

## 7.2 Reactor Trip

### 7.2.1 Description

Considerations, such as mechanical or hydraulic limitations on equipment or heat transfer requirements on the reactor core, define a safe operating region for the plant. Maneuvering of the plant within this safe operating region is permitted in response to normal power generation demands. The plant design provides margin to the safety limits so that an unsafe condition is not caused by the transients induced by normal operating changes. The plant control system attempts to keep the reactor operating away from any safety limit. Excursions toward a limit occur because of abnormal demands, malfunctions in the control system, or by severe transients induced by occurrence of a Condition II or III event, as discussed in Chapter 15. Hypothetical events (Condition IV) are analyzed with respect to plant safety limits. The safety system keeps the reactor within the safe region by shutting down the reactor whenever safety limits are approached. Reactor trip is a protective function performed by the protection and safety monitoring system when it anticipates an approach of a parameter to its safety limit. Reactor shutdown occurs when electrical power is removed from the rod drive mechanism coils, allowing the rods to fall by gravity into the reactor core.

The equipment involved in reactor trip is shown in simplified block diagram form in Figure 7.1-2. Section 7.1 provides a description of the equipment. The equipment involved is:

- Sensors and manual inputs
- Integrated protection cabinets
- Reactor trip switchgear

The protection system maintains surveillance of key process variables directly related to equipment mechanical limitations (such as pressure), and of variables which directly affect the heat transfer capability of the reactor (such as flow and temperature). Some limits, such as the overtemperature  $\Delta T$  setpoint, are calculated in the integrated protection cabinets from other parameters when direct measurement of the variable is not possible. Table 7.2-1 lists variables monitored for reactor trip.

Four redundant measurements, using four separate sensors, are made for each variable used for reactor trip. Analog signals are converted to digital form by analog-to-digital converters within the integrated protection cabinets. Signal conditioning is applied to selected inputs following the conversion to digital form. Following necessary calculations and processing, the measurements are compared against the applicable setpoint for that variable. A partial trip signal for a parameter is generated if one channel's measurement exceeds its predetermined or calculated limit. Processing of variables for reactor trip is identical in each of the four redundant divisions of the protection system. Each division sends its partial trip status to each of the other three divisions over isolated multiplexed data links. Each division is capable of generating a reactor trip signal if two or more of the redundant channels of a single variable are in the partial trip state.

The reactor trip signal from each of the four integrated protection cabinets is sent to the corresponding reactor trip switchgear breakers.

Each of the four reactor trip actuation divisions consists of two reactor trip circuit breakers. The reactor is tripped when two or more actuation divisions output a reactor trip signal. This automatic trip demand initiates the following two actions. It deenergizes the under-voltage trip attachments on the reactor trip breakers, and it energizes the shunt trip devices on the reactor trip breakers. Either action causes the breakers to trip. Opening the appropriate trip breakers removes power to the rod drive mechanism coils, allowing the rods to fall into the core. This rapid negative reactivity insertion causes the reactor to shutdown.

Bypasses of parameter channels used to generate reactor trip signals and of reactor trip actuation divisions are permitted as described in subsection 7.2.1.1.12. Single failure criterion is met even when one or two channels or divisions are bypassed. The reactor is automatically tripped if three or four channels or divisions are bypassed.

Subsection 7.2.1.1 provides a description of each of the reactor trip functions. Figure 7.2-1 shows the functional diagrams for reactor trips, as well as functional diagrams for other related plant functions.

### 7.2.1.1 Functional Description

The following subsections describe the specific reactor trip functions and are grouped according to the following nine conditions:

- Subsection 7.2.1.1.1 Nuclear Startup Trips
- Subsection 7.2.1.1.2 Nuclear Overpower Trips
- Subsection 7.2.1.1.3 Core Heat Removal Trips
- Subsection 7.2.1.1.4 Primary Overpressure Trips
- Subsection 7.2.1.1.5 Loss of Heat Sink Trips
- Subsection 7.2.1.1.6 Feedwater Isolation Trip
- Subsection 7.2.1.1.7 Automatic Depressurization Systems Actuation Reactor Trip
- Subsection 7.2.1.1.8 Core Makeup Tank Injection Trip
- Subsection 7.2.1.1.9 Reactor Trip on Safeguards Actuation
- Subsection 7.2.1.1.10 Manual Reactor Trip

Table 7.2-2 lists the reactor trips and summarizes the coincidence logic to trip. Table 7.2-3 provides the interlocks for each trip. Table 7.2-4, lists system level manual inputs to reactor trip functions.

#### 7.2.1.1.1 Nuclear Startup Trips

##### Source Range High Neutron Flux Trip

Source range high neutron flux trips the reactor when two of the four source range channels exceed the trip setpoint. This trip provides protection during reactor startup and plant

shutdown. It may be manually blocked and the high voltage source range detector power supply de-energized when the intermediate range neutron flux is above the P-6 setpoint value. It is automatically blocked by the power range neutron flux interlock (P-10). The trip may be manually reset when neutron flux is between P-6 and P-10. The reset occurs automatically when the intermediate range flux decreases below P-6. The channels can be individually bypassed at the integrated protection cabinets to permit channel testing during plant shutdown or prior to startup. This bypass action is indicated in the main control room.

Figure 7.2-1, sheet 3 shows the logic for this trip. This sheet also shows the development of permissive P-6 while P-10 is shown in Figure 7.2-1, sheet 4.

#### **Intermediate Range High Neutron Flux Trip**

Intermediate range high neutron flux trips the reactor when two of the four intermediate range channels exceed the trip setpoint. This trip, which provides protection during reactor startup, can be manually blocked if the power range channels are above approximately 10-percent power (P-10). The trip is automatically reset when the power range channels indicate less than 10-percent power. The intermediate range channels, including detectors, are separate from the power range channels. The intermediate range channels can be individually bypassed at the integrated protection cabinets to permit channel testing during plant shutdown or prior to startup. This bypass action is indicated in the main control room.

Figure 7.2-1, sheet 3 shows the logic for this trip. The development of permissive P-10 is shown in Figure 7.2-1, sheet 4.

#### **Power Range High Neutron Flux Trip (Low Setpoint)**

Power range high neutron flux (low setpoint) trips the reactor when two of the four power range channels exceed the trip setpoint.

The trip, which provides protection during startup, can be manually blocked when the power range channels are above approximately 10-percent power (P-10). The trip is automatically reset when the power range channels indicate less than 10-percent power.

Figure 7.2-1, sheet 3 shows the logic for this trip. The development of permissive P-10 is shown on Figure 7.2-1, sheet 4.

### **7.2.1.1.2 Nuclear Overpower Trips**

#### **Power Range High Neutron Flux Trip (High Setpoint)**

Power range high neutron flux (high setpoint) trips the plant when two of the four power range channels exceed the trip setpoint. It provides protection against excessive core power generation during normal operation and is always active. Figure 7.2-1, sheet 4 shows the logic for this trip.

### Power Range High Positive Flux Rate Reactor Trip

This trip protects the reactor when a sudden abnormal increase in power occurs in two out of the four power range channels. It provides protection against ejection accidents of low worth rods from midpower. It is always active. A channel is tripped when rate-sensitive circuits in the channel detect rates of change in nuclear power above the setpoint value. The channel trip is latched such that the partial trip signal does not disappear when the rate of change in power goes below the setpoint value. Once latched, the channel can only be reset from the main control room by manual action. The reactor is tripped when two out of the four rate channels have tripped.

Figure 7.2-1, sheet 4 shows the logic for this trip.

### 7.2.1.1.3 Core Heat Removal Trips

#### Overtemperature $\Delta T$ Reactor Trip

The overtemperature  $\Delta T$  trip provides core protection to prevent departure from nucleate boiling for combinations of pressure, power, coolant temperature, and axial power distribution. The protection is provided if the transient is slow with respect to piping transient delays from the core to the temperature detectors and pressure is within the range between the high and low pressure reactor trips. This setpoint includes corrections for changes in density and heat capacity of water with temperature and dynamic compensation for piping delays from the core to the loop temperature detectors. With normal axial power distribution, this reactor trip limit is always below the core safety limit. If axial peaks are greater than design, as indicated by the difference between upper and lower power range nuclear detectors, the reactor trip is automatically reduced according to the following calculation. Two hot leg temperature measurements per loop are combined with individual cold leg temperature measurements to form four  $\Delta T$  and  $T_{avg}$  signals.

The  $\Delta T$  setpoint for this trip is continuously calculated, with one set of temperature measurements per loop.

If  $\frac{\Delta T (1 + \tau_4 s)}{(1 + \tau_3 s)} \geq \Delta T \text{ setpoint}$ , a reactor trip is initiated.

$\Delta T$  setpoint is calculated from the following equation:

$$\Delta T_{\text{SETPOINT}} = \Delta T_o \left[ K_1 - K_2 \left( \frac{1 + \tau_1 s}{1 + \tau_2 s} \right) (T_{\text{avg}} - T_{\text{avg}}^o) + K_3 (P - P_0) - f_1 (\Delta\phi) \right]$$

Where:

- $\Delta T$  = Measured  $\Delta T$  by resistance temperature detector instrumentation
- $\Delta T_0$  = Indicated  $\Delta T$  at rated thermal power
- $T_{avg}$  = Average reactor coolant temperature ( $^{\circ}F$ )
- $T^{\circ}_{avg}$  = Nominal  $T_{avg}$  at rated thermal power
- $P$  = Pressurizer pressure (psig)
- $P_0$  = Nominal operating pressure
- $K_1$  = Preset bias
- $K_2$  = Preset gain which compensates for effects of temperature on the departure from nucleate boiling limits
- $K_3$  = Preset gain which compensates for effects of pressure on the departure from nucleate boiling limits
- $\tau_1, \tau_2$  = Preset constants which compensate for piping and instrument time delay(s)
- $\tau_4, \tau_5$  = Preset constants used in lead-lag compensator for  $\Delta T$
- $s$  = Laplace transform operator
- $f_1(\Delta\phi)$  = Function of the neutron flux difference between upper and lower ionization chamber flux signals

Two separate ionization chambers supply the upper and lower flux signal for each overtemperature  $\Delta T$  channel.

Increases in  $\Delta\phi$  beyond a predefined deadband results in a decrease in trip setpoint.

The required one pressurizer pressure parameter per loop is obtained from four separate sensors connected to pressure taps at the top of the pressurizer.

Figure 7.2-1, sheet 5, shows the logic for the overtemperature  $\Delta T$  trip function.

### Overpower $\Delta T$ Trip

The overpower  $\Delta T$  reactor trip provides confidence of fuel integrity during overpower conditions, limits the required range for overtemperature  $\Delta T$  protection, and provides a backup to the power range high neutron flux trip.

The  $\Delta T$  setpoint for this trip is continuously calculated for each loop.

If  $\Delta T \frac{(1 + \tau_4 s)}{(1 + \tau_5 s)} \geq \Delta T \text{ setpoint}$ , a reactor trip is initiated.

$\Delta T$  setpoint is calculated from the following equation:

$$\Delta T_{\text{SETPOINT}} = \Delta T_o \left[ K_4 - K_5 \frac{\tau_3 s}{(1 + \tau_3 s)} T_{\text{avg}} - K_6 (T_{\text{avg}} - T'_{\text{avg}}) - f_2(\Delta\phi) \right]$$

Where:

- $\Delta T$  = Measured  $\Delta T$  by resistance temperature detector instrumentation
- $\Delta T_o$  = Indicated  $\Delta T$  rated thermal power
- $f_2(\Delta\phi)$  = A function of the neutron flux difference between upper and lower long ionization chamber measurements
- $K_4$  = A preset bias
- $K_5$  = A constant which is equal to zero for decreasing  $T_{\text{avg}}$
- $K_6$  = A constant which is equal to zero for  $T_{\text{avg}}$  less than  $T'_{\text{avg}}$
- $T'_{\text{avg}}$  = Indicated  $T_{\text{avg}}$  at rated thermal power ( $^{\circ}\text{F}$ )
- $T_{\text{avg}}$  = Average reactor coolant temperature ( $^{\circ}\text{F}$ )
- $\tau_4, \tau_5$  = Preset constants used in lead-lag compensator for  $\Delta T$
- $\tau_3$  = Preset time constant
- $s$  = Laplace transform operator

The source of temperature and neutron flux information is identical to that of the overtemperature  $\Delta T$  trip, and the resultant  $\Delta T$  setpoint is compared to the same measured  $\Delta T$ . Figure 7.2-1, sheet 5, shows the logic for this trip function.

### **Reactor Trip on Low Pressurizer Pressure**

This trip protects against low pressure, which could lead to departure from nucleate boiling. The parameter sensed is reactor coolant pressure as measured in the pressurizer. This trip is automatically blocked when reactor power is below the P-10 permissive setpoint to allow control rod testing during cold, depressurized conditions. The trip is automatically reset when reactor power is above the P-10 setpoint.

Figure 7.2-1, sheet 5, shows the logic for this trip. The development of the P-10 permissive is shown in Figure 7.2-1, sheet 4.

### **Reactor Trip on Low Reactor Coolant Flow**

This trip protects against departure from nucleate boiling in the event of low reactor coolant flow. Pitot tubes in each reactor coolant cold leg are used to measure reactor coolant flow. The trip on low flow in any single cold leg is automatically blocked when reactor power is below the P-8 permissive setpoint, and the trip on low flow in multiple cold legs is automatically blocked when reactor power is below the P-10 permissive setpoint. This enhances reliability by preventing unnecessary reactor trips. The two trip functions are automatically reset when reactor power is above the P-8 and P-10 setpoints.

Figure 7.2-1, sheet 5 shows the logic for this trip. The development of permissives P-10 and P-8 are shown in Figure 7.2-1, sheet 4.

### **Reactor Trip on Reactor Coolant Pump Underspeed**

This trip protects the reactor core from departure from nucleate boiling in the event of a loss of flow in more than one loop. This protection is provided by tripping the reactor when the speed on two out of the four reactor coolant pumps falls below the setpoint. Loss of flow in more than one loop could be caused by a voltage or frequency transient in the plant power supply such as would occur during a station blackout. It could be caused by inadvertent opening of more than one reactor coolant pump circuit breaker. There is one speed detector mounted on each reactor coolant pump. The trip is automatically blocked when reactor power is below the P-10 permissive setpoint to enhance reliability by preventing unnecessary reactor trips. The trip is automatically reset when reactor power is above the P-10 setpoint.

Figure 7.2-1, sheet 5, shows the logic for this trip. The development of P-10 is shown in Figure 7.2-1, sheet 4.

Reactor coolant pump speed is detected by a probe mounted on the reactor coolant pump frame. The speed signal is transmitted to the protection and safety monitoring system to provide the input to the trip logic function.

The reactor coolant pump underspeed trip provides a direct measurement of the parameter of interest. It permits the plant to ride through many postulated voltage dip transients without reactor trip if safety limits are not violated. Selection of the underspeed trip setpoint and time

response provide for the timely initiation of reactor trip during the complete loss of flow accident and the limiting frequency decay event, consistent with the analysis results reported in Chapter 15.

The reactor coolant pump speed detectors perform their protective function (during the complete loss of flow accident and the limiting frequency decay event) in an environment (temperature, humidity, pressure, chemical, and radiation) that is not changed by the event. Therefore, it is not necessary to impose environmental qualification requirements on these detectors more restrictive than those imposed for use under rated conditions. The reactor coolant pump speed detectors are qualified for use under rated conditions with their performance verified by operation in the plant. The reactor coolant pump speed detectors are qualified to the most limiting vibrations experienced by pump operation.

#### **Reactor Coolant Pump Bearing Water Temperature Trip**

This trip is an anticipatory trip based on the expectation of a complete loss of reactor coolant flow if cooling water is lost to the reactor coolant pumps. This trip occurs before the reactor coolant pumps are tripped on the same measurement.

The reactor trip on high reactor coolant pump bearing water temperature in any single reactor coolant pump is automatically blocked when reactor power is below the P-8 permissive setpoint and the trip on high reactor coolant pump bearing water temperature in multiple pumps is automatically blocked when reactor power is below the P-10 permissive setpoint. This enhances reliability by preventing unnecessary reactor trips. The two parts of the trip are automatically reset when reactor power is above the P-8 and P-10 setpoints.

Figure 7.2-1, sheet 5, shows the logic for this trip.

#### **7.2.1.1.4 Primary Overpressure Trips**

##### **Pressurizer High Pressure Reactor Trip**

This trip protects the reactor coolant system against system overpressure. The same sensors used for the pressurizer low pressure reactor trip are used for the high pressure trip except that separate setpoints are used. The high pressurizer pressure protection trips the reactor when two out of the four pressurizer pressure channels exceed the trip setpoint. There are no interlocks or permissives associated with this trip function.

