6.3 EMERGENCY CORE COOLING SYSTEM

6.3.1 Design Bases

6.3.1.1 Summary Description

The emergency core cooling system (ECCS) and the safety injection system (SIS) are designed to provide core cooling in the unlikely event of a loss-of-coolant accident (LOCA). The ECCS prevents significant alteration of core geometry, precludes fuel melting, limits the cladding metal-water reaction, removes the energy generated in the core and maintains the core subcritical during the extended period of time following a LOCA.

The SIS accomplishes these functional requirements by use of redundant active and passive injection subsystems. The active portion of the SIS consists of high- and low-pressure safety injection pumps and associated valves; the passive portion consists of pressurized safety injection tanks.

In addition, the safety injection system functions to inject borated water into the reactor coolant system to add negative reactivity to the core in the unlikely event of a steamline rupture. Safety injection is also initiated in the event of a steam-generator tube rupture or a CEA ejection incident. The system is actuated automatically.

6.3.1.2 Criteria

6.3.1.2.1 Functional Design Bases

a. The shutoff head and flow rates of the high-pressure safety injection (HPSI) pump and low-pressure safety injection (LPSI) pump were selected to insure that adequate flow is delivered to the RCS to accomplish the functional requirements of Subsection 6.3.1.1.

b. Storage of fluid for the SIS is accomplished by the refueling water tank (RWT), which contains a sufficient amount of borated water to accomplish the functional requirements of Subsection 6.3.1.1.

c. The SIS is designed such that approximately equal flows are delivered to each injection point, regardless of break location.

6.3.1.2.2 Reliability Design Bases

a. The safety function of the ECCS can be accomplished assuming the failure of a single active component during the injection mode of operation, or a single active or limited-leakage passive failure of a component during the recirculation mode of operation. For failure analysis, all necessary supporting systems, including the onsite electrical power system, are considered a part of the safety injection system. A failure modes and effects analysis is presented in Table 6.3-2.

b. Components of the SIS and instrumentation which must operate during and following a LOCA are designed to operate in the environment as described in Section 3.11.

c. The SIS is designed to perform its safety functions for the entire duration of a LOCA.

d. The SIS meets seismic Category I requirements.

6.3.2 System Design

6.3.2.1 System Schematic

The SIS piping and instrumentation diagram is shown in Figure 6.3-1. The major components of this system are the high-pressure safety injection pumps, low-pressure safety injection pumps, safety injection tanks, high-pressure injection valves, and the low-pressure injection valves. In addition, the system uses the refueling water tank of the chemical and volume control system (Subsection 9.3.4).

6.3.2.2 Component Description

A summary of design parameters and codes for the major components is given in Table 6.3-1. Table 6.3-3 describes the process instrumentation, Table 6.3-4 provides flow data, and Table 6.3-5 lists NPSH and head-loss requirements. Subsection 6.3.3 specifies the components used to provide core protection for the complete spectrum of reactor coolant pipe breaks.

6.3.2.2.1 Safety Injection Tanks

The four safety injection tanks (SITs) discharge to the reactor coolant system following depressurization as a result of a LOCA. Each SIT is piped into a cold leg of the reactor coolant system (RCS) via a safety injection nozzle located on the RCS piping near the reactor vessel inlet. During normal plant operation each safety injection tank is isolated from the reactor coolant system by two check valves in series. The safety injection tanks automatically discharge into the RCS if RCS pressure decreases below SIT pressure during reactor operation.

The motor-operated isolation valves on the SIT discharge are interlocked with the pressurizer pressure measurement channels and open automatically as RCS pressure is reaches 500 psig (35.2 kg/cm^2). The interlock prevents inadvertent closure prior to or during an accident. After the valve is opened, it is locked open in the control room, and power to the motor is removed (see Section 7.6).

During normal power operation, the valve, although locked open, receives a confirmatory SIAS "OPEN" signal if the RCS pressure should inadvertently drop below 1770.4 psia (124.47 kg/cm^{2}A). During startup and shutdown operations, a variable setpoint is used as described in Subsection 7.2.1.1.1.6. During plant cooldowns, SIT pressure will be lowered to 400 psig (28.1 kg/cm^2) by the operator when RCS pressure reaches 625 psig (43.9 kg/cm^2). An interlock with pressurizer pressure will prevent the SIT valves from being closed until RCS pressure drops to 415 psig (29.2 kg/cm^2). Although the SIT isolation valves will be closed by the operator by the time RCS pressure is reduced to 400 psig (28.1 kg/cm^2), an SIAS will cause the valves to re-open. Inadvertent repressurization of the SITs during this mode of operation, due to a leaky nitrogen supply valve or by accidental tripping of a nitrogen supply valve switch, is prevented by having two fail-closed valves in series with separate hand switches on each SIT nitrogen supply line. The air supply actuating the nitrogen supply valves is controlled by solenoid valves. The two nitrogen supply valve solenoids on each SIT are connected to separate electrical buses via redundant and physically separated electrical trains. This ensures that a fault in one of the trains will not cause a spurious opening of both nitrogen supply valves. 574

If RCS pressure reaches 500 psig (35.2 kg/cm^2), an interlock with pressurizer pressure will automatically open the SIT isolation valves. The operator must repressurize the SITs when pressurizer pressure reaches 625 psig (43.9 kg/cm^2). Failure to do so will result in an alarm when pressurizer pressure reaches 700 psig (49.2 kg/cm^2).

The tank gas/water fractions, gas pressure, and outlet pipe size are selected to allow three of the four tanks to recover the core before significant clad melting or zirconium-water reaction can occur following a LOCA. The volume of water in the tanks is conservatively calculated assuming that all water injection prior to the end of the RCS blowdown is lost.

The tanks contain borated water at the minimum required boron concentration for refueling and are pressurized with nitrogen at a nominal pressure of 610 psig (42.9 kg/cm^2).

Redundant level and pressure instrumentation (described in more detail in Subsection 6.3.5.3 and Table 7.5-2) is provided to monitor the condition of the tanks. Sufficient visual and audible indication has been made available to the operator such that maintaining the SITs within the required Technical Specifications during various modes of plant operation is readily accomplished from the control room. Provisions have been made for sampling, filling, draining, and correcting boron concentration. Atmospheric vent valves are provided for tank venting. They are locked closed and the power to each valve is removed during normal plant operation. This prevents inadvertent tank venting during normal plant operation. SIT data are summarized in Table 6.3-1.

6.3.2.2.2 Low-Pressure Safety Injection Pumps

The low-pressure safety injection (LPSI) pumps serve two functions. One of these is to inject large quantities of borated water into the RCS in the event of a large pipe rupture. Sufficient flow is delivered under these conditions to satisfy functional requirements described in Subsection 6.3.1.1. The other function of the LPSI pumps is to provide shutdown cooling flow through the reactor core and shutdown cooling heat exchangers for normal plant shutdown cooling operation or as required for long term core cooling. A typical pump characteristic curve is presented in Figure 6.3-6. (Refer also to Subsection 5.4.7.)

During normal operation the LPSI pumps are isolated from the RCS by motor-operated valves. During safety injection, the LPSI pumps deliver water from the RWT to the RCS via the RCS safety injection nozzles whenever system pressure is below pump shutoff head.

Sizing of the LPSI pump is governed by the shutdown cooling function. The flow available with a single LPSI pump is sufficient to maintain a core ΔT at an acceptable level at the initiation of shutdown cooling (3.5 hours after shutdown).

The design temperature for the LPSI pumps is based upon the temperature of the reactor coolant at the initiation of shutdown cooling, about 350°F (176.7°C) nominal, plus a design tolerance, resulting in a temperature of 400°F (204.4°C). The design pressure for the LPSI pumps based upon the sum of the maximum pump suction pressure, which occurs at the initiation of shutdown cooling, and the pump shutoff head (see Subsection 5.4.7.)

The LPSI pumps are vertical, single-stage centrifugal units equipped with mechanical face seals backed up by a bushing, with a leakoff to collect the leakage past the seals. The seals are designed for operation with a pumped fluid temperature of 400°F (204.4°C). The pump motors are specified to have the capability of starting and accelerating the driven equipment, under load, to design point running speed within 5 seconds, based upon an initial voltage of 75% of the rated voltage at the motor terminals, and increasing linearly with time to 90% voltage in the first 2 seconds, and increasing to 100% voltage in the next 2 seconds.

The pumps are provided with drain and flushing connections to permit reduction of radiation levels before maintenance. The pressure-containing parts are fabricated from stainless steel; the internals are selected for compatibility with boric acid solutions. The pumps are provided with minimum flow protection to prevent damage when starting against a closed system. The LPSI pump data is summarized in Table 6.3-1. The shutdown cooling function of the pumps is described in Subsection 5.4.7.

6.3.2.2.3 High-Pressure Safety Injection Pumps

The primary function of the high-pressure safety injection (HPSI) pump is to inject borated water into the RCS if a break occurs in the RCS boundary. For small breaks, the RCS pressure remains high for a long period of time following the accident, and the HPSI pumps ensure that the injected flow is sufficient to meet the criteria given in Subsection 6.3.1. The HPSI pumps are also used during the recirculation mode to maintain a borated water cover over the core for extended periods of time following a LOCA. For long-term core cooling, the HPSI pumps are manually realigned for simultaneous hot- and cold-leg injection. This ensures flushing and ultimate subcooling of the core independent of break location. For small breaks, the HPSI pumps continue injecting into the RCS to provide makeup for spillage out the break while a normal cooldown is implemented.

During normal operation the HPSI pumps are isolated from the RCS by motor operated valves. During safety injection, the HPSI pumps deliver water from the refueling water storage tank to the RCS via the cold leg safety injection nozzles whenever RCS pressure falls below pump shutoff head. During the recirculation mode of operation, the pumps take suction from the containment sump.

The HPSI pumps are sized such that one pump (after consideration of spillage directly out the break) will supply adequate water to the core to match decay heat boiloff rates soon enough to minimize core uncovery and allow small break LOCAs to meet the performance criteria of 10 CFR 50.46. A typical pump characteristic curve is shown in Figure 6.3-7. The effectiveness of the pump during a steam line break is also analyzed to assure that the pumps are adequately sized.

Mechanical shaft seals are used and are provided with leakoffs which collect any leakage past the seals. The seals are designed for operation with a pumped fluid temperature of 350°F (176.67°C).

The pump motors are specified to have the capability of starting and accelerating the driven equipment, under load, to design point running speed within 5 seconds based on an initial voltage of 75% of the rated voltage at the motor terminals, increasing linearly with time to 90% voltage in the first 2 seconds, and increasing to 100% voltage in the next 2 seconds.

The pumps are provided with drain and flushing connections to permit reduction of radiation before maintenance. The pressure containing parts of the pump are stainless steel with internals selected for compatibility with boric acid solutions. The materials selected are analyzed to ensure that differential expansion during design transients can be accommodated.

The pumps are provided with minimum flow protection to prevent damage resulting from operation against a closed discharge. Also, individual HPSI pump ultrasonic flow meters provide low-flow alarming.

The design temperature is based on the saturation temperature of the reactor coolant at the containment design pressure plus a design tolerance. The design pressure for the high-pressure pumps is based on the shutoff head plus maximum containment pressure plus a design tolerance. The high-pressure pump data are summarized in Table 6.3-1.

6.3.2.2.4 Piping

Piping is specified to deliver borated safety injection water from the SITs and from the RWT via the safety injection pumps, to the safety injection nozzles in the RCS. The major piping sections are (refer to Figure 6.3-1):

a. From each safety injection tank to its respective RCS cold-leg safety injection nozzle;

b. Redundant piping from the RWT and containment recirculation sump to the suction of the high- and low-pressure safety injection pumps;

c. Redundant piping from the high-pressure safety injection pumps discharge to redundant high-pressure injection headers, each of which serves the four safety injection nozzles on the cold legs and one nozzle on each shutdown cooling suction line;

d. Redundant piping from the LPSI pump discharge to each low-pressure injection header, which serves two of the four safety injection nozzles.

The SIS piping is fabricated of austenitic stainless steel and is designed to ASME Code Section III. Flexibility and seismic loading analyses are performed by each Applicant to confirm the structural adequacy of the system piping.

6.3.2.2.5 Valves

The location, type, and size, type of operator, position (during the normal operating mode of the plant) and failure position of the SIS valves are shown in Figure 6.3-1. Pressure design rating and code design classification are also shown. A list of SIS valves is given in Table 6.3-6.

a. Relief Valves

Protection against overpressure of components within the SIS is provided by conservative design of the system piping, appropriate valving between high-pressure sources and low-pressure piping, and by relief valves. All lines within the high- and low-pressure systems from the RCS up to and including the safety injection valves are designed for full RCS pressure. In addition, the high-pressure header to which the charging pumps discharge is designed for full RCS pressure up to and including the header check valve. Relief valves are provided as required by applicable codes. All relief valves are of the totally enclosed, pressure-tight-type with suitable provisions for gagging.

A list of SIS relief valves is provided below.

1. SI-211, 221, 231, and 241, Safety Injection Tank Relief Valves.

The relief valves on the SITs are sized to protect the tanks against the maximum fill rate of liquid or gas into the SITs. They discharge into the containment. The set pressure is 700 psig (49.2 kg/cm^2) with a capacity of 6000 scfm (169.9 m^3/min. Std) of gas or 230 gpm (0.87 m^3/min) of liquid.

2. SI-473, Check Valve Leakage Relief Valve.

A relief valve is provided on the SIT and leakage return line.

This relief valve is sized to protect against overpressure of the line when relieving injection line pressure following check valve testing or during normal operation. It discharges into the reactor drain tank. The set pressure is 2050 psig (144.11 kg/cm^2) with a capacity of 35 gpm (132.5 L/min).

3. SI-474 and SI-407, Safety Injection Tank Fill Line Relief Valves.

Relief valves are located on the SIT fill line to protect against overpressure due to a temperature increase. SI-474 discharges to the reactor drain tank, and SI-407 discharges into the LPSI pump B room sump. They are set at 2050 psig (144.11 kg/cm^2) with a capacity of 10 gpm (37.85 L/min). 104

4. SI-439 and SI-449 Low-Pressure Safety Injection Relief Valves.

These valves protect each isolated LPSI line against the pressure developed due to a temperature increase. SI-439 discharge into the LPSI pump A room sump, and SI-449 discharge into the LPSI pump B room sump. The set pressure is 750 psig (52.73 kg/cm^2) with a capacity of 10 gpm (37.85 L/min) per valve. 104

5. SI-409 and SI-468 High-Pressure Safety Injection Relief Valves.

These valves are sized to protect the isolated high pressure headers against the pressure due to a temperature increase. SI-409 discharge into the CS pump B room sump, and SI-468 discharge into the LPSI pump A room sump. SI-409 is set at 2050 psig (144.11 kg/㎠), and SI-468 is set at 2485 psig (174.7 kg/㎠). Each has a capacity of 10 gpm (37.85 L/min). 104

6. SI-166 and SI-417, High Pressure Safety Injection Relief Valves.

These valves are designed to protect the HPSI headers from being damaged due to the pressure occurred by the thermal expansion in the headers and/or the charging pumps discharge. During normal operation, the charging pumps are isolated from these headers, so these valves only function to protect the HPSI headers from the thermal expansion. This line is maintained to lock closed during normal operation. SI-166 discharges into the LPSI pump B room sump and SI-417 discharges into the CS pump A room sump. The set pressure is 2485 psig (174.7 kg/㎠) with a capacity of 145 gpm (548.83 L/min) each. 104

7. SI-288, Low-Pressure Safety Injection Relief Valve.

This valve is sized to protect the isolated LPSI test line from pressure due to a temperature increase. It discharge into the LPSI pump A room sump. The set pressure is 750 psig (52.73 kg/㎠) with a capacity of 10 gpm (37.85 L/min). 104

8. SI-285 and SI-286, Safety Injection Relief Valves.

These valves are sized to protect the safety injection pump bypass flow lines against pressure due to a temperature increase. SI-285 discharge into the CS pump A room sump, and SI-286 discharge into the CS pump B room sump. The set pressure is 2050 psig (144.11 kg/㎠) with a capacity of 10 gpm (37.85 L/min). 104

b. Actuator-Operated Throttling and Stop Valves

The position of each valve, on loss of actuating signal or power supply (failure position), is selected to ensure safe operation. System redundancy is considered when defining the failure position of any given valve. Valve position indication is provided at the main control panel as indicated in Figure 6.3-1. A locking-type control switch on the main control panel and/or manual override handwheel is provided where necessary for efficient and safe plant operation. All actuator-operated valves have stem leakage controlled by a double packing, with a latern ring leakoff connection.

Pressure reducing devices are used to prevent the safety injection pumps from exceeding runout flow and for flow balancing during emergency operation.

c. Check Valves

All check valves are the totally enclosed type. Check valves in pump suction lines are of a low pressure drop type with flow resistance characteristics equal to or less than a swing check valve of the same size as the connecting pipe.

6.3.2.2.6 Containment Sump

Refer to Subsection 6.5.2 for detailed description of the containment sump.

6.3.2.3 Applicable Codes and Classification

Refer to Subsection 6.3.2.2 and Table 6.3-1.

6.3.2.4 Materials Specifications and Compatibility

The materials used in the construction of the SIS components are presented along with the component parameters in Table 6.3-1. Basically, all materials in contact with reactor coolant are austenitic stainless steel with stellite or equivalent material being used for valve seats. The materials of construction used in both the active and passive components have been evaluated and in each case it has been concluded that the materials selected are both compatible with the most severe environmental condition they will be exposed to and in accordance with all code requirements.

6.3.2.5 System Reliability

6.3.2.5.1 Safety Injection Tanks

The SITs containing borated water pressurized by a nitrogen cover constitute a passive injection system because no operator action or electrical signal is required for operation. Each tank is connected to its associated reactor coolant cold leg by a separate line containing two check valves which isolate the tank from the RCS during normal operation. When the reactor coolant pressure falls below the tank pressure, the check valves are open and discharging the contents of the tank into the RCS.

The evaluation in Subsection 6.3.3 demonstrates the adequacy of the quantity of coolant supplied. In order to prevent accidental over-pressurization of the shutdown cooling system, SIT pressure is decreased to 400 psig (28.1 kg/cm^2) when reactor coolant pressure is below 625 psig (43.9 kg/cm^2), and subsequently, the isolation valves on the tanks are closed. An interlock with pressurizer pressure prevents these valves from being closed if pressurizer pressure is greater than 415 psig (29.2 kg/cm^2). In the unlikely event of a LOCA during shutdown cooling, an SIAS will automatically open the SIT isolation valves.

Inadvertent repressurization of the SITs during shutdown cooling, due to a leaky nitrogen supply valve or the accidental tripping of a valve switch, is prevented by having two such fail-closed supply valves in series with separate hand switches. The air supply actuating the nitrogen supply valves is controlled by solenoid valves.

The two nitrogen supply valve solenoids on each SIT are connected to separate electrical buses via redundant and physically separated electrical trains. This is to ensure that a fault in one of the trains will not cause a spurious opening of both nitrogen supply valves.

The motor-operated isolation valves on the SIT discharge are interlocked with pressurizer pressure to open the valves automatically as system pressure is increased to 500 psig (35.1 kg/cm^2). When RCS pressure increases to 625 psig (43.9 kg/cm^2), the operator must repressurize the SITs. Failure to do so will result in an alarm at a pressurizer pressure of 700 psig (49.2 kg/cm^2). Further details of valve control are provided in Section 7.6.

The atmospheric vents on the SIT are locked closed, fail closed, and power to their solenoid valve is interrupted during operation with the RCS pressure greater than 700 psig (49.2 kg/cm^2). This ensures that the tank will not be vented during RCS power operation.

6.3.2.5.2 High-Pressure and Low-Pressure Safety Injection Subsystems

Two redundant HPSI subsystem trains are provided. One pump and the associated injection valves operate from one emergency power supply; the other pump and injection valves operate from a second independent source of emergency power. This provides the automatic operation of one complete, full-capacity subsystem in the unlikely event of concurrent loss-of-offsite power and the failure of an active component, including a standby generator.

Two redundant LPSI subsystems trains are provided. One pump and the associated valves operate from one emergency power supply; the other pump and injection valves operate from a second independent source of emergency power. This provides automatic operation of one complete, full-capacity subsystem in the unlikely event of a simultaneous loss-of-offsite power and the failure of an active component, including a standby generator.

All valves in the injection paths not receiving an SIAS are maintained locked in position by administrative controls.

Prevention of flow blockage in small diameter pipes, including the above piping, is accomplished by controlling the size and specific weight of particles in the injection water that enters the piping from the containment recirculation sump and RWT.

6.3.2.5.3 <u>Power Sources</u>

Independent electrical buses supply power to the SIS equipment. Each bus may receive power from:

a. offsite power supplies or
b. onsite emergency power supplies.

The safeguards initiation sensors, electrical controls, and electrical indication equipment normally receive power from four 120-volt ac buses. Four 125-volt station batteries with inverters are provided as a backup upon loss of all other sources of power.

System reliability is achieved with the following:

a. Two electrical buses, with each bus supplying power to a 100% capacity low-pressure pump, a 100% capacity high-pressure pump, associated valves, and associated support systems. (Each support system contains two full-capacity subsystems, one connected to each bus and one subsystem servicing each independent injection train.)

b. Two sources of power (normal and standby) to both buses, with automatic backup from the emergency generators.

c. Two emergency generators, each capable of supplying power for the minimum safeguards loads.

d. The system is designed such that a single electrical failure can neither spuriously initiate unnecessary injection flow nor prevent initiation of required injection flow.

A detailed description of the power sources is given in Section 8.3.

6 3.2.5.4 Capacity to Maintain Cooling Following a Single Failure

The SIS is designed to meet its functional requirements, even with the failure of a single active component during the injection mode of operation or with the single active or limited leakage passive failure of a component during the recirculation mode of operation. By providing proper redundancy of equipment, even with the single failure noted above, the minimum required safety injection equipment is always available.

A failure modes and effect analysis demonstrating this is given in Table 6.3-2. The analysis is based on the following assumptions:

a. One active failure is assumed to occur in the system.
b. Relief and check valve failures are not considered credible failures.
c. Failure to respond to an external signal is considered an active failure.

Minimum operability requirements for components of the ECCS are delineated in ~~Subsection 16.3.5~~ TS chapter 1 3.5. Consistent with these operability requirements and system failure modes, the minimum ECCS equipment that will operate during postulated accidents is discussed in Subsection 6.3.3. This equipment is required to mitigate the consequences of a LOCA initiated when the reactor is anywhere from hot shutdown to full-power operation, and will result in conservative results for other incidents where ECCS is required.

The following design features are provided in the system in order to meet the single failure criterion.

a. Redundant high- and low-pressure safety injection pumps.

b. Redundant piping and valving between RWT and safety injection pump suction.

c. Redundant piping between containment recirculation sump and safety injection pump suction.

d. Redundant HPSI and LPSI headers.

e. Four injection discharge points into the RCS cold legs and redundant injection discharge points into the RCS hot legs.

f. Separation of the redundant subsystems of the ECCS. No limited leakage passive failure, as defined in Subsection 3.1.2.31, or the effects thereof (such as flooding, spray impingement, steam, temperature, pressure, radiation, loss of NPSH, or loss of recirculation water inventory) during the recirculation mode precludes the availability of minimum acceptable recirculation capability. Minimum acceptable capability is defined as that which is provided by the operation of one subsystem.

g. Those portions of the SIS required for safe plant shutdown and cooldown are protected from the effects of high- and moderate-energy pipe ruptures, as described in Section 3.6.

6.3.2.6 Protection Provisions

The SIS is provided with protection from damage that could result from a LOCA by: (a) designing components to withstand the design-basis event environment including coolant chemistry, radiation, humidity, temperature and pressure resulting from the accident, (b) a seismic design that will withstand the stress imposed by a safe shutdown earthquake occurring simultaneously with a LOCA, and (c) protection from missiles in accordance with Section 3.5.

6.3.2.6.1 Capability to Withstand Design Basis Environment

Components located in the containment, such as remote-operated valves and instrumentation and control equipment, required for initiation of the SIS are designed to withstand the LOCA conditions of temperature, pressure, humidity, chemistry and radiation for the extended period of time required, as detailed in Section 3.11. These valves include the valves associated with fill, drain, and pressure control of the SITs which receive SIAS or are required to operate following an accident. The instrumentation includes the wide range level and pressure instrumentation associated with the SITs.

Insofar as practical, safety injection components required to maintain a functional status have been located outside the containment to eliminate exposure of this equipment to the post-LOCA conditions. The equipment outside the containment is designed in consideration of the chemical and radiation effects associated with operation following a LOCA. (Figure 6.3-1 indicates location of equipment inside or outside of the containment.)

The design life of the safety injection pumps is 40 years, corresponding to the life of the plant. Design pressures and temperatures are in excess of the maximum pressures and temperatures seen by the respective component during the worst or normal operating and design-basis conditions. Materials of construction for the pumps are compatible with the expected water-chemistry under normal and LOCA conditions. A radiation resistance requirement has been placed on the pumps consistent with Section 3.11.

6.3.2.6.2 Missile Protection

Protection from possible RCS generated missiles is afforded by locating all components outside the containment, except for the SITs. These tanks are located outside the biological shield such that protection from possible RCS generated missiles is provided.

6.3.2.6.3 Seismic Design

Since operation of the SIS is essential following a LOCA, it is considered Category I for seismic design. The general design basis for Category I equipment is that it must be able to withstand the appropriate seismic loads plus other applicable loads without the loss of design functions that are required to protect the public.

For the SIS this means that the components must be able to withstand the stresses resulting from emergency operation following a LOCA, simultaneous with the stresses resulting from the safe shutdown earthquake (SSE) without loss of function.

Refer to Section 3.7 for details on seismic design and analysis methods.

6.3.2.7 Required Manual Actions

The two modes of operation, injection and recirculation, are automatically initiated by a safety injection actuation signal (SIAS) and a recirculation actuation signal (RAS), respectively. Operator action is required to close the RWT discharge valves after verifying that containment recirculation sump discharge valves have opened after receiving a RAS.

Long-term core cooling is manually initiated at approximately 2 hours post-LOCA, at which time the hot-leg injection valves are opened to provide simultaneous hot- and cold-leg HPSI, which results in a circulation flow through the core. For small pipe breaks, the HPSI pumps provide makeup for spillage, while the RCS is cooled down and depressurized to shutdown cooling initiation conditions utilizing the steam-generator atmospheric dump valves and auxiliary feedwater system. For small break LOCAs the SITs must be vented to allow RCS depressurization. This is followed by manual SDC operation.

6.3.3 Performance Evaluations

6.3.3.1 Introduction and Summary

NSSC Notice 2014-21 (Reference 1) and 10 CFR 50.46 (Reference 2) provide the 735
acceptance criteria for the ECCS for light water-cooled reactors. The analyses presented in this section demonstrate that the YGN 3&4 design satisfies these criteria.

Analyses were performed for various break sizes of pump discharge leg. The most limiting break, that which limits the peak linear heat generation rate (PLHGR), was identified as the DEG/PD (double-ended guillotine at the pump discharge) break with discharge coefficient (C_D) of 0.8. The results of the 741
analyses demonstrate that for a PLHGR of 13.9 kW/ft (456 W/cm), the YGN 3&4 SIS design meets the Acceptance Criteria in References 1 and 2. Conformance is as follows:

Criterion (1) Peak Cladding Temperature. "The calculated maximum fuel element cladding temperature shall not exceed 2200 °F (1204 °C)."

The ECCS performance analysis yielded a peak cladding temperature of 1900.1 °F (1038.0 °C) for the C_D = 0.8 of DEG/PD 741
break.

Criterion (2) Maximum Cladding Oxidation. "The calculated total oxidation of the cladding shall nowhere exceed 0.17 times [17%] of the total cladding thickness before oxidation."

The ECCS performance analysis yielded a maximum cladding oxidation percentage of less than 1.4% for the C_D = 0.8 of DEG/PD break. 741

Criterion (3) Maximum Hydrogen Generation. "The calculated total amount of hydrogen generated from the chemical reaction of the cladding with water or steam shall not exceed 0.01 [1%] times the hypothetical amount that would be generated if all of the metal in the cladding cylinders surrounding the fuel, excluding the cladding surrounding the plenum volume, were to react."

The ECCS performance analysis yielded a maximum core-wide oxidation of less than 1% for the C_D = 0.8 of DEG/PD break. 741

Criterion (4) Coolable Geometry. "Calculated changes in core geometry shall be such that the core remains amenable to cooling."

The cladding swelling and rupture model, which is part of the ECCS performance Evaluation Model (Reference 8), accounts for the effects of changes in core geometry if such changes are predicted to occur. With these calculated changes in core geometry, core cooling was enough to lower temperatures. No further cladding swelling and rupture can occur since the calculations were carried to the point at which the cladding temperatures were decreasing and the RCS was depressurized. Thus, a coolable geometry has been demonstrated.

Criterion (5) Long-Term Cooling. "After any calculated successful initial operation of the ECCS, the calculated core temperature shall be maintained at an acceptably low value and decay heat shall be removed for the extended period of time required by the long-lived radioactivity remaining in the core."

The large and small break analyses (Subsections 6.3.3.2 and 6.3.3.3, respectively) show that the rapid injection of borated water from the SIS limits the peak cladding temperature and cools the core within a short period of time. The post-LOCA long term cooling analysis (Subsection 6.3.3.4) shows that the continued injection of borated water by the HPSI pump from the refueling water tank or the containment recirculation sump removes the decay heat resulting from the long-lived radioactivity remaining in the core.

6.3.3.2 Large Break Analysis

6.3.3.2.1 Evaluation Model

The analysis of large break LOCA transients is performed with applying the KREM (Reference 8). This realistic evaluation model was developed to comply with KINS/GT-N007-2 (Reference 4-1), NSSC Notice 2014-21 (Reference 1). 735

The KREM is composed of two computer codes, RELAPS5/MOD3/K(Reference 5) and CONTEMPT4/MOD5 (Reference 6). The RELAP5/MOD3.1/K code analyzes the thermal-hydraulic transient in the RCS including the thermal transient of fuel rods. The CONTEMPT4/MOD5 code is used to calculate the containment pressure transient which is used as a boundary condition for RELAP5/MOD3.1/K calculation. Mass and energy releases to the containment are provided by RELAP5/MOD3.1/K. The containment pressure/temperature transients and the mass/energy releases from the RCS are highly inter-dependent each other. Therefore, RELAP5/MOD3.1/K and CONTEMPT4/MOD5 were merged and each code interacts the calculation results in every time step.

As the KREM is a best estimate evaluation model, it is necessary to quantify the overall calculational uncertainties. The KREM adopted non-parametric statistics for this purpose, in which the confidence level increases as the number of sampling calculations are increased. 124 input vectors are generated based on the random sampling of 27 uncertainty parameters within their uncertainty ranges. The ranges and probability distribution functions of code specific uncertainty parameters, in contrast to plant specific parameters, were confirmed by the EDC (Experimental Data Covering) calculations against various separate-effect and integral-effect tests. The ranges and probability distribution functions of plant specific parameters were determined reflecting the current plant operation conditions. The generation of input vectors is followed by 124 code runs and the resultant peak clad temperatures are ordered in descending order. According to Wilks' formula, the third ranked peak clad temperature is a majoring one exceeding 95% probability with a confidence level of 95%.

It has been found that RELAP5/MOD3.1/K has some scale biases in the prediction of the emergency core cooling water bypass and the steam binding phenomena, which would cause an adverse effect on the core cooling during reflood. To take into account the effect of the scale biases, independent code runs are conducted following the procedure described in Reference 8.

6.3.3.2.2 Safety Injection System Parameters

The SIS consists of two HPSI pumps, two LPSI pumps and four SITs. Each HPSI pump injects to each cold leg, while each LPSI pump injects to two cold legs. Each SIT injects to a single cold leg. The HPSI and LPSI pumps are automatically actuated by a safety injection actuation signal (SIAS) that is generated by low pressurizer pressure.
The SITs automatically discharge when the RCS pressure decreases below the SIT pressure.

The most limiting single failure of the SIS for the large break analysis was considered to be one diesel generator failure in the SIS.

Therefore, the following safety injection flows were used in the analysis: 75% of the flow from one HPSI pump, 50% of the flow from one LPSI pump and 100% of the flow from three SITs. Minimum HPSI and LPSI pump flow rates were used in the analysis and the pumps were modeled to start injecting after reaching the SIAS setpoint with 30 and 50 seconds of delay time for HPSI and LPSI respectively.

6.3.3.2.3 Core and System Parameters

Table 6.3-8 lists important input parameters and initial conditions assumed in the calculations. These input parameters and initial conditions, other than the RCS flow rate and those related to the containment, represent the nominal or best estimate conditions of the RCS and associated safety system equipment at the time when the large break LOCA occurs. Some input parameters are included in 27 uncertainty parameters as shown in Table 6.3-7. The ranges and probability distribution functions of plant specific parameters are determined on reflecting the current plant operation conditions.

The large break analysis accounts for plugging up to 1,512 average length steam-generator tubes that may occur during the plant's lifetime. 741

In large break analysis, Beginning-Of-Cycle (BOC) is selected as most limiting. At BOC, the fuel stored energy is maximum because the pellet shrinks to the minimum size. This effect finally causes the maximum cladding temperature in large break LOCA analysis.

6.3.3.2.4 Containment Parameters

Subsection 6.2.1.5 presents the minimum containment pressure analysis that was used in ECCS performance analysis. It identifies the containment parameters used in the large break analysis. The values for the containment parameters were chosen to minimize containment pressure in order to minimize the core reflood rate.

6.3.3.2.5 Break Spectrum.

In the large break ECCS performance analysis using the KREM, it is necessary first to determine the limiting break size. According to the results of related sensitivity studies (Reference 8), the limiting large break is the Double Ended Cold Leg Guillotine (DECLG). Therefore, only the DECLG is considered in the break size sensitivity calculations. Calculations for the break sizes equal to 100%, 80%, and 60% of DECLG are performed.

6.3.3.2.6 Results and Conclusions

The results of the break size sensitivity calculations are summarized in Table 6.3-9 and 6.3-10. The transient behavior of the NSSS parameters listed in Table 6.3-11 is shown in Figures 6.3-8 to 6.3-11. The 124 SRS (Simple Random Sampling) calculations are performed assuming 100% DECLG, as the maximum peak clad temperature of the break size sensitivity occurs in the case of 100% DECLG break

As a results of 124 SRS calculations, the clad temperature and oxidation behavior are presented in Figure 6.3-12 and 6.3-13. Excluding the first and second highest clad temperature cases from the 124 SRS calculation results, maximum peak clad temperature and peak local oxidation is 1028.0 °C(1882.3 °F) of case 39 and 1.40% of case 32 exceeding 95% probability with 95% confidence level. 741
Scale bias evaluation cases are selected based on that their reflood clad temperatures are less than 100 °C (180 °F) of peak reflood clad temperature. The scale biases for the upper plenum de-entrainment and steam generator U-tube droplet break-up are independently evaluated, and those are added as a steam binding scale bias. The calculated scale biases are presented in Table 6.3-12. The clad temperature during reflood varies, however it does not exceed the peak clad temperature during blowdown period of 1028.0 °C(1882.3 °F). 741
Hence, the maximum peak clad temperature exceeding 95% probability with a confidence level of 95% is 1028.0 °C(1882.3 °F) from SRS calculations. The peak local oxidation is 2.04% in the case 32 741

In addition to the uncertainty of plant operation, the time step and plot frequency error of 10 °C(18 °F) is assumed as an uncertainty. Hot rod average oxidation is less than 1% which means that the core wide oxidation is less than 1%. The final maximum peak clad temperature, peak local oxidation, and core wide oxidation can be summarized as follows:

Maximum peak clad temperature = 1,028.0 °C + 10 °C
= 1,038.0 °C (1,900.4 °F) 741
Maximum peak local oxidation = 2.04%
Core wide oxidation < 1%

The clad temperature transient is terminated at a time when the core geometry is still amenable to cooling. As a result, the ability of removing decay heat generated in the fuel for an extended period of time will be provided.

6.3.3.3 Small Break Analysis

6.3.3.3.1 Evaluation Model

The small break analysis was performed using the MEST-approved NOTRUMP Evaluation Model for KSNP (Reference 3 and 3-1). This Evaluation Model satisfies the requirements described in Appendix K to 10 CFR 50 (Reference 2) and KINS/GT-N007-1 (Reference 4) and consists of the NOTRUMP and LOCTA-IV computer codes.

NOTRUMP (Reference 10, 11) is used to calculate the system thermal-hydraulic behavior during the small break LOCA. This code basically simulates the transient depressurization of the RCS, as well as describe the mass and energy of flow through the break. NOTRUMP applies one-dimensional governing equation and has the features of calculating the thermal non-equilibrium drift flux between the liquid and the steam, the counter-current flow, mixture level tracking logic in multiple stacked fluid nodes and regime-dependent heat transfer correlations. In NOTRUMP, the RCS is nodalized into volumes interconnected by flowpaths. The multinode capability of the NOTRUMP enables proper calculation of the behavior of the loop seal during a small break LOCA. The transient behavior of the system is determined from the governing equations of mass, energy and momentum applied throughout the system. The representation of the reactor core as heated control volumes with an associated bubble rise model to permit a transient mixture height calculation.

Clad thermal analyses are performed with the LOCTA-IV (Reference 7) computer code, which uses the RCS pressure, fuel rod power history, steam flow past the uncovered part of the core and mixture height history from the NOTRUMP hydraulic calculation as input.

6.3.3.3.2 Safety Injection System Parameters

The SIS consists of two HPSI pumps, two LPSI pumps and four SITs. Each HPSI pump injects to each cold leg, while each LPSI pump injects to two cold legs. Each SIT injects to a single cold leg. The HPSI and LPSI pumps are automatically actuated by a SIAS that is generated by either low pressurizer pressure or high containment pressure. The SITs automatically discharge when the RCS pressure decreases below the SIT pressure.

The small break analysis conservatively assumes that offsite power is lost upon reactor trip and therefore all safety injection pumps must await emergency diesel generator startup and load sequencing before they can start. The total time delay, from when the SIAS setpoint is reached to the time that full safety injection flow is delivered to the RCS, that is used in the analysis is 30 seconds for the HPSI pumps and 50 seconds for the LPSI pumps.

The worst single failure for the small break analysis assumes the failure of one of the emergency diesel generators to start. This failure causes a loss of both a HPSI pump and a LPSI pump and results in a minimum of safety injection water being available to cool the core. Because the broken loop safety injection is applied to the SIS (References 3, 11), 100% of the flow from one HPSI pump, one LPSI pump and four SITs for discharge leg break.

Table 6.3-13 presents the HPSI and LPSI pump flow rates, at each of the four injection points as a function of RCS pressure, that were used in the analysis.

6.3.3.3.3 Core and System Parameters

The significant core and system parameters, used in the small break analysis, are presented in Table 6.3-14.

The small break analysis accounts for plugging up to 1,512 average length steam-generator tubes. 741

Like the large break analysis, the small break analysis was performed at Beginning-Of-Cycle (BOC).

The small break LOCA analysis used a higher PLHGR than did the large break LOCA 511.8 W/cm(15.6 kW/ft) vs. 469.2 W/cm(14.3 kW/ft) because the large break 645
results are more limiting than the small break results. Since the small break results are governed mainly by the core level transient, the higher PLHGR does not significantly affect the small break results.

6.3.3.3.4 Containment Parameters

Containment parameters do not impact the small break analysis since the leak flow during a small break LOCA is always in critical flow. Therefore, other than the containment volume and the initial containment pressure, no containment parameters are employed for this analysis. The analysis used a containment volume of 2.877 × 10^6 ft^3 (81,468 m^3) and an initial containment pressure of 14.18 psia (0.997 kg/cm^2 A).

6.3.3.3.5 Break Spectrum

The small break analysis described in Reference 3-1 was performed for the breaks of 0.05 ft^2 (46.5 cm^2), 0.087 ft^2 (80.8 cm^2) and 0.1 ft^2 (92.9 cm^2) pump discharge leg and the 0.087 ft^2 (80.8 cm^2) break results in a highest cladding temperature. So, break spectrum analyses of YGN 3&4 was performed for 0.05 ft^2 (46.5 cm^2), 0.087 ft^2 (80.8 cm^2) and 0.1 ft^2 (92.9 cm^2) pump discharge leg breaks.

6.3.3.3.6 Results

Table 6.3-15 summarizes the important results of this analysis. Times of interest for the various break analyzed are presented in Table 6.3-17. The transient behavior of the NSSS parameters listed in Table 6.3-16 is shown in Figures 6.3-14 to 6.3-16. The 0.087 ft^2 (80.8 cm^2) break results in the highest cladding temperature, 1,355.2 °F (735.1 °C) of the small breaks 741 analyzed, which is more than 500 °F (278 °C) lower than the value for the limiting large break.

Based on the results of this analysis, it is concluded that YGN 3&4 SIS satisfies the acceptance criteria of Reference 1 & 2 for a complete spectrum of small break LOCAs. It is also adequate to perform its intended function of maintaining the integrity of core, thereby limiting radion releases to the environment.

"Delete"

6.3.3.3.7 Instrument Tube Rupture

In addition to the three small breaks discussed above, the rupture of an incore instrument tube was evaluated. A break equal in size to a completely severed instrument tube results in a 0.003 ft^2 (2.8 cm^2) break in the reactor vessel bottom head.

Following rupture of on instrument tube, the RCS depressurizes and a reactor scram signal and SIAS are generated due to low pressurizer pressure. The assumed loss-of-offsite power causes the reactor coolant pumps and the feedwater pumps to coastdown. After the 30-second delay required to start the emergency diesel generator and the HPSI pump, safety injection flow is initiated to the RCS. The auxiliary feedwater pumps are also started due to low steam-generator level, providing a source of cooling to the steam generators. Due to the assumed failure of one Class 1E diesel generator, only one HPSI pump and one train of auxiliary feedwater are available. (Four SITs and one LPSI pump are also available but do not inject due to the high RCS pressure.) The steam-generator secondary sides also become isolated at reactor trip.

The RCS depressurization continues, accompanied by a rise in steam-generator pressure, until the steam-generator pressure reaches the lowest setpoint of the main steam safety valves. The RCS depressurization then stops with the RCS pressure greater than the steam-generator pressure. At this point, the flow from the one operating HPSI pump (57.8 lbm/sec (26.2 kg/sec)) exceeds the leak flow (26.3 lbm/sec (11.9 kg/sec)). Therefore, the RCS will fill. The decay heat generated in the core is removed in the steam generators by steam flow through the main steam safety valves. Thus, the core will remain covered and cooled in this condition. The post-LOCA long term cooling procedures described in Subsection 6.3.3.4 are initiated at 1 hour to provide long term cooling.

6.3.3.4 Post-LOCA Long Term Cooling

6.3.3.4.1 General Plan

Long term cooling (LTC) is initiated when the core is quenched after a LOCA and is continued until the plant is secured. The objective of LTC is to maintain the core at safe temperature levels while avoiding the precipitation of boric acid in the core region. To accomplish this objective, the LTC analysis for YGN 3&4 was performed using the codes and methods documented in Reference 9.

The LTC plan for YGN 3&4 uses either of two procedures, depending on the break size. Shutdown cooling (SDC) system is initiated if the break is sufficiently small that successful operation of the SDC system is assured. For large break LOCAs, simultaneous hot- and cold-leg injection is used to maintain core cooling and boric acid flushing. The plant operator initiates the appropriate procedure based on the indicated RCS pressure.

Figure 6.3-19 shows the basic sequence of events and the time schedule for operator actions for the YGN 3&4 LTC plan. The time schedule gives a time range during which the action is to be accomplished. That is, it is assumed that the specified functional requirement will be operational within the time range given.

The operator's first action is to initiate cooldown by 1 hour post-LOCA by releasing steam from the steam generators. The steam is released through the turbine bypass system if it is available or through the atmospheric dump valves. Between 1 and 3 hours post-LOCA, the SITs are isolated or vented to avoid injecting a large quantity of nitrogen (noncondensible) gas into the RCS. Between 1 and 4 hours post-LOCA, pressurizer cooldown is initiated. Then between 2 and 3 hours post-LOCA, the HPSI pump discharge is realigned so that the total injection flow is divided about equally between the hot and cold legs.

If the RCS pressure is above 550 psia (38.7 kg/cm^{2}A) between 9 to 10 hours after the LOCA, the RCS is filled, which ensures that proper suction is available for entering SDC. Cooling of the RCS continues until the indicated RCS temperature is lower than the maximum SDC entry temperature including instrument uncertainty. The HPSI pumps are then throttled until RCS pressure is reduced to SDC entry pressure, including instrument uncertainty. All HPSI pump flow is then realigned back to the cold legs and SDC is initiated.

A prerequisite to throttling or terminating HPSI flow is that the RCS must be in a subcooled condition for the indicated RCS pressure. Therefore, while reducing RCS pressure to initiate SDC system operation, it is essential to maintain subcooling of the RCS consistent with emergency operating guidelines.

If the SDC system is inoperable, an alternative method for decay heat removal is the continued use of the steam generators. This requires the continued availability of auxiliary feedwater and the atmospheric dump valves or the turbine bypass system. If the SDC system becomes operable at some later time, it should be put into operation. This path is indicated by the dashed lines in Figure 6.3-19.

If the indicated RCS pressure has fallen below 550 psia (38.7 kg/cm^{2}A) at 9 to 10 hours, the break is too large for absolute assurance that proper suction is available for the SDC system. In this event, continued simultaneous hot- and cold-leg injection will cool the core and flush the reactor vessel indefinitely.

