SECTION 7

INSTRUMENTATION

7.1 GENERAL FEATURES

7.1.1 The main control room contains all the control and instrumentation essential to the operator during plant operation. Arrangement of control console and panels is shown in Drawings M-235 and M-236. The instrumentation and controls for the turbine-generator, feedwater heaters, condenser and auxiliaries are conventional.

7.1.2 The local panel boards provided contain annunciators, recorders, indicators, switches and controllers associated with nearby equipment and systems.

7.2 POWER CONTROL

7.2 The control rods are individually and manually set by the operator. This adjusts the reacto power level. The operator adjusts the setting as necessary to compensate for reactivity changes caused by fuel burnup and changes in xenon concentration and other variables effecting reactivity.

7.2.2 The turbine control mechanism includes a conventional governor and an initial pressure regulator. During normal operation the turbine admission valves are controlled by the initial pressure regulator. The turbine speed governor is set at some amount above the pressure regulator. The steam by-pass valve is normally closed, and all reactor steam flow is through the turbine. On abnormal conditions such as turbine trip, the bypass valve opens to dump steam directly to the condenser.

7.2.3 With the control system set up in this manner, the turbine follows the reactor output rather than system load changes. Turbine overspeed control is maintained in the conventional manner.

7.3 TURBINE PROTECTION DEVICES

7.3.1 If the turbine should overspeed due to sudden loss of electrical load, the speed governor signal will override the initial pressure regulator signal which normally controls the turbine admission valves. The admission valves close sufficiently to maintain satisfactory turbine speed. This causes the reactor pressure and reactivity to rise. The turbine bypass valve is opened by means of a pressure signal and dumps steam to the condenser.

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7.3.2 A turbine emergency overspeed governor is provided as a backup for the speed governor. Other conventional turbine protective devices include a low vacuum trip, thrust bearing failure trip, generator protective relay trip and manual trip. Each device will actuate closing of the stop valve.

7.3.3 A more detailed description of the turbine control and safety features is given in Section 5.6, with features shown in Drawing M-241.

7.4 CONTROL AT STARTUP

Upon control rod withdrawal, reactivity is increased from the cold shutdown condition until the reactor is brought to critical. After the initial criticality is attained, the rods are withdrawn until a period of about 30 seconds or longer is obtained. This period is maintained until a power level is reached at which a specified heating rate is established to bring up the temperature of the reactor vessel at the prescribed rate.

7.5 REACTOR SAFETY SYSTEM

7.5.1 General

7.5.1.1 The function of the reactor safety system is to protect equipment, plant and personnel by scramming the control rods, and in some cases, close the enclosure penetrations in the event of an unsafe or potentially unsafe condition.

7.5.1.2 The reactor safety system is illustrated by the following:

Drawing 198E157	Reactor Protection System
Table 7.1	Reactor Safety System Functions
Table 7.2	Reactor Safety Controls

7.5.1.3 The system consists of two independent, "fail-safe" safety channels which must both be de-energized to produce a scram and other safety system functions. The failure of a single component or power supply does not prevent a desired scram or cause an unwanted scram.

7.5.1.4 Certain sensing elements are continuously monitored so that an operation or failure is clearly indicated and identified for quick and easy maintenance.

7.5.1.5 A brief description of some of the emergency conditions and causes that would actuate the reactor safety system are outlined in the following paragraphs.

TABLE 7.1

REACTOR SAFETY SYSTEM FUNCTIONS

Sensors	Scram Reactor	Close Ventilation Ducts	Start Emergency Cooling	Close Enclosure Penetrations
High Neutron Flux	X	X		
Short Reactor Period	X	X		
High Reactor Pressure	X	X		
Very High Reactor Pressure			X	
Low Water Level in Reactor Vessel	X	X		X
Low Water Level in Steam Drum	X	X		
Closure of Steam Line Backup Isolation Valve	X	X		
Closure of Recirculation Water Line Valves	X	X		
High Condenser Pressure	X	X		
High Sphere Pressure	X	X		X
Loss of Auxiliary Power	X	X		X
High Scram Dump Tank Level	X	X		
Manual Scram	X	X		

TABLE 7.2

REACTOR SAFETY CONTROLS

Dectectors	CONTROL	LEVEL	Scram	Annunciate	Close Enclosure Penetrations	OTHER CONTROL
3	Flux-On Scale Interlock	<5%, any scale				Stop Rod Withdrawal
		.01 N				Bypass Period Scram
		1.1 N, any scale		X		
		1.25 N, any scale	X	X		
2	Period-Low Range	20 second		X		
2	Period-Intermediate Range	15 second		X		
	-Intermediate Range	10 second	X	X		
4	Low Reactor Pressure	200 psig				Startup Bypass; Initiate Core Spray
4	High Reactor Pressure	PR+50 psia	X	X		
2	Very High Reactor Pressure	PR+100 psia		X		Initiate Emergency Cooling
4	Low Reactor Water Level	El 610'6"	X	X	X	
4	Low Steam Drum Water Level	- 4"	X*	X		
4	Main Steam Isolation Valves	50% closed	X	X		
4	High Condenser Pressure	13" Hg abs.	X*	X		Bypassed During Startup
4	High Enclosure Pressure	2 psi diff.	X	X	X	
1	High Scram Dump Tank Level	10 inches B.C.		X		
4	High Scram Dump Tank Level	5/16 inches B.C.	X	X		
1	Manual Action	---	X	X		
32	Low Scram Accum. Pressure	1 accum. 2 accum.		X		Block Rod Withdrawal
4	Recirculation Line Valves	Closed	X*	X		

