9.3 PROCESS AUXILIARIES

9.3.1 COMPRESSED AIR SYSTEM

9.3.1.1 Design Bases

→(EC-41355, R307)

The compressed air system, consisting of the Instrument and Service Air Systems, is designed to provide a reliable supply of dry, oil-free air for pneumatic instruments and controls, pneumatically operated valves and the necessary service air for normal plant operation and maintenance. The system serves no safety function since it is not required to achieve safe shutdown or to mitigate the consequences of an accident. Air accumulators are provided on valves where instrument air is required for operation during the safe shutdown of the plant following an accident or to mitigate the consequences of an accident. Air accumulators required for containment isolation are provided with safety related remote makeup capability to ensure long term operability of the valves following loss of the plant instrument air system. Other safety-related air accumulators are capable of providing motive air to pneumatically operated valves for 10 hours. Procedures are established for operating manual handwheel overrides or lining up backup air supplies for continued safety function after 10 hours. Safety-related valves with air accumulators are listed in Table 9.3-1a and with nitrogen accumulators in Table 9.3-1b.

←(EC-41355, R307)

9.3.1.2 System Description

The compressed air system is shown schematically in Figure 9.3-1 (for Figure 9.3-1, Sheet 3, refer to Drawing G152, Sheet 3 and for Figure 9.3-1, Sheet 4, refer to Drawing G152, Sheet 4).

The compressed air system consists of the following:

a) two nonlubricated rotary instrument air compressors

b) one vertical instrument air receiver

c) two instrument air dryers with pre- and after-filters

d) three nonlubricated rotary station air compressors

e) one vertical station air receiver

f) piping, valves and instrumentation

Each instrument air compressor package consists of an inlet filter, compressor, moisture separator, heat exchanger and discharge filter. Water used in the liquid ring of the compressor is cooled in the heat exchanger by water from the Turbine Closed Cooling Water System. Air from these packages is discharged into the instrument air receiver by a common header. This compressed air is then passed through one of the instrument air dryers and filters assemblies. The compressed air system then divides into various branches. Two in. lines supply instrument air to the demineralizer plant, yard area, Turbine Building, Reactor Auxiliary Building, Reactor Building, Fuel Handling Building, Service Building, and intake structure. In the Turbine, Reactor Auxiliary and Reactor Buildings, these branches are divided into several sub-branches located at various elevations. The various air operated valves, pneumatic instruments and controls are supplied from these lines.

→(DRN 01-692, R11-A)

During normal operation, both instrument air compressors operate to maintain receiver pressure between 112-120 psig. The compressor designated as "standby" starts automatically if the instrument air receiver pressure fall below 105 psig, and continues to operate in a load/unload mode until manually stopped.

←(DRN 01-692, R11-A)

Station air compressor packages also consist of an inlet filter, compressor, moisture separator, heat exchanger and discharge filter. Compressed air from these packages is discharged into the station air receiver by a common header. Downstream of the receiver, the system is divided into various branches. Two inch lines supply service air to demineralizer plant, yard area, Turbine Building, Reactor Auxiliary Building, Reactor Building, Service Building, hot machine shop and decontamination room, Fuel Handling Building and intake structure. These branches are divided into several subbranches in all of these buildings and are located at various elevations. Service air is used for the operation of pneumatic tools, equipment used for plant maintenance, and for occasional air lancing of the wet cooling tower basin water to control microbiological growth.

A station air compressor maintains a pressure of 112-120 psig in the station air receiver. If the receiver pressure falls below 105 psig, the second station air compressor starts automatically. The Instrument Air and Service Air Systems are cross connected through a self actuated pressure control valve through which the Service Air System can feed the Instrument Air System.

The instrument air dryers are provided with a bypass so that when the dryer outlet pressure falls below 95 psig the bypass is automatically opened, thereby maintaining the pressure in the system. A strainer is installed in this line to coarse filter the air.

The instrument air dryers and filters are expected to remove 99% of particulate matter (oil and dust) over 0.3 microns in size, and reduce the moisture content to a dew point of -40°F at 100 psig. The equipment is subjected to the manufacturer’s required maintenance procedures to assure this cleanliness level.
➜
Some safety-related valves which are air operated are equipped with air filters. Normal operating procedures will assure that the filters are maintained clean. Unlikely clogging of the filter would result in loss of air to the valve, putting the valve to its fail safe position, thereby not interfering in its performance of safety-related function.
←
Design data for the compressed air system components is given in Table 9.3-2.

9.3.1.3 Safety Evaluation

Complete loss of instrument or service air during full power operation or under accident conditions does not reduce the ability of the reactor protective system or the engineered safety features and their supporting systems. to safely shut down the reactor or to mitigate the consequences of an accident.

Since the compressed air system serves no safety function, this system is not designed to any safety class or seismic requirements. The portion of instrument air and service air piping and valves penetrating the containment is designed to safety class 2 and seismic Category I requirements (refer to Subsection 6.2.4). The containment instrument air header outer isolation valve is designed to fail closed. The containment service air outer
isolation valve is locked closed because no compressed service air is required in the containment during normal plant operation.

Instrument Air System redundancy is provided by the two sets of instrument air compressor units plus the back up from the Service Air System. A total loss of instrument air is highly unlikely during normal operation.

Failure of compressed air equipment, including air receivers does not have any detrimental effect on safety related equipment, even if the failure produces missiles. Other than process lines, the compressed air equipment is located in the Turbine Building which does not house any safety related equipment.

The power supply for the station air compressor motors is from the Plant Auxiliary Power Distribution System. The power supply for the instrument air compressors is from the engineered safety features buses. If a loss of offsite power occurs, the instrument air compressors are tripped and manually reconnected to the emergency diesel generators for main control room operators convenience in plant shutdown.

Accumulators are provided on those valves where instrument air is required for operation during the safe shutdown of the plant following an accident or to mitigate the consequences of an accident. The accumulators are designed to seismic Category I requirements.

9.3.1.4 Testing and Inspection

The compressor packages are performance tested at the manufacturer's plant. The systems are inspected, cleaned and tested prior to service. Instruments are calibrated during testing and automatic controls are tested for actuation at the proper set points. Alarm functions are checked for operability and limits during plant operational testing. The system is operated and tested initially with regard to flow paths, flow capacity, and mechanical operability.

The compressed air system is in service during normal plant operation. System performance will therefore be checked by the performance of the components utilizing instrument or service air.

9.3.1.5 Instrument Application

The running station or instrument air compressors are loaded and unloaded between 112 and 120 psig in the air receivers. If the pressure falls below 105 psig, the standby compressor starts and runs in a loading/unloading fashion between 112 and 120 psig until manually stopped. The controls are located locally. If the air pressure in the instrument air receiver falls below the preset limit, a self actuated pressure control valve is opened, admitting service air into this system. Annunciation is provided in the main control room for the Instrument and Service Air Systems for the following conditions:

a) low air receiver pressure

b) high and low moisture separator level, and

Local instruments are provided to indicate pressure in the air receivers. In addition, the service and instrument air header pressures, are indicated in the main control room.

9.3.2 PROCESS SAMPLING SYSTEM

→
Process sampling is accomplished by a Primary Sampling System (PSL), a Secondary Sampling System (SSL), and an automatic gas analyzer panel (WGAP).

←

9.3.2.1 Design Bases

The PSL is designed to collect fluid and gaseous samples contained in the Reactor Coolant System (RCS) and associated auxiliary system process streams during all modes of operation from full power to cold shutdown without requiring access to the containment.

The SSL is designed to collect water and steam samples from the secondary cycle, makeup demineralizer and Steam Generator.

→(DRN 00-695)
The Waste Gas Analyzer Panel (WGAP) can be programmed to sample gas from the following locations: Holdup Tanks, Volume Control Tank, Gas Decay Tanks, Gas Surge Tank, Vent Gas Collection Header, Waste Gas Compressor Discharge, and Equipment Drain Tank.
←(DRN 00-695)

9.3.2.2 System Description

Figure 9.3-2 (for Figure 9.3-2, Sheet 3, refer to Drawing G162, Sheet 3) shows the flow diagrams for the PSL, SSL, and WGAP.

Provisions are made to assure that representative samples are obtained from well mixed streams or volumes of effluent by the selection of proper sampling equipment and location of sampling points as well as the proper sampling procedures.

The throttling valves in the sampling system have a limited flow coefficient (C_V) range. This range is based on the flow required and the differential head available under operating conditions. This limits the sample flow rate to the required value and prevents excessively high flow.

9.3.2.2.1 Primary Sampling System

The PSL takes samples from the RCS and auxiliary systems, as listed in Table 9.3-3, and brings them to a common location in the primary sampling room PSL panel in the Reactor Auxiliary Building (elevation -4ft. MSL) for analysis by the plant operating staff. The analyses performed on the samples determine fission and corrosion product activity levels, boron concentration, residual hydrazine, silica, lithium, pH and conductivity levels, crud concentration, dissolved gas concentration and chloride. The results of the analyses are used to regulate boron concentration, and monitor fuel rod integrity, to evaluate the performance of ion exchanger and filters, specify chemical additions to the various systems, and maintain the proper hydrogen and nitrogen overpressure in the volume control tank.

Table 9.3-3 includes the pressure and temperature for each primary sample point, as well as indicating whether the sample passes through the sample coolers.

The requirements for the PSL water chemistry are given in Subsection 9.3.4 for the reactor coolant and Subsection 10.3.5 for the steam generators.

The samples taken from the RCS pass through a run of piping long enough to ensure a minimum decay time of 90 seconds for short-lived radioactivity, including N-16, before the fluid leaves the containment.

→
The samples are cooled by individual heat exchangers to a maximum temperature of 120°F in the primary sampling room's PSL panel sample coolers and then reduced in pressure by pressure reducing valves.
←
The reactor coolant and pressurizer steam space samples may be collected in detachable sample cylinders for gas analysis.
→
Samples taken from the Safety Injection System, the CVCS, the RCS, and the Pressurizer are reduced in pressure by means of manually set throttling valves in the primary sampling room's PSL panel.

Low temperature and low pressure liquid samples from the Primary Water Storage System are routed directly to the primary sampling room's PSL panel.

Temperature, pressure and flow rate indication of all the above samples is provided in the PSL panel.
←
To obtain representative samples, the stagnant lines are purged for several volumes. If there is an indication of crud buildup, there is also the capability to use the system pressure to provide the motive force to achieve a higher purge rate.
→
All liquid samples of the PSL are connected to a common header and discharged to the BMS holdup tank or the Volume Control Tank.
←
The sample sink is of stainless steel construction with a raised edge to retain any splashed fluid. The sink area is provided with a hood equipped with an exhaust to the plant vent system. Demineralizer water is provided to flush and clean the sink. The sink drains by gravity through a water trap to the WMS chemical waste tank.

9.3.2.2.2 Secondary Sampling System
→
The SSL takes water and steam samples from the secondary cycle, makeup demineralizer and condensate transfer pump discharge, and Steam Generator as listed in Table 9.3-4 and brings them to a common location in the secondary Lab & sampling room SSL panel in the Reactor Auxiliary Building (elevation - 4 ft MSL) for analysis by the plant operating staff. Water quality analyses are performed to provide a basis for the control of the secondary cycle water chemistry, and Steam Generator integrity. The analyses performed on the samples are appropriate to determine pH, specific and cation conductivity levels, silica, sodium, dissolved oxygen and residual hydrazine concentrations.

Steam generator are monitored on a continuous basis. The steam generator samples are drawn from the lower portion of the steam generators. The samples are used for chemistry control. Solenoid valves are operated from the sampling room to allow the operator to select the desired steam generator sample source.

←

→
The steam generator samples are analyzed for radioactivity with one combined steam generator radiation monitor. Should the radiation level rise above a set limit, an alarm is activated in the main control room (see Subsection 11.5.2.4).
←
Each steam generator sample is automatically monitored for specific and cation conductivity, pH, silica and sodium. Should any of these parameters rise above operating limits, a local alarm is activated. In addition, cation conductivity, pH and sodium are also alarmed in the main control room. Grab sample provisions are also provided.

Table 9.3-4 includes the pressure and temperature for each sample point, as well as indicating whether the sample passes through a multi-tube heat exchanger, as well as the chiller-bath cooling coils.

The temperature control of the samples having a temperature of 141°F or above is accomplished by a multi-tube heat exchanger and an integrated automatic sample temperature control system (chiller-bath cooling coils) to maintain sample temperatures at 77°F ± 1°F, as required for the analyzers. The temperature control of the low temperature (below 141°F) samples is accomplished by using only the integrated automatic sample temperature control system.

The multi-tube heat exchanger is a compact, single shell unit designed to cool and condense several individual samples concurrently. The coils are internally baffled so that each coil is thermally insulated from one another allowing the adjustment of cooling water flow over each individual coil. The Component Cooling Water System removes heat from the heat exchanger.
→
The analyzers drain header is routed to the sample recovery tank and pumped to the industrial waste sump.

9.3.2.2.3 Waste Gas Analyzer Panel

Gas samples from the locations listed in 9.3.2.1 can be analyzed by the gas analyzer for potentially hazardous concentrations of oxygen and hydrogen. Samples may be collected in a sample vessel and taken to the radio-chemistry laboratory for further analysis. The gas analyzer is part of the WMS and is discussed in Section 11.3.
←
9.3.2.2.4 Metal Transport Sampling System

The Metal Transport Sampling System continuously obtains a representative sample of approximately 1,100 ml/min from the Feedwater (FW), Main Steam (MS), and Blowdown (BD) systems. This is accomplished by the use of sample probes which extend into the process piping approximately 1/3 of the pipe diameter. The samples are cooled below 120°F and approximately 100 ml/min is routed through a Millipore filter and the balance (1000 ml/min) is diverted through a bypass. The bypass flow is maintained continuously to reduce mineral depositing on the sample tubing which could be sloughed off by flow surges, water hammers and thermal expansion. The millipore filter is periodically isolated, removed and analyzed to monitor the accumulation of corrosion products.

9.3.2.3 Safety Evaluation

→

The Process Sampling System is not essential for safe plant shutdown. Safety features are provided to protect plant personnel and to prevent the spread of contamination from the primary/secondary lab sampling rooms when samples are being collected. The system is designed to limit radioactivity releases below the 10CFR20 limits under normal and failure conditions. The temperature and pressure of the various samples are reduced to minimize the possibility of local airborne activity. Instrumentation is provided in the sampling rooms to monitor the temperature and pressure of the samples before they are collected. Samples are normally taken only when the hood fan is operating. The Reactor Auxiliary Building Normal Ventilation System provides a backup means of maintaining the low airborne activity levels.

The sample lines penetrating the containment are each equipped with two pneumatically operated isolation valves which close upon receipt of a Containment Isolation Actuation Signal. The penetration piping and isolation valves are safety class 2 and seismic Category 1. The containment isolation valves are also designed to fail closed on loss of air supply (refer to Subsection 6.2.4). Remote control of these valves is provided to isolate any line failure which might occur outside of the containment. Should any of the remotely operated valves in the sampling system fail to close after a sample has been taken, backup manual valves in the sampling room may be closed.

←

9.3.2.4 Testing and Inspection

The system is inspected and cleaned prior to service. Demineralized water is used to flush each part of the system. The system is operated and tested initially with regard to flow paths, flow rate, thermal capacity and mechanical operability. Instruments are calibrated during plant hot functional testing. The set points of the relief valves are also checked at this time.

→

All automatic analyzers are calibrated and their output results verified. Proper sequencing of the WGAP solenoid valves are verified. The proper operation and availability of the Process Sampling System is proved inservice by its daily use during normal plant operation.

The sequencing operation of the WGAP is tested by observing proper solenoid valve operation and appropriate sample flow through the analyzer. The analyzer is calibrated against known hydrogen and oxygen sources.

←

The sampling systems are inspected during normal operation by observing proper operation of the components while samples are being drawn. The malfunction of automatic analyzers will be observed by inappropriate readouts on the recorders or by alarms.

9.3.2.5 Instrument Application

→

The PSL and SSL use local pressure, temperature and flow indicators to facilitate manual operation and to determine sample conditions before samples are drawn. The radiation monitor and microprocessor is housed in its own panel.

←

The plant monitoring computer records the sample parameters from the steam generator.

9.3.3 EQUIPMENT AND FLOOR DRAINAGE SYSTEMS

9.3.3.1 Design Basis

The Equipment and Floor Drain Systems collect waste liquids from the various plant operational systems and convey them from their points of origin by gravity, by pumps, or a combination thereof, to the appropriate Waste Management System collection tank. Gravity flow paths for the movement of waste water directly to the Waste Management System tanks are utilized whenever such design can be accomplished. When total gravity flow is precluded by abnormal or unusual conditions, liquids are routed by gravity to intermediate collection sumps or tanks and subsequently pumped to the Waste Management System collection tanks.

The radioactive drainage systems and non-radioactive drainage systems are designed to be totally isolated from each other. Therefore there is no potential for inadvertent transfer of radioactive contaminated fluids to a non-radioactive drainage system. Each area housing safety related equipment is provided with an independent drainage system and attendant sump to preclude the flooding of such areas from other drainage systems.

The Equipment and Floor Drainage Systems do not serve any safety function and are classified as non-nuclear safety. Therefore, they are not required to withstand the effects of adverse environmental phenomena such as earthquakes, tornadoes, hurricanes, floods, or the effects of high and moderate pipe breaks.

A Storm Water Drainage System is provided and sized for the design rain intensity storm condition of 5-1/2 in./hr.

Equipment and floor drainage piping in areas of potential or actual radioactive discharges are constructed in accordance with ANSI B31.1-0, Power Piping Specification, Winter 1975.

9.3.3.2 System Description

The drainage systems are divided into two major classifications; radioactive drainage systems and non-radioactive drainage systems. These classifications are further defined into subsystems for the purpose of identifications, isolation, routing and processing.

Radioactive Drainage Systems

a) Equipment Drain System

b) Floor Drain System

c) Detergent Waste System

d) Chemical Waste System

Non-Radioactive Drainage Systems

a) Storm Water Drainage System

b) Acid Waste and Vent System

c) Acid and Caustic Waste System

d) Oil Drainage Systems

e) Industrial Waste System

f) Sprinkler Discharge Drainage System

→

Equipment and Floor Drainage Systems are shown on Figures 9.3-3, 4 and 5 (for Figure 9.3-3, Sheet 1, refer to Drawing G173, Sheet 1).

←

The drainage system components consist of drain fittings specifically selected for a planned or anticipated liquid discharge, and a network of pipe, fittings, valves, sumps, and pumps to achieve rapid and unobstructed flow paths from the point of liquid influent to the point of treatment or disposal.

Table 9.3-5 lists construction materials and the type of joint for each subsystem. Each system component is engineered so as to be capable of conveying the designed volume of leakage expected. Uncontrolled large volumes of liquids released by pipe or equipment failure, or by tank overflow will spill upon the floor. All floors are pitched approximately 1/8 in. per ft. to a floor drain for rapid carry-off of such spillage.

Each gravity drainage system is designed using the normal anticipated maximum discharge in gallons per minute through an enclosed pipe flowing a maximum of 75 percent full. Horizontal drainage piping is sloped at a uniform rate of 1/4 in. per ft. as standard practice. Where conditions are such that standard pitch cannot be maintained, a pitch of 1/8 in. per ft. minimum is used. Fittings are drainage pattern whenever possible and are installed so as to provide a continuous extension of piping runs. Discharge headers from pumps are routed as true as possible to their final destination, keeping to a minimum turns and traps.

Cleanouts are provided on each drainage system to permit cleaning in the event a blockage occurs. The size of cleanouts are in direct proportion to the size of the pipe it serves, up to four in. Thereafter four in. cleanouts are standard for all larger pipes. Cleanouts are located where the change of direction in horizontal runs is 90 degrees or greater, at maximum intervals of 50 ft. on straight runs and at the base of all stacks. Piping runs encased or embedded in concrete or located in inaccessible areas have cleanouts extended to accessible locations.

9.3.3.2.1 Radioactive Drainage Systems

The radioactive drainage systems provide the interface between the RCS, reactor auxiliaries equipment, and the waste management treatment facilities. They provide for the drainage of equipment, tanks, and wetted surfaces during normal plant operation as well as anticipated large volume flow associated with abnormal or accident conditions.

9.3.3.2.1.1 Equipment Drain System

Reactor Auxiliary Building

Liquid discharges of reactor grade fluids from equipment, tanks, and miscellaneous leak-off points located at elevation -35 ft. MSL are collected by drain fittings located at the equipment discharge points and routed by gravity through piping buried in the mat to the equipment drain sump no. 1. Two sump pumps discharge the sump contents to the equipment drain tank through the recycle drain header.

→(DRN 00-695)

Liquid discharges of reactor grade fluids from equipment, tanks, and miscellaneous leak-off points located at elevation -4 ft. MSL and above are collected by the recycle drain header and routed by gravity to the equipment drain tank located on elevation -35 ft. MSL. The tank liquids are drained by means of the equipment drain tank pump through the reactor drain tank pump discharge header to the holdup tanks in the Boron Management System.

Reactor Building

Liquid discharges of reactor grade fluids from equipment and miscellaneous leak-off points are collected by the containment drain header and routed by gravity to the reactor drain tank. The reactor drain tank pump discharges the tank liquids to the holdup tanks in the Boron Management System.

←(DRN 00-695)

9.3.3.2.1.2 Floor Drain System

Reactor Building

Liquid discharges of low purity (non-reactor grade) wastes from equipment, tanks, miscellaneous leak-off points, and floor drainage are collected by drain fittings located at the equipment discharge point and by floor drains located at low points in the floors, and routed by gravity to the containment sump which is located at the lowest point within the reactor cavity. In entering the sump, all liquids pass through a leak detection tank which is located within the sump. This tank is equipped with a triangular weir. Liquids from the tank drain into the sump through the weir. Two sump pumps discharge the sump contents to the waste tanks through a radiation monitor located outside the containment.

Alternate flow paths are provided on the containment sump discharge header for decontamination washdown (see Subsection 9.3.3.2.1.3).

Reactor Auxiliary Building

Liquid discharges of low purity wastes from equipment, tanks, miscellaneous leak-off points, and floor drainage, are collected by drain fittings located at the equipment discharge points and by floor drains located at low points in the floors and routed by gravity to floor drain sumps at elevation -35 ft. MSL. Each sump is provided with two pumps which discharge the sump contents to the waste tanks.

Fuel Handling Building

Liquid discharges of low purity wastes from equipment, tanks, miscellaneous leak-off points, and floor drainage are collected by drain fittings located at the equipment discharge points and by floor drains located at low points in the floors and routed by gravity to the floor drain sump no. 1 at elevation -35 ft. MSL. Two pumps discharge the sump contents to the waste tanks.

9.3.3.2.1.3 Detergent Waste System

Reactor Building

For those periods when the reactor head laydown and wash area will be used for decontamination, the containment sump discharge header provides an alternate discharge path for removal of liquids containing those chemicals used for decontamination procedures. The flow path is directly to the laundry tanks.

Reactor Auxiliary Building

Liquid discharges containing chemical cleaning compounds from those areas and associated equipment listed on Table 9.3-6 are routed by gravity to the laundry tanks located on elevation -35 ft. MSL. All fixtures, equipment drains, and floor drains are provided with traps and are vented to the vent gas collection header.

Equipment drains and floor drains serving laundry process equipment on elevation -35 ft. MSL are routed to the detergent waste sump no. 1. Two sump pumps discharge the sump contents to the laundry tanks via the laundry tank collection header.

Fuel Handling Building

Drainage is provided for the spent fuel cask decontamination pit, refueling canal, and the spent fuel cask storage area for decontamination washdown of walls, floors, and fuel casks. Floor drains collect the waste water and route it to the refueling canal drain pump. The refueling canal drain pump discharge header provides two alternate flow paths. One flow path is provided directly to the laundry tanks for liquid from initial washdown with decontamination chemicals. The second flow path directs subsequent rinse water to the spent fuel pool.

9.3.3.2.1.4 Chemical Waste System

Reactor Auxiliary Building

→(DRN 00-1054)

Chemical wastes from the radio-chem laboratory and sampling room located at elevation -4 ft. MSL are routed by gravity to the chemical waste tank located at elevation -35 ft. MSL. The chemical waste pump routes the liquids through the waste concentrate storage tank to the waste management drumming station. Plumbing fixture vents are provided for vapor removal from the system. The vents are connected to the vent gas collection header.

←(DRN 00-1054)

9.3.3.2.1.5 Sump Operation

Sumps have been sized to accommodate all anticipated normal and transient leakage from the equipment they serve. All sumps throughout the plant have been provided with duplex full capacity pumps.

Level switch and level operated mechanical alternator are provided for controlling the sump level. The level control is delineated in the following steps.

a) When the level reaches the predetermined "High", the alternator starts the selected pump. The mechanical alternator initiates operation of the pumps alternately on successive low level incidences. The pump is also tripped automatically on low level.

b) If the level continues to rise and reaches the predetermined "High-High", the alternator will start the second pump.

c) An independent level switch is provided to detect that the level in the sump is high enough to necessitate operation of the standby pump and to initiate an alarm in main control room.

A local control switch is provided for each pump to enable its manual operation when level in the sump is between low and high extremes.

9.3.3.2.2 Non-Radioactive Drain Systems

The non-radioactive drainage systems provide the interface between various drainage discharge points and their respective internal and/or external waste treatment facilities. They provide for the draining of equipment, tanks, and flooded surfaces during normal plant operation, as well as of anticipated large volume flow associated with abnormal or accident conditions.

9.3.3.2.2.1 Storm Water Drainage System

The Storm Water Drainage System consists of various types of drain inlets and catch basins for storm water capture from structure roofs, plant grounds and roads, and an interconnected network of storm water piping for conveyance. It provides the entire plant site with the means to effectively collect accumulations of rainwater, and creates the flow path for offsite disposal.

Surfaces exposed and subjected to rainwater are sloped to the collection appurtenance; roof drains, deck drains, area drains, and catch basins. Drains have been selected so as to fully meet all pertinent requirements of the surface to be drained. Obstructions between high surface points and drain inlets have been minimized so as to affect accelerated and total drainage of the surface.

The building systems are designed as gravity systems with a minimum pipe slope of 1/4 in. per ft. for maximum self-cleaning velocity. Additionally, the systems are designed so as to minimize the deposit of solids and clogging, and with adequate cleanouts so arranged that the systems may be readily cleaned.

Total isolation from all other drainage systems preclude flooding due to abnormal weather conditions. The systems will provide storm water collection, conveyance, and offsite disposal without puddling or flooding of the plant site or structure roofs.

The Louisiana State Construction Code (1963), applicable to plumbing, is used for permissible square feet of drainage for a given pipe size and pitch, in terms of square feet of projected drainage area.

Reactor Building

Roof drains are provided around the circumference of the dome walkway. Leaders are embedded within the containment walls to points of exit from where they run exposed through the dry cooling tower areas to the yard Storm Water Drainage System.

→(DRN 01-0073)

9.3.3.2.2.1 Storm Water Drainage System

Cooling Tower Areas

→(DRN 99-0577; EC-2097, R301)

Area drains are provided to collect and route storm water to two area drain sumps (1&2) located at elevation -35 ft. MSL. Each sump is provided with two 270-gpm minimum capacity pumps, and radiation monitors are provided on the discharge of each sump. Flow can be diverted to one of three discharge paths for offsite disposal. The normal flow path discharges storm water into the Circulatory Water system for discharge to the Mississippi River. An alternate flow path is provided to allow discharge to the 40 Arpent Canal via the yard Storm Water Drainage System. Upon detecting high radiation activity, a simultaneous signal will automatically stop the pumps and alarm the operator who will then manually transfer the flow to the waste tanks in the Reactor Auxiliary Building.

In addition to the 270-gpm motor driven sump pumps, a single diesel powered sump pump with a minimum capacity of 300-gpm is provided in each cooling tower area. The pumps are provided with hoses which are used to discharge rainwater directly over the Nuclear Island exterior floodwall. These pumps are used to supplement the motor driven sump pumps during periods of intense rainfall, as described in Subsection 2.4.2.3.

←(EC-2097, R301)

If a loss of offsite power occurs during a discharge, both the pumps and monitors are de-energized. The operator can manually load the pumps onto the EDGs as described in Table 8.3-1. However, the monitor contacts remain in the “alarm” state and actuate a signal that locks out the pumps. A selector switch on the MCC cubicle of each sump pump allows the operator to bypass this condition until power is restored to the monitors.

←(DRN 99-0577; 01-0073)

9.3.3.2.2.2 Acid Waste and Vent System

Liquid wastes from battery rooms in the Reactor Auxiliary Building are routed to local neutralizing tanks for neutralization and then discharged to the Sanitary Drainage System for disposal. Each fixture and floor drain is provided with a local pipe vent which connects to a main vent. The main vent is extended through the roof to the atmosphere.

9.3.3.2.2.3 Acid and Caustic Waste System

Drains receiving intermittent acid and caustic wastes from the blowdown treatment area at elevation -4 ft. MSL of the Reactor Auxiliary Building are routed to a neutralizing tank at elevation -35 ft. MSL. The tank discharge is routed to the Oil Drainage System which routes the neutralized liquids to the oil sump No. 3.

9.3.3.2.2.4 Oil Drainage Systems

Diesel Oil Storage Tank Compartments

Each tank compartment is provided with its own individual sump (oil sump no. 1 and oil sump no. 2). Each sump is provided with two pumps which discharge to the Turbine Building Industrial Waste System (see Subsection 9.3.3.2.2.5).

Emergency Diesel Generator Rooms, Charging Pumps,
Emergency Diesel Oil Feed Tanks

These areas are provided with floor drains and equipment drains to collect oil spills from equipment and surrounding piping. Liquids are routed to the oil sump no. 3 at elevation -35 ft. MSL. Two sump pumps discharge the sump contents to the Turbine Building Industrial Waste System. Provisions for pumping the sump contents to local oil drums for offsite removal are available.

9.3.3.2.2.5 Industrial Waste System (Turbine Building)

The Industrial Waste System consists of floor drains, equipment drains, and curbed area oil collection drains. The system provides the means to collect and convey the various Turbine Building operational waste liquids from their points of collection to their ultimate disposal.

Floor drains are provided throughout the building to accept normal maintenance washdown as well as abnormal liquid discharges such as from a high or moderate energy piping rupture. Concrete floors are sloped to floor drains which are located at low points on the floors to facilitate drainage and prevent water puddles.

Equipment drains are provided for mechanical equipment such as pumps, tanks, and leak-off points. These drains serve to accept continual or intermittent discharge as part of routine operation. They additionally provide the means for equipment drain down in the event of maintenance when required, or for replacement of the equipment when necessary. For equipment requiring flushing on a regular or occasional basis, this system will provide that capability as well.

Floor drains and/or equipment drains are provided in curbed oil areas to service mechanical equipment using oil in their operation. Valves are placed on floor drain outlets to provide the capability of containing substantial oil spills within the curbs. Equipment drains are elevated above curbs to preclude their use as overflows. However, when this elevation presents drainage problems to the equipment it serves, closed equipment drains are utilized.

Concrete containment curbs are provided where hazardous chemicals associated with the Chemical Feed Skids are handled and stored. The volume of the curbed area will accommodate the failure of a single 345 gallon portable chemical shipping container. Drains are not provided in this area to allow for the neutralizing of any spilled chemicals prior to disposal as appropriate.

→ (DRN 99-0480, R11; 03-213, R12-B)

All Turbine Building drainage is routed to two industrial waste sumps, both located on elevation +15 ft. MSL. Two pumps are provided for each sump. Under normal conditions, industrial waste will be discharged through a radiation monitor to an oil separator located in the yard to affect separation of the oil. The water will then be pumped by the oil separator discharge pumps to the 40 Arpent Canal or the Circulating Water System discharge. In the event that the radiation monitor on the industrial waste discharge header detects a high radiation level, automatic valves are activated, closing the discharge path to the oil separator and opening the discharge path to the waste tanks in the Reactor Auxiliary Building. The monitor will also send a signal to sound an alarm in the main control room.

← (DRN 99-0480, R11; 03-213, R12-B)

9.3.3.2.2.6 Sprinkler Discharge Drainage System (Reactor Auxiliary Building)

Floor drains are provided in the electrical penetration and cable vault areas at elevation +35 ft. MSL to accept sprinkler discharge water in the event of sprinkler system activation. The drainage system is sized to accept a designed flow of 0.3 gpm for any 3000 sq. ft. of space (900 gpm). The Sprinkler Discharge Drainage System is routed by gravity directly to the yard Storm Water Drainage System for offsite disposal.

9.3.3.3 Safety Evaluation

Reactor Building sump pump discharge piping penetrating the containment is designed to seismic Category I and safety class 2 requirements. All other portions of the Equipment and Floor Drainage Systems are not designed to either seismic Category I or safety class requirements as they do not perform any safety function.

Each engineered safeguard features room is provided with the independent drainage and sumps to prevent flooding and thus assure the integrity of each train operation. The sumps and sump pumps have sufficient capacity to meet the guidelines of BTP APCSP 3-1 concerning internal plant flooding as a result of postulated piping failures (see Appendix 3.6A). In addition, the control room operator is alerted to water accumulation in these areas via Class 1E instrumentation (level indicator with annunciator), to facilitate isolation of the affected system.

The failure of non-safety related Equipment and Floor Drain system components which could affect the operation of safety related equipment, (i.e., mechanical equipment and piping, HVAC ducts, electrical cable trays and conduits, instrumentation and controls) have been investigated with respect to the area of influence of the failed component. Interactions are eliminated by adherence to criteria stated in Subsection 3.2-1.

9.3.3.4 Tests and Inspections

All portions of the Equipment and Floor Drainage Systems are subjected to a hydrostatic pressure test of at least 10 ft. head of water.

Welded joints in the radioactive Equipment and Floor Drainage Systems are visually inspected.

9.3.3.5 Instrumentation Applications

Level indicators and alarms are provided in the main control room for the monitoring of all sump operation modes.

The triangular weir of the leak detection tank located in the Reactor Building sump is precalibrated so that the level in the detection tank is transmitted to the main panel of the main control room. A predetermined high level (leakage rate) will sound an alarm.

9.3.4 CHEMICAL AND VOLUME CONTROL SYSTEM

9.3.4.1 Design Bases

9.3.4.1.1 Functional Requirements

The Chemical and Volume Control System (CVCS) is designed to perform the following functions:

a) Maintain the chemistry and purity of the reactor coolant during normal operation and during shutdowns;

b) Maintain the required volume of water in the Reactor Coolant System (RCS) compensating for reactor coolant contraction or expansion resulting from changes in reactor coolant temperature and for other coolant losses or additions;

c) Provide a controlled path for discharging reactor coolant to the Boron Management System (BMS) and venting gas to the Gaseous Waste Management System (GWMS). The BMS and GWMS are described further in Sections 11.2 and 11.3, respectively;

d) Control the boron concentration in the RCS to obtain optimum control element assembly (CEA) positioning, to compensate for reactivity changes associated with major changes in reactor coolant temperature, core burnup, and xenon variations, and to provide shutdown margin for maintenance and refueling operations;

e) Provide auxiliary pressurizer spray for operator control of pressure during the final stages of shutdown and to allow pressurizer cooling;

f) Provide a means for functionally testing the check valves which isolate the Safety Injection System (SIS) from the RCS;

g) Provide continuous measurement of reactor coolant boron concentration and fission product activity;

h) Collect the controlled bleedoff from the reactor coolant pump seals;

i) Leak test the RCS;

j) Inject concentrated boric acid into the RCS upon a safety injection actuation signal (SIAS);

k) Provide a means for filling the RCS;

→(EC-8458, R307)

l) Provide a means for hydrostatic testing of the RCS.

←(EC-8458, R307)

→(EC-4019, R305)

m) Inject zinc into the RCS from the Zinc Injection Skid, via the charging pumps, to reduce plant radiation dose rates and Primary Water Stress Corrosion Cracking (PWSCC) in plant materials.

←(EC-4019, R305)

9.3.4.1.2 Design Criteria

The CVCS is designed in accordance with the following criteria:

a) The CVCS is designed to accept RCS letdown when the reactor coolant is heated at the administrative rate of 75°F/hr and to provide the required makeup using two of three charging pumps when the reactor coolant is cooled at the rate of 75°F/hr;

b) The CVCS is designed to supply makeup water or accept excess reactor coolant as power decreases or increases;

c) The CVCS is designed to allow 10 percent step power increases between zero percent and 90 percent of full power and 10 percent step power decreases between 100 percent and 10 percent of full power, as well as for ramp changes of five percent of full power per minute between 15 and 100 percent power;

d) The volume control tank is sized with sufficient capacity to accommodate the inventory change resulting from a full to zero power decrease with no primary makeup water system operation, assuming that the volume control tank level is initially in the normal operating level band;

e) The CVCS provides a means for maintaining activity in the RCS within the limits specified in Section 11.1, corresponding to a one percent failed fuel condition and continuous full power operation;

f) The CVCS is designed to maintain the reactor coolant chemistry within the limits specified in Table 9.3-7;

g) Letdown and charging portions of the system are designed to withstand the design transients defined in Table 9.3-8 without any adverse effects, as applicable;

→(EC-8458, R307)

h) Components of the CVCS are designed in accordance with applicable codes as shown in Table 9.3-9. Safety classes and seismic categories are as shown in Table 3.2-1;

i) The environmental design conditions of the CVCS are given in Section 3.11;

j) The CVCS is designed to change the reactor coolant boron concentration to the value required for a reactor shutdown, for maintenance and/or refueling and to bring the reactor coolant to the refueling concentration. The capability of this system for changing the RCS boron concentration is shown in Table 9.3-11. The schedule of waste generation for the various plant maneuvers is shown in Table 9.3-12;

k) The CVCS is designed to allow for a safe plant shutdown following a loss of CVCS letdown flow.

←(EC-8458, R307)

9.3.4.2 System Description

9.3.4.2.1 System Functional Description

9.3.4.2.1.1 Plant Startup

Plant startup is the series of operations which brings the plant from a cold shutdown condition to a hot standby condition at normal operating pressure and zero power temperature with the reactor critical at a low power level.

The charging pumps and letdown backpressure valves are used during initial phases of RCS heatup to maintain the RCS pressure until the pressurizer steam bubble is established. One charging pump will normally operate during plant startup to cool the letdown fluid in order to establish a controlled heatup rate of the RCS within prescribed limitations and to maintain proper RCS pressure during this period.

Oxygen scavenging during plant startup is discussed in Subsection 9.3.4.2.1.4.

During the heatup, the pressurizer water level is controlled manually using the backpressure control valves and the letdown control valves. The letdown flow is automatically diverted to the BMS when the high level limit is reached in the volume control tank. The volume control tank is initially purged with nitrogen, prior to establishing the hydrogen blanket.

The RCS boron concentration may be reduced during heatup in accordance with shutdown margin limitations. The makeup controller is operated in the dilute mode, as described in Subsection 9.3.4.2.1.2, to inject a predetermined amount of primary makeup water at a preset rate. Technical Specifications are set to define those conditions of the CVCS necessary to assure safe reactor operation and shutdown.

9.3.4.2.1.2 Normal Operation

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The normal reactor coolant flow path through the CVCS is indicated by the heavy lines on the piping and instrumentation diagram, Figure 9.3-6 (for Figure 9.3-6, Sheet 1, refer to Drawing G168, Sheet 1).

Parameters for the CVCS are listed in Table 9.3-11. Equipment design parameters for the major components are shown in Table 9.3-9. Process flow, temperature and pressure data are given in Table 9.3-13 with locations corresponding to those noted in the ellipses on Figure 9.3-6 (for Figure 9.3-6, Sheet 1, refer to Drawing G168, Sheet 1). The tabulation of the process flow data is for three modes of purification loop operation and nine modes of makeup system operation. Basically, a letdown flow of 38 gpm is used for normal purification operation, a letdown flow of 82 gpm is used for intermediate purification operation, and a letdown flow of 126 gpm is used for maximum purification operation. Typical operating conditions are given for the various makeup system operating modes.

←

Normal operation includes hot standby operation and power generation when the RCS is at normal operating pressure and temperature.

Letdown flow from one cold leg passes through the tube side of the regenerative heat exchanger for an initial temperature reduction. The pressure is then reduced by a letdown control valve to the letdown heat exchanger operating pressure. The final reduction to the purification subsystem operating pressure and temperature is made by the letdown heat exchanger and letdown backpressure valve. The flow then passes through the purification filter in order to remove insoluble particulates from the reactor coolant. Flow is then directed through one or more of the purification ion exchangers. The normal purification ion exchanger contains mixed bed resin which becomes boron and lithium saturated through use and is used for removal of corrosion and fission products. The second purification ion exchanger contains mixed bed resin which becomes boron saturated through use and is used as necessary to control lithium concentration. The third purification ion exchanger contains anion resin only and is used for boron removal at the end of core cycle life when it is no longer practical to use feed and bleed for boron dilution because of the quantity of waste generated. Any of the three purification ion exchangers can be used for any function. Flow continues through a strainer and is sprayed into the volume control tank where hydrogen gas is absorbed by the coolant. Flow also enters the volume control tank from the reactor coolant pump controlled bleedoff header.