6.3.3.4.2 Assumptions Used in the Post-LOCA Long Term Cooling Analysis

The major assumptions used in performing the LTC analysis are listed below:

a. No offsite power is available.

b. The worst single failure is the failure of one of the two emergency diesel generators. This results in the following:

    1. One HPSI pump is operable (no LPSI pumps are used during the recirculation mode).

    2. One train of auxiliary feedwater is operable.

c. The concentration for boric acid precipitation is 29% by weight. This is the precipitation limit at 16.2 psia (1.14 kg/cm^{2}A), 217°F (103 °C). These conditions were calculated using a conservative ECCS model for containment pressure.

d. One of the two atmospheric dump valves on each steam generator is operable.

e. RCS cooldown begins at 1 hour post-LOCA.

f. The SITs are vented or isolated in establishing SDC conditions for the small break LTC procedure.

g. The pressurizer is cooled down in establishing SDC conditions for the small break LTC procedure.

h. RCS cooldown is terminated when the hot-leg temperature is below the SDC entry temperature, including instrument uncertainty.

i. Maximum instrument errors: RCS pressure 300 psi (21.1 kg/cm^2); RCS temperature 10 °F (5.55 °C).

j. Maximum values are used for the boric acid concentrations of all sources of boric acid.

k. Pump flow rates and initial water source inventories used in the calculation of maximum boric acid concentration are selected to maximize the boric acid concentration in the core.

6.3.3.4.3 Parameters Used in the Post-LOCA LTC Analysis

Significant core and system parameters used in the post-LOCA long term cooling analysis are presented in Table 6.3-18.

6.3.3.4.4 Results of the Post-LOCA LTC Analysis

The double-ended (9.8 ft^2 [9104 cm^2]) cold-leg break is the limiting break for long term boric acid accumulation in the inner vessel region. For a cold-leg break, the core flushing flow is the difference between the hot-leg injection flow rate and the core boiloff rate. The initiation of a simultaneous hot- and cold-leg HPSI pump flow rate of at least 294 gpm (1113 l/min) to each side between 2 and 3 hours post-LOCA provides a substantial and time-increasing core flushing flow, as shown in Figure 6.3-20. Figure 6.3-21 shows that, with no core flushing flow, boric acid would not begin to precipitate until after 3.3 hours post-LOCA. The margin provided for the prevention of boric acid precipitation by a core flushing flow of 20 gpm (75.7 l/min) is also shown in Figure 6.3-21. The time at which all hot-leg steam entrainment of injection water is terminated was calculated to be less than 1.2 hours post-LOCA. Therefore, the initiation of simultaneous hot- and cold-leg injection between 2 and 3 hours is after any potential for hot-leg entrainment is terminated and before boric acid is predicted to precipitate.

The small break LTC plan applies to those break sizes for which the RCS refills before all auxiliary feedwater is exhausted. The small break analysis determined that 23 hours is the minimum time required to exhaust all auxiliary feedwater during cooldown of the RCS. Additionally, the analysis predicts the RCS to refill at various times depending on break size as shown in Figure 6.3-22. As shown, a break size as large as 0.045 ft^2 (41.8 cm^2) refills within 9 hours. By 23 hours, the RCS will refill for even larger break sizes. Therefore, to allow a substantial time margin to avoid exhausting the auxiliary feedwater, a time of 9 to 10 hours was selected for the operator to decide if the small break LTC procedure is appropriate. These results demonstrate that breaks as large as 0.045 ft^2 (41.8 cm^2) will be able to use SDC for the long-term cooling and flushing of the core. The analysis determined that the large break procedures can flush the core for break sizes down to 0.003 ft^2 (2.8 cm^2). This overlap in break sizes for which either the large or small break procedures can be used is illustrated in Figure 6.3-23.

The operator chooses the appropriate procedure on the basis of indicated RCS pressure between 9 and 10 hours. Figure 6.3-23 lists the RCS pressure at 9 hours for a wide range of break sizes, and Figure 6.3-24 presents this information graphically. The decision pressure is selected as 550 psia (38.7 kg/cm^2A) such that, with consideration of the maximum RCS pressure measurement error, 300 psi (21.1 kg/cm^2), the operator is assured of selecting the proper procedure for any break size.

6.3.3.5 Sequence of Events and System Operations

Table 6.3-19 presents a chronological list of events which occur during two representative LOCAs: a small break of 0.05 ft^2 (46.5 cm^2) and a large break, C_D = 0.8 of DEG/PD. Table 6.3-19 extends from the occurrence of the break to the decision point at 9 to 10 hours when the operator decides whether or not to enter the shutdown cooling mode. 741

The safety functions for mitigation of LOCA events are described as follows.

Reactivity Control

Following the break, the RCS pressure drops rapidly. For small breaks, this results in the generation of a low pressurizer-pressure trip signal and the CEAs drop into the core. In the case of the large break, the insertion of the CEAs will probably occur by high-containment pressure trip signal but is not required, as the amount of voiding which occurs in the moderator introduces sufficient negative reactivity to make the reactor subcritical. At the low pressurizer-pressure trip setpoints, a safety injection actuation signal (SIAS) is generated and additional negative reactivity is added to the system in the form of borated water from the RWT. In the large break case, the RCS pressure drops low enough to allow discharge of the SITs and injection from both the HPSI and LPSI pumps. For the small break, only the HPSI pumps inject. For all breaks, the water level in the RWT will eventually drop sufficiently to result in the generation of a recirculation actuation signal (RAS). Upon generation of the RAS, the containment recirculation sump isolation valves open to supply the HPSI pumps during the recirculation phase.

Reactor Heat Removal

Following the loss of power to the non-ESF loads as a result of the turbine trip and the subsequent assumed loss-of-offsite power, the reactor coolant pumps coast down. For the small break, reactor heat removal takes place by means of natural circulation and the additional cooling capability of the relatively low enthalpy RWT water, introduced by the SIS. For the large break, reactor heat removal is accomplished by the SIS since conditions within the RCS prevent the establishment of natural circulation flow. Following the generation of the RAS, reactor heat removal continues through the use of the SIS in the recirculation mode.

Two hours after the LOCA, the operator manually aligns the HPSI pump discharge lines for simultaneous hot- and cold-leg injection. Nine to ten hours after the LOCA, the operator may initiate shutdown cooling provided that the RCS pressure has remained above 550 psia (38.7 kg/cm^2A). If RCS pressure is less than 550 psia, hot and cold leg injection is sufficient to cool the core and is continued.

Primary System Integrity

For small break LOCAs the RCS pressure is controlled by throttling the HPSI discharge valves. The operator will depressurize and isolate the SITs between 1 to 3 hours after the LOCA, as the RCS pressure is decreased toward the shutdown cooling entry level.

Secondary System Integrity

For all break sizes, the reactor trip will result in a turbine trip, and the coincident loss-of-offsite power will result in the loss of main feedwater flow. Since the steam bypass control system is not available due to loss of condenser vacuum on loss-of-offsite power, the secondary system pressure will increase and for some small breaks will reach the opening pressure of the main steam safety valves (MSSVs). In the cases where the MSSVs open, the lack of main feedwater will eventually result in the generation of an auxiliary feedwater actuation signal and the delivery of feedwater to both steam generators. The operator will initiate cooldown at 1 hour after the LOCA, using either the atmospheric dump valves or the steam bypass system. Along with the dump or bypass valves, the operator will utilize the auxiliary feedwater pumps. During the cooldown, the operator will reduce the setpoint to prevent the inadvertent generation of an MSIS.

Containment Integrity

Upon generation of an SIAS, the reactor containment fan coolers operate in the low speed mode to cool the containment atmosphere. The CCW system cools the RCFCs.

A containment spray actuation signal (CSAS) is generated on a high-high containment pressure signal. The CS pumps spray water from the RWT into the containment to reduce the temperature and pressure of the containment atmosphere. On the generation of an RAS, the containment recirculation sump isolation valves open to supply water to the CS pumps.

Combustible Gas Control

The containment sprays and reactor containment fan coolers act to mix the containment atmosphere and prevent the formation of hydrogen gas pockets. The operator actuates the containment combustible gas control system to control the hydrogen concentration in the containment atmosphere.

Radioactive Effluent Control

When the pressurizer pressure reaches the low-pressure setpoint, a CIAS is generated. Upon detection of high-high containment pressure, a CSAS is generated. The CIAS and CSAS result in the isolation of various containment primary and secondary systems to limit radioactive releases. The containment spray system functions to remove radioactive iodine from the containment atmosphere.

Control Room Habitability

The SIAS actuates the control room emergency ventilation system for control room habitability.

Restoration of AC Power

The emergency diesel generators are automatically started when an undervoltage condition is sensed on the associated ESF bus. For large break LOCAs, ac power is assumed to be lost at t = 0 seconds. For small break LOCAs, ac power is assumed to be lost following the reactor trip, and the failure of one emergency diesel generator is assumed. All required ESF loads are loaded onto the emergency diesel generators.

Spent Fuel Heat Removal

Spent fuel pool (SFP) cooling continues to operate during a LOCA condition, with or without a loss-of-offsite power. SFP cooling pumps are automatically loaded on the emergency DG's. SFP heat exchangers continue to receive component cooling water flow during a LOCA condition.

6.3.4 Tests and Inspections

During fabrication of the SIS components, tests and inspections are performed and documented in accordance with code requirements to assure high quality construction. Performance tests of components are performed, as necessary, in the vendor's facility. The SIS is designed and installed to permit inservice inspections and tests in accordance with ASME Code Section XI.

6.3.4.1 ECCS Performance Tests

Prior to initial plant startup, a comprehensive series of system flow tests will be performed to verify that the design performance of the system and individual components is attained.

6.3.4.2 Reliability Tests and Inspections

6.3.4.2.1 System Level Tests

After the plant is brought into operation, periodic tests and inspections of the SIS components and subsystems are performed to ensure proper operation in the event of an accident. The scheduled tests and inspections are necessary to verify system operability, since during normal plant operation, SIS components are aligned for emergency operation and serve no other function.

The tests defined permit a complete checkout, at the subsystem and component level, during normal plant operation. Satisfactory operability of the complete system can be verified during normal scheduled refueling shutdown. The complete schedule of tests and inspections of the SIS is detailed in ~~Chapter 16~~.
ITS

6.3.4.2.2 Component Testing

In addition to the system level tests described in Subsection 6.3.4.2.1, tests to verify proper operation of the SIS components are also conducted. These tests supplement the system level tests by verifying acceptable performance of each active component in the SIS. Pumps and automatic valves will be tested in accordance with ASME Section XI.

6.3.5 Instrumentation

6.3.5.1 Design Criteria

The instruments and controls for the SIS are designed in accordance with the applicable portions of IEEE 279-1971, "Criteria for Protection Systems for Nuclear Power Generating Stations." The controls are interlocked to automatically provide the sequence of operations required to initiate SIS operation. The instrumentation and controls which actuate and control the SIS are designed on the following basis.

a. Redundant instruments are provided for initiation of SIS actions. Four sensors are used for each of the critical parameters. A trip from any two of these four sensors initiates the appropriate SIS action. Circuits are run in separate wiring raceways to assure the availability of safety injection actuation signals.

b. Electric power required for SIS controls and instruments is supplied via two preferred ac buses. Emergency generators provide an alternate source of ac power.

Actuator-operated valves are provided with switch guards for the control switches where considered necessary to prevent unintentional misalignment of safety injection flow paths during power operation.

All valves that are not required to operate on initiation of safety injection or recirculation in the safety injection flow path are locked in the safety injection position during operation. Administrative controls ensure that the valves are locked in the correct position.

A further discussion of the instrumentation and control for safety injection initiation is given in Section 7.3.

6.3.5.2 System Actuation Signals

Operation of the SIS is controlled by two actuation signals. The first of these, the safety injection actuation signal (SIAS), initiates operation of the SIS in the event of low pressurizer pressure or high containment pressure. Both of these parameters provide an indication of a loss-of-coolant accident, which requires operation of the SIS. SIAS may be manually initiated from the control room. The second control signal is the recirculation actuation signal (RAS). This signal changes the operation mode of the SIS from injection with suction from the refueling water tank to recirculation with suction from the containment recirculation sump. The RAS is initiated by low RWT level. RAS and SIAS initiated manually or automatically. Changing from the injection mode of operation to recirculation permits continuous flow to the core when the RWT water supply is depleted.

6.3.5.2.1 Safety Injection Actuation Signal

Initiation of safety injection is derived from four independent pressurizer pressure sensors and four independent containment pressure sensors. Coincidence trip signals from two-out-of-four sensors for either parameter will automatically initiate safety injection. Automatic SIS operation is actuated at a pressurizer pressure of approximately 1770.4 psia (124.47 kg/cm^{2}A) during power operation or a containment pressure of approximately 1.9 psig 574 (133.75 cmH_2O). During startup and shutdown operations, a variable setpoint on the low pressurizer pressure is used. A further discussion of the SIAS is given in Section 7.3.

6.3.5.2.2 Recirculation Actuation Signal

Initiation of recirculation is derived from four(4) independent RWT level

sensors or manually from the control room. The automatic RAS requires a 7.6% 574
RWT level indication from two (2) of four (4) channels.

6.3.5.3 Instrumentation During Operation

The instrumentation provided for monitoring SIS components during SIS operation is discussed in this section. See Figure 6.3-1 for instrumentation readout locations and Figures 6.3-2 through 6.3-5 for component usage during the various modes.

6.3.5.3.1 Temperature

a. Shutdown Cooling Suction and Injection Temperature

RTDs and a recorder on each low-pressure injection header are used to measure and record the shutdown cooling water temperature as it enters and leaves the SIS. This readout is used to provide a measure of the overall system performance and provides information allowing the operator to adjust the cooldown rate. The recorder is located for easy access on the control room on the operator's console. Indication is provided on the remote shutdown panel. See Subsection 5.4.7 for further details.

6.3.5.3.2 Pressure

a. SIT Pressure

A wide-range pressure transmitter mounted on each SIT permits readings of each tank pressure in the control room and on the remote shutdown panel. Also, two narrow-range pressure transmitters permit readings of each tank pressure in the control room.

b. High and Low Pressure Safety Injection Pump Discharge Pressure

HPSI and LPSI pump discharge pressure are indicated in the control room.

6.3.5.3.3 Valve Position

a. SIT Isolation Valve Position

Valve position is indicated in the control room by redundant and diverse indicators. Indicator lights verify either the fully open or fully closed position, with an alarm if the valve is not fully open. In addition, continuous valve position monitoring indicates partially opened or partially closed valve position.

b. Shutdown Cooling System Valve Position

Valves that must be repositioned and valves used to control cooldown have position indication both inside the control room and at a location outside the control room.

c. Hot-Leg Injection Valve Position

Hot-leg injection valve position is indicated in the control room. Indicator lights verify either open or closed position. In addition, continuous valve position monitoring indicates partially-opened or partially-closed positions.

d. LPSI Header Isolation Valve Position

Valve position is indicated both inside the control room and at a location outside the control room.

6.3.5.3.4 Level

SIT Level

Wide-range water level for each SIT is indicated in the control room throughout the complete tank volume except for water above the upper level and below the lower level instrument taps. The instrument taps are approximately 5 inches (12.7 cm) below the upper tank tangent and approximately 5 inches (12.7 cm) above the lower tank tangent. This provides full range level indication based on a 34-ft (10.4-m) full range scale. Redundant level indication is provided based on a 4-ft (1.2-m) full scale range with the low tap 25 ft-8.5 in (7.8 m) above the lower tangent. Signal input for this indication is provided by a differential pressure transmitter.

6.3.5.3.5 Flow

a. Shutdown Cooling Flow

A shutdown flow indicator presents total shutdown cooling flow.

b. Safety Injection Flow

These flow channels indicate the flow rate in each of the four cold-leg safety injection lines and each of the two lines to the hot legs. Indication is in the control room.

6.3.5.4 Postaccident Monitoring Instrumentation

The instrumentation available for evaluation of postaccident performance is identified in Tables 7.5-2 and 7.5-3.

6.3.6 References

1. 원자력안전위원회 고시 제2014-21호, 제 3조, "가압경수로의 비상노심냉각계통의 성능에 관한 기준", 2014.11.22. 735

2. 10 CFR Part 50.46 and Appendix K or 10 CFR, Part 50, "Acceptance Criteria for Emergency Core Cooling Systems for Light Water Cooled Nuclear Power Reactors", Federal Register, Volume 39, Number 3, January 1974, and amended in Federal Register, Volume 53, September 1988.

3. KNF-TR-SGA-01001/N/A, Rev.1, "한국표준형 원전의 냉각재상실사고 해석을 위한 웨스팅하우스 평가모델", 2004. 6.

3-1. KNF-TR-DMR-04001/N/A, Rev. 0, "한국표준형 원전용 PLUS7 연료 설계 및 안전성 평가", 2006. 03.

4. KINS/GT-N007-2, "가압경수로형 원자력발전소 비상노심냉각계통 성능의 보수적 평가방법에 대한 기술지침서", 2004. 1.

4-1. KINS/GT-N007-2, "가압경수로형 원자력발전소 비상노심냉각계통 성능의 최적 평가방법에 대한 기술지침서", 2004. 1.

5. NUREG-5535, "RELAP5/MOD3 Code Manual," March 1998.

6. NUREG/CR-3716, "A Multi-compartment Containment System Analysis Program," March 1984.

NUREG/CR-4001, "An Improvement to CONTEMPT4/MOD5 Multi-compartment System Analysis Program for Ice Containment Analysis," September 1984.

7. F. M. Bordelon, et. al., "LOCTA-IV Program : Loss of Coolant Transient Analysis", WCAP-8301 (Proprietary) and WCAP-8305 (Non-Proprietary), June 1974.

8. TR-KHNP-0010, "한국표준형원전 LBLOCA 안전해석방법론," 2007.6.

9. "Post-LOCA Long Term Cooling Evaluation Model," CENPD-254-P-A, June 1980 (Proprietary).

10. P. E. Meyer, et. al., "NOTRUMP: A Nodal Transient Small Break and General Network Code", WCAP-10079-P-A (Proprietary) and WCAP-10080-NP-A (Non-Proprietary), August 1985.

11. N. Lee, et. al., "Westinghouse Small Break ECCS Evaluation Model Using the NOTRUMP Code", WCAP-10054-P-A (Proprietary) and WCAP-10081-NP-A (Non-Proprietary), August 1985.

S. M. Bajorek, et. al., "Addendum To The Westinghouse Small Break ECCS Evaluation Model Using The NOTRUMP Code For The Combustion Engineering NSSS", WCAP-10054-P-A Add. 1 (Proprietary) and WCAP-10054 Add. 1 (Non-Proprietary), March 1987.

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TABLE 6.3-1 (Sh. 1 of 2)

SAFETY INJECTION SYSTEM COMPONENT PARAMETERS

Low-Pressure Safety Injection Pumps

Quantity	2
Type	Single Stage, Vertical, Centrifugal
Safety Classification	2
Code	ASME III, Class 2
Design Pressure	750 psig (52.7 kg/cm^2)
Maximum Operating Suction Pressure	485 psig (34.1 kg/cm^2)
Design Temperature	400°F (204.4°C)
Design Flow Rate	4200 gpm* (15.9x10^3 L/min)
Design Head	335 ft (102.1 m)
Maximum Flow Rate	5000 gpm* (18.9x10^3 L/min)
Head at Maximum Flow Rate	290 ft (88.4 m)
Materials	Stainless Steel Type 304 316 or approved alternate
Seals	Mechanical
Brake Horsepower	470 hp (350.5 kW)

*Does not include 120 gpm (454.2 L/min) by-pass flow

High-Pressure Safety Injection Pumps

Quantity	2
Type	Multistage, Horizontal Centrifugal
Safety Classification	2
Code	ASME III, Class 2
Design Pressure	2050 psig (144 kg/cm^2)
Maximum Operating Suction Pressure	100 psig (7 kg/cm^2)
Design Temperature	350°F (176.7°C)
Design Flow Rate	815 gpm* (3034.8 L/min)
Design Head	2850 ft (868.7 m)
Maximum Flow Rate	1130 gpm* (4277 L/min)
Head at Maximum Flow Rate	1580 ft (451.6 m)
Materials	Stainless Steel, Type 304, 316 or approved alternate
Shaft Seal	Mechanical
Brake Horsepower	910 hp (678.9 kW)

*Does not include 85 gpm (321.7 L/min) by-pass flow

TABLE 6.3-1 (Sh. 2 of 2)

Safety Injection Tanks

Quantity	4
Safety Classification	2
Code	ASME III, Class 2
Design Pressure, Internal/External	700 psig/100 psig (49.2 kg/cm^2/7.03 kg/cm^2)
Design Temperature	200°F (93.3°C)
Operating Temperature	140°F (60°C)
Normal Operating Pressure	610 psig (42.9 kg/cm^2)
Volume, Total	2400 ft^3 (67.96 m^3)
Liquid	
Minimum	1790 ft^3 (50.7 m^3)
Nominal	1858 ft^3 (52.6 m^3)
Maximum	1927 ft^3 (54.6 m^3)
Fluid	Borated water, 4200 ppm boron nominal, 4400 ppm max.
Material	Clad - Stainless Steel, Type 304 316, or approved alternate Body - Carbon Steel, Type SA-516 Gr 7 or approved alternate

TABLE 6.3-2 (Sh. 1 of 17)

SAFETY INJECTION SYSTEM FAILURE MODE AND EFFECTS ANALYSIS

A. INJECTION MODE, SIT FILLING AND DRAINING

When pressurizer pressure drops below 1825 psia (128.3 kg/cm^2A) or containment pressure rise above 2.7 psig (0.19 kg/cm^2) during plant operation, a safety injection actuation signal (SIAS) will be generated and the SIS automatically goes into operation. The following pieces of equipment are actuated with the interfacing systems and components lined up as follows. RWT isolation valves (CH-530/531) and RWT isolation check valves (CH-305/306) are opened.

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failure	Method of Detection	Inherent Compensating Provision	Remarks and Other Effects
I.	LPSI Injection Mode						
1.	SCS suction line isol. valve SI-655 SI-656 SI-690 SI-691	a) Fails open	Mech. binding, elect. malf., corrosion	None	Periodic testing; Valve position indicator	Redundant series isolation valves (SI-653/655) are closed	Valve is normally locked closed
		b) Fails closed	Mech. binding, elect. malf., corrosion	None	Same as 1a)	None required	
2.	Shutdown purification valves SI-418 SI-419 SI-420 SI-421	a) Fails closed	Mech. binding, corrosion	None	Periodic testing; operator	None required	
		b) Fails open	Mech. binding, corrosion	None	Periodic testing; operator	Series isolation valves in CVCS (CH-363, 397)	Valve is normally Locked closed at valve
3.	LPSI pump suction isol. valve SI-683 SI-692	a) Fails open	Mech. binding elect. malf., corrosion	No effect during injection mode	Periodic testing; valve position indication in control room	None required during injection mode	
		b) Fails closed	Mech. binding, elect. malf., corrosion	Loss of affected injection flow	Same as 3a)	Redundant LPSI train	Valve is normally locked open

TABLE 6.3-2 (Sh. 2 of [illegible])

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failure	Method of Detection	Inherent Compensating Provision	Remarks and Other Effects
4.	LPSI pump suction test isol. valve SI-550 SI-555	a) Fails closed	Mech. failure	No impact on system operation.	Operator	None required	
		b) Fails open	Mech. failure, seal leakage	None	None	These drain valves/test conn. blind flanged	
5.	LPSI pump No. 1 or No.2	a) Fails to start on SIAS	Elect. malf.	Reduce flow to low pressure header	Low flow indication for F-306 or F-307; Pump "run" light; Periodic testing	Redundant LPSI pump	
6.	LPSI discharge line isol. valve SI-435 SI-447	a) Fails closed	Mech. binding, corrosion	Loss of one of LPSI injection lines	Periodic testing; Low flow indication for F-306 or F-307	Redundant LPSI train	Valve is normally locked open at valve
7.	LPSI pump recirculation isol. valve SI-668 SI-669	a) Fails closed	Mech. binding, elect. malf., corrosion	Possible damage to one LPSI pump	Periodic testing; None, unless pump overheats and fails; Valve position indicator; Low flow indication for F-300	Redundant LPSI pump	Valve is normally locked open
8.	Miniflow line to RWT isol. valve SI-659 SI-660	a) Fails closed	Mech. binding, elect. malf., corrosion	Possible damage to associated pump	Periodic testing; Valve position indicator; None, unless pump overheats and fails	Redundant pump	Valve is normally locked open

TABLE 6.3-2 (Sh. 2a of 17)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failure	Method of Detection	Inherent Compensating Provision	Remarks and Other Effects
	(Note : Failure modes c & d are applicable to SI-659 only.)	b) Fails open	Elect. malf.	None during HPSI recirculation mode	Valve position indicator in control room	Redundant series isolation valves (SI-666, SI-669, SI-667, and SI-668) are closed during recirculation mode	The mini-flow valves are normally open and are required to be closed during recirculation mode
		c) Initially open, re-opens due to lack of LOP reset, fails closed	Elect. malf., mech. binding	Same as 8a)	Same as 8a)	Same as 8a)	Same as 8a)
		d) Initailly open, re-opens due to lack of LOP reset, fails open	Elect. malf., mech. binding	Potential for draining one SIT during SIT fill operation	Valve position indicator, SIT level indicator	Operator can close redundant series isolation valve (SI-682, SI-611, SI-621, SI-631, or SI-641) to terminate draining of affected SIT.	Only HPSI pump No. 2 is used to fill SITs. Valves in HPSI pump No. 2 mini-flow path remain open during SIT fill operation.

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TABLE 6.3-2 (Sh. 3 of 17)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failure	Method of Detection	Inherent Compensating Provision	Remarks and Other Effects
9.	Crossover valve between LPSI pump discharge and SDCHX SI-685,694 SI-657,658	a) Fails open	Mech. binding, elect. malf., corrosion	Potential diversion of LPSI pump flow to containment spray system for SI-685, 694; None for SI-657, 658	Periodic testing; Valve position indication	Series isolation valves for SI-685/694, SI-657/658	Valve is normally locked closed
10.	SDCHX bypass flow control valve SI-306 SI-307	a) Fails closed	Mech. binding, elect. malf., corrosion	Loss of one of LPSI lines	Periodic testing; Valve position indication; Low flow indication for F-306 or F-307	Redundant train	Valve is normally locked open
		b) Fails open	Same as 10. a)	None	Periodic testing; Valve position indication; Flow indication for F-306 or F-307	None required	
11.	RWT line isol. valve SI-298	a) Fails closed	Mech. binding, corrosion	None	Operator	None required	
		b) Fails open	Same as 11. a)	None	Operator	Series isolation valves (SI-460/464) are closed	Valve is normally closed
12.	LPSI header isol. valve SI-615 SI-625 SI-635 SI-645	a) Fails closed	Elect, malf., mech. binding, corrosion	Loss of flow from LPSI pump to one of RCS cold legs	Periodic testing; position indication	Redundant LPSI train	HPSI pumps and SITs will continue to charge cold legs
		b) Fails to open on SIAS	Elect. malf., mech. binding, corrosion	Loss of flow from LPSI pump to one of RCS cold legs	Same as 12a)	Redundant LPSI train	
		c) Fails open	Elect. malf., mech. binding, corrosion	None	Same as 12a)	Redundant downstream check valves (SI-114/124/134/144) prevent backflow	

TABLE 6.3-2 (Sh. 4 of 17)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failure	Method of Detection	Inherent Compensating Provision	Remarks and Other Effects
13.	LPSI discharge flow rate indicator F-306 F-307	False indication	Elect. malf., mech. malf.	None	Periodic testing; Comparison with redundant indicators	Redundant train	
II.	HPSI Injection Mode						
14.	HPSI suction line isol. valve SI-470 SI-402	a) Fails closed	Mech. binding, corrosion	Loss of one of HPSI injection lines	Periodic testing; Operator; Loss of associated HPSI pump	Redundant HPSI train	Valve is normally locked open at valve
15.	HPSI pump suction test isol. valve SI-552 SI-553	a) Fails closed	Mech. failure	No impact on system operation. Unable to drain line section or test valves per ASME XI.	Operator	None required	
		b) Fails open	Mech. failure, seal leakage	None	None	These drain valves/test conn. blind flanged	
16.	HPSI pump No. 1 or No.2	a) Fails to start on SIAS	Elect. malf.	Reduce flow to high pressure header	Low pressure indication for P-308 or P-309; Pump "run" light; Periodic testing	Redundant HPSI pump	
17.	HPSI pump miniflow line orifice bypass valve SI-218 SI-219	a) Fails closed	Mech. failure seal leakage	Cannot provide an adequate condition for SIT refilling or HPSI pump testing	Operator	Orifice is available to provide an alternate flow path	
		b) Fails open	Same as 17a)	Reduce flow to RCS	None	Redundant train	Valve is normally closed at valve

TABLE 6.3-2 (Sh. 5 of 17)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failure	Method of Detection	Inherent Compensating Provision	Remarks and Other Effects
18.	HPSI pump miniflow isol. valve SI-666, SI-667	a) Fails closed	Mech. binding, elect. malf., corrosion	Possible damage to one HPSI pump	Valve position indicator; Periodic testing; None, unless pump overheats and fails	Redundant HPSI pump	Valve is normally locked open
19.	RWT return line isol. valve SI-400 SI-459	a) Fails open	Mech. binding, corrosion	None	Operator	Redundant series isol. valves (SI-461, 462,463,459) are closed	Valve is normally locked closed at valve
		b) Fails closed	Mech. binding, corrosion	Cannot provide an adequate condition for HPSI pump testing	Operator	Redundant flowpath exists to return refueling pool water to RWT prior to startup	
20.	HPSI discharge line isol. valve SI-476, SI-478	a) Fails closed	Mech. binding, corrosion	Loss of one of HPSI injection lines	Periodic testing; Low Pressure indication for	Redundant HPSI train P-308 or P-309	Valve is normally locked open at valve
21.	HPSIP pump orifice bypass valve SI-698 SI-699	a) Fails closed	Elect. malf., mech. binding, corrosion	Reduce flow to one of HPSI injection lines	Periodic testing; Valve position indication; Low pressure indication for P-308 or P-309	Redundant HPSI train	Valve is normally locked open
22.	HPSI hot leg injection line isol. valve SI-604 SI-609	a) Fails open	Elect. malf., mech. binding, corrosion	Potential diversion of HPSI injection flow to hot legs	Periodic testing; Valve position indication	Series isolation valves (SI-321/331, SI-509) are closed	Valve is normally locked closed during injection mode of operation
23.	Charging pump isol. valve SI-508, SI-509	a) Fails open	Mech. binding, operator	Potential loss of HPSI flow to charging pump subsystem	Operator	Series isolation check valve in CVCS (CH-440)	Valve is normally locked closed at valve

TABLE 6.3-2 (Sh. 6 of 17)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failure	Method of Detection	Inherent Compensating Provision	Remarks and Other Effects
24.	HPSI header isol. valve SI-616,617 SI-626,627 SI-636,637 SI-646,647	a) Fails closed	Mech. binding, elect. malf., corrosion	Decrese in ability to inject high pressure water in RCS	Valve position indication in control room; Periodic testing	Parallel redundant cold leg injection lines	
		b) Fails to open on SIAS	Same as 24a)	Same as 24a)	Same as 24a)	Same as 24a)	
		c) Fails open	Same as 24a)	None	Same as 24a)	None required	
25.	HPSI header injection flow indicator F-311/321 F-331/341	False indication	Elect. malf., mech. malf.	None	Periodic testing; Comparison with redundant indicators	Redundant train	

III. SIT Injection Mode

When pressurizer pressure is above 500 psig (35.1 kg/cm²), the SITs are isolated from the RCS by two check valves in series. If RCS pressure should fall below SIT pressure, the tanks will begin to discharge borated water into the RCS.

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failure	Method of Detection	Inherent Compensating Provision	Remarks and Other Effects
26.	SIT isol. valve SI-614 SI-624 SI-634 SI-644	a) Fails closed	Mech. binding, elect. malf., corrosion	Loss of flow from SIT to one of affected RCS cold legs	Valve position indication; Periodic testing	Redundant SIT flow to cold legs	Valve is normally locked open
		b) Fails open	Same as 26a)	Cannot isolate affected SIT when required	Same as 26a)	None, inline checks prevent reverse flow	
		c) Fails to open on SIAS	Same as 26a)	Same as 26a)	Same as 26a)	Same as 26a)	Same as 26a)

TABLE 6.3-2 (Sh. 7 of 17)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failure	Method of Detection	Inherent Compensating Provision	Remarks and Other Effects
27.	SI cold leg check valve leakage test isol. valve SI-618 SI-628 SI-638 SI-648	a) Fails closed	Mech. binding, air line separates from operator	None	Valve position indication in control room; Periodic testing	None required	Valve is normally locked closed
		b) Fails to close on SIAS	Elect. malf., seal failure, contamination	None	Same as 27a)	Redundant isolation valves in series prevent SI cold leg being drained	Valve is designed to fail closed and is normally closed
		c) Fails open	Seal failure, contamination	None	Same as 27a)	Same as 27b)	Same as 27b)
		d) Initially open, re-opens due to lack of LOP reset, fails open	Elect. malf., seal failure	None	Valve position indicator, periodic testing, SIT level indicator	Operator can close redundant series isolation valve (SI-661 or SI-682) to prevent affected SIT from being drained	Valve is designed to return to initial position following the interruption of power to the valve
		e) Initially open, re-opens due to lack of LOP reset, fails closed	Air line separation from valve operator	Cannot drain test line to determine the rate of back leakage of affected SI cold leg check valve when required	Same as 27d)	None	
28.	SIT fill and drain line air operated isol. valve SI-611 SI-621 SI-631 SI-641	a) Fails closed	Mech. binding, air line separates from operator	Cannot adjust the SIT water level when required	Valve position indication in control room; Periodic testing; SIT level	None required	Valve is normally closed

TABLE 6.3-2 (Sh. 7a of 17)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failure	Method of Detection	Inherent Compensating Provision	Remarks and Other Effects
		b) Fails to close on SIAS	Elect. malf., seat failure, contamination	None	Same as 28a) except SIT level	Redundant isolation valves in series (SI-322/332,661,682) prevent SIT being drained	Valve is designed to fail closed and is normally closed
		c) Fails open	Same as 28b)	None	Same as 28b)	Same as 28b)	Valve is designed to fail closed
		d) Initially open, re-opens due to lack of LOP reset, fails open	Elect. malf., seal failure	Potential for draining one SIT during SIT fill operation	Valve position indicator, SIT level indicator	Operator can close redundant series isolation valve (SI-661 or SI-682) to prevent affected SIT from being drained	Valve is normally closed, except during SIT fill/drain operation
		e) Initially open, re-opens due to lack of LOP reset, fails closed	Elect. malf., air line separation from valve operator	Cannot adjust the water of the affected SIT when required	Same as 28a)	Noen	Plant shutdown may occur if SIT level is outside the Tech Spec limits
29.	SIT nitrogen supply isol. valve SI-619,612 SI-629,622 SI-639,632 SI-649,642	a) Fails closed	Mech. binding, air line separates from operator	Cannot repressurize SIT when required	Position indication in control room; Periodic testing		Repair or plant shutdown
		b) Fails open	Mech. binding, seal failure, elect. malf.	None	Position indication in control room; periodic testing	Series isolation valves (SI-612/622/632/642) are closed	Valve is designed to fail closed

TABLE 6.3-2 (Sh. 7b of 17)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failure	Method of Detection	Inherent Compensating Provision	Remarks and Other Effects
		c) Initially open, re-opens due to lack of LOP reset, fails open	Elect. malf., seal failure	Loss of redundant isolation capability for nitrogen supply line to affected SIT	Same as 29a)	Redundant series isolation valve is unaffected	
		d) Initially open, re-opens due to lack of LOP reset, fails closed	Mech. binding, air line separation from valve operator	Same as 29a)	Same as 29a)	None	Same as 29a)

TABLE 6.3-2 (Sh. 8 of 17)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failure	Method of Detection	Inherent Compensating Provision	Remarks and Other Effects
30.	SIT vent valve SI-613,605 SI-623,606 SI-633,607 SI-643,608	a) Fails closed	Mech. binding, elect. malf.	Degradation of redundancy to vent the SIT for refill or relieve pressure	Position indication in control room; Periodic testing; No change in tank pressure when valve is opened	Redundant parallel vent line	
		b) Fails open	Mech. binding, elect. malf.	None	Position indication in control room; Periodic testing; Low SIT pressure		Power removed from valve until tanks are required to be vented
31.	SIT local sample line isol. valve SI-214 SI-224 SI-234 SI-244	a) Fails closed	Mech. failure	No impact on normal operation, unable to sample SIT contents	Operator	None	
		b) Fails open	Seal leakage, mech. failure	Minor loss of tank contents	Local leak detectors, radiation monitors	None	
The followings are lists of safety-related instrumentation in this mode of operation.							
32.	SIT level indicators L-311 L-321 L-331 L-341	False indication	Elect. malf., mech. malf.	None	Level indicators in control room; Periodic testing	None	SI-614/624/634/644 are closed by the operator when required
34.	SIT pressure indicators P-311,313 P-321,323 P-331,333 P-341,343	False indication	Elect. malf., mech. malf.	None, low alarm on SIT pressure coincident with RCS repressurization during startup for P-313/323/333/343	Periodic testing; Comparison with redundant indicator	Redundant pressure indicators for P-313, 323,333,343	SI-614/624/634/644 are closed by the operator when required

TABLE 6.3-2 (Sh. 8a of 17)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failure	Method of Detection	Inherent Compensating Provision	Remarks and Other Effects
35.	SIT drain line to RDT isolation valve SI-661	a) Initially open, re-opens due to lack of LOP reset, fails open	Elect. malf., seal failure	Potential for partially draining one SIT during drain operation	Valve position indicator in control room, SIT level indicator	Redundant series isolation valves prevent affected SIT from being drained	Valve is opened to drain SIT or relieve pressure from check valve leakage to CVCS RDT
		b) Initially open, re-opens due to lack of LOP reset, fails closed	Air line separation from valve operator	Cannot drain line CVCS RDT to determine the rate of back leakage of affected SI cold leg check valve or drain SIT to RDT when required.	Same as 35a)	None	same as 35a)
36.	SIT fill line isolation valve SI-682	a) Initially open, re-opens due to lack of LOP reset, fails open	Elect. malf., seal failure	Potential for draining one SIT during drain operation	Valve position indicator, SIT level indicator	Operator can close redundant series isolation valves to prevent the affected SIT from being drained	Valve is opened to adjust SIT level
		b) Initially open, re-opens due to lack of LOP reset, fails closed	Elec. malf., air line separation from valve operator	Cannot adjust the water level of the affected SIT when required.	Same as 36a)	None	Plant shutdown may occur if SIT level is outside Tech Spec Limits.

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TABLE 6.3-2 (Sh. 9 of 17)

B. SHORT-TERM RECIRCULATION MODE

When the RWT inventory is down to 9.9% of the inventory required to be available for safety injection mode of operation, a recirculation actuation signal (RAS) is generated. Basically, this is the same lineup as injection mode of operation above, with the following changes.

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failure	Method of Detection	Inherent Compensating Provision	Remarks and Other Effects
1.	RWT suction source comp's in CVCS (CH-530/531, CH-305/306) may change position.						
2.	Sump line isol. valve SI-674 SI-676	a) Fails closed on RAS	Mech. binding, elect. malf.	Effective loss of one HPSI pump during recirculation	Position indication; periodic testing; low flow indication for F-303 or F-304	Redundant sump line and pump	
		b) Fails to open on RAS	Same as 2a)	Same as 2a)	Same as 2a)	Same as 2a)	Valve is required to be opened on RAS
		c) Fails open	Same as 2a), contamination, seal failure	None	Periodic testing	None required on RAS	Valve is normally open on RAS
3.	LPSI pump No. 1 or No. 2	a) Fails to stop on RAS	Elect. malf.	LPSI pump dead headed, or possible damage due to insufficient NPSH	Pump "run" light; Periodic testing	Redundant SI train	Pump is designed to stop on RAS
4.	LPSI pump miniflow line isol. valve SI-668 SI-669	a) Fails to close on RAS	Mech, binding, elect. malf., contamination	None	Valve position indication; Periodic testing	Redundant isolation valves (SI-660, 659) are closed	Valve is required to be closed on RAS
5.	HPSI pump miniflow line isol. valve SI-666 SI-667	a) Fails to close on RAS	Mech. binding, elect. malf., contamination	None	Valve position indication; periodic testing	Redundant isolation valves (SI-660, 659) are closed	Valve is required to be closed on RAS

TABLE 6.3-2 (Sh. 10 of 17)

C. LONG-TERM RECIRCULATION MODE

At 1 hour after a LOCA, the operator initiates cooldown with the steam generators. Steam is relieved through the turbine bypass system if ac power is available or through the atmospheric dump system if power is unavailable. If shutdown cooling entry condition can be achieved within 4 hours, the SCS is placed in operation. If it appears that SCS cannot be achieved within 4 hours, then at 2-4 hours after the LOCA, the HPSI pump discharge lines are realigned so that the total injection flow is divided equally between the hot and cold legs. Basically, this is the same lineup as the short-term recirculation mode above, with the following changes and additions.

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failure	Method of Detection	Inherent Compensating Provision	Remarks and Other Effects
1.	HPSI pump discharge isol. valve SI-689 SI-699 SI-476 SI-478	a) Fails closed	Mech. binding, elect. malf.	Effective loss of one HPSI pump if SI-476 or 478 fails closed. None for SI-698,699	Position indication; for SI-698, 699; Low pressure indication for P-308 or P-309; Periodic testing	Redundant HPSI train	Valve is normally locked open
		b) Fails open during hot and cold legs injection	Same as 1a) seal failure for SI-698/699	Flow to the affected hot leg will be less than 50% of total flow. HPSI pump may exceed run out flow.	Periodic testing; Valve position indicator for SI-698/699	Same as 1a)	
2.	Hot leg injection line isol. valve SI-604 SI-609 SI-321 SI-331	a) Fails closed during hot and cold legs injection	Mech. binding, elect. malf.	Loss of one hot leg injection flow path	Position indication; Periodic testing	Redundant HPSI train	
		b) Fails open	Same as 2a) seal failure	None	Same as 2a)	None required	Valve is normally locked closed
3.	Hot leg check valve test isol. valve SI-322 SI-332	a) Fails to close on SIAS	Elect. malf., seal failure, contamination	None	Periodic testing; Valve position indicator	Redundant series isol. valves(SI-682)prevent hot leg injection being drained	Valve is designed to fail closed

TABLE 6.3-2 (Sh. 11 of 17)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failure	Method of Detection	Inherent Compensating Provision	Remarks and Other Effects
		b) Fails closed	Mech. binding, air line separates from operator	Cannot perform test on the hot leg injection line check valve	Same as 3a)		Repair
		c) Fails open	Seal failure, contamination	None	Same as 3a)	Same as 3.a)	Valve is normally closed and fail closed
		d) Initially open, re-opens due to lack of LOP reset, fails open	Elect. malf., seal failure	None	Same as 3a)	Redundant series isolation valves (SI-661, SI-682) prevent piping section from being drained	Valve is opened to test hot leg leakage
		e) Initially open, re-opens due to lack of LOP reset, fails closed	Mech. binding, air line separates from valve operator	Same as 3b)	Same as 3a)	None	Same as 3d)
4.	SCS suction line isol. valve SI-651 SI-652	a) Fails open	Mech. binding, elect. malf., seal failure	None	Periodic testing; Valve position indicator	Redundant series isolation valves (SI-653/654) are closed	Valve is normally locked closed
		b) Fails closed	Mech. binding, elect. malf.	None	Same as 4a)	None required	
5.	HP discharge to hot leg flow indicator F-390 F-391	False indication	Elect. malf.	None, unequal flow indication between hot leg and cold leg injection lines	Periodic testing; Comparison with redundant flow indicators	Redundant indicators	

TABLE 6.3-2 (Sh. 12 of 17)

D. CHECK VALVE ANALYSIS

The followings are lists of all Safety Injection System check valves which are analyzed in this part.

