# BACKGROUND INFORMATION

# FOR

# AP600

# SHUTDOWN

# EMERGENCY RESPONSE GUIDELINE

## SDG-1

## AP600 RESPONSE TO LOSS OF RCS INVENTORY

## DURING SHUTDOWN

**Rev. 2**

**July 31, 1996**


**WESTINGHOUSE ELECTRIC CORPORATION**
**ENERGY SYSTEMS BUSINESS UNIT**
**ADVANCED TECHNOLOGY BUSINESS AREA**
**P.O. BOX 355**
**PITTSBURGH, PENNSYLVANIA 15230**

## TABLE OF CONTENTS

## 1.0 INTRODUCTION

Guideline SDG-1, RESPONSE TO LOSS OF RCS INVENTORY DURING SHUTDOWN, is a Shutdown Guideline (SDG) that provides procedural guidance to maintain core cooling and to protect the reactor core in the event that RCS inventory is lost during plant shutdown conditions.

There is only one explicit transition to guideline SDG-1. It is from the Shutdown Safety Status Tree, SDF-0.1, on an ORANGE priority when the operator determines that either PRZR level is less than the CMT actuation setpoint SL01, or if RCS hot leg level is less than the IRWST injection setpoint SL02 while the SL01 signal is blocked.

After all of the appropriate actions in guideline SDG-1 are completed, the operator is instructed to return to the appropriate plant procedure after RNS is restored, or is instructed to evaluate plant status and return to the appropriate plant procedure if RNS is not restored.

## 2.0 DESCRIPTION

Guideline SDG-1, RESPONSE TO LOSS OF RCS INVENTORY DURING SHUTDOWN, provides actions to respond if RCS inventory is lost during Modes 5 and 6 plant shutdown conditions (i.e., when there is fuel in the reactor). This guideline is entered on an ORANGE priority from the Shutdown Safety Status Tree if the operator determines that either PRZR level is less than the CMT actuation setpoint SL01, or if RCS hot leg level is less than the IRWST injection setpoint SL02 while the SL01 signal is blocked. RCS inventory greater than SL02 is required to support RNS shutdown core cooling when required. Shutdown core cooling is needed at all times in Mode 5 and in Mode 6 when there is fuel in the vessel.

There are two plant conditions addressed in this guideline for a loss of RCS inventory during shutdown. These are: 1) with an open RCS, with an open RCS being defined as any opening in the RCS that cannot be readily closed from the control room, including an opened SG manway isolated from the RCS via the SG nozzle dams; and 2) a closed RCS, with a closed RCS being defined as an RCS secured (except for openings that can be closed from the control room) and filled (including the SG and PRHR tubes) to/above the low pressurizer level CMT actuation setpoint.

The response is different for each of these plant conditions; however, they all have the common goal of restoring RCS inventory and RNS cooling. The operator cannot exit this guideline without re-establishing RNS cooling.

Unless an alternate heat sink is established that directs reactor decay heat outside containment using either an SG or the spent fuel pit cooling system, decay heat is transferred to the containment atmosphere by allowing the RCS/IRWST fluid to heatup and boil. Potential actions with control grade systems or components to cool the containment atmosphere include operation of the containment fan coolers which include operation of the Central Chilled Water System, Component Cooling System and Service Water System.

## 3.0 RECOVERY/RESTORATION TECHNIQUE

The objective of the recovery/restoration technique incorporated into guideline SDG-1 is to provide actions for responding to a loss of RCS inventory and RNS cooling.

The following subsections provide a summary of the major action categories of operator actions and the key utility decision points for guideline SDG-1, RESPONSE TO LOSS OF RCS INVENTORY DURING SHUTDOWN.

### 3.1 High Level Action Summary

A high level summary of the actions performed in SDG-1 is given on the following page in the form of major action categories. These are described below in more detail.

- Actions To Feed The RCS If The RCS Is Open

  An open RCS is defined as any opening in the RCS that cannot be readily closed from control room, including an opened SG manway isolated from the RCS via the SG nozzle dams. The RCS should also be considered open, or the actions for an open RCS should be taken, if the RCS (including the SG and PRHR heat exchanger tubes) is not filled to the pressurizer low level CMT actuation setpoint.

  The first action taken under open RCS conditions is refilling the RCS inventory to greater than the RCS hot leg low level IRWST actuation setpoint (SL02). In addition to establishing/maintaining adequate RCS inventory, the actions taken include verifying ADS valves stages 1 to 3 are open and an attempt to restore RNS cooling. If RNS cooling cannot be established, then actions are initiated to protect personnel inside containment, establish containment closure and start available containment fan coolers.

- Actions To Feed The RCS If The RCS Is Closed

  The RCS is considered closed if RCS conditions are other than those as defined above for an open RCS. The actions taken under closed RCS conditions include checking and maintaining RCS inventory greater than the pressurizer low level CMT actuation setpoint (SL01) and an attempt to restore RNS cooling. If pressurizer level cannot be maintained greater that the low level CMT actuation setpoint (SL01), then CMT injection valves are verified open, ADS actuation is verified when the CMTs drain to the appropriate setpoints and the IRWST level is checked to determine if the containment sump recirculation valves should be opened. If RNS cooling cannot be established, then actions are taken to establish an RCS heat sink using either the SGs or PRHR, and actions are also initiated to protect personnel inside containment, establish containment closure and start available containment fan coolers.

