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7 INSTRUMENTATION AND CONTROL SYSTEMS

7.1 Summary Description

In order to achieve safe and efficient reactor operation, the important variables related to the reactor process, its systems, and its environment are monitored, processed and controlled. The NBSR Instrumentation and Control (I&C) System consists of five major subsystems: the Reactor Control System; the Reactor Protection System (RPS); the Engineered Safety Features (ESF); the Main Control Panel; and the Radiation Monitoring System. Each of these systems may be further subdivided: Reactor Control System has both manual and automatic modes; RPS has both nuclear and non-nuclear components; the ESF, which include the Emergency Cooling System, Confinement Building, and the Ventilation Systems; the Main Control Panel consists of instrumentation, controls, and annunciators; and the Radiation Monitoring System has both area and effluent monitoring capability. The interconnections and relationships among the various subsystems, components, instruments, and controls that comprise the NBSR I&C System are presented in a simplified block diagram in Figure 7.1.

Initial planning for the NBSR began in March 1958 when an application for a construction permit was submitted. Construction began in 1963. The reactor achieved initial criticality on December 7, 1967 and began full-power operation at 10 MWt on February 9, 1969. Operating License TR-5 was amended on May 16, 1984 to increase the licensed power level to 20 MWt. All of the instruments installed during the construction period were analog. Subsequent modifications to the reactor facility, including equipment upgrades have been made since the initial license. These new instruments have been either analog or a hybrid of digital and analog technology. The nuclear safety system, which is part of the RPS described in Section 7.4.1, remains entirely analog.

The term “digital hybrid” as used here implies an instrument that obtains an analog signal, transmits that signal to an analog-to-digital converter, and then makes the digital output available for display or other desired use. Setpoints and alarms may be altered by authorized personnel for both the analog and digital-hybrid instruments. However, the programming of the digital-hybrid instruments cannot be changed by the NBSR staff. The firmware for the digital hybrid instruments is installed by the manufacturer and cannot be field modified.

7.1.1 Reactor Control System

The Reactor Control System allows the NBSR reactor to be operated in either manual or automatic mode. In manual mode, the reactor operator manipulates the four shim safety arms and the regulating rod, as needed, to start up and shut down the reactor and to change power levels. In automatic mode, the flux controller automatically positions the regulating rod to maintain an operator-set reactor power level. The Main Control Panel provides the operator with all of the controls and instrumentation necessary to safely operate the reactor. The NBSR reactor is not equipped with a digital control console. At the NBSR, the Reactor Control System is also referred to as the Reactivity Control System.

The instruments used in the Reactor Control System are distinct from those used by the Reactor Protection System. The Reactor Control System is equipped with a number of design features and interlocks to ensure safe operation. The initiation of any scram signal will cause all reactivity control devices to be inserted. The NBSR does not have a pulse power capability.

7.1.2 Reactor Protection System

The Reactor Protection System (RPS) consists of nuclear and non-nuclear components. The Nuclear Instrumentation Channels monitor the reactor power level from the subcritical state at start-up through the power range. This system comprises two Source Range Channels, two Intermediate Range Channels, and three Power Range Channels. The two Source Range Channels each monitor reactor power (counts/second) and reactor period (seconds). These channels produce a withdraw prohibit signal when the count rate drops below 2 cps (Low Count Rate) or the period decreases below 15 seconds (Source Range Period Rod Stop). The two Intermediate Range Channels also monitor reactor power (amps) and reactor period (seconds). These channels have the following functions:

- De-energize the high voltage supplied to the Source Range detectors when the current exceeds 2×10^{-10} amps (Source Range High Voltage Disconnect);
- Produce a withdraw prohibit signal when the period decreases below 15 seconds (Intermediate Range Period Rod Stop),
- Initiate a reactor rundown when the period decreases below 10 seconds (Period Rundown), and,
- Scram the reactor when the period decreases below 5 seconds (Period Scram).

The three Power Range Channels each monitor reactor power. These channels disable the Intermediate Range Period Scram when the reactor power level on all three channels exceeds 10%. They initiate a reactor rundown when the power level on any of the three channels exceeds 115%. The power level at which they scram the reactor depends on the position of the Scram Level Selector Switch. During startup, the reactor operator sets the switch to scram the reactor at 13%. After startup, the reactor operator sets the switch to scram the reactor at 125%. The Coincidence Selector Switch determines if a scram signal occurs when any one of the three Power Range Channels exceed the setpoint (“1 of 3”coincidence) or if it requires that any two of the three channels must exceed their setpoint before a scram signal occurs (“2 of 3” coincidence).

The Process Instrumentation Channels monitor the process parameters. These parameters are primary coolant flow, primary coolant differential temperature across the core, and reactor vessel level. In addition, all parameters that are required by the technical specifications to cause a reactor scram have an input to the RPS. The Process Instrumentation is both diverse and redundant. The two Reactor ΔT Indicator Channels provide redundant inputs to the scram circuits as do Reactor Vessel Level Indicator Channel and Reactor Vessel Level Recorder Alarm Channel. The Reactor Outer Plenum Flow Recorder Channel, the Reactor Inner Plenum Flow Recorder Channel, and the Reactor Outlet Flow Indicator Alarm Channel provide diverse inputs to the scram circuits. Any channel that exceeds its setpoint will cause a scram. Once the setpoint is exceeded, the scram relays de-energize to remove power from the four shim safety arm clutches. This results in the shim safety arms dropping into the core by gravity, assisted by compressed spring force, thus shutting down the reactor.

7.1.3 Engineered Safety Features

Engineered Safety Features (ESFs) are designed to prevent accidents and control the release of radioactive materials to the environment should an accident occur. The NBSR ESFs include the Emergency Cooling System, Confinement Building, and the Ventilation Systems. ESFs may be automatically actuated by the protection instrumentation that monitors various parameters during the reactor's operation, or manually by the reactor operator. For example, in addition to shutting down the reactor, a major scram signal will actuate the Confinement Building Isolation System to prevent the release of radioactivity to the environment. This signal may be generated manually by the reactor operator, or automatically in response to high radiation levels detected by radiation monitors in the ventilation system. Engineered Safety Feature systems and components are discussed in detail in Chapter 6.

7.1.4 Main Control Panel

The NBSR Main Control Panel in the Control Room provides all of the information and controls needed by the operator to safely operate the reactor from a centralized location. The center, angled, portion of the console (Panels C, D, and E shown on Figure 7.2) provides all of the instrumentation and controls associated with the reactor. Nuclear instrumentation provides overlapping indication of reactor power level from startup to full power as well as indication of reactor period. Controls and indications are provided on this section of the console to control the shim safety arms, the automatic regulating rod, the primary and secondary cooling pumps, and the operation of the cooling tower. Three annunciator panels, located at the top of the vertical backboard on this portion of the console, alert the reactor operator to off-normal conditions in these systems as well as indicate the source of scrams and rundowns. An additional, three-window annunciator panel located just below the center annunciator panel alerts the operator to scram, rundown, and withdraw prohibit conditions.

The console to the left of the reactor controls (Panels F, G, H, J, K, L on Figure 7.2) provides instrumentation and controls associated with the auxiliary systems, experimental facilities, and radiation monitoring equipment. Two annunciator panels on this portion of the console alert the reactor operator to off-normal conditions in these systems. Each alarm is labeled with the underlying cause (e.g., Reactor D_2O Level High). In addition, the number of the annunciator panel and the individual alarm window (e.g., AN3-14) corresponds to the associated Annunciator Procedure (AP) number, thereby assisting the operator in quickly locating the appropriate alarm response procedure to take corrective action for each alarm condition.

The console to the right of the reactor controls (Panels A and B on Figure 7.2) includes the Nuclear Instrumentation Cabinet and additional instrumentation and controls associated with nuclear instrumentation, experimental facilities, and radiation monitoring equipment.

A second function of the display system is to provide essential information at the Emergency Control Station located outside of the Confinement Building in the basement level, B-2, of the NBSR office building, located adjacent to the Confinement Building. Information is available at this location for use during emergencies that result in the Confinement Building becoming inaccessible.

7.1.5 Radiation Monitoring System

The Radiation Monitoring System (RMS) consists of both area and effluent monitors. The area monitors provide indication of radiation levels throughout the containment building. These have been positioned at locations where either experimental work is performed or where work involving radioactive material is likely to be undertaken. As a result, the reactor operator can observe radiation levels and warn both experimenters and operations personnel of any unanticipated changes or hazards. The effluent monitors provide indication of the radioactivity of the air and water that leaves the building. All effluent paths are monitored. The monitored paths are exhaust air (gaseous and particulate), secondary coolant (beta-gamma) and sewer discharge (beta-gamma).

All area and effluent radiation monitors alarm in the control room. The effluent monitors can initiate a confinement building isolation as discussed in Section 7.1.3 of this report.

7.2 Design of Instrumentation and Control Systems

7.2.1 Design Criteria

Since the NBSR is a test reactor, there is no reason to continue operation during adverse conditions such as a severe natural phenomenon, a seismic event, or a fire. Administrative procedures require the reactor to be shut down should any of these events occur. Accordingly, while it is anticipated that the NBSR I&C System would remain operable during such circumstances, once a reactor shutdown has been achieved, there is no safety need for them to do so. The shutdown reactor is protected against damage as long as the reactor vessel integrity is maintained. The public is protected against potential radiation releases as long as the containment building integrity is preserved.

The following design criteria exist for the NBSR I&C System:

1. Elements of the I&C System that are important to safety include both redundancy and diversity. For example:
    - The RPS receives two Source Range Period Scram signals, two Intermediate Range Period Scram signals, and three Power Range High Flux Scram signals from the Nuclear Instruments.
    - The RPS receives redundant inputs from Reactor Vessel Level instruments and from Reactor ΔT instruments to initiate a reactor scram.
    - The RPS receives diverse inputs from reactor inlet flow channels and from reactor outlet flow channel to initiate a reactor scram.
    - The ESF actuation system receives redundant and diverse inputs from Irradiated Air Monitor Channel, Normal Air Monitor Channel and Stack Monitor Channel to initiate a reactor scram and seal the Confinement Building.

2. The RPS and the ESF automatically initiate operation to mitigate the consequences of abnormal conditions.

3. The I&C System is designed to be fail-safe.

4. A single failure will not prevent a safe shutdown of the reactor because of the diverse and redundant designs.

5. Most of the I&C System equipment is not required to operate during a credible accident. The requirement is for the reactor to be placed in a shutdown condition. Instruments for this purpose are supplied by emergency power.

6. The I&C System is completely protected from natural phenomena such as storms by the confinement building. Also, system components are securely mounted so that they are not damaged during a safe shutdown seismic event.

7. Most of the I&C System equipment is located in the Control Room. Detectors and signal transmitters are located outside of the Control Room. Those important to reactor safety are redundant or diverse and their signal cables are routed in separate cable trays and cable chases to prevent common mode failures.

Single failure criteria and the use of redundant and diverse channels are elements of the design bases for the Instrumentation and Control System. From accident analysis, different stages of reactor operation have been defined and adequate logic control chains have been developed to ensure safe operation under all conditions. The main parameters which are monitored and provide inputs to the logic chains are:

1. Primary coolant flow, level, and pressure;
2. Neutron flux level and period (rate of change);
3. Control Rod status (shim safety arms and regulating rod);
4. Experiment status;
5. Radioactivity levels; and
6. Electrical and Control Power status.

The logic control chains that are grouped within the reactor safety system are:

1. Major Scram (reactor trip and confinement isolation);
2. Reactor Scram (automatic and manual reactor trip);
3. Start Up Prohibit (disable reactor startup);
4. Withdraw Prohibit (disable control rod withdrawal);
5. Rundown (automatic insertion of all control rods); and
6. Experiment Scram.

7.2.2 Design-Basis Requirements

7.2.2.1 Reactor Control System

The control philosophy of the NBSR stems from the nature of the xenon poison problem, which is characteristic of high flux thermal reactors. After a shutdown, xenon poison builds up to levels which are exceedingly high. In order to be able to restart the reactor after shutdown without major core reloading, large excess reactivity and rapid rod withdrawal would be necessary, both of which are counter to safe operation. It was, therefore, decided to design a control system that stresses reliable operation and minimizes inadvertent reactor shutdown. Little, if any, reactivity is carried for xenon override, and rod withdrawal rates are conservatively slow. The control rods are designed to limit both reactivity and reactivity rate of change. The potential for false scrams is minimized through the use of redundant circuitry and coincidence logic

Of all the parameters that are measured and controlled, the thermal neutron flux level is the primary quantity that is measured for reactor operation and safety. The flux measuring instruments indicate over the entire range, from source range level to in excess of full power, and signal the safety system if the reactor power level exceeds a preset maximum.

Reactivity can be controlled in the NBSR by means of three separate systems: the regulating rod, the shim safety arms, and the top reflector dump. The latter two can be individually or collectively brought into action for reactor scram purposes.

The Reactor Control System has two modes of operation: manual and automatic. Manual mode is used to start up and shutdown the reactor, and to change power levels. Automatic mode is used for steady-state operation. While manual mode allows the reactor operator to manipulate all reactivity control devices (four shim safety arms and the regulating rod), automatic mode only moves the regulating rod. Several safety features are designed into the Reactor Control System. These safety features include:

- The Shim Safety Arms can be scrammed from any height in the reactor,
- The Shim Safety Arms and Regulating Rod are automatically inserted at normal speed upon receipt of a rundown signal, and
- The reactor operator can take manual control of the regulating rod at any time by simply moving the regulating rod control switch on the Main Control Panel.

There are several interlocks associated with the Reactor Control System:

- Scram: The Shim Safety Arms and Regulating Rod cannot be withdrawn to start up the reactor until all of the contacts in the Scram Logic String are closed, indicating that the parameters associated with these contacts are in their normal ranges, Control Power is ON and the Scram Relays are reset by the reactor operator. This ensures that scram protection is enabled before any reactivity control devices are withdrawn.

- Startup Prohibit: A reactor startup cannot commence until all of the contacts in the Startup Prohibit Logic String are closed, indicating that the parameters associated with these contacts are in their normal ranges, Control Power is ON and the Scram Relays are reset by the reactor operator. This ensures that scram protection is enabled and that operating conditions in the plant are stable and within their normal operating ranges prior to startup.

- Withdraw Prohibit: The Shim Safety Arms and Regulating Rod cannot be withdrawn until all of the contacts in the Withdraw Prohibit Logic String are closed, indicating that the parameters associated with these contacts are in their normal ranges. This ensures that the reactivity control devices are not withdrawn if there is either a Source Range Period Rod Stop signal or an Intermediate Range Period Rod Stop signal or if there is a Rundown signal.

- Automatic Regulating Rod Control: The Regulating Rod can be placed in the Automatic mode at any power level. The flux controller automatically positions the regulating rod to maintain an operator set reactor power level within ± ½% of the setting of the Power Demand Potentiometer. Operation will revert to Manual operation if a reactor scram signal occurs, the Regulating Rod reaches its full in or its full out positions, a 10% Servo Deviation alarm occurs indicating that the controller is not maintaining reactor power, or the Regulating Rod switch is operated.

- Rundown: The Shim Safety Arms and Regulating Rod are automatically inserted at their normal speed if any of the contacts in the Rundown Logic String open, indicating that the parameters associated with the contacts are not in their normal range. This will continue until such time that the condition causing the rundown clears and the contact closes (or rods reach the bottom). The parameters in this logic string include those process and nuclear instruments included in the Scram Logic String as well as additional parameters associated with the Cold Source, the Thermal Column and the Thermal Shield. The Rundown reduces reactor power level and possibly prevents a Reactor Scram from occurring.

Instruments associated with the Reactor Control System are located on the central, angled portion of the Main Control Panel (Sections C, D, and E in Figure 7-2). These include indication of reactor power level from the source range to the power range, reactor period, Shim Safety Arm position indicators, Regulating Rod position indicators, and the Servo Deviation meter. Four Shim Safety Arms switches, a Regulating Rod switch, a Shim Rod Gang switch, Manual-Automatic Transfer switch, and the NC-5 Range Select switch are located with these indicators.

7.2.2.2 Reactor Protection System

The RPS ensures that the limiting safety system settings (LSSS) are not exceeded as the result of transients of the type discussed in Chapter 13 of this SAR. The primary parameters of concern are the reactor power level, the reactor period, the reactor vessel level, the primary coolant flow, and the differential temperature across the core. Other parameters include Irradiated Air activity, Normal Air activity and Exhaust Stack activity. In addition to initiating a reactor scram, these last three parameters also initiate a Major Scram, sealing the Confinement Building to prevent the activity from escaping the building. The RPS also receives inputs from the Moderator Dump, Manual Scram, Experimental Scram switches as well as relays that monitor the Process Instruments 24 Vdc power supplies and the Nuclear Instruments ±10 Vdc power supplies.

The setpoints at which RPS action occurs are well below the limiting safety system settings. This conservative approach provides further assurance that a safety limit will not be approached. For example, the normal licensed operating power level is 20 MW. The scram is set at 125% of this level or 25 MW. The safety limit varies with plenum flow rate and core inlet temperature, but has a maximum value of about 50 MW. The RPS is both redundant and diverse as noted in Section 7.2.1 of this SAR.

7.2.2.3 Engineered Safety Features

The design basis for the NBSR ESF is that the safety features are actuated automatically by the protection instrumentation that monitors various parameters during reactor operation or manually by the reactor operator to prevent accidents or mitigate accidents, should they occur, by controlling the release of radioactive materials resulting from the accident to the environment. The ESFs are designed to prevent an uncontrolled release of radioactive material to the environment in the very unlikely event of a fuel element failure or a loss of coolant accident. For example, a reactor scram is automatically initiated and the Confinement Building is automatically isolated if any of the air activity monitoring channels exceed their setpoint. Details of the Engineered Safety Features are described fully in Chapter 6.

7.2.2.4 Main Control Panel

The design basis of the Main Control Panel is that the reactor operators be provided with a central location from which they can safely operate the reactor. Instrumentation associated with the primary coolant system, the secondary coolant system and the auxiliary systems provide the operator with the ability to monitor conditions throughout the plant. Controllers provide the operator with the ability to remotely start and stop equipment throughout the plant as well as to remotely open, close or throttle valves in the various systems. The Instrumentation and Controls (I&C) are grouped as described in Section 7.1.4 of this SAR. The parameters they monitor and the equipment they control are both diverse and redundant. An Annunciator System is provided on the panel to alert the operator to an abnormal condition and to facilitate both the diagnosis of the abnormal condition in the plant as well as the selection of the appropriate response to the condition.

A second requirement imposed on the display system is that essential information needed during an emergency which results in the Confinement Building becoming inaccessible is provided at the Emergency Control Station located in the basement level, B-2, of the adjacent office building.

7.2.2.5 Radiation Monitoring System

The design basis of the RMS is that the reactor operator be provided with information on radiation levels within the Confinement Building and the activity in the air within the building. In addition, the instruments are designed to automatically initiate a reactor scram and

Confinement Building isolation if air activity in excess of the setpoint is detected. The instruments are both diverse and redundant.

7.2.3 System Description

A summary of the instrumentation and control system is given here with an emphasis on the relationship among the five major subsystems. Detailed descriptions are given in Sections 7.3 thru 7.7 of this SAR. Appendix A of this chapter provides detailed descriptions of each of the instrument channels while Appendix 7B provides detailed information on the Annunciator System.

Figure 7.1 presents a simplified block diagram of the Reactor Instrumentation and Controls (I&C) System. It shows the important design aspects of the system and the interconnections and relationships among the five subsystems that comprise the I&C System. They are: the Reactor Control System, the Reactor Protection System, the Engineered Safety Features, the Main Control Panel, and the Radiation Monitoring System. This section will describe how the design and operation of the I&C System ensures the safe and reliable operation of the reactor and provides protection of the general public through the isolation of the Confinement Building. As shown in the figure, all of the monitored parameters are displayed on the Main Control Panel for the Reactor Operator to utilize during normal reactor operations and plant emergencies.

As indicated in Figure 7.1, eight separate nuclear instrument channels (NC-1 to NC-8) monitor the reactor power level from shutdown to full power operations. The detectors are located in instrument wells in the biological shield. Hence, they measure the leakage flux from the core. Source Range Channels NC-1 and -2 provide indication of level (counts/second) and period (seconds). Intermediate Range Channels NC-3 and -4 provide indication of level (amps) and period (seconds), and also provide reactor period trip signals to the RPS. Linear Channel NC-5 provides indication of reactor power (watts) to the automatic Flux Controller. Power Range Channels NC-6, -7, and -8 provide indication of reactor power (percent of maximum). They also provide reactor power trip signals to the RPS. All eight of these channels are displayed and recorded on the Main Control Panel for use by the Reactor Operator.

The Reactor Safety System, shown in Figure 7.7, is a hardwired relay logic ladder with multiple inputs and multiple functions. Refer to Table 7.6 for a list of the instrumentation designators used in the relay logic diagrams. A ladder rung is formed by multiple contacts wired in series with either a single relay or multiple relays wired in parallel. Each contact in a given rung represents a specific plant parameter and is controlled by the instrument or equipment associated with that parameter. Each rung in this ladder has a unique function assigned to it. Some of the functions are part of the RPS while the remaining functions are part of the Reactor Control System. Some examples of the assigned functions are Scram, Manual Scram, Withdraw Prohibit, Startup Prohibit, Rundown, and Regulating Rod controls.

Control power at 48Vdc is directly applied to the relay logic ladder by parallel redundant relay safety system power supplies EBA and EBB fed from Critical Power Panel CP-1 as shown in Figure 7.3. Power to the Critical Power Panel CP-1 is backed up by two redundant emergency diesel generators and the station battery via two redundant uninterruptible power supplies in the event that offsite power is unavailable as described in Chapter 8. This power distribution system design assures that control power is always available to all but the last three rungs of the relay logic ladder on the right-hand side of Figure 7.7. The reactor operator uses the Control Power key switch S-4 to apply control power for the remaining three rungs of this ladder: Startup Prohibit (rung 5) and Scram (rungs 4A & 4B). Before any reactivity control devices can be withdrawn, those plant parameters that control contacts in these three rungs of the logic ladder must be in their normal operating range and the reactor operator must close the Control Power key switch and reset the Scram relays.

The RPS controls the power to the electromagnets that couple the Shim Safety Arms to their respective drive motors. A trip of any of the Scram relays will cause a loss of power to all of the Shim Safety Arm magnets, thereby decoupling the arms from their respective drive motors and dropping the arms into the core by gravity assisted by compressed spring force, scramming the reactor.

The Scram function is part of the RPS. This function of the logic ladder has four Scram relays split between two parallel rungs (K103a and K103b in rung 4A and K103c and K103d in rung 4B). Control power for both rungs is controlled by the Reactor Operator through the Control Power key switch S-4. The two Intermediate Range Period Channels and the three Power Range Channels control relays in the Scram circuit. In addition to the contacts associated with these five Nuclear Instrument channels, redundant contacts are located in each of the two parallel rungs controlled by the Process Instrumentation Scram Channels, the Nuclear Instrumentation power supplies, the Process Instrumentation power supplies, Major Scram, the Moderator Dump, the Manual Scram, and the Experimental Scram functions. The reactor Scram circuit inputs are listed in Table 7.1. If all of the contacts in the Scram logic strings are closed, indicating that the plant parameters associated with these contacts are in their normal ranges, and the Control Power key switch is ON, then the reactor operator can reset the Scram relays by depressing the Scram Reset pushbuttons on the Main Control Panel. Once the Scram relays are reset, power is then available to the Startup Prohibit relays.

The Major Scram function is part of the RPS. The Normal Air Monitor Channel, Irradiated Air Monitor Channel and the Stack Monitor Channel control the relays in the Major Scram circuit. Upon the detection of an excessive activity level by any of the three channels, the Major Scram relays scram the reactor and initiate Confinement Building isolation. The Major Scram relays open contacts in the Scram logic string, thereby initiating a reactor scram. The relays also shut the doors at the entrances to the Confinement Building by tripping the Door Scram Relays (DSR), shift the ventilation lineup to recirculation mode by tripping the Fan Scram Relays (FSR), and close the Neutron Guide Isolation Valves.

The Moderator Dump function is part of the RPS. Negative reactivity can be inserted by removing the moderator from the area immediately above the reactor core. The Moderator Dump switch on the Main Control Panel provides a backup shutdown option to the reactor operator. The dump switch has contacts in the Scram logic string. Opening these contacts initiates a reactor scram, shutting down the reactor. Additional contacts in this switch open the Moderator Dump Valve DWV-9 shown on Figure 7.9, dumping primary coolant above the core into to the D_2O Storage Tank. These contacts also open the circuit breakers supplying power to the Main Coolant Pumps, stopping them.

The Reactor Control System controls the operation of the Shim Safety Arms and the Regulating Rod. It is enabled by the Startup Prohibit and the Withdraw Prohibit circuits. In the presence of a prohibit signal from either circuit, the reactor operator is prevented from withdrawing any reactivity control device, regardless of whether the reactor is being operated in Manual or Automatic mode.

The Startup Prohibit function is part of the Reactor Control System. It receives control power through contacts in the Scram relays. In this way, all Scram conditions must be cleared and the Scram relays reset before the Startup Prohibit relays can be energized. The Source Range Log Count Rate Channels and the Intermediate Range Log N Channels control relays in the Startup Prohibit circuit. This ensures that the reactor operator has visible indication of reactor power level before any reactivity control devices are withdrawn. In addition to the contacts associated with these four Nuclear Instrument channels, contacts controlled by the Emergency Cooling Tank Level Indicator Alarm Channel LIA-2, Reactor Vessel Overflow Indicator Channel FIA-2, Shim Safety Arm Clutch Current, Nuclear Instrument Test Fault, and Process Instrument Test Faults are wired in series with the Startup Prohibit relays. This ensures that the level in the Emergency Tank is in its normal operating range, that there is flow of primary coolant through the overflow line and that the Shim Safety Arm clutches are energized before any reactivity control devices can be withdrawn. Finally, the test fault contacts ensure that none of the channels of the Nuclear Instrumentation System and the Safety System Process Instruments are providing the reactor operator with false readings because they are in test mode. The input parameters to the Startup Prohibit circuit are listed in Table 7.2.

The Withdraw Prohibit function is part of the Reactor Control System. Control power at 48Vdc is directly applied to the relay logic ladder by parallel redundant relay safety system power supplies EBA and EBB fed from Critical Power Panel CP-1 as shown in Figure 7.3. Power to the Critical Power Panel CP-1 is backed up by two redundant emergency diesel generators and the station battery via two redundant uninterruptible power supplies (UPS) in the event that offsite power is unavailable. (see Chapter 8). This power distribution system design assures that control power is always available to the portion of the relay logic ladder that contains the Withdraw Prohibit function as shown on Figure 7.7. The Source Range Period Channels and the Intermediate Range Period Channels control relays in the Withdraw Prohibit circuit. These Rod Stop signals prevent the Reactor Operator from withdrawing any reactivity control devices when the reactor period is short. In addition to the Rod Stop inputs, contacts associated with the Rundown relays also control the Withdraw Prohibit relays. This prevents the Reactor Operator from attempting to withdraw any reactivity control device while the conditions causing a rundown are still present. The input parameters to the Withdraw Prohibit circuit are listed in Table 7.3.

The Rundown function is part of the Reactor Control System. Control power at 48Vdc is directly applied to the relay logic ladder by parallel redundant relay safety system power supplies EBA and EBB fed from Critical Power Panel CP-1 as shown in Figure 7.3. Power to the Critical Power Panel CP-1 is backed up by two redundant emergency diesel generators and the station battery via two redundant uninterruptible power supplies in the event that offsite power is unavailable. (see Chapter 8). This power distribution system design assures that control power is always available to the portion of the relay logic ladder that contains the Rundown function as shown in Figure 7.7. Selected primary plant parameters as well as selected Cold Source parameters control relays in this rung of the logic ladder. If any of the contacts in the Rundown logic string open, indicating an abnormal condition in the plant, then the four Shim Safety Arms and the Regulating Rod are driven into the reactor core to automatically reduce reactor power. A reactor rundown, once initiated, continues until the condition clears or until the reactivity control devices are fully inserted. The input parameters to the Rundown circuit are listed in Table 7.4.

The Shim Safety Arms and Regulating Rod positioning and indicating functions are part of the Reactor Control System. Control and indication is provided over the full range of operation of these devices. Digital indication of the shim arm positions is provided to the reactor operator on the Main Control Panel while analog indication of the regulating rod is provided. In addition to position indication, limit switches provide the full up and full down position information to the reactor operator.

The Main Control Panel displays nuclear, process and radiation information on a central location for use by the reactor operator. Selected channels are also recorded for trending purposes. Status of equipment and systems is provided by indicating lights and annunciator panels. Control switches for Shim Safety Arms, the Regulating Rod, as well as various pumps, valves and other plant equipment are provided on the panel. Switches to initiate a Reactor Scram, Moderator Dump or Major Scram are conveniently located on the Main Control Panel. The Main Control Panels in the control room consist of 11 instrument panels, labeled A through L (excluding I) as shown in Figure 7.2. The main control station is Panel D where the reactor shim safety arm, regulating rod controls, nuclear instrument displays and recorders, and annunciator panels AN-4 and AN-6. Immediately to the left is panel E containing the primary coolant system controls and instrumentation and annunciator panel AN-3; Immediately to the right is Panel C containing the secondary coolant system controls and instrumentation and annunciator Panel AN-5. To the left of the center, angled section of the Main Control Panel are: Panels F and G displaying radiation monitoring, emergency ventilation, AC and DC controls, and annunciator Panel AN-2; Panels H and J housing helium and D_2O purification controls and instruments; and Panels K and L contain controls and instruments for the thermal shield, storage pool, experimental cooling systems, and annunciator Panel AN-1. To the right of the center, angled section of the Main Control Panel are: Panel A, housing the nuclear instrumentation equipment; and Panel B, containing additional radiation monitors.

The Radiation Monitoring System consists of area monitors, duct monitors, and effluent monitors located throughout the facility to ensure that release of radioactive effluents to the environment is within the limits of the Technical Specifications. The output of each area monitor and duct monitor associated with the reactor is displayed and recorded on the Main Control Panel and alarmed on annunciator panel AN-2 if the output exceeds the alarm setpoint. If the radiation levels detected by the Normal Air Monitor, the Irradiated Air Monitor, or the Stack Monitor channels exceeds their trip setpoint, a Major Scram is automatically actuated shutting down the reactor and initiating a Confinement Building isolation.

7.2.4 System Performance Analysis

The NBSR I&C System has had an excellent performance history since the reactor achieved initial criticality on December 7, 1967. All of the equipment and subsystems that comprise the I&C System have been well designed and maintained. Components important to safety are both diverse and redundant. They are tested for operability and calibrated on a regular basis. All maintenance is documented and reviewed so that any trends, such as a drifting channel, become apparent. In addition, there is an ongoing program to upgrade and/or replace these systems, components and equipment with the latest available technology.

7.2.5 Conclusion

The design and performance of the I&C System meets or exceeds the design bases as described in Sections 7.2.2.1 thru 7.2.2.5, above. The Reactor Control System assures safe and reliable operation of the reactor. Interlocks ensure that scram protection is enabled and that the plant systems are operating normally before any reactor startup can occur. The RPS assures that the plant is automatically shutdown and placed in a safe condition should any of the primary parameters of concern generate a trip signal. These parameters are the reactor power level and reactor period signals from the Nuclear Instrumentation System and reactor vessel level, primary coolant flow, and primary coolant differential temperature signals from the Process Instrumentation System. The ESF assures the safety of the public by preventing or mitigating the effects of accidents that have the potential of releasing radioactive materials to the environment. The reactor is shutdown and placed in a safe condition and the Containment Building is isolated upon receipt of either a high Irradiated Air activity signal, a high Normal Air activity signal or a high Exhaust Stack activity signal. The Main Control Panel display provides the operator with all of the information and controls necessary to safely operate the reactor from a central location. Controls are grouped by systems. Meters, recorders, and annunciators provide the operator with indication of plant parameters. The RMS provides the reactor operator with radiation and activity levels throughout the facility.

7.3 Reactor Control System

The Reactor Control System provides for the withdrawal and insertion of the four Shim Safety Arms and the Regulating Rod. These are the normal mechanisms for the nuclear control of the NBSR reactor. The system consists of four individual shim safety arm withdraw/insert circuits, one Regulating Rod withdraw/insert circuit, their associated interlocks, and the automatic control circuit.

The Main Control Panel, shown in Figure 7.2, displays nuclear, process and radiation information on a central location for use by the reactor operator. Selected channels are also recorded for trending purposes. Status of equipment and systems is provided by indicating lights and annunciator panels. Control switches for Shim Safety Arms, the Regulating Rod, as well as various pumps, valves and other plant equipment are provided on the panel. Switches to initiate a Reactor Scram, Moderator Dump or Major Scram are conveniently located on the Main Control Panel.

Eight separate channels of Nuclear Instrumentation monitor the reactor power level and period continuously from shutdown to full power. A functional block diagram of the Nuclear Instrumentation is provided in Figure 7.4. The detectors are located in instrument wells located in the biological shield. Each detector location views the reactor core through a lead window. The purpose of this window is to shield the detectors from the strong gamma radiation field that would otherwise be present at the detector location as a result of the fission process. Hence, the detectors measure only the leakage flux from the core.