* Control function bypassed during refueling.
N = Flux at 100% power.
PR = Reactor primary pressure
B.C. = Below centerline of scram dump tank
Note 1) Reactor will be scrammed on loss of power to Safety System Channels No. 1 & 2.
2) The enclosure ventilation ducts will be closed whenever the reactor is scrammed.

7.5.2 High Pressure in Enclosure

A differential pressure between the inside and the outside of the reactor enclosure could indicate a major rupture within the enclosure. To monitor such a condition, four differential pressure sensing detectors are strategically located outside the reactor enclosure. These sensors are included in the reactor safety circuit as shown by Drawing 198E157. When a differential pressure greater than 2 psi exists, the ensuing signal initiates reactor scram and closure of sphere penetrations, including the ventilation ducts and main steam line. Independent high pressure signals energize the controls of the post-incident spray cooling system, setting in motion a 15-minute time delay mechanism that initiates the spray system in the event the operator does not manually shut off the system within the time delay period.

7.5.3 Low Water Level in Reactor

The occurrence of this condition could indicate a loss of water such that the reactor core may be uncovered. To protect against this condition, four water level switches are installed on the reactor vessel. These detectors are set to trip when the water drops to a level corresponding to an elevation of 610'6"; the top of the core is at an elevation of 607'9". In the event of such a trip, the reactor is scrammed and sphere penetrations including ventilation ducts and main steam line, are closed. This trip also energizes the controls of the core spray cooling system, with the functional actuation of these sprays depending upon simultaneous occurrence of low pressure (200 psig or less) in the reactor.

7.5.4 Low Water Level in Drum

This is an anticipatory type of signal which indicates a loss of water and could lead to low water level in the reactor. Four water level switches are installed on the steam drum to sense this condition. These detectors are set to trip when the water level drops 4 inches below normal operating level. In the event of such a trip, the reactor is scrammed, which initiates closure of the ventilation ducts.

7.5.5 High Pressure in Reactor

7.5.5.1 The occurrence of high pressure in the reactor could indicate trouble in the reactor system. Four pressure detectors are set to trip at 50 psi above the desired operating pressure. This trip setting protects against the collapsing of steam voids causing an increase in reactivity. In the event of high pressure and subsequent trip, the reactor is scrammed, which initiates closure of the ventilation ducts.

7.5.5.2 In the event that reactor pressure continues to rise after a reactor scram, which would have been initiated as indicated above, the emergency condenser is automatically brought into operation. Two pressure detectors are set to trip at "very high reactor pressure", corresponding to 100 psi above the desired operating pressure. This trip setting protects against damage to the core, yet is adequate to avoid lifting the safety relief valves. The trip initiates opening the valves to bring the emergency condenser into operation (See Section 5.8.6.4).

7.5.6 High Neutron Flux

The occurrence of high neutron flux would indicate a reactor output in excess of the safe level for continuous operation. Protection against such conditions is provided by the out-of-core reactor neutron monitoring system. The range settings and functional response of the reactor to a signal trip are given by Table 7.2 and described in the following Section 7.6.1.3.

7.5.7 Short Period

The occurrence of a short period would indicate an excessive rate of rise of reactor power during startup conditions. Protection against such conditions is provided by the out-of-core reactor neutron monitoring system. The trip and alarm settings and functional response of the reactor to a signal trip are given by Table 7.2 and described inthe following Sections 7.6.1.1 and 7.6.1.2.

7.5.8 Closure of Steam Line Backup Isolation Valve

7.5.8.1 Partial closing of this valve to 50% closure initiates reactor scram. The emergency condenser is brought on by a pressure rise in the reactor at 100 psi above reactor operating pressure setting.

7.5.8.2 This valve is automatically operated and will go closed with all conditions requiring penetration closure as indicated in Section 7.5.13, below.

7.5.9 Simultaneous Closure of Recirculation Waterline Valves

7.5.9.1 The closure of these valves would prevent coolant circulation to the core, and a prompt scram is initiated to prevent development of excessive fuel temperatures. Analysis has shown that one recirculation loop may be closed without damaging the core; therefore, the functional control is based on scramming the reactor only in the event that both recirculating loops are shut off by inadvertent closure of these valves.