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failure	Method of Detection	Inherent Compensating Provision	Remarks and Other Effects
1.	Sump suction isol. valve SI-205 SI-206	a) Fails open during injection mode	Mech. binding, corrosion	None	None	Series isolation valves SI-674, 676 prevent backflow during injection mode	
		b) Fails closed during injection mode	Mech. binding, corrosion	None	None	None	
		c) Fails open during long and short-term recirc. mode	Mech. binding, corrosion	None	None	None	
		d) Fails closed during long and short term recirc. mode	Mech. binding, corrosion	Effective loss of one HPSI train	Low HPSI flow	Redundant train	
2.	LPSI pump suction isol. valve SI-200 SI-201	a) Fails open (all modes)	Mech. binding, corrosion	None	None	None	
		b) Fails closed (all modes)	Mech. binding, corrosion	Effective loss of one LPSI train	None	Redundant LPSI train	

TABLE 6.3-2 (Sh. 13 of 17)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failure	Method of Detection	Inherent Compensating Provision	Remarks and Other Effects
3.	LPSI miniflow isol. valve SI-448 SI-451	a) Fails open during injection mode	Mech. binding, corrosion	None	None	None	
		b) Fails closed during injection mode	Mech. binding, corrosion	Potential pump damage and loss of one LPSI train	Flow instrument, F-300	Redundant train	
		c) Fails open during long and short-term recirc. mode	Mech. binding, corrosion	None	None	Series isolation valves (SI-669, 668) are closed	
		d) Fails closed during long and short term recirc. mode	Mech. binding, corrosion	None	None	None	
4.	HPSI miniflow isol. valve SI-424 SI-426	a) Fails open during injection mode	Mech. binding, corrosion	None	None	None	
		b) Fails closed during injection mode	Mech. binding, corrosion	Potential pump damage and loss of one HPSI train	Flow indicators, F-300	Redundant train	

TABLE 6.3-2 (Sh. 14 of 17)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failure	Method of Detection	Inherent Compensating Provision	Remarks and Other Effects
		c) Fails open during long and short-term recirc. mode	Mech. binding, corrosion	None	None	Series isolation valves (SI-666, 667) are closed	
		d) Fails closed during long and short term recirc. mode	Mech. binding, corrosion	None	None	None	
5.	LPSI discharge isol. valve SI-434 SI-446	a) Fails open (all modes)	Mech. binding, corrosion	None	None	Downstream check valves (SI-114/124/134/144) and upstream check valves (SI-201/200) prevent backflow from HPSI pump	
		b) Fails closed (all modes)	Mech. binding, corrosion	Loss of one LPSI train	Flow indicators for F-306,307; Periodic testing	Redundant LPSI train	
6.	LPSI header isol. valve SI-114 SI-124 SI-134 SI-144	a) Fails open during short and long term recirculation mode	Mech. binding, corrosion	Overpressurization of LPSI train	High LPSI pressure for P-306 or P-307; Low flow for F-306 or F-307; Leak detection provision	Redundant LPSI train and isolation of affected LPSI train; inline relief valves (SI-439, 449)	
		b) Fails closed during injection mode	Mech. binding, corrosion	Loss of flow from LPSI pump to one of the RCS cold legs	Low flow indicators for F-306,307; Periodic testing	Redundant LPSI train	

TABLE 6.3-2 (Sh. 15 of 17)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failure	Method of Detection	Inherent Compensating Provision	Remarks and Other Effects
7.	Cold leg injection line isol. valve SI-540 SI-541 SI-542 SI-543	a) Fails open (all modes)	Mech. binding, corrosion	Potential reduced boron concentration in safety injection piping during normal operation	None	Series check valves (SI-114/124/134/144, SI-113/123/133/143) prevent backflow, redundant train	
		b) Fails closed (all modes)	Mech. binding, corrosion	Loss of flow from safeguard pumps to one of the RCS cold legs	Periodic testing	Redundant cold leg	injection line
8.	RCS isol. valve SI-217 SI-227 SI-237 SI-247	a) Fails open (all modes)	Mech. binding, corrosion	Potential reduced boron concentration in safety injection piping during normal operation	High pressure alarm for P-319/329/339/349	Series check valves (SI-540/541/542/543) prevent backflow	
		b) Fails closed (all modes)	Mech. binding, corrosion	Loss of flow from safeguard pump to one of the RCS cold legs	Periodic testing	Testing program (with charging pump) exempts valves from single failure criteria	
9.	SIT discharge isol. valve SI-215 SI-225 SI-235 SI-245	a) Fails open (all modes)	Mech. binding, corrosion	Overpressurization of SIT's and reduced injection flow to RCS	SIT level and pressure increase during injection	Redundant SI train and isolation of affected SIT	
		b) Fails closed (all modes)	Mech. binding, corrosion	Loss of flow from safeguard pump to one of the RCS cold legs	Periodic testing	Testing program (with charging pump) exempts valves from single failure criteria	
10.	HPSI discharge isol.valve SI-404 SI-405	a) Fails open (all modes)	Mech. binding, corrosion	None	None	None	
		d) Fails closed (all modes)	Mech. binding, corrosion	Effective loss of one HPSI pump and flow path	Low HPSI flow for F-311/321/331/341	Redundant HPSI train	

TABLE 6.3-2 (Sh. 16 of 17)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failure	Method of Detection	Inherent Compensating Provision	Remarks and Other Effects
11.	HPSI header isol. valve SI-113 SI-123 SI-133 SI-143	a) Fails open (all modes)	Mech. binding, corrosion	None	None	Series check valves (SI-476, 478) prevent backflow	
		b) Fails closed (all modes)	Mech. binding, corrosion	Loss of flow from HPSI pump to one of the RCS cold legs	Flow indicators, F-311/321/331/341	Redundant HPSI train	
12.	HPSI header hot leg injection to SDC line isol. valve SI-522 SI-532	a) Fails open during long term recirc. mode	Mech. binding, corrosion	Reduced boron concentration in hot leg injection piping	Pressure indicators, P-390/391	Series check valves (SI-523/533) prevent backflow	
		b) Fails closed during long term recirc. mode	Mech. binding, corrosion	Loss of one HPSI hot leg injection flow	High flow indicators for cold legs, F-311/321/331/341; Periodic testing; Low flow indicators for F-390/391	Redundant HPSI and hot leg injection flow path	
		c) Fails open during injection and short term recirc. mode	Mech. binding, corrosion	None	None	Series isolation valves (SI-523/533, SI-523/533) are closed	
		d) Fails closed during injection and short term recirc. mode	Mech. binding, corrosion	None	Periodic testing	None	
13.	HPSI header isol. (hot leg injection) valve SI-523 SI-533	a) Fails open during long term recirc. mode	Mech. binding, corrosion	None	None	Series check valves (SI-522/532) prevent backflow	

TABLE 6.3-2 (Sh. 17 of 17)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failure	Method of Detection	Inherent Compensating Provision	Remarks and Other Effects
		b) Fails closed during longterm recirc. mode	Mech. binding, corrosion	Loss of one hot leg injection flow	High flow indicators for F-390/391, Periodic testing	Redundant HPSI and hot leg injection line	
		c) Fails open during injection and short term recirc. mode	Mech. binding, corrosion	None	None	Series isolation valves (SI-522/532, SI-321/331) are closed	
		d) Fails closed during injection and short term recirc. mode	Mech. binding, corrosion	None	Periodic testing	None required	

TABLE 6.3-3 (Sh. 1 of 2)

SIS SAFETY-RELATED PROCESS INSTRUMENTATION

Instrument	Number of Channels	Range	Postaccident Function
Primary System			
Pressurizer Pressure	4	0-3000 psia (0-210.9 kg/cm^{2}A)	Initiate SIAS, monitor primary system pressure
Pressurizer Pressure	4	0-750 psia (0-52.7 kg/cm^{2}A)	Monitor primary system pressure, provides interlocks on SCS suction valves and SIT isolation valves
Safety Injection System			
HPSI Cold-Leg Flow Rate	4	0-660.8 gpm (0-2500 L/min)	Monitor HPSI cold-leg injection flow (0-2838.7 L/min)
HPSI Hot-Leg Flow Rate	2	0-660.8 gpm (0-2500 L/min)	Monitor HPSI hot-leg injection flow
Shutdown Cooling/LPSI Flow Rate	2	0-6604 gpm (0-2500 L/min)	Monitor Shutdown Cooling/LPSI flow rate used to set shutdown cooling flow.
Shutdown Cooling Heat Exchanger Inlet and Outlet Temperature Indicator/ Recorder	2	40-392°F (4.4-200°C)	Monitor and record shutdown cooling performance. Used to control RCS cooldown rate.

TABLE 6.3-3 (Sh. 2 of 2)

Instrument	Number of Channels	Range	Postaccident Function
Safety Injection System			
Shutdown Cooling Heat Exchanger Outlet Temperature	2	40-392°F (4.4-200°C)	Monitor Shutdown Cooling Heat Exchanger performance.
Wide Range SIT Pressure	1 per tank	0-750 psig (0-52.7 kg/cm^2)	Monitor SIT pressure
RWT Level	4	0-100%	Initiate RAS, monitor RWT level
Wide Range SIT Level	1 per tank	0-100%	Monitor SIT Level
Containment			
Containment Pressure	4	-4 to 17 psig ((-300)-1200cm H_2O)	Initiate SIAS, MSIS, CIAS
Containment Pressure	4	-5 to 79.5 psig ((-400)-5600cm H_2O)	Initiate CSAS
Containment Pressure	2	-7.1 to 205.9 psig ((-500)-14500cm H_2O)	Monitor Containment Pressure

TABLE 6.3-4 (Sh. 1 of 2)

SAFETY INJECTION SYSTEM FLOW POINT DATA

A) INJECTION MODE (see Figure 6.3-2)

SIS Point	Flow, gpm (L/min)	SIS Point	Flow, gpm (L/min)
		50	120 (454)
2	11535 (43660)*	54	85 (322)
5	5120 (19379)	56	320 (1211)**
6	6415 (24281)*	57	405 (1533)**
12	5000 (18925)	61	565 (2139)
16	2500 (9462)	62	3065 (11601)
17	1215 (4599)	64	60065 (227340)
24	1130 (4277)	72	57000 (21574)
25	283 (1071)	82	810 (3066)**

B) SHORT-TERM RECIRCULATION MODE (see Figure 6.3-3)

SIS Point	Flow, gpm (L/min)	SIS Point	Flow, gpm (L/min)
1	6178 (23384)*	61	589 (2229)
17	1178 (4459)	64	589 (2229)
25	295 (1117)	72	0 (0)

* Assume 5000 gpm (18925 L/min) CSS flow
** Assumes 200 gpm (757 L/min) CSS minimum recirculation flow

TABLE 6.3-4 (Sh. 2 of 2)

C) LONG-TERM RECIRCULATION MODE (see Figure 6.3-4)

SIS Point	Flow, gpm (L/min)
1	6178 (23384)
17	1178 (4459)
24	589 (2229)
25	148 (560)
42	589 (2229)
47	589 (2229)
61	295 (1117)
64	295 (1117)

D) SHUTDOWN COOLING MODE (see Figure 6.3-5)

SIS Point	Flow, gpm(L/min)
10	5000 (18925)
13	*
14	5000 (18925)
16	2500 (9463)
31	*
37	5000 (18925)
39	5000 (18925)
64	2500 (9463)

* A flow of 5000 gpm (18925 L/min) is split between points 13 and 31 to maintain the RCS cooldown rate at 75°F/hr (42°C/hr) or less.

TABLE 6.3-5 (Sh. 1 of 2)

SAFETY INJECTION SYSTEM NPSH AND HEAD LOSS REQUIREMENTS

PUMP NPSH REQUIREMENTS:

	Flow/Pump gpm (L/min)	NPSH(1) ft (m)	Available NPSH ft (m)	
High-Pressure Pumps				
Injection Mode	1235*(4674)	22** (6.66)	50 (15.24)	
Recirculation Mode	1235 (4674)	22*** (6.66)	29 (8.84)	672
Long-Term Cooling Mode	1235 (4674)	22*** (6.66)	29 (8.84)	672
Low-Pressure Pumps				
Injection Mode	5120* (19379)	22** (6.66)	45 (13.72)	
Recirculation Mode	5120* (19379)	19.3** (5.88)	24 (7.32)	672
Ambient Temperature Recirculation Test	3500* (13248)	19+ (5.75)	64 (19.51)	

NOTES:

(1) NPSH values listed include a 10% margin over the required pump NPSH. 1

* Includes bypass flow.

** Based on the properties of water at 1 atmosphere and 100°F (37.8°C). All pumps taking suction from the RWT and operating at runout flows. (All pumps include one high pressure, one low pressure, and one containment spray pump operating on each train.)

*** Based on the properties of saturated water at 290°F (143.3°C). Other pumps taking suction from the containment sump at runout flows. 672

\+ Based on the properties of water at one atmosphere and 100°F (37.8°C). One LPSI pump taking suction from the containment recirculation sump.

TABLE 6.3-5 (Sh. 2 of 2)

SYSTEM HEAD LOSS REQUIREMENTS(1)

	Flow/Pump gpm (L/min)	Required System Resistance ft (m)
High-Pressure Pumps		
Injection Mode	1235 (4674)	1915 (583.7)*
Long-Term Cooling Mode	1178 (4459)	2082 (634.6)**
Low Pressure Pumps		
Injection Mode	5120 (19379)	305 (93.0)***
Ambient Temperature Recirculation Test	3500 (13248)	370 (112.8)+

1

NOTES:

(1) Water properties are based on 60°F (15.6°C) for injection mode and ambient temperature recirculation mode. For the long term cooling mode, 300°F (149°C) is used.

* Friction and elevation losses between the water level in the RWT at the start of recirculation and the outlet of the cold-leg injection nozzle and shutdown cooling nozzle on the hot let. One high-pressure pump operating.

** Friction and elevation losses between the minimum water level in the containment recirculation sump and the outlet of the cold-leg injection nozzle and shutdown cooling nozzle on the hot leg. One high-pressure pump operating.

*** Friction and elevation losses between the water level in the RWT at the start of recirculation and the outlet of the cold-leg injection nozzle. One low pressure pump operating.

\+ Friction and elevation losses through the entire flow path. One LPSI pump in operating taking suction from the containment sump and discharging to the RWT via the cross-connect lines normally used for in-service testing of the LPSI and CS pumps. Valves SI-306/307 and SI-657/658 must be set to the appropriate test position prior to starting this test in order to provide sufficient system resistance.

TABLE 6.3-6 (Sh. 1 of 8)

SAFETY INJECTION SYSTEM VALVE LIST

VALVE ID	VALVE TYPE*	OPER**	DESG PRES (psig)	DESG PRES (kg/cm²)	DES TMP (°F)	DES TMP (°C)	ENV***
I-161	R	N	750	52.73	400	204.44	D
SI-170	G	H	750	52.73	400	204.44	D
SI-172	G	H	750	52.73	400	204.44	D
SI-180	G	H	750	52.73	400	204.44	D
SI-182	G	H	750	52.73	400	204.44	D
SI-191	R	N	750	52.73	400	204.44	D
SI-193	R	N	750	52.73	400	204.44	D
SI-194	R	N	750	52.73	400	204.44	D
SI-200	C	N	485	34.09	400	204.44	D
SI-201	C	N	485	34.09	400	204.44	D
SI-202	G	H	750	52.73	400	204.44	D
SI-203	G	H	750	52.73	400	204.44	D
SI-205	C	N	100	7.030	350	176.66	D
SI-206	C	N	100	7.030	350	176.66	D
SI-207	G	H	100	7.030	350	176.66	D
SI-208	G	H	100	7.030	350	176.66	D
SI-218	G	H	2050	144.1	350	176.66	D
SI-219	G	H	2050	144.1	350	176.66	D
SI-257	G	H	750	52.73	400	204.44	D
SI-260	G	H	750	52.73	400	204.44	D
SI-262	G	H	750	52.73	400	204.44	D
SI-264	G	H	750	52.73	400	204.44	D
SI-266	G	H	750	52.73	400	204.44	D
SI-268	G	H	750	52.73	400	204.44	D
SI-285	R	N	2050	144.1	350	176.66	D
SI-286	R	N	2050	144.1	350	176.66	D
SI-288	R	N	750	52.73	400	204.44	D
SI-298	T	H	750	52.73	400	204.44	D
SI-306	G	M	750	52.73	400	204.44	D
SI-307	G	M	750	52.73	400	204.44	D
SI-400	G	H	2050	144.1	350	176.66	D
SI-402	T	H	100	7.030	350	176.66	D
SI-404	C	N	2485	174.7	650	343.33	D
SI-405	C	N	2050	144.1	350	176.66	D
SI-407	R	N	2050	144.1	350	176.66	D
SI-408	G	H	2050	144.1	350	176.66	D
SI-409	R	N	2050	144.1	350	176.66	D
SI-416	G	H	2485	174.7	650	343.33	D
SI-417	R	N	2485	174.7	650	343.33	D

TABLE 6.3-6 (Sh. 2 of 8)

VALVE ID	VALVE TYPE*	OPER**	DESG PRES (psig)	DESG PRES (kg/cm²)	DES TMP (°F)	DES TMP (°C)	ENV***
SI-418	T	H	485	34.09	400	204.44	D
SI-419	T	H	485	34.09	400	204.44	D
SI-420	T	H	750	52.73	400	204.44	D
SI-421	T	H	750	52.73	400	204.44	D
SI-424	C	N	2050	144.1	350	176.66	D
SI-426	C	N	2050	144.1	350	176.66	D
SI-427	G	H	2050	144.1	350	176.66	D
SI-429	G	H	2050	144.1	350	176.66	D
SI-433	G	H	750	52.73	400	204.44	D
SI-434	C	N	750	52.73	400	204.44	D
SI-435	T	H	750	52.73	400	204.44	D
SI-436	G	H	750	52.73	400	204.44	D
SI-437	G	H	750	52.73	400	204.44	D
SI-438	G	H	750	52.73	400	204.44	D
SI-439	R	N	750	52.73	400	204.44	D
SI-440	G	H	750	52.73	400	204.44	D
SI-441	G	H	750	52.73	400	204.44	D
SI-445	G	H	2050	144.1	350	176.66	D
SI-446	C	N	750	52.73	400	204.44	D
SI-447	T	H	750	52.73	400	204.44	D
SI-448	C	N	2050	144.1	350	176.66	D
SI-449	R	N	750	52.73	400	204.44	D
SI-451	C	N	2050	144.1	350	176.66	D
SI-459	G	H	2050	144.1	350	176.66	D
SI-460	T	H	750	52.73	400	204.44	D
SI-461	G	H	2050	144.1	350	176.66	D
SI-462	G	H	2050	144.1	350	176.66	D
SI-463	G	H	2050	144.1	350	176.66	D
SI-464	T	H	750	52.73	400	204.44	D
SI-465	G	H	2050	144.1	350	176.66	D
SI-470	T	H	100	7.030	350	176.66	D
SI-473	R	N	2050	144.1	350	176.66	B
SI-474	R	N	2050	144.1	350	176.66	B
SI-476	T	H	2485	174.7	650	343.33	D
SI-478	T	H	2050	144.1	350	176.66	D
SI-482	G	H	750	52.73	400	204.44	D
SI-483	G	H	750	52.73	400	204.44	D
SI-508	G	H	3025	212.6	200	93.3	D
SI-509	G	H	3025	212.6	200	93.3	D
SI-550	G	H	485	34.09	400	204.44	D

TABLE 6.3-6 (Sh. 3 of 8)

VALVE ID	VALVE TYPE*	OPER**	DESG PRES (psig)	DESG PRES (kg/cm²)	DES TMP (°F)	DES TMP (°C)	ENV***
2SI-552	G	H	100	7.030	350	176.66	D
SI-553	G	H	100	7.030	350	176.66	D
SI-555	G	H	485	34.09	400	204.44	D
SI-604	T	M	2485	174.7	650	343.33	D
SI-609	T	M	2485	174.7	650	343.33	D
SI-657	F	M	750	52.73	400	204.44	D
SI-658	F	M	750	52.73	400	204.44	D
SI-659	G	S	2050	144.1	350	176.66	D
SI-660	G	S	2050	144.1	350	176.66	D
SI-661	G	D	2050	144.1	350	176.66	B
SI-666	G	M	2050	144.1	350	176.66	D
SI-667	G	M	2050	144.1	350	176.66	D
SI-668	G	M	2050	144.1	350	176.66	D
SI-669	G	M	2050	144.1	350	176.66	D
SI-674	F	M	100	7.030	350	176.66	D
SI-676	F	M	100	7.030	350	176.66	D
SI-682	G	D	2050	144.1	350	176.66	A
SI-683	T	M	485	34.09	350	176.66	D
SI-685	T	M	750	52.73	400	204.44	D
SI-686	T	M	750	52.73	400	204.44	D
SI-692	T	M	485	34.09	400	204.44	D
SI-694	T	M	750	52.73	400	204.44	D
SI-696	T	M	750	52.73	400	204.44	D
SI-698	T	M	2485	174.7	650	343.33	D
SI-699	T	M	2050	144.1	350	176.66	D
SI-113	C	N	2485	174.7	650	343.33	A
SI-114	C	N	2485	174.7	650	343.33	A
SI-115	G	H	2485	174.7	650	343.33	D
SI-116	G	H	2485	174.7	650	343.33	D
SI-117	G	H	700	49.21	200	93.333	B
SI-119	G	H	700	49.21	200	93.333	B
SI-123	C	N	2485	174.7	650	343.33	A
SI-124	C	N	2485	174.7	650	343.33	A
SI-125	G	H	2485	174.7	650	343.33	D
SI-126	G	H	2485	174.7	650	343.33	D
SI-127	G	H	700	49.21	200	93.333	B
SI-129	G	H	700	49.21	200	93.333	B
SI-133	C	N	2485	174.7	650	343.33	A
SI-134	C	N	2485	174.7	650	343.33	A
SI-135	G	H	2485	174.7	650	343.33	D

TABLE 6.3-6 (Sh. 4 of 8)

VALVE ID	VALVE TYPE*	OPER**	DESG PRES (psig)	DESG PRES (kg/cm²)	DES TMP (°F)	DES TMP (°C)	ENV***
SI-136	G	H	2485	174.7	650	343.33	D
SI-137	G	H	700	49.21	200	93.333	B
SI-139	G	H	700	49.21	200	93.333	B
SI-143	C	N	2485	174.7	650	343.33	A
SI-144	C	N	2485	174.7	650	343.33	A
SI-145	G	H	2485	174.7	650	343.33	D
SI-146	G	H	2485	174.7	650	343.33	D
SI-147	G	H	700	49.21	200	93.333	B
SI-149	G	H	700	49.21	200	93.333	B
SI-166	R	N	2485	174.7	650	343.33	D
SI-169	R	N	2485	174.7	650	343.33	B
SI-179	R	N	485	34.09	400	204.44	B
SI-189	R	N	485	34.09	400	204.44	B
SI-210	G	H	2050	144.1	350	176.66	B
SI-211	R	N	700	49.21	200	93.333	B
SI-212	G	H	700	49.21	200	93.333	A
SI-213	G	H	700	49.21	200	93.333	A
SI-214	G	H	700	49.21	200	93.333	B
SI-215	C	N	2485	174.7	650	343.33	A
SI-216	G	H	2485	174.7	650	343.33	B
SI-217	C	N	2485	174.7	650	343.33	A
SI-220	G	H	2050	144.1	350	176.66	B
SI-221	R	N	700	49.21	200	93.333	B
SI-222	G	H	700	49.21	200	93.333	A
SI-223	G	H	700	49.21	200	93.333	A
SI-224	G	H	700	49.21	200	93.333	B
SI-225	C	N	2485	174.7	650	343.33	A
SI-226	G	H	2485	174.7	650	343.33	B
SI-227	C	N	2485	174.7	650	343.33	A
SI-228	G	H	700	49.21	200	93.333	A
SI-229	G	H	700	49.21	200	93.333	A
SI-230	G	H	2050	144.1	350	176.66	B
SI-231	R	N	700	49.21	200	93.333	B
SI-232	G	H	700	49.21	200	93.333	A
SI-233	G	H	700	49.21	200	93.333	A
SI-234	G	H	700	49.21	200	93.333	B
SI-235	C	N	2485	174.7	650	343.33	A
SI-236	G	H	2485	174.7	650	343.33	B
SI-237	C	N	2485	174.7	650	343.33	A
SI-238	G	H	700	49.21	200	93.333	A

TABLE 6.3-6 (Sh. 5 of 8)

VALVE ID	VALVE TYPE*	OPER**	DESG PRES (psig)	DESG PRES (kg/cm²)	DES TMP (°F)	DES TMP (°C)	ENV***
SI-239	G	H	700	49.21	200	93.333	A
SI-240	G	H	2050	144.1	350	176.66	B
SI-241	R	N	700	49.21	200	93.333	B
SI-242	G	H	700	49.21	200	93.333	A
SI-243	G	H	700	49.21	200	93.333	A
SI-244	G	H	700	49.21	200	93.333	B
SI-245	C	N	2485	174.7	650	343.33	A
SI-246	G	H	2485	174.7	650	343.33	B
SI-247	C	N	2485	174.7	650	343.33	A
SI-248	G	H	700	49.21	200	93.333	A
SI-249	G	H	700	49.21	200	93.333	A
SI-258	G	H	700	49.21	200	93.333	A
SI-259	G	H	700	49.21	200	93.333	A
SI-321	G	M	2485	174.7	650	343.33	D
SI-322	G	D	2485	174.7	650	343.33	A
SI-331	G	M	2485	174.7	650	343.33	D
SI-332	G	D	2485	174.7	650	343.33	A
SI-468	R	N	2485	174.7	650	343.33	D
SI-469	R	N	2485	174.7	650	343.33	B
SI-506	G	H	2485	174.7	650	343.33	B
SI-516	G	H	2485	174.7	650	343.33	B
SI-522	C	N	2485	174.7	650	343.33	A
SI-523	C	N	2485	174.7	650	343.33	A
SI-525	G	H	2485	174.7	650	343.33	D
SI-526	G	H	2485	174.7	650	343.33	D
SI-532	C	N	2485	174.7	650	343.33	A
SI-533	C	N	2485	174.7	650	343.33	A
SI-535	G	H	2485	174.7	650	343.33	D
SI-536	G	H	2485	174.7	650	343.33	D
SI-540	C	N	2485	174.7	650	343.33	A
SI-541	C	N	2485	174.7	650	343.33	A
SI-542	C	N	2485	174.7	650	343.33	A
SI-543	C	N	2485	174.7	650	343.33	A
SI-605	G	S	700	49.21	200	93.333	A
SI-606	G	S	700	49.21	200	93.333	A
SI-607	G	S	700	49.21	200	93.333	A
SI-608	G	S	700	49.21	200	93.333	A
SI-611	G	D	2050	144.1	350	176.66	A
SI-612	G	D	700	49.21	200	93.333	B
SI-613	G	S	700	49.21	200	93.333	A

TABLE 6.3-6 (Sh. 6 of 8)

VALVE ID	VALVE TYPE*	OPER**	DESG PRES (psig)	DESG PRES (kg/cm²)	DES TMP (°F)	DES TMP (°C)	ENV***
SI-614	T	M	2485	174.7	650	343.33	A
SI-615	G	M	2485	174.7	650	343.33	D
SI-616	G	M	2485	174.7	650	343.33	D
SI-617	G	M	2485	174.7	650	343.33	D
SI-618	G	D	2485	174.7	650	343.33	A
SI-619	G	D	700	49.21	200	93.333	B
SI-621	G	D	2050	144.1	350	176.66	A
SI-622	G	D	700	49.21	200	93.333	B
SI-623	G	S	700	49.21	200	93.333	A
SI-624	T	M	2485	174.7	650	343.33	A
SI-625	G	M	2485	174.7	650	343.33	D
SI-626	G	M	2485	174.7	650	343.33	D
SI-627	G	M	2485	174.7	650	343.33	D
SI-628	G	D	2485	174.7	650	343.33	A
SI-629	G	D	700	49.21	200	93.333	B
SI-631	G	D	2050	144.1	350	176.66	A
SI-632	G	D	700	49.21	200	93.333	B
SI-633	G	S	700	49.21	200	93.333	A
SI-634	T	M	2485	174.7	650	343.33	A
SI-635	G	M	2485	174.7	650	343.33	D
SI-636	G	M	2485	174.7	650	343.33	D
SI-637	G	M	2485	174.7	650	343.33	D
SI-638	G	D	2485	174.7	650	343.33	A
SI-639	G	D	700	49.21	200	93.333	B
SI-641	G	D	2050	144.1	350	176.66	A
SI-642	G	D	700	49.21	200	93.333	B
SI-643	G	S	700	49.21	200	93.333	A
SI-644	T	M	2485	174.7	650	343.33	A
SI-645	G	M	2485	174.7	650	343.33	D
SI-646	G	M	2485	174.7	650	343.33	D
SI-647	G	M	2485	174.7	650	343.33	D
SI-648	G	D	2485	174.7	650	343.33	A
SI-649	G	D	700	49.21	200	93.333	B
SI-651	T	M	2485	174.7	650	343.33	A
SI-652	T	M	2485	174.7	650	343.33	A
SI-653	T	M	2485	174.7	650	343.33	A
SI-654	T	M	2485	174.7	650	343.33	A
SI-655	T	M	485	34.09	400	204.44	D
SI-656	T	M	485	34.09	400	204.44	D
SI-690	G	M	485	34.09	400	204.44	D

TABLE 6.3-6 (Sh. 7 of 8)

VALVE ID	VALVE TYPE*	OPER**	DESG PRES (psig)	DESG PRES (kg/㎠)	DES TMP (°F)	DES TMP (℃)	ENV***	
SI-691	G	M	485	34.09	400	204.44	D	
SI-901	G	H	100	7.030	350	176.66	D	314
SI-902	G	H	100	7.030	350	176.66	D	314
SI-903	G	H	100	7.030	350	176.66	D	314
SI-904	G	H	100	7.030	350	176.66	D	314
SI-905	G	H	100	7.030	350	176.66	D	314
SI-906	G	H	100	7.030	350	176.66	D	314
SI-957	T	H	2485	174.7	650	343.33	A	
SI-958	T	H	2485	174.7	650	343.33	A	

TABLE 6.3-6 (Sh. 8 of 8)

* Valve Type

The following symbol s are used:

C - swing check
F - butterfly
G - globe
R - relief
T - gate

** Operator Type

The following symbols are used:

D - pneumatic diaphragm
H - hand
M - motor
N - none
S - solenoid

*** Environmental Service Conditions

The following categories are used:

A - containment environment: LOCA or steamline Break

B - containment environment: normal environment

C - primary auxiliary building environment: normal environment

D - primary auxiliary building environment: LOCA

See Subsection 3.11.2 for the extent of environmental qualification testing.

TABLE 6.3-7

RANGES AND DISTRIBUTIONS OF SAMPLING PARAMETERS

LARGE BREAK ECCS PERFORMANCE

No.	Parameter	Distribution	Mean	Uncertainty	Component	
1	Fq	Uniform	[redacted]	[redacted]	Fuel	645
2	Gap conductance	Uniform	[redacted]	[redacted]		
3	Fuel conductivity	Normal	[redacted]	[redacted]		
4	Core Power	Normal	[redacted]	[redacted]		
5	Decay heat	Normal	[redacted]	[redacted]		
6	Burst temperature dial	Uniform	[redacted]	[redacted]		
7	Burst strain dial	Uniform	[redacted]	[redacted]		
8	Oxidization dial	Normal	[redacted]	[redacted]		
9	Groeneveld chf dial	Normal	[redacted]	[redacted]	Core	
10	Chen nucleate boiling dial	Normal	[redacted]	[redacted]		
11	Zuber chf dial	Normal	[redacted]	[redacted]		
12	T_{min} dial	Uniform	[redacted]	[redacted]		
13	Dittus Boelter, liquid dial	Normal	[redacted]	[redacted]		
14	Dittus Boelter, vapor dial	Normal	[redacted]	[redacted]		
15	Bromley dial	Normal	[redacted]	[redacted]		
16	Weber number	Uniform	[redacted]	[redacted]		
17	Subcooled Cd	Normal	[redacted]	[redacted]		
18	2-Phase Cd	Normal	[redacted]	[redacted]		
19	RCS Flowrate, kg/s	Uniform	[redacted]	[redacted]	Loop	741
20	Pump Head Multiplier	Uniform	[redacted]	[redacted]		
21	Pump torque Multiplier	Uniform	[redacted]	[redacted]		
22	Pressurizer pr, bar	Normal	[redacted]	[redacted]	Pressurizer	
23	SIT pressure, bar	Uniform	[redacted]	[redacted]	SIT/Cold Leg	
24	SIT water vol., m^3	Uniform	[redacted]	[redacted]		
25	SIT water temp., K	Uniform	[redacted]	[redacted]		
26	SIP flow Multiplier	Uniform	[redacted]	[redacted]		
27	RWST water temp., K	Uniform	[redacted]	[redacted]		

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TABLE 6.3-8

INPUT PARAMETERS AND INITIAL CONDITIONS

LARGE BREAK ECCS PERFORMANCE

Parameter	Value
Core	
1. Core Power	2,815 MWt
2. Peaking Factor	2.318
3. Fuel Type	16 × 16 PLUS7
4. Axial Power Shape	Figure 6.3-17
5. Decay Heat	ANS79
6. Core Flow Rate	50.78×10^6 kg/h (111.96×10^6 lb/h)
Reactor Coolant System	
1. Reactor Vesel Flow Rate	52.36×10^6 kg/h (115.42×10^6 lb/h)
Pressurizer	
1. Pressure	158.2 kg/cm^{2}A (2,250 psia)
Steam Generator	
1. Feedwater Temperature	232.1°C (450°F)
2. Tube Plugging	18 %
3. Number of Tubes	6,702/1,512 (Unplugged/Plugged)
Safety Injection System	
1. SIT Water Volume	52.63 m^3 (1858 ft^3)
2. SIT Gas Pressure	43.29 kg/cm^{2}A (615.7 psia)
3. SIT Water Temperature	29.4°C (85°F)
4. Refueling Water Tank Temperature	26.6°C (80°F)
Containment	
1. Initial Pressure	0.997 kg/cm^{2}A (14.18 psia)
2. Initial Temperature	10°C (50°F)
3. Net Free Volume	81,468 m^3 (2.877×10^6 ft^3)
4. Number of Spray Pump	2
5. Spray Pump Actuation Delay	0 sec
6. Spray Flow Rate (2 Pump)	37,853 L/min (10,000 gpm)

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"Delete"

TABLE 6.3-9

FUEL ROD PERFORMANCE SUMMARY

Large Break Spectrum

		Break Size (%)		
		100	80	60
Blowdown	PCT (°C)	890.7	898.0	896.7
	PCT Location (m)	2.57	2.57	2.57
	PCT Time (sec)	5.5	6.7	7.9
Reflood	PCT (°C)	685.8	657.3	797.0
	PCT Location (m)	2.76	2.57	2.57
	PCT Time (sec)	63.0	59.5	54.0
Peak Local Oxidation (%)		1.186	1.190	1.222
PLO Location (m)		2.57	2.57	2.57
Core-Wide Cladding Oxidation (%)		< 1.0	< 1.0	< 1.0
Hot Rod Burst		No	No	No

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TABLE 6.3-10

TIME SEQUENCE OF IMPORTANT EVENTS FOR A SPECTRUM OF LARGE BREAK LOCAs

(Seconds After Break)

	Break Size (%)		
	100	80	60
Start	0.0	0.0	0.0
Reactor Trip Signal	6.6	6.6	6.6
Safety Injection Signal	6.6	6.6	6.6
SIT Injection Begin			
SIT 1 (Broken Cold Leg)	3.3	5.6	8.5
SIT 2 (Broken Loop Intact Cold Leg)	11.6	13.1	15.7
SIT 3 (Intact Loop Intact Cold Leg 1)	11.6	13.1	15.7
SIT 4 (Intact Loop Intact Cold Leg 2)	11.6	13.1	15.7
HPSI Injection Begins	35.41	35.41	35.42
LPSI Injection Begins	55.41	55.41	55.42
Bottom of Core Recovery[1)]	26.41	30.64	29.76
SIT Empty			
SIT 1 (Broken Cold Leg)	54.8	57.6	61.5
SIT 2 (Broken Loop Intact Cold Leg)	75.4	77.4	80.7
SIT 3 (Intact Loop Intact Cold Leg 1)	75.4	77.4	80.7
SIT 4 (Intact Loop Intact Cold Leg 2)	75.5	77.5	80.7

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1) Collapsed Liquid Level Reached at the Bottom of Active Core

TABLE 6.3-11

VARIABLES PLOTTED AS A FUNCTION OF TIME FOR EACH LARGE BREAK IN THE SPECTRUM

Sheet Number	Variable (Figures 6.3-8 to 6.3-10)
1	Peak Cladding Temperature
2	Core Pressure
3	Core and Downcomer Water Levels
4	Integrated Core Inlet Flow
5	Normalized Core Power

Sheet Number	Variable (Figures 6.3-11)
1*	Core Inlet and Outlet Flow
2*	Hot Spot Heat Transfer Coefficient
3*	Hot Spot Vapor Temperature
4*	Break Flow Rate
5*	Break Energy Flow Rate
6*	Hot Spot Fluid Quality
7*	Hot Channel Core Flow Rate
8*	SIT Flow Rate
9*	Safety Injection Pump Flow Rate
10*	Containment Pressure

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* Add limiting 100% cold leg DEGB results

Table 6.3-12
THE SUMMARY OF RESULTS OF
124 SRS CALCULATIONS AND BIAS EVALUATION

CASES		VALUE
LIMITING PCT[a)], CASE 39	PCT, °C	1,028.0
	TIME, SEC	6.4
	LOCATION, m	2.57
LIMITING REFLOOD PCT[b)], CASE 32	PCT, °C	851.9
	TIME, SEC	98.5
	LOCATION, m	2.76
MAXIMUM BIAS[c)] IS CALCULATED IN CASE 32		
BIAS, ECC WATER BYPASS	△ PCT, °C	0.0
BIAS, STEAM BINDING	△ PCT, °C	0.6
SUM	△ PCT, °C	0.6
FINAL REFLOOD PCT INCLUDING BIAS	PCT, °C	852.5
FINAL PCT INCLUDING BIAS	PCT, °C	1,028.0
LIMITING PLO[b)], CASE 32	PLO, %	1.398
MAXIMUM BIAS[c)] IS CALCULATED IN CASE 123		
BIAS, ECC WATER BYPASS	△PLO, %	0.000
BIAS, STEAM BINDING	△PLO, %	0.644
SUM	△PLO, %	0.644
FINAL REFLOOD PLO INCLUDING BIAS	PLO, %	2.042
FINAL PLO INCLUDING BIAS	PLO, %	2.042

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a) The limiting PCT is determined as the third highest value of 124 SRS calculations.

b) The limiting Reflood PCT and PLO are determined from 124 SRS calculations.

c) Maximum Bias is determined from sum of scale bias of ECC bypass and steam binding for the cases having Reflood PCT higher than limiting Reflood PCT minus 100°C(180 °F)

d) Due to fuel conductivity degradation effect, a PCT penalty, 39 °C (70 °F), must be added to LBLOCA results.

TABLE 6.3-13 (Sh. 1 of 2)

SAFETY INJECTION PUMPS MINIMUM DELIVERED FLOW TO RCS

(Assuming One Emergency Diesel Generator Failed)

RCS Pressure psig (kg/cm^2)	Flow Rate Per Injection Point*, gpm (L/min)			
	A_1	A_2	B_1	B_2
1600 (112.5)	0 (0)	0 (0)	0 (0)	0 (0)
1400 (98.4)	78 (295)	78 (295)	78 (295)	78 (295)
1200 (84.4)	119 (450)	119 (450)	119 (450)	119 (450) 3
1000 (70.3)	154 (583)	154 (583)	154 (583)	154 (583)
800 (56.2)	178 (674)	178 (674)	178 (674)	178 (674)
600 (42.2)	198 (749)	198 (749)	198 (749)	198 (749)
400 (28.1)	216 (818)	216 (818)	216 (818)	216 (818)
200 (14.1)	234 (886)	234 (886)	234 (886)	234 (886)
155 (10.9)	235 (890)	235 (890)	235 (890)	235 (890)
140 (9.84)	996 (3770)	996 (3770)	236 (893)	236 (893)
120 (8.44)	1449 (5485)	1449 (5485)	239 (905)	239 (905)
100 (7.03)	1690 (6397)	1690 (6397)	240 (908)	240 (908)
80 (5.6)	1891 (7158)	1891 (7158)	241 (912)	241 (912)
60 (4.2)	2093 (7923)	2093 (7923)	243 (920)	243 (920)

* Injection Point A_1 is asumed to be attached to the broken pump discharge leg.

TABLE 6.3-13 (Sh. 2 of 2)

RCS Pressure psig (kg/cm^2)	A_1	A_2	B_1	B_2
40 (2.8)	2269 (8589)	2269 (8589)	244 (924)	244 (924)
20 (1.4)	2433 (9210)	2433 (9210)	245 (927)	245 (927)
0 (0)	2563 (9702)	2563 (9702)	248 (939)	248 (939)

TABLE 6.3-14

GENERAL SYSTEM PARAMETERS AND INITIAL CONDITIONS

SMALL BREAK ECCS PERFORMANCE

Parameter	Value
Reactor Power Level (102% of Nominal)	2,871 MWt
Peak Linear Heat Rate of Hot rod	15.6 kW/ft (512 W/cm)
Axial Power Shape	Figure 6.3-18
Moderator Temperature Coefficient at Initial Density	0.0 △p/°F (0.0 △p/°C)
Safety Injection Tank Water Volume	1,927 ft^3 (54.6 m^3)
Safety Injection Tank Pressure	585 psia (41.1 kg/cm^2A)
Number of Safety Injection Pumps Operating	1 HPSI 1 LPSI
Safety Injection Delay Time	
High-Pressure Safety Injection Pump	30 sec
Low-Pressure Safety Injection Pump	50 sec
RCS Flow Rate (Total)	115.42×10^6 lb/h (52.36×10^6 kg/h)
Core Inlet Temperature	553.4°F (289.7°C)
Core Outlet Temperature	617.4°F (325.2°C)
RCS Pressure	2,250 psia (158.2 kg/cm^2A)
Steam Generator Tube Plugging Level	18 %
Number of Tubes Per Steam Generator	6,702/1,512 (Unplugged/Plugged) 741
Setpoints for ECCS Analyses	
Low Pressurizer Pressure Reactor Trip	1,555 psia (109.3 kg/cm^2A)
Low Pressurizer Pressure Safety Injection	1,555 psia (109.3 kg/cm^2A)

삭제

TABLE 6.3- 15

FUEL ROD PERFORMANCE SUMMARY
SMALL BREAK SPECTRUM

	Break Size, ft^2 (cm^2)		
	0.05 (46.5)	0.087 (80.8)	0.1 (92.9)
Peak Cladding Temperature (°F)	1,216.5	1,355.2	1,224.3
Peak Cladding Temperature Occurs (sec)	1,238.4	818.1	744.9
Peak Cladding Temperature Location (ft)	11.75	11.75	11.75
Core-Wide Cladding Oxidation (%)	< 1.0	< 1.0	< 1.0
Maximum Cladding Oxidation (%)	0.12	0.14	0.08
Maximum Cladding Oxidation Location (ft)	12.0	11.75	11.75
Hot Rod Burst Time (sec)	N/A	N/A	N/A
Hot Rod Burst Location (ft)	N/A	N/A	N/A

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TABLE 6.3-16

VARIABLES PLOTTED AS A FUNCTION OF TIME
FOR EACH SMALL BREAK IN THE SPECTRUM

Sheet Number	Variable (Figures 6.3-14 to 6.3-16)
1	Normalized Core Power
2	Core Pressure
3	Core Inlet Flow Rate
4	Break Flow Rate
5	Core Two-Phase Mixture Level
6	Hot Spot Heat Transfer Coefficient
7	Peak Cladding Temperature

TABLE 6.3- 17

TIME SEQUENCE OF IMPORTANT EVENTS FOR A SPECTRUM OF SMALL BREAK LOCAs

(Seconds After Break)

	Break Size, ft^2 (cm^2)		
	0.05 (46.5)	0.087 (80.8)	0.1 (92.9)
Start	0.0	0.0	0.0
Reactor Trip Signal	118.3	50.7	40.7
Safety Injection Signal	118.3	50.7	40.7
HPSI Pump On	147.2	79.6	69.6
Loop Seal Clearing	408.1	268.7	223.6
Core Uncovery Begins	737.7	257.4	206.4
SI Tanks On	2,101.5	793.2	716.1
Core Boiloff PCT	1,238.4	818.1	744.9
Core Uncovery Ends	1,821.3	864.7	772.4

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TABLE 6.3-18

GENERAL SYSTEM PARAMETERS AND INITIAL CONDITIONS - LONG TERM COOLING ECCS PERFORMANCE

Quantity	Value
Reactor Power Level (102% of Nominal)	2871 MWt
SDC Entry Temperature	400 °F (204.4 °C) (max.)
SDC Entry Pressure	410 psia (28.8 kg/cm^2 A) (max.)
Atmospheric Dump Valve Capacity/Valve	235 lbm/sec (107 kg/sec) at 1000 psia (70.3 kg/cm^2 A) (min.)
Auxiliary Feedwater in Condensate Storage Tank	300,000 gal (1,136,000 L)
Boric Acid Concentration	
RCS	0.85 wt% (1485 ppm)
RWT	2.52 wt% (4400 ppm)
SIT	2.52 wt% (4400 ppm)
Water Inventories for Boric Acid Precipitation analysis	
RCS	76800 gal (290715 L) (min.)
RWT	832000 gal (3149394 L (max.)
SIT	59850 gal (226552 L) (max.)
Pump Flow Rates for Boric Acid precipitation analysis	
HPSI Pump	700 gpm (2650 L/min) (min.)
LPSI Pump	3500 gpm (13249 L/min) (min.)
Containment Spray Pumps	3500 gpm (13249 L/min) (min.)

TABLE 6.3-19 (Sh. 1 of 2)

SEQUENCE OF EVENTS FOR REPRESENTATIVE LARGE AND SMALL BREAK LOCAs

	Large Break (CD=0.8 of DEG/PD)		Small Break (0.05 ft^2)		
Event	Setpoint or Value	Time (sec)	Setpoint or Value	Time (sec)	Success Path
Break occurs		0.0		0.0	
Core peak power	140%	0.14	103.8%	38.30	
Pressurizer “삭제” pressure reaches reactor trip and SIAS analysis setpoint	1712.5 psia (120.4 kg/cm^{2}A)	5.41	1555 psia (109 kg/cm^{2}A)	117.16	Reactivity control
Reactor trip and safety injection actuation signals generated		6.6		118.31	Reactivity control
SIT discharge begins	615.7 psia (43.29 kg/cm^{2}A)	5.6(Broken) 13.1(Intact)	585 psia (41.1 kg/cm^{2}A)	2101.54	Reactivity control
Reflood begins		30.6		NA	
Main steam safety valves begin to open		NA	1330.3 psia (93.5 kg/cm^{2}A)	126.90	Sec. sys. integrity
Maximum secondary pressure	1012 psia (71.2 kg/cm^{2}A)	4.0	1336.4 psia (94.0 kg/cm^{2}A)	129.92	
HPSI pump flow delivered to RCS		35.41		147.16	Reactivity control
SITs empty		77.4(Broken) 77.5(Intact)		NA	

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TABLE 6.3-19 (Sh. 2 of 2)

SEQUENCE OF EVENTS FOR REPRESENTATIVE LARGE AND SMALL BREAK LOCAs

Event	Large Break (CD= 0.8 of DEG/PD) Setpoint or Value	Large Break Time (sec)	Small Break (0.05 ft^2) Setpoint or Value	Small Break Time (sec)	Success Path
LPSI pump flow delivered to RCS		55.41		NA	Reactivity control
Main steam safety valves closed			1330.3 psia (93.5 kg/cm^{2}A)	1608.63	
Recirculation actuation signal	5% range	1200 - 7200	5% range	1200 - 7200	Reactivity control
Initiate cooldown		3600		3600	Sec. sys. integrity
Enter hot- and cold-leg injection mode		7200		7200	Reactor heat removal
Decision point for entry into shutdown cooling or continuation or hot- and cold-leg injection mode		32400		32400	Reactor heat removal

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NOTES:

(1) For the large break, loss of ac power is assumed at initiation of event (t= 0.0).

(2) For the small break, loss of ac power and start of the diesel generator occurs at time of PpL trip (t = 117.16).