Figure 7.2-1, sheet 6, shows the logic for this trip.

##### **Pressurizer High Water Level Reactor Trip**

This trip is provided as backup to the high pressurizer pressure reactor trip and serves to prevent water relief through the pressurizer safety valves. The high pressurizer water level protection trips the reactor when two out of the four pressurizer water level channels exceed the trip setpoint. The level signal is compensated for both reference leg temperature and

system pressure. The trip is automatically blocked when reactor power is below the P-10 permissive setpoint. This permits control rod testing with the plant cold and the pressurizer water solid. The trip is automatically reset when reactor power is above the P-10 setpoint.

Figure 7.2-1, sheet 6, shows the logic for the trip. The development of P-10 is shown in Figure 7.2-1, sheet 4.

#### **7.2.1.1.5 Loss of Heat Sink Trip**

##### **Reactor Trip on Low Water Level in any Steam Generator**

This trip protects the reactor from loss of heat sink in the event of a loss of feedwater to the steam generators. The reactor is tripped when two out of the four water level sensors in any steam generator produce signals below the setpoint value.

Figure 7.2-1, sheet 7, shows the logic for the trip. There are no interlocks or permissives associated with this trip.

#### **7.2.1.1.6 Feedwater Isolation Trip**

##### **High-2 Steam Generator Water Level in Any Steam Generator**

This function is an anticipatory trip based on the expectation that a reactor trip would occur after steam generator feedwater is isolated. The plant control system uses a lower steam generator water level setpoint, High-1, to close the feedwater control valves. This provides an interval for operator action to prevent total isolation of the steam generator and a reactor trip before the High-2 setpoint is exceeded. The trip on High-2 steam generator water level may be manually blocked below the P-11 permissive setpoint to allow control rod testing. The trip is automatically reset when the pressurizer pressure is above the P-11 setpoint.

Figure 7.2-1, sheet 10, shows the logic for this trip function.

#### **7.2.1.1.7 Automatic Depressurization Systems Actuation Reactor Trip**

A reactor trip is initiated if an automatic depressurization system actuation occurs either automatically or manually. This provides a reactor trip if the system is depressurized and a trip is not initiated from another source. The automatic depressurization system actuation function is discussed in subsection 7.3.1.2.4.

Manual automatic depressurization system actuation is initiated from either of two sets of controls in the main control room. Operating either of the two sets of controls also sends a reactor trip signal to the reactor trip switchgear breakers. Outputs on the control sets, physically and electrically separated, send their position status to the protection and safety monitoring system. These inputs de-energize the undervoltage trip attachments on the reactor trip breakers, causing them to trip open. Additional outputs interrupt power to the shunt trip

interposing relays, actuating the shunt trip attachments on each reactor trip circuit breaker. These provide a backup to the undervoltage trip of the breakers.

Figure 7.2-1, sheet 15 shows the logic for this trip function. There are no interlocks or bypasses associated with this trip.

#### **7.2.1.1.8 Core Makeup Tank Injection Trip**

A reactor trip is initiated if core makeup injection occurs either automatically or manually. Since core makeup tank injection results in a trip of the reactor coolant pumps, providing a reactor trip upon core makeup tank injection maximizes the margin to DNB at all power levels. The core makeup tank injection function is discussed in subsection 7.3.1.2.3.

Manual core makeup tank injection is initiated from either of two controls in the main control room. Operating either of the two controls also sends a reactor trip signal to the reactor trip switchgear breakers. Outputs on each control, physically and electrically separated, send their position status to the protection and safety monitoring system. These inputs de-energize the undervoltage trip attachments on the reactor trip breakers, causing them to trip open. Additional outputs on each control interrupt power to the shunt trip interposing relays, actuating the shunt trip attachments on each reactor trip circuit breaker. These provide a backup to the undervoltage trip of the breakers.

Figure 7.2-1, sheets 2 and 12 show the logic for this trip function. There are no interlocks or bypasses associated with this trip.

#### **7.2.1.1.9 Reactor Trip on Safeguards Actuation**

A reactor trip is initiated with any signal that causes a safeguards actuation. This reactor trip occurs whether the safeguards actuation is commanded automatically or manually. The means for actuating safeguards automatically are described in Section 7.3. This trip protects the core against a loss of reactor coolant or a steam line rupture.

Manual safeguards actuation is initiated from either of two controls in the main control room. Operating either of the two controls also sends a reactor trip signal to the reactor trip switchgear breakers. Outputs on each control, physically and electrically separated, send their position status to the protection and safety monitoring system. These inputs de-energize the undervoltage trip attachments on the reactor trip breakers, causing them to trip open. Additional outputs on each control interrupt power to the shunt trip interposing relays, actuating the shunt trip attachments on each reactor trip circuit breaker. These provide a backup to the undervoltage trip of the breakers.

Figure 7.2-1, sheets 2 and 11, show the logic for this trip function. There are no interlocks or bypasses associated with this trip.

#### 7.2.1.1.10 Manual Reactor Trip

The manual reactor trip consists of 2 controls in the main control room, either of which trip all 8 of the reactor trip switchgear breakers. The reactor trip circuit breakers contain both undervoltage and shunt trip attachments. The shunt trip acts as a diverse backup to the undervoltage trip in the breakers. Contacts on each control, physically and electrically separated, are in series with the undervoltage trip attachment on the reactor trip breakers, the shunt trip attachment interposing relays, and the power outputs at the integrated protection cabinet. Actuating either control interrupts power from the integrated protection cabinets to the undervoltage trip attachments, releasing them. It also interrupts power to shunt trip interposing relays, actuating the shunt trip attachments. The breakers trip when either the shunt trip attachments are energized or the undervoltage trip attachments are de-energized. Actuating either manual trip control causes each breaker to trip by initiating both of these actions.

Figure 7.2-1, sheets 2 and 13, show the logic for the manual trip. There are no interlocks or bypasses associated with this trip.

#### 7.2.1.1.11 Reactor Trip System Interlocks

The interlocks used in the reactor trip functions are designated as P-xx permissives. Table 7.2-3 provides a listing of these interlocks. These permissives are implemented at the channel level rather than at the logic level because plant availability has been determined to be improved using this technique of integrating permissives into each channel.

Manual blocks to reactor trip are listed on Table 7.2-4 and are described in the following subsections. The source, intermediate, low power, and steam generator water level manual blocks, when used in conjunction with the applicable permissives, are implemented during startup.

##### **Source Range Block (One Control for each Division)**

The source range reactor trip may be manually blocked upon the occurrence of the P-6 permissive and is automatically reset when the permissive condition is not met. The channel is automatically blocked upon the occurrence of the P-10 permissive with the block automatically removed when the P-10 condition is not met. Figure 7.2-1, sheet 3, shows these blocks.

##### **Intermediate Range Block (One Control for each Division)**

The intermediate range reactor trip may be manually blocked upon the occurrence of the P-10 permissive and is automatically reset when the permissive condition is not met. Figure 7.2-1, sheet 3, shows this block.

**Power Range (Low Setpoint) Block (One Control for each Division)**

The power range low setpoint reactor trip may be manually blocked upon the occurrence of the P-10 permissive and is automatically reset when the permissive condition is not met. Figure 7.2-1, sheet 3, shows this block.

**Steam Generator High-2 Water Level Block (One Control for each Division)**

The steam generator High-2 reactor trip may be manually blocked upon the occurrence of the P-11 permissive. This trip function is automatically reset when the permissive condition is not met. Figure 7.2-1, sheets 9, 10, and 11, illustrates the functional logic relating to this function.

**Automatic Rod Withdrawal Block**

An automatic rod withdrawal block occurs on a power range negative flux rate below the P-17 setpoint to block the remaining rods that are not inserted by the rapid power reduction system. Figure 7.2-1, sheet 4, shows this block function. This interlock is generated by the protection and safety monitoring system and forwarded to the plant control system for implementation.

**7.2.1.1.12 Bypasses of Reactor Trip Functions**

Each channel used in reactor trip can be bypassed, as discussed in subsection 7.1.2.10, except for reactor trips resulting from manual initiations. One channel can be bypassed for an indefinite period of time with the normal two-out-of-four trip logic automatically reverting to a two-out-of-three trip logic. Two channels can be bypassed for an indefinite period of time with the trip logic reverting to a one-out-of-two trip logic. Attempting to bypass more than two channels results in a reactor trip. The single failure criterion is met during bypasses.

The bypass is implemented automatically during online testing. Manual bypass is used during repair or maintenance of sensors or channel electronics.

**7.2.1.2 Design Basis for Reactor Trips**

This section provides the design bases information on the reactor trip function, including the information required by Section 3 of IEEE-279-1971. Reactor trip is a protective function generated as part of the protection and safety monitoring system. Those design bases relating to the equipment that initiates and accomplishes reactor trips are contained in subsection 7.1.4.1. The design bases presented here concern the variables monitored for reactor trips, the minimum performance requirements in generating the trips, and the requirements placed on reactor trips during various reactor operating modes.

**7.2.1.2.1 Design Basis: Generating Station Conditions Requiring Reactor Trip (Paragraph 1 of Section 3 of IEEE-279-1971)**

The generating station conditions requiring protective actions are analyzed in Chapter 15. Conditions that result in a reactor trip are listed in Table 15.0-6. This table correlates the accident conditions (II, III, or IV events) to each reactor trip.

**7.2.1.2.2 Design Basis: Variables, Levels, Ranges, and Accuracies Used in Reactor Trip Functions (Paragraphs 2, 5, 6, and 9 of Section 3 of IEEE-279-1971)**

The variables monitored for reactor trips are:

- Neutron flux
- Reactor coolant pump bearing water temperature
- Pressurizer pressure
- Water level in the pressurizer
- Reactor coolant flow in each loop
- Speed of each reactor coolant pump
- Water level in each steam generator
- Reactor coolant inlet temperature ( $T_{\text{cold}}$ ) in each loop
- Reactor coolant outlet temperature ( $T_{\text{hot}}$ ) in each loop
- Position of each manual reactor trip switch

The ranges, accuracies, and response times for each variable are listed on Table 7.2-1.

A discussion on levels that require reactor trip is contained in subsection 7.2.1.1.

The allowable values for the limiting safety-related system settings and the trip setpoint for reactor trips are in the technical specifications (Chapter 16).

**7.2.1.2.3 Design Basis: Spatially Dependent Parameters Used in Reactor Trip (Paragraph 3 of Section 3 of IEEE-279-1971)**

Radially varying coolant inlet temperature is not a concern since the resistance temperature detectors are located downstream of the reactor coolant pumps. The pumps provide mixing of the coolant so that radial temperature variations do not exist.

Radial neutron flux is not a spatially dependent concern because of core radial symmetry. Axial variation in neutron flux is used for calculations involving overtemperature and overpower  $\Delta T$ . Excore detectors furnish this axially-dependent information to the overtemperature and overpower calculators. See subsection 7.2.1.1.3.

#### **7.2.1.2.4 Design Basis: Operational Limits for Variables in Various Reactor Operating Modes (Paragraph 4 of Section 3 of IEEE-279-1971)**

During startup or shutdown, reactor trips are provided for three ranges of neutron flux (source, intermediate, and power range). The source range, intermediate range, and power range (low setpoint) trips are manually blocked when the appropriate power escalation permissives are present. The trips are automatically reset during power de-escalation. Subsection 7.2.1.1.1 describes these reactor trips. Their interlocks are described in subsection 7.2.1.1.11.

During testing or maintenance, functions are provided to bypass a channel monitoring a variable for reactor trip. Although no setpoints need to be changed for bypassing, the coincidence logic is automatically adjusted as described in subsection 7.2.1.1.12. The logic provides that the remaining redundant channels for that variable meet the single failure criterion. The two-out-of-four logic is automatically reinstated when the bypass is removed.

#### **7.2.1.2.5 Design Basis: Reactor Trips for Malfunctions, Accidents, Natural Phenomena, or Credible Events (Paragraph 8 of Section 3 of IEEE-279-1971)**

There are no reactor trip functions that directly shutdown the reactor on occurrence of either natural phenomena (such as seismic flood or wind) or internal events (such as fire or pipe whip). The operator can trip the reactor at any time by actuating the manual reactor trip.

Functional diversity is used to determine the reactor trips for accident conditions. Generally, two or more reactor trips occur for the transients analyzed in the accident analyses.

For example, protection is provided for the complete loss of coolant flow event by low reactor coolant pump speed and by low coolant flow reactor trips. Complete reliance is not made on a single reactor trip terminating a given event. Table 15.0-6 lists the reactor trips and the conditions which normally result in each trip.

Redundancy provides confidence that reactor trips are generated on demand, even when the protection system is degraded by a single failure. Reactor trips are four-way redundant. The single failure criterion is met even if one or two channels are bypassed, as discussed in subsection 7.2.1.1.12. The reactor is tripped automatically if an attempt is made to bypass three or more channels.

#### **7.2.1.3 System Drawings**

Functional diagrams of the reactor trip function are provided in Figure 7.2-1.

#### **7.2.2 Analyses**

##### **7.2.2.1 Failure Modes and Effects Analysis (FMEA)**

A failure modes and effects analysis is performed on the protection and safety monitoring system. Through the process of examining the feasible failure modes, it is concluded that the

AP600 protection system maintains safety functions during single point failures. The failure modes and effects analysis is documented in Reference 1.

#### **7.2.2.2 Conformance of the Reactor Trip Function to Applicable Criteria**

Reactor trip is a protective function generated by the AP600 protection and safety monitoring system. Requirements addressing equipment in the protection and safety monitoring system are presented in subsection 7.1.4.2. The discussions presented in this subsection address only the functional aspects of reactor trip.

##### **7.2.2.2.1 Conformance to the General Functional Requirements for Reactor Trip (Paragraph 4.1 of IEEE-279-1971, GDC-13, GDC-20)**

The protection and safety monitoring system initiates a reactor trip whenever a condition monitored by the system reaches a preset level. The reactor trips are listed in Table 7.2-2 and are discussed in subsection 7.2.1.1. The variables which are monitored for these trips are listed in subsection 7.2.1.2.2. Table 7.2-1 lists the ranges, accuracies, and response times for these variables. The reactor trip setpoints are listed in the technical specifications, Chapter 16.

As discussed in subsection 7.1.4.2.1, the setpoints set into the protection and safety monitoring system equipment provide a margin to the safety limits which are assumed in the accident analyses. The safety limits are based on mechanical or hydraulic limitations of equipment or on heat transfer characteristics of the reactor core. While most setpoints used for reactor trip are fixed, there are continuously calculated setpoints for the overtemperature and overpower  $\Delta T$  trips. Setpoints for reactor trip are selected on the basis of engineering design and safety studies. The setpoints provide a margin to allow for uncertainties and instrument errors.

The overtemperature and overpower conditions are not a directly measurable quantities. However, the process variables that determine overtemperature and overpower conditions are sensed and evaluated. Small isolated changes in various process variables may not individually result in reaching a core safety limit. However, the combined variations over time may cause the overtemperature or overpower limit to be exceeded. The design concept for reactor trips takes cognizance of this situation by providing reactor trips associated with individual process variables in addition to the overtemperature and overpower  $\Delta T$  safety limit trips. Process variable trips prevent reactor operation when a monitored value reaches a core or safety limit. Overtemperature and overpower  $\Delta T$  trips provide protection for slow transients. Other trips, such as low flow or high flux, trip the reactor for rapid changes in flow or flux respectively.

Table 15.0-6 summarizes events which normally result in reactor trips.

##### **7.2.2.2.2 Conformance to the Single Failure Criterion for Reactor Trip (Paragraph 4.2 of IEEE 279-1971, IEEE 379-1972)**

A single failure in the protection and safety monitoring system or the reactor trip actuation divisions does not prevent a reactor trip, even when the reactor trip channels are bypassed for

test or maintenance. Conformance of the equipment to this requirement is discussed in subsection 7.1.4.2.2. In addition to the redundancy of equipment, diversity of reactor trip functions is incorporated. Most Condition II, III, or IV events requiring a reactor trip are protected by trips from diverse parameters. For example, reactor trip, because of an uncontrolled rod cluster control assembly bank withdrawal at power, may occur on power range high neutron flux, overtemperature, overpower, pressurizer high pressure or pressurizer high water level. Reactor trip on complete loss of reactor coolant flow may occur on low flow or from the diverse parameter of low reactor coolant pump speed.