## MAJOR ACTION CATEGORIES IN SDG-1

- Actions To Feed The RCS If The RCS Is Open
- Actions To Feed The RCS If The RCS Is Closed

### 3.2 Key Utility Decision Points

There is one key utility decision point in this guideline when the operator must initiate actions to protect personnel inside containment. In Steps 9 and 25, the operator is instructed to evacuate non-essential personnel inside containment. The operator will have to determine which personnel must be evacuated from containment at this time in the guideline.

## 4.0 DETAILED DESCRIPTION OF GUIDELINE

This section provides a very detailed discussion of the generic guideline SDG-1 to facilitate procedure writing and training efforts. By presenting guideline background information in greater detail through the use of a structured format (i.e., step description tables and step sequence tables), applicability can be more easily determined. The separate and unique subsections containing this information follow.

### 4.1 Detailed Description of Steps, Notes, and Cautions

This section contains a one-page (or more) step description table for each separate guideline step, note, and caution. Notes and cautions are always presented relative to the step they precede.

The Step Description Tables for the steps and associated notes and cautions of guideline SDG-1 are presented on the following pages.

STEP 1

STEP: Check If RNS Pumps Should Be Stopped

PURPOSE: To stop the RNS pumps if RCS level is not adequate to support pump operation or if the pumps are cavitating.

BASIS:

Inadequate level in the RCS hot leg will result in pump cavitation and air ingestion. If air is ingested into the suction of the RNS pumps, the pumps are likely to start cavitating. The symptoms of cavitation are typically erratic behavior of pump current (oscillations between high amperage values and low amperage values), erratic behavior of pump flow and excessive pump noise. Pump suction pressure in the MCR will also oscillate. If any plant personnel are in the immediate vicinity of the pumps, loud audible noises may be heard when air ingestion starts. If no actions are taken, damage to the pumps may occur due to vibration and the pumps may eventually seize and stop running. As soon as the operator is aware that cavitation is occurring, actions should be initiated to protect the RNS pumps. The operator should stop the RNS pumps until the proper operating conditions are reestablished.

ACTIONS:

- Check if RNS pumps are running
- Determine if RCS hot leg level less than SL02
- Determine if RNS pumps are cavitating
- Stop RNS pumps if cavitating
- Go to Step 2 if RNS pumps not cavitating

INSTRUMENTATION:

- RCS hot leg level
- RNS pump operation status

CONTROL/EQUIPMENT:

Controls for RNS pumps

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

SL02 - Enter RCS low level IRWST actuation setpoint

STEP 2

STEP: Verify RCS Drain Path Isolation

PURPOSE: To isolate RCS drain paths to prevent further loss of RCS inventory.

BASIS:

A possible cause for the loss of RCS inventory could be attributed to excessive draining of the RCS. The two main paths that the operator can control from the main control room are the letdown path and the RNS IRWST return path. To prevent further reduction in RCS inventory, the operator should verify both paths are isolated.

ACTIONS:

- Verify RNS IRWST return line isolation
- Isolate RNS IRWST return line
- Verify letdown isolation
- Isolate letdown

INSTRUMENTATION:

- RNS IRWST return line status
- Letdown status

CONTROL/EQUIPMENT:

- Controls for RNS IRWST return line
- Controls for letdown

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

N/A

STEP 3 - NOTE

NOTE: The RCS is considered open when an opening exists that cannot be closed from the control room such as a SG manway.

PURPOSE: To remind the operator that the RCS is considered open if an opening exists that cannot for isolated from the control room.

BASIS:

An open RCS is defined as any opening in the RCS that cannot be readily closed from control room, including an opened SG manway isolated from the RCS via the SG nozzle dams.

ACTIONS:

N/A

INSTRUMENTATION:

N/A

CONTROL/EQUIPMENT:

N/A

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

N/A

STEP 3

STEP: Check RCS Status - OPEN

PURPOSE: To determine if the RCS is open

BASIS:

An open RCS is defined as any opening in the RCS that cannot be readily closed from control room, including an opened SG manway isolated from the RCS via the SG nozzle dams. The RCS should also be considered open, or the actions for an open RCS should be taken, if the RCS (including the SG and PRHR heat exchanger tubes) is not filled to the pressurizer low level CMT actuation setpoint.

ACTIONS:

Determine if RCS is open

INSTRUMENTATION:

N/A

CONTROL/EQUIPMENT:

N/A

KNOWLEDGE:

The operator should understand what is meant by an open RCS.

ADDITIONAL INFORMATION:

N/A

STEP 4

STEP: Verify Stage 1, 2, and 3 ADS Valves - OPEN

PURPOSE: To ensure an adequate RCS vent path is open to containment

BASIS:

In the April 10, 1987 event at Diablo Canyon Unit 2, the RCS reached boiling in 30 to 45 minutes. More importantly, this boiling caused RCS pressurization which was unanticipated. An RCS configuration can be postulated, with a blocked hot leg and a opening in the cold leg, which can result in the core being rapidly uncovered following initiation of boiling. Severe core damage can follow as soon as adiabatic heatup of the core reaches the point of rapid zirc-water chemical reaction.

By ensuring the Stage 1, 2 and 3 ADS valves are open ensures an adequate RCS hot leg vent path (via the PRZR surge line) is provided to prevent RCS pressurization and possible core uncovery as described above.

ACTIONS:

- Verify Stage 1, 2, and 3 ADS valves are open
- Manually open valves

INSTRUMENTATION:

ADS valve position indication

CONTROL/EQUIPMENT:

Manual ADS valve controls

KNOWLEDGE:

If the Protection and Safety Monitoring System (PMS) is unsuccessful in opening the ADS valves, the operator should be aware that the Diverse Actuation System (DAS) has provisions for manually opening the ADS valves from the DAS panel.