The charging pumps take suction from the volume control tank and pump the coolant into the RCS. One charging pump is normally in operation and one letdown control valve is controlled to maintain an exact balance between letdown flow rate plus reactor coolant pump bleedoff flow rate and charging flow rate. The charging flow passes through the shell side of the regenerative heat exchanger for recovery of heat from the letdown flow before being returned to the RCS.

→(EC-13560, R304)

When the Shutdown Cooling System is operational, a flow path through the CVCS can be established to remove fission and activation products. This is accomplished by diverting a portion of the flow from the shutdown cooling heat exchanger to the letdown line. The flow then passes through the purification filter, purification ion exchanger, the letdown strainer, and is returned to the suction of the low-pressure safety injection pumps.

←(EC-13560, R304)

→(DRN 00-1054, R11-A; 05-332, R14; EC-14241, R303)

A makeup system is provided for changes in reactor coolant boron concentration. Boron is initially added to the CVCS using the boric acid batching tank. Demineralized water is added to the boric acid batching tank via the primary water pumps, and the fluid is heated by immersion heaters. Boric acid powder is added to the heated fluid while the mixer agitates the fluid. A boric acid concentration as high as 12 w/o can be prepared. Electric immersion heaters maintain the temperature of the solution in the boric acid batching tank high enough to preclude precipitation. The boric acid is then drained to the boric acid makeup tanks. Concentrated boric acid solution, prepared in the batching tank, is then stored in the two boric acid makeup tanks. This boric acid solution is supplied to the volume control tank via the boric acid pumps, while the primary water stored in the primary water storage tank is supplied to the volume control tank via the primary water pumps. Four modes of operation by the makeup controller in the makeup subsystem are provided. In the dilute mode, a preset quantity of primary water is introduced into the volume control tank at a preset rate. In the borate mode, a preset quantity of boric acid is introduced at a preset rate. In the manual blend mode, the flow rates of the primary water and the boric acid can be preset to give any concentration of boric acid solution between zero and the refueling concentration. The manual mode is used to provide makeup to the refueling water storage pool and the safety injection tanks as well as the volume control tank. In the automatic mode, a preset blended boric acid solution is automatically introduced into the volume control tank upon demand from the volume control tank level controller. The concentration setting as adjusted periodically by the operator to match the boric acid concentration being maintained in the RCS. Preferred makeup is accomplished in manual mode.

←(DRN 00-1054, R11-A; 05-332, R14; EC-14241, R303)

The Chemical Addition Metering System provides a means of controlling the reactor coolant chemistry. Chemical additives for oxygen scavenging and pH control are prepared in the chemical addition tank and injected into the charging pump suction header by the chemical addition metering pump. These chemicals are transported to the charging pump suction with primary water. The tank is sized to hold a sufficient quantity of lithium to allow batch additions to the RCS. It will also hold a sufficient quantity of hydrazine to reduce the reactor coolant oxygen concentration to below the maximum acceptable level during startup or shutdown.

→(EC-4019, R305)
The Zinc Injection system provides a means of injecting zinc acetate dihydrate to the RCS via the suction side of the Charging Pumps. The Zinc Injection Skid will add zinc into the discharge side of the Chemical Addition Pumps via CVC-6051. The Chemical Addition discharge line connects to the suction side piping of the Charging Pumps between the Volume Control Tank (VCT) and the Charging Pumps. The Charging Pumps then deliver the zinc to the RCS to reduce radiation levels and Primary Water Stress Corrosion Cracking (PWSCC) in plant materials.
←(EC-4019, R305)

The volume of water in the RCS is automatically controlled using pressurizer level instrumentation. The pressurizer level setpoint is programmed to vary as a function of reactor power in order to minimize the transfer of fluid between the RCS and the CVCS during power changes. This linear relationship is shown on Figure 5.4-7. Reactor power is determined for this situation using the average reactor coolant temperature derived from hot and cold leg temperature measurements. A level error signal is obtained by comparing the programmed setpoint with the measured pressurizer water level. Volume control is achieved by automatic control of the standby charging pumps and a letdown control valve in accordance with the pressurizer level control program shown on Figure 5.4-7. Two parallel letdown control valves are provided. The letdown control valve chosen for operation is normally controlled by the pressurizer level control program to maintain letdown flow equal to the total charging flow minus the total reactor coolant pump controlled bleedoff flow. Normally, one charging pump is operated, but two or three pump operations can be selected for higher purification flow if desired. Proper level can normally be maintained by valve positioning; large changes in pressurizer level due to power changes or abnormal operations result in automatic operation of the standby charging pumps and/or modulation of the operating letdown control valve.

→(DRN 05-332, R14)
VCT Level (Hi & Low) is protected. The letdown flow is automatically diverted to the BMS when the highest permissible water level is reached in the volume control tank. A low-low level signal automatically closes the outlet valve on the volume control tank and switches the charging pump suction to the refueling water storage pool (RWSP).
←(DRN 05-332, R14)

9.3.4.2.1.3 Plant Shutdown

Plant shutdown is accomplished by a series of operations which bring the reactor plant from a hot standby condition at normal operating pressure and zero power temperature to a cold shutdown for maintenance and/or refueling. The schedule of waste generation for various plant maneuvers is shown in Table 9.3-12.
→(DRN 00-695, R11-B)
Should degasification be necessary, it is performed prior to plant cooldown by venting the volume control tank hydrogen overpressure and diverting the letdown flow to the holdup tanks in the BMS. Makeup is added to the volume control tank or charging pump suction in the normal manner.
←(DRN 00-695, R11-B)
The boron concentration in the reactor coolant is increased to the cold shutdown value in accordance with the technical specifications, primarily through the use of the boric acid makeup tanks.

During the cooldown, the charging pumps, letdown control valves and the letdown backpressure valves are used to adjust and maintain the pressurizer water level. High charging flow results in a low level in the volume control tank which initiates automatic makeup at the selected shutdown boron concentration. If the shutdown is for refueling the suction of the charging pumps is connected to the RWSP during plant cooldown. All of the charging flow may be used for auxiliary spray to cool the pressurizer in the event reactor coolant pumps are secured.

For a refueling shutdown, after the reactor vessel head is removed, the low pressure safety injection pumps take the borated water from the refueling water storage pool and inject the water into the reactor coolant loops via the normal flow paths thereby filling the refueling pool. The resulting concentration of the refueling pool and the RCS is above the lower operating boron concentration limitation of 1720 ppm (first cycle), 2150 ppm (equilibrium cycle) for the refueling water storage pool. Thus, the contents of the refueling pool can be returned directly to the refueling water storage pool prior to plant startup without hindering plant operations due to low boric acid storage concentration.

9.3.4.2.1.4 Chemistry and Purity Control

During normal operations and during plant shutdowns, the chemistry and purity of the reactor coolant are controlled to provide the following:

a) minimum reactor plant radiation levels to permit ready access for plant maintenance and operation,

b) avoidance of excessive fouling of heat transfer surfaces, and

c) minimum corrosion rate of materials in contact with reactor coolant.

The chemistry of the reactor coolant is described in Table 9.3-7.

The oxygen and chloride limits specified in Table 9.3-7 were established from the relationships between oxygen and chloride concentrations and the susceptibility to stress corrosion cracking of austenitic stainless steel. This relationship is described in References 1 and 2. This indicates that if the chloride ions and oxygen concentrations are maintained below the specified concentrations, chloride stress corrosion will not occur.

This data reveals that no chloride stress corrosion occurs at oxygen concentrations below approximately 0.8 ppm over the entire range of chloride concentrations. This oxygen limit was reduced by a factor of eight to give the conservative concentration of 0.1 ppm oxygen. The maximum amount of oxygen from air dissolved in water at 25°C is approximately eight ppm. At this concentration, a chloride concentration of less than approximately 1.5 ppm would preclude the possibility of chloride stress corrosion. This limit was reduced by a factor of 10 to provide a conservative chloride limit of 0.15 ppm.

The fluoride limit of 0.1 ppm for reactor coolant is based on the identification of the fluoride ion as a use of intergranular corrosion of sensitized austenitic stainless steels.[3] Based on this data, it is essential to minimize fluoride ions in the reactor coolant.

During the preoperational test period, 30 to 50 ppm of hydrazine is maintained in the reactor coolant whenever the reactor coolant temperature is below 150°F. This is done to prevent halide-induced corrosion attack of stainless steel surfaces which can occur in the presence of significant quantities of fluorides or chlorides and dissolved oxygen. During heatup, any dissolved oxygen is scavenged by hydrazine thus eliminating one necessary ingredient for halide-induced corrosion. Elimination of oxygen on heatup also minimizes the potential for general corrosion. At higher temperatures, the hydrazine decomposes, not necessarily completely, producing ammonia and a high pH which aids in the development of passive oxide films on RCS surfaces that minimize corrosion product release. The corrosion rates of Ni-Cr-Fe alloy-600 and 300 series stainless steels decrease with time when exposed to prescribed reactor coolant chemistry conditions. These rates approach low steady state values within approximately 200 days. The high pH condition produced by high ammonia concentration (to 50 ppm) minimizes corrosion product release and assists in the rapid development of the passive oxide film. Most of the film is established within seven days at hot, high pH conditions. This is discussed in Reference 4. To aid in maintaining the pH during this passivation period, lithium in the form of lithium hydroxide is added to the coolant and maintained within the limits given in Table 9.3-7.

By the end of the preoperational test period, any fluorides or chlorides have been removed from the system and concentrations in the coolant are maintained at low levels by reactor coolant purification and demineralized water addition. High hydrazine concentration is not required to inhibit halide-induced corrosion, but hydrazine, added at 1.5 times the oxygen concentration, (maximum of 20 ppm) is used during heatup to scavenge oxygen. This assures complete removal of oxygen on heatup while minimizing ammonia and nitrogen generation when hot and at power. When at power, oxygen is controlled to a very low concentration by maintaining excess dissolved hydrogen in the coolant. The excess hydrogen forces the water decomposition/synthesis reaction in the reactor core to water rather than hydrogen and oxygen. Any oxygen in the makeup water is also removed by this process.

→(DRN 06-1142, R15)

Since operating with a basic pH control agent results in lower general corrosion release rates from the RCS materials, and because the alkali metal lithium is generated in significant quantities by the core neutron flux through the reaction B-10 (n, alpha) Li-7, lithium is selected as the pH control agent. The production rate of lithium from this reaction is approximately 100 ppb per day at the beginning of core life and decreases with core lifetime in proportion to the decrease in boron concentration. However, even though lithium is the choice for pH control, there exists a threshold for accelerated attack on zircaloy at approximately 35 ppm lithium and therefore, the lithium concentration limits are specified as 0.2 to 3.5 ppm to provide a wide margin between the upper operating limit and the threshold for attack in the event any concentrating phenomena exist. The chemistry of the reactor coolant is maintained within specified limits by the purification ion exchangers and by controlling hydrogen and lithium concentration. Hydrogen, controlled in the reactor coolant by maintaining a hydrogen overpressure on the volume control tank is present to scavenge any oxygen which may be introduced into the RCS. Lithium is added in the form of lithium-7 hydroxide via the chemical addition tank and is present due to the B-10 (n. alpha) Li-7 reaction in the RCS. It is maintained within 0.2 to 3.5 ppm range to reduce the corrosion product solubility, resulting in fewer dissolved corrosion products circulating in the reactor coolant. Thus promoting a condition within the coolant for selective deposition of corrosion products on cooler surfaces (steam generator) rather than hot surfaces (core), and maintains a more tenacious passive oxide layer on out of core system surfaces. Early in core life, lithium production is the greatest and periodic removal by ion exchange is required to control the concentration below the upper limit.

←(DRN 06-1142, R15)

Various reactions taking place within the reactor during operation result in the production of tritium, which appears in the reactor coolant as tritiated water. See Section 11.1 for a discussion of tritium.

→(EC-4019, R305)

Zinc is added to the RCS from the Zinc Injection Skid in low concentrations to reduce plant radiation dose rates and reduce Primary Water Stress Corrosion Cracking (PWSCC) in plant materials. When zinc is added a chemical reaction occurs that incorporates zinc into the oxide film on all wetted austenitic stainless steel and nickel-based alloy components surfaces. The fundamental mechanism of zinc addition is a modification of the plant oxide films, eventually resulting in lowered corrosion rates. Zinc addition results in thinner oxide films and modification of the structure of the corrosion films. This leads to the preferential release of nickel and cobalt by the substitution of zinc with these elements. The modification of the oxide films results in material (PWSCC) and dose rate reduction benefits.

←(EC-4019, R305)

9.3.4.2.1.5 Reactivity Control

→(EC-14241, R303)

The boron concentration is preferentially controlled in manual during normal operation to obtain optimum CEA positioning to compensate for reactivity changes associated with changes in coolant temperature, core burnup, xenon concentration variations to provide shutdown margin for maintenance and refueling operations or emergencies.

←(EC-14241, R303)

The normal method of adjusting boron concentration is by the technique of feed and bleed. To change concentration, the makeup system supplies either demineralized water or concentrated boric acid to the volume control tank, and the letdown stream is diverted to the BMS. Toward the end of a core cycle, the quantities of waste produced due to feed and bleed operations become excessive due to the low boron concentration and at least one purification ion exchanger is used to reduce the RCS boron concentration. The ion exchanger used for deborating uses an anion resin initially in the hydroxyl form which is converted to a borate form as boron is removed from the bleed stream. The capability of the CVCS for changing the RCS boron concentration is shown on Table 9.3-11.

9.3.4.2.2 Component Description

The major components of the CVCS are described in this subsection. The principal component data summary including component design codes and materials of construction is given in Table 9.3-9.

a) Regenerative Heat Exchanger - The regenerative heat exchanger, located within the containment, conserves RCS thermal energy by transferring heat from the letdown stream to the charging stream and serves to minimize charging nozzle thermal transients. The heat exchanger is designed to maintain a letdown outlet temperature below 45O°F under all normal operating conditions. This component is designed to accommodate the transients listed in Table 9.3-8.

b) Letdown Heat Exchanger - The letdown heat exchanger, located within the Reactor Auxiliary Building, uses component cooling water to cool the letdown flow from the outlet temperature of the regenerative heat exchanger to a temperature suitable for long-term operation of the purification system. The unit is sized to cool the maximum rate of letdown flow from the maximum outlet temperature of the regenerative heat exchanger (450°F) to the maximum allowable temperature of the ion exchange resins (140°F).

   To prevent possible damage to the heat exchanger by excessive component cooling water flow, the flow control valves are preset to limit the flow to 1200 gpm (maximum). The cooling water flow rate is indicated in the main control room. This component is designed to accommodate the transients listed in Table 9.3-8.

c) Purification Filter - This filter, located in the Reactor Auxiliary Building, is designed to remove insoluble particles from the reactor coolant. The unit is designed to pass the maximum letdown flow without exceeding the allowable differential pressure across the element in the defined maximum fouled condition. Due to the buildup of high activity levels during normal operation, the unit is designed for efficient remote removal of the contaminated element assembly.

d) Purification Ion Exchangers- The three purification ion exchangers, located within the Reactor Auxiliary Building, are each sized for the maximum letdown flow rate. One purification ion exchanger is used continuously to remove impurities and radionuclides from the reactor coolant and one is used intermittently to control the lithium concentration in the reactor coolant. The third ion exchanger is used to reduce the reactor coolant boron concentration at the end of a core cycle. Any ion exchanger is capable of either function and operations procedures control specific usage.

→ (DRN 99-0971)

e) Not used.

← (DRN 99-0971)

f) Volume Control Tank- The volume control tank, located within the Reactor Auxiliary Building, is used to accumulate letdown water from the RCS to provide for control of hydrogen concentration in the reactor coolant and to provide a reservoir of reactor coolant for the charging pumps. The tank is sized to store sufficient liquid volume below the normal operating level band to allow a swing from full power to zero power without makeup operation, to provide a volume for in automatic makeup control band of 500 gallons, and to provide sufficient gas volume to prevent exceeding tank design pressure when undergoing an insurge from the RCS during a power increase from 0 to 100 percent power. The tank has hydrogen and nitrogen gas supplies and a vent to the Waste Management System to enable venting of hydrogen, nitrogen, helium, and fission gases. The volume control tank is initially purged with nitrogen to exclude oxygen and a hydrogen overpressure is then established.

g) Charging Pumps - The charging pumps, located in the Reactor Auxiliary Building, take suction from the volume control tank and return the purification flow to the RCS during plant steady state operations. Normally one pump is running to balance the letdown purification flow rate plus the reactor coolant pump controlled bleedoff flow rate. The second and third pumps are automatically started (stopped) as pressurizer level decreases (increases) due to plant unloading (loading) transients.

→ (DRN 99-0971)

The charging pumps are positive displacement type pumps, with an integral leakage collection system. Each charging pump is provided (with discharge pulsation dampeners. These consist of a stainless steel vessel (volume 2.5 gallons) and an ethylene - propylene rubber bladder charged with nitrogen. The pressure containing portions of the pump and internals are austenitic and/or 17-4PH, Condition H 1100 stainless steel materials for compatibility with pumped fluid chemistry.

← (DRN 99-0971)

→ (DRN 03-2063, R14)

h) Boric Acid Makeup Tanks - Two boric acid makeup tanks, located in the Reactor Auxiliary Building, provide a source of boric acid solution (2.8 w/o minimum) for injection into the RCS. Each tank is insulated, has redundant electrical strip heaters, and is capable of storing boric acid in concentrations up to 12 w/o. However, the tank insulation and strip heaters are not required to be maintained when the maximum boric acid concentration cannot exceed 3.5 w/o by the technical

← (DRN 03-2063, R14)

specifications. The combination of the BAM tanks and the refueling water storage pool contain sufficient volume to perform a safe shutdown following a loss of letdown at operation conditions. The total volume of both tanks is sufficient to bring the RCS to the refueling boron concentration during a cooldown for refueling.

i) Boric Acid Batching Tank - The boric acid batching tank, located in the Reactor Auxiliary Building and above the boric acid makeup tanks, is used for the preparation of concentrated boric acid which is gravity drained to the makeup tanks. The tank is designed to permit handling of up to 12 w/o boric acid. The tank is heated and insulated and receives demineralized water for mixing the boric acid solution. Sampling provisions, mixer, temperature controller and electric immersion heaters are an integral part of the batching system.

→(DRN 99-0971)

j) Boric Acid Pumps - The two boric acid pumps, located in the Reactor Auxiliary Building, take suction from the overhead boric acid makeup tanks and provide boric acid to the makeup subsystem and to the charging pump suction header. The capacity of each pump is greater than the combined capacity of all three charging pumps. The boric acid makeup pumps are also used to recirculate makeup tank contents, to pump from one makeup tank to the other, and to supply makeup to the RWSP. The pumps are single stage centrifugal pumps with mechanical seals and liquid and vapor leakage collection connections.

←(DRN 99-0971)

k) Chemical Addition Tank - The chemical addition tank , located in the Reactor Auxiliary Building, provides a means to inject chemicals into the charging pump suction header. Demineralized water is supplied for chemical dilution and flushing operations. The tank size is based on the maximum service requirements of lithium injection for a batch addition prior to hot functional testing.

l) Chemical Addition Metering Pump - The chemical addition metering pump provides a means of injecting chemicals into the suction of the charging pumps at a controlled rate.

→(DRN 99-0971; EC-4019, R305)

m) The Zinc Injection Skid – metering pumps provides the means of adding zinc acetate dihydrate to the RCS via the suction side of the Charging Pumps at a controlled rate.

←(DRN 99-0971; EC-4019, R305)

→ (DRN 99-0971)

n) Not Used.

← (DRN 99-0971)

o) Piping, and Valves - The CVCS piping is austenitic stainless steel. The cooling water side of the letdown heat exchanger is carbon steel. All piping is in accordance with ASME Code Section III, Class 1, 2 or 3, or ANSI B31.1.0, as applicable.

All CVCS valves have design features to limit stem leakage when in the open position.

→ (DRN 99-0971)

p) Electric Heaters - Redundant electrical heat tracing is installed on all piping, valves and other line-mounted components that may potentially contain greater than 3.5 w/o boric acid solutions. The portions of the system that that are heat traced are indicated on the piping and instrumentation diagrams, Figure 9.3-6 (for Figure 9.3-6, Sheet 1, refer to Drawing G168, Sheet 1).

← (DRN 99-0971)

Two independent full capacity electrical strip heater banks are installed on each boric acid makeup tank. The heaters are sized to compensate for heat loss through the tank insulation to the surroundings and to maintain the tank temperature above the saturation temperature and within the technical specification limits. The strip heaters are only required to be maintained operable when technical specifications allow a BAM tank boron concentration above 3.5 w/o. A common alarm with high and low temperature annunciation is provided for each boric acid makeup tank.

→ (DRN 99-0971)

The batching tank is provided with corrosion resistant electrical immersion heaters. The heaters are sized to supply sufficient heat in six hours to increase the temperature of 500 gallons of 12 w/o boric acid solution from 40°F to 160°F, including the heat of solution required to dissolve the boric acid granules. The boric acid is not added to the tank until the demineralized water temperature exceeds the final saturation temperature by at least 20°F.

← (DRN 99-0971)

q) Thermal Insulation - Thermal insulation is required for conservation of heat and to protect personnel from contact with high temperature piping, valves, and components. Equipment and sections of the system that are insulated are the regenerative heat exchanger, the charging and auxiliary spray lines downstream of the regenerative heat exchanger and the letdown line from the reactor coolant loop to the letdown heat exchanger. Thermal insulation on these sections is designed to limit heat losses to 65 Btu/hr/ft^2 (80 Btu/hr/ft^2 for reflective insulation), based on the maximum expected piping and component temperatures. Insulation on all stainless steel surfaces is limited to 20 ppm chloride content (200 ppm chloride content if stress corrosion inhibitor is used) to ensure that it will not cause stress corrosion oil stainless steel surfaces.

9.3.4.3 Safety Evaluation

9.3.4.3.1 Performance Requirements Capabilities and Reliabilities

The minimum amount of boric acid solution (allowed by technical specifications) stored in the boric acid makeup tank is sufficient to bring the plant to a safe shutdown condition following loss of letdown at any time during plant life with the highest worth CEA stuck out of the core, and with additional core shrinkage volume made up with refueling water storage pool water. Gravity feed lines from each boric acid makeup tank to the charging pump suction are provided to assure makeup and boron injection.

The charging pumps are used to inject concentrated boric acid into the RCS. With one pump normally in operation, the other charging pumps are automatically started by the pressurizer level control. The safety injection actuation signal (SIAS) will start pumps A and B, or pump AB, if it was assigned to replace pump A or B. The SIAS also causes the charging pump suction to be switched from the volume control tank to the boric acid pump discharge. Should the pumped boric acid supply be unavailable, the charging pumps are also lined up for gravity feed from the boric acid makeup tanks. Should the charging line inside the containment be inoperative for any reason, the line may be isolated outside of the containment, and the charging flow may be injected via the SIS. The malfunction or failure of one active component does not reduce the ability to borate the RCS since an alternate flow path is always available for emergency boration.

The capability of the CVCS to borate is not compromised by stopping letdown flow. Because safe shutdown can be achieved without letdown flow, this portion of the CVCS, which includes the letdown heat exchanger, has no specific requirement to function for post-accident operation. It is for this reason that the Component Cooling Water System serving the letdown heat exchanger is not Safety Class 2. Further, for accidents which involve a SIAS or CIAS, the letdown line is automatically isolated.

If the letdown temperature exceeds the maximum operating temperature of the resin in the ion exchangers (140°F) the flow will automatically bypass the ion exchangers.

The charging pumps, boric acid makeup pumps, and all related automatic control valves are connected to an emergency bus should the normal power supply system fail. There are two emergency diesel generator sets available for this service and the components are aligned to the diesels as designated in Table 9.3-14.

→ (DRN 99-0971)

The boric acid solution is stored in heated and insulated tanks. Automatic temperature controls and independent alarm circuits are included in the heating system. The tank heaters and associated instrumentation are not Class-1E.

← (DRN 99-0971)

Frequently used, manually operated valves located in high radiation or inaccessible areas are provided with extention stem handwheels terminating in low radiation and accessible control areas. Manually operated valves are provided with locking provisions if unauthorized operation of the valve is considered a potential hazard to plant operation or personnel safety.

A high degree of functional reliability is assured by providing standby components and by assuring fail-safe responses to the most probable modes of failure. Redundancy is provided as follows:

Component	Redundancy
→	
Purification Ion Exchangers	Three identical components
←	
Charging Pumps	Two standby, one operating pump
Charging Isolation Valve	One parallel, redundant valve
Letdown Control Valve	One parallel, standby valve
Letdown Backpressure Control Valve	One parallel, standby valve
Auxiliary Spray valve	One parallel, redundant valve
Boric Acid Pump	One parallel, standby pump
Boric Acid Makeup Tank	One standby tank

→

In addition to the component redundancy it is possible to operate the CVCS in a manner such that some components are bypassed. While the normal charging path is through the regenerative heat exchanger, it is also possible to charge through the high pressure safety injection header. It is possible to transfer boric acid to the charging pump suction header bypassing the volume control tank or by bypassing the makeup flow controls and the volume control tank. The purification filter and purification ion exchangers can be bypassed. Controls bleedoff flow can be routed to the quench tank rather than the volume control tank via the reactor coolant pump controlled bleedoff header relief.

←

9.3.4.3.2 Overpressure Protection

In order to provide for safe operation of the CVCS, relief valve protection is provided throughout the system. The following is a description of the relief valves that are located in the CVCS:

a) Intermediate Pressure Letdown Relief Valve - The relief valve down stream of the let down control valves protects the intermediate pressure letdown piping and letdown heat exchanger from overpressure. The valve capacity is equal to the capacity of both letdown control valves in the wide open position during startup operation. The relief valve is set to protect the intermediate pressure letdown piping and letdown heat exchanger.

b) Low Pressure Letdown Relief Valve - The relief valve downstream of the letdown backpressure control valves protects the low pressure piping, purification filters, ion exchangers, and letdown strainer from overpressure. The valve capacity is slightly greater than the capacity of the intermediate pressure letdown relief valve. The set pressure is equal to the design pressure of the low pressure piping and components.

→(DRN 00-364, R11)

b) 1) Letdown Line Thermal Relief Valve - A thermal relief valve is provided for the Letdown piping which passes through containment penetration number 26. The function of the thermal relief valve is to provide overpressure protection, due to the thermal expansion of water, for the portion of Letdown piping between containment isolation valves CVC-103 and CVC-109, during post-LOCA conditions. The thermal relief valve is located inside the primary containment, and discharges directly to the primary containment atmosphere. Operation of the thermal relief valve is only required during faulted plant conditions.

←(DRN 00-364, R11)

c) Charging Pump Discharge Relief Valve - The relief valve on the discharge side of the charging pumps are sized to pass the maximum rated flow of the associated pump with maximum backpressure, without exceeding the maximum rated total head for the pump assembly. The valves are set to open when the discharge pressure exceed the RCS design pressure by 10 percent.

d) Charging Pump Suction Relief Valve - The relief valve on the charging pump common suction header is sized to pass the maximum expected fluid thermal expansion rate that would occur if all pumps were operating with the discharge isolation valves closed. The set pressure is equal to the design pressure of the charging pump suction piping.

e) Volume Control Tank Relief Valve - The relief valve on the volume control tank is sized to pass a liquid flow rate equal to the sum of the following flow rates: the maximum operating flow rate from the reactor coolant pump controlled bleedoff line, the maximum letdown flow rate possible without actuating the high flow alarm on the letdown flow indicator, the design purge flow rate of the Process Sampling System, and the maximum flow rate that the boric acid makeup set pressure is equal to the design pressure of the volume control tank.

f) Volume Control Tank Gas Supply Relief Valve - The relief valve is sized to exceed the combined maximum capacity of the nitrogen and hydrogen gas regulators. The set pressure is lower than the volume control tank design pressure.

→(DRN 03-760, R13)

g) Reactor Coolant Pump Controlled Bleedoff Header Relief Valve - The relief valve at the reactor coolant pump controlled bleedoff header allows the controlled bleedoff flow to continue to the quench tank in the event that a valve in the line to the volume control tank is closed. It serves as an overpressure relief device for the portion of the Controlled Bleedoff piping between valves CVC-403, CVC-4061 and CVC-4064. The valve is sized to pass the flow rate required to assure closure of one excess flow check valve in the event of failure of the seals in one reactor coolant pump plus the normal bleedoff from the other reactor coolant pumps. The maximum relief valve opening pressure is less than the controlled bleedoff high-high pressure alarm pressure.

←(DRN 03-760, R13)

→(DRN 00-364, R11)

h) Reactor Coolant Pump Thermal Relief Valve - A thermal relief valve is provided for the Reactor Coolant Pump Controlled Bleedoff piping which passes through containment penetration number 44. The function of the thermal relief valve is to provide overpressure protection, due to the thermal expansion of water, for the portion of Reactor Coolant Pump Controlled Bleedoff piping between containment isolation valves CVC-401 and RC-606, during post-LOCA conditions. The thermal relief valve is located inside the primary containment, and discharges directly to the primary containment atmosphere. Operation of the thermal relief valve is only required during faulted plant conditions.

←(DRN 00-364, R11)

i) Heat Traced Piping Relief Valves - Relief valves are provided for those portions of the boric acid system that are heat traced and which can be individually isolated. The set pressure is equal to the design pressure of the corresponding portion of the system piping. Each valve is sized to relieve the maximum fluid thermal expansion rate that would occur if maximum duplicate heat tracing power were inadvertently applied to the isolated line.

Charging Line Thermal Relief Valve - The relief valve on the charging line downstream of the regenerative heat exchanger is sized to relieve the maximum fluid thermal expansion rate that would occur if hot letdown flow continued after charging flow was stopped by closing both charging line distribution valves with both auxiliary spray valves shut. The valve is a spring-loaded check valve.

9.3.4.3.3 Isolation of System

The letdown line and the reactor coolant pump controlled bleedoff line penetrate the containment with flow in the outward direction. The letdown line contains three pneumatically operated valves, two inside containment and one outside containment. The two pneumatically operated valves inside containment are automatically closed on a SIAS. One of the valves inside containment and the valve outside containment in the letdown line are automatically closed on a CIAS. The controlled bleedoff line contains two pneumatically operated valves, one inside and one outside the containment, which close automatically on a CIAS.

The charging pump discharge line carries flow in the containment. Within the containment this line branches into three lines. Two lines direct charging flow to reactor coolant loops 1A and 2A and the other line diverts flow as auxiliary spray to the pressurizer during a plant shutdown. All these lines are provided with check valves that preclude back flow from the reactor coolant loop. Each line to the loops has a normally open, fail-close solenoid operated isolation valve. The solenoid operated isolation valves for auxiliary spray are normally closed and fail closed. A fail open, locked open pneumatically operated valve with a handwheel is provided on the charging line just outside the containment. This valve remains open upon actuation of CIAS or SIAS to allow a path for makeup and boron injection, if necessary.

9.3.4.3.4 Leakage Detection and Control

The components in the CVCS are provided with welded connections wherever possible to minimize leakage to the atmosphere. However, flanged connections are provided on all pump suction and discharge lines, on relief valve inlet and outlet connections, on the volume control tank spray nozzle, and on the flow meters to permit removal for maintenance. Leakage from CVCS valves inside containment is monitored by the Reactor Coolant Pressure Boundary Leakage Detection System described in Subsection 5.2.5.

One charging pump is used to pressurize the RCS to operating pressure for the leakage test during plant startup operations.

The CVCS can also monitor the total RCS water inventory. If there is no leakage throughout the plant, the level in the volume control tank should remain constant during steady-state operation. Therefore, a decreasing level in the volume control tank alerts the operator to a possible leak somewhere in the system.

9.3.4.3.5 Natural Phenomena

The CVCS components are located in the Reactor Auxiliary Building and the containment and, therefore, would not be subject to the natural phenomena described in Chapter 3 other than seismic.

9.3.4.3.6 Radiological Evaluation

→ (DRN 00-364)

The CVCS is designed to limit radioactive releases to the environment to allowable limits for both normal operation and accident conditions. During normal operation, reactor coolant is diverted through the CVCS. As the coolant passes through the CVCS purification line, the temperature of the fluid is reduced. The coolant passes through the purification filter and reduces the concentrations of solid corrosion products. In addition, the concentration of selected soluble isotopes are reduced by the purification ion exchangers. Coolant is then normally returned to the RCS via the charging pumps. However, diversion of letdown flow to the BMS is performed where changes in coolant inventory or boron concentration is necessitated by startups, shutdown, fuel depletion, etc., or on the high volume control tank liquid level. A further discussion of this system is presented in Section 11.2. Appropriate CVCS equipment drains, vents, leakage, valve stem leakoffs, and relief valve discharges are routed to the BMS, with the exception of the CVCS system thermal relief valves discussed in Section 9.3.4.3.2. Sources containing fission gases, such as the volume control tank, have provisions for venting to the GWMS for storage and decay (see Section 11.3 for a further description).

← (DRN 00-364)

Since the CVCS letdown line penetrates the containment, it is isolated at the containment wall during accident conditions. Radioactive releases to the environment are negligible as sufficient isolation and containment shielding exists to provide the necessary boundary for retaining the harmful radiation.

9.3.4.3.7 Failure Mode and Effects Analysis

Table 9.3-15 shows a failure mode and effects analysis for the CVCS. At least one failure is postulated for each major component. Additionally, various component leaks throughout the safety-related subsystems are considered. In each case the possible cause of such a failure is presented as well as the local effects, detection methods and compensating provisions.

9.3.4.3.8 Compliance with Applicable General Design Criteria

Conformance with the NRC General Design Criteria is discussed in Section 3.1.

9.3.4.4 <u>Testing and Inspection Requirements</u>

Each component is inspected and cleaned prior to installation into the CVCS. A high velocity flush using inhibited water used to flush particulate material and other potential contamination from all lines in this system.

Instrumentation calibration is verified during preoperational testing. Automatic controls are tested for actuation at the proper set points and alarm functions are checked for operability and proper set points. The relief valve settings are checked and adjusted as required. All sections of the CVCS are operated and tested initially with regard to flow paths, flow capacity and mechanical operability. Pumps are tested to demonstrate head and capacity.

Prior to preoperational testing, the components of the CVCS are tested for operability. The components and subsystems checked include the following:

a) operation of all automatic and remote controlled valves;

b) operation of boric acid pumps;

c) operation of nitrogen and hydrogen pressurization systems;

d) charging pump operational check;

e) check of miscellaneous valve function, alarms and interlocks;

f) instrumentation on the boric acid makeup tanks, volume control tank and boric acid batching tank; and

g) inspection of all valves for proper flow direction.

The charging pumps permit leak testing of the RCS during plant start-up operations.

A charging pump is periodically used to check the operability and leak tightness of the check valves which isolate the RCS from the SIS.

→(DRN 00-691)

←(DRN 00-691)

As part of normal plant operation, tests, inspections, data tabulation and instrument calibrations are made to evaluate the condition and performance of the CVCS equipment and instrumentation. Data is taken periodically during normal plant operation to confirm heat transfer capabilities and purification efficiency. Pump and valve leakage is monitored.

Where required, in-service testing of valves and pumps, is performed in accordance with ASME Section XI, Subsections IWV and IWP. Appropriate vents, drains, and test connections are provided for this purpose.

9.3.4.5 Instrumentation Requirements

9.3.4.5.1 Temperature Instrumentation

a) Boric Acid Batching Tank Temperature - The batching tank temperature measurement channel controls the tank heaters. Local indication is provided to facilitate batching operations.

→(DRN 00-691)

b) Letdown Line Temperature - The regenerative heat exchanger letdown outlet temperature is indicated on the main control panel in the main control room and on the Remote Shutdown Panel, LCP-43. An alarm is provided in the main control room to alert the operator to abnormally high letdown temperature. The instrument provides a signal for closing the letdown stop valve inside containment at a setpoint above the high temperature alarm. The valve must be manually reopened to restore letdown flow.

←(DRN 00-691)

c) Letdown Heat Exchanger Outlet Temperature - This channel is used to control the component cooling water flow through the letdown heat exchanger to maintain the proper letdown temperature for purification system operation. Temperature is indicated on the main control panel.

→(DRN 00-691)

d) Ion Exchanger Inlet Temperature - This channel actuates isolation valves to bypass flow around the ion exchangers, if the letdown temperature exceeds the highest permissible ion exchanger operating temperature. Temperature indication and a high temperature alarm are provided in the main control room. Also, remote temperature indication is provided on the Remote Shutdown Panel, CP-43 outside the main control room. The flow control valve to the ion exchangers remains in the open position, on high temperature, if the control switch is in the "open" position. However, if the control switch is in the "auto" position, the valve will close on high temperature and then reopen when the temperature decreases.

←(DRN 00-691)

e) Volume Control Temperature - The volume control tank is provided with temperature indication on the main control panel. A high temperature alarm is provided in the main control room to alert the operator to abnormally high water temperature in the volume control tank.

f) Charging Line Temperature - The regenerative heat exchanger charging outlet temperature is indicated on the main control panel. This indication is used to monitor heat exchanger performance and verify that auxiliary spray initiation conditions are satisfied.

g) Boric Acid Makeup Tank Temperature - Each boric acid makeup tank is provided with redundant temperature measurement channels with local indication. A common high and low alarm provides annunciation in the main control room. Each measurement channel controls one of the two heater banks on the tank which prevents precipitation of the boric acid, but that are required to be maintained operable only when technical specifications allow a boron concentration of greater than 3.5 w/o.

9.3.4.5.2 Pressure Instrumentation

a) Letdown Backpressure Controller - The pressure measurement channel upstream of the letdown backpressure control valves controls these valves to maintain the proper intermediate letdown pressure. High and low pressure alarms are also provided in the main control room.

b) Ion Exchanger and Letdown Strainer Differential Pressures - Differential pressure indicators are provided to indicate the pressure loss across the ion exchangers and across the letdown strainer. The strainer differential pressure indicator has a local readout with a main control room high differential pressure alarm. Local readout only is provided for the ion exchanger differential pressure indication.

Periodic readings of these instruments will indicate any progressive loading of the units.

c) Boric Acid Pump Discharge Pressures - Discharge pressure of each pump is indicated locally. A low pressure alarm annunciating in the main control room is provided for both measurement channels.

d) Charging Line Pressure - Both indication and an alarm are provided for the charging line pressure at the main control panel and at the auxiliary control panel. A low charging line pressure alarm during normal operation is indicative of a charging line failure.

e) Reactor Coolant Pump Controlled Bleedoff Pressure - A pressure measurement channel is provided to measure the pressure at the reactor coolant pump controlled bleedoff header. Indication is provided at the main control panel, and the measuring device provides overpressure protection for RCS design pressure. A high alarm and a high-high alarm are annunciated at the main control panel. The high alarm indicates that a valve in the line to the volume control tank has been closed. The high-high alarm indicates that the controlled bleedoff flow to the volume control tank and the quench tank has stopped.

f) Charging Pump Suction Line Pressure Switches - A pressure switch on each charging pump suction manifold stops the associated charging pump on low suction line pressure in the absence of an SIAS, thus preventing damage due to cavitation.

g) Volume Control Tank Pressure - The volume control tank pressure is indicated at the main control panel. High and low pressure alarms are also provided at the main control panel. A high pressure alarm would indicate one or more of the following:

1) the automatic controls for the inlet valve have failed when the volume control tank level was increasing due to excessive letdown,

2) the automatic controls for stopping the boric acid makeup pumps have failed when the volume control tank level was increasing via automatic makeup,

3) the operator was filling the volume control tank in the manual makeup mode and did not stop at the high level indication, and/or

4) the hydrogen gas regulator valve setting was incorrectly adjusted or has failed.

A low pressure alarm would indicate a failure or improper setting to either the supply or vent gas regulator valve.

h) Charging Pump Packing Cooling System Pressure - The seal lubrication system pressure is indicated locally for each charging pump.

i) Charging Pump Packing Cooling System Low Pressure Switch - A low pressure switch on each charging pump seal lubrication system annunciates an alarm in the main control room on a low system pressure.

j) Charging Pump Packing Cooling System High Pressure Switch - A high pressure switch on each charging pump seal lubrication system annunciates an alarm in the main control room on a high system pressure.

k) Charging-Pump Lubricating Oil Pressure - The lubricating oil pressure for each charging pump oil lubrication system is indicated locally.

l) Charging Pump Lubricating Oil Low Pressure Switch - A pressure switch on each charging pump oil lubrication system precludes the operation of the associated charging pump on low oil pressure preventing damage to the pump bearings.

m) Purification Filter Differential Pressure - A differential pressure measurement channel is provided to indicate the pressure drop across the purification filter. The channel has a local readout with a high differential pressure alarm annnunciated in the main control room.

