23		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-17	NOT REQUIRED	68	5-40	2 POSITION SEL SW	NOT SELECTED	#1 #2 #3 PAR #5 #6 SRS NECK SHIM RODS	AS PER DWG 670-T-142	93	-	PUSH BUTTON	REACTOR RUN	REACTOR LOCKOUT	OFF - ON
24		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-18	NOT REQUIRED	69	5-41	2 POSITION SEL SW	NOT SELECTED	#1 #2 #3 PAR #5 #6 SRS NECK SHIM RODS	AS PER DWG 670-T-142	94	-	PUSH BUTTON	REACTOR RUN	REACTOR LOCKOUT	OFF - ON
25		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-19	NOT REQUIRED	70	5-42	2 POSITION SEL SW	NOT SELECTED	#1 #2 #3 PAR #5 #6 SRS NECK SHIM RODS	AS PER DWG 670-T-142	95	-	PUSH BUTTON	REACTOR RUN	REACTOR LOCKOUT	OFF - ON
26		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-20	NOT REQUIRED												
27		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-21	NOT REQUIRED												
28		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-22	NOT REQUIRED												
29		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-23	NOT REQUIRED												
30		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-24	NOT REQUIRED												
31		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-25	NOT REQUIRED												
32		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-26	NOT REQUIRED												
33		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-27	NOT REQUIRED												
34		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-28	NOT REQUIRED												
35		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-29	NOT REQUIRED												
36		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-30	NOT REQUIRED												
37		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-31	NOT REQUIRED												
38		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-32	NOT REQUIRED												
39		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-33	NOT REQUIRED												
40		DECITRAK	POSITION INDICATOR	NECK SHIM ROD SRS-34	NOT REQUIRED												
41	5-12	4 POSITION SEL SW	PREF. INSERT GROUP PREF WITHDRAW	OUTER SHIM DRIVE CM 3 & 4 MODE SELECT	AS PER DWG 670-T-142	66		SYNCHRO	POSITION INDICATOR	REGULATING ROD #1	NOT REQUIRED	96		KNOB	LEVEL VERNIER	SERVO #1 LEVEL	NOT REQUIRED
42	5-13	4 POSITION SEL SW	PREF. INSERT GROUP PREF WITHDRAW	OUTER SHIM DRIVE CM 1 & 2 MODE SELECT	AS PER DWG 670-T-142	67		SYNCHRO	POSITION INDICATOR	REGULATING ROD #2	NOT REQUIRED	97		KNOB	POTENTIOMETER	VERNIER ADJ	NOT REQUIRED
43	5-14	4 POSITION SEL SW	PREF. INSERT GROUP PREF WITHDRAW	OUTER SHIM DRIVE CM 3 & 4 MODE SELECT	AS PER DWG 670-T-142	68	5-65	2 POSITION SEL SW	PERIOD BYPASS	PERIOD BYPASS	AS PER DWG 670-T-142	98		KNOB	POTENTIOMETER	SERVO #2 LEVEL	NOT REQUIRED
44	5-15	4 POSITION SEL SW	PREF. INSERT GROUP PREF WITHDRAW	OUTER SHIM DRIVE CM 1 & 2 MODE SELECT	AS PER DWG 670-T-142	69	5-66	5 POSITION SEL SW	ADJUSTMENTS	MOR ADJUSTMENTS	AS PER DWG 670-T-144						
45	5-16	4 POSITION SEL SW	PREF. INSERT GROUP PREF WITHDRAW	OUTER SHIM DRIVE CM 3 & 4 MODE SELECT	AS PER DWG 670-T-142	70											

Fig. 2-2 Reactor control console arrangement.

or grouped. The switch is located on the right console, upper left.

4. Outer Shim Preferred Motion S-23: This switch is a four-position switch: "insert/withdraw", "insert", "off", and "withdraw". The switch is spring return to the "off" position and is used to move the cylinders as set up by the outer shim group selectors, S-13 through S-20. The switch is located on the right console, upper left.

(c) Neck Shim Rod Switches:

1. Neck Shim Individual Selectors, S-27 through S-30: These switches are seven-position switches: "group" and six individual positions. One switch is provided for each neck shim region and is used to select a rod for individual movement or rods for group movement. The switches are located on the right console, left.

2. Group Selector Neck Shims S-31 through S-54: These switches are two-position switches: "select" and "not select". There is one switch for each neck shim and is used to select the rod for group movement. The switches are located on the right console, left.

3. Neck Shim Rod Region Select S-63: This switch is a five-position switch: "off" and the four region positions. The switch is used to select a region of neck shim rods for movement. The switch is located on the right console, left top.

4. Neck Shim Motion S-55: This switch is a three-position switch: "insert", "off", and "withdraw". The switch is spring return to the "off" position and is used to move the region of rods selected by S-63 individually or grouped. The switch is located on the right console, left.

(5) Rod Position Indicators

(a) Safety Rod Position Indicators: There are eight of these position indicators

on the left console, top. The indicators read from 0 to 39 inches in increments of 1/4 inch.

(b) Outer Shim Control Cylinder Indicators: There are eight of these position indicators on the right console, top. The indicators read from 0 to 359.9 degrees in increments of 0.1 degree.

(c) Neck Shim Rod Indicators: There are 24 of these position indicators located on the right console. The indicators read from 0 to 99.9 inches in increments of 0.1 inch.

(6) Rod Motion Indicating Lights

A motion light is located under each motion switch. A red light is used to indicate rod withdrawal, and a green light is used to indicate rod insertion.

(7) Servo Switches

(a) Select MOR Servo Channel S-59: This switch is a two-position switch: "MOR No. 1" and "MOR No. 2". The switch is used to select the servo channel to be used for operation and is located on the right front console, top right.

(b) MOR Motion S-56: This switch is a five-position switch: "MOR fast raise", "MOR slow raise", "off", "MOR slow lower", and "MOR fast lower". The switch is spring return to "off" from the raise motion only and is used to move the MOR setpoint. The switch is located on the right front console, top left.

(c) Regulating Rod Manual and Automatic S-26: This switch is a three-position switch: "regulating rod manual", "neutral", and "run auxiliary". The switch is spring return to the neutral position and is used to select the mode of operation. The switch is located on the right front console, top center.

(d) Regulating Rod Motion S-64: This switch is a three-position switch: "insert", "off", and "withdraw". The switch is spring return to the "off"

position and is used to move the regulating rod when S-26 is in the "regulating rod manual" position. The switch is located on the right front console, top center.

(8) Galvanometer Switches

(a) Galvanometer Circuit Selector: This knob is a ten-position switch and is used to select the range of the galvanometer. The switch is located on the front console, left top.

(b) Galvanometer Coarse Knob: This knob operates a 0 to 10 pot and is used to adjust the galvanometer to the midrange. The knob is located on the front console, right.

(c) Galvanometer Fine Knob: This knob operates a 0 to 10 pot and is used to adjust the galvanometer to the midrange. The knob is located on the front console, right.

(9) Period Bypass S-65

This switch is a two-position switch: "off" and "bypass". The switch is spring return to the "off" position and is used to bypass the 30 second period trip, when the reactor is not in run. The switch is located on the front console, lower right.

b. Reactor Console Push Buttons

(1) Start S-1

The start button, when depressed at reactor start-up, energizes the start relay R-1-2. The start push button is located on the front console, left.

(2) Run S-2

The run button energizes the run relay R-1-4. The run push button is located on the front console, left.

(3) Period Reset

The period reset button is used to reset a 30-second period trip when reactor

is not in run. The push button is located on the front console, left.

(4) Manual Scram

The manual scram button, when depressed, energizes scram relays RS-1 and RS-2. The push button is located on the left front console, top left.

(5) Scram Reset

The scram reset button, when depressed, resets scram relays RS-1 and RS-2, and resets sigma preamplifiers. The push button is located on the left front console, top right.

(6) Acknowledge, Reset, and Test

These push buttons are used to operate the panalarm units mounted on the reactor panels. The buttons are located on the right front console, center.

c. Reactor Key S-0

The reactor lockout switch is a two-position switch: "on" and "off". The switch when turned to "on", energizes R-1-1. The switch is located on the front console, center bottom.

d. Regulating Rod Position Indicator

There are two of these indicators mounted on the front console. The position indicators read from 0 to 50 inches in increments of 0.1 inches.

e. Regulating Rod Region Indicating Lights

There are four amber lights for each regulating rod position indicator. These lights indicate which region the regulating rod being used occupies.

f. Fission Chamber Motion S-60 and S-61

These switches are three-position switches: "insert", "off", and "withdraw". The switches are spring returned to the "off" position and are used to move the fission chambers. The switches

are located on the left console, left end.

4. Nuclear Instrumentation and Control

The four basic functions of the nuclear instrumentation and control system are as follows (see Figure 2-3):

- (a) To start up and operate the reactor at fixed conditions throughout the core cycle.
- (b) To adjust power distribution.
- (c) To provide safe and reliable operation from the source level to the operating level.
- (d) To shut the reactor down without damage in the event of accidents, malfunctions, or operation outside of specified conditions.

The ATR nuclear instrumentation system is based on Oak Ridge designed equipment. This instrumentation uses electron tubes and circuitry for compatibility with the present equipment, operating, and maintenance experience of the MTR and ETR. The degree of reliability of this equipment and circuitry has been established at MTR and ETR. The system consists of three groups of neutron detectors and associated channels suitable for operation in the source and start-up, intermediate, and power level ranges. At least one decade of overlap is provided between two groups of channels to improve system reliability. The detector ranges, including overlap, are shown in Figure 2-5.

Duplicate independent channels (including detectors, circuitry, and instruments) are provided as a minimum in each of the three groups. Two fission chambers are used in the source and start-up ranges, while two compensated ion chambers are used in the Log N period range (intermediate). Four compensated ion chambers are also used in the power level range. Instrumentation is calibrated by a total heat balance and

measurements in each quadrant in the power level range and by foil activation in the start-up or intermediate range. A neutron source that provides a minimum readable count rate of two cps for the start-up channels with an unirradiated reflector is necessary to override a start-up interlock. An ample source of photo-neutrons is available for start-up from gamma-beryllium reactions after the reactor has been operated at power.

In addition to the above-mentioned neutron detector channels, an N-16 system has been provided to monitor lobe power changes and axial power shifts that can be caused by xenon perturbations.

A fission break monitor system and hazards channel are also provided.

a. Start-Up Instrumentation

The start-up instrumentation consists of two low-level, log-count-rate-meter circuit channels as shown in Figure 2-3. Each channel has a fission chamber sensitive to the low neutron densities in the clean cold reactor at source power, pre-amplifier, linear amplifier, log-count-rate meter, and recorder. Logarithmic count-rate meters and recorders indicate the rate of neutron production and are energized by pulses from the fission chambers. At start-up, these chambers are initially located in a position near the core midplane. As the power level increases, the chambers are withdrawn by electric motors to other predetermined positions to keep the recorders and meters on scale and prevent damage.

The fission chambers are ionization chambers coated with U-235 which fissions on interaction with neutrons (see Figure 2-6). This causes ionization within the chambers and produces detectable pulses of ion current in a low flux field. The fission chambers for the start-up channels are located in instrument thimbles Nos. 2 and 9 (see Figure 2-7).

The start-up channels range from source level (about $10^{-11}N_F$) to $10^{-5}N_F$

Fig. 2-3 Instrument system block diagram.

Fig. 2-4 Power level instrument relationships.

Fig. 2-5 Nuclear instrumentation.

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Fig. 2-6 Fission chamber assembly.

in adjustable increments of up to four decades. The fission chamber has a range of 1.5×10^0 to 1.5×10^5 n/cm²-sec. The neutron sensitivity of the fission chamber is 0.7 counts/sec per n/cm²-sec. After amplifying the pulses from the chamber, the signal is changed from a linear to a logarithmic function and recorded. Since the useful working range of the count-rate meter extends to only about 10^4 counts per second, provisions for increasing the system neutron flux range are made by an instrument drive mechanism which allows the operator to electrically withdraw the chamber to a predetermined position for further useful operation. These chambers operate at 300 dc volts from a power supply regulated to $\pm$ one percent.

The start-up detectors are subject to neutron shadowing by the control elements when the fission chambers are located in their thimbles below an elevation of one foot above the top of the core. The operator must exercise caution when starting up with detectors in this region to avoid misinterpreting the indicated neutron level.

b. Log N Period Channels

The two Log N period channels use compensated ion chambers to give reliable measurements of the neutron flux over a wide range in the presence of intense gamma radiation. This is accomplished by having the equivalent of two chambers, one sensitive to neutrons and gammas and the other sensitive to gammas alone. (See Figure 2-7.) The outputs are connected in opposition so that the net result is a signal indication of neutrons only. The chambers for the Log N period channels are located in instrument thimbles Nos. 4 and 11 (see Figure 2-8).

The chamber output current ranges from 5×10^{-11} to 1.5×10^{-4} amperes and has a neutron sensitivity of 2.2×10^{-14} amperes per n/cm²-sec. This signal feeds a logarithmic amplifier. The output of this amplifier is proportional

to the logarithm of the neutron flux. The period amplifiers are part of the safety system associated with the sigma bus. The period amplifiers are coupling devices between the Log N amplifiers and the sigma amplifiers (scram input device). The period amplifiers produce a voltage proportional to the rate of change of the logarithm of the neutron flux and convert the time rate of change signal to a voltage proportional to the period involved. This signal is transmitted to the sigma amplifiers. When this increases to a preset voltage representing a one-second period, an electronic scram results.

The signal from the Log N amplifiers is fed to Log N and period recorders. The Log N recorders, located in the reactor control panel, record on a six-decade strip chart the percent flux level of the reactor. Relay contacts on the Log N and period recorders are used to provide the power level setpoints needed for various interlocks and permissives in the control system. The period recorders indicate and record the period of the reactor. This is the time required for the neutron flux to increase by a factor of e.

c. Neutron Level Channels

The four neutron level channels use four compensated ion chambers. About four decades of power, 0.015 to 150 percent of rated power, can be measured. The output current from each ion chamber is transmitted to an amplifier. The linear amplifier output is transmitted to both a sigma amplifier and a power level recorder. The level channel chambers are located in instrument thimbles Nos. 1, 5, 8, and 12 (see Figure 2-8).

Each level amplifier has two input resistors, one greater than the other by a factor of 100. The higher resistor, used below N_L , causes the system to assume a higher power level and make the electronic scram and recorder safeties more readily available during start-up of the reactor. These resistors are automatically switched between S_{ag} and N_L .

Fig. 2-7 Nuclear instrumentation thimble positions.

An increase in flux increases the output voltage to the sigma bus until the trip voltage is reached and an electronic scram occurs.

d. Sigma Bus System

The ATR sigma bus system, shown in Figure 2-8, provides fast scram protection for the reactor. The circuit is entirely electronic so that no relay action is necessary. The six sigma amplifiers, two period channels, and four level channels are wired by shielded cable (the sigma bus) to the ten safety rod magnet amplifiers in service. The sigma bus will normally operate at 39 volts as recorded on the sigma bus voltage recorder on the RCP, and the magnet amplifiers supply the normal magnet current to hold the safety rod magnetic clutch. If a period sigma amplifier sees an input equivalent of a one-second period or if a level sigma amplifier sees the equivalent of a $1.2 N_F$ power level, a solid-state trip in the amplifier is actuated, and the sigma bus is immediately jumped to about 50 volts. As the sigma bus voltage increases, the output of the magnet amplifiers will decrease so that at a 50-volt input, the electromagnetic clutch holding current drops to zero. As the holding current decreases, the clutch releases, and all five safety rods scram. The sigma amplifier and sigma bus will remain in the tripped condition until reset with the "scram reset" push button on the reactor console.

e. Deviation Galvanometer

A deviation galvanometer on the reactor console indicates power error to the operator at various power levels. Three ranges and bias control allow operation over the power range of 1 to 100 percent of rated power. A selector switch is provided on the console for selection of the proper power range and sensitivity. The channel arrangement is shown in Figure 2-9. A signal from a compensated ion chamber is fed to a galvanometer through the selector switch.

The bias voltage is used to limit the range of the circuit and produce an error signal.

f. Hazard Channel

A single hazards channel is provided to indicate and record reactor power over the range of 0.2 to 2000 percent full power. This channel is similar to the start-up channels which consist of a fission chamber and log-count-rate-meter circuit. The chamber provided to produce the signal for a permanent record of reactor excursions is located in the high-density concrete between the reactor vessel and structural concrete where it is protected against physical damage.

g. N-16 Monitoring System

The N-16 system monitoring system, arranged as shown in Figure 2-10, is an array of 10 water sample tubes located in appropriate positions in the reactor core to bring samples from lobe regions to beta detectors. This system is independent of primary coolant water since demineralized makeup water is used on a once-through basis. The water flows up through an inner tube, reaches the core area where fast neutrons, proportional to lobe power, react with ^{16}O (n, p) to form N-16. The N-16 decays (beta-gamma) with a half-life of 7.4 seconds. The N-16 activated water takes about 15 seconds to travel from the core to the detectors. In addition to providing inter-lobe power comparisons, two of the sample tubes are arranged in the upper and lower sections of the center flux trap baffle to provide an indication of core power fluctuations in the axial direction that could occur if xenon perturbations should arise. Reliable flow control is provided to prevent the detectors from drifting off calibration.

The ten detector signals are fed to linear picoammeters that feed signal converters providing voltage signals to potentiometric-type recorders. The recorders supply signals to the data processing system which calculates lobe power allowing the reactor operator to maintain predetermined lobe power distribution.

Fig. 2-8 Reactor safety system.

Fig. 2- 9 Power level deviation monitor.

The detectors are calibrated by foil activation and thermodynamic measurement techniques.

h. Fission Break Monitors

Two fission break monitoring channels are provided to detect a release of fission products into the primary coolant system. Each channel consists of a gamma ionization chamber, a picoammeter, and a recorder. The detectors are located at the primary system outlet piping header. Delay time is several seconds.

Fig. 2-10 N-16 monitoring system.

i. Test Blocks

A system of test blocks is provided which permits the operator to disconnect certain instruments and circuits for test and repair (see Figure 2-11). Each pressure switch, recorder contact, or other contact-making device which can initiate a reactor power reduction is connected to the power reduction relays through a removable test block and a multiple-connection receptacle mounted permanently on the reactor control panel. The multi-prong test block which completes the normal operating circuits is kept plugged into its receptacle during normal reactor operation. In general, certain combinations of test blocks must be in place to permit a given operation.

Removing a test block from its receptacle opens the circuit between the initiating contact and the circuitry which activates alarms and power reductions and permits adjustment or repair of the initiating contact or keeps a defective contact isolated from the power reduction circuits. Obviously, whenever a test block is removed, the associated contacts can no longer protect the reactor against abnormal conditions. However, this protection is furnished in each case by a second set of instrumentation which monitors either the identical quantity or a closely related one. In either case the second set of instrumentation is connected through a separate test block so that the reactor remains protected as long as one or both of the associated test blocks are in place. The test blocks and receptacles are so wired that simultaneous removal of both blocks results in a relay scram. Nuclear or process quantities associated in this way form a "backup pair".

Whenever a test block is removed, such removal actuates the annunciator for the quantity associated with the test block. In addition, the test block removal is recorded by the data processing system. When two or more test blocks are removed, each actuates its respective annunciation and data system indication. There will be

no further action, provided that no two of the removed test blocks constitute a backup pair. However, if two test blocks constituting a backup pair are absent simultaneously, a relay scram will be initiated automatically.

Similar test blocks, with appropriate backup, are provided on the nuclear instrumentation channels so that the reactor cannot be operated unless test blocks are in place for at least one start-up channel, one Log N channel, and two power level channels. Two Log N channels must be in operation for low-power flux mapping runs.

In a few special cases, the test blocks function differently from the manner described above. Each safety rod upper limit switch is provided with a test block which opens the normal path of the limit switch (when the test block is pulled) and disconnects one side of the limit switch for test purposes. A scram signal will result if test blocks are removed from the upper limit switches of more than one installed safety rod.

The three shutdown test blocks SD-TB-1 through SD-TB-3 (dry dock test blocks) permit testing of the control rod mechanisms (safety rod, outer shim, and neck shim, respectively) during reactor shutdown. In the shutdown condition, pulling one of these test blocks permits a single rod of the corresponding type to be raised or lowered under manual control. Pulling more than one of these test blocks will initiate a scram and insert all rods that are withdrawn. At reactor power levels greater than $10^{-3} N_F$, pulling one shutdown test block initiates a scram.

j. Sandborn Recorder

The Sandborn Recorder is a two-channel oscillograph mounted in the control panel. The recorder can be patched such as to monitor the signal coming from the level preamplifiers or to monitor the sigma bus voltage. The instrument is an aid in detecting instrument malfunction.

INSTRUMENT TEST BLOCK SCHEDULE			
MARK NO.	DEVICE IDENTIFICATION OR DESCRIPTION	MARK NO.	DEVICE IDENTIFICATION OR DESCRIPTION
51-1	FRS-1-1C, 1D, 1E & 1F	51-41	HIG POWER LEVEL SOUTHWEST INNER LOBE
51-2	FRS-1-2C, 2D, 2E & 2F	51-42	HIG POWER LEVEL NORTHWEST INNER LOBE
51-3	FRS-1-3C, 3D, 3E & 3F	51-43	HIG POWER LEVEL NORTH OUTER LOBE
51-4	FRS-1-4C, 4D, 4E & 4F	51-44	HIG POWER LEVEL EAST OUTER LOBE
51-5	DTRS-1-1B, 1C & 1D	51-45	HIG POWER LEVEL SOUTH OUTER LOBE
51-6	DTRS-1-2B, 2C & 2D	51-46	HIG POWER LEVEL WEST OUTER LOBE
51-7	DTRS-1-3B, 3C & 3D	51-47	LOG N CHANNEL NO. 4
51-8	DTRS-1-4B, 4C & 4D	51-48	LOG N CHANNEL NO. 5
51-9	TRS-1-11B & 11C	51-49	REACTOR PERIOD CHANNEL NO. 4
51-10	TRS-1-12B & 12C	51-50	REACTOR PERIOD CHANNEL NO. 5
51-11	TRS-1-13B & 13C	51-51	NEUTRON LEVEL CHANNEL NO. 7
51-12	TRS-1-14B & 14C	51-52	NEUTRON LEVEL CHANNEL NO. 9
51-13	TRS-1-15B & 15C	51-53	NEUTRON LEVEL CHANNEL NO. 8
51-14	FRS-1-11C, 11F, 11B & 11H	51-54	NEUTRON LEVEL CHANNEL NO. 6
51-15	FRS-1-11C, 11D, 11E & 11F	51-55	COUNT RATE - CHANNEL NO. 1
51-16	FRS-1-12C, 12D, 12E & 12F	51-56	COUNT RATE - CHANNEL NO. 2
51-17	FRS-1-13C, 13D, 13E & 13F	51-57	SEISMIC SWITCH NO. 1
51-18	FRS-1-14C, 14D, 14E & 14F	51-58	SEISMIC SWITCH NO. 2
51-19	FRS-1-20A	51-59	UPPER LIMIT SWITCH SAFETY ROD SRSE
51-20	FRS-1-21A	51-60	UPPER LIMIT SWITCH SAFETY ROD SRE
51-21	FRS-1-6B	51-61	UPPER LIMIT SWITCH SAFETY ROD SRSE
51-22	FRS-1-20B	51-62	UPPER LIMIT SWITCH SAFETY ROD SRS
51-23	FRS-1-31E, 31F, 31G & 31H	51-63	UPPER LIMIT SWITCH SAFETY ROD SPRSW
51-24	LB-1-1C, 1D, 1E & 1F	51-64	UPPER LIMIT SWITCH SAFETY ROD SRW
51-25	DRY DOCK - SAFETY DOOR	51-65	UPPER LIMIT SWITCH SAFETY ROD SRW
51-26	DRY DOCK - OUTER SHIMS	51-66	UPPER LIMIT SWITCH SAFETY ROD SRN
51-27	DRY DOCK - RECK SHIMS	51-67	RAPID RESPONSE FISSION BREAK DETECTOR (R-FB-2)
51-28	PS-4-4B	51-68	RAPID RESPONSE FISSION BREAK DETECTOR (R-FB-3)
51-29	PS-4-4C	51-69	FRS-1-21B
51-30	FRS-1-23	51-70	COMMERCIAL SYSTEM LOW VOLTAGE BUS A-M-B
51-31	FRS-1-24	51-71	COMMERCIAL SYSTEM LOW VOLTAGE BUS A-M-C
51-32	FRS-1-6C	51-72	COMMERCIAL SYSTEM LOW VOLTAGE BUS B-A-B
51-33	LS-1-16	51-73	COMMERCIAL SYSTEM LOW VOLTAGE BUS B-M-C
51-34	WRS-1-1B & 1C	51-74	DIESEL SYSTEM LOW VOLTAGE Q-A-B
51-35	WRS-1-2B & 2C	51-75	DIESEL SYSTEM LOW VOLTAGE Q-B-C
51-36	WRS-1-3B & 3C	51-76	LS-1-11C, 11D, 11E, & 11F
51-37	WRS-1-4B & 4C	51-77	DPS-1-21C & 22C
51-38	HIG POWER LEVEL NORTHEAST INNER LOBE	51-78	DPS-1-23C & 24C
51-39	HIG POWER LEVEL SOUTHEAST INNER LOBE		

INSTRUMENT SCHEDULE			
MARK NO.	DESCRIPTION	MARK NO.	DESCRIPTION
1	ANNUNCIATOR	86	SELECTABLE READOUT 2-PEN RECORDER
2	PRIMARY COOLANT REACTOR INLET TEMPERATURE RECORDER	87	REACTOR COMPLEX TEMPERATURE RECORDER, 12 POINT
3	PRIMARY COOLANT REACTOR OUTLET TEMPERATURE RECORDER	88	HOLDING MAGNET CURRENT RECORDER, 16 POINT
4	R-ANY-1 STACK PARTICULATE ACTIVITY RECORDER	89	SIGNAL BUS VOLTAGE RECORDER
5	R-ANY-2 STACK ALPHA ACTIVITY RECORDER	90	INSTRUMENT TEST BLOCKS (SEE SCHEDULE AT LEFT)
6	6N POSITION PATCH PANEL WITH 4 CONNECTORS - SEE DRAWING 670-N-6 DET. 9	91	QUADRANT 1 CORE DIFFERENTIAL PRESSURE RECORDER
7	PRIMARY COOLANT QUADRANT 1 OUTLET FLOW RECORDER	92	QUADRANT 2 CORE DIFFERENTIAL PRESSURE RECORDER
8	PRIMARY COOLANT QUADRANT 2 OUTLET FLOW RECORDER	93	QUADRANT 3 CORE DIFFERENTIAL PRESSURE RECORDER
9	PRIMARY COOLANT QUADRANT 3 OUTLET FLOW RECORDER	94	QUADRANT 4 CORE DIFFERENTIAL PRESSURE RECORDER
10	PRIMARY COOLANT QUADRANT 4 OUTLET FLOW RECORDER	95	PRIMARY COOLANT QUADRANT 1 DIFFERENTIAL TEMPERATURE RECORDER
11	PRIMARY COOLANT TOTAL OUTLET FLOW RECORDER	96	PRIMARY COOLANT QUADRANT 2 DIFFERENTIAL TEMPERATURE RECORDER
12	R-ANY-3 STACK GASEOUS ACTIVITY RECORDER	97	PRIMARY COOLANT QUADRANT 3 DIFFERENTIAL TEMPERATURE RECORDER
13	R-ANY-4 STACK FISSION GAS ACTIVITY RECORDER	98	PRIMARY COOLANT QUADRANT 4 DIFFERENTIAL TEMPERATURE RECORDER
14	NEUTRON LEVEL RECORDER - RETRANSMITTER CHANNEL NO. 7	99	PRIMARY COOLANT REACTOR DIFFERENTIAL TEMPERATURE RECORDER
15	NEUTRON LEVEL RECORDER - RETRANSMITTER CHANNEL NO. 9	100	PRIMARY COOLANT QUADRANT 1 OUTLET TEMPERATURE RECORDER
16	REACTOR PERIOD RECORDER - RETRANSMITTER CHANNEL NO. 4	101	PRIMARY COOLANT QUADRANT 2 OUTLET TEMPERATURE RECORDER
17	REACTOR PERIOD RECORDER - RETRANSMITTER CHANNEL NO. 5	102	PRIMARY COOLANT QUADRANT 3 OUTLET TEMPERATURE RECORDER
18	WOR NO. 1 - POWER LEVEL SET - POINT WITH INDICATING LIGHTS	103	PRIMARY COOLANT QUADRANT 4 OUTLET TEMPERATURE RECORDER
19	WOR NO. 2 - POWER LEVEL SET - POINT WITH INDICATING LIGHTS	104	SELECTOR SWITCH FOR SAFETY ROD LOWER LIMIT AND SEAT SWITCH
20	NEUTRON LEVEL RECORDER - RETRANSMITTER CHANNEL NO. 8	105	ATR LOCAL EVACUATION
21	NEUTRON LEVEL RECORDER - RETRANSMITTER CHANNEL NO. 6	106	TELEPHONE TYPE KEY SWITCH
22	TOTAL WATER POWER RECORDER	107	SITE EVACUATION
23	LOG N RECORDER - RETRANSMITTER CHANNEL NO. 4	108	POWER ON PILOT LIGHT
24	LOG N RECORDER - RETRANSMITTER CHANNEL NO. 5	109	LOOP DISCONNECT SWITCHES FOR LOOPS 2A, 2B, 2C, 2D, 2E, 1A, 1B, 1C, AND 1D RESPECTIVELY
25	QUADRANT 1 WATER POWER RECORDER	110	RADIATION MONITORING AND HAZ RESET PUSH BUTTONS AND LIGHTS
26	QUADRANT 2 WATER POWER RECORDER	111	SAFETY SYSTEM BUS X TEST LAMP
27	QUADRANT 3 WATER POWER RECORDER	112	SAFETY SYSTEM BUS Y TEST LAMP
28	QUADRANT 4 WATER POWER RECORDER	113	SAFETY SYSTEM BUS N TEST LAMP
29	H ¹⁶ LEVEL RECORDER - RETRANSMITTER - NORTHEAST INNER LOBE	114	SAFETY SYSTEM BUS TEST PUSHBUTTON
30	H ¹⁶ LEVEL RECORDER - RETRANSMITTER - SOUTHEAST INNER LOBE	115	CONTROL SYSTEM POWER SUPPLY GROUND DETECTOR - INDICATING LIGHTS
31	H ¹⁶ LEVEL RECORDER - RETRANSMITTER - SOUTHWEST INNER LOBE	116	RELAY CABINET POWER SUPPLY GROUND DETECTOR - INDICATING LIGHTS
32	H ¹⁶ LEVEL RECORDER - RETRANSMITTER - NORTHWEST INNER LOBE	117	AMPLIFIER CIRCUIT #1 GROUND DETECTOR - INDICATING LIGHTS
33	H ¹⁶ LEVEL RECORDER - RETRANSMITTER - NORTH OUTER LOBE	118	AMPLIFIER CIRCUIT #2 GROUND DETECTOR - INDICATING LIGHTS
34	H ¹⁶ LEVEL RECORDER - RETRANSMITTER - EAST OUTER LOBE	119	AMPLIFIER CIRCUIT #3 GROUND DETECTOR - INDICATING LIGHTS
35	H ¹⁶ LEVEL RECORDER - RETRANSMITTER - SOUTH OUTER LOBE	120	LEVEL CHANNEL LOW RANGE - INDICATING LIGHT
36	H ¹⁶ LEVEL RECORDER - RETRANSMITTER - WEST OUTER LOBE	121	LEVEL CHANNEL NORMAL RANGE - INDICATING LIGHT
37	LOBBIE FISSION BREAK MONITOR RECORDER	122	RECORDERS DTRS - 1-1, 2, 3, 4 & 5 HIGH RANGE - INDICATING LIGHT
38	DEGASSING TANK VENT MONITOR RECORDER	123	RECORDERS DTRS - 1-1, 2, 3, 4 & 5 LOW RANGE - INDICATING LIGHT
39	LOG COUNT RATE RECORDER - RETRANSMITTER NO. 1	124	MISCELLANEOUS READOUT - 2 CHANNEL OSCILLOGRAPH
40	LOG COUNT RATE RECORDER - RETRANSMITTER NO. 2	125	OUTER SHIM DRIVE INNER LIMIT LIGHTS
41	PRIMARY COOLANT REACTOR DIFFERENTIAL PRESSURE RECORDER	126	BLOWN FUSE INDICATOR LIGHTS
42	PRIMARY COOLANT REACTOR INLET PRESSURE RECORDER	127	REACTOR ROOM SPARY ON PUSHBUTTON
43	FISSION - BREAK DETECTOR (R-FB-2)	128	REACTOR ROOM SPARY OFF PUSHBUTTON
44	FISSION - BREAK DETECTOR (R-FB-3)	129	SAFETY SYSTEM BUS G TEST LAMP
45	SELECTABLE READOUT 2-PEN RECORDER		

Fig. 2-11 Reactor control panel arrangement.

k. Reactor Top Count-Rate Meter

The reactor top count-rate meter is an indicator mounted on the reactor top with both a visible and audible alarm. The indicator can be selected to monitor either count-rate channel. This indicator will be used only during a shutdown.