ADDITIONAL INFORMATION:

N/A

STEP 5 - CAUTION - 1

CAUTION - 1: Personnel working in containment should be warned before refilling the RCS to avoid inadvertent contamination of personnel working near RCS openings

PURPOSE: To avoid personnel contamination from potentially radioactive gases or steam vapor when filling an open RCS

BASIS:

Refilling the RCS may purge out radioactive vapors or gases from any open RCS vents and contaminate personnel in the area. Therefore personnel working in the vicinity of any RCS openings should clear the area prior to filling the RCS.

ACTIONS:

N/A

INSTRUMENTATION:

N/A

CONTROL/EQUIPMENT:

N/A

KNOWLEDGE:

The operator should be cognizant of RCS opening locations and any work going on in these areas

ADDITIONAL INFORMATION:

N/A

STEP 5 - CAUTION - 2

CAUTION - 2: Only borated water should be added to the RCS to maintain adequate shutdown margin

PURPOSE: To inform the operator that inadvertant dilution of the RCS, without RNS, may result in a loss of (localized) shutdown margin while adding RCS makeup

BASIS:

Although the coolant boron should remain in the RCS (as opposed to transferring with the boiled-off steam) borated makeup should be added to the RCS to maintain localized shutdown margin since mixing in the RCS will be minimal under a loss of RNS conditions. The decay heat/boil-off rates during this time are low enough that boron precipitation is not a concern.

ACTIONS:

N/A

INSTRUMENTATION:

N/A

CONTROL/EQUIPMENT:

N/A

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

N/A

## STEP 5 - CAUTION - 3

CAUTION - 3: If RCS hot leg level remains less than (SL02) for greater than 30 minutes, automatic alignment for IRWST injection should be verified.

PURPOSE: To remind the operator that automatic alignment for IRWST injection will occur if RCS hot leg level remains less than (SL02) for greater than 30 minutes.

BASIS:

The IRWST will automatically align for injection to the RCS if RCS hot leg level remains less than (SL02) for greater than 30 minutes. If this happens, the operator should verify the proper alignment for IRWST injection.

ACTIONS:

N/A

INSTRUMENTATION:

RCS hot leg level indication
IRWST injection alignment

CONTROL/EQUIPMENT:

Controls for IRWST injection path

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

SL02 - Enter RCS low level IRWST actuation setpoint

STEP 5

STEP: Refill RCS

PURPOSE: To refill RCS hot leg level greater than the IRWST injection setpoint

BASIS:

Refilling the RCS level to greater than SL02 prevents unnecessary automatic IRW[illegible] and permits the restart of the RNS pumps. The preferred makeup source is CVS mak[illegible] the CMTs and IRWST remain available for injection if needed.

ACTIONS:

- Refill RCS hot leg level using CVS makeup pumps
- Refill RCS hot leg level using CMTs, gravity feed from IRWST to RNS suction, gravity feed from IRWST

INSTRUMENTATION:

- RCS hot leg level indication
- CVS RCS makeup instrumentation
- IRWST injection via RNS suction instrumentation
- IRWST injection instrumentation

CONTROL/EQUIPMENT:

Controls for:

- CVS RCS makeup
- IRWST injection via RNS suction
- IRWST injection

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

SL02 - Enter RCS low level IRWST actuation setpoint

STEP 6

STEP: Identify And Isolate Any RCS Leakage

PURPOSE: To prevent RCS inventory loss due to RCS leakage or RCS interfacing systems

BASIS:

To prevent RCS inventory loss due to RCS leakage or RCS interfacing systems.

ACTIONS:

Identify/isolate any RCS leakage

INSTRUMENTATION:

N/A

CONTROL/EQUIPMENT:

N/A

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

N/A

STEP 7

STEP: Check RCS Hot Leg Level - GREATER THAN (SL02)

PURPOSE: To determine if RCS hot leg level is greater than IRWST injection setpoint, SL02

BASIS:

The first action taken under open RCS conditions is checking and maintaining RCS inventory greater than the RCS hot leg low level IRWST actuation setpoint (SL02). If RCS hot leg level is less than SL02, then the operator should continue with subsequent steps while he tries to refill the RCS. Adequate RCS hot leg level is required for RNS operation.

ACTIONS:

Determine if RCS hot leg level is greater than SL02

INSTRUMENTATION:

RCS hot leg level indication

CONTROL/EQUIPMENT:

N/A

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

SL02 - Enter RCS low level IRWST actuation setpoint

## STEP 8 CAUTION

CAUTION: Starting an RNS pump may result in an RCS level decrease due to shrink or void collapse

PURPOSE: To warn the operator that an RCS level decrease, due to shrink or void collapse, may occur

BASIS:

Since RCS boiling (voiding) was used for temporary core cooling, initiation of RNS cooling may cause a void collapse with a resulting RCS level decrease.

ACTIONS:

N/A

INSTRUMENTATION:

RCS hot leg level indication

CONTROL/EQUIPMENT:

N/A

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

N/A

STEP 8

STEP: Try To Restore RNS Flow

PURPOSE: To instruct the operator to attempt to restore RNS Flow

BASIS:

A common concern, based on past plant designs, has been the loss of RNS because of inadequate water level above the RCS hot leg/RNS suction line interface. With an inadequate water level, air ingestion, caused by vortexing action, would cause the RNS pump to loose prime and therefore interrupt the RNS cooling function. The AP600 design incorporates specific features to address this concern consisting of: 1) a stepped nozzle RCS hot leg/RNS suction line interface which limits entrained air to no greater than five percent, 2) a sloped RNS suction line without any local highpoints to permit easy line refill after hot leg level is reestablished, 3) RCS layout is such that draining the SG primary side can be accomplished with a higher hot leg level and 4) Hot leg level indication. Therefore, hot leg level is maintained greater than SL02 to provide adequate RNS suction.