9.3.4.5.3 Level Instrumentation

→(DRN 00-695)

a) Volume Control Tank Level - One differential pressure level instrument provides volume control tank level indication at the main control panel in the main control room and on the auxiliary control panel outside the main control room. This instrument controls the starting and stopping of the automatic makeup system. This channel also provides a high level alarm at the main control panel. The alarm is set above the level at which letdown diversion to the BMS would normally occur. A low level alarm at the main control panel is set below the level at which automatic makeup would normally occur.

b) Volume Control Tank Level - A second differential pressure level instrument on the volume control tank automatically diverts letdown flow to the BMS on high level and switches charging pumps suction from the volume control tank to the refueling water storage pool and actuates a local low-low level alarm.

←(DRN 00-695)

c) Boric Acid Makeup Tank Level - Each boric acid makeup tank is provided with two level indicators. One readout indication is located at the main control panel, the other is indicated locally. High, low and low-low alarms are provided in the main control room to alert the operator to abnormal boric acid levels within the tank.

d) Charging Pump Packing Cooling Tank Level - Level indication is provided locally at the packing cooling tank.

e) Charging Pump Packing Cooling Tank Level Switch - A level switch on each packing cooling tank opens or closes the automatic fill valve which regulates the flow of demineralized water to the cooling tank. This type of control maintains the tank level within a predetermined operating range.

f) Charging Pump Crankcase Oil Level - A sight glass is provided on each Charging pump in order to monitor the oil level within the pump's crankcase.

9.3.4.5.4 Flow Instrumentation

a) Letdown Flow - An orifice-type flow meter indicates letdown flowrate. This channel indicates and actuates a high-flow alarm at the main control panel in the main control room. Also, remote flow indication is provided on the auxiliary control panel outside the main control room.

b) Deleted

c) Concentrated Boric Acid Flow - An electromagnetic flow meter is provided to measure the concentrated boric acid flow rate to the blending tee. This channel controls the boric acid control valve to obtain a preset flow rate. High and low flow alarms in the main control room are delayed after initiation of the makeup signal to allow the set flow rate to become established. The flow rate is recorded and the total quantity is indicated at the main control panel. In the borate mode of makeup controller operation, a preset batch quantity of boric acid can be added.

d) Primary Makeup Water Flow - A flow meter is provided to measure the primary makeup water flow rate to the blending tee. This channel controls the reactor makeup water control valve to obtain a preset flow rate. High and low flow alarms in the main control room are delayed to allow the set flow rate to become established. The flow is recorded and the total quantity is indicated at the main control panel. In the dilute mode of operation, a preset batch quantity of primary makeup water can be added.

e) Charging Flow - Charging flow rate indication and low flow annunciation are provided at the main control panel and at the remote shutdown panel.

f) Charging Pump Packing Cooling System Water Flow - The seal lubrication system water flow for each charging pump is indicated locally.

g) Volume Control Tank Hydrogen Gas Flow - A rotameter is located downstream of the hydrogen gas regulator to the volume control tank. This channel provides a local readout of hydrogen flow to the volume control tank.

h) Volume Control Tank Nitrogen Gas Flow - A rotameter is located downstream of the nitrogen gas regulator to the volume control tank. This channel provides a local readout of nitrogen flow to the volume control tank.

→(DRN 00-691)
←(DRN 00-691)

→(DRN 00-691, R11-A)
←(DRN 00-691, R11-A)

9.3.5 STANDBY LIQUID CONTROL SYSTEM (BWRs)

This system is not applicable to Waterford 3.

9.3.6 SHUTDOWN COOLING SYSTEM (RESIDUAL HEAT REMOVAL SYSTEM)

9.3.6.1 Design Basis

The Shutdown Cooling System (SDCS) is shown on the piping and instrumentation diagrams of Figure 6.3-1 (for Figure 6.3-1, Sheet 1, refer to Drawing G167, Sheet 1) as a subsystem of the Safety Injection System.

During shutdown cooling operation, a portion of the reactor coolant is diverted to the SDCS headers via the shutdown cooling nozzles located in the RCS hot legs. The flow is then cooled by circulating through two shutdown cooling heat exchangers via two low pressure safety injection pumps.

The cooled flow returns to the RCS through four low pressure safety injection headers connected to the cold legs. Plant cooldown rate is controlled by two flow control valves which permit proportioning the amount of shutdown cooling flow passing through the heat exchangers and heat exchanger bypass line.

→(EC-8458, R307)
Pilgrim 2 (Docket 50471) and all CE System 80 plants utilize a similar system.
←(EC-8458, R307)

9.3.6.1.1 Functional Requirements

The SDCS is used in conjunction with the main Steam Supply and main Feedwater Systems to reduce the temperature of the RCS in post shutdown periods from normal operating temperature to the refueling temperature. The Emergency Feedwater System is not used for normal shutdown except when the main Feedwater System is inoperable. The initial phase of the cooldown is accomplished by heat rejection from the steam generators to the condenser or atmosphere. After the reactor coolant temperature and pressure have been reduced to approximately 350°F and 377 psig, the SDCS is put into operation to reduce the reactor coolant temperature to the refueling temperature and to maintain this temperature during refueling.

The shutdown cooling heat exchangers (SDCHX) are also used for containment spray purposes, as discussed in Subsections 6.2.2 and 6.5.2.

The SDCS is used in conjunction with steam generator atmospheric dump and emergency feedwater (assuming loss of main feedwater) to cool down and depressurize the Reactor Coolant System following a small break LOCA (see Section 6.3).

9.3.6.1.2 Design Criteria

In addition to the functional requirements of Subsection 9.3.6.1.1, the following design requirements form the design basis for the SDCS:

a) The functional requirements in Subsection 9.3.6.1.1 must be met assuming the failure of a single component.

b) No single active failure will allow overpressurization of the SDCS. Positive isolation from the RCS is provided whenever the RCS is above the shutdown cooling initiation pressure of 377 psig (pressurizer). Isolation valves with appropriate interlocks are provided on the SDCS suction lines for this purpose. The valves and interlocks are discussed in Subsection 9.3.6.2.2.

   Overpressure protection from the safety injection tanks is discussed in Subsection 6.3.2.2.1.

   The SDCS is provided with appropriate relief valves for overpressure protection. Design basis for pressure relief capacity is discussed in Subsection 9.3.6.2.2.

c) No single failure of an active component during residual heat removal results in a loss of core cooling capability or prevents the initiation of shutdown cooling, either during normal plant cooldown or following an accident. A failure modes and effects analysis of the SDCS is provided in Table 9.3-16.

→(DRN 03-2063, R14; EC-8458, R307)

d) The shutdown cooling heat exchangers are sized to remove decay heat at 17 1/2 hours after shutdown based upon a refueling water temperature of 140°F and a component cooling water temperature of 90°F (both trains operable). The system is designed to attain a refueling temperature of 140°F in 24 1/4 hours after shutdown during normal conditions with both trains in operation. Further information on the cooldown times is provided in Subsection 9.3.6.3.

←(DRN 03-2063, R14; EC-8458, R307)

e) The SDCS is placed into operation when the RCS temperature and pressure are below 350°F and 377 psig, respectively.

f) Materials are selected to preclude system performance degradation due to effects of short and long term corrosion.

g) The safety and seismic classifications for the SDCS are given in Table 3.2-1.

h) In the event of a single active failure, and to assure availability of the system when required, redundant components are provided. Redundant components are powered from independent emergency power sources (see Section 8.3). Instrumentation to assure proper system operation is described in Subsection 9.3.6.2.2. Protection of system redundance is covered in Subsection 9.3.6.3.1.

i) The SDCS is designed, fabricated, inspected, tested and installed in accordance with the appropriate ASME codes (see Subsection 3.9.6 and 9.3.6.2.4).

9.3.6.2 System Description

9.3.6.2.1 Functional Description

→(DRN 00-703, R11-A)
The SDCS is shown in Figure 6.3-1 (for Figure 6.3-1, refer to Drawing G167, Sheets 2 and 3).
←(DRN 00-703, R11-A)

During shutdown cooling, reactor coolant is circulated by the low pressure safety injection (LPSI) pumps through the shutdown cooling heat exchangers to the LPSI headers and returned to the RCS cold legs through the four safety injection nozzles.

→(DRN 06-898, R15; EC-30976, R307)
The initial cooldown rate is maintained at 75°F/hr or less. The cooldown rate is manually controlled by adjusting the flow rate through the heat exchangers with temperature control valves SI-415A and SI-415B on the discharge of the heat exchangers.
←(DRN 06-898, R15)

→(DRN 00-703, R11-A)
With the shutdown cooling flow indicators, the operator maintains the desired total shutdown cooling flow rate by adjusting the amount of coolant which bypasses the shutdown cooling heat exchangers with flow control valves SI-129A and 129B. During initial cooldown the temperature differences for heat transfer are large, thus only a portion of the total shutdown flow is diverted through the heat exchangers. As cooldown proceeds, the temperature differences become less and the flow rate through the heat exchangers is increased. The flow is increased periodically until full shutdown cooling flow is through the shutdown cooling heat exchangers. This mode is maintained until the RCS reaches refueling temperatures.
←(DRN 00-703, R11-A; EC-30976, R307)

A warmup recirculation line is provided in the SDCS to limit thermal stress in the piping and components that would occur if a step change in temperature from ambient to reactor coolant temperature were permitted during system lineup. No credit is taken for warmup in equipment selection.

→(DRN 03-2063, R14)
The SDCS is designed to cool the RCS from 350°F and 377 psig to 140°F and atmospheric pressure in 24 1/4 hours. The cooldown is assumed to commence 3 1/2 hours after shutdown with two shutdown cooling heat exchangers and two LPSI pumps in operation.

The RCS can be brought to refueling temperature using one LPSI and one shutdown cooling heat exchanger. However, with the design heat load, the cooldown would be considerably longer than the specified 24 1/4 hour time period. One LPSI pump will provide sufficient flow through the core to maintain the core T at a value less than the full power ΔT (60°F).
←(DRN 03-2063, R14)

→(DRN 00-703, R11-A; EC-14765, R305)
SDCS components, where design pressure and temperature are less than the RCS design limits, are provided with overpressure protection devices. Each shutdown cooling suction line is equipped with three isolation valves in a series arrangement. Valves SI-401A and SI-405A / SI-4052A for Train A and SI-401B and SI-405B / SI-4052B for Train B are located inside containment while valves SI-407A (Train A) and SI-407B (Train B) are located outside containment. With this arrangement, a redundant, parallel shutdown cooling path is available should a single failure preclude the availability of one of the shutdown cooling trains.
←(DRN 00-703, R11-A; EC-14765, R305)

→(EC-14765, R305)
Each valve inside containment is provided with an interlock to prevent opening whenever the RCS pressure exceeds a preset value (see Subsection 9.3.6.2.2). In addition, during normal operation, the circuit breakers in the power circuits for motor operated valves ISI-V1504A and ISI-V1502B and DC power to the solenoids for valves SI-405A / SI-4052A and SI-405B / SI-4052B are locked in the open position to prevent inadvertent opening. Additional interlocks to prevent SDCS overpressurization are provided on the safety injection tank isolation valves, as described in Subsection 6.3.2.2.1. Both interlocks are discussed further in Section 7.6.
←(EC-14765, R305)

→(EC-935, R302)
To assure availability of the SDCS and positive isolation of the reactor coolant pressure boundary, the RCS isolating valves (SI-651 for train A and SI-665 for train B) are provided with pneumatic operators. The pneumatic double acting piston operators have a safety related air supply circuit incorporating three (3) accumulators and filled by Instrument Air (IA), with Essential Instrument Air (EIA) backup, is sized (600 gallons/valve) to accommodate valve strokes necessary for design basis accidents. The solenoid valve is fail open (vents) when de-energized to ensure that the valve will fail close on loss of power.
←(EC-935, R302)

→(EC-14765, R305)
Each shutdown train is powered from their respective buses to assure that power failure in one train will not jeopardize availability of the other train.
←(EC-14765, R305)

The containment isolation valves (SI-440 for train A and SI-441 for train B) are motor operated and are powered from their respective buses.

A pressure relief valve in each shutdown cooling suction line protects the system from overpressurization during system operation when the suction valves are open and the system is not isolated from the RCS. The valves are sized considering transients due to inadvertent operation of charging pumps, HPSI pumps, and pressurizer heaters. Additional pressure relief valves are provided to protect isolated sections of piping from thermal overpressure (see Subsection 9.3.6.2.2).

→(DRN 00-691, R11-A)
No single failure of an active component during residual heat removal will result in a loss of core cooling capability or prevent the initiation of shutdown cooling.
←(DRN 00-691, R11-A)

Each train receives power from a separate emergency power source, in the event that offsite power is unavailable during an accident. The two trains are physically separated from each other so that a failure and its consequential effects (i.e., fire, flooding, steam impingement, or missiles) in one train will not result in the failure of the other train.

The design location, arrangement and installation of the system and its components are such that it will withstand the effects of earthquakes and other natural phenomena, without loss of the capability of performing its safety function as specified in General Design Criterion 2 of 1OCFR50 Appendix A. Operability requirements and analysis of this system and components relative to NRC Regulatory Guides 1.29 and 1.48 are described in Section 3.2 and Subsection 3.9.3.

9.3.6.2.2 Equipment and Component Descriptions

a) Low Pressure Safety Injection Pumps

The LPSI pumps are used jointly as part of the SDCS and SIS. During all periods of plant operation, when SIS operability is required, the LPSI pumps are aligned for emergency core cooling operation.

During shutdown cooling, the LPSI pumps take flow from the reactor (hot leg) pipes and discharge through the shutdown cooling heat exchangers. The shutdown cooling flow is then returned to the RCS through the LPSI headers to the reactor inlet (cold leg) pipes. One low pressure safety injection pump is aligned to each shutdown cooling heat exchanger.

The LPSI pump design flow rate of 4050 gpm is based on maintaining a core ΔT (60°F) at shutdown cooling initiation 3 1/2 hours after shutdown. The LPSI pump characteristics and the available NPSH are further discussed in Section 6.3.

b) Shutdown Cooling Heat Exchangers (SDCHXs)

The SDCHXs remove core decay heat, RCS sensible heat, and safeguard pump heat during plant cooldown and cold shutdown. The SDCHXs are sized to maintain refueling water temperature

→(DRN 03-2063, R14)

(140°F) with the design component cooling water temperature of 90°F at 24 1/4 hours shutdown.

←(DRN 03-2063, R14)

A conservative fouling factor is assumed, resulting in an additional area margin for the heat exchangers. The SDCHX characteristics for the shutdown cooling mode are given in Table 9.3-17.

c) Piping

All SDCS piping is austenitic stainless steel. All piping joints and connections are welded except for a minimum number of flanged connections that are used to facilitate equipment maintenance or accommodate component design.

d) Valves

Design pressures and temperatures for the SDCS valves are provided in Table 9.3-18.

→(DRN 00-703, R11-A; EC-30976, R307)

Manual isolation valves are provided to isolate equipment for maintenance. Throttle valves (SI-129A, SI-129B, SI-415A and SI-415B) are provided for remote control of heat exchanger tube side and bypass flows. Position indication for these valves is provided in the main control room.

←(DRN 00-703, R11-A; EC-30976, R307)

Each shutdown cooling suction line is equipped with three remotely controlled isolation valves in a series arrangement with two valves inside containment and one valve outside containment. Position indication is provided for each of these valves in the main control room.

In addition to normal offsite power, independent emergency power supplies are provided for the isolation valve combination, arranged to assure that a single failure of an isolation valve or power supply does not preclude availability of the system or preclude positive isolation at the boundary with the RCS.

→(EC-14765, R305)

Since the SDCS is not designed to accommodate full RCS pressure, isolation of the system suction lines is assured by interlocks on the four suction line isolation valves inside containment. An independent interlock, utilizing pressurizer pressure, is provided for each of the valves. Each interlock is designed to prevent opening of its associated valve whenever pressurizer pressure is ≥ 392 psia. This pressure is the maximum allowable (including margin) shutdown cooling initiation pressure which will not result in overpressurization of the LPSI pump seals. An audible alarm sounds in the main control room whenever any of the valves is off the full closed position and pressurizer pressure is ≥ 392 psia. Each of the six suction line isolation valves is equipped with open/close position indication in the main control room. During normal operating conditions, the circuit breakers in the power circuits for motor operated valves (ISI-V1504A and ISI-V1502B) and DC power to the solenoids for valves SI-405A / SI-4052A and SI-405B / SI-4052B are locked in the open position to prevent inadvertent opening. Valve control circuitry and interlocks are discussed further in Section 7.6. Additional interlocks are provided on the safety injection tank isolation valves for overpressure protection of the SDCS. The safety injection tank (SIT) interlocks are discussed in Section 7.6 and Subsection 6.3.2.2.1.

←(EC-14765, R305)

→(DRN 00-703, R11-A)

Further protection from overpressurization is provided by relief valves SI-406A and SI-406B located in the shutdown cooling suction lines between the inside and outside containment isolation valves. The relief valve protects the system from all inadvertent RCS pressurization during SDCS operation when the suction line isolation valves are open. Each relief valve is designed to protect the system from overpressurization due to the worst combination of the following incidents: all backup pressurizer heaters energized, all charging pumps actuated, and all HPSI pumps actuated.

←(DRN 00-703, R11-A)

The SDCS relief valves are a direct-acting, spring-loaded, closed bonnet design with a single outlet. Figure 9.3-10 illustrates the valves. Relief fluid is collected in the containment sump. Design parameters are given in Table 9.3-22.

→(DRN 00-691, R11-A)

An operability evaluation for relief valves SI-486 and SI-487 was submitted to the NRC in W3P84-3491 dated December 14, 1984. The operability evaluation was based on water test data for a Crosby 6R8 JB-25-3-TD relief valve and steam test data for a 4P6 JB-56-TD and a 6RIO JB-56-TD relief valve. The operability evaluation correlated the test data to SDCS valve performance expected for plant transient conditions. The physical geometry, mechanical, materials, and functional characteristics of the Waterford 3 relief valves were evaluated. The operability evaluation demonstrated the operability of the SDCS relief valves at SDCS operating pressure and temperature conditions.

←(DRN 00-691, R11-A)

The NRC on the basis of the operability evaluation concluded in SSER 10, Section 5.4.3, that the Waterford 3 SDCS relief valves can adequately perform their intended function to relieve system over pressure and subsequently close.

→(DRN 00-92)

Additional relief valves provided in the system protect isolated sections of piping from thermal transient effects. Suitable provisions are made to collect the discharges from these overpressure protection devices. Valves SI-404B and SI-404A have a capacity of five gpm each with a setpoint of 2460 psig. Valves SI-408A and SI-408B have a capacity of five gpm each with a setpoint of 425 psig.

←(DRN 00-92)

9.3.6.2.3 Interface With Other Systems

a) Reactor Coolant System

→(DRN 00-691, R11-A; EC-14765, R305)

Temperature control during plant cooldown and refueling is accomplished by recirculating reactor coolant through the shutdown cooling heat exchangers. During normal operation, two valves, one motor operated and one pneumatic operated, in a series arrangement in each shutdown cooling suction line inside the containment provide isolation of the SDCS from the RCS. These isolation valves are provided with pressure interlocks, as described in Section 7.6. A third motor operated valve in each SDCS suction line outside containment provides containment isolation.

←(DRN 00-691, R11-A; EC-14765, R305)

b) Safety Injection System

During all periods of plant operation when required, the LPSI pumps are aligned for emergency core cooling (see Section 6.3).

c) Containment Spray System

During normal operation, the containment spray pumps are aligned to discharge through the shutdown cooling heat exchangers. This is the required alignment for emergency operation (operation following a LOCA). During shutdown cooling, the heat exchangers are isolated from the Containment Spray System (see Subsection 6.2.2).

d) Chemical and Volume Control System

Piping and valves are provided in the CVCS such that during shutdown cooling a portion of the flow can be bypassed from the outlet of the shutdown cooling heat exchangers through the letdown portion of the CVCS and returned to the shutdown cooling suction lines. Flow through this bypass stream provides filtration and ion exchange of the reactor coolant.

e) Refueling

The transfer of refueling water from the refueling water storage pool to the refueling pool may be accomplished using the SDCS at the start of refueling. After the reactor vessel head is removed, the HPSI pumps are used to transfer borated water from the refueling water storage pool to the refueling pool by discharging to the reactor coolant loops. The LPSI pumps or the containment spray pumps may also be used for this operation. At the end of refueling, the water is returned to the refueling water storage pool using the LPSI pumps. A connection is provided from the shutdown cooling heat exchangers discharge to the refueling water storage pool for this purpose.

f) Component Cooling Water System

The Component Cooling Water System provides the heat sink to which the residual heat is rejected. Cooling water flows through the shell side of the shutdown cooling heat exchangers and also functions to cool the shaft seals on the LPSI pumps as they circulate the heated reactor coolant (see Section 9.2).

g) Refueling Water Level Indicating System

The Refueling Water Level Indicating System (RWLIS) allows for the continuous monitoring of the RCS level during draindown (see Subsection 5.4.16).

9.3.6.2.4 Application Codes and Classifications

Piping	ASME III, Class 1, 2 or 3, as applicable (1971 Edition, up to and including Winter 1972 addenda)
Valves	ASME III, Class 1, 2 or 3, as applicable (1971 Edition, up to and including Summer 1973 addenda)
Heat Exchangers	Tubular Exchangers Manufacturing Association (TEMA) and ASME III Class C and Section VIB (1968 Edition, up to and including Summer 1970 addenda)

Further information on component classifications is given in Section 3.2.

9.3.6.3 Safety Evaluation

9.3.6.3.1 System Reliability Considerations

The SDCS is designed to perform its design function assuming a single failure, as described in Subsection 9.3.6.1.2, items A through C.

→(DRN 03-2063, R14)
To assure availability of the SDCS when required, redundant shutdown cooling trains are provided. The single failure of an active component during residual heat removal operations will not result in a loss of core cooling capability. The RCS can be brought to refueling temperature using one low pressure safety injection pump and one shutdown cooling heat exchanger, but the cooldown process would be considerably longer than the specified 24 1/4 hour time period.
←(DRN 03-2063, R14)
→(EC-30976, R307)
A loss of instrument air to the SDCS will not result in a loss of cooling ability. The air operated shutdown cooling heat exchanger bypass valves are equipped with a hand wheel, if local dose rates permit, for positioning upon loss of instrument air. A backup safety related control air supply is also available for valve control in the -15 RAB valve gallery for some SBLOCA cases that may not permit entry for hand wheel control due to high dose rates.
←(EC-30976, R307)
→(EC-935, R302)
The RCS isolating valves (SI-651 for train A and SI-665 for train B) are provided with pneumatic operators which have a safety related air supply circuit incorporating three (3) accumulators and filled by Instrument Air (IA), with Essential Instrument Air (EIA) backup, is sized (600 gallons/valve) to accommodate valve strokes necessary for design basis accidents.
←(EC-935, R302)

Inadvertent overpressurization of the SDCS is precluded by the use of pressure relief valves and interlocks installed on the shutdown cooling suction line isolation valves and safety injection tank isolation valves (see Section 7.6).

The instrumentation, control and electric equipment and power supplies pertaining to the SDCS were designed to applicable portions of IEEE Standard 279-1971, as described in Section 7.6 and IEEE Standard 308-1971.

In addition to normal offsite power sources, physically and electrically separated and redundant emergency power supply systems are provided to power safety related components. Refer to Chapter 8 for further discussion.

Since the SDCS is essential for a safe shutdown of the reactor, it is a seismic Category I system and designed to remain functional in the event of a safe shutdown earthquake.

For long-term performance of the SDCS without degradation due to corrosion, only materials compatible with the pumped fluid are used.

Environmental conditions are specified for system components to ensure acceptable performance in normal and applicable accident environments (see Section 3.11).

9.3.6.3.2 Manual Actions

The SDCS is a manually aligned and actuated system. Alignment to the shutdown cooling mode is accomplished via manual alignment of valves from the main control room, except for CS117A(B) which require local manual operation from the RAB-15 level valve gallery. Once system alignment to the shutdown cooling mode is accomplished, the system, and hence plant cooldown, can be controlled remotely from the main control room during normal plant conditions.

Valve actuations required for normal SDCS alignment and operation that are accomplished from the main control room are given in Table 9.3-20. In addition to the valves mentioned above, both low pressure safety injection pumps are activated from the main control room. Each pump may also be started from LCP-43 the remote shutdown panel.

For the most limiting single active failure, whereby only one SDCHX and one LPSI pump are in operation, the required manual actions are no greater than for normal shutdown cooling operation described above with all SDCS components operable.

→(EC-30976, R307)

For post-LOCA SDCS operation, a loss of air is assumed for flow control valves SI-129A and 129B since the air supplies for these valves are not seismically qualified. Under these circumstances, valves SI-129A and 129B fail open and cannot be remotely controlled from the main control room. The shutdown cooling process is then controlled by adjusting the flow rate of reactor coolant through the shutdown cooling heat exchangers remotely from the main control room with throttle valves SI-415A and SI-415B and adjusting total shutdown cooling flow locally by manually positioning valves SI-129A and SI-129B via hand wheel. If dose rates are too high to access the handwheels, cooldown is controlled by remotely shutting SI-129A and/or SI-129B via seismically qualified backup air supplies located in the -15 RAB valve gallery. Air is manually turned on and closes the valves bypassing and venting the original air volume tank that initially failed the valves open. All RCS flow is routed to the SDCHx where cooldown is controlled instead by setting SI-415A and SI-415B at the LPSI design flow rate and the shutdown heat exchanger CCW control valves CC-963A and CC-963B failed open. Analysis demonstrates that, with CC-963A(B) fully open, CCW piping temperature downstream of the SDC HX is less than the rated temperature of 270°F for RCS temperatures less than 350°F and that RCS cooldown limit of 100°F/hr will not be exceeded.

←(EC-30976, R307)

→(EC-8458, R307)

For a moderate energy line break during shutdown cooling the operator, within 20 minutes, will initiate corrective action in accordance with the emergency operating procedures. The most limiting break in the SDCS was determined to be a moderate energy critical crack break of 0.98 in^2 in the LPSI pump discharge line, with a maximum leak rate of 484 gpm. The total RCS water volume above the top of the hot leg is 3,046 ft^3, or 22,780 gallons (assuming an active tube volume for each steam generator of 1,356 ft^3). Given a 484 gpm leak rate the RCS

←(EC-8458, R307)

volume above the top of the hot leg has been decreased by 9,680 gallons in 20 minutes. Therefore, because the amount of SDCS fluid leakage over a 20 minute period is less than the RCS volume above the top of the hot leg, the top of the leg will not be uncovered before corrective action can be taken by the operator.

9.3.6.3.3 Performance Evaluation

→(DRN 03-2063, R14)

The design point of the SDCS is taken at 17 1/2 hours after plant shutdown. At this point, the heat load design basis is to maintain the 140°F refueling temperature with 90°F component cooling water. Two shutdown cooling heat exchangers plus two LPSI pumps were assumed to be in operation at the design flow of 4000 gpm each. The SDCHX size is determined at this point since it yields the greatest heat transfer area due to the relatively small ΔT between primary fluid and component cooling water.

The design heat load at 17 1/2 hours is based on decay heat at 17 1/2 hours assuming infinite reactor operation. Additional energy input to the RCS from two LPSI pumps running at design flow rate of 4000 gpm each was also included; no credit is taken for component energy losses to the external environment.

For the cooldown process from the shutdown cooling initiation temperature of 350°F to the refueling temperature of 140°F, the heat load utilized is comprised of the instantaneous decay heat, LPSI pump heat input and sensible heat of the primary and secondary liquid and metal masses. Metal mass is assumed to be steel with a specific heat of 0.12 Btu/lbm F. The temperature of the component cooling water to the SDCHX is taken as 90°F initially when 140°F refueling temperature is reached.

→(EC-8458, R307)

At each time interval in the cooldown, an iterative process is utilized to analyze transient performance whereby the permissible heat removal is established by balancing the available heat load with the SDCHX heat removal capability. Maximum cooldown rate is limited to ≤ 75°F/hr throughout the cooldown. For normal cooldown, two shutdown cooling trains can bring the RCS temperature to the refueling temperature of 140°F approximately 24 1/4 hours after shutdown.

With the most limiting single active failure in the SDCS, RCS temperature can be brought to the refueling temperature of 140°F in approximately 193 hours following shutdown using only one LPSI pump and one SDCHX. Design parameters for the SDCHX and for the CCWS are given in Tables 9.2-3, 9.2-9 and 9.3-17. Decay heat loading is defined in Subsection 6.3.1.2.

←(DRN 03-2063, R14, EC-8458, R307)

A failure modes and effects analysis for the SDCS can be found in Table 9.3-16. The analysis demonstrates the the SDCS can withstand any single active failure and still perform its design function. The analysis is based on the following assumptions:

a) one active failure of a component or a single operator error is assumed to occur in the system,

b) the analysis considers only failures that occur during the time period of SDCS operation,

c) relief and check valve failures are not considered credible failures, and

d) failure to respond to an external signal is considered an active failure.

→(LBDCR 15-028, R308A)

9.3.6.3.3.1 Natural Circulation Cooldown Analysis

The natural circulation cooldown analyses are accomplished in two phases, the first phase is the initial cooldown to shutdown cooling initiation temperature and pressure, then shutdown cooling system (FSAR Section 9.3.6) operation phase to cool to the reactor coolant system temperature of 200°F. For a loss of offsite power and associated natural circulation cooldown, the initial phase is accomplished through the emergency feedwater system (FSAR Section 10.4.9) and the atmospheric dump valves (FSAR Section 10.3). This equipment is used to reduce the reactor coolant system temperature and pressure to values that permit operation of the shutdown cooling system. This analyses utilizes the CENTS code (refer to FSAR Section 15.0.3.1.6 for the code description) to model the nuclear steam supply system transient. The shutdown cooling system removes core decay heat and provides long-term core cooling following the initial phase of reactor cooldown. These analyses calculate the time to cooldown the plant to cold shutdown conditions and the emergency feedwater inventory required.

The natural circulation cooldown analyses are used to demonstrate compliance with Branch Technical Position (BTP) 5-4. BTP 5-4 delineates the design requirements of the residual heat removal system that was formerly BTP Reactor System Branch (RSB) 5-1. These analyses demonstrate that the following BTP 5-4 paragraph B functional requirements are met.

1. The design shall be such that the reactor can be taken from normal operating conditions to cold shutdown using only safety-grade systems satisfying General Design Criteria 1 through 5.

2. The systems shall have suitable redundancy in components and features, and suitable interconnections, leak detection, and isolation capabilities to assure that for onsite electrical power system operation (assuming offsite power is not available) and for offsite electrical power system operation (assuming onsite power is not available) the system function can be accomplished assuming a single failure.

3. The systems shall be capable of being operated from the control room with either only onsite or only offsite power available. In demonstrating that the systems can perform their function assuming a single failure, limited operator action outside the control room is considered acceptable if suitably justified.

4. The systems shall be capable of bringing the reactor to a cold shutdown condition, with only onsite or offsite power available, within a reasonable period of time following shutdown, assuming the most limiting single failure.

The limiting single failure with respect to emergency feedwater inventory usage is the failure of an atmospheric dump valve. For this single failure, the atmospheric dump valve is permanently unavailable, forcing a cooldown on a single steam generator. Once on the shutdown cooling system, the cooldown proceeds rapidly, as two trains are available. The analysis demonstrates that sufficient safety related emergency feedwater inventory is available to achieve cold shutdown conditions. Figures 9.3-8a and 9.3-8b show the cooldown profile for the natural circulation cooldown with a failed atmospheric dump valve. The atmospheric dump valve actuators (FSAR Section 10.3.1) backup supply of motive gas is provided by Safety Class 3, Seismic Category I accumulators and provides a ten hour minimum supply. For this scenario, shutdown cooling entry conditions exceed 10 hours, thus procedural actions are credited for manually operating the remaining atmospheric dump valve handwheel or lining up backup air supplies for continued operation.
←(LBDCR 15-028, R308A)

→(LBDCR 15-028, R308A)

The limiting single failure with respect to the longest cooldown time is the loss of a DC bus. The loss of a DC bus causes that train emergency diesel generator and atmospheric dump valve control logic to fail. In this scenario, only one train of safety related equipment is available, and in particular only one shutdown cooling system train is available for cooldown from 350°F to 200°F. The transient credits local manual control of the atmospheric dump valve within the four hour hold period prior to cooldown initiation. Thus, the Waterford 3 plant is capable of being cooled to a cold shutdown condition with only offsite or onsite power available within a reasonable period of time of 40 hours.

CEN-259 (Reference 5) documents the results of a natural circulation cooldown test performed at San Onofre Nuclear Generating Station that is applicable to Waterford 3. This report shows that adequate boron mixing can be achieved with natural circulation and no letdown and that the cooldown can be achieved without the formation of a void in the upper head. This test was reviewed and approved by the NRC as applicable to Waterford 3 (Reference 6). Thus, the requirements of BTP RSB 5-4 are met.

The natural circulation cooldown analysis does not credit the operation of the pressurizer heaters. Therefore, operator action to energize the pressurizer heaters is not a time critical operator action.
←(LBDCR 15-028, R308A)

9.3.6.3.4 Loss of SDCS with RCS Partially Filled

In response to Generic Letter 87-12 dated July 9, 1987, a study was conducted to review accident scenarios initiated from the loss of SDC while the RCS was partially filled. A response was submitted in letter W3P87-1775 dated September 21, 1987.

If shutdown cooling is lost for an extended period of time, the RCS water temperature will increase. If boiling occurs and the RCS is open, then inventory will be lost. This could result in eventual core uncovery unless makeup flow is provided or SDC is re-established. If the RCS is closed, boiling will increase the pressure in the upper plenum causing the water level in the reactor vessel to be depressed down to the elevation of the RCP suction (e.g., core cooling is maintained since this level is above the top of the core). Condensation of steam in the RCS by the steam generators limits the pressure increase. The study concluded:

1. Reactor Coolant Pump (RCP) design is such that RCS pressurization of approximately 60 psig is necessary before significant water loss could occur when an RCP seal is removed.

→(DRN 03-2063, R14)

2. For a closed RCS (including RCP seal replacement), heat transfer (steam condensation) to a steam generator results in that generator boiling dry (with no makeup) in approximately 5 hours with a maximum RCS pressure of approximately 35 psig before boiling dry.

3. For an open RCS (removal of an RCP or steam generator manway) at one day after reactor shutdown, core uncovery will not occur until after 1.4 hours. This is based on the conservative assumption that no primary system steam is condensed in the steam generator(s). The time for core uncovery increases as the time after reactor shutdown increases.

←(DRN 03-2063, R14)

4. Steam generator heat removal and RCS makeup capability are the key parameters in extending the time to core uncovery.

5. In addition to restoring shutdown cooling, the event may be terminated at any time prior to core damage by high pressure safety injection (HPSI) flow.

The study confirmed that the postulated core damage scenario is within the Waterford 3 procedural and design basis capability to mitigate without fuel damage or the release of radioactive material.

9.3.6.4 Preoperational Testing

Preoperational tests are conducted to verify proper operation of the SDCS. The preoperational tests include verification of adequate shutdown cooling flow and verification of the operability of all associated valves. In addition, a preoperational hot functional performance test is made on the installed shutdown cooling heat exchangers.

For availability of the SDCS, components of the systems are periodically tested as part of the Safety Injection System testing, as described in Section 6.3. The system and component tests, together with shutdown cooling heat exchanger thermal performance data taken during refueling, are sufficient to demonstrate the continued operability of the SDCS.

In addition to flow tests, the SDCS also undergoes a series of preoperational and inservice pressure tests. Preoperational hydrostatic tests are conducted in accordance with Section III of the ASME Code while inservice pressure tests are carried out as required by Section XI of the ASME Code.

Leak testing will also be done on the portions of the SDCS outside containment as part of a leak reduction program as required by NUREG-0737.

For further discussion of preoperational and inservice testing on the SDCS and components, see Sections 3.9.6, 6.6 and 14.2.

9.3.6.5 Instrumentation Applications

Operation of the SDCS is controlled and monitored through the use of installed instrumentation. The instrumentation provides the capability to determine heat removal, cooldown rate, shutdown cooling flow and the capability to detect degradation in flow or heat removal capacity. The instrumentation provided for the SDCS consists of:

a) Temperature measurements - shutdown cooling heat exchanger inlet and outlet temperature and the temperature of the shutdown cooling flow to the low pressure header. All temperatures are indicated in the main control room. The shutdown cooling heat exchanger inlet temperatures and the low pressure header temperatures are recorded to facilitate control of the RCS cooldown rate.

b) Pressure measurements - LPSI header pressure and shutdown cooling heat exchanger inlet pressure. These pressures are indicated in the main control room and, when used with the low pressure pump performance curves, provide an alternate means of measuring system flow rate.

→(DRN 00-691, R11-A)

c) Total shutdown cooling flow rate is measured by the shutdown cooling flow indicators F-306 and F-307. With the aid of these flow indicators, the operator maintains the desired total shutdown cooling flow rate by adjusting the amount of coolant which bypasses the shutdown cooling heat exchangers. Shutdown cooling flow indication is also available at the Remote Shutdown Cooling Panel, CP-43.

←(DRN 00-691, R11-A)
→(DRN 06-886, R15)

d) Shutdown Cooling Alarms - One alarm is provided on CP-8 for Shutdown Cooling (SDC) Trouble. The LPSI flow inputs are monitored and will alarm for a low flow condition. The Core Exit Thermocouples (CET) are monitored for a temperature rise in the reactor core. The temperature rise of 2°F or greater per 4 minute average, when compared to the last 4 minute average, will activate the alarm.

The low flow alarm indicates a loss of flow from the LPSI train being used for shutdown cooling. The two independent CET indicators monitor the core exit conditions in accordance with Generic Letter 88-17.

←(DRN 06-886, R15)

The only instrumentation necessary following a postulated accident is the inlet temperature measurement of the SDCHXs and the temperature of the shutdown cooling flow in the low pressure header (TE 351 and TE 352). This instrumentation is designed to Class 1E requirements.

9.3.7 HYDROGEN SYSTEM

9.3.7.1 Design Bases

The hydrogen system serves no safety function and, therefore, has no safety design bases. The hydrogen system is designed to:

a) Supply the main generator gas cubicle sufficient hydrogen for use as the generator rotor coolant.

b) Supply sufficient hydrogen to the volume control tank of CVCS to control of hydrogen concentrations in the reactor coolant.

9.3.7.2 System Description

a) A completely automatic hydrogen supply system is provided with resupply and service coming from a vendor tube trailer. The system includes a tube trailer discharging stanchion, a grounding assembly, a pressure control unit, an excess flow manifold and a preassembled module of storage vessels with manifolding and interconnecting piping. The overall system and its operation is depicted in Fig. 9.3-9.

b) Specific Equipment Description

1) Gaseous Hydrogen Storage Bank

The total storage bank is composed of eight (8) ASME-coded gas storage tubes.

Each tube is a 24 in. O.D., 20 ft. 6 1/2 in. long seamless vessel. The maximum allowable working pressure is 2,450 psig and the test pressure is 3,675 psig. The hydrogen gas capacity of eight tubes together at 2,300 psig is 55,488 standard cu. ft. The design and materials data for bulk gas storage tubes is listed in Table 9.3-21.

2) Pressure Control Unit

The pressure control unit is an automatic pressure-reducing manifold mounted in a shop-fabricated control cabinet complete with accessories designed specifically for this installation. The automatic reducing manifold has two parallel pressure reducing regulators. The discharge pressure range of these regulators is 0 to 250 psig so that pressures can be adjusted if required. The unit is set to operate in the automatic mode by setting the regulators at 150 psig and valving PCV-2 regulator off for use as a standby. Other settings could also be selected or changed at any time. Pressure control switches sound an alarm when the active bank pressure is depleted to 200 psig. A pressure transmitter is provided to send system status information to a monitoring computer.

Additional features of the equipment are as listed below. The piping is all industry-standard brass, thus maintenance is virtually eliminated. The cabinet is provided with a support stand so it is free-standing and may thus be isolated from the storage bank for additional safety. Safety valves are provided and set to 250 psig to protect low pressure downstream piping. Pressure regulators, are designed for manifold-type service and are 2 stage so discharge pressure will be constant with a minimum of physical complexity.