#### **7.2.2.2.3 Conformance to the Requirements Covering Control and Reactor Trip Interactions (Paragraph 4.7 of IEEE 279-1971, GDC-24)**

The AP600 is designed to permit maneuvering of the plant in response to normal power generation demands without causing a reactor trip. The plant control system attempts to keep the reactor operating away from any safety limit. However, the selection of the reactor trip setpoints does not take credit for such control actions. The accident analyses in Chapter 15 assumes that the plant is at normal operation commensurate with the operating mode at the onset of the accident. If a control system action leads to more conservative results, that assumption is made. If failure of a control system to work leads to more conservative results, that assumption is made. In this way, reactor trips do not depend on control system actions.

As stated in subsection 7.7.1.12, it is considered advantageous to use certain protection data for control functions. Isolation devices are incorporated into these data links to prevent control system failures from degrading the performance of the protection system.

Failures in a protection channel monitoring a variable that is also used for control does not result in control system actions requiring protection by the redundant channels monitoring that variable. This is discussed in subsection 7.1.4.2.7.

#### **7.2.2.2.4 Conformance to Requirements on the Derivation of System Inputs for Reactor Trip (Paragraph 4.8 of IEEE 279-1971)**

To the extent feasible, inputs used for reactor trip are derived from signals that are direct measurements of the desired variables. Two exceptions exist, overtemperature and overpower, which cannot be directly measured. The process variables that do affect these parameters can be measured and they are used to continuously calculate the setpoints.

The overtemperature  $\Delta T$  trip setpoint is calculated from pressurizer pressure, reactor coolant temperature, and nuclear axial power shape. The setpoint is compared against measured  $\Delta T$ .

Overpower  $\Delta T$  is calculated from reactor coolant temperature and the nuclear axial power shape in the core. This value is compared against measured  $\Delta T$ .

The overtemperature and overpower  $\Delta T$  trips are described in subsection 7.2.1.1.3.

**7.2.2.2.5 Conformance to Requirements on Bypassing of Reactor Trip Functions (Paragraph 4.11, 4.12, 4.13, and 4.14 of IEEE 279-1971)**

With the exception of the manual reactor trips, reactor trip channels and the reactor trip actuation divisions are permitted to be bypassed as described in subsections 7.1.4.2.11 through 7.1.4.2.14. Paragraphs 4.11 through 4.14 of IEEE 279-1971 are discussed in those subsections.

Operating bypasses for reactor trips are described in subsection 7.2.1.1.11.

**7.2.2.2.6 Conformance to Requirements on Multiple Setpoints Used for Reactor Trips (Paragraph 4.15 of IEEE 279-1971)**

Multiple setpoints are not used for reactor trips on AP600.

**7.2.2.2.7 Conformance to the Requirement for Completion of Reactor Trip Once Initiated (Paragraph 4.16 of IEEE 279-1971, Regulatory Guide 1.62)**

Once initiated, reactor trips proceed to completion. Return to operation requires deliberate operator action to reset the reactor trip circuit breakers that are opened by the reactor trip signal. The circuit breakers cannot be closed while the reactor trip signals are present from the respective integrated protection cabinets. A manual control is provided in the main control room for resetting the reactor trip signals in each integrated protection cabinet following a reactor trip. Refer also to subsection 7.1.4.2.16.

**7.2.2.2.8 Conformance to the Requirement to Provide for Manual Initiation of Reactor Trip (Paragraph 4.17 of IEEE 279-1971, Regulatory Guide 1.62)**

The reactor is tripped by actuating one of two manual reactor trip controls from the main control room. The reactor is also tripped upon manual actuation of the automatic depressurization system, manual core makeup tank injection, or upon manual safeguards actuation. These reactor trips are described in subsections 7.2.1.1.7, 7.2.1.1.8, 7.2.1.1.9, and 7.2.1.1.10. Refer also to subsection 7.1.4.2.17.

**7.2.3 Combined License Information**

This section has no requirement for information to be provided in support of the Combined License application.

**7.2.4 References**

1. WCAP-13662 (Nonproprietary), "FMEA of Advanced Passive Plant Protection System," Revision 1, June 1998.

Table 7.2-1 (Sheet 1 of 3)

**REACTOR TRIP VARIABLES, LIMITS, RANGES, AND ACCURACIES  
(DESIGN BASIS FOR REACTOR TRIP)  
(NOMINAL)**

Protective Functions	Variables To Be Monitored	Range of Variables	Typical Accuracy	Typical Response Time (Sec) <sup>(1)</sup>
Source Range High Neutron Flux	Neutron flux	6 decades of neutron flux: 1 to 10 <sup>6</sup> counts per second	±11.0% of span	0.2
Intermediate Range High Neutron Flux	Neutron flux	8 decades of neutron flux overlapping source range by 2 decades and including 100% power	±12.5% of span	0.2
Power Range High Neutron Flux (Low Setting)	Neutron flux	1 to 120% of full power	±7.0% of span	0.2
Power Range High Neutron Flux (Hi-Setting)	Neutron flux	1 to 120% of full power	±7.0% of span	0.2
Power Range High Positive Flux Rate	Neutron flux	1 to 120% of full power	±1.0% of span	0.2 (step input of 20% full power)
Overtemperature ΔT			±11.5% of ΔT span	7.0 (T <sub>avg</sub> or ΔT)
	Reactor coolant inlet temp. (T <sub>cold</sub> )	490 to 610°F	±2.5% of span	6.0
	Reactor coolant outlet temp. (T <sub>hot</sub> )	530 to 650°F	±3.5% of span	6.0
	Pressurizer pressure	1700 to 2500 psig	±2.5% of span	1.5

Table 7.2-1 (Sheet 2 of 3)

**REACTOR TRIP VARIABLES, LIMITS, RANGES, AND ACCURACIES  
(DESIGN BASIS FOR REACTOR TRIP)  
(NOMINAL)**

Protective Functions	Variables To Be Monitored	Range of Variables	Typical Accuracy	Typical Response Time (Sec) <sup>(1)</sup>
Overpower $\Delta T$	Excure detector flux (power range)	-60 to +60% ( $\Delta\phi$ )		2.0
			$\pm 3.5\%$ of $\Delta T$ span	7.0 ( $T_{avg}$ or $\Delta T$ )
	Reactor coolant inlet temp. ( $T_{cold}$ )	490 to 610°F	$\pm 2.5\%$ of span	6.0
	Reactor coolant outlet temp. ( $T_{hot}$ )	530 to 650°F	$\pm 3.5\%$ of span	6.0
	Excure detector flux (power range)	-60 to +60% ( $\Delta\phi$ )	$\pm 7.0\%$ of span	0.2
Pressurizer Low Pressure	Pressurizer pressure	1700 to 2500 psig	$\pm 2.5\%$ of span	1.2
Pressurizer High Pressure	Pressurizer pressure	1700 to 2500 psig	$\pm 2.5\%$ of span	1.2
Pressurizer High Water Level	Pressurizer water level	0-100% of entire cylindrical portion of pressurizer	$\pm 2.25\%$ of span	1.6
Low Reactor Coolant Flow	Coolant flow	0 to 120% of rated flow	$\pm 3.0\%$ of span	1.6

Table 7.2-1 (Sheet 3 of 3)

**REACTOR TRIP VARIABLES, LIMITS, RANGES, AND ACCURACIES  
(DESIGN BASIS FOR REACTOR TRIP)  
(NOMINAL)**

Protective Functions	Variables To Be Monitored	Range of Variables	Typical Accuracy	Typical Response Time (Sec) <sup>(1)</sup>
Low Reactor Coolant Pump Speed	Pump speed	0 to 120% of rated speed	±0.2% of span	0.42 <sup>(2)</sup>
Low Steam Generator Water Level	Steam generator water level	0-100% of span (narrow range taps)	±2.0% of span	1.6
High Steam Generator Water Level	Steam generator water level	0-100% of span (narrow range taps)	±2.0% of span	1.6
Reactor Coolant Pump High Bearing Water Temperature	Reactor coolant pump bearing water temperature	70-450°F	±1.0% of span	2.0
Automatic or Manual Safeguards Actuation	See Table 7.3-4	See Table 7.3-4	See Table 7.3-4	See Table 7.3-4
Manual Reactor Trip	N/A	N/A	N/A	N/A
Automatic or Manual Depressurization System Actuation	See Table 7.3-4	See Table 7.3-4	See Table 7.3-4	See Table 7.3-4
Automatic or Manual Core Makeup Tank Injection	See Table 7.3-4	See Table 7.3-4	See Table 7.3-4	See Table 7.3-4
Reference Leg Temperature Compensation <sup>(3)</sup>	Ref. leg temperature	100-700°F	± 3.0% of span	1.5

1. Time from step change of the variable being monitored from 5% below to 5% above the setpoint. Value defined until the signal reaches the reactor trip breakers.
2. The time delay is the time to generate a trip after the pump speed has reached the trip setpoint during a speed decrease which is linear with respect to time.
3. This temperature compensation is not a protective function per se; however, these signals provide density compensation used in the pressurizer high water level protective function.

Table 7.2-2 (Sheet 1 of 2)

<b>REACTOR TRIPS</b>				
<b>Reactor Trip<sup>(1)</sup></b>	<b>No. of Channels</b>	<b>Division Trip Logic</b>	<b>Bypass Logic</b>	<b>Permissives and Interlocks (See Table 7.2-3)</b>
Source Range Reactor Trip	4	2/4	Yes <sup>(2)</sup>	P-6, P-10
Intermediate Range Reactor	4	2/4	Yes <sup>(2)</sup>	P-10
Power Range (Low Setpoint) Trip	4	2/4	Yes <sup>(2)</sup>	P-10
Power Range (High Setpoint) Trip	4	2/4	Yes <sup>(2)</sup>	----
High Positive Flux Rate Trip	4	2/4	Yes <sup>(2)</sup>	----
Reactor Coolant Pump Bearing Water	16 (4/pump)	2/4 in any single pump	Yes <sup>(2)</sup>	P-8
		2/4 in 2/4 pumps	Yes <sup>(2)</sup>	P-10
Overtemperature $\Delta T$	4 (2/loop)	2/4	Yes <sup>(2)</sup>	----
Overpower $\Delta T$	4 (2/loop)	2/4	Yes <sup>(2)</sup>	----
Pressurizer Low Pressure Trip	4	2/4	Yes <sup>(2)</sup>	P-10
Pressurizer High Pressure Trip	4	2/4	Yes <sup>(2)</sup>	----
Pressurizer High Water Level Trip	4	2/4	Yes <sup>(2)</sup>	P-10

Table 7.2-2 (Sheet 2 of 2)

## REACTOR TRIPS

Reactor Trip <sup>(1)</sup>	No. of Channels	Division Trip Logic:	Bypass Logic:	Permissives and Interlocks (See Table 7.2-3)
Low Reactor Coolant Flow	16 (4/cold leg)	2/4 in any single cold leg	Yes <sup>(2)</sup>	P-8
		2/4 in 2/4 cold legs	Yes <sup>(2)</sup>	P-10
Reactor Coolant Pump Underspeed	4 (1/pump)	2/4	Yes <sup>(2)</sup>	P-10
Low Steam Generator Water Level	4/steam generator	2/4 in any steam generator	Yes <sup>(2)</sup>	----
High-2 Steam Generator Water Level	4/steam generator	2/4 in any steam generator	Yes <sup>(2)</sup>	P-11
Automatic Safeguards Actuation	4	2/4	Yes <sup>(2)</sup>	----
Automatic Depressurization System Actuation	4	2/4	Yes <sup>(2)</sup>	----
Automatic Core Makeup Tank Injection	4	2/4	Yes <sup>(2)</sup>	----
Manual Safeguards Actuation	2 switches	1/2 switches	No	----
Manual Depressurization System Actuation	4 switches	2/4 switches	No	----
Manual Core Makeup Tank Injection	2 switches	1/2 switches	No	----
Manual Reactor Trip	2 switches	1/2 switches	No	----

1. Reactor Trip divisions are also bypassed with the logic as defined in 2. below.
  2. Bypass Logic = 2/4 with no bypasses; 2/3 with 1 bypass; 1/2 alarmed with 2 bypasses; automatic trip with three or four bypasses.
- No permissive or interlock.

Table 7.2-3 (Sheet 1 of 2)

## REACTOR TRIP PERMISSIVES AND INTERLOCKS

Designation	Derivation	Function
P-6	Intermediate range neutron flux above setpoint	Allows manual block of source range reactor trip
$\overline{P-6}$	Intermediate range neutron flux below setpoint	Automatically resets source range reactor trip
P-8	Power range nuclear power above setpoint	Permits reactor trip on low flow or reactor coolant pump high bearing water temperature in a single loop
$\overline{P-8}$	Power range nuclear power below setpoint	Blocks reactor trip on low coolant flow or reactor coolant pump high bearing water temperature in a single loop
P-10	Power range nuclear power above setpoint	<ul style="list-style-type: none"> <li>(a) Allows manual block of power range (low setpoint) reactor trip</li> <li>(b) Allows manual block of intermediate range reactor trip</li> <li>(c) Automatically blocks source range reactor trip (back-up to P-6)</li> <li>(d) Allows reactor trip on low coolant flow or reactor coolant pump high bearing water temperature in multiple loops</li> <li>(e) Allows reactor trip on low reactor coolant pump speed</li> <li>(f) Allows reactor trip on high pressurizer water level</li> <li>(g) Allows reactor trip on low pressurizer pressure</li> </ul>

Table 7.2-3 (Sheet 2 of 2)

## REACTOR TRIP PERMISSIVES AND INTERLOCKS

Designation	Derivation	Function
$\overline{P-10}$	Power range nuclear power below setpoint	<ul style="list-style-type: none"> <li>(a) Prevents the block of power range (low setpoint) reactor trip</li> <li>(b) Prevents the block of intermediate range reactor trip</li> <li>(c) Permits manual reset of each source range channel reactor trip</li> <li>(d) Blocks reactor trip on low coolant flow or reactor coolant pump high bearing water temperature in multiple loops</li> <li>(e) Blocks reactor trip on low reactor coolant pump speed</li> <li>(f) Blocks reactor trip on high pressurizer water level</li> <li>(g) Blocks reactor trip on low pressurizer pressure</li> </ul>
P-11	Pressurizer pressure below setpoint	Allows manual block of High-2 steam generator water level reactor trip
$\overline{P-11}$	Pressurizer pressure above setpoint	Automatically resets High-2 steam generator water level reactor trip
P-17 <sup>(1)</sup>	Power range nuclear power negative rate below setpoint	Blocks automatic rod withdrawal
$\overline{P-17}^{(1)}$	Power range nuclear power negative rate above setpoint	Permits automatic rod withdrawal

**Note:**

1. This interlock does not meet the July 1993 Final Policy Statement on Technical Specification Improvements criteria and is not included in the Technical Specifications.

