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Evaluation of Potential ERG and EPG Changes to Address NRC Bulletin 2003-01 Recommendations (PA-SEE-0085)

Volume 1 – Engineering Evaluations and Analyses Report

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EXECUTIVE SUMMARY

This Engineering Evaluations and Analysis Report (EEAR) provides a partial response to Project Authorization PA-SEE-0085. It has been prepared to support evaluation of potential Westinghouse Emergency Response Guideline (ERG) and Combustion Engineering Emergency Procedure Guideline (EPG) changes to address recommendations in NRC Bulletin 2003-01, "Potential Impact of Debris Blockage on Emergency Sump Recirculation at Pressurized-Water Reactors." This report will be revised to be the complete response to PA-SEE-0085 and will include the EPG and ERG simulator validation reports, the approved EPG/ERG documentation and the program implementation guidelines document. PA-SEE-0085 addresses only the operational recommendations in NRC Bulletin 2003-01.

This report addresses an evaluation of potential changes to the ERGs and EPGs as required by NRC Bulletin 2003-01 and the impact of these changes on the Technical Specifications, licensing and design basis, and operational issues associated with these potential changes. Evaluation of the risk impact of the proposed changes is also included. Licensees can use the results of this program when preparing plant-specific responses to NRC Bulletin 2003-01 with respect to the recommended interim compensatory measures that impact the ERGs and EPGs. Interim measures that can be used to reduce the risk associated with potential sump blockage are identified. Some of the recommended interim measures may result in permanent changes to the ERGs and EPGs.

This report provides generic support and guidance for those licensees that choose to include operational changes as part of their response to NRC Bulletin 2003-01. NRC Bulletin 2003-01 covers many aspects of potential sump blockage. These aspects include sump design, insulation design, housekeeping and others, as well as operational aspects. The support and guidance included in this report must be balanced against studies of the other aspects of potential sump blockage before a licensee implements any specific operational changes.

This report discusses potential operational changes from two viewpoints. One is to discuss specific candidate operator actions (COA) – one at a time. The other is to discuss candidate operator actions from a global and integrated perspective. The COA were selected from those outlined in NRC Bulletin 2003-01 and operations input from the Procedures Working Group of the Westinghouse Owners Group (WOG). Input was supplied for both Westinghouse type plants and Combustion Engineering (CE) type plants. Incorporation of any COA into a plant's Emergency Operating Procedures must be selected and justified by a licensee considering the trade off among operational, design and housekeeping aspects of NRC Bulletin 2003-01. This report provides guidance in assessing the operational part of the tradeoff, but does not provide plant specific recommendations.

Eleven COA were evaluated; ten for large dry containments and one for ice condenser containments. Some of the COA involved modifying existing termination criteria for containment spray or safety injection once has been confirmed that both (all) safety trains are fully up and running and other specific criteria are satisfied. The premise being, if after they have performed their safety function, unneeded pumps can be stopped sooner than currently allowed, then the time to switchover to containment recirculation could be extended and the fluid velocity through the sump lowered. These particular COA received extensive review and analyses to ensure that the proposed change would not adversely erode current operational margins. It was concluded that for most plants, early termination of one containment spray pump would be acceptable. In addition, termination of one high pressure (head) safety injection

pump after aligning for recirculation would be also applicable (assuming specific criteria are satisfied). Proposals to change current termination criteria for high and low head ECCS pumps before aligning for recirculation were not found to be risk beneficial and therefore are not recommended.

Incorporating an action to secure an operating containment spray or safety injection pump into a plant's operating procedures will require a plant specific justification if it is outside the plant's licensing basis. A single failure of the operating pump after manually securing the other pump must be assumed. The probability is high that the secured pump will restart, since it was running when shut down, but there will be a time when neither pump is running. Current licensing bases assume at least one pump running continuously.

This report also concludes that preparations for refill of the refueling water storage tank and response to loss of recirculation flow due to sump blockage should be implemented as modifications to the generic ERGs and EPGs. The balance of the COA may be implemented on a plant-specific basis if it is the best tradeoff choice to reduce the potential or magnitude of sump blockage from all the options addressed in NRC Bulletin 2003-01.

