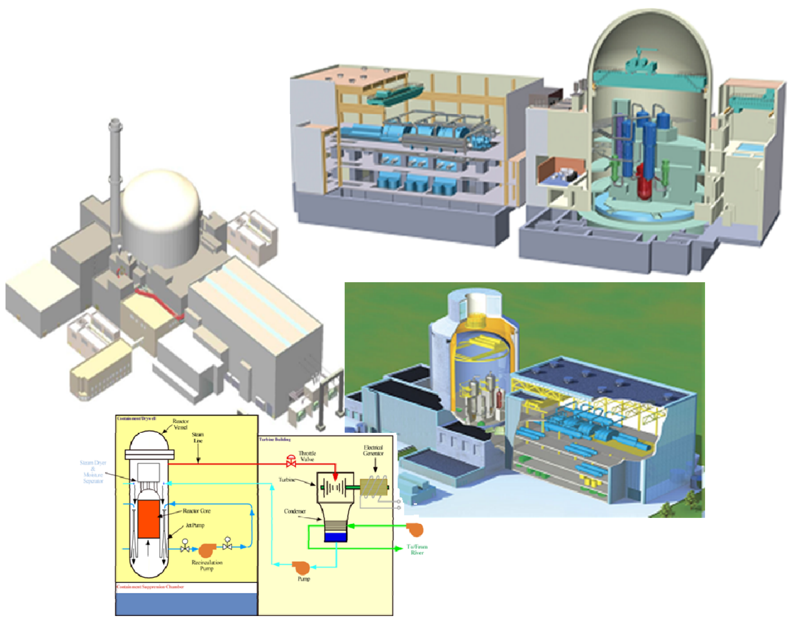
NUCLEAR REGULATORY COMMISSION

Reactor Technology Training Branch



Part I

Introduction to Reactor Technology - PWR

Chapter 2.0 Westinghouse Plant Description

UNITED STATES

NUCLEAR REGULATORY COMMISSION

HUMAN RESOURCES TRAINING & DEVELOPMENT

Introduction to Reactor Technology

This manual is a text and reference document for the Introduction to Reactor Technology. It should be used by students as a study guide during attendance at this course. This manual was compiled by staff members from the Human Resources Training & Development in the Office of Human Resources.

The information in this manual was compiled for NRC personnel in support of internal training and qualification programs. No assumptions should be made as to its applicability for any other purpose. Information or statements contained in this manual should not be interpreted as setting official policy. The data provided are not necessarily specific to any particular nuclear power plant, but can be considered to be representative of the vendor design.

U.S. Nuclear Regulatory Commission
Technical Training Center • Osborne Office Center
5746 Marlin Road • Suite 200
Chattanooga, TN 37411-5677
Phone 423.855.6500 • Fax 423.855.6543

Table of Contents

List of Figures

The information contained in this chapter pertains to current operational reactor designs. Advanced reactor designs are provided in separate chapters.

2.0 WESTINGHOUSE PLANT DESCRIPTION

2.0.1 Rod Control System

The Rod Control System provides operators with the capability to manually position control rods for startup, shutdown, and power operations. The system also provides automatic positioning of the control rods to maintain programmed T_{avg} during power operations.

2.0.2 Reactor Makeup System

The Reactor Makeup System is used to decrease and increase Reactor Coolant System boron concentration for reactivity control, and compensates for reactor coolant system leakage while maintaining a constant boron concentration.

2.0.3 Emergency Core Cooling System

The emergency core cooling systems provide capabilities to:

- Cool the core during accident conditions minimizing fuel damage
- Rapidly reflood the core with high, intermediate and low pressure water sources
- Long term flow path and heat sink for decay heat removal
- Maintain shutdown margin by injecting concentrated boric acid
- Control charging flow for chemical and volume control systems during normal operations

2.0.4 Reactor Protection System

The Reactor Protection System (RPS) prevents the release of radioactivity to the environment by preventing unsafe operation of the reactor which could lead to accident conditions.

To meet this objective, the RPS will act to prevent unsafe operation of the reactor which could lead to accident conditions. The prevention of unsafe operation is accomplished by the initiation of a reactor trip.

2.0.5 Containment and Containment Spray

The reactor containment building will contain and control any release of radioactivity to the environment under normal or emergency conditions. The Containment Spray System assists in protecting the integrity of the containment by reducing steam pressure and temperature. The structure also provides biological shielding for both normal and accident conditions.

2.0.6 Auxiliary Feedwater Systems

The auxiliary feedwater system provides feedwater to the steam generators to maintain a heat sink in the event that feedwater flow is lost, the unit trips, loss of offsite power, small break loss of coolant accident, and a source of feedwater during plant startups and shutdowns.

2.0.7 Cooling Water Systems

The cooling water systems provide component cooling for engineered safety feature systems, radioactive and non-radioactive plant equipment, and main condenser cooling. Systems that provide cooling water are the:

- Component Cooling Water system
- Service Water system
- Condenser Circulating Water system

2.0.8 Electrical Systems

The plant electrical system provides a reliable source of electrical power to systems important to safety, connections to the offsite distribution system (grid), and a source of power to systems for normal plant operation.

2.1 ROD CONTROL SYSTEM

2.1.1 Introduction

The purposes of the Rod Control System are:

- Provide manual positioning of the control rods for startup, shutdown, and power operations
- Provide automatic positioning of the control rods to maintain programmed Tavg during power operations

As stated above, one of the purposes of the rod control system is to maintain a programmed average temperature in the reactor coolant system by regulating the reactivity in the core. Deviation of the average temperature from the program temperature by more than a preselected amount results in automatic rod movement to return Tavg to program. The speed of this rod movement varies with the size of the temperature deviation. The direction of rod movement is dependent on whether the average temperature is higher or lower than the program temperature.

The control rods are separated into two functional categories:

- Shutdown banks
- Control banks

Each category consists of a number of individual banks. Each bank contains between 4 and 9 control rods, which are moved together. The shutdown banks are always in the fully withdrawn position during normal operation and are moved to this position at a fixed speed in manual control prior to criticality. The shutdown banks provide a large negative reactivity insertion upon a reactor trip to ensure the reactor achieves and maintains subcriticality. The control banks are the only rods that can be manipulated under automatic control. The control banks are used to change reactivity in the core to take the reactor critical and (under automatic control) change reactor coolant system average temperature.

A reactor trip signal causes all rods to fall by gravity into the core. Individual rod position indication and bank demand position indication are provided to the operator on the main control board.

2.1.2 System Description

In the automatic mode of control, the rod control system (Figure 2.1-1) uses three signals to control the positioning of the control rods. These are:

- Auctioneered high nuclear power
- Turbine first stage impulse pressure (Pimp)
- Auctioneered high Tavg

These inputs are used in two comparison circuits to develop a total error signal to be processed by the reactor control unit.

The power mismatch circuit compares auctioneered high nuclear power with Pimp. If a rate of change of the difference (Pimp - auctioneered high nuclear power) between the two signals exist, the power mismatch circuit will generate an error signal. The higher the rate of change of the difference, the higher the error signal will be.

The summing unit compares auctioneered high Tavg and Tref (the reference temperature generated from first stage impulse pressure). Any difference between the two signals (Tref - Tavg) produces an error signal. This error signal is algebraically summed with the error signal from the power mismatch circuit, and a total error signal is sent to the reactor control unit.

The reactor control unit generates an analog signal. The polarity and magnitude of this signal determine the speed and direction of rod motion. When in “automatic” on the bank selector switch, this analog signal is sent to the logic cabinet.

The logic cabinet processes the analog input signal into a digital output to the power cabinets. Within the logic cabinet, signals are developed that determine rod speed, direction, and which control bank/group of rods are to be moved. The rod stop interlocks interface in the logic cabinet to prevent rod motion at predefined conditions.

The power cabinets receive power from the rod drive motor-generator (mg) sets through the reactor trip and bypass breakers and distribute that power to the control rod drive mechanisms. Signals from the logic cabinet activate and deactivate components within the power cabinets that send power to the electrical coils of the selected control rod drive mechanisms. Each power cabinet can supply up to three groups of rods.

Manual control of the rods is selected from the bank selector switch in the “manual” position. This changes the logic cabinet input from the reactor control unit to the bank selector switch. Rod motion is achieved using the IN-HOLD-OUT switch.

2.1.3 System Design

The automatic rod control system is designed to maintain a programmed average temperature in the reactor coolant system by regulating the reactivity in the core. The system is capable of restoring the average temperature to within ± 1.5°Fof the programmed temperature following design load changes. The design load changes for the rod control system are:

- 5% per minute ramp increase or decrease
- ± 10% step change in load
- 50% step load decrease, with the aid of the automatic steam dump system

The above load changes are handled by the rod control system automatically when reactor power is between 15% and 100% power. Automatic rod control below 15% turbine load is not provided.

The rod control system is used to compensate for fast, short term, reactivity changes, such as those resulting from power changes and xenon peaking. Compensation for slower, long term effects, such as fuel depletion or gradual xenon and/or samarium changes, are accomplished by the adjustment of the reactor coolant system boron concentration via the chemical and volume control system.

2.2 REACTOR MAKEUP SYSTEM

2.2.1 System Description

The Reactor Makeup System (Figure 2.2-1) must be able to:

- Decrease Reactor Coolant System (RCS) boron concentration to add positive reactivity
- Increase reactor coolant system boron concentration to add negative reactivity
- Compensate for reactor coolant system leakage while maintaining a constant boron concentration

To decrease reactor coolant system boron concentration, pure water is added to dilute the reactor coolant. The source of this water is the primary water storage tank, which has a capacity of approximately 200,000 gallons. From the primary water storage tank, the water is pumped by the primary water transfer pump through a valve that controls the flowrate (FCV), through the blender, through an isolation valve, and into the volume control tank (VCT) via the inlet nozzle. If a large quantity of water is added, VCT level will increase until the level divert valve directs letdown flow to the holdup tanks.

An increase in boron concentration requires the addition of concentrated boric acid to the reactor coolant system. This evolution is called borating the RCS. Concentrated boric acid (≈ 7,000 ppm) is stored in the boric acid tanks, which have a capacity of 24,228 gallons each. The boric acid transfer pumps pump boric acid from the boric acid tanks, through the boric acid flow control valve, through the blender, through the boric acid isolation valve, and finally into the charging pump suction. A few facts concerning the boric acid flow path are listed below:

The piping in the boric acid flow path is heat traced with electrical heaters to ensure that the boric acid remains in solution.

Highly concentrated boric acid is not normally added through the volume control tank spray nozzle because the boric acid could crystallize and plug the flow nozzle.

Since the blender restricts boric acid flow, the emergency boration flow path is used in emergency situations

To compensate for normal reactor coolant system leakage, both boric acid and pure water are added. Additions made for this reason do not involve a change in RCS boron concentration. Boric acid and pure water are mixed in the blender with the outlet concentration being determined by the relative flowrates of the pure water and boric acid. The blended flow is adjusted by the operator to match the boric acid concentration in the reactor coolant system. From the blender, the solution enters the charging pump suction header via the boric acid isolation valve and is pumped into the reactor coolant system by a charging pump.

2.3 EMERGENCY CORE COOLING SYSTEMS

2.3.1 Introduction

The purposes of the emergency core cooling systems are as follows:

1. Emergency core cooling systems (Figure 2.3-1):
   - Provide core cooling to minimize fuel damage following a loss-of- coolant accident (LOCA)
   - Provide additional shutdown margin following a steam line break accident
2. Accumulators (passive system) (Figure 2.3-2):
   - Rapidly reflood the core following a LOCA
3. Residual heat removal system (active system) (Figure 2.3-3):
   - Provide low pressure, high volume safety injection to complete the reflooding of the core following a LOCA
   - Provide a flow path and heat sink for long term core cooling following a LOCA
   - Provide for decay heat removal during a plant cooldown below 350°F
4. Safety injection pump system (active system) (Figure 2.3-4):
   - Provide intermediate pressure, low volume safety injection for small to intermediate size LOCAs
5. High head safety injection system (active system) (Figure 2.3-5):
   - Provide high pressure, low volume safety injection for small to intermediate size LOCAs
   - Maintain shutdown margin by injecting concentrated boric acid from the refueling water storage tank following a steam line break
   - Provide charging flow for the chemical and volume control system during normal operations

The emergency core cooling systems (ECCS) are divided into several subsystems consisting of both passive and active systems. The passive system consists of large volume tanks containing borated water and pressurized with nitrogen. Their pressure is less than that of the reactor coolant system normal operating pressure. When the reactor coolant system pressure decreases below the accumulators' pressure during an accident, the nitrogen will force the borated water into the cold legs of the reactor coolant system.

The active systems consist of several pumping systems of varying discharge pressures and flow rates. These systems do not start until they receive an accident initiation signal (engineered safety features actuation). Once started, these systems will commence to inject

borated water into the reactor coolant system as reactor coolant system pressure decreases below the discharge pressure of the systems' pumps.

The ECCS is designed to cool the reactor core and provide additional shutdown capability following:

- A loss of coolant from the reactor coolant system in excess of normal makeup
- A steam generator tube rupture
- A pipe break in the main steam system

The emergency core cooling systems provide shutdown capability for the accidents listed above by means of chemical poison (boron) injection.

2.3.2 System Description

2.3.2.1 General Design Criteria

The ECCS are designed in accordance with 10 CFR 50 Appendix A General Design Criteria 35, 36, and 37. Criterion 35 is given below. Criteria 36 and 37 are associated with system testing.

- *A system to provide abundant emergency core cooling shall be provided. The system safety function shall be to transfer heat from the reactor core following any loss of reactor coolant at a rate such that:*
  - *Fuel and clad damage that could interfere with continued effective core cooling is prevented and*
  - *Clad metal-water reaction is limited to negligible amounts*
- *Suitable redundancy in components and features, and suitable interconnections, leak detection, isolation, and containment capabilities shall be provided to assure that for onsite electric power system operation (assuming offsite power is not available) and for offsite electric power system operation (assuming onsite power is not available) the system safety function can be accomplished, assuming a single failure*.