Table 7.2-4

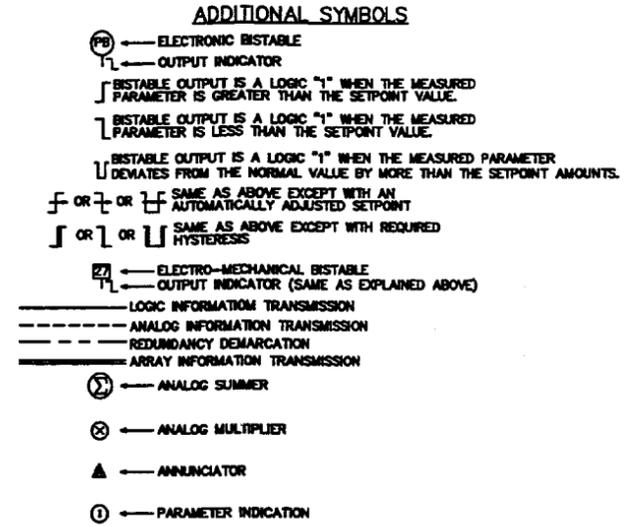
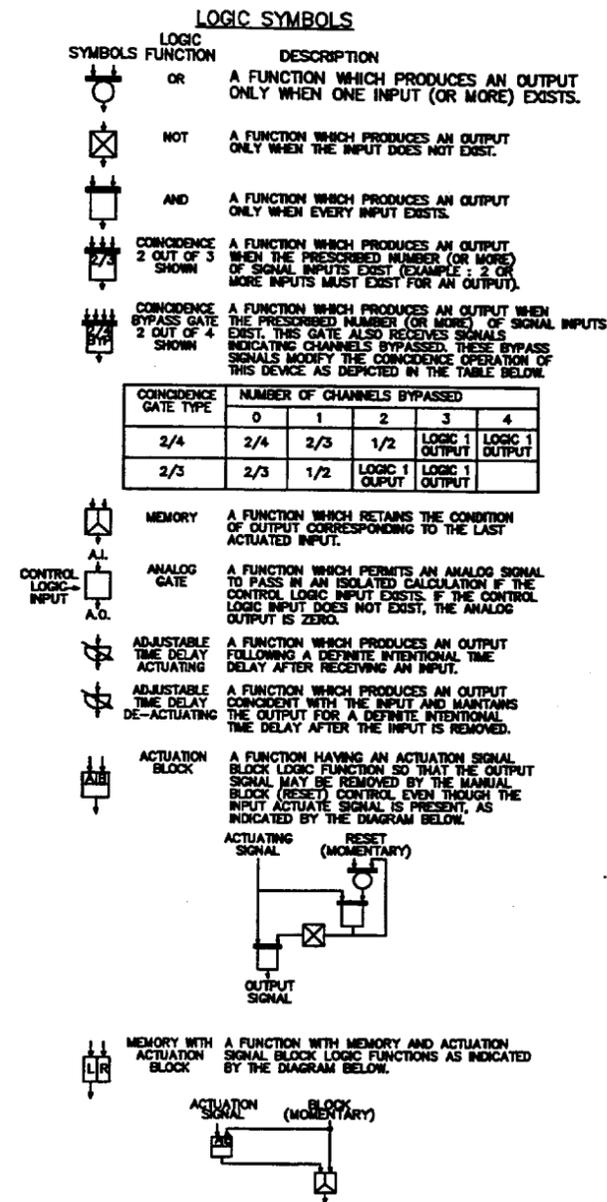
## SYSTEM-LEVEL MANUAL INPUTS TO THE REACTOR TRIP FUNCTIONS

Manual Control	To Divisions				Figure 7.2-1 Sheet
	A	B	C	D	
Manual Reactor Trip Control #1	A	B	C	D	2 & 13
Manual Reactor Trip Control #2	A	B	C	D	2 & 13
Reactor Trip Reset	A	B	C	D	13
Source Range Block, Division A	A				3
Source Range Block, Division B		B			3
Source Range Block, Division C			C		3
Source Range Block, Division D				D	3
Intermediate Range Block, Division A	A				3
Intermediate Range Block, Division B		B			3
Intermediate Range Block, Division C			C		3
Intermediate Range Block, Division D				D	3
Power Range Block (Low Setpoint), Division A	A				3
Power Range Block (Low Setpoint), Division B		B			3
Power Range Block (Low Setpoint), Division C			C		3
Power Range Block (Low Setpoint), Division D				D	3
Manual Safeguards Actuation Control #1	A	B	C	D	2 & 11
Manual Safeguards Actuation Control #2	A	B	C	D	2 & 11
Manual Core Makeup Tank Injection Control #1	A	B	C	D	2 & 12
Manual Core Makeup Tank Injection Control #2	A	B	C	D	2 & 12
Manual Depressurization System Actuation Control #1 & 2	A	B	C	D	2 & 15
Manual Depressurization System Actuation Controls #3 & 4	A	B	C	D	2 & 15

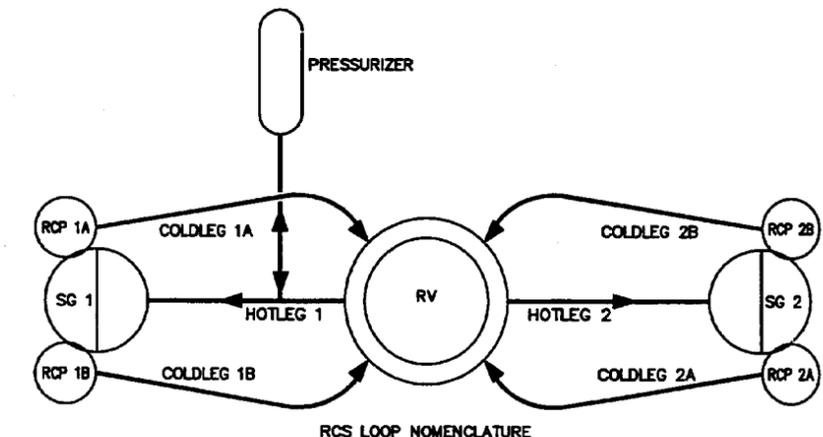
**Note:**

Controls are located in the main control room except as noted on the applicable sheet of Figure 7.2-1.

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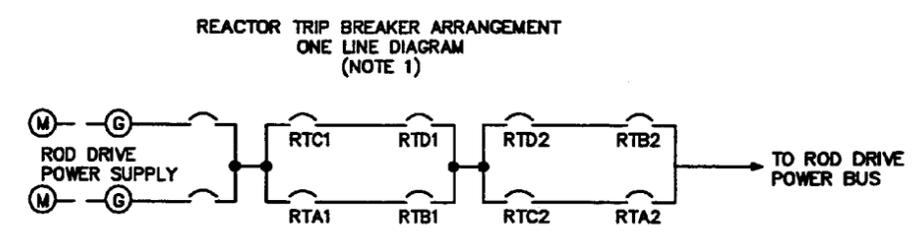
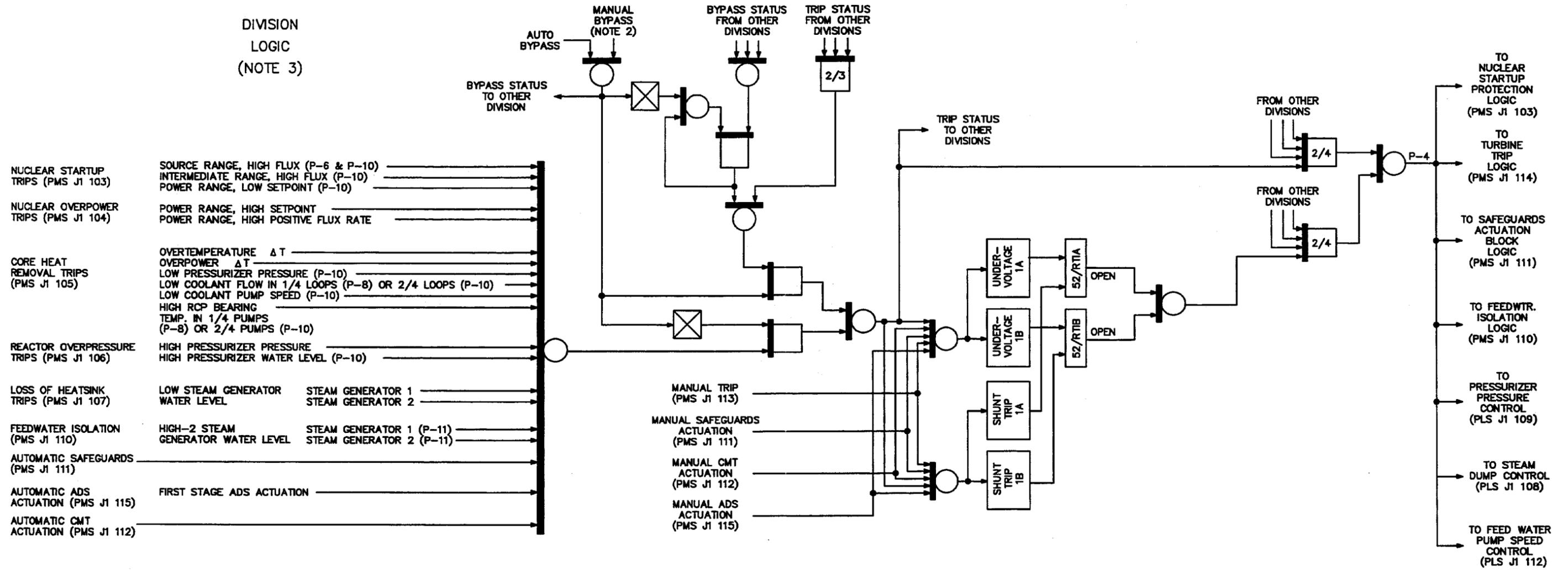
- ### DEVICE FUNCTION LETTERS AND NUMBERS
- |                                 |                            |
|---------------------------------|----------------------------|
| AS SEISMIC ACCELERATION CHANNEL | 20 ELECTRIC OPERATED VALVE |
| FB FLOW CHANNEL                 | 33 POSITION SWITCH         |
| PS POWER CHANNEL                | 52 AC CIRCUIT BREAKER      |
| LB LEVEL CHANNEL                | 63 PRESSURE SWITCH         |
| NC NUCLEAR CHANNEL              | 71 LEVEL SWITCH            |
| PB PRESSURE CHANNEL             | 80 FLOW SWITCH             |
| RC RADIATION CHANNEL            |                            |
| SB SPEED CHANNEL                |                            |
| TB TEMPERATURE CHANNEL          |                            |
| ZB POSITION CHANNEL             |                            |



FOR SIGNALS DERIVED FROM SENSORS IN THE HOT LEG AND COLD LEG (SUCH AS T<sub>AVG</sub>) THE FOLLOWING NOTATION WILL BE USED.

DEFINITION	LOOP
HOT LEG 1 & COLD LEG 1A	LOOP 1A
HOT LEG 1 & COLD LEG 1B	LOOP 1B
HOT LEG 2 & COLD LEG 2A	LOOP 2A
HOT LEG 2 & COLD LEG 2B	LOOP 2B

Figure 7.2-1 (Sheet 1 of 20)



- NOTES:
- TRIPPING ANY TWO OR MORE BREAKER SETS, BOTH 1 AND 2 BREAKERS DE-ENERGIZE THE ROD DRIVES. THE FULL LENGTH CONTROL RODS AND SHUTDOWN RODS ARE THEREBY RELEASED FOR GRAVITY INSERTION INTO THE REACTOR CORE.
  - FOUR CONTROLS, ONE FOR EACH PROTECTION DIVISION.
  - THIS CIRCUITRY IS FOURFOLD REDUNDANT. ONLY ONE DIVISION IS SHOWN WHICH IS TYPICAL OF THE OTHER DIVISIONS.

Figure 7.2-1 (Sheet 2 of 20)

Functional Diagram Reactor Trip Functions

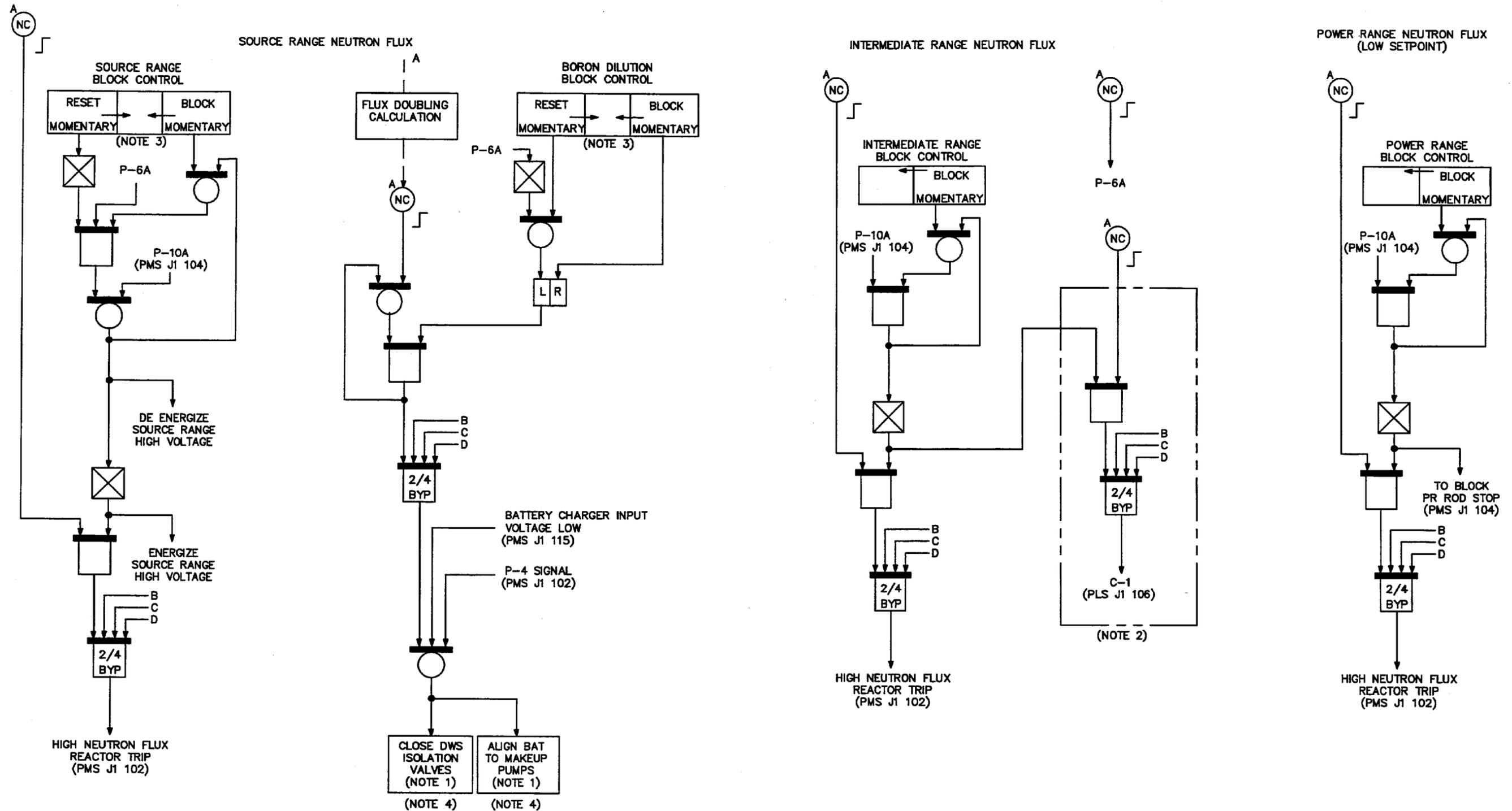
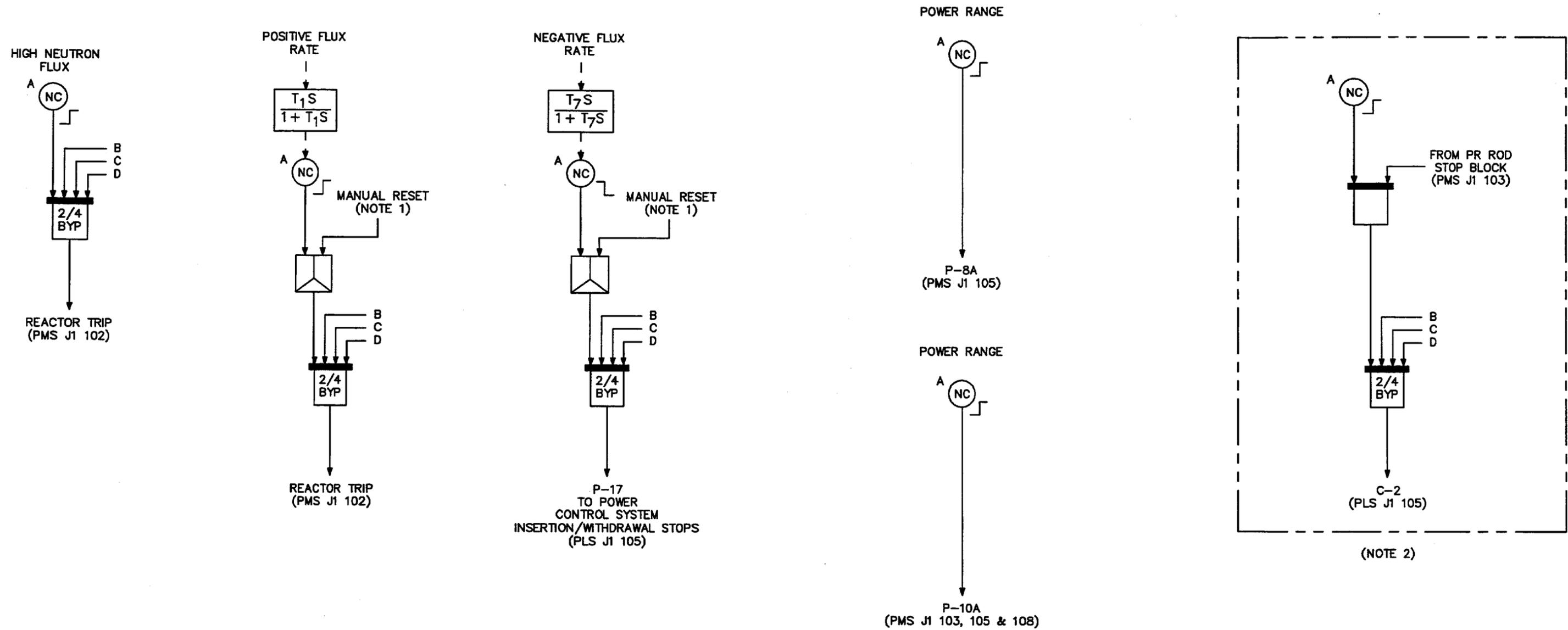