Source Range Channels NC-1 and -2 monitor the reactor power in the source range. Intermediate Range Channels NC-3 and -4 provide reactor period trip signals to the RPS. Linear Power Channel NC-5 provides a reactor power level signal to the automatic flux controller. Power Range Channels NC-6, -7 and -8 provide reactor power trip signals to the RPS. The neutron flux range covered by each level of nuclear instrumentation is presented on the graph shown in Figure 7-5. All eight channels are displayed and recorded on the Main Control Panel for use by the reactor operator.

Nuclear Instrumentation channels NC-1, -2, -6, -7, and –8 are powered by ±10Vdc from redundant pairs of +10Vdc power supplies and –10Vdc power supplies fed from Critical Power Panel CP-1 as shown on Figure 7-3. Power to the Critical Power Panel CP-1 is backed up by two redundant emergency diesel generators and the station battery via two redundant uninterruptible power supplies in the event that offsite power is unavailable. The voltage levels of the +10Vdc bus and the –10Vdc bus are continuously monitored by relays K07-19 and K07-20, respectively. If either of these two pairs of power supplies fail, a contact of these relays in the scram logic circuit will open causing the scram relays K103 in the safety system to de-energize which in turn will shut off the shim rod clutch current.

Nuclear instrumentation channels NC-3 and –4 are powered by local uninterruptible power supplies (UPS) that are fed from critical power panel CP-1. These units are designed to be fail-safe such that a loss of power will cause a reactor scram.

Linear channel NC-5 is powered by a 120 Vac outlet supplied from critical power panel CP-1. As mentioned previously, CP-1 is backed up by the diesel generators and station batteries.

A minimum of one decade of overlap is designed into the transition between Source Range and Intermediate Range Nuclear Instrumentation and between Intermediate Range and Power Range Nuclear Instrumentation. Normally, the photoneutron source is sufficiently strong that the two Source Range Channels are not necessary. As a result, these channels are normally de-energized and their detectors removed from the instrument wells. An interlock between the Source Range and the Intermediate Range channels of the Nuclear Instrumentation requires that the Source Range Channels be operating before rods can be withdrawn. Any time that the level on the Intermediate Range Nuclear Instruments is below 2×10^{-10} amps, then the Source Range Channels must be installed in order to withdraw any of the reactivity control devices. If the level on the Source Range Nuclear Instruments is below 2 CPS, withdrawal is also blocked. This prevents the reactor operator from inserting reactivity into the core without having a visible indication of the power level in the reactor. The Source Range channels are needed following extended shutdowns which result in the photoneutron source decaying to a level below that detectable by the Intermediate Range channels. They may also be needed for refueling following a full core off-load. The neutron flux range covered by each level of nuclear instrumentation is presented on the graph shown in Figure 7-5.

The Thermal Power Recorder Channel, BTUR, provides the reactor operator with direct indication of the thermal power output from the reactor core. This channel combines the output of the Reactor Vessel Outlet Flow Recorder Channel and the Reactor ΔT Recorder Channel to derive the thermal power level. These channels are calibrated annually and periodic calorimetric calibrations are performed to verify the thermal output of the reactor. The three Power Range Channels of the Nuclear Instrumentation are adjusted to read 100% power whenever the thermal output of the reactor is 20 MW (thermal).

The reactor control system is enabled by the Startup Prohibit and the Withdraw Prohibit circuits. In the presence of a prohibit signal from either circuit, the reactor operator is prevented from withdrawing any reactivity control device, regardless of whether the reactor is being operated in the Manual mode or the Automatic mode.

7.3.1 Circuitry

The Reactor Safety System, shown in Figure 7.7, is a hardwired relay logic ladder with multiple inputs and multiple functions. Each rung in this ladder has a unique function assigned to it. Some examples of the assigned functions are Scram, Manual Scram, Withdraw Prohibit, Startup Prohibit, Rundown, and Regulating Rod controls. A ladder rung is formed by multiple contacts wired in series with either a single relay or multiple relays. Each contact in a given rung represents a specific plant parameter and is controlled by the instrument or equipment associated with that parameter. Control power at 48Vdc is directly applied to the relay logic ladder by parallel redundant relay safety system power supplies EBA and EBB fed from Critical Power Panel CP-1 as shown in Figure 7-3. Power to the Critical Power Panel CP-1 is backed up by two redundant emergency diesel generators and the station battery via two redundant uninterruptible power supplies in the event that offsite power is unavailable as described in Chapter 8. This power distribution system design assures that control power is always available to all but the last three rungs of the relay logic ladder on the right-hand side of Figure 7-7. The reactor operator uses the Control Power key switch S-4 to apply control power for the remaining three rungs of this ladder: Startup Prohibit (rung 5) and Scram (rungs 4A & 4B). Before any reactivity control devices can be withdrawn, the reactor operator must close the Control Power key switch and reset the Scram relays.

7.3.1.1 Withdraw Prohibit Circuit

The Withdraw Prohibit function is implemented by rung 7 of the relay logic ladder. Control power at 48Vdc is directly applied to the relay logic ladder by parallel redundant relay safety system power supplies EBA and EBB fed from Critical Power Panel CP-1 as shown in Figure 7.3. This power distribution system design assures that control power is always available to the portion of the relay logic ladder that contains the Withdraw Prohibit function as shown on Figure 7.7. Table 7.3 lists the signal sources, trip settings, and annunciator channels for the Withdraw Prohibit Circuit. Contacts associated with Source Range Rod Stop (K07-04) and Intermediate Rod Stop (K07-02) are wired in series with the Withdraw Prohibit relays. This prevents the reactor operator from withdrawing any reactivity control device if the period of the reactor, as indicated by either the Source Range Channels or the Intermediate Range Channels, is less than 15 seconds. A contact associated with the Rundown relays (K107) is also wired in series with the Withdraw Prohibit relays. This prevents the reactor operator from attempting to withdraw any reactivity control device while the conditions causing the rundown are still present.

7.3.1.2 Startup Prohibit Circuit

The Startup Prohibit function is implemented by rung 5 of the relay logic ladder as shown on Figure 7.7. It receives its control power through contacts in the Scram relays. In this way, all Scram conditions must be cleared and the Scram relays reset before the Startup Prohibit relays can be energized. Table 7.2 lists the signal sources, trip settings and annunciator channels for the Startup Prohibit Circuit. Parallel contacts associated with the Intermediate Range Log N Channel and the Source Range Log Count Rate Channel are wired in series with the Startup Prohibit relays. This ensures that the reactor operator has visible indication of reactor power level before any reactivity control devices are withdrawn. Contacts associated with the Emergency Cooling Tank Level Indicator Alarm Channel LIA-2, Reactor Vessel Overflow Indicator Channel FIA-2, Shim Safety Arm Clutch Current, Nuclear Instrument Test Fault, and Process Instrument Test Faults are wired in series with the Startup Prohibit relays. This ensures that the level in the Emergency Tank is in its normal operating range, that there is flow of primary coolant through the overflow line and that the Shim Safety Arm clutches are energized before any reactivity control devices can be withdrawn. Finally, the test fault contacts ensure that none of the channels of the Nuclear Instrumentation System and none of the channels in the Safety System Process Instruments are in test mode.

7.3.1.3 Rundown Circuit

The Rundown function is implemented by rung 6 of the relay logic ladder as shown on Figure 7-7. Control power at 48Vdc is directly applied to the relay logic ladder by parallel redundant relay safety system power supplies EBA and EBB fed from Critical Power Panel CP-1 as shown in Figure 7.3. This power distribution system design assures that control power is always available to the portion of the relay logic ladder that contains the Rundown function as shown on Figure 7.7. Contacts associated with Nuclear Instrumentation and Process Instrumentation channels are wired in series with the Rundown relays. Table 7.4 lists the signal sources, the trip settings and the annunciator channels for the Rundown Circuit. Whenever any of these contacts open, indicating that the parameter associated with it is out of its normal range, the Rundown relays are de-energized. These relays open contacts in the Shim Safety Arm insertion circuits and the Regulating Rod insertion circuit, driving them into the core to automatically reduce reactor power. This reduction of power continues until such time that the condition causing the rundown clears and the contact closes. The Rundown Alarm on Annunciator Panel AN-6 alerts the reactor operator to the rundown condition. The specific source of the Rundown is annunciated on Alarm Panel AN-4.

7.3.1.4 Automatic Control Circuit

Linear Channel NC-5 provides linear indication of reactor power level and controls the reactor power level by automatically positioning the regulating rod. Appendix A discusses this channel in detail. The settings on the NC-5 Range Select switch vary from 0-2 W through 0-20 MW in eight steps. The power level range covered by the recorder and the indicator is 0-150% of the setting of the NC-5 Range Select switch.

The operator selects either manual or automatic operation with the Manual-Auto Transfer switch. In manual operation, the operator controls reactor power by inserting or withdrawing the Shim Safety Arms and/or the Regulating Rod. In automatic operation, the Flux Controller Card maintains reactor power level to within ½ % of the setting of the Power Demand potentiometer by moving the Regulating Rod in the appropriate direction. The Servo Deviation 2% alarm on Annunciator Panel AN-4 alerts the reactor operator to a larger than expected deviation of actual power level from the desired power level. The Servo Deviation 10% alarm on Annunciator Panel AN-4 not only alerts the operator to an unacceptably large deviation of actual power level from the desired power level but it also trips the Regulating Rod controller out of automatic operation. Any time that the reactor is operated in the manual mode, Reactor on Manual alarm on Annunciator AN-4 alerts the operator to this condition.

7.3.2 Reactivity Control Devices

7.3.2.1 Shim Safety Arms

The Shim Safety Arms are of the semaphore type, previously described in Chapter 4 of this SAR. The reactor power will normally be controlled by the Regulating Rod whose mechanical operation has been described previously in Chapter 4. The purpose of the arms is threefold:

1. To adjust for gross changes in reactivity;
2. To shut the reactor down quickly; and,
3. To have a negative reactivity worth greater than the maximum excess reactivity of the reactor.

The Shim Safety Arms will shut the reactor down and hold it sub-critical even after the water is cooled and the fission products have decayed.

The design of the Shim Safety Arm drive includes a spring which accelerates the arm into the core upon release of an electromagnetic clutch. The release time, including instrument response, clutch release, and the top 5^{o} of rod travel, is less than 220 milliseconds. The total time for the shim safety arm to fully insert, including instrument detection and signal propagation, is less than 500 milliseconds. The withdrawal rate of the shim safety arms is 0.04^{o}/sec. The arms can be inserted or withdrawn individually or as a group. Position indication is transmitted to the control panel for each arm individually.

Individual shim position switches allow the reactor operator to move each Shim Safety Arm individually. A Shim Rod Gang switch allows the operator to move all four Shim Safety Arms simultaneously. Indication is included for both full up and full down position.

Upon loss of electrical power, the Shim Safety Arm clutches de-energize, uncoupling the shim arm mechanisms from their drive motor. Gravity, assisted by a compressed spring in the shim arm mechanisms, drops the Shim Safety Arms into the core, shutting down the reactor.

7.3.2.2 Regulating Rod

The reactor power will normally be controlled by the Regulating Rod whose mechanical operation has been described previously in Chapter 4. Automatic Control Circuit, Section 7.3.1.4, describes the control circuitry for manual and automatic operation.

The rod is driven by two reversible 115 volt, 60 cycle AC servomotors in a drive assembly which positions a lead screw. Simultaneously, selsyn transmitters on the top of the motor transmit electrical signals to a position indicator assembly located on the control panel. Both coarse and fine control indications are transmitted by separately geared position transmitters. Gear reducers, giving speed reductions of 5:1 and 30:1 are coupled to the position transmitters so that the fine dial makes one revolution per inch of travel and the coarse dial makes one revolution per thirty inches of travel.

The Regulating Rod drive has a travel of approximately 29 inches and the servomotor drives the rod full travel in less than 20 seconds. The total rod worth is approximately 0.6% reactivity. The maximum rate of reactivity control with the regulating rod is approximately 0.05% per second, as determined by rod calibrations. By design, the withdrawal and insertion speeds of the Regulating Rod are the same whether in automatic mode or manual mode of operation.

While the Regulating Rod does not release and drop into the core during a reactor scram, it is automatically inserted by the Rundown circuit. Upon receipt of a scram signal, the Scram relays open, removing power to the Shim Safety Arm clutches. The Shim Safety Arms drop back into the core, shutting down the reactor. The Scram relays also remove power to the Startup Prohibit relays. One set of contacts in the Startup Prohibit relays is wired in series with the Rundown relays. De-energizing the Startup Prohibit relays generates a rundown signal, automatically inserting the Regulating Rod into the core at its normal speed during a scram condition.

Annunciator indication is included for both near up and near down position in addition to full up and full down position. This feature permits operators to take shim action before achieving full up or down conditions thereby permitting more nearly linear reactivity control with rod position.

7.3.2.3 Moderator Dump

In the remote event of difficulty of shim safety arm insertion of all four safety arms, provision is made for lowering of the top reflector to a level just above the top of the core. Reactivity measurements show the top reflector worth under normal operating conditions to be approximately 4% reactivity when shim arms are halfway, and about 10% reactivity when shim arms are fully out. This so-called "moderator dump" can be initiated manually by the reactor operator at the console by switch S-6. The relay control for the valve which operates the dump pipeline from the reactor tank is interlocked with the scram when S-6 is in the open position. If the top reflector level falls below a level associated with the alarm setpoint of Reactor Vessel Overflow, a startup prohibit is instituted.

7.3.3 Technical Specifications

Several Technical Specifications apply to the Reactor Control System.

7.3.3.1 Technical Specification 1.3, Definitions

This Technical Specification provides terms that are sufficiently important to be separately defined.

1. Channel Calibration is defined as an adjustment of the channel so that its output corresponds with acceptable accuracy to known values of the parameter that the channel measures. Calibration shall encompass the entire channel, including equipment actuation, alarm, or trip and shall include a channel test.
2. Operable means that the system or component is capable of performing its intended function, as determined by functional testing or indication.
3. Confinement integrity is defined to be met when all of the following conditions are met:
   (1) All piping that penetrates the confinement building and is open to the confinement interior is physically intact exterior to the confinement.
   (2) All automatic isolation valves in the ventilation, process piping and guide tubes are either operable or closed.
   (3) All automatic personnel access doors are capable of being closed and sealed or are closed and sealed.
   (4) Except during passage, one set of the reactor building vestibule doors at the northeast and southeast personnel entrances and the elevator entrance from the laboratory basement are closed or attended.
   (5) The reactor building truck door is closed and sealed.
   (6) All other piping penetrations are sealed within the reactor building and are capable of withstanding the confinement test pressure.
   (7) The building has passed its most recent leakage test.
4. Experiment is defined to mean any installed apparatus, device, or material that is not rigidly installed within the confines of the thermal shield and that is intended to be used for irradiations or other measurements.
5. Operable means that the system or component is capable of performing its intended function, as determined by functional testing or indication.
6. Reactor Shutdown condition is defined as occurring whenever any of the following conditions exist:
   (1) The reactor contains less than 2.2 kg U-235.
   (2) The reactor control power and the rod drive power key switch are locked in their “Off” position.
   (3) The reactor is in the rod drop test mode, and a senior licensed operator is in direct charge of the operation.
7. Reactor Operating condition is defined as occurring whenever it is not shutdown.
8. Reactor Shutdown Mechanisms are defined as those mechanisms involved in reactor shutdown and include:

(1) Rundown is the electrically driven insertion of all shim safety arms and the regulating rod at their normal operating speed.
(2) Scram is the spring assisted gravity insertion of all shim safety arms.
(3) Major scram is the spring assisted gravity insertion of all shim safety arms and automatic isolation of the confinement building.

7.3.3.2 Technical Specification 3.4, Reactor Control and Safety Systems

This Technical Specification applies to the reactor control and safety system operation. The Reactor Protection System (RPS) as described in the SAR is termed Reactor Safety System in the TS. The objective of this Technical Specification is to ensure proper operation of reactor control and safety system. The reactor is not operated unless the following requirements are met:

1. All four Shim Safety Arms are operable;
2. The reactivity insertion rate, using all four Shim Safety Arms, does not exceed 5.0 x 10^{-4} $\Delta\rho$/sec.;
3. The Scrams and Major Scrams are operable Table 3.1 of the Technical Specifications (NBSR 15); and
4. The Moderator Dump system is operable.

Although the NBSR could operate and could maintain a substantial shutdown margin with less than the four installed Shim Safety Arms, flux and rod worth distortions could occur by operating in this manner. Furthermore, operation of the reactor with one Shim Safety Arm known to be inoperable would further reduce the shutdown margin that would be available if one of the remaining three Shim Safety Arms were to suffer a mechanical failure that prevented its insertion.

A rod withdrawal accident for the NBSR has been analyzed and are discussed Chapter 13 and Appendix A of this SAR using the maximum insertion rate, corresponding to the maximum beginning-of-life rod worths with the rods operating at the design speed of their constant speed mechanisms. The analysis showed that the most severe accident, a startup from source level, is bounded by the maximum reactivity insertion accident, and will not result in core damage.

In the unlikely event that the Shim Safety Arms cannot be inserted, an alternate means of shutting down the reactor is provided by the moderator dump. The moderator dump provides a shutdown capability for any core configuration. Hence, it is also considered necessary for safe operation. It is shown (FSAR, NBSR 14, chapter 4) that the moderator dump provided sufficient negative reactivity to make the normal Start-Up (SU) core subcritical even with all four shim arms fully withdrawn.

7.3.3.3 Technical Specification 4.0, Surveillance Standards

This Technical Specification defines the periodicity of the surveillance testing program. Deviations from the specified performance frequencies for surveillance tests shall be permitted as follows:

1. 5-year: interval not to exceed 6 years.
2. Biennially: interval not to exceed 30 months.
3. Annually: interval not to exceed 15 months.

4. Semiannually: interval not to exceed 7 ½ months.
5. Quarterly: interval not to exceed 4 months.
6. Monthly: interval not to exceed 1 ½ months.
7. Weekly: interval not to exceed 10 days.
8. Daily: must be done during the calendar day.

A surveillance requirement with a due date occurring during a reactor shutdown period, except area radiation monitoring requirements of Technical Specification 4.8 (1) and environmental monitoring requirements of Technical Specification 4.9, may be deferred; all deferred surveillance tests shall be performed before resuming reactor operation, except when required for testing.

7.3.3.4 Technical Specification 4.3, Reactor Control and Safety System

This Technical Specification applies to the reactor control and safety system operation. The Reactor Protection System (RPS) as described in the SAR is termed Reactor Safety System in the TS. The objective of this Technical Specification is to ensure continued operability of reactor control mechanisms and safety system instrumentation. The following requirements are placed on the systems:

1. Reactivity worth of each Shim Safety Arm and the Regulating Rod shall be determined at least annually.
2. The withdrawal and insertion speeds of each Shim Safety Arm and the Regulating Rod shall be determined at least semiannually.
3. Scram times of each Shim Safety Arm drive shall be measured at least semiannually.
4. Reactor safety system channels shall be tested for operability before each reactor startup following a shutdown in excess of 24 hours, or at least quarterly. This test shall include a verification of proper safety system channel trip settings. The safety channels shall be calibrated annually.
5. A comparison of power range indication with flow-ΔT product shall be performed weekly when the reactor is operating above 5 MWt.
6. Following maintenance on any portion of the reactor control or reactor safety systems, the repaired portion of the system shall be satisfactorily tested before the system is considered operable.

Measurements of reactivity worths of the Shim Safety Arms have shown (over the many ears of operation) to vary slowly as a result of absorber burnup and only slightly with respect to operational core loading and experimental changes. An annual check will ensure adequate reactivity margins.

The Shim Safety Arm drives are constant speed mechanical devices. Scram is aided by a spring that opposes drive motion during arm withdrawal. Withdrawal and insertion speeds or scram time should not vary except as a result of mechanical wear. The surveillance frequency is chosen to provide a significant margin over the expected failure or wear rates of these devices. The Shim Safety Arms are considered operable if they drop the top 5 degrees within 220 msec. This value is consistent with the amount and rate of reactivity insertion assumed in analyzing the accident requiring the most rapid scram (Chapter 13).

Because redundancy of all important safety channels is provided, random failures should not jeopardize the ability of these systems to perform their required functions. However, to ensure that failures do not go undetected, frequent surveillance is required and specified.

Because various experiments require precise operating conditions, the NBSR has been designed to ensure that accurate recalibration of power level channels can be easily and frequently achieved. The calibration is performed by comparison of nuclear channels with the thermal power measurement channel (flow-ΔT product). Because of the small ΔT in the NBSR (about 15 ^{o}F at 20 MW) these calibrations will not be performed below 5 MW for 10 MW operation or below 10 MW for 20 MW operation. However, to ensure that no gross discrepancies between nuclear instruments and flow-ΔT indicators occur, comparisons (but not necessarily calibrations) are made above 5 MW.

7.4 Reactor Protection System

The Scram function of the logic ladder has four Scram relays split between two parallel rungs (K103a and K103b in rung 4A and K103c and K103d in rung 4B) as shown in Figure 7.7. Contacts associated with the Intermediate Range Period Scram signal, the Power Range High Flux Scram signal, the Process Instrumentation Power Supplies, and the Nuclear Instrumentation Power Supplies are wired in series with both parallel rungs. Two redundant sets of contacts associated with the Major Scram, the Moderator Dump, the Manual Scram, and the Experimental Scram are connected in series in both rung 4A and 4B. Two redundant sets of contacts associated with Reactor Outer Plenum Flow Recorder Channel FRC-3, Reactor Inner Plenum Flow Recorder Channel FRC-4, Reactor Vessel Level Indicator Channel LIA-40, and Reactor ΔT Indicator Channel TIA-40A are connected in series in rung 4A. Two redundant sets of contacts associated with Reactor Outlet Flow Indicator Alarm Channel FIA-40, Reactor Vessel Level Recorder Alarm Channel LRC-1 and Reactor ΔT Indicator Channel TIA-40B are connected in series in rung 4B. Finally, one set of contacts, referred to as "maintaining contacts," in each of the four Scram relays is wired in series with both parallel rungs. The normally open Scram Reset pushbuttons are wired in parallel with these relay contacts. The input parameters to the Scram circuit are listed in Table 7.1. If all of the contacts in the Scram Logic Strings are closed, indicating that the plant parameters associated with these contacts are in their normal ranges, and the Control Power key switch is ON, then the reactor operator can reset the Scram relays by depressing the Scram Reset pushbutton on the Main Control Panel. Once energized, the "maintaining contacts" (a.k.a. seal-in contacts) of the Scram relays will hold the relays energized, thereby allowing the reactor operator to release the reset pushbutton. Any scram that occurs de-energizes the Scram relays and opens their associated "maintaining contacts." This prevents the Scram relays from automatically becoming reset once the condition that caused the scram clears.

Each Scram relay controls the power to the Nuclear Instrumentation Output Cards that supply the current for the Shim Safety Arm Clutches. If all of the contacts in the Scram Logic Strings are closed, indicating that the plant parameters associated with these contacts are in their normal ranges, and the Control Power key switch S-4 is ON, then the reactor operator can reset the Scram relays by depressing the Scram Reset pushbutton on the Main Control Panel. Once the Scram relays are reset, power is then available to the Startup Prohibit relays.

The protection system supplies power to the electromagnets that couple the Shim Safety Arms to their respective drive motors. A trip of any of the Scram relays will cause a loss of power to all of the Shim Safety Arm magnets, thereby decoupling the arms from their respective drive motors and dropping the arms into the core, scramming the reactor.

The RPS ensures that the limiting safety system settings (LSSS) are not exceeded. It consists of both nuclear channels and non-nuclear channels. Table 7.1, Reactor Scram circuit, lists the source, the setpoint, and the alarm window associated with each reactor scram. Figure 7-1, Simplified Diagram of Instrumentation and Control System, shows the relationship between both the Nuclear Instrumentation and Process Instrumentation, and the Reactor Protection System.

7.4.1 Nuclear Instrumentation System

The Nuclear Instrumentation System for the NBSR consists of eight neutron flux monitoring channels. Each channel consists of a detector, high voltage and signal cabling, amplifiers, local and remote output display devices, and associated alarm, scram or control circuitry. A functional block diagram of the Nuclear Instrumentation is provided in Figure 7.4. Source Range Channels, NC-1 and -2, are used as startup channels. Intermediate Range Channels, NC-3 and -4, are wide range logarithmic channels that provide a Period Rundown signal during reactor startup whenever the reactor period is less than 10 seconds and a Period Scram signal during reactor startup whenever the reactor period is less than 5 seconds. Both of these functions are bypassed once the reactor is operating in the Power Range, above 10% power. Linear Channel, NC-5, provides input to the flux controller card. This channel automatically controls reactor power level to within ½ % of the setting of the Power Demand potentiometer. Finally, the Power Range Channels, NC-6, -7, and -8, are narrow range channels that provide a Rundown signal whenever the power level is greater than 115% power and a Reactor Scram signal whenever the power level is greater than 125% power. Detailed information on all eight Nuclear Instrumentation channels is presented in Appendix A of this chapter.

Neutron detectors are mounted in instrument wells located in the biological shield. Each detector location views the reactor core through a lead window. The purpose of this window is to shield the detectors from the strong gamma radiation field that would otherwise be present at the detector location as a result of the fission process. Hence, the detectors measure only the leakage flux from the core. A minimum of one decade of overlap is designed into the transition between Source Range and Intermediate Range Nuclear Instrumentation and between Intermediated Range and Power range Nuclear Instrumentation. The degree of overlap between the channels form the source range to full power operation is shown in Figure 7.5, Flux Coverage of the NBSR.

The Nuclear Instrumentation System is powered by the ±10Vdc Nuclear Instrument Power Bus which is energized by redundant pairs of +10Vdc power supplies and –10Vdc power supplies fed from Critical Power Panel CP-1, located in the Control Room, as shown on Figure 7.3. The voltage levels of the +10Vdc bus and the –10Vdc bus are continuously monitored by relays K07-19 and K07-20, respectively. If either of these two pairs of power supplies fail, a contact of these relays in the scram logic circuit will open causing the scram relays K103 in the safety system to de-energize which in turn will shut off the shim rod clutch current.

The Source Range and Power Range channels as well as the Nuclear Safety System receive their power from directly from the the ±10Vdc Nuclear Instrument Power Bus. Intermediate Range channels and the Linear channel are supplied by their own self-contained power supplies fed from the Nuclear Instrument Power Bus.

7.4.1.1 Period Channels

The Source Range Channels and the Intermediate Range Channels open contacts in the Withdraw Prohibit circuit when the reactor period is less than 15 seconds. This prevents the reactor operator from inserting positive reactivity by the withdrawal of any reactivity control devices whenever the reactor power level is increasing at a high rate as indicted by a short reactor period.

The Intermediate Range Channels open contacts in the Rundown circuit when the reactor period is less than 10 seconds. This causes the Shim Safety Arms and the Regulating Rod to be automatically inserted at their normal speed, inserting negative reactivity. This will continue until such time that the condition causing the rundown clears. A Period Rundown alarm lights on Annunciator AN-4 and a Rundown summary alarm lights on Annunciator AN-6 to alert the reactor operator to this condition.

The Intermediate Range Channels open contacts in the Scram circuit when the reactor period is less than 5 seconds. This causes the Shim Safety Arms to be fully inserted into the core and drives the Regulating Rod fully into the core at its normal speed. A Period Scram alarm lights on Annunciator AN-4 and a Scram summary alarm lights on Annunciator AN-6 to alert the reactor operator to this condition.

7.4.1.2 Reactor Power Level Channels

The Power Range Channels open contacts in the Rundown circuit when any two of the three channels indicate that reactor power level is greater than 115%. This causes the Shim Safety Arms and the Regulating Rod to be automatically inserted at their normal speed, inserting negative reactivity. This will continue until such time that the high reactor power condition causing the rundown clears. A High-Flux Rundown alarm lights on Annunciator AN-4 and a Rundown summary alarm lights on Annunciator AN-6 to alert the reactor operator to this condition.

The Power Range Channels open contacts in the Scram circuit when the reactor power level is greater than 125%. This causes the Shim Safety Arms to be fully inserted into the core and drives the Regulating Rod fully into the core at its normal speed. A high Flux High alarm lights on Annunciator AN-4 and a Scram summary alarm lights on Annunciator AN-6 to alert the reactor operator to this condition. Prior to reactor startup, the reactor operator reduces the trip level of the High Flux scram to 13% by use of the Scram Level Selector Switch. This action causes the High Flux trip setpoint to be reached much sooner than it would be reached during a rapid increase in reactor power level during a startup if the setpoint remained at 125%. Once the reactor power has reached the Power Range, the reactor operator returns the trip level of the High Flux scram to 125%.

During reactor startup, the Nuclear Safety System operates in "1 out of 3" coincidence. In this condition, a trip signal from any one of the three Power Range Nuclear Instruments will cause a scram to occur. Once the reactor has reached the Power Range, the reactor operator changes the Coincidence Selector switch to "2 out of 3" coincidence. In this condition, a trip signal from any two of the three Power Range Nuclear Instruments is needed to cause a scram to occur. This prevents spurious scrams from occurring and improves the reliability of the system.

7.4.2 Process Safety System

The process instrumentation utilized for the NBSR reactor is of solid state design utilizing transmission of standard 4 to 20mA direct current signals via two-wire instrumentation and control cables. The receivers, recorders, controllers, and bistable trips (monitor switches) are connected in series loop circuits powered from a redundant pair of ±24Vdc ungrounded Process Instrumentation Safety System power supplies. Two separate circuits from Critical Power Panel CP-1 feed power to each of the two Process Instrumentation Safety System power supplies as shown on Figure 7.3.

Table 7.1 lists the Scrams associated with operation of the NBSR reactor. The three flow channels (FRC-3, FRC-4, and FIA-40), the two level channels (LRC-1 and LIA-40), three radiation channels (RM3-4, RM3-5, and RM4-1), and the two temperature channels (TIA-40A and TIA-40B) are described in detail in Appendix 7A of this chapter.

7.4.3 Technical Specifications

See Section 7.3.3 above for a discussion of the Technical Specifications applicable to the reactor control and safety systems.

7.5 Engineered Safety Features Actuation

The NBSR Engineered Safety Features (ESF) ensure reactor safety and prevent uncontrolled release of radioactivity to the surrounding environment. Emergency cooling is initiated when conditions require. Confinement Building isolation and recirculation mode of the Emergency Ventilation System are either manually initiated by the reactor operator from the Main Control Panel or automatically by the Major Scram circuit. The Major Scram circuit has inputs from the Normal Exhaust Monitor Channel, the Irradiated Air Exhaust Monitor Channel and the Stack Exhaust Monitor Channel. High airborne activity detected by any of these three channels automatically initiates a Major Scram, shutting down the reactor and initiating Confinement Building closure. The ESF is described in detail in Chapter 6 of this SAR. The three monitoring channels are described in Appendix 7A of this chapter.

7.6 Control Console and Display Instruments

The Control Room, located on the second floor of the Confinement Building at the operations level, is the normal location from which reactor operations are conducted. All of the instrumentation and controls required by the operator to safely operate the reactor are conveniently located on the Main Control Panel. The arrangement and location of the Control Room are shown in Figure 7.2. The reactor supervisor's office is located immediately adjacent to the Control Room. A window in the front wall of the Control Room permits observation of the operations floor and the top of the reactor shield.

7.6.1 Outputs, Controls and Operator Interfaces

The Instrumentation and Control System permits remote operation of the reactor and remote control of essential systems associated with the reactor from a convenient location. The instrument panels inn the control room display the nuclear and process variables required by the operator for reactor operation. The controls, displays, indicating lights, and alarm windows for equipment in a given system are grouped together functionally on the Main Control Panel. When seated at the control desk, the reactor operator has an unobstructed view of all of the important instrument panels. The reactor and all of its associated systems can be operated during all phases of operation by means of the remote controls and switches. These controls permit the operator to regulate the primary and secondary system flows, operate all primary and support system pumps and valves, operate the Shim Safety Arms and Regulating Rod, and initiate immediate shutdown of the reactor in the event such action is required.

7.6.2 Arrangement

There are 11 instrument sub-panels which make up the Main Control Panel. These panels are shown in Figure 7.2. Panel A houses the Nuclear Instrumentation channels. Panel B has surveillance monitors and the radiation recorder. Panel C contains controls and instruments associated with the Secondary Coolant System, thermal power, and Linear Channel NC-5. Panel D is the main control station. This section has the controls and position indication for the Shim Safety Arms and Regulating Rod. It also has the Nuclear Instrumentation indicators and recorders. Panel E contains controls and instruments associated with the Primary Coolant System. Panels F and G have the controls and instruments associated with the Radiation Monitoring System, the emergency ventilation, and the AC/DC vital equipment power controls. Panels H and J contain the controls and instruments associated with the Helium and D_2O Purification System. Finally, panels K and L have the controls and instruments for the Thermal Shield System, the Storage Pool Cooling System and the Experimental Cooling System. Tables 7-5A thru 7-5I list the equipment on each panel. Appendix 7A describes all of the instrument channels.

Visual and audible alarms are provided in the Control Room for all plant parameters that can cause control rod action or that could potentially require the prompt attention of the operator. The Annunciator System contains six Annunciator Panels mounted on different sections of the Main Control Panel. Each Annunciator Panel contains individual lighted windows that provide the operator with the alarm status associated with each alarm point. Each lighted window provides a visual indication of an alarm. Each alarm has an associated Annunciator Procedure (AP series). Each annunciator panel has a unique audible alarm to give the operator an audible aid in distinguishing which panel has an alarm condition. The alarm cards for all of the channels in the system are housed in two equipment racks located immediately behind the Main Control Panel. Appendix 7B describes the Annunciation System in detail.