C. REACTOR CONTROL CIRCUITRY

1. General

To fully understand the operation of the ATR, it is necessary to become familiar with the control circuitry and the reactor design philosophy. It is the reactor control circuitry that provides the link between the reactor operator and the control mechanisms within the reactor. This circuitry is the intelligence network that performs the automatic control, safety, and interlock functions required by the design philosophy.

a. Design Philosophy

The major features of the reactor control design philosophy of the ATR are listed below:

- (1) The reactor will always be maintained in a safe condition. It is not possible to begin start-up until all necessary instruments are functioning properly and the required test blocks are in place.
- (2) It is not possible to move any safety or shim rod in the direction which raises power without deliberate conscious effort of the operator.
- (3) Instruments which initiate important power reductions are duplicated; therefore, redundant circuitry is employed.
- (4) If a power reduction is initiated, there is absolutely no way the operator can block or supersede it. The power reduction will continue until

the cause is cleared. At the same time, all circuits which could interfere are locked out. This circuit design guarantees that power will be reduced whenever demanded.

- (5) Two independent circuits are installed for each safety signal produced.
- (6) Coincidence safety instrumentation will not be used.
- (7) The use of safety circuits for any function other than safety is forbidden.
- (8) The control rod withdrawal speeds are chosen to assure protection against a start-up accident.
- (9) Criticality will not be achieved during safety rod withdrawal and will not be achieved without all safety rods in their uppermost positions.

To cover the reactor control circuitry comprehensively, a normal reactor start-up is described using the referenced drawings. In the design of the ATR control circuitry, a great deal of duplication was necessary because of the large number of control rods involved. Therefore, in the interest of time and space, the descriptive material will be limited to describing a typical circuit for each type of control mechanism.

b. Definitions

The following definitions are offered to aid in achieving understanding of the circuitry. Throughout the remainder of this chapter these standard terms will be used to describe the circuit's function.

Shim Rods: Control elements which provide a means of slowly adjusting reactivity while the reactor stays at power. The outer shim control cylinders and neck shim control rods are shim rods.

Safety Rods: A vertically moving poison assembly in the flux trap region specifically designed to rapidly reduce reactor power.

Fast Recovery Scram Safety Rod: One of the safety rods that withdraws at twice the speed of the other safety rods.

Regulating Rod: The neck rod under control of the servo mechanism for automatic power level control.

Withdrawing: Control action which reduces the poison in the core. (All controls are withdrawn to the "out" position.)

Inserting: Control action which increases the poison in the core. (All controls are inserted to the "in" position.)

Power Reduction: Any insertion of control rods including setbacks, reverse, and scrams.

MOR: A variable resistance device which establishes a power level setpoint in conjunction with an ion chamber and a fixed applied voltage over the range between 1 and 100 percent full power. Speeds for fast and slow MOR motion shall be approximately 90 seconds and eight minutes, respectively, for power setpoint changes between 1 and 100 percent.

Servo Channel: One of two duplicate systems which position a regulating rod to maintain reactor power level within the design limits of the MOR setting.

N: Parameter value established at full power (250 MW nominal).

N_F : Full power (250 MW nominal).

N_L : 1 percent of full power or $10^{-2}N_F$

SAG: 0.1 percent of full power or $10^{-3}N_F$.

Double-tracking: measurement of a quantity by means of two independent sensing elements connected by two independent chains of circuitry to two scram relays wired in a loop. An

example is measurement of flow by two separate flow elements.

Backup: Measurement of two different quantities, having a predictable relationship to each other, using two different sensing elements (one for each quantity) connected by two independent chains of circuitry to two scram relays. An example is measurement of reactor outlet temperature and reactor temperature rise.

c. References

In the following descriptive material, reference is made to various drawings. These B and W drawings have the prefix ATR-1075-MTR-670 followed by a T-number. Because all prefix numbers are the same, reference to drawings will be restricted to the T-number notation. For example, drawing ATR-1075-MTR-670-T-141 will hereafter be referred to as T-141. The following drawings will be referenced: T-11, -12, -90, -91, -120, -129, and -141 through -150.

The relays on these drawings are shown in their de-energized or "off-the-shelf" condition.

2. Start-up Interlocks

Prior to reactor start-up, it is necessary to make certain that reactor hardware and supporting facilities are functioning properly. The following material describes the control interlocks that prevent premature start-up.

a. Control Power

The power for the nuclear instrumentation is taken from the battery-backed system. The power reduction buses, the panel recorders, and the procedure lights are also powered from the battery-backed system.

The power for the control relay circuitry, the permissive bus, the

safety rods, and shim rods are taken from the diesel-commercial bus. The neck shims' and outer cylinders' insert bus must always be energized; therefore, power is supplied from the diesel bus and an automatic crosstie to the battery-backed system is provided. In the event of a power failure, there will be an automatic transfer of the shim insert bus to the battery-backed power as shown on drawing T-90. The magnet amplifiers are powered from the battery-backed system and are connected at the center of the "x"- and "y"-looped bus. The "x" and "y" loops supply all circuits that are vital to the operation of the control system. A looped circuit is a bus or circuit that forms a circle. The main advantage of a looped circuit is that one break in the loop will not cause any connected device to fail. Breaks in each side of either loop will cause the magnet amplifier to release the magnetic clutches on the safety rods, and the reactor will scram. One or two breaks in one side of the loop can be detected by the test circuit. For additional detail on the test circuit, refer to drawings T-63, -84 through -86.

The neck shim rods are powered from the diesel commercial bus in four separate sections or quadrants. Each quadrant is equipped with an undervoltage relay (27-2) as shown on drawing T-89. All rod withdrawal is prohibited if voltage fails to any one of the four quadrants.

b. Keyswitch S-0-1

Keyswitch S-0-1 is a keylock switch located in the center panel of the reactor control console. The key for this switch is retained by the shift supervisor. The key cannot be removed when in the "on" position. (See drawing T-141.) The operation of keyswitch S-0-1 energizes relay R1-1. Contacts of this relay perform the following functions:

- (1) Energizes the permissive bus

- (2) Energizes "reactor on" lights
- (3) Monitors the permissive bus voltage
- (4) Actuates a binary indication for the data system.

c. Start Button S-1-1

When the shutdown work is completed and the access port covers are bolted in place, the primary system is vented and pressurized, and normal flow is started. Start-up check sheets are completed on the primary coolant system, the reactor control system, and all associated facilities. With the completion of the start-up check sheets and after flow and pressure have been established, the reactor is ready to be started and taken up to power. The first step necessary to accomplish this was the turning of key-switch S-0-1. The next operation is to reset the scram bus and clear it. The third step is to push "start" button S-1-1, shown on T-141 in the upper left-hand section.

When S-1-1 is pushed, relay R1-2 is energized. Contacts of this relay will hold relay R1-2 energized until keyswitch S-0-1 is turned off. Contacts of Start relay R1-2 perform the following:

- (1) Energizes 10-second timer IT-1. (Contacts of IT-1 actuate after a 10-second time delay. See drawing T-141 Coordinate C2.)
- (2) Sounds start-up horn for 10 seconds (T-140, B-10).
- (3) Serves as a control interlock in the regulating rod permissive circuit (T-142, K-7).
- (4) Energizes the "start" light on the procedure panel (T-129, G-1).
- (5) Energizes MOR select relay, either R6-5 or R6-6 depending upon the position of the MOR S59 (T-144, B-4).

The MOR selector switch (S-59-1) which is located on the reactor control console is a two-position switch. Therefore, the selected MOR and its associated amplidyne are energized as soon as the start button is pushed. The selected amplidyne will continue to run until the key-switch is turned off. This circuit will be covered in greater detail later in the chapter.

d. Interlock Summary

The reactor control console is designed to serve as a control center and, as such, provides the reactor console engineer with a continuous indication of the condition of each control mechanism. A procedure light panel is located on the lower right-hand section of the left wing of the console for the purpose of keeping the reactor console engineer informed of conditions during the start-up or restricted (restart) regime.

To aid in following a typical start-up, an interlock summary will be periodically presented.

The following start-up interlocks have now been satisfied:

(1) Voltage is being supplied from the proper power systems to all panel instruments and control rods.

(2) All process parameters are in their normal safe operating range. All test blocks are in place.

(3) All nuclear instruments (including the magnet amplifiers) are energized. The magnetic clutches on the safety rods are energized.

(4) Keyswitch (S0-1) has been turned "on" energizing the "reactor on" lights. The intermittent timer IT-3 is operating and flashing the light on the procedure panel.

(5) The scram reset push button has been pressed, and the scram bus is cleared.

(6) All selector switches are in their "off" position.

(7) All shim rods are seated, and relay R1-13 is energized. The green lower limit light for each neck shim rod and outer cylinder is energized.

(8) All safety rods are seated, and relay R1-6 is energized. The green lower limit light and green seat light for each safety rod is energized.

(9) All shim and safety rod position indicators are reading zero.

(10) The log-count-rate recorders are reading source strength and are on scale (relay R1-5 is energized).

(11) The start button has been pressed, and the "start" light on the procedure panel as well as relay R1-2 are energized.

(12) Number 1 MOR has been selected by switch S59-1, and relay R6-5 is energized. Number 1 amplidyne is running. Number 2 MOR is automatically driven to N_F .

(13) Timer IT-1 has actuated and sounded the start-up horn for 10 seconds.

(14) Short period relay R1-12 is energized.

e. Safety Rod Withdrawal

There are eight safety rod mechanisms within the reactor core. Only five of the eight will be used initially, with the three spare drive units inactive.

The safety rod drive mechanism is a rack-and-pinion type of drive. The safety rod is driven to its upper or cocked position and remains there until scram action is initiated.

The safety rod is an aluminum tube with hafnium inserts which moves in the annulus between the flux trap baffle and the

pressure tube assembly. Upward motion is imparted to the safety rod by rotating a pinion on the rack attached to the lower part of the rack drive tube. The pinion is driven by a drive shaft which extends radially from the pressure tube to the electric motor, scram solenoid, scram springs, and scram coupling located outside the reactor vessel in the pipe corridor. Scram is initiated by de-energizing the scram clutch which disengages the electric motor from the drive shaft. Scram energy is a combination of the energies from gravity, spring motors, and the hydraulic pressure drop across the safety rod. The result of these energies is sufficient to drive the safety rod into the core. The controls used to manipulate the safety rods are located on the upper half of the left wing of the reactor control console. (See drawing T-12.) In accordance with the design philosophy, no control rod can be withdrawn until all the safety rods have been fully withdrawn. The safety rods cannot be withdrawn until the following interlocks have been satisfied:

- (1) The scram bus must be cleared and relays RS-1 and 2 de-energized.
- (2) The ten-second timer, IT-1, must be timed out.
- (3) All safety rods must be seated, and relay R1-6 energized.
- (4) Short period relay R1-12 must be energized indicating that reactor period is greater than 30 seconds.
- (5) At least one of the two log-count-rate recorders must be on scale, and relay R1-5 energized.
- (6) Both fission chambers must be stationary, and relay R8-2 de-energized.
- (7) Power must be available to all four sections of the shim insert bus, and relay R5-79 energized.
- (8) Intermittent timer, IT-3, must be operating properly (closes contacts one second each 5 seconds).

We are not concerned, at this time, with any condition other than start-up; therefore, the functions of relays, such as R13-5 and R13-1, will be covered later in the chapter.

When the above conditions are satisfied, the safety rod withdrawal permit procedure light is energized (see drawing T-129 coordinate 5H).

The five active safety rods can be operated in either the individual or group withdrawal mode. Individual operation moves any single rod while group operation moves any or all the safety rods that are so programmed.

The reactor console engineer determines the mode of operation by manipulating the appropriate selector switches. For this discussion, both modes of operation will be used, with individual safety rod withdrawal described first.

To withdraw safety rod SRN, selector switch S3 is placed in the "SRN" position, closing contacts S3-8, -16, and -18. When contact S3-16 is closed, a signal is given to the data system that SRN has been selected. Contact S3-18 energizes the safety rod "individual" indicating light on the procedure panel. Contact S3-8 sets up rod for withdrawal.

Selector switch S11 is placed in its "not selected" position, indicating that safety rod SRN is not selected for group operation. In the "not selected" position, switch S11 closes contact S11-2 (see drawing T-141, 15H) and energizes relay R2-24. Contacts of this relay energize the amber "rod selected" indicator light above the SRN rod position indicator.

Safety rod withdraw relay R2-26 is energized if all start-up interlocks are satisfied, and withdraw-insert switch S12 is held in its withdraw position. The red withdraw indicator light above switch S12 is energized by contacts of relay R2-26. Contacts of relay R2-26 (see drawing T-141, 15K) energize SRN withdraw relay R2-23 through normally closed contacts of the upper limit switch relay R9-8 and the

contacts of torque relay R9-32. The torque switch is designed to de-energize the torque relay any time the torque of the drive shaft exceeds a preset limit. Contacts of SRN withdraw relay R2-23 close to energize the 1/4-hp drive motor. The normal withdraw rate of four of the active safety rods is 4.5 inches per minute. Safety rod SRS is designated as the fast recovery rod and has a speed of 9 inches per minute.

During start-up, the intermittent timer (IT-3) contacts are closed one second each five seconds. When the withdraw-insert switch S12 is held in the withdraw position, withdraw relay R2-26 is energized through the contacts of intermittent timer IT-3, and the 1/4-hp drive motor is energized for one second and de-energized for four seconds. This off-on action restricts the safety rod withdraw rate to 1/5 its normal speed or 0.9 inches per minute.

As the safety rods leave their seated position, the green seat switch and lower limit lights are de-energized. It will take approximately 40 minutes to reach the upper limit. When the safety rod reaches the upper limit, relay R9-8 is de-energized and opens its contacts to energize the red upper limit light on the reactor control console and to stop the drive motors.

Group operation is similar to the individual mode except that selector switch S3 is now positioned to "GRP". In the GRP position, contacts S3-5 and -13 are closed. Contact S3-5 closes the circuit to the group selector switches, S4 through S11, shown on T-141, coordinate 1H. Contact S3-13 energizes the "group" indicator light on the procedure panel. (See T-129, 5I). Group selector switches, S4 through S11, are now individually switched to their "selected" position, indicating that each rod has been selected for group operation. When the group selector switches are in the "selected" position, relays R2-3, -6, -9, -12, -15, -18, -21, and -24 are energized, and the amber "rod selected" indicator lights above each position indicator are energized.

When safety rod withdraw-insert switch S12 is held in the withdraw position, all safety rods that have been selected for group operation will begin to withdraw at the same rate as the single rod was withdrawn (0.9 inch/minute).

It is to be noted that while four of the safety rods are withdrawing at 0.9 inch per minute, the fast recovery rod (SRS) is withdrawing at twice that speed or 1.8 inches per minute.

When the safety rods begin to move, their green "seat" and "lower limit" lights will be de-energized. The position of each safety rod is individually indicated on a rod position indicator. (See Drawing T-12.) As each safety rod reaches its upper limit point, relays R9-1 through -8 are de-energized. When the upper limit relays are de-energized, the red "upper limit" indicator light is energized, and the drive motor is stopped. When all safety rods have reached their upper limits, relay R1-7 is energized. (See drawing T-141, 8E.)

f. Regulating Rod Withdrawal

The design of the ATR requires that the reactor must not reach criticality until all safety rods are withdrawn. Because the safety rods are now fully withdrawn, other control rods can now be manipulated. The first rods to be withdrawn after the safety rods are the selected and standby regulating rods. The center neck shim rods in each of the four neck shim quadrants have been designated as regulating rods, and two of these are equipped with special servo-drive motors capable of driving the rods at speeds up to 50 inches per second; however, for manual control, their speed is limited to 5 inches per second.

There are no interlocks prohibiting the manual withdrawal of the regulating rods except that all safety rods must be withdrawn to their upper limit and relay R1-7 energized. (See drawing T-144, 13M.)

There are two separate servo channels each consisting of an ion chamber, an MOR, a manual loop position controller, a preamplifier, a power amplifier, an amplidyne, and a regulating rod. In order to move the regulating rod, it is first necessary to select the servo channel to which it is connected. Selector switch S59 selects either MOR No. 1 or MOR No. 2. This switch selects not only the MOR to be used, but also selects the servo channel associated with it. As previously noted, MOR No. 1 was chosen, and relay R6-5 was energized. When relay R6-5 was energized, MOR No. 2 was automatically driven, at fast speed, to its upper limit (see drawing T-144, 7B), and "MOR No. 2 N_F" procedure light was energized. Contacts of relay R6-5 connect the manual loop-position controller so that it can accept command signals from the manual insert-withdraw switch S64. (See T-150-5F.)

Manual regulating rod withdrawal is a two-hand operation. Manual selector switch S26 (T-142, 6J) energizes relay R4-8 through closed contacts of the "start" relay, R1-2. Relay R4-8 will remain energized as long as the spring-return, "manual-automatic" switch (S26) is held in the manual position. Contacts of relay R4-8 close to provide power to the manual insert-withdraw switch S64. When switch S64 is placed in the withdraw position, regulating rod withdraw relay R8-11 is energized, providing the following conditions are satisfied:

- (1) The fission chambers are stationary and relay R8-2 is de-energized.
- (2) All safety rods are withdrawn to their upper limit, and relay R1-7 is energized.

When contacts of R8-11 are closed, a withdraw signal is transmitted through the position loop controller to the amplidyne and, hence, No. 1 regulating rod withdraws. When No. 1 regulating rod withdraws above 20 inches, green "regulating rod No. 1 in range" indicator light on the procedure panel is energized.

Upon reaching 42 inches, the "in range" procedure light will be de-energized. Note that regulating rod withdrawal is downward.

The regulating rod servo motor is equipped with a dc brake which is designed to hold the regulating rod in place when it is serving as a standby regulating rod. Referring to T-150, 15F, it will be noted that when MOR No. 1 was selected, relay R6-5 was energized and when control relay R4-8 is energized, power is supplied to the rectifier and the brake is released.

In order to withdraw No. 2 regulating rod, it is necessary to switch MOR select switch S59 to MOR No. 2. In the MOR No. 2 position, relay R6-6 is energized. As contacts of relay R6-6 close, MOR No. 2 automatically lowers to N_L at fast speed through contacts R6-6 and R6-3. (See drawing T-144, 7B.) Relay R6-3 is energized through SAG relay R1-3 (see T-144, 2B), and MOR No. 1 is driven at fast speed through contacts R6-6 to its upper limit N_F (see drawing T-144, 4B). The procedure lights will change in accordance with the operation of the MOR.

When manual-automatic switch S26 is held in the manual position and withdraw-insert switch S64 is held in withdraw, No. 2 regulating rod will be withdrawn in the same manner as was No. 1 regulating rod.

g. Interlock Summary

The following events have taken place in addition to the start-up interlock listed in Section B-4:

- (1) All safety rods have reached their upper limits, and relay R1-7 is energized.
- (2) Both regulating rods have been fully withdrawn.
- (3) MOR No. 2 is now selected and at N_L. (The position of MOR No. 1 is N_F.)

(4) All red safety rod upper limit lights are energized.

(5) "Regulating rod above 20 inches" procedure light is energized along with the MOR position indicator lights.

(6) Safety rod selector switch S3 is in the GRP position.

(7) The reactor is not critical.

h. Neck Shim Rod Withdrawal

The ATR Core has a total of 24 hafnium control rods arranged in groups of six in each of the four neck regions. As mentioned before, the center shim rod in each region is designed to be used as a regulating rod; however, only two of the four will actually be used as regulating rods. The other two will be used as standard neck shim rods. Each neck shim rod is actuated vertically by a flexible cable and drive motor arrangement located in the rod access room. The follower section of the rod is below the poison section so that an upward motion of the rod constitutes withdrawal.

The controls for neck shim rod manipulation are located on the lower half of the right wing of the reactor control console. During reactor start-up, the neck shims can be operated singly or in a group of any number.

Prior to neck shim rod withdrawal, the following interlocks must be satisfied. (See drawing T-143, 16K.)

(1) Regulating rod manual control switch S-26 must be in the "off" position, and relay R4-8 must be de-energized.

(2) The reactor period must be greater than 30 seconds, and relay R1-12 must be energized.

(3) The intermittent timer IT-3 must be operating.

(4) All safety rods must be fully withdrawn, and relay R1-7 energized.

(5) The reverse bus must be cleared, and relays RR-1 and RR-2 de-energized.

(6) Voltage must be available on all four sections of the shim insert bus, and relay R5-79 must be energized.

(7) The fission chambers must be motionless, and relay R8-2 must be de-energized.

(8) Both regulating rods must be withdrawn above 20 inches, and relays R22-5 and R22-12 must be de-energized. When reactor control is in "run auxiliary", relay R4-10 is energized.

When the above conditions are satisfied, neck shim rod withdraw-insert switch S55 can be placed in the "withdraw" position, and withdraw relay R5-78 will be energized.

For the purpose of this discussion, an individual withdrawal of neck shim rod SNE-1 will be described.

The neck shim rods are arranged in four groups or regions: Group No. 1, northeast region; Group No. 2, southeast region; Group No. 3, southwest region; and Group No. 4, northwest region. Neck shim rod SNE-1 is the first shim rod in Group No. 1 of the northeast region. In order to withdraw an individual rod within this region, "neck region" selector switch S63 must be placed in the NE or Group No. 1 position. When in this position, contact S63 closes to energize relay R4-11 (see drawing T-142, 10M). Contacts of relay R4-11 energize the amber indicator light above the northeast region individual selector switch. On drawing T-143, upper left-hand corner, it will be noted that when region selector switch S63 is properly placed (relay R4-11 is energized), power becomes available to individual selector switch S27. When selector switch S27 is placed in position "one", contact S27-1 is closed. The northeast region has 6 two-position individual selector switches (S31 through S36) with which the operator selects those rods in

the northeast region which will be operated in the "group" mode. For the individual withdraw of SNE-1, selector switch S31 is switched into the "not selected" position, and contact S31-2 closes to energize relay R5-3. Contacts of relay R5-3 energize the amber "rod selected" indicator light located above the neck rod position indicator. When relay R5-78 is energized, SNE-1 relay R5-4 will also be energized through upper limit relay R10-17.

For group operation, individual selector switch S27 is placed in the GRP position, contact S27-1 opens and contacts S27-13 close. Group selector switches S31 through S36 can now be turned to their "selected" position. If reactor power is below N_L , relays R13-3 and R13-7 will be de-energized (T-143, 1B). If the shutdown test blocks are in place, relay R22-100 will be de-energized. The amber "rod selected" indicator light for each neck shim rod is energized when each rod is selected by its group selector switch.

By placing each of the four individual selector switches (S27, -28, -29, and -30) in their GRP position, it is possible to withdraw any rod that has been programmed by their individual "group" selector switch. It is not possible to operate in the "group" mode at reactor power levels above N_L .

i. Outer Cylinder Withdrawal

There are sixteen outer cylinders, each consisting of a vertical beryllium cylinder having curved hafnium plates attached to a 120 degree section of its circumference. The assembly rotates in the reflector section of the reactor core. There is a total of eight drive mechanisms, each driving two control cylinders. The drive shaft is directly coupled with the drive motor and operates at speeds of 20 degrees per minute with a full travel of 160 degrees. The controls for the outer cylinders are located on the upper half of the right wing of the reactor control console.

Like the neck shim rods, the outer cylinders can be operated in either the individual or group mode. Outer cylinders CN3 and CN4 have been chosen as typical examples (see drawing T-142). In order to manipulate outer cylinders CN3 and CN4, group selector switch S13 must be placed in the "off" position and outer cylinder "individual" selector switch S21 must be placed in the No. 1 position. When S21 is placed in this position, contact S21-1 closes to energize relay R3-3. Contacts of R3-3 energize the "rod selected" indicator light above the CN3 and CN4 position indicator.

It is possible to place the outer shim cylinders in either regular motion (as the safety and neck shim rods) or in "preferred motion". Preferred motion causes the preselected cylinders to move in accordance with their individual instruction; that is, one pair of cylinders may be programmed to insert upon preferred motion while another pair may be programmed to withdraw. This simultaneous inserting and withdrawal of shim rods is unique to ATR. In order to withdraw an outer cylinder, certain conditions must first be satisfied:

- (1) The fission chambers must not be in motion, and relay R8-2 must be de-energized.
- (2) There must be no automatic insertion demand, and relay R3-1 must be de-energized. Relay R3-1 will be de-energized if both regulating rods are withdrawn above 20 inches and relays R7-3 and R7-5 are de-energized. (See drawings T-144, 7H and T-142, 1F.)
- (3) If both regulating rods are above 16 inches, relays R7-2 and R7-4 are de-energized.
- (4) The reactor period must be bypassed or be greater than 30 seconds, and relay R1-12 must be energized.
- (5) All safety rods must be fully withdrawn. Relay R1-7 must be energized.

(6) Regulating rod manual control is not active, and relay R4-8 must be de-energized.

(7) Neither standard or preferred insert command is initiated, and relays R4-4 and R4-1 are de-energized.

(8) Power must be available to all four sections of the shim insert bus, and relay R5-79 must be energized.

If the above conditions are satisfied, the outer shim motion withdraw-insert switch (S22) can be placed in the "withdraw" position; and the individually selected outer cylinders, CN3 and CN4, will be energized.

For the purpose of this discussion, it will be assumed that some time during the withdrawal of the neck shim rods the reactor has gone critical and that the reactor power has begun to rise on a 40-second period. Relay R1-12 is still energized as the reactor period is greater than 50 seconds. We will also assume that the reactor power has raised above $10^{-5} N_F$ and the Log-N recorders have energized relays R13-5 and R13-1. It will be noted on drawing T-142, 1M that contacts of R13-5 and R13-1 bypass the contacts of the intermittent timer and, thus, allow the outer cylinders to be withdrawn at their standard speed of 20 degrees per minute. The intermittent timer light on the procedure panel will still be flashing, but the $10^{-5} N_F$ light will also be energized, indicating that the timer function is being bypassed. It may become necessary for the reactor console engineer to withdraw the fission chambers to keep the log-count-rate channels on scale.