The flow capability of these regulators is in excess of 14,000 scfh. Two gauges are provided on each regulator, with ranges of 0 to 400 psig and 0 to 4,000 psig respectively.

An explosion-proof pressure switch is provided set at 200 psig. The switch is located inside the control cabinet. Sufficient hand valves are provided to insure complete operational flexibility. The cabinet is painted inside and out, and the piping is purged.

3) Excess Flow Manifold

The excess flow manifold is included to safeguard the line against rupture between the hydrogen system and the generator. Because there is a great distance between the hydrogen station and the use point at the generator, the line may be damaged. If line damage should occur, then an unprotected hydrogen system will discharge at the maximum capacity of both regulators to the atmosphere, thus exposing personnel and property to possible fire damage and accumulation of gas which could result in an explosion. The excess flow manifold has an excess flow valve which is designed to close at 1000 scfh hydrogen flow. Should a line rupture occur, the flow would instantly reach 1000 scfh and the valve would close bubble-tight to cut off all hydrogen flow.

For purging initially filling, or other high flow requirements, the full flow bypass valve would be manually opened. Thus, full regulator capacity can be utilized.

If the excess flow valve were to fail, it can be bypassed, valved off, and removed without disturbing the hydrogen flow.

The bypass valve also serves as a device for reopening the excess flow valve, as the excess flow valve will remain closed until the pressure is equalized across it. By opening the bypass after the piping is repaired, the pressure is equalized and the excess flow valve opens for normal flow to the generators. The bypass is then closed.

4) Tube Trailer Discharging Stanchion

A stanchion-type tube trailer discharging stanchion is provided. The stanchion assembly consists of a flexible pigtail, shutoff valve, check valve, bleed valve, overfill regulator and necessary piping. The stanchion is supported by "L" -shaped aluminum "I" beam. Filling apparatus is thus separated from the control cabinet for safety and convenience.

9.3.7.3 Safety Evaluation

Bulk hydrogen storage system is located approximately 350 ft west of the turbine building in gas storage area as shown in Figure 1.2-1. Malfunction or failure of a component of the hydrogen system has no adverse effect on any safety related system or component.

During filling and purging the generator air content is maintained below 30 percent to ensure that an explosive mixture does not exist in the generator housing. During normal operation hydrogen gas purity is indicated and alarmed by the purity indicating transmitter and by the generator blower pressure gage.

9.3.7.4 Tests and Inspection

The hydrogen system is tested functionally under all anticipated operating conditions prior to initial plant startup. This verifies that all system units and controls function properly. The system is also tested during normal plant operation to ensure its operability.

9.3.7.5 Instrumentation Applications

Local pressure indicators located at the equipment are provided for monitoring the system pressure. A pressure switch will actuate low pressure alarm on the main control room annunciator panel.

9.3.8 POST-ACCIDENT SAMPLING SYSTEM

9.3.8.1 Design Basis

The Post-Accident Sampling System (PASS) is designed on the criteria set forth in NUREG-0660 and NUREG-0737, Item II.B.3 which deals with the implementation of capabilities for sampling reactor coolant and containment atmosphere during post-accident conditions.

The containment atmosphere hydrogen analyzer system is described in detail in section 6.2.5. The following is a description of the primary coolant and the safety injection sump sampling system referred to as the RC PASS (Reactor Coolant Post-Accident Sampling System). The RC PASS is capable of the following:

a) Obtaining a representative reactor coolant sample and a SIS sump sample (via the HPSI pump recirculation line to the RWSP).

b) Cooling the high temperature samples to allow for safe handling

c) Continuously sampling the reactor coolant for dissolved oxygen content and pH

d) Indication and recording of the dissolved oxygen concentration and pH of the liquid

e) Capturing a diluted liquid grab sample to analyze for chloride, boron and radioisotopes

f) Capturing an undiluted grab sample to analyze for chloride, boron and radioisotopes

g) Indication; and recording of the hydrogen content in the gas phase

h) Capturing a diluted gas grab sample to analyze for hydrogen, noble gases and gaseous radioisotopes

9.3.8.2 System Description

The RC PASS is shown on Figure 9.3-2 (for Figure 9.3-2, Sheet 3, refer to Drawing G162, Sheet 3).

The RC PASS consists of sample coolers selection and strainer station (Skid No. 1), Liquid Sample Panel (LSP or Skid No. 2), and the Process Control Panel (PCP of Skid No. 4). In addition, there are six auxiliary stations for obtaining diluted, undiluted, and full pressure liquid samples, gas grab samples, and for calibrating pH and dissolved oxygen sensors. The PASS is located in the wing area of the RAB.

Skid No. 1 and 3 are located at El. - 4' O" MSL.

Skids Nos. 2 and 4 are located at El. + 21' O". Skid No. 2 is situated in an accessible shielded room. The auxiliary stations are also located in an accessible shielded room adjacent to the Skid 2 room. Since post-accident radiation levels will be higher than during normal operating conditions, all system valves in direct contact with the reactor coolant are designed for this environment.

The reactor coolant sample or the SIS sump sample enters Skid No. 1 of the post accident sampling system (PASS) at a set flow rate. The sample passes through heat exchanger no. 2, cooled by train A of CCW, where its temperature is reduced prior to collection and analysis. The sample is then strained to remove any undissolved solids.

The sample is then directed to Skid No. 2 which serves the general purpose of directing sample flow past the necessary instrumentation required to analyze the sample. The multiple flow paths that are possible enable the operator to obtain single or simultaneous measurements. Flow paths are chosen and aligned by input signals to each solenoid valve originating from the Process Control Panel. Within Skid No. 2, the operator is capable of determining the pH and dissolved oxygen concentration of the process stream. Additionally, samples can be isolated, heated and then stripped using an inert gas directed to an in-line gas chromatograph for determination of the H_2 gas concentration. Also included in this skid are the utility fluids of demineralized water for flushing and sample dilution, argon stripping gas and instrument air.

If desired, alternate flow paths can be aligned to allow sample to be directed to the various auxiliary stations. The flow path chosen and the existing sampling conditions determines the type of grab sample that will be obtained.

The Process Control Panel (PCP) or Skid No. 4 is located away from the LSP and grab sample station cubicles in the open area adjacent to the Switchgear Room B on the +21'0" elevation. This panel, designed as a console and contains all of the readout devices for the LSP analyzers and instruments. In addition, the console also houses the remote valve switches used to actuate the LSP solenoid valves. With the exception of individual grab samples, all other system operations are performed from the PCP. The remote controls of the PCP permit operators to obtain sample data without being exposed to large volumes of potentially highly radioactive coolant.

9.3.8.3 Safety Evaluation

The RC PASS is designed in compliance with the requirements set forth in NUREG-0660; NUREG-0737, Item II.B.3 and Regulatory Guide 1.97. In-line instruments are available to quantify RCS dissolved oxygen, pH and hydrogen. The capability is provided to obtain and analyze reactor coolant samples in 3-hours or less from the time a decision is made to take a sample.

Grab samples are taken to the onsite lab which is capable of providing, within the 3-hour time frame, quantification of the following:

a) Radionuclides (noble gases, iodines, cesiums, and non-volatiles)

b) RCS boron concentration

c) RCS hydrogen concentration.

Grab sample analysis of RCS chlorides is accomplished within the 4-day time frame.

Design features and capabilities of the PASS that comply with NUREG-0660, and NUREG-0737, Item II.B.3, are listed below:

a) The system is capable of receiving a continuous sample, thus insuring a representative reactor coolant sample of the core area

b) A flow restriction orifice is provided inside the containment to limit reactor coolant losses from a rupture of the sample line

c) Deionized water and argon are provided to purge sample lines and dilute liquid and gas samples

d) The residues of the gas samples are returned to the containment or to the Gaseous Waste Management System.

e) The residues of the liquid samples are directed into the waste tanks or containment sump

f) The existing reactor coolant sampling system does not require an isolated auxiliary system to be placed in operation during post-accident conditions

→(DRN 00-691, R11-A)

g) Samples will be analyzed for dissolved gases (H_2). Additionally, the capability of obtaining a pressurized reactor coolant sample under post-accident conditions is available

←(DRN 00-691, R11-A)

h) The grab sample and the in-line calibration stations are located near Skid No. 2. The undiluted grab sample receiver and Skid No. 2 are shielded. The shielding requirements are based on the NUREG-0737 source terms in the reactor coolant and on the condition of a monthly averaged dose rate of 15 mr/hr at the shield wall

i) The sampling cabinet (Skid No. 2) is located in an enclosure of NEMA 12 classification with a top vent. The vent from Skid No. 2 and the vents from the diluted liquid grab sample ports are connected to the plant HVAC system. Thus, any gaseous effluents from these sources will be filtered through charcoal absorbers and HEPA filters

j) Grab sample chloride analysis will be performed on or off site within 4 days of the sample being taken.

The PASS is not required to assure any of the following conditions:

a) The integrity of the RCPB

b) The capability to shut down the reactor and maintain it in a safe shutdown condition

→(DRN 04-977, R14)

c) The ability to prevent or mitigate the consequence of an accident which could result in potential offsite exposures in excess of 10CFR50.67 guideline exposures.

←(DRN 04-977, R14)

The PASS is isolated from the RCPB and the containment and therefore is NNS and does not meet seismic Category I requirements.

All lines in the PASS are constructed of corrosion-resistant stainless steel. Each portion of the system is designed for source pressure and temperature. Overpressure protection is provided through a pressure relief valve which discharges to the waste tanks.

The system is designed to minimize pipe runs and grab sample sizes thus minimizing radiation exposure and the effects of equipment failure.

All PASS valves located in an inaccessible post-accident area are environmentally qualified.

All electrically powered components associated with post-accident sampling are capable of being supplied with power and operated within thirty minutes of an accident in which there is core degradation, assuming loss of offsite power.

9.3.8.4 Testing and Inspection

Each component will be inspected and cleaned prior to installation. The system will be operated and tested initially with regard to flow paths, flow and thermal capacity, and mechanical operability. Instruments will be calibrated during testing.

Data will be taken during normal plant operation to confirm that the sample heat exchangers and pressure reducing valve in the system are properly set to give the desired conditions for sampling. The PASS will be exercised and parameters tested (as allowed by normal operation) at least once every six months.

9.3.8.5 Instrumentation Application

All necessary instrumentation and control for satisfactory operation of the Reactor Coolant Post-Accident Sampling System is provided and located on the Process Control Panel.

All equipment is arranged in a manner conducive to safety as well as ease of inspection, maintenance, operation and calibration.

I&C Readout on the Process Control Panel is listed below.

Liquid flow	Indicator
pH	Indicator-Recorder
Dissolved 0_2	Indicator-Recorder
H_2 Analyzer	Recorder
Temperature	Indicator
Pressure	Indicator

9.3.9 NITROGEN SYSTEM

9.3.9.1 Design Bases

→(EC-41355, R307)

The nitrogen system is designed to provide a reliable supply of nitrogen for the nitrogen accumulators on pneumatically operated valves and the necessary nitrogen for normal plant operation and maintenance. Nitrogen accumulators are provided as a backup source of compressed gas for various safety-related valves needed to mitigate the consequences of an accident or for the safe shutdown of the plant following an accident. Safety-related valves serviced by nitrogen accumulators are listed in Table 9.3-1b. Safety related Nitrogen accumulators are capable of providing motive air to pneumatically operated valves for 10 hours. Procedures are established for operating manual handwheel overrides or lining up backup air supplies for continued safety function after 10 hours.

←(EC-41355, R307)

9.3.9.2 System Description

The completely automatic storage and supply system is resupplied from a vendor tanker/trailer. The system withdraws liquid nitrogen from the storage vessel, compresses and vaporizes it for storage in high pressure storage tubes. The high pressure nitrogen is then withdrawn and regulated for delivery to the system. The pump controls monitor the storage tubes capacity and automatically refill when required. The pump is in a standby status at all times. The pumping system is protected from overpressure by safety switches and relief devices. Pressure, temperature, and liquid level switches send signals to the pump control panel for start, stop and emergency shutdown.

9.3.9.2.1 Specific Equipment Description

Gaseous Nitrogen Storage Bank

The storage bank is composed of three ASME-coded gas storage tubes. Each tube is a 24" O.D., 22' 6-1/2" long seamless vessel. The maximum allowable working pressure is 2,450 psig and the test pressure is 3,675 psig.

High Pressure Control Manifold

This manifold maintains constant regulated final line pressure adjustable between 0-1,000 psig. The active regulator controls and the reserve regulator is used as a standby in the event the active regulator fails. Pressure transmitters are installed on the inlet side of the manifold for remote monitoring of system pressure.

Tube Trailer Discharging Stanchion

A stanchion-type tube trailer discharging station is provided for service from a tube trailer in the event of a liquid system failure. The stanchion assembly consists of a flexible pigtail, shutoff valve, check valve, a bleed valve and necessary piping. Filling apparatus is thus separated from the modular storage bank assembly for safety and convenience.

→(DRN 99-1082, R11)

High Pressure Nitrogen System Safety Class 2 Relief Valve

Relief Valve NG-1523 is installed to protect the safety related nitrogen accumulators and RCB Penetration No. 14 from over-pressurization should the non-safety related pressure reducing valves NG-147A(B) and the non-safety related pressure relief valves NG-149 and/or NG-1505 fail to function properly. NG-1523 is located at the (+)46.00' elevation of the Reactor Auxiliary Building Wing Area, adjacent to nitrogen accumulators V and VI. An exception is taken to ASME Code Subsection NC-7153 in that a locked open isolation valve (NG-1522) is located upstream of relief valve NG-1523. FSAR Section 6.3.2.5.4 reflects that relief valve failures are not considered credible failures and ANSI N658-1976 specifically exempts active failure of code safety relief valves so single failure is not applicable.

←(DRN 99-1082, R11)

→(EC-41095, R307)

Backup Air Supply to Accumulators 1 and 2

Backup Air bottles are provided that may be manually aligned to re-pressurize the Nitrogen Accumulators 1 & 2 following a design basis event concurrent with a loss of Instrument Air. This feature enables control room operators to realign Essential Chiller cooling water valves from the Wet Cooling Towers to the Dry Cooling Towers to preserve Wet Cooling Tower basin water inventory.

←(EC-41095, R307)

9.3.9.3 Safety Evaluation

A complete loss of the nitrogen supply system during full power operation does not reduce the ability of the reactor protective system or the engineered safety features and their supporting systems to safely shutdown the reactor or to mitigate the consequences of an accident.

The nitrogen supply system exclusive of the nitrogen accumulators is a non-safety-related system, serves no safety function and is not designed to seismic requirements. The portion of the nitrogen piping and valves penetrating the containment is designed to Safety Class 2 and seismic Category I requirements (refer to Subsection 6.2.4). The containment nitrogen header outer isolation valve is designed to fail closed.

→(EC-41355, R307)

The nitrogen accumulators provide a backup source of compressed gas to operate pneumatic safety-related valves in the event of a loss of instrument air. Table 9.3-lb lists all safety-related valves provided with backup nitrogen accumulators. The accumulators are designed to Safety Class 3 and seismic Category I requirements. They are sized to permit sufficient stroking of all specified valves in the course

←(EC-41355, R307)

→(EC-41355, R307)

of performing their safety-related functions. Upon a loss of instrument air, a low pressure signal will open the respective nitrogen supply valves. Nitrogen that is stored in the accumulators will then charge the valve operators' supply lines permitting continued valve operation. Safety related nitrogen accumulators are capable of providing motive air to pneumatically operated valves for 10 hours. Procedures are established for operating manual handwheel overrides or lining up backup air supplies for continued safety function after 10 hours.

←(EC-41355, R307)

9.3.9.4 Tests and Inspection

The nitrogen system is tested functionally prior to initial plant startup. These tests verify that all system units and controls function properly. The system is also tested during normal plant operation to ensure its operability.

9.3.9.5 Instrumentation Applications

Local pressure indicators located at the equipment are provided for monitoring the system pressure. Pressure switches will actuate a low pressure alarm on the main control room annunciator panel.

SECTION 9.3 REFERENCES

1 - Williams, W. L.,. Corrosion, 13539t, 1957.

2 - Proceedings of Conference: Fundamental Aspects of Stress Corrosion Cracking, 1967.

3 - Ward, C. T., Mathis, D. L., and Stachle, R. W., "Intergranular Attack of Sensitized Austenitic Stainless Steels by Water Containing Fluoride Ions", Corrosion, NACE, Vol. 25, No. 9, September 1969.

4 - Miller, D. A. and Bryant, P.E.C., Corrosion and Coolant Chemistry Interactions in Pressurized Water Reactors, National Association of Corrosion Engineers Conference, March 1970.

5 - CEN-259, "An Evaluation of the Natural Circulation Cooldown Test Performed at the San Onofre Nuclear Generating Station", January 1984.

→(LBDCR 15-028, R308A)

6 - NRC Safety Evaluation for Natural Circulation Cooldown, April 8, 1988.

←(LBDCR 15-028, R308A)

SAFETY CLASS VALVES WITH AIR ACCUMULATORS

Valve Tag	Figure	Valve Tag	Figure
		CC MVAAA710 (2CC-F243A/B)	9.2-1 *
		CC MVAAA641 (2CC-F146A/B)	9.2-1 *
CC MVAAA135A (3CC-B201A)	9.2-1 *	CC MVAAA713 (2CC-F147A/B)	9.2-1 *
CC MVAAA135B (3CC-B203B)	9.2-1 *	CC MVAAA807A (2CC-F154A1)	9.2-1 *
CC MVAAA134B (3CC-B262B)	9.2-1 *	CC MVAAA808A (2CC-F155A2)	9.2-1 *
CC MVAAA134A (3CC-B265A)	9.2-1 *	CC MVAAA808B (2CC-F156B1)	9.2-1 *
CVRMVAAA201 (2HV-B156A)	9.2-1 *	CC MVAAA807B (2CC-F157B2)	9.2-1 *
CVRMVAAA101 (2HV-B157B)	9.2-1 *	CC MVAAA823A (2CC-F158A1)	9.2-1 *
CS MVAAA125A (2CS-F305A)	Dwg. G163	CC MVAAA822A (2CC-F159A2)	9.2-1 *
CS MVAAA125B (2CS-F306B)	6.3-35	CC MVAAA822B (2CC-F160B1)	9.2-1 *
→(EC-935, R302)			
SI MVAAA405A (1SI-V1503A)	6.3-1 **	CC MVAAA823B (2CC-F161B2)	9.2-1 *
SI MVAAA405B (1SI-V1501B)	6.3-1 **	CC MVAAA963A (3CC-F130A)	9.2-1 *
←(EC-935, R302)			
		CC MVAAA636 (3CC-TM169A/B)	9.2-1 *
		CC MVAAA620 (3CC-FM138A/B)	9.2-1 *

- For Figure 9.2-1, Sheet 4, refer to Drawing G160, Sheet 4 and for Figure 9.2-1, Sheet 6, refer to Drawing G160, Sheet 6

→(EC-935, R302)

** For Figure 6.3-1, Sheet 2, refer to Drawing G167, Sheet 2.

←(EC-935, R302)

TABLE 9.3-1b Revision 10 (10/99)

SAFETY CLASS VALVES WITH NITROGEN ACCUMULATORS

→

Valve Tag	Figure	Valve Tag	Figure
ACCMVAAA126A (3CC-TM290A	9.2-1 *	CC MVAAA301A (3CC-F272A)	9.2-1 *
ACCMVAAA126B (3CC-TM291B)	9.2-1 *	CC MVAAA301B (3CC-F273B	9.2-1 *
CC MVAAA114A (3CC-F113A/B)	9.2-1 *	CC MVAAA322A (3CC-F274A)	9.2-1 *
CC MVAAA115A (3CC-F114A/B)	9.2-1 *	CC MVAAA322B (3CC-F275B)	9.2-1 *
CC MVAAA115B (3CC-F115A/B)	9.2-1 *	EFWMVAAA224B (2FW-V853A)	10.4-2 **
CC MVAAA114B (3CC-F116A/B)	9.2-1 *	EFWMVAAA228B (2FW-V850B)	10.4-2 **
CC MVAAA126B (3CC-F112A/B)	9.2-1 *	EFWMVAAA223B (2FW-V854B)	10.4-2 **
CC MVAAA126A (3CC-F109A/B	9.2-1 *	EFWMVAAA229B (2FW-V849A	10.4-2 **
CC MVAAA127A (3CC-F110A/B)	9.2-1 *	EFWMVAAA229A (2FW-V84F7B)	10.4-2 **
CC MVAAA127B (3CC-F111A/B)	9.2-1 *	EFWMVAAA228A (2FW-V848A)	10.4-2 **
ACCMVAAA112A (3CC-F276A)	9.2-1 *	EFWMVAAA224A (2FW-V851B)	10.4-2 **
ACCMVAAA112B (3CC-F277B)	9.2-1 *	EFWMVAAA223A (2FW-V852A)	10.4-2 **
ACCMVAAA139A (3CC-F278A)	9.2-1 *	CC MVAAA727 (3CC-F120A)	9.2-1 *
ACCMVAAA139B (3CC-F279B)	9.2-1 *	CC MVAAA563 (3CC-F121B)	9.2-1 *
MS MVAAA116A (MS-PM629A)	10.2-4	CC MVAAA200A (3CC-F122A)	9.2-1 *
MS MVAAA116B (2MS-PM630B)	10.2-4	CC MVAAA200B (3CC-F123B)	9.2-1 *
		SI MVAAA106A (2SI-L103A	6.3-1 (for Fig. 6.3-1 Sht 1, refer to Dwg. G167, Sht. 1)
		SI MVAAA106B (2SI-L104B)	6.3-1 (for Fig. 6.3-1, Sht 1, refer to Dwg. G167, Sht. 1)

• For Figure 9.2-1, Sheet 4, refer to Drawing G160, Sheet 4 and for Figure 9.2-1, Sheet 6, refer to Drawing G160, Sheet 6.

** For Figure 10.4-2, Sheet 1, refer to Drawing G153, Sheet 1.

←

DESIGN DATA FOR COMPRESSED AIR SYSTEM COMPONENTS

Service and Instrument Air Compressors	
Type	Horizontal, nonlubricated, rotary, single stage
Quantity	5 (2-Instrument air, 3-service air)
Capacity, SCFM	280
Operating Pressure, psig	112-120
Design Pressure, psig	130
Speed, rpm	1770
→ (DRN 99-0674)	
Brake Horsepower, hp	130 @ 120 psig
← (DRN 99-0674)	
Materials of Construction	
Casing	Bronze
Head	Cast Iron
Rotor	Bronze
Shaft	Steel
Driver	
Type	Electric Motor
Rating/Speed	150 hp/1800 rpm
Voltage/Phase/Frequency	460 V/3 ϕ/60 Hz
Service Factor	1.15
Intake Filter Silencer	
Type	Dry Type, Air Maze
Heat Exchanger	
Type	Shell and Tube
Material:	
Shell	Red Brass
Tubes	Admiralty

TABLE 9.3-2 (Sheet 2 of 3) Revision 7 (10/94)

DESIGN DATA FOR COMPRESSED AIR SYSTEM COMPONENTS

Heat Exchanger (Cont'd)	
Tube Sheets	Forged Brass
Air Receiver	
Type	Vertical
Quantity	2 (1-Instrument air, 1-Service air)
Capacity, cu ft	100
Design Pressure, psig	150
Design Temperature, °F	125
Diameter, inches	42
Height, feet	10
Material	Carbon Steel
Prefilter	
Type	Cartridge
Quantity	2
Capacity, SCFM	300
Filtration	99.97% of all particles 0.3 - 0.6 microns or larger
Air Dryer	
Quantity	Two
Type	Heatless
Capacity, SCFM	300
Desiccant	Activated Alumina
Dew Point	-40°F at 100 psig
Drying Chambers, Quantity	2

TABLE 9.3-2 (Sheet 3 of 3)

DESIGN DATA FOR COMPRESSED AIR SYSTEM COMPONENTS

Afterfilter

Quantity	Two
Type	Cartridge
Capacity, SCFM	600
Filtration	99.985% removal of all particles 0.3 microns or larger

TABLE 9.3-3 Revision 15 (03/07)

PRIMARY SAMPLE POINTS

Points	Source	Analytical Components	Pressure Design (psig)	Pressure Operating (psig)	Temperature Design F	Temperature Operating F	Sample Coolers
P1	Primary Coolant	Grab Sample, Sample Vessel	2485	2350	650	616	2
P2	Pressurizer Surge Line	Grab Sample	2485	2350	700	653	1
P3	Pressurizer Steam Space	Grab Sample, Sample Vessel	2485	2350	700	653	2
P4A & P4B	Shutdown Cooling Suction Line	Grab Sample	440	415	400	350	1
P5A & P5B	High Pressure Safety Injection Pump Mini Flow Line	Grab Sample	1950	1800	400	350	1
P6	Purification Filter Inlet	Dissolved Hydrogen Analyzer, Grab Sample, Sample Vessel	200	100	250	120	1
P7	Purification Filter Outlet - Ion Exchanger Inlet	Grab Sample, Sample Vessel	200	100	250	120	1
P8	Ion Exchanger Outlet	Grab Sample	200	100	250	120	1
→(DRN 06-901, R15) P9 ←(DRN 06-901, R15)	Volume Control Tank	Sample Vessel	75	50	250	120	1
P10	Primary Water Storage Tank	Grab Sample	150	104	125	92	1

SECONDARY SAMPLE POINTS

Sample Points	Source	Analytical Components	Pressure Design (psig)	Pressure Operating (psig)	Temperature Design F	Temperature Operating F	Sample Coolers	Chiller Bath Cooling Coils
→(DRN 05-251, R14; EC-8465, R307)								
S1	Main Steam No. 1	Grab Sample,Silica, Cation Conductivity, (Sodium, S2)	1085	945	555	540	1	1
S2	Main Steam No. 2	Grab Sample,Silica, Cation Conductivity, (Sodium, S1)	1085	945	555	540	1	1
←(EC-8465, R307)								
S3A	Condenser Hotwell 1A	Grab Sample, Cation Conductivity, (Sodium, S6)	Atmos.	2.26” Hg	125	105		1
S3B	Condenser Hotwell 2A	Grab Sample, Cation Conductivity, (Sodium, S6)	Atmos.	2.26” Hg	125	105		1
S4A	Condenser Hotwell 1B	Grab Sample, Cation Conductivity, (Sodium, S6)	Atmos.	2.26” Hg	125	105		1
S4B	Condenser Hotwell 2B	Grab Sample, Cation Conductivity, (Sodium, S6)	Atmos.	2.26” Hg	125	105		1
S5A	Condenser Hotwell 1C	Grab Sample, Cation Conductivity, (Sodium, S6)	Atmos.	2.26” Hg	125	105		1
S5B	Condenser Hotwell 2C	Grab Sample, Cation Conductivity, (Sodium, S6)	Atmos.	2.26” Hg	125	105		1
→(EC-8465, R307)								
S6	Condensate Pump Discharge	Grab Sample,Silica, Cation Conductivity, pH, Hydrazine, DO (Sodium, 3A & B, 4A & B, 5A & B)	610	482	150	106		1
→(DRN 06-843, R15)								
S7	Combined Heater Drain Pump Discharge	Grab Sample	642	634	388	363	1	
←(DRN 05-251, R14; 06-843, R15; EC-8465, R307)								

TABLE 9.3-4 (Sheet 2 of 3) Revision 307 (07/13)

Sample Points	Source	Analytical Components	Pressure Design (psig)	Pressure Operating (psig)	Temperature Design F	Temperature Operating F	Sample Coolers	Chiller Bath Cooling Coils
→(DRN 05-251, R14; 06-843, R15; EC-8465, R307)								
S7A	Drain Collector Train 1A	Grab Sample	1085	804	550	521	1	
S7B	Drain COllector Tank 2A	Grab Sample	1085	804	550	521	**	
S7C	Drain Collector Tank 1B	Grab Sample	1085	804	550	521	**	
S7D	Drain Collector Tank 2B	Grab Sample	1085	804	550	521	**	
←(DRN 06-843, R15; EC-8465, R307)								
S8	Combined Heater Outlet	Grab Sample,Silica, Specific Conductivity Cation Conductivity pH, DO, Sodium, (Hydrazine, S8E)	1400	1080	480	449	1	1
→(DRN 06-843, R15; EC-8465, R307)								
S8A	Moisture Separator Drain Tank 1A	Grab Sample	265	179	411	379	1	
S8B	Moisture Separator Drain Tank 2A	Grab Sample	265	179	411	379	***	
S8C	Moisture Separator Drain Tank 1B	Grab Sample	265	179	411	379	***	
S8D	Moisture Separator Drain Tank 2B	Grab Sample	265	179	411	379	***	
←(DRN 06-843, R15)								
S8E	Feedwater Pumps Suction	Grab Sample (Hydrazine, S8)	610	482	388	370	1	1
←(EC-8465, R307)								
S9A	Makeup Demineralizer Effluent	Grab Sample (Sodium, Silica, Spec. Conductivity, S9B)	125	90	125	92	-	1
→(DRN 06-843, R15)								
S9B	Condensate Transfer Pump Discharge	Grab Sample (Sodium, Silica, Spec. Conductivity, S9A)	150	90	120	109	-	****
←(DRN 05-251, R14; 06-843, R15)								

TABLE 9.3-4 (Sheet 3 of 3) Revision 307 (07/13)

Sample Bath Points	Source	Analytical Components	Pressure Design (psig)	Pressure Operating (psig)	Temperature Design F	Temperature Operating F	Sample Coolers	Chiller Cooling Coils
→(DRN 05-251, R14; EC-8465, R307)								
S21 A&B	Steam Generator Blowdown 1	Grab Sample Radiation*, pH, Silica, Sodium, (S22) Specific, Cation Conductivity	1085	945	555	540	1	1
S22 A&B	Steam Generator Blowdown 2	Grab Sample Radiation*, pH Silica, Sodium, (S21) Specific Cation Conductivity	1085	945	555	540	1	1
←(EC-8465, R307)								
S23	Steam Generator Blowdown Demineralizer Effluent	Grab Sample Silica, Sodium, Cation Conductivity	175	150	150	120	1	1
→(DRN 01-775, R12-A)								
	Steam Generator Blowdown Discharge to CWS & Low Volume Wastewater Basin	Local Grab Sample & Composite Sampler (Proportional)	175	150	150	120	-	-
←(DRN 01-775, R12-A)								
S24	Feedwater upstream of the Steam Generators	0.45 micron Millipore filter	1400	1080	480	449	1	-
→(EC-8465, R307)								
S25	Main Steam common header in TGB	0.45 micron Millipore filter	1085	945	555	540	1	-
S26	Steam Generator no. 2 Blowdown	0.45 Micron Millipore filter	1085	945	555	540	1	-
←(DRN 05-251, R14; EC-8465, R307)								

*Common system for SP No. S21 and S22, one radiation monitor supplied by CE.

→(DRN 06-843, R15)
** Share line with S7A
*** Share line with S8A
**** Share line with S9A
←(DRN 06-843, R15)

TABLE 9.3-5

SUB-SYSTEM CONSTRUCTION MATERIALS

Radioactive Drainage Systems

Systems	Pipe & Fittings	Type of Joint
Floor Drain System	Stainless Steel - sch. 40	Buttweld
Equipment Drain System	Stainless Steel - sch. 40	Buttweld
Detergent Waste System	Stainless Steel - sch. 40	Buttweld
Chemical Waste System	Stainless Steel - sch. 40	Buttweld

Non-Radioactive Drainage Systems

Store Water Drainage System	Cast-iron/galvanized st.	Gasket/mechanical joint
Acid Waste & Vent System	High silicon cast iron	Mechanical joint
Acid & Caustic Waste System	PPL lined carbon steel	Flanged
Oil Drainage Systems	Cast-iron/galvanized st.	Gasket/screwed
Industrial Waste System	Yoloy galvanized steel	Screwed
Sprinkler Discharge Drainage System	Galvanized steel	Mechanical joint

TABLE 9.3-6

DECONTAMINATION AREAS

Area	Elevation	Equipment
a) Central Decon Facility	+21.00 ft. MSL	Ultrasonic & rinse tanks Work bench sink Spray was booth Turbulator Parts laydown areas Floor drains
b) Health Physics Personnel Decon Area	-4.00 ft. MSL	Hot showers Hot lavatories Floor drains
c) Laundry Room	-4.00 ft. MSL	Washing machines Service sink Floor drains
d) Radio-chem Lab	-4.00 ft. MSL	Dishwasher

TABLE 9.3-7 Revision 305 (11/11)

REACTOR COOLANT AND REACTOR MAKEUP WATER CHEMISTRY

1. MAKEUP WATER

Analysis	Normal
Chloride (C1)	<0.15 ppm
Conductivity	<2.0 μmhos/cm[3]
pH	6.0 - 8.0 (1)
Fluoride (F)	<0.10 ppm

2. PRIMARY WATER

Analysis	Hot Functionals (3)	Cycle One Initial Criticality	Power Operation (8)
pH (77 F)	9.0 - 10.4	4.5 - 10.2	4.5 - 10.2
Conductivity	(4)	(4)	(4)
Hydrazine	30 - 50 ppm	1.5 Oxygen ppm	1.5 x Oxygen ppm (max. 20 ppm)
Ammonia	<50 ppm	<50 ppm	<0.5 ppm
Dissolved Gas	<10 cc (STP)/kg H_20	-	(7)
→(DRN 06-1142, R15)			
Lithium	1 - 2 ppm	1.0 - 2.0 ppm	0.2- 3.5 ppm
←(DRN 06-1142, R15)			
Hydrogen	-	25 - 50 cc (STP)H_2/ Kg (H_20)(6)	25 - 50 cc (STP)H_2/ Kg (H_2O)
Oxygen	<0.1 ppm	<0.1 ppm	<0.1 ppm
Suspended Solids	<0.5 ppm, (2 ppm max.)	<0.5 ppm, (2 ppm max.)	0.5 ppm, (2 ppm max.)
Chloride	<0.15 ppm	<0.15 ppm	< 0.15 ppm
Fluoride	<0.1 ppm	<0.1 ppm	< 0.1 ppm
Boron	--	1720-2300 ppm	2050-2900 ppm (5)
→(EC-4019, R305)			
Zinc Acetate Dihydrate	--	--	≤ 40 ppb (Max Target) ≤ 80 ppb (Plant Transient)
←(EC-4019, R305)			

Notes:

(1) May be as low as 5.8 if proven due to CO_2 absorption.

(2) Deleted

(3) Special hot conditioning limits:

Temperature: <350°F
Time: 7-10 days

(4) Consistent with concentration of additives.

(5) As needed for reactivity control

(6) Not applicable during core load.

(7) Prior to shutdown and depressurization, reduce hydrogen concentration to <5 cc/Kg (H_2O) to limit the possibility of explosive mixtures.

(8) These limits are minimum requirements. Plant specific procedures may impose more restrictive limits than specified in this Table.

TABLE 9.3-8

CVCS DESIGN TRANSIENTS

The components and piping in the CVCS are designed to accommodate, without adverse effect, the flow and thermal transient responses which result from the following plant evolutions:

1. Plant Startup - It is assumed that the plant is started 500 times during the 40 year design life of the plant.

2. Ramp Power Change (15 Percent to 100 Percent at 5 Percent/Min.) - It is assumed that a ramp change in power from 15 to 100 percent at the rate of 5 percent/minute with a step increase of 10 percent occurs 17,000 times during the life of the plant.

3. Ramp Power Change (100 percent to 15 Percent at -5 Percent/Min.) - It is assumed that a ramp change in power from 100 percent to 15 percent at the rate of -5 percent/minute with a step decrease of 10 percent occurs 17,000 times during the life of the plant.

4. Reactor Trip - It is assumed that the reactor is tripped from 100 percent power 500 times during the 40 year design life of the plant.

5. Maximum Purification - It is assumed that the CVCS is switched from the normal purification mode to the maximum purification mode 11,000 times during the life of the plant.

6. Loss of Charging - It is assumed that the charging flow is stopped 100 times during the life of the plant.

7. Loss of Letdown - It is assumed that the letdown flow is stopped 100 times during the life of the plant.

8. Plant Cooldown - It is assumed that the plant is cooled down 500 times during the 40 year design life of the plant.

TABLE 9.3-9 (Sheet 1 of 7) Revision 15 (03/07)

PRINCIPAL COMPONENT DESIGN DATA SUMMARY

	Design Parameters		Operating Parameters				
Component	Parameter	Description	Parameter	Normal	Min Letdown/ Max Charging	Max Letdown/ Max Charging	Max Letdown/ Min Charging
Regenerative heat exchanger	Quantity	1	Tube side, letdown				
	Type	Shell and tube, vertical					
	Code	ASME Section III, Class 2(1971)	Flow (gpm @ 120 °F)	38	30	126	126
	Tube side, letdown		Inlet temp. °F	550	550	550	550
	Fluid	Reactor Coolant	Outlet temp. °F	254	152	362	439
	Design pressure, psig	2,485	Shell side, Charging				
	Design temperature, °F	650					
	Materials	Austenitic stainless steel (seamless tubes)	Flow gpm @ 120°F	44	132	132	44
	Pressure lost at 128 gpm, psi	25	Inlet temp °F	120	120	120	120
→(DRN 06-843, R15)	Normal flow gpm	38	Outlet temp °F	393	223	320	476
←(DRN 06-843, R15)							
	Design flow gpm	128					
	Shell side, charging						
	Fluid	Reactor coolant, boric acid ≤ 12 wt%					
	Design pressure, psig	3,025					
	Design temperature, °F	650					
	Materials	Austenitic stainless steel					
	Pressure loss at 132 gpm, psi	24.6					
	Normal flow, gpm	44					
	Design flow, gpm	132					
Letdown heat Exchanger	Quantity	1	Tube side, letdown				
	Type	Shell and tube horizontal	Flow, gpm @ 120°F	38	30	126	126
	Tube side, letdown	ASME Section III,	Inlet temp. °F	254	152	362	439
	Code	Class2(1971)	Outlet temp. °F	120	120	120	130
	Fluid	Reactor coolant	Shell side, cooling water				
	Design pressure, psig	650					
	Design temperature, °F	550					
	Pressure loss at 128 gpm psi	42.1	Flow, gpm @ 120°F	176.6	34.6	1197.6	1176.4
→(DRN 06-843, R15)	Normal flow, gpm	38	Inlet temp °F	100	100	100	100
←(DRN 06-843, R15)							
	Design, gpm	128	Outlet temp. °F	141.2	128.6	130	144.3
	Materials	Austenitic stainless steel (seamless tubes)					

TABLE 9.3-9 (Sheet 2 of 7) Revision 304 (06/10)

Design Parameters

Component	Parameter	Description
Letdown heat exchanger (Cont'd)	Shell side, cooling water	
	Code	ASME Section III, Class 3 (1971)
	Fluid	Inhibited water
	Design pressure, psig	150
	Design temperature, °F	250
	Materials	Carbon steel
	Normal flow, gpm	176.6
	Design flow, gpm	1,200
	Pressure loss at 1197.6 gpm, psi	15
Purification filter	Quantity	1
	Type	Resin bonded glass fiber and polyster
→(DRN 99-0971; EC-13560, R304)		
	Design temperature, °F	250
	Design pressure, psig	200
	Design flow, gpm	250
	Normal temperature, °F	120
	Normal pressure, psig	60-110
	Normal flow, gpm	37
	Clean ΔP at 250 gpm, psi	10
	Loaded ΔP at 250 gpm, psi	25
	Removal Rating Absolute (Beta Method)	≤20 microns
	Fluid	Reactor coolant
	Code	ASME III, Class C (1968/Summer 1970)
←(EC-13560, R304)		
	Shell materials, wetted	Austenitic stainless steel
Purification ion exchangers	Quantity	3
	Type	Flushable
	Design pressure, psig	200
	Design temperature, °F	250
	Normal operating temperature, °F	120
	Normal operating pressure, psig	40-75
	Resin volume, total, ft^3 each	36.2
	Resin volume, useful, ft^3 each	32.0
	Normal flow, gpm	38
	Design flow, gpm	128
	Code for vessel	ASME III, Class 2 (1968/Summer 1970)
←(DRN 99-0971)		

TABLE 9.3-9 (Sheet 3 of 7) Revision 11 (05/01)

Design Parameters

Component	Parameter	Description
	Maximum ΔP at 128 gpm psi	5
Purification ion exchangers (Cont'd)	Retention screen size	80 U.S. mesh
	Material	Austenitic stainless steel
	Fluid	Reactor coolant
	Resin type	Cation/anion mixed bed for purification, anion bed for deborating
→ (DRN 99-0971)		
Volume control tank	Quantity	1
	Type	Vertical, cylin drical
	Internal volume, gal	4,780
	Design pressure, internal, psig	75
	Design pressure, external, psig	15
	Design temperature, °F	250
	Normal operating pressure, psig	25-50
	Normal operating temperature, °F	120
	Normal spray flow, gpm	38
	Blanket gas, during plant operation	Hydrogen
	Fluid	Reactor coolant, boric acid, <12 w/o
	Material	ASME SA-240, Type 304
	Code	ASME III, Class C (1968/Summer 1970)
Charging pumps	Quantity	3
	Type	Horizontal, positive Displacement, triplex
	Design pressure, psig	2,735
	Design temperature, °F	250
	Capacity per pump, gpm	44
	Normal discharge pressure, psig	2,350
	Normal suction pressure, psig	40-65
	Normal temperature of pumped fluid, °F	120
	NPSH available, psia	6.5
	Pump rating (hp)	100
← (DRN 99-0971)		

TABLE 9.3-9 (Sheet 4 of 7) Revision 11 (05/01)

Design Parameters

Component	Parameter	Description
Charging pumps (Cont'd)	Materials in contract with with pumped fluid	Austenitic and/or 17-4PH, Condition H 1100 stainless steel
	Fluid	Reactor coolant, boric acid ≤12 w/o
	Code	ASME III, Class 2 (1968/March 1970)
→ (DRN 99-0971)		
Pulsation Dampeners	Quantity	3 (discharge of pumps only)
	Vessel material	SA-240 SS 304
	Vessel volume, gallons (Nominal)	2.5
	Design pressure, psig	3,125
	Design temperature, °F	250
	Design flowrate, gpm	44
	Maximum operating pressure, psig	2735
	Normal temperature, °F	120
	Bladder material	Ethylene propylene rubber
	Precharge pressure, psig	1,606
	Outlet pressure pulsation, psi	
	Full amplitude	92
	Half amplitude	46
	Code	ASME III, Class 2 (1974/Winter 1976)
← (DRN 99-0971)		

TABLE 9.3-9 (Sheet 5 of 7) Revision 9 (12/97)

Design Parameters

Component	Parameter	Description
Boric acid pumps	Quantity	2
	Type	Centrifugal, horizontal
	Design pressure, psig	150
	Design temperature, °F	250
	Design head, ft	231
	Design flow, gpm	143
→	Normal operating temperature, °F	100° F to 110° F
←	Normal suction pressure psig available	9
	NPSH at the design flow, ft	20
	Motor, hp	25
	Fluid, boric acid maximum, w/o	3.5
	Material in contact with liquid	Austenitic stainless steel
	Code	ASME III, Class 3 (1971/Summer 1972)
Boric acid makeup tanks	Quantity	2
	Type	Vertical, cylindrical
	Volume, ea. gal.	11,800
	Design pressure, internal, psig	15
	Design pressure, external, psig	0
	Design temperature, °F	200
→	Normal operating temperature, °F	100° F to 110° F
←	Number heaters	6*
	Type heater	Electrical strip*
	Heater capacity, KW ea	2.25 KW (2 banks of 3 ea)
	Fluid, boric acid, maximum wt%	3.5
	Material	ASME SA-240, Type 304
	Code	ASME III, Class 3 (1968/Summer 1970)

* Heater operability is only required when technical specifications allow a boric acid makeup tank boron concentration in excess of 3.5 w/o.