Figure 7.2-1 (Sheet 3 of 20)

Functional Diagram  
Nuclear Startup Protection



NOTES:

1. FOUR MOMENTARY CONTROLS, ONE FOR EACH DIVISION.
2. THIS CIRCUIT DOES NOT PERFORM A SAFETY-RELATED FUNCTION.

Figure 7.2-1 (Sheet 4 of 20)

Functional Diagram  
Nuclear Overpower Protection

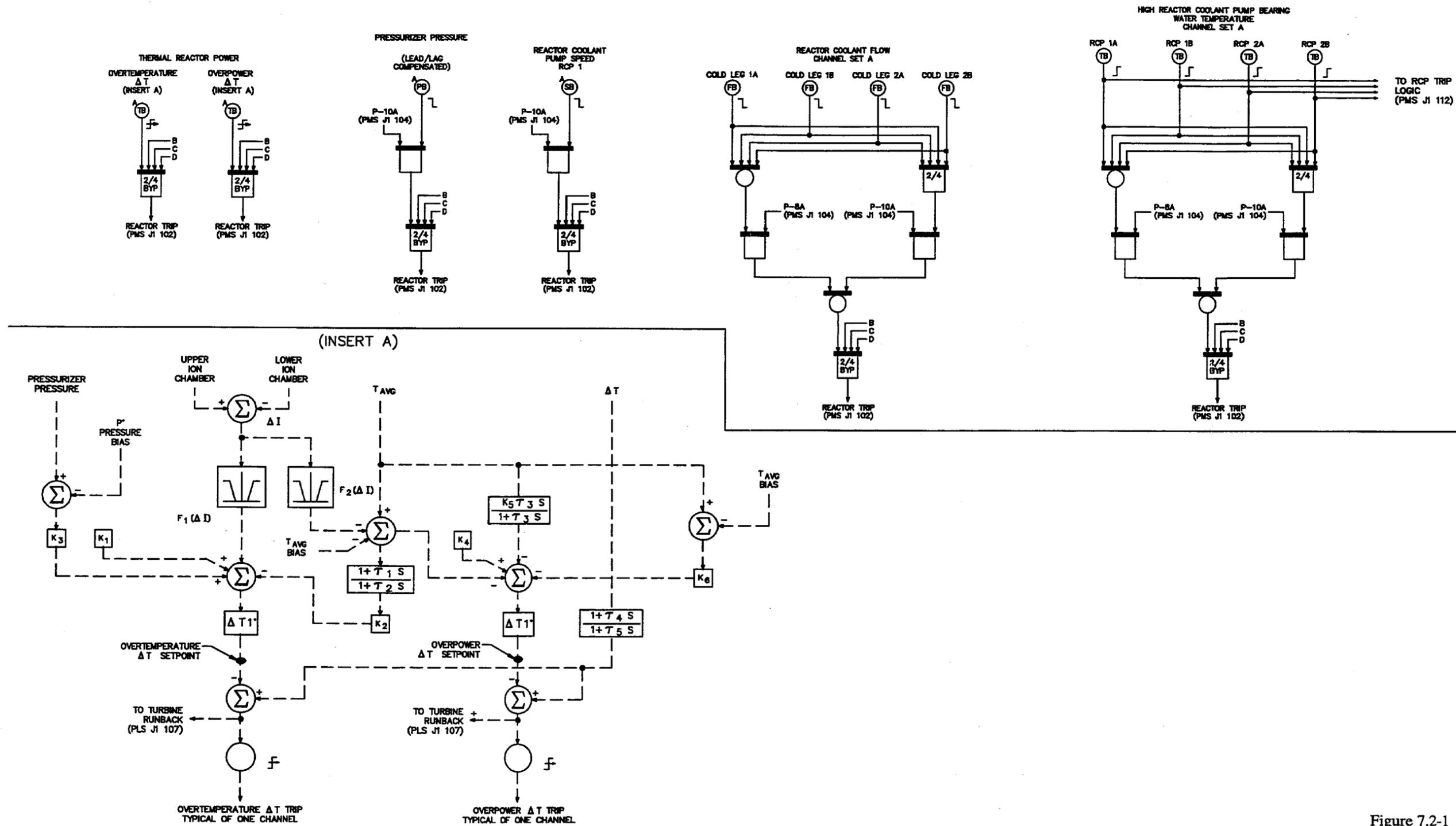


Figure 7.2-1 (Sheet 5 of 20)

Functional Diagrams  
Core Heat Removal Protection

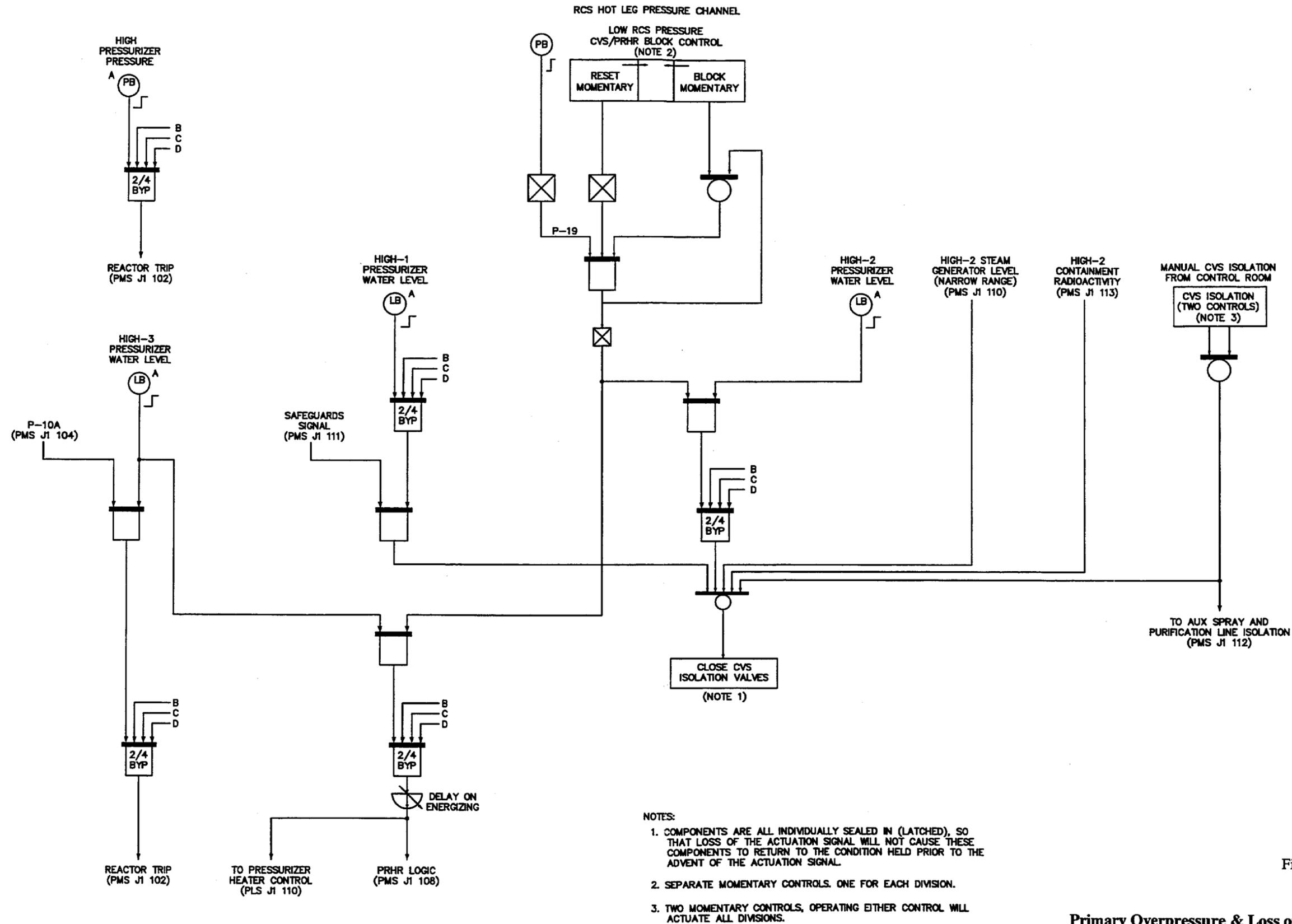


Figure 7.2-1 (Sheet 6 of 20)

**Functional Diagram  
Primary Overpressure & Loss of Heat Sink Protection**

LOW STEAM GENERATOR WATER LEVEL (NARROW RANGE)

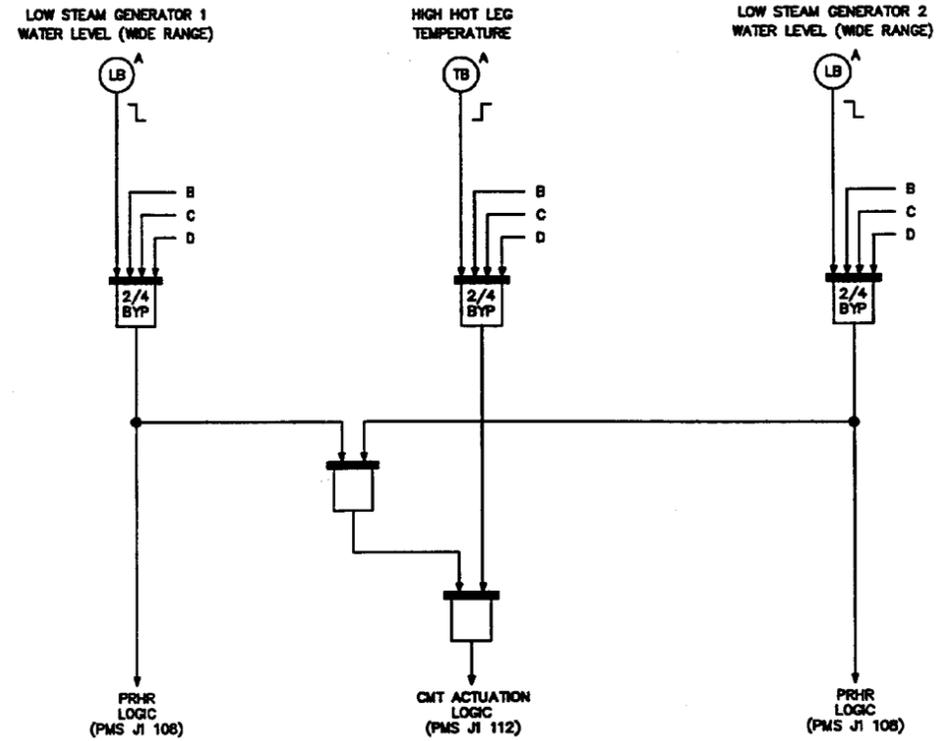
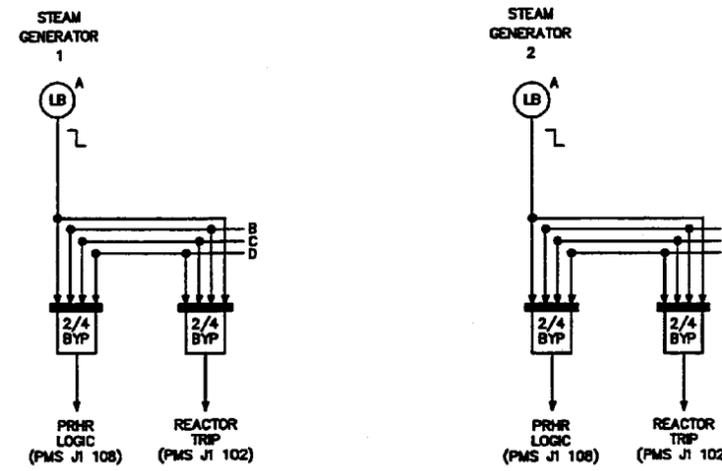


Figure 7.2-1 (Sheet 7 of 20)

Functional Diagrams  
Loss of Heat Sink Protection

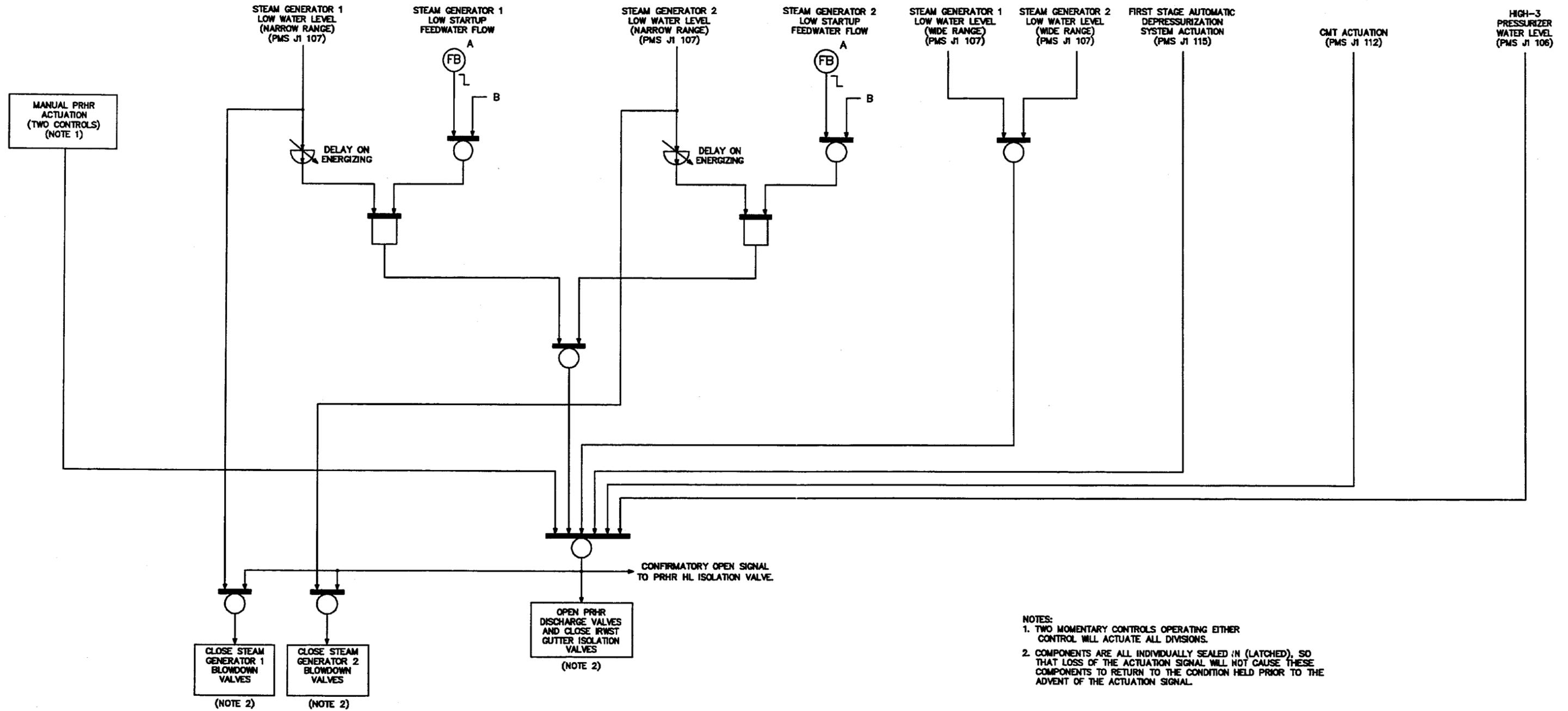
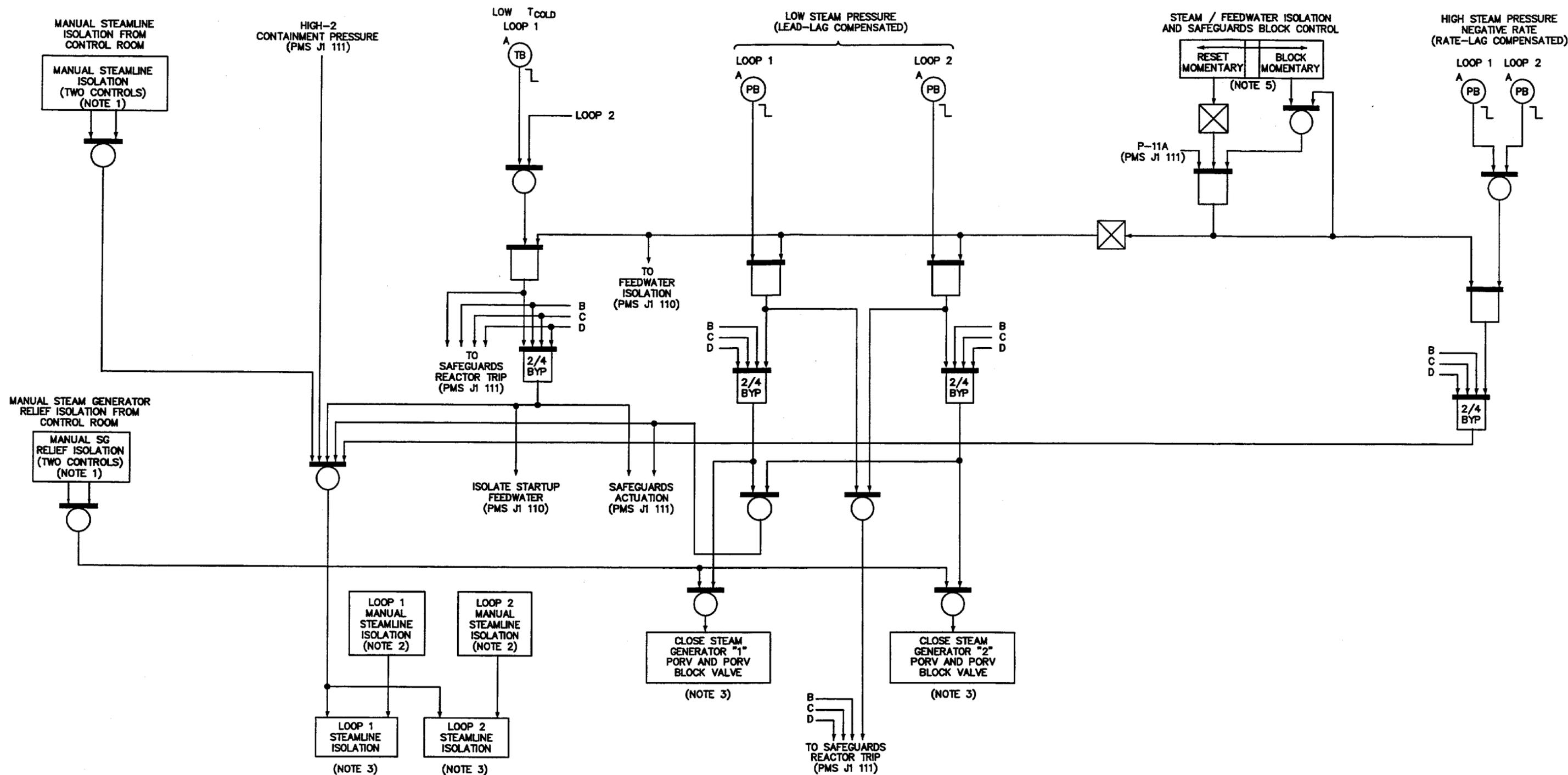