Going back again to the different modes of cylinder operation, drawing T-142 will show that in the "group" mode, cylinders CN3 and CN4 are selected by placing the individual selector switch S21 in the GRP position. This opens contacts S21-1 and closes S21-6, -12, -14, -16, -27, -30, -31, and -34. Group selector switches S13 through S20 have four

positions: "off", "preferred insert", "group", and "preferred withdraw". When switch S13 has been placed in the GRP position, contact S13-2 closes, and the "rod selected" indicator light is energized through contacts of relay R3-3. The withdrawal of those cylinders programmed for "group" operation will be accomplished when withdraw-insert switch S22 is placed in the "withdraw" position.

If cylinders CN3 and CN4 are to be programmed as preferred motion rods, group selector switch S13 would be placed in either the "preferred withdraw" or the "preferred insert" position. For this discussion, S13 should be placed in "preferred insert". Let us assume that cylinders CE1 and CE2 are programmed for "preferred withdraw". Selector switch S14 would then be placed in the "preferred withdraw" position.

"Preferred motion permit" interlocks as shown on drawing T-142 are the same as those for regular shim withdrawal. When preferred motion switch S23 is placed in the "withdraw" position, cylinders CN3 and CN4 will begin to insert. When preferred motion switch S23 is placed in the "insert-withdraw" position, contacts S23-1 close, and cylinders CN3 and CN4 begin to insert; contacts S23-2 close, and cylinders CE1 and CE2 begin to withdraw.

j. Interlock Summary

The following denotes the status of the ATR reactor start-up up to this point:

- (1) The reactor has gone critical and power is increasing on a 40-second period
- (2) All safety rods are fully withdrawn
- (3) The desired number of neck shim rods have been positioned
- (4) The outer shim cylinders have been positioned to their desired locations
- (5) Reactor power is above $10^{-5} N_F$. When reactor power reached $10^{-5} N_F$,

the Log N recorder energized relays R13-5 and R13-1. Contacts of these relays bypass the intermittent timer (IT-3) contacts in the "withdraw permit" circuit of the shim rods. Contacts of relays R13-5 and R13-1 also bypass the log-count-rate recorder contacts. Contacts R1-5 and shim-in-limit contacts R1-13 as well as the intermittent timer contacts in the safety rod withdraw permit circuit (see T-141-18K).

(6) No. 2 MOR is positioned at N_L , and its amplidyne is running. Both regulating rods are fully withdrawn.

3. Run Auxiliary or Automatic Control

After the reactor has become critical, manual withdrawal of the control rods is sufficient to slowly increase the reactor power. At power levels in the range of 1 to 100 percent where it is desired to maintain constant flux densities, manual control is no longer precise enough; therefore, a method of automatically maintaining the reactor power is provided.

The shift from manual control to automatic control must be a smooth operation, one that causes little or no power fluctuation. To accomplish this smooth transition, the regulating rods were fully withdrawn early in the start-up sequence, and the selected (No. 2) MOR driven to its lower limit N_L .

a. SAG

When reactor power is increased to SAG ($10^{-3}N_F$), the Log N recorders energize relays R13-6 and R13-2. When contacts of these relays are closed the following events take place:

(1) As shown on drawing T-144, coordinate 13B, both fission chambers are withdrawn to their upper limit.

(2) SAG relay R1-3 is energized. Contacts of relay R1-3 energize the SAG procedure light.

(3) Range change timer IT-2 is energized. At power levels below SAG, the four power level channels operate in range No. 1 or the high sensitivity range where the gain of each channel is increased by a factor of 100. When reactor power is increased to SAG, timer IT-2 is energized, and 11.5 seconds later contacts of this timer close to energize relay R7-11. When relay R7-11 is energized, the four reactor power level channels switch to range No. 2 or normal sensitivity to reduce the gain by a factor of 100.

Associated with the reactor power level recorders is a high-level scrampoint ($1.2N_F$). When the reactor power level is below SAG, the level channels are reading on range No. 1. Indicated reactor power of N_F would then correspond to an actual power of N_L . If reactor power was actually increasing on a reactor period of less than five seconds when the power reached SAG, the power level channels would still be in range No. 1 sensitivity and would indicate a power level in excess of $1.2N_F$, causing a scram at an actual power of $1.2N_L$. The time (IT-2) is set to operate its contacts 11.5 seconds after being energized because it takes 11.5 seconds for reactor power to increase from SAG to N_L on a 5-second period.

b. Run

As noted above, both fission chambers have been fully withdrawn which has closed contacts R12-17 and R12-20. Reactor power is above $10^{-3}N_F$ which energized SAG relay R1-3. If the two conditions described above are satisfied, the "run" push button can be pushed to energize run relay R1-4. Contacts of relay R1-4 will close to hold the "run" relay energized. Contacts of the "run" relay de-energize the intermittent timer IT-3 (see drawing T-141, 5D). When the reactor is in the "run" regime, short period trip relay R1-12 is held in by passing the 30-second period requirements. This makes it possible for the reactor to

be increased on a shorter period than 30 seconds, but still restricts the reactor to a 7-second period. The "run" procedure light is energized when in the "run" regime; contacts of relay R1-4 prohibit either fission chamber from being lowered (T-144, 11C).

c. Manual-Run Auxiliary Selector Switch S26.

The reactor is now in the "run" regime which means that control can be switched into automatic control. In order to switch into "run auxiliary", both regulating rods must be above 42 inches, and "run" relay R1-4 must be energized. The selected MOR (No. 2) is positioned at N_L , and its associated amplidyne is running. Reactor power is approaching N_L on a slow period, and when the N_L procedure indicating light is energized, power has reached N_L . When the Log N recorders indicate that power is above N_L , relays R13-3 and R13-7 are energized. When these relays are energized, group withdrawal of all neck shim rods is prohibited. (See drawing T-143, 9H.)

The conditions described above are now satisfied; therefore, when switch S26 is placed in the "run auxiliary" position, relay R4-10 is energized. When run auxiliary relay is energized, the following takes place:

(1) The servo channels are switched into control of the reactor, and the signals coming from the servo ion chamber are balanced against the MOR signal. This error or difference signal is amplified and drives the selected regulating rod in the appropriate direction to maintain reactor power.

(2) Contacts of relay R4-10 energize the rectifier on the selected regulating rod brake, and the brake is released allowing the rod to move upon command (see drawing T-150, 15F).

(3) The "run auxiliary" procedure light is energized.

4. Operation at Full Power

The reactor is now in automatic control. It is possible for the operator to continue to use the neck shim rods and outer cylinders as necessary to achieve the desired power balance as long as the active regulating rod stays within the proper operating range. If the selected regulating rod is inserted below 20 inches when in the automatic mode, shim rod withdrawal is prohibited (see drawings T-142, 3H, and T-143, 17K). If for any reason, while the reactor is in the automatic regime and the selected regulating rod is inserted below 16 inches, relay R7-2 is energized (see drawing T-144, 6H). Contacts of relay R7-2 will prohibit outer cylinder withdrawal and actuate a preferred insert of the outer cylinders that have been selected for preferred insert (see drawing T-142, 4K). Once the selected regulating rod has inserted below 16 inches, relays R7-2 or R7-4 will remain energized until the selected regulating rod has been withdrawn above 20 inches; therefore, a "preferred insert" will continue until the selected regulating rod has been forced to withdraw to 20 inches. Preferred insert is a power reduction caused by the insertion of preselected outer cylinders. Should the selected regulating rod be inserted to below 12 inches, relay R7-3 or R7-5 is energized. Contacts of relay R7-3 or R7-5 energize relay R3-1. Contacts of relay R3-1 cause all withdrawn outer cylinders to insert. This insertion will continue until the selected regulating rod has been withdrawn above 20 inches (see drawing T-144, 6H, and T-142, 1G).

5. Low Power Operation

Low power operation of the reactor is necessary to conduct flux measurements and perform instrument calibration. These tests are usually run at low pressure and flow; therefore, a certain number of scram parameters must be bypassed and other parameters substituted. These tests are usually conducted at reactor power levels near N_L .

Before conducting these low power tests, all start-up interlocks must be satisfied and the reactor brought critical using standard procedures. In order to be able to operate in automatic control, it will be necessary to physically insert the servo ion chamber to a higher flux region. In order to maintain a higher degree of safety, all four power level ion chambers will be inserted to a higher flux. The Log N ion chambers will remain in their fixed position.

The bypassing-the-low-pressure and flow parameters are shown on drawing T-148, 10G. When both the Log N recorders are reading below $3N_L$, relays R13-8 and R13-4 are de-energized. When the fire-water valve is not fully open (as it will be at flow), relay R7-10 will be energized (see T-144, 16H). When the reactor pressure is less than 30 psig, relay R8-12 is energized (see T-144, 15M). If the above three conditions are satisfied, the "high power scram" parameters, as shown on T-148, 12G, will be isolated.

The low-power scram parameters are added to the scram bus during low-power operation. When both Log N recorders are reading less than $3N_L$, relays R13-4 and R13-8 are de-energized. When reactor pressure is below 30 psig, relay R8-12 is energized. Contact from these three relays add the "low-power scram" parameters to the scram circuit as shown on drawing T-148, coordinate 3B.

6. Power Reduction Circuitry

Normal reactor operation is defined by a combination of power level and power distribution, flow, pressure, and temperature. The capacity of the reactor system to remove heat from the fuel plates is dependent on the proper combinations of these physical quantities. Each, in turn, must be kept within controlled limits. Deviations of these physical parameters toward a less safe condition can cause overheating of the fuel plates. If the deviation from the normal is sufficiently large, the heat transfer mechanism will be greatly reduced, and the

fuel plates may become steam blanketed with the possibility of fuel melting after sufficient heat is added. Thus, it can be seen that severe plant damage can be inflicted and large quantities of fission product released unless the action of the safety system is adequate. The criterion of damage to the ATR is to prevent the hot spot in the fuel element from reaching the burnout condition. This is the criterion to which the safety system must be designed.

a. Scram

The most drastic control system action is the scram. There are three types of scrams. A fast recovery scram releases the rod with the double-speed drive. The relay scram and the electronic scram both release all safety rods and, in addition, after a timed interval, drive in all neck rods and outer shim control cylinders by initiating a reverse. The relay scram is initiated through relay contacts or recorder switches. The electronic scram is initiated by the voltage on the sigma bus which biases the magnet amplifier. This reduces the magnet current and causes release of all safety rods. The electronic scram does not depend on an instrument response or the mechanical movement response of a recorder. Following any scram, the shim rods are prohibited from withdrawing until the safety rods have been restored to their fully withdrawn position.

All reactor and process parameters that actuate a relay scram are shown on drawing T-148. The large majority of these parameters are identified and require little additional description; therefore, a detailed contact analysis will not be made.

Associated with the relay scrams are certain logic functions required by the design philosophy.

It is required that all safety rods remain fully withdrawn during reactor operation. To ensure that this is actually the case, the relay logic shown on drawing

T-144, 15C where, if after all the safety rods are withdrawn any two safety rods drop or leave their fully withdrawn position, relay R6-20 will be energized. Contacts of relay R6-20 will cause a relay scram (see drawing T-148, 18E).

During start-up below the "run" regime should any safety rod leave its fully withdrawn position "safety sag scram" relay R7-7 is energized (see drawing T-144, 12M). Contacts of relay R7-7 actuate a scram (see T-148, 16E).

Whenever an experimental facility actuates a fast recovery scram (FRS) and reactor power is below $3N_L$, the fast recovery scram is converted to a full scram by energizing relay R7-8 (see drawing T-144, 13H).

As noted above, a fast recovery scram drops the high-speed safety rod into the core. An FRS is actuated only by parameters on the experimental loops. FRS relays will remain energized as long as the cause remains. When FRS relays are energized, 60-second timer, IT-4, is energized. If the initiating parameter is still out of limits 60 seconds after energizing the FRS relays, relay R1-8 is energized and actuates a full scram (see drawing T-141, 8D).

Following a reactor scram and when all withdrawn safety rods have dropped into the core, it is advisable to insert the neck shim rods and outer cylinders. However, due to a certain unavoidable amount of false scrams and scrams of short duration, it is desirable to delay the insertion of the shims. To accomplish this, scram delay timers IT-7 and IT-8 are employed. Upon receiving a scram signal, contacts of scram relays RS-1 and RS-2 energize timer IT-7 and IT-8. Timer contacts close to seal each timer energized through contacts of relay R1-7. The timer will remain energized until all safety rods are fully withdrawn. After some time delay, contacts close in the reverse circuit to cause all neck shim rods and outer cylinders to insert.

b. Reverse

A reverse control action inserts all the shim rods (neck shims and outer shim control cylinders) and the selected regulating rod. The shim rods are inserted until the reverse clears or until they reach their LLS. The regulating rod is inserted to the No. 1 range (six inches). The shim rods insert in their normal mode of operation and the regulating rod inserts at five inches per second.

When either of the reverse relays RR-1 or -2 is energized, an RR-1 or -2 contact closes in the outer shim control cylinder circuitry (T-142) energizing relay R3-1. The contacts of R3-1 relay close in the insert bus of all outer shim control cylinders. Contacts of RR-1 and -2 in the neck shim circuitry (T-143) close energizing relay R5-1, -20, -39, and -58. The contacts of R5-1, -20, -39, and -58 close in the insert bus for each region of the neck shims. The reverse also energizes relay R4-15 in the regulating rod circuitry (T-142). Relay R4-15 is sealed in by its own contact and to de-energize R4-15 the reactor has to be taken out of run auxiliary. A contact of R4-15 closes to energize relay R8-10. A R8-10 contact closes to automatically insert the regulating rod to six inches.

All reactor and process parameters that actuate a reverse are shown on T-147. The parameters are identified and require little additional description; therefore, a detailed contact analysis will not be made.

Associated with the reverse are certain logic functions required by the design philosophy.

When the reactor key switch, SO-1, is turned to "off" shutting the reactor down, a reverse is actuated. This is to insure that upon shutdown, all the shim rods are inserted.

To insure the reactor is in the run regime when the reactor is in power operation, a reverse is energized at $3 N_L$ if the

reactor is not run. Also, if the fire-water valve is not fully open at $3 N_L$ a reverse is actuated. This prevents the reactor from going to power with the fire-water valve partially closed.

It is possible for a setback to actuate when the reactor is in manual, which would mean that no reactor power reduction would result. A setback is converted to a reverse when the reactor is in manual.

A setback below N_L also converts to a reverse. This action is used to reduce reactor power further if the abnormal condition still exists at N_L . This provides additional protection for the reactor and process parameters.

A manual scram also actuates a reverse. Since a manual scram is a deliberate act, it is felt that upon initiating a manual scram, the operator desires maximum shutdown and therefore, a manual scram actuates the reverse.

A loss of battery-backed power also initiates a reverse. (Whether it be via diesel-commercial power failure or loss

of inverter.) This action insures that not only the scram occurs but that all shims are inserted before all sources of shim insertion power is lost.

c. Setback

A setback drives the selected MOR to its LLS. There are two rates of setbacks; the fast setback (FSB) and slow setback (SSB). The FSB will cause the selected MOR to be lowered from its ULS to its LLS in 90 seconds. The SSB lowers the selected MOR from its ULS to its LLS in 480 seconds.

When the FSB relays, RSB-3 and RSB-4, energize (T-147), they close contacts in the fast lower circuitry (T-144) of the selected MOR. When the SSB relays, RSB-1 and RSB-2, energize (T-147), they close contacts in the slow lower circuitry (T-144) of the selected MOR.

A setback will convert to a reverse at N_L (the point at which the MOR's cannot be lowered any further) or when the reactor is in the manual mode of operation.

CHAPTER III

REACTOR OPERATION

A. REACTOR START-UP

1. Start-up Check Lists

A reactor start-up begins when the reactor top-head access ports are bolted in place and the five top-head, power-driven, shielding doors, which cover the access ports, are closed. However, before the reactor is started for normal operation, all associated process systems, auxiliary systems, and experimental loops must be operating at safe conditions.

At this time, various checks and tests are performed on the reactor controls and instruments, as well as experiment safety interlocks and instruments. Start-up check lists are provided to assure that all conditions necessary for a safe reactor start-

up have been performed and are, in fact, completed.

The start-up checks are performed by the process operator, reactor engineer (reactor console engineer), reactor electronic technician, senior reactor engineer, assistant shift supervisor, and shift supervisor.

When the start-up check lists have been completed, reviewed, and approved by the shift supervisor, he checks all outstanding safe-work permits for unfinished or unsafe equipment; all persons interested in start-up are notified; and a final check is made to assure that all equipment is operating properly. The shift supervisor, having been satisfied that everything is in readiness, gives approval for reactor start-up.

a. Process Operator Preliminary Checks

ATR OPERATION BRANCH

Start-up Check Lists

Cycle _____ Date _____

PROCESS OPERATOR

- (1) Process logs checked for abnormalities.
- (2) Danger and operations tags checked.
- (3) All process instruments on and operating.
- (4) Secondary flow normal -- M-1, M-2, M-3, M-4^[a].
- (5) UCW flow normal -- M-5, M-6^[a].
- (6) Emergency recirculation flow normal -- M-10, M-11^[a].

- (7) Primary flow normal -- M-6, M-7, M-8, M-9[a].
- (8) Pressurizing flow normal -- M-14, M-15[a].
- (9) Warm seal pumps operating -- M-82, M-83[a].
- (10) HDW flow normal -- M-35, M-36[a].
- (11) Gland seal pump operating -- M-40, M-41[a].
- (12) Diesel generator operating -- M-42, M-43[a].
- (13) Building exhaust fan operating -- HVE-17A, HVE-17B[a].
- (14) Degassing tank exhaust fan operating.
- (15) Utility MG running normally and battery bank breaker closed.
- (16) Instrument MG running normally and battery bank breaker closed.
- (17) Instrument inverter running normally.
- (18) Reactor controls and instruments on regulated power.
- (19) Reactor vessel fire-water valve locked open (GT-T-1-84).
- (20) Diesel fire-water block valves open (GT-K-4-16 and GT-K-4-19).
- (21) UCW emergency flow to secondary heat exchanger block valve open (GT-K-2-11).
- (22) Secondary flow to UCW system block valve open (GT-K-2-8).
- (23) Building seal doors closed.
- (24) Heat exchanger pit door closed and locked.
- (25) Outer cylinder drive corridor door closed.
- (26) All hatch covers in place.
- (27) Thimble cooling air flow normal (Instrument air in nozzle access trench) 12 each to Nuclear Instrument thimbles.
- (28) Gland seal flow and pressure normal at Station 1.
- (29) Gland seal flow and pressure normal at Station 2.
- (30) Gland seal flow and pressure normal at Station 3.
- (31) Gland seal flow and pressure normal at Station 4A.
- (32) Gland seal flow and pressure normal at Station 4B.
- (33) Gland seal flow and pressure normal at Station 5.

- (34) Gland seal flow and pressure normal at Station 6.
- (35) Gland seal flow and pressure normal at Station 7.
- (36) Gland seal flow and pressure normal at Station 9.
- (37) Gland seal flow and pressure normal at Station 10.
- (38) Gland seal flow and pressure normal at Station 11.
- (39) Gland seal flow and pressure normal at Station 12.
- (40) Gland seal flow and pressure normal at Station 14.
- (41) All hot and warm drain covers in place.
- (42) Instrument air pressure normal.
- (43) HPA normal -- M-65, M-66^[a].
- (44) Regulating Rod Lubricators operating properly.
- (45) 670-E-15 MCC (Diesel-Commercial) on Diesel Power.
- (46) Safety Rod Bleeder valves (Maintenance Seals) open.

[a] Circle number of operating equipment.

b. Reactor Console Engineer Preliminary Checks

REACTOR CONSOLE ENGINEER

- (1) Control room log book checked.
- (2) Control room instruments on.
- (3) Four level recorders read zero.
- (4) Period recorders read infinity.
- (5) N₁₆ recorders read zero.
- (6) Count-rate meter checked for proper response; moving lights and recorder on scale.
- (7) Proper chart speed selected on Log N, period, level and CRM recorders.
- (8) Total water power and quadrant power recorders read zero.
- (9) Total primary flow and quadrant flow recorders read normal (after instrument zero).
- (10) Reactor differential pressure and quadrant differential pressure normal (after instrument zero).

- (11) Desired MOR No. ____ at N_L , MOR No. ____ at N_F .
- (12) Set point vernier at midrange.
- (13) Flux level galvanometer correct range.
- (14) Safety rod lower limit and seat switches selectors in proper position.
- (15) Manual scram check of all safety rods.
- (16) Position of neutron level chambers. Inserted (LLS) ____ out (ULS) ____.
- (17) Servo chambers. Inserted (LLS) ____ out (ULS) ____.

c. Electronic Technician Preliminary Checks

REACTOR ELECTRONIC TECHNICIAN

<u>Item</u>	<u>Time Checked</u>	<u>Hours Check Valid</u>
(1) Drop time and release time data sheet complete and attached to this list.	_____	8
(2) Instrument log book checked.	_____	8
(3) Inspect amplifier, relay, and power distribution cabinets. Inspect instrument cubicles, console, and instruments for test wiring, tags, plugs out, and other abnormal conditions.	_____	8
(4) Power distribution breakers closed.	_____	8
(5) Emergency insert breakers closed.	_____	8
(6) Check the four emergency insert systems for operation with the exercise switch.	_____	8
(7) Instrument cabinet instruments on.	_____	8
(8) Control room instruments on.	_____	8
(9) Pre-amp instrument cabinet instruments on.	_____	8
(10) Experiment radiation instruments on.	_____	8
(11) Test block covers in place.	_____	8
(12) Balance servo amplifier	_____	4
(13) Count rate amplifiers calibrated	_____	4
(14) Stack radiation monitors on scale	_____	8

(15) Fission break monitors on scale and calibrated	_____	4
(16) Check the 5 ground detector indicating lights	_____	8
		Hours
		Check
		Valid
<u>Item</u>	<u>Time Checked</u>	
(17) Perform, with assistance from the reactor engineer, reactor electronic scram checks as follows:		
(a) Calibrated Log N amplifiers	_____	4
(b) Withdraw each of the safety rods three inches	_____	
(c) Slowly increase the input signal to a sigma amplifier until it trips the sigma bus. Voltage should increase to 50 V, and all the safety rods should drop.	_____	4
(d) Reset the sigma amplifier	_____	
(e) Slowly increase the input signal to each of the other sigma amplifiers until each trips. Each amplifier trip should raise the sigma bus voltage to 50 V.	_____	4
Input signal at trip points for:		
No. 1 period sigma amp _____		
No. 2 period sigma amp _____		
No. 1 level sigma amp _____		
No. 2 level sigma amp _____		
No. 3 level sigma amp _____		
No. 4 level sigma amp _____		
(f) Reset the sigma amplifiers		
(g) Push the manual scram button on each level sigma amplifier. Sigma bus must increase to at least 50 V.	_____	4
(18) Sigma amplifier lights normal	_____	4
(19) Reset magnet currents to ____mA for normal operation.	_____	4
(20) When all power reductions are clear and all test blocks are in place, push the safety system bus test button. All four lights should continue to burn.	_____	4

SAFETY ROD DROP TIME AND RELEASE TIME DATA SHEET

		<u>Value</u>	<u>Date/Initial</u>
SRSE	Release Time	_____	_____
	Drop Time	_____	_____
SRS	Release Time	_____	_____
	Drop Time	_____	_____
SRSW	Release Time	_____	_____
	Drop Time	_____	_____
SRNW	Release Time	_____	_____
	Drop Time	_____	_____
SRN	Release Time	_____	_____
	Drop Time	_____	_____

d. Senior Reactor Engineer Pre-
liminary Checks

SENIOR REACTOR ENGINEER

- (1) "W" switch check list completed and attached.
- (2) Lead experiments normal (recorders on and etc).
- (3) Reactor vessel pre-start-up check sheet completed and attached.
- (4) Nozzle access trench door closed and locked.
- (5) Console operator check list completed.
- (6) Loop experiments normal and ready for start-up.
- (7) Electronic technician's check list completed.
- (8) Annunciator boards cleared. Exceptions listed and approved by the shift supervisor.
- (9) Control room test block covers in place. Exceptions listed and approved by shift supervisor.
- (10) Data system operating properly.
- (11) Access port covers in place and bolted down.

REACTOR VESSEL PRE-START-UP CHECK LIST

- (1) Inventory completed.
- (2) All fuel elements seated.
- (3) Upper tank surfaces (cover plates, flow distribution screens, etc) inspected and cleaned of foreign objects.
- (4) Core cleaned and inspected for miscellaneous debris.
- (5) Sight glasses accounted for.
- (6) Transfer tube cover seated (checked with hook tool).
- (7) Pressure tube locator ties latched.
- (8) Visual check that experiment lead tubes are clamped.
- (9) Log book reviewed.
- (10) Pinboard checked and cleared.
- (11) Outer capsule irradiation facilities checked and clean.
- (12) Fuel element storage areas inspected.
- (13) Transfer baskets removed from tank.
- (14) Reactor handling tools removed from tank.
- (15) Shutdown schedule completed and signed off.
- (16) Reactor top "CRM" turned off.
- (17) Reactor vessel "upper" and "lower" drain valves closed.

W-SWITCH CHECK LIST

Location	Conditions	Loop 1A	Loop 1B	Gas Cooled Loop 1C	PW Loop 1D	NR Loop 2A	NR Loop 2B	NR Loop 2C	NR Loop 2D	NR Loop 2E
Reactor Console	Loop Transfer switch on									
	Loop Annunciators cleared									
Experiment Console	All test plugs replaced									
	Reactor simulation -- amphenol plug connected to reactor circuit									
	SS-1 Setpoint testing switch in a spare position									
	SS-1 Setpoint testing switch pushed in.									

Exceptions:

e. Assistant Shift Supervisor Preliminary Checks

ASSISTANT SHIFT SUPERVISOR

- (1) Reactor filled and pressure checked for leaks at top-head, bottom-head, shim rod and safety rod access ports and nozzle trench area.
- (2) Subpile room door closed and locked.
- (3) Rod access room door closed.
- (4) Top-head shielding in place.
- (5) Process operator check list completed.
- (6) Reactor instruments zeroed (flow, pressure, ΔP , and ΔT).
- (7) Senior reactor engineer check list completed.

f. Shift Supervisor Preliminary Checks

SHIFT SUPERVISOR

- (1) All interested persons notified for start-up.
- (2) Safe work permits cleared.
- (3) All check lists completed and approved.
- (4) Start-up approved for Flux Run or Reactor Operation.
- (5) Safety Tags checked and approved for start-up.

2. Start-up Scram Checks

Before the reactor is allowed to start-up, manual and electronic scram checks are performed to assure that the reactor shutdown and safety circuitry is operating correctly. The scram checks are performed by the reactor console engineer in conjunction with the reactor electronic technician. The scram checks will be performed, without deviation, as set forth in the ATR Standard Practice Manual. The scram checks are valid only if the primary coolant system is at operating conditions with respect to pressure and flow.

Prior to starting the scram checks, the response of each start-up channel

(count-rate system) is checked. By use of selector switches S-60 and S-61, the fission chambers are moved out of the core individually or one at a time. As the chamber moves out of the core, its respective log count-rate recorder should show fewer counts per second. After the response check, the fission chambers should be repositioned to the most sensitive (furthest inserted) or start-up position.

a. Manual Scram Checks

After all reactor start-up checks are completed, except for the manual and electronic scrams, the reactor is ready for start-up. The reactor console operator will turn the reactor "on" and the scram checks

will be performed. The manual scram checks on the safety rods are performed first. All five safety rods are pulled three to six inches and then the manual "scram" button on the reactor control console is pushed. The rods are checked for proper rod seating and rod drive rundown. A "reverse" and "scram" annunciator should be received on the annunciator panel.

The neck shim rods and outer control cylinders are checked for operability after the manual scram check of the safety rods is completed.

After making sure that all safety rods and outer shim cylinders are fully inserted, pull dry dock test block SD-TB-3 (R-22-100). Pulling this test block allows neck shim withdrawal. It bypasses the intermittent timer and safety rod upper limit restrictions, and its use is allowed only as set forth by the provisions of the Standard Practice Manual. The neck shims are withdrawn three to six inches and then the manual "scram" button on the reactor control console is pushed. The "scram" and "reverse" annunciator should be received, and all neck shim rods should immediately start inserting. Check each rod for proper rod drive rundown and "in-limit" lights.

After making sure that all safety rods and neck shim rods are fully inserted, both regulating rods are pulled to above 20 inches in "manual", then dry dock test block SD-TB-3 (R-22-100) must be reinstalled and dry dock test block SD-TB-2 (R-22-99) pulled. The outer shim cylinders are rotated 5 to 10 degrees and then the manual "scram" button on the reactor control console is pushed. The "scram" and "reverse" annunciators should be received, and all outer shim cylinders should immediately start inserting. In addition, the selected regulating rod will also insert. Check each outer cylinder for proper rod drive rundown and "in-limit" lights. After the selected regulating rod has run down and while the reverse is still valid, select the standby regulating rod and allow it to run down. Check each regulating rod for proper rod drive rundown action, limit light operation and indicator response.

Reinstall dry dock test block SD-TB-2 (R-22-99).