7.5.9.2 Protection against a "cold-water accident" is provided by interlocking. The valves on either side of the recirculating pumps are interlocked with pump power such that each valve must be in its proper position before the pump motor can be started. If the suction valve to the pump is closed, the motor will be tripped. If the discharge valve and bypass valve are closed, the motor will be tripped. The butterfly valves are interlocked (see also Section 5.4.2.4) so that closure of both valves beyond a preset amount of travel will initiate a reactor scram. These interlocks insure that the pumps can be started only with the suction and bypass valves open, and discharge valve closed.

7.5.10 High Condenser Pressure

7.5.10.1 High condenser pressure is used as an indication that:

a) The low pressure turbine casing is in danger of being overheated; and

b) That the main condenser is no longer available as a heat sink for the reactor output. The low vacuum trip system consists of the following devices: two pressure switches for each reactor safety channel; the turbine mechanical low vacuum trip valve which trips the turbine stop valve; a pressure switch which closes or prevents opening of the main steam bypass valve; and a backup pressure switch which actuates both the turbine trip solenoid and the bypass valve. These devices are all actuated by loss of condenser vacuum and are provided to give duplicate and independent initiation for scramming the reactor and isolating the main condenser. The reactor is scrammed at a lower setting before the turbine is tripped.

7.5.10.2 Loss of vacuum is caused by:

a) Loss of power to the circulating water pumps;

b) Excessive air inleakage; or

c) Automatic closing of the off-gas valve from high activity signal.

7.5.10.3 In the event that the condenser becomes unavailable for reactor heat dissipation, the condenser is isolated from the reactor by the indicated action of the turbine stop and bypass valves. The subsequent pressure rise in the reactor brings on the emergency condenser at PR+100 psia (see Section 7.10.7).

7.5.11 Loss of Auxiliary Power

7.5.11.1 The safety system is supplied from the AC auxiliary power system through isolating motor-generator sets which have enough energy stored in their flywheels to carry them through power system disturbances lasting up to 3 seconds. If power is unavailable, the reactor will be scrammed.

7.5.11.2 Power supply to the reactor safety system is shown in Drawing 932C611.

7.5.12 High Level in Scram Dump Tank

A high water level in the scram dump tank would prevent high-speed insertion of the control rods. Four level switches are provided to scram before a level (5/16 inches below the tank centerline)is reached, which would prevent high-speed insertion. Another level switch trip at 10 inches below the tank centerline, is provided to annunciate before the scramming level is reached.

7.5.13 Penetration Closure Conditions

The following conditions close all automatically operated open enclosure penetrations:

High pressure in enclosure

Low water level in reactor

Manual penetration-closure trip

Loss of auxiliary power

7.5.14 Manual Action

7.5.14.1 A manual trip is provided to enable the operator to scram the reactor in case of an unusual or unforeseen emergency. Initiation of such a scram also causes closure of the ventilation ducts.

7.5.14.2 A manual trip is provided to enable the operator to initiate closure of all automatically operated open enclosure penetrations. Such action initiates closing of the main steam line backup isolation valve, and when this valve is 50% closed, a signal (see Section 7.5.8, above) initiates a scram of the reactor.

7.5.14.3 As described in Section 5.8, operation of the emergency condenser is initiated by the reactor safety system signal of very high pressure in the reactor. Manual initiation of valve operation to either actuate or isolate the emergency condenser is possible from the control room to enable the operator to take appropriate action in the event of tube failure in the emergency condenser.

7.5.15 Reactor Safety System Bypass

7.5.15.1 Most safety system bypassing is accomplished by the safety system selector switch which is key-locked and has five mode positions; shutdown, refueling, bypass-dump tank, startup and run. Certain reactor safety system trip functions may be bypassed when this system is in a particular mode as shown in Table 7.3 as follows:

TABLE 7.3

REACTOR SAFETY SYSTEM BYPASS

Mode Position	Trip Functions Bypassed
Run	None
Startup	High Condenser Pressure
(a)Bypass Dump Tank	Low Steam Drum Water Level Recirculation Water Line Valves Closed Steam Line Backup Isolation Valve Closed High Condenser Pressure (b)High Water Level in Scram Dump Tank
Refuel	Low Steam Drum Water Level Recirculation Water Line Valves Closed Steam Line Backup Isolation Valve Closed High Condenser Pressure
Shutdown	(c)None

(a) Control rod withdrawal is prevented by interlock while switch is in this mode position.

(b) Bypass of this trip function is necessary to enable emptying the dump tank after a scram.

(c) With the mode switch in the "Shutdown" position, both the scram circuit and the control rod withdrawal circuit are open. The ventilating duct circuit power supply is transferred to a point which provides penetration closure protection through signals from "high sphere pressure" and "low water level in reactor vessel." This permits normal ventilation in the containment vessel during shutdown when the control rods are held in the full-in position. None of the reactor safety system signals are bypassed since there is no need to withdraw control rods.

7.5.15.2 Maintenance of the neutron monitors may be performed by tripping one of the three neutron monitors in either channel, which then leaves one operating trip in each safety channel.