2.3.2.2 ECCS Acceptance Criteria

The ECCS must also meet the requirements of 10 CFR 50.46, "Acceptance Criteria for Emergency Core Cooling Systems for Light Water Nuclear Power Reactors," which in part reads:

- *Each light water reactor fuel with uranium oxide pellets within cylindrical zircaloy cladding shall be provided with an emergency core cooling system which shall be designed such that its calculated cooling performance following postulated loss of coolant accidents conforms to the following criteria:*
  - *Calculated peak cladding temperature remains less than 2200°F,*

- *Maximum cladding oxidation shall not exceed 0.17 times the total cladding thickness*
- *Maximum hydrogen generation shall not exceed 0.01 times the hypothetical amount generated from the chemical reaction of the cladding with water,*
- *Changes in core geometry will allow for core cooling flow, and*
- *Long term cooing can be maintained.*

2.3.2.3 General Description

The principal components of the emergency core cooling system which provide core cooling immediately following a loss of coolant accident are the accumulators, the safety injection pumps, the centrifugal charging pumps, the residual heat removal pumps, the refueling water storage tank, and the associated valves and piping. The order of component injection into the reactor coolant system is dependent upon the size of the break.

For large pipe ruptures, the reactor coolant system (RCS) would be depressurized and voided of coolant rapidly, and a high flow rate of emergency coolant is required to quickly cover the exposed fuel rods and limit possible core damage. This high flow rate is provided by the passive cold leg accumulators, charging pumps, safety injection pumps, and the residual heat removal pumps discharging into the cold legs of the RCS.

Emergency cooling is provided for small ruptures primarily by the high head injection pumps. Small ruptures, equivalent diameter of 6 inches or less, are those which do not immediately depressurize the reactor coolant system below the accumulator discharge pressure. The centrifugal charging pumps deliver borated water from the refueling water storage tank at the prevailing RCS to the cold legs of the RCS.

2.4 REACTOR PROTECTION SYSTEM

2.4.1 Introduction

The purpose of the Reactor Protection System (RPS) is to prevent the release of radioactivity to the environment. To meet this objective, the RPS will act to prevent unsafe operation of the reactor which could lead to accident conditions. The prevention of unsafe operation is accomplished by the initiation of a reactor trip by the RPS. If an accident does occur, the RPS will actuate the engineered safety features (ESF) which are designed to mitigate the consequences of an accident.

The dictated safe operating limits, bounded by reactor trips and engineered safety features actuation, are monitored by sensors to detect the necessary parameters. These parameters are measured by analog circuitry for trip setpoint comparison and compared in digital logic circuitry to initiate reactor trip or engineered safety features actuation. Trip actuation is based on the number of analog signals that have exceeded their respective setpoints. These four basic functions (monitoring, measuring, comparing, and initiating) are performed by the RPS.

2.4.2 Reactor Protection System Design

A reliable system of reactor protection is needed to guarantee the integrity of the reactor systems and avoid undue risk to the health and safety of the public. The system must be capable of supplying reactor and component trip signals and initiating engineered safety features to provide the required degree of protection for all normal operating and casualty conditions. A block diagram of the reactor protection scheme is shown in Figure 2.4-1 (showing all reactor trip signals and associated interlocks). The nuclear and process instrument systems send trip signals to the logic matrices. When an unsafe condition is sensed, a signal is sent to the protection cabinets. If a reactor trip is required, the protection cabinets will send a signal to the reactor trip breakers. Tripping of these breakers will remove power from the control rod drive mechanisms allowing the rods to drop into the reactor core. If a safety features actuation is required, the protection cabinets will actuate the appropriate ESF devices. Permissive signals are also provided by the logic trains to allow automatically or manually initiated interlocks and bypasses.

2.4.2.1 Design Features

The high degree of reliability required of the RPS is attained by the incorporation of the following features:

- <u>Redundancy</u> - Maintaining at least 100% backup ensures redundancy. The two in-series reactor trip breakers is an example. Either breaker performing its intended function (opening on a reactor trip signal) will provide full protection.
- <u>Independence</u> - Physical as well as electrical separation of sensors, power supplies, and equipment help ensure independence. The object is to prevent any failure or

accident from rendering more than one redundant sensor, channel, or device inoperable.

- Diversity - Providing more than one way of performing a function or of monitoring a parameter is an example of diversity. Since reactor coolant system flow is important to safety operation, diverse methods of detecting low flow conditions are used. Elbow flow taps and/or pump breaker open position indicators can cause a reactor trip on low flow.
- Fail Safe - The most likely failure of this or any electrical system would be a loss of input power. If power is lost to a channel, it fails to the tripped condition. If power is lost to the logic train, a reactor trip will result.
- Testability - On line testing of the RPS is provided to ensure that this system will perform its functions as designed. Calibration and testing of the various portions of the RPS, such as individual channel detectors, bistable trip setpoints, or the logic racks, can be performed without preventing or causing a protective function.
- Single Failure Criteria - The single failure or loss of a protection channel or component will not prevent the RPS from performing its design function. This includes all systems and components that are actuated if the RPS generates an engineered safety features actuation.

The protection system is designed to be independent of the control systems. In certain applications, the control signals and other non-protective functions are derived from individual protective channels through isolation amplifiers. The isolation amplifiers are classified as part of the RPS. Non-protective functions include those signals used for control, remote process indication, and computer monitoring. The isolation amplifiers are designed such that a short circuit, open circuit, or the application of either ac or dc voltage on the isolated output portion of the circuit (i.e., the non-protective side of the circuit) will not affect the input (protective) side of the circuit. The signals obtained through the isolation amplifiers are never returned to the protective racks.

Where failure of a protection system component can cause a process excursion which requires protective action, the protection system can withstand another independent failure without loss of protective action.

2.4.2.2 System Description

A simplified diagram of the RPS is shown in Figure 2.4-2. This diagram is shown with only one of the protective features, using signal transmitters associated with four channels, such as pressurizer pressure. These pressure transmitters will provide an analog (variable) signal to the analog cabinets. The analog cabinet, with the use of bistables (B/S), will compare the analog signal with a preselected setpoint. If the analog signal is equal to or exceeds the setpoint (sensing an unsafe condition) the bistable will trip (turn off). A bistable

is essentially an electronic switch that is either on or off. Note that a loss of power for the bistable turns its output off so it "fails safe" on a loss of power.

The logic section of the RPS is divided into two independent, separate, and redundant trains (Train 'A' and Train 'B'). Each receives a digital (on or off) signal from the analog cabinets' bistables. The logic section is that portion of the RPS where the coincidence for a particular trip is determined. If an unsafe condition of operation occurs, such as pressurizer pressure low on two out of four (2/4) instruments, then a reactor trip signal is transmitted from the logic sections to the undervoltage (UV) coils of the reactor trip breakers.

De-energizing the UV coil on the series reactor trip breakers causes the breakers to trip (open). Opening either of these breakers removes all power from the control rod drive power cabinets, which in turn de-energizes all the magnetic coils on the rod drive mechanisms, allowing the rods to fall into the reactor core. If an engineered safety features actuation is required, the logic sections will actuate (open, close, start, or stop) the appropriate safety equipment.

Permissive signals are also provided by the logic sections. Permissive signals allow for automatic or manual (with the use of control board switches) bypassing or blocking of certain reactor trips and ESF signals when they are not required. The RPS is designed so that if a particular trip is bypassed and plant conditions change where this trip may be required to ensure plant safety, the trip will be automatically unblocked.

2.4.3 Engineered Safety Features Actuation

The engineered safety features (ESF) are provided to limit the effects of and limit the offsite dose due to a reactor coolant system pipe rupture or steam break accident. A large volume of boric acid solution (refueling water storage tank) is available to ensure a continuous core coverage and heat removal and to counteract the positive reactivity effect associated with the cooldown resulting from a steam break. Any ESF signal (sometimes labeled SI for safety injection) will initiate actions to place the plant in a stable, safe shutdown condition (Figure 2.4-3). Regardless of the accident or condition initiating the ESF actuation, the following events are implemented by the RPS:

- Reactor trip
- Safety injection sequence - The high head injection portion of the chemical and volume control system is aligned to the reactor coolant system cold legs, the high head centrifugal charging pumps are started, and the residual heat removal and safety injection pumps are started (residual heat removal and safety injection systems will already be aligned to inject from the refueling water storage tank into the cold legs).
- Phase 'A' containment isolation - Dual isolation valves in all non-essential containment penetration lines are shut. The only exceptions to this isolation of non-

essential lines are the component cooling water supply and return lines for the reactor coolant pumps (RCPs) and the main steam line isolation valves (MSIVs). The RCPs, although not essential, can be used to circulate coolant through the core. The MSIVs can be kept open because they are part of a high pressure, closed cycle system. While they are open, the steam dump system may be used to remove core heat. The MSIVs will go closed if the initiating signal is the high steam line flow ESF. This is done to keep all four steam generators from blowing down on the (assumed) downstream steam line break.

- Auxiliary feedwater initiation - The auxiliary feedwater system provides a reliable, safety grade source of water to the steam generators to ensure a heat sink is available.
- Main feedwater isolation - Main feedwater is isolated to limit an inadvertent cooldown if an unisolable steam break occurs.
- Emergency diesel generator startup - The diesel generators are the power source for emergency system onsite if offsite power should be lost. They are started "just in case" the offsite power is unavailable. The diesels will run in standby and will not supply ESF loads until required by a loss of offsite power.
- Auxiliary cooling system lineup - The service water system and the component cooling water system will align to their "ESF modes," and the correct number of pumps in each system will automatically start.
- Control room intake duct isolation - The ventilation supply to the control room will realign to a self-contained habitability system to prevent smoke or radioactivity levels in the auxiliary building from causing control room evacuation.
- Containment ventilation isolation - The containment purge and exhaust system is periodically used to ventilate containment atmosphere prior to personnel entry. These systems will be isolated in case they are running when an accident occurs.

2.4.3.1 ESF Descriptions

The engineered safety features are initiated when the RPS sensory and logic network detect the occurrence of either a loss of coolant accident or a steam line break. Both of these accidents require certain safety features to be employed to ensure the safety of the public and the reactor core. Whatever the nature of the accident, the functions of the engineered safety features are to:

- Put the plant in a safe shutdown configuration (including both a reactor trip and boron injection)
- Provide cool borated water at a rate sufficient to prevent gross core damage from a loss of coolant accident

- Isolate containment from the outside environment to limit radioactive effluent releases
- Provide a heat sink in the form of auxiliary feedwater so the residual heat of the core can be removed
- Provide a source of reliable emergency power (diesel generators) in case offsite power is unavailable.

2.4.3.2 ESF Actuation Signals

There are five Safety Injection (SI) actuation signals, four automatic plus manual. Each is discussed below.

- Low pressurizer pressure - This signal is designed specifically to be indicative of a loss of coolant accident. It may be manually blocked by the operator to allow normal cooldown and depressurization of the plant. The permissive interlock is P-11.
- High containment pressure - This signal is designed to serve as a backup to the loss of coolant accident protection (low pressurizer pressure) and the upstream break protection (high steam line differential pressure). This is conceivable if the size of the assumed break is large enough to cause an increase in containment pressure, but too small to trigger the initiation signal associated with the accident. The setpoint is usually 10% of design pressure of the containment.
- High steam line flow rate coincident with either low steam line pressure or low-low reactor coolant system average temperature - This combination of parameters would occur if a steam line break occurs downstream of the isolation and check valves. A break in this area would essentially be common to all steam lines. It would also tend to drop steam pressures and reduce reactor coolant system temperature. This signal may also be manually blocked to allow normal shutdown and cooldown. The permissive interlock is P-12. (Note: This actuation signal will also shut all four main steam line isolation valves.)
- Steam line high differential pressure - This signal would be indicative of a steam line break upstream of the steam line isolation and check valves. A break in this area would result in the affected steam line pressure dropping to a level significantly lower than the other steam lines due to the check valve seating in the affected line.
- Manual - This allows the operator to initiate SI from either of two main control board locations.

2.5 CONTAINMENT AND CONTAINMENT SPRAY

2.5.1 Introduction

This section discusses the design of the reactor containment building that will contain and control any release of radioactivity to the environment under normal or emergency conditions. Also included is the Containment Spray System, which will help to protect the integrity of the containment by reducing steam pressure and temperature. The structure provides biological shielding for both normal and accident conditions.

2.5.2 Containment System Description

Several types of containment structures have been designed. Those designs in prevalent use incorporate steel vessels or concrete vessels lined with steel plate. Steel vessels can be cylindrical or spherical in shape. Reinforced concrete vessels, which may in some cases be post-tensioned, are cylindrical with hemispherical domes.

The containment consists of a prestressed, reinforced concrete, cylindrical structure with a hemispherical dome. The floor of containment is a conventionally reinforced concrete slab with a central cavity and instrument tunnel to house the reactor vessel. A continuous peripheral tendon access galley below the base slab is provided for the installation and inspection of the vertical post-tensioning system (Figure 2.5-1).

The base slab, cylinder, and dome are reinforced by steel bars, as required by the design loading conditions. Additional reinforcement is provided at discontinuities in the structure and the major penetrations in the shell.

The interior of the containment is lined with carbon steel plates welded together to form a barrier, which is essentially leak tight.

The post-tensioning system used for the shell and dome of the containment employs tendons. These tendons are unbonded, each consisting of 170 one-quarter inch, high strength, steel wires and anchoring components. The prestressing load is transferred to steel bearing plates embedded in the structure. The ultimate strength of each tendon is approximately 1,000 tons. The unbonded tendons are installed in tendon ducts and tensioned in a predetermined sequence. The tendon ducts consist of galvanized, spiral wrapped, semi-rigid corrugated steel tubing, designed to resist construction loads. After tensioning, a petroleum based corrosion inhibitor is pumped into the duct.

The post-tensioning system is divided into two sets of tendon patterns. One set consists of 86 inverted U-shaped tendons which extend through the full height of the cylindrical wall over the dome. They are anchored at the bottom of the base slab. The other set consists of 135 tendons forming the circumferential (hoop) tendons. Three buttresses, located 120° part, extend the full vertical height of the containment. The hoop tendons are anchored to one buttress, extend through the next, and are anchored to the third buttress. Each tendon extends around 240° of the containment building.

2.5.3 Containment Spray System

2.5.3.1 System Description

The Containment Spray System (CSS) (Figure 2.5-2) consists of two 100 percent capacity trains of equipment. The system operates in two modes. The injection mode flowpath takes a suction from the Refueling Water Storage Tank (RWST), to the containment spray pumps, where sodium hydroxide (NaOH) is mixed with the RWST water, and delivers to the containment spray headers. The recirculation mode flowpath takes a suction from the recirculation sump, to the containment spray pumps, where NaOH is mixed in if any is left over from the injection mode, delivering water to the spray headers.

Each train consists of a containment recirculation sump, a containment spray pump, a spray additive eductor, and a series of spray headers and nozzles. Common to both trains are the RWST and the spray additive tank. The containment spray system serves no function during normal plant operations, only operating during an accident which results in high containment pressure.