Figure 7.2-1 (Sheet 8 of 20)

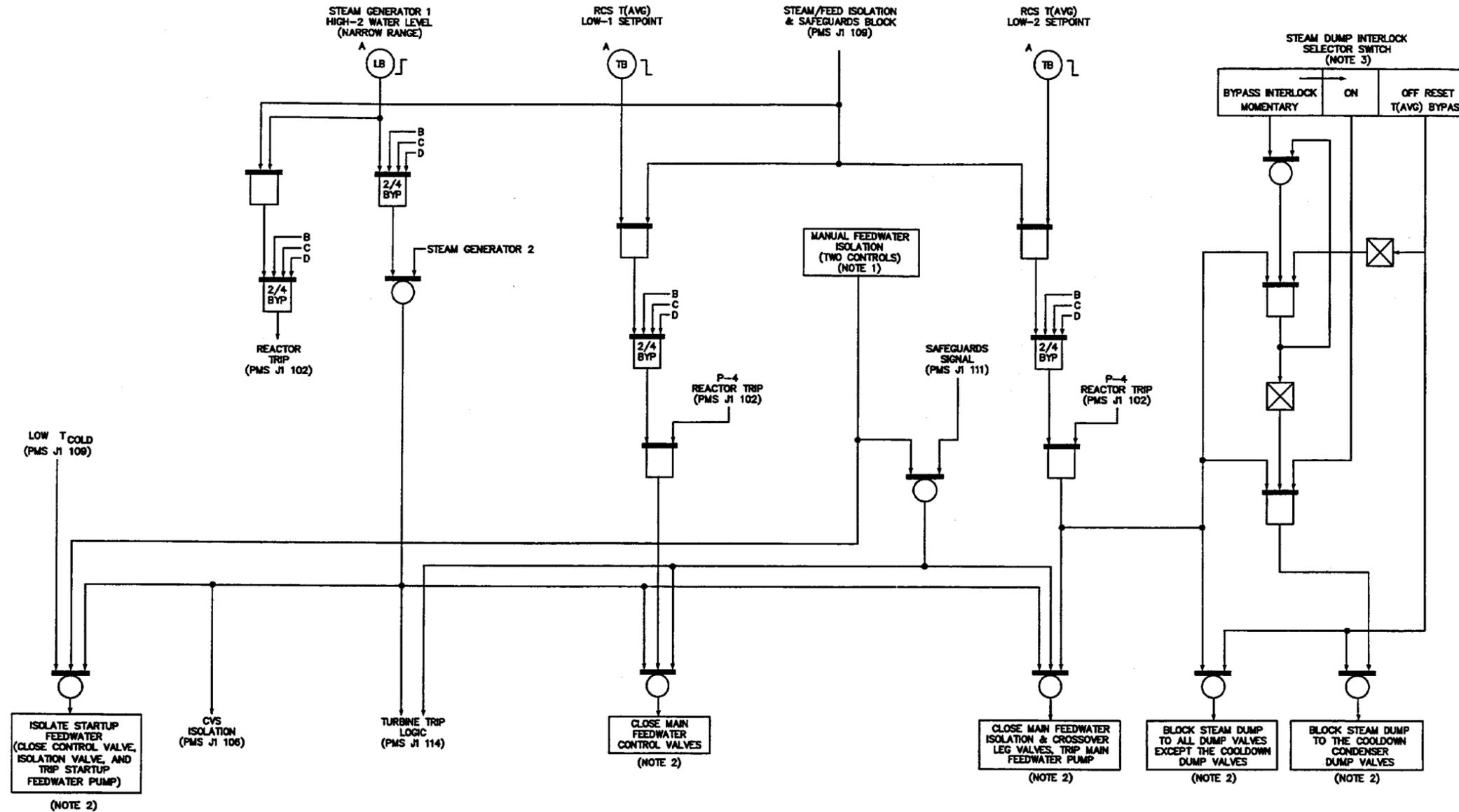
Functional Diagram  
Loss of Heat Sink Protection



- NOTES:
1. TWO MOMENTARY CONTROLS OPERATING EITHER CONTROL WILL ACTIVATE ALL DIVISIONS.
  2. THESE CONTROLS ARE NOT REDUNDANT.
  3. COMPONENTS ARE ALL INDIVIDUALLY SEALED IN (LATCHED), SO THAT LOSS OF THE ACTUATION SIGNAL WILL NOT CAUSE THESE COMPONENTS TO RETURN TO THE CONDITION HELD PRIOR TO THE ADVENT OF THE ACTUATION SIGNAL.

Figure 7.2-1 (Sheet 9 of 20)

**Functional Diagram  
Steamline Isolation**



- NOTES:
1. TWO MOMENTARY CONTROLS. OPERATING EITHER CONTROL WILL ACTUATE ALL DIVISIONS.
  2. COMPONENTS ARE ALL INDIVIDUALLY SEALED IN (LATCHED), SO THAT LOSS OF THE ACTUATION SIGNAL WILL NOT CAUSE THESE COMPONENTS TO RETURN TO THE CONDITION HELD PRIOR TO THE ADVENT OF THE ACTUATION SIGNAL.
  3. MOMENTARY CONTROLS, ONE FOR EACH DIVISION.

Figure 7.2-1 (Sheet 10 of 20)

**Functional Diagram  
Feedwater Isolation**

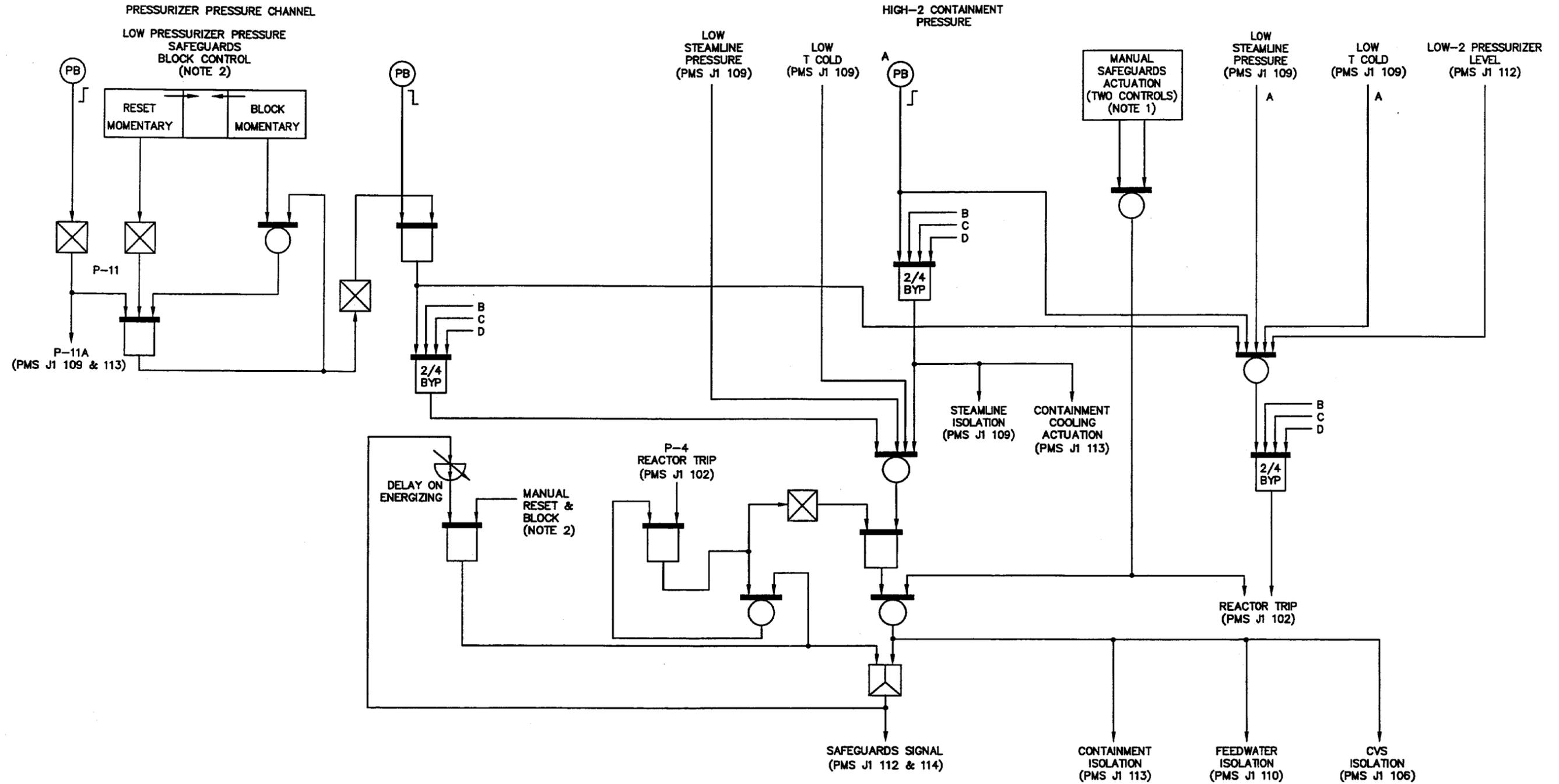


Figure 7.2-1 (Sheet 11 of 20)

**Functional Diagram  
Safeguards Actuation**

**NOTES:**

1. TWO MOMENTARY CONTROLS. OPERATING EITHER CONTROL WILL ACTUATE ALL DIVISIONS.
2. SEPARATE MOMENTARY CONTROLS. ONE FOR EACH DIVISION.

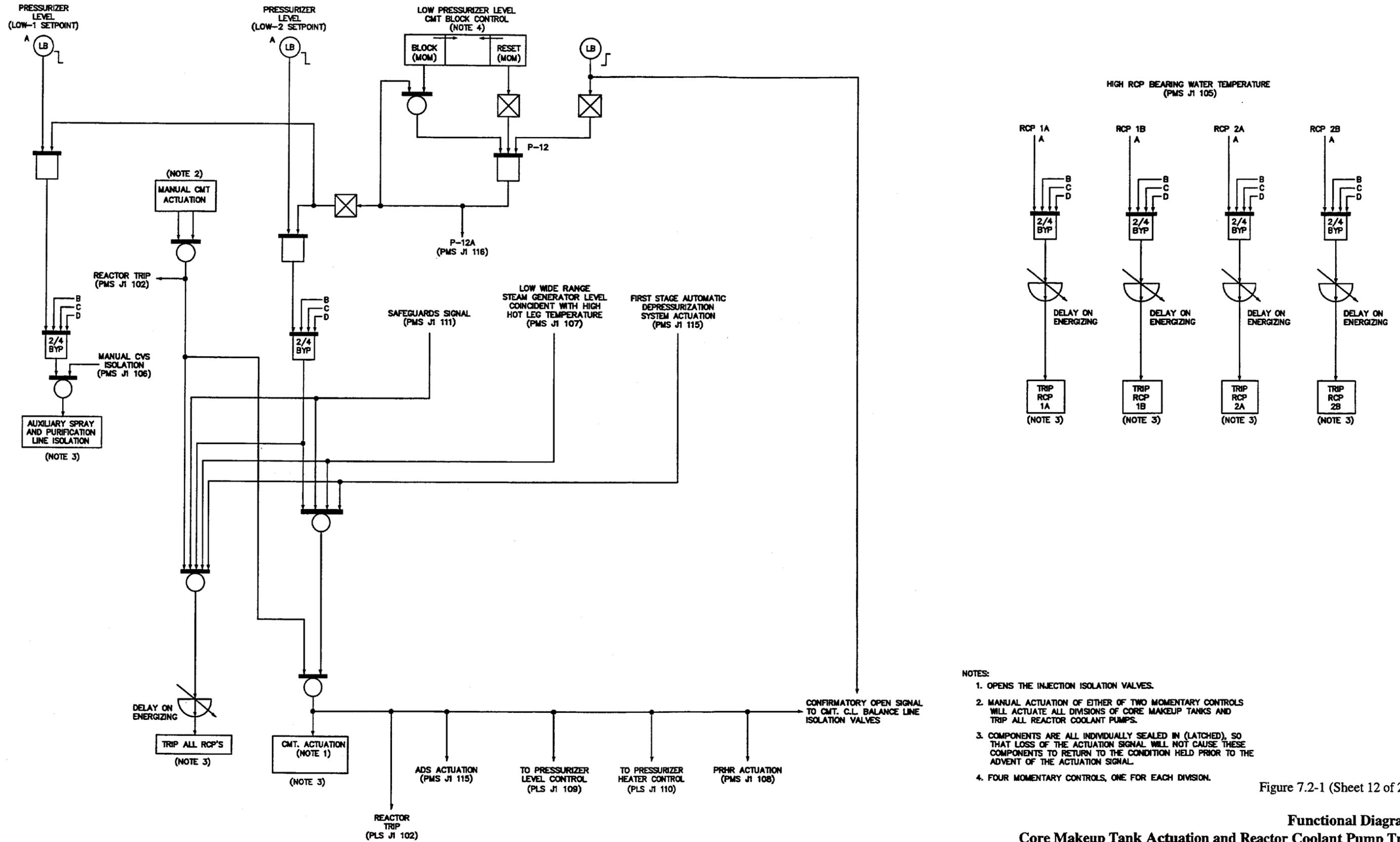


Figure 7.2-1 (Sheet 12 of 20)