Malfunctions or any deviations from normal in performing the above checks are to be noted in the operations log and called to the attention of the shift supervisor immediately.

b. Electronic Scram Checks

The electronic scram checks are to be done with the assistance of the reactor electronic technician. These scram checks determine the proper functioning of the control circuitry and will be done after the manual scram checks are completed.

3. Start-up Procedure

When the reactor console engineer receives start-up approval from the shift supervisor, the console key-lock switch is closed and the "start" button is pushed. Since other operations have already been accomplished, as required by the start-up check lists, this action provides electrical power to the control circuits and to the safety rod drive motors.

This also energizes the "reactor on" lights throughout the area and the reactor building and sounds the "start-up warning horn" for a 10-second period. In addition, the intermittent timer starts operating, allowing rod withdrawal for 1 second out of each 5 seconds.

It might be well to note here that rod withdrawal is not allowed unless at least one of the two count-rate meters is reading "on-scale". The fission chambers have a range of about four decades, and they can be adjusted to three different positions in the core by small electric motors. These three predetermined positions in the core are selected so as to keep the recorders and meters on scale during reactor start-up and operation and to prevent chamber damage due to excessively high neutron fluxes.

The start-up channels range from source level (about 10^{-11} Np) to 10^{-5}

N_F. See Figure 3-1. This provides a range of 1 to 1.5×10^5 n/cm²-sec.

During the initial reactor start-up, a neutron source was required to provide the minimum readable count rate of one count per second to override the start-up interlock. After power operation, the irradiated beryllium reflector provides an ample source of photoneutrons for start-up.

a. Pulling Rods

The start-up control circuitry requires that all of the safety rods be withdrawn to their ULS before any of the other control rods can be withdrawn. Therefore, the 16 outer control cylinders and the 24 neck shim rods must be in the fully inserted position before any of the safety rods can be withdrawn.

If the safety rods are at their LLS and all of the above conditions are satisfied, the five safety rods can be withdrawn one second out of every five seconds individually or as a group. The total time required to reach the ULS, or the fully withdrawn position, will be approximately 45 minutes.

During safety rod withdrawal, if the reactor power should reach sag (0.1 Log N) before all safety rods reach their ULS, the reactor will be scrammed. This, of course, prevents the reactor from operating with an insufficient shutdown potential. Also, after the safety rods reach their ULS, a scram will be received should one or more rods drop accidentally or be lowered so that the ULS contact is lost, provided the reactor is below sag or 10^{-3} N_F on the Log N's. A scram will also be received under the same conditions stated above when the reactor is above sag if the reactor controls have not yet been placed in "run".

These safety features are required to maintain the philosophy that all safeties have to be withdrawn to their ULS before the reactor can go critical.

After the safety rods reach their ULS, it is necessary to completely withdraw the two regulating rods to Range 6 (See Figure 3-2). It is good operating practice to withdraw the regulating rods after the safety rods are withdrawn since it places the selected regulating rod in the proper position to effect a smooth power transition from the "manual" (control rods) to the "automatic" (regulating rod) control mode. After both regulating rods are withdrawn to Range 6, the regulating rod which is to be used during the following cycle, should be re-selected by repositioning the selector switches as required in the start-up check list.

At this point in the start-up procedure, the required number of neck shim rods will be withdrawn.

NOTE

The critical positions for the outer control cylinders and the neck shim rods will be approximated for each cycle in the ATR Critical Facility, and transmitted to ATR operations sometime prior to the scheduled start-up. The reactor will be brought to criticality, as directed by the shift supervisor, by withdrawing those rods specified in the procedure received from the ATR Critical Facility.

The start-up procedure will specify exactly, by position, which neck shim rods are to be withdrawn. Since neck shims are either "fully inserted" or "fully withdrawn", the specified neck shim rods will be "fully withdrawn" in intermittent. With the specified number and location of neck shim rods withdrawn, the reactor can then be taken critical with the outer control cylinders, and no rod manipulations will be required to effect the required power split between the lobes.

After the required neck shim rods (as specified in the start-up procedure) have been withdrawn to their ULS, the outer control cylinders will be withdrawn

Fig. 3-1 Power level instrument relationships.

Fig. 3-2 Regulating rod control ranges.

according to the sequence specified in the start-up procedure.

During the outer control cylinder rotation (withdrawal) a critical assembly will start forming and the count-rate meter will start indicating a neutron population increase. The period recorders will begin to indicate in the positive direction, and the rod withdrawal rate will be limited to maintaining a period greater than 30 seconds.

NOTE

The fission chambers are subject to neutron shadowing by the outer control cylinders at any position in the core except when fully withdrawn (full-out position). This is expected to be quite pronounced during the initial start-up, but it is anticipated that after full power operation the large built-in neutron source will offset this effect somewhat. In any event, the reactor console engineer should exercise caution when

starting up with the fission chambers inserted to avoid misinterpreting the indicated neutron level.

If the period recorders drive upscale to a period of 30 seconds or less, "withdraw permit" will be lost and rod withdrawal will cease even though the intermittent timer will continue to operate. To regain "withdraw permit", the console operator must push the "period reset" button located on the reactor control console.

NOTE

Once the safety rods reach their ULS, the only restriction placed on rod withdrawal as far as the count-rate meter is concerned is that the fission chambers cannot be in motion. In other words, it is possible for the count-rate meter to go completely off-scale because the console operator will still have the ability to withdraw rods.

Therefore, during start-up, after the safety rods have been withdrawn to their ULS, the count-rate meter will be kept on scale by manually withdrawing the fission chambers. This is accomplished by use of the manual "insert -- withdraw" switch located on the reactor control console.

As reactor power continues to increase, the Log N recorders will come on-scale at a power level of 250 watts (0.0001% or $10^{-6} N_F$). See Figure 3-1.

Rod withdrawal is restricted to intermittent until the Log N recorders reach $10^{-5} N_F$ (0.001%). At this point, continuous full-speed rod withdrawal is possible.

b. Transition from "Start" to "Run"

Outer control cylinder rotation (with drawal) continues from $10^{-5} N_F$ (0.001 on the Log N recorder) to $10^{-3} N_F$ or "sag" (0.1 on the Log N recorder). During this withdrawal period, the console operator continues to restrict the reactor to a period greater than 30 seconds and keeps the count-rate meter on scale. In addition, of course, all nuclear instruments are continually monitored for any abnormalities.

When one or both of the Log N recorders reaches "sag" (0.1) the fission chambers of the log count-rate system will automatically withdraw to their outer-most position, provided they have not been placed in the outermost position previously while under manual control.

In addition, at "sag", the following occurs:

(1) "Sag" relay R-1-3 automatically picks up and lights the " $N > 10^{-3} N_F$ - sag" light on the procedure panel.

(2) The operator is allowed to place the reactor controls in automatic

by pushing the "run" button (after the fission chambers are in the "out" position).

NOTE

The reactor should be put in "run" as soon as possible since "run" bypasses the safety rod scram circuit R-7-7. That is, a dropped safety rod will not scram the reactor if power is above "sag" provided the controls are in the "run" regime.

(3) "Sag" has one other very important function: to energize timer IT-2. Eleven and one-half seconds after timer IT-2 has been energized, its contacts close and energize level range change relay R-7-11, which changes the range of the four neutron level channels to range No. 2 which is low or normal sensitivity.

This circuit has the following two fundamental design functions: First, if, during the 11.5 seconds timed period, reactor power increases from "sag" to $1.2 N_L$, the reactor will scram. This means that the reactor must be restricted to a period of 5 seconds or longer.

In other words, a reactor period of 5 seconds, held for 11.5 seconds, will raise reactor power from 10^{-3} (sag) to $10^{-2} (N_L)$ (1 decade) which is just under the scram point prior to a range change. Therefore, the reactor period should be held to 30 seconds or greater during the period of power raise between "sag" and " N_L ".

Second, it gives a scram if reactor power increases to $3 N_L$ during the low power operation (if the neutron level chambers are not inserted. If the detectors are inserted a scram will be received at $1.2 N_L$).

NOTE

If the neutron level chambers are not inserted and reactor power is

increased to $3 N_L$, range change relay R-7-11 de-energizes and changes the level channels to Range No. 1 (which is high sensitivity), and this causes a high level scram from the level recorders (see Section A-5 below for more detail).

The decade above "sag" is the transition point between the "start" and the "run" regimes and as soon as one or both of the Log N recorders pass through "sag" ($10^{-3} N_F$) the "run" button should be pushed.

When "run" relay R-1-4 picks up, the intermittent timer stops operating, and the "run" relay seals in. The "30-second period trip" in the "short period trip" circuit is bypassed, and a 7-second period is now required before withdrawal permit is lost. The fission chambers are prohibited from being inserted; the scram at $3 N_L$ in "start" is invalidated; the "safety sag scram" circuit is invalidated (a dropped safety rod will not scram the reactor when controls are in "run"); and it allows reactor control to be switched to "run auxiliary" if both regulating rods are at or above 42 inches (Range 6).

When "run auxiliary" relay R-4-10 picks up and seals in, it closes the "preferred and auto -- insert" circuit on the outer control cylinders. (This circuit automatically inserts outer control cylinders if the regulating rod goes below 16 inches.) It also allows the regulating rod to come into operating range when power reaches N_L .

4. Power Operation

As reactor power approaches N_L ($10^{-2} N_F$ or 2.5 MW) on the Log N recorders, the servo-error meter will start moving toward zero, and the selected regulating rod will automatically insert into the core to maintain reactor power at $10^{-2} N_F$ (N_L). Reactor power is held at this level while operations personnel thoroughly check the experimental systems and the radiation levels around the area. An announcement is made at

this time, throughout the entire area, that reactor power is at N_L .

At N_L the process operator will be requested to adjust the primary coolant system inlet temperature setpoint to maintain the desired inlet temperature and to start up the secondary coolant system if he has not done so already. Cooling tower fans are turned on, as necessary, to maintain the primary coolant system inlet temperature at the desired setpoint.

At N_L , the ability to withdraw neck shim rods in a group is lost, and any withdrawal of these rods at or above this power requires individual selection.

CAUTION

Good operating practice dictates that no more than one neck shim rod be in an intermediate position while reactor power is at or above $3 N_L$ unless recovering from a power reduction.

At N_L , the reactor is considered to be critical although actual criticality, the point at which the power is self-sustaining without further rod withdrawal, will have occurred at a lower power level. Actual criticality and N_L ($10^{-2} N_F$) vary only slightly with respect to actual rod position, and the difference is negligible for all but exact technical measurements.

After the area and experiments have been checked and the shift supervisor is satisfied that everything is in readiness, he will give his approval to increase the reactor power. The reactor power will be increased stepwise (see applicable SPM); the size of the steps will be determined by the various experimental and process requirements.

The last two decades of power, from 1.0 to 100 on the Log N's, are controlled by the servo system; and reactor power increases are made by increasing the setting of the reactor power setpoint. When the setpoint is increased, the servo-error meter will indicate a deviation

between the existing power and the new power setting. The regulating rod will automatically withdraw to a position that will satisfy the reactor setpoint (MOR), which is zero percent deviation on the servo-error meter. Should the regulating rod withdraw beyond Range 5 (42 inches), it is restored to Range 5 (20 to 42 inches) by withdrawal of selected outer control cylinders.

When the reactor reaches full power, another radiation survey is made of the area; any adjustments necessary are made at this time to get the experiments operating at the required conditions for the upcoming cycle. In addition, all process parameters are brought to normal operating conditions as soon as possible, and the reactor power verified.

5. Flux Run Operation

The ATR is designed to operate at low power (2.5 MW or less) with the primary coolant system at atmospheric pressure and with the refueling ports removed. The prime purpose of this operation is to allow flux mapping of the core.

Reactor power can be automatically controlled when operation is between sag and N_L , but manual control must be used at lower power levels. The reactor is cooled during this type of operation by utilizing the flow from both emergency coolant pumps and the utility cooling water system to remove heat from the secondary side of the primary heat exchangers.

Reactor start-up for flux runs is identical to a normal start-up with three very important exceptions. First, flux wires will have been inserted in certain specified locations throughout the reactor vessel. Second, the four neutron level chambers, located in instrument thimbles T-1, -5, -8, and -12, will have been lowered to their lower limit switches during the pre-start-up check. These four chambers are raised and lowered from the reactor control console with a switch arrangement similar to the CRM's. Third,

the two servo-channel detectors located in thimbles T-3 and -10 will have been lowered to their lower limit switches. This will position the detectors such that they read 2 decades higher than the Log N channels. This establishes a range on the MOR from $10^{-2} N_L$ to N_L , which corresponds to 1 to 100 percent of MOR setting. (It is planned to motorize the servo-chamber drives and neutron level chambers so they can be operated from the console. In the meantime, they are raised and lowered manually from the nozzle access trench area.)

When the neutron level recorders read N_F with real power at N_L because chambers in the lowered position are in a neutron population a factor of 100 higher than normal, all level safety circuits behave as if the reactor actually is at N_F . Range change relay R-7-11 keeps the channels in Range 2 (normal) so long as real power, as seen on Log N's, is below $3 N_L$ and pressure is below 30 psig. If real power exceeds $3 N_L$, relay R-7-11 de-energizes; the neutron level channels will switch to the high sensitivity range; and the reactor will scram. However, the $1.2 N_L$ safety setpoint on the neutron level recorders will have scrambled the reactor at a real power level of $1.2 N_L$ before this happens.

It is important to understand that this safety circuit performs its safety functions regardless of the position of the chambers. The neutron level channels stay in Range 2 (low sensitivity or normal operating position) anytime reactor pressure is less than 30 psig and reactor power is below $3 N_L$. However, with the neutron level chambers inserted, all level recorders will read 100 percent when reactor power is actually N_L ; and a scram will be received at an indicated power level of $1.2 N_F$, which is an actual power level of $1.2 N_L$. If, however, the neutron level chamber detectors are not inserted, the level channels will automatically switch to Range 1 (high sensitivity) at a real power level of $3 N_L$ and produce a scram.

B. NORMAL REACTOR OPERATION

After xenon and other poisons have reached full power equilibrium, control rod movement to maintain the proper regulating rod range will decrease to a uniform rate governed by reactor fuel burnup. Control rod withdrawal will continue until the reactor core has been depleted or the reactor is deliberately scrammed for shutdown.

During this period of normal operation, the reactor operating personnel will perform various routine duties to assure safe and efficient reactor operation. Although all duties of the reactor engineers cannot be covered in the following section, a general outline of their duties is given.

1. Duties of Reactor Engineers

a. Reactor Control Console

While a reactor engineer is at the reactor control console, he is responsible for the proper operation of the reactor. He will be expected to hold reactor power at a constant value by repositioning the shim rods, raising or lowering the MOR, or a combination of both. As the regulating rod withdraws to compensate for fuel burnup, he will be expected to adjust the control rods according to the approved rod withdrawal program to keep the regulating rod within its operating range and to maintain the proper power split between the lobes. The reactor console operator will maintain close surveillance of all reactor instruments for proper operation. Any abnormal behavior or malfunction of the reactor instrumentation will be immediately reported to the shift supervisor and the reactor electronic technician, and corrective action will be taken, within the limits defined in the Standard Practice Manual, to maintain the reactor in a safe operating condition. Instrument readings and data on the critical reactor parameters will be taken periodically and logged on data sheets to maintain an operating history of the reactor.

At the beginning of each shift and periodically throughout the shift, all

control room instruments will be visually checked to verify that they are operating properly. Log book entries are started by recording the names of everyone working that shift. Everything that happens during the shift should be recorded in the log; power reductions, annunciators received, etc. The time must also be recorded when various events occur. Every effort should be made to maintain an adequate log, recording everything that happens even if it seems of little consequence at the time. Many times the small items turn out to be extremely important. It is frustrating to try to trace the history of some specific event with inadequate log book entries. An adequate log is also required so that oncoming shifts will know exactly what has happened previously.

At least once per shift (preferably early in the shift) all charts are to be marked where the pen is indicating, and the time and date are to be written on the chart (the electronic technician will mark the nuclear instruments). At this time, the instruments should be checked for proper operation, adequate ink supply, and synchronization, as well as each time they are read. At the first of each shift and periodically throughout the shift, the data system should be checked for proper operation.

b. Basement

In general, the basement reactor engineers will be responsible for the safe efficient operation of the loop experiments under their jurisdiction. They must be capable of adjusting the various experimental operating parameters in order to fulfill the objectives of the various experiments. Loop operating parameters are set forth in the applicable experiment operation manual and the instruction letter which is issued each cycle.

At the beginning of each shift, after relief information has been received, a quick check of all loop operating parameters should be made, then a complete review of the experimental logs should be made. The experimental logs should contain all information that has transpired

during the previous shifts, such as, valve changes and why they were made, routine duties performed, abnormal conditions encountered and what corrective action was taken, etc. All valve changes should be immediately indicated on the pinboard so that it is up to date at all times.

At least once per shift (preferably early in the shift), all charts are to be marked where the pen is indicating, and the time and date are to be written on the chart. The instruments should be checked for proper operation, adequate ink supply, and synchronization at this time, as well as each time they are read.

Near the end of the shift, a complete verbal report should be given to the senior reactor engineer of the status of each experiment or area under the basement reactor engineer's jurisdiction.

c. Senior Reactor Engineer

During normal operation, the senior reactor engineer will man a duty station only as occasional relief for the other engineers. He is normally left free to move about, checking reactor and experiment operations. What the reactor engineer does is the senior reactor engineer's responsibility, and his job is to keep himself fully informed of their activities. The operation of the reactor and its experiments are his prime interest. The senior reactor engineer, the assistant shift supervisor, or the shift supervisor, will be present in the reactor control room during all power increases and will ensure that all reactor console manipulations are carried out in a correct and safe manner. He also makes periodic checks on all experiments to ensure that they are being operated at approved conditions. His other main area of responsibility is records, including those of the reactor and experiments. The control room log book and data sheets should be personally checked by him to ensure that they are complete and correct. He also receives, checks, and sorts the reactor and experiment charts and data before they are turned over to the assistant shift supervisor.

2. Console Manipulation

a. Switching Regulating Rods

Although switching regulating rods at power will be an infrequent operation, it should be thoroughly understood by everyone.

Switching regulating rods not only requires prior approval of the shift supervisor but requires that either the senior reactor engineer, assistant shift supervisor, or shift supervisor actually be present in the control room before and during the switching operation.

Once the decision has been made to switch the regulating rods, the reactor power is lowered approximately 5 MW. This allows some flexibility in power fluctuations during the procedure without fear of fuel element meltdown.

Since one of the objectives during the switching procedure is to lose as little power as possible, the deviation galvanometer is adjusted to zero after reactor power has stabilized. Then the regulating rods are switched by inserting an outer shim control cylinder in order to withdraw (cock) the regulating rod in use. When the regulating rod cocks the "MOR servo-channel selector" switch is rapidly positioned from the selected channel (one being used) to the standby channel (one to be used). The deviation galvanometer is again adjusted back to zero by withdrawing the same outer shim control cylinder that was used to cock the regulating rod. If the selected regulating rod does not come into operating range during power adjustments (deviation galvanometer adjustment), the proper MOR should be lowered until the selected regulating rod comes into operation. Reactor power is now raised back to normal.

It should be emphasized that all nuclear instrumentation, especially the neutron levels are closely watched during the above procedure.

b. Adjusting Ion Chambers

As the flux level in the reactor core varies throughout a cycle of operation, the Log N and neutron level recorders will reflect this change. It is mandatory that these instruments be kept near their N_F position so that the nuclear protective circuitry will function as designed. Therefore, immediately after reaching full power and as necessary during the reactor cycle, the reactor console engineer will reposition the neutron level chambers from the reactor control console so as to keep the neutron level recorders reading N_F at all times during full reactor power operation.

Repositioning these chambers requires that a special key be obtained from the shift supervisor. This key will open the "key-lock" switch, located on the reactor control console; and the key's function is to turn power "on" and "off" to the ion chamber drive motors.

A selector switch, also located on the reactor control console, has to be positioned to the chamber that is to be moved and then the "withdraw-insert" switch is used to position the chamber as required.

At completion of chamber adjustments, the "key-lock" switch is turned to "off", and the key is removed and given back to the shift supervisor.

C. ABNORMAL REACTOR OPERATION

1. Power Reductions

The action taken following a power reduction will vary with the type of power reduction received. Power recovery will be governed by the condition causing the power reduction, but in no case will the reactor be returned to power with an unsafe operating condition. Reactor power will not be raised after a power reduction without the shift supervisor's approval.

a. Setback

The slow and fast setbacks are identical except for the rate of decrease and

refers to a reduction of reactor power by the insertion of the selected regulating rod.

When a signal for an automatic reactor slow setback is received by the reactor control circuitry, the reactor console engineer should insert preselected outer shim control cylinders to try to keep the selected regulating rod between 20 and 42 inches (Range 5).

A fast setback's action is too fast to allow any control of the selected regulating rod; and unless a fast setback is quickly cleared, the regulating rod drives in to 16 inches (Range 4) and then 12 inches (Range 3) and picks up the "automatic preferred insert" of the selected "outer shim control cylinder" and the "automatic insertion" of all "outer shim control cylinders", respectively. When picked up, these actions seal-in until the selected regulating rod is withdrawn above 20 inches (see Figure 3-2).

If the setback signal has not cleared by the time reactor power as indicated on the Log N reaches N_L , the setback signal is converted into a reverse signal, and an automatic insertion of all neck and outer cylinder shims is initiated.

While the setback is in progress, the reactor console engineer or someone else in the reactor control room, should announce over the "intercom system" that the reactor is in a setback condition. In addition, all annunciators received and the sequence in which they are received should be recorded immediately in the log book.

As soon as the setback signal clears, the negative period can be checked by withdrawing (rotating) outer shim control cylinders. If not already done, an immediate investigation should be initiated to determine the cause of the setback. However, even though the setback clears and the reason for the setback is well understood and corrected, the reactor console engineer will make no attempt to recover reactor power without authorization from the shift supervisor.

After receiving authorization from the shift supervisor, the reactor power can be raised by use of the MOR if reactor power is above N_L as indicated on the Log N recorders.

However, if reactor power has dropped to sag ($10^{-3}N_F$) or below, the selected regulating rod must be withdrawn and reactor power raised as outlined in Section A-3.

NOTE

On power recoveries, fast rod withdrawal is permitted, provided reactor power is above $10^{-5}N_F$.

Reactor power should be raised as rapidly as possible to 140 MW since this is the xenon override point for the ATR. After xenon is substantially burned out and frequent shim rod motion has ceased, lobe power should be balanced, if necessary, and the reactor returned to full power in the normal manner.

b. Reverse

When the reactor receives a reverse signal, all outer shim control cylinders, all neck shim rods, and the selected regulating rod insert. The regulating rod drives in at the rate of 5 inches per second, and reactor control drops out of servo. All rods will stop inserting after the reverse signal clears.

The reactor console engineer should immediately lower the MOR, on fast lower, to 60 percent. As soon as the reverse signal clears and approval is received from the shift supervisor to raise power, the selected regulating rod should be fully withdrawn by the procedure outlined in Section A-3. Reactor power should be raised as rapidly as possible to the 140-MW xenon override point (which corresponds to the 60 percent MOR setting) where the selected regulating rod will come into range for automatic control.

In case the reverse is of long duration and reactor power drops below sag, the

recovery procedure is as outlined in Section A-3 (normal start-up), except the safety rods will already be withdrawn to their ULS.

c. Fast Recovery Scram

A fast recovery scram is a quick reduction of reactor power accomplished by the release of one safety rod (called the fast recovery scram rod). A full relay scram will be received automatically if the fast recovery scram (FRS) signal does not clear in 60 seconds or if reactor power drops below $3 N_L$ before the FRS signal clears.

The reactor console engineer should immediately lower the MOR to 60 percent. As soon as the FRS signal clears and approval is received from the shift supervisor to raise power, the FRS rod must be withdrawn to its ULS.

No other shim rod withdrawal is permitted until this safety rod ("S" rod) reaches its ULS. On fast withdrawal of nine inches per minute, four minutes is required to reach ULS.

Reactor power is now raised as rapidly as possible to 140 MW by withdrawing the outer shim control cylinders and neck shim rods. The selected regulating rod will come into range at the 60 percent MOR setting since it withdraws on a FRS.

d. Full Scram

There are two types of full scrams; relay and electronic. The relay or slow scram is initiated through relay or recorder contacts, and an electronic or fast scram is initiated by a change in voltage on the sigma bus which biases the magnet amplifiers so as to release all of the safety rod magnetic clutches.

Either type of scram results in an extremely rapid reduction of reactor power to below N_L . The safety rods are inserted by a combination of gravity, coolant flow, and the accelerating springs,

and all rods are inserted into the core in less than 300 milliseconds after the scram signal is received.

In addition, after a timed interval (13 to 25 minutes), a scram signal closes a contact in the reverse circuit which starts the insertion of all outer shim control cylinders, neck shim rods, and the regulating rod. This insertion will always take place unless the scram signal is cleared and the safety rods withdrawn to their upper limit switches prior to the end of the timed interval.

After the timed interval described above, all neck shims and outer shim control cylinders will insert to their LLS unless the safety rods are withdrawn to their ULS. In other words, as long as reactor power remains above $10^{-5}N_F$, the safety rods can be withdrawn simultaneously with an automatic rundown of the neck shims and outer shim control cylinders. However, as soon as the five safety rods reach their ULS, the reverse signal will clear, and the automatic insertion of the neck shims and outer shim control cylinders will cease.

If, however, reactor power drops below $10^{-5}N_F$ after the timed interval, all neck shims and outer shim control cylinders will have to reach their LLS before safety rods can be withdrawn.

As soon as possible after receiving a scram, the reactor console engineer should announce over the paging system that the reactor has scrammed; all pertinent information should be recorded in the log book; and the MOR should be lowered to the xenon override point of 60 percent. The course of the scram should be investigated and the condition rectified. The "scram reset" button must be pushed to clear the scram.

As soon as approval is received from the shift supervisor to raise power, the safety rods should be withdrawn, as a group, to their ULS. The regulating rods are then withdrawn to their ULS and

power raised as rapidly as possible to the 60 percent MOR setpoint according to the procedure outlined in Section A-3.

If reactor power drops below sag, reactor control reverts to the "start" regime, and power will have to be increased slowly (high period) from $10^{-3}N_F$ (sag) to $10^{-2}N_F(N_L)$ because of the action of timer IT-2 in range change relay R-7-11 circuit. See Section A-3-b-(3).

2. Other Abnormal Operating Conditions

a. Control Rods

(1) Safety Rods

A dropped safety rod can be caused by scram action of a sigma amplifier, failure of a magnet amplifier, failure of a magnet, or a magnet current that has drifted below normal. The position indicator on the dropped rod will travel as fast as the rod to zero; the regulating rod will cock, and reactor power will decrease rapidly. The seat and lower limit lights will also indicate the rod is down. If the trouble is located and readily remedied, the rod can be fully withdrawn to its normal operating position.

A stuck safety rod will be accompanied by no change in the position indicator, and, eventually, power to the drive motor will be cut off by action of the torque limiter switch. However, if the position indicator stops and the motor continues to operate, as indicated by the "withdraw" light, the position indicator may have failed. Withdrawal should be stopped immediately for reasons given in the torque switch failure paragraph. A stuck safety rod can be repaired only after the reactor has been shut down.

Failure of a safety rod upper limit switch, as indicated by the rod being at the upper limit with the upper limit light out, can be bypassed by removing a safety rod upper limit switch test block. However, the removal of two of these test blocks will cause a scram.

Torque switch failure in conjunction with an upper limit switch failure or a stuck safety rod will cause the clutch to slip severely. The "insert-withdraw" switch should be released as soon as this condition is recognized to prevent extensive damage to the electromagnetic clutch. The symptoms that accompany this condition are as follows: position indicator stopped and the withdraw light "on" indicating that the drive motor is still operating. It will be difficult to distinguish between torque switch failure and position indication failure. If the reactor is at sufficient power, such as during a recovery from a fast recovery scram, a reactivity check will be a positive means of determining which type failure has occurred.

Seat switch failure is indicated by the rod being at the lower limit with the lower limit light on, the position indicator reading zero, and the seat light out. Reactor operation is not affected. The seat switch can not be replaced until the reactor is shutdown.

Lower limit switch failure is indicated by the rod being at the lower limit (seat light on and position indicator at zero) with the lower limit light out. Lower limit switch failure can be bypassed if necessary (such as, just after a scram to re-energize relay R-1-6 to get the withdraw premissive that is necessary to withdraw safety rods) by turning the safety rod lower limit and seat switch selector to the "seat switch" position. The selectors are numbered the same as the safety rods and are normally in the LLS position. To operate the selector to the "seat switch" position, push for momentary contact or push and rotate 30° clockwise for maintained contact.

(2) Neck Shims

If a neck shim rod sticks, a torque limiter coupling will disengage the drive shaft from the motor on excessive torque. This will be indicated by

an indicating light on the reactor control console which shows withdrawal or insertion with no movement of the position indicator and no change in reactivity. The torque limiter will reset automatically when the overload is removed or the motor is stopped. The reactor must be shut down to repair a neck shim that is stuck.

Each neck shim rod is equipped with an upper and lower limit switch. If these switches fail, overtravel of the rod can result; however, the rods have mechanical stops at both ends. If the mechanical stops are reached, the torque limiter should disengage the rod drive. Indication of this condition would be a withdrawal or insertion indicating light with the position indicator at 0 or 48 inches. These limit switches can be serviced in the neck shim drive area with the reactor operating.

Position indication failure is indicated by withdrawal or insertion of the neck shim rod with a corresponding change in reactivity and no change in position indication. The position indicator can be serviced in the neck shim drive area with the reactor operating.