2.5.3.2 System Design

The CSS is an engineered safety features (ESF) system. It is a subsystem of both the containment heat removal system and the fission product removal and control system. As an ESF system, it is safety related. The system safety design bases are:

- The CSS is protected from natural phenomena such as earthquakes, tornadoes, and flooding.
- The CSS will perform its design functions while sustaining a single active failure coincident with a loss of offsite power.
- Provisions are made for component testing during plant operations.

Component isolation to combat leakage is built into the CSS. The CSS, in conjunction with the other containment heat removal systems, is capable of removing enough heat following a postulated accident to keep containment pressure below its design value. The CSS water does not contain substances that would be unstable in a post-LOCA environment, or would cause extensive corrosion of equipment, or release of combustible gas in containment.

The CSS will provide a spray solution in the pH range of 9.5 to 11.0 and a final recirculation sump pH of at least 8.5.

The CSS is capable of reducing iodine and other fission product concentrations in containment such that offsite radiation doses are within the guidelines of 10 CFR 100.

There are two functional objectives of CSS:

- Reduce containment pressure and temperature following a LOCA or steam break in containment to less than 60 psig

- Limiting offsite radiation levels to within the guidelines of 10 CFR 100
- Pressure control in the containment is accomplished as the system sprays cool RWST water over the large containment volume. The water absorbs heat and condenses the steam present from a LOCA or steam break.

A LOCA will cause the release of radioactive iodine gas, a fission product of great concern. The sprayed water absorbs the radioactive iodine gas. Sodium hydroxide is added to the spray water to increase its pH.

2.6 AUXILIARY FEEDWATER SYSTEM

2.6.1 Introduction

The purpose of the auxiliary feedwater system is to provide feedwater to the steam generators to maintain a heat sink for the following conditions:

- Loss of main feedwater
- Unit trip and loss of off-site power
- Small break loss of coolant accident (LOCA)
- Provide a source of feedwater during plant startup and shutdown

2.6.2 System Description

The Auxiliary Feedwater (AFW) System (Figure 2.6-1) consists of two subsystems, one of which utilizes a single turbine-driven pump, and the other consisting of two electric motor driven pumps. Each of the two subsystems can deliver feedwater from the condensate storage tank (normal supply) or the service water header (backup supply) to all four steam generators. The reactor coolant pumps will transfer heat from the reactor core to the steam generators, where water delivered by the AFW system is converted to steam. The steam dump control system will provide for steam release and, therefore, heat removal from the steam generators to the circulating water system in the main condenser. The circulating water system transfers the heat to the environment.

In the event of a loss of off-site power, the reactor coolant pumps lose power and no longer supply forced circulation of coolant through the core. Natural circulation in the reactor coolant system will now transfer the heat from the core to the steam generator. The AFW system is essential for core decay heat removal under these conditions. Since the condenser circulating water pumps also lose power, the condenser steam dumps are not available for steam release from the steam generators. The steam generator power operated relief valves are used to relieve the steam directly to the atmosphere.

The AFW system is also essential in supporting core decay heat removal during a small break loss of coolant accident. During a small break LOCA, the injection flow rate from the emergency core cooling systems is not sufficient to provide adequate flow through the core for decay heat removal. This is because of the reactor coolant system backpressure effect on emergency core cooling system flow and the slow reactor coolant system depressurization rate resulting from the coolant discharge through the small break. Decay heat removal via the reactor coolant system and heat transfer to the steam generators is necessary for core cooling considerations under small break LOCA conditions. During a large break LOCA, the emergency core cooling system flow alone is adequate to provide core cooling since the rapid reactor coolant system pressure reduction allows a much higher emergency core cooling system flow rate through the core.

Since the AFW system is necessary to mitigate the consequences of some accident scenarios, the operability of the system is an important consideration in risk analysis space. Several accident sequences contain the AFW system, and the loss of the system can be a major contributor to the total core damage frequency at some nuclear plants.

Because the AFW system operability is important, the complete AFW system, with the exception of the normal suction supply from the condensate storage tank, has been designed to Seismic Category I specifications. In the event that the condensate storage tank is not available, the Seismic Category I service water system is available as a backup suction source for the AFW pumps. The service water system is only used as a backup source because of the potential damage to the steam generator tubes from the raw water (lake, river, ocean, etc.) in the service water system.

The AFW pumps will automatically start upon actuation of one of the following start signals:

- Steam generator low-low level
- Loss of both main feedwater pumps
- Loss of one main feedwater pump with power above 80%
- An engineered safety features actuation signal
- Loss of off-site power

2.6.3 Component Description

2.6.3.1 Motor Driven Pumps

The AFW system is supplied with two motor driven pumps, each of which is powered from a different vital electrical distribution bus. The motor driven pumps are designed so that if only one pump is available, it can supply enough feedwater to two steam generators to cool the reactor coolant system to a point at which the residual heat removal system can be utilized for cooldown.

2.6.3.2 Turbine Driven Pump

The single turbine driven auxiliary feedwater pump has the same discharge capacity as both motor driven pumps combined. The steam supply to drive the turbine driven pump is from the Seismic Category I portion of either of two main steam lines. The steam from the turbine is exhausted to the environment.

2.6.3.3 Level Control Valves

The level in the steam generators is controlled by means of level control valves. These valves are maintained in their full open position so that maximum AFW flow will be delivered to the steam generators when an actuation signal is received. These valves will be modulated by the operator to maintain the level in the steam generators.

2.6.3.4 Condensate Storage Tank

The Condensate Storage Tank (CST) serves as the normal supply to the AFW pumps. A minimum amount of water is required by Technical Specifications (T.S.) to meet design considerations for cooldown. The hotwell level control system can affect the level in the CST by either making up to the hotwell if the level in the hotwell is low or rejecting water to the CST if the level in the hotwell is too high. To ensure the T.S. minimum amount of water in the condensate storage tank is available for use by the AFW system, the connection for the hotwell makeup system will tap into the CST at a level above the minimum requirement. This prevents a malfunction in the hotwell makeup system from dropping the level of the condensate storage tank below the minimum level required by T.S. This is accomplished by locating the tap in the side of the CST at an elevation above the minimum level or by using a standpipe inside the tank which is above the minimum level for the hotwell makeup system.

2.6.4 Operations

During plant startup, the AFW system supplies a controllable reduced feedwater flow rate necessary to maintain proper steam generator water level. The AFW system is able to supply adequate feed flow to maintain proper steam generator levels up to approximately two percent power, at which time the Main Feedwater System is started.

2.6.5 Summary

The AFW system is provided to ensure that an adequate amount of feedwater is supplied to the steam generators in the event of a loss of main feedwater, a unit trip coincident with a loss of off-site power, or a small break LOCA. This is necessary to maintain a proper heat sink to dissipate reactor decay heat. The AFW system will also be used during startups and shutdowns when the main feedwater system is not in service and when only a small amount of feedwater is required.

2.7 COOLING WATER SYSTEMS

2.7.1 Component Cooling Water System

2.7.1.1 Introduction

The purposes of the Component Cooling Water System are to:

- Provide cooling for systems or components that contain radioactive fluids
- Provide cooling for engineered safety features systems and components
- Provide a barrier between systems that contain radioactive fluids and the environment

2.7.1.2 System Description

The Component Cooling Water (CCW) system is an engineered safety features support system that transfer heat to the service water system from components that process potentially radioactive fluids. It is a closed loop, low pressure system that acts as a barrier between these potentially radioactive systems and the environment. It is operated at a lower pressure than the systems it removes heat from, and the service water system which cools it. Any leakage in the heat exchangers will leak into the component cooling water system. Leakage into the system will be detected by an increasing surge tank level, and if the leakage is from a radioactive system, it will be detected by radiation monitors.

2.7.1.3 System Design and Operation

As shown in Figure 2.7-1, CCW system consists of three centrifugal pumps, three heat exchangers, a surge tank, and interconnecting piping. The CCW system is used during all phases of plant operation. It is a Seismic Category I system with a design pressure of 150 psig and a design temperature of 200°F. It is designed to meet single failure criteria. One pump and one heat exchanger are sufficient to meet design heat loads. The pumps and heat exchangers are physically and electrically separated, with the C pump being powered from either train. An accident will start two pumps, one from each train. If a normally operating pump is taken out of service, the C pump will be powered from the associated train's electrical bus and valved into the system to supply that train's loads. There is a key-lock system to prevent two pumps from being powered from the same train.

The surge tank provides suction for the pumps and allows for expansion, contraction, in-leakage, and makeup for out-leakage. The tank has a baffle to separate the two trains in order to meet passive failure requirements during the recirculation phase of a loss of coolant accident. Level detectors on the tank will alarm on high or low level. The tank is vented to the auxiliary building atmosphere. High radiation in the pump suction lines will automatically close the vent.

The CCW system supplies cooling water to the following components:

- Residual heat removal heat exchangers
- Residual heat removal pumps
- Safety injection pumps
- Charging pumps
- Reactor coolant pump motors and thermal barriers
- Letdown heat exchanger
- Excess letdown heat exchanger
- Seal water heat exchanger
- Spent fuel pit heat exchanger
- Sample heat exchangers
- Reactor vessel support cooling
- Boric acid evaporator condensers
- Waste gas compressors
- High temperature containment penetrations

Non-vital loads will be isolated on an engineered safety features actuation signal. The Excess Letdown Heat Exchanger is isolated on a phase A containment isolation signal and reactor coolant pumps on a phase B containment isolation signal.

The CCW system can be a significant contributor to core damage frequency due to the cooling provided to the charging (high pressure safety injection) pumps and the thermal barrier heat exchanger on the reactor coolant pump. A complete loss of CCW for an extended period of time would result in no cooling to the reactor coolant pump seal package and lead to a seal failure loss of coolant accident. Since the charging pumps would not be available for injection (again, due to the loss of CCW), the core would eventually uncover.

2.7.2 Service Water System

2.7.2.1 Introduction

The purpose of the Service Water system is to provide the heat sink for all non-radioactive plant equipment *except* the main condenser.

2.7.2.2 System Design and Operation

The Service Water system is an engineered safety features support system which supplies continuous cooling water to the power plant. It is used to cool safety and non-safety related components. The three service water pumps take a suction on the lake, river, ocean, or cooling tower, and discharge through the various systems and components. The heat picked up in the various loads is then returned to the environment (Figure 2.7-2).

The Service Water system is divided into two trains, which are physically and electrically independent. The A and B pumps are powered from the A and B buses, respectively, while the C pump can be powered from either bus and will be used as a backup to the A and B pumps. During normal operations, the A and B pumps will run to supply their associated equipment. The non-safety related equipment can be supplied by either train of service water.

The non-safety related portion of the service water system is the heat sink for all non-safety related plant equipment except for the main condenser. It is used during normal operation and non-accident conditions. The non-safety related portion of the service water system will be isolated on an engineered safety features signal to separate it from the safety related essential service water portion of the system. A partial list of the typical loads on the non-safety related portion of the service water system would include:

- Main generator hydrogen coolers
- Main generator stator cooling water coolers
- Main turbine lube oil coolers.

The safety related portion of the service water system may also be called the essential service water system. The essential service water system is the ultimate heat sink for all vital equipment. It is used during all phases of plant operation. The essential service water system is designed to be Seismic Category I and meets single failure criteria.

The following safety related components are supplied by the service water system:

- Component cooling water heat exchangers
- Containment fan coolers
- Diesel generator coolers
- Control room air conditioning condensers
- Auxiliary building ventilation cooling coils
- Auxiliary feedwater pumps emergency supply

The Service Water system can also be a significant contributor to core damage frequency. A loss of the service water system can lead to a seal failure loss of coolant accident due to the loss of cooling of the CCW heat exchangers.

2.7.3 Circulating Water System

2.7.3.1 Introduction

The purpose of the Condenser Circulating Water system is to provide cooling water to the main condenser tubes and acts as a heat sink for the turbine and steam dump systems.

2.7.3.2 System Design and Operation

The three circulating water pumps are powered from non-essential electrical buses and take suction from the intake forebay through traveling screens. The traveling screens filter out any small trash which might clog condenser tubes. Two pumps are normally required at full load, but all three may be used in warm weather or to meet environmental Technical Specification requirements on condenser differential temperature. Controls and instrumentation are provided in the main control room to enable the plant operator to modulate the various system valves and vary the number of pumps in service.

The three circulating water pumps discharge into a common header to supply the main condenser (Figure 2.7-3). The cooling water circulates through the tubes of the main condenser and then out through the outlet structure. In cold climates, part of the condenser outlet flow may be diverted back to the inlet for ice melting in the inlet structure. Planned releases from the liquid radioactive waste system are mixed with the discharge water from both the service water and circulating water systems to ensure proper dilution before reaching the environment.

The Circulating Water system does not contribute to core damage frequency since the atmospheric relief valves on the steam lines provide a heat sink as a backup to the main condenser for decay heat removal.

2.8 ELECTRICAL SYSTEMS

2.8.1 Introduction

The purposes of the plant electrical system are to:

- Provide a reliable source of electrical power to systems important to safety
- Provide a connection to the offsite distribution system (grid)
- Provide a source of power to systems for normal plant operation (non-safety systems)

2.8.2 System Description

General Design Criterion 17 of 10 CFR 50, Appendix A contains the requirements for the electrical distribution system. The criterion requires onsite and offsite distribution to be independent of each other to supply the engineered safety features. The onsite system should be capable of handling a single failure. There are many electrical system designs which would meet the criterion. One system will be described in this chapter.

To meet the General Design Criterion, the electrical systems are designed to provide multiple reliable power sources to unit components and equipment in addition to supplying power to the utility's transmission network (Figure 2.8-1). The on-site electrical systems are referred to as "auxiliary" electrical systems. The station auxiliary power is normally supplied by the main generator by way of unit auxiliary transformers. If the main generator is unavailable or tripped, station auxiliary power is supplied from the utility's transmission network via the system auxiliary transformers. In the event of a total loss of auxiliary power from off-site sources, power required for safe shutdown and/or accident response is supplied from diesel generators located on-site.

The station auxiliary electrical system is designed to ensure electrical isolation and physical separation of the redundant power supplies for station equipment required for safety. Due to the limitations imposed on the amount of power which the diesel generators can deliver, the auxiliary power system is separated into vital (Class 1E) equipment buses which can be supplied by the diesels, and nonvital equipment buses, which are not required for safe shutdown or accident response, and are not supplied by the diesels on a loss of off-site power.