The RNS has redundant equipment. If a failure in one train occurs, the other train can be placed in service. The RNS pumps are automatically loaded onto the standby diesel generators if they were operating at the time of loss of normal power. The operator may have to manually load the RNS pumps onto the standby diesel generators if the automatic loading feature fails. The following supporting systems are also required to provide prompt restoration of RNS cooling: SWS, CCS and PLS. After RNS is restored, the desired cooldown rate is established and the operator transitions to the appropriate plant procedure.

ACTIONS:

- Start an RNS pump
- Maintain RCS hot leg level greater than SL02
- Determine if RNS cooling has been restored
- Establish desired RCS cooldown rate
- Go to appropriate plant procedure

INSTRUMENTATION:

- RNS cooling performance status indication
- Hot leg level indication

CONTROL/EQUIPMENT:

- RNS controls required for RCS cooling
- Controls for RNS support systems

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

SL02 - Enter RCS low level IRWST actuation setpoint

STEP 9

STEP: Check If Fourth Stage ADS Should Be Actuated

PURPOSE: To determine if Fourth Stage ADS should be actuated

BASIS:

Fourth stage ADS actuation is required if CMT level cannot be maintained above the CMT fourth stage ADS actuation setpoint or if RCS hot leg level is low. Following ADS actuation, the operational procedure is to start the normal residual heat removal system. The normal residual heat removal system provides injection into the RCS from the IRWST at about 100 psig. This injection stops the CMT injection and prevents the fourth stage ADS valves from being actuated. Fourth stage ADS will be required and actuated if there is a normal residual heat removal system equipment or operator failure. On fourth stage ADS actuation, the fourth stage ADS isolation valves and the IRWST injection isolation valves open and allow gravity draining injection to the RCS from the IRWST.

ACTIONS:

- Determine if fourth stage ADS should be actuated
- Determine if CMT level is less than SL05
- Determine if RCS hot leg level decreases to less than SL04
- Manually actuate fourth stage ADS
- Verify fourth stage ADS isolation valves open
- Manually open fourth stage ADS valves
- Verify IRWST injection isolation valves open
- Manually open IRWST injection isolation valves

INSTRUMENTATION:

Indication for

- CMT level
- RCS hot leg level
- ADS fourth stage isolation valve position
- ADS fourth stage valve position
- IRWST injection isolation valve position indication

CONTROL/EQUIPMENT:

Controls for

- ADS fourth stage isolation valves
- ADS fourth stage valves
- IRWST injection isolation valves

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

- SL04 RCS hot leg level greater than bottom of hot legs
- SL05 CMT fourth stage ADS actuation setpoint

STEP 10

STEP: Check IRWST Level

PURPOSE: To verify the containment sump recirculation valves are automatically opened to align the plant in the recirculation mode

BASIS:

On low level in the IRWST, the containment sump recirculation valves are automatically opened to align the plant in the recirculation mode. In this mode, water is recirculated from the containment sump through the containment sump recirculation lines into the reactor vessel under either gravitational force or by using the normal residual heat removal system. This step verifies that the containment sump recirculation valves are open.

ACTIONS:

- Determine if IRWST is less than SL06
- Verify containment sump recirculation valves are open
- Manually align valves as necessary

INSTRUMENTATION:

Indication for

- IRWST level
- Containment sump recirculation valve position

CONTROL/EQUIPMENT:

Containment sump recirculation valve controls

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

SL06 IRWST level for transfering RNS to contaiment sump

STEP 11

STEP: Initiate Actions To Protect Personnel Working In Containment

PURPOSE: To ensure personnel inside containment are protected from a potential adverse radiological environment

BASIS:

When the core starts boiling, steam and/or gases may be released into containment through vents in the RCS. The release of steam into containment can create a habitability (temperature) concern for operators who may be in the area to perform recovery actions. The potential exists for release of radioactive materials from the RCS into containment causing a personnel contamination problem.

Any non essential personnel inside containment should be evacuated. As an additional precautionary measure, essential personnel entering containment may need to take additional protective measures such as respirators, breathing air or special protective clothing. Containment radiation should be periodically monitored and at some point, it may be necessary to evacuate essential personnel from containment.

ACTIONS:

Initiate actions to protect personnel working in containment

INSTRUMENTATION:

Containment radiation monitoring

CONTROL/EQUIPMENT:

N/A

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

N/A

STEP 12

STEP: Initiate Actions To Establish Containment Closure

PURPOSE: To establish a boundary to prevent the release of fission products

BASIS:

Since RNS cooling has been lost, and initial attempts to restore RNS cooling have been unsuccessful, actions must be taken to address the possibility of core uncovery and subsequent fuel damage due to RCS inventory loss. Since two of the three radiological barriers may be open (the RCS and containment), actions must be taken to close containment and provide a barrier to the release of radioactive materials should the event proceed to core damage. Containment closure must be accomplished before the onset of core damage. Once containment closure is initiated, closure should continue until controlled and stable decay heat removal has been restored (either RNS cooling or stable heat removal via the secondary plant) and the RCS is returned to a controlled and stable condition.

ACTIONS:

Initiate actions to establish containment closure

INSTRUMENTATION:

N/A

CONTROL/EQUIPMENT:

N/A

KNOWLEDGE:

Means to establish containment closure

ADDITIONAL INFORMATION:

Specific guidelines for establishing containment closure during typical shutdown conditions. Containment closure as discussed in this step includes establishing the desired position of available containment isolation valves to minimize release outside containment.