"삭제"

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SAFETY INJECTION SYSTEM P&ID
(Sheet 1 of 4)

Figure 6.3-1

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SAFETY INJECTION SYSTEM P&ID
(Sheet 2 of 4)

Figure 6.3-1

KOREA ELECTRIC POWER CORPORATION
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SAFETY INJECTION SYSTEM P&ID
(Sheet 3 of 4)

Figure 6.3-1

KOREA ELECTRIC POWER CORPORATION
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SAFETY INJECTION SYSTEM P&ID
(Sheet 4 of 4)

Figure 6.3-1

KOREA ELECTRIC POWER CORPORATION
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SAFETY INJECTION SYSTEM FLOW DIAGRAM - INJECTION MODE
(Sheet 1 of 2)

Figure 6.3-2

KOREA ELECTRIC POWER CORPORATION
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SAFETY INJECTION SYSTEM FLOW
DIAGRAM - INJECTION MODE
(Sheet 2 of 2)

Figure 6.3-2

KOREA ELECTRIC POWER CORPORATION
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SAFETY INJECTION SYSTEM FLOW DIAGRAM - SHORT-TERM RECIRCULATION MODE
(Sheet 1 of 2)
Figure 6.3-3

KOREA ELECTRIC POWER CORPORATION
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SAFETY INJECTION SYSTEM FLOW DIAGRAM - SHORT-TERM RECIRCULATION MODE
(Sheet 2 of 2)
Figure 6.3-3

KOREA ELECTRIC POWER CORPORATION
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SAFETY INJECTION SYSTEM FLOW
DIAGRAM - LONG-TERM
RECIRCULATION MODE
(Sheet 1 of 2)
Figure 6.3-4

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SAFETY INJECTION SYSTEM FLOW DIAGRAM - LONG-TERM RECIRCULATION MODE
(Sheet 2 of 2)
Figure 6.3-4

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SAFETY INJECTION SYSTEM FLOW DIAGRAM - SHUTDOWN COOLING MODE
(Sheet 1 of 2)

Figure 6.3-5

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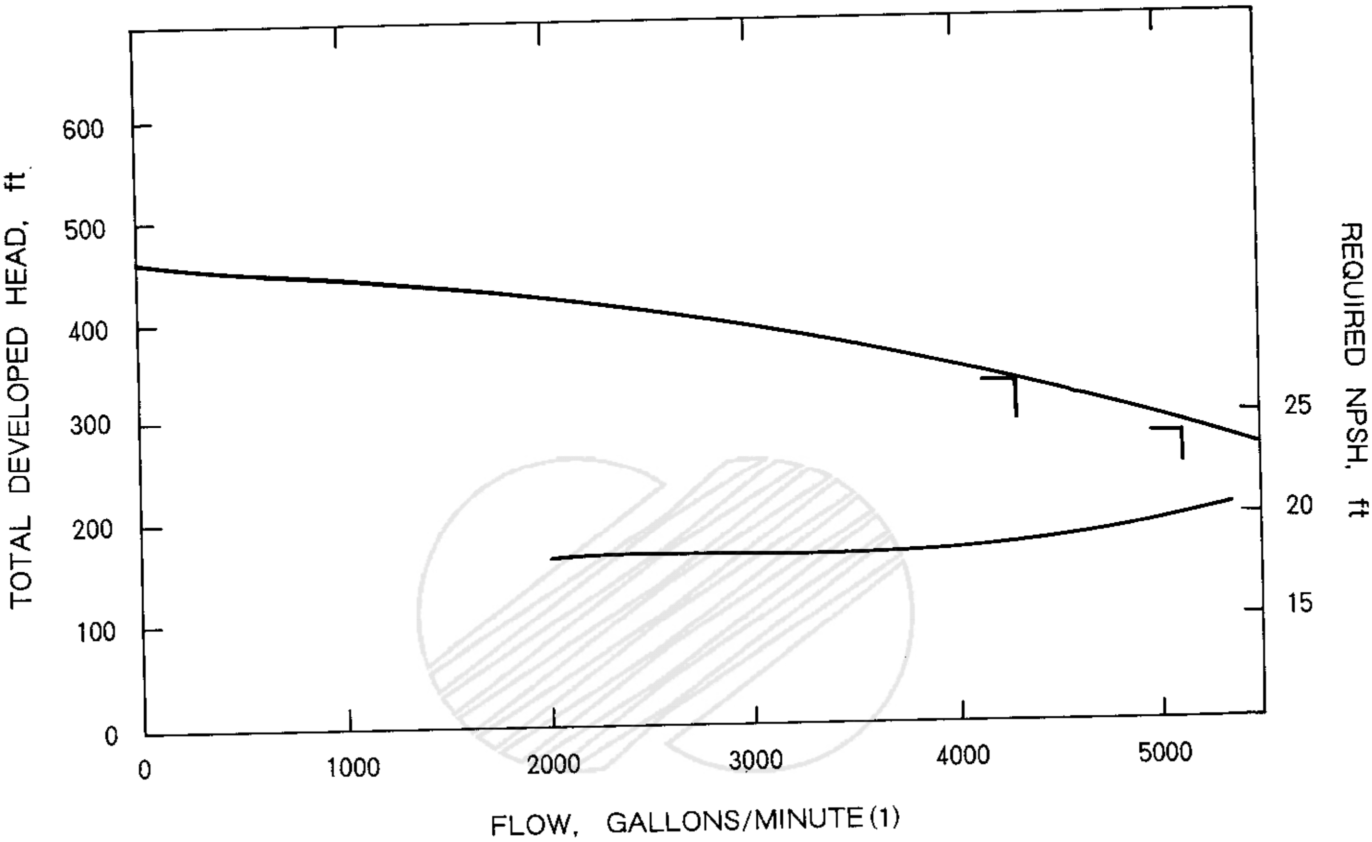
SAFETY INJECTION SYSTEM FLOW DIAGRAM - SHUTDOWN COOLING MODE
(Sheet 2 of 2)

Figure 6.3-5



Note 1 : FLOW INCLUDES 120 GPM (454 L/MIN) BYPASS FLOW

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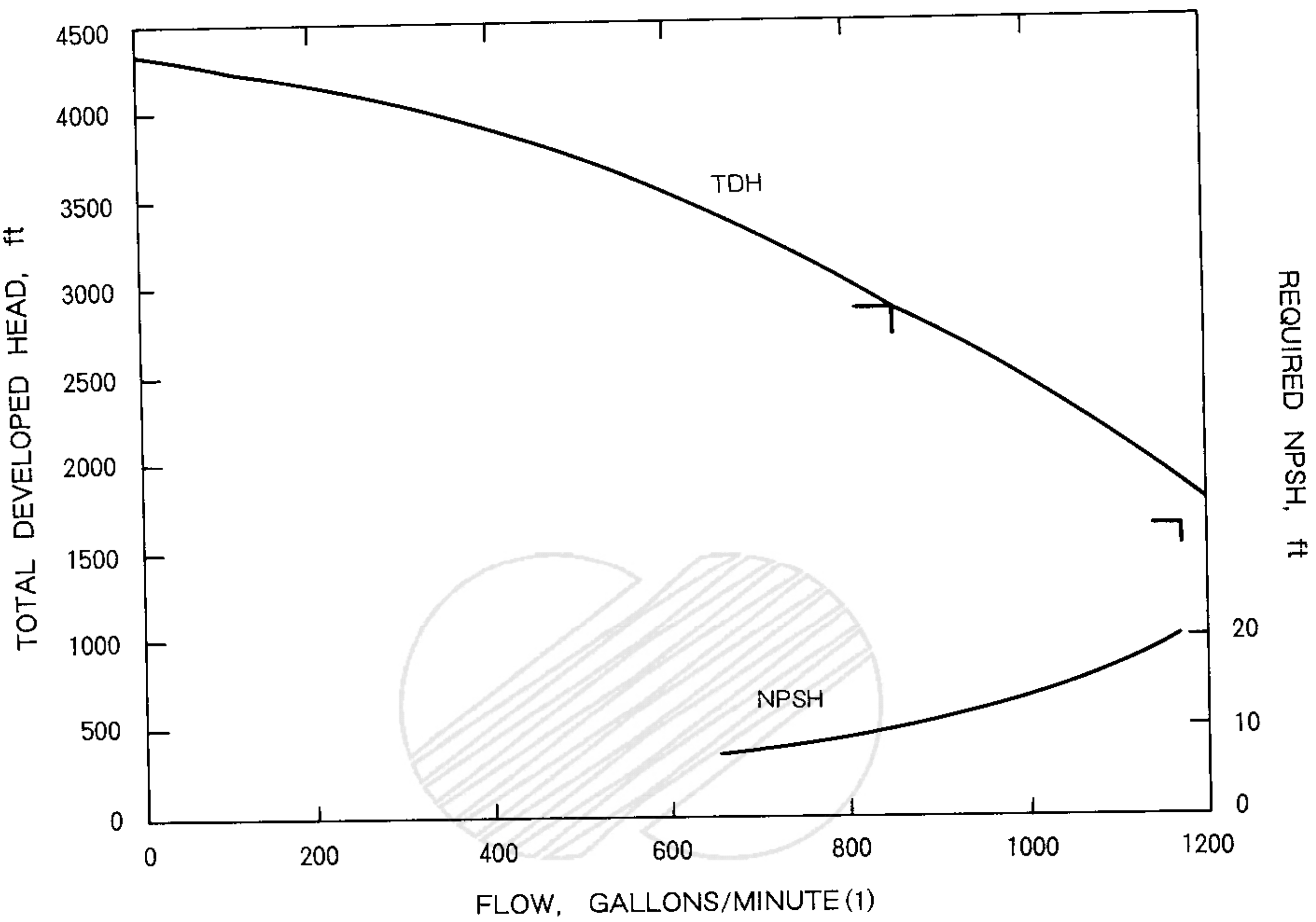
LOW-PRESSURE SAFETY INJECTION PUMP - TYPICAL HEAD AND NPSH CURVES

Figure 6.3-6



Note 1 : FLOW INCLUDES 85 GPM (322 L/MIN) BYPASS FLOW

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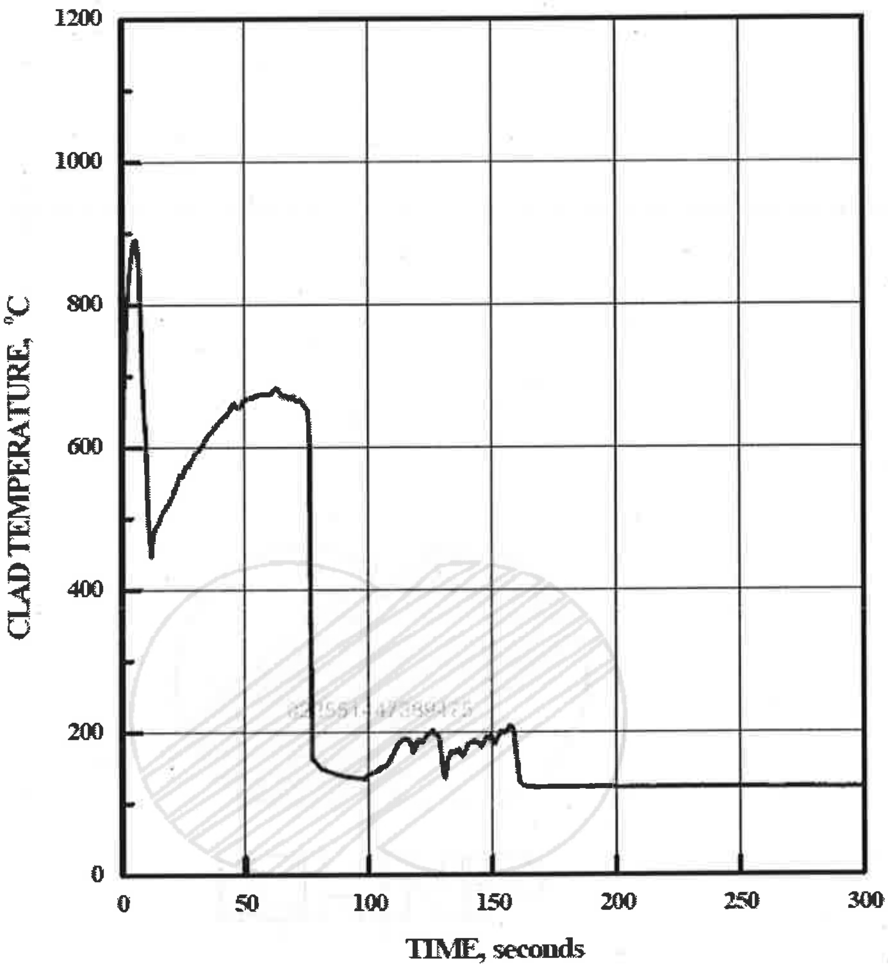
HIGH-PRESSURE SAFETY INJECTION
PUMP - TYPICAL HEAD AND NPSH CURVES

Figure 6.3-7



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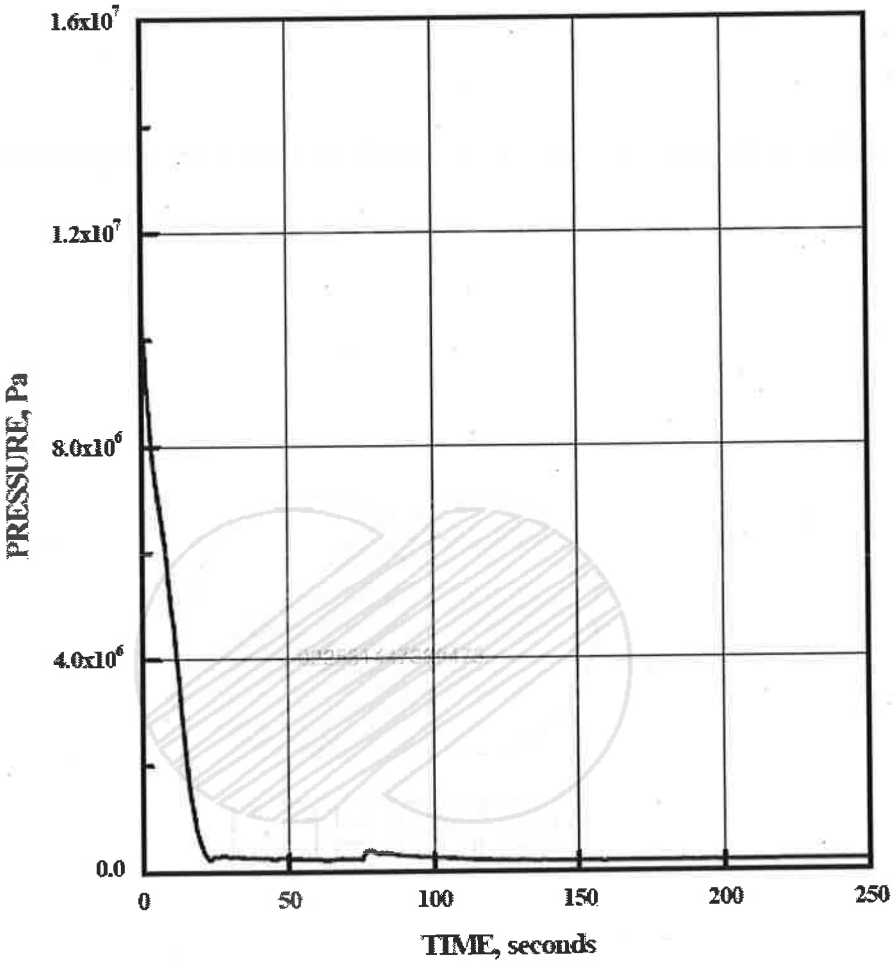
Peak Cladding Temperature
1.0 × DEG/PD

Figure 6.3-8 (Sheet 1 of 5)



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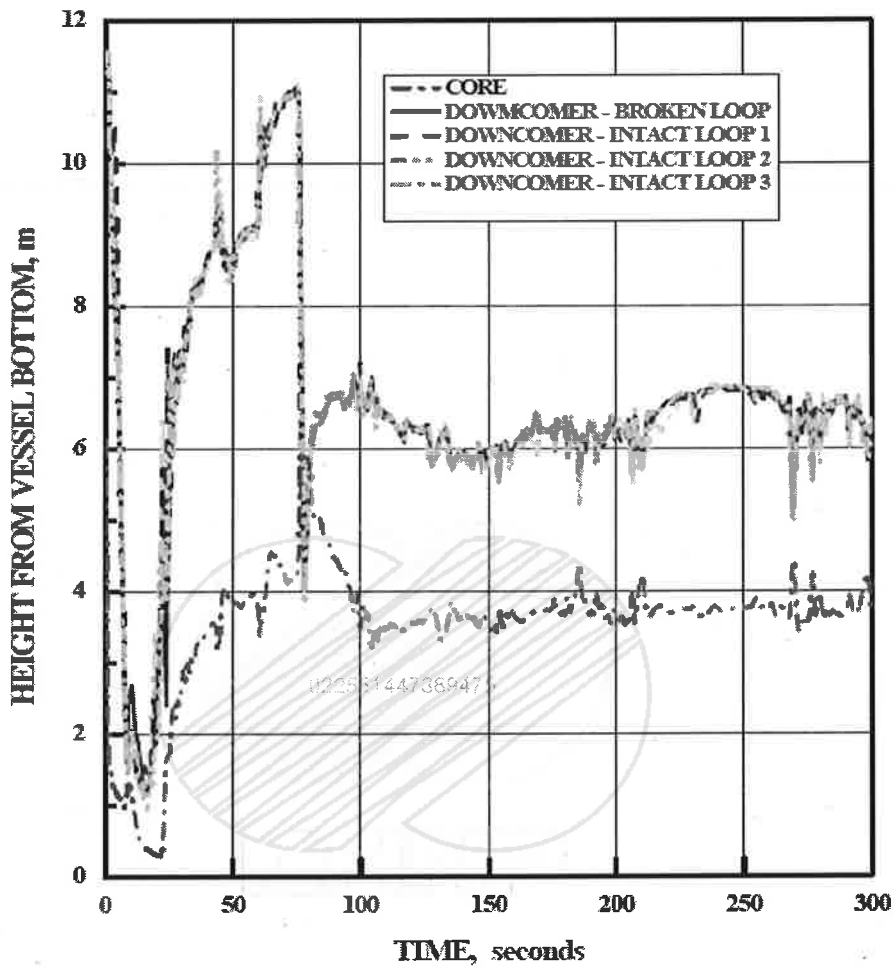
Core Pressure
1.0 × DEG/PD

Figure 6.3-8 (Sheet 2 of 5)



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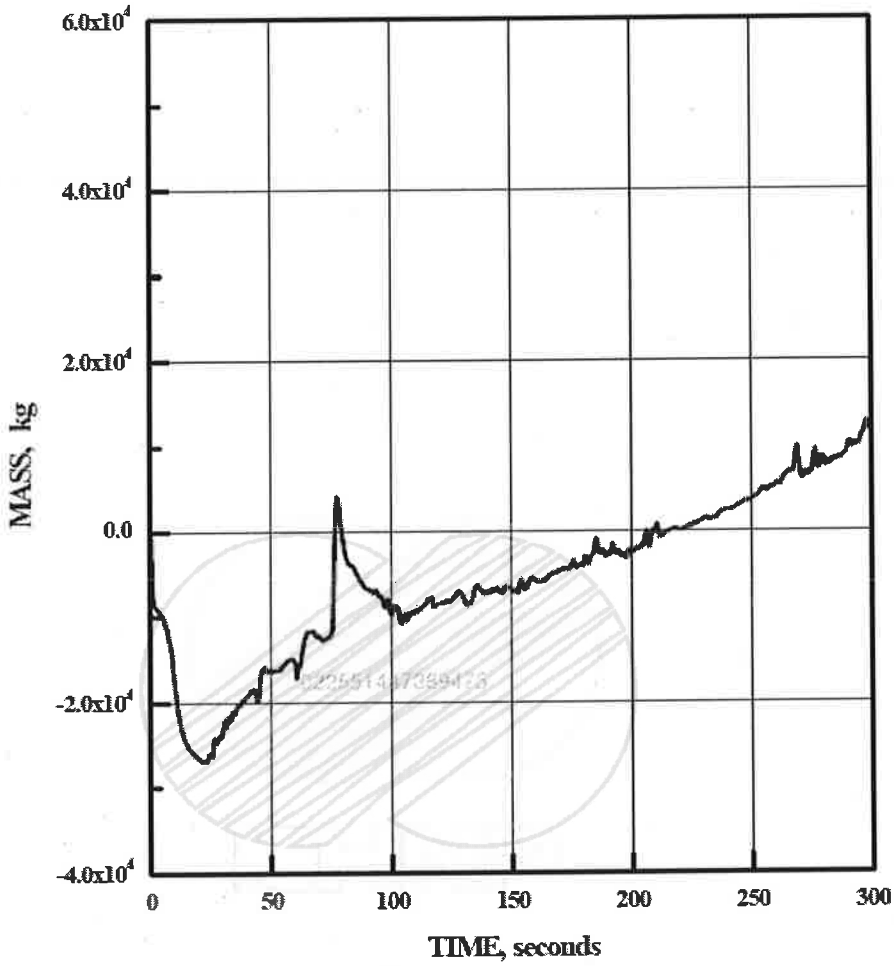
Core and Downcomer Water Level
1.0 × DEG/PD

Figure 6.3-8 (Sheet 3 of 5)



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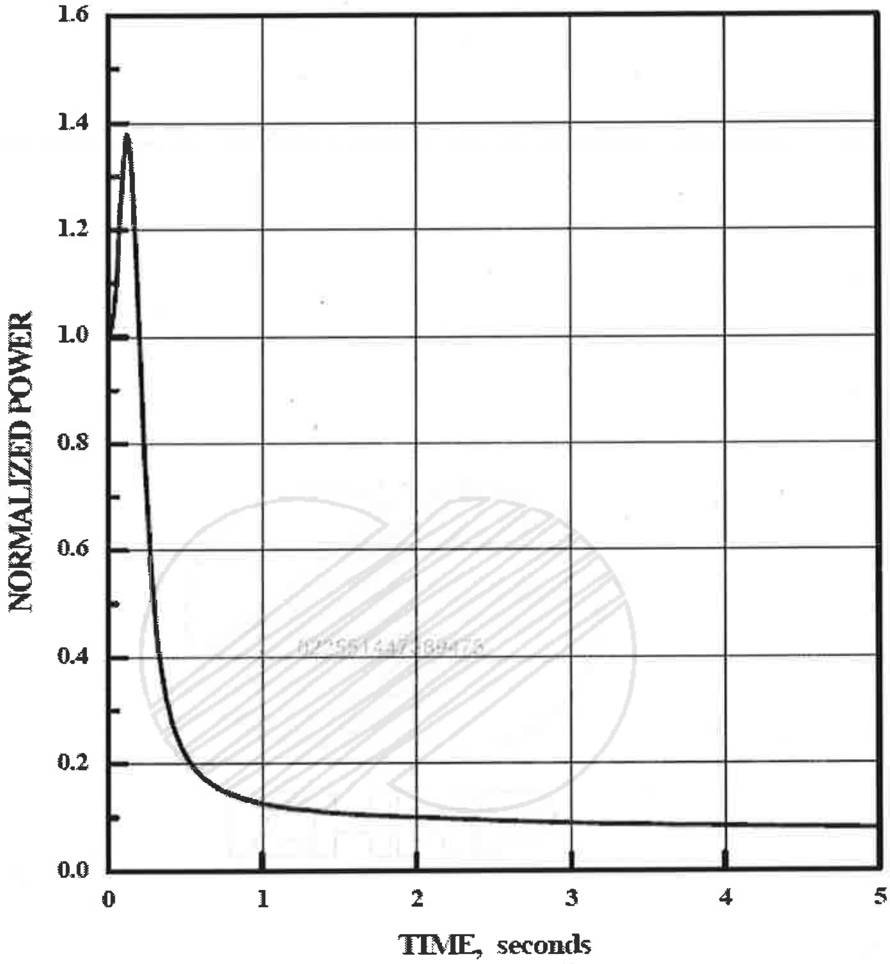
Integrated Core Inlet Flow
1.0 × DEG/PD

Figure 6.3-8 (Sheet 4 of 5)



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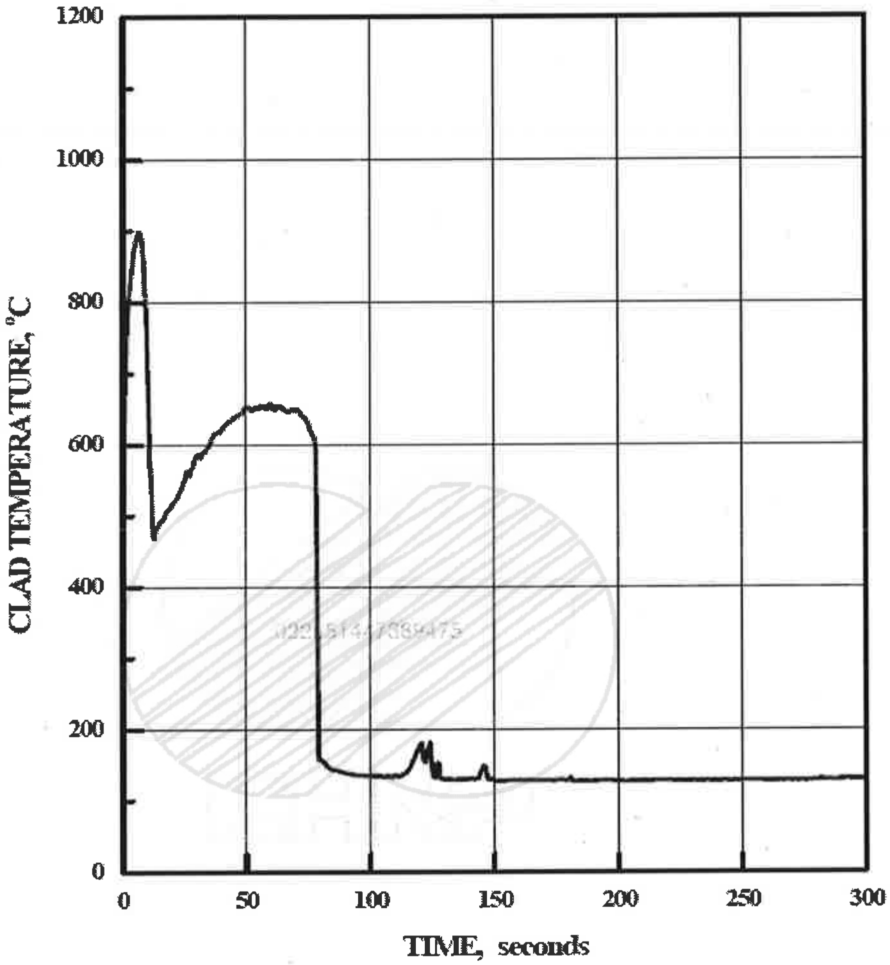
Normalized Power
1.0 × DEG/PD

Figure 6.3-8 (Sheet 5 of 5)



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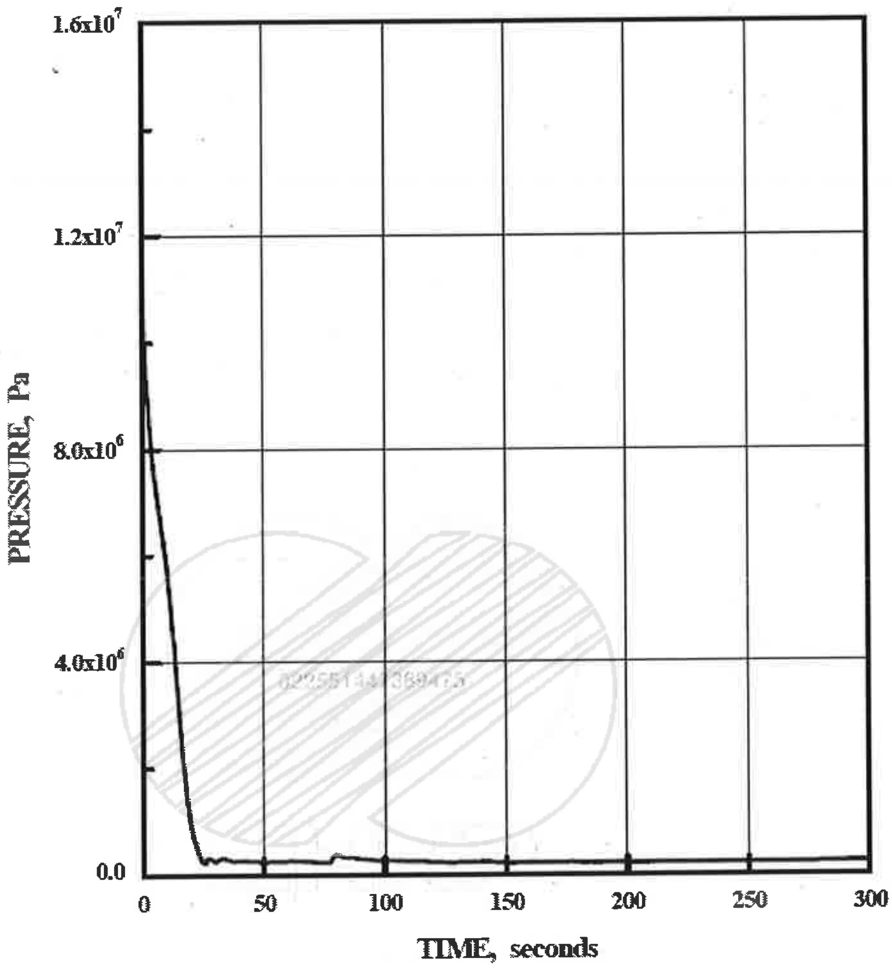
Peak Cladding Temperature
0.8 × DEG/PD

Figure 6.3-9 (Sheet 1 of 5)



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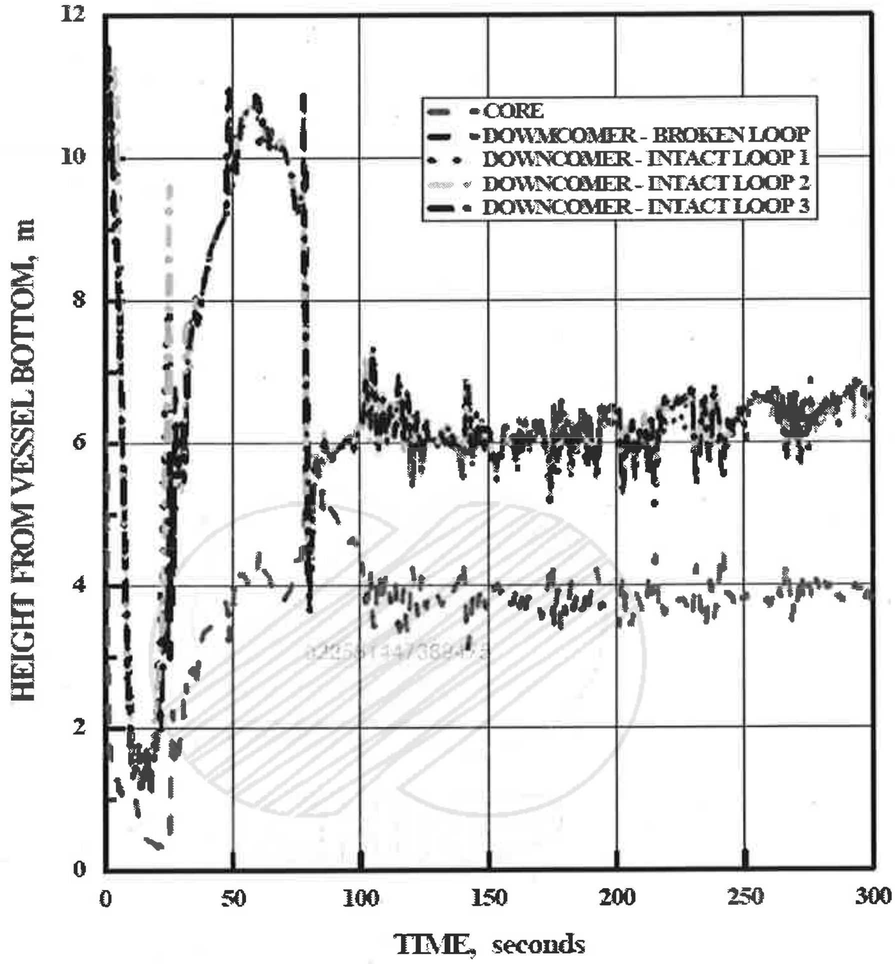
Core Pressure
0.8 × DEG/PD

Figure 6.3-9 (Sheet 2 of 5)



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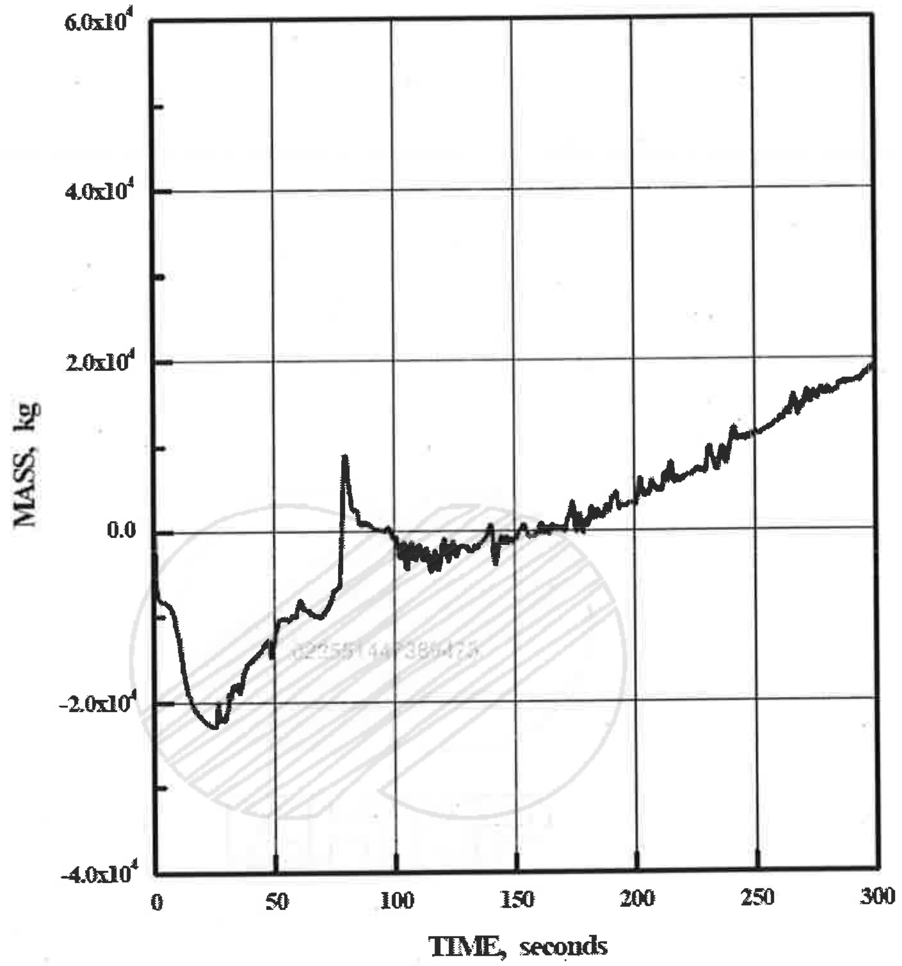
Core and Downcomer Water Level
0.8 × DEG/PD

Figure 6.3-9 (Sheet 3 of 5)



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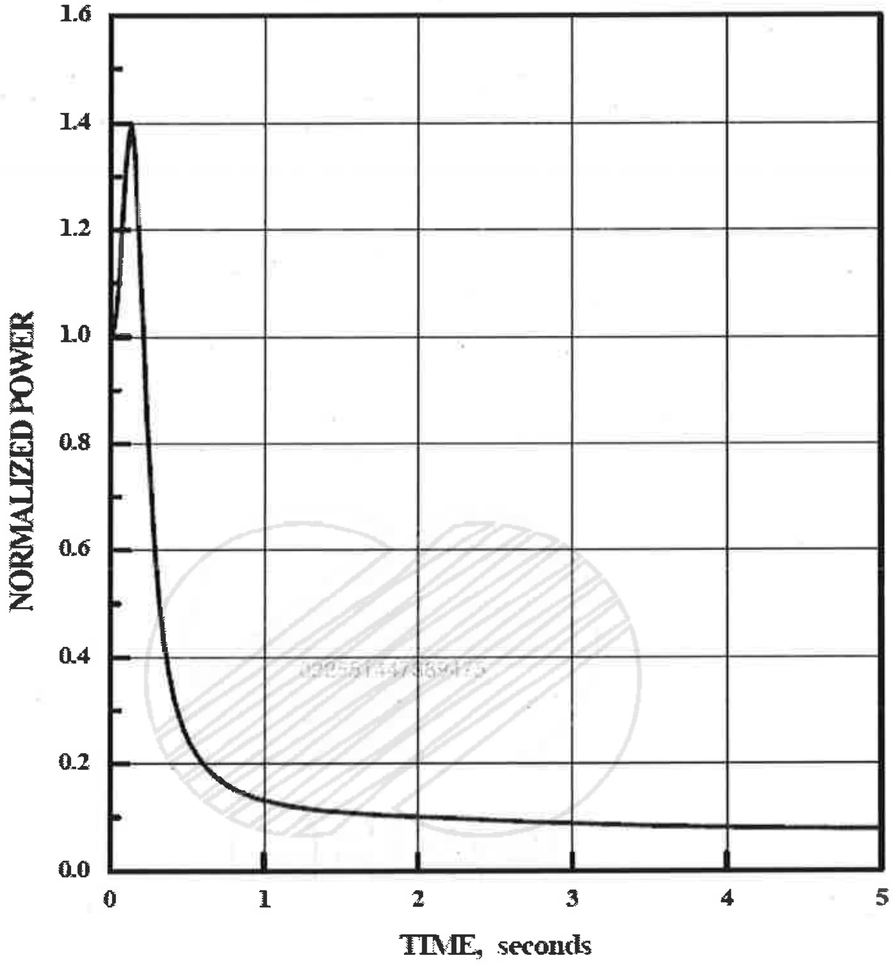
Integrated Core Inlet Flow
0.8 × DEG/PD

Figure 6.3-9 (Sheet 4 of 5)



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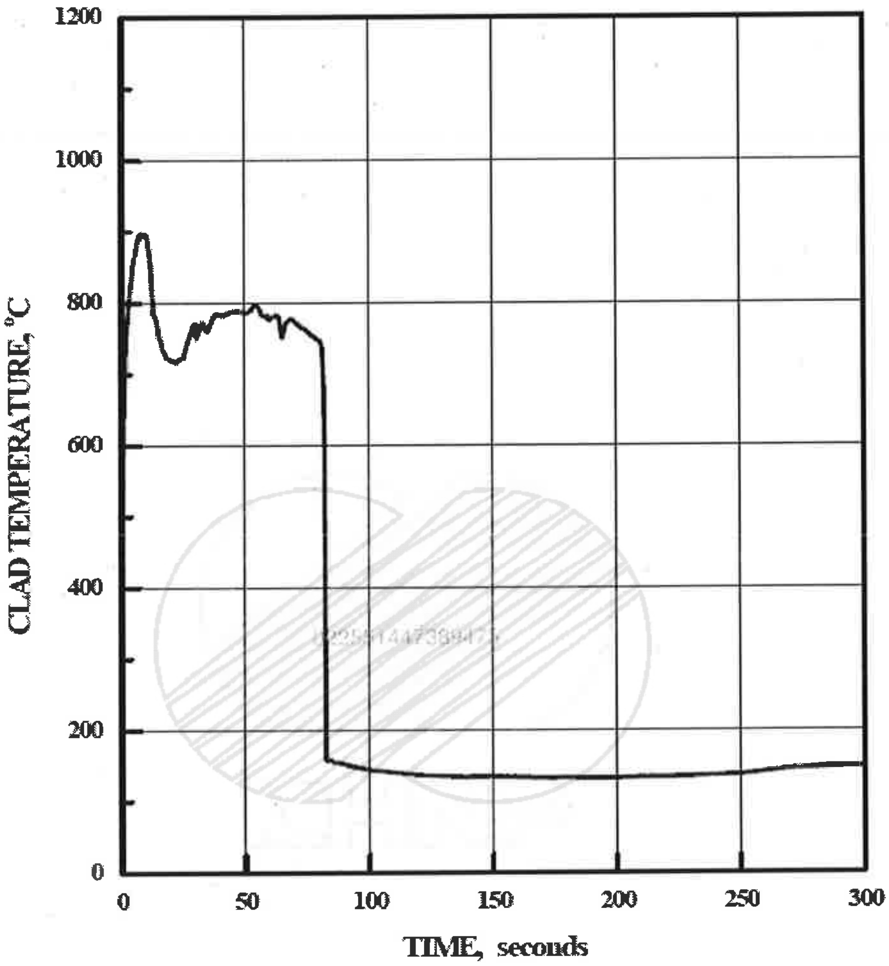
Normalized Power
0.8 × DEG/PD

Figure 6.3-9 (Sheet 5 of 5)



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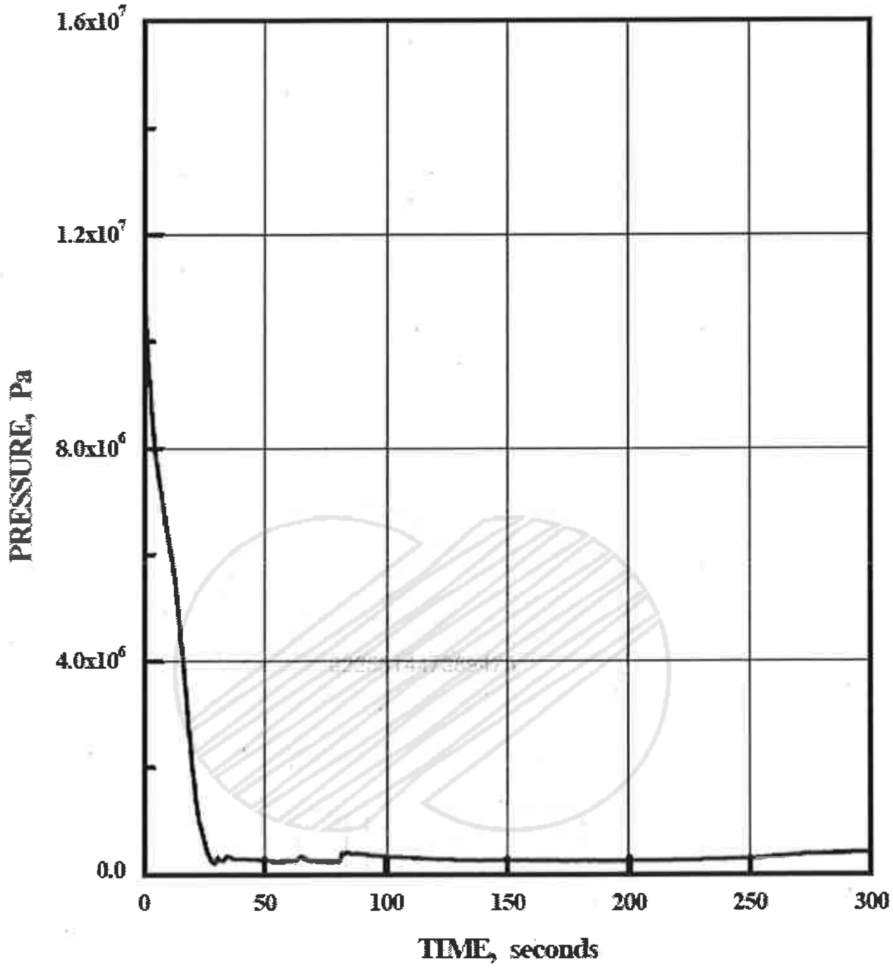
Peak Cladding Temperature
0.6 × DEG/PD

Figure 6.3-10 (Sheet 1 of 5)



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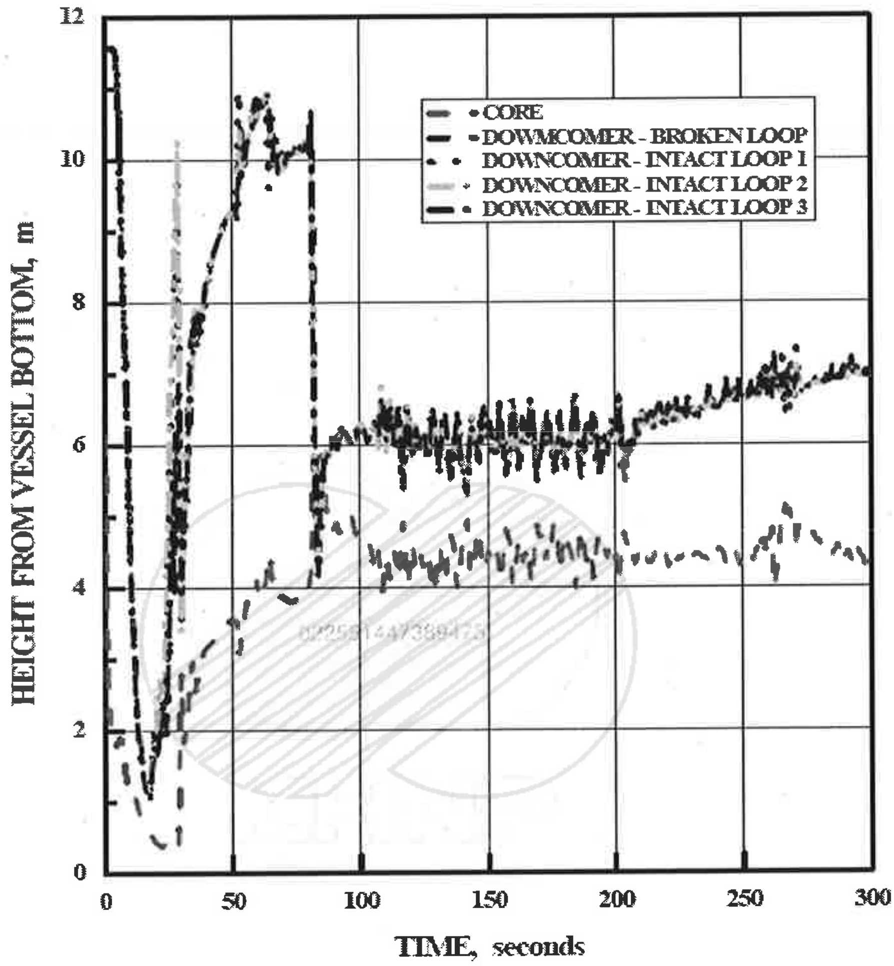
Core Pressure
0.6 × DEG/PD