Functional Diagram  
Core Makeup Tank Actuation and Reactor Coolant Pump Trip

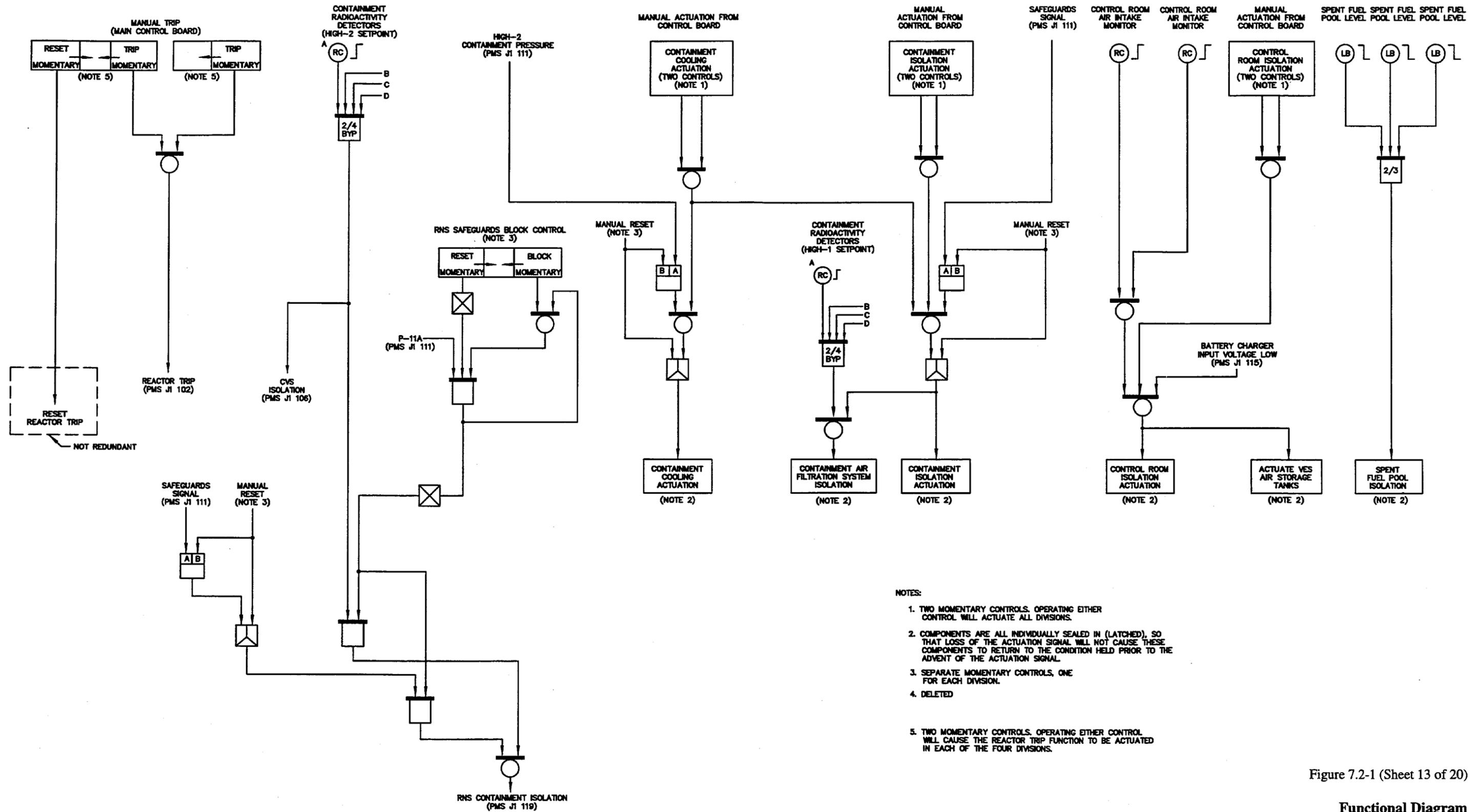
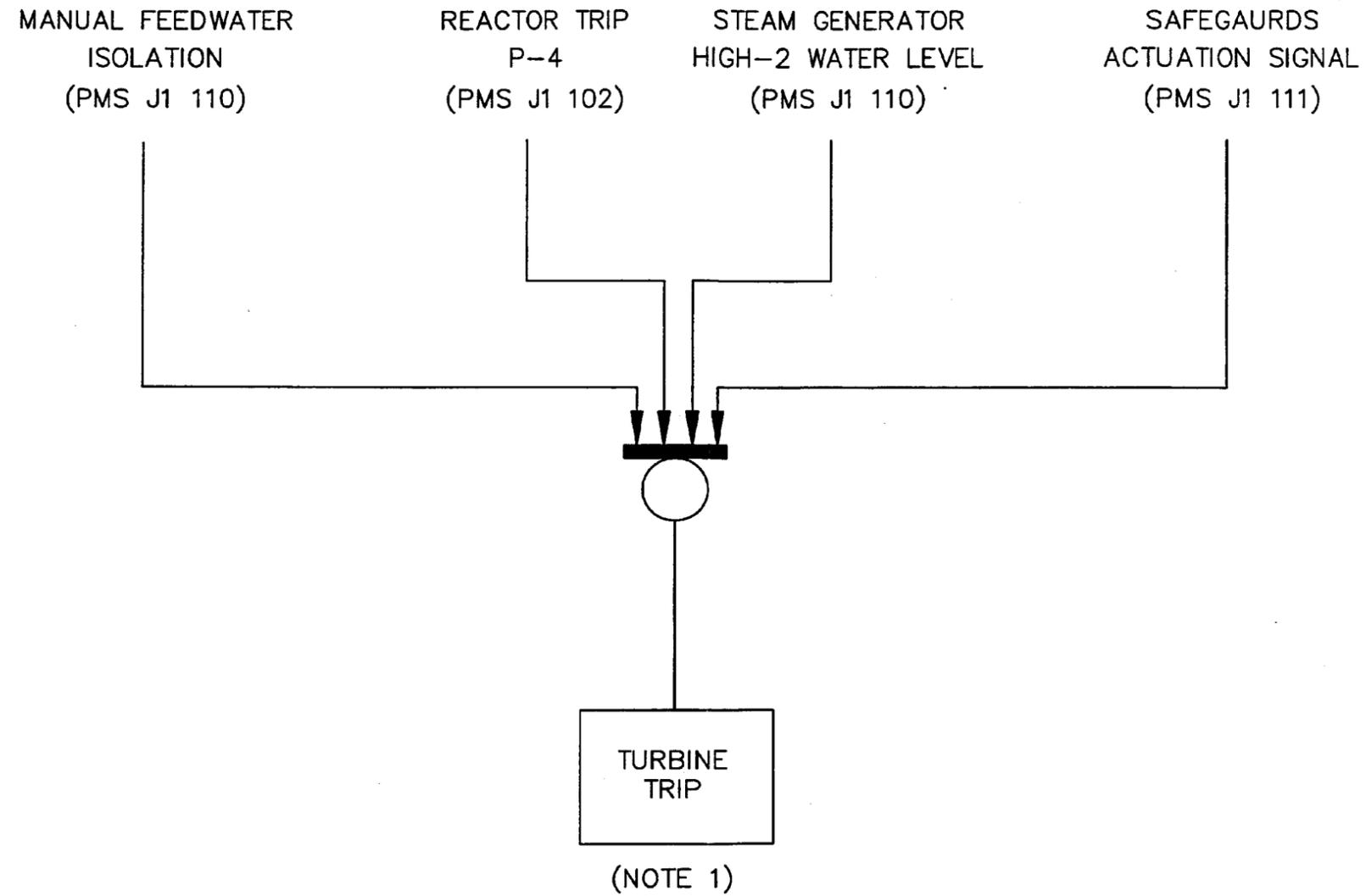


Figure 7.2-1 (Sheet 13 of 20)

Functional Diagram  
Containment and Other Protection

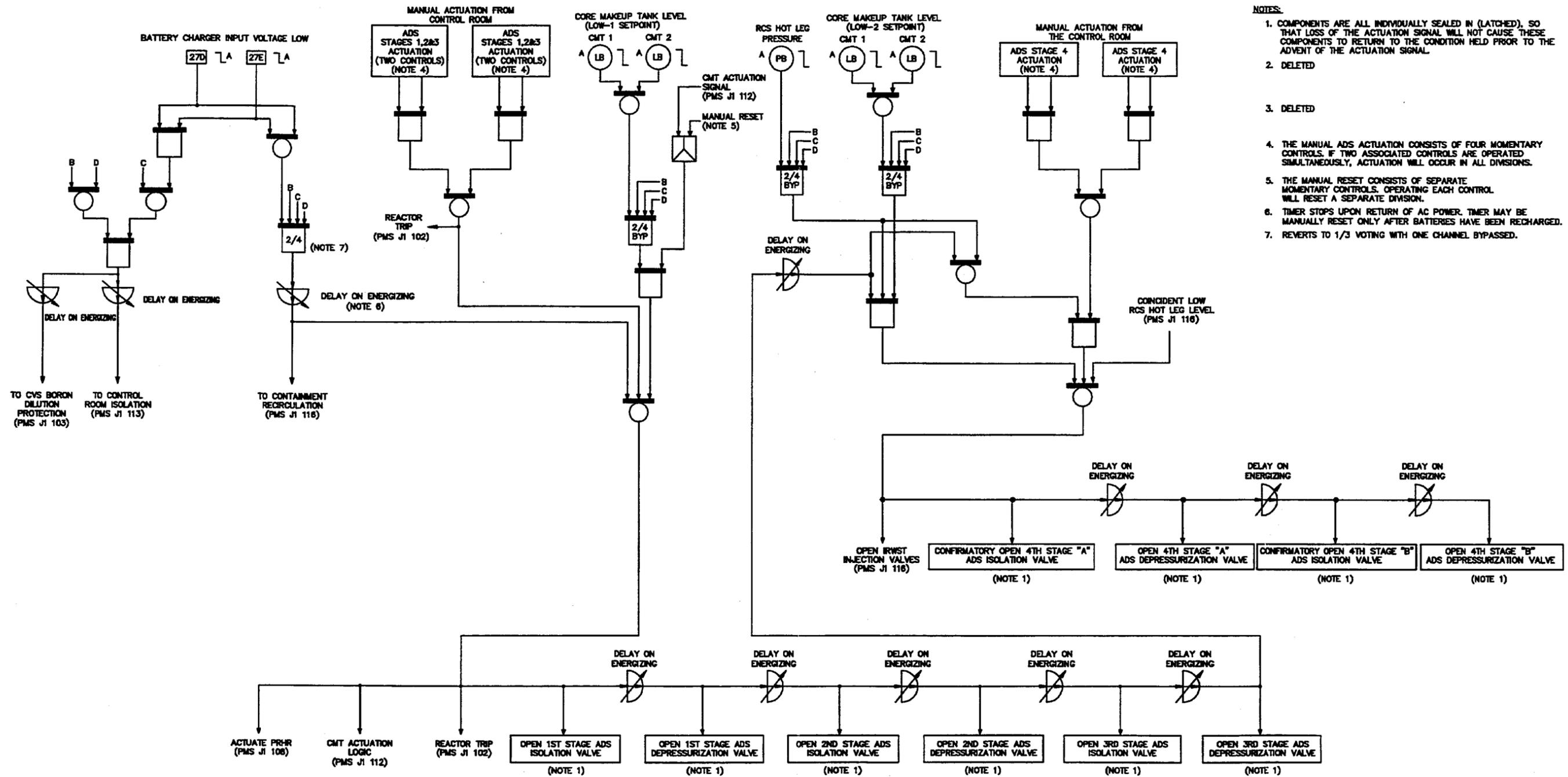


NOTES:

1. COMPONENTS ARE INDIVIDUALLY SEALED IN (LATCHED) SO THAT LOSS OF THE ACTUATION SIGNAL WILL NOT CAUSE THESE COMPONENTS TO RETURN TO THE CONDITION HELD PRIOR TO THE ADVENT OF THE ACTUATION SIGNAL.

Figure 7.2-1 (Sheet 14 of 20)

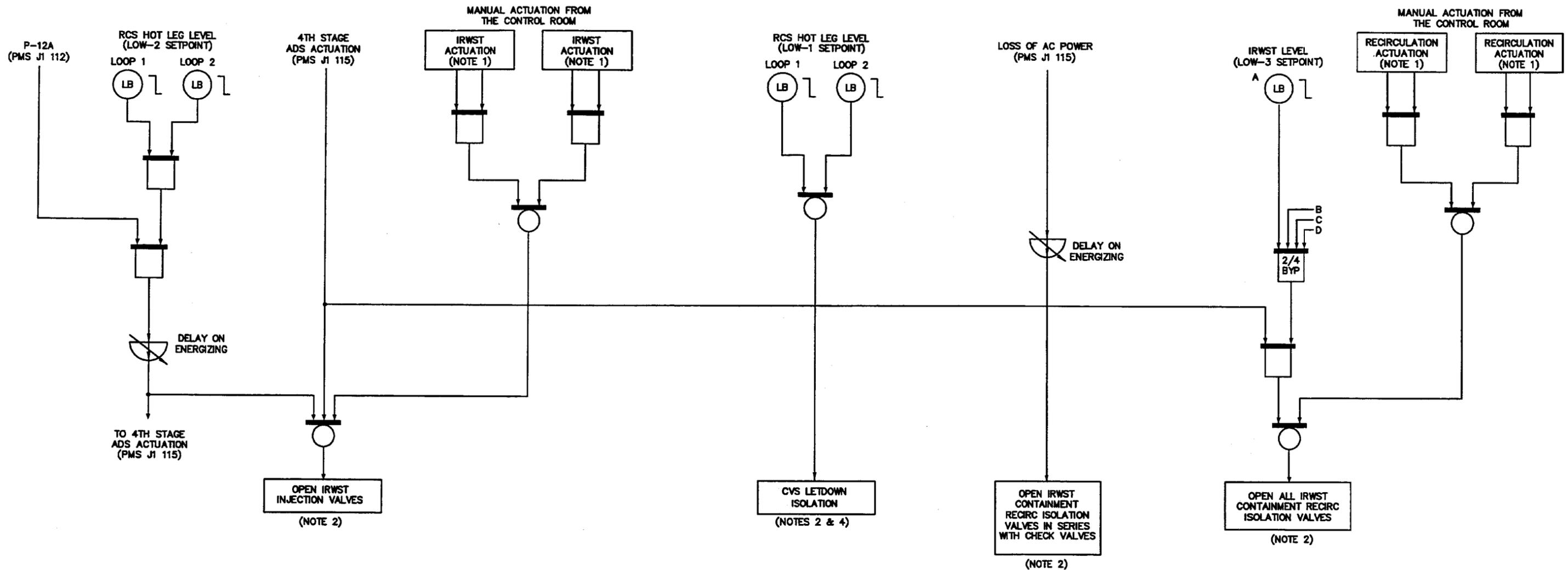
**Functional Diagram  
Turbine Trip**



- NOTES:
1. COMPONENTS ARE ALL INDIVIDUALLY SEALED IN (LATCHED), SO THAT LOSS OF THE ACTUATION SIGNAL WILL NOT CAUSE THESE COMPONENTS TO RETURN TO THE CONDITION HELD PRIOR TO THE ADVENT OF THE ACTUATION SIGNAL.
  2. DELETED
  3. DELETED
  4. THE MANUAL ADS ACTUATION CONSISTS OF FOUR MOMENTARY CONTROLS. IF TWO ASSOCIATED CONTROLS ARE OPERATED SIMULTANEOUSLY, ACTUATION WILL OCCUR IN ALL DIVISIONS.
  5. THE MANUAL RESET CONSISTS OF SEPARATE MOMENTARY CONTROLS. OPERATING EACH CONTROL WILL RESET A SEPARATE DIVISION.
  6. TIMER STOPS UPON RETURN OF AC POWER. TIMER MAY BE MANUALLY RESET ONLY AFTER BATTERIES HAVE BEEN RECHARGED.
  7. REVERTS TO 1/3 VOTING WITH ONE CHANNEL BYPASSED.