STEP 13

STEP: Start Available Containment Fan Coolers

PURPOSE: To ensure all available containment fan coolers are running to remove containment heat

BASIS:

The intent of this step is to remove heat from containment resulting from coolant boiling off in the RCS. Note that steam vented off via ADS stages 1, 2 and 3 will be condensed and captured via the ADS spargers in the IRWST. Therefore, until the IRWST starts steaming, the heat load on the containment fan coolers should be minimal.

ACTIONS:

Start available containment fan coolers

INSTRUMENTATION:

Containment fan cooler instrumentation

CONTROL/EQUIPMENT:

Controls for containment fan coolers

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

N/A

STEP 14

STEP: Return to Step 3

PURPOSE: To re-evaluate RCS opened/closed status and transition to appropriate procedure actions as required

BASIS:

To continue attempts to restore RNS cooling.

ACTIONS:

Return to Step 3

INSTRUMENTATION:

N/A

CONTROL/EQUIPMENT:

N/A

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

N/A

**STEP 15**

STEP: Check If CMTs Should Be Actuated

PURPOSE: To determine if CMT injection is necessary to replenish RCS inventory

BASIS:

CMT actuation based on low level in the pressurizer (SL01) is available in mode 5 except when it is blocked for reduced inventory operations. Actions for reduced inventory operation are addressed in steps 3 through 12. The RCS should be filled and pressurizer level expected to be normal when this step is performed. If RCS inventory is being lost such that pressurizer level drops to less than SL01, the operator should verify that the automatic CMT actuation has occurred.

ACTIONS:

- Determine if pressurizer level is greater than SL02
- Verify that CMT injection valves are open
- Manually open CMT valves

INSTRUMENTATION:

- PRZR level indication
- CMT injection valve position indication

CONTROL/EQUIPMENT:

Controls for CMT injection valves

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

SL01 - Enter PRZR level CMT actuation setpoint during shutdown

STEP 16

STEP: Verify PRHR Actuated

PURPOSE: To ensure that PRHR is aligned to cool to reactor core

BASIS:

PRHR is automatically actuated on CMT actuation. The operator should verify that the PRHR isolation valves are open for cooling the reactor core.

ACTIONS:

- Verify that PRHR isolation valves are open
- Manually open PRHR isolation valves

INSTRUMENTATION:

PRHR isolation valve position indication

CONTROL/EQUIPMENT:

Controls for PRHR isolation valves

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

N/A

STEP 17

STEP: Check If ADS Should Be Actuated

PURPOSE: To determine if ADS should be actuated based on prevailing plant conditions

BASIS:

The automatic depressurization system (ADS) actuation is required if core makeup tank (CMT) level cannot be maintained above the first stage ADS actuation setpoint or if RCS hot leg level is low. If ADS actuation is required, then the operator verifies that the first three ADS stages have operated successfully. The second and third stage ADS are actuated after a time delay.

If ADS is actuated, (or if CMT level is approaching the first stage ADS setpoint) the operator is directed to align the normal residual heat removal system to inject the in-containment refueling water storage tank (IRWST) to the RCS to prevent the need for fourth stage ADS actuation. The normal residual heat removal system provides injection into the RCS from the IRWST at about 100 psig. This injection stops the CMT injection and prevents the fourth stage ADS valves from being actuated.

ACTIONS:

- Detemine if ADS should be actuated
- Determine if CMT level is less than SL03
- Determine if RCS hot leg level is greater than SL04
- Determine if (ST01) seconds have elapsed from first stage ADS signal
- Determine if (ST02) seconds have elapsed from second stage ADS signal
- Verify actuation of first three ADS stages
- Manually open first,second and third stage ADS valves
- Align normal residual heat removal system to inject into RCS

INSTRUMENTATION:

Indication for

- CMT level
- RCS hot leg level
- ADS actuation
- ADS valve position
- ADS isolation valve position
- Normal residual heat removal system suction valve position
- Normal residual heat removal system discharge valve position
- Normal residual heat removal system pump status indication

CONTROL/EQUIPMENT:

Controls for

- ADS valves
- ADS isolation valves
- Normal residual heat removal system suction valve
- Normal residual heat removal system discharge valve
- Normal residual heat removal system pump

KNOWLEDGE:

Aligning RNS to inject into the RCS does not require the closing of the RNS suction valves from the RCS

ADDITIONAL INFORMATION:

- SL03 CMT low level ADS actuation
- SL04 RCS hot leg level greater than bottom of hot legs
- ST01 Time delay for second stage ADS actuation
- ST02 Time delay for third stage ADS actuation

STEP 18

STEP: Check If Fourth Stage ADS Should Be Actuated

PURPOSE: To determine if Fourth Stage ADS should be actuated based on CMT level

BASIS:

Fourth stage ADS actuation is required if CMT level cannot be maintained above the CMT fourth stage ADS actuation setpoint or if RCS hot leg level is low. Following ADS actuation, the operational procedure is to start the normal residual heat removal system. The normal residual heat removal system provides injection into the RCS from the IRWST at about 100 psig. This injection stops the CMT injection and prevents the fourth stage ADS valves from being actuated. Fourth stage ADS will be required and actuated if there is a normal residual heat removal system equipment or operator failure. On fourth stage ADS actuation, the fourth stage ADS isolation valves and the IRWST injection isolation valves open and allow gravity draining injection to the RCS from the IRWST.

