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OPERATING GUIDELINES FOR SMALL BREAKS
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2.1 If the ESFAS has been initiated automatically because of low RC pressure, immediately secure all RC pumps.

2.2 Verify control room indications support the alarms received, verify automatic actions, and carry out standard post-trip actions.

2.3 Balance high-pressure injection (HPI) flow between injection lines when HPI is initiated.

2.4 Verify that appropriate once-through steam generator (OTSG) level is maintained by feedwater control (low level limit with RC pumps operating, emergency level without RC pumps operating).

2.5 Monitor system pressure and temperature. If saturated conditions occur, initiate HPI.

2.6 If ESFAS has been bypassed due to heatup or cooldown, initiate safety injection.

CAUTION: If 50°F subcooling criteria is met, throttle HPI flow per Step 3.4. If RCS is not 50°F subcooled, continue full safety injection until 50°F subcooling is attained.

*May not occur on all small breaks.

3.0 PRECAUTIONS

3.1 If the ESFAS has been initiated on low RC presure, termination of RC pump operation takes precedence over all other immediate actions.

NOTE: If ESFAS has been actuated on high RB pressure, then monitor RC pressure and trip RC pumps once pressure decreases below the ESFAS low pressure setpoint.

3.2 If ESFAS has been initiated, the RC pump's tripped, and the RCS determined to be at least 50°F subcooled, the operator should establish as quickly as possible if the cause for the depressurization is due to either a LOCA or non-LOCA (overcooling) event. Proceed to Step 4.4 for non-LOCA events.

NOTE: With no RCPs running, the degree of subcooling is determined by averaging the five <u>highest</u> incore thermocouple temperature readings.

3.3 If the HPI system has actuated because of low pressure conditions, it must remain in operation until one of the following criteria is satisfied:

1. The LPI system is in operation and flowing at a rate in excess of 1000 GPM* in each line and the situation has been stable for 20 minutes.

or

2. All hot and cold leg temperatures are at least 50°F below the saturation temperature for the existing RCS pressure

and

the action is necessary to prevent the indicated pressurizer level from going off-scale high.

NOTE: If 50°F subcooling cannot be maintained, the HPI shall be reactivated.

NOTE: The degree of subcooling beyond 50°F and the length of time HPI is in operation shall be limited by the pressure/temperature considerations for the vessel integrity (see Section 3.4).

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*For Arkansas Nuclear One use 2630 GPM to either injection line.

3.4 Pressure/Temperature considerations for vessel integrity are dependent on whether or not RC pumps are operating as follows:

3.4.1 If RC pumps are operating, and the reactor coolant is ≥ 50°F subcooled, the reactor vessel downcomer pressure/temperature (P-T) combination shall be kept within the normal NDT limits of technical specifications.

NOTE: With one or more RC pumps operating use any cold leg RTD as an indication of reactor vessel downcomer temperature.

3.4.2 If NO RC pumps are operating, the RC pressure/temperature combination shall be kept within the no forced flow region of Figure 1.

NOTE: With NO RC pumps operating, the RC temperature shall be determined by averagining the five highest incore thermocouple temperature readings.

3.4.2.1 When the reactor coolant is ≥ 50°F subcooled, continually reduce the HPI flow rate to maintain the P/T limits of Figure 1.

NOTE: Maintaining the reactor coolant 50°F subcooled takes precedence over the Brittle Fracture Limit of Figure 1.

3.4.2.2 As soon as RC pressure/temperature is below the maximum limit of the DHRS, start the DHRS and maintain the RC pressure/temperature within the limits of the DHRS.

NOTE: Until the HPI flow is terminated, the temperature must be kept within the NO Forced Flow region of Figure 1.

3.5 Pressurizer level may be increasing due to RCS reaching saturated conditions or a break on top of the pressurizer.

3.6 If high activity is detected in a steam generator, isolate the leaking generator. It is recommended that both steam generators not be isolated.

3.7 Other indications which can confirm the existence of a LOCA:

3.7.1 RC drain tank (quench tank) pressure (rupture disk may be blown).

3.7.2 Increasing reactor building sump level.

3.7.3 Increasing reactor building temperature.

3.7.4 Increasing reactor building pressure.

3.7.5 Increasing radiation monitor readings inside containment.

3.7.6 Reactor coolant system temperature becoming saturated relative to the RCS pressure.

3.7.7 Hot leg temperature equals or exceeds pressurizer temperature.

3.7.8 Increase in the excore neutron detector indications.

NOTE: In conjunction with the indications in 3.10.1, this could be an indication of inadequate core cooling.

3.8 HPI cooling requirements could deplete the borated water storage tank, and initiation of LPI flow from the reactor building sump to the HPI pumps would be required.

3.9 Alternate instrument channels should be checked as available to confirm key parameter readings (i.e., system temperatures, pressures and pressurizer level).

3.10 Maintain a temperature versus time plot and a corresponding temperature pressure plot on a saturation diagram. Using hot leg RTD's and highest incore thermocouple reading, these plots will make it possible to track the plant's condition through plant cooldown.

3.10.1 If either of the following indications of inadequate core cooling exist, go to Section 4.5.

1. Hot leg RTD's read superheated for the existing RCS pressure.
2. Incore thermocouple temperature reads superheated for the existing RCS pressure.

3.10.2 If primary temperature and pressure is decreasing along the saturation curve then subcooled conditions will be established. This will be indicated by primary system pressure no longer following the saturation curve, as primary system temperature decreases. When this occurs, primary system pressure should be controlled by adjusting HPI flow, to maintain 50°F subcooling. The degree of subcooling beyond 50°F shall be controlled within the limits defined in Section 3.4.

3.11 Component cooling water (CCW) and seal injection should be maintained to the RC pumps to insure continued service or the ability to restart the pumps at a later time.

3.11.1 Normal limits and precautions apply for RC pump operation.

3.11.2 If the RC pumps are tripped for any reason, seal injection should be maintained to ensure long term seal integrity.

4.0 FOLLOWUP ACTIONS

4.1 Identification and Early Control

4.1.1 If HPI has initiated because of low pressure, control HPI in accordance with Steps 3.3 & 3.4.

4.1.2 If both HPI trains have not actuated on ESFAS signal, start second HPI train if possible. Balance HPI flows.

4.1.3 If RC pressure decreases continuously, verify that core flood tanks (CFTs) and low pressure injection (LPI) have actuated as needed, and balance LPI.

4.1.4 If cause for cooldown/depressurization is determined to be due to a non-LOCA overcooling event and the RCS is at least 50°F subcooled then proceed to Section 4.4.

4.1.5 Attempt to locate and isolate leak if possible. Letdown was isolated in Step 2.2. Other isolatable leaks are PORV (close block valve) and between valves in spray line (close spray and block valve).

4.1.6 Determine availability of reactor coolant pumps (RCPs) and main and auxiliary feedwater systems. If feedwater is not available, go to 4.2. If feedwater is available, go to 4.3.

4.2 Actions if Feedwater is not Available

4.2.1 Throughout the following steps maintain maximum HPI flow per Step 3.4 and restore feedwater as soon as possible.

4.2.2 If the subcooling margin is adequate and RCPs are operating, go to one pump. If RCPs are not operating, go to Step 4.2.5 below.

4.2.3 If RCS pressure increases, open PORV and leave open.

NOTE: If the PORV cannot be actuated, the safeties will relieve pressure.

4.2.4 When feedwater is recovered, restore OTSG levels in a controlled manner. Close PORV or block valve, if possible. Proceed to Step 4.3.2.

4.2.5 If no RCPs are operating, open PORV, maintain HPI flow.

NOTE: If the PORV cannot be actuated, the safeties will relieve pressure.

4.2.6 When feedwater flow is restored, raise OTSG levels to 95% on the operate range, close PORV or block valve, if possible.

NOTE: OTSG level should be monitored periodically during the fill process. Levels > 95% on the operating range must be avoided to preclude feedwater carryover to the steamlines.

4.2.7 Verify natural circulation in the RCS by observing:

4.2.7.1 Cold leg temperature is saturation temperature of secondary side pressure within approximately 5 minutes.

4.2.7.2 Primary ΔT (THOT-TCOLD) becomes constant.

4.2.8 Go to Step 4.3.4.1.

4.3 Actions with Feedwater Available to One or Both Generators

4.3.1 Maintain one RCP running per loop (stop other RCPs). If no RCPs operating (due to a loss of offsite power or due to manual securement per Section 2.0), go to Step 4.3.4 below.

4.3.2 Allow RCS pressure to stabilize.

4.3.3 Establish and maintain OTSG cooling by adjusting steam pressure via turbine bypass and/or atmospheric dumps. Cooldown at 100°F per hour to achieve an RC pressure of 250 psig. Refer to Precaution 3.10 for development of temperature and pressure plots. Isolate core flood tanks when 50°F subcooling is attained and RC pressure is less than 700 PSIG. Go into LPI cooling per Appendix A.

4.3.4 If RCPs are not operating:

4.3.4.1 Establish and control OTSG level to 95% on the operate range. Verify the conditions in Step 4.2.7.

NOTE: OTSG levels greater than 95% on the operating range must be avoided to preclude feedwater carryover into the steamlines.