TABLE 9.3-9 (Sheet 6 of 7) Revision 15 (03/07)

Design Parameters

Component	Parameter	Description
Boric acid batching tank	Quantity	1
	Type	Vertical, cylindrical
	Internal volume, gal	630
	Design pressure	Atmospheric
	Design temperature, °F	200
	Normal operating temperature, °F	150-155
	Type heater	Electrical immersion
	Number of heaters	3
	Heater capacity, kW ea	15
	Fluid, boric acid, maximum w/o	12
	Material	ASME SA-240, Type 304
	Code	None
	Mixer type	One 1/2 hp portable, single blade propeller mixer; 42 in. long shaft; wetted parts are stainless steel
Chemical addition tank	Quantity	1
	Internal volume, gal	18
	Design and normal operating pressure, psig	150/100
	Design temperature, °F	150
	Normal operating temperature, °F	40-120
	Material	Austenitic stainless steel
	Code	None
Chemical addition metering pump	Quantity	1
	Type	Positive displacement (variable capacity)
→(DRN 06-843, R15)		
	Design pressure, psig	165
←(DRN 06-843, R15)		
	Design temperature, °F	150
	Capacity, gph, max	40
→(DRN 06-843, R15)		
	Normal discharge pressure, psig	15-20
←(DRN 06-843, R15)		
	Normal suction pressure, psig	Atmospheric
	Normal temperature of pumped fluid, °F	40-120
	Pump rating (hp)	1/2
	Materials in contact with pumped fluid	Austenitic stainless steel
	Fluid	N_2H_4, (max 35 wt%) $LiOH-H_2O$ (max 37,167 ppm Li)

TABLE 9.3-9 (Sheet 7 of 7) Revision 12 (10/02)

Design Parameters

Component	Parameter	Description
	Code	None
→(DRN 99-1031)		
Process (Note 1)	Quantity	1
radiation	Detection principle	Gamma-ray scintillation
monitor	Vessel Design pressure, psig	200
←(DRN 99-1031)		
	Internals Design temperature, °F	150
	Normal operating temperature, °F	110
	Normal flowrate, (gpm)	3-5
	Normal operating pressure (psig)	53
	Instrument range (μci/cc)	10^{-4} to 10^{+2} Rb^{88} gamma
	Code	ASME VIII, Div. 1 (1974)
	Fluid	Reactor coolant
→(DRN 99-1031)		
Boronometer (Note 1)	Quantity	1
←(DRN 99-1031)	Vessel design temperature, °F	250
	Internals design temperature, °F	150
	Vessel design pressure, psig	200
	Normal operating temperature, °F	120
	Normal flowrate, gpm	0.5
	Normal operating pressure, psig	60-110
	Instrument range, ppm boron	0-5000
	Accuracy, sample	± 1% ± 5 ppm
	Code for vessel	ASME VIII, Div. 1 (1974/Summer 1976)
	Fluid	Reactor Coolant

→(DRN 99-1031)

Note 1: These devices have been functionally Abandoned-in-place by DC 3432.

←(DRN 99-1031)

Table 9.3-10 has been deleted.

TABLE 9.3-11 Revision 307 (07/13)

CHEMICAL AND VOLUME CONTROL SYSTEM PROCESS PARAMETERS

Item	Value
Normal letdown and purification flow, gpm	38
Maximum letdown and purification flow, gpm	126
Normal charging flow, gpm	44
Maximum charging flow, gpm	132
Reactor coolant pump controlled bleedoff, 4 pumps gpm	6
→(DRN 03-2063, R14) Normal letdown temperature from RCS loop, F ←(DRN 03-2063, R14)	543
Normal charging temperature to RCS loop, F	410
Normal ion exchanger operating temperature, F	120
→(DRN 03-2063, R14) Boric acid makeup tank boron concentration, boric acid, minimum weight % ←(DRN 03-2063, R14)	2.8
→(EC-8458, R307) Refueling water storage pool boron concentration, boric acid, minimum weight % ←(EC-8458, R307)	1.173

→(EC-8458, R307)
←(EC-8458, R307)

TABLE 9.3-12

SCHEDULE OF WASTE GENERATION

Source	Quantity[(a)] (gal/yr at 120 F)
Refueling shutdown and startup (refueling at the end of core life)	106,507
Cold shutdowns and startups (to 5% subcritical)	
At 30% core life	57,651
At 60% core life	80,909
At 90% core life	154,111
Hot critical shutdowns and startups	
At 55% core life	58,200
At 65% core life	72,800
Boron dilution (fuel burnup waste to 30 ppm boron)	252,300
Back-to-back cold shutdowns and startups (to 5% subcritical at 85% core life)	183,857

(a) For a UO_2 core.

→ (DRN 99-0971)

TABLE 9.3-13[c][e] (Sheet 1 of 4) Revision 11 (05/01)

← (DRN 99-0971)

CHEMICAL AND VOLUME CONTROL SYSTEM PROCESS FLOW DATA

CVCS NORMAL PURIFICATION OPERATION (One Charging Pump in Operation)[a]

CVCS Location:	1	1a	2	2a	3	3a	4	4a	5	6	6a	7	7a	7b	7c	7d	8	9	9a
Flow (gpm)	38	38	38	38	38	38	38	38	38	37	37	1	1	1/2	1/2	1	38	38	38
Press (psig)	2215	2206	2203	2197	469	467	462	460	63	63	60	63	63	63	63	31	31	30	30
Temp. (F)	550	550	254	254	254	254	120	120	120	120	120	120	120	120	120	120	120	120	120

CVCS INTERMEDIATE PURIFICATION OPERATION (Two Charging Pumps in Operation)[a]

CVCS Location:	1	1a	2	2a	3	3a	4	4a	5	6	6a	7	7a	7b	7c	7d	8	9	9a
Flow (gpm)	82	82	82	82	82	82	82	82	82	81	81	1	1	1/2	1/2	1	82	82	82
Press (psig)	2215	2176	2164	2141	496	488	468	460	75	75	71	77	77	77	77	45	45	43	43
Temp. (F)	550	550	320	320	320	320	120	120	120	120	120	120	120	120	120	120	120	120	120

CVCS MAXIMUM PURIFICATION OPERATION (Three Charging Pumps in Operation)[a]

CVCS Location:	1	1a	2	2a	3	3a	4	4a	5	6	6a	7	7a	7b	7c	7d	8	9	9a
Flow (gpm)	126	126	126	126	126	126	126	126	126	125	125	1	1	1/2	1/2	1	126	126	126
Press (psig)	2215	2124	2099	2054	536	519	477	460	102	101	96	106	106	106	106	74	73	69	68
Temp. (F)	550	550	362	362	362	362	120	120	120	120	120	120	120	120	120	120	120	120	120

CVCS NORMAL PURIFICATION OPERATION (One Charging Pump in Operation)[a]

CVCS Location:	10	10a	10b	10c	11	12	13	13a	13b	13c	14a,b,c,d	14e	14f	14g	14h
Flow (gpm)	38	38	38	44	44	44	44	44	44	44	1.5	0	6	6	6
Press (psig)	29	28	25	29	40	2322	2304	2301	2291	2291	62	62	39	30	28
Temp. (F)	120	120	120	120	120	120	120	393	550	550	150	150	150	150	150

CVCS INTERMEDIATE PURIFICATION OPERATION (Two Charging Pumps in Operation)[a]

CVCS Location:	10	10a	10b	10c	11	12	13	13a	13b	13c	14a,b,c,d	14e	14f	14g	14h
Flow (gpm)	82	82	82	88	88	88	88	88	88	88	1.5	0	6	6	6
Press (psig)	40	38	25	29	40	2408	2340	2329	2291	2291	62	62	39	30	28
Temp. (F)	120	120	120	120	120	120	120	354	550	550	150	150	150	150	150

CHEMICAL AND VOLUME CONTROL SYSTEM PROCESS FLOW DATA

CVCS MAXIMUM PURIFICATION OPERATION (Three Charging Pumps in Operation)[a]

CVCS Location:	10	10a	10b	10c	11	12	13	13a	13b	13c	14a,b,c,d	14e	14f	14g	14h
Flow (gpm)	126	126	126	132	132	132	132	132	132	132	1.5	0	6	6	6
Press (psig)	63	59	25	29	40	2550	2401	2376	2291	2291	62	62	39	30	28
Temp. (F)	120	120	120	120	120	120	120	320	550	550	150	150	150	150	150

CVCS MAKEUP SYSTEM OPERATION - AUTOMATIC MODE (Blended Boric Acid Concentration - 900 PPM)[b]

CVCS Location:	15	15a	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	30a	31	32	33
→ (DRN 99-0971)																					
Flow (gpm)	143	143	143	9*	9*	0	9*	123*	123*	132	0	0	0	134*	126*	8*	8*	134*	0	0	0
← (DRN 99-0971)																					
Press (psig)	11	9	109	109	108	30	36	100	36	36	30	109	30	109	80	80	17	0	30	30	30
Temp. (F)	160*	160*	160*	160*	160*	160*	160*	104	104	120	120	160*	160*	160*	160*	160*	160*	160*	160*	160*	160*

CVCS MAKEUP SYSTEM OPERATION - AUTOMATIC MODE (Blended Boric Acid Concentration - 900 PPM)[b]

CVCS Location:	15	15a	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	30a	31	32	33
Flow (gpm)	143	143	143	22	22	22	0	0	0	0	0	0	22	121	113	8	8	121	0	0	0
Press (psig)	11	9	109	109	107	31	37	100	15	15	30	109	30	109	80	80	17	0	30	30	30
Temp. (F)	160*	160*	160*	160*	160*	160*	160*	104	104	120	120	160	160	160	160	160	160	160	160	160	160

CVCS MAKEUP SYSTEM OPERATION - DILUTE MODE (Three Charging Pumps Operating)[b]

CVCS Location:	15	15a	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	30a	31	32	33
Flow (gpm)	143	143	0	0	0	0	0	126	126	126	0	0	0	143	136	7	7	136	0	0	0
Press (psig)	11	9	109	109	109	30	36	100	36	36	30	109	30	109	78	78	30	0	30	30	30
Temp. (F)	160*	160*	160*	160*	160*	160*	160*	104	104	170	170	160*	160*	160*	160*	160	160	160	160	160	160

CVCS MAKEUP SYSTEM OPERATION - MANUAL MODE (Blended Boric Acid Concentration - 2150 PPM)[b]

CVCS Location:	15	15a	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	30a	31	32	33
Flow (gpm)	143	143	143	22*	22*	0	22*	110*	110*	132	0	0	0	121*	113*	8*	8*	121*	0	0	0
Press (psig)	11	9	109	109	107	30	36	100	35	35	30	106	30	109	80	80	17	0	30	30	30
Temp. (F)	160*	160*	160*	160*	160*	160*	160*	104	104	120	120	120	160*	160*	160*	160*	160*	160*	160*	160*	160*

CHEMICAL AND VOLUME CONTROL SYSTEM PROCESS FLOW DATA

CVCS MAKEUP SYSTEM OPERATION - EMERGENCY BORATION (SIAS) (Via Boric Acid Makeup Pumps - One Pump is Operating; Three Charging Pumps Operating)(b)(d)

CVCS Location:	15	15a	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	30a	31	32	33
Flow (gpm)	142	142	142	132	0	0	0	0	0	0	0	132	132	10	0	10	10	10	0	0	0
Press (psig)	11	9	110	110	110	108	15	100	15	15	30	108	109	110	110	110	0	0	30	30	30
Temp. (F)	160*	160*	160*	160*	160*	160*	160*	104	104	160*	120	160*	160*	160*	160*	160*	160*	160*	160*	160*	160*

CVCS MAKEUP SYSTEM OPERATION - EMERGENCY BORATION (SIAS) (Via Gravity Feed)(b)

CVCS Location:	15	15a	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	30a	31	32	33
Flow (gpm)	66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	66	66	132
Press (psig)	11	11	11	11	11	6	15	100	15	15	6	11	6	11	0	0	0	0	11	11	6
Temp. (F)	160*	160*	160*	160*	160*	160*	160*	104	104	160*	120	160*	160*	160*	160*	160*	160*	160*	160*	160*	160*

CVCS MAKEUP SYSTEM OPERATION - SHUTDOWN BORATION(b)

CVCS Location:	15	15a	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	30a	31	32	33
Flow (gpm)	143	143	143	22	22	0	22	22	22	44	0	0	0	121	113	8	8	121	0	0	0
Press (psig)	11	9	109	109	107	30	31	100	31	31	30	109	30	109	80	80	17	0	30	30	30
Temp. (F)	160*	160*	160*	160*	160*	160*	160*	104	104	160*	120	160*	160*	160*	160*	160*	160*	160*	160*	160*	160*

CVCS Makeup System Operation - Boric Acid Batching

CVCS Location:	34	35	36	37	38
Flow (gpm)	50	50	70	70	70
Pressure (psig)	92	0	0	0	0
Temperature (F)	104	104	150	150	150

→(EC-4019, R305)
CVCS Makeup System Operation - Chemical Addition / Zinc Injection
←(EC-4019, R305)

CVCS Location:	39	40	41	42	43	44	45
Flow (gpm)	1	1	1	1	1	1	1
Pressure (psig)	100	30	30	30	30	30	30
Temperature (F)	104	104	104	104	104	104	104

CHEMICAL AND VOLUME CONTROL SYSTEM PROCESS FLOW DATA

Notes:

a. The pressure drop across the purification filter, ion exchanger and letdown strainer varies with loading. The pressure drops as shown are given with minimal crud deposition. The pressure in the volume control tank varies and affects the pressures at locations 3 and 14a through 14g, 20, 22 and 23 proportionally.

b. The data shown for the various modes of operation is typical. The pressure in the isolated piping of the CVCS makeup system will normally be 0 psig but may be as high as 200 psig before the relief valve lifts.

c. Since line pressure drops are dependent on piping and equipment elevations and assumed pipe lengths were used for calculation purposes, the pressure values are approximate.

d. Value shown for three pump operation. Following SIAS, two or three pumps may be operating.

→ (DRN 99-0971, R11; 03-275, R12-B)

e. Deleted.

←(DRN 03-275, R12-B)

* Temperature values and flow values will change depending on the actual Boric Acid Makeup Tank concentration. With a concentration < 3.5 weight % Boric Acid, the tank will be maintained at 100 degrees Fahrenheit.

← (DRN 99-0971, R11)

TABLE 9.3-14 Revision 9 (12/97)

CVCS COMPONENT DIESEL LOADING

Please refer to FSAR Table 8.3-1.

TABLE 9.3-15 (Sheet 1 of 60) Revision 12 (10/02)

CHEMICAL AND VOLUME CONTROL SYSTEM (BORON ADDITION PORTION)

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
→(DRN 99-1031)							
1.	Demineralized water supply to valve 7CH-V624 (CH-119) PMU-134	a. Fails in closed position	Mechanical failure	Unable to add makeup water to boric acid batching tank to makeup a batch of boric acid solution.	Operator	None Required	
		b. Fails partially open	Seat leakage, contamination	Possible makeup water leakage into tank when makeup water pumps are operating.	(water in tank)	Operator	None Required
2.	Boric acid batching mixer BAM-EMTR-64AB-9	a. Fails to start or mix	Motor failure, broken agitator	Unable to mix boric acid solution properly. Possible stratification in solution. Possible boron precipitation in lines connecting batch tank to B/A make-up tanks.	Operator	Batch can be mixed using paddle if necessary	SUfficient reserve in BAMT until fault is corrected.
3.	Boric acid batching tank local sample valve, 7CH-V610-8 (CH-120) BAM-102	a. Fails closed (unable to open)	Mechanical failure	Unable to obtain a local sample when making up a batch of boric acid solution.	Operator detection	None	Boric acid batching tank is generally empty, except during boric acid solution batching.
←(DRN 99-1031)							
		b. Fails partially open	Seat leakage, contamination	Local boric acid solution spill when making up a batch of boric acid solution.	Operator	None	Sufficient reserve in BAMT
4.	Boric acid batching tank immersion heater, H-213	a. Fails off	Electrical failure, open circuit.	Unable to heat boric acid solution. Possible precipitation of boric acid in the batching tank when making up a batch of boric acid solution.	Temperature indicator-controller, TIC-213.	None	Sufficient reserve in BAMT until fault is corrected.
		b. Fails full on	Electrical failure- short circuit	Boric acid solution overheated while making up the batch. Possible heater damage	Temperature indicator controller, TIC-213	Manual power breaker	Same as 4 a.

TABLE 9.3-15 (Sheet 2 of 60) Revision 12 (10/02)

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
5.	Temperature indicator-controller, TIC-213	a. Erroneous high temperature indication or controls temp. low	Electrical or mechanical failures	The heater would be continuously off resulting in underheating of the boric acid solution and possible boric acid precipitation.	Operator	None	Operator should be able to keep the boric acid in solution by mixing. Then the batch can be drained, the controller repaired and a new batch made up.
→(DRN 99-1031)							
		b. Erroneous low temperature indications or controls temp. high.	Electrical or mechanical failure	The heater would be continuously on resulting in the boric acid solution being overheated.	None while solution	Hand switch to turn off heater in batching tank if detected.	
6.	Boric acid batching tank drain valve, 7CH-V610-9 (CH-121) BAM-101	a. Fails in closed position	Mechanical failure	Uable to drain and flush boric acid batching tank after making up a batch of boric acid solution.	Operator	None required	Same as 4 a.
		b. Fails partly open	Seat leak, contamination	Leakage from batching tank to the waste management system.	Visual, decrease in batch tank level.	None	
7.	Boric acid batching tank outlet valve 7CH-V616-1 (CH-122) BAM-103	a. Fails in closed position	Mechanical failure	Unable to add boric acid solution to boric acid makeup tanks.	Operator	None	Same as 4 a.
		b. Fails partly open	Seat Leakage contamination	Loss of boric acid solution (possibly of low concentration) to the discharge header while making up a batch of concentrated boric solution.	Operator	Series normally closed valve downstream of 7CH-V616	All failure modes which could result in batching errors significantly affecting make-up tank concentration are detectable by periodic local sampling.

←(DRN 99-1031)

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
→(DRN 99-1031)							
8.	Boric acid batching tank outlet relief 7CH-R190 (CH-123) BAM-104	a. Opens spuriously	Spring failure, set point drift	Flow back to batching tank from outlet line	Possi ble increase in batching tank level.	None	This is a thermal relief valve, designed to relieve back to the batching tank.
←(DRN 99-1031)							
		b. Fails to open	Mechanical failure	Possible excessive damage to batching tank discharge lines due to heat up of liquid trapped in lines.	Periodic test	None	
		c. Fails to reseat	Contamination	Seat leak. Same as 7 b.	Same as 8 a.	None	
→(DRN 99-1031)							
9.	Boric acid batching strainer BAM-MSTRN-0001	a. Fails to strain	Perforated strainer element	Possible introduction of particulate matter to boric acid make-up tanks when adding boric acid from boric acid batching tank.	Periodic inspection	Replacement	
←(DRN 99-1031)							
		b. Plugged	Particle build-up	Slow boric acid solution addition rate to boric acid make-up tanks. Possibly unable to add boric acid solution to the make-up tanks from the batching tank.	Operator	Replacement	
→(DRN 99-1031)							
10.	Boric acid batching tank BAM-MTNK-0003	a. External leakage	Mfg. Defect, corrosion	Some loss of boric acid solution while making-up a batch.	Operator	None	
11.	Boric acid batching tank stop valve to: BAMT "A" 7CH-V616-2 (CH-124) BAM-105A BAMT "B" 7CH-V616-3 (CH-135) BAM-105B	a. Fails in closed position	Mechanical failure	Unable to add boric acid solution to one boric acid make-up tank.	Operator	Two redundant 100% capacity boric acid make-up tanks.	
		b. Fails partly open	Seat leakage, contamination	Possible overfilling of one make-up tank while transferring boric acid from the batching tank to the other make-up tank.	Boric acid makeup tank level indicators and high level alarms from LIT-206 or LIT-205	Each make-up tank has an overflow line which drains to the WMS	
←(DRN 99-1031)							

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
12.	Boric acid batching tank discharge line heat tracing circuit A & B	Fails off	Open circuits, Elect. Malf.	Possible boron precipitation if there was boric acid solution left in the lines. Decrease in temp. in heat traced lines.	Malfunction of heat tracing annunciated by alarm.	Redundant heat tracing circuits	
13.				DELETED			
14.	Boric acid make-up tank level transmitters LIT-206 and LIT-208 (for tanks A and B respectively).	a. Erroneous low level indications and/or Low or Low-Low level alarms.	Electrical or mechanical malfunction	No direct impact on system. Possible overfilling of boric acid make-up tank when transferring boric acid from the batching tank.	Local level indicators LI-CH-0240 & LI-CH-0241 for tanks A & B respectively would provide verification of actual tank level. Operator detects overfilling.	Each tank has an overflow line to protect it against overpressurization.	
→(DRN 99-1031)		b. Indicates high	Electrical or mechanical malfunction	Possible undetected low level condition in make-up tank.	Local level indicators LI-CH-0240 & LI-CH-0241 for tanks A & B respectively would provide verification of actual tank level. Boric acid pump pressure indicators PIS-206 or PIS-208 should alarm on low pressure if a tank actually drains down.		

←(DRN 99-1031)

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
→(DRN 99-1031)							
15.	Boric acid make-up tank A heaters H-206, H-207	a. Fails low or off	Electrical failure	Cooldown of boric acid solution. Possible precipitation of boric acid in tank, possible deboration incident of tank A is being used for boron addition.	Temperature indicator controllers TIC-206, TIC-207 alarm on low temperature.	Two redundant full capacity heaters. Two redundant make-up tanks.	Boron concentration level in the tank ≤ 3.5 weight percent does not require heat tracing. Heaters could be eliminated.
		b. Fails full on	Electrical failure	Excessive heatup of boric acid solution. Possible to increase boric acid concentration if water is "boiled" away. Ultimately leads to boric acid precipitation in tank.	Temperature indicators controllers; TIC-206, and TIC-207 alarm on high temperature. Periodic local sample.	Fully redundant make-up tank can be used while heater is being repaired.	Manual power breakers for the heaters would allow the failed heater to be removed from service, and the redundant heater could assume temperature control.
←(DRN 99-1031)							
16.	Boric acid make-up tank A temperature indicators-controllers; TIC-206 & TIC-207	a. Controls temperature low or erroneous high temp. indication	Mechanical or electrical malfunction	Cooldown of boric acid solution. Possible boric acid precipitation in tank.	Redundant temperature indicator-controller with low temperature alarm.	Fully redundant temperature indicator-controller with heater is capable of maintaining required temperature.	
→(DRN 99-1031)							
		b. Controls temperature high or erroneous low temp. indication	Electrical or mechanical malfunction	Excessive heatup of boric acid solution. Possible boiling and boric acid concentration increase. Possible eventual boric acid precipitation.	Redundant temperature indicator-controller with high temperature alarm. Peridic local sample.	Redundant boric acid make-up tank to supply boric acid solution at required temperature and concentration.	
←(DRN 99-1031)							
17.	Boric acid make-up tank B heaters, H-208 and H-209	Same as 15	Same as 15	Same as 15	Temp. Indicator/ controllers TIC-208, TIC-209 alarm on low/high temp.	Same as 15	
18.	Boric acid make-up tank B, temperature indicators-controllers, TIC-208 and TIC-209.		Same as 16				

TABLE 9.3-15 (Sheet 6 of 60) Revision 12 (10/02)

FAILURE MODE AND EFFECTS ANALYSIS

→(DRN 99-1031)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
19.	Boric acid make-up tank drain valves; 3CH-V658A	a. Fails in closed position	Mechanical failure	No impact on normal system operation, unable to drain make-up tank.	Operator	None Required	
	(CH-127) BAM-110A 3CH-V658B (CH-137) BAM-110B	b. Fails partly open	Seat leakage contamination	Loss of boric acid solution from make-up tank to the WMS	Level indicators with low and low-low level alarms, level sensor with low level alarms.	2 redundant full capacity boric acid make-up tanks.	
20.	Boric acid make-up tanks outlet manual valves, 3CH-V101A	a. Fails open	Mechanical failure	No impact on normal system operation. Unable to isolate a boric acid make-up tank for repair.	Operator	Make-up tanks can be isolated using other valves.	In general, make-up tanks will not be isolated while plant is in operation.
	(CH-131) BAM-112A 3CH-V103B (CH-142) BAM-112B	b. Fails closed	Mechanical failure	Unable to re-establish boron addition from affected tank.	Operator	2 redundant make-up tanks.	Valves are normally locked open.
21.	Boric acid make-up tanks local sample valves;	a. Fails in closed position	Mechanical failure	Unable to obtain local sample of boric acid solution	Operator	None	
	3CH-V615 (CH-128) BAM-111A 3CH-V615 (CH-139) BAM-111B	b. Fails partly open	Seat leakage, contamination	Local spill of boric acid solution from make-up tank. Loss of boric acid solution inventory from one tank.	Low level alarms on make-up tank, level indicators and sensors if tank drains down.	Two redundant full capacity boric acid make-up tanks.	
22.	BAMT Gravity feed motor-operated valves, 3CH-V106A (CH-509) BAM-113A 3CH-V107B (CH-508) BAM-113B	a. Fails in closed position	Mechanical failure, valve operator malfunction. Loss of power.	Loss of one of two gravity feed boron addition lines used for boron addition during safety injection.	Valve position indicator in control room.	Two redundant gravity feed, boron addition lines, one for each B.A. Make-up tank. Also boric acid pumps are used for boron addition. Handwheel on valve.	

←(DRN 99-1031)

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
→(DRN 99-1031)							
22.	BAMT Gravity feed motor-operated valves 3CH-V106A (CH-509) BAM-113A 3CH-V107B (CH-508) BAM-113B (Cont'd)	b. Fails to open position or partly open	Valve operator malfunction, spurious signal	Unwanted an uncontrolled addition of boric acid solution to primary coolant. Increased boron concentration in primary coolant. Possibly one boric acid make-up tank drained.	Valve position indicator in control room, low level alarms from make-up tank level indicator and sensor. Increased RCS boron level.	Affected boric acid make-up tank can be isolated for valve repair. Redundant make-up tank available for controlled boron addition and shutdown requirements.	
23.	BAMT Gravity feed header check valve, 2CH-V128A/B (CH-190) BAM-115	a. Fails closed	Mechanical failure, blockage	Loss of both gravity feed boron injection lines. (These lines are used for boron addition during safety injection.)	None	Redundant paths for boron addition through boric acid pumps and valve 3CH-V112 A/B. (CH-514) BAM-133	
→(DRN 01-193)							
		b. Fails open	Mechanical failure	Some back leakage of primary coolant into gravity feed boron injection lines or possible BAM pump runout.	None	Gravity feed boration flow path available.	
←(DRN 01-193)							
24.	BAMT Gravity feed header sample isolation valve, 3CH-V615-7 (CH-189) BAM-114	a. Fails closed	Mechanical failure	No impact on normal system operation. Unable to take local sample.	Operator	None Required	Manually operated one inch valve-normally closed.
		b. Fails partly open	Contamination	Seat leakage. Boric acid solution will drain from part of gravity feed boron addition line. Some loss of boric acid solution during safety injection.	Operator	None	
25.	Boric acid pump suction isolation manual valves, 3CH-V102A (CH-145), BAM-118A 3CH-V104B (CH-143) BAM-118B	a. Fails open	Mechanical failure	Unable to isolate affected boric acid pump for repair.	Operator	Discharge isolation valve for appropriate boric acid make-up tank can be closed.	Closing the BAMT discharge isolation valve will remove one of the redundant boron addition trains.
←(DRN 99-1031)							

FAILURE MODE AND EFFECTS ANALYSIS

→(DRN 99-1031)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
25.	Boric acid pump isolation suction manual valves, 3CH-V102A (CH-145), BAM-118A 3CH-V104B (CH-143) BAM-118B (Cont'd)	b. Fails in the closed position	Mechanical failure	Unable to re-establish boric acid solution flow through affected pump. Loss of one normal boron addition path.	Operator	Redundant pump and boron addition path	Appropriate only after pump maintenance. Valve is normally open during operation.
26.	Boric acid make-up tank outlet manual cross-connect 3CH-V105A/B (CH-144) BAM-117	a. Fails in closed position	Mechanical failure	No impact on normal operation. Unable to establish cross-flow from one BAMT to opposite boric acid pump.	Operator	None Required	
		b. Fails partly open	Contamination	Seat leakage. The operating boric acid pump will tend to draw down the redundant BAMT	Level indicators in the redundant boric acid make-up tank (BAMT).	None Required	
27.	Boric acid pump casing vent valves, 7CH-V612 (CH-373), (CH-367)	a. Fails open	Mechanical failure	No impact on system operation.	Operator	None Required	Valves normally open-manually operated.
		b. Fails in closed position	Mechanical failure	Possible trapped air pocket in pump after maintenance. Pump cavitation.	Operator	Redundant boric acid pump can be used.	
28.	Boric acid pump cavity seal drain valves, 7CH-V612 (CH-368), (CH-388)	a. Fails in closed position	Mechanical failure	No impact on normal operation. Unable to drain affected pump for maintenance.	Operator	None Required	
		b. Fails partly open	Contamination	Seat leakage. Minor amount of boric acid make-up flow discharged to waste management system rather than to volume control tank or primary system.	None	None Required	

←(DRN 99-1031)

FAILURE MODE AND EFFECTS ANALYSIS

→(DRN 99-1031)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
29.	Boric acid pumps A and B BAM-MPMP-0001A BAM-MPMP-0001B	a. Operating pump fails	Shaft shear, shaft seizure, motor failure, electrical failure.	Loss of normal boron addition.	Low pressure alarm from pump discharge pressure indicator, PI-206 or PI-208 low flow alarm from boron addition flow "indicator," FRC-210Y.	Redundant pump on standby started manually.	
		b. Spurious start of standby pump	Spurious signal.	Possible excessive boron addition.	Pump discharge pressure indicators; PI-206 or PI-208 flow rate controller: FRC-210Y, high flow rate alarm; pump status lights in control room.	Make-up controller will close flow control valve, CH-21OY. Pump min. flow lines will take rest of flow.	Manual power breakers for pumps would allow pumps to be stopped in event of this type of failure.
		c. Standby pumps fails to start.	Mechanical binding, motor failure, "air binding."	Unable to bring pump on line for boron addition. Loss of one path for shutdown boron addition.	Pump discharge pressure indicator low pressure alarm, pump status indicators in control.	For normal boron addition, redundant pump. For shutdown, each BAMT is capable of meeting the shutdown boron addition requirements through its pump or its gravity feed line.	
30.	Boric acid pump discharge indicators; PI-206, PI-208	a. Erroneous low pressure indication or alarm.	Electrical or mechanical malfunction	No direct impact on system operation.	Flow rate indicator-controller, FRC-21OY, if boration in progress.	None Required	These pressure indicators DO NOT have a control function.
		b. Erroneous high pressure indication.	Electrical or mechanical malfunction	No direct impact on system operation.	Flow rate indicator-controller, FRC-21OY, if boration in progress.	None Required	

←(DRN 99-1031)

FAILURE MODE AND EFFECTS ANALYSIS

→(DRN 99-1031)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
31.	Boric acid pump discharge check valves. 3CH-V108A (CH-155), BAM-129A	a. Fails in closed position	Mechanical binding, blockage	Unable to establish normal boron addition flow through affected pump. Effective loss of one pump for shutdown boron addition.	Pump discharge pressure indicator.	Redundant boric acid pump for normal boron addition, plus gravity feed path for safety injection boron addition.	
	3CH-V110B (CH-154) BAM-129B	b. Fails partly open	Seat leakage, contamination	Possible small reduction in boron addition flow due to leakage into standby pump discharge lines. Gradual level increase in standby BAMT. No effect with both Boric Acid Pumps working.	BAMT level indicators, on standby BAMT, low flow indications and possibly alarm from flow rate control-ler, FRC-21OY.	Standby pumps discharge isolation valve can be closed until check valve is repaired.	Applies only to valves for standby boric acid make-up pump while normal boration is in progress.
32.	Boric acid pump discharge manual isolation valves; 3CH-V109A (CH-153), BAM-131A	a. Fails in open or partly open position	Mechanical failure, contamination	Unable to isolate affected pump for repair, seat leakage.	Operator	Appropriate discharge check valve & a blind flange can be used for isolation if needed.	
	3CH-V111B (CH-152) BAM-131B	b. Fails in closed position	Mechanical failure	Unable to establish boration flow through affected pump Effective loss of one make-up pump for boron addition.	Operator	Redundant pump available for boration. Gravity feed line available for boron addition. Safety injection.	Applies only if the pump has been down for repair, valve normally open.
33.	Boric acid pump discharge header manual stop valve 3CH-V606-1 (CH-161), BAM-136	a. Fails in open or partly open position	Mechanical failure, contamination	Unable to isolate flow rate controller, FRC-21OY for repair, seat leakage.	Operator	Upstream isolation can be achieved by closing valves (3CH-V109A), BAM-131A and (3CH-V111B), BAM-131B and downstream isolation can be achieved using valve CH-21OY, BAM-141.	
	3CH-V606-2 (CH-172) BAM-139	b. Fails in closed position.	Mechanical failure	Unable to re-establish normal boration flow path.	Operator	None	Applies only after flow rate controller, FRC-21OY has been down for repair.

←(DRN 99-1031)

TABLE 9.3-15 (Sheet 11 of 60) Revision 12 (10/02)

FAILURE MODE AND EFFECTS ANALYSIS

→(DRN 99-1031)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
34.	Boric acid make-up flow rate controller, FRC-210Y	a. Controls boration flow too low	Electrical or mechanical malfunction	Possible deboration of primary coolant during automatic boration.	Possibly see high pressure indication on Boric Acid pump discharge pressure indicator.	None	
		b. Controls boration flow too high	Electrical or mechanical malfunction	Gradual over-boration of primary coolant. Slow reactor power decrease.	Reactor power indicators.	None	
35.	Boric acid make-up flow control valve, 3CH-FM172A/B (CH-21OY) (Air Operated) BAM-141	a. Excessive flow restriction (closed too much)	Shaft binding, valve operator malfunction	Low boric acid solution flow rate. Possible deboration of primary coolant.	Low flow alarm from flow rate control-ler, FRC-21OY.	None	Make-up controller can be switched to manual to add the proper boric acid make-up flow.
		b. Insufficient flow restriction (open too much)	Shaft binding, valve operator failure	Excessive boric acid flow rate, over-boration of primary coolant system.	High flow rate alarm from flow controller, FRC-21OY, low discharge pressure indications from B.A. pump discharge pressure indicator.	Make-up controller can be adjusted to increase make-up water flow rate to attain proper blend. When required level is achieved in VCT, the Boric Acid pump can be stopped.	

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TABLE 9.3-15 (Sheet 12 of 60) Revision 12 (10/02)

FAILURE MODE AND EFFECTS ANALYSIS

→(DRN 99-1031)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
36.	Boric acid makeup discharge check valve, 3CH-V617 (CH-186) BAM-146	a. Fails partly open	Contamination seat leakage	Possible backflow of make-up water into the boration lines when make-up water being added to VCT.	None	None Required	
		b. Fails in closed position	Mechanical failure, blockage	Unable to establish normal boration flow. Possible de-boration of primary system.	Flow rate control-ler, FRC 21OY, low flow alarm, make-up pump high discharge pressure indications on PI-206, PI-208	None	When boration makeup flow not in progress makeup controller can be switched to "Borated Mode" to add proper boric acid makeup flow to primary system
37.	Primary make-up water flow rate controller, FRC-210X	a. Controls make-up water flow too low	Electrical or mechanical malfunction (senses flow too high)	Low make-up water mix ratio for boration flow. Excess boric acid added to primary coolant system. Reactor power decrease.	Reactor power indicators, possibly high discharge pres-sure from RMW pumps.	None	
		b. Controls make-up water flow too high	Low flow sensor output, electrical or mechanical failure	Too much make-up water mixed with boric acid solution. Gradual deboration of primary coolant system.	Possibly low discharge pressure indications from RMW pumps.	None	
38.	Primary make-up line manual isolation valves, 7CH-V114 (CH-183), PMU-142 7CH-V113 (CH-195) PMU-136	a. Fails in open position or partly open	Mechanical failure, contamination	Seat leakage, unable to isolate flow rate transmitter PMU-1FT-210X for repair.	Operator	Isolation can be achieved by closing other valves.	
		b. Fails in closed position	Mechanical failure	Unable to re-establish make-up water flow to VCT	Operator	None Required	These manual valves are closed only to repair flow rate controller.