1 INTRODUCTION AND BACKGROUND

This is the Engineering Evaluations and Analysis Report (EEAR), a partial response to Project Authorization PA-SEE-0085. It has been prepared to support each licensee's evaluation of potential Westinghouse Emergency Response Guideline (ERG) or Combustion Engineering Emergency Procedure Guideline (EPG) changes to address recommendations in NRC Bulletin 2003-01, "Potential Impact of Debris Blockage on Emergency Sump Recirculation at Pressurized-Water Reactors." The complete response to PA-SEE-0085 will be a revision to this document that will include the EPG and ERG simulator validation reports, the approved EPG/ERG revision documentation and the program implementation guidelines document. Complete licensee responses to NRC Bulletin 2003-01 have addressed or will address, on a plant specific basis, all aspects of the Bulletin, including plant modifications, operational changes, license amendment requests, administrative changes and other modifications. Each response to NRC Bulletin 2003-01 must balance the relative benefits and risks of potential changes and justify those being implemented by the licensee. This Engineering Evaluations and Analysis Report, in response to PA-SEE-0085, generically addresses only the operational recommendations contained in NRC Bulletin 2003-01.

On June 9, 2003, the NRC issued NRC Bulletin 2003-01, "Potential Impact of Debris Blockage on Emergency Sump Recirculation at Pressurized-Water Reactors." It was issued to inform licensees of the potential for additional adverse effects due to debris blockage of flow paths necessary for Emergency Core Cooling System (ECCS) and Containment Spray System (CSS) recirculation and containment drainage. These additional adverse effects were based on NRC-sponsored research that identified the potential susceptibility of Pressurized Water Reactor (PWR) recirculation sump screens to debris blockage in the event of a High Energy Line Break (HELB) that would require ECCS and CSS operation in the recirculation mode.

NRC Bulletin 2003-01 required licensees to provide a written response within 60 days in accordance with 10 CFR 50.54(f) to either:

1. State that the ECCS and CSS recirculation functions have been analyzed with respect to the potentially adverse post-accident debris blockage effects identified in the NRC Bulletin are in compliance with 10 CFR 50.46(b)(5) and all existing applicable regulatory requirements (Option 1), or

2. Describe any interim compensatory measures that have been or will be implemented to reduce the risk which may be associated with the potentially degraded or nonconforming ECCS and CSS recirculation functions until an evaluation to determine compliance has been completed (Option 2).

On July 7, 2003, the Westinghouse Owners Group (WOG) issued letter WOG-03-341, Transmittal of Response Template for NRC Bulletin 2003-01, "Potential Impact of Debris Blockage on Emergency Sump Recirculation at Pressurized-Water Reactors." WOG -03-341 transmitted a template that was developed to assist in preparing plant-specific responses to NRC Bulletin 2003-01. This WOG-developed template was prepared under the WOG 2003 Issues Review Group Program as guidance for preparing plant-specific responses. The interim compensatory measure discussions and examples contained in the template were not all inclusive, and must be determined and confirmed on a plant specific basis.

One of the Bulletin 2003-01 recommendations associated with changes to the Emergency Operating Procedures (EOPs) is to shut off one train of ECCS and/or CSS. The template recommended that licensees wait until the generic evaluation of the changes to the ERGs/EPGs was completed before implementing plant specific changes to the EOPs. A March 31, 2004 date for completing this effort was provided in the template. This EEAR provides that generic evaluation.

Accurate assessments of the impact of containment sump blockage on plant risk are difficult to perform because modeling of the potential for sump blockage, and the timing and significance of debris on ECCS equipment performance are not well understood at this time. Several assessments have been performed to attempt to quantify the risk based on varying sets of assumptions and models. The compensatory measures of interest from a risk perspective are guidance and procedures to:

1. Minimize the draw-down of the Refueling Water Storage Tank (RWST or RWT) thereby delaying the time at which recirculation would be required,