4.3.4.2 If RC pressure is decreasing, wait until it stabilizes or begins increasing. If it begins increasing, go to Step 4.3.4.4.

4.3.4.3 Proceed with a controlled cooldown at 100°F/hr by controlling steam generator secondary side pressure. Monitor RC pressures and temperatures during cooldown and proceed as indicated below:

4.3.4.3.1 If RC pressure continues to decrease, following secondary side pressure decreases and with primary system temperatures indicating saturated conditions, continue cooldown until an RC pressure of 150 psi is reached, and proceed to Step A.4 of Appendix A.

4.3.4.3.2 If RC pressure stops decreasing in response to secondary side pressure decrease and reactor system becomes subcooled, check to see that the following conditions are both satisfied:

A) All hot and cold leg temperatures are below the saturation temperature for the existing RCS pressure.

and

B) The hot and cold leg temperatures are decreasing in response to steam generator secondary temperature decrease.

If these conditions are satisfied and remain satisfied, continue cooldown to achieve an RCS temperature (cold leg) of 280°F, and proceed to Step A.1 of Appendix A.

NOTE: If the conditions above are met below 700 PSIG, the core flood tanks should be isolated.

4.3.4.3.3 Start a reactor coolant pump, if the primary system is 50°F subcooled in both hot and cold legs and primary system pressure is above 150 PSIG. If the 50°F subcooling margin is ever lost, immediately trip RCPs. If forced circulation is achieved, proceed to Step 4.3.

4.3.4.3.4 If RC pressure stops decreasing and the conditions of 4.3.4.3.2 are not met or cease to be met or if RC pressure begins to increase, then proceed to Step 4.3.4.4 below.

4.3.4.4 Restore RCP flow (one per loop) when possible per the instructions below. If RC pumps cannot be operated and pressure is increasing, go to Step 4.3.4.6.

4.3.4.4.1 If pressure is increasing, starting a pump is permissible at RC pressure greater than 1600 PSIG.

4.3.4.4.2 If reactor coolant system pressure exceeds steam generator secondary pressure by 600 PSIG or more "bump" one reactor coolant pump for a period of approximately 10 seconds (preferably in operable steam generator loop). Allow reactor coolant system pressure to stabilize. Continue cooldown. If reactor coolant system pressure again exceeds secondary pressure by 600 psi, wait at least 15 minutes and repeat the pump "bump". Bump alternate pumps so that no pump is bumped more than once in an hour. This may be repeated, with an interval of 15 minutes, up to 5 times. After the fifth "bump", allow the reactor coolant pump to continue in operation.

4.3.4.4.3 If pressure has stabilized for greater than one hour, secondary pressure is less than 100 PSIG and primary pressure is greater than 250 PSIG, bump a pump, wait 30 minutes, and start an alternate pump.

4.3.4.5 If forced flow is established, go to Step 4.3.3.

4.3.4.6 If a reactor coolant pump cannot be operated and reactor coolant system pressure reaches 2300 PSIG, open pressurizer PORV to reduce reactor coolant system pressure. Reclose PORV when RCS pressure falls to 100 psi above the secondary pressure. Repeat if necessary. If PORV is not operable, pressurizer safety valves will relieve overpressure.

4.3.4.7 Maintain RC pressure as indicated in 4.3.4.6 if pressure increases. Maintain this cooling mode until an RC pump is started or steam generator cooling is established as indicated by establishing conditions described in 4.3.4.3.1 or 4.3.4.3.2. When this occurs, proceed as directed in those steps. Go to Step 4.3.2 if forced flow is established.

4.4 Non-LOCA Overcooling Transient with Feedwater Available

4.4.1 Immediately restart a RC pump in each loop if the RCS is 50°F subcooled.

4.4.2 Control steam pressure via turbine bypass or atmospheric dump valves to stabilize or control plant heatup.

NOTE: Considerable HPI may have been added to the RCS. Therefore, to prevent RCS from going solid, the above action may be necessary.

4.4.3 As long as the RCS is maintained 50°F subcooled, throttle HPI/MU and letdown flow to maintain pressurizer level at ∿ 100 inches.

4.4.4 Using turbine bypass valves and feedwater system, control steam generators as needed to limit plant heatup until RC pressure control can be re-established with the pressurizer.

NOTE: Cold RCS water may have been added to the pressurizer; therefore, a period of time may elapse before normal RC pressure control can be established with the pressurizer heaters.

4.4.5 Once pressure control is re-established, use normal heatup/cooldown procedure to establish desired plant conditions.

4.5 Actions for Inadequate Core Cooling

4.5.1 Immediate steps for inadequate core cooling

NOTE: If RC pumps are running, do not trip pumps. This supercedes instructions in Section 2.1.

4.5.1.1 Verify HPI/LPI systems are functioning properly with maximum flow. Start makeup pump(s), if possible, to increase injection flow.

4.5.1.2 Verify steam generator level is being controlled at 95% on operate range.

CAUTION: Reference leg boiling could give false level indication.

4.5.1.3 Depressurize operative steam generator(s) to establish a 100°F/hr decrease in secondary saturation temperature.

4.5.1.4 Ensure core flood tank isolation valves are open.

4.5.1.5 If reactor coolant system pressure increases to 2300 PSIG open pressurizer PORV to reduce reactor coolant system pressure. Reclose PORV when RCS falls to 100 PSIG above the secondary pressure. Repeat if necessary. If PORV is not operable, pressurizer safety valves will relieve pressure.

4.5.1.6 Proceed immediately to 4.5.2.

4.5.2 When the indicated incore thermocouple temperatures or hot leg RTD temperatures are superheated for the existing RCS pressure, operator action shall be based on conditions determined from Figure 3, by a sample of the highest incore thermocouple temperature readings to determine the core exit thermocouple temperature.

NOTE: More than one thermocouple temperature reading should be used (for example use the average of 5).

4.5.3 When the incore thermocouple temperature has been determined per Section 4.5.2, go to the section indicated below.

Incore Thermocouple Temperature	Section
Incore Tc ≤ Saturation	4.1.6
Curve 1 ≤ Incore Tc < Curve 2 Figure 3	4.5.4
Incore Tc ≥ Curve 2 Figure 3	4.5.5

NOTE: The incore thermocouple temperature readings shall be continuously monitored. If the temperature is between saturation and Curve 1 Figure 3, only the preceeding actions will be taken until the indicated incore thermocouple temperatures return to saturation temperature for the existing RCS pressure or the temperature increases to Curve 1 Figure 3.

4.5.4 Actions for curve 1 ≤ Incore Tc < Curve 2 Figure 3.

4.5.4.1 If RC pumps are not operating, start one pump per loop (if possible). This instruction supersedes previous instructions to trip RC pumps.

NOTE: Do not bypass normal interlocks.

4.5.4.2 Depressurizer operative steam generator(s) as rapidly as possible to 400 PSIG or as far as necessary to achieve a 100°F decrease in secondary saturation temperature.

4.5.4.3 Open the PORV, as necessary, to maintain RCS pressure within 50 psi of steam generator secondary side pressure.

NOTE: If steam generator depressurization was not possible, open PORV and leave open.

4.5.4.4 Immediately continue plant cooldown by maintaining 100°F/hr. Decrease in secondary saturation temperature to achieve 150 PSIG RCS pressure.

CAUTION: If auxiliary feed pump is supplied by main steam, do not decrease pressure below that pressure necessary for auxiliary feed pump operation.

4.5.4.5 If the average incore thermocouple temperature increases to Curve 2 Figure 3 proceed immediately to Section 4.5.5.

4.5.4.6 When RCS pressure reaches 150 PSIG, go to Appendix "A".

4.5.5 Actions for Incore Tc ≥ Curve 2 Figure 3

4.5.5.1 If possible, start all RC pumps. Starting interlocks should be defeated if necessary.

NOTE: In order to minimize the possibility of a fire due to bypassing some interlocks, the following precautions should be observed: 1) Do not defeat the overload trip circuit and 2) If CCW is not restored to the motor within 30 minutes, trip the RC pump. It should be recognized that starting the RC pumps without cooling and/or injection water will probably fail the pump seals and may cause the pump shaft to break. However, some core cooling will be provided prior to destruction of the pump. Breakage of the pump shaft will not cause consequential damage outside of the pump.

4.5.5.2 Depressurize the operative steam generator(s) as quickly as possible to atmospheric pressure.

CAUTION: If auxiliary feed pump is supplied by main steam, do not decrease pressure below that pressure necessary for auxiliary feed pump operation.

4.5.5.3 Open the pressurizer PORV and leave open.

NOTE: The RCS will depressurize and the LPI system should restore core cooling.

4.5.5.4 When incore thermocouple temperatures return to the saturation temperature for the existing RCS pressure; and the LPI system is delivering flow, proceed as follows:

4.5.5.4.1 Close the pressurizer PORV; reopen if RCS pressure increases above 150 PSIG.

4.5.5.4.2 Decrease to two (2) RC pump operation (one per loop).

4.5.5.4.3 Isolate the core flood tanks.

4.5.5.4.4 Maintain steam generator pressure at atmospheric or as low as possible if maintaining auxiliary feed pump in operation off of main steam.

4.5.5.4.5 Control HPI per 3.3.

4.5.5.4.6 Monitor BWST level as lo-lo level limits are approached, align LPI system for suction from RB sump. Close the LPI BWST suction valves.