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FAILURE MODE AND EFFECTS ANALYSIS

→(DRN 99-1031)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
39.	Primary make-up flow control valve, 7CH-F115 (CH-210X) PMU-144	a. Fails to allow flow increase on signal (doesn't open wider)	Shaft binding, valve operator malfunction	Low Primary make-up water flow rate. Possible over-boration of primary coolant system.	Low flow alarm from flow rate controller, FRC-210X possible high discharge pressure indications from RMW pump(s).	Make-up flow rate controller FRC 210X can be adjusted to throttle back boric acid flow to attain proper mix ratio. Can stop pumps and close valve 3CH-F117A/B (CH-512) CVC-510 to terminate makeup.	
		b. Fails to close on signal	Shaft binding, valve operator malfunction	High Primary make-up water flow rate. Possible deboration of primary system.	High flow alarm from flow rate controller, FRC-210X. Possible low discharge pressure indications from RMW pump.	Make-up controller can be adjusted to increase boric flow to attain proper mix ratio. Can stop pumps and close valve 3CH-F117A/B (CH-512) CVC-510 to terminate makeup.	
40.	Primary makeup water supply check valve 3CH-V116A/B (CH-184) PMU-146	a. Fails closed	Mechanical failure, blockage	Unable to establish Primary make-up water flow. Possible over boration of primary system.	Low flow alarm from flow rate controller FRC-210X. Possible high discharge pressure indications from RMW pump(s).	None	
		b. Fails partly open	Mechanical failure or contamination	Possible back leakage of boric acid solution into make-up water lines. Possible precipitation of boric acid in make-up water lines.	None	None	Applies only when Primary makeup is not in progress.
41.	Make-up control air operated stop valve to the VCT 3CH-F117A/B (CH-512) CVC-510	a. Fails to open	Mechanical failure, valve operator malfunction	Unable to establish make-up flow to VCT.	Valve position indicator in control room. Low flow alarms from make-up flow controllers.	Boration flow can be routed directly to the charging pump suction through gravity feed line, or through 3CH-V112A/B, (CH-514) BAM-133.	Make-up flow can be manually directed to charging pump suction.

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FAILURE MODE AND EFFECTS ANALYSIS

➜(DRN 99-1031)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
41.	Make-up control air operated stop valve to the VCT 3CH-F117A/B (CH-512) CVC-510 (Cont.)	b. Spurious closure during make-up	Valve operator malfunction, spurious signal.	Sudden termination of make-up flow.	Valve position indicator in con-trol room, low flow alarms from flow rate controllers, FRC-210X, and FRC-21OY.	Same as 41 a. If spurious signal, can clear and reopen valve.	Same as 41 a.
		c. Fails to close on SIAS signal.	Valve operator malfunction, mechanical failure.	Portion of boric acid solution diverted to VCT during shutdown boron addition. Reduced amount of boron addition to primary system.	Valve position indicator in control room.	None required	It would take several unusual conditions before this failure would cause less than the contents of one BAMT to be injected i.e., VCT at low level, boration in progress at moderate to high rate, and one BAMT drawn down close to low level and an SIAS.
42.	Make-up header to the VCT check valve, 2CH-V118A/B (CH-188) CVC-511	a. Fails in closed position	Mechanical failure, contamination	Unable to establish make-up flow to Volume Control Tank.	Low flow alarms from flow rate controllers, FRC-210X and FRC-210Y.	Make-up flow can be routed directly to the charging pump suction through manual valve 3CH-V119A/B (CH-196) CVC-502 & air operated valve 3CH-V121A/B (CH-504) CVC-507	
		b. Fails partly open	Seat leakage, contamination	Possibly some back leakage of primary coolant into make-up line downstream of valve 3CH-F117A/B.	None	None Required	
43.	Make-up header local sample valve, (Manual) 3CH-V615-6 (CH-185) CVC-501	a. Fails in closed position	Mechanical failure	Unable to obtain local sample from make-up line. No impact on system operation.	Operator	None	Normally closed-manually operated valve.
		b. Fails partly open	Contamination	Seat leakage. Local spill of boric acid solution. Minor reduction of make-up flow possible.	Local leak detectors	None	

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FAILURE MODE AND EFFECTS ANALYSIS

→(DRN 99-1031)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
44.	Boric acid make-up to the RWSP isolation manual valve. 3CH-V119A/B (CH-196) CVC-502	a. Fails in closed position	Mechanical failure	Unable to route make-up flow directly to charging pump suction.	Operator	Normal make-up path to VCT.	This is an alternate make-up path. Manual valve.
		b. Fails partly open	Contamination	Seat leakage. Refueling water storage pool discharge lines contaminated with boric acid solution. Possible boric acid precipitation at valve 3CH-V121A/B (CH-504) CVC-507	None	None	The refueling water tank discharge line to charging pump suction is filled so boric acid solution contamination would be a slow process.
45.	Boric acid make-up to the RWSP check valve, 3CH-V120A/B (CH-193) CVC-503	a. Fails in closed position	Mechanical failure, contamination	Unable to route make-up flow directly to charging pump suction.	Low flow alarms from flow rate control lers FRC-210X and FRC-21OY.	Normal make-up path to VCT available.	
		b. Fails partly open	Contamination	Seat leakage. Possible dilu-tion of boric acid solution with RWT water.	None	Valve 3CH-V119A/B provides required isolation.	
46.	Primary make-up water supply to charging pump suction. 7CH-V619 (CH-180) PMU-140	a. Fails in closed position	Mechanical failure	Unable to dilute primary system coolant directly through charging pump(s).	Operator	Normal dilution path through VCT.	This is an alternate dilution path and is used only with caution because it bypasses the control system.
		b. Fails partly open	Seat leakage, contamination	Unwanted direct dilution of primary coolant system.	Flow indications from flow rate controller FRC-210X.	None	Valve is normally locked closed.
47.	Primary make-up water supply to charging pump suction check valve. 2CH-V620 (CH-179) PMU-141	a. Fails in closed position	Mechanical failure, blockage	Unable to dilute primary system coolant directly through charging pump(s).	Operator	Normal dilution path through VCT.	
		b. Fails partly open	Contamination	Seat leakage. Contamination of reactor make-up water with primary coolant.	None	Valve CH-V619 (CH-180) PMU-140 provides required isolation.	

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FAILURE MODE AND EFFECTS ANALYSIS

→(DRN 99-1031)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
48.	Boric acid makeup manual bypass of 3CH-V112A/B. (CH-514) BAM-133 3CH-V606-3 (CH-174) BAM-138	a. Fails in closed position	Mechanical failure	Unable to establish "alternate path" safety injection boron injection if primary path is unavailable.	Operator	Gravity feed boron injection lines.	
		b. Fails partly open	Seat leakage, contamination	Gradual over boration of primary coolant system.		None	
49.	Make-up control bypass to charging pump suction check valve 2CH-V130A/B (CH-177) BAM-135	a. Fails in closed position	Mechanical failure - blockage	Unable to establish "pumped" safety injection boron injection flow path.	High discharge pressure indications from boric acid make-up pumps	Gravity feed boron injection lines.	
		b. Fails partly open	Seat leakage, contamination	Possible dilution of boration lines with primary coolant.	None	Valves 3CH-V112A/B (CH-514) BAM-133 and 3CH-V606-3 (CH-174) BAM-138 provide isolation.	
50.	Make-up controls bypass to charging pump air operated suction valve 3CH-V112A/B (CH-514) BAM-133	a. Fails in closed position or fails to open on SIAS	Mechanical failure, valve operator malfunction.	Loss of "pumped" boron injection capability during safety injection.	Valve position indicator in control room, high discharge pressure indications from B.A. make-up pumps.	Gravity feed boron injection lines	There is an alternate "pumped" boron injection path through valve 3CH-V606-3 (CH-174 BAM-138, a manually operated valve.
		b. Fails open or partly open	Spurious signal, valve operator malfunction or seat leakage.	Over boration of primary coolant if boric acid pumps are running.	Possibly low flow alarms from flow rate controller FRC-21OY.	Can stop boric acid make-up pumps.	
51.	Make-up control bypass header to charging suction sample valve 3CH-V615-5 (CH-176) BAM-134	a. Fails in closed position	Mechanical failure	Unable to obtain local sample of boron injection line contents to determine boron concentration.	Operator	None	

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FAILURE MODE AND EFFECTS ANALYSIS

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No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
51.	Make-up controls bypass header to charging pumps suction sample valve 3CH-V615 (CH-176) BAM-134 (Cont'd)	b. Fails partly open	Seat leakage, contamination	Possible gradual drainage of boron injection line. Some loss of boric acid solution during shutdown boration.	Possibly high level alarm from drain sump level detectors	None	
52.	Primary make-up water line relief valve, 7CH-R180 (CH-376) PMU-145	a. Fails in closed position	Mechanical failure, setpoint drift	Loss of make-up water line over pressure protection in the event that valve 3CH-F117A/B (CH-512) CVC-510 is tripped closed while RMW pumps are operating.	Periodic test	None	
		b. Spuriously opens	Setpoint drift	Some diversion of make-up water flow during boration/ dilution. Possible over-boration due to improper mix ratio.	Possibly a high flow alarm or short term high flow indication from flow rate controller FRC-210X.	None	
		c. Failure to reseat	Contamination	Seat leakage (see 52 b).	None	None	
53.	Boric acid make-up tank air operated recirculation isolation valves, 3CH-F170A (CH-510), BAM-126A 3CH-F171B (CH-511) BAM-126B	a. Fails in closed position	Mechanical failure, valve operator malfunction. Loss of air power	Possible boric acid concentration stratification in tank.	Valve position indicator in control room. High discharge pressure indication from associated boric acid pump.	Some recirculation is possible through associated Boric Acid pump's mini-flow bypass line.	These valves are normally open and continuous recirculation is in progress if pumps are on.
		b. Fails in the open position	Mechanical failure, valve operator malfunction.	Unable to terminate recirculation flow especially on SIAS. Decreased boron injection rate during safety injection. However total amount not affected because other paths available.	Valve position indicator in control room. Low discharge pressure indications from associated Boric Acid pump.	Gravity feed injection line, plus pumping will continue until BAMT is empty.	

←(DRN 99-1031)

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FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
→(DRN 99-1031)							
54.	Boric acid make-up tank recirculation line manual isolation valves, 3CH-V613-2 (CH-158), BAM-122A 3CH-V613-1 (CH-151), BAM-122B 3CH-V131A, BAM-127A 3CH-V653B BAM-127B	a. Fail in open position	Mechanical failure	Unable to isolate BAMT recirc. line for Boric Acid pump or recirc. line repair. Unable to establish tank to tank transfer of boric acid solution while boration in progress.	Operator	None Required	Normally open manual valves
		b. Fails in closed position	Mechanical failure	Unable to re-establish normal recirc. flow for affected BAMT. Isolates thermal relief valves (see 57) from BAMTs	Operator	Same as 53 a. and thermal reliefs discharge to both BAMT's simultaneously.	
55.	Boric acid pump make-up recirculation line manual cross-connect valve, 3CH-V613-3 (CH-159) BAM-123	a. Fails in closed position	Mechanical failure	Unable to make tank to tank transfer of boric acid solution.	Operator	None Required	
		b. Fails partly open	Contamination	Seat leakage. Some cross flow between BAMTS during recirculation of one or both tanks.	Level indications in BAMTs if only one tank being recirculated, otherwise none.	None Required	
56.	Boric acid pumps min-flow manual valves, 3CH-N173A, (CH-134) BAM-125A 3CH-N174B (CH-148) BAM-125B	a. Fails in open position	Mechanical failure	Unable to isolate Boric Acid pump min-flow bypass line for pump maintenance. Unable to throttle pump bypass flow.	Operator	None Required	Manually operated normally throttled needle valve.
		b. Fails in closed position	Mechanical failure	Unable to establish Boric Acid pump bypass flow on start-up. Possible damage to pump if started against a closed system.	Operator	Valve 3CH-F170A (CH-510) BAM-126A 3CH-F171B (CH-511) BAM-126B can be used by operator.	
←(DRN 99-1031)							

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FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
→(DRN 99-1031)							
57.	Deleted						
←(DRN 99-1031)							
→ (DRN 99-0971)							
58.	Concentrated boric acid lines heat tracing	a. Fails off or low	Electrical malfunction control malfunction	Cooldown of concentrated boric acid in static line segments. Precipitation of boric acid and potential plugging of lines where boric acid concentration exceeds 3.5 w/o.	Malfunction of heat tracing annunciates an alarm. .	Two independent and reduncant heat tracing circuits.	
← (DRN 99-0971)							

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
58.		b. Fails to high output	Electrical or control mal-function	Excessive heating of boric acid solution.	All boric acid line sections that can be restricted have thermal relief valves that relieve to the BAMTs.		
59.	Boric acid make-up tanks 1 and 2	a. Leakage	Corrosion mfg. defect	Loss of all or part of the contents of one BAMT.	Low level alarms from level indicator and level sensor in affected BAMT.	2 fully redundant BAMTs.	
→(DRN 99-1031)							
60.	Boration bypass air operated control valve; 3CH-F175A/B (CH-522) BAM-143	a. Fails in closed position	Mechanical failure, loss of air or power	Loss of direct boration capability.	Valve position in-dicator in control room, flow rate controller, FRC-210Y, low flow indications.	Direct boration can be accomplished manually via valves 3CH-V119A/B (CH-196) CVC-502 and 3CH-V121A/B (CH-504) CVC-507.	
		b. Fails open	Spurious signal, seat leakage	Concentrated boric acid diverted to charging pump suction during make-up. Over boration of RCS.	Flow rate controller FRC-21OY,	For spurious signal, clear signal and close valve, for seat leakage close isolation vale 3CH-V606-4 (CH-175) BAM-145.	
61.	3CH-F175A/B (CH-522) BAM-143 outlet stop valve (manual) 3CH-V606-4 (CH-175) BAM-145	a. Fails open	Mechanical failure	No impact on normal system operation. Unable to isolate direct boration control valve for maint.	Operator	None Required	Normally open, manual valve
		b. Fails closed	Mechanical failure	Unable to establish direct boration flow	Operator	None Required	
62.	Boric acid make-up tank vent valves; 7CH-V614-1 BAM-106B 7CH-V614-2 BAM-106A	a. Fails open	Mechanical failure	No impact on system operation	Operator	None Required	Normally open manual valves.
		b. Fails closed	Mechanical failure	Loss of tank venting, possible pressure differential between tanks. Possible overpressuri-zation.	Operator	None required, tanks are not pressurized.	
←(DRN 99-1031)							

TABLE 9.3-15 (Sheet 21 of 60) Revision 12 (10/02)

CHEMICAL AND VOLUME CONTROL SYSTEM (CVCS)

FAILURE MODE AND EFFECTS ANALYSIS

→(DRN 99-1031)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
1.	Letdown stop air operated valve inside containment 1CH-F1516A/B (CH-515) CVC-101	a. Fails open	Mechanical binding	Unable to automatically terminate letdown flow on high temperature. Possible damage to downstream components. Loss of double isolation of letdown line on SIAS.	Position indication in control room. Temperature alarm, TIC-221. Flow indicator, FI-202	Remote manual closure of redundant valve for hi temp. condition. Series redundant valve closes on SIAS.	Potential compensation - CCW flow through letdown HX increased by TIC-224. Problem only if regenerative HX discharge temp. exceeds 450°F.
		b. Fails closed	Air or Power failure or spurious signal	Loss of letdown flow. Possible overcharging of RCS.	Low flow alarm, FI-203. Position indicator in control room, flow indicator, FI-202.	None	Letdown not required for safe shutdown of plant.
2.	Letdown containment air operated isolation valve inside containment 1CH-F2501A/B (CH-516) CVC-103	a. Fails open	Mechanical binding	Unable to automatically isolate letdown lines on SIAS or CIAS.	Position indicator in control room. Flow indicator, FI-202.	Series redundant valve, 1CH-F1516A/B (CH-515) CVC-101, closes on SIAS, 1CH-1518A/B (CH-523) CVC-109, closes on CIAS.	
		b. Fails closed	Air or power failure, mechanical failure or spurious signal	Same as 1 b.			
3.	Regenerative heat exchanger	a. Plugged tubes	Corrosion buildup, boron buildup, foreign material in RCS.	Reduced letdown flow.	Flow indicator, FI-202 or FI-203	None	Complete plugging of all tubes is unlikely. Flow deterioration should be detected long before complete plugging occurs.
		b. Insufficient heat transfer	Scale buildup on tubes	Letdown temperature from regenerative HX may exceed 450°F. Possible damage to downstream components.	Temperature indicator and alarm, TIC-221.	Temp. indicator/controller, TIC-221 will close valve 1CH-F1516A/B (CH-515) CVC-101, if temp. exceeds 470°F, thus terminating letdown.	

←(DRN 99-1031)

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CHEMICAL AND VOLUME CONTROL SYSTEM (CVCS)

FAILURE MODE AND EFFECTS ANALYSIS

→(DRN 99-1031)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
3.	Regenerative heat exchanger (Cont'd)	c. External leakage	Casing crack, seat leakage on vent valve, 2CH-V1503 (CH-443) CVC-213	Reduction to letdown flow, primary coolant released inside containment.	Eventually containment radiation monitors, possibly flow indicator FI-202, excessive make-up rate.	None	If HX leak is serious, it will be readily detected, and the heat exchanger can be isolated
		d. Flow path cross leakage	Corrosion, vibration were, Mfg. defect.	Possible contaminant buildup in primary coolant, reduced ability to change boron concentration, reduced effectiveness of charging pumps.	Possible effect on temp., boron levels and radiation.	None	If leak is large, CVCS letdown samples will not be consistent with RCS samples.
4.	Temperature indicator-controller, TIC-221.	a. False indication of high temp.	Electro-mechanical failure, set-point drift.	Valve 1CH-F1516A/B (CH-515) CVC-101 closed, loss of letdown flow.	Low flow alarm, FI-203, flow indicator, FIC-202, 1CH-F1516A/B (CH-515) CVC-101 position indicator in control room.	None	
		b. False indication of low or normal temp.	Electro-mechanical failure.	Possible loss of detection for high temp. letdown flow.	Temp. Indicator, TIC-223, TIC-224.	None. (TIC-223 will tend to increase CCW flow thru letdown HX to compensate for hi temp. flow. On hi temp., TIC-224 will divert flow to protect components.	This failure causes no problem unless there is a coexistent hi temp. will cause alarm from TIC-224.
5.	Letdown containment isolation air operated valve outside containment, 2CH-F1518A/B (CH-523) CVC-109	a. Fails open	Mechanical binding	Loss of redundant isolation of letdown line on CIAS.	Position indicator in control room.	Series redundant valve, 1CH-F2501A/B (CH-516) CVC-103, close on CIAS	
		b. Fails closed	Air or power failure, mechanical failure, or spurious signal.	Same as 1 b.			

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CHEMICAL AND VOLUME CONTROL SYSTEM (CVCS)

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
→(DRN 99-1031)							
6.	Letdown control air operated valve, 2CH-FM1536A/B (CH-110P) CVC-113A 2CH-FM1535A/B (CH-110Q) CVC-113B	a. Regulates low	Valve operator failure, mech. failure, false signal	Reduced letdown flow.	Low flow indication on flow indicator, FI-202. Low pressure indication on PIC-201. Possible PZR level increase. Charging pumps may cycle more than normal.	Parallel redundant control valve can be placed in operation by opening isolation valves.	One of two parallel redundant control valves is normally isolated by manual isolation valves while other valve controls flow. Flow control can be switched by opening isolation valves for standby control valve, and closing isolation valves for "operating" control valve.
		b. Regulates hi	Valve operator failure, spurious signal	Increased letdown flow.	Flow indicator, FI-202, pressure indication PIC-201, possible PZR level decrease.	Parallel redundant control valve.	
←(DRN 99-1031)							
		c. Fails closed	Air or Power failure, spurious signal	Loss of letdown flow, possible overcharging of RCS. Possible overpressurization of RCS during shutdown cooling.	Flow indicator, FI-202, pressure indication from PIC-201. Valve position indication in control room.	Parallel redundant control valve can be valved in.	Rapid overpressurization of RCS if this failure occurs during shutdown cooling.
→(DRN 99-1031)							
7.	Letdown control valve isolation manual valves; 2CH-V1523-1 (CH-341), CVC-111A 2CH-V1523-2 (CH-343), CVC-111B 2CH-V1505-1 (CH-342), CVC-113A 2CH-V1505-2 (CH-344) CVC-113B	a. Fails open	Mechanical failure	No impact on system function. Unable to isolate one control valve for standby or maintenance.	Operator	Two series redundant isolation valves for each control valve.	One set of isolation valves normally closed (for standby control valve) other set is open (for operating control valve.)
		b. Fails closed	Mechanical failure	Unable to transfer letdown flow control to standby control valve.	Operator	None if the operating flow control valve has malfunctioned.	
←(DRN 99-1031)							
		c. Seat leakage	Contamination	Possible boron precipitation on standby control valve due to primary coolant leaking into the space betwseen the isolation valve and the standby control valve, and cooling.	Operator	None	

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CHEMICAL AND VOLUME CONTROL SYSTEM (CVCS)

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
→(DRN 99-1031)							
8.	Letdown line relief valves, 2CH-R626A/B (CH-345) CVC-115 2CH-R629A/B (CH-354) CVC-126	a. Fails closed	Mechanical failure, setpoint drift	No direct impact on system operation. Loss of overpressure protection for potentially closed line section.	Periodic test	None	
←(DRN 99-1031)							
		b. Fails open	Setpoint drift, mechanical failure	Primary coolant discharged to holdup tanks.	Excessive use of makeup water, possible low flow indications on flow indicator, FI-202. Possible low pressure indications on PIC-201.	None	
→ (DRN 00-1638)							
8a.	Letdown line thermal relief valve CVC-1081	a. Fails closed	Mechanical failure. Setpoint drift.	No direct impact on system operation. Loss of overpressure protection for portion of Letdown line bounded by containment isolation valves CVC-103 and CVC-109 following a LOCA.	Periodic test	None	
		b. Fails open	Mechanical failure. Setpoint drift.	Primary Coolant discharged inside primary containment.	Excessive use of makeup water. Radiation detectors. Possibly low flow indication on FI 202. Possibly low pressure Indications on PIC-201.	None	Letdown line must be isolated until relief valve can be repaired or replaced.
← (DRN 00-1638)							
→(DRN 99-1031)							
9.	Shutdown cooling manual isolation to LHX 2CH-V644A/B (CH-436) SI-423	a. Fails closed	Mechanical failure	Unable to use CVCS for purification of shutdown cooling flow.	Operator	Purification of the primary coolant during shutdown cooling can be accomplished via normal letdown and charging.	
←(DRN 99-1031)							

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CHEMICAL AND VOLUME CONTROL SYSTEM (CVCS)

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
9.	Shutdown cooling isola- tion to LHX 2CH-V644A/B (CH-463)	b. Seat leakage	Contamination	Primary coolant diverted to shutdown cooling system during normal letdown.	Possibly flow indicator FI-202.	Series redundant check valve and isolation valve in shutdown cooling system.	
10.	Letdown heat exchanger	a. Tube leak	Corrosion, mfg. defect	Contamination of component cooling water with primary coolant.	CCW radiation moni- tors, possibly low flow indication on FI-202, CCW surge tank level increase, excessive use of make-up water.	None	
		b. Tubes plugged	Corrosion buildup, boron buildup, contaminant buildup	Reduced letdown flow.	Flow indicator, FI-202 and FI-203	None	
→(DRN 99-1031)							
		c. Insufficient heat transfer	Scale buildup, malfunction of CCW flow control valve.	High temp. discharge from HX, possible damage to downstream components.	Temperature indicator-controller, TIC-224, alarms on high temp.	Temp. Indicator-controller, TIC-223, will sense hi temp. and increase CCW flow through HX	Temp. Indicator-controller, TIC-224, will divert hi temp. letdown flow past Ion Exchangers.
←(DRN 99-1031)							
		d. External leakage	Casing crack, Seat leakage on vent valve, CH-444.	Primary coolant released outside containment	Area radiation monitors, Local leak detection, flow indication from FI-202, excessive use of make-up water.	None	When leak is located, letdown flow can be terminated and HX can be isolated for repair.
11.	Letdown line vent valves (6 valves)	a. Fails closed	Mechanical failure	No impact on system operation.	Operator	None Required	
		b. Seat leakage	Contamination	Primary coolant released, either inside containment or outside containment.	Radiation monitors, local leak monitors.	Vent valves are capped.	When leak is located, letdown flow can be terminated, and appropriate line section isolated to repair valve.

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CHEMICAL AND VOLUME CONTROL SYSTEM (CVCS)

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
12.	Letdown line drain valves (13 valves)	a. Fails closed	Mechanical failure	No impact on system operation.	Operation	None Required	
		b. Seat leakage	Contamination	Primary coolant diverted to drain header and BMS during letdown.	Equip. drain tank level indication, possibly low flow indication from FI-202.	None Required	
→(DRN 99-1031)							
13.	Temperature Indicator-controller, TIC-223	a. False low temperature indication	Electro-mechanical malfunction	Letdown HX CCW control valve will be throttled back, resulting in decreased heat removal in letdown HX. High temp. discharge from letdown HX and possible damage to downstream components.	Temp. indicator-controller, TIC-224 alarms on high temp.	TIC-224 will divert letdown flow past the ion exchangers.	
←(DRN 99-1031)							
		b. False high temperature indication	Electro-mechanical malfunction	Letdown HX CCW control valve will be opened, resulting in increased heat removal in letdown HX. Low temperature discharge from letdown HX not considered a problem.	Low temp. indication from TIC-224	None Required	
→(DRN 99-1031)							
14.	Temperature indicator-controller, TIC-224	a. False low temperature indication	Electrical or mechanical malfunction	Failure to bypass ion exchanger.	Temperature indicator TIC-223.	None Required	
		b. False high temperature indication	Electrical or mechanical malfunction	Ion exchanger bypass valve opened. Buildup of corrosion products in primary coolant. Loss of boron and radiation monitoring.	TIC-224 alarms on hi temp. Also use TIC-223 or TIC-221 to assess temp. Position indication on (CH-520) CVC-140 and 2CH-W136A/B.	None	This condition drives valves 2CH-W136A/B (CH-520) CVC-140 to their safe position.
15.	Pressure indicator-controller, PIC-201	a. False low pressure indication	Electrical or mechanical malfunction	Letdown pressure control valve will start to close, thus reducing letdown flow. Letdown flow control valve will open to counteract. May lift relief valve, 2CH-R626A/B (CH-345) CVC-115.	Flow indicator, FI-201, PIC-201 will alarm on low pressure	None	
←(DRN 99-1031)							

CHEMICAL AND VOLUME CONTROL SYSTEM (CVCS)

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
15.	Pressure indicator-controller, PIC-201 (Cont'd)	b. False high pressure indication	Electrical mechanical malfunction	Letdown pressure control valve will open, increasing letdown flow. Letdown flow control valve will close to counteract.	Possible hi level alarm on VCT. Low level alarm on PZR. High letdown flow alarm before letdown valve reduces flow.	As PZR level drops, the letdown flow control valve will close.	Possible PIC-201 hi. Pressure alarm.
→(DRN 99-1031)							
16.	Letdown Back-Pressure control air operated valve; 2CH-PM627A/B (CH-201Q), CVC-123A 2CH-PM628A/B (CH-201P) CVC-123B	a. Fails to close properly on decreased upstream pressure	Valve operator malfunction, mechanical binding	Some pressure decrease down-stream. Possible flashing in letdown HX may result in excessive letdown temp.	Pressure indicator controller, PIC-201, alarms on lo press. hi temp. alarm from TIC-224.	Parallel redundant control valve can be manually valved in and activated.	Two pressure control valves, one active and other on standby. Standby valve is isolated by manual valves.
		b. Fails to open properly on increased upstream pressure	Valve operator malfunction, mechanical binding	Pressure increase upstream in letdown HX. May lift 2CH-R626A/B (relief valve). Possible reduced letdown flow.	Pressure Indicator-controller PIC-201 alarms on high pressure.	Same as above.	Relief valve 2CH-R626A/B (CH-345) CVC-115 protects against overpressure.
		c. Fails closed	Air or power failure, spurious signal	Loss of letdown flow. Possible overpressurization of RCS, especially during shutdown cooling. May lift 2CH-R626A/B (CH-345) CVC-115. PZR level increase.	Pressure indicator / controller, PIC-201 alarms on hi press. valve position indication control room, Flow indicator, FI-201, PZR HI. LVL alarm.	Parallel redundant valve can be manually valved in and activated during normal operation. PZR level controls will stop backup charging pumps.	If this occurs during shutdown cooling, RCS over-pressurization will happen very rapidly as system is solid.
17.	Letdown Back-pressure control valve isolation manual valves; 2CH-V605-1 (CH-347) CVC-121A 2CH-V640A/B (CH-349) CVC-125A 2CH-V605-2 (CH-348) CVC-121B 2CH-V641A/B (CH-350) CVC-125B	a. Fails open	Mechanical binding	No impact on system perfor-mance. Unable to isolate one pressure control valve for standby status or maintenance.	Operator	Series redundant isolation valve.	Two sets of isolation valves, one set normally closed for standby pressure control valve, other set normally open for pressure control valve in operation.
		b. Fails closed	Mechanical binding	Unable to transfer letdown pressure control to standby pressure control valve.	Operator	None if operating pressure control valve has malfunctioned.	
←(DRN 99-1031)							

CHEMICAL AND VOLUME CONTROL SYSTEM (CVCS)

FAILURE MODE AND EFFECTS ANALYSIS

→(DRN 99-1031)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
17.	Letdown Back-pressure control valve isolation manual valves; 2CH-V605-1 (CH-347), 2CH-V640A/B (CH-349), CVC-125A 2CH-V605-2 (CH-348), CVC-121B 2CH-V641A/B (CH-350), CVC-125B (Cont'd)	c. Seat leakage	Contamination	Possible boron precipitation on standby pressure control valve due to primary coolant leaking into the space between the isolation valve and the control valve and cooling.	Operator	None	
18.	Letdown line air operated sample valves 2CH-F661A/B (CH-525), CVC-131, 2CH-F660A/B (CH-526) CVC-131 2CH-F643A/B (CH-527) CVC-139	a. Fails open	Mechanical failure	No impact on system performance Unable to use valve to isolate letdown sample line.	Operator	Series redundant valves (normally closed) in sampling system.	Valves normally closed manually operated.
		b. Fails closed	Mechanical failure	No direct impact on system operation. Unable to obtain letdown sample	Unable to establish sample flow.	None Required	Same as above.
19.	Boronometer and process radiation monitor line isolation valve, 2CH-V608 (2 valves)	a. Fails open	Mechanical failure	No impact on system operation. Unable to isolate boronometer and PRM line for maintenance.	Operator	Series redundant isolation valves for boronometer and PRM.	These valves are closed by DC 3432 to functionally abandon-in-place the Boronometer and Process Radiation Monitor.
		b. Fails closed	Mechanical failure	Unable to establish flow thru boronometer and PRM. Loss of boron and radiation monitoring.	Operator	None Required	

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CHEMICAL AND VOLUME CONTROL SYSTEM (CVCS)

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
20.	Letdown flow indicator FI-202	a. False low flow indications	Electrical or mechanical malfunction	No direct impact on system operation.	Letdown Pressure PIC-201 and temperature TIC-223, or TIC-224 indications.	None Required	
		b. False high flow indication	Electrical or mechanical malfunction	No direct impact on system operation.	FI-202 alarms on hi flow indications. Letdown pressure indicators should allow assessment of false flow indication.	None Required	
→(DRN 99-1031)							
21.	Boronometer and process radiation monitor inlet control valve; 2CH-F195A/B (CH-521)	a. Fails open	Mechanical malfunction, valve operator malfunction	No impact on normal operation. Possible damage to boronometer and PRM if hi temp. letdown condition develops.	Testing. Valve position indication in control room if hi temp. condition exists.	None unless temp. is high enough to cause TIC-221 to close valve 1CH-F1516A/B and terminate letdown.	This valve is functionally Abandoned-in-place by DC 3432.
		b. Fails closed	Mechanical failure, valve operator failure, spurious signal	Loss of boronometer and process radiation monitor (PRM) effectiveness.	Flow indicator, FI-203, alarms on low flow.	None	
22.	Boronometer and process radiation monitor isolation valves; 7CH-V603 (CH-410) (CH-411) 7CH-V205-5 7CH-V205-6	a. Fails open	Mechanical failure	No impact on system operation. Unable to isolate boronometer or PRM for maintenance.	Operator	Series redundant isolation valves on boronometer/PRM line.	These valves are closed by DC 3432 to functionally Abandoned-in-place the Boronometer and Process Radiation Monitor.
		b. Fails closed	Mechanical failure	Unable to establish flow through either boronometer or PRM.	Operator	None Required	
23.	Boronometer	A. False low boron concentration indication	Electrical or mechanical malfunction	No direct impact on system operation.	Boronometer low concentration alarm and cross-check with sampling system.	Sampling system provides a backup method of determining boron concentration.	The Boronometer has been functionally Abandoned-in-place by DC 3432. Chemistry sampling is now the primary means of determining boron concentration.

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CHEMICAL AND VOLUME CONTROL SYSTEM (CVCS)

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
23.	Boronometer	False indications of high boron con-centration	Electrical or mechanical malfunction	NO direct impact on system operation.	Boronometer high concentration alarm and cross-check with sampling system	Sampling System backup.	
→(DRN 99-1031)							
24.	Process radiation monitor	a. False high radiation level indications	Electrical malfunction	No direct impact on system operation.	PRM high level alarm, iodine analysis.	Sampling System backup.	The Process Radiation Monitor has been functionally Abandoned-in-place by DC 3432.
		b. False low radiation level in-dication	Electrical malfunction	No direct impact on system operation. May not detect a fuel element failure if one occurs.	Iodine analysis.	Sampling System backup.	Chemistry sampling and Area Radiation Monitors are now the primary means of detecting high activity in the letdown piping.
25.	Flow indicator FI-203	a. False low flow alarms	Electrical or mechanical malfunction	No direct impact on system operation.	Periodic test	None	The letdown flow indicator has been functionally Abandoned-in-place by DC 3432.
		b. False high flow indication	Electrical or mechanical malfunction	No direct impact on system operation.	Periodic test	None	
26.	Boronometer/pro-cess radiation monitor outlet check valve 2CH-V676	a. Fails open	Mechanical failure	No impact on system operation.	None	None Required	This valve has been functionally Abandoned-in-place by DC 3432.
		b. Fails closed	Mechanical failure, blockage	Same as 21 b.			
27.	Process radiation monitor local sample vale	a. Fails closed	Mechanical failure	No impact on system operation. Unable to sample PRM or to flush PRM.	Operator	None Required	This valve has been functionally Abandoned-in-place by DC 3432.
		b. Seat leakage	Contamination	Release of primary coolant outside containment.	Local leak detectors, local radiation monitors, flow indicator FI-203	None Required	
←(DRN 99-1031)							

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CHEMICAL AND VOLUME CONTROL SYSTEM (CVCS)

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
→(DRN 99-1031)							
28.	Process radiation monitor primary water flush valve, 7DW-V690	a. Fails closed	Mechanical failure	No impact on system operation. Unable to flush PRM with demineralized water.	Operator	None Required	This valve has been functionally Abandoned-in-place by DC 3432.
		b. Seat leakage	Contamination	Primary coolant diverted to demineralized water system.	Low flow indication from flow indicator FI-203	Series redundant isolation valves in demineralized water system.	
29.	Deleted						
←(DRN 99-1031)							
30.	Purification filter bypass valve, 2CH-V630 (CH-355)	a. Fails closed	Mechanical failure	No impact on normal system operation. Unable to bypass filter for maintenance.	Operator	None Required	
		b. Seat leakage	Contamination	Minor letdown flow diverted past filter. Reduced filter efficiency.	Delta-P indicator PDI-202	None	
		c. Fails open	Mechanical failure	Reduced filter efficiency, reduced flow to PRM and boronometer.	Delta-P indicator, PDI-202, flow indicator, FI-203.	None	
31.	Purification filter isolation valves; 2CH-V33A/B (CH-358), 2CH-V135A/B (CH-360)	a. Fails open	Mechanical failure	No impact on system operation. Unable to isolate filter for maintenance.	Operator	None	
		b. Fails closed	Mechanical failure	Unable to reestablish flow through filter after maintenance.	Operator, Delta-P indicator PDI-202.	None	Valves are normally open manually operated.

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CHEMICAL AND VOLUME CONTROL SYSTEM (CVCS)

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
32.	Purification filter	a. Does not filter	"Punch-through" of the element	Particle buildup in ion exchangers. EVentually escessive ion exchanger Delta-P or radiation levels.	Differential pressure detector PDI-202, differntial pressure detector PDI-203, PDI-205, or PDI-207. Sampling system downstream of filter.	Ion exchanger can remove particulate matter. Filter can be isolated and repaired while maintaining letdown flow through bypass valve , 2CH-V630.	Extremely unlikely failure mode.
→(DRN 99-1031)							
	CVC-MFLT-0001	b. Blocked	Element plugged with particulate matter	Reduced letdown flow.	PDI-202 high diff. Press. alarm, FI-202 low flow indication.	Letdown flow can bypass the filter through valve 2CH-V630 (CH-355) CVC-138 while elements are being replaced.	
33.	Differential Pressure indicator PDI-202	a. Erroneous low differential pressure indications	Electrical or mechanical malfunction	No impact on system operations. May fail to detect blocked/dirty filter.	Operator	None	
		b. Erroneous high differential pressure indication	Electrical or mechanical malfunction	No impact on system operation.	No improvement when bypass valve is opened.	None	
34.	Ion exchanger air operated bypass valve, 2CH-W136A/B (CH-520) CVC-140	a. Fails in the "IX" position	Valve operator malfunction, mechanical malfunction	No direct impact on system operation. Unable to bypass ion exchangers on high temp. discharge from letdown HX. Possible damage to ion exchangers resin.	None until demand, then the valve position indicator and respective IX diff. pres. indicator, PDI-203, 205 or 207, and hi temp. alarm from TIC-224.	Alternate bypass flow paths can be manually aligned.	
←(DRN 99-1031)							
		b. Fails to the "bypass IX" position	Valve operator malfunction, mechanical failure, spurious signal, loss of air or power	Ion exchangers bypassed, buildup of fission products in primary coolant.	Valve position indicator, respective IX diff. press. indicator, PDI-203, 205, or 207	None	Feed and bleed can be u sed to control RCS chemistry and radioactivity.

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CHEMICAL AND VOLUME CONTROL SYSTEM (CVCS)

FAILURE MODE AND EFFECTS ANALYSIS

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No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
35.	Purification Ion Exchanger (IX) isolation manual valves; 2CH-V139A (CH-369), CVC-144A 2CH-V145A (CH-378) CVC-155A	a. Fails open	Mechanical failure	No direct impact on system operation. Unable to isolate IX #A when other IX placed in service.	Operator	For 2CH-V139A, none. For 2CH-V145A, can close valve 2CH-V148A/B.	
		b. Fails closed	Mechanical failure	Unable to reestablish letdown flow through IX #A.	Operator	Parallel redundant purification IXB or IXC.	Valves normally open.
36.	Ion Exchanger inlet check valves; 2CH-V140A (CH-370), CVC-146A 2CH-V144B (CH-384), CVC-146B 2CH-V142A/B (CH-403) CVC-146C	a. Fails open	Mechanical failure	No impact on normal system operation.	None	Manual isolation vavle upstream.	
		b. Fails closed	Mechanical failure	Unable to establish letdown flow through affected IX.	IX differential pressure indicator, PDI-203, 205 or 207	None	
37.	Ion exchanger manual valves; 2CH-V637 (CH-371), CVC-150A 2CH-V638 (CH-386), CVC-150B 2CH-V639 (CH-401) CVC-150C	a. Fail closed	Mechanical failure	No impact on system operation. Unable to vent IX during fill operations.	Operator	Redundant vent valves to atmosphere.	Manual valves normally open when IX is idle, closed when IX is in operation.
		b. Fails open	Seat leakage	Minor leakage of potentially radioactive gas or liquid from IX to waste management system.	Operator	Redundant normally closed vent isolation valve down-stream of IX vents to WMS designed for radioactive gases.	
38.	Ion exchanger atmospheric manual vent valves, 2CH-V669-2 CVC-149A 2CH-V669-1 CVC-149B 2CH-V669-3 CVC-149C	a. Fails closed	Mechanical failure	No impact on system operation.	Operator	Redundant vent valves to waste management system.	
		b. Seat leakage	Contamination	Minor leakage of potentially radioactive gas or liquid to atmosphere.	Local radiation monitors.	Valves are capped.	