2. Provide additional guidance for diagnosis of sump blockage that could limit recirculation capabilities,

3. Provide additional water for continued use of the RWST, and

4. Identify or provide other means of injecting into the Reactor Coolant System (RCS) to maintain core cooling.

This EEAR addresses an evaluation of related potential changes to the ERGs and EPGs as recommended by NRC Bulletin 2003-01 and the impact of these changes on the Technical Specifications, licensing and design basis, and operational issues. A generic evaluation of the risk impact of the proposed changes is also included. The results of this program are being used to evaluate generic changes to the ERGs and EPGs. Licensees can use the results of this program when preparing plant-specific EOP changes in responses to NRC Bulletin 2003-01 with respect to the recommended interim compensatory measures. It identifies operational interim measures that can be used to reduce the risk associated with potential sump blockage. Some of the recommended interim measures may result in permanent changes to the ERGs and EPGs.

Each COA was evaluated, one at a time, within the context of the Westinghouse and CE generic plant emergency procedure guidelines. Each COA was evaluated to:

- Determine if the action has a measurable effect on the time to recirculation or recirculation flow velocities in the sump

- Determine if the action results in peak cladding temperature, containment pressure and post accident dose rates less than allowables

- Determine if the action is within generic licensing basis assumptions

This report also provides generic support and guidance for those licensees that choose to include operational changes as part of their response to NRC Bulletin 2003-01. NRC Bulletin 2003-01 covers many aspects of potential sump blockage. These aspects include sump design, insulation design, housekeeping and others, as well as operational aspects. The support and guidance included in this report must be balanced against studies of the other aspects of potential sump blockage before a given plant implements any specific operational changes.

This report discusses potential operational changes, Candidate Operator Actions (COA), from two viewpoints. One is to discuss specific COA – one at a time. The other is to discuss COA from a global and integrated perspective. The COA were selected from NRC Bulletin 2003-01 and operator input from the Procedures Working Group of WOG. Selection of COA was based on:

- Were they identified in NRC Bulletin 2003-01
- Could they increase the time to automatic switchover to recirculation
- Could they reduce the velocity of recirculation through the sump

At this point, two other rules were applied: ignore potential licensing actions (like 50.59 or license amendment) and do not require plant modifications. Other sources of sump blockage risk reduction addressed by the Bulletin were also ignored.

Incorporation of any COA into a plant's EOPs will be done via the normal EOP change process for new revisions to the generic owners group guidelines (ERGs/EPGs) in accordance with utility administrative control procedures. EOPs must be selected and justified by a specific plant's trade off among operational, design, licensing and administrative concerns. This report provides guidance in performing the operational part of the tradeoff, but does not provide definitive, plant-specific recommendations.

Eleven COA were evaluated; ten for large dry containments and one for ice condenser containments. Some of the COA involved manually securing an operating containment spray or safety injection pump once it is established that both (all) safety trains are fully up and running and other specific criteria are satisfied. By manually securing a pump "early," the time to automatic switchover to containment recirculation is extended or the fluid velocity through the sump is lowered, or both. This should reduce the potential for, or magnitude of, sump blockage. Incorporating any of the COA into a plant's operating procedures will require a plant-specific justification that the change does not create a situation outside the plant's licensing basis. The eleven COA are:

1. Secure one containment spray pump before recirculation alignment

2. Manually initiate one train of containment sump recirculation earlier

3. Terminate one train of HPSI/high-head injection after recirculation alignment

4. Terminate LPSI/RHR pump prior to recirculation alignment

5. Refill refueling water storage tank

6. Inject more than one RWST volume from refilled/diluted RWST or by bypassing RWST

7. Provide more aggressive cooldown and depressurization following a small break LOCA

8. Provide guidance on symptoms and identification of containment sump blockage

9. Develop contingency actions in response to: containment sump blockage, loss of suction, and cavitation

10. Terminate HPSI/high-head injection prior to recirculation alignment

11. Delay containment spray actuation for small break LOCA in ice condenser plants

This EEAR is organized to be consistent with PA-SEE-0085 work scope description. Following this Introduction section is Section 2 describing the evaluation assumptions on reference plants and operator action times. Sections 3 through 18 address each of the Tasks in PA-SEE-0085 except for those associated with generic ERG/EPG change verification using simulators. Simulator verification tasks are addressed in Volumes 2 and 3 of this report. Individual COA descriptions and evaluations are included in Appendix A.