Figure 7.2-1 (Sheet 15 of 20)

Functional Diagrams  
Automatic RCS Depressurization Valve Sequencing

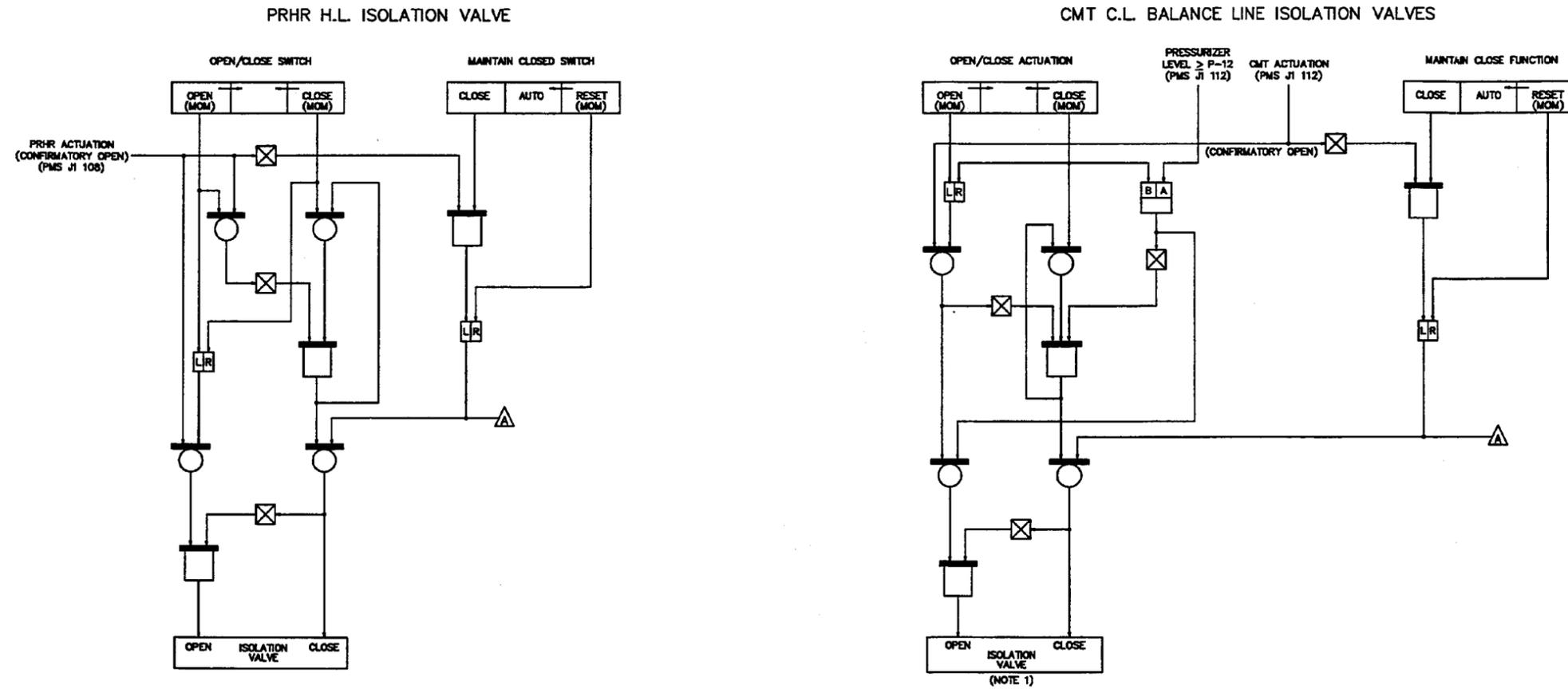


NOTES:

1. THE MANUAL ACTUATION CONSISTS OF FOUR MOMENTARY CONTROLS. IF TWO ASSOCIATED CONTROLS ARE OPERATED SIMULTANEOUSLY, ACTUATION WILL OCCUR IN ALL DIVISIONS.
2. COMPONENTS ARE ALL INDIVIDUALLY SEALED IN (LATCHED), SO THAT LOSS OF THE ACTUATION SIGNAL WILL NOT CAUSE THESE COMPONENTS TO RETURN TO THE CONDITION HELD PRIOR TO THE ADVENT OF THE ACTUATION SIGNAL.
3. THE MANUAL RESET CONSISTS OF SEPARATE MOMENTARY CONTROLS. OPERATING EACH CONTROL WILL RESET A SEPARATE DIVISION.
4. CVS LETDOWN ISOLATION ALSO OCCURS DURING CONTAINMENT ISOLATION. SEE PMS J1 113.

Figure 7.2-1 (Sheet 16 of 20)

Functional Diagrams  
In-Containment Refueling Water Storage Tank Actuations



- NOTES:
1. THIS LOGIC IS REPEATED FOR EACH VALVE.
  2. THE CONTROLS ARE LOCATED IN THE MAIN CONTROL ROOM AND DUPLICATED AT THE REMOTE SHUTDOWN WORK STATION, BUT ARE NOT FUNCTIONAL AT BOTH LOCATIONS SIMULTANEOUSLY.

Figure 7.2-1 (Sheet 17 of 20)

**Functional Diagram  
Passive Residual Heat Removal and  
Core Makeup Tank Isolation Valve Interlocks**

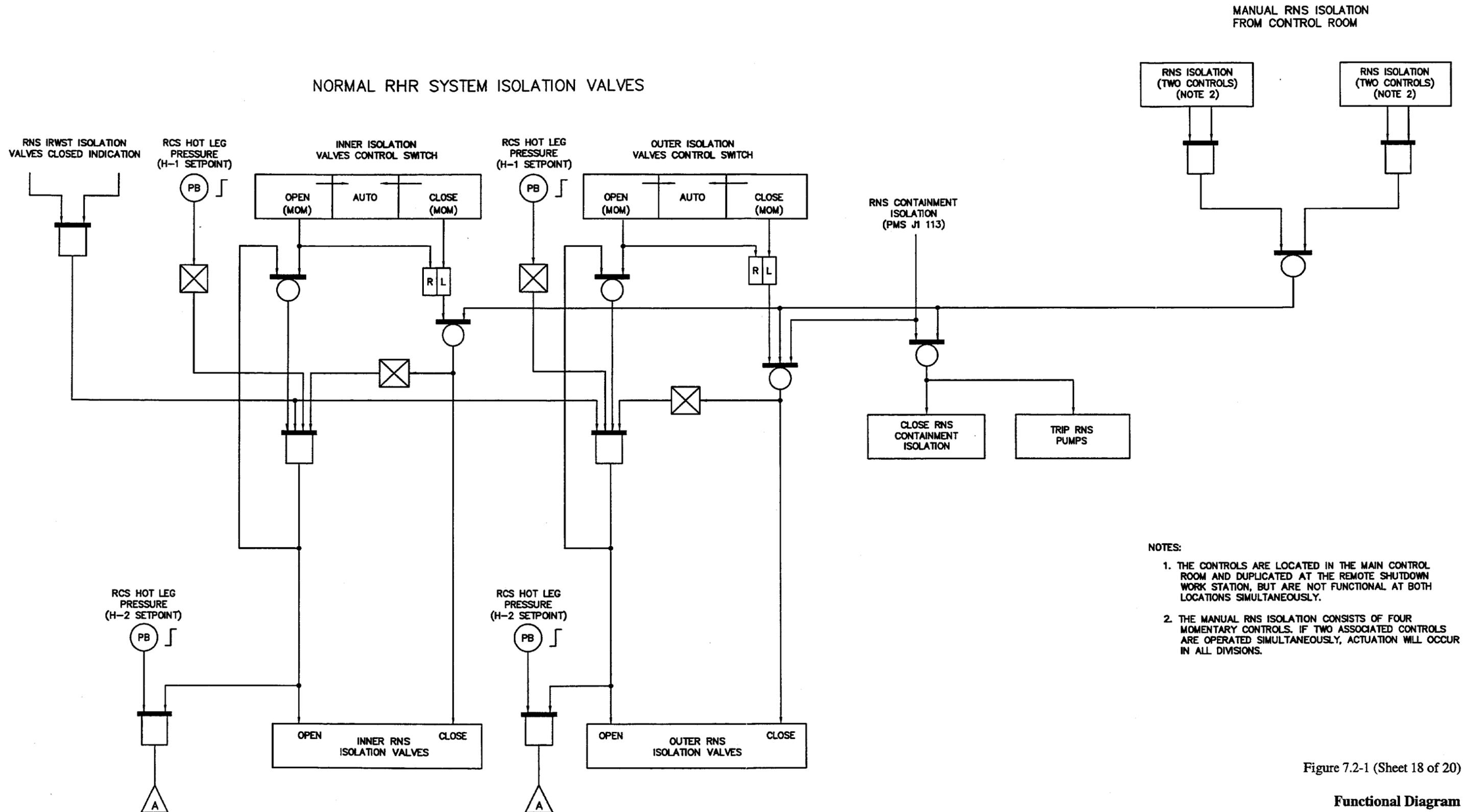


Figure 7.2-1 (Sheet 18 of 20)

**Functional Diagram  
Normal Residual Heat Removal System  
Isolation Valve Interlocks**

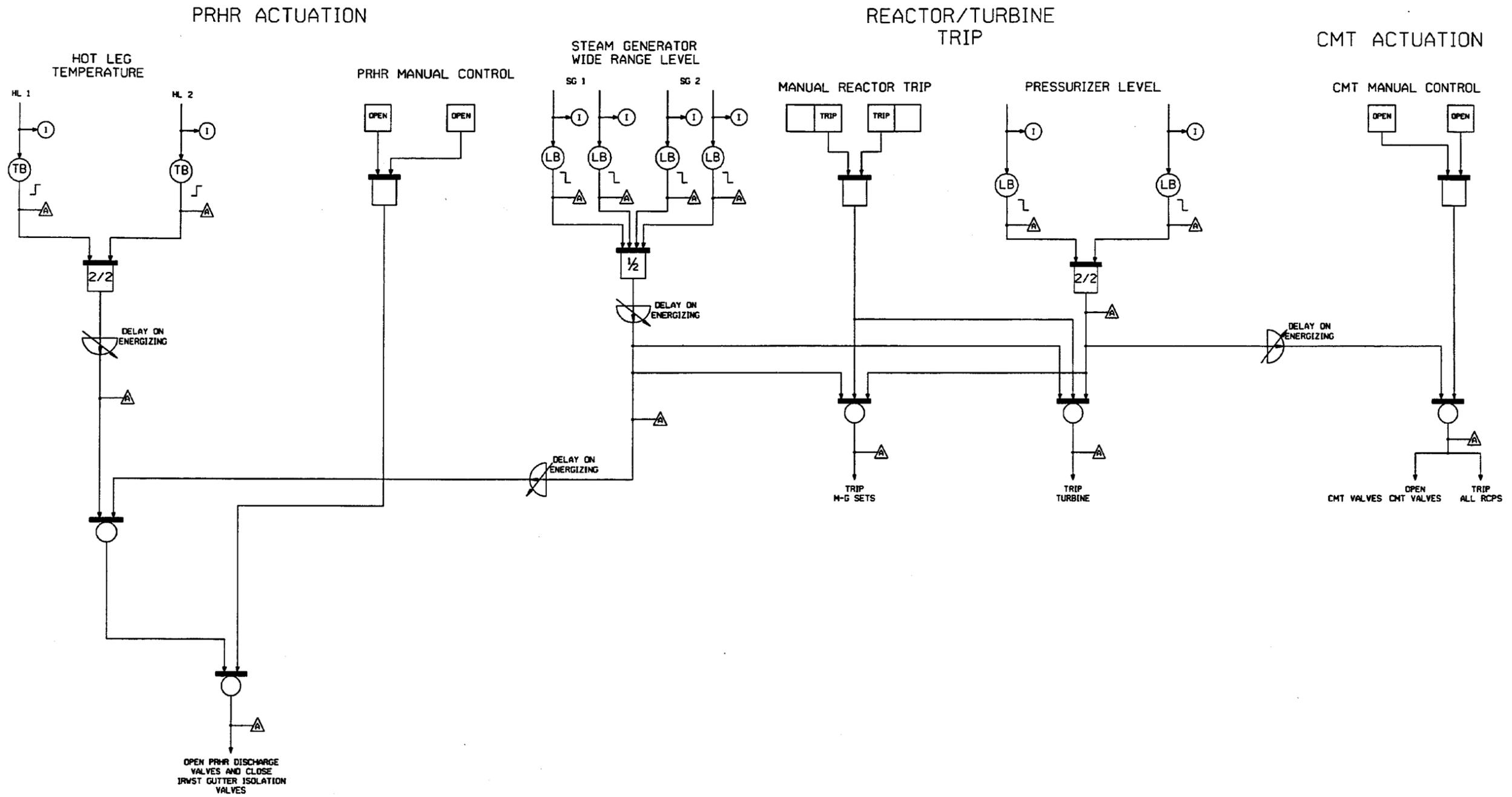
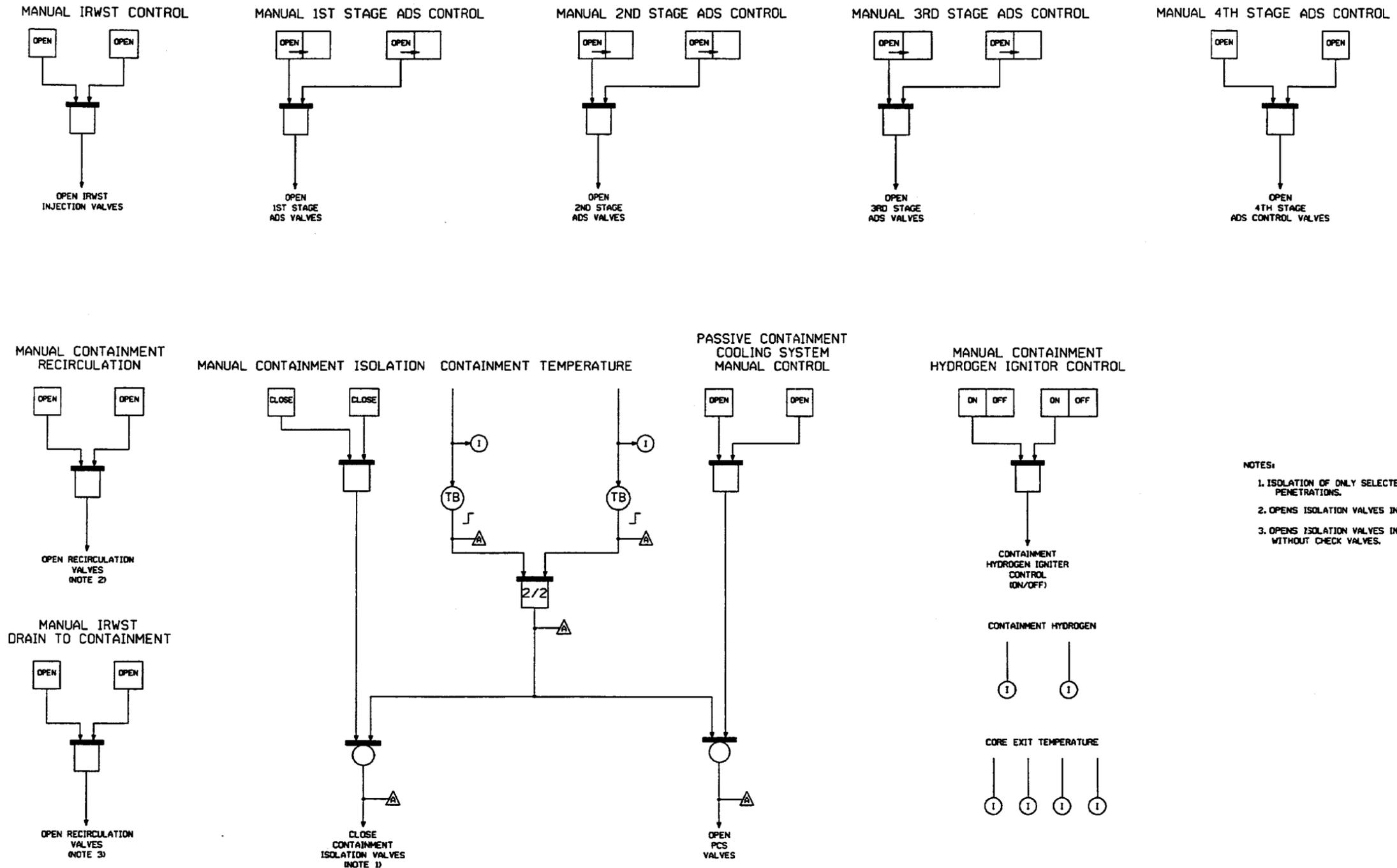


Figure 7.2-1 (Sheet 19 of 20)

**Functional Diagram  
Diverse Actuation System Logic  
Automatic Actuations**



- NOTES:
1. ISOLATION OF ONLY SELECTED CONTAINMENT PENETRATIONS.
  2. OPENS ISOLATION VALVES IN SERIES WITH CHECK VALVES.
  3. OPENS ISOLATION VALVES IN RECIRCULATION LINES WITHOUT CHECK VALVES.

Figure 7.2-1 (Sheet 20 of 20)

**Functional Diagram**  
**Diverse Actuation System Logic, Manual Actuations**