The vital (Class 1E) equipment buses are designed to provide two power trains with physical separation and the capability of electrical separation. Each train can be powered by its own diesel generator upon loss of normal power. This train separation and backup power supply (diesel generator) ensures that a single failure in the auxiliary power system will not compromise safe shutdown or accident response capability. Batteries are provided as a source of power for vital instrumentation, control power, emergency lighting, etc. They are maintained fully charged by battery chargers which receive power from the vital AC buses.

2.8.3 Component Description

2.8.3.1 500 KV Network Transmission

The main generator output is stepped up from 22 KV to 500 KV (thousand volts) by the two half-sized main transformers and fed into the 500 KV switchyard via two main generator output breakers. Only one breaker is needed to carry the full output of the generator to the transmission network. Most of the power is transmitted off-site to the utility's network by several separate high voltage power lines. Some of the generator output is used to power plant loads via the unit auxiliary transformers. The same power lines that are used to transmit the power to the transmission network will be used to supply power to the unit when the main generator is not available.

The prime mover of the generator is the steam driven main turbine. The rotating armature (rotor) is cooled by hydrogen, and the stationary conductors (stator) are cooled by demineralized water.

2.8.3.2 Auxiliary Electrical System

The auxiliary electrical system provides a reliable source of power to all plant auxiliaries required during any normal or emergency mode of plant operation. The system is designed such that sufficient independence (or isolation) between the various sources of electrical power is provided to guard against concurrent loss of all auxiliary power. The auxiliary electrical system is also designed to provide a simple arrangement of buses, requiring a minimum of switching to restore power to a bus in the event that its normal supply is lost.

The normal power supply the auxiliary electrical system is the main generator by way of the two unit auxiliary transformers, to the two 4160 volt AC nonvital buses. If the normal source of power is lost, a fast transfer occurs which opens the breaker from the unit auxiliary transformer and closes the breaker from the system auxiliary transformer. The fast transfer occurs very rapidly (within five cycles) to prevent the loss of major equipment, specifically the reactor coolant pumps. Power to the auxiliary electrical system is now supplied from an off-site source to the nonvital 4160 volt AC buses and from there to the rest of the auxiliary electrical system. Normal switch over from off-site to on-site supply occurs at approximately 15% power.

2.8.3.2.1 Non-Vital Distribution

The 4160 volt AC and 480 volt AC plant auxiliary equipment which are nonvital to safe shutdown and have large power requirements will be supplied from the 4160 volt AC nonvital buses. Reactor coolant pumps, condenser circulating water pumps, condensate pumps, etc. are in this category. The equipment is divided between the two buses to provide diversity.

Two 480 volt AC nonvital buses are supplied from the 4160 volt nonvital buses via the 4160/480 volt AC transformers. Smaller nonvital loads such as motor control centers, small pumps, and nonessential lighting are fed from these buses.

2.8.3.2.2 Vital Distribution

The two 4160 volt vital buses normally receive power from the 4160 volt nonvital buses. If this source of power is lost, the diesels will automatically start (on the undervoltage) and tie into the 4160 volt vital buses while the breakers from the nonvital buses open. This prevents nonvital equipment from overloading the diesels during a loss of off-site power. The “1A” 4160 volt vital bus feeds all of the equipment of engineered safety features train “A,” while bus “1B” supplies the train “B” equipment. Included as loads on the 4160 volt AC vital buses are the residual heat removal pumps, safety injection pumps, centrifugal charging pumps, component cooling water pumps, service water pumps, and the auxiliary feedwater pumps.

Four vital 480 volt AC buses supply the smaller vital loads, such as essential lighting, battery chargers, pressurizer heaters, and ventilation and cooling fans. Power to the 480 volt AC vital buses is received from the two 4160/480 volt transformers.

The four 125 volt DC buses are each supplied by a battery and a battery charger. The battery charger is sized to carry all loads on the DC bus and to keep the battery fully charged. The battery charger receives its power from the 480 volt AC vital bus. Loads such as emergency lighting, computer inverter, electrical distribution breaker controls, and control power are fed from the 125 volt DC buses. Some designs may incorporate a manually operated crosstie breaker between the “A” train and “B” train DC buses. This crosstie is provided for plant flexibility such as performing maintenance on various equipment that would normally supply the affected DC bus. If the battery charger is lost, the batteries are designed to provide power to the DC buses for a specified time period.

Four buses supply power for reactor protection (four protection channels, 1 bus assigned to each channel) and for the engineered safety features instrumentation and control. The relative importance of these buses is apparent in the number and diversity of the power supplies to these buses. Normal power comes from an inverter/auctioneer. This device compares its two inputs and selects the higher voltage to be passed on to the 120 volt AC vital instrument bus. One input is from the 125 volt DC control bus. The other is from the 480 volt AC vital bus via a 480/120 volt transformer. This 120 volt AC supply is rectified to 125 volt DC, then delivered to the auctioneer. The auctioneer selects the higher of the two inputs, inverts it to 120 volt AC, and delivers it to the 120 volt AC bus. Since these two sources are in turn supplied by highly reliable sources (diesel, battery), a very dependable power supply is ensured. In addition to the inverter/auctioneer, each 120 volt AC vital instrument bus can also receive power from the 480 volt AC vital bus. This is supplied via a 480/120 volt AC transformer and a normally open, manually operated breaker.

2.8.3.3 Emergency Diesel Generator

If both sources of normal auxiliary power are lost (unit auxiliary transformer and system auxiliary transformer), the equipment essential to safe shutdown will be supplied by the Seismic Class I diesel generators. These diesels will automatically start and tie onto the 4160 volt AC vital buses on a loss of voltage on the bus. Each diesel is designed to reach rated speed and be ready to accept load within ten seconds, and accept full load within thirty seconds after receiving a start signal. The diesel generators will start on an engineered safety features actuation signal or a loss of power on its associated vital bus. The generator tie breaker to the bus will not close unless the bus is de-energized.

To prevent overloading and tripping the diesel, the major loads are automatically stripped off the bus before the diesel generator output breaker closes. The loads will then be sequenced back onto the bus one at a time. The entire sequence takes about 60 seconds and is accomplished by an automatic sequencer. The sequencer also prevents overloading by loading only the equipment considered vital to a safe shutdown.

There are two sequencers that are used. The first is the blackout sequencer. It will sequence on loads that are needed after a loss of offsite power to maintain the reactor in a shutdown condition. This includes the auxiliary cooling water systems, the auxiliary feedwater systems, and the charging pumps. If an accident has occurred and the engineered safety features has been actuated, the loss of coolant accident sequencer will sequence on the equipment needed to combat an accident. This will include the loads sequenced on for the loss of offsite power and the other emergency core cooling systems and containment spray if needed.

2.8.4 Summary

The electrical power system is perhaps the most important engineered safety feature installed in the nuclear power unit. A major purpose of the system is to supply a reliable source of power, under all conditions, to systems that are required for plant safety. Examples of safety systems and components are: (1) engineered safety features valves and pump motors, (2) control power for engineered safety features equipment, and (3) instrumentation required to monitor plant status during normal and abnormal events. In addition to its safety purpose, the electrical power system supplies energy to auxiliary systems that are required for the generation of electricity and provides the necessary connections for the transmission of generated power to the consumer.