7.6.3 Main Control Panel

Indicators, controllers, and recorders are mounted on the vertical surfaces of the backboard portions of the Main Control Panel while control switches and pushbuttons are on the desktop console portion of the panel. Status lights for pumps and valves are mounted adjacent to their associated control switches. All of the instruments and controls necessary for the safe operation of the reactor are grouped by system.

The central, angled section of the Main Control Panel provides the operator with the controls and instruments associated with the reactor, the Primary Coolant System and the Secondary Coolant System. The middle portion of this section, Panel D, has the remote indicators and recorders for all of the Nuclear Instrumentation channels, the control switches and position indicators for the four Shim Safety Arms and for the Regulating Rod, pushbuttons for the Annunciator System, and the Scram pushbutton. It also has two Alarm Panels. Individual alarm windows on Alarm Panel AN-4 alert the reactor operator to the source of Scrams, Rundowns and Withdraw Prohibit. Individual alarm windows on summary Alarm Panel AN-6 alert the reactor operator to a Scram, a Rundown and a Withdraw Prohibit.

The left portion of this section, Panel E, has the indicators and recorders for the Primary Coolant System and the control switches for the D_2O Main Circulating Pumps, D_2O Shutdown Pumps, and primary system valves. It also contains individual alarm windows on Alarm Panel AN-3 that alert the reactor operator to the status of conditions in the Primary Coolant System.

The right portion of this section, Panel C, has Linear Channel NC-5, the Thermal Power recorder, the indicators and recorders for the Secondary Coolant System, and the control switches for the Main Secondary Cooling Pumps, the Secondary Auxiliary Booster Pumps, Secondary Shutdown Pump, and secondary system valves. The Control Power key switch, Rod Drive Power key switch, the Scram reset pushbutton, and an Alarm Panel are also located on this section of the Main Control Panel. Individual alarm windows on Alarm Panel AN-5 alert the reactor operator to the status of conditions in the Secondary Coolant System.

Auxiliary systems, radiation monitoring instruments and ventilation systems instruments and controls are located on Panels F through L. Alarm Panel AN-1, located on Panel L, presents individual alarm windows that alert the reactor operator to the status of conditions associated with the experimental facilities. Alarm Panel AN-2, located on Panel F, presents individual alarm windows that alert reactor operator to the status of conditions in the Auxiliary Systems.

7.6.4 Emergency Control Station

The Emergency Control Station is located outside of the Confinement Building on the B-2 level (Basement) of Building 235. It provides a safe, central location to monitor the conditions of the reactor in the unlikely event that the Control Room or the Confinement Building must be evacuated. The Emergency Control Station area is normally locked for security purposes. The two main panels located at this station are the Emergency Ventilation Control Panel and the Liquid Hot Waste Control Panel. They are discussed in Sections 7.6.6.1 and 7.7.7.2, respectively.

7.6.5 Manual Scram Stations

In addition to the Scram buttons on the Main Control Panel, five manual Scram stations are located throughout the Confinement Building. Each station consists of a momentary pushbutton that has contacts in the Scram relay logic string (rung 2 of the relay logic diagram in Figure 7.7). They are located on each of the walls of the first floor of the Confinement Building and on the north exterior wall of the Sub-Pile Room in the Process Room.

7.6.6 Panels Outside of the Control Room

7.6.6.1 Emergency Ventilation Control Panel

The Emergency Ventilation Control Panel is located at the Emergency Control Station on the B-2 Basement level of Building 235. This panel has remote indication of two of the channels of the Area Radiation Monitor Channels. Channel RM1-1, the area monitor located on the east wall of C-100, provides the operator at the Emergency Control Station with indication of radiation levels on the first floor of the Confinement Building in the vicinity of the access doors. Channel RM1-8, the area monitor located on the east wall of the Process Room, provides the operator with the radiation levels in the Process Room. The panel also has remote indication of four channels of air activity. Irradiated Air Monitor Channel RM3-4, Normal Air Monitor Channel RM3-5, and Stack Monitor Channels RM4-1 and RM4-2 provide the operator with remote indication of the air activity in the Emergency Ventilation System. This panel has control switches and indicating lights for Emergency Exhaust Fans EF-5 and EF-6 as well as indicating lights for selected dampers in the Emergency Ventilation System. Finally, this panel has indicating lights for all of the doors to the Confinement Building and indicating lights and a control power key switch for the Neutron Guide Isolation Valves.

7.6.6.2 Neutron Guide Isolation Valve Panels

There are two Neutron Guide Isolation Valve Panels, one located in the Guide Hall and the other in the Confinement Building, which provide indication and control for the Neutron Guide Isolation Valves. Seven Neutron Guides transport cold neutrons from the Cold Neutron Source cryostat located in the Confinement Building to the experimental stations located in the Guide Hall. Since these seven neutron guide tubes penetrate confinement, isolation valves are provided on each of the tubes that close upon actuation of a Major Scram signal to seal these openings through the Confinement Building wall. These panels provide operations staff with control and position indication for the seven isolation valves. Alarms on Annunciator Panel AN-1 alert the reactor operator to a Neutron Guide Isolation Valve not fully shut condition.

The Neutron Guide Isolation Valve Panel located in the Guide Hall has pushbutton switches used to open or shut the seven Neutron Guide Isolation Valves. This panel is located in the south side of the hall on the catwalk over the neutron guides. Each of the seven open pushbuttons has a key-operated switch wired in series with it to isolate the control power from the opening circuit. This allows the reactor operations staff to maintain control over the isolation valves. The open and shut pushbuttons also provide valve fully open indication and valve fully closed indication. Power for this panel comes from the Critical Power Panel CP-1 in the Main Control Panel by way of the Neutron Guide Isolation Valve Panel located in C-100 (see Figure 7.3).

The Neutron Guide Isolation Valve Panel located in Room C-100 of the Confinement Building has valve fully open and valve fully shut indication. This panel has pushbutton switches to shut the valves only Power for this panel comes from the Critical Power Panel CP-1 in the Main Control Panel (see Figure 7.3).

Valve position indication for the seven Neutron Guide Isolation Valves and a control power switch are also provided on the Emergency Ventilation Control Panel, discussed in Section 7.6.6.1, above.

7.6.6.3 Beam Tube Control Panels

Each of the nine Beam Tubes has a control panel used to open and close that tube's beam shutter. Each panel has open and close indication as well as a key operated control switch. This allows the reactor operations staff to maintain control over the beam ports.

7.6.7 Day/Night Switch

The Day/Night switch enables remote indication of the Reactor Vessel Low Level and the Tritium alarms at the NIST Security Office, located in the basement of Building 101. Normally, the reactor facility is manned around the clock during power operations and refueling shutdown conditions. During this period of time, the Day/Night switch is kept in the "Day" position, inhibiting the remote alarms. On the rare occasions when the reactor is shutdown and the building is locked, such as may occur on a holiday, the Day/Night switch is place in the "Night" position, permitting remote indication of the alarm conditions, should they occur. In the unlikely event that an alarm should occur, NIST Security would contact operations personnel to alert them to the abnormal condition.

7.7 Radiation Monitoring Systems

The NBSR Radiation Monitoring System (RMS) consists of area monitors, duct monitors and effluent monitors located throughout the facility. The system ensures that the release of radioactive effluents to the environment is within the limits of the NBSR Technical Specifications which provide that, with certain very specific exemptions, any release of radioactive effluents will conform to 10 CFR Part 20, the Code of Federal Regulations.

The output of each area monitor and duct monitor associated with the reactor is displayed and recorded in the Control Room on the Main Control Panel. Any monitor will initiate an alarm on Alarm Panel AN-2 or AN-4 if its output exceeds a preset trip level. This will alert the reactor operator to the abnormal condition. Additionally, if the trip levels of the Normal Air Monitor, the Irradiated Air Monitor or the Stack Monitor channels exceed their trip set point, a Major Scram is initiated, shutting the reactor down and initiating Confinement Building isolation. Appendix 7A describes all of the radiation monitoring instrument channels and Appendix 7B presents the individual alarm windows on each annunciator panel.

7.7.1 Area Radiation Monitor Channels

Area Radiation Monitors are located throughout the facility.

Area Radiation Monitor Channels, RM1-1 through RM1-10, measure and record selected areas in the Confinement Building for radiation. Detectors are mounted on the walls in the Confinement Building to monitor radiation levels. Each detector location has a local meter that indicates the radiation level and an alarm and warning light that alerts the occupants to any high radiation level. Remote indication and alarm is provided on the Main Control Panel in the Control Room for each of the ten channels. A summary AREA MONITOR RADIATION HIGH alarm, AN2-14, alerts the reactor operator to a high radiation condition in the Confinement Building (see Appendix 7A, Appendix 8A and Table 7.B.2).

Rabbit Lab Radiation Area Monitor Channel, RM1-15, monitors room C-001 for high radiation levels in the vicinity of the rabbit receivers. Local indication only is provided at the entrance to this room. Audible and visual alarm signals are provided locally and remotely on the Main Control Panel (C-001 RADIATION HIGH alarm, AN2-13) in the Control Room.

The Guide Hall Area Monitor System measures and records the radiation level at selected points in the Guide Hall. Detectors are mounted on the exterior walls of the Guide Hall around its perimeter and in the storage and truck loading area. Each detector location has a local meter that indicates the radiation level and an alarm and warning light that alerts the occupant to any high radiation level. Remote indication, recording and alarm are provided on the equipment rack located at the south entrance to the Guide Hall.

7.7.2 Duct Filter Monitor Channels

Duct Filter Monitor Channels, RM1-11 thru RM1-13, measure the radiation levels in the exhaust duct filters for the reactor Confinement Building. They monitor the duct filters on the suction sides of the Irradiated Air Exhaust Fan EH-4, the Normal Air Exhaust Fan EF-3, and the Reactor Basement Recirculation Fan EF-27. Indication and alarm for each channel are provided on the Main Control Panel in the Control Room. This alerts the reactor operator to a high radiation condition in the associated duct filter (see Appendix 7A and Appendix 8A). These channels also feed a radiation high signal to the summary AREA MONITOR RADIATION HIGH alarm, AN2-14.

The Duct Filter Monitor System for the Warm Labs outside of Reactor Confinement monitor the radiation levels in the exhaust duct filters serving the labs in the basement of the Confinement Building and in the office building adjacent to the Confinement Building. The system is a computer based data acquisition system located in Room A-134. The system monitor provides a graphical depiction of the floor plan for Building 235. Each of the eighteen channels is located on this floor plan in the associated room. Level and status is provided for each location.

7.7.3 Major Scram Radiation Channels

Irradiated Air Monitor Channel RM3-4, Normal Air Monitor Channel RM3-5, and Stack Monitor Channel RM4-1, measure the activity levels in the exhaust air leaving the Confinement Building. Air samples from the Irradiated Air, the Normal Air, and the Stack exhaust ducts are continuously supplied to radiation detectors. Remote indication and alarms (AN47, AN4-6, and

AN4-8, respectively) are provided on the Main Control Panel in the Control Room. A high activity level on any one of these channels initiates a Major Scram, shutting down the reactor and initiating Confinement Building closure. This plant response is an automatic Engineered Safety Feature for the NBSR. The alarm alerts the reactor operator to a high activity level within the exhaust air from the Confinement Building. The instrument channels are described in detail in Appendix 7A-8H, 8I, and 8J.

7.7.4 Secondary Cooling N-16 Radiation Channels

Secondary Cooling N-16 Radiation Monitoring Channels, RM3-1 and RM3-3, monitor the secondary coolant for the presence of N-16. The presence of N-16 is indicative of a primary to secondary leak. A sample line taps off of the secondary header after the Main Heat Exchangers. A small amount of secondary water is continuously diverted through the two detectors. Indication and alarms are provided locally at the equipment rack in the Pump House and remotely on the Main Control Panel (SECONDARY COOLANT ACTIVITY HIGH alarm, AN2-17) in the Control Room. An alarm on either of these two channels alerts the reactor operator to a high activity condition in the secondary coolant. The instrument channels are described in detail in Appendix 7A-8E and 8G

7.7.5 Helium Sweep Gas Radiation Channel

Helium Sweep Gas Radiation Monitor Channel, RM3-2, checks for the presence of fission products in the Helium Sweep System. The presence of fission products is indicative of a fuel cladding failure. A sample line diverts a portion of the helium gas from the system through a sample chamber. The rate meter provides local indication at the monitoring station located on the Reactor Mezzanine and remote indication on the Main Control Panel. It also provides an input signal to Radiation Recorder RR-1 located in the Control Room for trending. The rate meter has an alarm output that supplies a signal to the Annunciator System on the Main Control Panel (HELIUM SWEEP ACTIVITY HIGH alarm, AN2-16) in the Control Room. The alarm alerts the reactor operator to the presence of fission products in the Helium Sweep System (see in Appendix 7A-8F).

7.7.6 Ventilation Tritium Monitor

Tritium Monitor Channel samples the air within the Confinement Building for the presence of tritium. An ion chamber located on the B-1 level of the Confinement Building is supplied with air samples drawn by an associated blower from several different sample points located throughout the ventilation system. The tritium concentration detected by the ion chamber is monitored and recorded in the Control Room, with an alarm (AN2-15) set to alert the reactor operator to an abnormal tritium level. A loss of flow through the detector will also initiate the same alarm.

7.7.7 Waste System Control Panels

7.7.7.1 Liquid Waste Control Panel

This control board serves the waste collection and disposal system. It is located in the basement of the cold wing at the Emergency Control Station. Digital indicators provide the operator with liquid volume information for the Retention Tank and both Holdup Tanks. A three channel recorder stores this information for trending purposes. This panel also has controls and indicating lights for the valves and pumps associated with the three tanks. Additional detailed information on the instruments can be found in Appendix 7A of this Chapter.

7.7.7.2 Remote Liquid Waste Panel

Remote indication of the volume of liquid waste in the Retention Tank and the two Holdup Tanks is provided on the panel in Health Physics Lab, Room B-126. Additional detailed information on these instruments can be found in Appendix 7A of this Chapter.

7.7.8 Health Physics Instrumentation

Fixed and portable instruments are used throughout the facility. Portable instruments include survey instruments for use by operations personnel, health physicist, and experimental users. Fixed instruments include proportional counters, half-body monitors, hand and foot monitors, and continuous air monitors. These instruments are discussed in detail in Chapter 11 of the SAR.

7.8 References

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Table 7.1: Reactor Scram Inputs

Scram	Source	Trip Setting	Annunciator No.
Manual Scram	Scram Button on MCP or Manual Scram Stations		4-1
Moderator Dump	Moderator Dump on MCP		4-2
Safety Sys. Process Instr. Power Off	Process Instr. P/S		5-44
High Flux	NC-6, NC-7 and NC-8	125% / 13%	4-3
Period Scram	NC-3 and NC-4	5 Sec.	4-4
Nuclear Instrument Power Off	Nuclear Instrument P/S		4-5
Building Exhaust Activity High	RM3-5	50k CPM	4-6
Irradiated Air Activity High	RM3-4	50k CPM	4-7
Stack Activity High	RM4-1	50k CPM	4-8
Outlet Flow Low	FIA-40	6,500 gpm	4-9
14 In. Inlet Flow Low	FRC-3	5,000 gpm	4-10
10 In. Inlet Flow Low	FRC-4	1,400 gpm	4-11
Differential Temperature “A” High	TIA-40A	20 ^{o}F	4-12
Differential Temperature “B” High	TIA-40B	20 ^{o}F	4-13
Vessel Level “Recorder” Low	LRC-1	140 in.	4-14
Vessel Level “Indicator” Low	LIA-40	140 in.	4-15
Experimental Scram	Not used at this time.	N/a	4-16

Table 7.2: Startup Prohibit Inputs

Startup Prohibit	Source	Trip Setting	Annunciator No.
Period Bypass	NC-6, NC-7 and NC-8	>10% Power	4-45
Low Log N Signal	NC-3 and NC-4	<2x10^{-10}Amps	4-44
Low Count Rate Signal	NC-1 and NC-2	< 2 CPS	4-44
Rods Not Seated	K-105		4-42
Emergency Cooling Tank Level	LIA-2	50 in.	4-48
Clutch Power	NI Output Current	<80/>160mA	4-43
Reactor D_2O Overflow Low	FA-2	5 gpm	4-47
NI Test Fault	NI Test Switches		4-41
Reactor Vessel Level R/D* Bypass	LIA-40		4-50
Thermal Column Flow R/D* Bypass	FCA-7		4-51
Thermal Shield Flow R/D* Bypass	FIA-15		4-52
BTUR R/D* Bypass	BTUR		4-53
Nuclear R/D* Bypass	NI Instrument		4-54
Cold Source Pressure R/D* Bypass	P-1A and P-1B		4-55
Cold Source Flow R/D* Bypass	FIA-8A and FIA-8B		4-56
Process Instrument Test Panel	PTS-A and PTS-B		4-49
Experimental Interlock	K-100		4-46

*R/D = Rundown

Table 7.3: Withdraw Prohibit Inputs

Withdraw Prohibit	Source	Trip Setting	Annunciator No.
Intermediate Range Period Rod Stop	NC-3 and NC-4	15 sec.	4-34
Source Range Period Rod Stop	NC-1 and NC-2	15 sec.	4-33
Rod Drop Test	K-116		
Rods Not Seated	K-105		
Rundown	K-107		

Table 7.4: Rundown Circuit

Rundown	Source	Trip Setting	AN-4 Window
Intermediate Range Period Rundown	NC-3 and NC-4	10 Sec.	4-17
High Flux Rundown	NC-6, NC-7 and NC-8	115% Power.	4-18
Reactor Outlet Temperature High	TIA-2	130 ^{o}F	4-19
Rod On Test	K-116		4-20
Reactor Vessel Level Low	LIA-40	145 in.	4-21
Thermal Column Flow Low	FIA-7	5 gpm	4-22
Thermal Power High	BTUR	23 MW	4-23
Thermal Shield Flow Low	FIA-15	250 gpm	4-24
Cold Source H_2 Press. “A” High	P-1A	5 psid	4-25
Cold Source H_2 Press. “B” High	P-1B	5 psid	4-26
Cold Source D_2O Flow “A” Low	FIA-8A	5 gpm	4-27
Cold Source D_2O Flow “B” Low	FIA-8B	5 gpm	4-28
Rods Not Seated	K-105		
Startup Prohibit	K-104A		

Table 7.5A: Main Control Panel (MCP) Instrumentation & Controls – Panel A

MCP Panel A	Designator
Source Range Channel	NC-1
Source Range Channel	NC-2
Intermediate Range Channel	NC-3
Intermediate Range Channel	NC-4
Power Range Channel	NC-6
Power Range Channel	NC-7
Power Range Channel	NC-8
Nuclear Safety System Channel	NC-9
Experimental Interlock Key Switch	S-7
Rod Drop Test Key Switches	S-11A & S-11B
Logic Selector Key Switch	

Table 7.5B: Main Control Panel Instrumentation & Controls – Panel B

MCP Panel A	Designator
Radiation Recorder	RR-11
Television Monitor	
Television Monitor	

Table 7.5C: Main Control Panel Instrumentation & Controls – Panel C

MCP Panel C	Designator	Component	Range
Annunciator Panel No. 5	AN-5	Alarm Window	
Linear Channel	NC-5	Drawer	0-2W to 0-20MW
BTUR, React. Delta-T & React. Flow	BTUR	Recorder	0-30 MW/0-20 ^{o}F/0-10k gpm
Secondary Header Flow	FIA-12	Meter	0-12,000 gpm
HE-1A Secondary Flow	FI-22	Meter	0-6,000 gpm
HE-1B Secondary Flow	FI-23	Meter	0-6,000 gpm
Secondary Auxiliary Flow	FI-17	Meter	0-1,000 gpm
Cooling Tower Level	LIC-9	Meter	0-50 in.
HE-1A Pri./Sec. Delta Press.	PIA-30	Meter	0-50 psi
HE-1B Pri./Sec. Delta Press.	PIA-40	Meter	0-50 psi
Reactor Inlet Temperature Recorder	TRC-3	Recorder	50-150 F
Reactor Inlet Temperature Controller	TRCA-3	Controller	0-100%
Cooling Tower Temp.	TIA-12	Meter	30-130 F
HE-1A Sec. Outlet Temp.	TI-13	Meter	50-150 F
Sec. Header Inlet Temp.	TI-14	Meter	50-150 F
HE-1B Sec. Outlet Temp.	TI-33	Meter	50-150 F
Control Power Switch		Key Switch	Off-On
Rod Drive Power		Key Switch	Off-On
Dry Door Controls – Section 1		Pushbutton	Open (Red) / Shut (Green)
Dry Door Controls – Section 2		Pushbutton	Open (Red) / Shut (Green)
Dry Door Controls – Section 3		Pushbutton	Open (Red) / Shut (Green)
Scram Reset		Pushbutton	Momentarily Close Contacts
Wet Door Control – Section 1		Pushbutton	Open (Red) / Shut (Green)
Wet Door Control – Section 2		Pushbutton	Open (Red) / Shut (Green)
Wet Door Control – Section 3		Pushbutton	Open (Red) / Shut (Green)
Cooling Tower Fan No. 1		Switch	Fast-Stop-Slow
Cooling Tower Fan No. 2		Switch	Fast-Stop-Slow
Cooling Tower Fan No. 3		Switch	Fast-Stop-Slow
SCV-5		Switch	Open-Close
SCV-50		Switch	Open-Auto-Close
Sec. Aux. Bstr. Cooling Pump No. 1		Switch	Off-On
Sec. Aux. Bstr. Cooling Pump No. 2		Switch	Off-On
Sec. Shutdown Cooling Pump		Switch	Off-Auto
Secondary Pump No. 1		Switch	Off-On
Secondary Pump No. 2		Switch	Off-On
Secondary Pump No. 3		Switch	Off-On
Secondary Pump No. 4		Switch	Off-On
Secondary Pump No. 5		Switch	Off-On
Secondary Pump No. 6		Switch	Off-On

Table 7.5D: Main Control Panel Instrumentation & Controls – Panel D

MCP Panel D	Designator	Component	Range
Annunciator Panel No. 4	AN-4	Alarm Window	
Annunciator Panel No. 6	AN-6	Alarm Window	
Flux Recorder	NC-1&-2	Recorder	$1\text{-}10^5$ CPM
Log Count Rate Meter	NC-1&-2	Meter	$1\text{-}10^5$ CPM
Period Source Range Meter	NC-1&-2	Meter	-30 to ∞ to +3 sec.
Flux Recorder	NC-3&-4	Recorder	$10^{-10}\text{-}10^{-3}$ Amps
Log N Level Meter	NC-3&-4	Meter	$10^{-10}\text{-}10^{-3}$ Amps
Period Intermediate Range Meter	NC-3&-4	Meter	-30 to ∞ to +3 sec.
Period Recorder	NC-3&-4	Recorder	-30 to ∞ to +3 sec.
Linear Channel	NC-5	Meter	0-150%
Flux Recorder	NC-5 & NC-6,7,8	Recorder	0-150%
Power Channel	NC-6	Meter	0-150%
Power Channel	NC-7	Meter	0-150%
Power Channel	NC-8	Meter	0-150%
No. 1 Shim Position		Meter	0-40 deg.
No. 2 Shim Position		Meter	0-40 deg.
No. 3 Shim Position		Meter	0-40 deg.
No. 4 Shim Position		Meter	0-40 deg.
Regulating Rod Position – Coarse		Meter	0-29 in.
Regulating Rod Position – Fine		Meter	0-1.00 in.
Servo Deviation		Meter	-15 % to 0 to +15 %
Power Demand		Rheostat	Variable Resistor
Annunciator & Scram Reset		Pushbutton	Momentarily Close Contacts
Annunciator Acknowledge		Pushbutton	Momentarily Close Contacts
Annunciator Test		Pushbutton	Momentarily Close Contacts
Scram		Pushbutton	Momentarily Open Contacts
Channel Select		Switch	NC-6/NC-7/NC-8
Intermediate Range Channel Select		Switch	NC-3/NC-4
Source Range Channel Select		Switch	NC-1/NC-2
Manual- Auto Transfer		Switch	Manual – neutral – Auto
NC-5 Range Select		Switch	0-2 W to 0-20 MW
Regulating Rod Position Switch		Switch	In-Hold-Out
Shim No. 1 Position Switch		Switch	In-Hold-Out
Shim No. 2 Position Switch		Switch	In-Hold-Out
Shim No. 3 Position Switch		Switch	In-Hold-Out
Shim No. 4 Position Switch		Switch	In-Hold-Out
Shim Rod Gang		Switch	In-Hold-Out

Table 7.5E: Main Control Panel Instrumentation & Controls – Panel E

MCP Panel E	Designator	Component	Range
Annunciator Panel No. 3	AN-3	Alarm Window	
Reactor Overflow	FIA-2	Meter	0-30 gpm
HE-1A Outlet Flow / Outer Plenum Flow Recorder	FR-20 / FRC-3	Recorder	0-5k gpm / 0-8k gpm
HE-1B Outlet Flow / Inner Plenum Flow Recorder	FR-21 / FRC-4	Recorder	0-5k gpm / 0-4k gpm
Reactor Outlet Flow	FIA-40	Meter	0-10,000 gpm
Reactor Vessel Level	LRC-1	Recorder	0-200 in.
Emergency Tank Level	LIA-2	Meter	0-60 in.
Storage Tank Level	LIA-3	Meter	0-175 in.
Reactor Vessel Level	LIA-40	Meter	60-200 in.
Reactor Outlet Temperature	TR-2	Recorder	50-200 F
HE-1A Outlet Temperature/ HE-1B Outlet Temperature Recorder	TR-4 / TR-5	Recorder	50-150 F
Differential Temperature "A"	TIA-40A	Meter	0-30 F
Differential Temperature "B"	TIA-40B	Meter	0-30 F
Major Scram		Pushbutton	Momentarily Open Contacts
D_2O Pump DP-1		Switch	Hand-Off-On
D_2O Pump DP-2		Switch	Hand-Off-On
D_2O Pump DP-3		Switch	Hand-Off-On
D_2O Pump DP-4		Switch	Hand-Off-On
Outer Plenum Throttle Valve DWV-1		Switch	Open-Close
Inner Plenum Throttle Valve DWV-2		Switch	Open-Close
Isolation Valve Pump DP-1 DWV-3		Switch	Open-Auto-Close
Isolation Valve Pump DP-2 DWV-4		Switch	Open-Auto-Close
Isolation Valve Pump DP-3 DWV-5		Switch	Open-Auto-Close
Isolation Valve Pump DP-4 DWV-6		Switch	Open-Auto-Close
Reactor Overflow Valve DWV-10		Switch	Open-Close
Reactor Vessel Outlet Isolation Valve DWV-19		Switch	Open-Close

Table 7.5F: Main Control Panel Instrumentation & Controls – Panel F and G

MCP Panel F and G	Designator	Component	Range
Annunciator Panel No. 2	AN-2	Alarm Window	
Area Monitor C-100E	RM1-1	Meter	10^{-2}-10^{4} mRem/hr
Area Monitor C-100N	RM1-2	Meter	10^{-2}-10^{4} mRem/hr
Area Monitor C-100W	RM1-3	Meter	10^{-2}-10^{4} mRem/hr
Area Monitor C-100S	RM1-4	Meter	10^{-2}-10^{4} mRem/hr
Area Monitor C-200 Ceiling	RM1-5	Meter	10^{-2}-10^{4} mRem/hr
Area Monitor C-200W	RM1-6	Meter	10^{-2}-10^{4} mRem/hr
Area Monitor C-004S	RM1-7	Meter	10^{-2}-10^{4} mRem/hr
Area Monitor C-006E	RM1-8	Meter	10^{-1}-10^{5} mRem/hr
Area Monitor C-007W	RM1-9	Meter	10^{-1}-10^{5} mRem/hr
Area Monitor Control Room	RM1-10	Meter	10^{-2}-10^{4} mRem/hr
Duct Filter Monitor EF-3	RM1-11	Meter	20-200,000 CPM
Duct Filter Monitor EF-4	RM1-12	Meter	20-200,000 CPM
Duct Filter Monitor EF-27	RM1-13	Meter	20-200,000 CPM
Secondary N-16 Channel	RM3-1	Meter	10-10^{6} CPM
Fission Product Channel	RM3-2	Meter	10-10^{6} CPM
Secondary N-16 Channel	RM3-3	Meter	10-10^{6} CPM
Irradiated Air Channel	RM3-4	Meter	10-10^{6} CPM
Normal Air Channel	RM3-5	Meter	10-10^{6} CPM
Stack Monitor Channel	RM4-1	Meter	10-10^{6} CPM
Stack Monitor Channel	RM4-2	Meter	10-100 CPM
Back Door		Ind. Lights	Open (Red)/Shut(Green)
Elevator Door		Ind. Lights	Open (Red)/Shut(Green)
North Door		Ind. Lights	Open (Red)/Shut(Green)
Process Door		Ind. Lights	Open (Red)/Shut(Green)
South Door		Ind. Lights	Open (Red)/Shut(Green)
Sub-Pile Door		Ind. Lights	Open (Red)/Shut(Green)
Truck Door		Ind. Lights	Open (Red)/Shut(Green)
Shut-Dn. Cool #2 Iso. Valve DWV-7		Switch	Open/Close
Shut-Dn. Cool #1 Iso. Valve DWV-8		Switch	Open/Close
Moderator Dump Valve DWV-9		Switch	Close/Open
Reactor Pump Up Valve DWV-11		Switch	Open/Close
Reactor Quick Fill Valve DVW-12		Switch	Open/Close
Emerg. Tank Drain Valve DWV-13		Switch	Open/Close
Sump Pit To Emerg. Tank DWV-20		Switch	Open/Close
Sump Pit To Storage Tank DWV-21		Switch	Open/Close
Exp. D_2O Emergency Cooling Valve DWV-29 & -30		Switch	Open/Close
Reactor Quick Fill Valve DWV-31		Switch	Open/Close
Emerg. Cooling To Reserve Tank Valve DWV-32 & -33		Switch	Open/Close

(**Table 7.5F Main Control Panel Instrumentation & Controls – Panels F and G** - Continued)

MCP Panel F and G	Designator	Component	Range
Emergency Cooling To Plenums Valves DWV-34 & -35		Switch	Open/Close
Fuel Transfer Overflow Vlv DWV-37		Switch	Open/Close
Dilution Exhaust Fan EF-2		Switch	Hand-Off-Auto
1st & 2nd Flr Exh Fans EF3 & EF-23		Switch	Hand-Off-Auto
Irradiated Air Exhaust Fan EF-4		Switch	Hand-Off-Auto
AC Power Emerg. Exhaust Fan EF-5		Switch	Auto-Off-Stby
DC Power Emerg. Exhaust Fan EF-5		Switch	Hand-Off-Auto
AC Power Emerg. Exhaust Fan EF-6		Switch	Auto-Off-Stby
DC Power Emerg. Exhaust Fan EF-6		Switch	Hand-Off-Auto
Basement Exhaust Fan EF-27		Pushbutton	Start/Stop
Second Floor Booster Fan SF-1		Pushbutton	Start/Stop
Supply Fan 1st & 2nd Floor SF-2		Pushbutton	Start/Stop
First Floor Booster Fan SF-3		Pushbutton	Start/Stop
Basement Supply Fan SF-11		Pushbutton	Start/Stop
Lab & Pool Booster Fan SF-12		Pushbutton	Start/Stop
Decon. Recirc. Fan SF-19		Switch	Bldg.-Off-Process Room
AC Power Shut-Dn. Cool. Pump #1		Switch	Auto-Off-Standby
AC Power Shut-Dn. Cool. Pump #2		Switch	Auto-Off-Standby
DC Power Shut-Dn. Cool. Pump #1		Switch	Hand-Off-Auto
DC Power Shut-Dn. Cool. Pump #2		Switch	Hand-Off-Auto
Emergency Sump Pump		Switch	On/Off
Sump Pit To Hot Waste		Switch	On/Off

Table 7.5G: Main Control Panel Instrumentation & Controls – Panel H

MCP Panel H	Designator	Component	Range
D_2O IX Inlet/Outlet Conductivity	CRA1-2A/ CRA1-2B	Recorder	0-µS
D_2O HE-2 Flow	FIA-5	Meter	0-120 gpm
D_2O IX Flow	FIA-6	Meter	0-30 gpm
Thermal Column Flow Controller	FCA-7	Controller	0-100%
Cold Source Flow (A)	FIA-8A	Meter	0-25 gpm
Cold Source Flow (B)	FIA-8B	Meter	0-25 gpm
Helium Flow	FIA-9	Meter	0-30 scfm
D_2O IX Injection Flow	FI-18	Meter	0-60 gpm
HE-2 Sec. Flow	FI-26	Meter	0-300 gpm
Thermal Column Tank Level	LCA-4	Meter	0-85 in.
Thermal Column Surge Tank Level	LIA-4A	Recorder	0-35 in.
HE Gas Holder & CO2 Gas Holder Level Recorder	LRCA-5 /LRCA-6	Recorder	0-48 in.
Cold Source Press. (A)	P-1A	Meter	-15 to 100 psi
Cold Source Press. (B)	P-1B	Meter	-15 to 100 psi
D_2O Exp. Cooling Press. Cont.	PIC-2	Controller	0-100 psi
Recombiner Outlet Pressure	PIA-3	Meter	0-10 in. H_2O
Recombiner Inlet Pressure	PIA-4	Meter	0-20 in. H_2O
HE-1B Pri./Sec. Delta Press.	PIA-32	Meter	0-50 psi
D_2O HE-2 Outlet Temperature	TIA-6	Meter	50-125 F
D_2O HE-2 Inlet Temperature	TI-7	Meter	50-125 F
Thermal Column Tnk. Outlet Temp.	TIA-8	Meter	50-125 F
Recombiner Internal/Outlet Temperature	TRA-10/ TRA-11	Recorder	50-200 F 50-200 F
Cold Source D_2O Outlet Temp.	TI-35	Meter	50-200 F
HE-2 Sec. Outlet Temperature	TI-36	Meter	50-125 F
DWV-23 Cold Source Flow Controller		Controller	0-100%
D_2O IX Injection Flow DWV-39		Controller	0-100%
D_2O HE-2 Flow DWV-22		Controller	0-100%
#1 Storage Tank Pump Isolation Valve DWV-14		Switch	Open/Close
#2 Storage Tank Pump Isolation Valve DWV-15		Switch	Open/Close
Pre-Filter Isolation Valve DWV-16		Switch	Open/Close
D_2O Exp. Return Isolation Valve DWV-24		Switch	Open/Close
D_2O Exp. Cool. Isolation Valve DWV-26		Switch	Open/Close