Figure 6.3-10 (Sheet 2 of 5)



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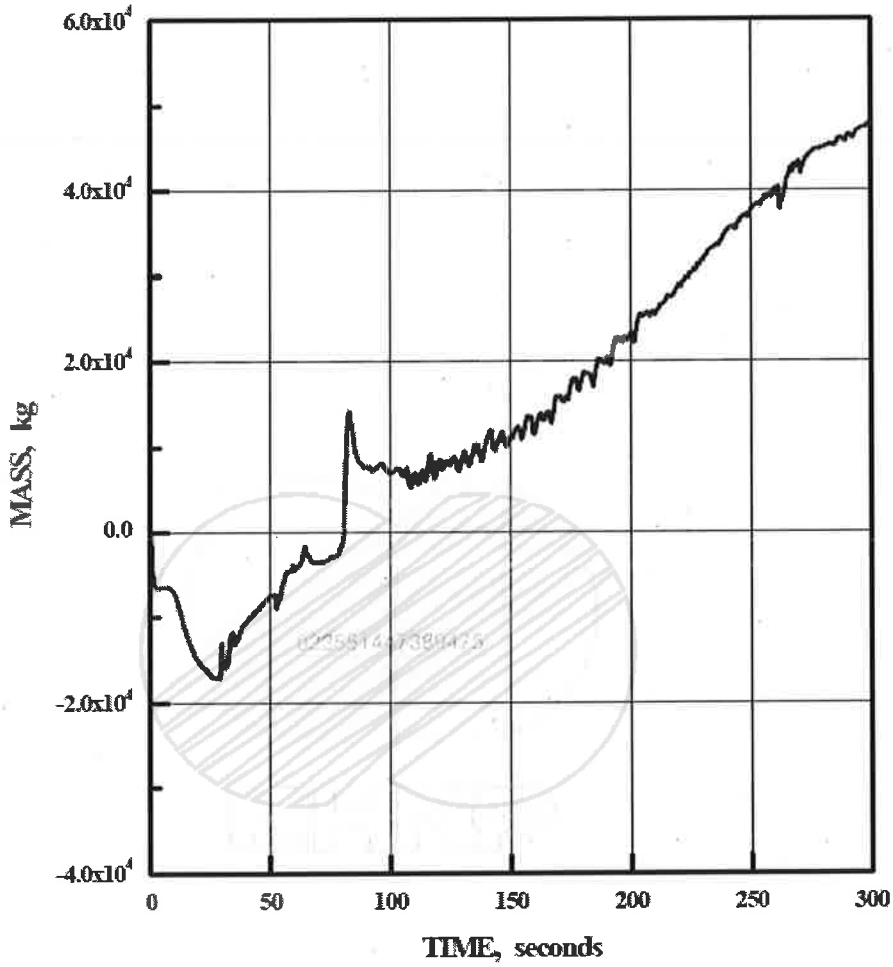
Core and Downcomer Water Level
0.6 × DEG/PD

Figure 6.3-10 (Sheet 3 of 5)



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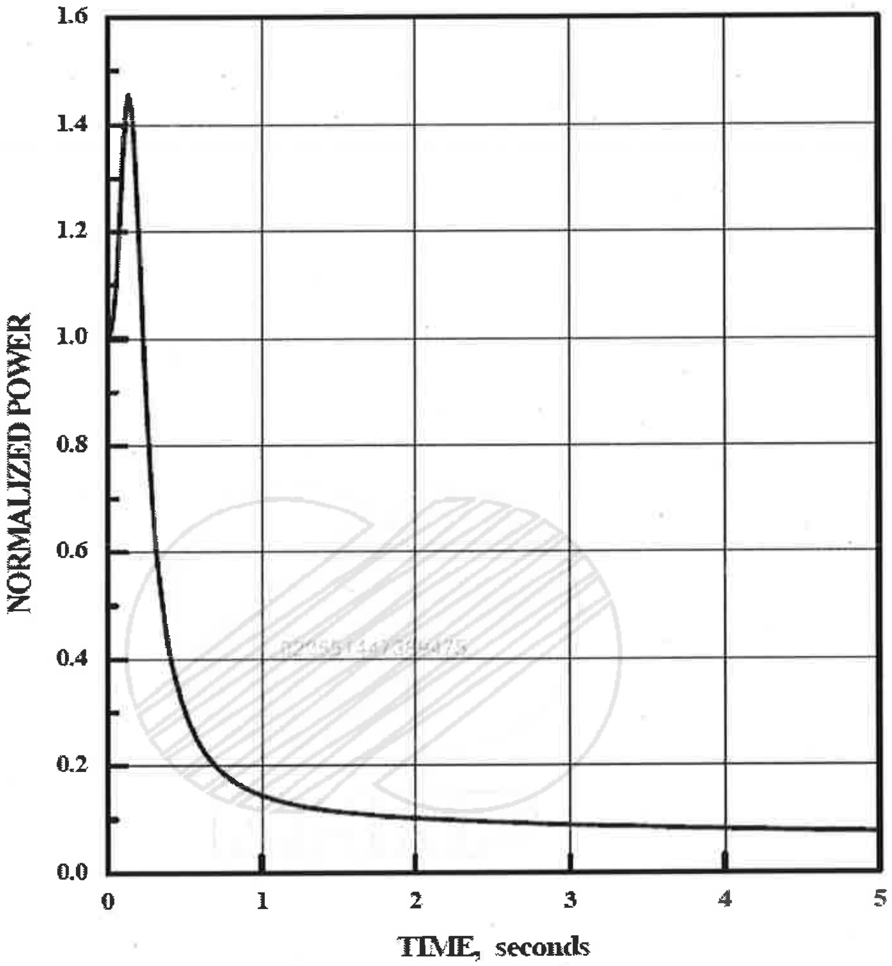
Integrated Core Inlet Flow
0.6 × DEG/PD

Figure 6.3-10 (Sheet 4 of 5)



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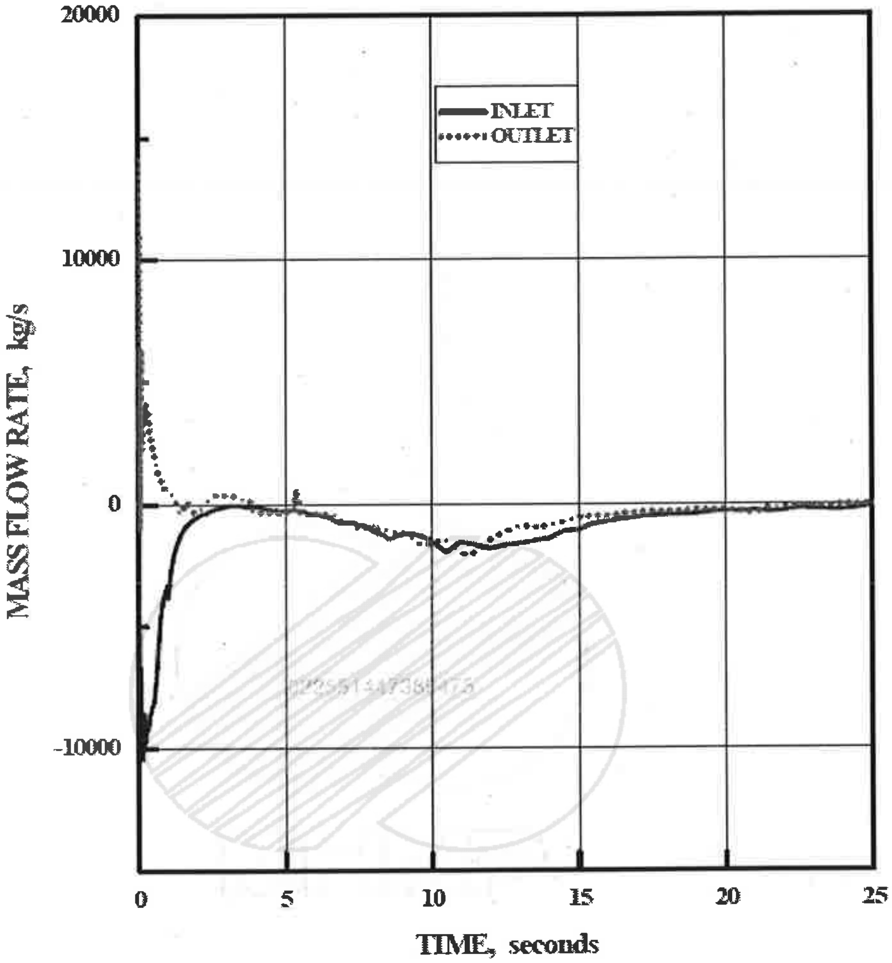
Normalized Power
0.6 × DEG/PD

Figure 6.3-10 (Sheet 5 of 5)



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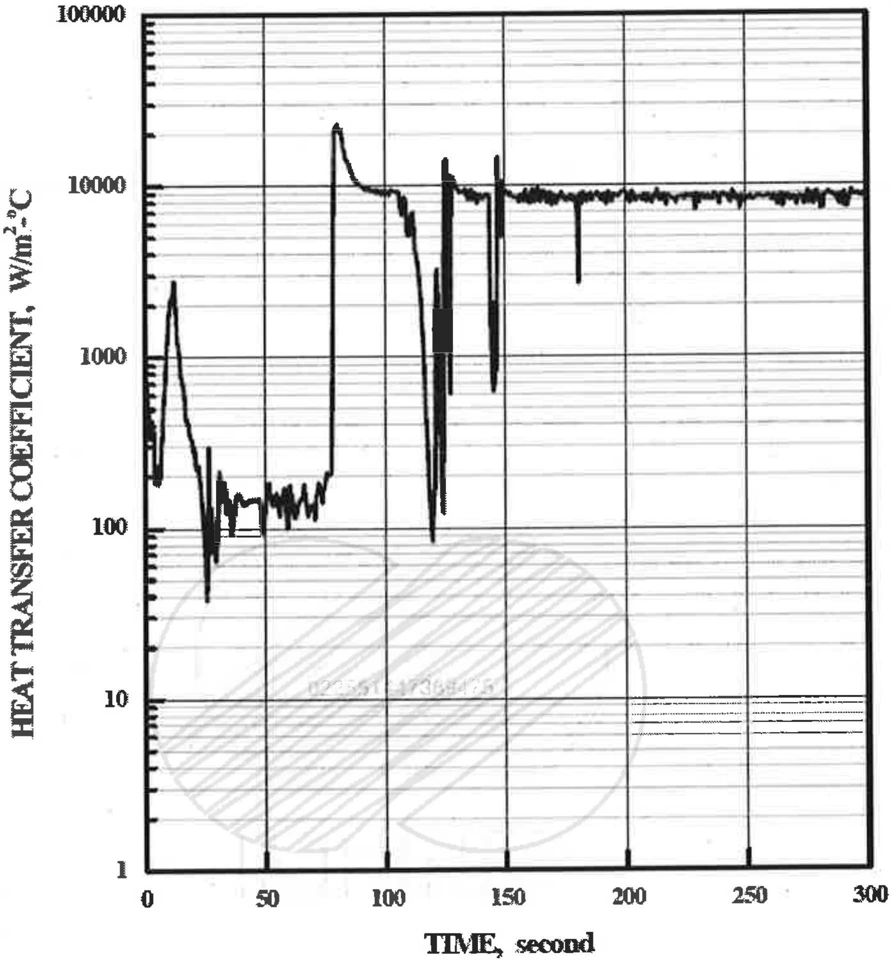
Core Inlet and Outlet Flow Rate
0.8 × DEG/PD

Figure 6.3-11 (Sheet 1 of 10)



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YONGGWANG 3 & 4
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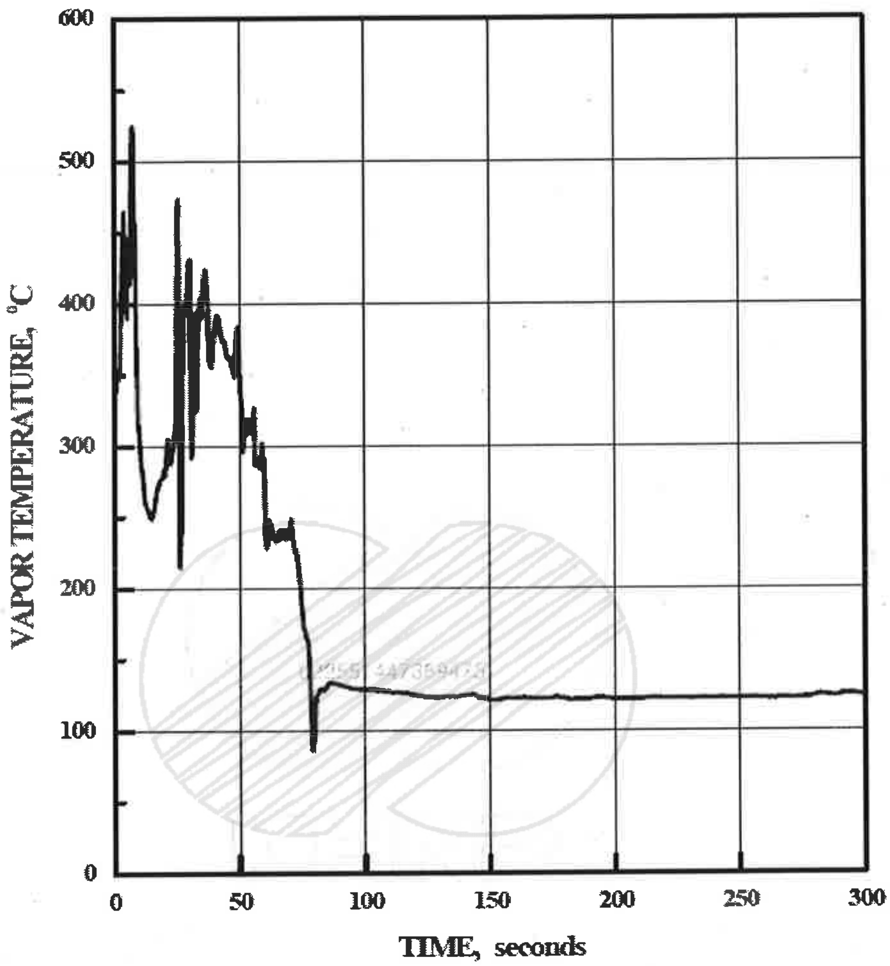
Hot Spot Heat Transfer Coefficient
0.8 × DEG/PD

Figure 6.3-11 (Sheet 2 of 10)



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YONGGWANG 3 & 4
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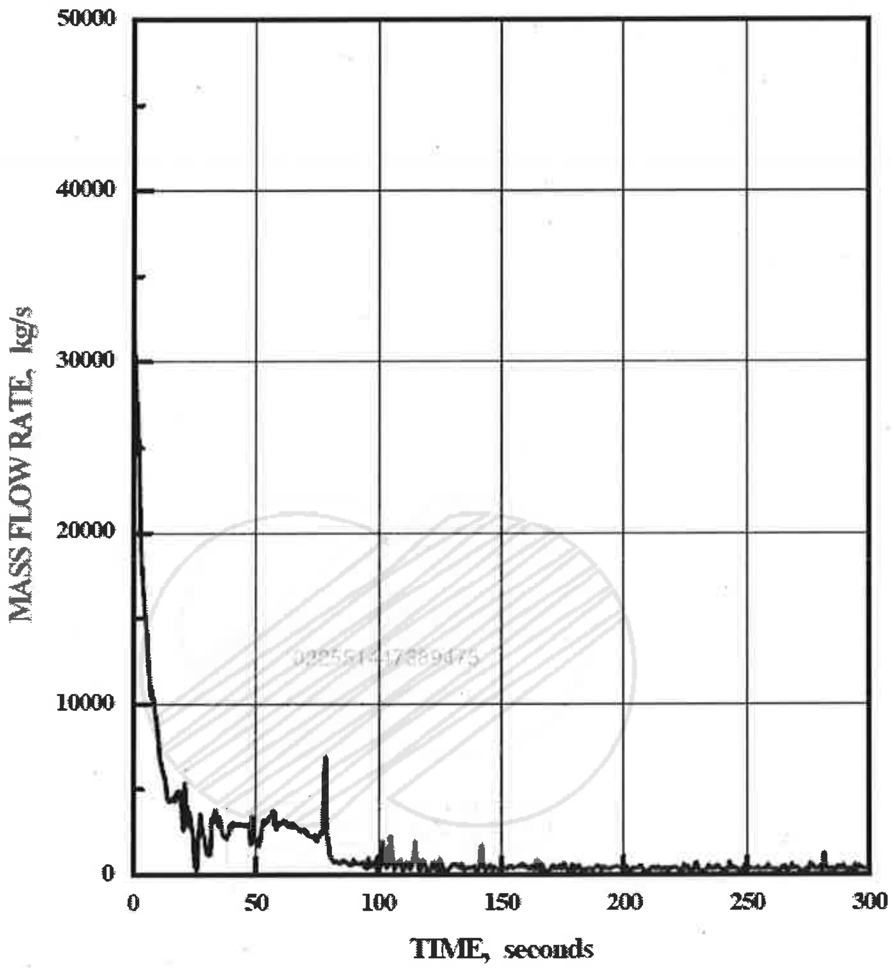
Hot Spot Vaper Temperature
0.8 × DEG/PD

Figure 6.3-11 (Sheet 3 of 10)



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YONGGWANG 3 & 4
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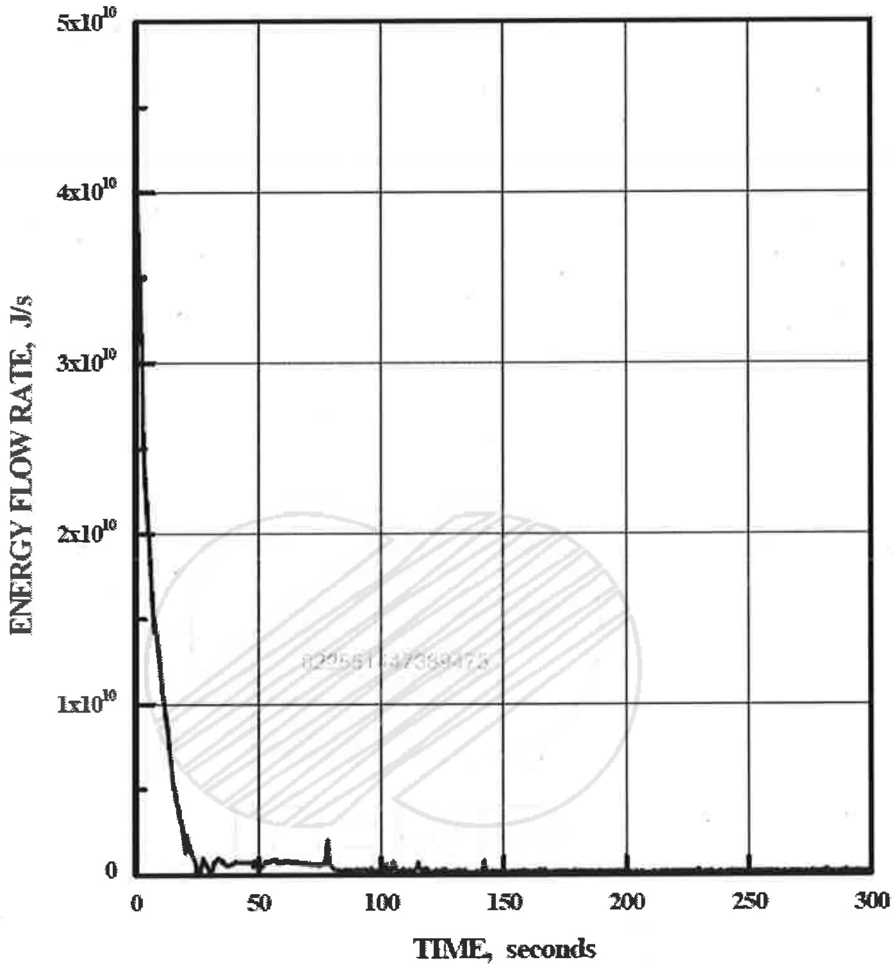
Break Flow Rate
0.8 × DEG/PD

Figure 6.3-11 (Sheet 4 of 10)



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YONGGWANG 3 & 4
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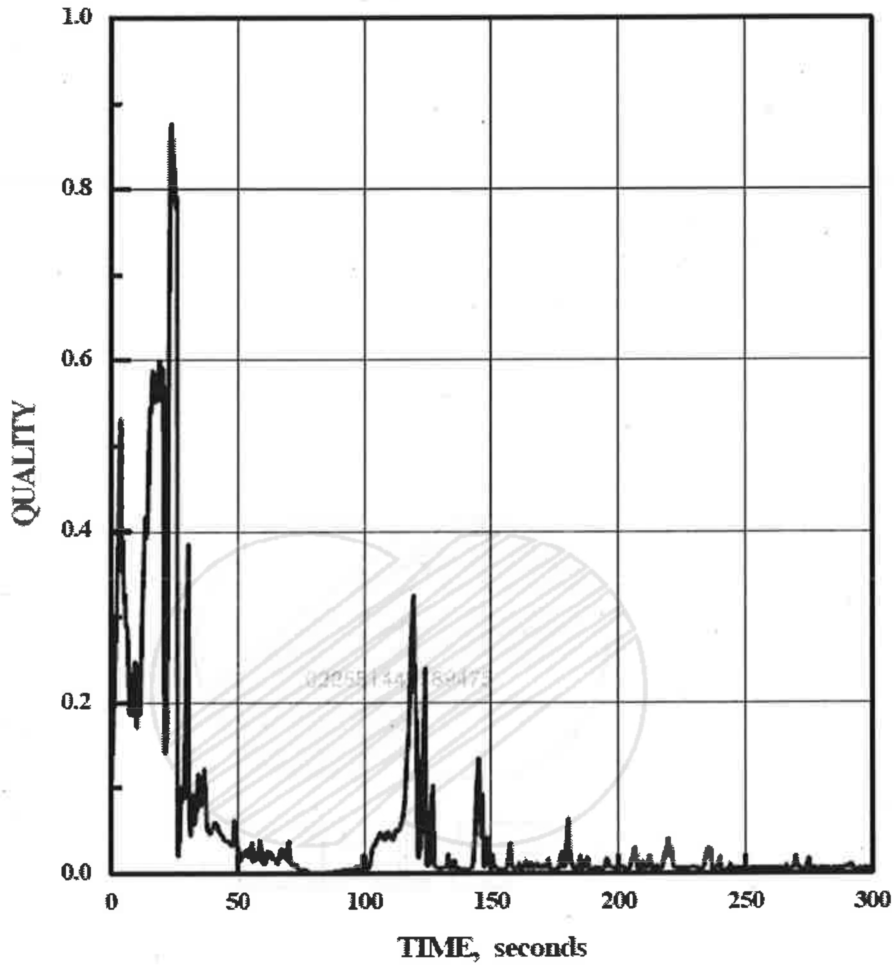
Break Energy Flow Rate
0.8 × DEG/PD

Figure 6.3-11 (Sheet 5 of 10)



KOREA HYDRO & NUCLEAR POWER COMPANY
YONGGWANG 3 & 4
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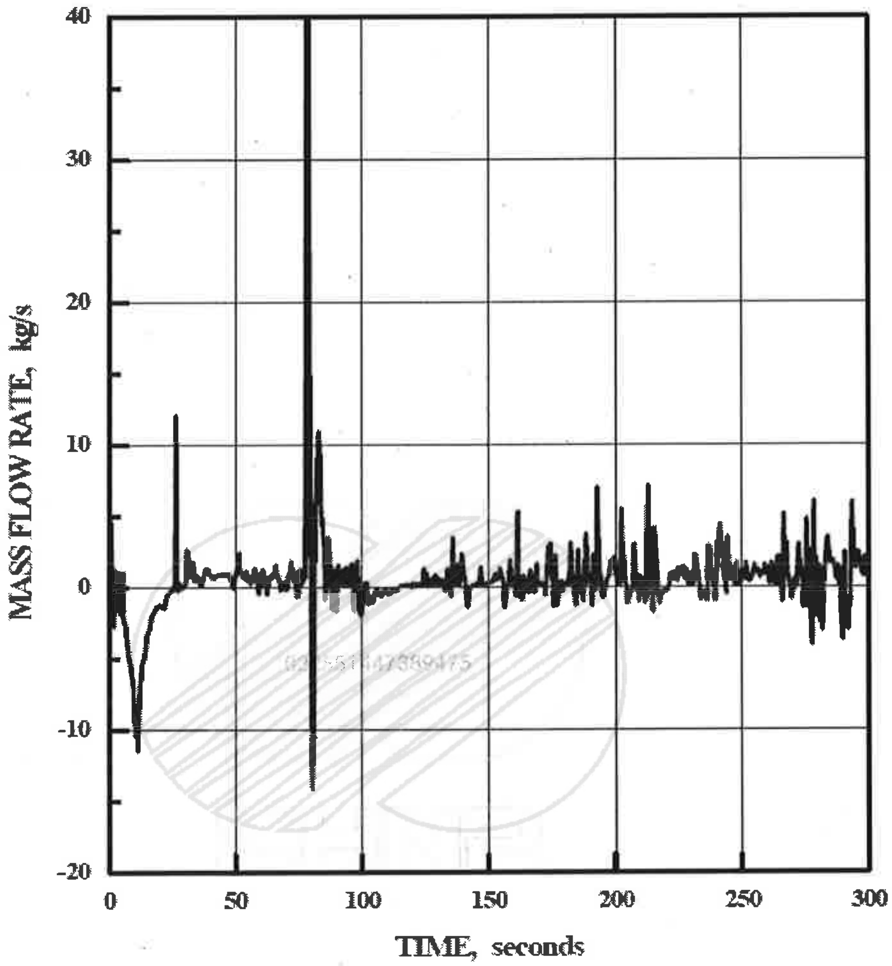
Hot Spot Fluid Quality
0.8 × DEG/PD

Figure 6.3-11 (Sheet 6 of 10)



KOREA HYDRO & NUCLEAR POWER COMPANY
YONGGWANG 3 & 4
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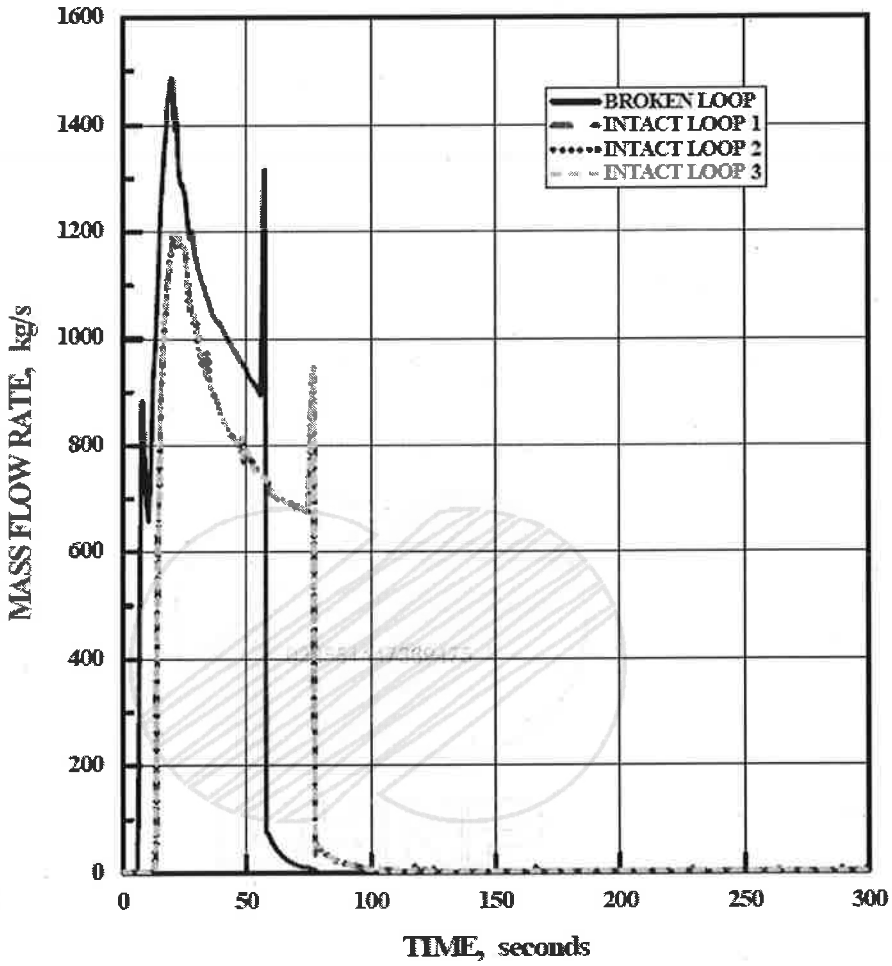
Hot Channel Core Flow Rate
0.8 × DEG/PD

Figure 6.3-11 (Sheet 7 of 10)



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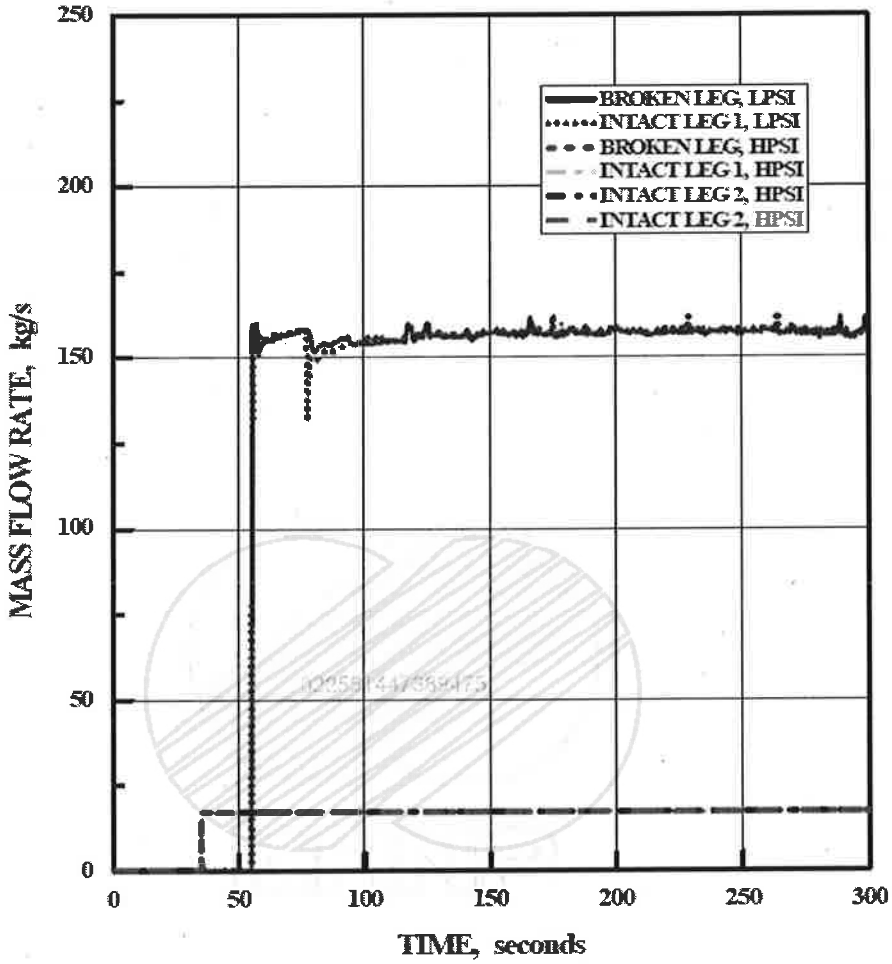
SIT Flow Rate
0.8 × DEG/PD

Figure 6.3-11 (Sheet 8 of 10)



KOREA HYDRO & NUCLEAR POWER COMPANY
YONGGWANG 3 & 4
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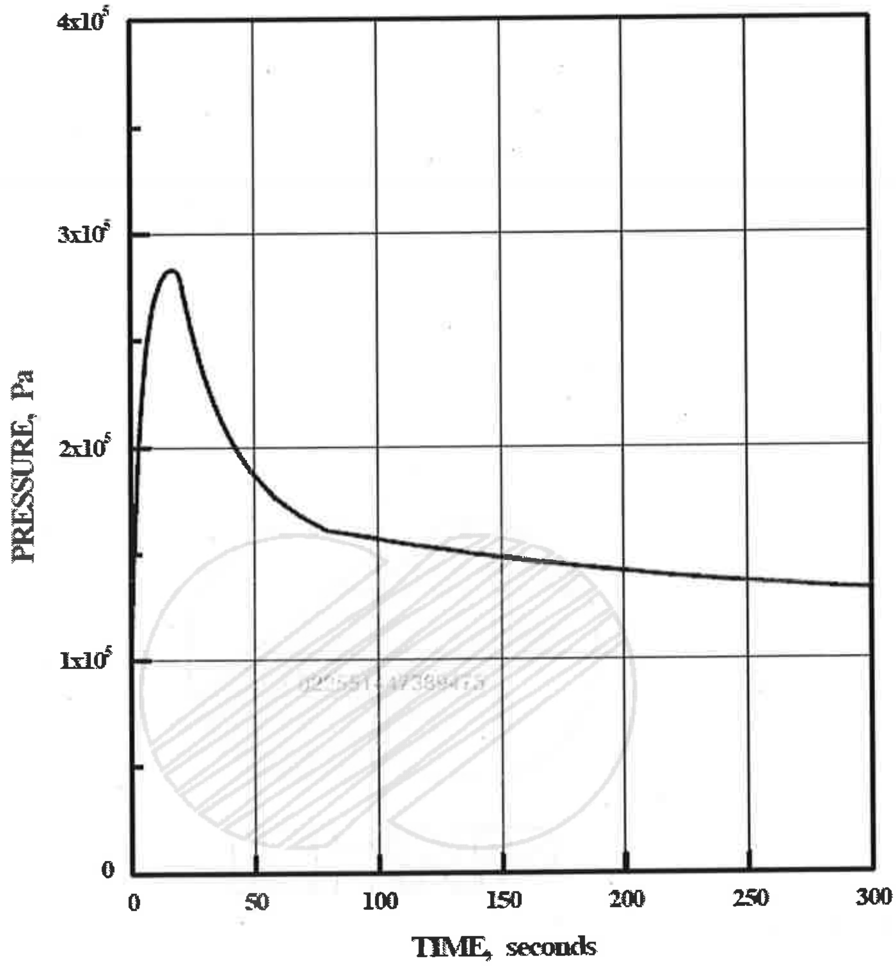
Safety Injection Pump Flow Rate
0.8 × DEG/PD

Figure 6.3-11 (Sheet 9 of 10)



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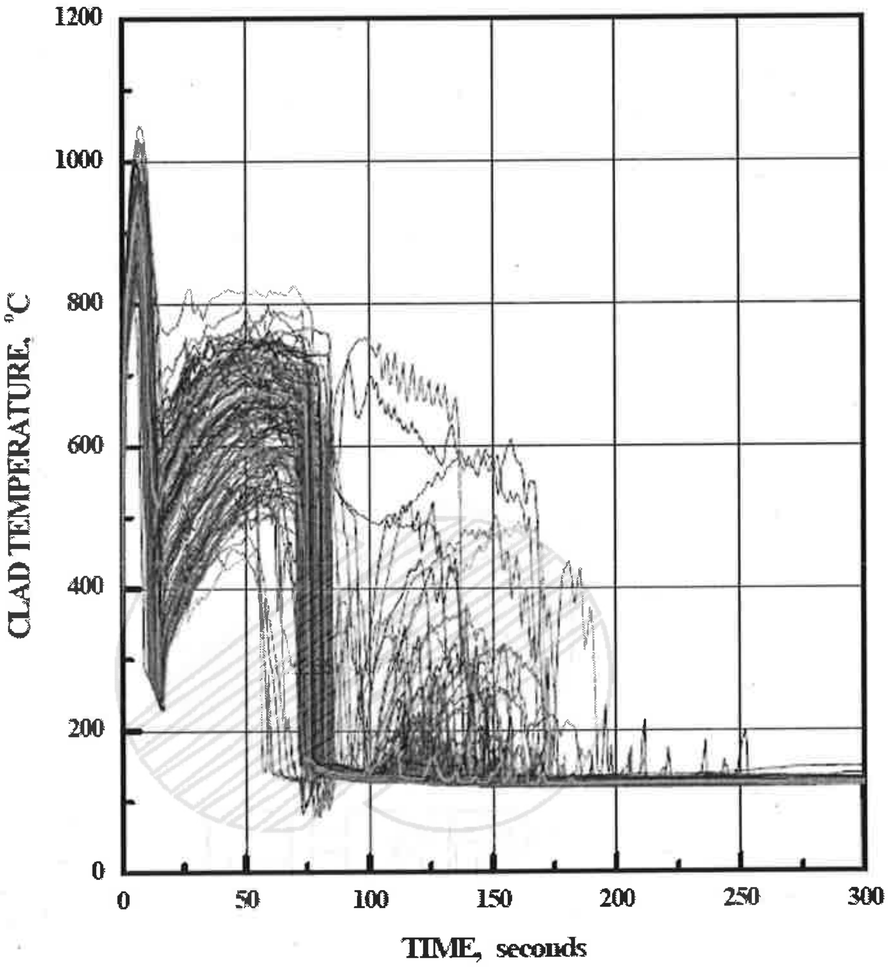
Containment Pressure
0.8 × DEG/PD

Figure 6.3-11 (Sheet 10 of 10)



KOREA HYDRO & NUCLEAR POWER COMPANY
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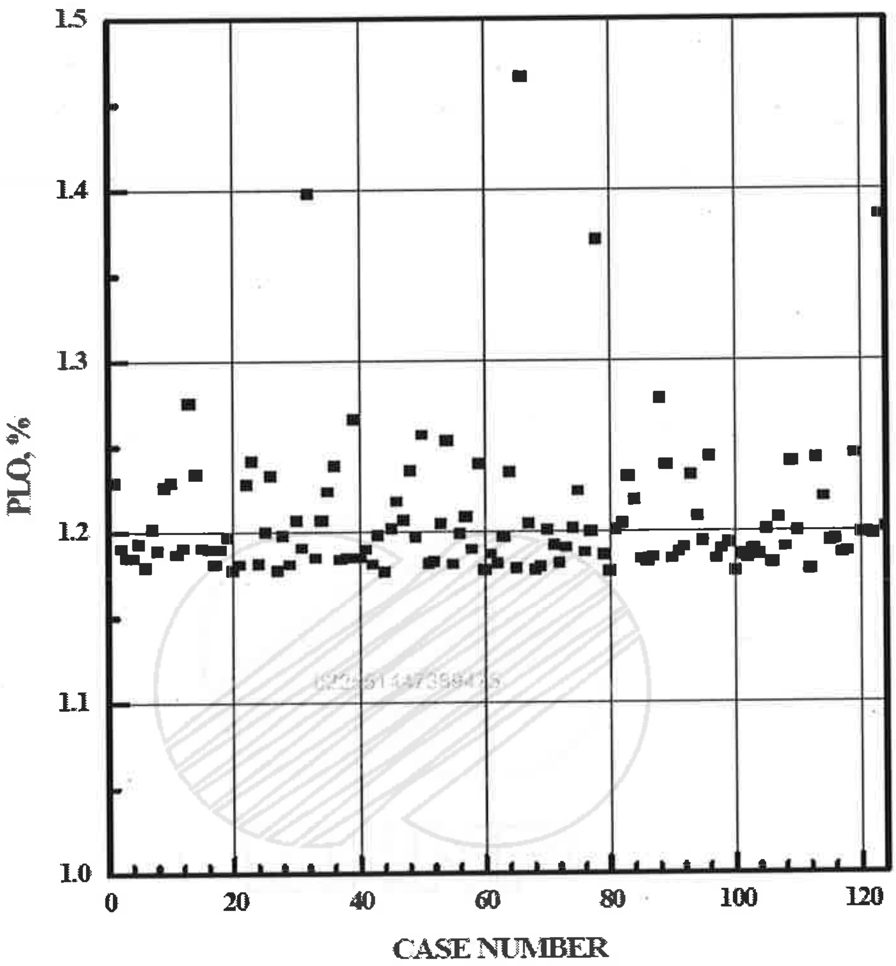
Hot Spot Clad Temperature from SRS Calculation

Figure 6.3-12



KOREA HYDRO & NUCLEAR POWER COMPANY
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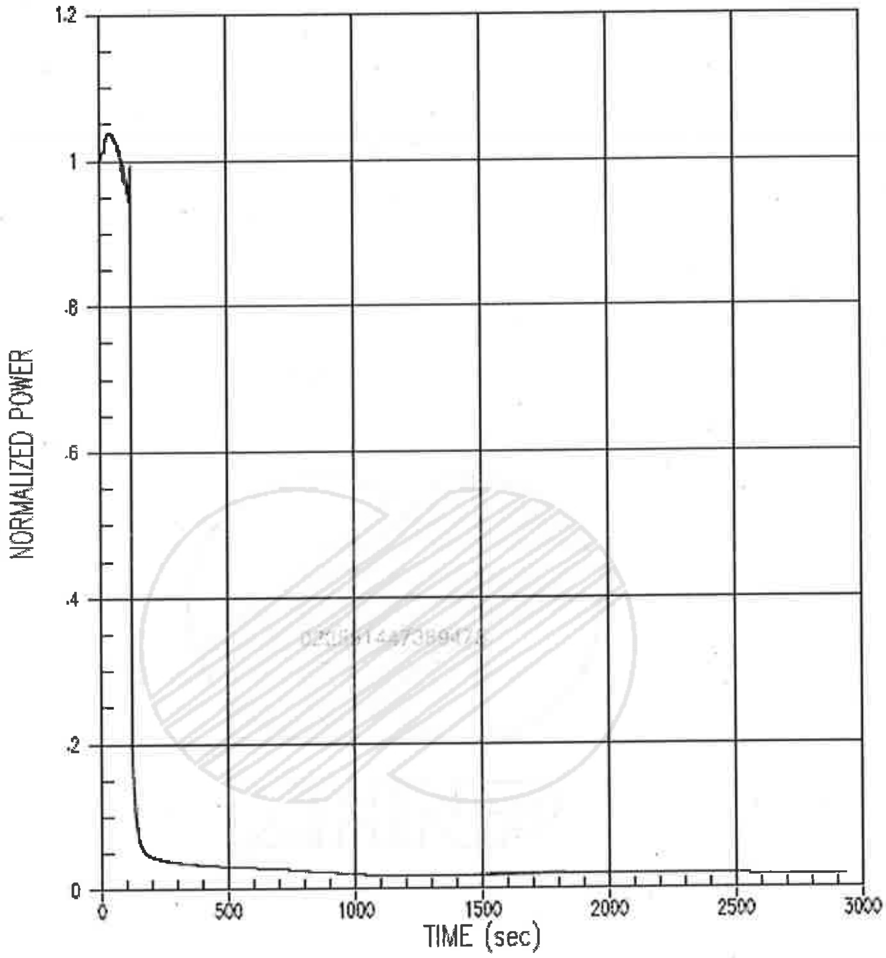
Peak Local Oxidation from SRS Calculation

Figure 6.3-13



KOREA HYDRO & NUCLEAR POWER COMPANY
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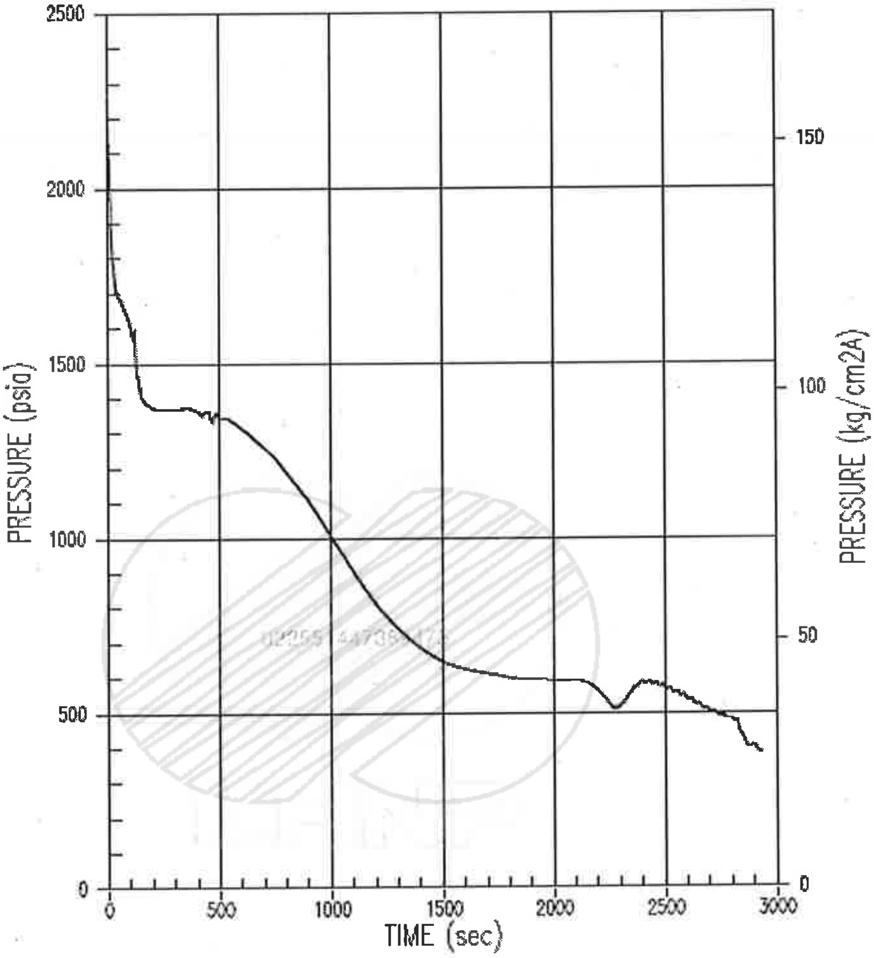
Normalized Core Power
0.05 ft^2 Break