Licensees may use this report as guidance for determining the relative risk or benefit of implementing one or more of the COA. The overall implementation strategy for any given plant must include consideration of the other aspects of NRC Bulletin 2003-01 as well as any required changes to the plant's license basis. For example, one must continue to assume a single failure of the operating pump after the manual securing of a redundant pump. The probability is high that the secured pump will restart, since it was running when shut down, but there will be a time when neither pump is running. Most current licensing bases assume at least one pump running continuously. An example discussion of potential changes to a plant's single failure criteria is given in Section 3. Response of a generic plant to the condition where no pumps are running is discussed in Sections 5, 6, and 12.

This report concludes that all of the COA evaluated, except manually securing a safety injection pump prior to automatic switchover to containment recirculation, may be useful in reducing the risk or impact of sump blockage. It concludes that preparations for refill of the refueling water storage tank and response to loss of recirculation flow due to sump blockage should be implemented as generic ERG/EPG modifications. It also concludes that the other COA should be considered for implementation based on each plant's risk of potential sump blockage considering all other commitments made in response to NRC Bulletin 2003-01.

2 EVALUATION ASSUMPTIONS

To provide a consistent set of assumptions for generic evaluations of potential operator actions, reference plants for the Combustion Engineering and Westinghouse designed plants are described in Sections 2.1 and 2.2, respectively. Also, a common set of assumed time durations for operator actions is defined in Section 2.3.

2.1 COMBUSTION ENGINEERING REFERENCE PLANT

2.1.1 Safety Injection System (SIS)

A SIS diagram is shown in Figure 2.1-1. The major components of this system are the refueling water tank, two high-pressure safety injection pumps, two low-pressure safety injection pumps, two shutdown cooling heat exchangers, four safety injection tanks, eight high-pressure injection valves and four low-pressure injection valves.

Following an incident which results in a Safety Injection Actuation Signal (SIAS), safety injection pumps automatically start and high- and low-pressures injection valves automatically open. If the incident results in a containment pressure increase sufficient to initiate a Containment Spray Actuation Signal (CSAS), the containment spray pumps are automatically started. The specific pumps and valves which operate depend on what type of power is available. If standby (offsite) power is available then all equipment operates. If standby power is not available the safeguards loads are divided between the two plant emergency diesel-generators.

During the injection mode of operation the safety injection pumps take suction from the Refueling Water Tank (RWT) and inject borated water into the Reactor Coolant System (RCS). If the RCS pressure drops below approximately 215 psig the four safety injection tanks will discharge 33,000 gallons of borated water into the RCS. The safety injection tanks are a passive injection means since no electrical signal, operator action or outside power source is required for the tanks to function.

When the RWT level drops to 10% of the volume dedicated to SIS, a Recirculation Actuation Signal (RAS) is generated which switches the High Pressure Safety Injection (HPSI) pump and containment spray pump suction from the RWT to the containment building sump. The RAS also stops the low-pressure safety injection pumps. Once initiated, recirculation continues until terminated or modified by operator action.

The shutdown cooling heat exchangers and low-pressure safety injection pumps are also used during plant cooldown to remove core decay heat and reactor coolant system sensible heat. Following cooldown they are used to maintain a constant reactor coolant system temperature while the plant is at cold shutdown.

The LPSI pumps are centrifugal pumps with a rated design flow of 3000 gpm at a head of 350 ft. The run out flow is 4500 gpm at 235 ft. The HPSI pumps are centrifugal pumps with a rated design flow of 313 gpm at a head of 2300 ft. The run out is 685 gpm at a head of 800 ft. Both the HPSI and Low Pressure Safety Injection (LPSI) pumps operate at 400 hp.

Safety Injection Tanks

The four safety injection tanks discharge their contents to the RCS following depressurization as a result of a Loss of Coolant Accident (LOCA). Each tank is connected to a cold leg of the RCS via safety injection nozzle located on the RCS piping near the reactor vessel inlet. During normal plant operation each safety injection tank is isolated from the RCS by two check valves in series. The safety injection tanks automatically discharge into the RCS if the reactor coolant system pressure decreases below safety injection tank pressure during reactor operation. Each tank has a minimum liquid volume of 1420 ft^3 and operates at a pressure between 600 and 625 psia.