(3) Outer Shim Cylinders

An outer shim cylinder could become immovable from several different causes. A buildup of crud or foreign particles between the rotating cylinder and the reflector blocks or in the gear box could become serious enough to cause binding. The mechanical seal or any of the bearings in the drive line or cylinder assembly might seize and stop rod movement. A torque limiter coupling will disengage the motor from the drive shaft on excessive torque caused by a stuck cylinder. The indication at the reactor control console will be the indicating lights showing insertion or withdrawal with no movement of the position indicator and no change in reactivity. The torque limiter will reset automatically when the motor is slowed or stopped or the overload removed. The reactor would

have to be shutdown to repair a stuck cylinder.

Each cylinder has a lower limit switch that is actuated by gland seal water flow through a port on the rod when the cylinder is at the lower limit. In addition, each pair of cylinders have upper and lower limit mechanical switches which are mounted on the drive line. These switches stop rod movement by interrupting power to the motors. The rod drives have a mechanical stop on both ends of travel. If the limit switches fail and this stop is reached, the torque limiter will disengage the drive shaft. There is an additional backup mechanical stop at both ends of travel located at the cylinders themselves. This stop will stop rod movement if both the limit switches and the drive shaft mechanical stop should fail simultaneously. The indication at the reactor control console will be insertion and withdrawal indicating lights with the cylinder position indication beyond the normal limits and not moving. The flow switch limit switches can be serviced anytime in the second basement, but the mechanical switches will be in too high a radiation field with the reactor at full power.

Position indication failure is indicated when there is no change in the position indication when the rod is withdrawn or inserted with a corresponding change in reactivity. Also position indication can be compared to the data system shim cylinder indication since a separate position indication system supplies its signal. All parts of the position indication system can be serviced during reactor operation except for the position transmitter itself which is in the motor area.

(4) Regulating Rod

A stuck regulating rod would be detected by a drift in reactor power and a servo-error indication with no resultant change in regulating rod position indication. As the servo error increases, the signal to the amplidyne will increase until the breaker supplying power to the

amplidyne is tripped. The other regulating rod may be selected for servo control, but the reactor must be shut down to repair the stuck regulating rod.

Each regulating rod is equipped with seven switches at 0, 6, 12, 16, 20, 42, and 48 inches of withdrawal. Failure of any one of these switches can be detected if the position indicator shows the rod to be at that position with no corresponding control action being initiated. These switches may be serviced in the neck shim drive area with the reactor operating.

Position indicator failure can be detected by inserting or withdrawing a shim rod without changing the position indication of the regulating rod or the reactor power level. The servo-error meter will also indicate a servo-error, then return to balance. The other regulating rod may be selected, and the faulty position indicator may be serviced from the neck shim drive area when the reactor is operating.

b. Loss of Electrical Power

(1) Commercial Power Outage

In the event of either a complete or a partial commercial power outage, the reactor will be scrammed due to the action of the undervoltage relays. On a complete outage, all of the primary and secondary coolant pumps will stop; however, the primary emergency coolant pumps will continue to operate and are capable of removing all of the decay heat from the reactor. The reactor cannot be restarted until commercial power is available and normal flow established.

(2) Diesel Power Outage

Loss of diesel power will scram the reactor due to the action of the undervoltage relays, and all plant equipment which is fed from the diesel bus will stop. The diesel-commercial motor control center will automatically switch to commercial power, and any equipment fed from this motor control center which

has a maintained contact will continue to run. Some plant equipment which is fed from the diesel bus has a standby unit which is fed from the commercial bus; and if the running unit stops, the standby unit will start. The reactor cannot be restarted until diesel power is available.

(3) Loss of the Motor Generators

(a) If the utility motor generator fails, power will still be available for operation of the switchgear and the dc primary emergency coolant pump from the battery bank. The reactor will not be scrammed; there will, however, be an annunciator at the process control room and at the reactor control panel.

(b) Loss of the instrumentation ac power inverter motor generator will scram the reactor due to the action of the undervoltage relays. Power will be lost to the nuclear instrumentation and the data system electronics. Power can be made available, however, from the standby transformer. This will require manually closing the breaker.

If the instrumentation dc power motor generator set fails, the instrumentation ac power inverter motor generator set will continue to run since it is supplied power from the battery bank. The reactor will be scrammed, however, due to the frequency fluctuation. The frequency will drop to approximately 58 cps when the instrumentation dc power motor generator set fails and the battery assumes the load. Details of the ATR electrical system may

be obtained from Chapter XII of this manual.

c. Instrument Failure

Sufficient duplicate safety-shutdown instrumentation has been incorporated into the reactor to allow temporary operation at power without the full complement of instruments in service. It is assumed that it will be necessary to perform calibrations or minor instrument repair without shutting down the reactor. Therefore, test blocks have been provided on certain reactor parameters so that they may be temporarily removed from the reactor safety circuitry. The specific instruments which may be removed from the safety circuitry at any one time are set forth in the ATR Standard Practices Manual, and deviations from this SPM are strictly prohibited. The philosophy governing removal of any instrument from the safety circuitry is that every parameter must be monitored by at least one, and in some cases two, instrumentation systems. Any time such monitoring is unavailable due to instrument malfunctioning, the reactor must be shutdown for instrument repair. In the case of certain critical instruments, if the minimum number is not in service, the reactor will automatically be scrammed, ie, one neutron level recorder and two N-16 recorders.

All nuclear and process instrumentation test blocks are located on the reactor control panel. Removal of any test block will require the approval of the shift supervisor.

CHAPTER IV

REACTOR SHUTDOWN

A. PRE-SHUTDOWN PLANNING

The ATR will normally operate on a three-week cycle which consists of four days of shutdown and seventeen days of operation. Reactor shutdown time must be held to a minimum since a reactor's operating record is measured in megawatt-days safely produced and, even more basic, because plant costs continue during shutdown at about \$750 per hour. Therefore, advance planning and manpower scheduling is very important to eliminate or minimize any foreseeable holdups or bottle-necks during shutdowns. Many factors have to be taken into account since there may be up to 100 independent but interrelated jobs to be accomplished in the time allotted for a shutdown using the available manpower. The TRA maintenance department is presently using the "critical path" method of job and manpower scheduling. The method, utilizing computer programs, permits prediction of shutdown length, craft requirements at any time during shutdown, and what job schedule will lead to minimum reactor downtime. The results of the computer programs are published prior to each shutdown as the "Shutdown Node Diagram". In order for the reader to gain a better understanding of this scheduling method, a hypothetical ATR shutdown schedule is shown in Figure 4-1. The steps that go into the preparation of this schedule are explained below. For a more detailed description of critical path scheduling techniques, refer to IDO-16738.

The Maintenance, Plant Engineering, and Project Engineering Branches are required to formulate and submit the shutdown jobs to be performed to the TRA Planning and Scheduling Branch at least one week before the published shutdown date. These jobs will be in the form of a node diagram covering estimated specific

craft manhours required and will be accompanied by the work request for the job. The Planning and Scheduling Branch will then sort the jobs by specific experiment or plant system and make up a node diagram for each experiment covering all jobs to be done on that experiment and the specific craft manhours for each job. Representatives from Operations, Maintenance, and Planning and Scheduling will meet on Tuesday of the week preceeding shutdown to work out an exact job schedule with respect to necessary job progression and manpower available. The result of this meeting is the maintenance shutdown schedule which will be in final form by Thursday morning. This node diagram is the working schedule for the shutdown and is distributed to all interested parties. The Operations Coordinator will use this document to write the reactor shutdown schedule and to make up the Operation's Composite Node Diagram. This composite node diagram and the reactor schedule will normally be published Friday preceeding the shutdown. As the shutdown progresses, the completed jobs will be "red-lined" on the composite node diagram as soon as a specific item is completed. This allows the shift supervisors and other interested personnel to determine which jobs are ahead of schedule, which are behind, and what items must be emphasized during the shift to keep the shutdown progressing smoothly forward.

The project engineer for each experiment also writes an experiment information letter for each cycle. This letter is sent to Operations about a week before shutdown and lists any special cooldown procedures to be used and the jobs (with work request numbers) to be done on the experiment during shutdown. The experiment operating parameters and special procedures to be used during the next reactor operation period are also listed.

Fig. 4-1 Hypothetical ATR shutdown.

B. REACTOR PREPARATION

As far as Operations is concerned, shutdown preparations will also start during the week before actual shutdown. All reactor and hand tools to be used during a shutdown must be checked for operation and all damaged or broken tools repaired or replaced. This tool check will include underwater lights and in-tank sight glasses. During the eight hours immediately preceeding shutdown, most experimenters require special pre-shutdown tests or samples. These special items will be detailed in the experiment information letter or operating manual and must be completed before the normal shutdown time of 1200 Sunday.

Scheduled reactor shutdowns afford the opportunity of live-checking the reactor safety circuitry. Each reactor and process instrument or circuit that can originate a reactor power reduction will be live-checked periodically. The general procedure is to turn the recorder off and manually move the pointer in the unsafe direction. The reactor will shut itself down as the indication passes through the setpoints. Unless it is desired to test the shim delay insert timer (IT-7 and -8), the manual scram button should be pushed before the reactor is locked out. The process water operators will start a two-hour degassing period followed by a one-hour demineralized water flush after the reactor is locked out and the key returned to the shift supervisor. These procedures are necessary to reduce the activity levels in the primary coolant system before the top head is opened. During this three-hour period, the reactor engineers will suit up for tank work and assist the health physicists in preparing the reactor top monitors and setting up the contamination control ribboned areas. The reactor top CRM must also be checked for proper operation and alarms. The process operator will inform the shift supervisor when the degas-flush period is completed and the reactor tank work may proceed.

C. ROUTINE TANK OPERATIONS

The five top-head shielding blocks are run back using the pneumatic wrench and the reactor upper drain and vent opened. When the reactor top warm waste tank level indicator shows no further increase, two adjacent refueling port covers are removed using the impact wrench and 2-ton crane. The vent duct gates for these two ports should be opened and the vent ducts and adapters installed to purge the top dome of radioactive gasses. Another refueling port cover should then be removed to aid the purge. When any of these covers are removed, constant Health Physics monitoring is required and the health physicist in attendance will approve the removal of the remaining port covers. When he gives approval, one of the vent duct gates may be closed, its vent duct removed, and the refueling port seal protective covers installed in four positions. The fifth position must always be connected to the vent system to prevent the spread of airborne contamination from the reactor tank.

The next step is to install the in-tank lights and make an initial tank inspection. Any unusual items or out of the ordinary observations should be noted in the reactor top log. The drop tube cover is removed using the wrench tool and large safety hook tool and stored on the in-tank storage bracket. The outer pressure tube locator ties are unlatched and removed to provide access to the fuel elements around the outer flux trap baffles. A quantity of fuel, the specific positions as listed in the reactor shutdown schedule, must be removed to the in-tank storage racks and replaced with dummy filler pieces to ensure nuclear safety during shutdown operations. To reduce coolant flow channeling, only one element or filler should be out of the core at a time. When the dummy fillers are in place, a flux wire bucket will be transferred to the tank from the canal and the full cycle flux monitors discharged. The wires must

be handled using a safety latch hook tool so none will be dropped and lost. Any broken or missing wires should be noted in the reactor top log. After all full cycle flux monitors are removed and the full bucket transferred to the canal, the capsule experiments in the tank are discharged. The capsule experiments and baskets are also handled with the safety latch hook tool.

The reactor shutdown is scheduled so that the NR experiment removals will start about 0800 Monday morning. The preparation of these experiments should begin about 0400 Monday which, due to the reactor design, will not interfere with Operation's tank work. The detailed procedures for preparing an experiment for removal are found in the loop operating manual. Briefly, the procedure requires depressurizing the loop, removing the transfer plate shield plug and connector plug retainer, and unplugging the specimen thermocouples. The closure plug locking ring is then unscrewed with the lock ring tool and the assembly lifted about two inches and rotated 90° to make sure it is free in the tube. The transfer sleeve O-ring on the in-pile tube should be checked for damage, after which the specimen thermocouples should be reconnected until the sample is removed. The transfer plate shield plug should be carefully reinserted so it does not rest on top of the lifting adapter. Actual sample removal involves use of the NR cask to transfer the samples from the in-pile tube to the canal. When a sample is ready to be discharged, its specimen thermocouples are disconnected and the transfer sleeve inserted around the lifting adapter and filled with demineralized water. If the sleeve leaks, the transfer sleeve O-ring on the in-pile tube must be replaced. The NR cask is lowered over the proper hole on the transfer plate and the bayonet adapter on the cask winch locked to the sample's lifting adapter. The cask is then filled with demineralized water and the sample lifted into the cask. When a sample is either discharged from or inserted into an in-pile tube, all five top-head shielding doors must be closed

to reduce the main floor radiation levels. With the sample fully in the cask, as determined by a Health Physics survey, the cask lower door is closed and the cask moved to the sample transfer station. At this station, the sample is lowered into the canal for later transfer to the experimenter's water pits or to the experiment facility at the east end of the ATR canal. In-pile sample removal will occupy the reactor tank until sometime Monday evening.

The next tank job will be the removal and replacement of the flux wires in the safety rods. The wire holders are unscrewed and discharged using a special flux wire handling tool which incorporates a socket and positive latch to firmly hold the monitor during removal. After the four monitor holders are removed from a safety rod, the poison plates or flux trap fillers may be changed. The poison plates require a special tool to unlatch the assembly from the guide tube. The special plate handling tool should be used instead of a hook tool to remove both the plate assemblies and the aluminum fillers or stops. Only one rod may be serviced at a time since this operation involves temporarily removing a considerable amount of nuclear poison from the core.

Once work is completed on the safety rods, the drop tube cover will be replaced and the reactor water level lowered to the lower drain (elevation 92 feet 4 inches) to prepare the reactor tank for lead insertion and removal. The reactor top warm waste tank level indicator should be closely watched during draining so the warm waste tank does not overflow. These leads, or instrumented capsules, are located in the I, OS, and ON positions and clamped to a bracket on the reactor vessel T-bars with the instrument leads exiting through a reactor nozzle. Each lead will have specific insertion and removal procedures in its operating manual which state any precautions necessary. Since these lead experiments are usually quite fragile and most will be ruined if reactor water is allowed into the instrument tube,

great care must be used during all lead handling. The leads incorporate an in-tank connector to facilitate this handling. In order to remove a lead, it will be unclamped, the in-tank connector undone, and the top section removed. This work requires a man in-tank on a boson's chair; hence, constant Health Physics surveillance is required. After the nozzle penetration is plugged, the lead is lifted as high as radiation fields allow, the lead tube cut, and a water-tight cap installed. When all leads to be removed are cut and capped and the empty nozzle penetrations plugged, the reactor water level may be raised and the leads discharged to the canal. The drop tube cover must be reinstalled and the water level lowered to install a lead experiment. The lower section is carefully set into place while precautions are taken so that the instrument leads are not damaged. The top section is then inserted in the proper nozzle penetration, the instrumentation leads pulled through to the nozzle trench, and the in-tank connector made up. A pressure test will then be run on the connector to detect a faulty seal that could allow reactor water into the tube. If the seals are tight, the lead can be clamped, the nozzle penetration sealed, and the reactor water level returned to normal.

After lead experiment insertions and removals are complete, any work to be done on the neck shim rods or outer shim cylinders may proceed. The inner pressure tube ties must be unlatched from around the pressure tubes and swung out of the way to gain access to the neck shim rods and sleeves. Procedures for removal and replacement of the neck shim rods, regulating rods, outer shim cylinders, or their respective drives will be found in Chapter III of the ATR Operating Manual. Since precise procedures and maintenance help are required, the procedures will not be summarized here.

The reactor may not be refueled until all shim and safety rod work has been completed. This is to take advantage of the poisons in the used fuel for additional

shutdown margin. The refueling will normally be with new elements unless a mid-cycle shutdown is contemplated; in which case, a partially burned core from the canal may be installed. During refueling, constant Health Physics monitoring is required since the fuel must be lifted to within 12 feet of the reactor surface to clear the drop tube. The reactor top CRM must be carefully observed to warn of an inadvertent criticality. Specific rules for new and spent fuel handling are listed in the SPM's and must be rigidly adhered to. The dummy filler piece positions will not be refueled until after all in-pile tube samples are reinstalled.

The reactor is now being prepared for the next cycle start-up; therefore, the capsules and flux monitors (FM) to be irradiated must be installed. Capsule and flow restrictor insertion should be completed before any flux monitors are installed so that dropped FM will not go through the core. After these items are installed, the reactor core and reflector positions must be inventoried. This inventory involves accounting for each position in the reactor and determining its contents and experiment depth measurement in each facility in use. The inventory is one of the most important shutdown jobs as the consequences of a missing experiment or misplaced experiment can be very severe. Operations will be furnished the exact depth measurements for each hole in use and these should check closely with actual measurements. Any discrepancies should be immediately resolved. If a lead experiment inventory is incorrect, it must be unclamped and reseated or completely removed and spacer lengths checked. In the case of an incorrect capsule inventory, the basket should be discharged to the canal and the basket loading rechecked. Any extraneous material in the reactor tank should also be noted and removed if at all possible.

All the preceeding reactor tank work should be completed by Friday morning of shutdown week so that the in-pile tube

samples may be reinstalled. The installation is essentially the reverse of the removal procedures. The samples will have been unloaded to the canal and moved to the test assembly storage rack in the reactor building proper. They are then moved one by one to the cask transfer station, loaded into the NR cask, and reinserted wet into the appropriate tube. Precise location records must be kept since the five NR and one DRD samples are physically interchangeable and any mixup would have serious results. At best, the shutdown would be delayed while the discrepancies were resolved; and at worst, a sample meltdown could occur. After all in-pile tube samples have been inserted and pressure tested, the eight dummy filler pieces may be removed and these positions refueled. The pressure tube locator ties will also be reinstalled.

The reactor is now essentially ready for start-up as fuel is installed and all samples and flux monitors are in. The Operation's shutdown work now consists of checking and cross-checking to make sure all reactor components are installed properly and no loose items are left in-tank. The core and upper portions of the tank are meticulously inspected and all foreign matter removed. The reactor top tool and equipment pinboard is checked, and all missing items located. It is a firm axiom that the reactor will never be sealed for start-up without all pinboard items accounted for. The time spent in this checking is small compared to the consequences of a fuel element flow blockage with the reactor at power. Only when the shift supervisor on duty is satisfied that the reactor "sponge count" is correct will the drop tube cover be seated and bolted down and the in-tank lights removed. The refueling port covers are then reinstalled and bolted down after which the vent duct gates may be closed. The reactor engineer on the reactor top will run a hose from the reactor top vent to the canal, close the upper drain, and request that the process operator fill the reactor tank. When the tank is thoroughly vented, the vent is closed and the refueling port covers

checked for leakage. The shielding doors are not rolled in until the port covers have been leak checked at full primary system pressure.

D. NONROUTINE TANK OPERATIONS

All nonroutine tank operations are covered by detailed procedures and these procedures should be followed closely. Such nonroutine jobs would include in-pile tube replacement, rod drive replacement, beryllium block changeout, and other items which require major component dismantling. The procedures for these jobs are in the loop or reactor operating manuals and will be revised as improved component handling methods develop. All in-tank components except the core support assembly are removable and it is conceivable that they will eventually be removed.

A second phase of nonroutine tank work is the operation of the reactor for flux runs and gamma heat runs. These special reactor measurements are necessary to obtain correlations between the ATR and ATRC. A flux run requires the insertion of possibly 100 special flux wires in the reflector and neck shim regions. The accountability of these wires is vital since they are not designed for full-power, full-flow conditions. The gamma heating in the reactor is measured by small diameter gamma chambers which are inserted into dry aluminum tubes in the reflector region. Chambers will be moved up and down in the tubes and the tubes moved to various positions to get a radial and axial gamma scan of the reactor. Both gamma and flux runs are carried out under open-head conditions at power levels of 2 megawatts or less.

E. NONTANK OPERATIONS

The rest of the reactor plant and equipment has been far from idle during a shutdown. Very few pieces of equipment in the building are available for

maintenance or inspection while the reactor is operating, due to high radiation fields or interconnections with the reactor control circuitry. The hypothetical shutdown schedule (Figure 4-1) illustrates some of the many jobs and their interrelationships.

In the nonnuclear portion of the reactor, equipment will be inspected, tested, and sometimes modified or replaced as conditions dictate. A testing reactor is continually in a state of change as experiments and experimental programs are started, modified, or discontinued. Piping must be installed or rerouted, electrical services installed, and other utility systems modified as the experiment load fluctuates. Some of this work can be done with the reactor operating, but most tie-ins to existing systems have to be done during shutdown. These jobs must be accomplished in addition to the base plant modifications for improvement of reactor operation or safety.

Work on the experimental piping, equipment, or instrumentation is almost entirely limited to shutdown periods. The experimental loops are designed to operate the test specimens at their limits so almost no experimental equipment can safely be taken out of service with the reactor operating. The node diagram illustrates typical loop shutdown jobs such as ion exchange resin changeout, hot crud filter changeout, and wiring modifications.

In addition to the maintenance jobs, about 300 instrument setpoints require checking and resetting each shutdown.

It is the responsibility of each reactor engineer to be familiar with the job or jobs he is expected to accomplish each shift. Shift rotation schedules and shutdown node diagrams can be integrated so that a reactor engineer knows what is ahead. Normally, shift meetings will be held on the Saturday preceeding shutdown, and the shift supervisors and senior reactor engineers will review the shutdown schedule. Any out of the ordinary jobs will be discussed, and all questions about procedures or problems resolved. Once the shutdown begins, things can get rather hectic so a good idea of what is to be accomplished is essential. It is also the responsibility of each reactor engineer to clearly understand each job he is assigned. If the job procedure is unclear or he is at all unfamiliar with the system, he should ask the senior reactor engineer to clear up the details. Months may pass between the time a reactor engineer repeats a shutdown job, so review of flow sheets and wiring diagrams is always a good first step to any job. When the maintenance department personnel go to work on a system, they will assume the system is in a safe condition. The reactor engineer assigned to the job must ensure that it is safe.

CHAPTER V

PRIMARY COOLANT SYSTEM

A. SYSTEM DESCRIPTION

The ATR primary coolant system includes facilities for reactor heat removal, reduction of radioactivity in the reactor coolant, sealing water for pumps and reactor vessel penetrations, and reactor cooling water pH control.

The primary coolant system is a light water, medium pressure, low temperature, forced flow, closed loop constructed principally of stainless steel. Heat absorbed by the coolant flowing through the reactor core is transferred to the secondary coolant system in heat exchangers and dissipated to atmosphere in the cooling tower.

A simplified sketch of the reactor coolant flow path is shown on Figure 5-1.

The coolant is circulated by three primary pumps, and a fourth is maintained as a standby unit. The pumps discharge into a common 36-inch reactor supply line, through a remote operated flow control valve, and into two 24-inch reactor vessel inlet lines entering near the bottom of the vessel.

Figure 5-2 shows the flow path within the reactor vessel.

Coolant flows upward outside of the core reflector tank with approximately 95 percent directed around the thermal

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Fig. 5-1 Simplified primary coolant system.

Fig. 5-2 Reactor vessel coolant flow path.

shield between the inlet flow baffle and the vessel wall. The remainder passes upward between the reflector tank and the flow baffle.

Above the core, flow reverses to a downward direction, through the core area into the flow distribution tank.

The distribution tank is divided into four quadrants with an outlet line from each quadrant. The four outlets rise to above the core, exit from the vessel, and terminate into one 36-inch return line in the rod access corridor. Each outlet line is instrumented to measure flow and temperature rise to determine the portion of reactor power produced in each quadrant.

Reactor outlet coolant passes through five heat exchangers, having common supply and discharge headers, to the pump suction. Coolant temperature is controlled by varying the secondary flow through the heat exchangers.

System pressure is maintained by pumping a constant volume of makeup water into the circulating stream from a degassing tank and bleeding a varying amount back into the degassing tank. Excess gasses are removed by an air stream drawn through the degassing tank.

A surge tank is connected to the pump suction header and serves to dampen rapid pressure transients. The tank contains 95 percent water and 5 percent air when the system is operating at normal pressure and flow.

Two emergency pumps are provided, one normally operating, to ensure that the reactor will be adequately cooled during shutdown, flux runs, and upon failure of the main circulating pumps. One pump is driven by an ac motor that may be powered by either commercial or diesel power. The other pump is driven by a dc motor and battery bank, and will continue to operate if both commercial and diesel power are lost.

An 8-inch fire-water line is connected to the reactor vessel by four 2-inch lines through the bottom closure. Two self-operated valves in the 8-inch supply line are closed when the vessel water level is above the four outlet lines. Should the vessel level fall to the outlet lines, approximately four feet above the core, these valves open to supply sufficient water to ensure the fuel elements remain covered.

In order to maintain the reactor coolant free from impurities and to remove fission products following a fission break, a small side stream is circulated through the bypass demineralizer system.

A simplified sketch of the bypass demineralizer is shown in Figure 5-3.

The bypass demineralizer consists of two cation beds and two anion beds piped to provide flow through any combination of units. Supply to the units is taken just

Fig. 5-3 Bypass demineralizer.

downstream of the flow control valve. The effluent reenters the main circulating stream at the pump suction header.

Demineralizer supply may also be taken from the primary pump suction header through the pressurizing pumps. When the primary water is contaminated in excess of the disposal limit, the pressurizing pumps are used to route flush water through the bypass demineralizer before disposal to the MTR leaching pond.

Provisions are incorporated for regeneration of the anion units and for disposal of the cation resin.

The gland seal system provides a source of water for pump and vessel penetration seals, purging, and N_{16} monitoring. Two sources of supply and uses are provided: (a) fresh demineralized water and (b) reactor coolant drawn from the circulating stream. In general, fresh water is used where leakage to the reactor building atmosphere may release radioactivity, and reactor coolant is used for purging where external leakage is not expected. The two subsystems are known as primary seal water and warm seal water.

Figure 5-4 is a simplified sketch of the gland seal system.

Primary seal water is supplied and distributed by two pumps, one normally operating. To ensure that seal leakage will be seal water, rather than contaminated primary water, the seal water is regulated to different pressures dependent upon the usage. Seal water is supplied to several distribution stations throughout the building and to individual uses from the stations.

Warm seal water is also supplied and distributed by two pumps, one normally operating. The pumps draw suction from the primary pump suction header and supply several distribution stations. When the primary coolant system is shutdown, the warm seal pumps are shutdown and primary seal water is valved to supply the warm seal system.

Primary system pH is controlled by injection of nitric acid and/or by varying flow through the bypass demineralizer. Two positive displacement pumps, one normally operating, draw from an acid supply and discharge into the reactor return line. A pH recorder-controller

Fig. 5-4 Simplified gland seal system.

automatically adjusts the pump speed as required. Varying the portions of cation and anion flow also influences pH and reduces the amount of acid required.

B. CONTROLS AND INSTRUMENTS

Primary system flow, pressure, and tank water level measurements are achieved by using standard pneumatic ΔP cell, transmitters, and receivers. Except for main flow control, the process control valves are remote pneumatically operated, either automatically from a controller or from a manual control station. The valves may be either air-to-close or air-to-open, the selection based on fail-safe operation.

The main flow is controlled with a butterfly valve driven by an electric motor and gear case called a limitorque drive. The valve is remotely operated with a manual control station.

The system temperatures are measured with resistance temperature bulbs (RTD). Each temperature element is a group of four RTD's, one a spare,

inserted in thermowells. The transmitters and recorders are electronic.

Radioactivity within the coolant loop is monitored by a fission break monitor. A sample of the bypass cation effluent is routed through a small anion column to drain. The I-135 collected on the columns is monitored by a scintillation detector.

Ten N16 monitors are supplied demineralized water from the primary gland seal water pumps and discharged into the warm waste system. The monitors are inserted through the vessel bottom closure, eight in the beryllium surrounding the core and two into the center flux trap baffle. The outlet from each tube is monitored to indicate the relative flux or power level throughout the reactor.

C. OPERATION

During reactor shutdown, the vessel top closure is opened and the primary system placed in shutdown conditions. These conditions are (a) pressure reduced

to atmosphere, (b) flow provided by one emergency pump, and (c) the reactor vessel upper drain valve opened.

When operations require personnel to enter the reactor vessel, the water level is lowered to the lower drain line and emergency flow stopped.

Flux runs are conducted with the system in normal shutdown conditions with the exception that both emergency pumps are operated.

At completion of reactor shutdown and flux run, if scheduled, the vessel is closed, filled, and vented, and the primary system returned to operating conditions. Normal operating conditions are:

(1) System pressure 355 psig at the reactor inlet.

(2) Reactor pressure drop 100 psig giving a total flow of approximately 48,000 gpm.

(3) Pressurizing flow 200 gpm.

(4) Degassing flow approximately 270 gpm.

(5) Gland seal input approximately 70 gpm.

(6) Bypass demineralizer flow 200 gpm.

(7) pH 5-6.

(8) One emergency pump operating with 250 gpm recirculation flow.

(9) Reactor inlet temperature 125°F.

(10) Reactor outlet temperature 167°F.

Additional detail of the primary coolant system equipment and operating instructions are contained in the ATR Operating Manual, Chapter IV.

SECONDARY COOLANT SYSTEM

A. DESCRIPTION

Four secondary coolant pumps circulate secondary cooling water through the shell side of the primary heat exchangers to remove the reactor heat from the primary coolant system (see Figure 6-1). The heated secondary cooling water then flows over the cooling tower where the heat is dissipated to the atmosphere. The water then flows from the cooling tower basin to the coldwell and the secondary pump suction to complete the secondary coolant loop. Secondary coolant flow rate to the heat exchangers is adjusted by control valve TCV-1-10 to maintain a constant primary inlet water temperature to the reactor.