Figure 6.3-14 (Sheet 1 of 7)



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YONGGWANG 3 & 4
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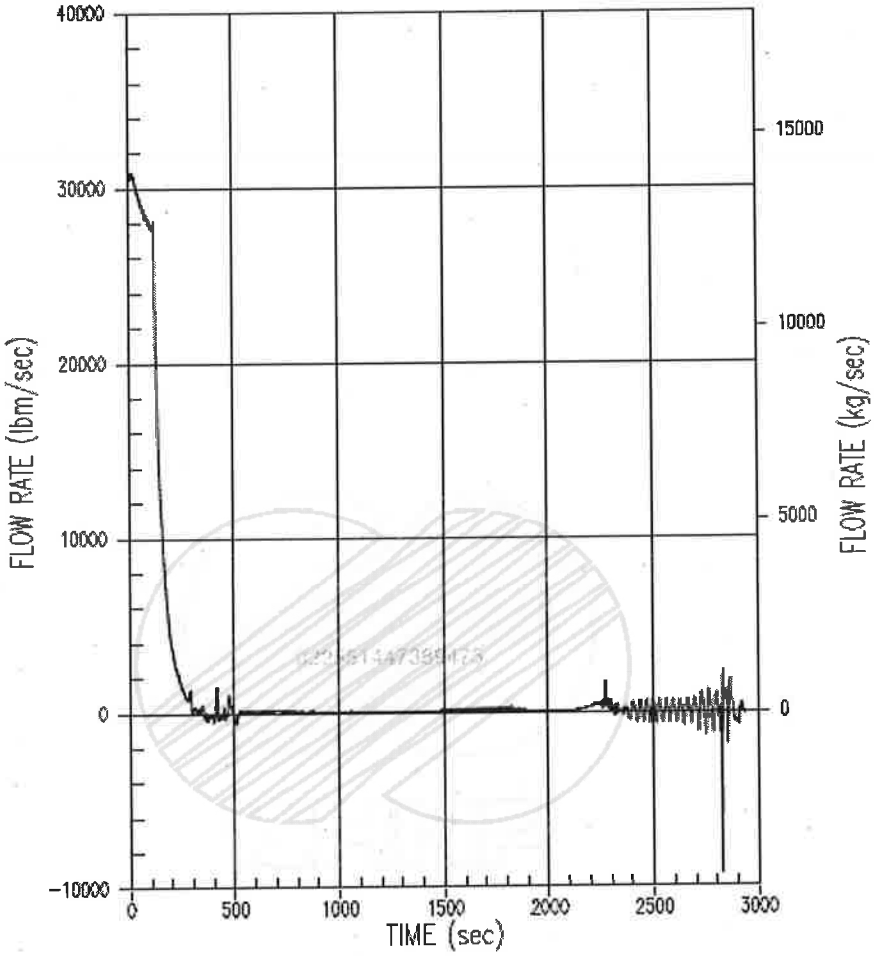
Core Pressure
0.05 ft^2 Break

Figure 6.3-14 (Sheet 2 of 7)



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YONGGWANG 3 & 4
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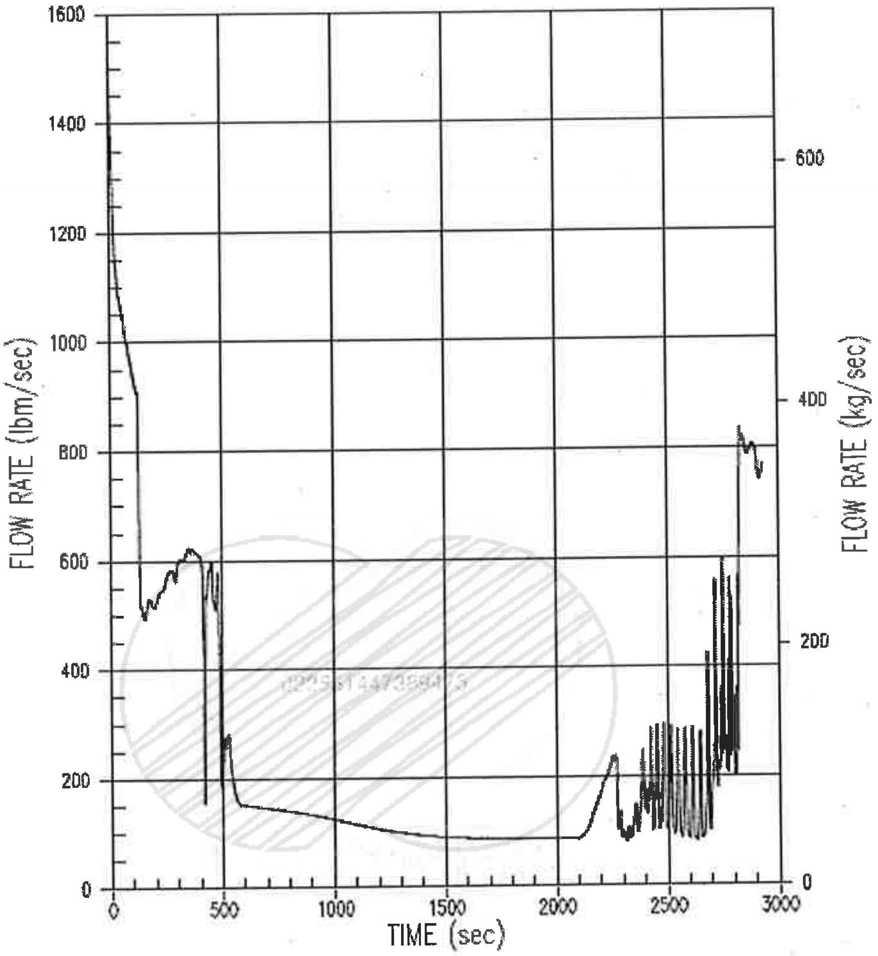
Core Inlet Flow Rate
0.05 ft^2 Break

Figure 6.3-14 (Sheet 3 of 7)



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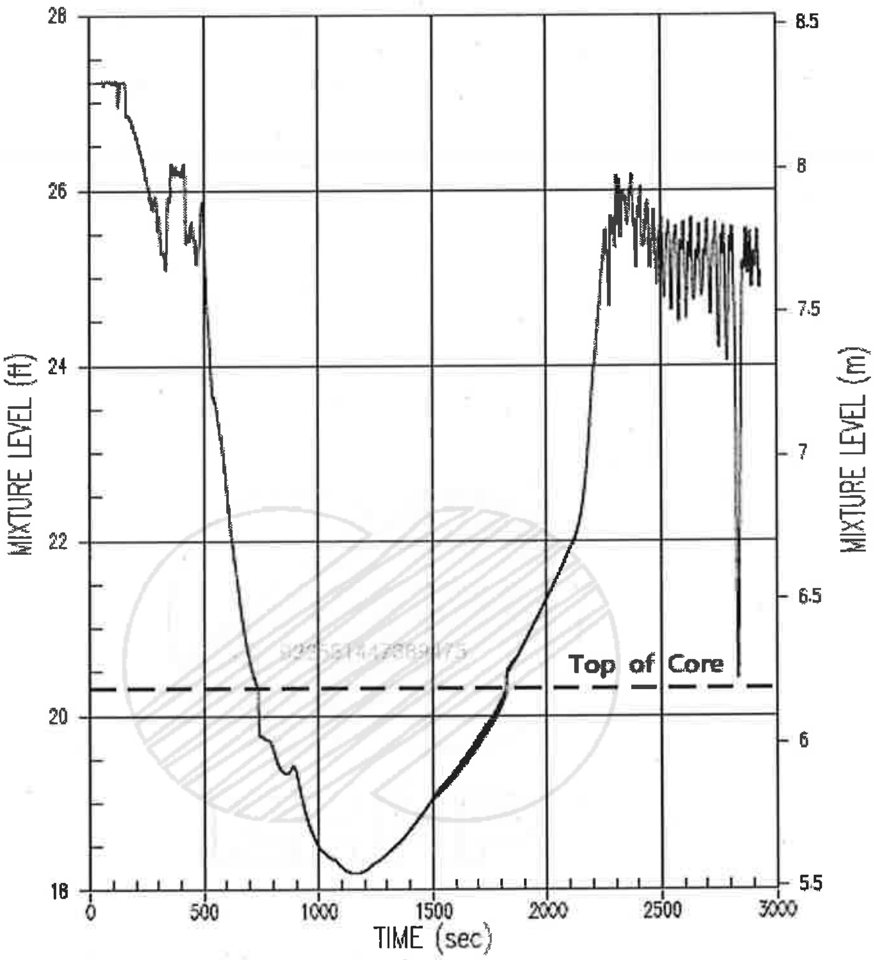
Break Flow Rate
0.05 ft^2 Break

Figure 6.3-14 (Sheet 4 of 7)



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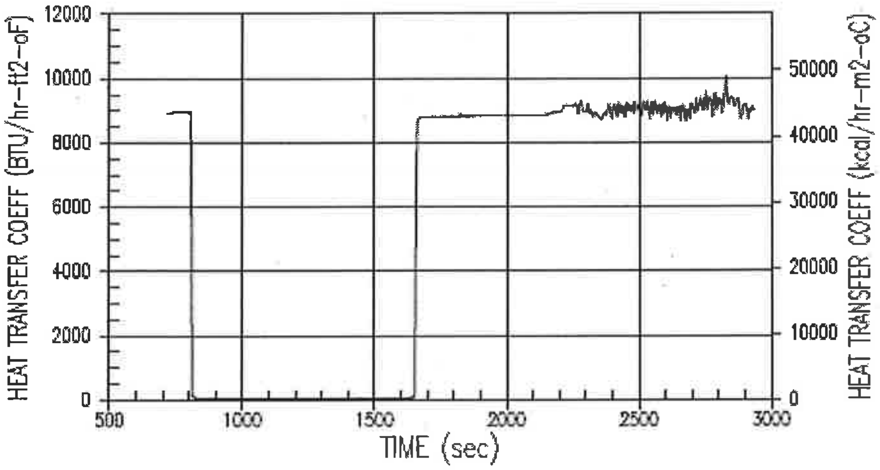
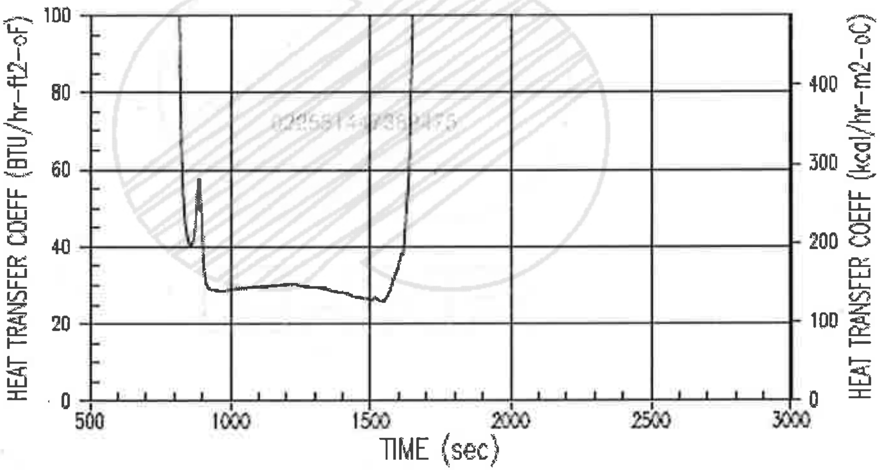
Core Two-Phase Mixture Level
0.05 ft^2 Break

Figure 6.3-14 (Sheet 5 of 7)





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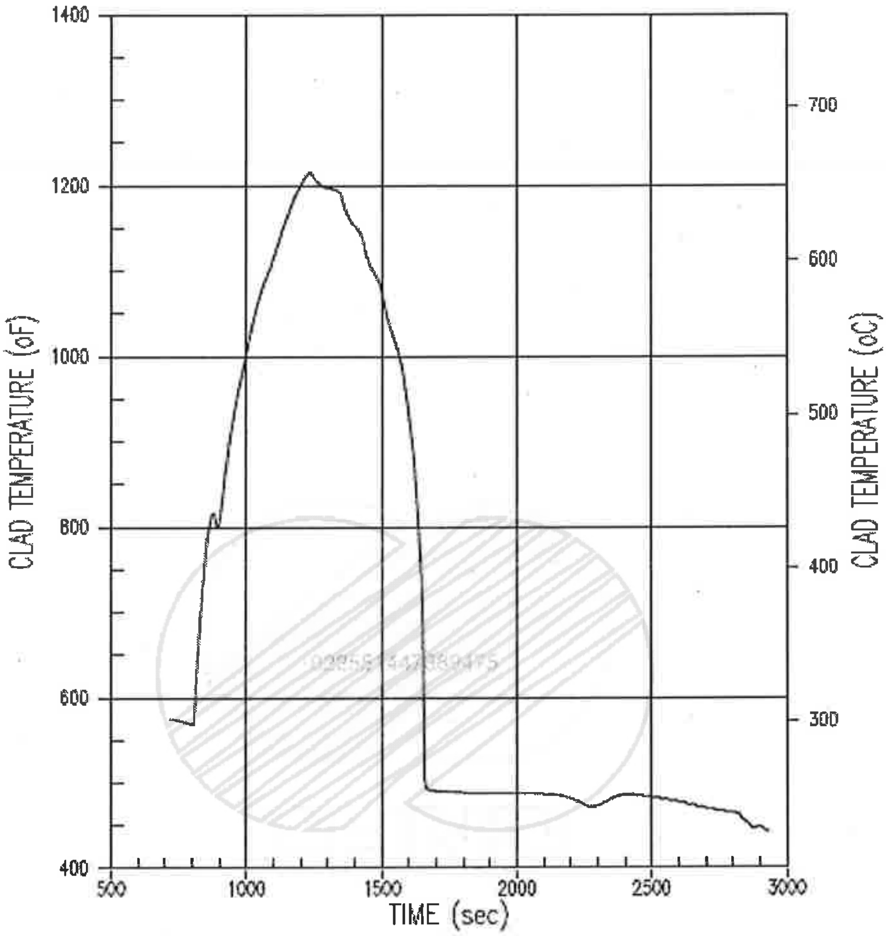
Hot Spot Heat Transfer Coefficient
0.05 ft^2 Break

Figure 6.3-14 (Sheet 6 of 7)



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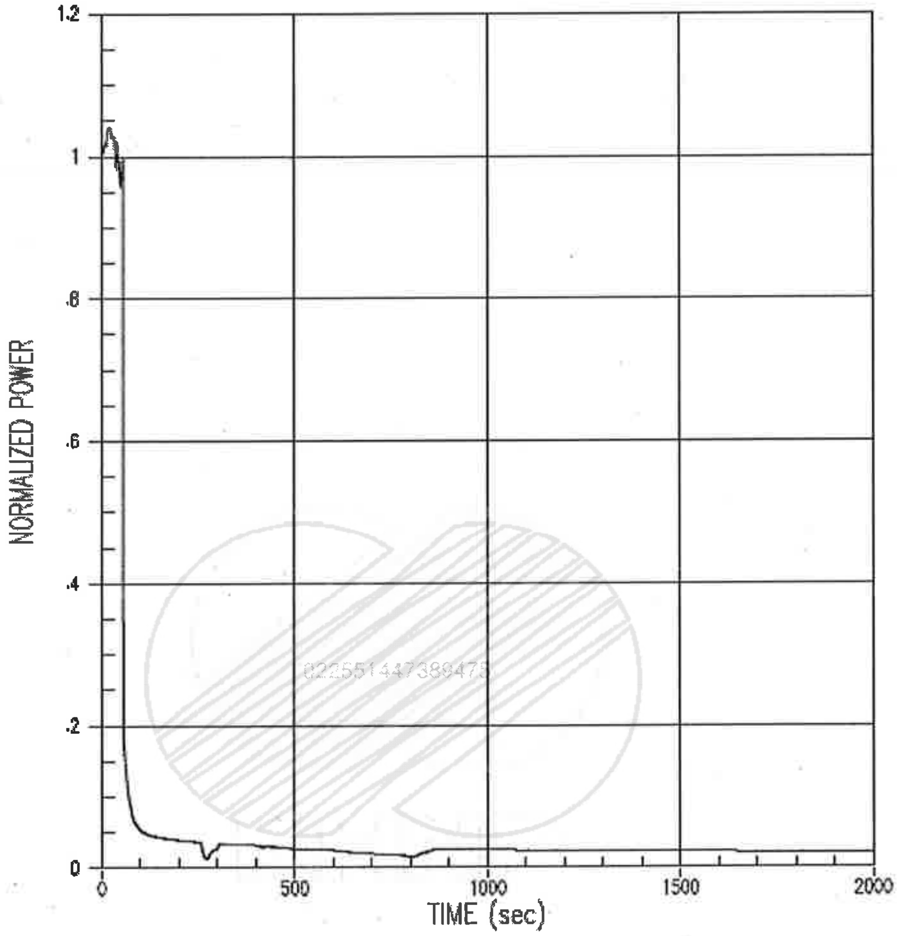
YONGGWANG 3 & 4
FSAR

Peak Cladding Temperature
0.05 ft^2 Break

Figure 6.3-14 (Sheet 7 of 7)



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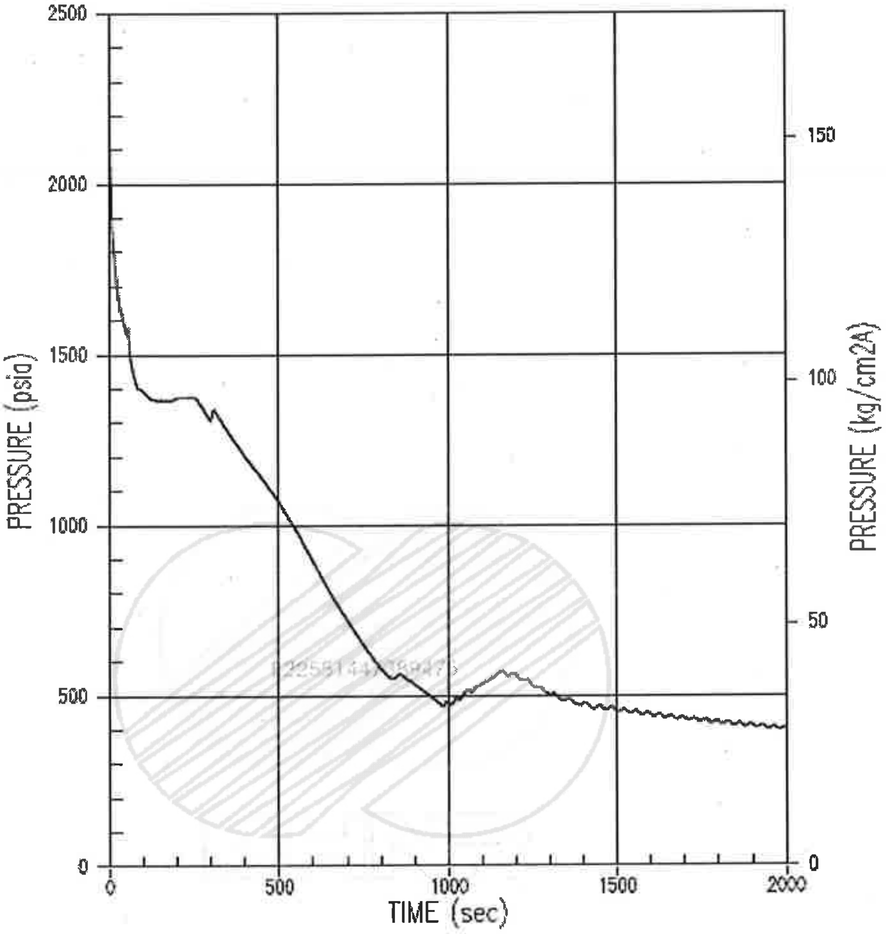
Normalized Core Power
0.087 ft^2 Break

Figure 6.3-15 (Sheet 1 of 7)



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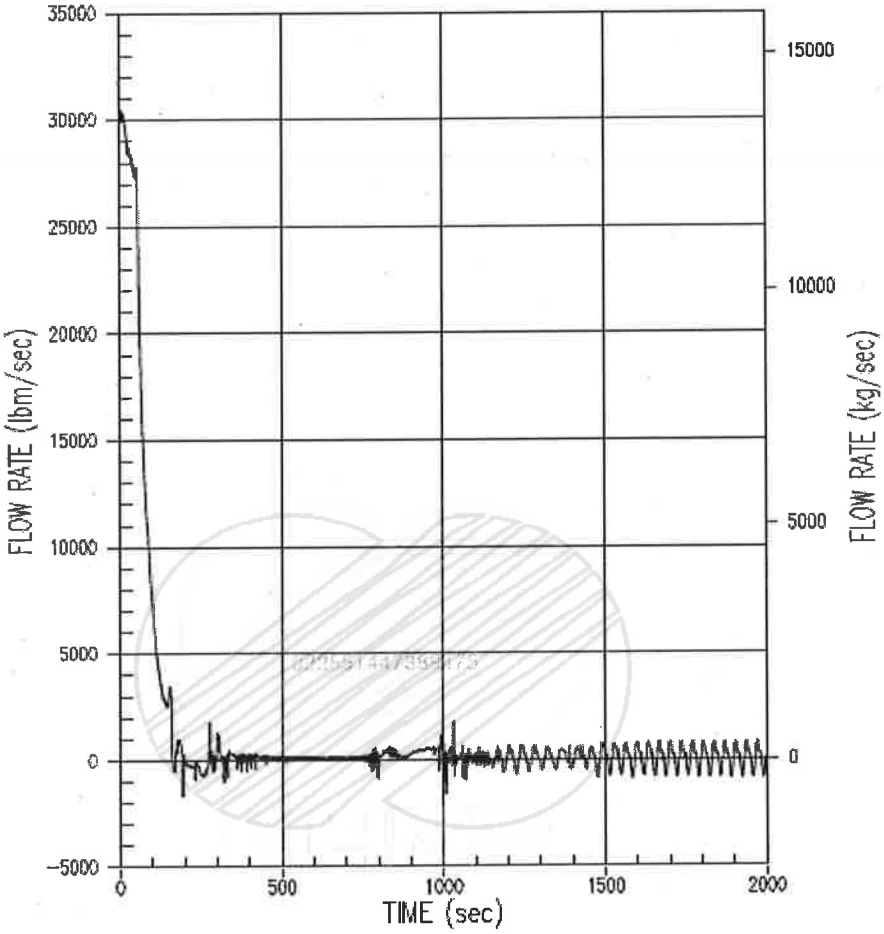
Core Pressure
0.087 ft^2 Break

Figure 6.3−15 (Sheet 2 of 7)



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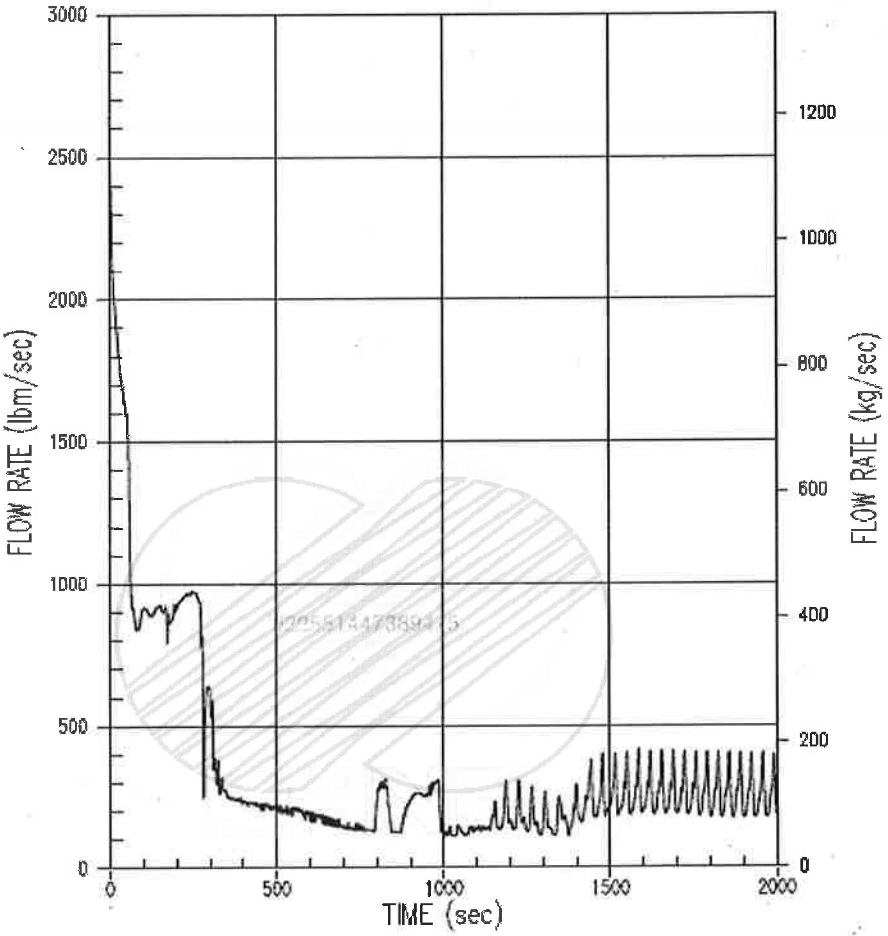
Core Inlet Flow Rate
0.087 ft^2 Break

Figure 6.3-15 (Sheet 3 of 7)



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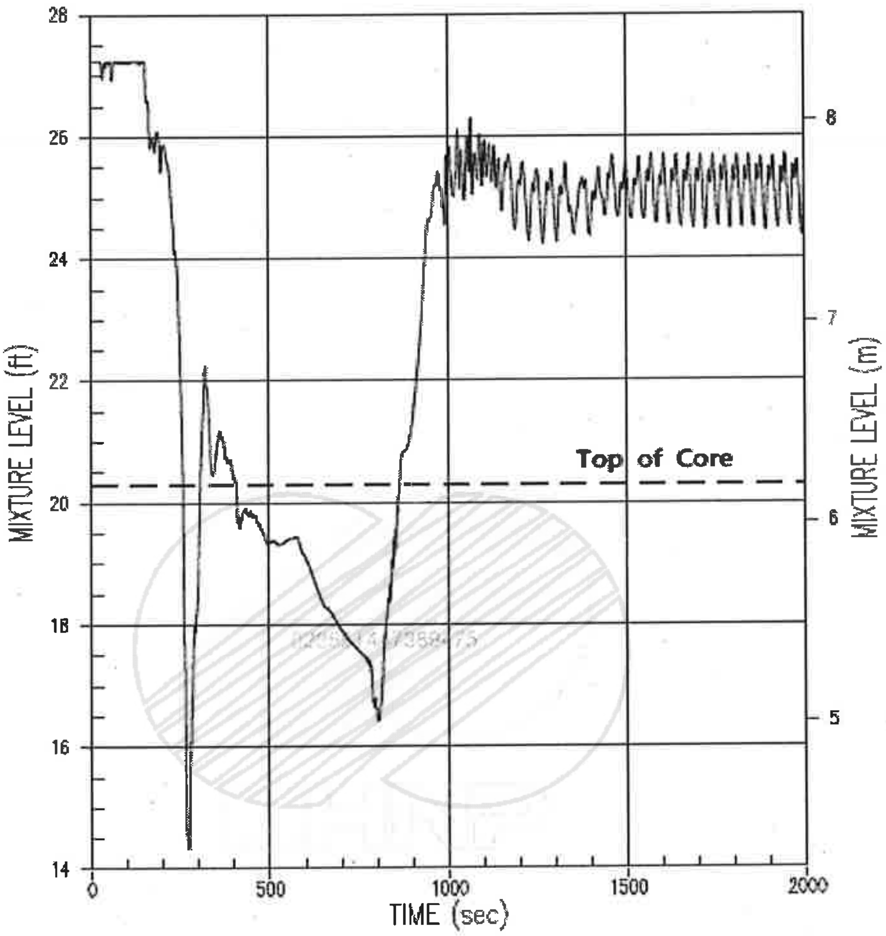
Break Flow Rate
0.087 ft^2 Break

Figure 6.3-15 (Sheet 4 of 7)



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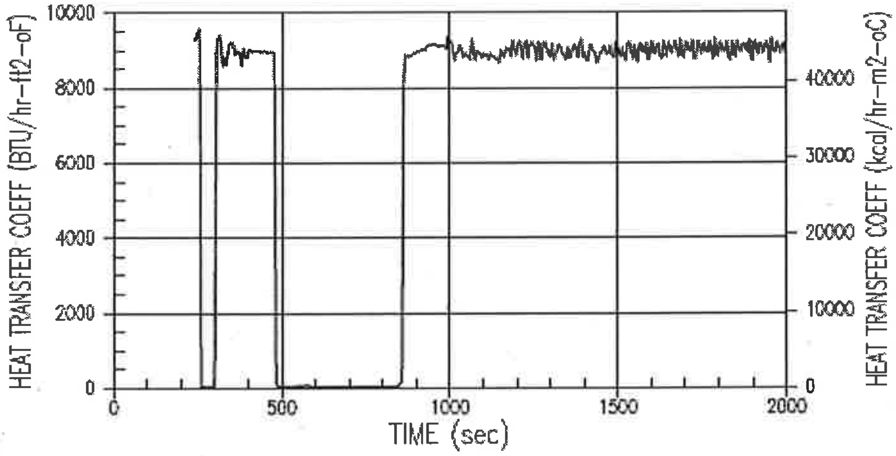
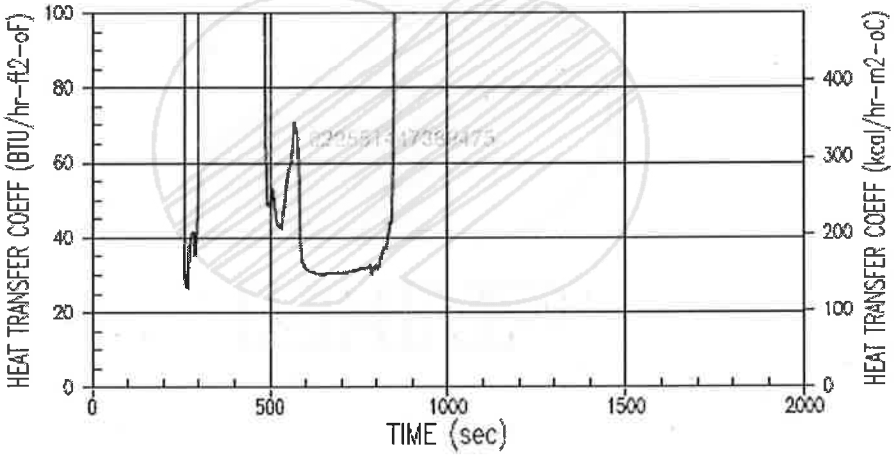
Core Two-Phase Mixture Level
0.087 ft^2 Break

Figure 6.3-15 (Sheet 5 of 7)





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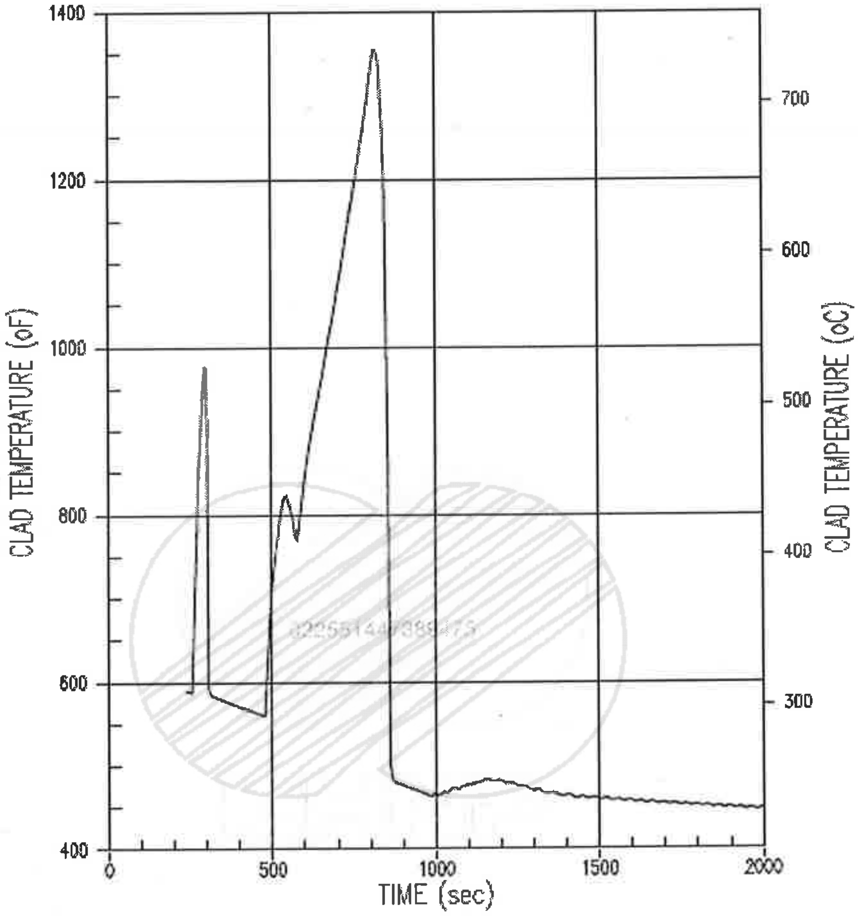
Hot Spot Heat Transfer Coefficient
0.087 ft^2 Break

Figure 6.3-15 (Sheet 6 of 7)



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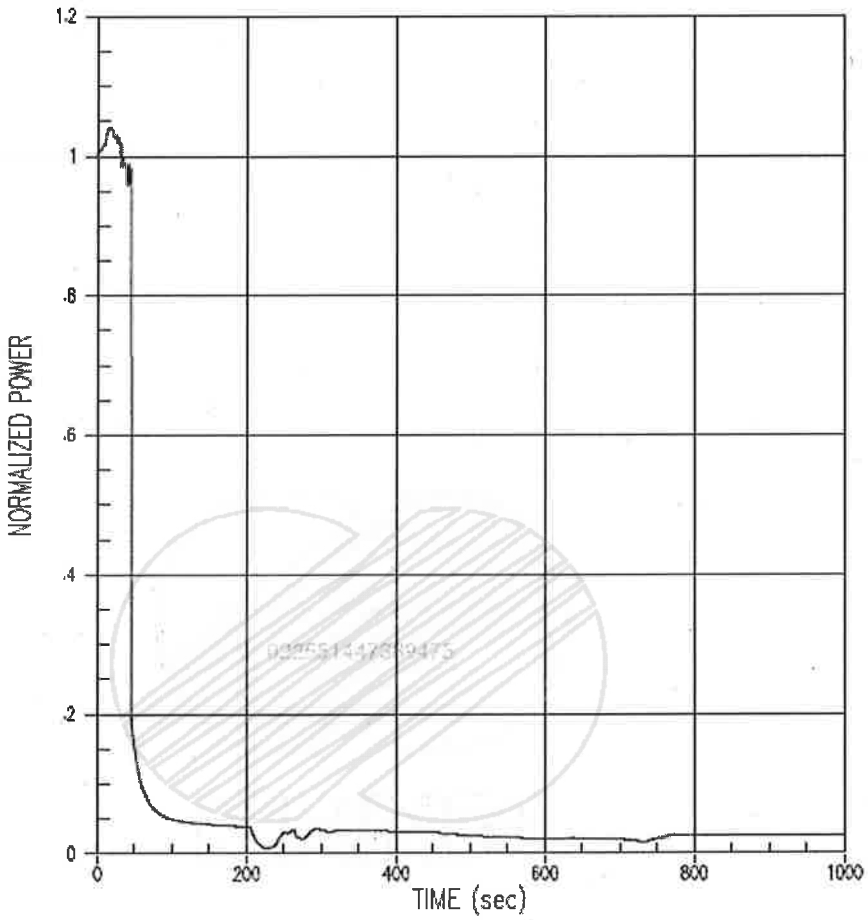
Peak Cladding Temperature
0.087 ft^2 Break

Figure 6.3-15 (Sheet 7 of 7)



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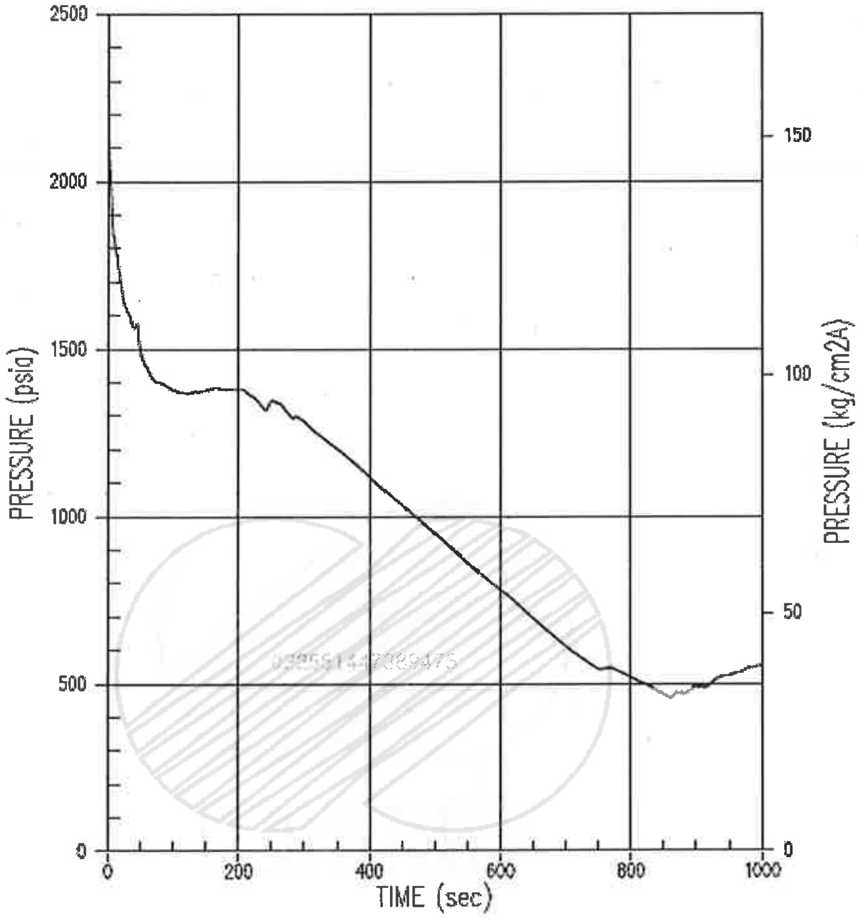
Normalized Core Power
0.1 ft^2 Break

Figure 6.3-16 (Sheet 1 of 7)



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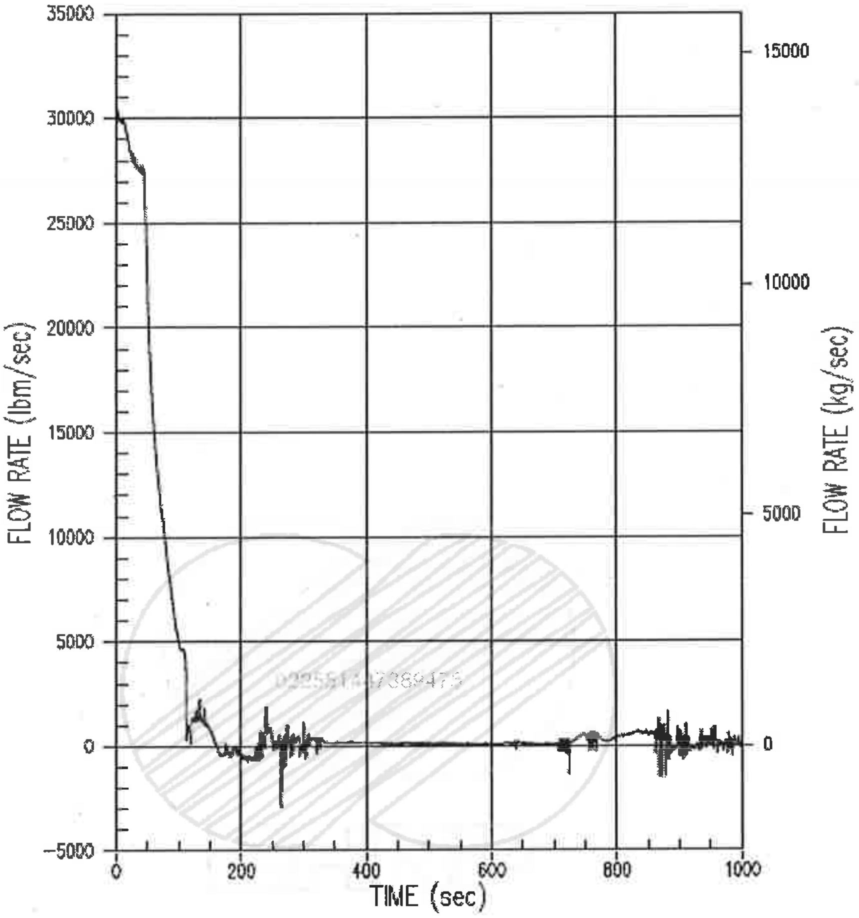
Core Pressure
0.1 ft^2 Break

Figure 6.3-16 (Sheet 2 of 7)



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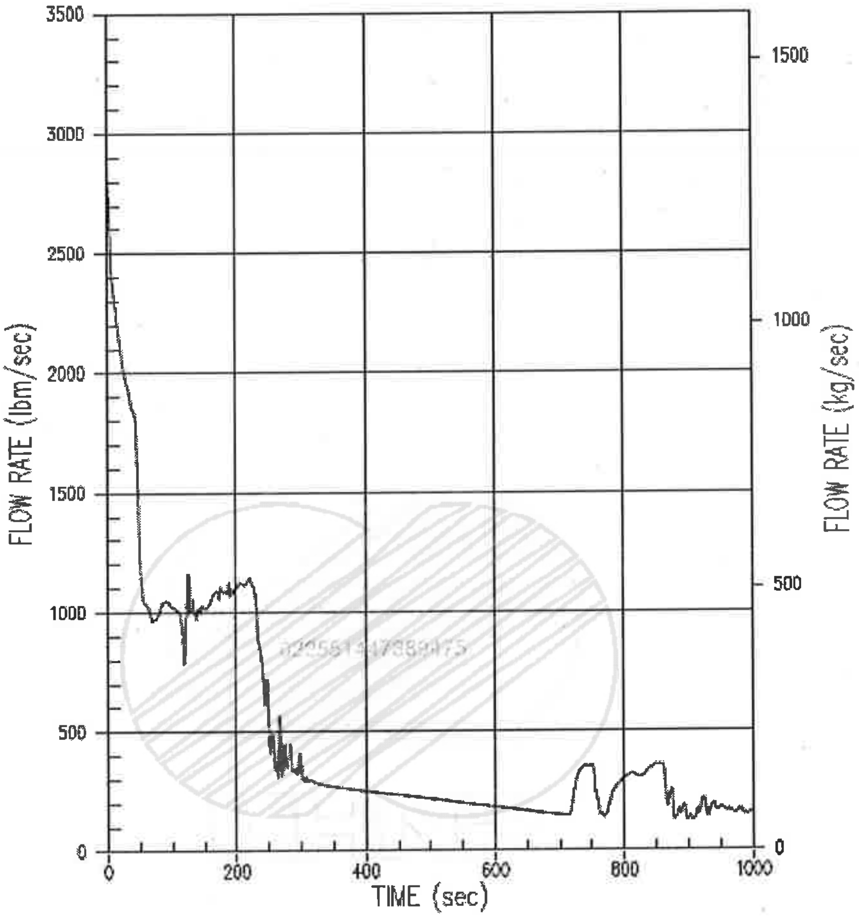
Core Inlet Flow Rate
0.1 ft^2 Break

Figure 6.3-16 (Sheet 3 of 7)



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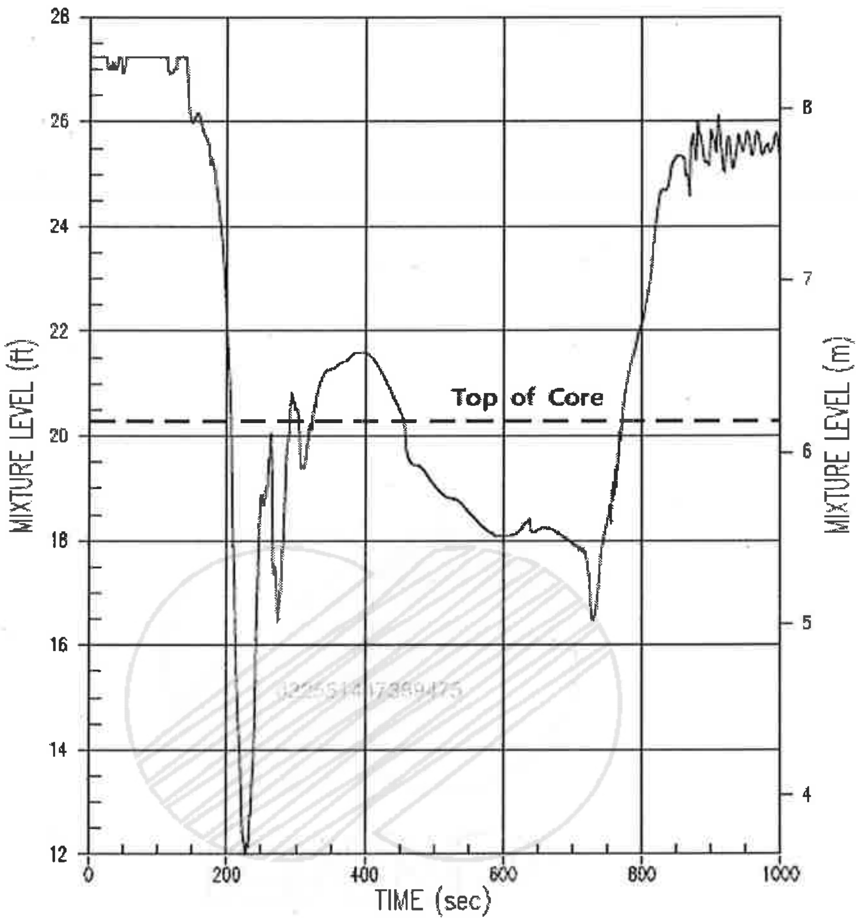
Break Flow Rate
0.1 ft^2 Break