7.6 REACTOR NEUTRON MONITOR SYSTEM

7.6.1 Out-of-Core Monitors

An instrumentation system, as shown in Drawing 198E134, is provided to monitor the neutron level of the reactor from a startup through full power. The instrumentation covers a range of nine decades with 3 "types of instrumentation": a) Startup, b) Period or Intermediate Range, c) Flux Level or Power Range.

7.6.1.1 Startup Range

With the initial fuel loading, neutron sources are inserted in the reactor core to assure a count rate of several impulses per second. The startup instrumentation covers the range upward to about 10^7 counts per minute. Two channels of instrumentation monitor this phase of the operation. The startup channel neutron detectors are proportional counters. The average rate of the series of pulses is measured on a count rate meter with a logarithmic scale in order to encompass six decades of measurement. The count rate is recorded continuously. An additional circuit differentiates the log count rate and indicates the reactor period at this low level on a period meter. A short period at this low level, as shown in Table 7.2, is annunciated. The detectors are suspended in guide tubes opposite the core outside the pressure vessel. These detectors are positioned by remote means from the control console to any of three positions.

7.6.1.2 Log-N and Period Range

This instrumentation system is concerned primarily with the rate at which the neutron flux is increasing. Two channels of instrumentation monitor the reactor flux as it rises toward full power. The period channel detectors are gamma compensated ion chambers. These log-N channels overlap the previous startup channels. The output of the gamma compensated ion chamber is passed to a log-N amplifier which indicates the logarithm of the current input on a scale covering from 10^{-7} power to full power. The output of the log-N amplifier is continuously recorded. A time derivative of the output, the reactor period, is also indicated visually and audibly if either channel approaches a short reactor period, and a scram is initiated when the trip point is exceeded in accordance with the levels shown in Table 7.2. As discussed below and shown in Table 7.2, the period channel trips are bypassed at 1% of full power. These period channel detectors are suspended in guide tubes; they are positioned by manual means at any desired location within the guide tubes.

7.6.1.3 Flux Level or Power Range

7.6.1.3.1 As the reactor reaches about 10^{-2} of full power, boiling begins and the steam voids cause the period measurements to fluctuate. In order to avoid spurious scrams, the period channels are bypassed from the safety circuits at this point. Six decades below the period bypass, the power level instrumentation starts indicating, and monitors the reactor through full power. There are three channels of instrumentation to cover this range. The power range channel detectors are gamma compensated chambers. The output is fed into a linear flux amplifier with fast response characteristics. The power level is read on a meter indicating the percent of full power and is continuously recorded. A warning is annunciated if any of the three flux level indicators exceeds a set scale reading on any range setting. A scram signal to insert rods is initiated whenever two of the three power level indicators show neutron fluxes equal to or greater than the level shown in Table 7.2. These neutron monitoring detectors are suspended in guide tubes with positioning by manual means.

7.6.1.3.2 The voltage supplies to the neutron monitor chambers are designed so that they cannot be adjusted below 800 volts, which is 200 volts above saturation voltage for the chambers. On loss of voltage to the neutron sensitive portion of a chamber, the output of the picoammeter drops below the downscale trip point. The safety system circuits are designed so that a downscale trip on one instrument, and a high indication trip on either of the other two instruments will scram the reactor. Each neutron monitor has its own individual power supply and power supply output voltage is continuously indicated in the control room.

7.6.2 In-Core Flux Monitor System

7.6.2.1 The in-core flux monitor system is used to determine the neutron flux distribution at points throughout the reactor core in both the axial and radial planes under power conditions. Flux is monitored in eight radial positions located throughout the core. In each position, the flux is monitored at three elevations, giving a total of 24 measurements for the complete core.

7.6.2.2 Flux is measured by miniature fission chambers located at the desired points of measurement. The three chambers for one channel are fabricated into one assembly with the chambers spaced at approximately two-foot intervals. The signal is carried in mineral-insulated stainless steel sheathed cable. The cable is welded to the ion chambers to make a pressure-tight assembly.

7.6.2.3 The ion chamber assemblies are mounted through a nozzle and encasement, which penetrates the bottom of the reactor vessel. The chamber leads pass through a high pressure connection at the bottom of the reactor vessel and terminate in an electrical connector located at the end of the assembly outside of the reactor vessel.

7.6.2.4 The cables from the electrical connectors on each assembly are routed to amplifiers with indicating instruments and alarm on the control panel. An integrated rod position and in-core flux level display is provided on the main panel.

7.6.2.5 The use of in-core monitors will be required at specific times to provide data to verify analytical predictions during initial power operation and major rod programming. At such times, sufficient in-cores shall be operable to provide this comparison data. The in-core flux monitoring channels will not be used to initiate reactor scram, and these monitors are not connected in the reactor safety system. Connection of the in-cores to the safety system is considered unnecessary because (1) the reactor core is relatively small, and (2) the out-of-core instrumentation is more reliable and provides proper detection of core conditions. Since to our knowledge no spatial neutron flux oscillations have been detected in any boiling water reactor using UO_2 as fuel, use of in-core monitors as protection against such oscillations, previously thought to be necessary at Dresden, is not required.