ACTIONS:

- Determine if fourth stage ADS should be actuated
- Determine if CMT level is less than SL05
- Determine if RCS hot leg level decreases to less than SL04
- Manually actuate fourth stage ADS
- Verify fourth stage ADS isolation valves open
- Manually open fourth stage ADS valves
- Verify IRWST injection isolation valves open
- Manually open IRWST injection isolation valves

INSTRUMENTATION:

Indication for

- CMT level
- RCS hot leg level
- ADS fourth stage isolation valve position
- ADS fourth stage valve position
- IRWST injection isolation valve position indication

CONTROL/EQUIPMENT:

Controls for

- ADS fourth stage isolation valves
- ADS fourth stage valves
- IRWST injection isolation valves

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

- SL04 RCS hot leg level greater than bottom of hot legs
- SL05 CMT fourth stage ADS actuation setpoint

**STEP 19**

STEP: Check IRWST Level

PURPOSE: To verify the containment sump recirculation valves are automatically opened to align the plant in the recirculation mode

BASIS:

On low level in the IRWST, the containment sump recirculation valves are automatically opened to align the plant in the recirculation mode. In this mode, water is recirculated from the containment sump through the containment sump recirculation lines into the reactor vessel under either gravitational force or by using the normal residual heat removal system. This step verifies that the containment sump recirculation valves are open.

ACTIONS:

- Determine if IRWST is less than SL06
- Verify containment sump recirculation valves are open
- Manually align valves as necessary

INSTRUMENTATION:

Indication for

- IRWST level
- Containment sump recirculation valve position

CONTROL/EQUIPMENT:

Containment sump recirculation valve controls

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

SL06 IRWST level for transfering RNS to containment sump

**STEP 20**

STEP: Evaluate Long Term Plant Status

PURPOSE: To determine long term plant status and future recovery actions

BASIS:

The equipment used to establish long term core cooling and inventory control is the same equipment that is used to recover from design basis LOCAs and is designed to function in the long term so that plant recovery is possible. This allows the plant staff to evaluate the event and develop recovery procedures so that the plant can be repaired and brought back to service.

ACTIONS:

N/A

INSTRUMENTATION:

N/A

CONTROL/EQUIPMENT:

N/A

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

N/A

**STEP 21**

STEP: Go To Appropriate Plant Procedure

PURPOSE: To direct the operator to the proper procedure following completion of the steps in this guideline

BASIS:

Now that the guideline steps have been completed, the operator should continue plant operation and/or recovery going to the appropriate normal plant procedure or abnormal plant procedure.

ACTIONS:

Go to appropriate plant procedure

INSTRUMENTATION:

N/A

CONTROL/EQUIPMENT:

N/A

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

## STEP 22 - CAUTION - 1

CAUTION -1: Personnel working in containment should be warned before refilling the RCS to avoid inadvertant contamination of personnel working near RCS openings

PURPOSE: To avoid personnel contamination from potentially radioactive gases or vapors when filling an open RCS

BASIS:

Refilling the RCS may purge out radioactive vapors or gases from any open RCS vents and contaminate personnel in the area. Therefore personnel working in the vicinity of any RCS openings should clear the area prior to filling the RCS.

ACTIONS:

N/A

INSTRUMENTATION:

N/A

CONTROL/EQUIPMENT:

N/A

KNOWLEDGE:

The operator should be cognizant of RCS opening locations and any work going on in these areas

ADDITIONAL INFORMATION:

N/A

## STEP 22 CAUTION - 2

CAUTION - 2: Only borated water should be added to the RCS to maintain adequate shutdown margin

PURPOSE: To inform the operator that inadvertant dilution of the RCS, without RNS, may result in a loss of (localized) shutdown margin while adding RCS makeup

BASIS:

Although the coolant boron should remain in the RCS (as opposed to transferring with the boiled-off steam) borated makeup should be added to the RCS to maintain localized shutdown margin since mixing in the RCS will be minimal under these loss of RNS conditions. The decay heat/boil-off rates during this time are low enough that boron precipitation is not a concern.

ACTIONS:

N/A

INSTRUMENTATION:

N/A

CONTROL/EQUIPMENT:

N/A

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

N/A

STEP 22

STEP: Maintain PRZR Level - GREATER THAN (SL01)

PURPOSE: To maintain pressurizer level greater than the CMT actuation setpoint during shutdown

BASIS:

The preferred makeup source is CVS makeup so that the CMTs and IRWST remain available for injection if needed. Maintaining pressurizer level greater than SL01 prevents unnecessary automatic CMT actuation.

ACTIONS:

- Maintain pressurizer level using CVS makeup pumps
- Maintain pressurizer level using CMTs, gravity feed from IRWST, gravity feed from IRWST to RNS suction

INSTRUMENTATION:

- Pressurizer level indication
- CVS RCS makeup instrumentation
- IRWST injection instrumentation
- IRWST injection via RNS suction instrumentation

CONTROL/EQUIPMENT:

Controls for:
- CVS RCS makeup
- IRWST injection
- IRWST injection via RNS suction

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

SL01 PRZR level CMT actuation setpoint during shutdown

STEP 23

STEP: Check If CMT Injection Should Be Isolated

PURPOSE: To isolate CMT injection if it is not needed

BASIS:

If pressurizer level is above the CMT actuation setpoint, then CMT injection into the RCS is not necessary and can be stopped.

ACTIONS:

- Determine if pressurizer level is greater than SL01
- Close CMT injection valves

INSTRUMENTATION:

Indication for

- Pressurizer level
- CMT injection valve position indication

CONTROL/EQUIPMENT:

Controls for CMT injection valves

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

SL01 PRZR level CMT actuation setpoint during shutdown

## STEP 24 - CAUTION

CAUTION: Starting an RNS pump may result in an RCS level decrease due to shrink or void collapse

PURPOSE: To warn the operator that a PRZR level decrease, due to shrink or void collapse, may occur

BASIS:

Since RCS boiling may occur as a result of losing RNS cooling and without any other RCS heat sunk, re-initiation of RNS cooling may cause a void collapse with a resulting PRZR level decrease.