Figure 6.3-16 (Sheet 4 of 7)



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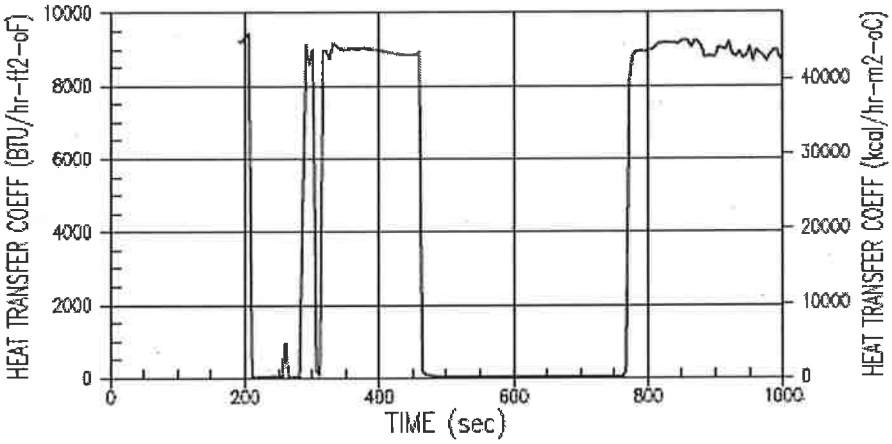
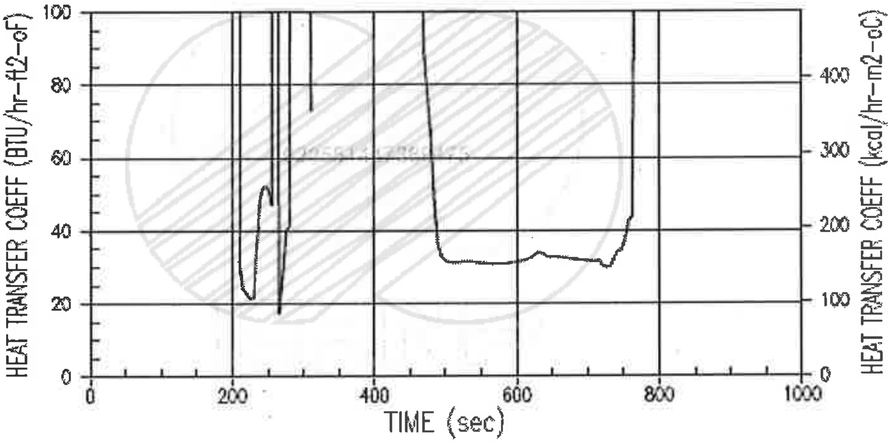
Core Two-Phase mixture Level
0.1 ft^2 Break

Figure 6.3-16 (Sheet 5 of 7)





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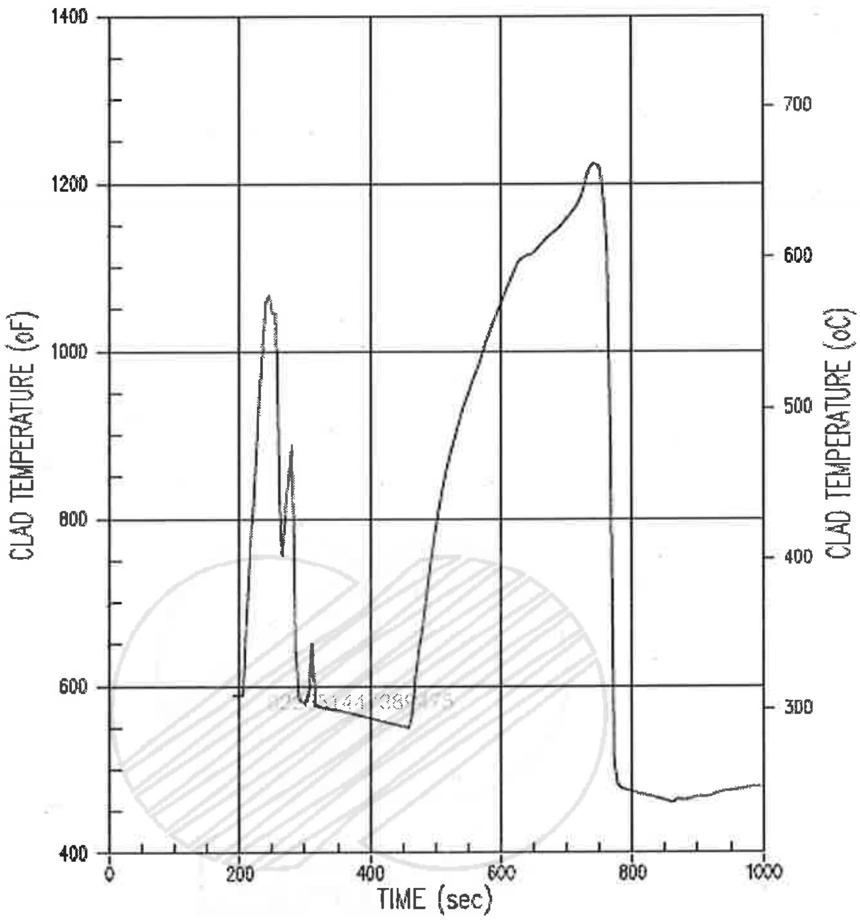
Hot Spot Heat Transfer Coefficient
0.1 ft^2 Break

Figure 6.3-16 (Sheet 6 of 7)



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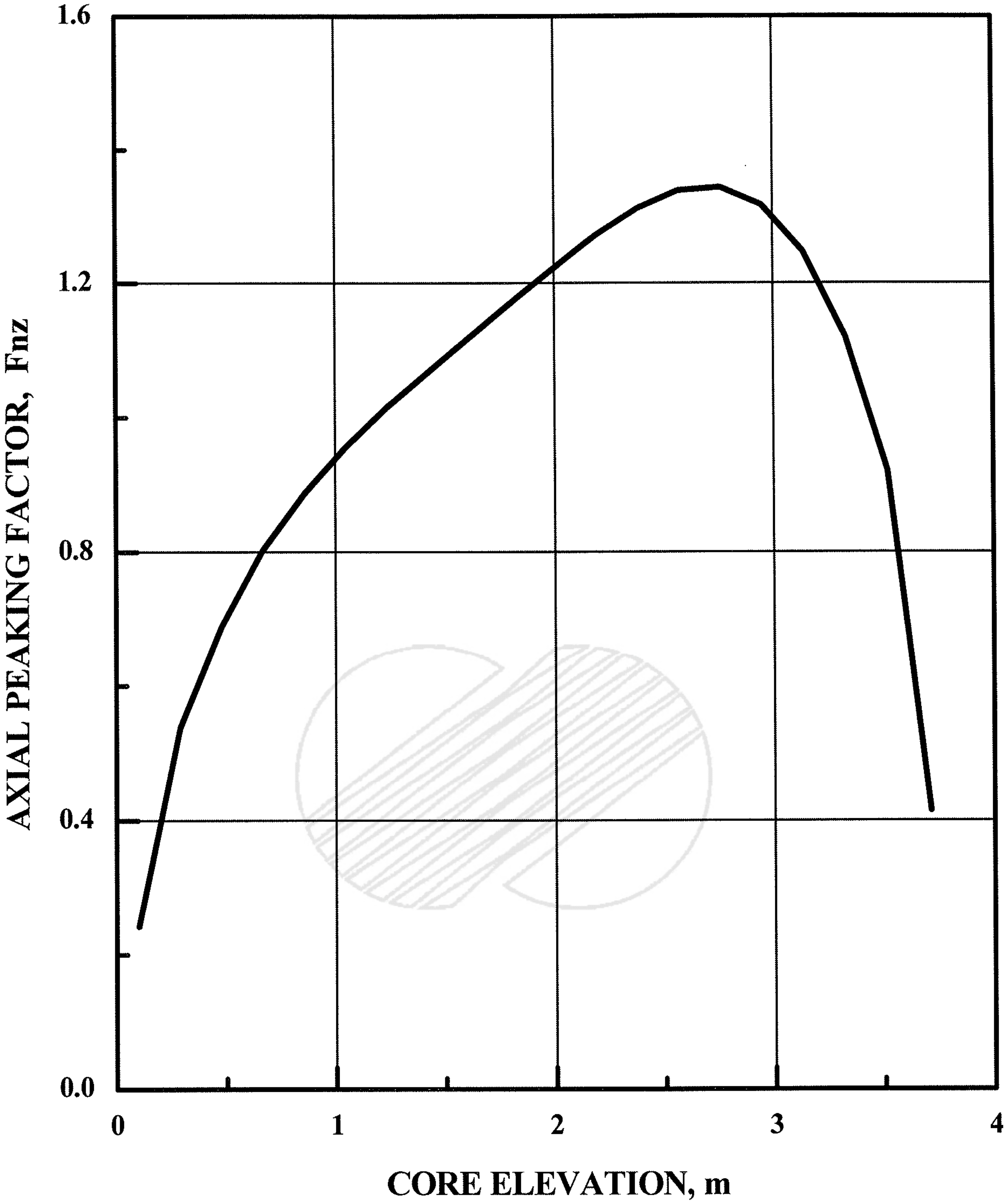
Peak Cladding Temperature
0.1 ft^2 Break

Figure 6.3-16 (Sheet 7 of 7)



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Axial Power Shape for Large Break LOCA

Figure 6.3-17

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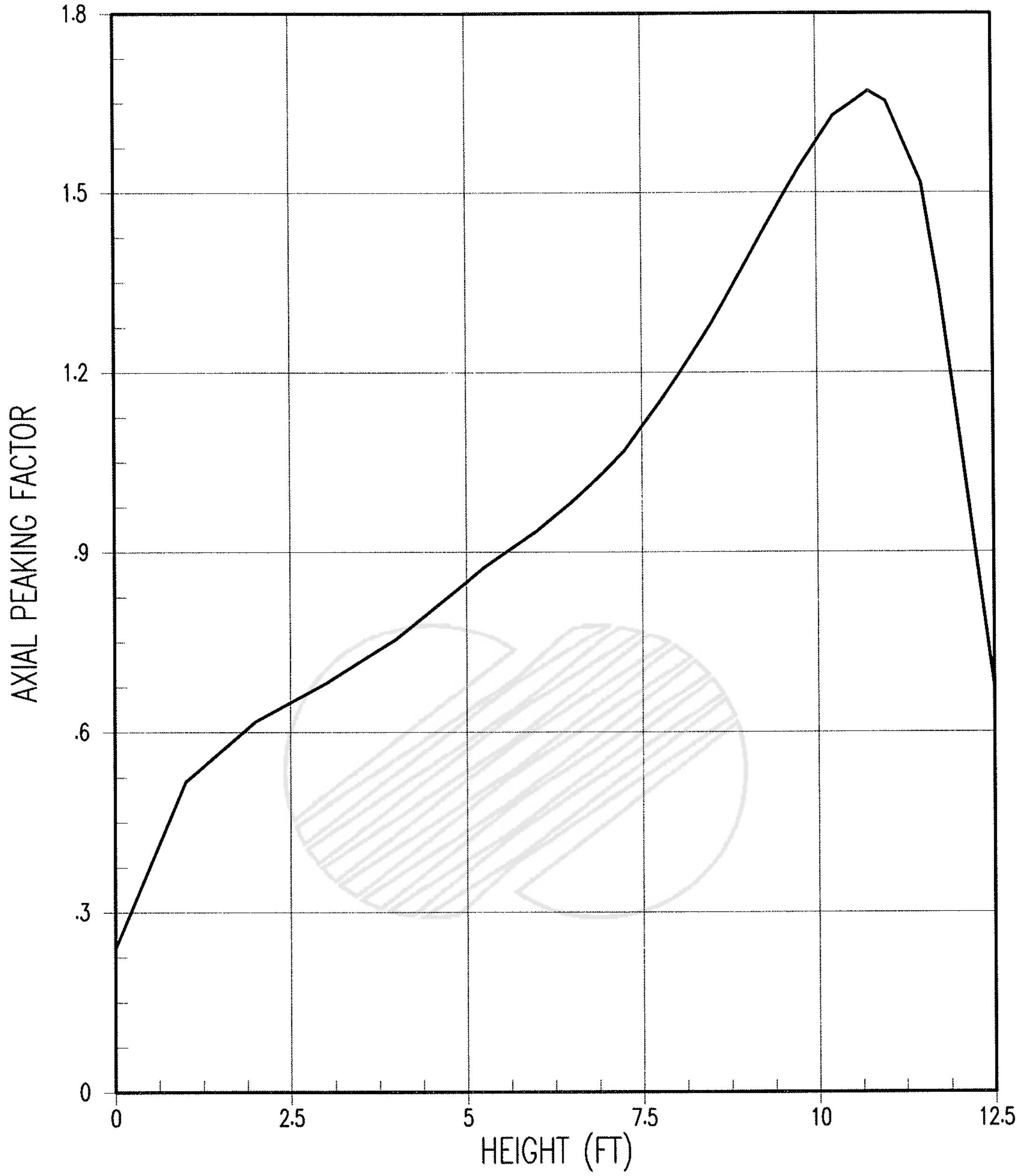

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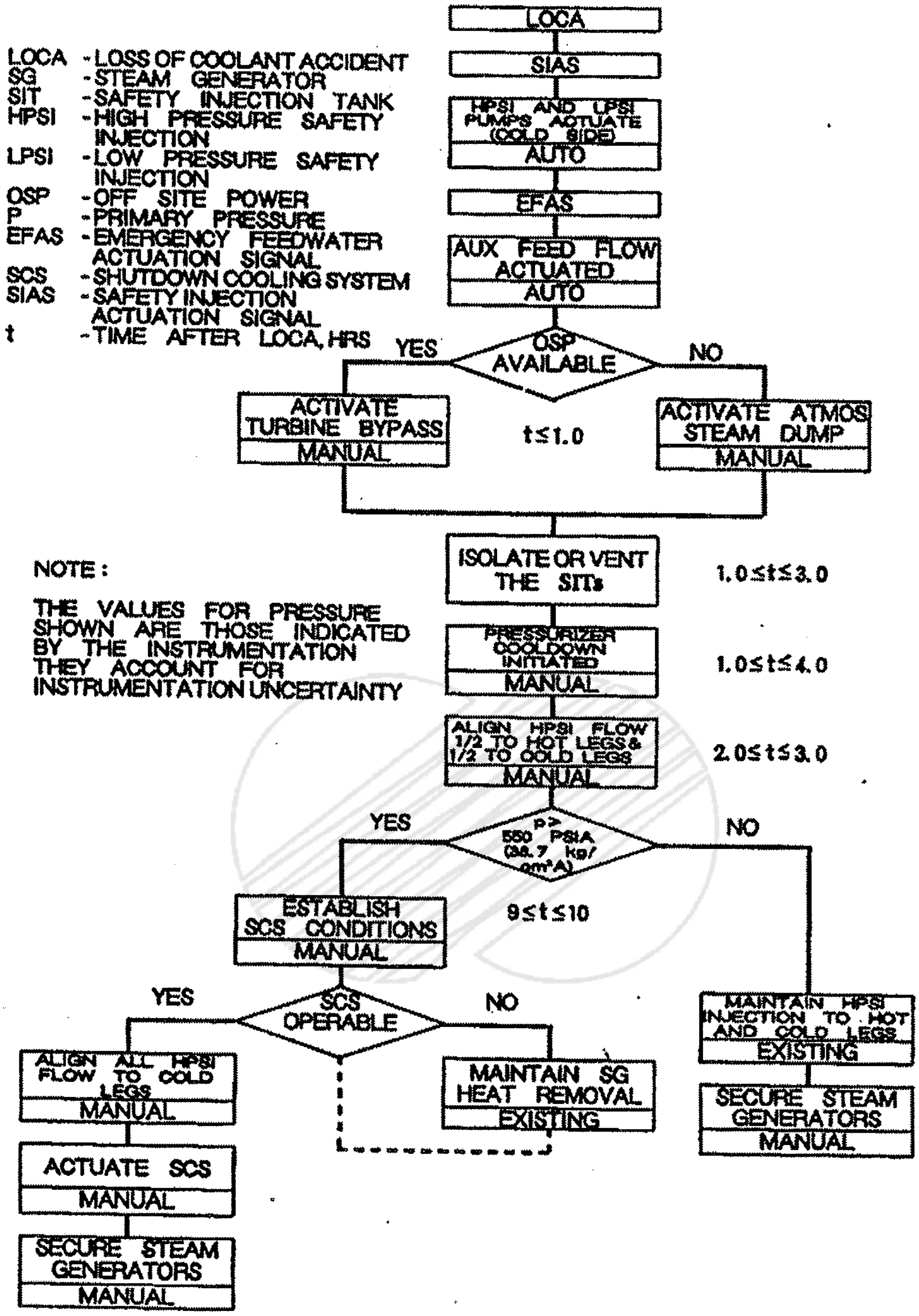
Axial Power Shape for Small Break LOCA

Figure 6.3-18



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LONG TERM COOLING PLAN

Figure 6.3-19

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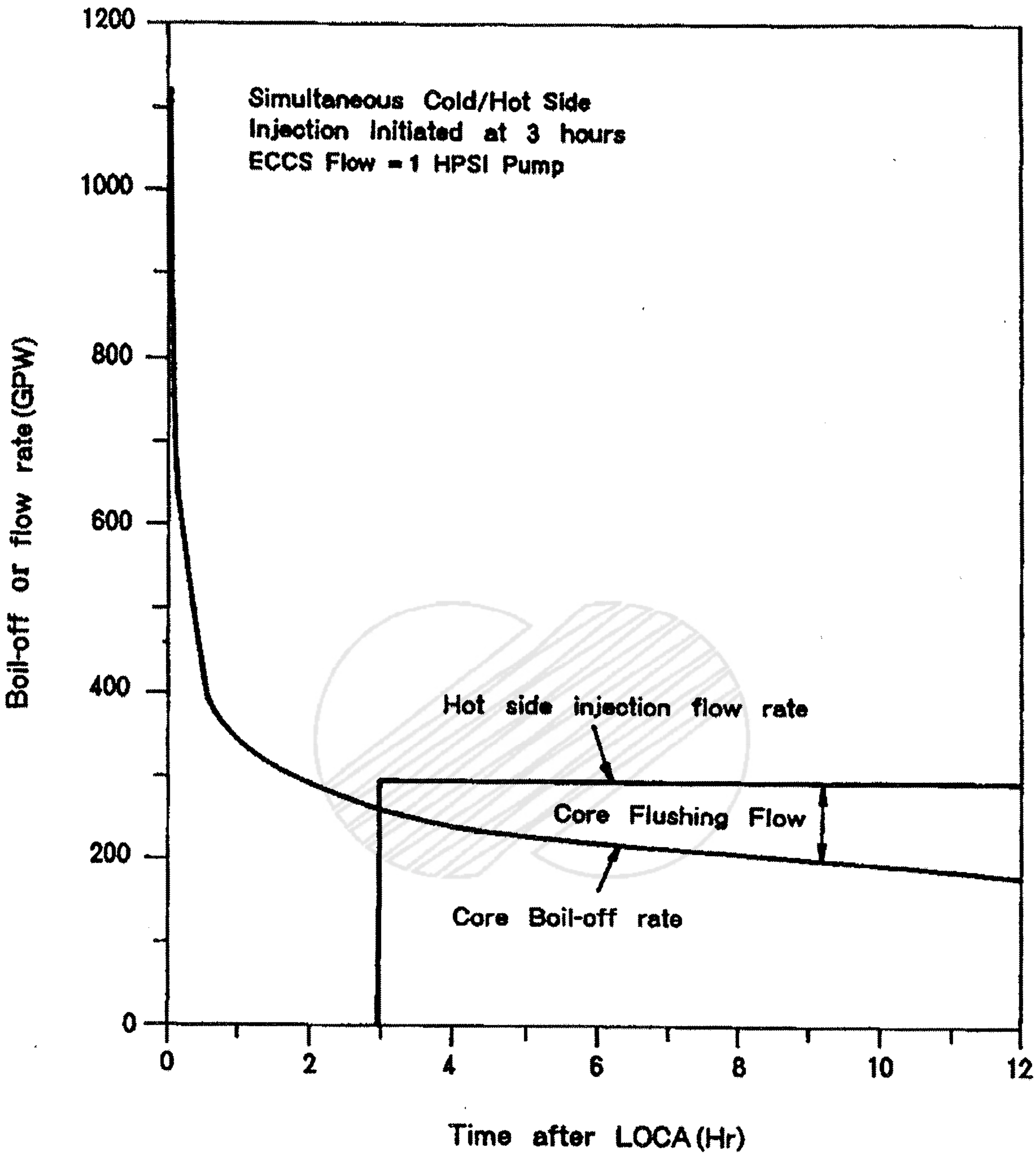

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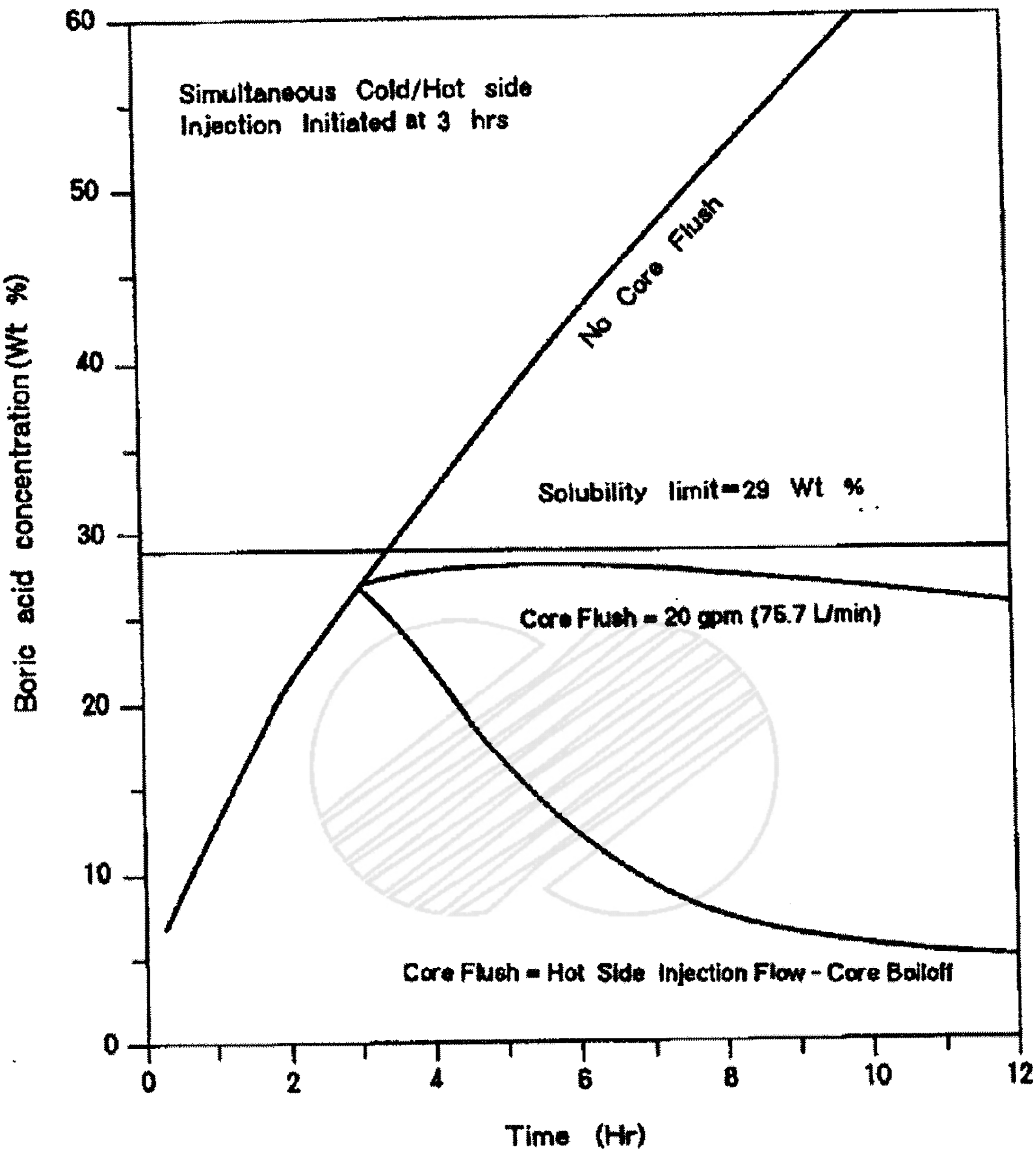
CORE FLUSH BY HOT SIDE
INJECTION FOR 9.8 ft^2 (9104 cm^2)
COLD LEG BREAK

Figure 6.3-20



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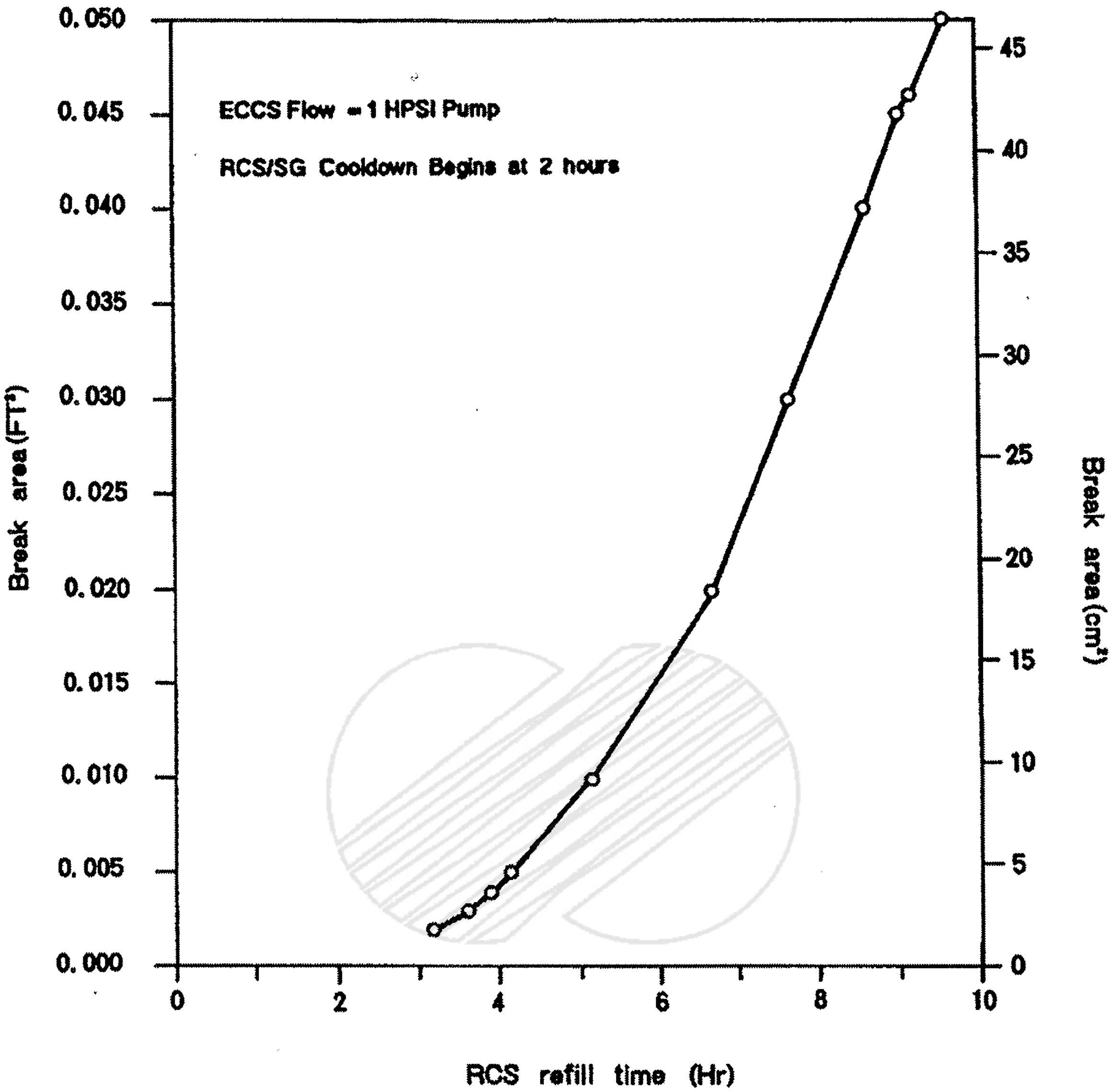
INNER VESSEL BORIC ACID CONCENTRATION VS. TIME

Figure 6.3-21



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RCS REFILL TIME VS. BREAK AREA

Figure 6.3-22

SIMULTANEOUS HOT LEG/ COLD LEG INJECTION COOLS CORE AND FLUSHES BORIC ACID FROM VESSEL

REFILL OF RCS DISPERSES BORIC ACID THROUGHOUT SYSTEM AND SG's ARE ABLE TO COOL RCS TO SDC TEMPERATURE.

BREAK SIZE		RCS PRESSURE AT 9 HRS	
(ft²)	(cm²)	(PSIA)	(kg/cm² A)
0.5	464.5	23.	1.6
0.35	325.2	25.	1.8
0.2	185.8	57.	4.0
0.05	46.5	61.	4.3
0.046	42.7	61.	4.3
0.045	41.8	74.	5.2
0.04	37.2	79.	5.5
0.03	27.9	94.	6.6
0.02	18.6	144.	10.1
0.01	9.3	349.	24.6
0.005	4.6	796.	56.0
0.004	3.7	971.	68.3
0.003	2.8	1146.	80.6
0.002	1.9	1333.	93.7

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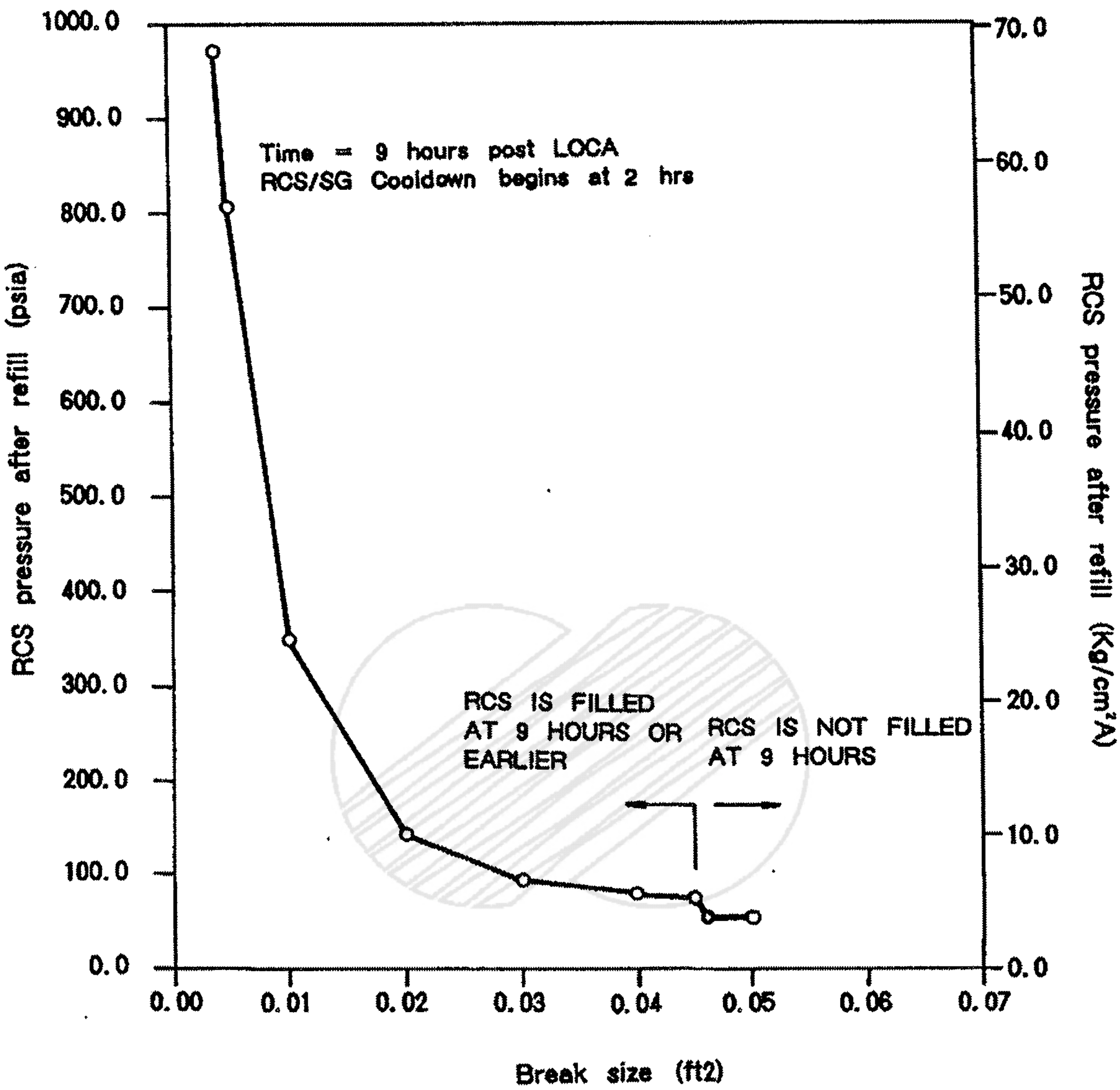
OVERLAP OF LTC MODES IN TERMS OF COLD LEG BREAK SIZE

Figure 6.3-23



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RCS PRESSURE AFTER REFILL
VS. BREAK AREA

Figure 6.3-24

6.4 HABITABILITY SYSTEMS

Habitability systems are designed to ensure that the main control room operator is adequately protected in the space served by the control room HVAC system against the effects of accidental releases of toxic and radioactive gases in compliance with Criterion 19 of 10 CFR 50, Appendix A. The control room habitability systems include the control room HVAC system with an emergency makeup air cleaning unit, shielding, radiation monitoring, smoke detection and removal capability. Adequate food, water storage, breathing air, sanitary facilities, and medical supplies are provided to meet the requirements of operating personnel during and after an incident. Habitability system for the TSC (technical support center) is described in Section 9.4.

6.4.1 Design Bases

The design bases of the habitability systems upon which the functional design is established are as follows:

a. The habitability systems are housed within a structure capable of withstanding the effects of natural phenomena, such as earthquakes, typhoons, and internal and external missiles.

b. The habitability systems are designed to support a minimum of five people within the control room envelope during all normal conditions and at least 30 days of accident operating conditions.

c. A minimum of 8 hours of food supplies are provided for the main control room staff during emergency, with additional food supplies onsite as needed. Unlimited water supply and onsite first aid are available.

d. Sanitary facilities are provided for the main control room operating personnel within the control room envelope.

e. Adequate self-contained breathing apparatus are available inside the control room envelope. Face mask respirators and 6-hour bottled air supplies are provided for the emergency staff.

f. The dose equivalent received by the main control room personnel does not exceed 5 rem whole-body or its equivalent to any part of the body for the duration of the accident in accordance with 10 CFR 50, Appendix A, General Design Criteria (GDC) 19. Refer also to Chapter 15.

g. The control room HVAC system supplys partially filtered recirculated air and emergency filtered makeup air for control room envelope pressurization, using dual inlet design with manual selection of the intakes.

h. The control room HVAC system is designed to maintain the main control room at ambient conditions provided in Section 3.11. Redundant trains of HVAC equipment are provided. Detailed design bases relative to the control room HVAC system are discussed in Subsection 9.4.1.

i. An analysis has determined that the toxic gas concentration at the control room intake is in accordance with Regulatory Guide 1.78. Toxic gas sources originating from both inside and outside the plant were considered (See discussion in Subsection 6.4.3.3). As described in Subsection 6.4.4.2, use of a sodium hypochlorite biocide system eliminates the potential for an onsite chlorine hazard.

j. The control room HVAC system is designed to operate effectively both during and after a design-basis accident (DBA), such as a loss-of-coolant accident (LOCA), with a simultaneous loss-of-offsite power and a safe shutdown earthquake (SSE). A single failure to any one of the system components is considered simultaneously with the DBA.

k. Radiation monitors and smoke detectors located in the outside air intakes, will continuously monitor the control room HVAC system outside air. Area radiation monitors are provided in the main control room. Smoke detectors are provided in the supply and the return air ductwork from the control room envelope. Detection of high radiation or products of combustion is alarmed in the main control room and related protection functions are automatically initiated for radiation and manually for smoke detection by operator. 1

6.4.2 System Design

6.4.2.1 Definition of Control Room Envelope

The control room envelope consists of the main control room, HVAC equipment rooms, toilet, kitchen, office, control room office, computer room, and electrical equipment rooms.

6.4.2.2 Ventilation System Design

The control room HVAC system is described in detail in Subsection 9.4.1 and shown in Figure 9.4-1. Table 9.4-1 lists the major components in the control room HVAC system. The safety and seismic classification of various components of the control room HVAC system is provided in Section 3.2.

All system components are protected from internally and externally generated missile.

A layout of the control room envelope showing doors, corridors, stairwells, and shielded walls, and the placement and type of equipment is given in Figure 6.4-1.

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The description of controls and instrumentation for the control room HVAC system, including smoke detectors and radiation monitors, is included in Subsection 6.4.6 and Section 7.3.

A detailed description of the control room HVAC system makeup air cleaning unit is presented in Subsection 6.5.1.

6.4.2.3 Leaktightness

The control room envelope is designed for low-leakage construction. All conduits, cable trays, and penetrations are sealed. All entrances used for normal access to the control room envelope are provided with airlocks. All isolation dampers are designed for fast closure and tight shutoff. The outside air supply of 4000 cfm (113.3 m^3/min) is introduced in the control room envelope to maintain approximately 0.125 in. (3.2 mm) W.G. positive pressure with respect to the surrounding areas in addition to providing makeup air for the toilet exhaust. During isolation of the control room as a result of the presence of toxic gases or smoke outside, the makeup air and the kitchen and toilet exhaust air dampers are closed manually. The toilet and kitchen exhaust fans, if operating, will be stopped manually or automatically. 305

6.4.2.4 Interaction with Other Zones and Pressure-Containing Equipment

The control room HVAC system serves only rooms in the main control room envelope. Air from the toilets and kitchen rooms is exhausted to the diesel-generator room exhaust shaft. Low-leakage isolation dampers are provided for the exhaust from the toilets and the kitchen.

The primary auxiliary building and secondary auxiliary building areas adjacent to the main control room envelope are at negative pressure with respect to the control room envelope pressures at all times, except during accident conditions when the secondary auxiliary building may be at ambient pressure.

Normal access paths between the main control room envelope and surrounding areas are airlocked (two doors in series) to minimize system interaction. Single doors (e.g., to stairwells) are administratively controlled.

6.4.2.4.1 High Energy Lines

The main steam and feedwater lines are routed between containment and the turbine building through the main steam enclosures which are located at el. 165′- 0" along the outer edges of the primary auxiliary building. Due to the physical arrangement of the plant, portions of the main steam enclosures (room numbers 165-P04A/B) are directly above portions of the control room pressure boundary (the electrical equipment rooms 144-P02A/B). In order to assure control room habitability for postulated high energy line break (HELB) of the main steam or feedwater lines routed in the main steam enclosures, the following features have been included in the design:

a. The floor slabs of the main steam enclosures are heavily reinforced concrete slabs which are 4′-6" thick (including 6" fill slab).

b. The floor slabs are fully designed to accommodate the dynamic effects (pipe whip impact and jet impingement loading) of postulated MS and FW HELBs for the worst location and break orientation.

c. The floor slab design criteria for HELB impact and loading do not permit overstress, perforation, or spallation of concrete ensuring that the slab will remain both globally and locally intact, thus preventing intrusion of water or steam into the control room spaces.

d. The full length of the main steam enclosure floor slab incorporates a protected waterproof membrane located between the base and fill slabs, providing additional assurance that intrusion of water or steam into the control room spaces below is not possible.

The dynamic pipe break effects of postulated MS and FW HELB are greater than those for other high energy lines routed in the main steam enclosures. Due to the physical arrangement of the plant, there are no other high energy piping systems for which postulated HELB could jeopardize control room habitability.

6.4.2.4.2 Pressurized Tanks

The CO_2 storage bottles supplying the control room underfloor manual suppression system (refer to Subsection 6.4.3.3) are located in the access corridor outside the control room envelope (el. 144'-0", column-row 13/AA). Thus, rupture of a bottle would not impact control room habitability. Portable dry chemical fire extinguishers are located within the control room envelope (refer to Appendix 9.5A). Inadvertent discharge of an extinguisher would not impact control room habitability.

There are no other pressurized tanks that could, upon failure, transfer hazardous material to the control room envelope.

6.4.2.5 Shielding Design

The design-basis accident for the main control room area shielding is the large break LOCA inside the containment. The control room shielding is designed to reduce the radiation doses to control room personnel from all potential accident sources to below the limits specified in General Design Criterion 19 of 10 CFR 50, Appendix A.

6.4.3 System Operation Procedures

6.4.3.1 Normal Operation Conditions

The control room HVAC supply and return systems are in operation. These systems are started by control switches located in the main control room.

6.4.3.2 High Radiation Detection Conditions

On detection of high radiation in one of the two outside air intakes, a CREVAS (control room emergency ventilation actuation system) signal is generated which automatically starts the associated emergency makeup cleaning unit. This removes the radioactive iodine and particulates from the makeup air supply to the control room HVAC system. Monitors and a dual inlet design are used to enhance the main control room operator's ability to select a "clean air" inlet to provide makeup air required for pressurization through the emergency makeup air cleaning system.

6.4.3.3 Toxic Gas Detection Condition

As discussed in Subsection 6.4.1 (Item i), an analysis was performed in accordance with Regulatory Guide 1.78 for main control room habitability. The chemicals stored at various locations of the station, including chemical storage areas, the chemical handling room, and the auxiliary boiler building, were evaluated.

The results of the analysis indicate that ammonium hydroxide is the only chemical that could reach toxic concentrations in the main control room after an accidental release. The sources are the above ground ammonium hydroxide tanks, located adjacent to the YGN 1&2 turbine buildings. The YGN 3&4 ammonium hydroxide storage tanks were buried to eliminate the addition of a new hazard source.

In the event of an accidental release from YGN 1&2, the control room occupants would be aware of the presence of ammonia by its odor [mode of detection (human nose) in accordance with R.G. 1.78] before toxic concentrations would occur. Provisions are made 1) to allow manual isolation of the control room HVAC outside air intakes and operation of the system at 100% recirculation mode, and 2) to provide an adequate supply of bottled air in the main control room. Ammonia detectors at the control room intake are not installed for the following reasons:

(1) Chemical concentrations will continue to increase, due to infiltration, even after the control room HVAC system is placed in recirculation mode. Breathing apparatus and a breathing air supply are provided to protect the operators from toxic concentrations. The installation of ammonia detectors will not improve the plant's capability to protect the operators or eliminate the need for the breathing air system. Reliance on human detection will provide the same level of protection.

(2) The potential for spurious alarm signals is high, based on experience at U.S. plants.

A manually actuated CO_2 fire suppression system is provided for the main control room underfloor area. A pre-discharge time delay, audio and visual alarms, and an abort switch are provided for personnel safety. In addition, an odorizer is provided in the CO_2 supply to alert personnel that a system discharge has occurred.

6.4.3.4 Smoke Detection Condition

Smoke detectors are provided in both the outside makeup air intakes and the control room supply and return air ducts. Upon detection of smoke in the outside makeup air intake, similar action will be taken to isolate the control room as was taken in the toxic gas detection condition.

On detection of smoke in any fire area of the control room envelope, smoke is removed by the smoke removal system fan.

6.4.4 Safety Evaluation

The control room HVAC system is designed to maintain a habitable environment compatible with the prolonged service life of safety-related components in the control room envelope under all of the station operating conditions except during fire, when it may not be habitable. During fire, controls for safe shutdown are carried out from the remote shutdown panel. The system is provided with redundant equipment trains to ensure meeting the single failure criteria. The equipment trains are powered from redundant nuclear safety-related buses and will be operable during loss-of-offsite power. All the control room HVAC system equipment (except for certain non-essential electric duct heaters and steam humidifiers, and the toilet and kitchen exhaust system) and surrounding structures are designed as seismic Category I.

6.4.4.1 Radiological Protection

The control room environment during a design-basis accident satisfies the requirements of General Design Criterion 19 of 10 CFR 50, Appendix A for radiation protection. The radiation source model includes the source listed in Table 6.4-1.

The introduction of a minimum quantity of outside air is required to maintain the control room areas at a positive pressure with respect to surrounding areas. In order to minimize the airborne radiation in the control room, dual air intakes with manual selection and redundant radiation detectors at each air intake are provided.

The makeup air and the partially recirculated air is filtered through HEPA and carbon adsorber that have a total iodine and particulate removal efficiency of 99%. Refer to Subsection 6.4.1 (Design Basis) and Subsection 6.4.2 (System Design) for additional information on control room habitability.

6.4.4.2 Toxic Gas Protection

Significant quantities of hazardous chemicals are not anticipated to be stored or transported outside of the station boundaries, up to a distance of 5 miles (8 km) from the site, as indicated in Subsection 2.2.3. As discussed in

Subsection 6.4.3.3, a hazards analysis in accordance with USNRC Regulatory Guides 1.78 was performed to evaluate chemicals that would be stored or transported within the Yonggwang station boundaries. A sodium hypochlorite biocide system will be used, thus eliminating an onsite chlorine hazard. The only chemical determined to pose a control room habitability hazard is ammonium hydroxide, which could generate ammonia gas in the event of an accidental release. The operators would be able to detect the presence of ammonia gas by smell, before toxic concentrations are reached. In such an event, the operators would manually place the control room HVAC system in 100% recirculation mode.

Similarly, the control room envelope can be isolated manually in case of noxious gas intrusion such as smoke.