7.6.3 <u>Wire Irradiation</u>

7.6.3.1 A calibration tube is provided in each in-core ion chamber assembly which allows a small diameter wire to be inserted into the assembly during reactor operation. This tube extends the full length of the assembly and adjacent to each ion chamber.

7.6.3.2 When the wires are inserted, each ion chamber and the portions of wire adjacent to it, experience approximately the same neutron flux. Since the wire extends the full active fuel length, an axial neutron flux distribution is obtained at each radial location of monitor assemblies.

7.6.3.3 The wires are run in and out of the reactor, using a wire insertion tool which is located in a shielded area near the bottom of the reactor vessel. The wires are pushed through an extension of the calibration tube which penetrates the shield wall and connects with the ion chamber assembly on the bottom of the reactor vessel. After irradiation, the wires are withdrawn into the case of the insertion tool. Each wire will be counted along its length. The counts at each interval are then plotted and the location of ion chambers indicated on the plot from the known location of the chambers.

7.7 CONTROL ROD SYSTEM INSTRUMENTATION AND CONTROL

7.7.1 Rod Withdrawal Limit Conditions

In order to insure that the protection system controls are set properly during the startup period, withdrawal of control rods is prevented, when certain conditions are not met, as follows:

7.7.1.1 Interlocks on the lowest three range positions are provided on the power level instrumentation to prevent control rod withdrawal. These interlocks insure that the reactor power level instrumentation is set down to its most sensitive range, so that at no time during startup can the flux level rise more than a factor of 1.25 before a scram results from high flux trip. This limits the power level which can be achieved in an excursion.

7.7.1.2 Control rod withdrawal is prevented by the above interlocks during startup whenever the period log-N amplifier is not operating.

7.7.1.3 Interlocks are provided to prevent control rod withdrawal with low pressure in any two of the scram accumulator tanks.

7.7.1.4 Control rod withdrawal is prevented by interlocks if the scram dump tank is bypassed.

7.7.2 Rod Withdrawal During Refueling

Interlocks are provided to prevent all motion with any of the refueling cranes (namely, jib crane, transfer cask winch and monorail crane), which are positioned over the reactor whenever any control rod is not fully inserted in the core during fuel loading or fuel manipulation

7.7.3 Control Rod Position Indicating System

7.7.3.1 The position indicating system provides simultaneous digital read-out of the position of each of the control rods. Position indication in 3 inch increments is provided throughout the stroke of each rod. The colored background of the digital readout indicates when a rod is at an "all-out" or "all-in" position.

7.7.3.2 The position indicators and rod selection pilot lights for each rod are grouped together and arranged on the control room panel in a pattern simulating the relative locations of the rods in the core. This display is integrated with the in-core monitor system readout.

7.7.3.3 This indicating system is shown in Drawing 198E151.

7.7.4 Hydraulic System Instrumentation

The operating condition of the control rod hydraulic system is continuously monitored by pressure, level and position monitoring equipment. These devices indicate locally and transmit signals to the control room for the inlet and outlet scram valve positions, annunciate loss of accumulator gas pressure, water level in the gas side of the accumulator and dump tank water level. Hydraulic system flows, differential pressure PR+30 and PR+200, and hydraulic system pressure are indicated on the control console.

7.7.5 Manual and Automatic Shutdown

7.7.5.1 Rapid insertion of control rods is accomplished automatically by hydraulic accumulators in response to conditions which result in a coincidence trip of safety system sensors. A single trip from any safety detector not bypassed will trip the associated safety channel. Since both safety channels must be tripped to scram the reactor, the possibility of scramming from a malfunctioning individual circuit element is minimized.

7.7.5.2 Manual control for rapid insertion of control rods is also provided in the control room to be used at the discretion of the reactor operator.

7.7.5.3 Rapid insertion of control rods, when initiated either automatically by the safety system, or by the manual scram switch, is accomplished by de-energizing the solenoid scram pilot valves, thereby allowing the inlet and outlet scram valves to open. The outlet scram valves relieve the pressure on top of the rod piston to a dump tank, and the inlet scram valve supplies hydraulic pressure from an accumulator to the bottom of the rod piston which forces the control rod into the core.

7.8 LIQUID POISON SYSTEM CONTROL

Emergency injection of liquid poison is initiated manually from the control console. In order to insure against accidental initiation, two control switches are provided in series, each of which must be closed individually to energize the injection valves. A separate manual control is provided to close the injection line isolation valve (CV-4020 on Drawing M-107) and stop the flow of liquid poison, if desired. This valve is a normally open air operated valve (See Drawing M-107). Indication of poison tank pressure is provided to assure that the tank has become pressurized; and poison tank level switches indicate that the tank is emptying.

7.9 REACTOR INSTRUMENTATION (Drawing M-121)

7.9.1 Reactor Temperature

Twenty thermocouples are attached to critical locations on the steam drum and pressure vessel. Six thermocouples are attached to the drum, with the remaining 14 attached to the pressure vessel. All of these thermocouple temperatures are recorded on the main control panel. These thermocouples are used to observe and determine the heating and cooling rates of the pressure vessel and steam drum.