Refueling Water Tank (RWT)

The RWT is an atmospheric tank containing water borated to approximately 1900 ppmb. The RWT is sized to contain sufficient water to fill the refueling water canal, transfer tube and the refueling cavity to a depth of 24 feet above the reactor vessel flange for refueling operation. This required volume is 500,000 gallons. Actual tank volume is 554,000 gallons.

The RWT also provides the reservoir of borated water for the injection mode operation of the Safety Injection System (SIS). The RWT is designed to store borated water for use by the Containment Spray (CS), HPSI and LPSI pumps. The Technical Specifications level accounts for the following volumes of water:

1. **Injection Flow**: A quantity of 313,600 gallons is maintained to provide a minimum of 20 minutes of injection flow for the CS, LPSI and HPSI pumps. This quantity is determined using conservative system run out flow for all pumps.

2. **Unusable Volume**: All stored water below a line six inches above the upper edge of the suction is considered <u>unusable</u>. This quantity of 60,000 gallons is considered in the Technical Specifications determination.

3. **Transfer Allowance**: An additional volume of 23,600 gallons is stored to account for the time (90 seconds) required to transfer to the recirculation mode. This quantity conservatively assumed that both LPSI pumps fail to stop on receipt of the Recirculation Actuation Signal (RAS) and continue to draw the transfer process.

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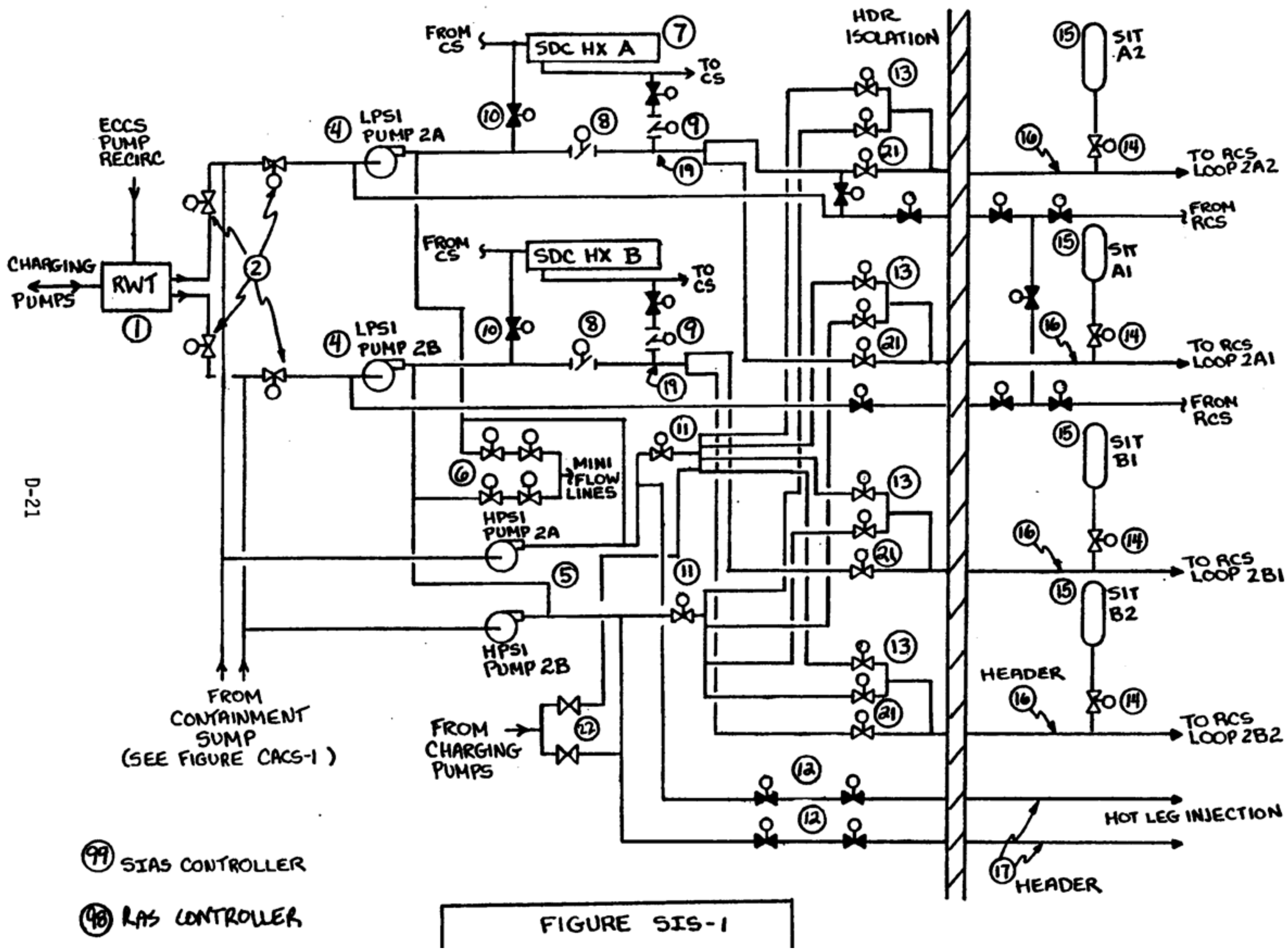