In accordance with plant emergency plans and procedures, self-contained breathing apparatus each with a 6-hour air supply is provided for control room personnel (at least five individuals) to assure control room habitability in the event of occurrences described above.

If the manual underfloor CO_2 suppression system is actuated, it is assumed that the control room will be evacuated. Safe shutdown of the plant can be accomplished from the remote shutdown panels. Also, analysis has shown that, even for a full discharge of the suppression system, the oxygen concentration in the control room will remain above 19% by volume.

6.4.5 Testing and Inspection

The control room HVAC system and its components are tested in a program consisting of:

a. factory and component qualification tests,

b. onsite preoperational testing, and

c. subsequent onsite periodic testing and atmospheric filter unit test in accordance with Technical Specifications.

Written startup test procedures establish minimum acceptable values for all tests. Test results recorded as a matter of performance record enable early detection of faulty performance.

The initial test program is discussed in Chapter 14. Equipment is factory inspected and tested in accordance with the applicable equipment specifications, codes, and quality assurance requirements. System ductwork equipment are inspected during various construction stages for quality control. Construction tests are performed on all components, and the system is balanced for the design airflows, water flows, and system operating pressure. Response time of radiation monitors, smoke detectors, and damper closure times are checked and tested to ensure adequate isolation provisions. Controls, instrumentation, interlocks, and safety devices on each system are cold checked, calibrated, adjusted, and tested to ensure proper sequence of operation.

An outline of proposed testing is as follows:

The control room HVAC system has been shown to be capable of maintaining a positive pressure inside the control room envelope, to preclude airborne radioactivity inleakage as would be necessary after a DBA. The acceptance criteria is based on system performance. The outleakage from the control room HVAC envelope do not exceed the design makeup airflow, while the design positive pressure of approximately 0.125 inch (3.175 mm) W.G. is maintained.

6.4.6 Instrumentation Requirements

All the instruments and controls for the control room HVAC system are electric and/or electronic. Further details are provided in the following:

a. Each redundant control room HVAC system has a local control panel, and each is independently controlled. Important operating functions are controlled and monitored from the main control room.

b. Instrumentation is provided to monitor important variables associated with normal operation and abnormal conditions are alarmed on the main control board.

c. A radiation detection system is provided to monitor the radiation levels at the control room outside air intake A and B. These monitors generate a CREVAS (control room emergency ventilation actuation system) signal, which controls the makeup air cleaning unit fan and main control room outside air intake dampers. Upon initiation of CREVAS, the outside air intake damper automatically closes and the air is rerouted through the makeup air cleaning unit. A high radiation alarm is also provided on the main control board.

d. The control room HVAC system is designed for automatic environmental control with manual starting of fans.

e. A manually actuated water deluge system is provided for each carbon adsorber bed. Refer to Subsection 9.5.1

f. The various instruments of the control system are described in detail in Section 7.3.

g. The pressure differential across the HEPA filter is annunciated on the main control board. The airflow through the air cleaning unit is indicated, and low and high airflow rate is annunciated on the main control board. High and low fan differential pressure and fan trip are also alarmed on the main control board.

TABLE 6.4-1

LOCA SOURCES IMPACTING MAIN CONTROL ROOM RADIATION PROTECTION

Containment Post-LOCA Sources

Effluent Cloud from Containment Leakage

Post-LOCA Airborne Sources Inside the Main Control Room

Post-LOCA Airborne Sources Located in Buildings Surrounding the Main Control Room (i.e., Primary Auxiliary Building)

Air Cleaning Units Sources that Are Required to Operate Post-LOCA:

a. ECCS Equipment Room Exhaust Air Cleaning Unit.

b. Control Room Makeup Air Cleaning Units.

Post-LOCA Liquid Radiation Sources Contained in Piping and Equipment Located Outside the Containment Building

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

CONTROL ROOM ENVELOPE
(Sheet 1 of 2)

Figure 6.4-1

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

CONTROL ROOM ENVELOPE
(Sheet 2 of 2)

Figure 6.4-1

6.5 FISSION PRODUCT REMOVAL AND CONTROL SYSTEMS

6.5.1 Engineered Safety Feature (ESF) Filter Systems

ESF filters are provided for the following systems, which are required to perform safety-related functions subsequent to a design-basis accident (DBA):

a. Control Room Emergency Makeup System

This system is part of the control room HVAC system and is utilized to clean the makeup and partial recirculated air to the control room of any carryover of iodine and particulates following a LOCA (refer to Subsection 9.4.1).

b. Emergency Core Cooling System (ECCS) Equipment Room Exhaust System

This system is part of the ECCS equipment room HVAC system. This system is utilized to filter postulated iodine and particulate concentrations in the exhaust air from ECCS equipment rooms following a design-basis accident (refer to Subsection 9.4.5.3).

c. Fuel Building Emergency Exhaust System

This system is part of the fuel building HVAC system and is utilized to reduce potential iodine and particulate concentrations in the exhaust air from the fuel building following a fuel handling accident (refer to Subsection 9.4.2).

6.5.1.1 Design Bases

6.5.1.1.1 Control Room Emergency Makeup System

a. This system is part of the control room HVAC system and is designed to provide filtered makeup air to the control room envelope. The system will start in response to any one of the following signals: 1

1. Engineered safety feature actuation system (ESFAS)-safety injection actuation signal (SIAS).

2. ESFAS-control room emergency ventilation actuation signal (CREVAS).

3. Manually by a hand switch on the main control board. 1

b. The capacity of the emergency makeup air cleaning unit is based on the following air quantity requirements:

1. Maintain the control room envelope at approximately 0.125 in. (3.2 mm) W.G. positive pressure with respect to the adjacent area 375

2. Limit the dose equivalent received by the main control room personnel to 5 rem whole-body, or its equivalent to any part of the body, for the duration of the accident in accordance with 10 CFR 50, Appendix A, General Design Criterion 19.

c. The makeup air cleaning units are designed to exhibit a removal efficiency of no less than 99.5% on radioactive methyl iodine and no less than 99.97% on all particulate matter, 0.3µm and larger.(Activated carbon bed depth : 4 inches or greater) 537

d. The makeup air system is designed to meet single failure criteria and is safety-related and seismic Category I.

6.5.1.1.2 Emergency Core Cooling System (ECCS) Equipment Room Exhaust System

a. This system is part of the ECCS equipment room HVAC system and is designed to maintain negative pressure in the primary auxiliary building with respect to surroundings and to filter potential particulate and iodine concentrations from the ECCS room exhaust air, based on postulated leakages from ECCS equipment.

This system is designed to start:

1. manually by a control switch on the main control board, and
2. automatically on receipt of an ESFAS-SIAS.

b. The capacity of the air cleaning unit is based on the air quantity required for maintaining the primary auxiliary building approximately 0.125 in. (3.175 mm) W.G negative pressure with respect to the surroundings.

c. Each air cleaning unit is designed for a removal efficiency of no less than 99.5% on radioactive elemental forms of iodine and no less than 99.97% on all particulate matter, 0.3μm and larger.(Activated carbon 537 bed depth : 4 inches or greater)

d. The system is designed to meet single failure criteria and is classified as safety-related and seismic Category I.

6.5.1.1.3 Fuel Building Emergency Exhaust System

a. This system is part of the fuel building HVAC system and is designed to treat the exhaust air from the building following a fuel handling accident. The system will start in response to one of the following signals:

1. Engineered safety feature actuation system (ESFAS) fuel building emergency ventilation actuation signal (FBEVAS).

2. Manually by a hand switch on the main control board.

b. The capacity of the emergency exhaust system is based on the air quantity required to maintain the fuel building at approximately a negative 0.125 in. (3.175 mm) W.G. with respect to atmospheric pressure.

c. The exhaust filter unit is designed to exhibit a removal efficiency of no less than 99.5% on radioactive methyl iodine and no less than 99.75% on all particulate matter, 0.3μm and larger.(Activated carbon bed depth : 4 inches or greater) 537

6.5.1.2 Design Description

Each ESF air cleaning unit is designed to meet the requirements of Regulatory Guide 1.52 with clarifications as defined in Section 1.8 and as follows:

a. Each air cleaning system has two 100% redundant trains, each powered by separate electric power division.

b. Each air cleaning unit consists of a moisture separator, an electric heating coil, a prefilter, a space electric heating coil, a HEPA 1 filter, carbon adsorbers, a post HEPA filter, a fan and housing. Water drains for the moisture separator and carbon adsorbers sections are provided.

c. Each air cleaning unit is provided with instrumentation in accordance with ASME N509-1989. For further details, refer to Subsections 9.4.1.5, 537 9.4.2.5, and 9.4.5.3.5, and Section 7.3.

d. Each air cleaning unit is designed to permit periodic testing and inspection of system components, in accordance with ASME N509-1989 and 537 Subsection 6.5.1.4.

e. The low leakage isolation dampers are provided where isolation is required. The damper is designed to meet the requirements of Section 1 5.9 of ASME N509-1989. 537

f. A fan induces the air through the air cleaning unit. The fan performance is based on the maximum density when the air cleaning unit is operating at the design flow conditions. All air cleaning units are draw-through type. The fan is designed to meet the requirements of Section 5.7 of ASME N509-1989. 1 537

g. The moisture separator is designed to remove any entrained water droplets and moisture to minimize water loading of the filters. The moisture separator meets qualification requirements similar to those in Mine Safety Appliance Research (MSAR) Report 71-45 and Section 5.4 of ASME N509-1989. 1 537

h. The electric heaters are sized to reduce the humidity of the airstream to less than 70% relative humidity for the worst inlet conditions to ensure high iodine removal capability of the carbon absorber. The heater meets the requirements of UL 1096 and of Section 5.5 of ASME N509-1989. 537

i. A non-safety related space electric heating coil is provided to maintain the relative humidity in the air cleaning unit at or below 70% during the times when the air cleaning unit is not operating.

j. The prefilter is designed to exhibit no less than 85% efficiency based on ASHRAE Std. 52-76 and is designed to meet the requirements of Section 5.3 of ASME N509-1989. 537

k. The pre-high-efficiency particulate air (HEPA) filter, provided to protect the carbon adsorber from particulate loading, is water resistant, capable of a minimum removal efficiency of 99.97% on particulate matter 0.3 μm or larger. All (HEPA) elements are fabricated to meet the requirements of Section 5.1 of ASME N509-1989. 1 537

l. The carbon adsorber is Type III with adsorbent and is designed to meet the requirements of Section 5.2 of ASME N509-1989 except bed cell type and Section FE OF ASME AG-1-1997. The quantity of carbon adsorbers 1 537 is based on retention of 2.5 mg iodine/g carbon.

The bed dimensions are so designed that the air has at least a 0.25-second residence time in charcoal per 2 inches (50.8 mm) of bed depth. Means are provided for filling and removing carbon into and from the adsorber cells.

Test canisters are provided for each carbon adsorber. The quantity of test canisters is based on expected operational frequency. These canisters contain the same depth as in the carbon adsorber. The canisters are installed in a location where they will be exposed to same airflow conditions as the adsorbent in the system.

A fire detection system is installed for each carbon adsorber to detect conditions downstream of the adsorber before they result in adsorber fire. A two stage temperature alarm system is provided. Activation of the first stage is annunciated in the main control room and automatically trips the fan and isolates the air cleaning unit. When the second stage is annunciated, the station fire brigade is summoned to the air cleaning unit site to manually initiate the fire protection system. Fire water deluge nozzles are permanently mounted within the housing. The nozzles are piped to an accessible location outside the housing and provided with redundant leaktight isolation valves. The pipe is permanently connected to the plant's fire protection system in lieu of manual hose connection. Thus, actuation 1 of the fire deluge valve is indicated in the main control room.

m. The post-HEPA filter is provided downstream of the adsorber to trap carbon fines that may be entrained by the airstream. The requirements of the HEPA filter is the same as that in Item 6.5.1.2.k.

n. Full-size access door is provided adjacent to each component of the air cleaning unit. Access doors have transparent portholes to allow inspection of components without violating the train integrity. The spacing between filter sections is based on ease of maintenance considerations.

The number of normally open drains is kept to a minimum to reduce possibilities of degrading the pressure boundary or bypassing the filter banks. The drains are designed in accordance with the recommendations of DOE-HDBK-1169-2003 and ASME N509-1989. 537

o. The air cleaning unit filter housing and mounting frame are all-welded construction, heavily reinforced, and built to low-leakage requirements 1 and are designed to meet the requirements of Section 5.6 of ASME N509-1989. 537

p. Interior lights with external light switches are provided between all air cleaning unit components to facilitate inspection, testing, and replacement of components.

q. Ductwork transverse joints will be either gasketed flange, seal-welded flange, or butt-welded. Longitudinal seams are either all-welded, seal-welded, or mechanical in accordance with SMACNA-High Pressure Duct Standard (e.g., Pittsburgh Lock or ACME Lock Seam). Duct construction and air leak tests will be in accordance with ASME N509-1989, with exceptions as noted in Section 1.8 for Regulatory Guide 1.52. Rev.3. 537

r. The equipment parameters of various system components are given in Subsections 9.4.1, 9.4.2, and 9.4.5.3.

6.5.1.3 Design Evaluation

6.5.1.3.1 Control Room Emergency Makeup System

On receipt of ESFAS-CREVAS, as noted in Subsection 6.5.1.1.1, the emergency makeup air cleaning units work in conjunction with the control room HVAC system to maintain habitability in the control room. A detailed system design evaluation is given in Subsections 6.4.4 and 9.4.1.

6.5.1.3.2 ECCS Equipment Room Exhaust System

On receipt of SIAS, as noted in Subsection 6.5.1.1.2, the ECCS equipment room exhaust system is designed to preclude direct exfiltration of contaminated air from primary auxiliary building following a design-basis accident. A detailed system evaluation is included in Subsection 9.4.5.3.

6.5.1.3.3 Fuel Building Emergency Exhaust System

On receipt of ESFAS-FBEVAS, as noted in Subsection 6.5.1.1.3, the fuel building emergency exhaust system is designed to preclude direct exfiltration of contaminated air from the fuel building following a fuel drop accident that could result in abnormally high airborne radiation in the fuel building. A detailed system evaluation is given in Subsection 9.4.2.

6.5.1.4 Tests and Inspections

a. The ESF air cleaning systems and their components are thoroughly tested in a program consisting of the following:

   1. Factory and component qualification tests

   2. Onsite preoperational testing

   3. Onsite periodic testing

   Written test procedures will establish minimum acceptable values for all tests. Test results will be recorded as a matter of performance record, thus enabling early detection of reduced performance.

b. The factory and component qualification tests consist of the following:

1. Air cleaning unit housing - a leak test and liquid penetrant test, per Section 6 of ASME N509-1989, of all welds that could cause bypass leakage around HEPA filters or carbon adsorber beds

2. Moisture separator - qualification test or objective evidence to demonstrate compliance with specified design criteria

3. HEPA filters - qualification and production test per ASME AG-1-1997 FC5000.

4. HEPA filter and carbon adsorber mounting frames - pressure leak test across filterless, covered bank in accordance with Section 7 of ASME N509-1989

5. Adsorbent beds - model test of bed or objective evidence to demonstrate flow pressure characteristics and channeling effects 537

6. Adsorbent - qualification tests per ASME N509-1989

7. Fans - rated or tested in accordance with ASME N509-1989, Subsections 5.7.1 and 5.7.2, to establish fan performance curves and fan rating. Fans are statically and dynamically balanced in accordance with ASME N509-1989, Subsection 5.7.3.

8. Heater - high-temperature cutout test, and entering and leaving air temperature tests are performed in accordance with ASME N509-1989, Section 5.5, and ASME N509-1989, Section 14

9. Prefilter - objective evidence or certification that the ASHRAE efficiency specified is attained in accordance with ASME N509-1989, Subsection 5.3.3

10. Dampers - shop tests or objective evidence demonstrating leak-tightness closure times, etc., in accordance with ASME N509-1989, Subsections 5.9.7.2 and 5.9.8. 537

c. The onsite preoperational tests of ESF air cleaning systems and their components are performed in accordance with ASME N509-1989. The individual system tests are discussed in Chapter 14. 537

d. Onsite periodic testing - the onsite periodic tests of ESF air cleaning system and their components are performed in accordance with ASME N509-1989. The acceptance criteria for laboratory test of carbon are in accordance with the plant technical specification outlined in ITS 4.16. 537

6.5.2 Containment Spray System Fission Product Removal

The containment spray system (CSS) is an ESF system, the functions of which are to reduce pressure and temperature in the containment atmosphere following a postulated loss-of0coolant-accident (LOCA), and to remove radioactive fission products from the containment atmosphere. These functions are performed by spraying water into the containment atmosphere through a large number of nozzles on spray headers located in the containment dome. Reduction of pressure and temperature in the containment with the CSS is discussed in Subsection 6.2.2.

Radioiodine in its various forms is the fission product of primary concern in the evaluation of a LOCA. It is absorbed by the containment spray from the containment atomosphere. To enhance this iodine absorption capacity of the spray, the spray solution is adjusted to an alkaline pH that promotes iodine hydrolysis, in which iodine is converted to nonvolatile forms.

Discussed herein are the spray additive portion of the system and the containment spray system's fission product removal capability following a LOCA.

6.5.2.1 Design Bases

The following design bases are used for the fission product removal design of the containment spray system. Additional design bases are included in Subsection 6.2.2.1, in which the capability of the spray system to remove heat from the containment atmosphere is discussed.

a. The CSS is designed to provide a spray solution, while the spray additive portion of the system is in operation, with a hydrazine concentration of 50 to 100 ppm during the hydrazine injection phase. The sump chemical additive is designed to raise the pH of the sump solution above 7.0 within the first 4 hours following a LOCA, and thereafter maintain the pH between 7.0 and 8.5.

b. The CSS is capable of reducing the iodine and particulate fission product inventories in the containment atmosphere such that the offsite radiation exposures resulting from a design basis LOCA are within the plant siting dose guidelines of 10 CFR 100 and meet the General Design Criteria of Appendix A of 10 CFR 50 for the control room and TSC habitability.

6.5.2.2 System Design

6.5.2.2.1 General Description

The containment spray system (CSS) is designed to deliver a spray solution of borated water and chemical additive into the containment atmosphere with a hydrazine concentration of 50 to 100 ppm. The CSS, with the aid of hydrazine, is capable of removing sufficient iodine from the containment atmosphere such that the offsite radiation exposures resulting from a design basis LOCA are within the dose guidelines of 10 CFR 100, and the thyroid dose to the control room and TSC inhabitants are within the limits specified in Appendix A of 10 CFR 50.

To prevent iodine from reevolution into the containment atmosphere, the sump pH is strictly controlled between the range of 7.0 and 8.5 by passive sump chemical addition during the recirculation phase. Tri-sodium phosphate (TSP) powder, which is typically used as a sump chemical additive with passive mechanism, is normally contained in the baskets and has the chemical characteristics of high solubility in water. In addition, the baskets are designed to allow a large surface area of TSP powder to be in contact with the sump water for easy and rapid dissolution, resulting in a chemical equilibrium condition of mixed solution within 4 hours following a LOCA. The baskets are located on the containment basement floor outside the secondary shield wall, and readily submerged and flooded by sump water due to the low elevation of the baskets.

The spray additive subsystem of the CSS, shown schematically in Figure 6.2-61, 1 consists of one spray additive tank, a spray additive pump, valves, and connecting piping per each train. The system uses the containment spray pumps and spray headers, as described in Subsection 6.2.2.1, to deliver and distribute the spray additive solution to the containment atmosphere. Initially, water from the refueling water tank (RWT) is used as the water source for containment spray. During the recirculation phase, each train takes suction from separate containment recirculation sumps. Hydrazine is added from the spray additive tank into the water from the RWT or the containment recirculation sump, and pumped to the spray ring headers and nozzles.

Parts of the CSS in contact with borated water or the hydrazine spray additive, or mixtures of the two, consist of austenitic stainless steel or an equivalent corrosion resistant material.

The austenitic stainless steel spray additive tank contains a sufficient amount of 50 to 100 ppm hydrazine spray additive solution to bring the containment recirculation sump fluid to a minimum concentration of 50 ppm during the hydrazine injection phase.

Each spray header layout is oriented to provide more than 90 percent area coverage at the operating floor of the containment building.

6.5.2.2.2 Component Description

The mechanical components of the spray additive subsystem are described in Subsection 6.2.2.2.2. The spray additive subsystem component design parameters are given in Table 6.2-51. 1

6.5.2.2.3 System Operation

System flow rates and the duration of operational modes are presented in Subsection 6.2.2.

Operation of the CSS and the containment spray additive subsystem ensures that iodine removal requirements are fulfilled during both the injection phase and the recirculation phase. During the injection phase, the CSS provides a spray solution, while the spray additive portion of the system is in operation, with a hydrazine concentration of 50 to 100 ppm at least for 4 hrs.

During the recirculation, the TSP contained in baskets is submerged in sump water and dissolved rapidly raising the pH of mixed sump solution to a value above 7.0 within 4 hours following a LOCA. After complete dissolution of TSP, the long-term containment recirculation sump pH is maintained between 7.0 and 8.5.

The containment iodine removal credit assumed in the calculation of offsite doses following a LOCA is provided in Section 15.6.

6.5.2.3 Design Evaluation

6.5.2.3.1 Sump Solution pH Evaluation

The pH evaluation for the sump water during long-term recirculation phase has been made to ensure that the calculated minimum and maximum pH values under any possible water chemistry conditions caused by a LOCA are bounded between

7.0 and 8.5.

During short-term injection phase, the sump water pH was not evaluated since the fission product removal function is performed by fresh spray water and hydrazine as spray additive. This continues for at least 4 hours.

The principal water sources that contribute to the sump pH are RCS water inventory, SIT water inventory, and RWT water inventory.

The minimum sump pH of 7.0 was used to determine the minimum required TSP quantity based on the following :

a. Maximum water sources
b. Maximum boron concentrations for each water source
c. Minimum sump water temperature during recirculation.

The maximum sump pH was calculated from the previously determined TSP and based on the following :

a. Minimum water sources
b. Minimum boron concentrations for each water source
c. Maximum sump water temperature during recirculation.

Table 6.5-1 shows the input parameters used for the sump pH analysis. The chemical reaction among the boric acid and TSP in aqueous solution was considered under base and acid equilibrium conditions and at a range of sump water temperatures that varies from 120°F (48.9°C) to 300°F (148.9°C) for the post-LOCA period.

The calculated minimum sump water pH is 7.0 with the TSP of 20,000 lbm (9072 kgm). Also, the maximum sump water pH was determined to be 8.0 with the same TSP quantity as minimum pH. These results prove that at any point following a LOCA, the long-term sump water pH can be controlled between 7.0 and 8.5, which is as required for long-term iodine retention during recirculation phase.

6.5.2.3.2 Iodine Removal Effectiveness Evaluation

The spray iodine removal analysis is based on the assumption that :

a. Only one out of the two spray pumps is operating
b. The ECCS is operating at its maximum capacity.

The CSS pumps are switched to the recirculation mode when the low alarm level is reached in the RWT.

The containment volume covered by spray is conservatively assumed as the gross volume above the operating floor and refueling canal minus the unsprayed region above the operating floor. A list of unsprayed regions above the operating floor is shown in Table 6.5-2.

The spray system is assumed to directly spray approximately 75 percent of the total containment net free volume for conservatism. The remaining 25 percent of the total containment volume does not get sprayed directly because of obstructions to the falling spray drops. However, the major portion of the containment not directly sprayed still has good communication with directly sprayed volumes while a minor portion has restricted communication. A list of the sprayed regions and unsprayed regions within the containment is provided in Table 6.5-2.

Hydrazine is added to the spray solution to ensure efficient and rapid removal of the iodine from the containment atmosphere. The hydrazine also inhibits reevolution of the iodine from the containment spray into the containment atmosphere during the initial phases of recirculation when the containment sump water is used as the spray medium. Hydrazine is required to prevent reevolution of iodine until the TSP has had time to dissolve and produce a recirculation spray solution pH between 7.0 and 8.5. A spray solution pH between 7.0 and 8.5 inhibits reevolution of iodine from the containment spray. Thus, once the desired spray solution pH is attained, hydrazine addition is no longer necessary. The time required to attain a spray solution pH between 7.0 and 8.5 via TSP is 4 hours. (The containment spray pump flow rate of 3500 gal/min (13248.7 L/min) per pump is used in the calculation.)

Although the iodine removal capability remains high under these conditions, no credit is taken for iodine removal after the decontamination factor (DF) of 100 is reached during the injection mode.

6.5.2.3.2.1 Calculation Model

Based on Regulatory Guide 1.4, three species of iodine are postulated to exist airborne in the containment atmosphere following a LOCA. These are the elemental, particulate, and organic species. The spray removal models for these iodine species are described below (Reference 1). It is conservative to assume that organic iodides are not removed by either spray or wall deposition.

a. Elemental Iodine Removal Model

Elemental iodine is the dominant iodine specie in postaccident containment atmosphere. It is removed at an appreciable rate by both spray drop absorption and by wall deposition. Models for these two removal processes are described as follows.

1) Absorption of Spray Drops

An important factor to determining the effectiveness of sprays against elemental iodine vapor is the concentration of iodine in the spray solution. Experiments with fresh sprays having no dissolved iodine were observed to be quite effective in the scrubbing of elemental iodine even at a pH as low as 5. However, solutions having dissolved iodine, such as the sump solutions that recirculate after an accident, may revolatilize iodine if the solutions are acidic. So, absorption models of elemental iodine by spray drops are separated into the injection phase and recirculation phase.

The basic model of the containment atmosphere and spray system is given by Parsley. The containment atmosphere is viewed as a black box having a sprayed volume, V, and containing iodine at some uniform concentration Cg. Liquid enters at a flow of F volumes per unit time, containing iodine at a concentration of CL1, and leaves at the same flow at concentration CL2.

A material balance for the containment as a function of time is given by:

[redacted] (6.5-1)

where :

CL1 = the iodine concentration in the liquid entering the dispersed phase, g/cm^3

CL2 = the iodine concentration in the liquid leaving the dispersed phase, g/cm^3

V = sprayed volume of containment, cm^3

Cg = the iodine concentration in the containment atmosphere, g/cm^3

F = the spray flow rate, cm^3/sec

t = spray time, sec

An absorption efficiency, E, which may be described as the fraction of saturation, is defined as :

[redacted] (6.5-2)

In addition the equilibrium distribution of iodine between the vapor and liquid phases is given by :

[redacted] (6.5-3)

where :

H = the iodine partition coefficient, (g/l of liquid)/(g/l of gas)

CL* = the equilibrium concentration in the liquid, g/cm^3

Substitution of equation (6.5-3) into equation (6.5-2) yields

[redacted] (6.5-4)

Solving for (CL2 - CL1) and inserting the result into Eq. (6.5-1) gives:

[redacted] (6.5-5)

During the injection phase, CL1 = 0, so that

[redacted] (6.5-6)

This equation can be integrated to solve for Cg. The concentration of iodine in the containment atmosphere during injection as a function of time is given by:

[redacted] (6.5-7)

where:

Cgo = the initial iodine concentration in the containment atmosphere, g/cm^3

Eq. (6.5-7) is applicable up to the time the spray solution is recirculated. From Eq. (6.5-7), the spray removal coefficient, λ_e, is given by:

[redacted] (6.5-8)

The sump solution at the end of injection is assumed to contain fission products washed out from the reactor core as well as those removed from the containment atmosphere. The radiation absorbed by the sump solution, if the solution is acidic, would generate hydrogen peroxide in sufficient amount to react with both iodide and iodate ions and raise the possibility of elemental iodine re-evolution. For sump solutions having pH values less than 7, molecular iodine vapor should be conservatively assumed to evolve into the containment atmosphere.

Long-term iodine retention is calculated on the basis of the expected long-term partition coefficient. Long-term iodine retention may be assumed only when the equilibrium sump solution pH, after mixing and dilution with the primary coolant and ECCS injection, is above 7. This pH value is achieved by the onset of the spray recirculation mode.

The absorption efficiency, E, may be calculated from the well-mixed drop model.

In the well-mixed drop model, mass transfer resistance inside the drop is neglected. The solute concentration on the liquid side of the gas/liquid interface is equated to the average concentration in the drop. While liquid phase mass transfer resistance is neglected, gas/liquid equilibria are properly accounted for in this model. The drop absorption efficiency may be expressed as ;

[redacted] (6.5-9)

The above expression represents a first-order approximation if a well-mixed droplet model is used for the spray efficiency. The expression is valid for λ_e values equal to or greater than 10 per hour. λ_e is limited to 20 per hour to prevent extrapolation beyond the existing data for boric acid solutions with a pH of 5. The elemental iodine decontamination factor (DF) is defined as the maximum concentration in the containment atmosphere divided by the concentration of iodine in the containment atmosphere at some time after decontamination. DF for the containment atmosphere achieved by the containment spray system is determined from the following equation :

[redacted] (6.5-10)

where H is the effective iodine partition coefficient, V_s is the volume of liquid in containment sump and sump overflow, and V_c is the containment net free volume less V_s.

2) Deposition of Iodine

Surface deposition of iodine occurs as the result of several transport processes which occur in series. Regions of transport include : the bulk gas phase, the gas boundary layer, the liquid film, and the solid wall surface. Of these, transport in the gas boundary layer has been shown to be the controlling step.

The iodine plateout coefficient in the containment is given by:

[redacted] (6.5-11)

where:

λ_w = removal rate coefficient due to surface deposition
K_g = average mass transfer coefficient
A = surface area for wall deposition
V = volume of contained gas

b. Particulates Iodine Removal Model

The removal of particulate iodine by sprays is a more complex process than gaseous absorption because a number of mechanisms contribute significantly to capture. The spray removal rate for particulate iodine can be related to spray parameters and to the single drop collection efficiency by considering the spray to be an assemblage of single drops. The relating equation is:

[redacted] (6.5-12)

where:

C = particulate iodine concentration in containment atmosphere, kg/m^3

λ_p = spray removal rate constant for particulate iodine, sec^{-1}
h = drop fall height, m
F = spray flow rate, m^3/sec
E = single drop collection efficiency
D = mean spray drop diamter, m
V = volume of contained gas phase, m^3

From a review of available large scale test results on aerosol washout, a conservative estimate of particulate iodine washout can be obtained by choosing E/D values as follows :

$E/D = 0.1\ cm^{-1}$, for $0.02 \le C/C_o \le 1.0$
$E/D = 0.01\ cm^{-1}$, for $C/C_o < 0.02$

Therefore, spray removal rate constant for particulate iodine is:

[redacted] (6.5-13)

[redacted] (6.5-14)

In the above expressions C/C_o represents the ratio of airborne concentration, C, at time t to initial concentration C_o, computed for an instantaneous release at time zero.

6.5.2.3.2.2. <u>Calculation</u>

a. Elemental iodine removal

The SPIRT (A program for the calculation of spray iodine removal transients) computer code (Reference 1) is used to analyze the elemental iodine removal effectiveness of containment spray. A description of the mathematical models used in the code has been presented in Subsection 6.5.2.3.2.1.

The spectrum of drop sizes emitted from the spray nozzles in this code is represented as a two-parameter log-normal distribution function and this distribution is represented by a finite number of discrete drop size groups. All calculation equations involving drop size are then repeated for each drop size group. The drop size distribution used in this analysis is based on data obtained from the SPRACO 47-0714-17 (1713A) nozzle as shown in Fig. 6.5-1 (Reference 2).

Each spray additive pump delivers 35% hydrazine solution to the spray solution to ensure that the concentration of hydrazine is maintained within the range of 50 to 100 ppm and efficient and rapid removal of the iodine from the containment atmosphere. Containment spray pump flow rates of 3500 gpm (13,248.7 L/min) per pump are used in the calculations for conservatism.

For the equilibrium elemental iodine decontamination factor (DF) calculation, the liquid volume in the containment is given in Table 6.5-3. In this analysis minimum water volume is used for conservatism. The gaseous volume is determined by subtracting the liquid volume from the containment net free volume given in Table 6.5-3.

Section 15.6 utilizes a maximum decontamination factor of 100 to determine the offsite thyroid doses following a LOCA. To achieve this DF, an equilibrium partition coefficient of 5000 must be maintained throughout the accident. Based on the addition of hydrazine and control of pH values for the containment sump, the equilibrium partition coefficient is maintained at 5000 and no reevolution of iodine will occur.

The input parameters and results of the containment spray iodine removal analysis are given in Table 6.5-3.

In order to conservatively compute the value of the removal constant by wall deposition for elemental iodine, containment wall surface area impacted upon by spray is minimized. The mass transfer parameters were evaluated for a single conservative containment temperature of 280°F (137.8°C). The use of these conservative values yields elemental iodine removal constants by washout and wall deposition of 36.4 hr^{-1} and 0.15 hr^{-1}, respectively. Since an iodine removal constant larger than 20 hr^{-1} by washout is beyond the experimental evidence, the resultant elemental iodine removal constant is 20.15 hr^{-1}.

b. Particulate iodine removal

Spray removal rate for particulate iodine can be calculated by Equation (6.5-13) or (6.5-14). The range of C/Co value is assumed between 0.1 and 0.01 for simplicity and conservatism. Based on Equation (6.5-14), E/D is equal to 0.01 cm^{-1}. The resulting spray removal constant for particulate iodine is calculated to be 0.552 hr^{-1}.

6.5.2.4 Tests and Inspections

Preoperational testing is performed on the system in accordance with the test description in Chapter 14. Periodic testing is performed in accordance with ~~Chapter 16, Technical Specifications~~.
ITS

6.5.2.5 Instrumentation Applications

The containment spray system is provided with instrumentation and controls to allow the operator to monitor the status of the system, and to identify malfunctioning components that should be isolated. All instrumentation receives emergency onsite power from separate, redundant, and train-aligned power supplies.

Level indication is provided locally and in the control room to monitor spray additive tank availability. A low-level alarm will denote loss of the stored hydrazine solutions. A low-low level signal will stop the spray additive pump. Level switches are also provided to close the spray additive subsystem isolation valves at the low-low spray additive tank level setpoint.

Flow indication in the control room is provided to monitor system operation and to facilitate periodic inservice testing.

Redundant pressure indication and alarms are provided on the spray additive tanks to assure that the integrity of the nitrogen cover gas is maintained. Pressure indication is provided downstream of the spray additive pumps to facilitate periodic inservice testing.

The containment spray actuation signal (CSAS) initiates spray additive subsystem operation by opening the isolation valves and starting the spray additive pumps.

6.5.2.6 Materials

The CSS materials are discussed in Subsection 6.2.2.6.

6.5.3 Fission Product Control Systems

6.5.3.1 Primary Containment

The primary containment consists of a post-tensioned, reinforced concrete structure with cylindrical walls, hemispherical dome, and base slab, lined with welded 0.25 inch (6.35 mm) steel plates, forming a continuous leaktight pressure boundary. Details of the containment structural design are discussed in Section 3.8. Layout drawings of the containment structure are given in the general arrangement drawings in Section 1.2.

The containment walls, liner plate, mechanical and electrical penetrations, isolation valves, hatches, and locks function to limit release of radioactive materials, subsequent to postulated accidents, such that the resulting offsite doses are less than the guideline values of 10 CFR 100. The containment isolation system design is discussed in Subsection 6.2.4.

Long-term containment pressure response to design basis accidents is discussed in Subsection 6.2.1. Relative to this time period, the CSS is operated to reduce iodine concentrations and containment atmospheric temperature and pressure from the time commencing with system initiation until containment pressure has returned to normal. CSS actuation times are discussed in Subsections 7.3.1 and 6.2.1.

The primary containment fission product control system during normal plant operating conditions consist of the low-volume purge system. The system is operated during power operation to control any fission products prior to personnel access to the containment. For further discussion of this system, refer to Subsection 9.4.6.2.2.

Redundant, safety-related hydrogen recombiners are provided for the containment atmosphere as the primary means of controlling postaccident hydrogen concentrations. The combustible gas control system is discussed in Subsection 6.2.5.

The post-LOCA purge system is provided to aid in postaccident cleanup. This system may be used to purge the combustible gas in the containment atmosphere during power generation and after a LOCA. For further discussion of this system, refer to Subsection 9.4.6.2.3.

6.5.3.2 Secondary Containment

This Subsection is not applicable to YGN 3&4.

6.5.4 Ice Condenser as a Fission Product Cleanup System

This Subsection is not applicable to YGN 3&4.

6.5.5 References

1. NUREG/CR-0009, "Technological Bases for Models of Spray Washout of Airborne Contaminants on Containment Vessels", USNRC, 1978.

2. "SPRACO Spatial Droplet Size Distribution of 47-0714-17 (1713A) Nozzle" SPRACO Co.

3. ANSI/ANS 56.5, "PWR and BWR Containment Spray System Design Criteria."

TABLE 6.5-1

INPUT PARAMETERS FOR SUMP pH ANALYSIS

Water Source and Chemistry	Minimum pH	Maximum pH
RCS Water		
Water Volume, ft^3 (m^3)	11,600 (328)	11,600 (328)
Boron Concentration, ppm	1,500	0
SIT Water		
Water Volume, ft^3 (m^3)	7,700 (218)	7,200 (204)
Boron Concentration, ppm	4,400	2,300
RWT Water		
Water Volume, ft^3 (m^3)	105,300 (2982)	77,400 (2192)
Boron Concentration, ppm	4,400	4,000
Sump Water Temperature, °F (°C)	120 (48.9)	300 (148.9)

Table 6.5-2

SPRAYED AND UNSPRAYED REGIONS

Description	Volume, ft^3 (m^3)
(A) Total containment net free volume	2.727E6 (7.722E4)
(B) Gross volume above the operating floor	2.215E6 (6.272E4)
Refueling canal	2.420E4 (685.2)
(C) Volume of pressurizer compartment	1.920E4 (543.7)
Volume of steam generator compartments	9.300E4 (2633.5)
Volume of missile shield, CEDM HVAC, and regions below	1.100E4 (311.5)
Volume of RCFC and regions below	3.120E4 (883.5)
Sprayed volume fraction :	
Calculated value *	78%
Value used in iodine removal analysis	75%
Unsprayed volume fraction :	
Calculated value	22%
Value used in iodine removal analysis	25%

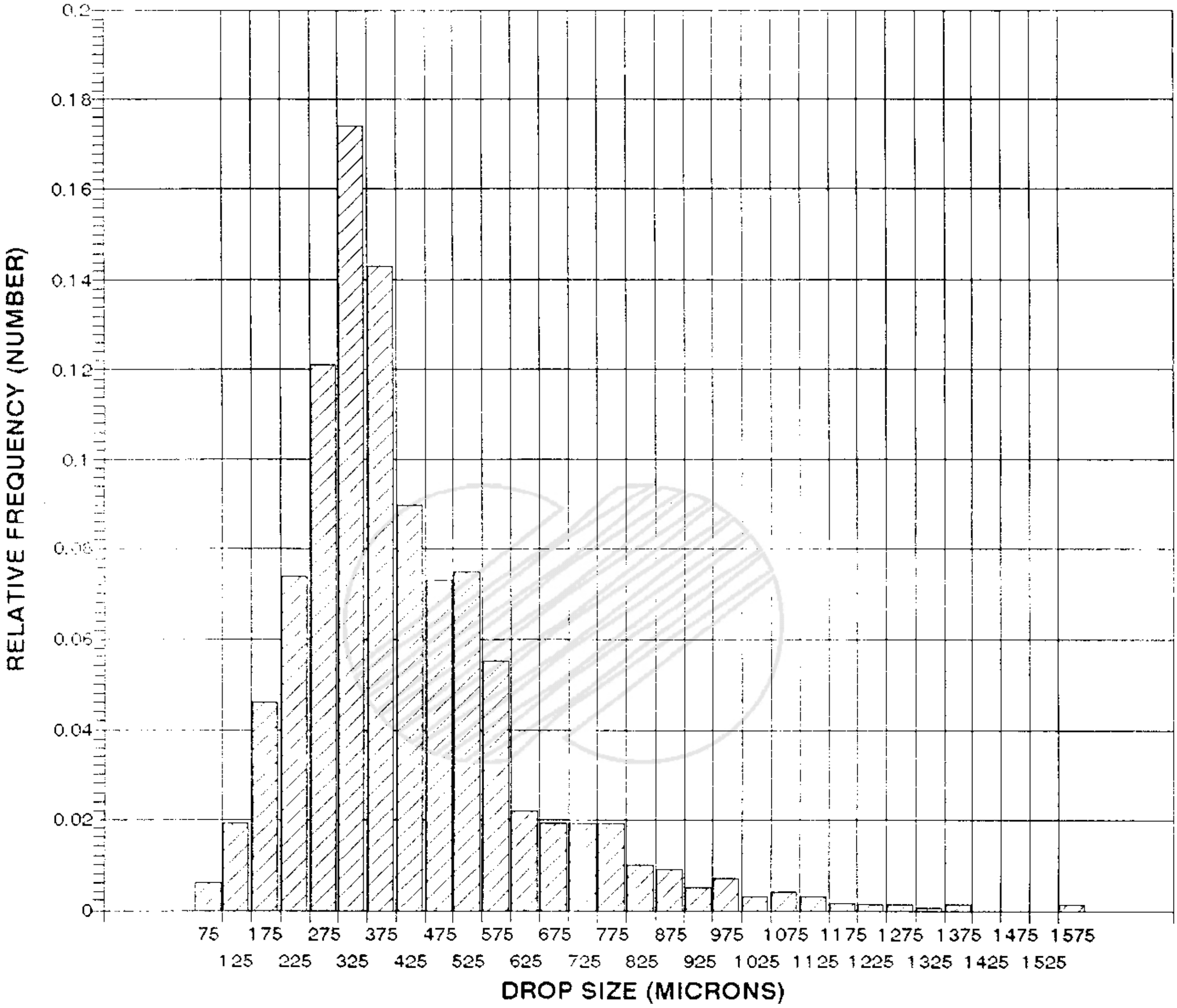
* Sprayed volume fraction is computed as $\frac{B-C}{A}$.

Table 6.5-3

INPUT PARAMETERS AND RESULTS OF CONTAINMENT SPRAY IODINE REMOVAL ANALYSIS

Total containment free volume, ft^3 (m^3) Sprayed containment free volume, ft^3 (m^3)	2.727×10^6 (7.722×10^4) 2.045×10^6 (5.791×10^4)
Net spray flow rate per train, gal/min (L/min)	3,500 (13,248.7)
Droplet fall distance assumed, ft (m)	88 (26.8)
Maximum drop size, cm	0.160
Containment wall surface area impacted upon by spray, ft^2 (m^2)	72,382 (6724.5)
Liquid volume of the containment, ft^3 (m^3) Maximum Minimum	 1.25×10^5 (3539.6) 9.54×10^4 (2701.4)
Partition coefficient (elemental iodine)*	5,000
Iodine removal coefficient (during injection phase), hr^{-1}/train Elemental, λ_e Particulate, λ_p	 20.15 0.55
Decontaimination Factor, DF used in accident calculations Calculated DF	 100 183

* This value is obtained from ANSI/ANS 56.5 for hydrazine (N_2H_4) addition. (Reference 3)



KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

CONTAINMENT SPRAY DROP SIZE DISTRIBUTION

Figure 6.5-1

6.6 INSERVICE INSPECTION OF CLASS 2 AND 3 COMPONENTS

This section describes the inservice inspection program for Quality Group B and C components.

6.6.1 Components Subject to Examination

All Quality Group B and C components under the scope of Subsections IWC and IWD of ASME Code Section XI, including those listed in Tables IWC-2500-1 and IWD-2500-1 of Section XI, will be examined, to the fullest extent possible, in accordance with the ASME Code requirements. Specific examinations are described and justified in the detailed inservice inspection program

6.6.2 Accessibility

The design arrangement of Class 2 and 3 system components provides, to the extent possible, adequate clearances to conduct code-required examinations at the required inspection interval. Specific exceptions to the above are identified, and alternate examinations with adequate accessibility are described and justified in the detailed inservice inspection program.

6.6.3 Examination Techniques and Procedures

The examination techniques and procedures described in Section XI of the ASME Code are used to the extent possible. Specific exceptions to the above are identified, and alternate techniques and procedures are described and justified in the detailed inservice inspection program.

6.6.4 Inspection Intervals

An inspection schedule for Class 2 and 3 system components is developed with the guidance of Section XI, Subarticles IWC-2400 and IWD-2400, respectively.

6.6.5 Examination Categories and Requirements

Inservice inspection categories for Class 2 and 3 system components are in agreement with Section XI, Articles IWC-2000 and IWD-2000, respectively. Whenever the requirements of the category cannot be met, the specific exception is identified and alternate requirements are justified in the detailed inspection program.

6.6.6 Evaluation of Examination Results

Evaluation of the examination results of Class 2 and 3 components is in accordance with Articles IWA-3000 and IWC-3000 of Section XI, respectively. Repair procedures for Class 2 and 3 components comply with requirements of Articles IWC-4000 and IWD-4000, respectively.

6.6.7 System Pressure Test

The program for Class 2 and 3 system pressure testing complies with the criteria of Articles IWC-5000 and IWD-5000, respectively.

6.6.8 Augmented Inservice Inspection To Protect Against Postulated Piping Failures

Longitudinal and circumferential welds in high-energy fluid system piping between containment isolation valves (discussed in Subsection 3.6.2) receive an augmented inservice inspection to the extent practicable. For closed systems inside containment, where no inboard isolation valve is provided, the augmented inspection program is applied to the piping between the outboard valve and the first rigid pipe connection to the containment penetration or the first pipe whip restraint inside containment. Any protective measures for these piping systems, such as structures and guard pipes, are designed to the extent feasible so as not to prevent inservice inspection as specified in Section XI of the ASME Code. The augmented inservice examination completed during each inspection interval includes 100% volumetric examination of the entire length of the circumferential and longitudinal pipe welds between containment isolation valves. If a guard pipe is used, inspection ports are provided in the guard pipe to permit inspection of circumferential welds.

6.6.9 Code Exemptions

Exemptions from the ASME Code examination requirements, as permitted by IWC-1220, are listed in the inservice inspection program.

6.6.10 Relief Requests

Requests for relief from the ASME Code requirements are evaluated in accordance with Section 50.55a of 10 CFR 50.