NOTE: If HPI is required per 3.3, align LPI and HPI in piggyback mode. Close HPI suction valves to BWST.

4.5.5.4.7 Go to Appendix "A".

APPENDIX A - LPI COOLING

A.1 Determine if primary coolant is at least 50°F subcooled. If not, go to Step A.3.

A.1.1 Start LPI pumps. If both pumps are operable, go to Step A.2. For one LPI pump operable maintain OTSG cooling and proceed as follows. The operable LPI pump will be used to maintain system inventory.

A.1.2 Obtain primary system conditions of ≤ 280°F and ≤ 250 PSIG.

A.1.3 Align the discharge of the operable LPI pump to the suctions of the HPI pumps and take suction from the BWST. If the BWST is at the low level alarm, align LPI suction from the RB sump and shut suction from BWST.

A.1.4 Start the operable LPI pump specified above. The HPI-LPI systems will now be in "piggy back" and HPI flow is maintaining system pressure.

A.1.5 Go to single RC pump operation.

A.1.6 When the second LPI pump is available, align it in the decay heat mode and commence decay heat removal. (Decay heat system flow greater than 1000 GPM)*. Secure remaining RC pump when decay heat removal is established.

CAUTION: Verify that adequate NPSH exists for the decay heat pump in the DH removal mode. If inadequate, transfer to LPI mode.

A.1.7 Reduce reactor coolant pressure to 150 PSIG by throttling HPI flow. Control RC temperature using the decay heat system cooler bypass to maintain system pressure at least 50 psi above saturation pressure, to assure that NPSH requirements for the decay heat pump are maintained.

A.1.8 Secure the HPI pump and shift the LPI pump supplying it to the LPI injection mode.

A.1.9 Reduce reactor coolant temperature to 100°F by controlling the decay heat system cooler bypass.

NOTE: If one of the LPI/decay heat pumps is lost, return to OTSG cooling using natural circulation or one reactor coolant pump. Go to A.1.1.

*For Arkansas Nuclear 1 use 2630 GPM.

A.2 Cooldown on Two LPI Pumps

A.2.1 Maintain RCS pressure at $\leq$ 250 PSIG and reduce RCS temperature to $\leq$ 280°F.

A.2.2 Align one LPI pump in the decay heat removal mode.

A.2.3 Secure one RC pump if two are operating.

A.2.4 Start the decay heat pump in the decay heat removal mode, and when decay heat system flow is greater than 1000 GPM*, secure the running RC pump.

A.2.5 Reduce RC pressure to 150 PSIG by throttling HPI flow. Control RC temperature to maintain at least 50 psi margin to saturation pressure.

A.2.6 Start the second LPI pump in the LPI injection mode. Secure HPI pump.

A.2.7 Shift LPI suction from the BWST to the reactor building sump when lo-lo level limits are approached.

A.2.8 Reduce reactor coolant temperature to 100°F by controlling the decay heat system cooler bypass.

NOTE: If one of the LPI/decay heat pumps is lost, return to OTSG cooling using natural circulation or one RC pump. Go to A.1.1.

A.3 Cool Down RC System at Saturation

A.3.1 Maintain RC pressure at $\leq$ 250 PSIG.

A.3.2 Align one LPI pump to suction of the HPI pumps and the suction to the reactor building sump. (Shut BWST suction valve for this pump.)

A.3.3 When the BWST level reaches the lo-lo level limits, start the LPI pump and shut the HPI pump suction from the BWST.

A. When primary system temperature becomes subcooled by at least 50°F, go to A.1.1.

A.4 Cooldown without Reactor Coolant Pumps

A.4.1 RCS initial conditions are: pressure 150 psi, temperature at saturation.

A.4.2 Align low pressure injection system for suction from reactor building sump and place into service.

*For Arkansas Nuclear 1 use 2630 GPM.

A.4.3 Balance LPI injection and control RC temperature with decay heat coolers.

A.4.4 Isolate core flood tanks.

A.4.5 Go to Step A.1.1 and follow the procedure given there, ignoring the instructions relating to RC pump operation.

PART II: SMALL BREAK PHENOMENA - DESCRIPTION OF PLANT BEHAVIOR

1.0 INTRODUCTION

A loss-of-coolant accident is a condition in which liquid inventory is lost from the reactor coolant system. Due to the loss of mass from the reactor coolant system, the most significant short-term symptom of a loss-of-coolant accident is an uncontrolled reduction in the reactor coolant system pressure. The reactor protection system is designed to trip the reactor on low pressure. This should occur before the reactor coolant system reaches saturation conditions. The existence of saturated conditions within the reactor system is the principal longer-term indication of a LOCA and requires special consideration in the development of operating procedures.

Following a reactor trip, it is necessary to remove decay heat from the reactor core to prevent damage. However, so long as the reactor core is kept covered with cooling water, core damage will be avoided. The ECCS systems are designed to respond automatically to low reactor coolant pressure conditions and take the initial actions to protect the reactor core. They are sized to provide sufficient water to keep the reactor core covered even with a single failure in the ECCS systems. Subsequent operator actions are required ultimately to place the plant in a long-term cooling mode. The overall objective of the automatic emergency core cooling system and the followup operator actions is to keep the reactor core cool.

A detailed discussion of the small break LOCA phenomenalogy is presented in this section. This discussion represents Part II of the operating procedure guidelines for the development of detailed operating procedures. Part I presents the more detailed step-by-step guidelines.

The response of the primary system to a small break will greatly depend on break size, its location in the system, operation of the reactor coolant pumps, the number of ECCS trains functioning, and the availability of secondary side cooling. RCS pressure and pressurizer level histories for various combinations of parameters are presented in order to indicate the wide range of system behavior which can occur for small LOCA's.

2.0 IMPACT OF RC PUMP OPERATION ON A SMALL LOCA

With the RC pumps operating during a small break, the steam and water will remain mixed during the transient. This will result in liquid being discharged out the break continuously. Thus, the fluid in the RCS can evolve to a high void fraction as shown in Figure 1. The maximum void fraction that the system evolves to, and the time it occurs, is dependent on the break size and location. Continued RC pump operation, even at high system void fractions, will provide sufficient core flow to keep cladding temperatures within a few degrees of the saturated fluid temperature.

Since the RCS can evolve to a high void fraction for certain small breaks with the RC pumps on, a RC pump trip by any means (i.e., loss of offsite power, equipment failure, etc.) at a high void fraction during the small break transient may lead to inadequate core cooling. That is, if the RC pumps trip at a time period when the system void fraction is greater than approximately 70%, a core heatup will occur because the amount of water left in the RCS would not be sufficient to keep the core covered. The cladding temperature would increase until core cooling is re-established by the ECC systems. For certain break sizes and times of RC pump trip, acceptable peak cladding temperatures during the event could not be assured and the core could be damaged. Thus, prompt operator action to trip the RC pumps upon receipt of a low pressure ESFAS signal is required in order to ensure that adequate core cooling is provided. Following the RC pump trip, the small break transient will evolve as described in the subsequent sections.

3.0 SMALL BREAKS WITH AUXILIARY FEEDWATER

There are four basic classes of break response for small breaks with auxiliary feedwater. These are:

1. LOCA large enough to depressurize the reactor coolant system.
2. LOCA which stabilizes at approximately secondary side pressure.
3. LOCA which may repressurize in a saturated condition.
4. Small LOCA which stabilizes at a primary system pressure greater than secondary system pressure.

The system transients for these breaks are depicted in Figure 2.

3.1 LOCA Large Enough to Depressurize Reactor Coolant System

Curves 1 and 2 of Figure 2 show the response of RCS pressure to breaks that are large enough in combination with the ECCS to pressurize the system to a stable low pressure. ECCS injection easily exceeds core boil-off and ensures core cooling. Curves 1 and 2 of Figure 3 show the pressurizer level transient. Rapidly falling pressure causes the hot legs to saturate quickly. Cold leg temperature reaches saturation somewhat later as RC pumps coast down or the RCS depressurizes below the secondary side saturation pressure. Since these breaks are capable of depressurizing the RCS without aid of the steam generators, they are essentially unaffected by the availability of auxiliary feedwater. Upon receipt of a low pressure ESFAS signal, the operator must trip all RC pumps and verify that all ESFAS actions have been completed. The operator must also balance HPI flows such that flow is available through all HPI injection nozzles even if only one HPI is available. The operator should also balance LIP flows, should the system be actuated, to ensure flow through both lines. The operator needs to take no further actions to bring the system to a safe shutdown condition. Rapid depressurization of the steam generators would only act to accelerate RCS depressurization. It is, however, not necessary. Restarting of the RC pumps is not desirable for this class of break.

Long-term cooling will require the operator to shift the LPI pump suction to the reactor building sump.

3.2 LOCA which Stabilizes at Approximately Secondary Side Pressure

Curve 3 of Figure 2 shows the pressure transient for a break which is too small in combination with the operating HPI to depressurize the RCS. The steam generators are, therefore, necessary to remove a portion of core decay heat. Although the system pressure will initially stabilize near the secondary side pressure, RCS pressure may eventually begin falling as the decay heat level decreases. Curve 3 of Figure 3 shows pressurizer level behavior. The hot leg temperature quickly equalizes to the saturated temperature of the secondary side and controls primary system pressure at saturation. The cold leg temperature may remain slightly subcooled. If the HPI refills and repressurizes the RCS, the hot legs can become subcooled. The immediate operator action is to trip the RC pumps upon receipt of the low pressure ESFAS signal and then verify ESFAS functions. The operator must then balance HPI in order to ensure flow through each high pressure injection line.