Figure 2.1-1 Safety Injection System (System #05)

Component List for
Safety Injection

1. Refueling Water Tank
2. RWT Isolation Valve (4)
3. Blank
4. LPSI Pump (2)
5. HPSI Pump (2)
6. HPSI and LPSI Miniflow Isolation Valves (4)
7. SCS Heat Exchanger (2)
8. SCS Heat Exchanger Bypass Flow Control Valve (2)
9. SCS Heat Exchanger Outlet Valve (2)
10. SCS Heat Exchanger Inlet Flow Valve (2)
11. HPSI Hot Leg Injection Orifice Bypass Valve
12. HPSI Hot Leg Injection Flow Control Valve (4)
13. HPSI Flow Control Valve (12)
14. SIT Isolation Valve (4)
15. SIT (4)
16. SIS Header (4)
17. Hot Leg Injection Header (2)
18. Blank
19. LPSI Header (2)
20. Blank
21. LPSI Flow Control Valve (4)
22. Charging Pump to SIS Header Isolation Valve (2)
98. RAS Controller
99. SIAS Controller

2.1.2 Containment Atmosphere Control System (CACS)

The CACS is provided to remove heat from the containment, thereby reducing the containment pressure and temperature and maintaining them at acceptably low levels following an accident. The CACS is arranged into two independent 100% capacity subsystems, each of which is comprised of one Containment Spray System (CSS) train and two fan coolers. Heat removal is achieved by the simultaneous operation of the two subsystems.

The CSS is designed to remove both heat and fission products from a post-accident containment atmosphere by spraying water from ring headers located high in the containment.

The CACS fan coolers are designed to operate during normal plant operation and following a LOCA or Main Steam Line Break (MSLB) inside containment. The outlets of the fan coolers are connected to a ductwork system which transports cooled air to various regions of the containment atmosphere.

Containment Spray System (CSS)

The CSS consists of two independent and redundant trains each consisting of a spray pump, shutdown heat exchanger, piping, valves and spray header as shown in Figure 2.1-2. The system has two modes of operation:

1. The initial injection mode, during which the system draws water from the RWT.

2. The recirculation mode during which the CSS takes suction from the containment sump for long term cooling.

Containment spray is automatically initiated following receipt of the Containment Spray Actuation Signal (CSAS), which is a coincidence of the Safety Injection Actuation Signal (SIAS) and the high-high containment pressure signal of 11 psig. Upon receipt of the CSAS, the Containment Spray (CS) pumps are started and isolation valves are opened. The CS pumps take suction from the RWT and spray borated water directly into the containment atmosphere. Although the spray water first passes through the shutdown heater exchanger, no significant heat load is placed on the exchanger during this mode of operation. This period of injection lasts for a minimum of 20 minutes assuming system run out flow for two HPSI pumps, two LPSI pumps and two CS pumps, with the RWT at the Technical Specification level.