7.9.2 Feedwater and Reactor Water Level Control System

7.9.2.1 The water level in the steam drum is controlled by a three-element level control system. This control system uses the measurement of steam flow, feedwater flow and steam drum water level. Signals proportional to each of these measurements feed into the control system. Normally, the steam flow signals equal that of the feedwater. Any mismatch in these results in a correcting signal to the feedwater control valve. The water level measurements adds or subtracts from this signal to the control valve, if the detected level varies from the designed range.

7.9.2.2 A bias signal proportional to steam flow is applied to the level measurement signal so that the water level set point varies with load. This results in programmed level control. For high loads, the level stabilizes at the upper limit to provide volume for shrinkage as any load decreases. Conversely, at low loads, the level is maintained at the lower limit to allow for water volume swell on load increase.

7.9.2.3 The water level, steam flow and water flow rates are recorded and indicated in the control room. The water level indication is a completely independent level system from the level recording system and by a switch located on the console, either one can be used for controlling. Both level systems are independently pressure-compensated for accurate reading throughout the range. Both feedwater and steam flow are integrated. A manual automatic switch is provided on the console so the control valve may be operated manually if desired.

7.9.2.4 In addition to the two level systems used in the feedwater control, there are two independent steam drum level indicator systems that read-out in the control room.

7.9.3 Pressure Instruments

Pressure is measured at each end of the steam drum. One measurement is indicated and the other recorded in the control room on the main control panel. High pressure is also annunciated. Reactor pressure is measured, and is indicated on the main control panel.

7.9.4 Reactor Recirculating Loop Instrumentation

7.9.4.1 The recirculating water flow of each loop is measured, and is indicated on the main control panel, and is recorded on the auxiliary panel in the control room.

7.9.4.2 The differential pressure across the circulating pump is measured, and is indicated on the main control panel.

7.9.4.3 The pump seals are fully instrumented with pressures and temperatures being measured, indicated and annunciated in the control room, thereby providing the operator with the information necessary to determine the condition of the seals (Drawing M-237).

7.9.4.4 The recirculating pump motors are fully instrumented with bearing temperatures recorded and bearing oil level and vibration annunciated.

7.10 STEAM SUPPLY SYSTEM INSTRUMENTATION

7.10.1 Turbine and Main Steam Control System

7.10.1.1 Control and supervisory equipment for the turbine-generator are conventional and are arranged for remote operation from the control board located in the control room. Turbine lubrication oil and extraction pressures are transmitted to receivers on the control board, as are turbine throttle steam, first stage and the exhaust pressures.

7.10.1.2 The turbine steam bypass valve is also arranged for manual operation from the control console.

7.10.1.3 Turbine extraction bleeder trip valves of the conventional type are furnished on the high pressure and intermediate pressure heater extraction lines. These valves are arranged to close on a turbine trip and/or high level in the heater and are provided with remote manually operated test valves. These control functions are shown in Drawing M-241.

7.10.2 Condensate Control System

7.10.2.1 Main condenser controls are conventional and include a vacuum trip arranged to close the turbine stop valve and trip the reactor safety system. Level control of demineralized water make-up to the condenser and condensate rejection from the condensate pump discharge downstream of the demineralizers is also provided. Condensate hot-well level and condenser temperature and vacuum are recorded on the control board. Abnormally high or low hotwell level and low condenser vacuum, i.e., high back pressure, are annunciated on the main annunciator panel. Conductivity measurement of the condensate from each half of the condenser hotwell monitors condenser cooling water leakage. A sample connection in the condensate header upstream of the demineralizer allows for laboratory determination of dissolved oxygen as a guide to the performance of the gas removal system and de-aerating section of the condenser.

7.10.2.2 Condensate recirculation to the condenser, actuated from low feedwater flow, insures minimum flow requirements of condensate through the air ejector and gland seal condensers.

7.10.2.3 Instrumentation for the condensate demineralizer regeneration system is provided on a local control panel.

7.10.2.4 Each demineralizer is arranged for manual start and shutoff. The differential pressure head across all demineralizers is indicated with high pressure head annunciated on the local panel. Regeneration is arranged for manual start, with automatic control of the sequence during regeneration and shutoff.

7.10.3 Feedwater Heater Control System

7.10.3.1 Controls on the feedwater heaters are conventional, utilizing level controllers on each heater shell for normal cascading of drains to the lower pressure heater or condenser, and for high level dump to the condenser.

7.10.3.2 Further increase in the condensate level in any heater past the dump level is annunciated on the main annunciator panel, while a still higher level in both the intermediate and high pressure heaters will close the respective turbine extraction bleeder trip valves to prevent back flow of water to the turbine. Pressure and temperature test points are provided on each feedwater heater condensate inlet and outlet nozzle and on each heater drain nozzle. Local heater shell pressure gages are provided for use during maintenance.