Followup action by the operator is to raise the emergency feedwater level to 95% on the operating range and check for established natural circulation. This is done by gradually depressurizing the steam generators. If this test fails, intermittent bumping of a RC pump should be performed as soon as one is available. Continued depressurization of the steam generators with natural circulation leads to cooling and depressurization of the RCS. The operator's goal is to depressurize the RCS to a pressure that enables the ECCS to exceed core boil-off, possibly refill the RCS, and to ultimately establish long-term cooling.

3.3 LOCA which may Repressurize in a Saturated Condition

Curve 4 of Figure 2 shows the behavior of a small break that is too small, in combination with the HPI, to depressurize the primary system. Although steam generator feedwater is available, the loss of primary system coolant and the resultant RCS voiding will eventually lead to interruption of natural circulation. This is followed by gradual repressurization of the primary system. It is possible that the primary system could repressurize as high as the pressurizer safety valve setpoint before the pressure stabilizes. This is shown by the dashed line in Curve 4. Once enough inventory has been lost from the primary system to allow direct steam condensation in the regions of the steam generators contacting secondary side coolant, the primary system is forced to depressurize to the saturation pressure of the secondary side.

Since the cooling capabilities of the secondary side are needed to continue to remove decay heat, RCS pressure will not fall below that on the secondary side. HPI flow is sufficient to replace the inventory lost to boiling in the core, and condensation in the steam generators removes decay heat energy. The RCS is in a stable thermal condition and it will remain there until the operator takes further action. The pressurizer level response is characterized by Curve 3 of Figure 3 during the depressurization, and Curve 4 of Figure 3 during the temporary repressurization phase. The dashed line indicates the level behavior if pressure is forced up to the pressurizer safety valve setpoint. During this transient, hot leg temperature will rapidly approach saturation with the initial system depressurization, and it will remain saturated during the whole transient. Cold leg temperature will approach saturation as circulation is lost, but may remain slightly subcooled during the repressurization phase of the transient. Later RCS depressurization could cause the cold leg temperatures to reach saturation. Subsequent refilling of the primary system by the HPI might cause temporary interruption of steam condensation in the steam generator as the primary side level rises above the secondary side level. If the depressurization capability of the break and the HPI is insufficient to offset decay heat, the primary system will once more repressurize. This decreases HPI flow and increases loss through the break until enough RCS coolant is lost to once more allow direct steam condensation in the steam generator. This cyclic behavior will stop once the HPI and break can balance decay heat or the operator takes some action.

The operator's immediate action is to trip the RC pumps upon receipt of the low pressure ESFAS signal and verify the completion of all ESFAS functions. The operator should then balance HPI flow. Following that, he should raise the steam generator level to 95% of the operating range and check for natural circulation. If it is positive, he should depressurize the steam generators, cool and depressurize the primary system, and attempt to refill it and establish long-term cooling. If the system fails to go into natural circulation, he should open the PORV long enough to bring and hold the RCS near the secondary side pressure. Once natural circulation is established or a RC pump can be bumped, he will be able to continue depressurizing the RCS with the steam generators and establish long-term cooling.

3.4 Small LOCA which Stabilizes at P > Psec

Curve 5 of Figure 2 shows the behavior of the RCS pressure to a break for which high pressure injection is being supplied and exceeds the leak flow before the pressurizer has emptied. The primary system remains subcooled and natural circulation to the steam generator removes core decay heat. The pressurizer never empties and continues to control primary system pressure. The operator needs to trip the RC pumps and ensure that ESFAS actions have occurred. Throttling of HPI is permitted only after RCS subcooling of 50°F has been established, the pressurizer has refilled, and natural or forced circulation has been verified. A restart of the RC pumps under these conditions is desirable for plant control.

3.5 Small Breaks in Pressurizer

The system pressure transient for a small break in the pressurizer will behave in a manner similar to that previously discussed. The initial depressurization, however, will be more rapid as the initial inventory loss is entirely steam.

The pressurizer level response for these accidents will initially behave like a very small break without auxiliary feedwater. The initial rise in pressurizer level shown in Figure 4 will occur due to the pressure reduction in the pressurizer and an insurge of coolant into the pressurizer from the RCS. Once the reactor trips, system contraction causes a decreasing level in the pressurizer. Flashing will ultimately occur in the hot leg piping and cause an insurge into the pressurizer. This ultimately fills the pressurizer. For the remainder of the transient, the pressurizer will remain full. Toward the later stages of the transient, the pressurizer may contain a two-phase mixture and the indicated level will show that the pressurizer is only partially full. Except for closing the PORV block valve, operator actions and system response are the same for these breaks as for similar breaks in the loops.

4.0 SMALL BREAKS WITHOUT AUXILIARY FEEDWATER

There are three basic classes of break response for small breaks without auxiliary feedwater. These are:

1. Those breaks capable of relieving all decay heat via the break.
2. Breaks that relieve decay heat with both the HPI injection and via the break.
3. Breaks which do not automatically actuate the HPI and result in system repressurization.

The system pressure transients for these breaks are depicted in Figure 5.

4.1 LOCA's Large Enough to Depressurize Reactor Coolant System

Class 1 (Curve 1 of Figure 5), RC system pressure decreases smoothly throughout the transient. For the larger breaks in this class, CFT actuation and LPI injection will probably occur. For the smaller breaks of this class only, CFT actuation will occur. Auxiliary feedwater injection is not necessary for the short-term stabilization of these breaks. The pressurizer level for this transient rapidly falls off scale. Operator action and plant response are similar to those described for this class of breaks with a feedwater supply.

4.2 LOCA's Which Reach a Semi-Stabilized State

For Class 2 (Curve 2 of Figure 5) breaks, the RC pressure will rapidly reach the low pressure ESFAS trip signal (about two to three minutes). With the HPI's on, a slow system depressurization will be established coincident with the decrease in core decay heat. No CFT actuation is expected. Auxiliary feedwater is not necessary for the short-term stabilization of these breaks. The pressurizer level for this transient rapidly falls off scale.

The operator needs to trip the RC pumps upon the low pressure ESFAS signal, verify completion of all ESFAS functions, and try to establish secondary side cooling. Balancing of the HPI must also be performed. If steam generator feedwater cannot be obtained and RCS pressure is increasing, the operator should open the PORV and provide all the HPI and makeup capability possible. The goal is to depressurize and cool the core with the ECCS, the PORV, and the break. If secondary side cooling is again established, the operator should verify natural circulation, and if unavailable, bump a RC pump to complete RCS cooldown with the steam generators. At this point, the PORV can be closed, the system refilled, and long-term cooling established.

4.3 Small LOCA's Which do not Actuate the ESFAS

Automatic ESFAS actuation will not occur for Class 3 (Curve 3 of Figure 5) breaks. Once the SG secondary side inventory is boiled off, system repressurization will occur as the break is not capable of removing all the decay heat being generated in the cor System repressurization to the PORV or the pressurizer safety ves will occur for smaller breaks in this class. For the "zero" break case, repressurization to the PORV will occur in the first five minutes. Operator action is required within the first 20 minutes to ensure core coverage throughout the transient. For the 177-FA lowered-loop plants, this action can be either manual actuation of the auxiliary feedwater system or the HPI system.

The establishment of auxiliary feedwater will rapidly depressurize the RCS to the ESFAS actuation pressure, and system pressure will stabilize at either the secondary side SG pressure or at a pressure where the HPI equals the leak rate. Upon receipt of the low pressure ESFAS signal, the operator must trip the RC pumps.

For the Class 3 breaks, pressurizer level response will be as shown in Figure 6. The minimum refill time for the pressurizer is that for the "zero" break and is shown in Figure 6. After initially drawing inventory from the pressurizer, the system repressurization will cause the pressurizer level to increase, possibly to full pressurizer level. Once the operator action to restore auxiliary feedwater has been taken, the system depressurization will result and cause an outsurge from the pressurizer. Complete loss of pressurizer level may result. For the smaller breaks in Class 3 which result in a system repressurization following the actuation of the HPI system, pressurizer level will increase and then stabilize.

Without auxiliary feedwater, both the hot and cold leg temperatures will saturate early in the transient and, for the Class 1 and 2 breaks, will remain saturated. For the Class 3 breaks, once auxiliary feedwater is established, the cold leg temperatures will rapidly decrease to approximately the saturation temperature corresponding to the SG secondary side pressure and will remain there throughout the remainder of the transient. Hot leg temperatures will remain saturated throughout the event.

The operator needs to manually initiate all ESFAS actions, balance HPI flow, and attempt to restore secondary side cooling. In the meantime, he should actuate the makeup pump and open the PORV in order to cool the core and limit the RCS repressurization. Once feedwater is available, he can close the PORV and continue the RCS cooldown and depressurization with the steam generators. If natural circulation has not been established, he can bump a RC pump to cause forced circulation. The goal is to depressurize to where the ECCS can refill the RCS and guarantee long-term cooling.