Table 7.5H: Main Control Panel Instrumentation & Controls – Panel J

MCP Panel J	Designator	Component	Range
Emergency Tank Make Up Valve DWV-40		Switch	Open/Close
Reactor Pump Up Isolation Valve DWV-134		Switch	Open/Close
HE Blower #1 & Discharge Valve HEV-6		Switch	On-Off-Standby
HE Blower #2 & Discharge Valve HEV-7		Switch	On-Off-Standby
HE-2 Sec. Inlet SCV-12		Switch	Open/Close
#1 Thermal Column Pump		Switch	Auto-Off-Standby
#2 Thermal Column Pump		Switch	Auto-Off-Standby
D_2O Exp. Cool. Booster Pump 1		Switch	Auto-Off-Standby
D_2O Exp. Cool. Booster Pump 2		Switch	Auto-Off-Standby
D_2O Storage Tank Pump #1		Switch	Auto-Off-Standby
D_2O Storage Tank Pump #2		Switch	Auto-Off-Standby
CO_2 Make Up		Switch	Open-Shut-Auto
CO_2 Purge Fan		Switch	Off-neutral-On
HE Make Up		Switch	Open-Shut-Auto

Table 7.5I: Main Control Panel Instrumentation & Controls – Panel K and L

MCP Panel K and L	Designator	Component	Range
Annunciator Panel No. 2	AN-2	Alarm Window	
Storage Pool Water Conductivity	CIA-4	Meter	0-20 micromhos
Storage Pool IX Inlet/Outlet Conductivity	CIA-5	Meter	0-20 micromhos
Thermal Shield Water Conductivity	CIA-6	Meter	0-20 micromhos
Thermal Shield Inlet/Outlet Conductivity	CIA-7	Meter	0-20 micromhos
Exp. Demin. Water IX Inlet Flow	FIA-10	Meter	0-15 gpm
Exp. Demin. Cooling Water Flow	FIA-11	Meter	0-160 gpm
Storage Pool Cooling Flow	FIA-13	Meter	0-150 gpm
Storage Pool IX Flow	FIA-14	Meter	0-15 gpm
Thermal Shield Cooling Water Flow	FIA-15	Meter	0-750 gpm
Thermal Shield IX Flow	FIA-16	Meter	0-15 gpm
Thermal Shield HX Sec. Flow	FI-27	Meter	0-750 gpm
Exp. Demin. Water Tank Level	LIA-7	Meter	0-135 in.
Thermal Shield Storage Tank Level	LIA-8	Meter	0-125 in.
Exp. Demin. Pressure Controller	PIC-1	Controller	0-100 psi
Thermal Shield pH		Meter	2-12
Storage Pool Water Temperature	TIA-15	Meter	25-125 F
Thermal Shield HX Inlet Temperature	TIA-16	Meter	50-125 F
Thermal Shield HX Sec. Outlet Temperature	TIA-17	Meter	50-125 F
Exp. Demin. Water HX Inlet Temperature	TI-21	Meter	50-125 F
Thermal Shield Storage Tank Inlet Temperature	TIA-22	Meter	50-125 F
Thermal Shield Floor Header Outlet Temperature	TIA-23	Meter	50-125 F
Exp. Demin. Water HX Outlet Temperature	TIA-31	Meter	50-125 F
Thermal Shield Sec. Inlet Valve Controller		Controller	0-100%
Thermal Shield HX Bypass Valve Controller		Controller	0-100%
Neutron Guide Control Power		Switch	Off-On
Power Rabbit System		Switch	Off-On
RT-2 Enable		Switch	Off-On
Exp. Demin. Water Pump #1		Switch	On-Off-Standby
Exp. Demin. Water Pump #2		Switch	On-Off-Standby

(**Table 7.5I Main Control Panel Instrumentation & Controls – Panel K and L** - Continued)

MCP Panel K and L	Designator	Component	Range
Helium Compressor Sec. Cooling Pump #1		Switch	On-Off-Standby
Helium Compressor Sec. Cooling Pump #2		Switch	On-Off-Standby
Storage Pool IX Booster Pump		Switch	Hand-Off-Auto
Storage Pool Pump #1		Switch	On-Off-Standby
Storage Pool Pump #2		Switch	On-Off-Standby
Thermal Shield Pump #1		Switch	On-Off-Standby
Thermal Shield Pump #2		Switch	On-Off-Standby
Thermal Shield Pump #1 Isolation Valve TSV-1		Switch	Open-Close
Thermal Shield Pump #2 Isolation Valve TSV-2		Switch	Open-Close
Thermal Shield IX Isolation Valve TSV-3		Switch	Open-Close
Thermal Shield IX Isolation Valve TSV-4		Switch	Open-Close
Thermal Shield Return Isolation Valve TSV-6		Switch	Open-Close

Table 7.6: Instrumentation Designators

AN	ANNUNCIATOR
BTUR	BTU RECORDER
CA	CONDUCTIVITY ALARM
CC	CONDUCTIVITY CELL
CI	CONDUCTIVITY INDICATOR
CIA	CONDUCTIVITY INDICATOR
CR	CONDUCTIVITY RECORDER
CRA	CONDUCTIVITY RECORDER
CS	CONDUCTIVITY SWITCH
EPC	ELECTRO PNEUMATIC
FA	FLOW ALARM
FC	FLOW CONTROLLER
FCA	FLOW CONTROL ALARM
FD	FLOW DETECTOR
FI	FLOW INDICATOR
FIA	FLOW INDICATOR ALARM
FIC	FLOW INDICATOR
FIT	FLOW INDICATOR
FR	FLOW RECORDER
FRC	FLOW RECORDER CONTROLLER
FS	FLOW SWITCH
FT	FLOW TRANSMITTER
HIC	HAND INDICATOR
LA	LEVEL ALARM
LC	LEVEL CONTROLLER
LI	LEVEL INDICATOR
LIA	LEVEL INDICATOR ALARM
LIC	LEVEL INDICATOR CONTROLLER
LR	LEVEL RECORDER
LS	LEVEL SWITCH
LT	LEVEL TRANSMITTER
PA	PRESSURE ALARM
PC	PRESSURE CONTROLLER
PG	PRESSURE GAGE
PI	PRESSURE INDICATOR
PIC	PRESSURE INDICATOR
PR	PRESSURE RECORDER
RRC	RADIATION RECORDER AND CONTROLLER
PS	PRESSURE SWITCH
SFA	SCRAM FLOW ALARM
SLA	SCRAM LEVEL ALARM
SPA	SCRAM PRESSURE ALARM
STA	SCRAM TEMPERATURE ALARM
TA	TEMPERATURE ALARM
TC	TEMPERATURE CONTROL
TI	TEMPERATURE INDICATOR
TIA	TEMPERATURE INDICATOR ALARM
TIC	TEMPERATURE INDICATOR
TR	TEMPERATURE RECORDER
TRC	TEMPERATURE RECORDER
TS	TEMPERATURE SWITCH
TT	TEMPERATURE TRANSMITTER

Table 7.7A: Load List Critical Power Panel 1 (CP-1)

Breaker	Load
1	Main Control Panel Outlets
2	Main Control Panel Lights
3	48 Vdc Safety System Power Supply EBA
4	48 Vdc Safety System Power Supply EBB
5	Nuclear Instrumentation Power Supplies (Standby)
6	Annunciator Panel
7	Critical Power Panel 3 (CP-3)
8	Critical Power Panel 2 (CP-2)
9	Neutron Guide Isolation Valve (NGIV) Control Panel and Building Evacuation Alarms.
10	Nuclear Instrumentation Power Supplies (Main)
11	Sub-Pile Room and Storage Pool Electronics
12	AC Valve Power
13	Main Control Panel Section B Outlets and 24 Vdc Process Instrument Power Supply
14	Page System
15	Area Monitors, Duct Filter Monitors, Remote Electronics Panel, Main Control Panel Section A Outlets, and 24 Vdc Process Instrument Power Supply
16	Pneumatic Rabbit System
17	Conductivity Rack

Table 7.7B: Load List Critical Power Panel 2 (CP-2)

Cubicle	Load
1	Radiation Monitors RM3-1, RM3-2 and RM4-1
2	Building Pressure Transmitter & Building Exhaust Flow
3	Radiation Monitor RM3-4
4	ACV-30/37
5	Radiation Monitors RM3-4 & RM3-5 Vacuum Pump No. 1
6	Rabbit System Control Panel
7	Radiation Monitors RM3-4 & RM3-5 Vacuum Pump No. 2
9	Gas Holder Level Controls (He & CO_2 Make-Up)
11	Body Monitor
13	Radiation Monitor RM3-5

Table 7.7C: Load List Critical Power Panel 3 (CP-3)

Breaker	Load
11	Building Fire Alarm
15	Simplex Panel
16	Emergency Diesel Battery Chargers
17	Emergency Lighting Panel X-1
18	Electronic Relay Cabinet (Lobby Computer)
19	Building Services Annunciator Panel
20	Mechanical Relay Cabinet
22	NIST Security Relay Cabinet
23	Hot Waste Control Panel
24	Clock Relay Cabinet
27	Diesel Oil Transfer Pump
28	H/F CTR A-134

Table 7.8A: Load List 125 Vdc Distribution Panel

Breaker	Load
2	Battery Disconnect Breaker
3	Feed to DC MCC Load Center
4	T-9 20 kVA UPS
8	DC Power Panel 1 (DCP-1)
10	T-10 20 kVA UPS

Table 7.8B: Load List DC Power Panel 1 (DCP-1)

Breaker	Load
1	Emergency Lighting
4	Plant Annunciator Panel
8	Lobby Annunciator Panel
12	Health Physics Office Annunciator Panel
16	PS-108

Table 7.8C: Load List DC Power Panel 2 (DCP-2)

Breaker	Load
1	Emergency Lighting
3	Scram Relays (FSR & DSR) & Moderator Dump
6	ACV-5 & -9
7	ACV-4, -8, & -10
10	MCC A-5 Control Power for Breakers 1 & 2 and “A” Emergency Diesel
11	RWV-1, -2, -3, -13, & -16
12	DC Valve Power
13	MCC B-6 Control Power for Breakers 3 & 4 and “B” Emergency Diesel
15	ACV-12 and PC-151