The cooling tower is equipped with six fans that can be operated at two speeds forward and one speed reverse. The heat removed from the secondary cooling water is controlled by adjusting the fan speeds to maintain the desired secondary coolant water temperature. The fans are periodically operated in reverse during cold weather to remove any ice accumulation from the cooling tower.

Secondary water losses due to evaporation and blowdown are compensated by makeup water pumped from the TRA raw water storage tanks. This makeup water and the circulating secondary cooling water are treated with sulfuric acid, Dianodic (Betz E-194), and chlorine to minimize piping corrosion, biological fouling of the cooling water, and chemical attack on the cooling tower wooden structure (see Figure 6-2). Solids are concentrated by evaporation of secondary cooling water in the cooling tower. A portion of the circulating secondary coolant is "blown down" to waste to control solids concentration.

Interconnection of the secondary and UCW systems is provided in two places. The systems are interconnected in the cooling tower pumphouse to provide secondary cooling water flow to the UCW system in case of mechanical or electrical failure of both UCW pumps. In the reactor building first basement, the two systems are interconnected through a line containing a flow control valve. This valve serves a dual purpose: (1) it opens to a preset stop during a commercial power failure to provide emergency flow of UCW to the secondary coolant system for removal of reactor decay heat and (2) the valve is positioned with a manual loader during low power reactor operation and flux mappings to provide the necessary controlled low flow rates of cooling water to the primary heat exchangers.

Radiation monitors are installed in the secondary coolant outlet line of each primary heat exchanger to detect leakage of radioactive primary coolant into the secondary coolant system.

For more detailed system descriptions and operating procedures see Volume 2 of the ATR Safety Analysis Report and Chapter V of the ATR Operating Manual.

B. OPERATION

1. Flow

Secondary cooling water is circulated through the secondary system by four, vertical turbine-type pumps rated at 8600 gpm and driven by 350 hp motors. The flow in the secondary system is controlled by air-operated butterfly valve TCV-1-10.

The flow of secondary water through the shell side of the heat exchangers is varied to regulate the amount of heat removed from the primary system, therefore maintaining a constant primary coolant reactor inlet temperature.

Temperature sensing element TE-1-10 measures the temperature of the primary coolant near the reactor inlet. This temperature signal goes to temperature controller TRC-1-10, which in turn positions control valve TCV-1-10 to maintain the desired primary coolant temperature. Control valve TCV-1-10 can also be regulated by a cascade control system that compares primary and secondary water power and primary inlet temperature, then sends a control signal to the valve.

2. Temperature

The temperature of the secondary water is controlled by regulating the air flow through the cooling tower. The operator adjusts fan speeds to maintain the desired secondary coolant temperature. The fans are controlled from push-button stations on the tower or in the process control room.

3. Emergency Flow

The secondary system acts as an emergency flow source for the UCW system. The connecting line between the two systems in the cooling tower pump-house contains check valve CK-D-2-7 that is normally held closed by the higher pressure of the UCW system (75 versus 63 psig). When the UCW system is shut-down or the pumps stop operating due to diesel electrical power failure, the secondary system pressure will open the check valve and approximately 2000 gpm of secondary cooling water will then flow through the UCW system.

All four secondary coolant pumps stop if there is a commercial power failure. To provide for removal of reactor decay heat, the secondary and UCW systems are interconnected in the reactor first basement. When commercial power fails,

control valve FCV-2-4 in this connecting line opens to a preset stop to allow 1500 gpm of utility cooling water flow to the shell side of the primary heat exchangers. This valve must be reset upon restoration of commercial power. Control valve FCV-2-4 can be positioned by manual loader FRML-2-4 to provide controlled flow rates up to 2000 gpm of utility cooling water to the secondary coolant system. This flow path is utilized for removal of primary coolant heat during low power runs and flux mapping.

4. Cooling Tower Blowdown and Makeup

The evaporation of the secondary water in the cooling tower results in an increasing concentration of solid materials in the secondary water. An equilibrium concentration of total solids at four times the solids concentration in the makeup water is accomplished by purging some of the high solid concentration water from the secondary system and replacing it and the evaporation losses with low solid concentration makeup water from the TRA raw water storage. Blowdown flow is regulated by positioning control valve FCV-2-2 with manual loader FRML-2-2. Makeup water is pumped to the coldwell by one of two cooling tower makeup pumps located in the MTR raw water pump-house. One pump will provide 2500 gpm, and this added to the 600 gpm discharged from the experimental cubicle air chillers provides sufficient makeup to overcome total evaporation and blowdown losses of approximately 2700 gpm when the reactor is operating at 250 MW. The makeup water flow from the cooling tower makeup pumps is regulated by LCV-2-1 to maintain a constant coldwell water level.

It would be inefficient and expensive to purge any more chemicals to the drain system than is necessary; yet chemical and hardness ion concentrations can get too high due to evaporation. Optimum operating conditions for the secondary system occur when the hardness ions are about four times more concentrated in the secondary water than in the raw makeup water. An operator determines

the total hardness concentration every four hours and adjusts the blowdown rate to maintain total hardness at four cycles or 600 to 840 ppm.

5. Water Treatment

The pH level and Dianodic (Betz E-194) concentration must be accurately maintained between set control limits to minimize piping corrosion and chemical attack on the cooling tower structure. Sulfuric acid is added by vertical positive displacement pumps with a capacity of 0 to 25 gph. The speed of the acid pump motor is automatically regulated by re-

corder-controller pH RCS-2-1 to maintain secondary coolant pH between 6.0 and 6.3. Dianodic injection into the secondary cooling water is accomplished with two 0 to 26 gph positive displacement pumps to maintain Dianodic concentration at 11 to 14 ppm.

Concentrated chlorine solution is added three times a week to the secondary coolant system to minimize biological fouling of the cooling water. The chlorine concentration in the circulating coolant is increased to and maintained at 1 ppm for four hours to ensure that all types of biological material are eliminated.

CHAPTER VII

SUPPLEMENTARY WATER SYSTEMS

A. UTILITY COOLING WATER SYSTEMS (UCW)

1. Description (See Figure 7-1)

The UCW system supplies treated water for cooling the HDW system, the diesel generators, and in some cases the primary system. The system uses the cooling tower basin as its source of water and the cooling tower to expell the absorbed heat. The system is designed to continuously supply 3050 gpm at 75 psig.

The UCW pumps take suction from the deepwell portion of the cooling tower coldwell and supplies 2050 gpm to the HDW heat exchangers and 500 gpm to each diesel generator system. Each line to the diesel generator system carries UCW in parallel through the tube side of the lube oil heat exchanger, 670-M-44 or -45, and the shell side of the combustion air cooler, 670-M-86 or -87. The two lines join and UCW flows through the tube side of the jacket water heat exchanger, 670-M-58 or -59, and into the system return header.

The supply line to the HDW heat exchangers carries UCW in series through the shell side of HDW heat exchanger, 670-M-33, and then the shell side of HDW heat exchanger, 670-M-34. The heated UCW is then returned to the secondary coolant system return header and then to the cooling tower.

A line connecting the secondary pump discharge header to the UCW pump discharge header provides a backup for a loss of the UCW pumps. The check valve in this line is normally held shut by the higher discharge pressure of the UCW pumps.

The UCW and SCS are also connected in the reactor building by a line containing flow control valve FCV-2-4. This

valve is used to control flow from the UCW to SCS during a commercial power outage or during reactor flux mapping.

The fire-water system provides backup for the UCW supply to the diesel engines. Flow control valve PCV-4-7 in the fire-water line is normally closed. This valve automatically opens on low UCW supply pressure to the diesels.

The UCW pumps are installed in the deepest section of the cooling tower coldwell. This location allows the use of these pumps for draining or pumping out the coldwell.

2. Operation

Under normal operation, one UCW pump will supply 3050 gpm to the UCW system. In the event of a running pump failure, the standby pump will automatically start.

On loss of diesel power and subsequent loss of the UCW pumps, the check valve between the secondary pumps discharge header and the UCW pumps discharge header will open. This will allow approximately 2000 gpm of secondary coolant water to serve the UCW system.

On loss of commercial power and subsequent loss of the secondary pumps, control valve FCV-2-4 opens automatically to a preset position to pass 1500 gpm of UCW to the primary heat exchangers for reactor decay heat removal. Control valve FCV-2-4 is also used during reactor flux mapping operations to remove reactor heat via the primary heat exchangers. A manual loader permits increasing or decreasing the flow quantity to the SCS during low power reactor operations. The flow of UCW to the HDW heat exchangers is 2050 gpm during normal operations. On loss of commercial power, this flow is automatically reduced to 1050 gpm by control valve FCV-4-5.

On complete loss of commercial and diesel power with loss of both secondary cooling and utility cooling water pumps and subsequent loss of UCW pressure, control valve PCV-4-7 opens to pass approximately 500 gpm fire water for emergency operation of one diesel engine.

In the event of an instrument air outage, FCV-2-4 will open to supply 1000 gpm to the secondary heat exchangers and FCV-4-5 will close reducing the UCW flow to the HDW heat exchangers to 1050 gpm.

3. References

ATR Operating Manual -- Section VI.

ATR Safety Analysis Report -- Section X-2.

B. HIGH PRESSURE DEMINERALIZED WATER SYSTEM (HDW)

1. Description (See Figure 7-2)

The HDW system is a pressurized demineralized water loop used for removing heat from the in-pile experiments and experiment auxiliary equipment. It is designed to supply a total flow of 1635 gpm at 200 psig. Since the loop is constructed of carbon steel (except for arsenical copper heat exchanger tubes), a sodium chromate corrosion inhibitor is injected into the system to minimize carbon steel corrosion.

Of the 1635 gpm discharged by the HDW circulation pumps, 575 gpm passes through the tube side of heat exchanger 670-M-34 to be cooled from 130 to 100°F by 85°F UCW on the shell side. This 100°F HDW supply is used to remove heat from the experimental loop canned rotor pumps and purification coolers. The remaining 1060 gpm of 130°F water is used to remove heat from the experimental loop heat exchangers. The HDW is discharged from the experimental heat exchangers at 196°F, and when mixed with the 120°F

HDW from the experimental loop equipment, the temperature of the combined flow is 170°F. The 170°F HDW is cooled to 130°F on the tube side of a second heat exchanger, 670-M-33, by 85°F UCW on the shell side. The HDW then flows to the suction of the circulation pumps to complete the circuit.

A 100 gallon carbon steel expansion tank is connected to the system at the pump suction and is used to accommodate system volume changes, dampen pressure surges, and maintain a constant 140 psig suction pressure to the circulation pumps.

The level in the expansion tank is automatically maintained by either adding 245 psig and seal water through LCV-7-2A or draining water through LCV-7-2B.

The HDW supply pressure is held constant by pressure control valve PCV-7-1 which controls bypass flow between the pump discharge and suction.

2. Operation

Under normal operation, one pump will be running on diesel power and the standby pump will be selected for commercial power. In the event of a diesel power failure or a running pump failure, the standby pump will automatically start on commercial power and continue to supply water to the HDW loop.

The chromate concentration in the loop is held between 700 and 800 ppm by periodically pumping concentrated sodium chromate solution into the system with a chemical feed pump.

In the event of an instrument air outage, all system components fail to the safe position and the system continues to supply water for cooling.

3. References

ATR Operation Manual -- Section VII

ATR Safety Analysis Report -- Section X-3

Fig. 7-1 Utility cooling water flow diagram.

C. LOW PRESSURE DEMINERALIZED WATER SYSTEM (LDW)

1. Description (See Figure 7-3)

Demineralized water for the Test Reactor Area is produced and distributed from demineralizer building MTR-608. The demineralized water system is comprised of three demineralizer trains with a combined capacity of 600 to 650 gpm, two 100,000 gallon water storage tanks, two 500 gpm water transfer pumps, and two 1000 gpm reactor flush pumps. Operation of this system is under the direction of the MTR Operations Branch.

Demineralized water received at the ATR is distributed throughout the plant as a supply of high purity water. The normal uses of LDW are: primary system flushing, primary system makeup, experimental system makeup, experimental system cooling, canal system filling and purging, underwater saw operation, reactor transfer tube operation, and as a source of purified water for the several process and sample laboratories.

2. Operation

During normal operation LDW to the ATR flows through the four-inch bypass line around FCV-8-68. This line will adequately supply an LDW flow of 300 gpm at 80 psig. When flow through the bypass exceeds 300 gpm, the building pressure will start to decrease. This in turn lowers the gland seal pump suction and discharge pressure and may effect the N-16 monitor and gland seal flows. Thus, for operation where the LDW flow to the building will exceed 300 gpm, FCV-8-68 is opened.

At the MTR demineralizer building, one 500 gpm demineralized water transfer pump will normally be running to supply LDW to MTR-ETR and ATR. On a low pressure signal, the second 500 gpm pump will start automatically. Thus, both pumps have a capacity of about 1000 gpm for all three plants. To exceed this 1000 gpm

flow, a 1000 gpm flush pump must be manually started.

3. References

ATR Operating Manual -- Section IX

ATR Safety Analysis Report -- Section VI-3

MTR Demineralizer Area Manual - IDO-16371-1

D. RAW, FIRE, AND DOMESTIC WATER SYSTEMS

1. Description (See Figure 7-4)

The Test Reactor Area raw water and fire-water systems supply a continuous flow of raw water to the various facilities for cooling tower makeup water, demineralizer plant raw water, miscellaneous cooling services, fire protection, and potable and domestic water services.

Raw water is drawn from three deepwells, located along the north perimeter of the TRA area, by three vertical turbine pumps which discharge into three 500,000 gallon ground level storage tanks. Water from the three 500,000 gallon tanks feeds six MTR-ETR feed water pumps, two fire pumps, and the two ATR cooling tower makeup pumps.

The MTR-ETR feed water pumps supply raw water to the 150,000 gallon raw water overhead reservoir, plant demineralizer, normal fire-water loop, and raw water distribution system. The ATR raw water supply taps the existing TRA raw water lines near the TRA demineralizer building.

The fire-water system, normally floating on the raw water overhead reservoir, is supplemented by the two fire pumps, one electric and one gasoline. One pump will automatically start in the event of a pressure drop in the

fire-water loop piping. The ATR fire-water loop taps the existing TRA fire loop east of the ATR reactor building.

Domestic or blended water is supplied from the TRA demineralizer building where raw water has been softened, stored in a 10,000 gallon storage tank, and pumped to the various distribution points by one of two blended water pumps.

2. Operation

a. Raw Water System

The following services are provided by the raw water system in the ATR area: bearing and stuffing box coolant for the primary coolant pumps and the primary pressurizing pumps; cooling water to various air conditioning units, air washers, and air handling units throughout the building; cooling water for the condensate heat exchanger; cooling water for the experimental loop surge tank level transmitter impulse lines; and a water supply for the rod access area sump eductors. Cooling tower makeup and the cooling tower chlorinator are also supplied by raw water.

b. Fire-Water System

ATR outside fire protection is afforded through a system of nine fire hydrants and five hose houses located strategically around the area in such a manner that each building is serviced by at least two hydrants.

Building protection is accomplished in three ways: fire-hose racks, six sprinkler systems servicing 16 areas of the building, and many portable extinguishers.

The ATR cooling tower is protected by a dry pipe, pressure actuated, deluge system and two fire-hose stations located on the top of the cooling tower.

Additional fire water is provided for utility cooling water emergency makeup and emergency fire-water supply to the reactor vessel.

The reactor spray system, for washing the air and walls of the reactor room, is also supplied from the ATR fire loop. The spray system is provided to wash the area of fission product contamination, especially iodine, which might result from a reactor accident.

c. Domestic Water System

Domestic water (potable, blended, or cold soft water) is supplied from common TRA facilities. Uses in the ATR building include laboratories, drinking fountains, toilets, showers, emergency showers, and diesel-generator jacket water makeup.

3. References

ATR Operating Manual -- Section VIII

ATR Safety Analysis Report -- Section XI.

Fig. 7-3 Low pressure demineralized water system flow diagram.

Fig. 7-4 Raw, fire, and domestic water systems flow diagram.

CHAPTER VIII

LIQUID WASTE SYSTEMS

A. UNCONTAMINATED WASTE

1. Description

Two classifications of uncontaminated liquid waste from the ATR are made. Water from the cooling tower blowdown and basin drain, heating and ventilating equipment, and transmitter impulse line cooling coils is designated as cold waste. This water flows by gravity to manhole 22C and then to the TRA disposal well.

Uncontaminated waste from the ATR sanitary facilities is designated as sanitary waste and flows by gravity to the TRA sewage treatment plant.

2. Reference Material

ATR Operating Manual, Section XIII

ATR Safety Analysis Report, Section XI-3

B. WARM WASTE SYSTEM

1. Description (see Figure 8-1)

The warm waste system provides drainage for radiologically warm liquids from various sources at the ATR. Included in these sources are the various types of building drains, canal drains, reactor tank drains, fission break and N_{16} monitor drains, and the overflow from the primary degassing tank. In addition, the rod access area sump eductors and the canal cleaning system pump discharge into this system.

Water entering the system from any of the above sources is routed by a series of risers and laterals to the 5000 gallon warm waste tank 670-M-28 where it passes

through a removable strainer and is then temporarily stored. The tank is located in the south cubicle under the motor floor area half way between the rod-access room and the second basement. It is vented to the cubicle exhaust plenum chamber through HVE-8; in this manner the system is maintained under a slight vacuum to prevent radioactive gas contamination of working areas.

Two vertical turbine pumps, 670-M-31 and -32, are mounted in the warm waste tank with the pump motors located above the tank shielding on the motor floor. Each pump has a capacity of 250 gpm, normally discharging to the TRA retention basin.

The warm waste tank level is controlled automatically, by a double track level system, over a predetermined range. Normal control is provided by a displacer-weight system. Level indication is provided by a bubbler system and is read on 0 to 100 percent gauges at process control panel "B" and at the motor floor area. In addition, this system provides the high and low level alarms and starts and stops the warm waste pumps should the displacer-weight control system fail.

Additional provisions are incorporated on the pump discharge piping for recirculation to the tank and for sampling.

The warm waste tank cubicle is equipped with an instrumented sump which alarms at a high level setting indicating leakage of the tank or the connecting piping.

All the piping leading to the warm waste tank and the tank itself are constructed of stainless steel. The pumps

are cast iron with steel column pipe, and the buried lines leading to the retention basin are ductile cast iron.

2. Operation

Control and selector switches for the warm waste pumps are located on process control panel "B". By preferring either 670-M-31 or M-32 using the selector switch and placing both pump control switches in the "auto" position, the preferred pump automatically maintains the warm waste tank level as governed by the displaced-weight type control system inside the tank. The nonpreferred pump will start at a slightly higher level in the event the preferred pump cannot maintain the desired level or if the preferred pump fails. Either or both pumps can also be operated manually from the process control panel. When operating in manual control, however, care must be used not to pump the tank down below minimum submergence for the pumps.

Sampling is performed by closing the pump discharge valves and manually operating a pump through the recirculation line to thoroughly mix the tank contents. The water sample is taken from the warm waste sample station on the motor floor area.

When necessary, the water collected by the rod access area sumps is removed by valving raw water to the sump eductors. Water in the sumps is removed by the venturi effect and discharged to the warm waste tank.

In general, all drains to the warm waste system not equipped with covers are trapped, preventing the escape of air activity. These drains with covers are kept closed when not in use, except for a select few which are left open to allow a passage of air down through the system and out the cubicle exhaust plenum. These specific drains are marked as to their function.

One of the warm waste pumps is

supplied by diesel power, the other commercial power. In the event of a loss of one power supply, the warm waste tank level will adequately be maintained by the alternate pump.

A loss of instrument air will cause an erroneous level indication; however, the displacer-weight level control is not dependent on instrument air and will maintain the proper tank level.

In an extreme case it is possible to exceed the removal capacity of both warm waste pumps, causing the tank to overflow. Contaminated water could back up into the vent line, flowing into the heating and ventilating ductwork and back filling the hot waste tank cubicle sump, causing a considerable spread of contamination. For this reason, when draining a large amount of water into the warm waste system, close surveillance of the tank level is mandatory and the draining rate kept within the limits of the pumps.

In addition to warm waste collections made in the warm waste tank, a sump pump in the heat exchanger vault sump discharges liquid waste into the 10-inch reactor flush line downstream of reactor flush valve GB-A-1-36. The sump pump, 670-M-100, operates automatically to keep the heat exchanger vault pit empty of water due to leakage on either the primary or secondary side of the heat exchangers. The sump pump is also used when draining the primary or secondary side of the heat exchangers.

3. Reference Material

ATR Operating Manual, Section XIII

ATR Safety Analysis Report, Section XI-3

C. HOT EXPERIMENTAL WASTE SYSTEM

1. Description (see Figure 8-1)

The hot experimental waste system

provides drainage for high activity radioactive waste from experimental sources. These sources include loop cubicle and sample area drains, loop header drains around the reactor vessel on the main floor, nozzle trench drain, and in-pile tube lower catcher pocket drains. Block valves admitting water to the system are closed except at the time of draining. The in-pile tube lower catcher pocket drains are provided with a common block valve between the drain and the hot waste tank which is also normally closed.

Lateral and riser piping carry the waste water to the 1000 gallon hot experimental waste tank 670-M-27. As the water enters the tank it passes through a removable strainer and is then stored. The tank, located in the north cubicle under the motor floor area, is also vented to the cubicle exhaust plenum through HVE-8, providing a slight vacuum on this system.

Two vertical turbine pumps, 670-M-29 and -30, are mounted in the hot experimental waste tank with the pump motors located above the tank shielding on the motor floor. Each pump has a capacity of 25 gpm. The pump discharge piping provides three flow routes, recirculation and sampling, to the TRA hot storage area or to the warm waste tank.

A bubbler system supplies level indication and high and low alarms for the hot experimental waste tank, with the level being controlled manually.

The hot experimental waste tank cubicle is equipped with an instrumented sump which alarms at a high level setting indicating leakage of the tank or connecting piping.

The system is constructed entirely of stainless steel.

2. Operation

As stated above, the hot experimental waste tank level is manually controlled. Prior to disposing of the contaminated water, a measurement of the activity

level must be made. The system is valved for recirculation and either of the pumps is run by placing its control switch on process control panel "B" to the "start" position. After the tank contents are thoroughly mixed, a sample is taken and the pump shut down. If the activity level of the sample is within the limits of the warm waste system, the hot waste is valved and pumped to the warm waste tank. Activity levels greater than the warm waste limits require the hot waste to be valved and pumped to the MTR hot waste storage. In either event, the hot experimental waste tank level, as the 0 to 100 percent gauge on process control panel "B" indicates, is closely watched to prevent pumping below the minimum submergence.

Before any drainage is made to the hot waste system, the tank level is checked and adjusted. Close observation of the tank level during draining is necessary to prevent overflowing through the vent line to the hot waste tank cubicle sump.

All drains to this system are covered when not in use with the exception of those drains designated to remain open to provide a passage of air down through the system and out the cubicle exhaust plenum.

One of the hot waste pumps is supplied by diesel power, the other by commercial power. During the loss of one of the power supplies a pump remains available for use as necessary.

Loss of instrument air will cause an erroneous level indication. All drainage to the hot waste system should be stopped during this time since the tank could overflow or, if pumping, the level could be lowered below the minimum submergence level of the pump.

3. Reference Material

ATR Operating Manual, Section XIII

ATR Safety Analysis Report, Section XI-3

CHAPTER IX

ELECTRICAL SYSTEMS

A. GENERAL DESCRIPTION

Electrical power for the National Reactor Testing Station is supplied from the Northwest Power Pool and is transmitted via the Goshen substation to the Scoville substation. From the Scoville substation a 132 kV loop is used to furnish power to the site substations. From Scoville the 132 kV loop extends to ICPP, TRA, NRF, TAN, EBR-II, and Spert substations and then returns to Scoville.

At the TRA substation, the 132 kV is reduced to 13,800 volts for distribution to MTR, ETR, and ATR. 13,800 volt commercial power is supplied to ATR and ETR from two 20,000 kVA 132/13.8 kV transformers. The ETR and the ATR share common terminals at each transformer; however, there are individual feeders to each plant.

The ATR electrical distribution facilities consist of five separate systems as follows:

Commercial Power

Diesel Power

Diesel-Commercial Power

Instrumentation AC Battery-Backed Power

Utility DC Power

Distribution voltages are shown in Table 9-1.

The electrical distribution systems are shown on the following one-line wiring diagrams located at the end of this chapter.

Figure 9-1 Main one-line wiring diagram.

Figure 9-2 Auxiliary one-line wiring diagram, sheet 1.

Figure 9-3 Auxiliary one-line wiring diagram, sheet 2.

Figure 9-4 250 volt dc and 120/208 V ac one-line diagram.

B. SYSTEM DESCRIPTION

1. Commercial Power System

TABLE 9-1

ELECTRICAL DISTRIBUTION VOLTAGES

<u>Voltage</u>	<u>Commercial</u>	<u>Diesel</u>	<u>Diesel-Commercial</u>	<u>Battery-Backed</u>	<u>Battery-Backed</u>
13,800 V ac -- 3 phase				ac	dc
4,160 V ac -- 3 phase	X	X			
480 V ac -- 3 phase	X	X	X		
120/208 V ac -- 1 and 3 phase	X		X	X	
250 V dc					X

a. 13,800 Volt System

From the secondary sides of two 132/13.8 kV transformers, 8T3-5 and -6, power is supplied to the 13,800 volt switch gear in building MTR-623. The 13,800 volt ATR switchgear consists of three air circuit breakers 5B3-7, -8, and -78. 5B3-7 is the circuit breaker to feeder A, and 5B3-8 is the breaker to feeder B. 5B3-78 is a tie breaker connecting the 13,800 volt feeders A and B. Breaker 5B3-78 is normally closed and will prevent an outage at ATR if one feeder breaker (5B3-7 or -8) should open. Breakers 5B3-7, -8 and -78 are normally operated, by supervisory control, from the CFA control house. These breakers may, however, be manually operated from the TRA control house (MTR-623).

From the 13,800 volt switchgear, power is supplied, by way of over-head and underground cables, to the primary side of 13,800/4160 volt transformers, 774-E-1 and -2. Feeder A (breaker 5B3-7) supplies transformer 774-E-1, and feeder B (breaker 5B3-8) supplies transformer 774-E-2.

There are sufficient protective relays on all the 13,800 volt feeders to protect the system from transformer or line faults.

b. 4160 Volt System

The secondary sides of the 13,800/4160 volt transformers, 774-E-1 and -2, are connected to the 4160 volt commercial bus sections A and B. Commercial bus section A (670-E-1) is supplied from transformer 774-E-1, and section B (670-E-2) is supplied from transformer 774-E-2. The 4160 V switchgear is located in the switchgear area first basement of the ATR reactor building, MTR-670.

A disconnecting switch, which is normally open, serves as a tie between the 4160 volt commercial bus sections A and B. This switch is not a circuit breaker and is not to be operated under load. The tie

switch will normally be locked, and operation will not be permitted without approval from the Reactor Shift Supervisor.

From the two sections of the switchgear, power is distributed at 4160 volts. Each section of the switchgear, ie, A and B, includes main circuit breakers for the control of feeders to motors rated at 150 hp and above and to the 4160/480 volt transformers which feed the 480 volt commercial buses.

To minimize electrical equipment outages, similar loads are divided between the two buses. Power is supplied from the two bus sections as follows:

Commercial Bus A (670-E-1)

Primary Coolant Pumps 670-M-8 and -9

Secondary Coolant Pumps 671-M-3 and -4

No. 4 Deepwell Pump 672-M-1

4160/480 V Transformer 670-E-4

Commercial Bus B (670-E-2)

Primary Coolant Pumps 670-M-6 and -7

Secondary Coolant Pumps 671-M-1 and -2

4160/480 V Transformer 671-E-1

4160/480 V Transformer 670-E-6

All the 4160 volt switchgear circuit breakers are electrically operated, using 250 V dc power which is supplied from the utility dc power system. Operation of feeder circuit breakers to motor loads is from some remote control point such as the PCP. Operation of the breakers for the 4160/480 volt transformer feeders is from a local switch at the switchgear.

There are sufficient protective relays on all the 4160 volt feeders to protect the operating equipment from under voltage and overcurrent. There are also protective relays on the transformers and incoming buses to protect the system in the event of transformer or line faults.

c. 480 Volt System

The secondary sides of transformers 670-E-4, -6, and 671-E-1 are, respectively, connected to the 480 volt commercial bus A (670-E-5), 480 volt commercial bus B (670-E-7), and the 480 commercial cooling tower bus (671-E-2).

Power is distributed from the three 480 volt commercial bus sections for use throughout the plant. The 480 volt bus sections, A and B, are located in the switchgear area of the first basement. The cooling tower section is located in the cooling tower pumphouse.

Each section of the switchgear includes main circuit breakers for the control of feeders to motors rated at 60 to 125 hp, to motor control centers, and to experimenters power panels.

The 480 volt switchgear is electrically operated. The power for operation is 250 V dc supplied from the utility power system. The breakers for all motor loads are operated from remote control switches located at the various control panels such as the PCP. The feeders to the motor control centers are locally operated at the switchgear.