4.4 Small Breaks in Pressurizer

See the writeup for small breaks in pressurizer with feedwater.

Small breaks in the pressurizer will differ from those in the loops in the same manner as those previously described in the section addressing small breaks in the pressurizer with auxiliary feed. .

5.0 TRANSIENTS WITH INITIAL RESPONSE SIMILAR TO A SMALL BREAK

Several transients give initial alarms similar to small breaks. These transients will be distinguished by additional alarms and indications or subsequent system response.

Overcooling transients such as steam line breaks, increased feedwater flow, and steam generator overfill can cause RCS pressure decreases with low-pressure reactor trip and ESFAS actuation. But steam line breaks actuate low steam pressure alarms for the affected steam generator, and steam generator overfills result in high steam generator level indications. The overcooling transients will repressurize the primary system because of HPI actuation, and will return to a subcooled condition during repressurization. The immediate actions for both overcooling and small break transients are the same, including tripping of the RC pumps.

The operator will recognize overcooling events during repressurization, if not sooner, and is instructed to throttle HPI and restart the RC pumps, if subcooled conditions are established, by the small break operating instructions.

A loss-of-feedwater transient will result in a high reactor system pressure alarm but does not give an ESFAS actuation alarm.

A loss of integrated control system power transient starts with a high RC pressure trip. After the reactor trip, this becomes an overcooling transient and will give low reactor system pressure and possible ESFAS actuation. Steam generator levels remain high and the system becomes subcooled during repressurization.

Design features of the B&W NSS provide automatic protection during the early part of small break transients, thereby providing adequate time for small breaks to be identified and appropriate action taken to protect the system. The only prompt manual operator action required is to trip the RC pumps once the low pressure ESFAS signal is reached.

6.0 TRANSIENTS THAT MIGHT INITIATE A LOCA

There are no anticipated transients that might initiate a LOCA since the PORV has been reset to a higher pressure and will not actuate during anticipated transients such as loss of main feedwater, turbine trip, or loss of offsite power.

However, if the PORV should lift and fail to reset, there are a number of indications which differentiate this transient from the anticipated transients identified above. These include:

o ESFAS actuation
o Quench tank pressure/temperature/level alarms
o Saturated primary system o Rising pressurizer level

These additional signals will identify to the operator that in addition to the anticipated transient, a LOCA has occurred. In the unlikely event that small breaks other than a malfunctioning PORV occur after a transient, they can be identified by initially decreasing RCS pressure and convergence to saturation conditions in the reactor coolant. Small break repressurization, if it occurs, will follow saturation conditions. By remaining aware of whether the reactor coolant remains subcooled or becomes saturated after transients, the operator is able to recognize when a small break has occurred.

7.0 HPI THROTTLING

Maintaining adequate core cooling is the most important concern during a small break LOCA. This requires keeping the core covered with subcooled reactor coolant. Because of instrument errors, it is necessary to maintain a 50°F subcooling margin to saturation. During forced flow (RCPs on) the amount of subcooling can be determined by the hot and cold leg RTDs. However, with NO forced flow, the core exit thermocouples must be used to determine the amount of subcooling. During a small break LOCA, sufficient HPI flow is necessary to assure adequate core cooling. Therefore it is critical that HPI flow is not throttled unless the reactor coolant is greater than 50oF subcooled. Beyond 50°F subcooled, certain cases require throttling of HPI flow to avoid exceeding other limits. These cases are A. to ensure reactor vessel integrity, B. prevent pressurizer level from going off-scale high, and C. allow termination of HPI flow once LPI cooling is assured. Each of these cases is discussed in detail as follows:

A. Reactor Vessel Integrity

The RCS pressure/temperature combination must be kept within certain limits to assure reactor vessel integrity. These limits are dependent on whether there is 1. Forced Flow, or 2. NO Forced flow:

1. Forced Flow

As long as the reactor coolant pumps (RCPs) are running, the RCS pressure and temperature must be kept within the normal technical specification NDT limits (Region I & II of Figure 1). With RCPs running, any cold Leg RTD can be used to determine the temperature for comparison to the NDT limit.

Also, while the initial temperature drop will be determined by the size of the break, as soon as temperature control is achieved the rate of cooldown should be limited to ≤ 100°F/hr.

2. No Forced Flow

If the RCPs are NOT running, the RC pressure/temperature combination must be kept within the No Forced Flow region of Figure 1, (Region II). The "Interim Brittle Fracture Limit" of Figure 1 is based on an analysis of thermal shock to the reactor vessel wall. With no RCPs running, cold HPI water could enter the downcomer and stream down the reactor vessel wall with relatively little mixing with the vent valve flow. The resulting thermal shock to the reactor vessel wall could exceed the brittle fracture limit if the RCS pressure is not reduced below an allowable value within a certain amount of time. Recent analyses indicate that throttling the HPI flow to maintain the "Interim Brittle Fracture Limit" of Figure 1 will meet the required pressure limits. The "Interim Brittle Fracture Limit" of Figure 1 is based on several conservative assumptions, consequently, small violations of this limit are more tolerable than similar violations of the 50° subcooling margin. However, if the "Interim Brittle Fracture Limit" is exceeded, the RCS pressure should be reduced to regain the no forced flow operating region as quickly as possible.

Several actions are important to ensure that the brittle fracture limit is not exceeded during a small break LOCA. These include a.) continuous monitoring of thermocouple temperatures, b.) maintaining RCS pressure control and, c.) restoring natural circulation if possible.

a) Monitoring Thermocouple Temperatures

With no RCPs running, the average of the five highest thermocouple temperature readings should be used to determine the RC temperature for Figure 1. This will assure that the 50°F subcooling margin is maintained and that the brittle fracture limit is not exceeded.

b) RCS Pressure Control

With no RCPs running, throttling the HPI flow is the best method for gradually reducing RCS pressure. Also, without primary to secondary heat transfer, the rate of cooldown is dependent on HPI cooling through the break (opening the PORV is necessary only if the break is so small that RCS pressure begins increasing). Therefore, careful and consistent throttling of HPI flow is the only available means to ensure that the RC pressure/temperature combination re mains within the no forced flow operating region of Figure 1.

c) Restoring Natural Circulation

If RCPs are tripped, natural circulation should be obtained to provide some HPI mixing as well as providing good heat transfer from the primary to secondary coolant. With natural circulation, the cold HPI water will mix with cold leg flow and reduce the thermal shock to the reactor vessel. However, the RC pressure/temperature should still be maintained within the no forced flow operating region of Figure 1. Natural circulation is verified by (1) cold leg temperature is saturation temperature of secondary side pressure and (2) primary ΔT ($T_{Hot} - T_{Cold}$) becomes constant at 50°F. The brittle fracture concern is eliminated entirely when RCPs are running and RCS P/T is maintained within Tech Spec NDT limits. Therefore, as soon as 50°F subcooling is obtained in the RCS, a RCP should be restarted. Then the reactor vessel downcomer pressure/temperature should be kept within the normal NDT limits.

B. Prevent Pressurizer Level From Going Off-Scale High

Provided that the RCS is at least 50°F subcooled, HPI flow should be throttled if necessary to prevent the indicated pressurizer level from going off-scale high. Under these conditions, the primary system is solid. Continued HPI flow at full capacity may result in a solid pressurizer and would result in a lifting of the PORV and/or the pressurizer code safety valves. This may in turn lead to a LOCA. Thus, HPI flow should be throttled to maintain a stable inventory in the RCS. However, if the 50oF subcooling cannot be maintained, the HPI shall be immediately reactivated.

C. Termination of HPI Flow Once LPI Cooling is Assured

For certain small breaks, system depressurization will result in LPI actuation. Since the LPI is designed to provide injection at a greater capacity than the HPI, termination of the HPI is allowed. However, this action should only be taken if the flow rate through each line is at least 1000 gpm* and the situation has been stable for 20 minutes. The 20-minute time delay is included to ensure that the system will not repressurize and result in a loss of the LPI fluid. In the event of a core flooding line break, the LPI fluid entering the broken core flooding line will not reach the vessel. Thus, in order to ensure that fluid is continually being injected to the RV for all breaks, the LPI must be providing fluid through both lines. The 1000 gpm is equivalent to the flow from two HPI pumps and ensure that upon termination of the HPI pumps, adequate flow is being delivered to the RV.