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CHEMICAL AND VOLUME CONTROL SYSTEM (CVCS)

FAILURE MODE AND EFFECTS ANALYSIS

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No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
39.	Ion exchanger resin addition air operated valves; 2CH-F200A (CH-540), CVC-151A 2CH-F202B (CH-541), CVC-151B 2CH-F201A/B (CH-542) CVC-151C	a. Fails closed	Mechanical Failure	No impact on system operation. Unable to add resin to IX.	Operator	None Required	Manual, normally closed valves.
		b. Fails open	Seat leakage	No impact on system operation.	Operator	Resin addition lines are blind flanged.	
40.	Ion exchanger resin sluice outlet manual valves; 2CH-V157A (CH-380), CVC-152A 2CH-V159B (CH-391), CVC-152B 2CH-V158A/B (CH-400) CVC-152C	a. Fails closed	Mechanical failure	No impact on system operation. Unable to flush spent resin from IX.	Operator	None Required	Manual, normally closed valve.
		b. Fails open	Seat leakage	Leakage of primary coolant and resin to spent resin tank.	Operator	Normally closed drain valve in series (7WM-V151) at inlet of spent resin tank.	
41.	Ion exchanger resin sluice inlet manual valves; 2CH-V633 (CH-379), CVC-154A 2CH-V635 (CH-390), CVC-154B 2CH-V634 (CH-399) CVC-154C	a. Fails closed	Mechanical failure	No direct impact on system. Unable to flush resin from ion exchangers.	Operator	None Required	
		b. Seat leakage	Contamination	Leakage of primary coolant to resin sluice header.	Excessive use of makeup water.	None Required	
42.	Deleted						

←(DRN 99-1031)

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FAILURE MODE AND EFFECTS ANALYSIS

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No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
43.	Purification ion exchanger B and C header inlet valve, 2CH-V137A/B (CH-374) CVC-141	a. Fails closed	Mechanical failure	Unable to establish "single path" flow through IXB or IXC.	Operator	IXB or IXC can be used in series with IXA, which does not require use of this valve.	Normally closed manual valve.
		b. Fails open	Seat leakage	Primary coolant leakage into "Inlet header." Possible boron precipitation.	None	None Required	
44.	Purification ion exchanger B inlet manual valve 2CH-V143B (CH-383) CVC-144B	a. Fails closed	Mechanical failure	Unable to establish flow through IXB.	Operator	IXA or IXC can be used.	Only IXB can remove lithium.
		b. Fails open	Seat leakage	No impact.	Operator	IXB is isolated from letdown flow by valves 2CH-V137A/B (CH-374) CVC-141 and 2CH-V138A/B (CH-392) CVC-142.	
45.	Purification ion exchanger C inlet manual valve 2CH-V141A/B (CH-404) CVC-144C	a. Fails closed	Mechanical failure	Unable to establish flow through IXC.	Operator	Use IXA, IXB, or feed and bleed boron removal.	Normally closed-manual valve.
		b. Fails open	Seat Leakage	None	Operator	"Series redundant" valves, 2CH-V138A/B (CH-392) CVC-142, 2CH-V156A/B (CH-394) CVC-158, 2CH-V146A/B (CH-398) CVC-155C, closed.	
46.	Purification ion exchanger B and C manual inlet cross connect. 2CH-V138A/B (CH-392) CVC-142	a. Fails closed	Mechanical failure	Unable to put PIX C on line.	Operator	Flow path through valve 2CH-V156A/B (CH-394) CVC-158.	
		b. Fails open	Seat leakage	No impact on normal system operation.	Operator	Other isolation valves in header protect ion exchangers.	
47.	Isolation valve, series purification flow line manual valve 2CH-V155A/B (CH-381) CVC-156	a. Fails closed	Mechanical failure	Unable to use PIX A in series.	Operator	PIX B can be used alone.	Normally closed-manual valve.
		b. Fails open	Seat leakage	None unless PIX B or C in use without PIX A, then bypass A.	Ion exchanger differential pres- sure indicator, PDI-205.	None	

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No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
48.	Isolation Valve, series purification line isolation manual valve 2CH-V156A/B (CH-394) CVC-158	a. Fails closed	Mechanical failure	Unable to use the three ion exchangers in series.	Operator	PIX A and deborating IX can be used in series.	Normally closed-manual valve.
		b. Fails open	Seat leakage	Possible bypass of PIX C..	PIX C differential pressure indicator	Isolation valve 2CH-V149A/B.	
49.	Purification ion exchanger B outlet manual valve 2CH-V147B (CH-389) CVC-155B	a. Fails closed	Mechanical failure	Unable to put PIX B on line.	Operator	Feed and bleed operations.	Normally closed-manual valve.
		b. Fails open	Seat leakage	Long term leakage of primary coolant into IX. Possible overfill thru vent.	None	None	
50.	Purification ion exchanger C discharge outlet manual valve 2CH-V146A/B (CH-398) CVC-155C	a. Fails closed	Mechanical failure	Unable to put PIX C on line.	None	PIX A and B can be used in series.	Normally closed-manual valve.
		b. Fails open	Seat leakage	Same as 49 b.			
51.	Purification ion exchanger A and B manual outlet cross-connect 2CH-V148A/B (CH-382) CVC-157	a. Fails open	Mechanical failure	Unable to establish effective series flow through purification ion exchangers A and B.	Operator	PIX B can be used independently.	Normally open-manual valve.
		b. Fails closed	Mechanical failure	Unable to reestablish independent flow through PIX A.	Operator	Letdown flow can be diverted past ion exchangers while valve is repaired.	
52.	Purification ion exchanger B and PIX C manual outlet cross-connect 2CH-V149A/B (CH-395) CVC-159	a. Fails open	Mechanical failure	Unable to establish series flow through all three ion exchangers.	Operator	None Required	
		b. Fails closed	Mechanical failure	Unable to reestablish independent flow through PIX A or B or series flow through PIX A and B.	Operator	Same as 51 b.	

←(DRN 99-1031)

TABLE 9.3-15 (Sheet 37 of 60) Revision 12 (10/02)

CHEMICAL AND VOLUME CONTROL SYSTEM (CVCS)

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
→(DRN 99-1031)							
53.	Purification ion exchangers A, B, and C. CVC-MIX-0001A CVC-MIX-0001B CVC-MIX-0001C	a. Ineffective ion removal	Degraded resin	Primary coolant fission products concentration increases. Decreased boron removal capability at "end of cycle".		Redundant IX or feed and bleed.	
		b. Plugged	Particulate contamination	Decreased letdown flow. Decreased boron removal capability at "end of cycle".	Ion exchanger differential pressure indicators, PDI-203, 205, and 207.	Redundant IX or feed and bleed.	
	CVC-MIX-0001A CVC-MIX-0001B CVC-MIX-0001C	c. External leakage	Cracked container, corrosion, mfg. defect.	Primary coolant released out-side containment.	Local leak rate and radiation monitors, ion exchanger differential pressure indicators, PDI-203, 205, and 207.		
←(DRN 99-1031)							
54.				Deleted			
55.	Ion exchanger differential pressure indicator PDI-203, PDI-205, PDI-207	a. Erroneous Low pressure indication	Electrical or mechanical malfunction	No direct impact on system operation. Unable to detect a plugged IX.	Test	None Required	
		b. Erroneous high pressure indication	Electrical or mechanical malfunction	No direct impact on system operation. May lead to early resin change.	Periodic test. No improvement when standby IX placed on line.	None Required	
→(DRN 99-1031)							
56.	Letdown strainer inlet isolation manual valve 2CH-V150A/B (CH-415) CVC-160	a. Fails open	Mechanical failure	No impact on normal system operation. Unable to isolate letdown strainer for maintenance.	Operator	Redundant isolation valve.	Normally open-manual valve.
		b. Fails closed	Mechanical failure	Unable to reestablish letdown flow through ion exchangers.	Operator	Ion exchangers can be bypassed while valve is repaired.	
←(DRN 99-1031)							

CHEMICAL AND VOLUME CONTROL SYSTEM (CVCS)

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
57.	Differential Pressure indicator PDI-204	a. Erroneous low pressure indication	Electrical or mechanical malfunction	No impact on system operation.	Periodic Test	None Required	
		b. Erroneous high pressure indication	Electrical or mechanical malfunction	No direct impact on system operation. May lead to early maintenance on strainer.	Periodic Test Possible Hi diff. Pres. alarm	None Required	
58.	Letdown strainer	a. Plugged	Containment buildup	Reduced letdown flow.	Diff. pres. indicator PDI-204, high dp alarm.	Strainer and ion exchangers can be bypassed while strainer repaired	
		b. Fails to strain properly	"Ruptured" element	Particulates and resin possibly deposited in volume control tank. Possible contamination of charging pumps.	Same as above.	Same as above.	
		c. External leakage	corrosion, mfg. defect	Primary coolant released outside containment.	Local leak and radiation monitors.	Same as above.	
→(DRN 99-1031)							
59.	Letdown Strainer Drain valve 2CH-BV623 (CH-419)	a. Fails closed	Mechanical failure	No impact on system operation. Unable to drain strainer for maintenance.	Operator	None Required	
	CVC-162	b. Fails open	Seat leakage	Primary coolant released to spent resin tank.	Diff. press. indicator, PDI-204. Excessive use of makeup water.	None Required	
60.	Shutdown cooling purification return line isolation manual valve, 2CH-V302A/B	a. Fails closed	Mechanical failure	No impact on normal operation. Unable to use ion exchangers for purification of shutdown cooling flow.	Operator	None	
	(CH-439) CVC-164	b. Fails open	Seat leakage	Letdown flow diverted to shutdown cooling header.	None	Series redundant isolation valves in shutdown cooling system.	

←(DRN 99-1031)

TABLE 9.3-15 (Sheet 39 of 60) Revision 12 (10/02)

CHEMICAL AND VOLUME CONTROL SYSTEM (CVCS)

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
→(DRN 99-1031)							
61.	Letdown strainer isolation manual valve 2CH-V152A/B (CH-418) CVC-166	a. Fails open	Mechanical failure	No impact on normal system operation. Unable to isolate letdown strainer for maintenance.	Operator	None Required	Normally open-manual valve.
		b. Fails closed	Mechanical failure	Same as 56 b.	Operator	None	Letdown flow would have to be terminated to repair valve.
62.	Volume Control Tank Bypass air operated valve 2CH-W153A/B (CH-500) CVC-169	a. Fails open to the volume control tank	Valve operator malfunction, mechanical failure	No impact on normal system operation, but unable to bypass letdown flow to the boron management system on high level in VCT or to remove radioactivity that ion exchangers could not remove.	VCT level detectors, LIC-226, LC-227 position indicator in Control Room	None	Letdown flow would have to be terminated to repair valve
←(DRN 99-1031)							
		b. Fails to the bypass position	Valve operator malfunction, spurious signal	Unplanned release of primary coolant to boron management system. Decrease in VCT level.	VCT level detectors LIC-226, LC-227. Position indicator in Control Room.	Termination of letdown flow until valve is repaired. During bypass make-up will maintain VCT level.	
→(DRN 99-1031)							
63.	Vol. Cont. tank inlet check valve 2CH-V154A/B (CH-101) CVC-172	Fails closed	Corrosion	Inability to establish letdown flow.	Low level in vol. cont. tank alarm, LIC-226.	On low low level in VCT, charging pumps will switch suction to the refueling water tank.	
		Fails open	Contamination	None during normal system operation.	None	During VCT bypass mode of operation, potential leakage of the VCT cover gas to the BMC is prevented by valve CH-500.	
←(DRN 99-1031)							
64.	Purification ion exchanger outlet header isolation valve CVC-1661	a. Fails open	Mechanical failure	No impact on normal system operation. Primary coolant diverted to VCT during shutdown cooling purification causing possible loss of SDC during mid-loop operation	Operator	Non required.	Normally open manual valve.
		b. Fails closed	Mechanical failure	Unable to reestablish letdown flow.	Operator	None.	Letdown not required for safe shutdown of plant.

TABLE 9.3-15 (Sheet 40 of 60) Revision 13 (04/04)

CHEMICAL AND VOLUME CONTROL SYSTEM (REACTOR COOLANT PUMP CONTROLLED BLEEDOFF)

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
→(DRN 99-1031, R12)							
1.	Reactor coolant pump controlled bleedoff excess flow check valves, 2CH-V1519 (CH-301), RC-409A 2CH-V1520 (CH-302), RC-409B 2CH-V1521 (CH-303), RC-509A 2CH-V1522 (CH-304) RC-509B	a. Fail closed	High Tension spring, plugged, mechanical failure	Loss of controlled seal bleed-off for reactor coolant pump. Possible damage to RCP seals due to overheating. Pressure buildup in bleed-off line.	Flow Temp and pressure indicators and alarm on the individual bleedoff lines inside containment.		Associated RCP must be shutdown.
		b. Fail open	Mechanical failure, contamination	Possible excessive flow of high temperature primary coolant coolant into VCT. Possible thermal damage to charging system, possible pressure surge in controlled bleed-off line.	VCT temperature indicator, TI-225. Pressure indicator PI-215, high alarm.	Valve 2CH-F1512A/B (CH-505) CVC-401 can be closed terminating all bleed-off to VCT. Bleed-off will be routed to quench tank via relief valve, 2CH-R1515A/B. (CH-199) RC-603	This mode most important if ther is also concurrent RCP seal degradation, because the primary coolant system pressure is the driving force for controlled bleed-off.
←(DRN 99-1031, R12)							
→(DRN 03-2021, R13)							
2.	Pressure indicator PI-215	a. Erroneous low pressur indication	Electrical or mechanical malfunction	No direct impact on system operation.	Vapor seal cavity pressure indicators.	None Required	The pressure indicator is used to verify a minimum reactor pump seal controlled bleedoff backpressure as recommended by the RCP seal vendor. Throttling with the RCP controlled bleedoff outlet head isolation valve should not be done without checking the individual vapor seal cavity pressure indicators.
		b. Erroneous high pressure indications and alarms	Electrical or mechanical malfunctions	No direct impact on system operation.	Same as 2 a.	None Required	
←(DRN 03-2021, R13)							

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
→(DRN 99-1031)							
3.	Reactor coolant pump controlled bleedoff relief valve, 2CH-R1515A/B (CH-199) RC-603	a. Spuriously open	Setpoint drift, mechanical failure.	Unplanned release of primary coolant to quench tank.	Pressure indicator PI-215, quench tank pressure indicator.	Valve 2CH-F1514A/B (CH-507) RC-602 can be closed to isolate the relief valve.	Flashing, reduced cooling.
		b. Fails closed	Mechanical failure, blockage.	No impact on normal system operation. Loss of bleed-off header over pressure protection.	Periodic Test	None	
←(DRN 99-1031)							
→ (DRN 00-1638)							
3a.	Reactor coolant pump controlled bleed off thermal relief valve (RC-6061)	a. Fails closed	Mechanical failure. Set point drift	No impact on normal system operation. Loss of over pressure protection for the portion of the bleed off line bounded by containment isolation valves CVC-401 and RC-606.	Periodic Test	None	
		b. Fails open	Mechanical failure. Set point drift	Primary coolant discharged inside primary containment.	Excessive use of makeup water. Radiation detectors.	None	Controlled bleed off line must be isolated until relief valve is repaired or replaced.
← (DRN 00-1638)							
		c. Fails to reseat	Contamination	Seat leakage	Periodic Test	Same as 3 a.	Possible detection via quench tank pressure indicator
→(DRN 99-1031)							
4.	Reactor coolant pump controlled bleedoff relief air operated valve stop 2CH-F1514A/B (CH-507) RC-602	a. Fails open	Mechanical failure, operator malfunction.	No impact on normal system operation. Unable to isolate relief valve on a loss of AC transient resulting in reduction in primary coolant inventory.	Periodic Test	None	No serious effect on loss of A/C transient.
		b. Fails closed	Mechanical failure, valve operator malfunction, spurious signal.	NO direct impact on normal system operation. Loss of bleed-off header over pressure protection.	Valve position indicator in control room.	None	
←(DRN 99-1031)							

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
→(DRN 99-1031, R12)							
5.	Reactor coolant pump controlled bleed-off con-tainment isola-tion air operated valve,	a. Fails open	Mechanical failure, operator malfunction.	Partial loss of containment isoaltion capabaility. No impact on normal system operation.	Valve position indicator in control room, periodic test.	Manual throttle valve, 2CH-N1511A/B (CH-198) CVC-403, can be closed. Series redundant isolation valve.	Since bleed-off is to a closed system, cont. isolation is not solely dependent on the isolation valve.
	2CH-F1512A/B (CH-505), CVC-401 2CH-F1513A/B (CH-506)	b. Fails closed	Mechanical failure, valve operator malfunction, loss of power	Loss of all controlled bleed-off flow to the VCT. Possible damage to pump seals due to overheating. Pressure build-up in the bleed-off line.	Valve position indicator in control room, pressure indicator, PI-215, bleed-off flow and temp indicators.	Controlled bleed-off will be routed to the quench tank.	
→(DRN 03-2021, R13)							
6.	Reactor coolant pump controlled bleedoff Outlet Header	a. Fails closed	Mechanical failure, binding	Unable to establish controlled bleed-off flow to VCT on startup.	Operator	Startup delayed until valve repaired.	
	Isolation manual Valve, 2CH-N1511A/B (CH-198) CVC-403	b. Fails open	Mechanical failure, binding	Unable to throttle controlled bleed-off flow properly.	Operator	None	Maintaining the RCP controlled bleedoff outlet header isolation valve in the open position should ensure the back pressure is maintained as recommended by the RCP seal vendor. Throttling of the valve should not normally be required.
←(DRN 03-2021, R13)							
7.	Reactor coolant pump controlled bleedoff back-flow to the sampling system	a. Fails closed	Mechanical failure	Loss of sample system purge capability and heat exchanger pressure protection.	None Required	None Required	Sampling can not be accomplished until fault is corrected.
	check valve 2CH-V622 (CH-197) PSL-181	b. Fails open or partly open	Seal leakage, contamination	Unplanned loss of primary coolant to sampling system.	None	Series redundant check valves in sampling system.	
←(DRN 99-1031, R12)							

TABLE 9.3-15 (Sheet 43 of 60) Revision 12 (10/02)

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
→(DRN 99-1031)							
8.	Reactor coolant pump controlled bleedoff header drain to the RDH 2CH-V623-3, CVC-406	a. Fails closed	Mechanical failure	No impact on normal operation, cannot drain section of pipe for repair.	Operator	Parallel redundant drain valve.	
		b. Fails open	Seat leakage	Divert part of bleed-off flow to RDH.	RDH level indicator	None	
9.	Reactor coolant pump controlled bleedoff header vent 2CH-V623 CVC-405	a. Fails closed	Mechanical failure	No impact on system operation.	Operator	None	
		b. Fails open	Seat leakage	Divert part of the bleed-off flow	None	Capped	
←(DRN 99-1031)							
→(DRN 01-994)							
10.	Reactor coolant pump controlled bleed-off backpressure control valve (CVC-4063)	a. Fails open	Mechanical failure	Unable to throttle controlled bleed-off flow properly.	Operator	Valve can be isolated and flow can be manually throttled in a parallel path.	
		b. Fails closed	Mechanical failure	Loss of all controlled bleed-off flow to the VCT. Possible damage to pump seals due to overheating. Pressure buildup in the bleed-off line.	Press, bleed-off flow and temp indicators	Controlled bleed-off will be routed to the quench tank.	
11.	Reactor coolant pump controlled bleed-off manual backpressure control valve (CVC-4061)	a. Fails open	Mechanical failure	Unable to throttle controlled bleed-off flow properly.	Operator	Manual valve CVC-403 can be adjusted to throttle controlled bleed-off flow.	
		b. Fails closed	Mechanical failure	No impact.	None	Controlled bleed-off flow will be maintained through CVC-4063.	
12.	Reactor coolant pump controlled bleed-off backpressure control drain valves CVC-40621 CVC-40631	a. Fails open	Seat leakage	Divert part of the bleed-off flow.	None	Capped	Drain valves normally closed - manual valve
←(DRN 01-994)							

TABLE 9.3-15 (Sheet 44 of 60) Revision 12 (10/02)

CHEMICAL AND VOLUME CONTROL SYSTEM (CHEMICAL ADDITION PORTION)

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
→(DRN 99-1031)							
1.	Primary makeup water supply to the chemical addition tank. 3CH-V625 (CH-312) PMU-139	a. Fails closed	Mechanical failure, binding	Unable to add makeup water to the chemical addition tank.	Operator	None Required	Manually operated valve - normally closed.
		b. Fails open	Seat leakage	Possible leakage of makeup water to the chemical addition tank and dilution of chemical solution if make-up pumps are operating. Pressurization of the chemical addition tank.	Operator	None Required	No effect unless chemical addition is in progress.
←(DRN 99-1031)							
2.	Chemical addition tank chemical fill valve, 7CH-V625 (CH-313)	a. Fails closed	Mechanical failure	Unable to add chemicals to tank.	Operator	None Required	Manually operated valve - normally closed
		b. Fails open	Seat leakage	No impact	Operator	None Required	
3.	Chemical addition tank vent valve, 7CH-V625 (CH-447)	a. Fails closed	Mechanical failure, binding.	Unable to vent tank when filling or draining. Possible pressure buildup on fill. Possible to draw a vacuum on drain.	Operator	None Required	
		b. Fails open	Seat leak	Unable to add chemicals	Operator	None Required	
→(DRN 99-1031)							
4.	Chemical addition tank drain valve, 7CH-V625-8 (CH-310) CVC-602	a. Fails closed	Mechanical failure	No impact on normal operation unable to drain excess chemical solution, or waste solution when cleaning tank.	Operator	None Required	Drain valve normally closed - manual valve.
←(DRN 99-1031)							
		b. Fails open	Seat leakage	Unwanted loss of chemical solution to waste management system when chemical solution in tank.	None	None Required	Chemical addition tank is generally empty. Usually make up a "batch" only when required.

FAILURE MODE AND EFFECTS ANALYSIS

→(DRN 99-1031)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
5.	Chemical Addition tank CVC-MTNK-0001	a. External leakage	Mfg. defect, corrosion	Chemical solution spill. Reduced chemical addition capability (less volume available).	Operator	None Required	The chemical addition is a 18 gal. SS tank. It is generally empty. Chemical solution is made up only when it is needed, and is added to primary coolant at that time. This is not a storage tank.
6.	Chemical addition strainer and Metering Pump isolation valves 7CH-V625-7 (CH-309) CVC-603 7CH-V625-6 (CH-307) CVC-605	a. Fail closed	Mechanical failure	Unable to add chemical solution to primary coolant system	Operator	None Required	
		b. Fail open	Seat leakage	No impact	None Required	Series redundant valves	The chemical addition tank is generally empty except when making up a batch of chemical solution for addition to the primary coolant system. Therefore, both valves are generally dry.
7.	Chemical addition strainer CVC-MSTRN-0002	a. Plugged	Containment buildup	Chemical addition rate reduced. If screen completely plugged, unable to add chemical solution to primary coolant system.	Operator	None Required	
		b. Doesn't strain out contaminants	Perforated strainer element.	Small amounts of contaminants possibly released to primary coolant system.	Periodic examination	None Required	
		c. External leakage	Corrosion, Mfg. defect.	Some loss of chemical solution while adding it to the primary coolant system.	Operator	None Required	

←(DRN 99-1031)

TABLE 9.3-15 (Sheet 46 of 60) Revision 305 (11/11)

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
→(DRN 99-1031, R12)							
8.	VCT liquid backflow to the chemical addition tank check valve, 2CH-V611 (CH-308) CVC-606	a. Fails closed	Mechanical failure, blockage.	Unable to add chemical solution to primary coolant system.	Operator	None Required	
		b. Fails open	Seat leakage	Leakage of primary coolant into chemical addition line. Possible boron precipitation on valve 7CH-V625-6 (CH-307) CVC-605	Operator	None Required	
9.	Chemical addition strainer drain valve 7CH-V623 (CH-107) CVC-604	a. Fails open	Mechanical failure	Loss of chemical solution to drain header.	Operator	None Required	
		B. Fails closed	Mechanical failure	Unable to drain strainer after chemical addition.	Operator	Drain valve 7CH-V625-8 (CH-310) CVC-602	
10.	Chemical Addition Metering Pump CVC-MPMP-0002	a. Pump fails	Electrical or Mechanical	Unable to add chemical solution to primary coolant system	Operator	None Required	
←(DRN 99-1031, R12)							
→(EC-4019, R305)							
11.	Zinc Injection Skid CVC-MINJ0001	a. Component failure; Pump, Valve, Tank, Power Supply	Electrical or Mechanical	Unable to add chemical solution to primary coolant system	Operator	None required	
←(EC-4019, R305)							

TABLE 9.3-15 (Sheet 47 of 60) Revision 12 (10/02)

CHEMICAL AND VOLUME CONTROL SYSTEM (CHARGING AND VOLUME CONTROL)

FAILURE MODE AND EFFECTS ANALYSIS

→(DRN 99-1031)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
1.	Volume Control Tank (VCT) vent line Manual Isolation Valves; 3CH-V618 (CH-100), GWM-118 2CH-V604-1 (CH-102) CVC-175	a. Fails in open position or partly open	Mechanical failure, contamination	Unable to isolate vent line for Control Valve or pressure regulator valve maintenance. Seat leakage.	Operator	If Pressure Regulator Valves maintenance is required, control valve. 2CH-F185A/B, can be used for partial isolation. Also, Valves in VGSH.	
		b. Fails in closed position	Mechanical failure	Unable to vent VCT. Possible overpressurization of VCT.	Operator, High VCT Pressure Alarm	VCT relief valve 2CH-R182 A/B (CH-115) CVC-182 protects against overpressure.	This mode applies only if valves have been closed for vent line maintenance.
2.	VCT vent line control valves, 2CH-F185A/B (CH-513) GWM-112	a. Fails in closed position	Mechanical failure, valve operator malfunction	Unable to vent VCT. Possible overpressurization of VCT.	Valve position Indicator in Control Room. VCT pressure indicator, PI-225.	Same as above.	
		b. Fails in open position	Mechanical failure	Unable to automatically isolate VCT vent line to terminate venting.	Valve position indicator in Control Room. H_2 analysis at gas analyzer.	Pressure Regulator Valve 7CH-PM179A/B (CH-414) GWM-114, manual isolation valve, 2CH-V604, (CH-102) CVC-175, if not time constraint.	
3.	VCT vent line pressure regulator 7CH-PM179A/B (CH-414) GWM-114	a. Controls pressure too high	Sensor malfunction, valve operator malfunction, failure.	Possible overpressurization of VCT.	VCT pressure indicator PI-225, High Pressure Alarm.	Relief Valve, 2CH-R182A/B (CH-115) CVC-182 provides some overpressure protection for VCT.	
		b. Controls pressure too low	Sensor mal-function, valve operator mal-function, mechanical failure.	Possible overpressurization VCT. Possible excessive releases of radioactive gases, possible overpressurization of vent gas system header. Excessive use of H_2 blanket gas.	VCT pressure indicator PI-225, H_2 flow indicator FI-225. H_2 analysis of gas.	Downstream pressure control valve will close to protect VGSH. Thereby terminating "Blowdown" of VCT.	Charging pumps may trip on low suction pressure.

←(DRN 99-1031)

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
→(DRN 99-1031)							
4.	VCT vent line "Downstream" pressure regulator 7CH-PM178A/B (CH-406) GWM-116	a. Controls pressure too high	Sensor malfunction, valve operator malfunction, mechanical failure.	Possible overpressurization of VGSH.	Pressure indicator PI-225, alarm.	Relief valve at the waste gas surge tank provides overpressure protection.	
		b. Controls pressure too low	Sensor malfunction, valve operator malfunction mechanical failure.	VCT venting restricted, possible pressure buildup in VCT.	Pressure indicator PI-225, alarm	Relief valve 2CH-R182A/B (CH-115) CVC-182 provides VCT overpressure protection.	
←(DRN 99-1031)							
5.	Pressure indicator, PI-225	a. Erroneous low pressure indications or alarms	Electrical or mechanical malfunction	No direct impact on normal system operation. Possible undetected high pressure condition in VCT.	Test	VCT pressure is automatically regulated by vent valves and the blanket gas system.	
		b. Erroneous high pressure indications or alarms	Electrical or mechanical malfunction	No direct impact on normal system operation. Possible undetected low pressure condition in VCT.	Test	VCT pressure is automatically controlled by vent line pressure control valves and the blanket gas system.	
→(DRN 99-1031)							
6.	VCT to Gas Analyzer stop 2CH-V662A/B (CH-104) CVC-173	a. Fails in open position	Mechanical failure, contamination	Unable to isolate Gas Analyzer for maintenance.	Operator, periodic test	None Required	
←(DRN 99-1031)							
		b. Fails in closed position	Mechanical failure	Unable to analyze gas in VCT.	Operator	None	Applies only if valve has been closed for Gas Analyzer maintenance.
7.	VCT temperature indicator TI-225	a. Erroneous low temperature indication	Electrical or mechanical malfunction	No direct impact on normal system operation. Possible undetected high temperature condition in VCT.	Test	None Required	

TABLE 9.3-15 (Sheet 49 of 60) Revision 12 (10/02)

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
7.	VCT temperature indicator TI-225 (Cont'd)	b Erroneous high temperature indication or alarms	Electrical or mechanical malfunction	No direct impact on normal system operation. Possible undetected low temperature condition in VCT.	Test	None Required	
→(DRN 99-1031)							
8.	VCT H_2 Regulator Isolation valves; 7CH-V664-1 (CH-107), HG-202	a. Fails in open position	Mechanical failure, contamination	Unable to isolate pressure regulating valve, 7CH-V654, for maintenance. No impact on normal system operation.	Operator	None Required	
	7CH-V664-2 (CH-108) HG-204	b. Fails in closed position	Mechanical failure	Unable to provide VCT with H_2 Blanket Gas. Possible low pressure in VCT. Possible low H_2 concentration in primary coolant.	Blanket gas flow indicator, FI-225. VCT pressure indicator, PI-225, low pressure alarm.	None	
9.	VCT H_2 Pressure regulator 7CH-P654 (CH-502) HG-203	a. Controls pressure too high	Sensor malfunction, valve operator failure, mechanical failure	Possible overpressurization of VCT with H_2. Possible High H_2 concentration in Primary coolant.	Blanket Gas flow indicator FI-225. High Pressure alarm from Pressure Indicator PI-225.	The VCT pressure regulating vent valves will attempt to maintain VCT at required pressure after operator opens valve 2CH-F185A/B (CH-513) GWM-112.	Relief Valve 2CH-R182A/B (CH-115) CVC-182 prevents overpressure.
←(DRN 99-1031)							
		b. Controls pressure too low	Sensor malfunction, valve operator failure, mechanical failure	Possible underpressure condition in VCT. Possible decrease in primary coolant H_2 concentration. See Remarks.	Blanket Gas flow indicator FI-225, Low Pressure alarm from Pressure Indicator, PI-225.	VCT vent line pressure regulating valve 3CH-PM179A/B will close to prevent further pressure drop.	A spurious low pressure condition in the VCT will cause all charging pumps to trip on suction pressure.
→(DRN 99-1031)							
10.	VCT N_2 Regulator Isolation valves; 7CH-V664-3 (CH-109), NG-222	a. Fails in closed position	Mechanical failure system.	No impact on normal system operation. Unable to purge VCT to waste management.	None	Two series redundant valves plus a pressure regulating valve.	
	7CH-V664-4 (CH-110) NG-224	b. Fails partly open	Contamination	Possible inadvertent release of N_2 to the VCT. Reduced H2 concentration in primary coolant. Seat leakage.			
←(DRN 99-1031)							

TABLE 9.3-15 (Sheet 50 of 60) Revision 12 (10/02)

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
→(DRN 99-1031)							
11.	VCT N_2 pressure Regulator 7CH-P655 (CH-503) NG-223	a. Regulates pressure too high	Sensor malfunction, valve operator failure.	No impact on normal system operation. Possible over-pressurization of VCT during purge.	Flow indicator, FI-225. High pressure alarm from pressure indicator PI-225.	VCT is open to waste management system during purge. Pressure regulating valves in vent line will tend to reduce overpressure.	
←(DRN 99-1031)							
		b. Regulates pressure too low	Sensor malfunction, valve operator failure, mechanical failure.	No impact on normal system operation. Possible incomplete purge of VCT.	Flow indicator, FI-225. Low Pressure alarms or indica- tions from pressure indicator PI-225.	None	
→(DRN 99-1031)							
12.	VCT gas relief valve 7CH-R186 (CH-105) CVC-178	a. Fails in closed position	Mechanical failure, Blockage, set point drift.	No impact on normal system operation. Loss of over-pressure protection for Blanket Gas and purge header.	Periodic Test	None	
		b. Spuriously opens	Mechanical failure, set-point drift	Loss of H_2 or N_2 to vent gas system header.	Flow indicator FI-225.	None	Check Valve 2CH-V607 (CH-112) CVC-177 will prevent blowdown of VCT if this failure occurs.
←(DRN 99-1031)							
		c. Fails to reseat	Contamination	Loss of H_2 or N_2 to vent gas system header.	Periodic test, possibly waste gas surge tank pressure indicator	None	
13.	Blanket Gas and purge header flow indicator, FI-225	a. Erroneous low flow indications.	Electrical or mechanical malfunction	No impact on system operation.	Possibly Pressure Indicator PI-225	None Requried	FI-225 has no control function. Is indicator only.
		b. Erroneous high flow indications	Electrical or mechanical malfunction	No impact on system operation.	Possibly Pressure Indicator, PI-225.	None Required	
→(DRN 99-1031)							
14.	VCT gas line liquid backflow check valve 2CH-V607 (CH-112) CVC-177	a. Fails in closed position.	Mechanical failure, blockage	Unable to add N_2 or H_2 to VCT Possible decrease in VCT pressure. Possible decrease in primary coolant H2 concentration. Unable to purge VCT.	Flow Indicator FI-225, possibly pressure indicator PI-225.	None	Charging pump, may trip on low suction pressure
←(DRN 99-1031)							

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
→(DRN 99-1031)							
14.	Blanket Gas and purge header check valve, 2CH-V607 (CH-112) CVC-177 (Cont'd)	b. Fails open or partly open	Contamination	Possible back leakage of radioactive gases into blanket gas and purge header possible pressurization of header by VCT.	None	The pressure regulating valves in the header should prevent contamination of the H_2 & N_2 supplies. Relief valve, 7CH-R186 (CH-105) CVC-178, provides over-pressure protection.	
←(DRN 99-1031)							
15.	VCT level indicator controller, L-226	a. Erroneous low level indication or alarm	Electrical or mechanical malfunction	Potential over-filling of VCT with Boric Acid solution or makeup water from boron addition subsystem	None	On high VCT level controller LC-227 will switch letdown flow to waste management system.	
		b. Erroneous high level indication or alarm	Electrical mechanical malfunction	Early termination of makeup flow. Normal primary coolant system losses not compensated for with makeup. Possible gradual emptying of VCT.	None	On low-low VCT level, level controller, LC-227, will switch the charging pump suction from the VCT to the refueling water storage pool (RWSP).	
→(DRN 99-1031)							
16.	VCT level control, LC-227	a. Erroneous low-low level alarm	Electrical or mechanical malfunction	Possible Inadvertent Transfer of charging pump suction from VCT to RWSP and letdown flow to the waste management system.	Comparison with level indicator, LI-226	VCT level indicator LI-226	
←(DRN 99-1031)							
		b. Erroneous high level indications	Electrical or mechanical malfunction	Possible inadvertent diversion of letdown flow to waste management system. Potential emptying of VCT.	Level indicator, LI-226	On low VCT level, level indicator, controller, LIC-226, will initiate makeup flow.	
→(DRN 99-1031)							
17.	VCT local sample valve, 2CH-V608-2 (CH-116) CVC-180	a. Fails in closed position	Mechanical failure	Unable to obtain local sample of VCT contents.	Operator	None Required	
		b. Fails partly open	Seat leakage, contamination	Local spill, outside contain-ment, of radioactive primary coolant. Gradual loss of inventory from VCT.	Local spill and radiation monitors, possibley VCT level sensor indication/ actuation LIC-226, LC-227	Valves in sample system act as a backup.	
←(DRN 99-1031)							

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
→(DRN 99-1031)							
18.	VCT Drain Valve, 2CH-V608-3 (CH-117) CVC-181	a. Fails in closed position	Mechanical failure	No impact on normal operation, unable to drain VCT.	Operator	None Required	
←(DRN 99-1031)							
		b. Fails partly open	Contamination	Gradual loss of primary coolant inventory to boron management system.	Possibly VCT level sensors indication/ actuation LIC-226, LC-227.	Boron addition subsystem compensates for minor coolant losses.	
→(DRN 99-1031)							
19.	VCT liquid Relief Valve 2CH-R182A/B (CH-115) CVC-182	a. Fails in closed position	Mechanical failure, blockage, set-point drift.	No impacts on normal system operation. Loss of VCT, discharge line overpressure protection.	Periodic Test	VCT will act as a Pressure Surge Tank for a short period.	
←(DRN 99-1031)							
		b. Spuriously opens	Setpoint drift, Mechanical failure	Minor loss of primary coolant inventory to hold-up tank.	Possibly VCT level sensors indication/ actuation LIC-226, LC-227.	Boron addition subsystem will compensate for minor coolant losses.	
		c. Fails to reseat	Contamination	Minor loss of coolant to hold-up tank.	Same as 19b.	Same as 19b.	
→(DRN 99-1031)							
20.	VCT outlet air operated valve 2CH-V123A/B (CH-501) CVC-183	a. Fails in open position on close signal	Mechanical failure, valve operator malfunction	Possible emptying of VCT. Possible air aspiration into charging pumps suction.	Valve position indicator in control room, possibly VCT level sensors indication/ actuation LIC-226, LC-227.	Charging pump suction is switched to RWSP or BAMTs if 2CH-V123A/B (CH-501) CVC-183 is signaled closed. These water sources may be sufficient to prevent air aspiration into charging pumps.	
		b. Fails to the closed position	Spurious signal, mechanical failure, valve operator malfunction.	Loss of charging flow. Loss of charging pump suction.	Charging pump suction pressure switch shuts off pumps. Valve position indicator in control room. Low charging flow alarm.	Charging pump suction can be manually switched to RWSP from control room. Pumps are protected by low suction pressure trips.	
		c. Fails in closed position	Mechanical failure valve operator malfunction	Unable to establish charging flow from VCT.	Valve position indicator in control room.	Charging pumps can take suction from the RWT through valve, 3CH-V121A/B. (CH-504) CVC-507	Normal charging flow is from the VCT, so this valve is generally open.
←(DRN 99-1031)							

FAILURE MODE AND EFFECTS ANALYSIS

→(DRN 99-1031)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
21.	VCT outlet check vavle 2CH-V124A/B (CH-118) CVC-184	a. Fails in closed position	Mechanical failure, blockage	Unable to establish charging flow from VCT.	Charging pump suc-tion pressure switch shuts off pumps. Low charging flow alarm	Charging pump suction can be switched to RWSP from control room.	Pumps are protected by low suction pressure trip.
		b. Fails in open position or partly open	Contamination	Potential back leakage into VCT Discharge Lines when charging pumps are taking suction from BAMT or RWSP.	None	Valve 2CH-V123A/B (CH-501) CVC-183 provides positive isolation for line.	
22.	Refueling water storage pool to charging pump suction check valve 2CH-V129A/B (CH-191) CVC-508	a. Fails in closed position	Mechanical failure, blockage	Unable to switch charging pump suction from VCT to RWSP on low VCT level. Loss of charging flow.	Low suction pressure switch from charging pump suction pressure controllers shuts off pumps. Low charging flow alarm from flow indicator FI-212.	Charging pump suction pressure controllers will stop charging pumps on low suction pressure.	In case of emergency charging pump suction can be switched to BAMTs from control room.
		b. Fails partly open	Contamination	Potential back leakage of primary coolant in RWSP when charging from VCT.	None	RWSP suction line isolation valve 3CH-V121A/B (CH-504) CVC-507 provides positive isolation for RWSP.	
23.	Refueling water storage pool to charging pump suction isolation air operated valve, 3CH-V121A/B (CH-504) CVC-507	a. Fails in closed position	Mechanical failure, operator malfunction	Same as 22 a.	Same as 22 a, plus valve position indicator in control room.	Same as 22 a.	Same as 22 a.
		b. Fails partly open, or fails to the open position	Seat leakage or spurious signal, valve operator malfunction, mechanical failure	Unwanted addition of refueling water to primary system. Loss of RWSP Inventory. Increase in boron concentration in primary system.	Eventually - RWT Level Indicators and alarms, also, for "fails to open position" - valve position indicator in control room.	Manual isolation valve. 3CH-V122A/B (CH-192) CVC-504 can be closed until valve 3CH-V121A/B (CH-504) CVC-507 is repaired.	