There are four 480 V commercial motor control centers located throughout the plant. The motor control centers include manually operated main air circuit breakers and electrically operated magnetic contactors. The air circuit breakers control feeders to lighting transformers, power recepticals, cranes, and similar circuits not requiring remote electrical control. The magnetic contactors are for the control of motors up to 50 hp.

d. 120/208 Volt Commercial Power Lighting Distribution

From the 480 volt motor control centers, power is distributed to 16 lighting transformers which reduce the voltage to 120/208 volts. Power is supplied from the transformers to 17 lighting panels. The distribution panels include manually operated air circuit breakers for controlling feeders to the lighting circuits. The panels are located throughout the buildings at convenient local control points.

In general, one section of each lighting panel is fed from a transformer associated with the 480 volt commercial motor control centers, and one section is fed from a 120/208 volt diesel-commercial distribution panel.

2. Diesel Power System

a. Diesel Generators

To supply a source of power which is independent of commercial power, two diesel driven generators have been installed. The loads from the diesel bus have been selected so that important plant loads will be operated from or will be automatically transferred to the diesel power system in the event of a commercial power outage. One diesel generator will run continuously while the other unit will be on standby. All ATR and experiment pumps, heaters, and ventilation equipment necessary for safe reactor shutdown on loss of commercial power are operated from or will be transferred to the diesel bus.

The diesel generators have a capacity of 1875 kVA at 0.8 power factor (1500 kW), 4160 volts, 60 cycle, 3 phase.

The diesel engines are started by injecting high pressure air into the cylinders. This high pressure air is supplied by two air compressors which are located in the auxiliary equipment room of the second basement. The diesel fuel

for the units is supplied from the TRA diesel fuel storage tanks which are located at the site tank farm northeast of the ATR. A diesel fuel day tank is located north of the ATR building, and fuel is supplied to it from the TRA tank farm. The oil level in the day tank is controlled by an automatic controller which will start and stop the fuel oil transfer pumps as necessary.

The diesel engines are manually started and stopped. If for any reason the running unit should stop, it will be necessary to start the standby unit, as automatic starting is not available.

The diesel engines are cooled by potable water in a closed loop system. The closed loop system consists of circulating pumps, surge tank, and heat exchangers. The potable water is circulated through the tube side of the heat exchanger, and UCW is circulated on the shell side of the exchanger. In the event of a UCW outage, fire water may be used on the shell side of the heat exchanger.

b. 4160 Volt Distribution

The 4160 volt diesel bus consists of one section of 4160 volt switchgear which is located in the switchgear area of the first basement. The switchgear includes the following items:

- (1) Generator main circuit breakers
- (2) Generator and excitation control equipment
- (3) Main Circuit breakers for the control of feeders
- (4) A spare main circuit breaker position.

Energized from the 4160 volt diesel bus is the utility cooling water pumps 671-M-5 and -6 and the 4160/480 volt transformer 670-E-8.

It is possible to put a breaker into the spare position and energize the diesel

bus from the 4160 volt commercial bus B. This, however, is not considered good operating practice as the system does not have sufficient protective devices. At some later date, the system may be redesigned and protective devices installed so that operation with the diesel bus energized from the commercial power source will be permissible.

c. 480 Volt Distribution

The 480 volt diesel bus (670-E-9) is fed from the secondary side of the 4160/480 volt transformer (670-E-8). From the diesel switchgear (670-E-9), which is located in the switchgear area of the first basement, power is distributed at 480 volts.

The switchgear includes main air circuit breakers for control of feeders to motors rated at 60 to 125 hp, to diesel motor control centers, to experimenters power panels, and to the diesel-commercial motor control center.

There are two motor control centers designated as 480 volt diesel motor control centers A and B. The motor control centers include manually operated main air circuit breakers to reactor bridge crane and personnel elevator which have self-contained starting controls. The magnetic contactors are for the control of motors rated up to 50 hp.

3. Diesel-Commercial System

a. 480 Volt Diesel-Commercial Motor Control Center (670-E-15)

The diesel-commercial motor control center may be energized from either the 480 volt diesel bus (670-E-9) or the 480 volt commercial bus B (670-E-7). The normal source of power, however, is the 480 volt diesel bus. If a diesel power outage should occur, the source of power will automatically be transferred to the commercial bus. When diesel power has been restored, the motor control center will automatically be transferred back to the diesel bus. The 480 volt diesel and

commercial feeder breakers are electrically interlocked so that it is impossible to have both breakers closed at the same time.

The purpose of the diesel-commercial system is to have a very reliable source of power available for certain important plant loads. The following are energized from the 480 volt diesel-commercial motor control center:

(1) Regulating rod amplidyne motor generators

(2) Transformer for reactor control rod drives

(3) Transformers for lighting distribution panels

(4) 480 volt experimenters power panels

(5) Primary emergency coolant pump and warm seal water booster pumps

(6) Diesel engine auxiliary equipment.

b. 120/208 Volt Distribution

Power at 120/208 volts is distributed from four panels designated as 120/208 volt diesel-commercial distribution panels.

Each panel includes manually operated air circuit breakers for control of feeders to lighting panels, reactor and process control panels, data processing system, and communication and alarm panels.

4. Instrumentation AC Battery-Backed Power System

In the operation of a nuclear reactor, it is mandatory that power be available for reactor instrumentation and control. The instrumentation ac battery-backed power supply will supply power for nuclear instrumentation and emergency shim drive insertion. The emergency shim insert

bus is actuated upon loss of the normal power source, ie, the diesel-commercial power. The instrumentation ac battery-backed power system can supply power for approximately 50 minutes after all other power sources are lost. This ensures safe reactor shutdown in the event of unforeseen power outages.

The instrumentation ac battery-backed power system consists of two motor generators (the instrumentation dc power MG set 670-E-25 and the instrumentation ac power inverter MG set 670-E-27); a 120-cell, 250-volt battery bank; a standby transformer; and the necessary control panels.

The instrumentation ac power motor generator (hereafter referred to as dc-ac MG set) is a dc motor driving an ac generator. The instrumentation dc power motor generator (hereafter referred to as ac-dc MG set) is an ac motor driving a dc generator.

The dc-ac MG set will normally supply power at 120/208 volts, 60 cps, 3 phase to the following:

(1) Reactor control instrumentation and protection

(2) Data system electronics

(3) Shim motor drive emergency insert bus.

The ac generator 120/280 voltage and frequency output is closely regulated as is required for instrumentation power.

The dc motor of the dc-ac MG set is energized from the dc generator of the ac-dc MG set and battery bank 670-E-59. The ac motor of the ac-dc MG set is energized from the 480 volt diesel bus.

During normal operation, the ac-dc MG set will be supplying power to the dc-ac MG set and simultaneously float charging the 250 volt battery bank.

In the event of a diesel power outage, the ac-dc MG set will stop. The dc-ac MG set will continue to run, being supplied power from the battery bank.

The batteries will, of course, be discharged during the diesel power outage; and it will be necessary to recharge them after restoration of power. The batteries are recharged by increasing the generated voltage of the ac-dc MG set. It will be necessary to shut down the dc-ac MG set during recharge.

When the dc-ac MG set is shut-down, it is possible to supply power for reactor control and instrumentation from the standby transformer. This transformer is energized from the 480 volt commercial bus. The standby transformer is not a reliable source of power for reactor control and will, therefore, not be used during reactor operation.

5. Utility DC Power System

The purpose of the utility dc power system is twofold. First, it supplies power at 250 volts dc for operation of the dc primary emergency coolant pump 670-M-11; and secondly, it supplies power at 250 volts dc for switchgear operation.

The utility dc power system consists of the utility motor generator, a 120-

cell, 250-volt battery bank, and the necessary control panels.

The utility motor generator is an ac motor driving a dc generator. The ac motor is energized from the 480 volt diesel bus. The 250 volt dc output of the generator is used for switchgear operation, charging the battery bank, and operation of the dc primary emergency coolant pump.

During normal operation, the utility dc motor generator will be supplying power at 250 volts dc for switchgear operation and dc primary emergency coolant pump operation and simultaneously float charging the battery bank. In the event of a diesel power outage, the motor generator will stop. Power will, however, be available from the battery bank for switchgear operation and for operation of the emergency coolant pump. The batteries are capable of operating the dc primary emergency coolant pump for approximately one hour.

After a diesel power outage, it may be necessary to recharge the batteries. This will depend on the length of the outage and the equipment that was operated.

If more detail on the ATR electrical system is desired, refer to Chapter 15 of the ATR Operating Manual and the ATR Safety Analysis Report, Chapter 9.

CHAPTER X

HEATING AND VENTILATING SYSTEMS

A. DESCRIPTION

The ATR building ventilation system is sectionalized, and the individual systems are independent of each other, with certain specific areas being secured by the radiation monitoring system. For all practical purposes, the flow of air is from a clean to a potentially contaminated area to exhaust. (See Figure 10-1.)

Instruments are located throughout the building and throughout the exhaust system to sense radioactivity in the heating and ventilation system. This system is known as the "radiation monitoring system" (RMS). The RMS is interlocked with the H and V system and, depending on activity or radiation, isolates the various systems or the entire system.

The main reactor floor and the first and second basements are considered gas-tight areas and are served by three units: a supply unit, a main exhaust system, and roof ventilators. The supply systems close automatically on high radioactive signal; the exhaust system and roof ventilators are also interlocked with the RMS to prevent discharge of high activity to atmosphere. All duct work which passes through fire walls or through floors incorporates dampers at the point of penetration to ensure closure and prevent carry-over of contaminated air or smoke in case of fire.

The various areas are provided with auxiliary exhaust systems which generally are utilized in the summer to relieve the 100 percent outside air supply. Some of the systems are utilized the entire year when servicing rest rooms, locker rooms, and hooded connections. These systems use roof ventilators or blowers to exhaust to atmosphere.

The heating system design is based on a winter ambient temperature of minus 20°F. Steam is supplied from the MTR steam plant at 125 psig and reduced at ATR to 30 psig. All steam condensate from the heating systems is collected and returned to the steam plant. In winter 20 to 80 percent of the air is recirculated to conserve heat; in summer when the outside temperature is 60°F or above, recirculated air is reduced to approximately zero.

The counting room, reactor control room, and the process control room each have a self-contained air conditioning unit that regulates the temperature at 72°F winter and summer.

The cubicles, subpile room, and the rod access room each have coolers with circulating fans to maintain a space temperature of approximately 74°F. Well water is used as a coolant, and the units operate winter and summer. These systems recirculate the air within the cubicle or room and are independent of the heating and ventilation systems.

A graphic representation of each piece of equipment and system is provided on the control panels located at three different areas.

B. SYSTEMS

1. System Number 1

System number 1 (HVS-1) commonly called the gastight area, consists of the main reactor floor, the outer shim rod drive service area, safety rod drive service area, piping corridor, and the main building first and second basements area. Normal air flow through this system is

Fig. 10-1 Reactor building H and V schematic diagram.

64,800 cfm which is approximately 6 changes of air per hour for the main floor and 4 changes of air per hour for the first and second basements.

This area may be partly isolated or the entire area sealed off due to high radiation and/or air activity depending on the severity as controlled by the RMS relays Nos. 1 and 2.

During summer operations, the air supply is drawn in from outside through filters, air washer, and regulating dampers. During the winter, approximately 80 percent of the supply is outside air and 20 percent is recirculated. The air passes through filters, regulating dampers, and a double bank of steam heating coils designed to maintain a space temperature of 72°F.

Additional equipment for this system consists of:

(1) Roof ventilator HVR-1 exhausts 10,000 cfm of air from the reactor main floor during the summer and is normally shut down in winter.

(2) Exhaust fan HVE-1A or -1B draws 15,000 cfm from the reactor main floor and discharges it through duct work to either the primary heat exchanger area, during normal operation, or to the main exhaust plenum on a RMS No. 2 shutdown.

(3) Exhaust fan HVE-22 is used as a transfer fan to move 25,000 cfm from the primary pump motor area to the primary heat exchanger area to improve primary pump motor ventilation.

(4) Exhaust fan HVE-3A and -3B draws 15,000 cfm from the second basement and discharges it through duct work to the primary pump motor area.

(5) Exhaust fan HVE-2 is used to move 10,000 cfm of air from the first to the second basement.

(6) Exhaust fans HVE-5 and -6 each draw 5000 cfm of air from the first and second basements through the cubicles and discharge into the main exhaust plenum.

(7) Exhaust fan HVE-16 draws 2800 cfm of air from the pipe corridor and discharges it into the main exhaust plenum.

(8) Exhaust fan HVE-7 draws 10,000 cfm of air from the reactor annulies and discharges into the main exhaust plenum.

(9) Exhaust fan HVE-8 draws 1000 cfm of air from the waste tank area, subpile, and rod access rooms and discharges into the main exhaust plenum.

(10) Exhaust fan HVE-18 draws 150 cfm from the degassing tank and discharges into the main exhaust plenum.

(11) Exhaust fan HVE-4 draws 39,850 cfm of air from the primary heat exchanger area during normal operation and discharges into the main exhaust plenum. During an RMS No. 2 shutdown, HVE-4, HVE-1A, or -1B exhaust air from the reactor operating area to the main exhaust plenum.

(12) Exhaust fan HVE-17A and -17B exhaust 64,800 cfm of air from the main exhaust plenum to the stack.

(13) Chiller units HVH-3 through -9 are rated for 1000 cfm of air each and are located in the cubicles. Each unit recirculates the air within its cubicle and cools the air from 95 and 74°F using well water as a coolant. The well water is discharged to the cooling tower basin or to the leaching pond via MTR.

(14) Chiller unit HVH-10 is rated for 2400 cfm of air and is located in the subpile room. The unit recirculates the air within the room and cools the air from 95 to 74°F using well water as a coolant.

(15) Chiller unit HVH-11 is rated for 1500 cfm of air and is located in the rod access room. The unit recirculates the air within the room and cools the air from 95 to 77°F using well water as a coolant.

(16) This system operates from the graphic panel located in the utility area south of the diesel-generators.

2. System Number 2

System number 2 (HVS-2) services the critical facility area which includes the critical facility reactor floor, office area, rest rooms, hallways, storage room, and sample preparation laboratory. Normal air flow through this system is 12,500 cfm which is approximately four changes of air per hour. This system does not tie-in with the gastight area.

During summer operation, the air supply is drawn in from the outside through filters and regulating dampers. During the winter, approximately 14 percent of the supply is outside air and 86 percent is recirculated. The air passes through filters, dampers, and a single bank of steam heating coils designed to maintain a space temperature of 72°F.

Additional equipment for this system consists of:

(1) Exhaust fan HVE-11 which exhausts 1650 cfm of air from the rest rooms, winter and summer.

(2) Exhaust fan HVE-15 exhausts 900 cfm of air from the sample preparation laboratory, winter and summer.

(3) Roof ventilator fan HVR-2 exhausts 10,700 cfm of return air to atmosphere in summer, and is normally shut down in winter.

This system operates from the graphic panel board located on the ATRC main floor.

3. System Number 3

System number 3 (HVS-3) services the storage canal area, the general storage and laydown area, and the hood over the primary acid addition system. Normal air flow through the system is 23,500 cfm which is approximately 4 changes of air per hour. This system does not tie into the gastight area.

During summer operations, the air supply is drawn in from the outside through a filter and regulating dampers. During the winter, approximately 32 percent of the supply is outside air and 68 percent is recirculated. The air passes through filters, dampers, and a single bank of steam heating coils designed to maintain a space temperature of 72°F.

Additional equipment for this system consists of:

(1) Exhaust fan HVE-19 which exhausts 1350 cfm of air from the hood over primary acid addition system.

(2) Gravity roof ventilator HVG-1 exhausts 6150 cfm of air to atmosphere.

(3) Two roof ventilator fans HVR-3 and -4 exhaust 16,000 cfm of air to atmosphere in summer and are shut down in winter. These fans are located over the canal.

This system operates from the graphic panel located on the east balcony over the canal area.

4. System Number 4

System number four (HVS-4) services the 2nd floor offices, the rest rooms, and the office spaces on the 1st floor. Normal air flow through this system is 13,500 cfm which is approximately 10 changes per hour for the offices, 15 changes in the rest rooms, and 4 changes per hour in the utility areas.

The reactor shift supervisors office, corridor, and office number 110 are supplied with air from system four; the reactor control room is supplied by air-conditioning system No. 2. Office 110 is part of the gastight area and is equipped with dampers to separate the two systems in case of RMS shutdown.

During summer operation, the air supply is drawn in from the outside through filters and regulating dampers. During the winter, approximately 25 percent of the supply is outside air and 75 percent is recirculated. The air passes through filters, dampers, and a single bank of steam heating coils designed to maintain a space temperature of 72°F.

Additional equipment for this system consists of:

(1) Exhaust fan HVR-8 exhausts 4100 cfm of air from the rest rooms winter and summer.

(2) Exhaust fan HVE-14 exhausts 750 cfm of air from the hood in the utility room (Health Physics shift office), winter and summer.

(3) Exhaust fan HVE-12 is normally shut down in winter and exhausts 10,050 cfm of return air to atmosphere in summer.

This system operates from the graphic panel located on east balcony over the canal area.

5. System Number 5

System number 5 (HVS-5) services the first and second basement (north side), the battery room, primary pump motor area, and the diesel generator room and adjacent utility space. Normal air flow through this system is 79,250 cfm which is approximately 4 changes of air per hour.

The first and second basements are part of the gastight area, and a butterfly damper will isolate these areas. The dam-

per is controlled by RMS, which closes the damper on high radiation signal, and seals the basements.

During summer operations, the air supply is drawn in from the outside through filters, an air washer, and regulating dampers. During the winter, approximately 22 percent of the air supply is outside air and 78 percent is recirculated. The air passes through filters, dampers, and a single bank of steam heating coils designed to maintain a space temperature of 60°F. In addition, a 5 kW electrical reheat coil is located in the branch duct to the utility offices and is designed to maintain a space temperature of 70°F.

Additional equipment for this system consists of:

(1) Three roof ventilator fans, HVR-5, -6, and -7, which are located over the diesel-generator pit. Normally these fans will not operate in winter. In summer, these fans exhaust a total of 41,000 cfm of air.

(2) Exhaust fan HVE-10 which is normally shut down in winter exhausts 18,500 cfm of return air to atmosphere in summer.

(3) Exhaust fan HVE-13 exhausts 2060 cfm of air, winter and summer, and services the tool room, the water laboratory, mens' rest room, utility office, and the north stairway.

(4) Exhaust fan HVE-9 exhausts 2000 cfm of air from the first basement battery room, winter and summer.

This system operates from the graphic panel located in the utility area south of the diesel-generator pit.

6. Auxiliary Systems

a. Critical Facility Counting Room Air Treatment System

Air Treatment System (HVA-1) supplies 5050 cfm of treated air to the

critical facility counting room, winter and summer. The unit recirculates 80 percent of the air and uses 20 percent outside air. 750 cfm of air from the counting room is discharged into the sample preparation laboratory.

The unit is a self-contained, 10-ton unit with supply fan, damper, air filter, steam coil, cooling coil, and two Freon compressors designed to maintain a space temperature of 72°F.

b. Reactor Control Room Air Treatment System

Air Treatment System (HVA-2) supplies 7000 cfm of treated air to the computer room, instrument repair room, and reactor control and instrument room, winter and summer. The unit recirculates 80 percent of the air and uses 20 percent outside air. The reactor control and instrument room is provided with a relief duct to office No. 110 with an RMS-operated butterfly damper, since office No. 110 is not part of the gastight area.

The unit is a self-contained, 20-ton unit with additional electrical reheat coils in the branch ducts to the computer room and instrument repair room. The unit is equipped with supply fan, dampers, air filter, steam coil, cooling coil, and two Freon compressors to maintain a space temperature of 72°F.

c. Process Utility Control Room Air Treatment System

Air Treatment System (HVA-3) supplies 2800 cfm of treated air to the process control room, winter and summer. The unit recirculates 80 percent of the air and uses 20 percent outside air. Discharge of air from this system is over the stairway west of the control room.

The unit is a self-contained, 7-1/2-ton unit with supply fan, dampers, air filter, steam coil, cooling coil, and one Freon compressor designed to maintain a space temperature of 72°F.

d. Heating and Ventilation System for the Cooling Tower Pump House

Ventilation is by two roof exhaust fans rated at 25,500 cfm. When the fans are manually started, two motor-operated dampers open to allow outside air to enter the building. Heat is furnished by three steam-operated space heaters rated at 221,000 Btu/hr and are thermostat controlled. The chlorine room, which is sealed off from the main pump house, is ventilated by a roof exhaust fan rated at 450 cfm.

e. Steam Condensate System

System HVP-1 collects steam condensate from the reactor building and the cooling tower pump house, and returns the condensate to MTR-609 for reuse.

C. OPERATIONS

1. Normal Operations

Each system can be operated manually or automatically from its individual graphic panel.

Steam coils are used for heating the air just after the air enters the building plenum. The air temperature is controlled by thermostats which are located in the individual areas. The steam coils are protected against freeze-up by a thermostat locally mounted which overrides the room thermostat.

The dampers are all operated by spring return air cylinders except the main exhaust damper near the stack which has a double-acting air cylinder. All dampers close when the air pressure drops to 100 psig; normal air pressure is 125 psig. When an RMS actuates, a three-way solenoid valve is de-energized venting the cylinder air pressure, and the return spring closes the damper. Upon resetting the RMS, the solenoid valve is energized and the damper opens. In addition to automatic operation, the dampers may be

opened manually. A small air tank is pressurized by instrument air and connected to the air cylinder through a manual three-way valve. The damper may be opened manually by this valve at any time.

Flow of air through the H and V system has been balanced; to maintain this balance, all doors leading from one system to another must be closed. Unless unforeseen changes are made to the systems, the louver and damper setting should not be changed from their present setting. Balancing the system requires many man-hours of work.

After loss of power or following an RMS shutdown, the H and V system must be restarted manually from their respective panels.

2. Abnormal Operations

The radiation monitoring system (RMS) has the function of isolating the various gastight areas and adjacent areas in case of high radiation level and/or air activity.

An RMS No. 1 shutdown stops all supply fans and exhaust blowers and closes all dampers in the air ducts to completely seal off the entire gastight area from the adjacent areas. An RMS No. 1 shutdown is actuated by a signal from a monitor located by the pneumatic-operated damper at the base of the exhaust stack, or by a monitor at the exhaust plenum.

An RMS No. 2 shutdown stops the gastight area supply fans, selected transfer fans, and closes dampers to isolate the gastight area from adjacent areas. Essentially, an RMS No. 2 shutdown allows the reactor gastight area to be vented to the stack. Since the gastight area will be under a slight vacuum and the adjacent area under a slight pressure, leakage between areas will be inward. An RMS No. 2 shutdown is actuated from one of several monitors located on the main reactor floor or in the 1st or 2nd basements.

An RMS No. 3 shutdown stops all supply fans and exhaust fans, and closes all dampers to isolate the critical facility area. No other areas are affected by this shutdown. An RMS No. 3 shutdown is actuated from one of several monitors located in the critical facility area.

An RMS No. 4 shutdown stops all supply fans and exhaust fans and closes all dampers to isolate the canal and lay-down area. No other areas are affected by this shutdown. An RMS No. 4 shutdown is actuated from one of several monitors located in the canal and lay-down areas.

3. Emergency Operations

Forced evacuation of the building may be accompanied by a loss of commercial power or diesel power or both. The "emergency electrical diesel generator start-up panel" (ESP) provides a remote means for reactivating a diesel generator and connecting it to the diesel bus for restoration of essential services.

Both main and field breakers for either diesel generator may be activated from the panel which will bypass all radiation monitoring system interlocks. The following equipment may be manually activated from this panel.

(1) Utility cooling water pump	671-M-5
(2) Utility cooling water pump	671-M-6
(3) Instrument dc-MG set	670-E-25
(4) Utility dc-MG set	670-E-22
(5) Primary pump motor area
transfer fan	670-HVE-3B
(6) Utility area supply fan	670-HVS-5
(7) Main exhaust fan	670-HVE-17B
(8) Reactor area supply fan	670-HVS-1
(9) Reactor area supply
exhaust fan	670-HVE-1B

CHAPTER XI

RADIATION PROTECTION AND MONITORING

A. SHIELDING

1. General Description

The ATR shielding is designed for a maximum dose rate of 0.25 mrem/hr in full-time occupancy locations. The principal reactor biological shielding consists of ordinary concrete supplemented by three feet of high density concrete opposite the core region and special inserts of lead, steel, and polyethylene in certain locations. The shielding walls of the experimental cubicles consist primarily of high density concrete. The canal walls and floor are composed of ordinary concrete.

2. Reactor Vessel

a. Nozzle Trench

The shielding around the vessel in the nozzle trench area is designed to restrict the general radiation level in the trench to 12.5 mrem/hr or less, three hours after shutdown. No access is allowed in the nozzle trench during operation. The shielding consists of the two-inch-thick vessel support skirt which surrounds the pressure vessel and extends from the floor of the capsule trench to the four-inch vessel wall section.

b. Top-Head Shield

The concrete in the working platform is 12 inches thick and is designed to restrict the dose rate at its upper surface to 1.0 mrem/hr or less during normal full power operation. The shield cylinder is sized to restrict the transient dose rate during specimen transfer to 1 rem/hr or less at the shield surface. The cylinder shielding is composed of three inches of steel and nine inches of lead. During operation, the dose rate at the shield cylinder surface is computed to be less than 1.0 mrem/hr. The design of the loop transfer

shield plate is based on the same criteria as those for the shield cylinder, and results in a shielding thickness of 15 inches of steel. The top-head ring shield is composed of four inches of lead, two inches of steel, and is designed to reduce the dose rate around the top-head area to less than 1.0 mrem/hr during normal full power operation.

c. Primary Biological Shield

The reactor vessel is surrounded by a composite shield which includes three feet of high-density magnetite concrete, two and one-half feet of structural concrete, and five and one-half feet of ordinary concrete. The concrete completely surrounds the vessel except in the area shielded by the working canal water. One hour after shutdown, the dose rate in the piping corridor from sources within the reactor vessel is calculated to be less than 1 mrem/hr. A three-foot thickness of magnetite concrete shielding separates the nozzle trench from the reactor floor area.

The pipe corridor, which contains the primary and test loop piping, separates the 2.5-foot-thick and 5.5-foot-thick sections of primary shield. At full power, the dose rate from N-16 at the outer surface of this shield is calculated to be 6 mrem/hr. The dose rate from the operating core is negligible.

3. Primary System Shielding

a. Coolant Loop Shielding

The primary coolant piping is shielded by a minimum of five and one-half feet of ordinary concrete. The maximum dose rate at the outer surface of this shield is calculated to be 6 mrem/hr. The walls around the heat exchanger room are of the same dimensions with a maximum dose rate of 6 mrem/hr at the outer shield

surface. The floor above the heat exchanger room is six feet of ordinary concrete. The maximum dose rate at the floor surface is computed to be 1.5 mrem/hr.

b. Primary Pump Cubicles

The wall between the pump cubicles and heat exchanger area is five and one half feet of ordinary concrete. This reduces the radiation level from sources in the heat exchanger room to 2.5 mrem/hr in the pump cubicle. The walls between the pump cubicles are four feet thick and the calculated dose rate in any cubicle from an adjacent cubicle is 7 mrem/hr. The exterior walls of the pump cubicles are also four feet thick with a resulting dose rate of 7 mrem/hr in the motor area.

4. Subpile and Rod Access Rooms

The subpile room is shielded from the core by 10 feet of water in the reactor vessel and by the one-foot-thick vessel bottom head. One hour after shutdown, the dose rate from the core through this shielding is computed to be less than 1 mrem/hr. The wall between the working canal and the subpile room consists of four feet of ordinary concrete. This wall is designed to limit the dose rate from a spent fuel element stored in the deep end of the canal to 7.5 mrem/hr in the subpile room. The steel door in the subpile room is 10 inches thick and is sized for a dose rate outside the door of 2.5 mrem/hr.

Three feet of concrete, four inches of steel, and six inches of polyethylene shield the rod access room from the core radiation and from N-16 in the test loops. Dose rates from these sources were computed to be less than 2 mrem/hr in the rod access room during full power operation. Where the test loop traps and exit piping are imbedded in the subpile room floor, the concrete is replaced by 6.5 inches of lead below the piping and 7.5 inches below the trap. The polyethylene is required below the lead and steel to ensure adequate attenuation of

the neutrons from N-16 in the test loop coolant. The magnetite concrete wall between the piping corridor and the rod access room is three feet, eight inches thick. The maximum dose rate in the rod access room is 8 mrem/hr. The total dose rate from all sources is less than 10 mrem/hr.

5. Canal Shielding

The canal bottom below the fuel element storage racks is seven feet of ordinary concrete. The dose rate below this floor is less than 1.0 mrem/hr. Where the canal floor passes over the experimental cubicles, 5.5 feet of ordinary concrete is used, leading to a dose rate of 5.0 mrem/hr in the cubicles. Seven feet of ordinary concrete is provided for the lower portion of the canal walls, with resulting dose rates at the outer surface of the shields less than 1.0 mrem/hr.

6. Experimental Loop Cubicles

The walls and floors between cubicles are sized for a dose rate of 2.5 mrem/hr inside a cubicle (with test loop shutdown) from an adjacent operating cubicle. The walls are constructed of magnetite concrete blocks and are two feet, eight inches thick; the floors consist of four feet, six inches of ordinary concrete. The cubicle ceilings in the first basement are made of ordinary concrete, five feet in thickness, in order to meet the 1.0 mrem/hr design level on the reactor floor.