ACTIONS:

N/A

INSTRUMENTATION:

PRZR level indication

CONTROL/EQUIPMENT:

N/A

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

N/A

STEP 24

STEP: Try To Restore RNS Flow

PURPOSE: To instruct the operator to attempt to restore RNS Flow

BASIS:

A common concern, based on past plant designs, has been the loss of RNS because of inadequate water level above the RCS hot leg/RNS suction line interface. With an inadequate water level, air ingestion, caused by vortexing action, would cause the RNS pump to loose prime and therefore interrupt the RNS cooling function. The AP600 design incorporates specific features to address this concern consisting of: 1) a stepped nozzle RCS hot leg/RNS suction line interface which limits entrained air to no greater than five percent, 2) a sloped RNS suction line without any local highpoints to permit easy line refill after hot leg level is reestablished, 3) RCS layout is such that draining the SG primary side can be accomplished with a higher hot leg level and 4) Hot leg level indication. Therefore, hot leg level is maintained greater than SL02 to provide adequate RNS suction.

The RNS has redundant equipment. If a failure in one train occurs, the other train can be placed in service. The RNS pumps are automatically loaded onto the EDGs if they were operating at the time of loss of normal power. The operator may have to manually load the RNS pumps onto the EDGs if the automatic loading feature fails. The following supporting systems are also required to provide prompt restoration of RNS cooling: SWS, CCS and PLS. After RNS is restored, the desired cooldown rate is established and the operator transitions to the appropriate plant procedure.

ACTIONS:

- Start an RNS pump
- Maintain RCS hot leg level greater than SL02
- Determine if RNS cooling has been restored
- Establish desired RCS cooldown rate
- Go to appropriate plant procedure

INSTRUMENTATION:

- RNS cooling performance status indication
- PRZR level indication

CONTROL/EQUIPMENT:

- RNS controls required for RCS cooling
- Controls for RNS support systems

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

SL01 - Enter PRZR level CMT actuation setpoint during shutdown

STEP 25

STEP: Establish RCS Heat Sink Using SGs

PURPOSE: To provide an RCS heat sink using available SG(s)

BASIS:

The plant condition required for this step is a "closed" RCS, which has already been determined. By definition, a closed RCS requires that the RCS (including the SG tubes) be filled to at least the PRZR CMT actuation level setpoint (SL01). In addition to a closed RCS, an SG must be available. An SG is available if the secondary side of a non-ruptured, non-faulted SG is filled to approximately normal level, and atmospheric steam release capability via the SG power operated relief valves (PORVs) is operable (with the plant shutdown, steam dump to the condenser would not be available).

The ADS valves remain in the position they were in at the time this step is reached. Subcooled core cooling will take place until the RCS and SGs reach saturation based on SG secondary side atmospheric pressure. With the ADS valves and RCS closed, the RCS will slightly pressurize above atmospheric pressure to an equilibrium value required to remove core decay heat. This plant configuration will permit RCS/SG natural circulation to transfer core decay heat to the SGs. The SGs remain at atmospheric pressure with steam release to the atmosphere. Since SG pressure will be maintained at atmospheric pressure via the open SG PORVs, saturated core cooling will take place at approximately 212°F. RCS inventory will be monitored and controlled via Step 15. SG feedwater will be required, as necessary, depending on the length of time RNS cooling is lost to maintain secondary inventory.

If the ADS valves remain open, this method of saturated core cooling will not be effective since no temperature gradient will develop to promote natural circulation. Very little, if any, temperature gradient between the RCS and SG will exist because both the RCS and SG(s) will remain at atmospheric pressure when the ADS valves and SG PORVS are open.

ACTIONS:

- Determine if any SGs are available
- Try to restore SGs to service
- Feed SGs to establish and maintain SG level
- Open respective SG PORVs

INSTRUMENTATION:

- SG level indication
- SFW operation instrumentation
- RCS hot leg, cold leg and SG temperature indication
- SG PORV position indication
- ADS valve position indication
- Hot leg level indication

CONTROL/EQUIPMENT:

Controls for:

- SFW operation
- SG PORV operation

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

N/A

STEP 26

STEP: Establish RCS Heat Sink Using PRHR

PURPOSE: To provide an RCS heat sink using the PRHR heat exchanger

BASIS:

The passive residual heat removal system (PRHRS) is designed to cool the RCS using natural circulation from the RCS through the PRHR heat exchanger (PRHRHX) during the initial cooldown phase (of plant shutdown) before RNS cooling is initiated. The PRHR heat exchanger uses the IRWST as a heat sink normally maintained at containment ambient temperature. Aligning the PRHRS to cool the RCS will provide a heat sink for the RCS although it may not be very effiective until the RCS heats up. If PRHR cooling can not be placed in service; at an RCS temperature of (ST03)°F, the operator is instructed to open all ADS valves to initiate a feed and bleed mode of cooling for the RCS and to prevent further pressurization of the RCS.