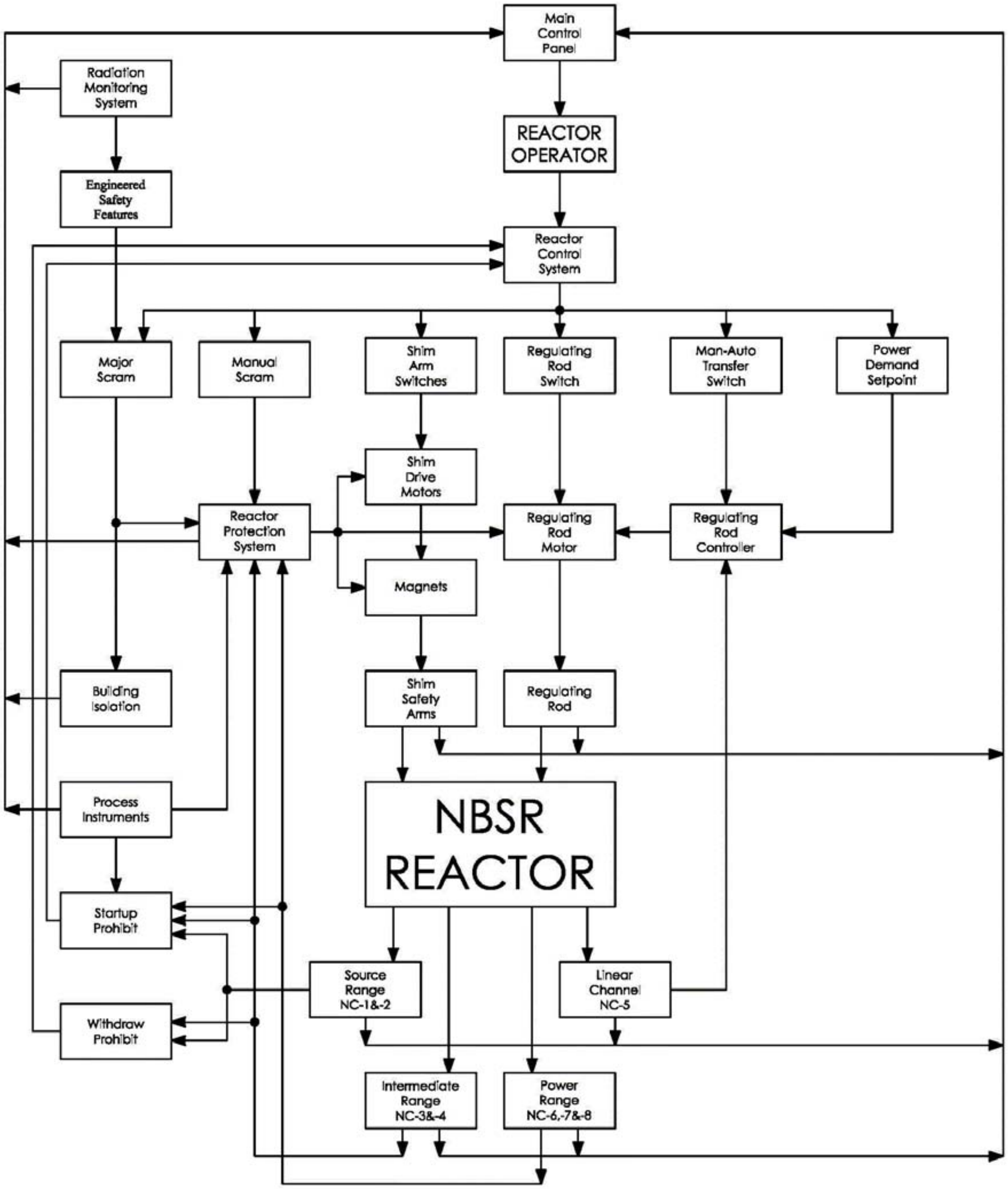

Figure 7.1: Simplified Block Diagram – NBSR I&C System

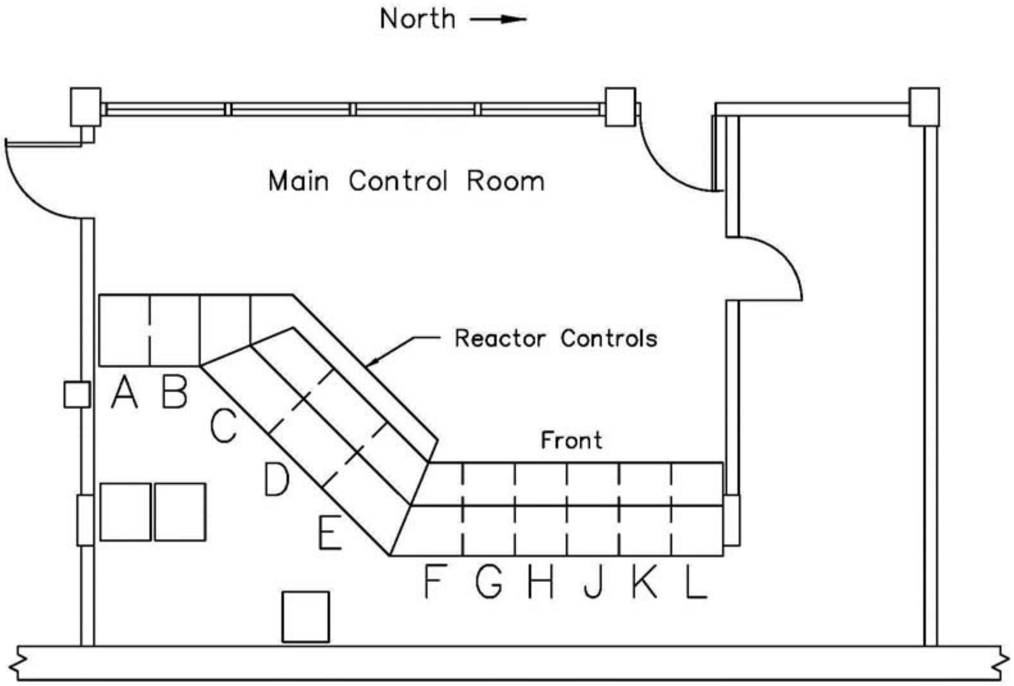

Figure 7.2: Control Room Panel Arrangements

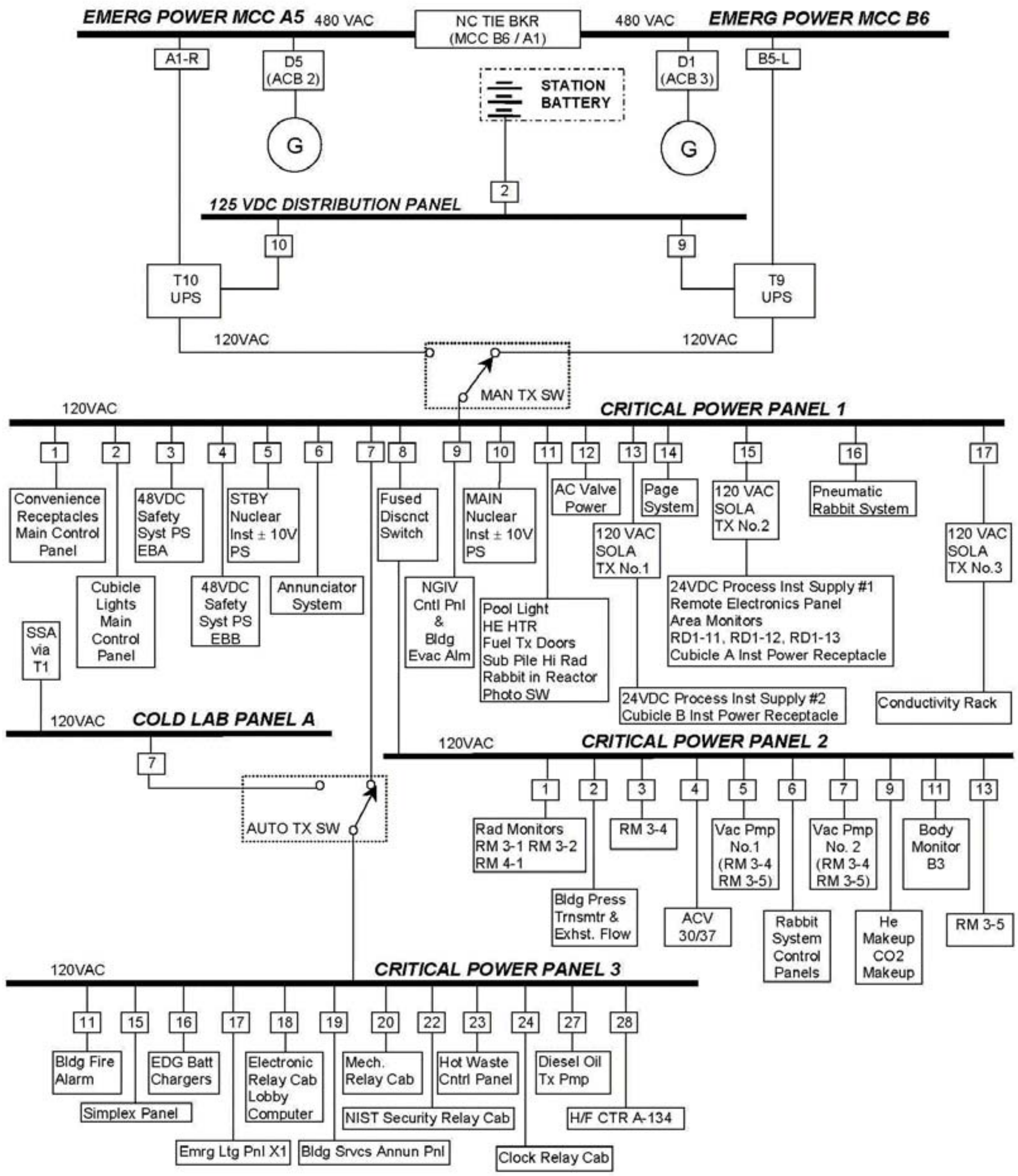

Figure 7.3: Single Line Diagram Of The Instrument Power System

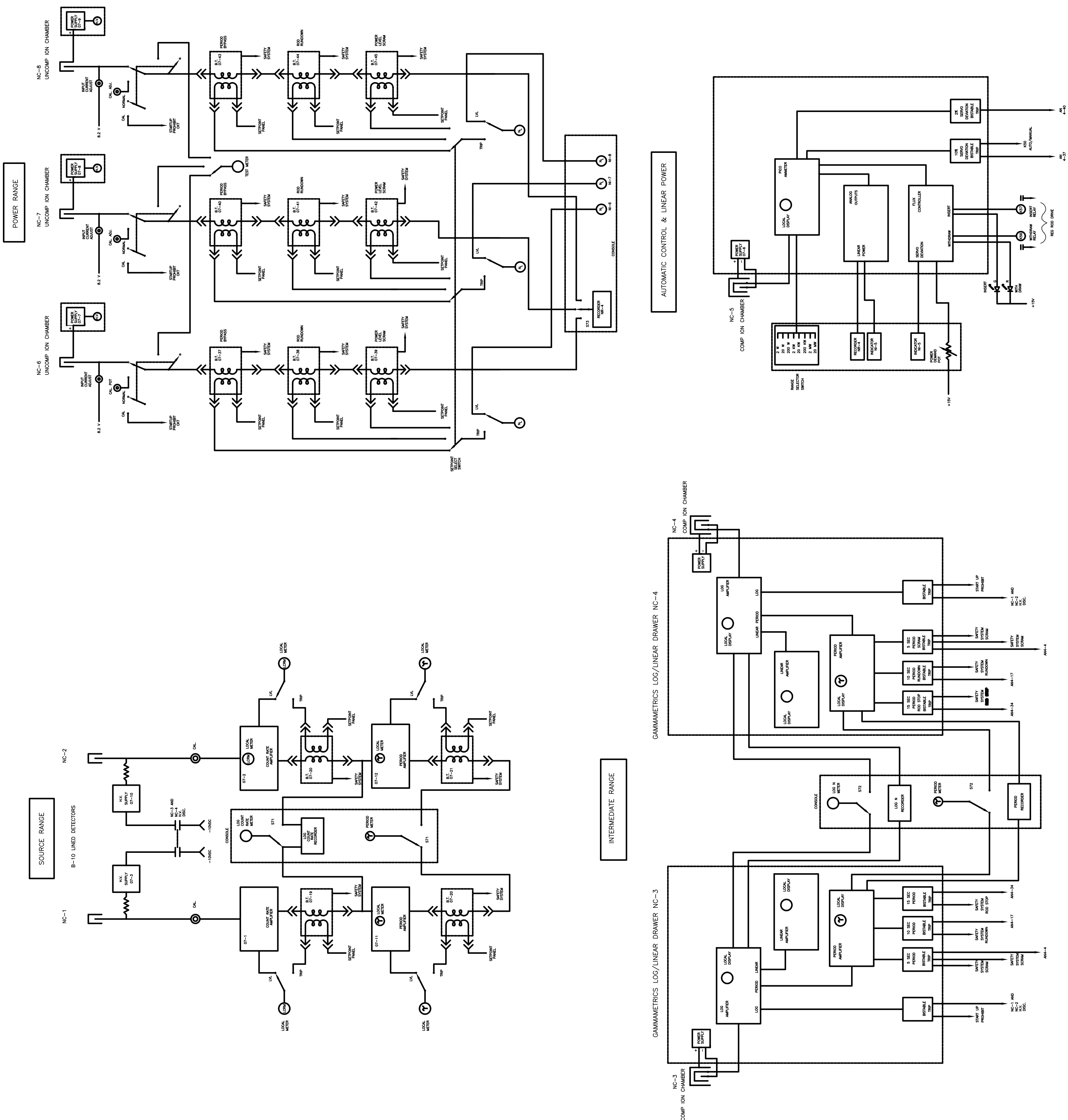

Figure 7.4: Functional Block Diagram of the Nuclear Instrumentation

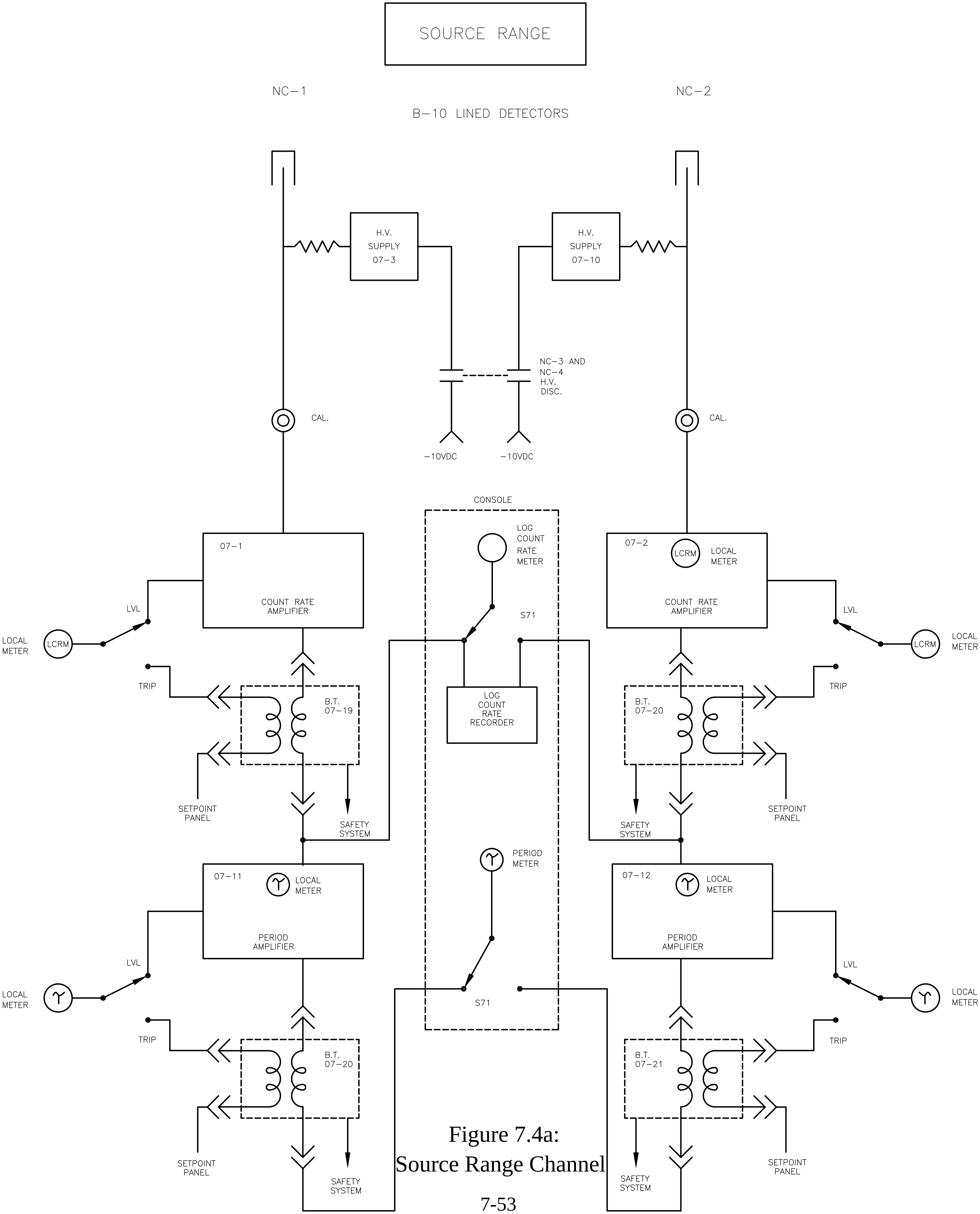

Figure 7.4a:
Source Range Channel

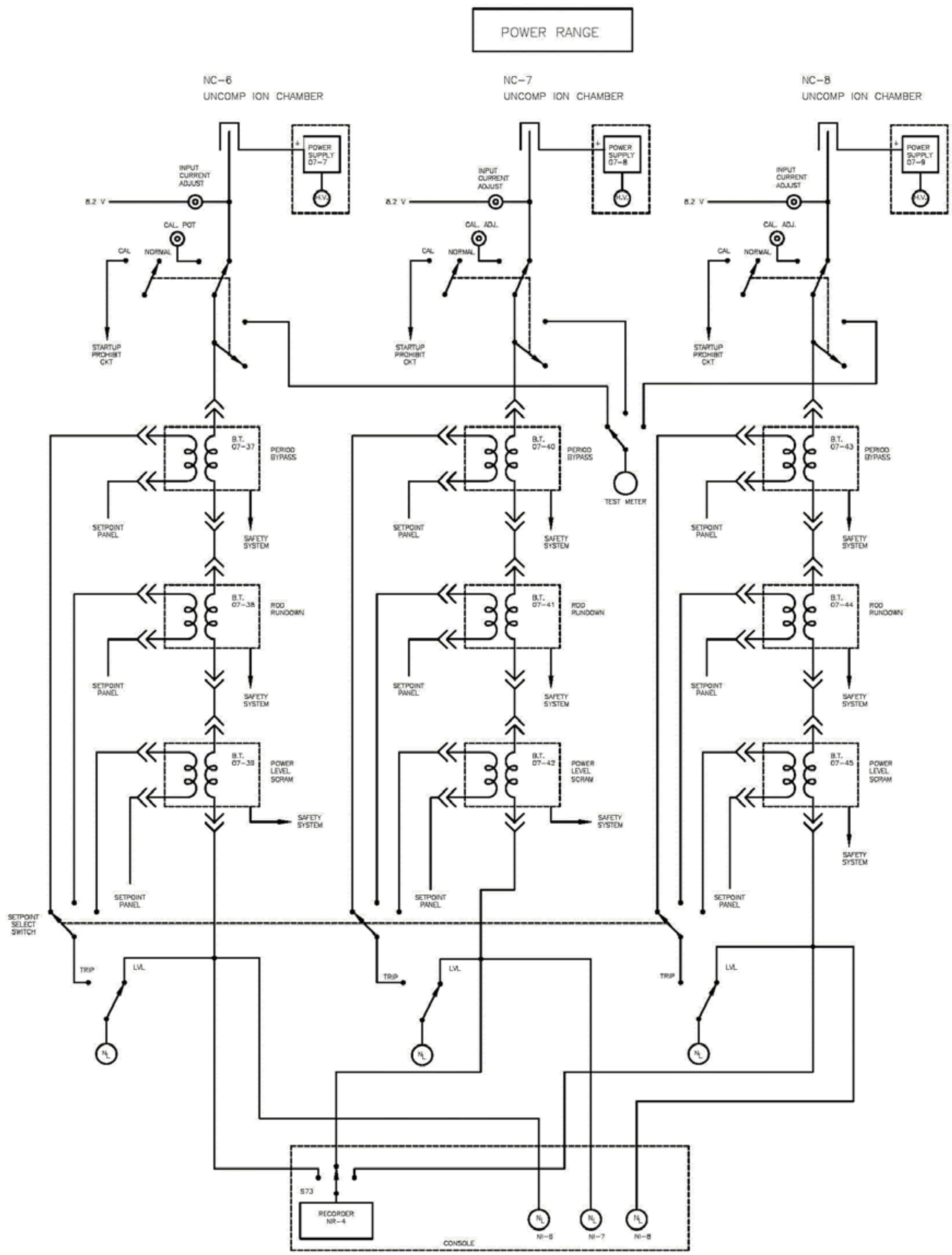

Figure 7.4b: Intermediate Range Channel

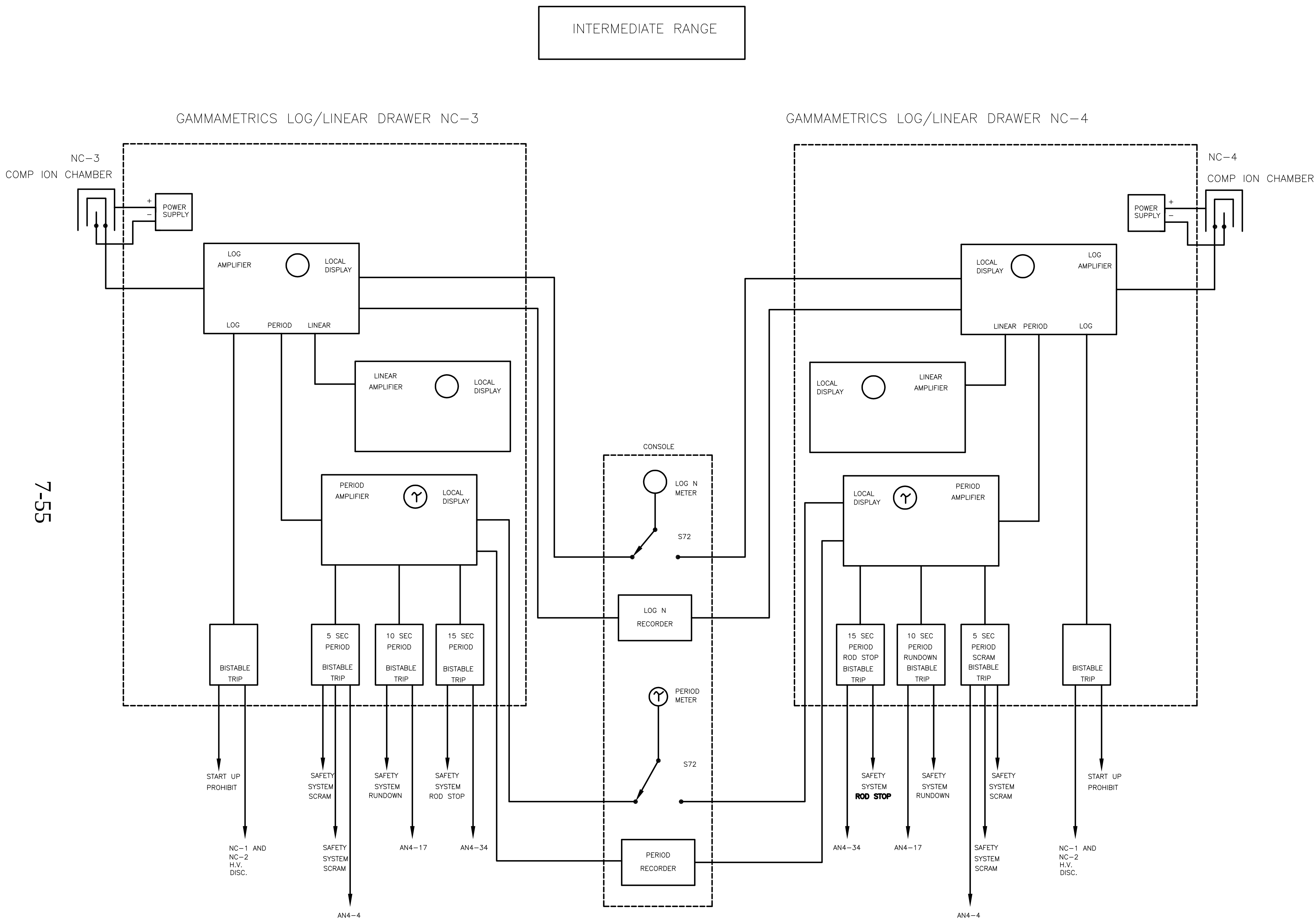

Figure 7.4c: Power Range Channel

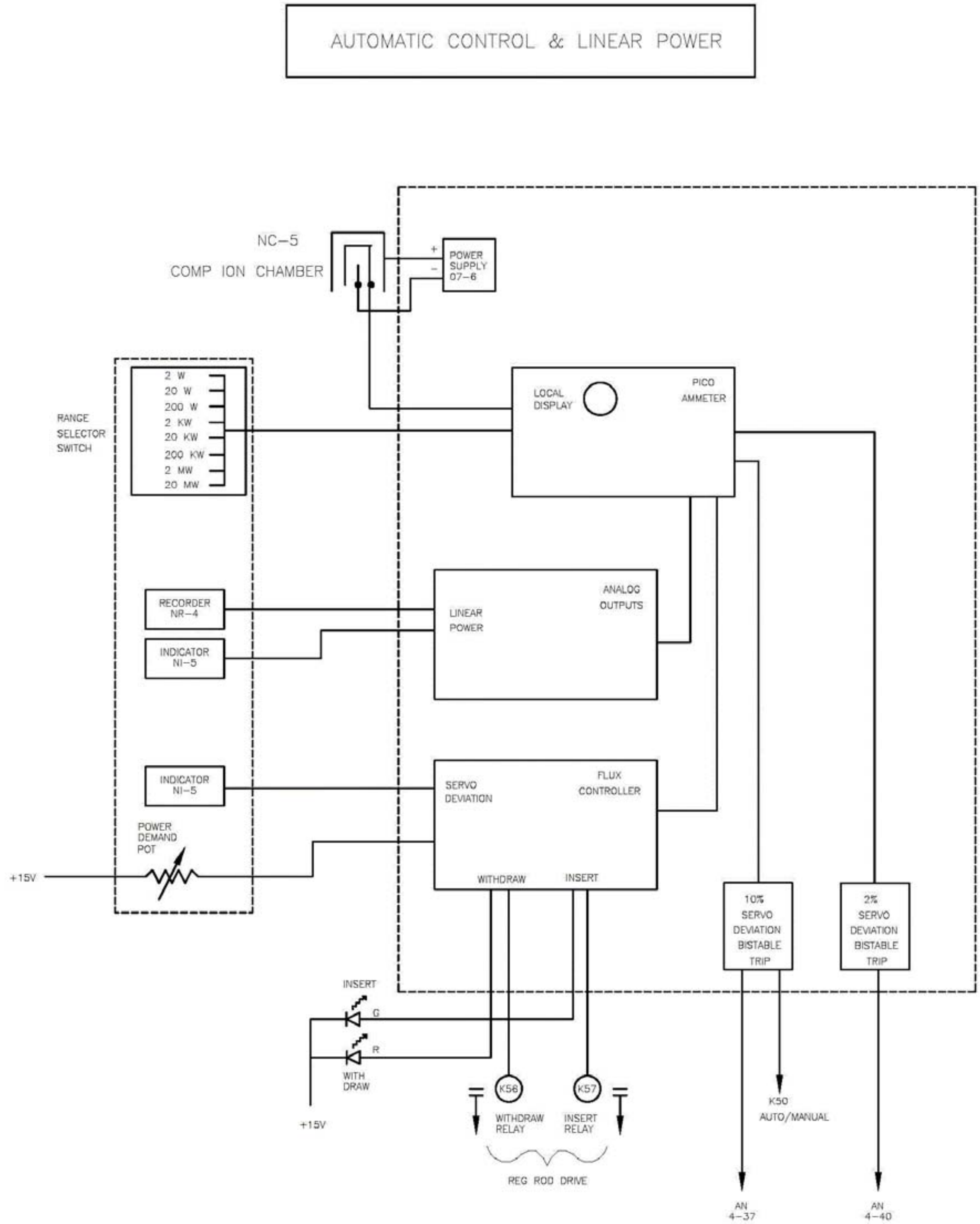

Figure 7.4d: Automatic Control and Linear Channel

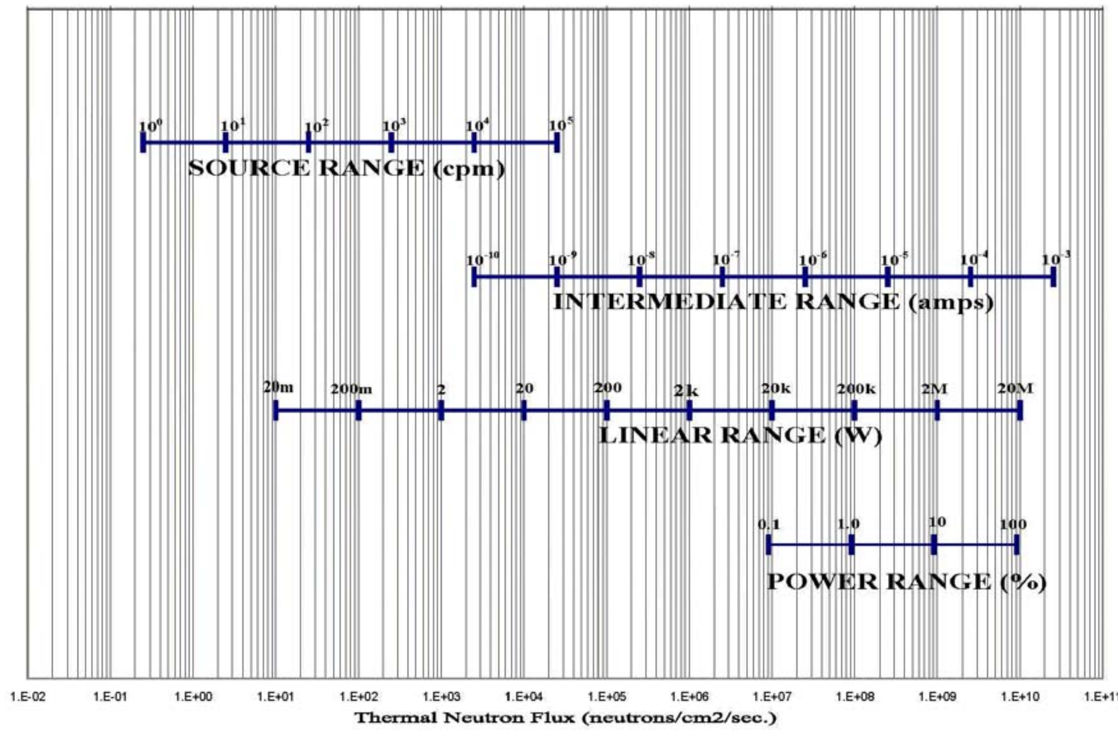

Figure 7.5: Flux coverage of the NBSR

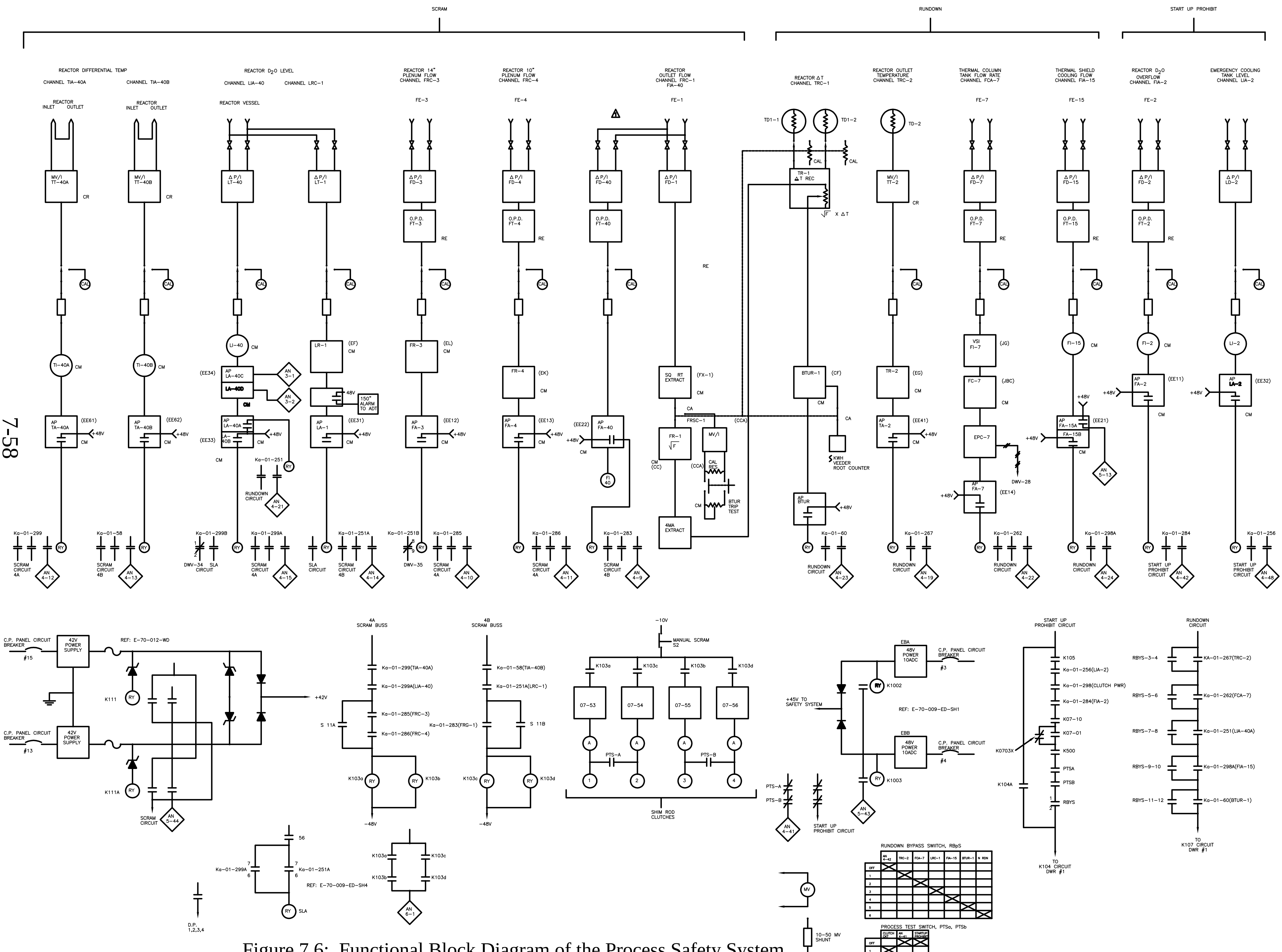

Figure 7.6: Functional Block Diagram of the Process Safety System

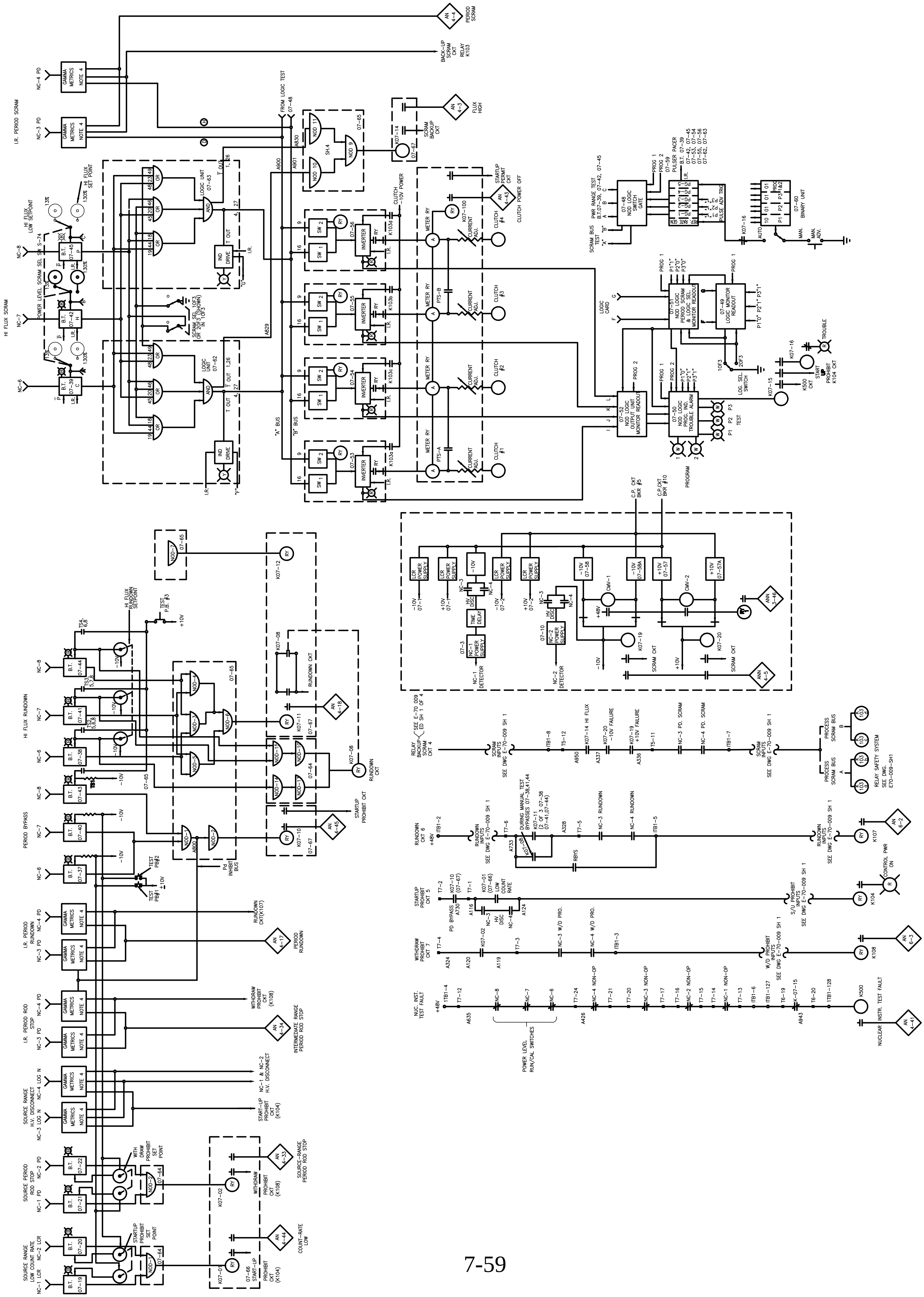

Figure 7.7: Nuclear Safety System Logic Block Diagram

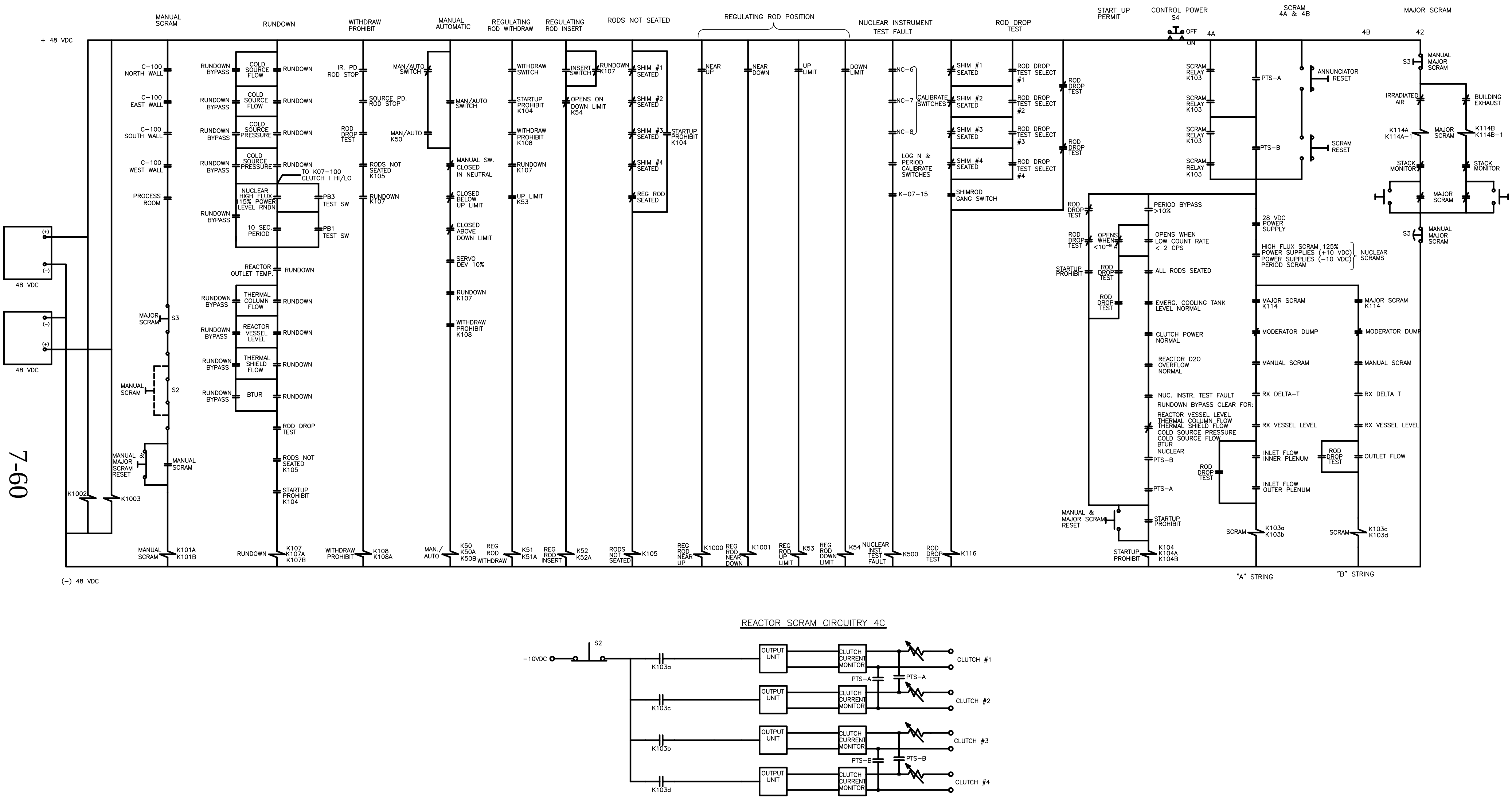

Figure 7.8: Control Logic Diagram

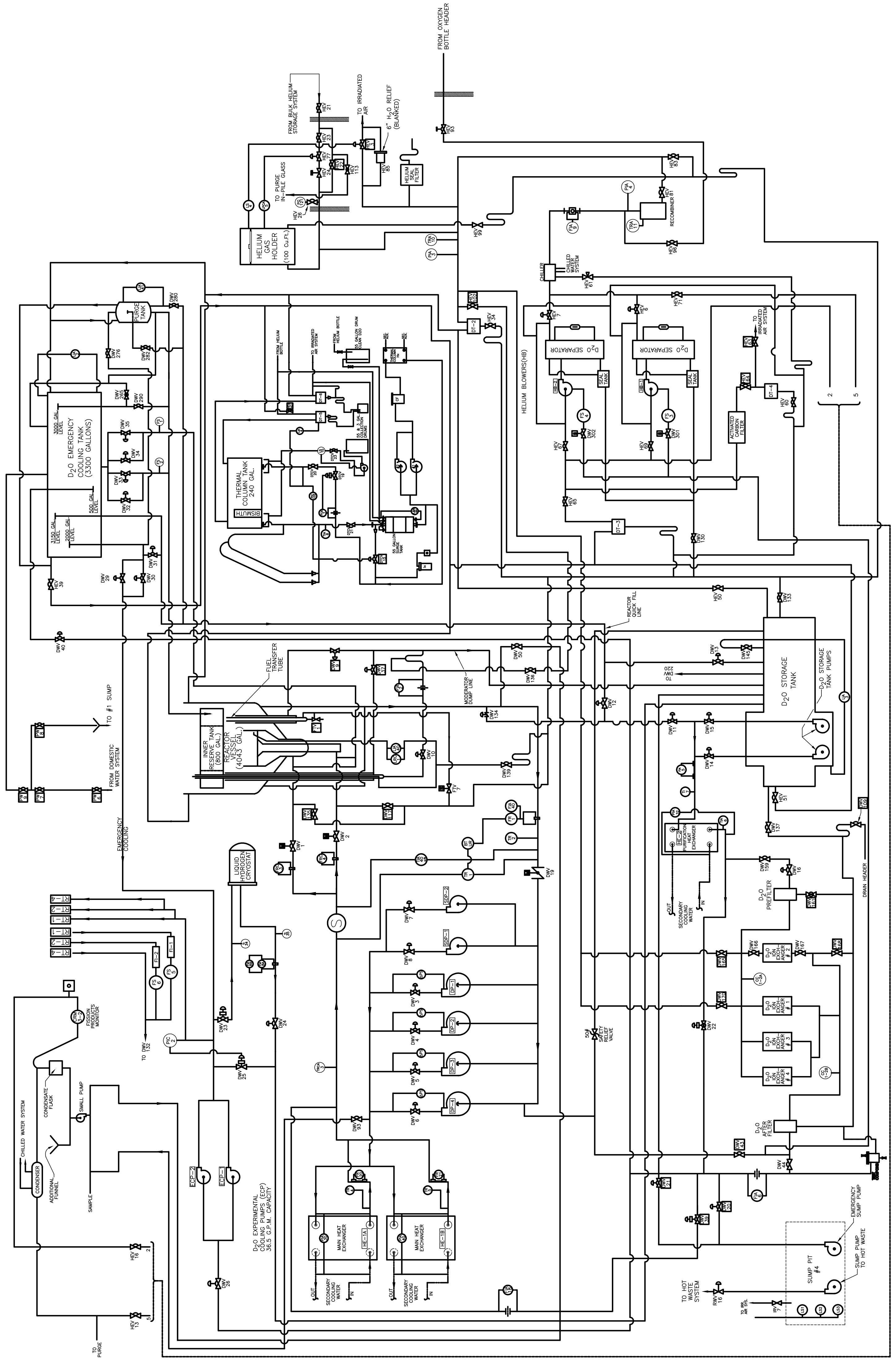

Figure 7.9: Primary Coolant System Piping & Instrumentation Diagram (P&ID)

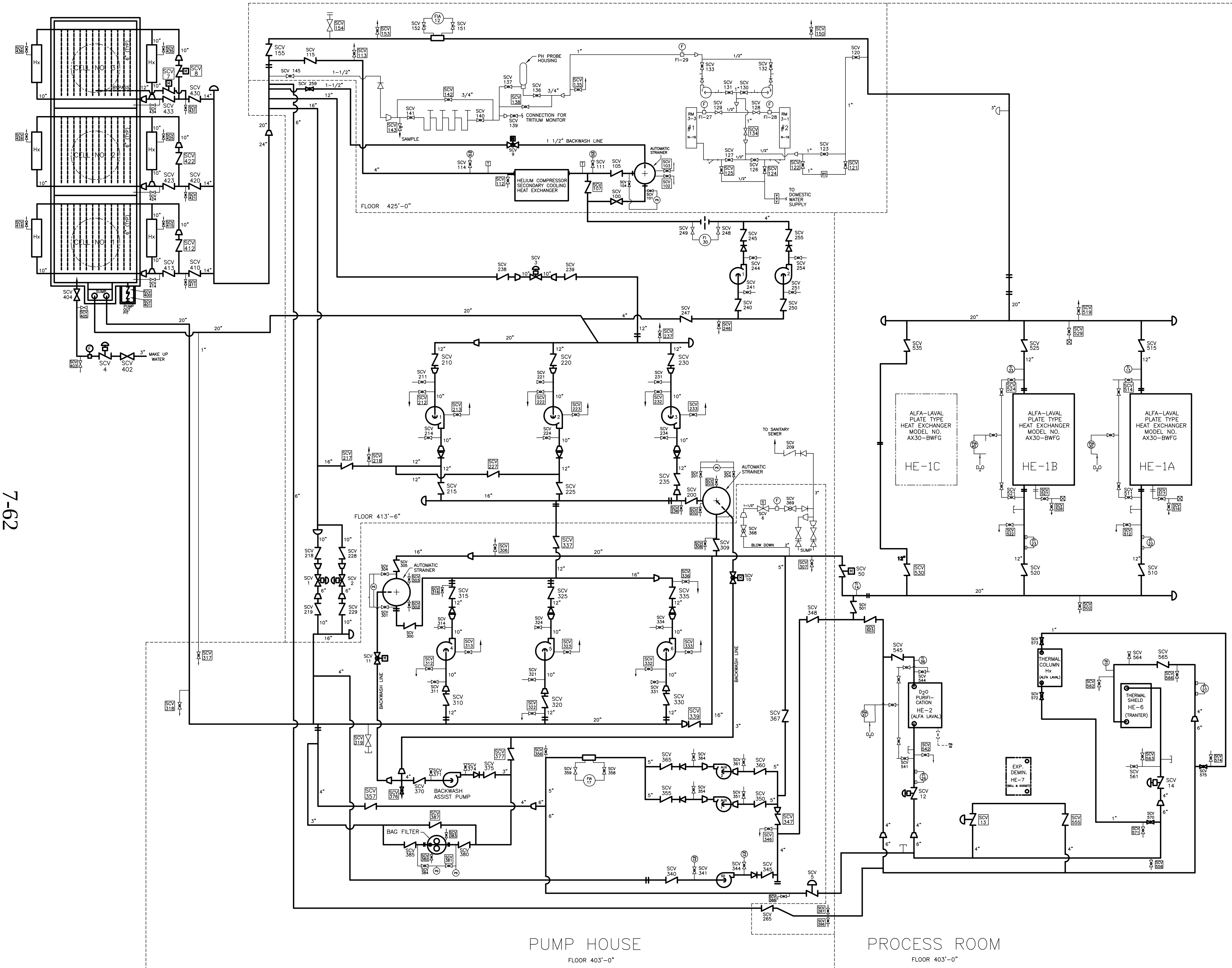

Figure 7.10: Secondary Coolant System Piping & Instrumentation Diagram (P&ID)

Appendix 7A: Description of Instrument Loops

The NBSR has an extensive Instrumentation System that displays the information needed to safely operate the reactor from the centrally located Main Control Panel in the Main Control Room. Various process parameters, equipment status, and alarms are physically arranged on the panel according to the systems in which they are located. Electrical power for the instruments is supplied by Critical Power Panels as shown on Figure 7-3. The Critical Power Panels loads lists, including the instrumentation loads, are presented in Tables 7-7A, -7B, and –7C. Chapter 8 Electrical Power Systems discusses the electrical distribution system in detail.

1 Conductivity

1. Primary D_2O Ion Exchanger Inlet Conductivity Recorder Channel, CRA1-2A, and Primary D_2O Ion Exchanger Outlet Recorder Channel, CRA1-2B, measure the conductivity of the heavy water processed by the purification train. By measuring the conductivity prior to and following the resin beds, the effectiveness of the ion exchangers is monitored. Conductivity Cell CC1-2A is installed in the inlet piping to the ion exchanger columns while Conductivity Cell CC1-2B is installed in the outlet piping. Cell CC1-2A connects to Conductivity Transmitter CT-2A. The transmitter supplies a signal to Conductivity Recorder CR1-2A. The transmitter also supplies a signal to the Annunciator System. REACTOR IX INLET CONDUCTIVITY HIGH alarm, AN3-7, alerts the reactor operator to a high conductivity condition on the inlet to the ion exchangers. Cell CC1-2B connects to Conductivity Transmitter CT-2B. The transmitter supplies a signal to Conductivity Recorder CR1-2B. The transmitter also supplies a signal to the Annunciator System. REACTOR IX OUTLET CONDUCTIVITY HIGH alarm, AN3-8, alerts the reactor operator to a high conductivity condition on the outlet from the ion exchangers. The indicated range of both channels is 0-3 µS. The normal reading is < 1 µS while the alarm is set at 2.5 µS.

2. Storage Pool Water Conductivity Indicator Channel, CIA-4, measures the conductivity of the Storage Pool water. Conductivity Cell CC-4 is located in the inlet piping to the storage pool ion exchanger column. Cell CC-4 connects to Conductivity Transmitter CT-4. The transmitter supplies a signal to Storage Pool Water Conductivity Indicator CI-4. The transmitter also supplies a signal to the Annunciator System. STORAGE POOL CONDUCTIVITY HIGH alarm, AN5-17, alerts the reactor operator to a high conductivity condition on the inlet to the ion exchanger. The indicated range is 0-20 µS. The normal reading is ~1 µS while the alarm is set at 5 µS.

3. Storage Pool Ion Exchanger Outlet Conductivity Indicator Channel, CIA-5, measures the conductivity of the Storage Pool water processed by the ion exchanger. Conductivity Cell CC-5 is located in the outlet piping. Cell CC-5 connects to Conductivity Transmitter CT-5. The transmitter supplies a signal to Storage Pool IX Outlet Conductivity Indicator CI-5. The transmitter also

supplies a signal to the Annunciator System. STORAGE POOL CONDUCTIVITY HIGH alarm, AN5-17, alerts the reactor operator to a high conductivity condition on the outlet from the ion exchanger. The indicated range is 0-20 μS. The normal reading is ~1 μS while the alarm is set at 5 μS.

4. Thermal Shield Water Conductivity Indicator Channel, CIA-6 measures the conductivity of the thermal shield water. Conductivity Cell CC-6 is located in the thermal shield piping. Cell CC-6 connects to Conductivity Transmitter CT-6. The transmitter supplies a signal to Thermal Shield Water Conductivity Indicator CI-6. The transmitter also supplies a signal to the Annunciator System. THERMAL SHIELD CONDUCTIVITY HIGH alarm, AN5-16, alerts the reactor operator to a high conductivity condition in the Thermal Shield water. The indicated range is 0-20 μS. Normal reading is ~1 μS while the alarm is set at 5 μS.

5. Thermal Shield Ion Exchanger Outlet Conductivity Indicator Channel, CIA-7, measures the conductivity of the thermal shield water processed by the ion exchanger. Conductivity Cell CC-7 is located in the outlet piping from the Thermal Shield Ion Exchanger. The transmitter supplies a signal to the Thermal Shield Ion Exchanger Outlet Conductivity Indicator CI-7. The transmitter also supplies a signal to the Annunciator System. THERMAL SHIELD CONDUCTIVITY HIGH alarm, AN5-16, alerts the reactor operator to a high conductivity condition in the Thermal Shield water. The indicated range is 0-20 μS. Normal reading is ~1 μS while the alarm is set at 5 μS.