7. Demineralizer Vaults

The vaults are shielded by three feet, six inches of concrete block followed by a valve corridor of three feet, six inches and a final eight-inch concrete protective wall surrounding the valve corridor. The hatch covers in the floor above the vault consist of five feet, six inches of concrete. The dose rates from the resin beds at the areas adjacent to the walls and ceiling of the vaults are variable and are, therefore, under administrative control.

8. Radiation Control Areas

Shielding for certain areas has been provided for limited access during particular periods of the overall operation. It is uneconomical to provide shielding in these areas to cover all eventualities. These areas are placed under administrative control with respect to entry procedures and times of access. A list of these areas together with possible radiation sources are shown in Tables

11-I and -II.

B. RADIATION MONITORING SYSTEM

1. General Description

The purpose of the ATR radiation monitoring system is to detect, indicate, and record radiation levels at selected

TABLE 11-I

SUMMARY OF CALCULATED DOSE RATES

Location	Maximum Calculated Dose Rate During Full Power Operation (mrem/hr)	Maximum Calculated Dose Rate After Shutdown (mrem/hr)
Outside reactor concrete shield	6.0	< 1.0
Outside experiment H ₂ O loop cubicles (N-16 activity only)	2.5	< 1.0
Inside experiment H ₂ O loop	5.0 from adjacent operating cubicles (N-16 only); 6.0 from reactor and primary piping	< 1.0
Subpile room	No Access	1 from core through vessel bottom head (does not include streaming through bottom-head penetrations)
Rod access room	10.0	< 2.5
Floor above heat exchangers	1.5	< 1.0
Reactor area, first floor	1.0	< 1.0 except during specimen and loop component transfer
Reactor vessel top head	1.0	< 1.0 except during specimen and loop component transfer < 25 during fuel transfer
Above storage canal and at floor level near parapet	1.0	1.0
Above storage canal during spent fuel transfer	50.0 transient	50.0 transient
Below storage canal		1.0
Outside walls of storage canal	1.0	1.0
Outside pipe tunnel	6.0	< 1.0
Motor area outside pump cubicles	7.0	< 1.0
Inside pump cubicles	4.0 from heat exchangers and piping, 7.0 from adjacent pump cubicle	
Nozzle access trench	No Access	12.5 from core and stored fuel (does not include streaming through vessel penetrations)
Office areas	< 0.25	< 0.25 except during specimen and loop component transfer

TABLE 11-II

RADIATION CONTROL AREAS

Location	Operation	Radiation Source
Nozzle access trench	Removal of instruments and irradiated capsules	Streaming through instrument wells and capsule penetrations, activated capsules
Subpile room	Experiment loop removal, general maintenance	Contaminated experiment loops, streaming through in-pile loop penetrations, spent fuel elements passing through transfer chute
Pipe corridor	Maintenance on rod drive mechanisms	Contaminated experiment loops, spent fuel passing through transfer chute
Experiment loop test cubicles	Maintenance on test loop equipment	Contaminated test loops
Reactor area, first-floor	Removal of activated loop components	Streaming out of top and bottom of transfer cask
Reactor top-head area, top-head shield removal	Spent fuel removal, general maintenance	Contaminated experiment loops, raised fuel elements
Top-head shield, and cask transfer station	Transfer of test specimen	Test specimen
Demineralizer Vault Areas	Change out of resin	Fission products and activated crud

points throughout the ATR facility. At pre-set radiation levels alarms are activated. Interlock relays are provided to control certain ventilation equipment at preset high radiation levels. The ATR radiation monitoring system is composed of 36 beta-gamma area and process monitors, 23 airborne particulate monitors, 17 portal monitors, 3 hand and foot monitors, a stack monitoring system, 3 ruptured fuel element monitors, and 4 interlock relays. All components of the system alarm on both the Health Physics monitoring panel and the reactor control panel.

2. Beta-Gamma Area and Process Monitors

The beta-gamma area and process monitors detect direct beta-gamma radiation in the ATR plant area. Each channel operates as a GM tube feeding the indicating meter by means of a ratemeter

at low intensities and as an ionization chamber feeding the indicating meter a direct current as the GM pulse output saturates at high intensities. In the event of abnormal operation, when fields exceed 5000 R/hr, the ionization current of the sensor tube is sufficient to drive and hold the meter at full scale and in alarm condition without any current from the ratemeter circuit. In the abnormal range from full scale to 50,000 R/hr, the channel will provide an output signal sufficient for full scale deflection of the meter.

Power for the operation of the 36 detectors is supplied from the Health Physics monitoring panel. The detectors are connected to the power supplies on the HP panel according to the following schedule, so that a power supply failure will not leave an entire area of the plant without monitoring and so that no more than one interlock function will be lost per failure:

<u>Power Supply</u>	<u>Channel Number</u>
A	GM 4, 5, 5x*, 20, 28, 29
B	GM 1, 2, 2x, 10, 21, 27
C	GM 16, 17, 22, 23, 23x
D	GM 3, 7, 11, 24, 24x, 26
E	GM 6, 6x, 8, 12, 14, 19
F	GM 9, 13, 15, 18, 25, 25x
G	GM 30, 31, 32, 33, 34, 34x
H	GM 35, 35x, 36

*Designates interlock signal

The detectors of Channels 1 through 29 drive local meters and visible and audible

alarms. Power for these alarms is supplied from either the detector or its power supply without recourse to local ac power supplies. The local meter-visible alarm units for Channels 30 through 36 are mounted on the process control panel. Power for the "acknowledge button" for these channels is taken from a source on the process control panel. Alarm signals from any of the 36 channels actuate an annunciator on the reactor control room panel. Recorders and station indicators for each detector are mounted on the Health Physics monitoring panel.

The following tabulation gives the channel number, location, range, and electrical power source of each of the detectors:

CHANNEL NO.	LOCATION	DETECTOR RANGE	ELECTRICAL POWER SOURCE Feeder Equip. No.-Breaker Unit No.	
Note: The power panel in the HP Shift Office is fed from breaker #3 of 670-E-73. Breakers noted below refer to HP power panel, not 670-E-73.				
1	Hallway of Office Building Mezzanine	.1 mR/hr - 100 R/hr	Power Panel	7
2	Hallway of Critical Facility Mezzanine	.1 mR/hr - 100 R/hr	Power Panel	7
3	First Floor, Above Reactor Head	.1 mR/hr - 100 R/hr	Power Panel	11
4	First Floor, Reactor Handrail	.1 mR/hr - 100 R/hr	Power Panel	5
5	First Floor, Critical Facility, West of Canal	.1 mR/hr - 100 R/hr	Power Panel	5
6	First Floor, Control Room	.1 mR/hr - 100 R/hr	Power Panel	13
7	First Floor, Utility Area	.1 mR/hr - 100 R/hr	Power Panel	11
8	First Floor, Storage Canal, East End	.1 mR/hr - 100 R/hr	Power Panel	13

CHANNEL NO.	LOCATION	DETECTOR RANGE	ELECTRICAL POWER SOURCE	
			Feeder Equip. No.-Breaker Unit No.	
9	First Floor, Storage Canal, West End	.1 mR/hr - 100 R/hr	Power Panel	15
10	First Floor, Storage Canal, Central Area	.1 mR/hr - 100 R/hr	Power Panel	7
11	First Floor, Laydown Area over Exchanger Vault	.1 mR/hr - 100 R/hr	Power Panel	11
12	First Floor, Reactor Room, West Side	.1 mR/hr - 100 R/hr	Power Panel	13
13	First Floor, Reactor Room, East Side	.1 mR/hr - 100 R/hr	Power Panel	15
14	First Basement, Outside Cubicle 1A	.1 mR/hr - 100 R/hr	Power Panel	13
15	First Basement, Outside Cubicle 1B	.1 mR/hr - 100 R/hr	Power Panel	15
16	First Basement, Outside Cubicle 1C	.1 mR/hr - 100 R/hr	Power Panel	9
17	First Basement, Outside Cubicle 1D	.1 mR/hr - 100 R/hr	Power Panel	9
18	First Basement, Outside Doorway to Emergency Pumps	.1 mR/hr - 100 R/hr	Power Panel	15
19	First Basement, Utility Area	.1 mR/hr - 100 R/hr	Power Panel	13
20	First Basement, Canal Viewing Window	.1 mR/hr - 100 R/hr	Power Panel	5
21	Second Basement, Outside Sample Area 2B	.1 mR/hr - 100 R/hr	Power Panel	7
22	Second Basement, Outside Cubicle 2C	.1 mR/hr - 100 R/hr	Power Panel	9
23	Second Basement, Outside Sample Area 2D	.1 mR/hr - 100 R/hr	Power Panel	9
24	Second Basement, By Condensate Keg	.1 mR/hr - 100 R/hr	Power Panel	11
25	Second Basement, Outside Heat Exchanger Vault	.1 mR/hr - 100 R/hr	Power Panel	15

CHANNEL NO.	LOCATION	DETECTOR RANGE	ELECTRICAL POWER SOURCE	
			Feeder Equip. No.	-Breaker Unit No.
26	Subpile Room, Entrance Tunnel under Pipe Corridors	.1 mR/hr - 100 R/hr	Power Panel	11
27	Subpile Room, Outside Shielding by Door	.1 mR/hr - 100 R/hr	Power Panel	7
28	Neck Shim Rod Drive Room, Outside Door	.1 mR/hr - 100 R/hr	Power Panel	5
29	Motor Room, East Wall of Warm Waste Room	.1 mR/hr - 100 R/hr	Power Panel	5
30	Outlet Line of Heat Exchanger #1 (670-M-2)	.01 mR/hr - 10 R/hr	Power Panel	17
31	Outlet Line of Heat Exchanger #2 (670-M-3)	.01 mR/hr - 10 R/hr	Power Panel	17
32	Outlet Line of Heat Exchanger #3 (670-M-4)	.01 mR/hr - 10 R/hr	Power Panel	17
33	Outlet Line of Heat Exchanger #4 (670-M-5)	.01 mR/hr - 10 R/hr	Power Panel	17
34	At Air Exhaust Stack Breech	.1 mR/hr - 100 R/hr	Power Panel	17
35	At Exhaust Plenum, Second Basement	.1 mR/hr - 100 R/hr	Power Panel	17
36	Primary Degassing Tank Vent	.1 mR/hr - 100 R/hr	Power Panel	17

On all 36 channels, the alarms are actuated by meters such that when the reading exceeds the setpoint of the fully adjustable meter relay the following alarm sequence is actuated:

(1) An alarm light at each station indicator and an alarm bell on the associated power supply.

(2) A light and a bell at each remote indicator.

(3) Reactor control room annunciator #8.

(4) Automatic shutoff of the alarm lights, bells, annunciator contacts, and interlock signals shall be provided except for the station indicator light (located on the Health Physics monitoring panel), which remains lit to provide "memory" when the radiation level falls below the preset level.

(5) Channels GM 2, 5, 6, 23, 24, 25, 34, and 35 are provided with fully adjustable trip points which actuate interlocking relays with the heating and ventilating system. These trip points operate at higher levels of radiation

than the meter relay alarm points and are completely independent of them.

(6) All contacts open to alarm, interlock, annunciate, or warn of low power.

3. Airborne Particulate Monitors

The 23 cart-mounted airborne particulate monitors utilize end window GM detectors to detect the presence of radioactive particulates in the plant air. Each monitor has an automatic range change ratemeter with linear ranges of 0-2000, 0-10,000, and 0-20,000 counts per minute.

The ratemeter is equipped with a non-overloading safety device to prevent the lack of pulses from a completely saturated tube from appearing as a low count rate.

Six carts (Channels 1 through 6) are equipped as mobile units with recorders so that they may be positioned at any location in the plant. Channels 7 through 23 are equipped for remote recording on the Health Physics monitoring panel and remain in stationary locations.

The following listing gives the channel number, location, and electrical power source for each of the monitors:

CHANNEL NO.	LOCATION	ELECTRICAL POWER SOURCE	
		Feeder Equip. No.-	Breaker Unit No.
1-6	Varies as Needed	Wall Outlets, Commercial Diesel Bus 115V - 60 cycle ac	
7 X	First Floor, Reactor Working Canal	LP-4	2
8 X	First Floor, West Canal Area	LP-4	6
9 X	First Floor, East Canal Area	LP-3	3
10 X	Critical Facility	LP-7	5
11	Reactor Control Room	LP-2B	4
12	Hallway by Health Physics Field Office	LP-5	3
13	First Floor, Sample Preparation Laboratory	LP-7	6
14 X	First Floor, East Reactor Area	LP-2B	6
15	First Basement, East of Cubicles	LP-8	3
16	First Basement, South of Cubicles	LP-9	5
17	First Basement, West of Cubicles	LP-9	3

CHANNEL NO.	LOCATION	ELECTRICAL POWER SOURCE	
		Feeder Equip. No.	- Breaker Unit No.
18	Second Basement, South of Cubicles	LP-12	5
19	Second Basement, East of Cubicles	LP-10	5
20	Second Basement, Southwest of Cubicles	LP-11	6
21	Second Basement, At Fan Room Door	LP-11	4
22	First Floor, General Storage and Laydown Area	LP-4	5
23	First Floor, Process Control Room	LP-3	2

Power for the recorders for the 17 stationary carts is obtained from a fused power panel on the Health Physics monitoring panel.

The alarm sequence for the 23 airborne particulate monitors is as follows:

(1) When a change from the 2K to the 10K range occurs, the amber light will burn continuously for 12 to 15 seconds and then start to flash on a 2 to 5 second cycle. The bell will ring for 12 to 15 seconds and then go silent.

(2) When a change from the 10K to the 20K range occurs, the red alarm light will start flashing on and off on a 2 to 5 second cycle and will continue to do so until the count rate meter changes scales. The bell will simultaneously start to ring intermittently on a 2 to 5 second cycle and will continue to ring in this manner until the count rate meter changes scales or the bell is silenced by the bell interrupter switch.

(3) All alarms are annunciated on the Health Physics monitoring panel. High

level alarms are annunciated on the reactor control panel.

(4) Interlock actuations controlled by the CAM units are produced by the electronic trip point of the DeVar recorders mounted in the Health Physics monitoring panel in conjunction with the repeat relay controlled by the high level window of the annunciator.

4. Hand and Foot Monitors

Three hand and foot monitors are located in the ATR plant area. Each monitor is a completely integrated system providing detection of beta-gamma contamination of the hands and feet. Each unit consists of a pedestal-mounted cabinet with foot deck and hand cavities.

Each unit has an individual ratemeter for each hand and each foot. A fifth ratemeter is provided for an external probe which can be used for monitoring the head or clothing of personnel. An alarm light for high activity is provided for each individual channel. Alarms automatically reset after 10 seconds. Audible alarm for high activity is provided by a high fre-

quency buzzer. A loud speaker with variable volume control annunciates the clicks from all channels. The counting range of each channel is adjustable from 0-500, 0-2000, 0-5000, and 0-20,000 counts per

minute.

The following listing gives the instrument number, location, and electrical power source of the hand and foot monitors:

CHANNEL NO.	LOCATION	ELECTRICAL POWER SOURCE	
		Feeder Equip. No. - Breaker Unit No.	
1	Corridor by Shift Supervisor's Office	LP-5	3
2	Corridor from Critical Facility	LP-7	1
3	Outside Process Control Room	LP-3	6

5. Portal Monitors

The portal monitors installed in the ATR facility automatically compensate for changes in the existing radiation background of the area. An abrupt change in the count rate, such as that caused by a contaminated person passing near the monitor, is quickly detected and

alarmed. The positions of the portal monitors were selected so that all personnel will pass through a portal monitor whenever leaving a potentially radioactive area.

The following listing gives the number, location, and electrical power source of the 17 portal monitors:

CHANNEL NO.	LOCATION (Doorway Number)	ELECTRICAL POWER SOURCE	
		Feeder Equip No. - Breaker Unit No.	
1	Entry, Health Physics Issue Room (D-12)	LP-5	3
2	South Reactor Area (D-14)	LP-12	2
3	Critical Facility, West Entrance (D-16)	LP-7	1
4	West Storage Canal Area (D-18)	LP-9	4
5	North Storage and Laydown Area (D-20)	LP-4	2
6	North Utility Area (D-22)	LP-3	5
7	East Storage Canal (D-25)	LP-8	4

CHANNEL NO.	LOCATION (Doorway Number)	ELECTRICAL POWER SOURCE	
		Feeder Equip No. - Breaker Unit No.	
8	Office Building Corridor (D-28)	LP-5	3
9	Office Entrance (D-30)	LP-5	3
10	West Reactor Area (D-49)	LP-7	1
11	Northwest Reactor Area (D-50)	LP-4	2
12	Northeast Reactor Area (D-52)	LP-2B	5
13	East Storage Canal Area (D-54)	LP-8	4
14	West Storage Canal Area (D-67)	LP-4	2
15	Critical Facility, South Entrance (D-71)	LP-7	1
16	Utility Storage Area (Head of Stairway #3)	LP-3	6
17	Office Building Mezzanine (D-101)	LP-5	1

Each portal monitor unit contains 11 GM detectors. With two exceptions, four tubes are positioned on each side of the unit, one overhead, and two in the floor. PM-8 has three detectors on each side, three in the floor, and two overhead; PM-12 has seven detectors positioned in the floor and four detectors positioned along the west side of the doorway.

6. Stack Monitoring System

a. Location

The stack monitoring system is located outside the fan room in the northwest corner of the second basement. Recorders connected with this system are located on the Health Physics monitoring panel and on the reactor control room instrument panel.

b. Description

The stack gas is sampled by an iso-kinetic nozzle 50 feet downstream in the underground portion of the stack duct through a two-inch stainless steel sampling line. A flow divider located in the second basement provides a sampling valve so that the gas can flow through one-inch stainless steel lines to both the stack monitoring system and to the sample port or through the stack monitoring system only. The sample port is valved to permit a gas sample to be taken for spectral or other analyses. The one-inch line leading to the monitoring system first goes through a tracer lab filter tape transport for continuous particulate monitoring. The filter drive mechanism is a solid perforated capstan which limits the air bypass around the filter

tape to < 2 percent. The standard speed of the filter paper advance is 1 inch/hr, and a regular spool of gauze-backed HV-70 filter paper provides approximately 25 days of continuous usage. Alarms are provided to indicate lack of paper and a tear in paper. The particulate activity is monitored by an MD-5B Gamma Scintillation Detector Assembly. The MD-3B Alpha Scintillation Detector is placed six inches downstream of the sampled area to allow for a six-hour decay of the short-lived, natural occurring radon and thoron daughter products.

From the particulate monitor the gas sample passes to a Tracerlab model MG-1A Gaseous Monitor which contains a gamma scintillation detector. From here the sample flows through a charcoal filter to effect iodine removal and then through a Tracerlab model MX-14C pumping system equipped with a muffler and a Magnahelix flow indicator. The gas will then flow through a pressure reducing orifice to a valving arrangement whereby the sample may be directed either to the stack or through a delay tank (two minute delay for 10 cfm flow) to a particulate monitor similar to the one mentioned above. Note: The delay allows a portion of the noble gas activities present to decay and form particulate daughters. Since the daughters of the fission product noble gases are radioactive while the daughter of Argon-41 is not, a determination can be made of the gaseous activity measured previously that was due to fission products. The sample will then be directed to be stack.

7. Ruptured Fuel Element Monitors

a. Iodine Fission Break Monitor

The iodine fission break monitor is designed to detect releases of significant radioactive iodine fission products into the primary coolant system from a ruptured fuel element or experimental fuel capsule.

The detector equipment is located in a cabinet in the waste tank motor area below the second basement level with a

recorder and annunciator located in the reactor control room and on the Health Physics monitoring panel in the Health Physics office. A cabinet to house the electronics is located in the second basement, outside and southeast of cubicle 2D.

A metered flow of primary coolant water is drawn from the outlet line of the primary coolant cation demineralizer header, through pipe corridors to the bottom of the sample cabinet, then through a glass wool filter and an anion resin column, and is discharged to the warm waste tank directly below the motor area. A low flow annunciator is located on the Health Physics monitoring panel.

A scintillation detector is positioned by the anion resin column to monitor the concentrated iodine activity collected on the anion resin. This detector is operated with a discriminator setting of about 0.8 MeV to bias out activity from Cr-51 and Mo-99 radicals which also concentrate in the anion column. The higher radiations are predominantly iodine. The distance between the detector and the anion column can be varied to keep the instrument on the proper scale.

b. Fast Fission Break Monitors

Two fission break monitoring channels are provided to immediately detect a release of fission products into the primary coolant system. Each channel consists of a gamma ionization chamber, a microammeter, and a recorder. The detectors are located at the primary system outlet piping header with the electronics housed in a cabinet located in the 1A experimental cubicle sample corridor. Delay time is several seconds. Two microammeters are located on the Health Physics monitoring panel in the Health Physics office, and two recorders are located in the reactor control room. Each location also has an annunciator.

8. Interlock Relays for Heating and Ventilation System

Located on the Health Physics monitoring panel are four interlock relays

for the purpose of actuating interlocks with the heating and ventilating system. The purpose of these interlocks is to control the release of airborne contamination to the environs in the event of a serious unplanned event at the ATR. These relays open to perform the interlock action and have contacts to actuate two indicating lights (one on the Health Physics monitoring panel and the other in the reactor control room). The interlock relays will reactuate if they are reset while an activating condition still exists. The interlocks may be positively overridden by means of a pushbutton located at the emergency diesel start-up panel. All input signals to the interlock relays that do not require a coincidence for actuation are provided with test blocks on the Health Physics monitoring panel which enables calibration and testing without shutting off the ventilation system.

Interlock relay number 1 is actuated by a high radiation signal from either the stack breach monitor (GM 34) or from the exhaust plenum monitor (GM 35). When interlock relay number 1 opens, the following occurs:

- (1) The stack breeching damper closes.
- (2) Main exhaust fans HVE-17A and HVE-17B shut off.
- (3) The following equipment associated with the reactor area supply system shuts off:
 - (a) HVS-1 and three associated butterfly dampers
 - (b) HVR-1 butterfly damper
 - (c) HVS-4 two butterfly dampers

- (d) HVS-5 two butterfly dampers
- (e) HVE-9 and one butterfly damper
- (f) HVA-2 and three associated butterfly dampers
- (g) HVE-4

Interlock relay number 2 is actuated by any one of the following:

- (1) A coincidence of interlock signals from CAM 7 and CAM 14 located in the reactor room.
- (2) A two-out-of-three coincidence of GM 2, GM 5, and GM 6 which surround the reactor.
- (3) A two-out-of-three coincidence of GM 23, GM 24, and GM 25 located in the second basement.

When interlock relay number 2 opens, the reactor area supply systems are again shut off as shown for interlock relay number 1 (3) above, and the exhaust from HVE-1 is routed to the main exhaust plenum by means of two dampers.

Interlock relay number 3 is actuated by the ATRC airborne particulate monitor CAM 10. When this relay opens, the ATRC supply system (HVS-2) and associated dampers are shut off.

Interlock relay number 4 is actuated by either CAM 8 or CAM 9 which monitor the canal. When this relay is opened, the storage canal ventilation system (HVS-3) is shut off along with the associated motor-operated dampers and roof ventilators.

CHAPTER XII

CANAL OPERATIONS

A. CONSTRUCTION

The canal is constructed of reinforced concrete with polyvinyl chloride water stops in the concrete construction joints. The canal is completely lined with stainless steel sheet to the top of the parapet. The parapet rises three feet above the main floor level. A system of seepage drains is provided in the concrete behind the lining to locate leaks and to prevent any pressure buildup between the concrete and the stainless steel lining. The west end of the canal includes provision for westward extension to the proposed hot cell facility.

A vertical lift door in the north wall of the reactor room and over the canal separates the reactor room from the canal area. This door is of solid steel plate with an inflatable gasket around the perimeter except for the bottom edge which extends two feet below canal water level. A bulkhead, mounted on the south face of the door, extends to the bottom of the canal and operates as part of the door. The working canal forms the seal between the door and the bulkhead, thus creating a gastight area on the reactor side. This door and bulkhead will also prevent draining the canal inadvertently in case of an equipment rupture on the reactor side. The wall between the main reactor floor and the canal area is of fireproof construction and is considered gastight.

The canal is functionally divided into four compartments, the reactor working canal, storage canal, critical facility canal, and the experimenters canal. The canal is 8 feet wide except for the critical facility canal which is 10 feet wide. Length of the canal is approximately 156 feet. Depth of the canal varies, the reactor working area is 45 feet, the area under the ATRC (reactor) is 23 feet, the ex-

perimenters section is 39 feet, and the remaining sections are 20 to 22 feet.

The floor of the canal is constructed to support 40,000 pound casks if spaced no closer than 5 feet from center lines.

A viewing window is located in the experimenters section of the canal. The window is 4 feet thick, constructed of high density laminated glass, and is inset 3 feet into the concrete wall to protect the glass surface. The total glass thickness plus the water in the inset gives shielding protection equivalent to the 7-foot-thick concrete wall. The dry side of the window is sealed (except when in use) by a steel plate which is designed to withstand full canal water pressure.

A shielded handling cask which mates with the top-head shield is used for transferring the irradiated test assemblies between the reactor and the canal. Spent fuel elements and small irradiated test specimens are passed underwater directly into the canal through the drop tube.

Canal drains are located in all five sections of the canal, each section of which may be isolated by inserting water tight bulkheads. The drains are valved on the outside wall of the canal and connected with the warm waste tank located approximately 52 feet below the normal canal water level. If one of the drain valves is inadvertently left open, canal water will discharge to the warm waste tank at a rate between 1400 and 1600 gpm. Assuming a nearly empty warm waste tank, the tank high level alarm will sound in the process control room in approximately three minutes, and corrective action can be initiated. With the bulkheads in place and an open drain valve it would take over 14 minutes to

drop the canal water level to the top of any stored fuel elements.

The reactor working canal contains a drop tube located in the 45-foot-deep section and is used for transferring items to and from the reactor. The drop tube will be used when transferring spent fuel, expended control elements, capsule experiments, etc. The remainder of the reactor working canal is 22 feet deep and contains a loop cask transfer station for discharging an experiment from the transfer cask, a loop test assembly storage rack, a pressure tube storage rack, a handling tool rack, and two spent fuel storage racks. The fuel storage racks, with a capacity of 40 elements each, will hold spent fuel elements for a short period or until they can be transferred to the normal storage racks in the storage canal. The storage canal contains space for cask storage, irradiated hardware baskets, fuel element storage racks for 140 elements, underwater saw, saw table, a horizontal storage rack for experiment loop pressure tubes, test assembly storage racks, and a handling tool rack with tools. A 39-foot-deep portion is provided at the east end of the canal to permit handling of an entire loop experiment test assembly preparatory to shipment.

Storage space for casks and other equipment is provided on the floor north and south of the storage canal. A truck aisle is provided north of the canal with rolling steel doors in the east and west building walls. An equipment hatch to serve the first basement is provided in the west end of the canal truck aisle. The live load floor loading for this area is 2000 pounds per square foot.

Truck access to the critical facility is by a rolling steel door in the west wall. Fire walls separate the critical facility area from the storage canal and reactor areas. The critical facility canal may be isolated from the storage canal by a vertical lift fire door and an insulated bulkhead.

The canal area is served by a 30-ton

capacity, traveling bridge type crane electrically operated and floor controlled. A 2-ton capacity jib crane, hand crank operated with electric hoist and trolley, is located over the working canal. The primary purpose of the 2-ton crane is to transfer the pressure tubes and test assemblies from the reactor to the working canal. A 15-ton capacity, electrically operated, floor controlled traveling bridge crane is located in the critical facility.

A canal vacuum cleaning device and surface skimmers are used to clean accumulated debris from the canal. Canal drains and vacuum cleaning waste are discharged to the warm waste system.

A portable bridge spanning the canal and running on the parapet walls is provided for access across the canal and for canal handling operations. A removable concrete beam is used to support one side of the bridge when crossing the tee portion of the working canal.

The critical facility canal contains a low power operating mock-up of the ATR reactor core where measurements can be made to support fuel element and facility calculations and determine reactivity effects including previously irradiated fuel elements or other components.

B. OPERATIONS

The canal is filled with demineralized water and is purged by a continuous makeup and drain of 60 gpm. Water level is normally one foot below the top of the canal parapet. A purge of 60 gpm combined with natural evaporation maintains an average temperature of 85°F based on six spent fuel cores stored in the canal. An insulated bulkhead, normally in position, isolates the critical facility canal which will be maintained at a higher temperature.

Purge water to the canal is taken from the ATR demineralized supply header. Purge to each section of the canal can be regulated by individual valves; the

total supply of all regulating valves is indicated by flow indicator FI-8-11 located on the north wall of the canal in the first basement. An eight-inch quick-fill valve, GT-P-8-18, is located on the north wall of the canal in the first basement.

Irradiated spent fuel elements are stored in the canal from 90 to 130 days for cooling purposes. After the end boxes have been removed, the elements are removed from the canal by means of a 15-ton shielded cask. The cask is equipped with a boron poison basket insert sized for nine fuel elements. Water is used as an internal coolant and the outside of the cask has cooling fins. The cask is also equipped with a top access plug and a

lifting bail for handling purposes.

Under normal operating condition, pH of the water in the canal will be controlled by using sulphuric acid to maintain a pH of 5.5 to 6.5. Samples of canal water will be taken daily and analyzed for chlorides, conductivity, and radioactivity.

C. EMERGENCY OPERATIONS

In case of an emergency when the water level in the canal is dropping and cannot be controlled and before the demineralized water supply is exhausted, add fire water via hoses from the nearest fire hydrants. When the source of leakage is located, relocate irradiated fuel elements if necessary and isolate the leaking section using the spare bulkheads.