ACTIONS:

- Determine if PRHR is available
- Align PRHR to cool RCS
- Open all ADS valves if PRHR is not available and RCS temperature reaches (ST03)°F

INSTRUMENTATION:

Instrumentation for:

- PRHR operability status
- PRZR level indication

CONTROL/EQUIPMENT:

Controls for:

- PRHR operation
- ADS valves

KNOWLEDGE:

The operator should be aware of IRWST cooling capabilities provided by RNS, SFS and containment fan coolers. If PMS is unsuccessful in opening/closing the ADS valves or actuating PRHR, the operator should be aware that the Diverse Actuation System (DAS) has provisions for manually opening/closing the ADS valves or actuating PRHR from the DAS panel.

ADDITIONAL INFORMATION:

ST03 - Enter normal RNS cut-in temperature

STEP 27

STEP: Initiate Actions To Protect Personnel Working In Containment

PURPOSE: To ensure personnel inside containment are protected from a potential adverse radiological environment

BASIS:

When the core/IRWST starts boiling, steam and/or gases may be released into containment through vents in the IRWST. The release of steam into containment can create a habitability (temperature) concern for operators who may be in the area to perform recovery actions. The potential exists for release of radioactive materials from the RCS/IRWST into containment causing a personnel contamination problem.

Any non essential personnel inside containment should be evacuated. As an additional precautionary measure, essential personnel entering containment may need to take additional protective measures such as respirators, breathing air or special protective clothing. Containment radiation should be periodically monitored and at some point, it may be necessary to evacuate essential personnel from containment.

ACTIONS:

Initiate actions to protect personnel working in containment

INSTRUMENTATION:

- Containment Temperature indication
- Containment radiation monitoring

CONTROL/EQUIPMENT:

N/A

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

N/A

**STEP 28**

STEP: Initiate Actions To Establish Containment Closure

PURPOSE: To establish a boundary to prevent the release of fission products

BASIS:

Since RNS cooling has been lost, and initial attempts to restore RNS cooling have been unsuccessful, actions must be taken to address the possibility of core uncovery and subsequent fuel damage due to RCS inventory loss. Since two of the three radiological barriers may be open (the RCS and containment), actions must be taken to close containment and provide a barrier to the release of radioactive materials should the event proceed to core damage. Containment closure must be accomplished before the onset of core damage. Once containment closure is initiated, closure should continue until controlled and stable decay heat removal has been restored (either RNS cooling or stable heat removal via the secondary plant) and the RCS is returned to a controlled and stable condition.

ACTIONS:

- Initiate actions to establish containment closure

INSTRUMENTATION:

N/A

CONTROL/EQUIPMENT:

N/A

KNOWLEDGE:

Means to establish containment closure

ADDITIONAL INFORMATION:

Specific guidelines for establishing containment closure during shutdown conditions and using the passive core cooling systems (i.e., PXS/PRHR and PCC). Containment closure as discussed in this step includes establishing the desired position of available containment isolation valves to minimize release outside containment.

STEP 29

STEP: Start Available Containment Fan Coolers

PURPOSE: To ensure all available containment fan coolers are running to remove containment heat

BASIS:

The intent of this step is to remove heat from containment resulting from the IRWST boiling off to containment. Note that subcooled PRHR cooling will occur, and steam vented off via ADS stages 1, 2 and 3 will be condensed and captured via the ADS spargers in the IRWST. Therefore, until the IRWST starts steaming, the heat load on the containment fan coolers should be minimal.

ACTIONS:

Start available containment fan coolers

INSTRUMENTATION:

Containment fan cooler instrumentation

CONTROL/EQUIPMENT:

Controls for containment fan coolers

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

N/A

STEP 30

STEP: Return To Step 15

PURPOSE: To return to the initial procedure step that addresses recovery with a closed RCS

BASIS:

Steps 15 to 29 form a loop of recovery actions with closed RCS conditions. Since RNS cooling has not been re-established, as evaluated in Step 24, the operator is sent back to the beginning of this loop to re-evaluate the status of RCS cooling and restoration of RNS cooling of the RCS.

ACTIONS:

Return to Step 15

INSTRUMENTATION:

N/A

CONTROL/EQUIPMENT:

N/A

KNOWLEDGE:

N/A

ADDITIONAL INFORMATION:

N/A

## 4.2 Step Sequence Requirements

This section consists of a table which presents the existing guideline sequence and identifies the interchangeability of guideline steps for the benefit of the procedure writer.

The Step Sequence Table for SDG-1 is provided on the following page. The interchangeability of guideline steps is identified by the numbers in the column to the right of each guideline step.

## STEP SEQUENCE FOR SDG-1

| STEP | | SEQUENCE |
|---|---|---|
| 1. | Check If RNS Pumps Should Be Stopped | 1 |
| 2. | Verify RCS Drain Path Isolation | 2 |
| 3. | Check RCS Status - OPEN | 3 |
| 4. | Verify Stage 1, 2 and 3 ADS Valves - OPEN | 4 |
| 5. | Refill RCS | 5 |
| 6. | Identify And Isolate Any RCS Leakage | 6 |
| 7. | Check RCS Hot Leg Level - GREATER THAN (SL02)) | 7 |
| 8. | Try To Restore RNS Flow | 8 |
| 9. | Check If Fourth Stage ADS Should Be Actuated | 9 |
| 10. | Check IRWST Level | 10 |
| 11. | Initiate Actions To Protect Personnel Working In Containment | 11 |
| 12. | Initiate Actions To Establish Containment Closure | 11 |
| 13. | Start Available Containment Fan Coolers | 11 |
| 14. | Return To Step 3 | 12 |
| 15. | Check If CMTs Should Be Actuated | 13 |
| 16. | Verify PRHR Actuated | 14 |
| 17. | Check If ADS Should Be Actuated | 15 |
| 18. | Check If Fourth Stage ADS Should Be Actuated | 16 |
| 19. | Check IRWST Level | 17 |