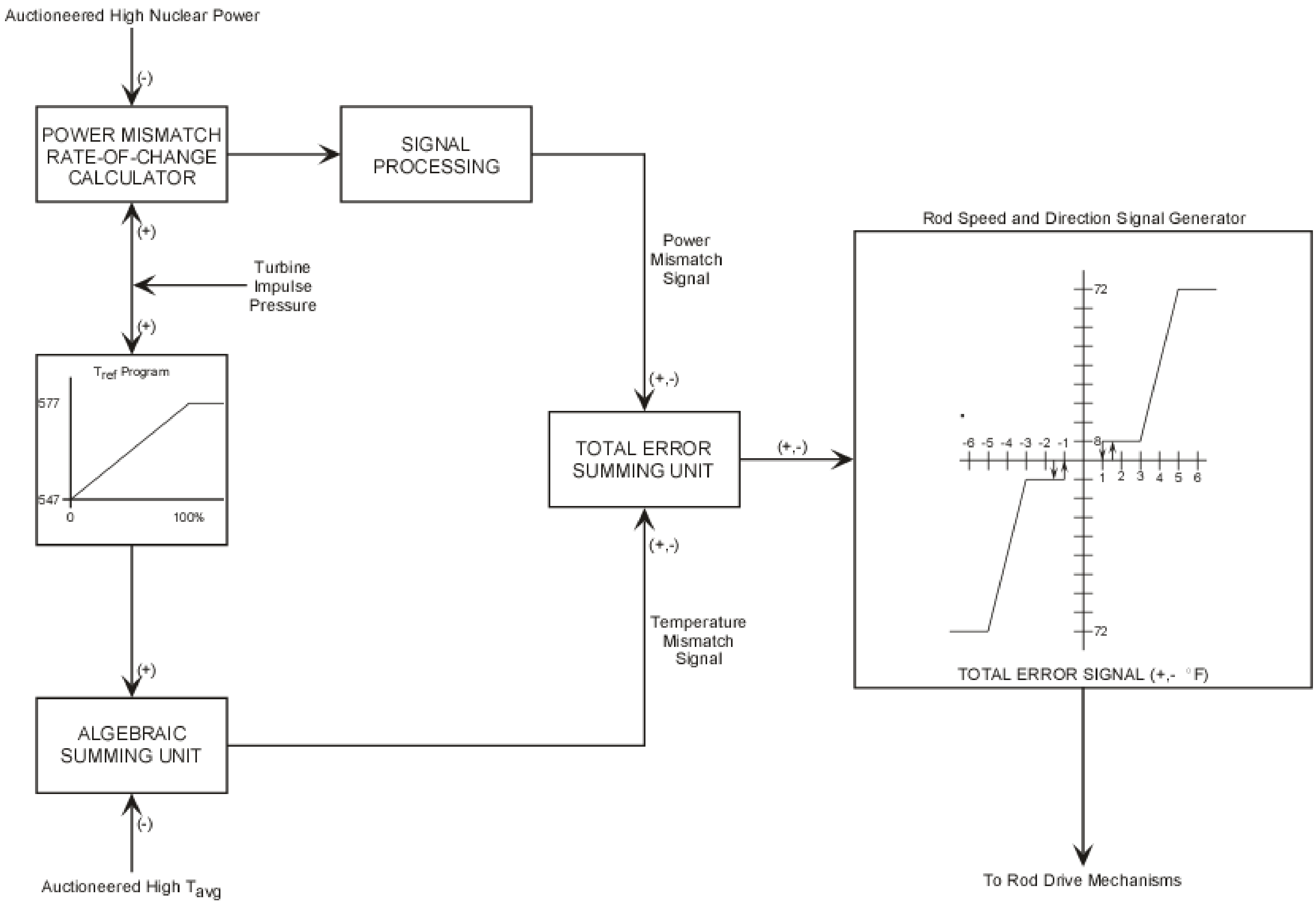


Figure 2.1-1, Rod Control System Block Diagram

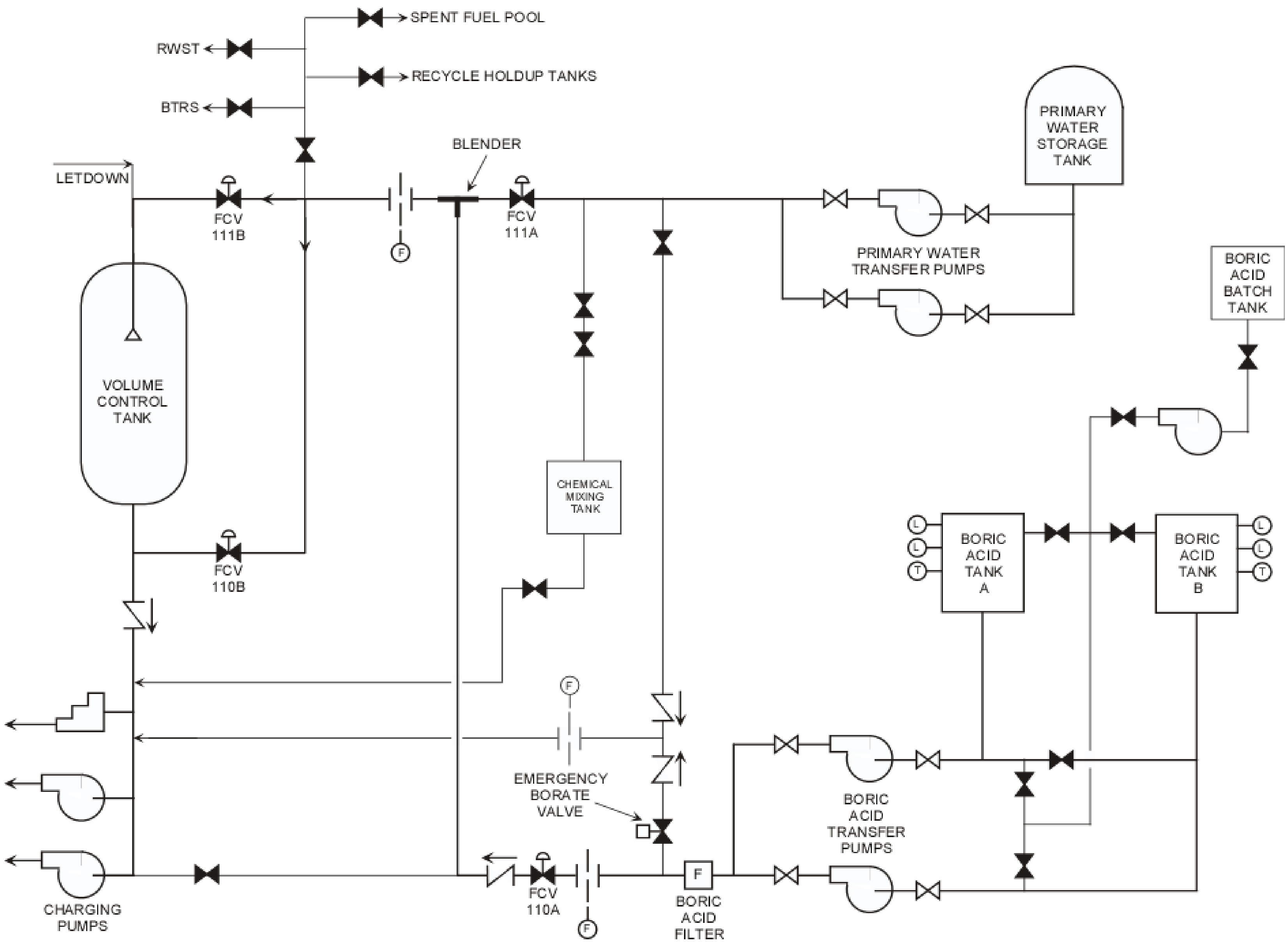


Figure 2.2-1, Reactor Makeup System

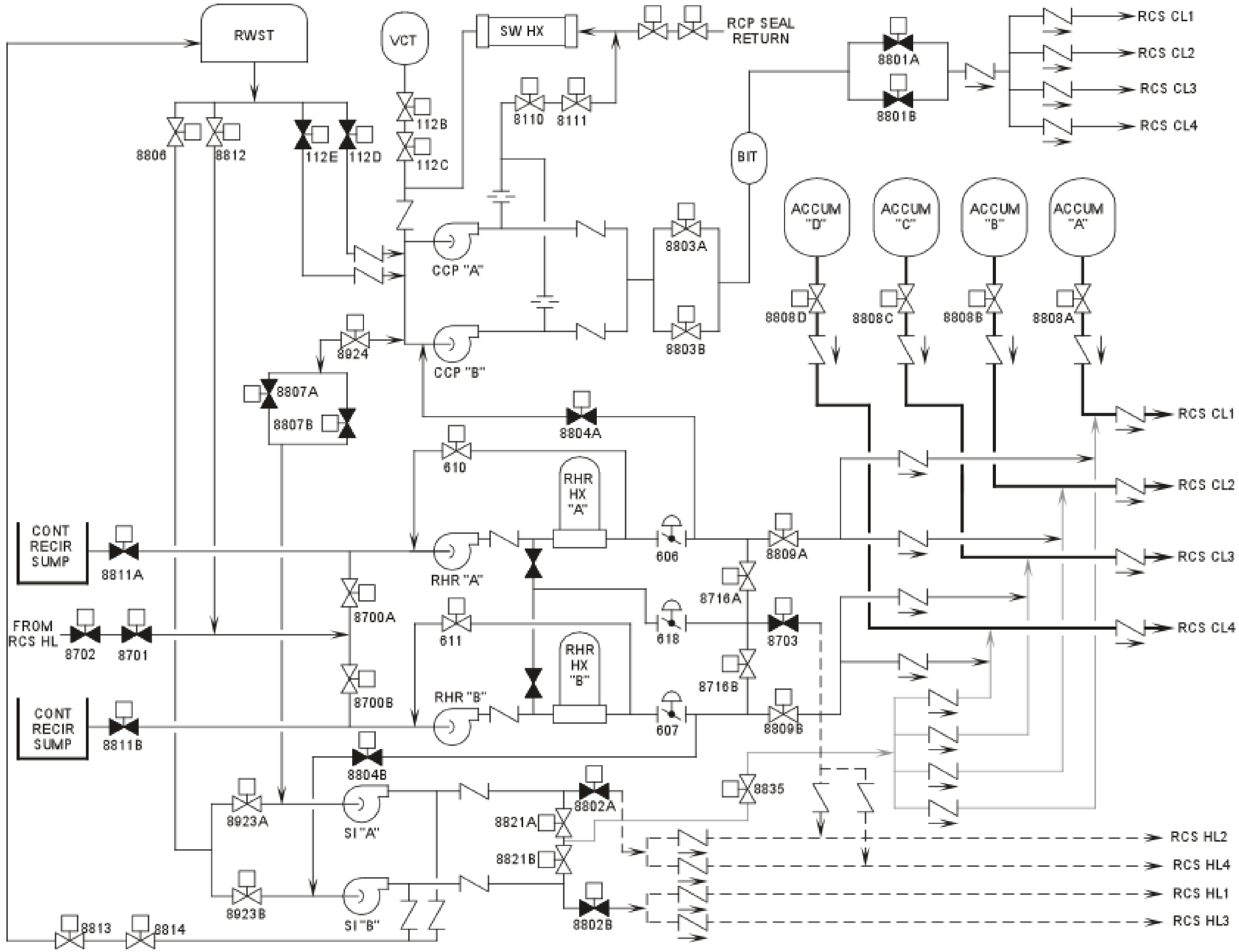


Figure 2.3-1, ECCS Composite

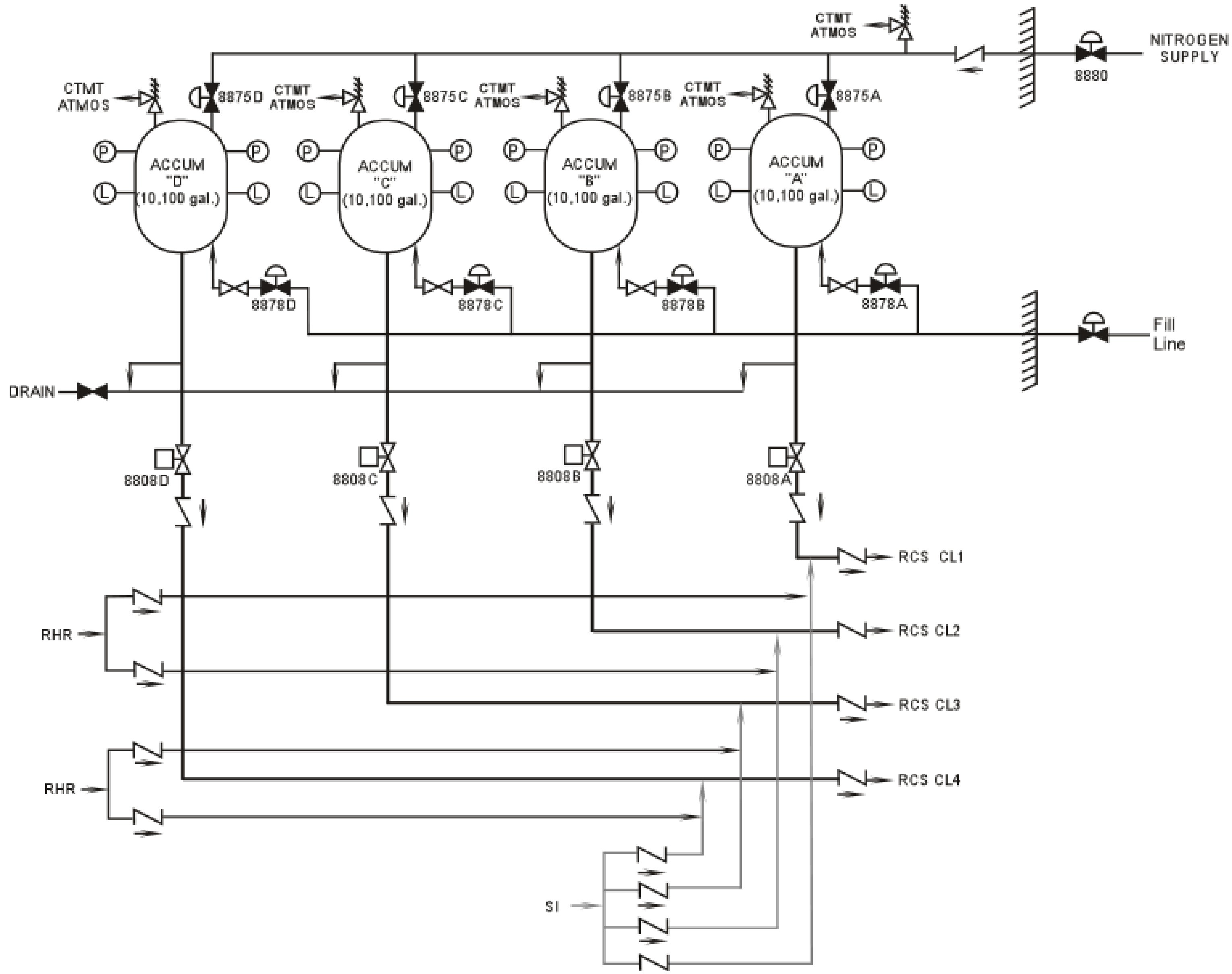


Figure 2.3-2, Cold Leg Accumulator System

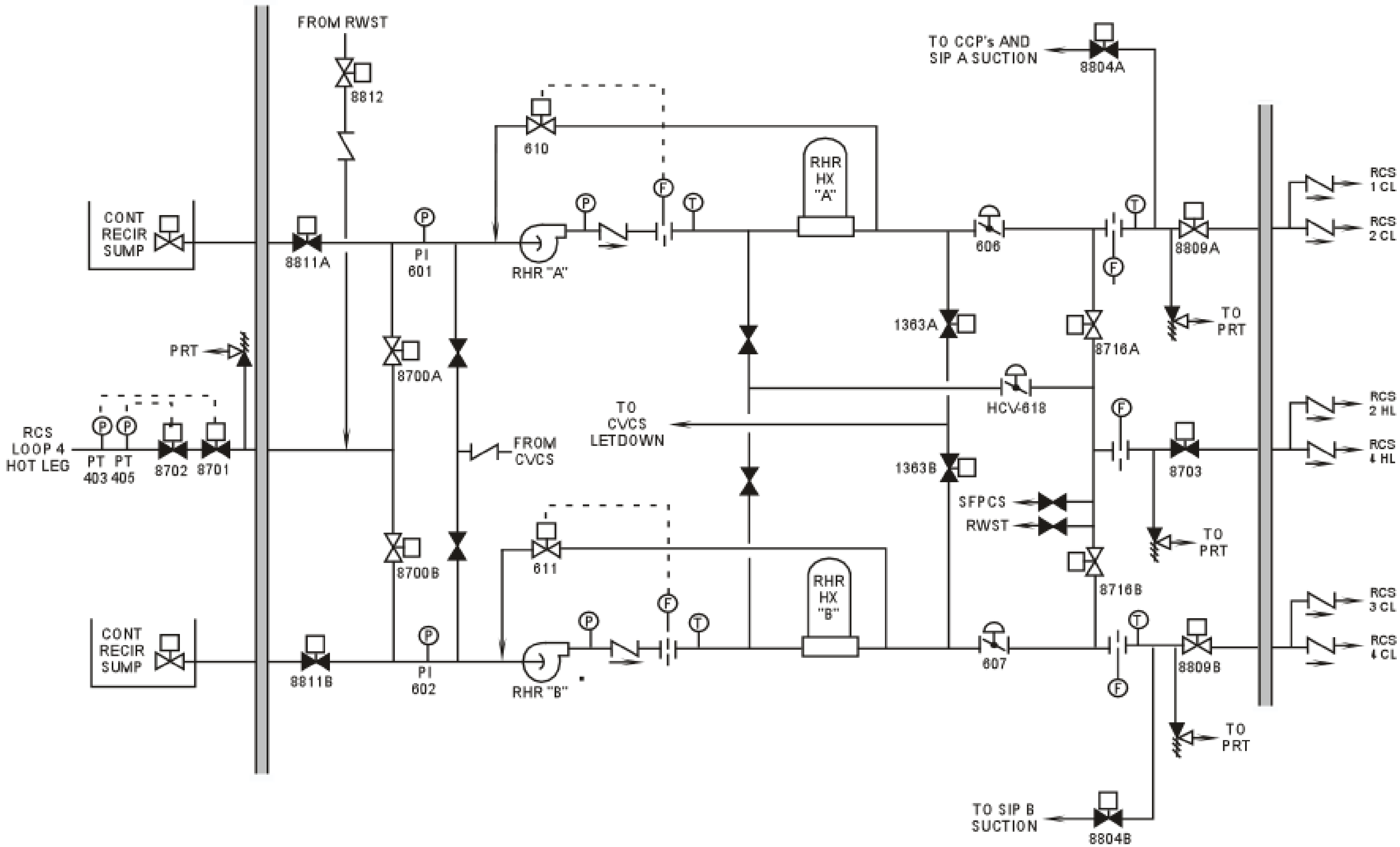