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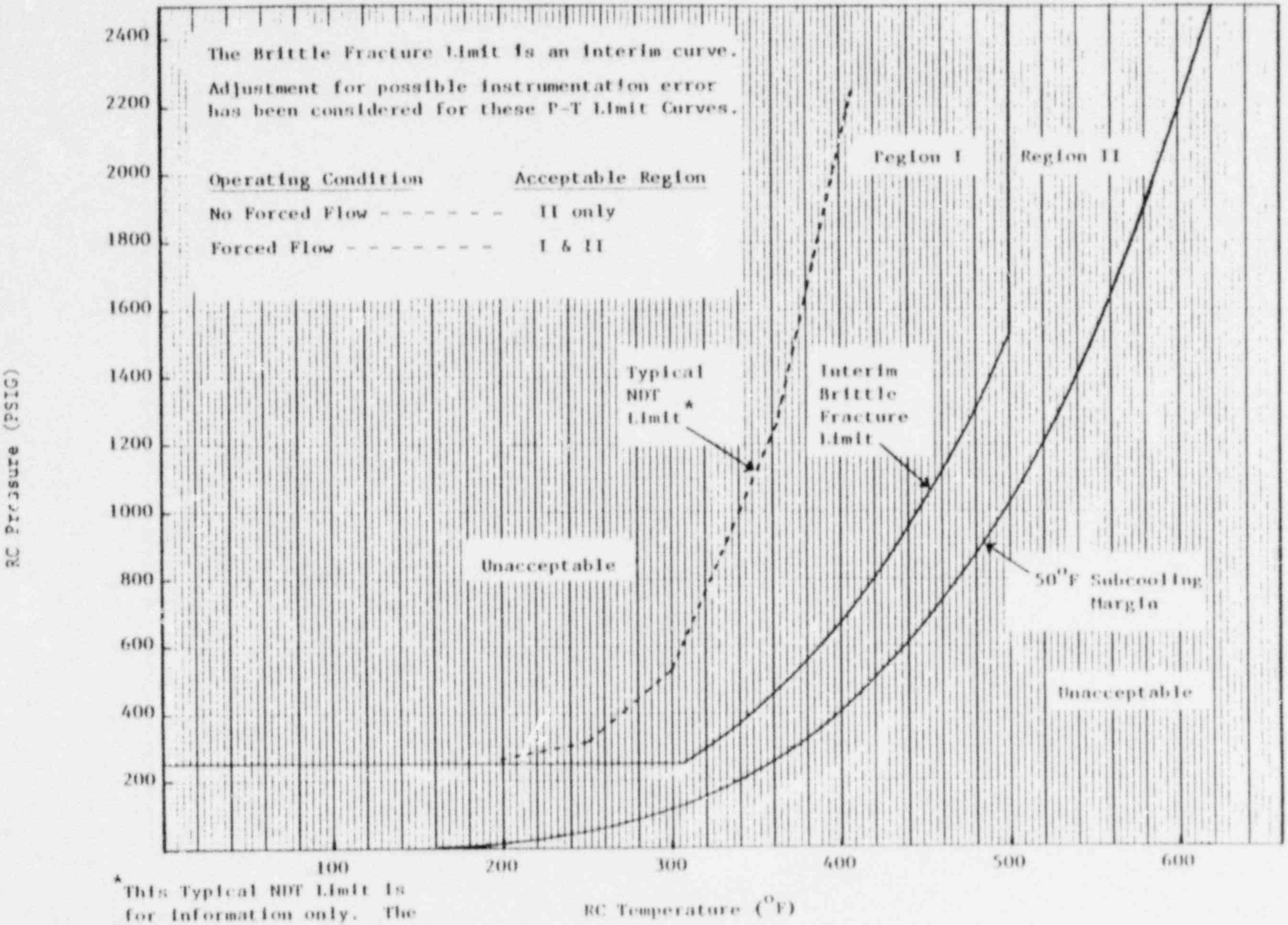
*For Arkansas Nuclear One use 2630 GPM to either injection line.

Figure 1: RC Pressure/Temperature Limits



The Brittle Fracture Limit is an interim curve.

Adjustment for possible instrumentation error has been considered for these P-T Limit Curves.

Operating Condition	Acceptable Region
No Forced Flow - - - - - - -	II only
Forced Flow - - - - - - - -	I & II

*This Typical NDT Limit is for information only. The plant specific curve should be optained from Tech. Spec.