7.10.4 Reactor Feedwater Pump Recirculation

Each reactor feed pump is provided with a solenoid valve, actuated air diaphragm control valve and multiple orifices which recirculate feedwater to the condenser to maintain minimum flow through the pumps. The actuating signal is provided by a low flow switch in the feedwater line to the reactor. When the total feedwater flow falls below the minimum required to prevent overheating of the pumps, both recirculation valves open and remain open until the flow demand of the reactor increases sufficiently to protect the pumps.

7.10.5 Make-up Water Control System

7.10.5.1 The water levels in the demineralized water and the condensate storage tank are indicated locally and in the control room with abnormally high or low level annunciated on the main annunciator panel. High level in the demineralized water tank also trips closed the raw water supply to the make-up demineralizer.

7.10.5.2 The make-up demineralizer system is arranged for manual start with automatic shutoff at high level in the storage tank, as noted above. Automatic shutoff also occurs at high effluent conductivity or completion of a preset flow cycle, either of which indicates a requirement for regeneration of the demineralizer bed.

7.10.5.3 Instrumentation for the make-up demineralizer system is provided on a local control panel, on the turbine operating floor. Regeneration is arranged for manual start with automatic regeneration cycle shutoff and employs a conventional technique using sulfuric acid and caustic soda as reagents. Full flow regulation in the make-up water to the demineralizer is accomplished by remote manual control from the local demineralizer control panel.

7.10.6 Reactor Cleanup Control System

7.10.6.1 The reactor cleanup system instruments and controls are located on a local panel in the reactor enclosure.

7.10.6.2 Controls include remote manual valves for throttling cleanup flow, isolation of the cleanup loop in the event of a severe leak and resin sluicing and recharging. A pressure switch prevents opening the resin charging line before relieving the pressure in the demineralizer vessel. A temperature switch annunciates and trips off the cleanup pump to protect the resin bed.

7.10.7 Reactor Emergency Cooling

7.10.7.1 The emergency condenser is initiated automatically upon a high pressure signal, PR+100 psia, which is above the normal steam bypass pressure control point, but below the lowest relief valve setting. The actuation signal opens the two motor-operated valves in the condensate return lines to allow the thermal siphon between the main steam drum and the emergency condenser to operate. The functional operation is described in Section 5.8.6.4.

7.10.7.2 In the event of a leak in one of the two sets of condensing coils, both the inlet and drain valves of that coil can be remotely closed.

7.11 FUEL RUPTURE DETECTION SYSTEM

This system is shown in Drawing 198E234. The occurrence of a fuel element rupture is determined by continuously monitoring the gases from the air ejector discharge. Specifically, a single channel gamma ray spectrometer is provided to monitor and record the level of krypton or xenon isotopes. Before the radiation level of noble gases can be determined, it is necessary to age the gas sample for a time of about two minutes and, therefore, a variable holdup time is provided in the sampling line. This allows for decay of nitrogen-16 and oxygen-19 before the samples are monitored and recorded.

7.12 PROCESS RADIATION MONITORING

7.12.1 Air Ejector Off-Gas Monitoring

7.12.1.1 Continuous monitoring of the air ejector off-gas radioactivity is required during power operation of the reactor to provide continuous audit of release to the environs. This avenue of release is closed by a valve when the activity level approaches the limit for allowable discharge.

7.12.1.2 The off-gas monitor is capable of indicating (and recording) radioactivity which would yield in excess of 50 curies per second release to the stack. (Estimated release rates of gas radioactivity during plant power operation, are given in Section 9.) At a release rate of forty (40) curies per second, a trip circuit initiates action of a time delay switch which, in turn, trips the off-gas shutoff valve closed after a preselected delay (adjustable up to 15 minutes; off-gas holdup time is about 30 minutes). At a release rate of four (4) curies per second, another trip circuit causes an alarm to be sounded in the control room. Resolution of radioactive gas release rates as low as 1000 microcuries per second is possible.

7.12.1.3 The off-gas flow rate to the stack is measured, indicated and recorded. The off-gas monitoring equipment is calibrated to read curies per unit volume so that the flow rate is necessary to determine curies per unit time.

7.12.4 To provide continuous, reliable monitoring at this key point, two identical monitors are used. The above fuel rupture detection system is functionally combined with this off-gas monitor system to provide backup monitoring.

7.12.2 Stack Gas Monitor System

7.12.2.1 An isokinetic probe permanently fixed in the stack approximately one-third up from the base, collects stack gas (and particulate) samples that are withdrawn with a gas pump through flow-metering and regulating equipment. The sample is passed through a replaceable filter which is located upstream from the gas sampler. The filter is periodically removed and checked for particulate contamination. After filtering, the continuous flow gas sample is presented to the continuous monitoring gamma spectrometer.

7.12.2.2 The gamma activity of the sample is monitored with a dual channel gamma spectrometer that is employed so that one channel may monitor the gross gamma activity and the other channel may monitor a single energy or band of energies. Both levels are recorded continuously. The gross activity level as may be monitored in one channel is used to show significant changes in over-all stack discharge, and the other channel monitoring specific isotopes is used to establish discharge rates.