Figure 2.3-3, Residual Heat Removal System

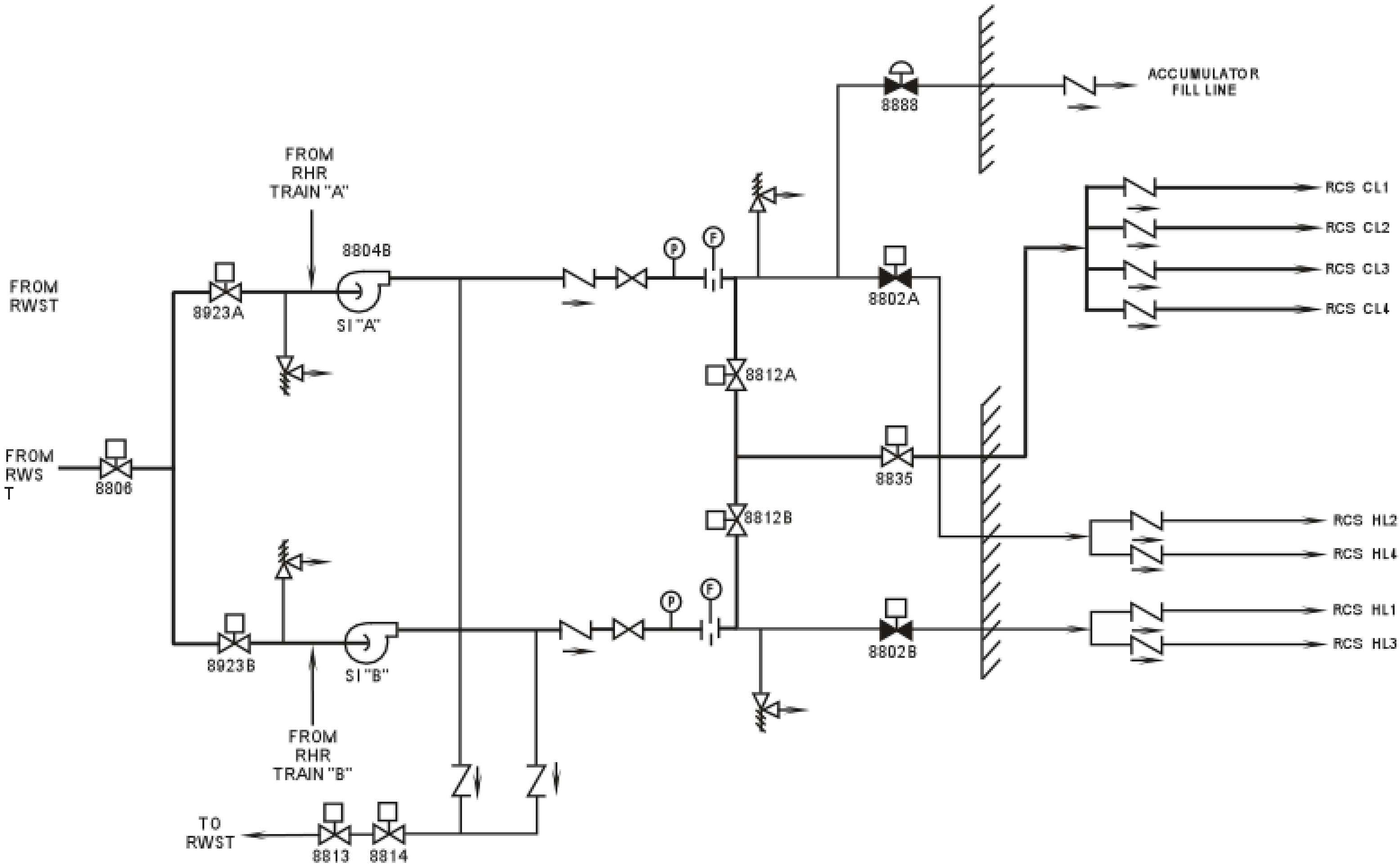


Figure 2.3-4, Safety Injection System

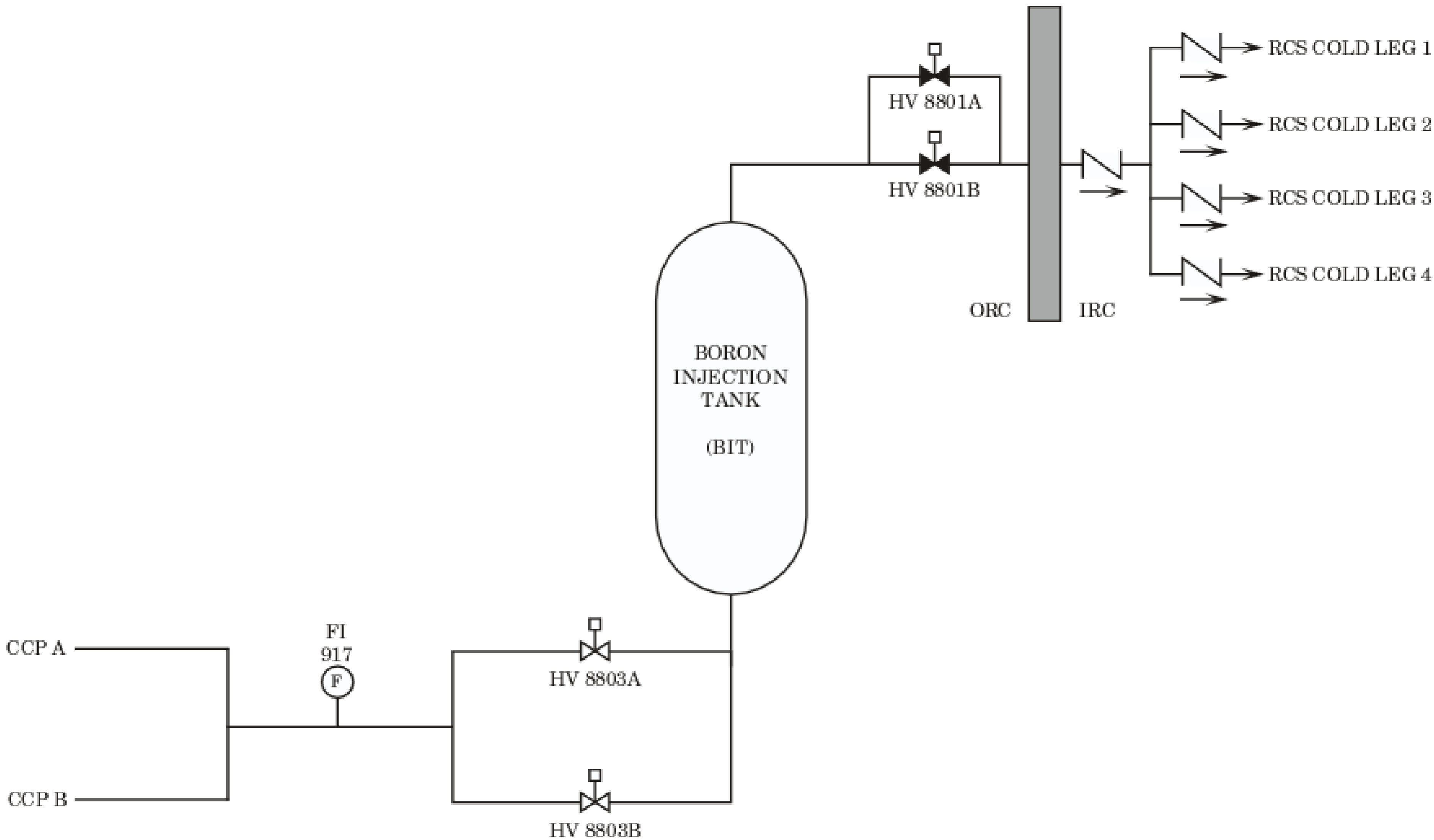


Figure 2.3-5, High Head Injection System

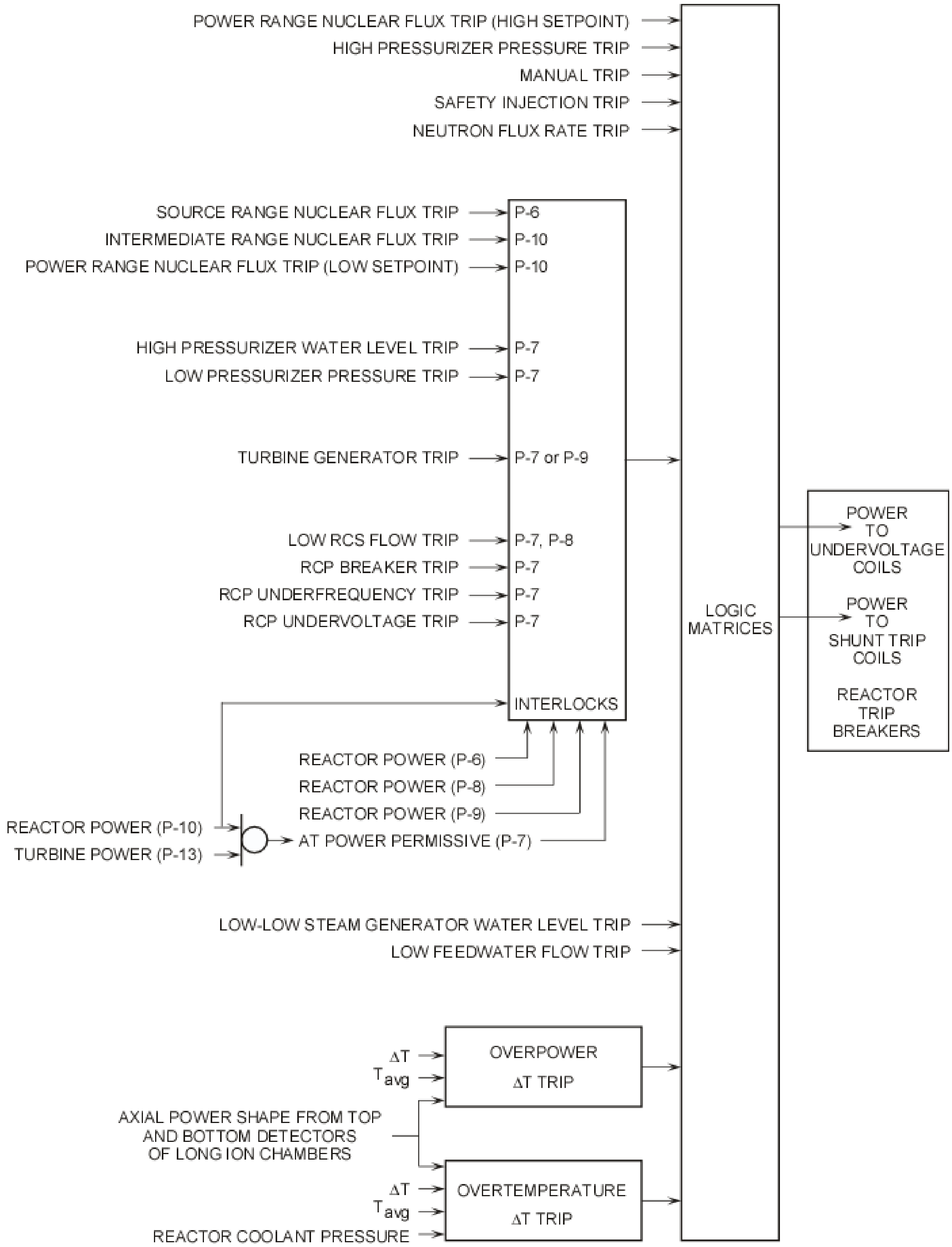


Figure 2.4-1, Reactor Protection System, Block Diagram

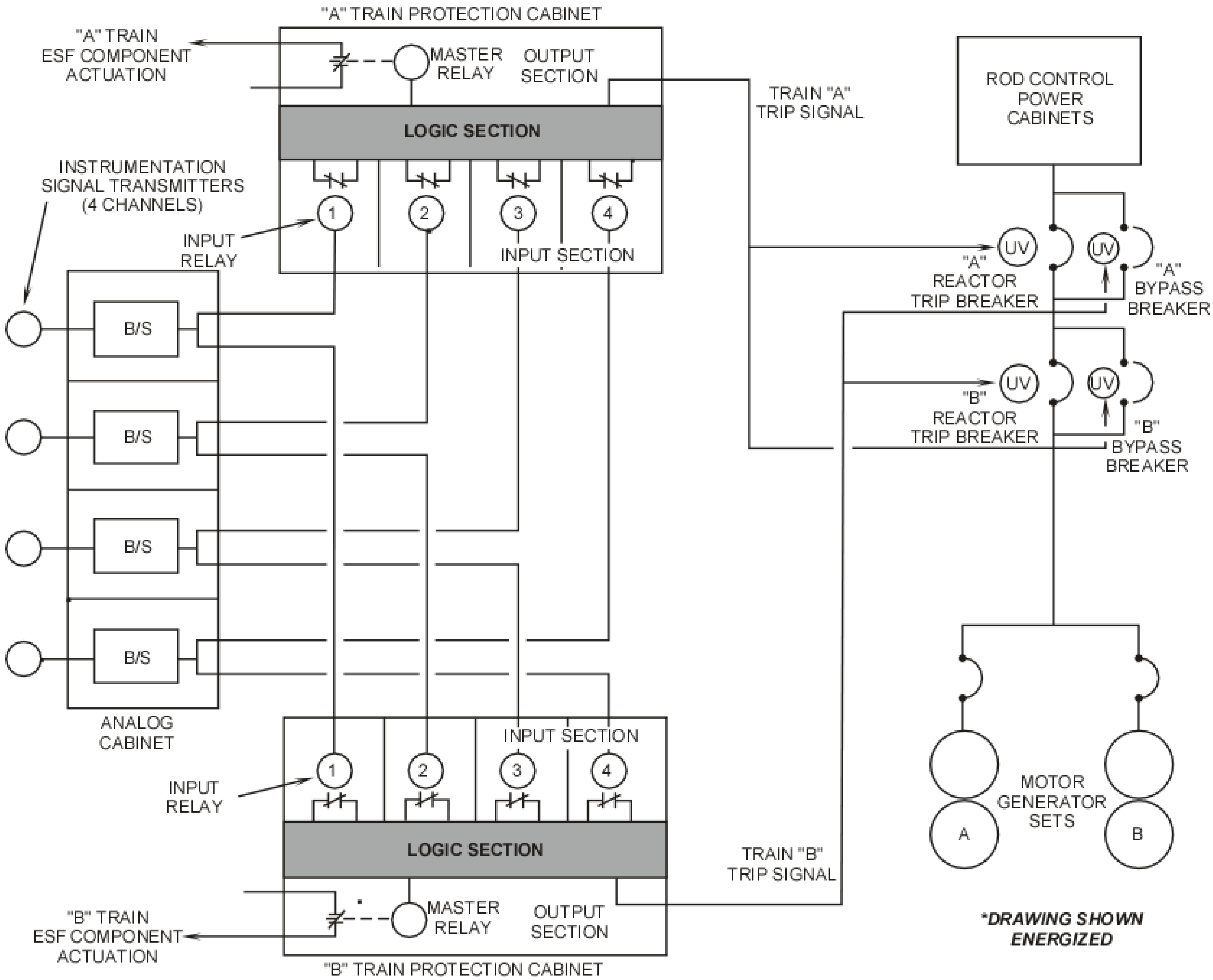