2 Flow

1. Reactor Vessel Outlet Flow Recorder Channel, FR-1, and Reactor Outlet Flow Indicator Alarm Channel, FIA-40, provide redundant measurement of the reactor outlet flow from the reactor. Outlet flow is measured by an 18-inch venturi, FE-1, common to both channels. A differential pressure across this venturi of 133.47 in. H_2O corresponds to a flow of 10,000 gpm through it. Sensing lines connect the high- and low-pressure ports on the venturi to Flow Transmitters FT-1 and FT-40. Flow Transmitter FT-1 supplies an electrical signal to Thermal Power Recorder, BTUR. Alarm contacts in the recorder de-energize the BTUR Rundown Relay, Ka-01-60, initiating a reactor rundown and supplying a signal to the Annunciator System. THERMAL POWER HIGH alarm, AN4-23, alerts the reactor operator to a high thermal power level in the core. Flow Transmitter FT-40 supplies an electrical signal to Flow Indicator FI-40 and Flow Alarm FA-40. The alarm unit de-energizes the Outlet Flow Low Scram Relay, Ka-01-283, initiating a reactor scram and supplying a signal to the Annunciator System. OUTLET FLOW LOW alarm, AN4-9, alerts the reactor operator to a low flow condition in the Reactor Outlet Header. The range of both channels is 0-10,000 gpm. Section 5.2.2.6.5, Thermal Power, discusses how the flow signal is modified to produce the power signal used by the BTU Recorder Channel, BTUR.

2. Reactor Vessel Overflow Indicator Channel, FIA-2, measures the flow of primary coolant in the overflow line from the top of the reactor vessel, thus assuring that the vessel is filled to normal operating level. Overflow is measured by a 3-inch orifice, FE-2, installed in the reactor overflow piping. A differential pressure across this orifice of 50.0 in. H_2O corresponds to a flow of 30 gpm through it. Sensing lines connect the high- and low-pressure ports on the orifice to Flow Transmitter FT-2. This flow transmitter supplies an electrical signal to Flow Indicator FI-2 and Flow Alarm FA-2. The alarm unit de-energizes the Reactor D_2O Overflow Relay, Ka-01-284, initiating a Start-Up Prohibit and supplying a signal to the Annunciator System. D_2O OVERFLOW LOW alarm, AN4-47, alerts the reactor operator to a low flow condition in the Reactor Overflow Line. The range of the channel is 0-30 gpm.

3. Reactor inlet flows are sensed by two channels. Reactor Outer Plenum Flow Recorder Channel, FRC-3, measures the flow of primary coolant into the core through the outer plenum while Reactor Inner Plenum Flow Recorder Channel, FRC-4, measures the flow of primary coolant into the core through the inner plenum. Outer plenum flow is measured by a 14-inch venturi, FE-3, installed in the reactor outer plenum piping. A differential pressure across this venturi of 199.2 in. H_2O corresponds to a flow of 8,000 gpm through it. Sensing lines connect the high- and low-pressure ports on the venturi to Flow Transmitter, FT-3. This flow transmitter supplies an electrical signal to Flow Recorder FR-3 and to Flow Alarm FA-3. The alarm unit de-energizes the 14" Inlet Flow Low Scram Relay, Ka-01-285, initiating a reactor scram and supplying a signal to the Annunciator System. The 14 IN. INLET FLOW LOW alarm, AN4-10 alerts the reactor operator to a low flow condition in the Reactor Outer Plenum line. The range of the channel is 0-8,000 gpm. Inner plenum flow is measured by a 10-inch venturi, FE-4, installed in the reactor inlet plenum piping. A differential pressure across this venturi of 204.8 in. H_2O corresponds to a flow of 4,000 gpm through it. Sensing lines connect the high- and low-pressure ports on the venturi to Flow Transmitter FT-4. This flow transmitter supplies an electrical signal to Flow Recorder FR-4 and to Flow Alarm FA-4. The alarm unit de-energizes the 10" Inlet Flow Low Scram Relay, Ka-01-286, initiating a reactor scram and supplying a signal to the Annunciator System. The 10 IN. INLET FLOW LOW alarm, AN4-11, alerts the reactor operator to a low flow condition in the Reactor Inner Plenum line. The range of the channel is 0-4,000 gpm.

4. D_2O to Purification HE-2 Flow Indicator Channel, FIA-5, measures the flow of heavy water though the D_2O Purification Heat Exchanger HE-2. Ultrasonic Flow Element FE-5 and Flow Transmitter FT-5 supply a flow signal to Flow Indicator FI-5 and Flow Alarm FA-5. The ultrasonic flow element is mounted on the inlet piping of the primary side of the heat exchanger. HE-2 INLET FLOW LOW alarm, AN3-9, alerts the reactor operator to a low flow condition on the primary side of the purification heat exchanger. The range of the channel is 0-120 gpm.

5. D_2O Ion Exchanger Flow Indicator Channel, FIA-6, measures the flow of heavy water through the purification train. Flow is measured by a 1 ½-inch orifice, FE-6, in the purification train piping on the outlet of the after-filter. A differential pressure across this orifice of 50.0 inches H_2O corresponds to a flow of 30 gpm through it. Sensing lines connect the high- and low-pressure ports on the orifice to Flow Transmitter FT-6. This transmitter supplies an electrical signal to Flow Indicator FI-6 and Flow Alarm FA-6. REACTOR IX FLOW LOW alarm, AN3-6, alerts the reactor operator to a low flow condition through the purification filters and ion exchanger beds. The range of the channel is 0-30 gpm.

6. Thermal Column Flow Indicator Control Channel, FCA-7, measures the flow of thermal column cooling water. Flow is measured by a 2-inch orifice, FE-7, located in the thermal column tank inlet piping. A differential pressure across this orifice of 50.0 inches H_2O corresponds to a flow of 50 gpm through it. Sensing lines connect the high- and low-pressure ports on the orifice to Flow Transmitter FT-7. This transmitter supplies an electrical signal to Flow Controller FIC-7 and Flow Alarm FA-7. The alarm unit de-energizes the Thermal Column Flow Rundown Relay, Ka-01-262, initiating a reactor rundown and supplying a signal to the Annunciator System. THERMAL COLUMN FLOW LOW alarm, AN4-22, alerts the reactor operator to a low flow condition in the Thermal Column System. The range of the channel is 0-50 gpm.

7. Cooling water flow to the Neutron Cold Source is measured by redundant channels, Cold Source D_2O Cooling Water Flow Indicator Channel A, FIA-8A, and Cold Source D_2O Cooling Water Flow Indicator Channel B, FIA-8B. Flow is measured by a 1 ½-inch venturi, FE-8, installed in the cold source cooling water outlet piping. A differential pressure across this venturi of 39.06 in. H_2O corresponds to a flow of 25 gpm through it. Sensing lines connect the high- and low-pressure ports on the venturi to Flow Transmitter FT-8A and to Flow Transmitter FT-8B. These flow transmitters supply an electrical signal to Flow Indicators FI-8A and -8B and to Flow Alarm FA-8A and -8B, respectively. Signals are also sent to the Cold Source programmable logic controller (PLC). The alarm units initiate a reactor rundown and supply signals to the Annunciator System. COLD SOURCE D_2O FLOW "A" LOW alarm, AN4-27, and COLD SOURCE D_2O FLOW "B" LOW alarm, AN4-28, alert the reactor operator to a low flow condition in the D_2O cooling lines to the Cold Source. The range of both channels is 0-25 gpm.

8. Helium Flow Indicator Alarm Channel, FIA-9, measures the flow of helium from the recombiner. The rotameter, FE-9, is mounted in the 1-inch piping at the inlet to the helium heater. The rotameter is a variable area-type flow meter. It is mounted vertically with the small end at the bottom. The gas enters at the bottom, flows up around the float and exits at the top. The float is free to move up and down in the tube in proportion to the fluid flow rate and the annular area between the float and the tube. The float assumes a position, in dynamic

equilibrium, when the pressure differential across the float plus the buoyancy effect balances the weight of the float. The float is magnetically coupled to a pointer and a transmitter that sends a 4-20 mAdc current to the control room that is linear with respect to the flow through the flow element. This transmitter supplies a signal to the Helium Flow Indicator FI-9 and Flow Alarm FA-9. HELIUM SYSTEM FLOW LOW alarm, AN3-21, alerts the reactor operator to a low flow condition in the Helium System. The range of the channel is 0-30 scfm.

9. Experimental Demineralized Water System Ion Exchanger Flow Indicator Channel, FIA-10, measures the flow of water through the Experimental Demineralized Water System Ion Exchanger. Flow is measured by a 1-inch orifice, FE-10, located in the inlet piping to the ion exchanger. A differential pressure across this orifice of 50.0 inches H_2O corresponds to a flow of 15 gpm through it. Sensing lines connect the high- and low-pressure ports on the orifice to Flow Transmitter FT-10. This flow transmitter supplies an electrical signal to Flow Indicator FI-10 and Flow Alarm FA-10. EXP. DEMIN. IX FLOW LOW alarm, AN1-26, alerts the reactor operator to a low flow condition in through the ion exchanger. The range of the channel is 0-15 gpm.

10. Experimental Demineralized Water System Cooling Water Flow Indicator Channel, FIA-11, measures the flow of water through Experimental Demineralized Water System Heat Exchanger HE-7. Flow is measured by a 4-inch orifice, FE-11, located in the cooling water outlet piping from the heat exchanger. A differential pressure across this orifice of 100.0 inches H_2O corresponds to a flow of 160 gpm through it. Sensing lines connect the high- and low-pressure ports on the orifice to Flow Transmitter FT-11. This flow transmitter supplies an electrical signal to Flow Indicator FI-11 and Flow Alarm FA-11. EXP. DEMIN. FLOW LOW alarm, AN1-27, alerts the reactor operator to a low flow condition in the Experimental Demineralized System. The range of the channel is 0-160 gpm.

11. Secondary Cooling Water Flow Indicator Channel, FI-12, measures the flow of secondary coolant through the common discharge header on the outlet side of Main Heat Exchangers HE-1A and -1B. Flow is measured by a 20-inch venturi, FE-12, located in the secondary piping between the heat exchangers and the cooling tower. A differential pressure across this venturi of 240.0 inches H_2O corresponds to a flow of 12,000 gpm through it. Sensing lines connect the high- and low-pressure ports on the venturi to Flow Transmitter FT-12. This flow transmitter supplies an electrical signal to Flow Indicator FI-12 and Flow Alarm FA-12. SECONDARY COOLING FLOW LOW alarm, AN5-4, alerts the reactor operator to a low flow condition in the Secondary Header. The range of the channel is 0-12,000 gpm.

12. Storage Pool Cooling Flow Indicator Channel, FIA-13, measures the flow of cooling water through Storage Pool Heat Exchanger HE-8. Flow is measured by a 2-inch orifice, FE-13, located in the outlet piping form the heat exchanger.

A differential pressure across this orifice of 100.0 inches H_2O corresponds to a flow of 150 gpm through it. Sensing lines connect the high and low-pressure ports on the orifice to Flow Transmitter FT-13. This flow transmitter supplies an electrical signal to Flow Indicator FI-13 and Flow Alarm FA-13. STORAGE POOL FLOW LOW alarm, AN5-19, alerts the reactor operator to a low flow condition in the Storage Pool Cooling System. The range of the channel is 0-150 gpm.

13. Storage Pool Ion Exchanger Flow Indicator Channel, FIA-14, measures the flow of water through the Storage Pool ion exchanger. Flow is measured by a 1 ½-inch orifice, FE-14, located in the outlet piping from the Storage Pool Purification Booster Pump. A differential pressure across this orifice of 50.0 inches H_2O corresponds to a flow of 15 gpm through it. Sensing lines connect the high- and low-pressure ports on the orifice to Flow Transmitter FT-14. This flow transmitter supplies an electrical signal to Flow Indicator FI-14 and Flow Alarm FA-14. STORAGE POOL IX FLOW LOW alarm, AN5-20, alerts the reactor operator to a low flow condition through the ion exchanger. The range of the channel is 0-15 gpm.

14. Thermal Shield Cooling Water Flow Indicator Channel, FIA-15, measures the flow of cooling water through the Thermal Shield System. Flow is measured by a 6-inch orifice, FE-15, located in the outlet piping from Thermal Shield Heat Exchanger HE-6. A differential pressure across this orifice of 250.0 inches H_2O corresponds to a flow of 750 gpm through it. Sensing lines connect the high- and low-pressure ports on the orifice to Flow Transmitter FT-15. This flow transmitter supplies an electrical signal to Flow Indicator FI-15 and Flow Alarm FA-15. The alarm unit de-energizes the Thermal Shield Flow Rundown Relay, Ka-01-298A, initiating a reactor rundown and supplying a signal to AN4-24 in the Annunciator System. THERMAL SHIELD FLOW LOW alarm, AN5-13, alerts the reactor operator to a low flow condition in the Thermal Shield System, and does not cause a rundown. The range of the channel is 0-750 gpm.

15. Thermal Shield Ion Exchanger Flow Indicator Channel, FIA-16, measures the flow of water through the Thermal Shield ion exchanger. Flow is measured by a 1 ½-inch orifice, FE-16, located in the inlet piping to the Thermal Shield ion exchanger. A differential pressure across this orifice of 50.0 inches H_2O corresponds to a flow of 15 gpm through it. Sensing lines connect the high- and low-pressure ports of the orifice to Flow Transmitter FT-16. This transmitter supplies an electrical signal to Flow Indicator FI-16 and Flow Alarm FA-16. THERMAL SHIELD IX FLOW LOW alarm, AN5-14, alerts the reactor operator to a low flow condition through the Thermal Shield ion exchanger. The range of the channel is 0-15 gpm.

16. Secondary Auxiliary Cooling Flow Channel, FIA-17, measures the combined flow of secondary coolant to D_2O Purification Heat Exchanger HE-2, Thermal Shield Heat Exchanger HE-6, Experimental Demineralized Water Heat

Exchanger HE-7, and Thermal Column Heat Exchanger. Flow is measured by a 5-inch venturi, FE-17, located in the common header piping on the outlet from the Secondary Auxiliary Pumps. A differential pressure across this venturi of 106.7 inches H_2O corresponds to a flow of 1,000 gpm through it. Sensing lines connect the high- and low-pressure ports on the venturi to Flow Transmitter FT-17. This flow transmitter supplies an electrical signal to Flow Indicator FI-17. The range of the channel is 0-1,000 gpm.

17. D_2O Injection Flow Indicator Channel, FIA-18, measures the flow of primary coolant injected into the inlet header when D_2O Injection Control Valve DWV-39 is opened. Flow is measured by a 1 ½-inch orifice, FE-18, located in the D_2O injection line on the discharge side of DWV-39. A differential pressure across this orifice of 150.0 inches H_2O corresponds to a flow of 60 gpm through it. Sensing lines connect the high- and low-pressure ports on the orifice to Flow Transmitter FT-18. This flow transmitter supplies an electrical signal to Flow Indicator FI-18. The range of the channel is 0-60 gpm.

18. HE-1A Primary Coolant Flow Recorder Channel, FR-20, measures and records the flow of primary coolant through Main Heat Exchanger HE-1A. Ultrasonic Flow Element FE-20 and Flow Transmitter FT-20 supply a flow signal to Flow Recorder FR-20. The ultrasonic flow element is mounted on the primary piping on the outlet side of Main Heat Exchanger HE-1A. The range of the channel is 0-5,000 gpm.

19. HE-1B Primary Coolant Flow Recorder Channel, FR-21, measures and records the flow of primary coolant through Main Heat Exchanger HE-1B. Ultrasonic Flow Element FE-21 and Flow Transmitter FT-21 supply a flow signal to Flow Recorder FR-21. The ultrasonic flow element is mounted on the primary piping on the outlet side of Main Heat Exchanger HE-1B. The range of the channel is 0-5,000 gpm.

20. HE-1A Secondary Cooling Water Flow Indicator Channel, FI-22, measures the flow of secondary coolant through Main Heat Exchanger HE-1A. Ultrasonic Flow Element FE-22 and Flow Transmitter FT-22 supply a flow signal to Flow Indicator FI-22. The ultrasonic flow element is mounted on the secondary piping on the inlet side of Main Heat Exchanger HE-1A. The range of the channels is 0-6,000 gpm.

21. HE-1B Secondary Cooling Water Flow Indicator Channel, FI-23, measures the flow of secondary coolant through Main Heat Exchanger HE-1B. Ultrasonic Flow Element FE-23 and Flow Transmitter FT-23 supply a flow signal to Flow Indicator FI-23. The ultrasonic flow element is mounted on the secondary piping on the inlet side of Main Heat Exchanger HE-1B. The range of the channels is 0-6,000 gpm.

22. HE-2 Secondary Cooling Water Flow Indicator Channel, FI-26, measures the flow of secondary coolant through D_2O Purification Heat Exchanger HE-2.

Ultrasonic Flow Element FE-26 and Flow Transmitter FT-26 supply a flow signal to Flow Indicator FI-26. The ultrasonic flow element is mounted on the secondary piping on the inlet side of D_2O Purification Heat Exchanger HE-2. The range of the channel is 0-300 gpm.

23. HE-6 Secondary Cooling Water Flow Channel, FI-27, measures the flow of secondary coolant through Thermal Shield Heat Exchanger HE-6. Ultrasonic Flow Element FE-27 and Flow Transmitter FT-27 supply a flow signal to Flow Indicator FI-27. The ultrasonic flow element is mounted on the secondary piping on the outlet side of Thermal Shield Heat Exchanger HE-6. The range of the channel is 0-750 gpm.

24. Helium Compressor Secondary Flow Channel, FI-30, measures the flow of secondary coolant through the Helium Compressor Secondary Cooling Heat Exchanger. Flow is measured by a 4-inch orifice, FE-30, located in the common header piping on the outlet from the Helium Compressor Secondary Cooling Pumps. A differential pressure across this orifice of 240.0 inches H2O corresponds to a flow of 500 gpm through it. Sensing lines connect the high- and low-pressure ports on the orifice to Flow Transmitter FT-30. This flow transmitter supplies an electrical signal to Flow Indicator FI-30 for local indication only on the first floor of the Pump House. A signal is sent to the Cold Source programmable logic controller (PLC). The range of the channel is 0-500 gpm.

3 Leak Detectors

The D_2O Leak Detection System monitors flanges, joints, seals, and other places of likely leakage in the D_2O systems. If leakage is detected, a Control Room annunciation alerts the reactor operator.

If a leak should occur, the water will cause a short circuit across the input terminals of the electronic leak detection monitor, energizing the associated relay. The relay contacts actuate points on the Control Room annunciator.

The leak detector sensing unit for pump seals, flanges, and other joints is a printed circuit grid on fiberglass board. The board has a 1 inch rim to contain the water leakage. The board is approximately 3-1/2 inches by 2-1/2 inches with 1/16 inch width metallic strips which are spaced 1/16 inch apart so that a drop of water completes the circuits.

The valve bonnet leak detectors are automotive-type spark plugs. If a leak occurs in the valve diaphragm the spark plug electrodes will be wetted and complete the circuit to the detector's amplifier.

The controller has been mounted in a panel together with manually operated switches located adjacent to the control panel. Normally each controller will monitor up to 5 leak detector points. If any one of the 5 sensors detects a drop of water the controller relay is de-energized causing a Control Room alarm and illuminating a red lamp adjacent to the switch. The operator then rotates the switch, which extinguishes the lamp, until the lamp re-illuminates--thus indicating the trouble point. The unit is fail-safe to loss of power, control signal, or relay coil opening.

A test position on this switch substitutes a known value of resistance into the circuit thereby permitting the operator to verify the operation of the annunciator at any time. The system design will permit the monitoring of up to 80 leak detector points.

4 Level

1. Reactor Vessel Level Recorder Alarm Channel, LRC-1, measures and records the level of the primary coolant in the reactor vessel. Sensing lines connect the variable leg of Level Transmitter LT-1 to the bottom of the Reactor Vessel and the reference leg to the Helium Sweep region over the core. This level transmitter supplies an electric signal to Level Recorder LR-1 and Level Alarms LA-1 and -2 that is proportional to the level of D_2O in the reactor vessel. The alarm units de-energize the Reactor Vessel Level "Recorder" Low Scram Relays, Ka-01-251A and -251B, to initiate a reactor scram, permit opening Emergency Cooling Valve DWV-35, secure operation of the Main D_2O Circulation Pumps, supply an alarm signal to the NIST emergency console (activated only when the DAY/NIGHT switch is in the NIGHT position), and supply a signal to the Annunciator System. VESSEL LEVEL "RECORDER" LOW alarm, AN4-14, alerts the reactor operator to a low level condition in the Reactor Vessel. The alarm unit also supplies a signal to the NIST Emergency Console (activated only when the DAY/NIGHT switch is in the NIGHT position). The range of the channel is 0-200 inches. LRC-1 and LIA-40 are redundant level channels.

2. Emergency Cooling Tank Level Indicator Alarm Channel, LIA-2, measures the level of the emergency coolant in the D_2O Emergency Cooling Tank. Sensing lines connect the variable leg of Level Transmitter LT-2 to the bottom of the tank and the reference leg to the helium blanket in the top of the tank. This level transmitter supplies an electrical signal to Level Indicator LI-2 and Level Alarm LA-2 that is proportional to the level of emergency coolant in the D_2O Emergency Cooling Tank. The alarm unit de-energizes the Emergency Cooling Tank Relay, Ka-01-256, initiating a Start-Up Prohibit and supplying a signal to the Annunciator System. EMERGENCY TANK LEVEL LOW alarm, AN4-48, alerts the reactor operator to a low level in the Emergency Cooling Tank. The range of the channel is 0-60 inches.

3. D_2O Storage Tank Level Channel, LIA-3, measures the level of the heavy water in the D_2O Storage Tank. Sensing lines connect the variable leg of Level Transmitter LT-3 to the bottom of the storage tank and the reference leg to the helium blanket in the top of the tank. This level transmitter supplies an electric signal to Level Indicator LI-3 and to Level Alarm LA-3 that is proportional to the level of D_2O in the storage tank. D_2O STORAGE TANK LEVEL LOW alarm, AN3-13, alerts the reactor operator to a low level in the storage tank while D_2O

STORAGE TANK LEVEL HIGH alarm, AN3-14, alerts the reactor operator to a high level. The range of the channel is 0-175 inches. The first 50 inches of indicated storage tank level is sump level.

4. Thermal Column Level Indicator Alarm Channel, LI-4, measures the level of water in the Thermal Column Tank. Sensing lines connect the variable leg of Level Transmitter LT-4 to the bottom of the Thermal Column Tank through the inlet feed to the tank and the reference leg to the helium blanket in the top of the tank through drain trap DT-5. This level transmitter supplies an electric signal to Level Indicator LI-4 and Level Alarm LA-4 that is proportional to the level of D_2O in the tank. THERMAL COLUMN LEVEL ABNORMAL alarm, AN3-11, alerts the reactor operator to either a low level condition in the tank or to a high level condition. The range of the channel is 0-85 inches.

5. Thermal Column Surge Tank Level Recorder Alarm Channel, LIA-4A, measures the level of water in the Thermal Column Surge Tank. Sensing lines connect the variable leg of Level Transmitter LT-4A to the bottom of the surge tank and the reference leg to the helium blanket in the top of the surge tank. This level transmitter supplies an electric signal to Level Recorder LR-4A that is proportional to the level of D_2O in the surge tank. The recorder has two alarm outputs: a low level alarm and a low level shut-off to protect the Thermal Column Pumps. THERMAL COLUMN SURGE TANK LEVEL LOW alarm, AN3-29, alerts the reactor operator to a low level condition in the surge tank. The range of the channel is 0-35 inches.

6. Helium Gas Holder Level Control Channel, LRCA-5, measures, records and controls the volume of gas in the Helium Gas Holder. The cover to the gas holder drives a single-turn potentiometer. The resistance varies from minimum to maximum as the volume in the gas holder varies from empty to full. A level transmitter supplies an electric signal to Level Recorder LR-5 that is proportional to the level (or volume) of helium in the gas holder. HELIUM GAS HOLDER LEVEL LOW alarm, AN3-23, alerts the reactor operator to a low level condition in the Helium Gas Holder. Limit switches automatically operate a helium supply valve to maintain the volume of gas in the holder. The range of the channel is 0-48 inches.

7. CO_2 Gas Holder Level Control Channel, LRCA-6, measures, records and controls the volume of gas in the CO_2 Gas Holder. The cover to the gas holder drives a single-turn potentiometer. The resistance varies from minimum to maximum as the volume in the gas holder varies from empty to full. A level transmitter supplies an electric signal to Level Recorder LR-6 that is proportional to the level (or volume) of CO_2 in the gas holder. CO_2 GAS HOLDER LEVEL LOW alarm, AN3-25, alerts the reactor operator to a low level condition in the CO_2 Gas Holder. Limit switches automatically operate a CO_2 supply valve to maintain the volume of gas in the holder. The range of the channel is 0-48 inches.

8. Experimental Demineralized Water System H_2O Storage Tank Level Channel, LIA-7, measures the level of water in the Experimental Demineralized Water System Water Storage Tank. Sensing lines connect the variable leg of Level Transmitter LT-7 to the bottom of the tank and the reference leg to the top of the tank. This level transmitter supplies an electric signal to Level Indicator LI-7 and Level Alarm LA-7 that is proportional to the level of water in the tank. EXP. DEMIN. STORAGE TANK LEVEL ABNORMAL alarm, AN1-28, alerts the operator to either a low level condition in the tank or to a high level condition. The range of the channel is 0-135 inches.

9. Thermal Shield Storage Tank Level Indicator Alarm Channel, LIA-8, measures the level of water in the Thermal Shield Storage Tank. Sensing lines connect the variable leg of Level Transmitter LT-8 to the bottom of the Thermal Shield Storage Tank and the reference leg to the top of the tank. This level transmitter supplies an electric signal to Level Indicator LI-8 and Level Alarm LA-8 that is proportional to the level of water in the tank. THERMAL SHIELD STORAGE TANK LEVEL ABNORMAL alarm, AN5-15, alerts the reactor operator to either a low level condition in the tank or to a high level condition. The range of the channel is 0-125 inches.

10. Cooling Tower Basin Level Controller Channel, LIC-9, measures and controls the level of the cooling tower. Sensing lines connect the variable leg of Level Transmitter LT-9 to a bubbler tube in the basin and the reference leg is vented to atmosphere. The back-pressure in the bubbler tube is proportional to the depth of the water in the basin. This level transmitter supplies an electric signal to Level Controller LC-9, Level Indicator LI-9, and Level Alarm LA-9. The controller maintains an adequate head of water for the main secondary coolant pumps by controlling Secondary Coolant Makeup Valve SCV-4. COOLING TOWER LEVEL LOW alarm, AN5-2, alerts the reactor operator to a low level condition in the basin while COOLING TOWER LEVEL HIGH alarm, AN5-3, alerts the reactor operator to a high level condition. The range of the channel is 0-50 inches.

11. Retention Tank Level Channel, LIA-13, measures the level of wastewater in the Retention Tank. Level transmitter LT-13 is mounted to the tank. Level detection is based upon the magnetostricitve principle. The level transmitter supplies an electric signal to Level Indicator LI-13 that is proportional to the level of water in the tank. This level indicator converts the electric signal to one that is proportional to the volume in the tank and retransmits it to Level Recorder LR-13. The level indicator also has contacts that are used to automatically control the level in the tank by energizing one of the two Retention Tank Pumps to pump water in the Retention Tank to the on-line Hold Up Tanks. The range of the channel is 0-1,000 gallons.

12. Hold Up Tank Number 1 Level Channel, LIA-14, measures the level of wastewater in Hold Up Tank Number 1. Level transmitter LT-14 is mounted to the tank. Level detection is based upon the magnetostrictive principle. The

level transmitter supplies an electric signal to Level Indicator LI-14 that is proportional to the level of water in the tank. This level indicator converts the electric signal to one that is proportional to the volume in the tank. The range of the channel is 0-5,000 gallons.

13. Hold Up Tank Number 2 Level Channel, LIA-15, measures the level of wastewater in Hold Up Tank Number 2. Level transmitter LT-15 is mounted to the tank. Level detection is based upon the magnetostrictive principle. The level transmitter supplies an electric signal to Level Indicator LI-15 that is proportional to the level of water in the tank. This level indicator converts the electric signal to one that is proportional to the volume in the tank. The range of the channel is 0-5,000 gallons.

14. Pump Pit Level Controller Alarm Channel, LCA-19, controls the level of water in the Storage Pool. Pressure switches PS-11, -12 and -13 connect to a bubbler tube in the pool. The back-pressure in the tube is proportional to the depth of water in the pool. Pressure switches PS-11 and -12 operate to maintain the level of water in the storage pool. At the low level control point, PS-12 actuates to open Make-Up Water Valve WTV-1 and initiate STORAGE POOL LEVEL LOW alarm, AN5-21, and STORAGE POOL MAKE-UP ON alarm, AN5-22. At the high level control point, PS-11 actuates to close Make-Up Water Valve WTV-1 and resets the two alarms. PS-13 operates as a backup to PS-12 to close Make-Up Water Valve WTV-1 and initiates STORAGE POOL PUMP-PIT LEVEL HIGH alarm, AN5-24.

15. Reactor Vessel Level Indicator Channel, LIA-40, measures and displays the level of the primary coolant in the reactor vessel. Sensing lines connect the variable leg of Level Transmitter LT-40 to the bottom of the reactor vessel and the reference leg to the Helium Sweep region over the core. This level transmitter supplies an electric signal to Level Indicator LI-40 and Level Alarms LA-40A/B and -40C/D that is proportional to the level of D_2O in the reactor vessel. As the water level in the reactor drops, alarm unit LA-40C/D de-energizes the Reactor Vessel Level Rundown Relay, Ka-01-251, initiating a reactor rundown and supplying a signal to the Annunciator System. VESSEL LEVEL LOW alarm, AN4-21, alerts the reactor operator to a rundown. If water level continues to drop, it then de-energizes the Reactor Vessel "Indicator" Low Scram Relays, Ka-01-299A and -299B, to initiate a reactor scram, permit opening Emergency Cooling Valve DWV-34, secure operation of the Main D_2O Circulation Pumps, and supply a signal to the Annunciator System. VESSEL LEVEL "INDICATOR" LOW alarm, AN4-15, alerts the reactor operator to a reactor scram. Alarm Unit LA-40A/B supplies the Annunciator System with abnormal level alarms. REACTOR D_2O LEVEL HIGH alarm, AN3-1, and REACTOR D_2O LEVEL LOW alarm, AN3-2, alert the reactor operator to a high or low level condition in the reactor vessel. The range of the channel is 60-200 inches. LRC-1 and LIA-40 are redundant level channels.

16. Purge Tank Level Indicator Channel, LI-41, measures the level of water in the Purge Tank. Sensing lines connect the variable leg of Level Transmitter LT-41 to the bottom of the Purge Tank and the reference leg to the top of the tank. This level transmitter supplies an electric signal to Level Indicator LI-41, which is located at the Purge Tank. The range of the channel is 0-70 inches.

5 Nuclear Instruments

1. Source Range Channels, NC-1 and -2, provide logarithmic indication of power level below the operating range of the Intermediate Range Channels. The channels consist of a detector, Log Count Rate Amplifier, Period Amplifier, High Voltage Power Supply, local and remote indicators, remote recorders, and various bistable trips, and alarms. The proportional counters, located in an instrument well within the biological shield surrounding the reactor vessel, measures the leakage flux from the reactor over five decades of operation. The detector for each channel is as follows:

Type:	Boron coated, proportional counter
Make/Model:	Reuter-Stokes model RS-P7-0812-117 (or equivalent)
High Voltage:	500 – 800 Vdc
Fill Gas:	Argon-CO_2, 20 cm Hg
Sensitivity:	4 cps/nV

The detectors are positioned manually in their thimbles by adjusting the detector height using a flexible steel cable. The upper end of each instrument tube provides a stepped section for a shield plug. The chamber positioning cable and coaxial cables are routed through a recess in the side of the instrument wells. The connections for the cables are made in boxes on top of the biological shield and the cables are routed from the reactor top to the Control Room through individual conduit. The length of the cables is approximately 100 feet. Triaxial signal cables are used for the source range channels ND-1 and ND-2.

For each channel, the Log Count Rate Amplifier (LCRA) receives an input signal from the detector described above. The amplifier displays the count rate on a logarithmic scale from 1 to 10^5 counts per second (cps). The display can be switched between the input from the detector and the trip setpoint. The amplifier also drives a meter and recorder on the reactor console and provides an input to the Period Amplifier. The LCRA has a discriminator setting to adjust the sensitivity of the amplifier electronics to optimize operation.

The Period Amplifier displays the reactor period on a scale of –30 to ∞ to +3 seconds. Like the LCRA display, this display can be selected to show the period or the period setpoint. The period amplifier also provides an output to a meter on the reactor console. The period amplifier has built-in test switches that allow the operator to perform a 3-point check of the display accuracy.

The High Voltage Power Supplies are slightly different in appearance for NC-1 and NC-2, however, their function is the same: provide approximately 800 Vdc to the detectors for each channel. The power supplies are adjustable, however, adjustment is not typically required.

Bistable trip cards in the system provide contact outputs for alarms and protective features as follows:

Variable	Setpoint	Function	Annunciator
Log Count Rate	2 cps	Permits Reactor Startup	AN4-44
Period	15 seconds	Withdraw Prohibit	AN4-33

The NC-1 and NC-2 high voltage is turned off when both the intermediate range channels indicate greater than 2 x 10^{-10} Amps. This action is accomplished by the intermediate range channels described below. Typically, once the intermediate range channels begin indicating, the source range detectors are removed from their wells and stored outside the reactor to prevent damage to the detectors.

As the reactor power reaches the 10% level all startup and intermediate period safety functions are automatically inhibited. This action is accomplished by the power range channels described below.