FIGURE 2

PRESSURE VS TIME-SMALL BREAKS WITH AUXILIARY FEEDWATER

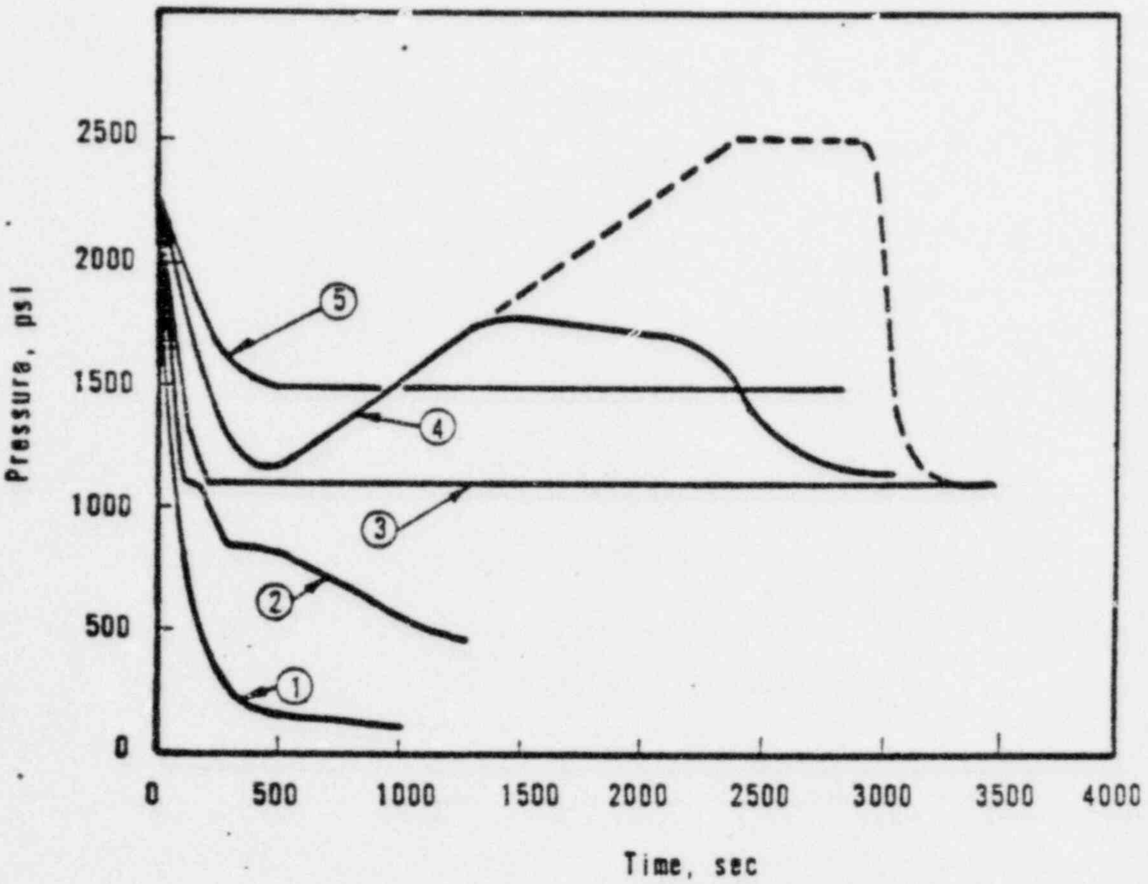


FIGURE 3

PRESSURIZER LEVEL VS TIME-SMALL BREAKS WITH AUXILIARY FEEDWATER

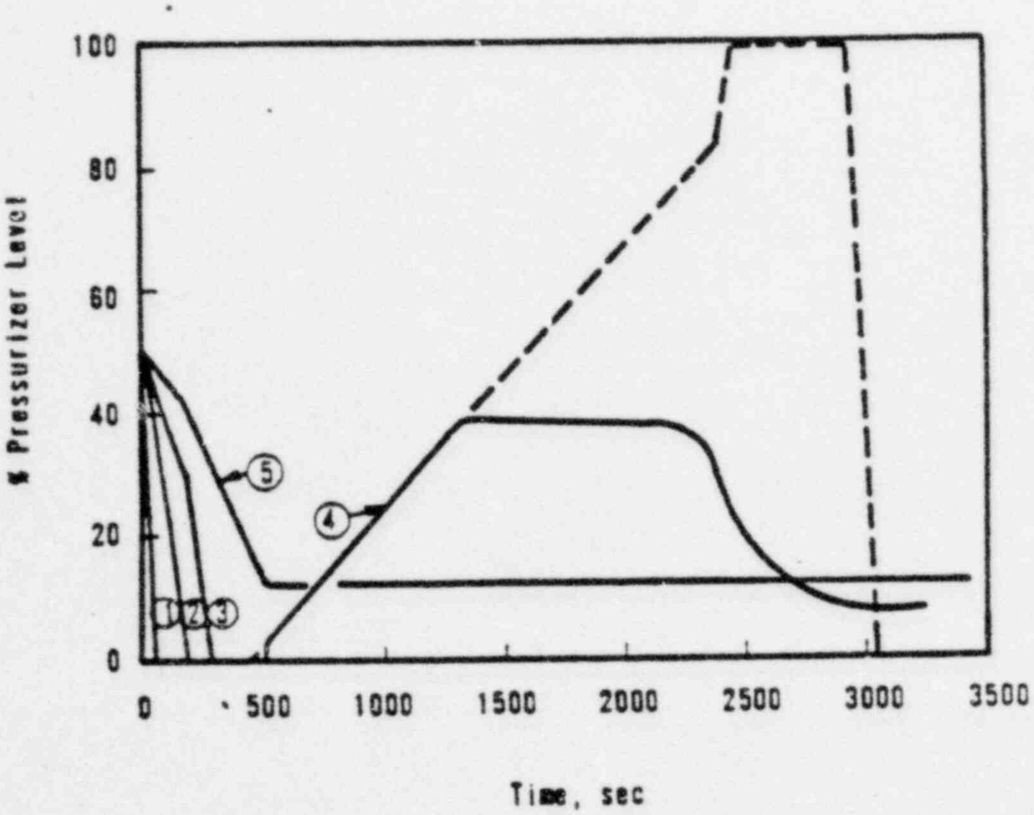


FIGURE 4

PRESSURIZER LEVEL VS TIME FOR SMALL BREAK IN PRESSURIZER

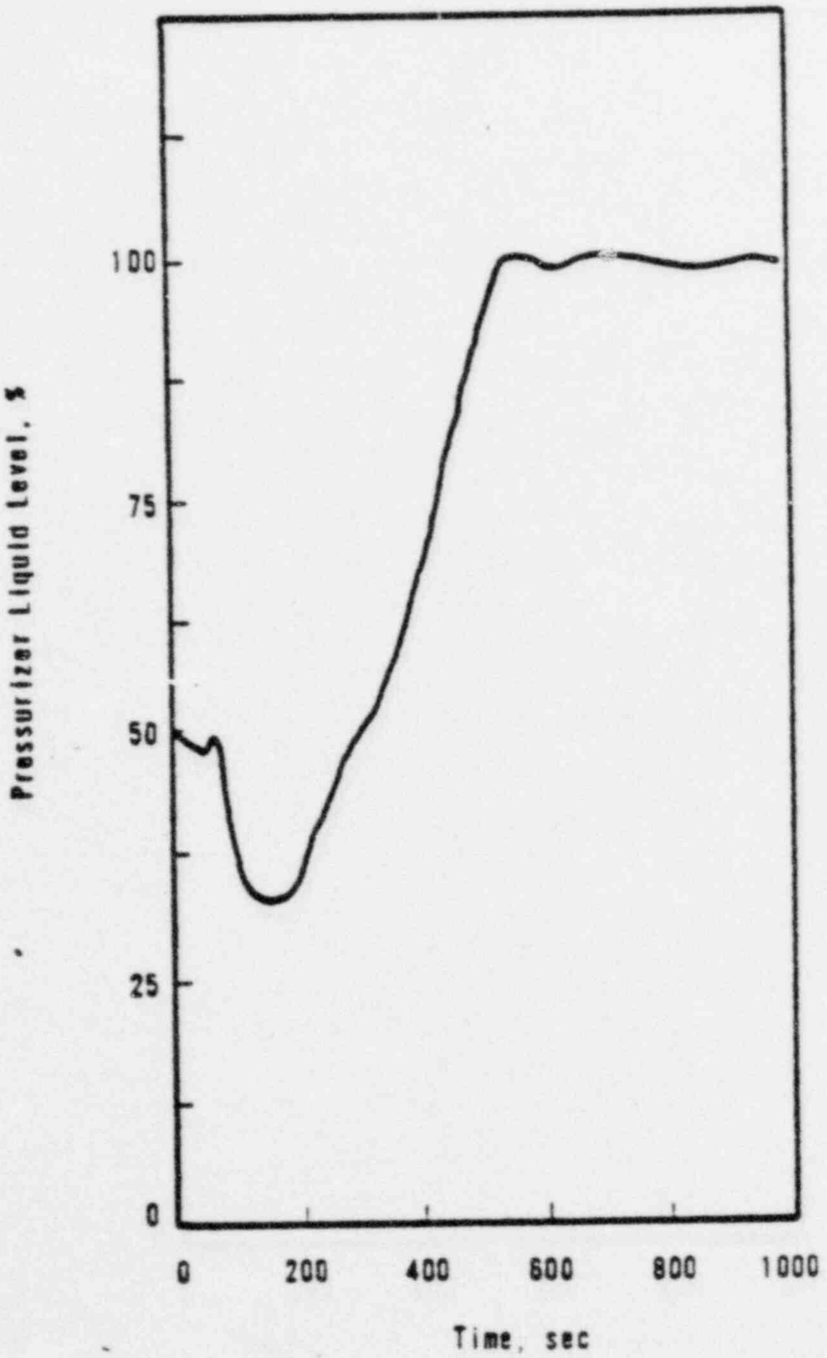


FIGURE 5

SYSTEM PRESSURE VS TIME-SMALL BREAKS
W/O AUXILIARY FEEDWATER

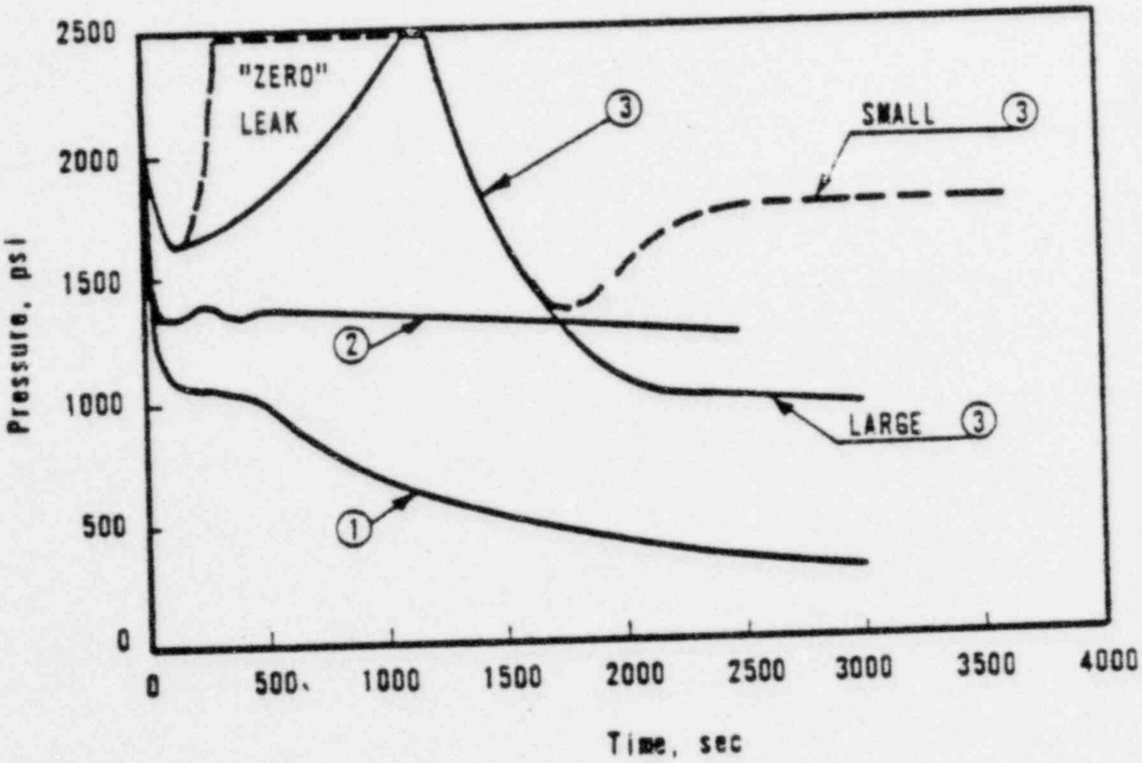
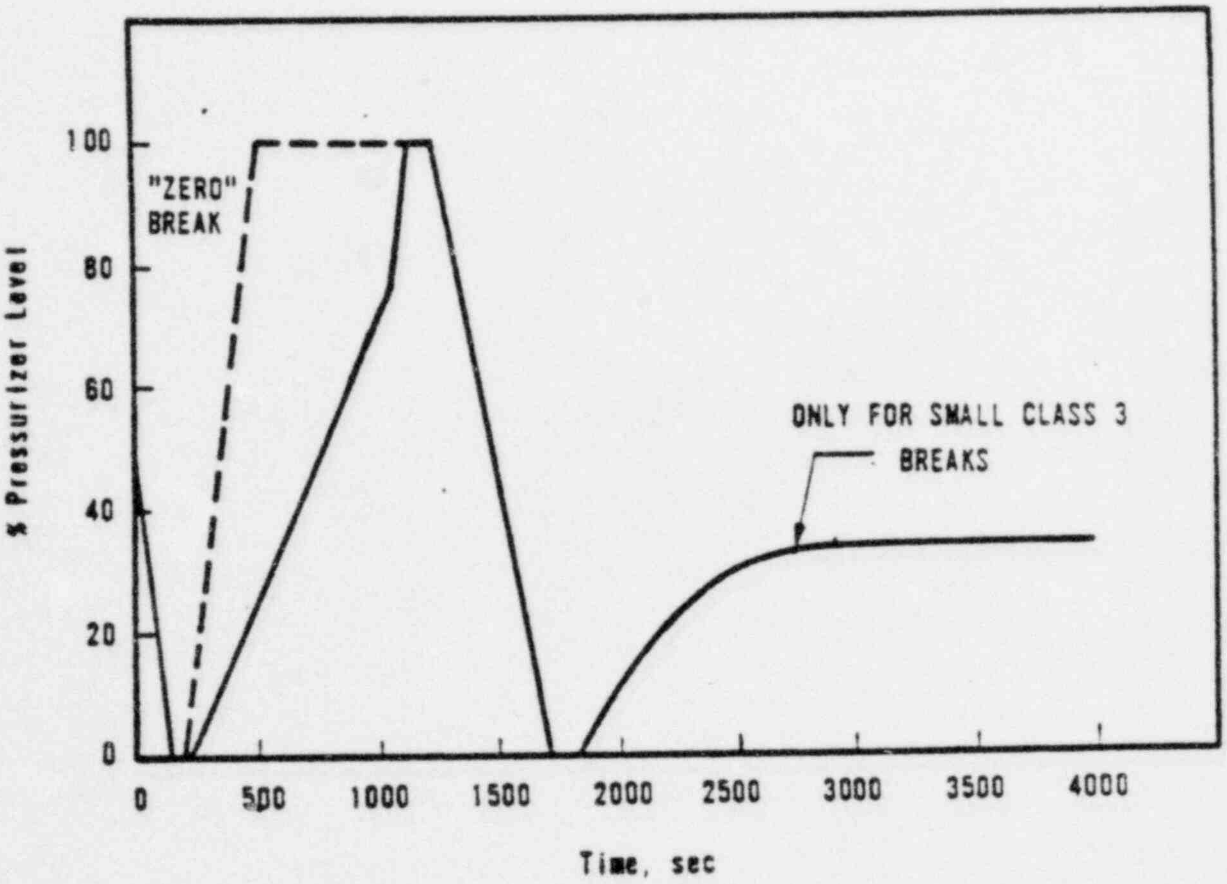