Figure 2.4-2, Reactor Protection System

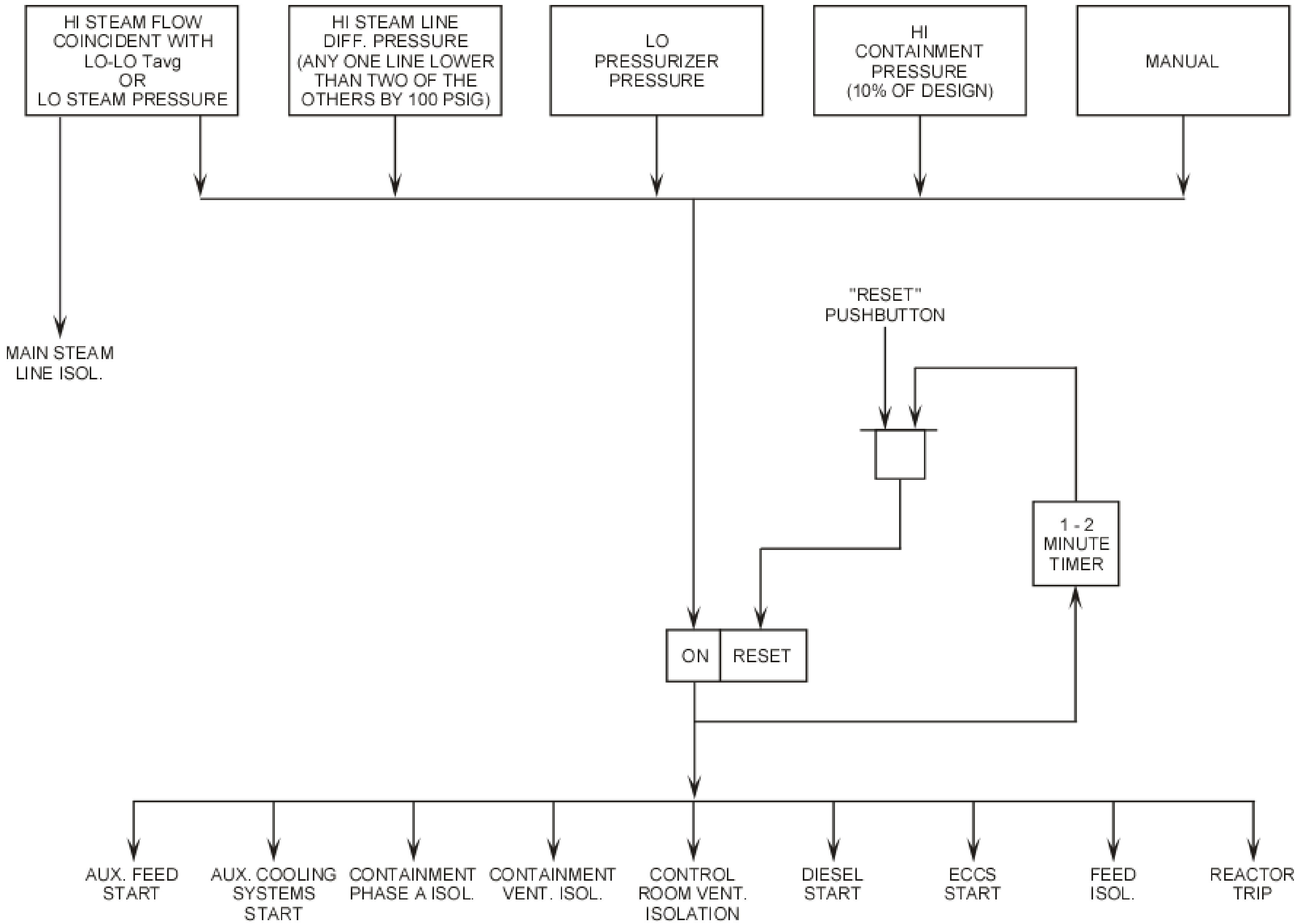


Figure 2.4-3, Safety Injection Actuation Logic

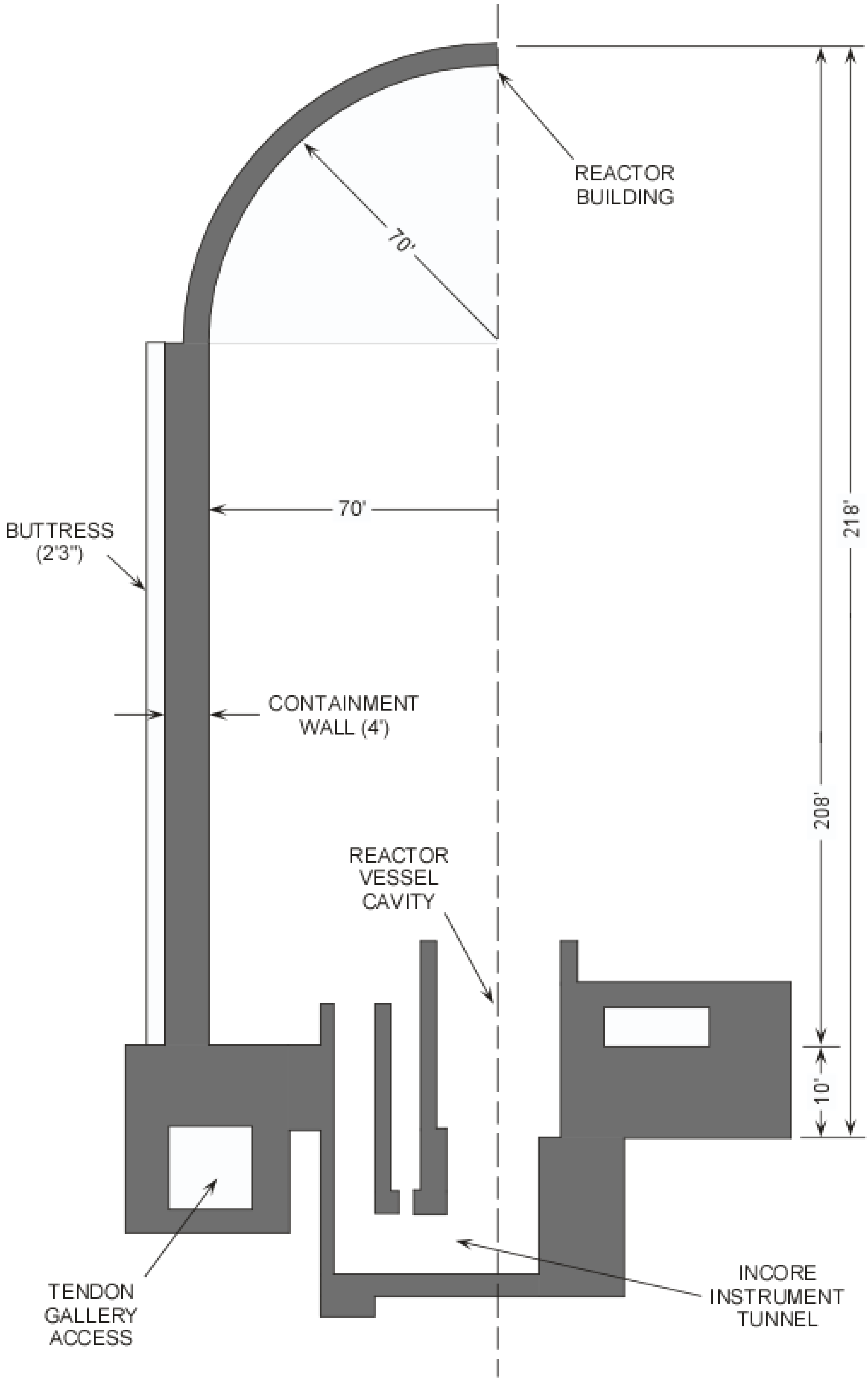


Figure 2.5-1, Containment Building Outline

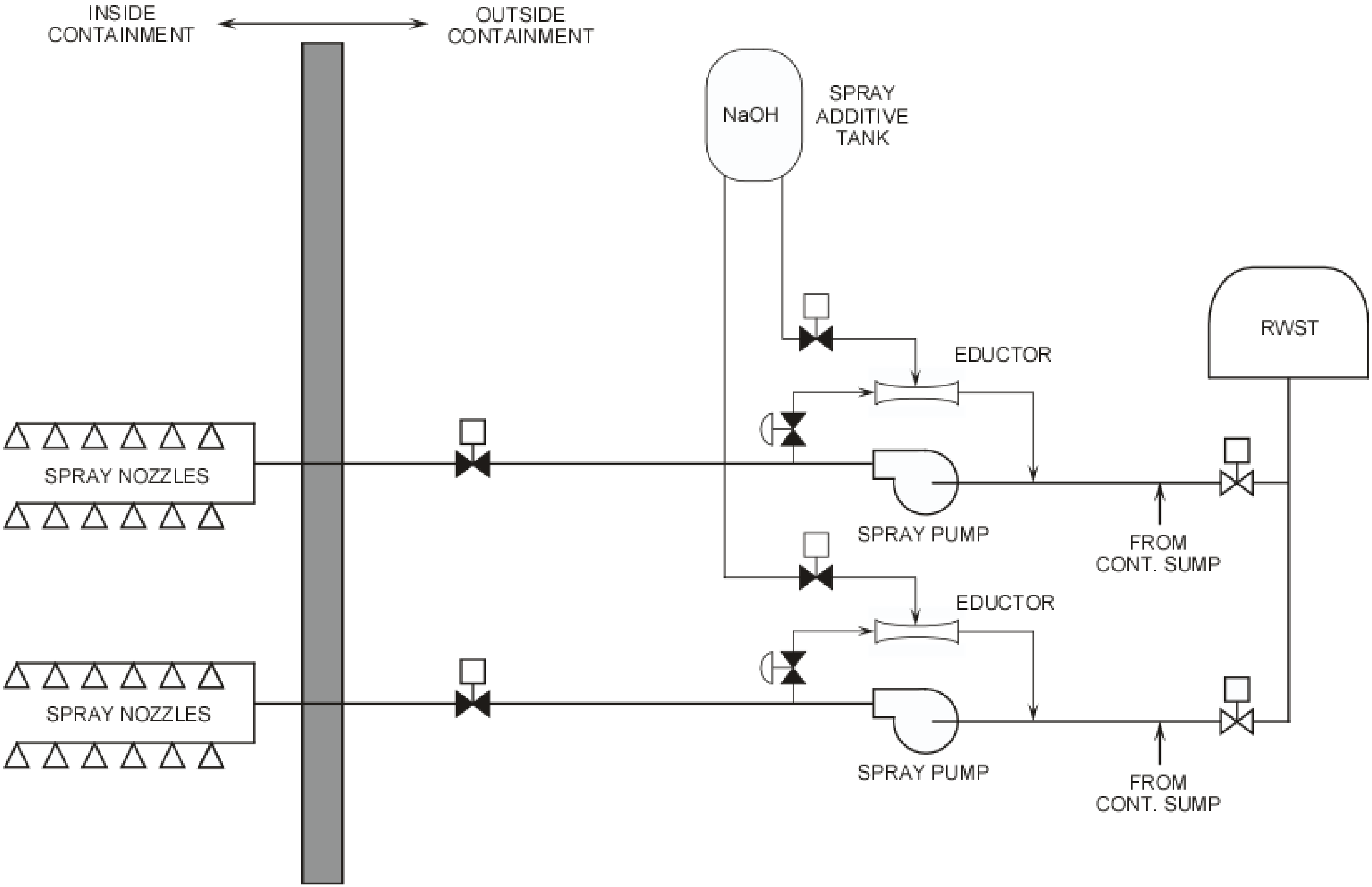


Figure 2.5-2, Containment Spray

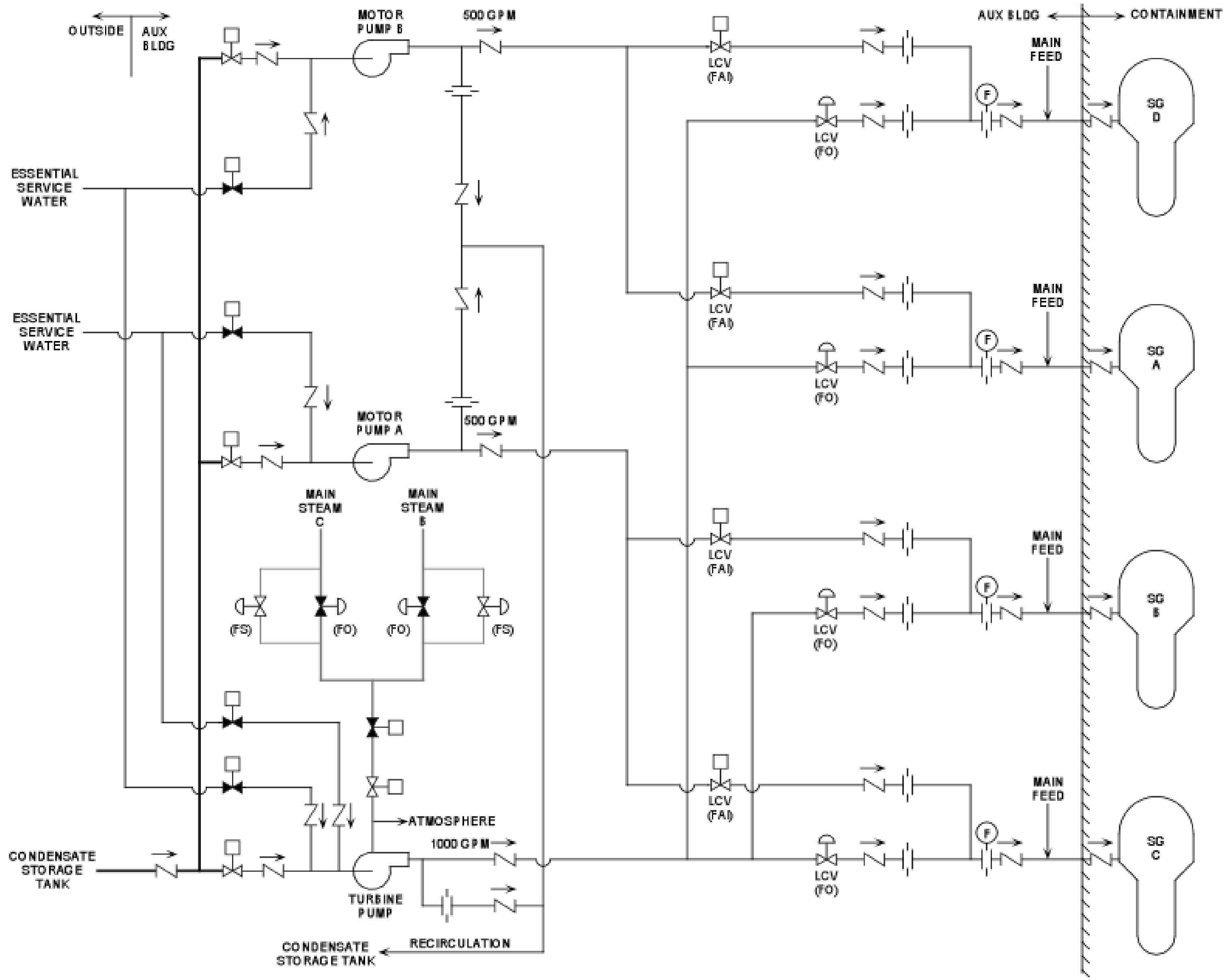


Figure 2.6-1, Auxiliary Feedwater System