←(DRN 99-1031)

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FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
→(DRN 99-1031)							
24.	RWSP to charging pump isolation manual valve 3CH-V122A/B (CH-192) CVC-504	a. Fails in open position	Mechanical failure	No impact on normal operation Unable to isolate line for maintenance.	Operator	None	
		b. Fails in closed position	Mechanical failure	Same as 22 a.	Operator	None	CH-192 is normally open-manually operated valve. It is closed only for line maintenance.
25.	Charging pump suction header relief valve, 2CH-R184A/B (CH-311) CVC-185	a. Opens spuriously	Mechanical failure, setpoint drift.	Gradual loss of primary to boron management system.	Equip. drain. Sump #1. Level 1	The makeup control automatically compensates for minor losses.	
←(DRN 99-1031)							
		b. Fails in closed position	Mechanical failure, blockage, setpoint drift.	No impact on normal operation. Loss of overpressure protection for a potentially closed line section.	Periodic Test	None	
		c. Fails to reset	Contamination	Same as 25 a.	Periodic Test	None	
→(DRN 99-1031)							
26.	Charging pump isolation manual valve pairs, suction and discharge; 2CH-V125A (CH-316), CVC-188A 2CH-V1501-4 (CH-339), CVC-196A 2CH-V127A/B (CH-319), CVC-188AB 2CH-V1501-2 (CH-337), CVC-196AB 2CH-V126B (CH-322), CVC-188B 2CH-V1501-1 (CH-336) CVC-196B	a. Fails in open position	Mechanical failure	Unable to isolate affected pump for maintenance test.	Operator	None	
		b. Fails in closed position	Mechanical failure	Unable to establish charging flow through affected pump after maintenance test.	Operator	None	
←(DRN 99-1031)							

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
→(DRN 99-1031)							
27.	Charging pump drain valve pairs, suction and discharge;	a. Fails in closed position	Mechanical failure	Unable to drain affected pump for maintenance	Operator	None	
	2CH-V608-4 (CH-317), CVC-189A 2CH-V1504-9 (CH-329), CVC-193A 2CH-V608-5 (CH-320) CVC-189AB 2CH-V1504-10 (CH-332), CVC-193AB 2CH-V608-6 (CH-323), CVC-189B 2CH-V1504-11 (CH-335) CVC-193B	b. Fails partly open	Contamination	Gradual loss of primary coolant and reduction of VCT level. Also, for dishcarge drain valve, minor reduction in charging flow.	Equip. drain. Sump #1 level	Same as 25 a.	
←(DRN 99-1031)							
28.	Charging pump suction pressure indicator con-trollers, PC-224 X, Y, Z	a. Erroneous high pressure indications	Electrical or Mechanical Malfunction	Loss of protection for the charging pump on low suction pressure.	Suction pressure indicators on other charging pumps.	Redundant charging pumps.	
		b. Erroneous low pressure indications	Electrical or Mechanical Malfunctions	Charging pumps shutoff on low suction pressure.	Charging line flow indicator FI-212. Suction pressure indicators on other charging pumps.	Redundant charging pumps - started by pressurizer level controls.	
→(DRN 99-1031)							
29.	Charging pump discharge check valves; 2CH-V1502-1 (CH-328), CVC-194A 2CH-V1502-2 (CH-331), CVC-194A/B 2CH-V1502-3 (CH-334) CVC-194B	a. Fails in closed position	Mechanical failure, blockage	Unable to establish charging flow through affected pump.	Charging line flow indicator FI-212	Redundant charging pumps, plus discharge safety relief valve provides overpressure protection for affected pump.	
←(DRN 99-1031)							

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
→(DRN 99-1031)							
29.	Charging pump discharge check valves; 2CH-V1502-1 (CH-328), CVC-194A 2CH-V1502-2 (CH-331), CVC-194A/B 2CH-V1502-3 (CH-334) CVC-194B (Cont'd)	b. Fails partly open	Contamination	No impact on normal operation. Some back leakage of primary coolant into standby charging pumps.	None	None Required.	
30.	Charging pump discharge pressure relief 2CH-R1526A (CH-326), CVC-192A 2CH-R1527A/B (CH-325), CVC-192AB 2CH-R1528B (CH-324) CVC-192B	Spuriously opens	Set-point drift	Part of charging pump discharge diverted back to the pump suction. Reduced charging flow.	Low flow indication from charging flow indicator FI-212.	Redundant charging pumps available for use.	
		b. Fails in closed position	Mechanical failure, blockage	No immediate impact on system. Loss of overpressure protection for affected pump's discharge line. Loss of Min-flow by pass recirculation capability for pump.	Periodic Test	None	
		c. Fails to reseat	Contamination	Same as 30 a.	Periodic Test	None	
31.	Charging pumps, CP-A, B, A/B CVC-MPMP-0001A CVC-MPMP-0001AB CVC-MPMP-0001B	a. Operating pump fails	Electrical or Mechanical seal failure, low NPSH	Loss of charging flow. Low pressurizer level. High letdown temp.	Charging flow indicator FI-212, low flow alarms, low pressure alarm from PI-212. Low pressurizer level. Abnormal RHX letdown temp.	2 additional redundant pumps.	
←(DRN 99-1031)							
		b. Standby pump fails to start	Electrical or Mechanical failure	Unable to meet charging requirement in excess of 1 pump capacity. Unable to establish charging flow from affected pump.	Pump run indicator in control room, flow indicator, FI-212.	Redundant standby pump available	

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
	Charging pumps, CP-A, B, A/B CVC-MPMP-0001A CVC-MPMP-0001AB CVC-MPMP-0001B (Cont'd)	c. Spurious start of standby pump	Electrical Malfunction, switching failure	Sudden excess charging flow rate. Possible inventory reduction in VCT. Possible increase in pressurizer level. Rapid change in boron concentration in RCS is a dilution or addition is in progress.	Charging flow indicator, FI-212, charging pressure indicator, PI-212, possibly VCT and pressurizer level indicators. Pump "run" indicator in control room. RHX letdown temp. decrease.	Pressurizer level control will increase letdown flow and/or turn off one charging pump.	
→(DRN 99-1031)							
32.	Charging pump discharge cross-connect 2CH-V1501-3 (CH-338) CVC-203	a. Fails in open position	Mechanical failure	Unable to pressure test HPSI system while charging is in progress.	Operator	None	
		b. Fails in closed position	Mechanical failure	Effective loss of one charging pump.	Operator	2 redundant charging pumps.	
33.	Charging pump/ HPSI pump header isolation valve, 2CH-V1501-5 (CH-340) CVC-199	a. Fails closed	Mechanical failure	Unable to test HPSI system with charging pumps, unable to use HPSI header for charging with the charging pumps.	Operator	None	
		b. Fails partly open	Contamination	Seat leakage. Possible inadvertent pressurization of HPSI header.	Pressure Indicators on HPSI headers	Pressure relief valves on HPSI headers.	
34.	Charging pump to HPSI header check valve, 2CH-V1502-4 (CH-440) CVC-202	a. Fails in closed position	Mechanical failure	Same as 34 a.	Pressure Indicators on HPSI headers	None	
		b. Fails partly open	Contamination	Seat leak. No impact on system	None	Line is isolated by valve CH-340	
35.	Charging pressure indicator PI-212	a. Erroneous low pressure indications or alarms.	Electrical or mechanical malfunction	No direct impact on system	Flow indicator, FI-212.	None	
		b. Erroneous high pressure indications	Electrical or mechanical malfunction	NO direct impact on system.	Flow indicator, FI-212.	None	
←(DRN 99-1031)							
36.	Charging Line Flow Indicator, FI-212	a. Erroneous low flow indications or alarms.	Electrical or mechanical malfunction	No direct impact on system operation or control.	Pressure Indicator PI-212. Pressurizer level indicator and letdown flow instru-ment, F-202.	None Required	

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
	Charging Line Flow Indicator, FI-212 (Cont'd)	b. Erroneous high flow indications	Electrical or mechanical malfunctions	NO direct impact on system operation or control.	Pressure Indicator, PI-212. Pressurizer level indicator and letdown flow instrument, F-202.	None Required	
→(DRN 99-1031)							
37.	Charging pump discharge header manual stop valve; 2CH-V1506 (CH-429) CVC-208	a. Fails in open position	Mechanical failure	No impact on normal operation. Unable to isolate charging line for maintenance.	Operator	Depending on conditions, could use charging pump manual isolation valves.	
		b. Fails in closed position	Mechanical failure	Unable to re-establish charging through normal path. Loss of letdown.	Operator	Can charge through HPSI headers if required.	
38.	Charging line isolation air operated valve outside contain-ment 2CH-F1529A/B (CH-524) CVC-209	a. Fails in closed position	Mechanical failure, spurious signal	Unable to establish charging flow through normal path.	Flow indicator FI-212, pressure in-dicator, PI-212, low alarms. Valve position indicator.	Can charge through HPSI headers if required.	
		b. Fails open	Mechanical failure, loss of air or power	Unable to isolate charging line to pressure test HPSI system	Valve position indicator	Manual isolation valve 2CH-V1506 (CH-429) CVC-208	
←(DRN 99-1031)							
39.	Charging Line temperature in-dicator, TI-229	a. Erroneous low temperatur readings	Electrical or mechanical malfunction	No direct impact on normal system operation or control.	Temperature indica-tor, TI-221.	None Required	
		b. Erroneous high temperature indica-tions.	Electrical or mechanical malfunction	No direct impact on normal system operation or control.	Temperature indica-tor, TI-221.	None Required	
→(DRN 99-1031)							
40.	Auxiliary Spray solenoid valves, 1CH-E2505A (CH-517) CVC-ISV-0216A 1CH-E2505B CVC-ISV-0216B	a. Fails in closed position	Loss of Power, Mechanical fail-ure, valve oper-ator malfunction.	Loss of one auxiliary spray path	Valve position indi-cators in control room.	Two redundant auxiliary spray paths.	
		b. Fails open	Valve operator malfunction, spurious signal.	Possible inadvertent depress-urization of primary system.	Pressurizer level and pressure indica-tors and alarms.	None	Valves are normally locked closed.

←(DRN 99-1031)

TABLE 9.3-15 (Sheet 59 of 60) Revision 12 (10/02)

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
→(DRN 99-1031)							
41.	Auxiliary spray check valves, 1CH-V2502-1 (CH-431) CVC-217A 1CH-V2502-4 CVC-217B	a. Fails closed	Mechanical failure, blockage	Loss of one auxiliary spray flow path.	Possibly flow indicator, FI-212, pressure indicator, PI-212, Temperature indicator TI-224, or high pressurizer pressure.	Two redundant parallel auxiliary spray valves.	
		b Fails partly open	Contamination	Possible back leakage of pressurizer spray flow into auxiliary spray line. No impact on system operation.	None	Auxiliary spray valves are normally closed, providing isolation.	
42.	Charging isolation solenoid valves; 1CH-E2503A (CH-519), CVC-ISV-0218A 1CH-E2504B (CH-518) CVC-ISV-0218B	a. Fails closed	Loss of power, Mechanical failure, valve operator malfunction	Loss of one primary charging path.	Valve position indicator in control room, pressure indicator, PI-212	Two redundant primary charging paths.	
		b. Fails open	Mechanical failure, valve operator malfunction.	Unable to terminate charging flow to one charging line. Reduced aux. spray during cooldown operations when RCP';s are secured.	Valve position indicator in control room. Pressure indicator, PI-212	Terminate total charging flow at some point upstream.	
43.	Charging Line check valves; 1CH-V2502-2 (CH-432) CVC-221B 1CH-V2502-3 (CH-433) CVC-221A	a. Fails in closed position	Mechanical failure, blockage	Loss of one primary charging path.	Pressure indicator, PI-212.	Two redundant primary charging paths.	
		b. Fails partly open	Contamination	No impact on normal operation. Possible back leakage of primary coolant into charging lines when charging not in progress.	None	Charging control valves provide positive isolation.	
44.	Charging Line swing-check valve; 1CH-V2506 (CH-435) CVC-219	a. Fails partly open	Contamination	No impact on normal system operation. Possible back leakage of primary coolant into charging lines when charging not in progress.	None	Check valve 1CH-V2502-3 (CH-433) CVC-221A will limit back leakage through 1CH-V2506 (CH-435) CVC-219	
←(DRN 99-1031)							
		b. Fails in closed position	Mechanical failure, blockage	Loss of thermal relief protection for charging line when charging control valves are closed.	None	None	

FAILURE MODE AND EFFECTS ANALYSIS

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Remarks
→(DRN 99-1031)							
45.	1CH-E2503A CH-519 CVC-ISV-0218A bypass isolation valve; 1CH-V2507 (CH-434) CVC-220	a. Fails in open position	Mechanical failure	Unable to isolate charging line bypass swing-check valve for maintenance.	Operator	None	
		b. Fails in closed position	Mechanical failure	Same as 44 b.	Operator	None	
			Operator Error	Same as 44 b.			
46.	Charging Line drain valves, 2CH-V1504-14 CVC-210 2CH-V1504-6 CVC-200 2CH-V1547 CVC-204 2CH-V1508-2 CVC-215	a. Fail in closed position	Mechanical failure	No impact on normal system operation. Unable to drain a section of the charging line for maintenance.	Operator	None Required.	
		b. Seat leakage	Contamination	Primary coolant released to drain headers	Excessive use of makeup water. Possible indications from charging line flow and pressure indicators.	None	
47.	Charging pump discharge pulsation dampeners; CVC-MACC-0001A CVC-MACC-001B CVC-MACC-0001A/B	Fails to damp pressure pulses on pump startup	Mechanical failure	Pressure Pulse transients in chargine line. Possible damage to downstream equipment.	Erratic indications on PI-212 and FI-212, noise.	None Required.	Problem serious only if repeated pump starts are made with a failed pulsation dampeners.
←(DRN 99-1031)							
48.	CVCS CHRG PUMPS RECIRC & RELIEF LINE VENT VALVES CVC-1922A CVC-1922B CVC-1922A/B	a. Fails in closed position	Mechanical failure	No impact on normal operation	none	None Required.	Vent valve normally closed manual valve.
		b. Fails partly open	Seat leakage	Unwanted loss of boric acid to waste management system	none	Line capped downstream	

FAILURE MODE AND EFFECTS ANALYSIS
SHUTDOWN COOLING SYSTEM (SDCS)

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This FMEA covers failures that impact the function and operation of the Shutdown Cooling System (SDCS). Specifically, failures are considered which impact the operator's ability to initiate one or both trains of SDC or which impact core decay heat removal once the system is in operation. Refer to FSAR Table 6.3-1 for a FMEA of the Safety Injection System.

No	Name[1]	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Effect Upon	Remarks and Other Effects
1.	SDCS suction isolation valve 1SI-V1504A (SI-652), 1SI-V1502B (SI-666), 1SI-V1503A (SI-651), 1SI-V1501B (SI-665), 2SI-V327A (SI-440), 2SI-V326A (SI-441)	a. Fails to open	Mechanical binding, operator malfunction	Cannot initiate one train of SDC	Valve position indication in control room	Redundant flow train available. Operator must maintain at least one RCS loop (with SG and RCP) operable	Decreased cooldown rates	See plant Technical Specifications for SDCS/loop operability requirements
		b. Inadvertently closed	Operator error	Loss of one train of SDC	SDC trouble alarm in control room	Redundant decay heat removal success paths. Operator restores SDC flow.	N/A	Technical Specifications permit only one SDC train to be operable in Mode 6 provided water level is ≥ 23 feet above reactor flange
2.	Relief valves 1SI-R2501A (SI-469), 1SI-R2502B (SI-464), 2SI-R339A (SI-486), 2SI-R340B (SI-487), 2SI-R614A (SI-468), 2SI-R612B (SI-478)	a. Fails to open	Mechanical binding, blockage	Possible over-pressurization of SDCS piping and/or RCS	Operator	Redundant relief path available for LTOP valves	N/A	
		b. Fails to reseat	Seat leakage, spring failure	Loss of primary coolant to drain header (or containment sump) during shutdown cooling. Possible loss of SDC.	RWLIS, RCSLMS, RCS pressure	None required. One train of SDC would be degraded, but the redundant train would be available	N/A	

[1] Valve tag numbers (SI-XXX) in this Table are CE valve numbers.
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FAILURE MODE AND EFFECTS ANALYSIS
SHUTDOWN COOLING SYSTEM (SDCS)

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No	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Effect Upon	Remarks and Other Effects
3.	SDCS suction line drain and vent valves to SDC vacuum priming pumps 1SI-V2503-1, -2, -3, -4	a. Fails in closed position	Mechanical binding	Unable to vent gases at system high point	Operator	Redundant decay heat removal success paths in the event flow cannot be established due to gas binding	N/A	
		b. Inadvertently opened	Operator error	Leakage of primary coolant inside containment	Operator	Two series redundant valves prevent inadvertent flow	N/A	
4.	Return cross over valves 2SI-V353A (SI-400), 2SI-V346B (SI-450)	a. Fails to open	Mechanical binding	Unable to initiate pre-shutdown cooling warm-up recirculation cycle for one line	Operator	Redundant shutdown cooling line	N/A	
		b. Inadvertently opened	Operator error	A portion of shutdown cooling flow will short circuit the core through the warm up lines	Operator	Redundant decay heat removal success paths. Operator restores SDC flow	N/A	
5.	Manual isolation valves 2SI-V303A/B (SI-442), 2SI-V352 (SI-479)	a. Fails in open position	Mechanical binding	Unable to isolate SDCS line for maintenance	Operator	None required	N/A	
		b. Inadvertently closed	Operator error	Loss of one SDCS suction line	SDC trouble alarm in control room	Redundant decay heat removal success paths. Operator restores SDC flow.	N/A	Manual valves, normally locked open

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FAILURE MODE AND EFFECTS ANALYSIS
SHUTDOWN COOLING SYSTEM (SDCS)

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No	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Effect Upon	Remarks and Other Effects
6.	Shutdown cooling suction line sample valves 2SI-F624A (SI-443), 2SI-F623B	a. Fails in closed position	Mechanical binding, valve operator	No impact on SDC. Unable to sample SDC suction line.	Local valve position indicator	None required	N/A	
		b. Inadvertently opened	Operator error	No impact on SDC function	Operator	Series redundant isolation valve in sampling system prevents inadvertent flow	N/A	
7.	CVCS shutdown purification line isolation valves 2SI-V341A, 2SI-V342B	a. Fails in closed position	Mechanical binding	Unable to purify shutdown cooling flow	Operator	None required	N/A	
		b. Inadvertently opened	Operator error	No impact on SDC function	None	Series redundant isolation valves in CVCS prevent inadvertent flow	N/A	
8.	LPSI suction line isolation valves 2SI-B301A (SI-444), 2SI-B302B (SI-432)	Fails in open position	Mechanical binding	Possible to draw partial suction from RWSP or containment sump during shutdown cooling	Operator, possibly RWSP level alarms	Redundant isolation valves in RWSP and containment sump lines	N/A	

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FAILURE MODE AND EFFECTS ANALYSIS
SHUTDOWN COOLING SYSTEM (SDCS)

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No	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Effect Upon	Remarks and Other Effects
9.	LPSI pump A, B	Fails	Electrical, mechanical failure	Loss of one SDC train	SDC trouble alarm in control room	Redundant decay heat removal success paths	Decreased cooldown rates	Technical Specifications permit only one SDC train to be operable in Mode 6 provided water level is ≥ 23 feet above reactor flange
10.	LPSI pump discharge check valves 2SI-V333A (SI-433), 2SI-V334B (SI-423)	a. Fails in closed position	Mechanical binding, blockage	Unable to establish shutdown cooling flow through one LPSI pump	Low flow indication from flow indicator controller SI IFIC0306, -307	Redundant parallel LPSI pump and shutdown cooling line	N/A	
		b. Fails in open position	Mechanical binding, blockage	No impact on shutdown cooling	None required	None required	N/A	
11.	LPSI pump discharge isolation valves 2SI-V309A (SI-446), 2SI-V310B (SI-434)	a. Fails in open position	Mechanical binding	No impact on shutdown cooling. Unable to isolate one LPSI pump for maintenance.	Operator	None required	N/A	
		b. Inadvertently closed	Operator error	Unable to establish shutdown cooling flow through one LPSI pump. Loss of one SDC train.	Operator, SDC trouble alarm in control room	Redundant decay heat removal success paths	N/A	This is a manual valve that is normally locked open

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FAILURE MODE AND EFFECTS ANALYSIS
SHUTDOWN COOLING SYSTEM (SDCS)

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No	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Effect Upon	Remarks and Other Effects
12.	SDC HX isolation valves (motor) 2SI-V306A (SI-452), 2SI-V305B (SI-453), 2SI-V307A (SI-457), 2SI-V308B (SI-456)	a. Fails in closed position	Mechanical binding	Unable to establish shutdown cooling flow through one heat exchanger	Operator	Redundant heat Exchanger	N/A	Locked closed valves
		b. Inadvertently closed	Operator error	Loss of one SDC train	SDC trouble alarm in control room	Redundant decay heat removal paths. Operator restores SDC flow.	N/A	
13.	SDC HXs CS MHX0001A, B	a. Inefficient heat removal	Low CCW flow, containment buildup, Partial blockage of tubes	Reduced cooldown rate	Differential temperature – recorders SI ITR0351, -352; temperature indicators CS ITI0303X, Y	Flow through heat exchanger can be increased by operator to compensate for reduced cooldown rate	N/A	
		b. Excessive heat removal	High CCW flow rate, low CCW temperature	Increased cooldown rate. Possible thermal shock to primary coolant system.	Differential temperature recorders SI ITR0351, -352; temperature indicators CS ITI0303X, Y	Flow through heat exchanger can be decreased by operator to compensate for high cooldown rate	N/A	
		c. Cross leakage	Corrosion, manufact. defects	Contamination of CCW system with primary coolant	Radiation monitors in CCW system	HX can be isolated and SDC completed using remaining HX	N/A	
14.	Pressure Transmitters CS IPT0303X, Y	Erroneous pressure indication	Electrical or mechanical failure	No impact on SDC. Backup process monitor only	Operator	None required	N/A	

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FAILURE MODE AND EFFECTS ANALYSIS
SHUTDOWN COOLING SYSTEM (SDCS)

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No	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Effect Upon	Remarks and Other Effects
15.	Temperature indicators CS ITI0303X,Y	Erroneous temperature indication	Electrical or mechanical failure	No impact on SDC. Backup process monitor only	Operator	None required	N/A	
16.	Isolation valves 2SI-V344A, 2SI-V343B	a. Fails in closed position	Mechanical binding	Unable to divert portion of shutdown cooling flow to CVCS for purification. No impact on SDC function.	Operator	Flow can be diverted to CVCS from the other SDC line	N/A	
		b. Inadvertently opened	Operator error	Portion of SDC flow diverted to CVCS. No impact on SDC function.	Operator	Series redundant valve in CVCS prevents inadvertent flow	N/A	
17.	Isolation valves 2SI-V345A, 2SI-V319B	a. Fails in closed position	Mechanical binding	No impact on SDC	None required	None required	N/A	
		b. Inadvertently opened	Operator error	Portion of SDC flow diverted to RWSP. Loss of primary coolant inventory.	RWLIS/RCSLMS, RCS pressure, flow indication in drain line to RWSP	Redundant SDC train available. Operator isolates flow path and restores RCS inventory	N/A	Normally closed, locked closed manual valves
18.	SDC control valves 2SI-FM318A (SI-657), 2SI-FM349B (SI-656)	a. Fails to open	Mechanical binding, valve operator malfunction	Unable to establish SDC flow through one heat exchanger	Valve position indicator in control room	Redundant decay heat removal success paths	Decreased cooldown rates	
		b. Controls flow through heat exchanger too low	Erroneous position indication	Reduced flow through one heat exchanger. Reduced cooldown rate.	Low differential temperature indication from SI ITR0351, -352	Redundant SDC line. Operator can throttle valve to get desired differential temperature.	N/A	

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FAILURE MODE AND EFFECTS ANALYSIS
SHUTDOWN COOLING SYSTEM (SDCS)

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No	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Effect Upon	Remarks and Other Effects
	(Continued from previous page)	c. Controls flow through heat exchanger too high	Erroneous position indication	Excessive flow through one heat exchanger. Excessive cooldown rate.	High differential temperature indication from SI ITR0351, -352	Redundant SDC line. Operator can throttle valve to get desired differential temperature.	N/A	
19.	Pressure indicators SI IPI0306 SI IPI0307	a. Reads high	Electrical, mechanical malfunction	No impact on SDC	Operator	None required	N/A	
		b. Reads low	Electrical, mechanical malfunction	No impact on SDC	Operator	None required	N/A	
➔(EC-30976, R307)								
20.	Flow control valves SI MVAAA129A (2SI FM317A/SI-307) SI MVAAA129B (2SI FM348B/SI-306)	a. Fails open	Mechanical binding	Unable to control SDC flow bypassing one heat exchanger; reduced cooldown rate on one line	Low differential temperature indication from temperature recorder SI ITR0351, -352	Redundant decay heat removal success paths	Decreased cooldown rate	
		b. Bypass flow controlled high	Mechanical binding, valve operator malfunction	Excessive flow past one heat exchanger, reduced cooldown rate	Low differential temperature indication from temperature recorder SI ITR0351, -352	Redundant decay heat removal success paths	Same as above	
		c. Bypass flow controlled low	Valve operator malfunction	Insufficient heat exchanger bypass flow in one line, but no impact on SDC ability to perform safety function	High differential temperature indication from temperature recorder SI ITR0351, -352	None required. However, operator would override controller	N/A	
		d. Fails open	Loss of control air	Unable to control SDC flow bypassing both heat exchangers; reduced cooldown rate on both lines	Low differential temperature indication from temperature recorder SIITR0351, -0352	Operator can manually throttle handwheel of 129 valve on available train or close valve with alternate air supply	N/A	

🡐(EC-30976, R307)

FAILURE MODE AND EFFECTS ANALYSIS
SHUTDOWN COOLING SYSTEM (SDCS)

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No	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Effect Upon	Remarks and Other Effects
21.	Flow indicator controller SI IFIC0306, -307	a. Reads high	Electrical or mechanical malfunction	Flow control valve in affected line is throttled back, resulting in low SDCHX bypass flow. Excessive cooldown rate.	High differential temperature indication from temperature recorder SI ITR0351, -352	Redundant decay heat removal success paths	N/A	
		b. Reads low	Electrical or mechanical malfunction	Flow control valve in affected line is throttled open, resulting in increased flow past SDCHX. Decreased cooldown rate.	Low differential temperature indication from temperature recorder SI ITR0351, -352	Redundant decay heat removal success paths	N/A	
22.	Differential temperature recorder SI ITR0351, -352	a. Reads high	Electrical or mechanical malfunction	No direct impact on SDC, but possible incorrect flow throttling by operator resulting in reduced cooldown rate	Operator	Redundant decay heat removal success paths	Decreased cooldown rates	Cooldown can be achieved at "normal" rate using backup temperature indicators for control reference
		b. Reads low	Electrical or mechanical malfunction	No direct impact on SDC, but possible incorrect flow throttling by operator resulting in excessive cooldown rate	Operator	Redundant decay heat removal success paths	Increased cooldown rates	Cooldown can be achieved at "normal" rate using backup temperature indicators for control reference
23.	LPSI header relief valves 2SI-R350B, 2SI-R613A/B	a. Fails to open	Mechanical binding, setpoint drift	No impact on shutdown cooling. Loss of over-pressure protection for potentially closed line section.	Periodic test	None required	N/A	
		b. fails to reseat	Seat leakage, spring failure, setpoint drift	Primary coolant diverted to waste tanks during shutdown cooling	Possibly waste tank level indicators, RWLIS, RCSLMS	None required	N/A	

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FAILURE MODE AND EFFECTS ANALYSIS
SHUTDOWN COOLING SYSTEM (SDCS)

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No	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Effect Upon	Remarks and Other Effects
24.	LPSI header isolation valves 2SI-V1549A1 (SI-615), 2SI-V1539B1 (SI-625), 2SI-V1541A2 (SI-635), 2SI-V1543B2 (SI-645)	a. Fails to open	Mechanical binding, valve operator malfunction	Cannot establish flow in one of four SDC flow paths	Valve position indicator in control room, pressure and temperature indicators on affected line	Redundant SDC line, plus other decay heat removal success paths	Decreased cooldown rates	The unblocked line on the affected LPSI header may not pass the full LPSI pump discharge flow
		b. Fails open	Mechanical binding, valve operator malfunction	No impact on SDC	Valve position indicators in control room	None required		
25.	LPSI header check valves 1SI-V1517RL1A (SI-114), 1SI-V1518RL1B (SI-124), 1SI-V1519RL2A (SI-134), 1SI-V1520RL2B (SI-144)	a. Fails in closed position	Mechanical binding, blockage	Loss of one of four SDC flow paths, reduced cooldown rate	Pressure and flow indicators in affected line	Redundant SDC line plus second line on header still useable	Extended time required for SDC	If one of the two lines on a LPSI header is closed off, the other line can take some but not all of the lost flow
		b. Fails in open position	Seat leakage, mechanical binding	No impact on SDC	None	None required	N/A	
26.	HPSI header check valves 1SI-V1522RL1A (SI-113), 1SI-V1523RL1B (SI-123), 1SI-V1524RL2A (SI-133), 1SI-V1525RL2B (SI-143)	a. Fails in closed position	Mechanical binding, blockage	No impact on SDC	None	None required	N/A	
		b. Fails partly open	Seat leakage	Diversion of primary coolant to HPSI header during SDC	None	Isolation valves in HPSI header	N/A	

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FAILURE MODE AND EFFECTS ANALYSIS
SHUTDOWN COOLING SYSTEM (SDCS)

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No	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Effect Upon	Remarks and Other Effects
27.	SIT isolation valves 1SI-V1505TK1A (SI-614), 1SI-V1506TK1B (SI-624), 1SI-V1507TK2A (SI-634), 1SI-V1508TK2B (SI-644)	a. Fails to close	Mechanical binding, valve operator malfunction	No impact on SDC. Cannot isolate one SIT.	Valve position indication in control room	Operator action to depressurize SIT	N/A	
		b. Inadvertently opened	Operator error	No effect on SDC function. Possibly exceed SDCS/RCS pressure limits.	Operator	Operator action to close valve and/or depressurize SIT	N/A	
28.	LPSI line pressure indicators SI IPI0319, SI IPI0329, SI IPI0339, SI IPI0349	Erroneous pressure alarms (high or low)	Electrical or mechanical malfunction	No impact on SDC	Possibly pressure indicator CS IPI0303X,Y	None required	N/A	
29.	SI header check valves 1SI-V1509RL1A (SI-217), 1SI-V1511RL1B (SI-227), (SI-V1513RL2A (SI-237), 1SI-V1515RL2B (SI-247)	a. Fails in closed position	Mechanical binding, blockage	Loss of one SDC flow path	Pressure transmitters SI IPT0319, -329, -339, -349	Redundant SDC header, plus other line on affected header still available	Extended time required for SDC	
		b. Fails in open position	Mechanical binding	No impact on SDC	None	None required	N/A	

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FAILURE MODE AND EFFECTS ANALYSIS
SHUTDOWN COOLING SYSTEM (SDCS)

No	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Effect Upon	Remarks and Other Effects
30.	Safety injection line pressure bleed valves 1SI-F1551TK1A (SI-618), 1SI-F1552TK1B (SI-628), 1SI-F1553TK2A (SI-638), 1SI-F1554TK2B (SI-648)	a. Fails in closed position	Mechanical binding, valve operator malfunction	No impact on SDC	None required	None required	N/A	
		b. Inadvertently opened	Operator error	No impact on SDC function	Operator	Series redundant valve in line to RWSP prevents inadvertent flow	N/A	
31.	LPSI mini recirc line solenoid valves 2SI-E1587A, 2SI-E1588B	Fails in open position	Mechanical binding, seat leakage	Radioactive fluid may be introduced into RWSP from LPSI pump. Unable to initiate one train of SDC.	Operator, valve position indication	Redundant decay heat removal success paths	N/A	Fail open solenoid valves
32.	Containment spray header isolation valves 2CS-F305A, 2CS-F306B	Inadvertently opened	Operator error	Possible diversion of a portion of SDC flow through spray header. Possible loss of SDC flow	Spray flow indication, RWLIS, RCSLMS, SDC trouble alarm	Redundant decay heat removal flow paths. Operator takes action to isolate leak and refill RCS	N/A	
→(DRN 02-1054, R12)								
33.	LPSI Header Auto Vent Isolation valves SI-ISV-6011 SI-ISV-6012	Inadvertently left open or fails open	Operator error. Loss of power failed solenoid	Redundant valve provided, no effect on system	Periodic testing	None required	N/A	Fail open
←(DRN 02-1054, R12)								
→(DRN 02-1636, R12-A)								
34.	LPSI Header Auto Vent Isolation Valves SI ISV 14023A & SI ISV 14024A	a. Inadvertently opened	Operator error	No impact on SDC	Operator, valve position indication locally (SI 14024A) in control room (SI 14023A)	None	N/A	
		b. Fails closed	Loss of power	No impact on SDC	Operator, valve position indication locally (SI 14024A) in control room (SI 14023A)	None	N/A	
←(DRN 02-1636, R12-A)								

TABLE 9.3-17 (Sheet 1 of 2) Revision 14 (12/05)

SHUTDOWN COOLING HEAT EXCHANGER DATA

Parameter	Value
Quantity	2
Type	Shell and tube horizontal U-Tube
→ (DRN 99-1092, R11)	
Surface transfer rate (Btu/hr F-ft^2)	299
← (DRN 99-1092, R11)	
Heat transfer area per heat exchanger, ft^2	7000
Tube side:	
Fluid	Reactor coolant
Design pressure, psig	650
Design temperature, F	400
Material	Austenitic stainless steel
Shell side:	
Fluid	Component cooling water
Design pressure, psig	150
Design temperature, F	250
Material	Carbon steel
→(DRN 03-2063, R14)	
At 17 1/2 hours after shutdown:	
Tube side:	
→ (DRN 99-1092, R11)	
Flow, million lbm/hr	1.969
← (DRN 99-1092, R11)	
Inlet temperature, F	140
→ (DRN 99-1092, R11)	
Outlet temperature, F	118.5
← (DRN 99-1092, R11; 03-2063, R14)	

TABLE 9.3-17 (Sheet 2 of 2) Revision 14 (12/05)

SHUTDOWN COOLING HEAT EXCHANGER DATA

Parameter	Value
Shell side:	
→(DRN 03-2063, R14)	
Flow, million lbm/hr - HX	1.495
←(DRN 03-2063, R14)	
Inlet temperature, F	90
→ (DRN 99-1092, R11)	
Outlet temperature, F	116
→(DRN 03-2063, R14)	
Heat load (million Btu/hr-HX)	42.24
← (DRN 99-1092, R11; 03-2063, R14)	

TABLE 9.3-18

SHUTDOWN COOLING SYSTEM VALVES
DESIGN PRESSURES AND TEMPERATURES

Valve	Valve No.	Design Pressure, psig	Design Temp. F
Shutdown Cooling Flow Control	SI-307	650	400
	SI-306	650	400
	SI-657	650	400
	SI-656	650	400
Low Pressure Safety Injection Header Isolation	SI-615	2485	650
	SI-625	2485	650
	SI-635	2485	650
	SI-645	2485	650

Table 9.3-19 has been deleted.

TABLE 9.3-20 (Sheet 1 of 2) Revision 305 (11/11)

REQUIRED VALVE ACTUATIONS ACCOMPLISHED FROM THE MAIN CONTROL ROOM

Valve No.	Valve	Operation
SI-452	SDCHX inlet isolation	Open
SI-453	SDCHX inlet isolation	Open
SI-400	Warmup Bypass	Open/Close
SI-450	Warmup Bypass	Open/Close
SI-456	SDCHX return line isolation	Open
SI-457	SDCHX return line isolation	Open
SI-651	Shutdown cooling suction line isolation	Open
→(EC-14765, R305) SI-4052A ←(EC-14765, R305)	SI-405A Bypass Fill Valve	Open/Close
SI-652	Shutdown cooling suction line isolation	Open
SI-665	Shutdown cooling suction line isolation	Open
→(EC-14765, R305) SI-4052B ←(EC-14765, R305)	SI-405B Bypass Fill Valve	Open/Close
SI-666	Shutdown cooling suction line isolation	Open
SI-440	Shutdown cooling suction line isolation	Open
SI-441	Shutdown cooling suction line isolation	Open
SI-615	LP header injection	Open
SI-625	LP header injection	Open
SI-635	LP header injection	Open
SI-645	LP header injection	Open
SI-659	Miniflow isolation	Close
SI-660	Miniflow isolation	Close
SI-667	Miniflow isolation	Close
SI-668	Miniflow isolation	Close
SI-306	SDCHX bypass flow control	Throttle

TABLE 9.3-20 (Sheet 2 of 2) Revision 12 (10/02)

Valve No.	Valve	Operation
SI-307	SDCHX bypass flow control	Throttle
SI-656	SDCHX flow control	Throttle
SI-657	SDCHX flow control	Throttle
SI-614	SIT isolation	Close
SI-624	SIT isolation	Close
SI-634	SIT isolation	Close
SI-644	SIT isolation	Close
SI-611	SIT drain[a]	Open/Close
SI-621	SIT drain[a]	Open/Close
SI-631	SIT drain[a]	Open/Close
SI-641	SIT drain[a]	Open/Close
SI-682	RWST return line containment isolation[a]	Open/Close
SI-605 or	SIT vent[b]	Open/Close
SI-613	SIT vent[b]	Open/Close
SI-606 or	SIT vent[b]	Open/Close
SI-623	SIT vent[b]	Open/Close
SI-607 or	SIT vent[b]	Open/Close
SI-633	SIT vent[b]	Open/Close
SI-608 or	SIT vent[b]	Open/Close
SI-643	SIT vent[b]	Open/Close
→(DRN 02-1040)		
SI-ISV-6011 or	LPSI Header Auto Vent Isolation	Open/Close
SI-ISV-6012	LPSI Header Auto Vent Isolation	Open/Close
←(DRN 02-1040)		

(a) Valves required for reducing pressure in the SIT's under normal operation (see Section 6.3)

(b) Valves required for alternate means of SIT pressure reduction under normal operation (see Section 6.3). Valves required for reducing pressure in the SIT's under accident conditions (see Section 6.3).

TABLE 9.3-21

DESIGN AND MATERIALS DATA FOR BULK GAS STORAGE TUBES

1)	Design Standard.	ASME BPV Code Section VIII and Code Case 1205
2)	Design Temperature	Minus 20°F to Plus 200°F
3)	Service.	Noncorrosive Gas, Nonshock
4)	Vessel Material.	ASME SA-372, Class IV
	Minimum Tensile.	105,000 psi Minimum
	Yield.	65,000 psi Minimum
5)	Fabrication.	Each Vessel Shall be Seamless Type with Swaged Ends
6)	Heat Treatment	Normalize and Temper
7)	Inspection	ASME Certified and National Board Commissioned
8)	Stamping	ASME and National Board per Code Case 1205
9)	Registration	Registered with National Board
10)	Exterior	Shot Blast and Magnaflux Inspection Paint One (1) Coat Zinc Chromate Primer and One (1) Coat Enamel
11)	Interior	Shot Blast Free of Loose Scale and Blow Down with Dry Oil-Free Air. Purge with Dry Nitrogen and Plug for Shipment

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TABLE 9.3-21A Revision 9 (12/97)

DESIGN AND MATERIALS DATA FOR ESSENTIAL AIR ACCUMULATORS

1)	Design Standard	DOT 3AA in accordance with CFR Section 49, Part 178.37
2)	Service Pressure/Temperature	2400 PSIG at 70 DEFG (10% overfill is allowed)
3)	Service	Compressed air, Nonshock
4)	Vessel Material	ANSI 4130X chrome-moly steel
5)	Fabrication	Seamless forged construction
6)	Heat Treatment	Quench and Temper
7)	Inspection	Cochrane Laboratories as approved by the Associate Administrator for hazardous Materials Safety, in accordance with CFR49, Part 173.300a, registered in accordance with ISO 9001/EN29001/ANSI
8)	Stamping	DOT 3AA-2400 Serial Number Manufacturers Symbol Authorized Inspectors Mark Test Date, Overfill Mark
9)	Exterior	Blasted, buffed, baked enamel
10)	Interior	Blasted, washed, visually inspected prior to valve installation

←

TABLE 9.3-22 Revision 11 (05/01)

SHUTDOWN COOLING SYSTEM RELIEF VALVE PARAMETERS

Design Pressure:	440 psig
Design Temperature:	400°F
Fluid:	Reactor Coolant (Water)
Set Pressure:	415 psig
→ (DRN 01-369)	
Capacity:	3345 gpm
← (DRN 01-369)	
Accumulation:	10%
Blowdown:	10%
Maximum Back Pressure:	0-70 psig
Materials:	
Body:	SA182 Gr F304
Nozzle:	SA479 Type 304
Disc:	SA479 Type 304
Manufacturer:	Crosby Valve & Gage Company
ASME Code Date:	Section III ’71 Edition through Winter ’73 Addenda