2. Intermediate Range Channels, NC-3 and -4, provide logarithmic indication of power level from 10^{-10} to 10^{-3} amps. The channels consist of a compensated ion chamber, a Log N Amplifier, Period Amplifier, High Voltage Power Supply, local and remote indicators, remote recorders, various bistable trips, and alarms. The ion chambers, located in instrument wells within the biological shield surrounding the reactor vessel, measure the leakage flux from the reactor over seven decades of operation. The detector for each channel is as follows:

Type:	Boron coated, electrically compensated ion chamber
Make/Model:	Westinghouse – WL8074
High Voltage:	500 Vdc
Fill Gas:	Nitrogen, 1 Atm
Sensitivity:	4.4 x 10^{-14} amp/nV (neutron)
	2.3 x 10^{-11} amp/R/hr (gamma, uncompensated)

The electronics of each channel are identical. The drawer contains a Log N amplifier, Period Amplifier, and High Voltage Power Supply. The front panel of each drawer has a Log N display, a Period display and a Linear Display.

The Log N portion of the drawer measures and displays the detector current from 10^{-10} to 10^{-3} Amps. This value is displayed on an LCD segmented bar graph and a digital display in the form "X.X E-X". The Log N amplifier has a bistable trip output that disconnects the high voltage from the source range nuclear instrumentation above 2 x 10^{-10} Amps. Adjacent to the Log N bar graph is a bar graph showing the High Voltage Disconnect setpoint. The Log N amplifier has two 4 - 20 mAdc analog output signals, one drives a recorder and the other a meter on the reactor console. The NC-3 Log N output signal also provides an input to the Cold Source computer.

There are three internal calibration currents built into the drawer that are actuated by pushbuttons on the front panel. These currents (100 pA, 0.1 µA, and 1 mA - labeled “Power Cal”) check the operation of the amplifier at low, mid, and high-scale. These pushbuttons are spring return to normal and are connected to the startup permit circuit to prevent reactor startup unless all the switches are in the normal position.

The Period portion of the drawer calculates the rate of change reactor power. The period display has a range of –30 to ∞ to +3 seconds. There is a digital display and a segmented LCD bar graph to display the period. Adjacent to the period bar graph is the setpoint bar graph. The following list shows the drawer setpoints and their associated functions:

Variable	Setpoint	Function	Annunciator
Log N	2x10^{-10} Amps	HV Disconnect	N/A
Period	15 Seconds	Withdraw Prohibit	AN4-34
Period	10 Seconds	Rundown	AN4-17
Period	5 Seconds	Scram	AN4-4

The output relays are “fail-safe”, such that they are energized during normal operation and de-energize to cause a protective action. A loss of power also de-energizes these relays initiating a protective action.

With no pushbuttons pressed the Withdraw Prohibit setpoint is displayed. When pressed, the “Rundown Setpoint” and “Scram Setpoint” pushbuttons cause their respective setpoints to be displayed on the setpoint bar graph.

Each drawer has a pushbutton that injects a 3 second period to check full scale on the period displays. There is also a pushbutton that injects a slowly increasing period signal to verify the response of the indicators and setpoints. Both of these pushbuttons are also spring return to normal and are connected to the startup permit circuit in order to prevent a reactor startup while any button is pressed.

The Intermediate Range drawers also have high voltage and compensating voltage power supplies built-in. The settings of these power supplies are set internally to the drawer. Although the detectors are compensated ion chambers, the electrical compensation is not needed, therefore the compensating voltage is not used. Each high voltage power supply is set for 500 Vdc as required by the detector. The drawer monitors the high voltage output and if the actual voltage deviates by more than 5%, an alarm is generated.

The intermediate range channels furnish a reactor trip by two different methods. One set of contacts from each channel interfaces with "A" and "B" scram buses. NC-3 and NC-4 switch between –10 and 0 Vdc to provide a scram signal on buses A900 (Bus "A") and A901 (Bus "B"), respectively. A 0 Vdc signal on either of these buses trip the output units which shuts off current to the shim rod clutches.

Another set of contacts from each drawer interfaces with the scram relay logic to de-energize the K103(A-D) relays. These scram relays also trip the output units which shuts off current to the shim rod clutches. This provides a diverse means of shutting down the reactor.

3. Linear Channel, NC-5, provides linear indication of reactor power level and controls the reactor power level by automatically positioning the regulating rod. The channel consists of a compensated ion chamber, electronics drawer, range selector switch, power demand potentiometer, servo deviation meter, manual-automatic transfer switch, power level meter, and recorder. The ion chamber, located in an instrument well within the biological shield surrounding the reactor vessel, measures the leakage flux from the reactor over five decades of operation. The current output from the chamber ranges from 10^{-9} to 10^{-4} amps. The electronics drawer contains a pico-ammeter that measures this output current. The NC-5 Range Select switch sets the range of the channel. Outputs from the drawer supply the Servo Deviation meter, remote recorder, and remote meter.

   The Flux Controller card in the electronics drawer maintains reactor power level to within ½ % of the setting of the Power Demand potentiometer by moving the regulating rod in the appropriate direction. Two deviation alarms compare the actual power level, as indicated by the output of the electrometer, to the programmed power level, as indicated by the setting of the Power Demand potentiometer. SERVO DEVIATION 2% alarm, AN4-40, alerts the reactor operator to a larger than expected deviation of actual power level from the desired power level. SERVO DEVIATION 10% alarm, AN4-37, not only alerts the operator to an unacceptably large deviation of actual power level from the desired power level but it also trips the regulating rod controller out of automatic operation. The settings of NC-5 Range Select switch are: 2 W, 20W, 200 W, 2 kW, 20 kW, 200 kW, 2 MW and 20 MW. The ranges of the recorder and indicator are 0-150% of the setting of NC-5 Range Select switch.

   The electronics drawer also contains high voltage and compensating voltage power supplies and has built-in testing functions to verify drawer operation.

   With the Manual-Auto Transfer switch in manual position, the reactor operator controls the position of the regulating rod by using the Reg Rod switch to drive the rod into the core or out of it. In the automatic position, the flux controller card automatically controls the position of the regulating rod to maintain the desired power level.

4. Power Range Channels NC-6, -7, and -8, provide linear indication of reactor power. Each channel consists of an uncompensated ionization chamber (UIC), power supply, local and remote power level meters, remote recorder, and Input Units in the Reactor Safety System. The channels measure reactor power level from 0-150%. The three ion chambers are located in instrument wells within the biological shield surrounding the reactor vessel. An output current of 400 µamps from the UIC corresponds to a reactor power level of 100 %. The current is measured locally by a microampere meter on the Nuclear Instrumentation panel and remotely by a meter and recorder located on the Main Control Panel. This same output current from the UIC also flows through a voltage divider network at each Input Unit. The outputs from the Input Units supply various logic units within the Reactor Safety System.

5. Nuclear Safety System Channel, NC-9, combines all of the inputs from the nuclear instrumentation and performs the required safety system action to protect the NBSR. This system is composed of bistable trip units, logic cards, NOD units (NOR gates), output cards and relay cards.

   Bistable Trip Units are used to generate the Source Range Low Count Rate signal, the Source Range Period Rod Stop signal, the Period Bypass signal, the High Flux Rundown signal, and the High Flux Scram signal. The Logic Units determine if a scram is initiated upon receipt of any high flux scram signal from NC-6, -7 or -8 ("1 out of 3" coincidence) or if it requires two high flux scram signals from NC-6, -7 or -8 ("2 out of 3" coincidence). The Negative OR Diode (NOD) units each contain 15 NOR gates used for combinational decision making. The Output Units provide the current to maintain the shim safety arm clutches energized. Finally, the Relay Cards interface the safety channel with the rod control circuits, the scram circuits and the annunciator circuits. They provide electrical isolation and separation between the safety system circuits and the other circuits.

   These units are the original Leeds & Northrup equipment installed when the reactor was first built. The Source Range High Voltage Disconnect, the Intermediate Range Period Rod Stop, the Intermediate Range Period Rundown, and the Intermediate Range Period Scram functions are performed in new instrument drawers manufactured by Gamma-Metrics. These drawers are self-contained and interface directly with the rod control circuits, the scram circuits and the annunciator circuits. They provide the electrical isolation and separation between the safety system circuits contained within them and the other circuits.

6 Power

1. Thermal Power Recorder Channel, BTUR, measures and records the thermal power output from the reactor. Reactor Vessel Outlet Flow Recorder Channel, FR-1, supplies an electric signal to the BTUR Recorder that is proportional to the flow of primary coolant through the reactor. Reactor ΔT Recorder Channel, TR-1, applies a signal to the BTUR Recorder that is proportional to the differential temperature across the reactor. The BTUR Recorder combines these two inputs to derive the reactor power level for display and recording. Alarm contacts in the recorder de-energize the BTUR Rundown Relay, Ka-01-60, initiating a reactor rundown and supplying a signal to the Annunciator System. THERMAL POWER HIGH alarm, AN4-23, alerts the reactor operator to a high thermal power level in the core. The range of the channel is 0-30 MW.

7 Pressure

1. Experimental Demineralized Water Pressure Indicator Control Channel, PIC-1, maintains the pressure in the Experimental Demineralized Water system by varying the position of the system bypass valve, DCV-1. Sensing lines connect Pressure Transmitter PT-1 to the Experimental Demineralized Water supply header. This pressure transmitter supplies an electric signal to Pressure Controller PIC-1 and Pressure Alarm PA-1. The pressure controller compares the measured pressure to the desired pressure setpoint established by the reactor operator. When the measured pressure exceeds the setpoint, the pressure controller sends an electric signal to Electro-pneumatic Pressure Controller EPC-1 to open the bypass valve to dump water to the Experimental Demineralized Water Tank, thereby reducing the pressure in the supply line. When the measured pressure drops below the setpoint, the controller closes the bypass valve, thereby increasing the pressure. EXP. DEMIN. PRESSURE ABNORMAL alarm, AN1-30, alerts the reactor operator to either a low pressure condition in the supply header or to a high pressure condition. The range of the channel is 0-100 psi.

2. Experimental D_2O Pressure Indicator Control Channel, PIC-2, maintains the pressure in at the discharge of the Experimental Cooling Pumps by varying the position of Pressure Regulating Valve DWV-25. Sensing lines connect Pressure Transmitter PT-2 to the common pump discharge header. This pressure transmitter supplies an electrical signal to Pressure Controller PIC-2 and Pressure Alarm PA-2. The pressure controller compares the measured pressure to the desired pressure setpoint established by the reactor operator. When the measured pressure exceeds the setpoint, the pressure controller sends an electric signal to Electro-pneumatic Pressure Controller EPC-6 to open the Pressure Regulating Valve to dump water to the D_2O Storage Tank, thereby reducing the pressure in the discharge header. When the measured pressure drops below the setpoint, the controller closes the bypass valve, thereby increasing the pressure. EXP. D_2O COOLING PRESSURE LOW alarm, AN3-4,

alerts the reactor operator to a low pressure condition on the discharge from the Experimental Cooling Pumps. The range of the channel is 0-100 psi.

3. Recombiner Outlet Pressure Indicator Channel, PIA-3, measures the outlet pressure on the Recombiner. Sensing lines connect Pressure Transmitter PT-3 to the discharge header from the Recombiner. This pressure transmitter supplies an electric signal to Pressure Indicator PI-3 and Pressure Alarm PA-3. RECOMBINER OUTLET PRESSURE ABNORMAL alarm, AN3-17, alerts the reactor operator to either a low pressure condition on the discharge header from the Recombiner or to a high pressure condition. The range of the channel is 0-10 inches H_2O.

4. Recombiner Inlet Pressure Indicator Channel, PIA-4, measures the inlet pressure to the Recombiner. Sensing lines connect Pressure transmitter PT-4 to the inlet header to the Recombiner. This pressure transmitter supplies an electric signal to Pressure Indicator PI-4 and Pressure Alarm PA-4. RECOMBINER INLET PRESSURE HIGH alarm, AN3-18, alerts the reactor operator to a high pressure condition on the inlet header to the Recombiner. The range of the channel is 0-20 inches H_2O.

5. Reactor Building Pressure Indicator Channel, PI-10, measures the differential pressure between confinement and outside atmosphere. The high pressure side of Pressure Transmitter PT-10 senses the atmospheric pressure in the Confinement Building. The low pressure side of the transmitter senses the atmospheric pressure in the B-2 level of the adjacent office building. Indication is provided at the Emergency Control Station. The range of the channel is -4 to +10 inches H_2O.

6. Building Leak Check Controller Channel, PIC-11, measures and maintains the Confinement Building pressure by regulating the dampers in the supply and exhaust ducts that serve the building. The channel is comprised of a vacuum controller and a pressure controller that operate in tandem to maintain the internal pressure of the Confinement Building between 2 in. H_2O vacuum and 6 in. H_2O pressure. The pressure controller modulates a 3-15 psi air signal to position dampers ACV-13 and -14 on discharge side of the building supply fan. The vacuum controller modulates a 3-15 psi air signal to position dampers ACV-15 and -16 on the suction side of the building exhaust fan. The range of the Vacuum Channel is 0-5 in. H_2O while the range of the Pressure Channel is 0-10 in. H_2O.

7. Process Room Pressure Controller Channel, PC-27, measures and maintains the Process Room pressure by regulating the position of the dampers in the exhaust ducts from the room. The controller modulates a 3-15 psi air signal to position damper ACV-3 in the exhaust line from the Process Room. The range of the channel is -1.0 to 0 to +1.0 inches H_2O.

8. HE-1A Primary/Secondary Differential Pressure Indicator Channel, PIA-30, measures the differential pressure between the primary and secondary sides of Main Heat Exchanger HE-1A. Sensing lines connect the high pressure port on Pressure Transmitter PT-30 to the inlet piping on the primary side of HE-1A and the low pressure port to the inlet piping on the secondary side. This pressure transmitter supplies an electric signal to Pressure Indicator PI-30 and Pressure Alarm PA-30. HE-1A PRESS. DIFF. LOW alarm, AN5-5, alerts the reactor operator to a low ΔP condition across the heat exchanger. The range of the channel is 0-50 psid.

9. HE-2 Primary/Secondary Differential Pressure Indicator Channel, PIA-32, measures the differential pressure between the primary and secondary sides of Purification Heat Exchanger HE-2. Sensing lines connect the high pressure port on Pressure Transmitter PT-32 to the inlet piping on the primary side of HE-2 and the low pressure port to the inlet piping on the secondary side. This pressure transmitter supplies an electric signal to Pressure Indicator PI-32 and Pressure Alarm PA-32. HE-2 PRESS. DIFF. LOW alarm, AN3-10, alerts the reactor operator to a low ΔP condition across the heat exchanger. The range of the channel is 0-50 psid.

10. HE-1B Primary/Secondary Differential Pressure Indicator Channel, PIA-40, measures the differential pressure between the primary and secondary sides of Main Heat Exchanger HE-1B. Sensing lines connect the high pressure port on Pressure Transmitter PT-40 to the inlet piping on the primary side of HE-1B and the low pressure port to the inlet piping on the secondary side. This pressure transmitter supplies an electric signal to Pressure Indicator PI-40 and Pressure Alarm PA-40. HE-1B PRESS. DIFF. LOW alarm, AN5-6, alerts the reactor operator to a low ΔP condition across the heat exchanger. The range of the channel is 0-50 psid.

11. Cold Source Hydrogen Pressure "A" Channel, PAI-50A, measures the differential pressure between the hydrogen in the Liquid Hydrogen Cold Source and the Helium pressure in the surrounding ballast tank. Sensing lines connect these locations to Pressure Transmitter PT-50A. This pressure transmitter supplies an electric signal to Pressure Indicator PI-50A and Pressure Alarm PA-50A. A signal is also sent to the Cold Source programmable logic controller(PLC). The alarm unit initiates a reactor rundown and supplies a signal to the Annunciator System. COLD SOURCE H_2 PRESS. "A" HIGH alarm, AN4-25, alerts the reactor operator to a high pressure condition in the liquid hydrogen lines of the Cold Source. The range of the channel is -15 to +100 psi.

12. Cold Source Hydrogen Pressure "B" Channel, PAI-50B, measures the differential pressure between the hydrogen in the Liquid Hydrogen Cold Source and the Helium pressure in the surrounding ballast tank. Sensing lines connect these locations to Pressure Transmitter PT-50B. This pressure transmitter supplies an electric signal to Pressure Indicator PI-50B and Pressure Alarm PA-50B. A signal is also sent to the Cold Source programmable logic

controller(PLC). The alarm unit initiates a reactor rundown and supplies a signal to the Annunciator System. COLD SOURCE H_2 PRESS. “B” HIGH alarm, AN4-26, alerts the reactor operator to a high pressure condition in the liquid hydrogen lines of the Cold Source. The range of the channel is -15 to +100 psi.

13. Pressure Controller Channel, PIC-102, measures and maintains the pressure of cooling water supplied to the Thermal Column Tank. The controller senses the pressure of the water in the line feeding the tank. It regulates the position of the upstream dump valve, DTCV-15, to maintain a constant supply pressure for the tank by opening the valve to dump cooling water to the Thermal Column Surge Tank to reduce the pressure at the inlet to the Thermal Column Tank or closing the valve to increase the pressure. The range of the channel is 0-15 pisg.

14. Emergency Fan Controller, SPC-150, measures and maintains the pressure between the Confinement Building and the outdoor atmosphere. The controller modulates a 3-15 psi air signal to dampers in the air exhaust line. The range of the channel is -1.0 to 0 to +1.0 inches H_2O.

15. Emergency Standby Fan Controller Channel, SPS-150, controls the operation of the Emergency Fans EF-5 and EF-6. When the negative building pressure of the Confinement Building exceeds -0.1 in. H_2O during the building closure following a Major Scram, the standby emergency exhaust fan is stopped. The range of the channel is -1.0 to 0 to +1.0 inches H_2O.

16. Vacuum Breaker Controller, SPS-151, monitors the vacuum, or negative pressure, in the Confinement Building. When the negative building pressure of the Confinement Building exceeds -2.5 inches H_2O, Reactor Emergency Relief Valve ACV-12 opens.

8 Radiation

1. Area Radiation Monitor Channels, RM1-1 thru RM1-10, monitor selected areas in the Confinement Building for radiation. Table 7A-1 lists the locations and ranges of each channel. The detectors are Geiger-Mueller tubes sensitive to gamma radiation. They are located in various locations throughout the building. Each channel is comprised of a detector, a local indicator, and a remote alarm and readout unit. Each readout unit provides input signals to Radiation Recorder RR-1 located in the Main Control Room for trending. They also have alarm outputs that supply signals to the Annunciator System. AREA MONITOR RADIATION HIGH alarm, AN2-14, alerts the reactor operator to a high radiation condition in the Confinement Building. RM1-1 C-100 East Wall Area Monitor and RM1-8 C-006 East Wall Area Monitor also provide remote indication at the Emergency Control Station.

Table 7A-1: Area Radiation Monitor Channels.

Channel	Location	Range
RM1-1	C-100 East Wall	10^{-2}-10^{4} mR/Hr
RM1-2	C-100 North Wall	10^{-2}-10^{4} mR/Hr
RM1-3	C-100 West Wall	10^{-2}-10^{4} mR/Hr
RM1-4	C-100 South Wall	10^{-2}-10^{4} mR/Hr
RM1-5	C-200 Ceiling	10^{-2}-10^{4} mR/Hr
RM1-6	C-200 West Wall	10^{-2}-10^{4} mR/Hr
RM1-7	C-004 South Wall	10^{-2}-10^{4} mR/Hr
RM1-8	C-006 East Wall	10^{-1}-10^{5} mR/Hr
RM1-9	C-007 West Wall	10^{-1}-10^{5} mR/Hr
RM1-10	Control Room	10^{-2}-10^{4} mR/Hr

2. Duct Filter Monitor Channels, RM1-11 thru RM1-13, monitor the radiation levels in the exhaust duct filters for the reactor confinement building. Channel RM1-11 monitors the duct filters on the suction side of Irradiated Air Exhaust Fan EF-4. The detector is a Geiger-Mueller tube sensitive to the beta and gamma radiation associated with the airborne activity trapped in the filters. It is mounted in the ductwork between the pre-filter and the filter of the Irradiated Air Exhaust System. Channel RM1-12 monitors the duct filters on the suction side of Normal Air Exhaust Fan EF-3. The detector is a Geiger-Mueller tube sensitive to the gamma radiation associated with the airborne activity trapped in the filters. It is mounted in the ductwork between the pre-filter and the filter of the Normal Air Exhaust System. Channel RM1-13 monitors the duct filters on the suction side of Reactor Basement Recirculation Fan EF-27. The detector is a Geiger-Mueller tube sensitive to the gamma radiation associated with the airborne activity trapped in the filters. It is mounted in the ductwork between the pre-filter and the filter of the Reactor Basement Exhaust System. Each channel is comprised of a detector and an alarm and readout unit mounted in the Main Control Panel. Each readout unit provides input signals to Radiation Recorder RR-1 located in the Main Control Room for trending. They also have alarm outputs that supply signals to the Annunciator System. AREA MONITOR RADIATION HIGH alarm, AN2-14, alerts the reactor operator to a high radiation condition in the Confinement Building. The ranges of these channels are 20 to 200k cpm.

3. Rabbit Lab Radiation Area Monitor Channel, RM1-15, checks for radiation in room C-001 in the vicinity of the rabbit receivers. The detector is a Geiger-Mueller tube sensitive to gamma radiation. A pre-amplifier connects the detector to the counting circuits in the count rate meter. The pre-amplifier matches the impedance of the tube to the impedance of the input circuit and shapes the pulse signal for processing by the rate meter. The rate meter provides local indication at the door to C-001. It has an alarm output that supplies a signal to the Annunciator System. C-001 RADIATION HIGH alarm,

AN2-13, alerts the reactor operator to a high radiation condition in the Rabbit Lab. The range of the channel is 0.1-10,000 mR/hr.

4. The Duct Filter Monitor System for the Warm Labs Outside of Reactor Confinement monitors the radiation levels in the exhaust duct filters serving the labs in the office building adjacent to the Confinement Building. The system also monitors selected hood filters in the labs located in the basement of the Confinement Building. The system is composed of eighteen channels (RM2-1 thru RM2-20), three 6-channel counters and central data acquisition computer and alarm interface unit. Thirteen channels utilize dual probes, while the remaining five channels utilize single probes. Table 7A-2 lists the locations and ranges of each channel. The detectors are Geiger-Mueller tubes sensitive to the beta and gamma radiation associated with the airborne activity trapped in the filters. Each detector is mounted in the ductwork near the filter they monitor. Each detector has its own pre-amplifier which feeds one of the inputs of the three 6-channel counters. The counters process the signal from each detector and transmit a data package to the central data acquisition computer located in Room A-134 where this information is decoded and displayed. A summary alarm alerts the Health Physicist to a high radiation condition in the filters for one of the labs being monitored. The alarm interface unit activates the alarm buzzer and warning light in the affected lab to alert any occupants of the high radiation condition in the filters.

Table 7A-2: Area Radiation Monitor Channels.

Channel	Room	Location	Range
RM2-1	B-154	Hot Lab 1	20-200K
RM2-2	B-153	Hot Lab 2	20-200K
RM2-3	B-152	Hot Lab 3	20-200K
RM2-4	B-147	Warm Lab 1	20-200K
RM2-5	B-145	Warm Lab 2	20-200K
RM2-6	B-143	Warm Lab 3	20-200K
RM2-7	B-144	Warm Lab 4	20-200K
RM2-8	B-142	Warm Lab 5	20-200K
RM2-9	C-002	Hoods 7/8	20-200K
RM2-10	C-001	Hood 1	20-200K
RM2-11	C-002	Hoods 6/9	20-200K
RM2-12	C-001	Hoods 2/3	20-200K
RM2-13	B-140	Warm Lab 6	20-200K
RM2-15	C-001	Hoods 4/5	20-200K
RM2-17	B-121	Semi Warm Lab 3	20-200K
RM2-18	B-122	Semi Warm Lab 4	20-200K
RM2-19	B-123	Semi Warm Lab 5	20-200K
RM2-20	B-124	Semi Warm Lab 6	20-200K

5. Secondary Cooling N-16 Radiation Monitor Channel, RM3-1, is one of two redundant channels that check for the presence of N-16 in the secondary coolant. A sample line taps off of the secondary header after Main Heat Exchanger HE-1A and -1B. A small amount of secondary water is continuously diverted through the N-16 Monitoring Station located in the Pump House. Radiation Detector RD3-1 is mounted in this piping. The probe is a Geiger-Mueller tube sensitive to the beta emitted by the decaying N-16 atom. A pre-amplifier connects the detector to the counting circuits in the rate meter. The pre-amplifier matches the impedance of the tube to the impedance of the input circuit and shapes the pulse signal for processing by the rate meter. The rate meter provides local indication at the monitoring station and remote indication on the Main Control Panel. It also provides an input signal to Radiation Recorder RR-1 located in the Main Control Room for trending. The rate meter has an alarm output that supplies a signal to the Annunciator System. SECONDARY COOLANT ACTIVITY HIGH alarm, AN2-17, alerts the reactor operator to a high activity condition in the secondary coolant. This channel duplicates Secondary Cooling N-16 Radiation Monitor RM3-3 discussed below.

6. Helium Sweep Gas Radiation Monitor Channel, RM3-2, checks for the presence of fission products in the Helium Sweep System. A sample line diverts a portion of the helium gas from the system through a sample chamber for continuous monitoring by Radiation Detector RD3-2. The probe is a Geiger-Mueller tube sensitive to the betas emitted by the decaying fission products. A pre-amplifier connects the detector to counting circuits in the rate meter. The pre-amplifier matches the impedance of the tube to the impedance of the input circuits and shapes the pulse signal for processing by the rate meter. The rate meter provides local indication at the monitoring station located on the Reactor Mezzanine and remote indication on the Main Control Panel. It also provides an input signal to Radiation Recorder RR-1 located in the Main Control Room for trending. The rate meter has an alarm output that supplies a signal to the Annunciator System. HELIUM SWEEP ACTIVITY HIGH alarm, AN2-16, alerts the reactor operator to the presence of fission products in the Helium Sweep System. The range of the channel is $10\text{-}10^6$ cpm.

7. Secondary Cooling N-16 Radiation Monitor Channel, RM3-3, is one of two redundant channels that check for the presence of N-16 in the secondary coolant. A sample line taps off of the secondary header after Main Heat Exchanger HE-1A and -1B. A small amount of secondary water is continuously diverted through the N-16 Monitoring Station located in the Pump House. Radiation Detector RD3-3 is mounted in this piping. The probe is a Geiger-Mueller tube sensitive to the beta emitted by the decaying N-16 atom. A pre-amplifier connects the detector to the counting circuits in the rate meter. The pre-amplifier matches the impedance of the tube to the impedance of the input circuit and shapes the pulse signal for processing by the rate meter. The rate meter provides local indication at the monitoring station and remote indication on the Main Control Panel. It also provides an input signal to

Radiation Recorder RR-1 located in the Main Control Room for trending. The rate meter has an alarm output that supplies a signal to the Annunciator System. SECONDARY COOLANT ACTIVITY HIGH alarm, AN2-17, alerts the reactor operator to a high activity condition in the secondary coolant. The range of the channel is $10\text{-}10^6$ cpm. This channel duplicates Secondary Cooling N-16 Radiation Monitor RM3-1 discussed above.

8. Irradiated Air Monitor Channel, RM3-4, is one of two channels that check the exhaust air leaving the Confinement Building for activity. A sample line taps off of the ventilation duct for Irradiated Air. An air pump pulls air from the duct through a gas sampler chamber at a rate of 10 cfm. Radiation Detector RD3-4 is mounted in this chamber. The probe is a Geiger-Mueller tube sensitive to the betas emitted by the airborne radioactivity. A pre-amplifier connects the detector to the counting circuits in the log count rate meter. The pre-amplifier matches the impedance of the tube to the impedance of the input circuit and shapes the pulse signal for processing by the rate meter. The rate meter provides local indication at the equipment station on the Reactor Mezzanine or B-1 Level and remote indication on the Main Control Panel in the Control Room and at the Emergency Control Station on the Basement or B-2 Level of the adjacent office building. It also provides an input signal to Radiation Recorder RR-1 located in the Main Control Room for trending. The rate meter has alarm outputs that supply the Major Scram circuits and the Annunciator System. IRRADIATED AIR ACTIVITY HIGH alarm, AN4-7, alerts the reactor operator to a high activity condition in the Irradiated Air system. The range of the channel is $10\text{-}10^6$ cpm.

9. Normal Air Monitor Channel, RM3-5, is one of two channels that check the exhaust air leaving the Confinement Building for activity. A sample line taps off of the ventilation duct for Normal Air. An air pump pulls air from the duct through a gas chamber. The probe is a Geiger-Mueller tube sensitive to the betas emitted by the airborne radioactivity. A pre-amplifier connects the detector to the counting circuits in the log count rate meter. The pre-amplifier matches the impedance of the tube to the impedance of the input circuit and shapes the pulse signal for processing by the rate meter. The rate meter provides local indication at the equipment station on the Reactor Mezzanine or B-1 Level and remote indication on the Main Control Panel in the Control Room and at the Emergency Control Station on the Basement or B-2 Level of the adjacent office building. It also provides an input signal to Radiation Recorder RR-1 located in the Main Control Room for trending. The rate meter has alarm outputs that supply the Major Scram circuits and the Annunciator System. BUILDING EXHAUST ACTIVITY HIGH alarm, AN4-6, alerts the reactor operator to a high activity condition in the Normal Air system. The range of the channel is $10\text{-}10^6$ cpm.

10. Stack Monitor Channel, RM4-1, is one of two channels that check the exhaust air leaving the Confinement Building through the building exhaust stack for activity. Radiation Detector, RD4-1, is mounted in the stack. The probe is a

Geiger-Mueller tube sensitive to the beta emitted by the airborne activity. A pre-amplifier connects the detector to the counting circuits in the rate meter. The pre-amplifier matches the impedance of the tube to the impedance of the input circuits and shapes the pulse signal for processing by the rate meter. The rate meter provides local indication in the Monitor Room and remote indication on the Main Control Panel in the Control Room and at the Emergency Control Station. It also provides an input signal to Radiation Recorder RR-1 located in the Main Control Room for trending. The rate meter has alarm outputs that supply the Major Scram circuits and the Annunciator System. STACK ACTIVITY HIGH alarm, AN4-8, alerts the reactor operator to a high activity condition in the exhaust stack. The range of the channel is $10\text{-}10^6$ cpm.

11. Stack Monitor Channel, RM4-2, is one of two channels that check the exhaust air leaving the Confinement Building through the building exhaust stack for activity. Radiation Detector, RD4-2, is mounted in the stack. The probe is a Geiger-Mueller tube sensitive to the beta emitted by the airborne activity. A pre-amplifier connects the detector to the counting circuits in the rate meter. The pre-amplifier matches the impedance of the tube to the impedance of the input circuits and shapes the pulse signal for processing by the rate meter. The rate meter provides local indication in the Monitor Room and remote indication on the Main Control Panel in the Control Room and at the Emergency Control Station. It also provides an input signal to Radiation Recorder RR-1 located in the Main Control Room for trending. The range of the channel is $10\text{-}10^6$ cpm with action levels delineated for operator guidance. This channel is primarily used for qualitative rather quantitative analysis.

12. Guide Hall Area Monitor System monitors the radiation levels in the Guide Hall. The system is comprised of fifteen channels located around the perimeter of the hall and in the storage and truck loading area. The detectors are Geiger-Mueller tubes sensitive to gamma radiation. Each channel is comprised of a detector, a local indicator and alarm, and a remote alarm and readout unit. The local alarm alerts personnel in the vicinity of a high radiation level. A recorder trends each of the fifteen channels. The ranges of the channels are $0.01\text{-}10^3$ mR/hr.

13. Tritium Monitor Channel samples the air within the Confinement Building for the presence of tritium. An ion chamber located on the B-1 level of the Confinement Building is supplied with air samples drawn by an associated blower from different sample points. Sample points are located at selected points throughout the ventilation system. The tritium concentration detected by the ion chamber is monitored and recorded in the Control Room, with an alarm set to alert the reactor operator to an abnormal tritium level. A loss of flow through the detector will also initiate the same alarm.

9 Temperature

1. Reactor ΔT Recorder Channel, TR-1, measures the differential temperature of the primary coolant across the reactor. Two precision thermohms, TD1-1 and TD1-2, are installed in the 18-inch primary piping on the inlet and outlet side of the reactor vessel to provide continuous monitoring and recording of the ΔT. The differential temperature signal is applied to Thermal Power Recorder, BTUR. The range of the channel is 0-20 ^{o}F.

2. Reactor Outlet Temperature Recorder Channel, TRA-2, measures the temperature of the primary coolant leaving the reactor. A resistance temperature detector (RTD), TE-2, is mounted in the 18-inch outlet piping of the reactor. An R-to-I converter, TT-2, converts the resistance measurement to an electrical signal that is applied to Temperature Recorder TR-2 and to Temperature Alarm TA-2. The alarm unit de-energizes the Reactor Outlet Temperature Rundown Relay, Ka-01-267, initiating a reactor rundown and supplying a signal to the Annunciator System when the outlet temperature is too high. REACTOR OUTLET TEMPERATURE HIGH alarm, AN4-19, alerts the reactor operator to a high coolant temperature on the outlet from the reactor. The range of the channel is 50-200 ^{o}F.