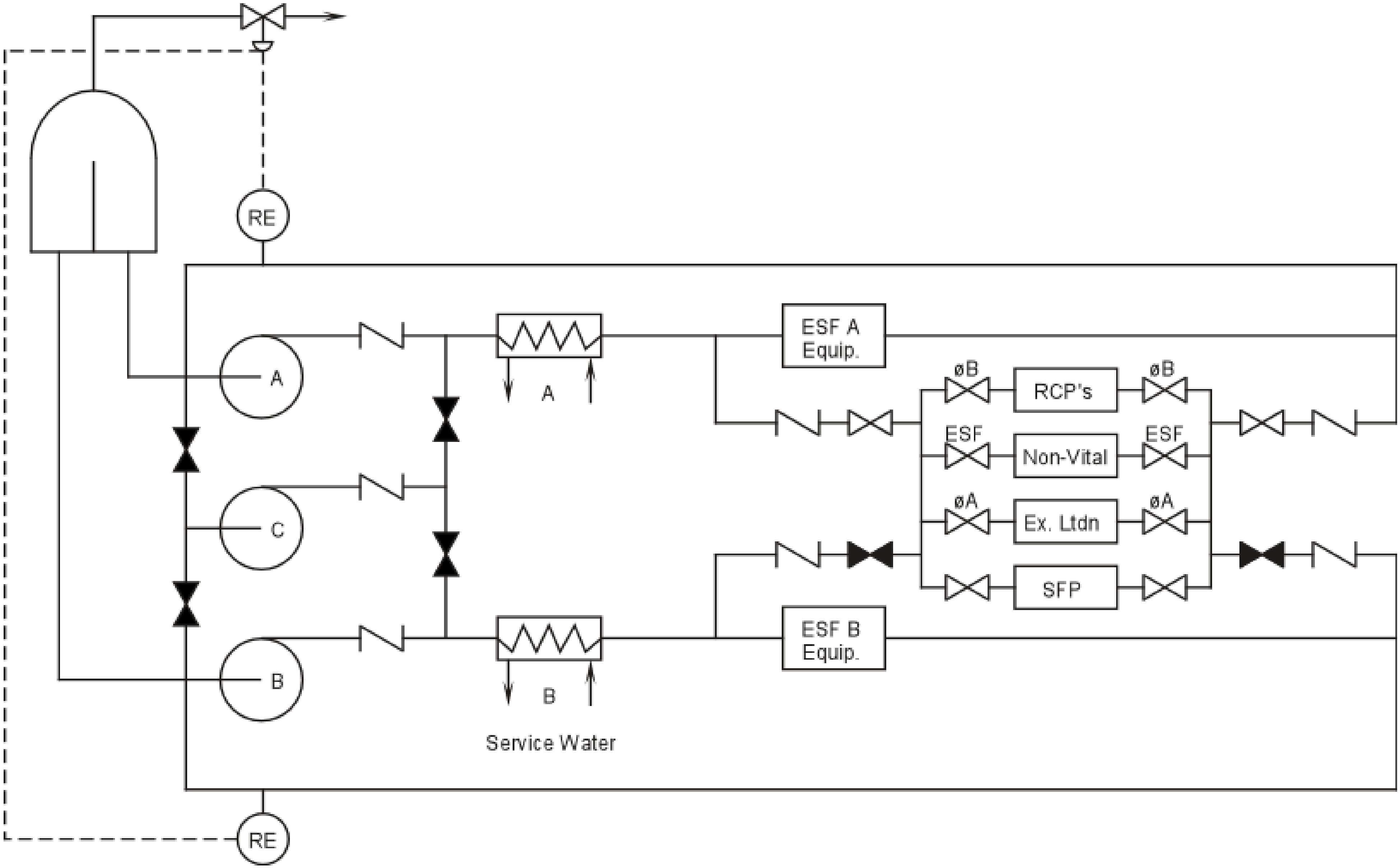


Figure 2.7-1, Component Cooling Water System

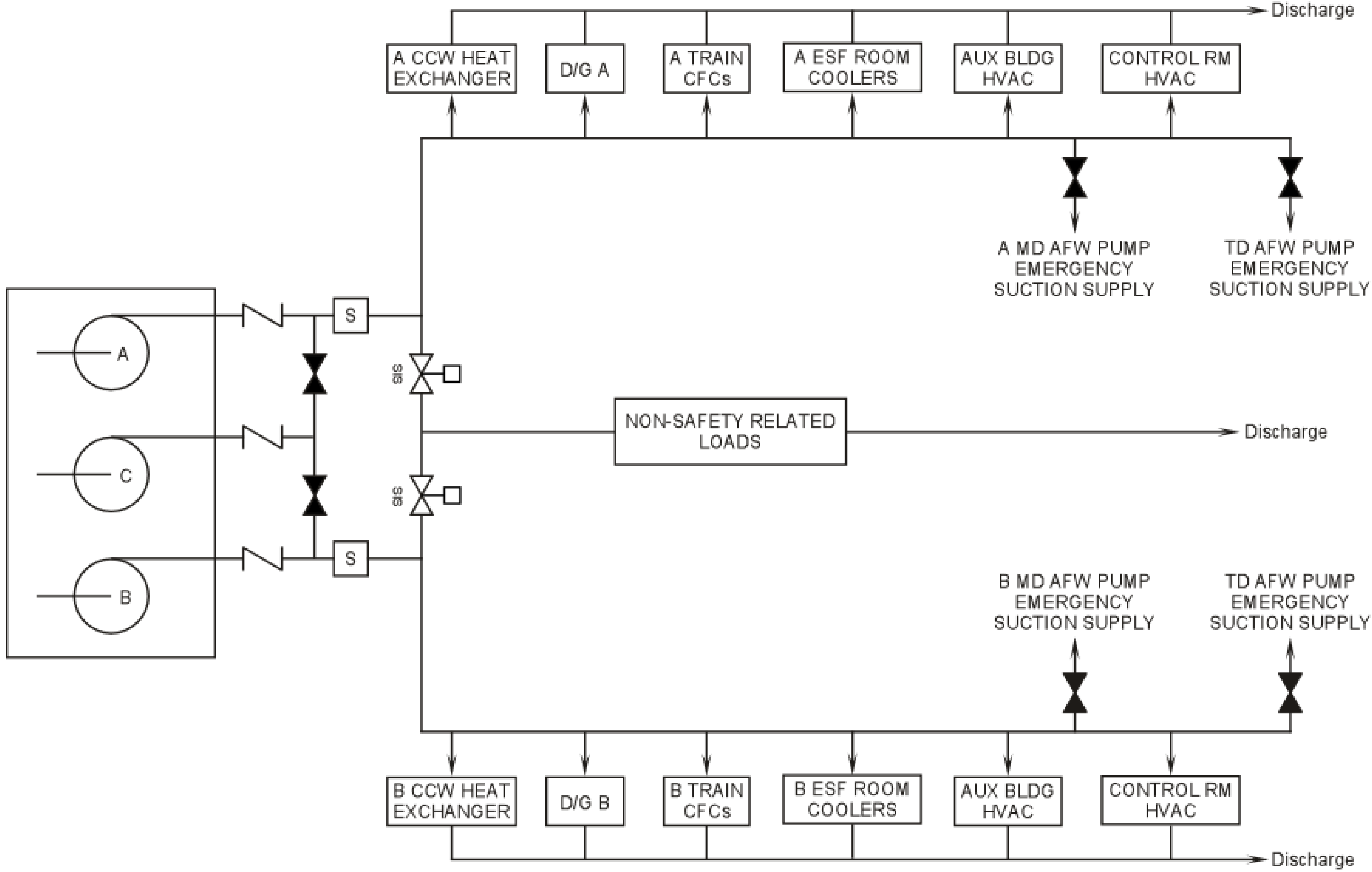


Figure 2.7-2, Service Water System

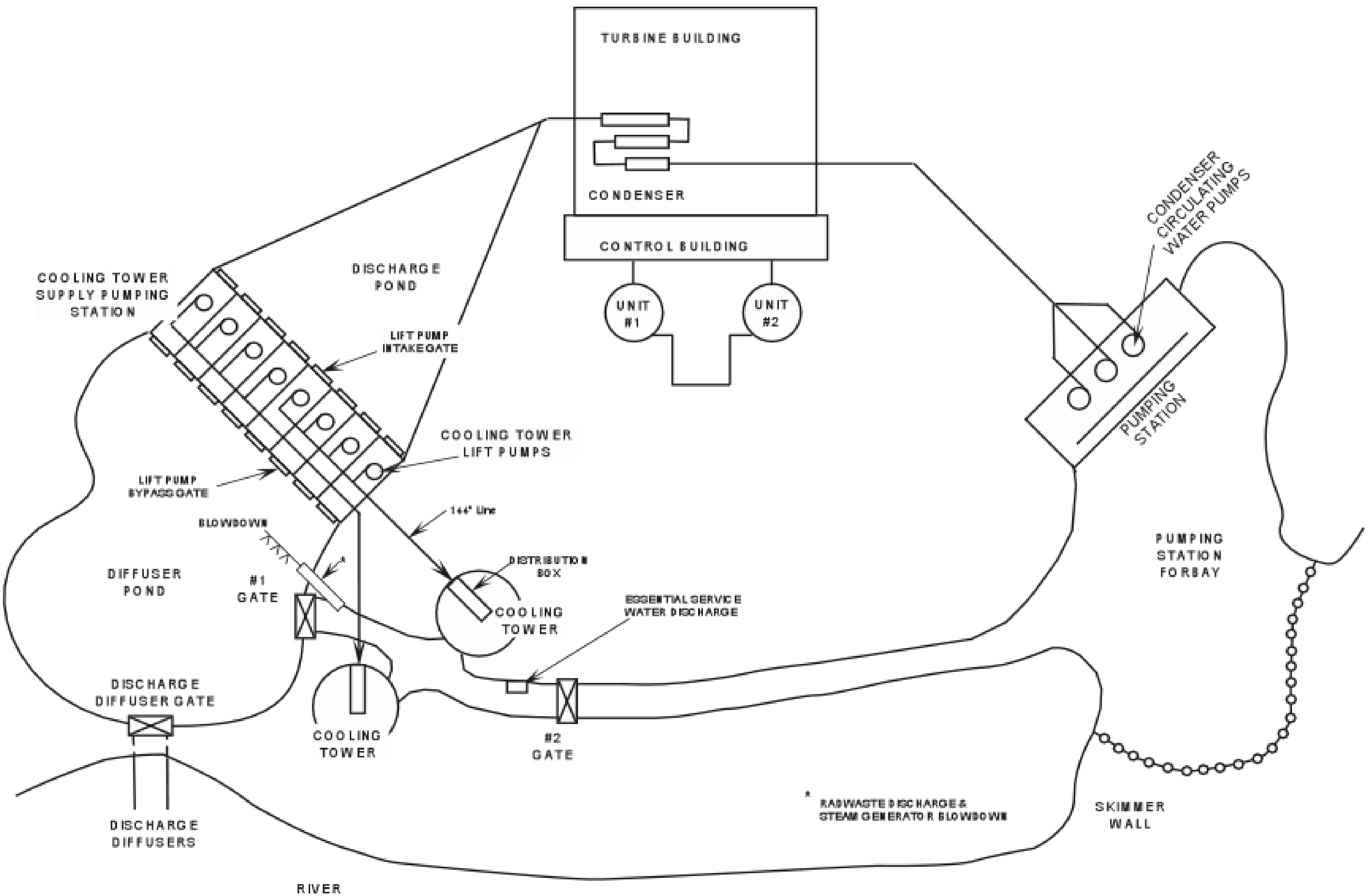


Figure 2.7-3, Condenser Circulating Water System

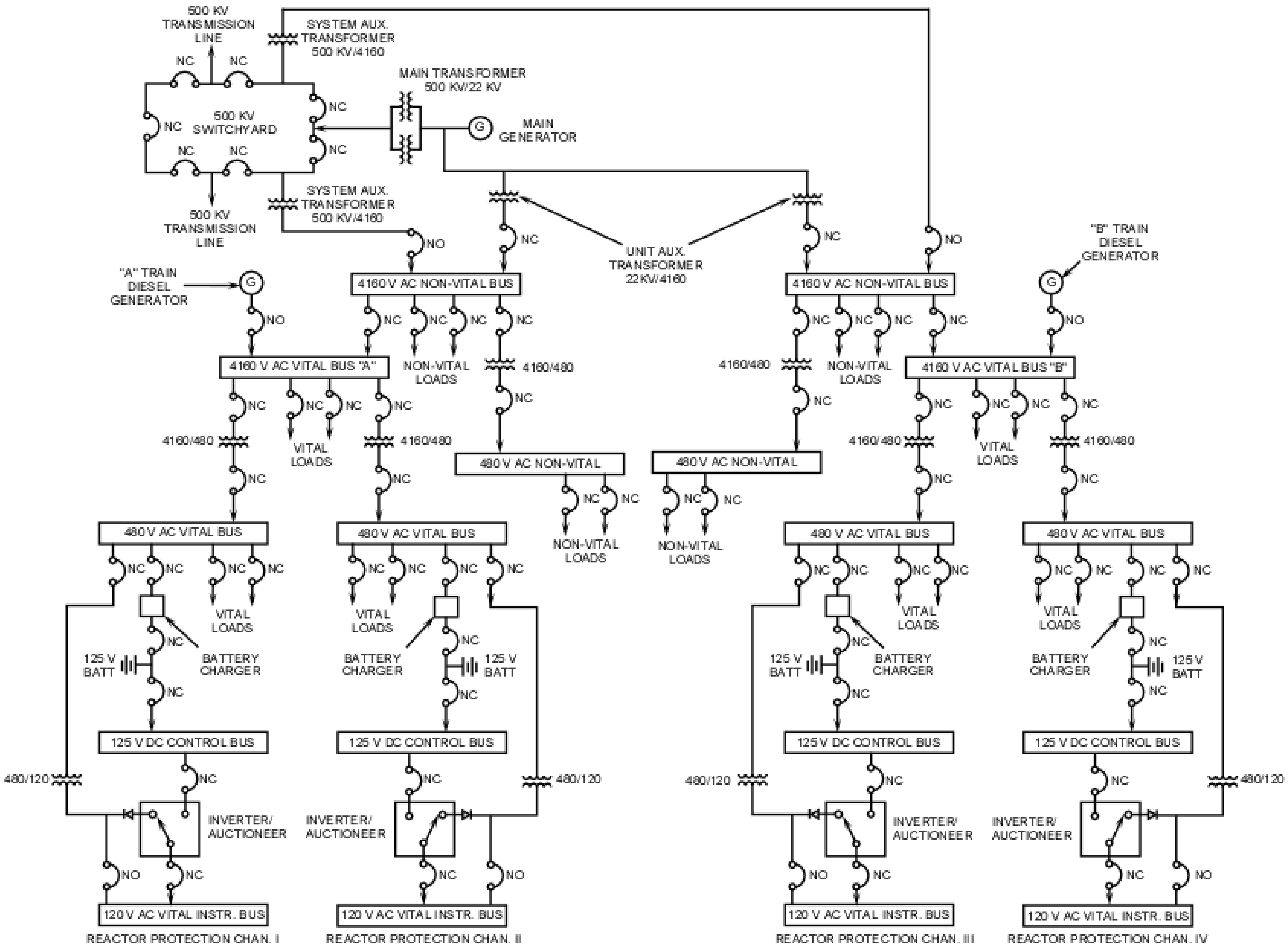


Figure 2.8-1, Typical Power Station Electrical Diagram