7.12.2.3 The gamma detecting and monitoring equipment has sufficient sensitivity to detect a release rate of 50 microcuries of nitrogen-13 per second, and a range sufficient to monitor a release rate of one curie per second of an equilibrium mixture of fission gases.

7.12.3 <u>Emergency Condenser Vent Monitor</u>

In the event of tube failure in the emergency condenser, radioactive material could be released to the environs. This vent is monitored to detect a release of radioactive material.

7.12.4 <u>Process Liquid Monitor System</u>

7.12.4.1 Certain process streams are monitored continuously for gamma radioactivity to alert operating personnel in the event of (a) a variation from normal and/or (b) an excessive release of radioactive material off plant. These monitors consist of scintillation-type detectors. (Estimated release rates of liquid radioactive wastes during plant power operation are given in Section 9 of this report.) The process streams monitored are as follows:

Waste Demineralizer Effluent

Reactor Enclosure Cooling Water

Reactor Service Water

Main Condensate Demineralizer Influent

Circulating Water Discharge.

7.12.4.2 The monitors for "Reactor Service Water" and "Circulating Water Discharge" are sensitive to very low levels of contamination, since these streams are normally noncontaminated. The monitors are capable of resolving a concentration as low as 3×10^{-6} microcuries of iodine-131 per cc.

7.12.4.3 The other process streams are normally contaminated to various levels depending on operating conditions and impurities present.

7.12.4.4 The main condensate demineralizer loop monitor is capable of resolving a concentration as low as 3×10^{-6} microcuries of iodine-131 per cc.

7.12.4.5 The reactor enclosure cooling water monitor is capable of resolving up to 20 microcuries of sodium-24 per cc, if sodium chromate is used as an additive, or as low as 5×10^{-5} microcuries of silica-31 per cc, if lithium silicate is used as an additive.

7.12.4.6 The waste demineralizer monitor is capable of resolving concentrations greater than those limits established by licensing regulations for discharge of waste liquids.

7.12.5 Complementary Facilities for Process Monitoring

The chemical laboratory includes equipment for performing appropriate analytical procedures in radiochemical and non-radioactive material analyses. A separate shielded room containing counting equipment is provided in connection with the radiochemical analyses.

7.13 AREA AND PERSONNEL MONITORING

7.13.1 Area Monitoring System

7.13.1.1 The area monitoring system is a 20-channel system, utilizing industrial-grade equipment. The individual detectors are located in strategic points throughout the reactor building and turbine building. A 20-point recorder is common to all the monitor stations. Each monitoring channel is indicated and alarmed in the control room. The main board annunciator alarms in the event that any of the locations have a high radiation trip.

7.13.1.2 Scintillation-type detectors are used. There are four stations equipped with an indicator and alarm (horn and red light) mounted adjacent to the detector.

7.13.1.3 Detector stations are located as follows:

a) In the Sphere

i. Over the personnel lock

ii. On the N. W. wall of the sphere at elevation 607' (to see emergency and equipment locks)

iii. On the wall south of the reactor at elevation 640' (to see area involved in refueling), with indicator and alarm

iv. On the N. W. wall of the sphere at elevation 582' (to see stairs to and from this area)

v. Control rod drive equipment area

vi. Over the spent-fuel storage pool (to cover refueling operation), with indicator and alarm.

b) In the Turbine Building

i. In the condenser area near the access door, with indicator and alarm

ii. On the shield wall south of the condenser to "see" passage to and from the shop.

iii. In the condensate demineralizer room near the entry to the room

iv. On elevation 597'-0", opposite access control area

v. At the junction of the office corridor and the viewing area

vi. In access control area and laundry room

vii. Control room

viii. On elevation 608'-6", locker room

ix. On elevation 597'-0", entrance to personnel monitoring station

x. Inside door of turbine enclosure

xi. Near entrance (inside) to the liquid waste vault, with indicator and alarm

xii. Elevation 608'-6", stairway No. 8.

7.13.2 Personnel Monitoring Devices

7.13.2.1 The personnel monitoring in the entry lobby consists of a portal-type monitor. This will measure high beta/gamma and in the case of high radiation levels in the immediate vicinity, an audible and visual alarm will be given in the immediate area.

7.13.2.2 A threshold-type monitor along with a portable hand probe is installed in the access to the lunchroom and in the access control room. There is both an audible and visual alarm in both locations in case of a high beta/gamma count on the counter.

7.13.2.3 Portable personnel monitoring instrumentation is available for appropriate monitoring during plant operation.

7.13.3 Instrument Calibration Facility

The radiation instrument calibration facility consists of a detached building with a shielded well and a lift mechanism for positioning a radioactive source at precise levels within the well. This facility provides for on-site calibration of the plant radiation monitoring instruments. Calibration will be done by positioning the instrument over the well and checking its response to predetermined levels of radiation from the source.