FIGURE 6

PRESSURIZER LEVEL VS TIME-CLASS 3
BREAKS W/O AUXILIARY FEEDWATER



APPENDIX A
INADEQUATE CORE COOLING - DESCRIPTION OF PLANT BEHAVIOR

1.0 INTRODUCTION

Following a loss-of-coolant accident (LOCA) in which the reactor trips, it is necessary to remove the decay heat from the reactor core to prevent damage. Core heat removal is accomplished by supplying cooling water to the core. The water which is available for core cooling is a portion of the initial reactor coolant system (RCS) water inventory plus any water injected by the emergency core cooling system (ECCS). The heat added to the cooling water is removed via the steam generator and/or the break.

As long as the reactor core is kept covered with a mixture of water and steam, core damage will be avoided. If the supply of cooling water to the core is decreased or interrupted, a lower mixture level in the core will result. If the upper portions of the core becomes uncovered, cooling for those regions will be by forced convection to superheated steam which is a low heat transfer regime. Continued operation in the steam cooling mode will result in elevated core temperatures and subsequent core damage.

2.0 LOSS OF RCS INVENTORY WITH REACTOR COOLANT PUMPS OPERATING

With the RC pumps operating during a small break, the steam and water will remain mixed during the transient. This will result in liquid being discharged out the break continuously. Thus, the fluid in the RCS can evolve to a high void fraction. The void fraction of the RCS indicates the ratio of the volume of steam in the RCS to the total volume of the RCS.

Since the RCS can evolve to a high void fraction for certain small breaks with the RC pumps on, a RC pump trip by any means (i.e., loss of offsite power, equipment failure, etc.) at a high void fraction during the small break transient may lead to inadequate core cooling. That is, if the RC pumps trip at a time period when the system void fraction is greater than approximately 70%, a core heatup will occur because the amount of water left in the RCS would not be sufficient to keep the core covered. The cladding temperature would increase until core cooling is re-established by the ECC systems. .For certain break sizes and times of RC pump trip, acceptable peak cladding temperatures during the event could not be assured and the core could be damaged. Thus, prompt operator action to trip the RC pumps upon receipt of a low pressure ESFAS signal is required in order to ensure that adequate core cooling is provided. Following the RC pump trip, the small break transient concerns about inadequate core cooling will be the same as described in the previous section.

If the RC pumps can not be tripped by the operator, the continued forced circulation of fluid throughout the RCS will keep the core cooled. However, if little or no ECCS is being provided to the RCS, the fluid in the RCS will eventually become pure steam due to the continued energy addition to the fluid provided by the core decay heat. Under these circumstances, an inadequate core cooling situation will exist. Since the heat removal process under forced circulation is better than the steam cooling mode described below for the pumps off situation, the operator actions and indications described in the subsequent section are sufficient for inadequate core cooling with the RC pumps operating.

3.0 LOSS OF RCS INVENTORY WITHOUT REACTOR COOLANT PUMPS OPERATING

Without the RC pumps operating, the cooling of the core is accomplished by keeping the core covered with a steam-water mixture. As the fluid in the core is heated, some of it or all of it may be turned to steam. If insufficient cooling water is available to maintain the steam-water mixture covering the core, the core exit fluid temperatures will begin to deviate from the saturation temperature corresponding to the pressure of the RCS. One immediate indication that inadequate core cooling may exist in the core is that the temperature of the core exit thermocouples and hot leg RTD's are superheated. At this condition inadequate core cooling is evident as the core will be partially uncovered. However, the degree of uncovery is not severe enough to cause core damage. This condition is not expected to occur but is not, by itself, a cause for extreme action. If the ECCS systems are functioning normally, the temperatures should return to saturation without any actions beyond those outlined for a small break. For incore thermocouple temperature indicating superheated conditions, the operator should (a) verify emergency cooling water is being injected through all HPI nozzles into the RCS, (b) initiate any additional sources of cooling water available such as the standby makeup pump, (c) verify the steam generator level is being maintained at the emergency level (d) if steam generator level is not at 95% of operating range raise level to the 95% level, (e) if the desired steam generator level cannot be achieved, actuate any additional available sources of feedwater such as startup auxiliary feedwater pump, (f) establish 100°F/hr cooldown of RCS via steam generator pressure control, (g) open core flooding line isolation valves if previously isolated, and (h) if RC pressure increases to 2300 psig open the pressurizer PORV to reduce RC pressure and reclose PORV when RC pressure falls to 100 psi above the secondary pressure. These actions are directed toward depressurization of the RCS to a pressure at which the ECCS water input exceeds core steam generation. The alignment of other sources of cooling water is the recognition that the injection of the HPI system alone is not sufficient to exceed core boil off.

If the incore thermocouple indications reach Curve #1 on Figure 3 in Part I, the peak fuel cladding temperature has reached approximately 1400°F. Above this temperature level there is a potential for cladding rupture. Also, the zircaloy cladding water reaction will begin to add a significant amount of heat to the fuel cladding thereby greatly increasing the possibility of core structural damage unless adequate core cooling is restored. Non-condensible gas formation will increase rapidly from this level of fuel clad temperature.

For incore thermocouple temperature indications at or exceeding Curve #1 on Figure 3 in Part I, the operator should (a) start one RC pump in each loop, (b) depressurize the steam generator as rapidly as possible to 400 psig or as far as necessary to achieve a 100°F decrease in saturation temperature, (c) immediately continue the plant cooldown by maintaining a 100°F/hr decrease in secondary saturation temperature to achieve 150 psig RC pressure, (d) open the pressurizer pilot operated relief valve (PORV), as necessary, to relieve RCS pressure and vent non-condensible gases. The operator action in starting the RC pumps will provide forced flow core cooling and will reduce the fuel cladding temperatures. The rapid depressurization of the steam generators will help to depressurize the primary system to the point where the core flooding tanks will actuate. Stopping the depressurization at 400 psig (or at a reduction in saturation temperature of 100°F) will maintain the tube to shell temperature difference within the 100°F design limit. The continued cooldown to 150 psig will reduce the primary system pressure to the point where the Low Pressure Injection System can supply cooling. The opening of the PORV will also help to depressurize the primary system. The PORV should be closed when the primary pressure is within 50 psi of the secondary pressure and then should only be used as necessary to maintain the primary system pressure at no greater than 50 psi above the secondary system pressure. This method of operation will minimize the loss of water from the primary system through the PORV.

If the incore thermocouple readings reach Curve #2 on Figure 3 in Part I, the peak cladding temperature is approximately at the 1800°F level. This is a very serious condition. At this level of clad temperature, significant amounts of non-condensible gas are being generated and core damage may be unavoidable. Extreme measures are required by the operator to prevent major core damage. The goal of these actions is to depressurize the RCS to a level where the core flooding tanks will fully discharge and the LPI system can be actuated thus providing prompt core recovery. The operator should (a) depressurize the steam generators as rapidly as possible, (b) start the remaining RC pumps and (c) open the PORV and leave it open.

For a very small or non-LOCA event, the core decay heat removal is accomplished via the steam generators. If that heat removal is decreased or lost, the natural circulation of fluid within the RCS may be reduced or stopped. The loss of natural circulation for core cooling will eventually boil off the remaining water inventory in the core and lead to inadequate core cooling and elevated core temperature. Indications of loss of steam generator heat sink include (a) a low level in the steam generator with low steam pressure, (b) temperature indicators in hot legs show saturated temperatures, (c) increasing RCS pressure. The operator should try to establish emergency feedwater as quickly as possible and immediately actuate the HPI system to restore natural circulation and RCS heat removal. If auxiliary feedwater is not available and there is no break in the RCS, the system will repressurize and decay heat will be removed by opening the PORV and maximizing HPI addition.