3. Reactor Inlet Temperature Recorder Controller Channel, TRCA-3, measures the temperature of the primary coolant entering the reactor. A resistance temperature detector (RTD), TE-3, is mounted in the 18-inch inlet piping of the reactor. An R-to-I converter, TT-3, converts the resistance measurement to an electrical signal that is applied to Temperature Controller TC-3, to Temperature Recorder TR-3 and to Temperature Alarm TA-3. The temperature controller compares the measured temperature to the desired temperature setpoint established by the reactor operator. When the measured temperature exceeds the setpoint, the temperature controller sends an electric signal to Elector-pneumatic Pressure Controller EPC-T3 to close Cooling Tower Bypass Valves SCV-1 and -2, thereby increasing the flow of secondary cooling water to the cooling tower and decreasing the temperature of the secondary water supplied to Main Heat Exchangers HE-1A and -1B. When the measured temperature drops below the setpoint, the controller opens the bypass valves, thereby increasing the temperature of the secondary cooling water. REACTOR INLET TEMPERATURE ABNORMAL alarm, AN3-3, alerts the reactor operator to either a low temperature condition in the primary coolant at the inlet to the reactor or to a high temperature condition. The range of the channel is 50-150 ^{o}F.

4. Heat Exchanger HE-1A D_2O Outlet Temperature Channel, TR-4, measures and records the temperature of the primary coolant leaving Main Heat Exchanger HE-1A. Thermocouple, TE-4, is mounted in the 12-inch outlet piping from the heat exchanger. Temperature Transmitter TT-4 converts the thermocouple junction potential to an electric signal that is applied to Temperature Recorder TR-4. The range of the channel is 50-150 ^{o}F.

5. Heat Exchanger HE-1B D_2O Outlet Temperature Channel, TR-5, measures and records the temperature of the primary coolant leaving Main Heat Exchanger HE-1B. Thermocouple, TE-5, is mounted in the 12-inch outlet piping from the heat exchanger. Temperature Transmitter TT-5 converts the thermocouple junction potential to an electric signal that is applied to Temperature Recorder TR-5. The range of the channel is 50-150 ^{o}F.

6. Heat Exchanger HE-2 D_2O Outlet Temperature Indicator Channel, TIA-6, measures the temperature of the heavy water leaving D_2O Purification Heat Exchanger HE-2. Thermocouple, TE-6, is mounted in the 4-inch outlet piping from the heat exchanger. Temperature Transmitter TT-6 converts the thermocouple junction potential to an electric signal that is applied to Temperature Indicator TI-6 and Temperature Alarm TA-6. REACTOR IX INLET TEMPERATURE HIGH alarm, AN3-5, alerts the reactor operator to high temperature condition in the Primary Purification System. The range of the channel is 50-125^{o}F.

7. Heat Exchanger HE-2 D_2O Inlet Temperature Indicator Channel, TI-7, measures the temperature of the heavy water entering D_2O Purification Heat Exchanger HE-2. Thermocouple, TE-7, is mounted in the 4-inch inlet piping to the heat exchanger. Temperature Transmitter TT-7 converts the thermocouple junction potential to an electric signal that is applied to Temperature Indicator TI-7. The range of the channel is 50-125 ^{o}F.

8. Thermal Column Tank Outlet Temperature Indicator Channel, TIA-8, measures the temperature of the cooling water leaving the Thermal Column Tank. Thermocouple, TE-8, is mounted in the 2 inch outlet piping from the tank. Temperature Transmitter TT-8 converts the thermocouple junction potential to an electric signal that is applied to Temperature Indicator TI-8 and Temperature Alarm TA-8. THERMAL COLUMN TEMPERATURE HIGH alarm, AN3-12, alerts the reactor operator to a high temperature condition in the cooling water leaving the Thermal Column Tank. The range of the channel is 50-125 ^{o}F.

9. Recombiner Outlet Temperature Recorder Channel, TRA-10, measures and records the temperature of the helium leaving the Recombiner. Thermocouple, TE-10, is mounted in the 4-inch outlet piping form the Recombiner. Temperature Transmitter TT-10 converts the thermocouple junction potential to an electric signal that is applied to Temperature Recorder TR-10 and Temperature Alarm TA-10. RECOMBINER OUTLET TEMPERATURE HIGH alarm, AN3-20, alerts the reactor operator to a high temperature condition in the helium leaving the Recombiner. The range of the channel is 50-200 ^{o}F.

10. Recombiner Internal Temperature Recorder Channel, TRA-11, measures and records the temperature inside the Recombiner. Thermocouple, TE-11, is mounted in the Recombiner. Temperature Transmitter TT-11 converts the thermocouple junction potential to an electric signal that is applied to Temperature Recorder TR-11 and Temperature Alarm TA-11. RECOMBINER

INTERNAL TEMPERATURE LOW alarm, AN3-19, alerts the reactor operator to a low temperature condition within the Recombiner. The range of the channel is 50-200°F.

11. Cooling Tower Basin Temperature Indicator Alarm Channel, TIA-12, measures the temperature of the water in the cooling tower basin. Thermocouple, TE-12, is mounted in the basin of the cooling tower. Temperature Transmitter TT-12 converts the thermocouple junction potential to an electric signal that is applied to Temperature Indicator TI-12 and Temperature Alarm TA-12. COOLING TOWER TEMPERATURE LOW alarm, AN5-1, alerts the reactor operator to a low water temperature condition in the basin. The range of the channel is 30-130 °F.

12. Heat Exchanger HE-1A Secondary Outlet Temperature Channel, TI-13, measures the temperature of the secondary cooling water leaving Main Heat Exchanger HE-1A. Thermocouple, TE-13, is mounted in the 12-inch outlet piping from the heat exchanger. Temperature Transmitter TT-13 converts the thermocouple junction potential to an electric signal that is applied to Temperature Indicator TI-13. The range of the channel is 50-150 °F.

13. Secondary Header Inlet Temperature Channel, TI-14, measures the temperature of the secondary cooling water entering Main Heat Exchangers HE-1A and -1B. Thermocouple, TE-14, is mounted in the 20-inch secondary header piping. Temperature Transmitter, TT-14, converts the thermocouple junction potential to an electric signal that is applied to Temperature Indicator TI-14. The range of the channel is 50-150 °F.

14. Storage Pool Water Temperature Indicator Channel, TIA-15, measures the temperature of the cooling water leaving the Storage Pool Heat Exchanger. Thermocouple, TE-15, is mounted in the outlet piping from the heat exchanger. Temperature Transmitter TT-15 converts the thermocouple junction potential to an electric signal that is applied to Temperature Indicator TI-15 and Temperature Alarm TA-15. STORAGE POOL HX TEMPERATURE HIGH alarm, AN5-18, alerts the reactor operator to a high temperature condition on the outlet from the heat exchanger. The range of the channel is 25-125 °F.

15. Thermal Shield HX Outlet Temperature Indicator Channel, TIA-16, measures the temperature of the water leaving the Thermal Shield Heat Exchanger. Thermocouple, TE-16, is mounted in the outlet piping from the heat exchanger. Temperature Transmitter TT-16 converts the thermocouple junction potential to an electric signal that is applied to Temperature Indicator TI-16 and Temperature Alarm TA-16. THERMAL SHIELD HX OUTLET TEMP. HIGH alarm, AN5-10, alerts the reactor operator to a high temperature condition on the outlet from the heat exchanger. The range of the channel is 50-125 °F.

16. Thermal Shield Heat Exchanger Secondary Outlet Temperature Channel, TIA-17, measures the temperature of the secondary cooling water leaving the

Thermal Shield Heat Exchanger. Thermocouple, TE-17, is mounted in the 4-inch outlet piping from the heat exchanger. Temperature Transmitter TT-17 converts the thermocouple junction potential to an electric signal that is applied to Temperature Indicator TI-17 and Temperature Alarm TA-17. THERMAL SHIELD HX SEC. OUTLET TEMP. HIGH alarm, AN5-9, alerts the reactor operator to a high temperature condition on the secondary outlet of the heat exchanger. The range of the channel is 50-125 ^oF.

17. Experimental Demineralized Water HX Inlet Temperature Indicator Channel, TI-21, measures the temperature of water entering Experimental Demineralized Water Heat Exchanger. Thermocouple, TE-21, is mounted in the inlet piping to the heat exchanger. Temperature Transmitter TT-21 converts the thermocouple junction potential to an electric signal that is applied to Temperature Indicator TI-21. The range of the channel is 50-125 ^oF.

18. Thermal Shield Storage Tank Inlet Temperature Indicator Channel, TI-22, measures the temperature of water entering Thermal Shield Storage Tank. Thermocouple, TE-22, is mounted in the inlet piping to the tank. Temperature Transmitter TT-22 converts the thermocouple junction potential to an electric signal that is applied to Temperature Indicator TI-22 and a controller that modulates secondary valves SCV-550 and -560. The range of the channel is 50-125 ^oF.

19. Thermal Shield Floor Header Outlet Temperature Indicator Channel, TIA-23, measures the temperature of the water in the floor header. Thermocouple, TE-23, is mounted in the floor header piping. Temperature Transmitter TT-23 converts the thermocouple junction potential to an electric signal that is applied to Temperature Indicator TI-23 and Temperature Alarm TA-23. FLOOR HEADER OUTLET TEMPERATURE HIGH alarm, AN5-11, alerts the reactor operator to a high water temperature condition in the Thermal Shield Floor Header. The range of the channel is 50-125 ^oF.

20. Thermal Shield Ring Header Outlet Temperature Indicator Channel, TCA-24, measures the temperature of the water in the ring header. Thermocouple, TE-24, is mounted in the ring header piping. Temperature Transmitter TT-24 converts the thermocouple junction potential to an electric signal that is applied to Temperature Controller TC-24 and Temperature Alarm TA-24. RING HEADER OUTLET TEMPERATURE HIGH alarm, AN5-12, alerts the reactor operator to a high water temperature condition in the Thermal Shield Ring Header. The controller modulates valve TSV-15, thermal shield HX bypass valve. The range of the channel is 50-125 ^oF.

21. Experimental Demineralized Water Heat Exchanger Outlet Temperature Indicator Channel, TIA-31, measures the temperature of the water leaving the Experimental Demineralized Water Heat Exchanger. Thermocouple, TE-31, is mounted in the outlet piping from the heat exchanger. Temperature Transmitter TT-31 converts the thermocouple junction potential to an electric

signal that is applied to Temperature Indicator TI-31 and Temperature Alarm TA-31. EXP. DEMIN. HX OUTLET TEMPERATURE HIGH alarm, AN1-25, alerts the reactor operator to a high temperature condition in the water leaving the heat exchanger. The range of the channel is 50-125 ^{o}F.

22. Heat Exchanger HE-1B Secondary Outlet Temperature Channel, TI-33, measures the temperature of the secondary cooling water leaving Main Heat Exchanger HE-1B. Thermocouple, TE-33, is mounted in the 12-inch outlet piping from the heat exchanger. Temperature Transmitter TT-33 converts the thermocouple junction potential to an electric signal that is applied to Temperature Indicator TI-33. The range of the channel is 50-150 ^{o}F.

23. Cold Source Inlet Temperature Indicator Channel, TI-34, measures the temperature of the D_2O cooling water entering the cold source. A resistance temperature detector (RTD), TE-34, is mounted in the 1 ½-inch piping supplying cooling water to the Cold Source. An R-to-I converter, TT-34, converts the resistance measurement to an electrical signal that is applied to the cold source computer. The range of the channel is 10-93.3 C.

24. Cold Source Outlet Temperature Indicator Channel, TI-35, measures the temperature of the D_2O cooling water leaving the cold source. A resistance temperature detector (RTD), TE-35, is mounted in the 1 ½-inch piping returning cooling water from the Cold Source. An R-to-I converter, TT-35, converts the resistance measurement to an electrical signal that is applied to the cold source computer and to Temperature Indicator, TI-35. The range of the channel is 50-200 ^{o}F (10-93.9 C).

25. Heat Exchanger HE-2 Secondary Outlet Temperature Channel, TI-36, measures the temperature of the secondary cooling water leaving D_2O Purification Heat Exchanger HE-2. Thermocouple, TE-36, is mounted in the 4-inch outlet piping from the heat exchanger. Temperature Transmitter TT-36 converts the thermocouple junction potential to an electric signal that is applied to Temperature Indicator TI-36. The range of the channel is 50-125 ^{o}F.

26. Redundant Reactor ΔT Indicator Channels, TIA-40A and -40B, measure the differential temperature across the reactor core. Temperature elements TE-40A-I and TE-40A-O are applied to Temperature Transmitter TT-40A. An output signal proportional to the temperature difference is applied to Temperature Indicator, TI-40A, and to Temperature Alarm, TA-40A. Temperature elements TE-40B-I and TE-40B-O are applied to Temperature Transmitter, TT-40B. An output signal proportional to the temperature difference is applied to Temperature Indicator, TI-40B, and to Temperature Alarm, TA-40B. The alarm units have outputs that supply a signal for reactor scram and annunciator. The range of both channels is 0-30 ^{o}F.

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Appendix 7B: Annunciator System Details

The Annunciator System provides the reactor operator with the status of equipment in the primary, secondary and auxiliary systems of the reactor. Two alarm cabinets, located behind the Main Control Panel, contain 267 alarm channels. Currently, 174 of the channels are used; the remaining 93 channels are available for future needs or as installed spares. The alarms are grouped according to their systems: Primary Coolant System, Secondary Coolant System, Reactor Protection System, Auxiliary System, and Experimental Facilities. Each group is displayed on a separate alarm light box located on the Main Control Panel adjacent to the instrumentation for that system. A single set of acknowledge, reset and test push buttons is located on the Main Control Panel for use by the reactor operator. Each alarm point has an Alarm Procedure (AP) identified by the Annunciator Panel and the alarm number. The Annunciator System receives its power from the Instrument Power Bus which is powered from Critical Power Panel. The Electrical Power System is described in Chapter 8.

Annunciator AN-1 provides the reactor operator with information on the status of equipment associated with the various experiments. The alarm light box is mounted on the left hand portion of the console, convenient to the operator. The alarm windows in the light box are arranged in a pattern five columns wide by fourteen rows high. Currently, 38 of the possible 70 alarm points are used. Table 7B-1 lists the alarm points and their setpoints. Those points not listed are installed spares. Figure 7B-1 shows the light box arrangement.

Annunciator AN-2 provides the reactor operator with information on the status of equipment associated with the various reactor auxiliary systems, including radiation monitoring instrumentation. The alarm light box is mounted on the left hand portion of the console, convenient to the operator. The alarm windows in the light box are arranged in a pattern six columns wide by seven rows high. Currently, 19 of the possible 42 alarm points are used. Table 7B-2 lists the alarm points and their setpoints. Those points not listed are installed spares. Figure 7B-2 shows the light box arrangement.

Annunciator AN-3 provides the reactor operator with information on the status of equipment associated with the Primary Coolant System. The alarm light box is mounted on the right hand, or angled portion of the console, convenient to the operator. The alarm windows in the light box are arranged in a pattern eight columns wide by six rows high. Currently, 33 of the possible 48 alarm points are used. Table 7B-3 lists the alarm points and their setpoints. Those points not listed are installed spares. Figure 7B-3 shows the light box arrangement.

Annunciator AN-4 provides the reactor operator with information on the status of the reactor protection circuits. The alarm light box is mounted on the right hand, or angled portion of the console, convenient to the operator. The alarm windows in the light box are arranged in a pattern eight columns wide by seven rows high. Currently, 50 of the possible 56 alarm points are used. Table 7B-4 lists the alarm points and their setpoints. Those points not listed are installed spares. Figure 7B-4 shows the light box arrangement.

Annunciator AN-5 provides the reactor operator with information on the status of equipment associated with the Secondary Coolant System. The alarm light box is mounted on the right hand, or angled portion of the console, convenient to the operator. The alarm windows in the light box are arranged in a pattern eight columns wide by six rows high. Currently, 31 of the possible 48 alarm points are used. Table 7B-5 lists the alarm points and their setpoints. Those points not listed are installed spares. Figure 7B-5 shows the light box arrangement.

Annunciator AN-6 provides the reactor operator with information on the status of the Scram, Rundown and Withdraw Prohibit signals. The alarm light box is mounted on the right hand, or angled portion of the console, convenient to the operator. The alarm windows in the light box are arranged in a pattern three columns wide by one row high. All three alarm points are used. Table 7B-6 lists the alarm points. Figure 7B-6 shows the light box arrangement.

Table 7B.1: Annunciator AN-1 Alarms.

No.	Alarm	Setpoint	Units	High/Low
1	BT-1 Open			
2	BT-2 Open			
3	BT-3 Open			
4	BT-4 Open			
5	BT-5 Open			
6	BT-6 Open			
7	BT-7 Open			
8	BT-8 Open			
9	BT-9 Open			
11	GT-1E Open			
12	GT-2W Open			
15	Boral Curtain Raised			
16	NG-1 Open			
17	NG-2 Open			
18	NG-3 Open			
19	NG-4 Open			
20	NG-5 Open			
21	NG-6 Open			
22	NG-7 Open			
24	Chilled Water Exp. Cooling Pump Failure			
25	Exp. Demin. HX Outlet Temperature High	110	^{o}F	High
26	Exp. Demin. IX Flow Low	8	gpm	Low
27	Exp. Demin. Flow Low	100	gpm	Low
28	Exp. Demin. Storage Tank Level Abnormal	100 50	inches inches	High Low
30	Exp. Demin. Pressure Abnormal	80 50	psig psig	High Low
36	Process Room Door Open			
37	Subpile Room Door Open			
38	Back Door Open			
41	Rabbit Blower On			
46	Rabbit In RT-1			
47	Rabbit In RT-2			
48	Rabbit In RT-3			
49	Rabbit In RT-4			
50	Rabbit In RT-5			
51	Rabbit In RT-1 Receiver			
52	Rabbit In RT-2 Receiver			
53	Rabbit In RT-3 Receiver			
54	Rabbit In RT-4 Receiver			
69	Refrigerator Trouble			
70	Cold Source Trouble			

Table 7B.2: Annunciator AN-2 Alarms.

No.	Alarm	Setpoint	Units	High/Low
1	Reserve Tank Flow Low	20	gpm	Low
2	Plenum Flow Low	11	gpm	Low
3	Sump Pit #4 Level High	38	inches	High
4	Sump Pit #4 Level Medium	20	inches	High
5	Sump Pit #4 Level Low	2	inches	Low
6	Leak Detectors			
7	Simplex Alarm Panel			
8	B-1 Alarm			
9	Storage Pool Door			
13	C001 Radiation High	6	mrem/hr	High
14	Area Monitor Radiation High	2.5 or 10 x bkgnd	mrem/hr	High
15	Tritium Activity High	variable	DAC	High
16	Helium Sweep Activity High	50,000	cpm	High
17	Secondary Coolant Activity High	200	cpm	High
31	RD3-4 & RD3-5 Flow Low	8	cfm	Low
34	Air Trouble	85	psig	Low
35	DWV-3, -4, -5, & -6 Low Pressure	60	psig	Low
36	Pump Room Alarm			

Table 7B.3: Annunciator AN-3 Alarms.

No.	Alarm	Setpoint	Units	High/Low
1	Reactor D_2O Level High	164	inches	High
2	Reactor D_2O Level Low	150	inches	Low
3	Reactor Inlet Temperature Abnormal	110 80	^oF ^oF	High Low
4	Exp. D_2O Cooling Pressure Low	25	psig	Low
5	Reactor IX Inlet Temperature High	120	^oF	High
6	Reactor IX Flow Low	10	gpm	Low
7	Reactor IX Inlet Conductivity High	2.5	μmhos	High
8	Reactor IX Outlet Conductivity High	2.5	μmhos	High
9	HE-2 Inlet Flow Low	25	gpm	Low
10	HE-2 Press. Diff. Low	5	psig	Low
11	Thermal Column Level Abnormal	59 49	inches inches	High Low
12	Thermal Column Temperature High	120	^oF	High
13	D_2O Storage Tank Level Low	35	inches	Low
14	D_2O Storage Tank Level High	45	inches	High
16	Rabbit Tip D_2O Flow Low	11	gph	Low
17	Recombiner Outlet Pressure Abnormal	5 1	in. H_20 in. H_20	High Low
18	Recombiner Inlet Pressure High	10	in. H_20	High
19	Recombiner Internal Temperature Low	140	^oF	Low
20	Recombiner Outlet Temperature High	130	^oF	High
21	Helium System Flow Low	15	cfm	Low
22	Helium Blow-Off Valve Open	45	inches	High
23	Helium Gas Holder Level Low	2	inches	Low
24	Helium Sweep Make-Up Pressure Low	10	psig	Low
25	CO_2 Gas Holder Level Low	3	inches	Low
26	CO_2 Pressure Relief Valve Open	5	in. H_20	High
27	CO_2 Blow-Off Valve Open	45	inches	High
28	CO_2 Make-Up Pressure Low	10	psig	Low
29	Thermal Column Surge Tank Level Low	15	inches	Low
41	Rod Drive Power Failure	90	Vac	Low
43	T-9 UPS Trouble			
44	T-10 UPS Trouble			
45	DC Ground	50k	Ohms	Low
46	10-Volt Nuclear Instrument Power Failure			

Table 7B.4: Annunciator AN-4 Alarms.

No.	Alarm	Setpoint	Units	High/Low
1	Manual Scram			
2	Moderator Dump			
3	Flux High	125 13	% %	High High
4	Period Scram	5	sec.	Low
5	Nuclear Instrument Power Off			
6	Building Exhaust Activity High	50,000	cpm	High
7	Irradiated Air Activity High	50,000	cpm	High
8	Stack Activity High	50,000	cpm	High
9	Outlet Flow Low	6,500	gpm	Low
10	14 In. Inlet Flow Low	5,000	gpm	Low
11	10 In. Inlet Flow Low	1,400	gpm	Low
12	Differential Temperature “A” High	20	^oF	High
13	Differential Temperature “B” High	20	^oF	High
14	Vessel Level “Recorder” Low	140	inches	Low
15	Vessel Level “Indicator” Low	140	inches	Low
16	Experimental Scram			
17	Period Rundown	10	sec.	Low
18	High-Flux Rundown	115	%	High
19	Reactor Outlet Temperature High	130	^oF	High
20	Rod-Test On			
21	Vessel Level Low	145	inches	Low
22	Thermal Column Flow Low	5	gpm	Low
23	Thermal Power High	23	MW	High
24	Thermal Shield Flow Low	250	gpm	Low
25	Cold Source H_2 Press. “A” High	5	psid	High
26	Cold Source H_2 Press. “B” High	5	psid	High
27	Cold Source H_2 Flow “A” Low	5	gpm	Low
28	Cold Source H_2 Flow “B” Low	5	gpm	Low
33	Source-Range Period Rod-Stop	15	sec.	Low
34	Intermediate Range Period Rod-Stop	15	sec.	Low
36	Reactor On Manual			
37	Servo Deviation 10%	10	%	High
38	Reg. Rod Control Limit	7	in.	Top/Bottom
40	Servo Deviation 2%	2	%	High
41	Nuclear Instrument Test-Fault			
42	Rods Not Seated			
43	Clutch Power Off	80/160	mA	Low/High
44	Count-Rate Low	2	cps	Low
45	Period By-Passed	10	%	High
46	Experimental Interlocks			
47	D_2O Overflow Low	5	gpm	Low
48	Emergency Tank Level Low	50	inches	Low
49	Instrument Test On			
50	Vessel Level Rundown Bypass			
51	Thermal Column Flow Rundown Bypass			
52	Thermal Shield Flow Rundown Bypass			
53	BTUR Rundown Bypass			
54	Nuclear Rundown Bypass			
55	Cold Source Press. Rundown Bypass			
56	Cold Source Flow Rundown Bypass			

Table 7B.5: Annunciator AN-5 Alarms.

No.	Alarm	Setpoint	Units	High/Low
1	Cooling Tower Temperature Low	40	^oF	Low
2	Cooling Tower Level Low	28	inches	Low
3	Cooling Tower Level High	48	inches	High
4	Secondary Cooling Flow Low	7,000	gpm	Low
5	HE-1A Press. Diff. Low	5	psi	Low
6	HE-1B Press. Diff. Low	5	psi	Low
9	Thermal Shield HX Sec. Outlet Temp. High	120	^oF	High
10	Thermal Shield HX Outlet Temp. High	120	^oF	High
11	Floor Header Outlet Temperature High	120	^oF	High
12	Ring Header Outlet Temperature High	120	^oF	High
13	Thermal Shield Flow Low	300	gpm	Low
14	Thermal Shield IX Flow Low	8	gpm	Low
15	Thermal Shield Storage Tank Level Abnormal	100 50	inches inches	High Low
16	Thermal Shield Conductivity High	5	μmhos	High
17	Storage Pool Conductivity High	5	μmhos	High
18	Storage Pool HX Temperature High	70	^oF	High
19	Storage Pool Flow Low	50	gpm	Low
20	Storage Pool IX Flow Low	8	gpm	Low
21	Storage Pool Level Low	17.5	feet	low
22	Storage Pool Make-Up On	30	inches	Low
23	Storage Pool Pump-Pit Level Low	30	inches	Low
24	Storage Pool Pump-Pit Level High	4	inches	High
25	Refueling Helium Pressure Low	10	psig	Low
33	A, B, C & D Wing Fire Alarm			
34	E Wing Fire Alarm			
35	Guide Hall Fire Alarm			
36	Cooling Tower Fire Alarm			
41	Diesel "A" Failure To Start			
42	Diesel "B" Failure To Start			
43	48-Volt Relay Power Failure			
44	28-Volt Process Instrument Power Failure			

Table 7B.6: Annunciator AN-6 Alarms.

No.	Alarm
1	Scram
2	Rundown
3	Withdraw Prohibit

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Figure 7B.1: ANNUNCIATOR AN-1 Arrangement.

BT-1 OPEN	BT-2 OPEN	BT-3 OPEN	BT-4 OPEN	BT-5 OPEN
BT-6 OPEN	BT-7 OPEN	BT-8 OPEN	BT-9 OPEN	
GT-1E OPEN	GT-2W OPEN			BORAL CURTAIN RAISED
NG-1 OPEN	NG-2 OPEN	NG-3 OPEN	NG-4 OPEN	NG-5 OPEN
NG-6 OPEN	NG-7 OPEN		CHILLED WATER EXP. COOLING PUMP FAILURE	EXP. DEMIN. HX OUTLET TEMPERATURE HIGH
EXP. DEMIN. IX FLOW LOW	EXP. DEMIN. FLOW LOW	EXP. DEMIN. STORAGE TANK LEVEL ABNORMAL		EXP. DEMIN. PRESSURE ABNORMAL
PROCESS ROOM DOOR OPEN	SUBPILE ROOM DOOR OPEN	BACK DOOR OPEN		
RABBIT BLOWER ON				
RABBIT IN RT-1	RABBIT IN RT-2		RABBIT IN RT-4	RABBIT IN RT-5
RABBIT IN RT-1 RECEIVER	RABBIT IN RT-2 RECEIVER		RABBIT IN RT-4 RECEIVER	
			REFRIGERATOR TROUBLE	COLD SOURCE TROUBLE

Figure 7B.2: ANNUNCIATOR AN-2 Arrangement.

RESERVE TANK FLOW LOW	PLENUM FLOW LOW	SUMP #4 LEVEL HIGH	SUMP #4 LEVEL MEDIUM	SUMP #4 LEVEL LOW	LEAK DETECTORS
SIMPLEX PANEL	B-1 ALARM	STORAGE POOL DOOR			
C-001 RADIATION HIGH	AREA MONITOR RADIATION HIGH	TRITIUM ACTIVITY HIGH	HELIUM SWEEP ACTIVITY HIGH	SECONDARY COOLANT ACTIVITY HIGH	
RD 3-4 & 3-5 FLOW LOW			AIR TROUBLE	DWV-3,4,5&6 PRESSURE LOW	PUMP ROOM ALARM

Figure 7B.3: ANNUNCIATOR AN-3 Arrangement.

REACTOR D2O LEVEL HIGH	REACTOR D2O LEVEL LOW	REACTOR INLET TEMPERATURE ABNORMAL	EXP. D2O COOLING PRESSURE LOW	REACTOR IX INLET TEMPERATURE HIGH	REACTOR IX FLOW LOW	REACTOR IX INLET CONDUCTIVITY HIGH	REACTOR IX OUTLET CONDUCTIVITY HIGH
HE-2 INLET FLOW LOW	HE-2 PRESS. DIFF. LOW	THERMAL COLUMN LEVEL ABNORMAL	THERMAL COLUMN TEMPERATURE HIGH	D2O STORAGE TANK LEVEL LOW	D2O STORAGE TANK LEVEL HIGH		RABBIT TIP D2O FLOW LOW
RECOMBINER OUTLET PRESSURE ABNORMAL	RECOMBINER INLET PRESSURE HIGH	RECOMBINER INTERNAL TEMPERATURE LOW	RECOMBINER OUTLET TEMPERATURE HIGH	HELIUM SYSTEM FLOW LOW	HELIUM BLOW-OFF VALVE OPEN	HELIUM GAS HOLDER LEVEL LOW	HELIUM SWEEP MAKE-UP PRESSURE LOW
CO2 GAS HOLDER LEVEL LOW	CO2 PRESSURE RELIEF VALVE OPEN	CO2 BLOW-OFF VALVE OPEN	CO2 MAKE-UP PRESSURE LOW	THERMAL COLUMN SURGE TANK LEVEL LOW			
ROD DRIVE POWER FAILURE		T-9 UPS TROUBLE	T-10 UPS TROUBLE	DC GROUND	10-VOLT NUCLEAR INSTRUMENT POWER FAILURE		

Figure 7B.4: ANNUNCIATOR AN-4 Arrangement.

MANUAL SCRAM	MODERATOR DUMP	FLUX HIGH	PERIOD SCRAM	NUCLEAR INSTRUMENT POWER OFF	BUILDING EXHAUST ACTIVITY HIGH	IRRADIATED AIR ACTIVITY HIGH	STACK ACTIVITY HIGH
OUTLET FLOW LOW	14 IN. INLET FLOW LOW	10 IN. INLET FLOW LOW	DIFFERENTIAL TEMPERATURE "A" HIGH	DIFFERENTIAL TEMPERATURE "B" HIGH	VESSEL LEVEL "RECORDER" LOW	VESSEL LEVEL "INDICATOR" LOW	EXPERIMENTAL SCRAM
PERIOD RUNDOWN	HIGH-FLUX RUNDOWN	REACTOR OUTLET TEMPERATURE HIGH	ROD-TEST ON	VESSEL LEVEL LOW	THERMAL COLUMN FLOW LOW	THERMAL POWER HIGH	THERMAL SHIELD FLOW LOW
COLD SOURCE H2 PRESS. "A" HIGH	COLD SOURCE H2 PRESS. "B" HIGH	COLD SOURCE D2O FLOW "A" LOW	COLD SOURCE D20 FLOW "B" LOW				
SOURCE-RANGE PERIOD ROD-STOP	INTERMEDIATE RANGE PERIOD ROD-STOP		REACTOR ON MANUAL	SERVO DEVIATION 10%	REG. ROD CONTROL LIMIT		SERVO DEVIATION 2%
NUCLEAR INSTRUMENT TEST-FAULT	RODS NOT SEATED	CLUTCH POWER OFF	COUNT-RATE LOW	PERIOD BY-PASSED	EXPERIMENTAL INTERLOCKS	D2O OVERFLOW LOW	EMERGENCY TANK LEVEL LOW
INSTRUMENT TEST ON	VESSEL LEVEL RUNDOWN BYPASS	THERM. COL. FLOW RUNDOWN BYPASS	THERM. SHIELD FLOW RUNDOWN BYPASS	BTUR RUNDOWN BYPASS	NUCLEAR RUNDOWN BYPASS	COLD SOURCE PRESS. RUNDOWN BYPASS	COLD SOURCE FLOW RUNDOWN BYPASS

Figure 7B.5: ANNUNCIATOR AN-5 Arrangement.

COOLING TOWER TEMPERATURE LOW	COOLING TOWER LEVEL LOW	COOLING TOWER LEVEL HIGH	SECONDARY COOLING FLOW LOW	HE-1A PRESS. DIFF. LOW	HE-1B PRESS. DIFF. LOW		
THERMAL SHIELD HX SEC. OUTLET TEMP. HIGH	THERAML SHIELD HX OUTLET TEMP. HIGH	FLOOR HEADER OUTLET TEMPERATURE HIGH	RING HEADER OUTLET TEMPERATURE HIGH	THERMAL SHIELD FLOW LOW	THERMAL SHIELD IX FLOW LOW	THERMAL SHIELD STORAGE TANK LEVEL ABNORMAL	THERMAL SHIELD CONDUCTIVITY HIGH
STORAGE POOL CONDUCTIVITY HIGH	STORAGE POOL HX TEMPERATURE HIGH	STORAGE POOL FLOW LOW	STORAGE POOL IX FLOW LOW	STORAGE POOL LEVEL LOW	STORAGE POOL MAKE-UP ON	STORAGE POOL PUMP-PIT LEVEL LOW	STORAGE POOL PUMP-PIT LEVEL HIGH
REFUELING HELIUM PRESSURE LOW							
A,B,C&D WING FIRE ALARM	E WING FIRE ALARM	GUIDE HALL FIRE ALARM	COOLING TOWER FIRE ALARM				
DIESEL “A” FAILURE TO START	DIESEL “B” FAILURE TO START	48-VOLT RELAY POWER FAILURE	28-VOLT PROCESS INSTRUMENT POWER FAILURE				

Figure 7B-6: ANNUNCIATOR AN-6 Arrangement.

SCRAM	RUNDOWN	WITHDRAW PROHIBIT