The CS pumps are single stage, vertical, centrifugal pumps with a discharge capacity of 2850 gpm at a containment peak pressure 44 psig. The pumps operate at a constant speed requiring an average of 500 hp at 4KV.

When 10% of the SIS dedicated volume in the RWT is reached, the RAS is initiated. This closes RWT isolation valves in 90 seconds and open containment sump isolation valves in 30 seconds. During recirculation, spray flow drawn from the sump is first cooled by the shutdown heat exchanger before returning to the containment through the spray nozzles.

Containment Fan Cooling System

The containment fan cooling system, shown in Figure 2.1-3, consists of four coolers and a ducted air distribution system. Each fan cooler consists of an axial flow fan, two speed motor, casing, two banks of cooling coils and back draft dumper.

The system has two modes of operation which are:

1. **Normal Operation**: During which three fan coolers are operating at a rated flow of 60,000 CFM each, with high speed motor operation.

2. **Accident Operation**: During which at least two fan coolers are operating at a reduced flow of 39,600 CFM each, with low speed motor operation.

During normal operation three of the four fan coolers are operating at the higher of the two speeds. Upon receipt of SIAS, the four fans are automatically placed into low speed operation (39,600 CFM).

Each fan cooler unit is sized to remove one-third of the total normal containment heat load. During normal operation, containment ambient temperature is limited to an average of 120°F when the units are supplied with 100°F component cooling water.

Each cooling coil bank is made up of coil sections connected to supply and return manifolds of the Component Cooling Water System (CCWS). Coils are horizontal tube, vertical plate-fin type and are mounted on a structural frame.

Containment Spray System/Iodine Removal System (CSS/IRS)

The CSS is provided to perform the dual functions of removing heat and fission products from a post-accident containment atmosphere. The fission product removal function is carried out by the Iodine Removal System (IRS), operating in conjunction with the CSS. The IRS remove radio-iodines from the containment atmosphere following a LOCA by adding controlled amounts of hydrazine to containment water spray. The CSS can perform its function following a single active equipment failure coincident with a loss of offsite power.

The CSS consists of two independent and redundant loops. Connected to each CSS loop is an independent train of the IRS consisting of a constant volume metering pump, solenoid-operated isolation valve, IRS tank and associated piping and valves.

Component Listing for
Containment Atmosphere Control System (CACS-06)

1. Containment Spray Pump (2)
2. Containment Spray Pump Suction Isolation Valve to RWT (2)
3. Containment Spray Header Isolation Valve (2)
4. Containment Spray Header (2)
5. Containment Cooling Fan (4)
6. Containment
7. Blank
8. Hydrogen Recombiner (2)
9. Hydrogen Analyzer (2)
10. Containment Sump
11. Containment Sump SIS/CSP Suction Isolation Valves (2)
99. CSAS Controller

2.1.3 Containment Isolation System (CIS) (07)

The CIS provides the means of isolating fluid systems that pass through containment penetrations to confine any radioactivity that may be released into the containment atmosphere following a postulated Design Basis Accident (DBA). There is no one particular system for complete containment isolation, but isolation design is provided applying acceptance criteria common to penetrations in many different fluid systems.

Conditions requiring containment isolation:

1. Automatic initiation of a CIAS occurs when a high containment pressure of 5 psig or a high containment radiation level of 10R/hr is detected, or when a SIAS is initiated. This provides diversity of parameters sensed for the initiation of containment isolation.

2. The CIAS closes fluid line penetration isolation valves not required for operation of the Engineered Safety Features.

3. The CIS is designed so that no single active failure (in conjunction with loss of offsite power) could results in offsite doses or doses to operators in the control room in excess of 10 CFR 100 and General Design Criteria 19, respectively.

4. The main steam and feedwater valves close on MSIS and the valves for the component cooling water for the reactor coolant pump motors close on SIAS.

5. Containment isolation valves on lines serving engineered safety feature systems are not closed automatically by the CIAS, but may be closed by remote manual operation from the control room.

Component Listing for
Containment Isolation System (CIS-07)

1. Containment Isolation Valves (Applicable to many systems)
99. CIAS Controller

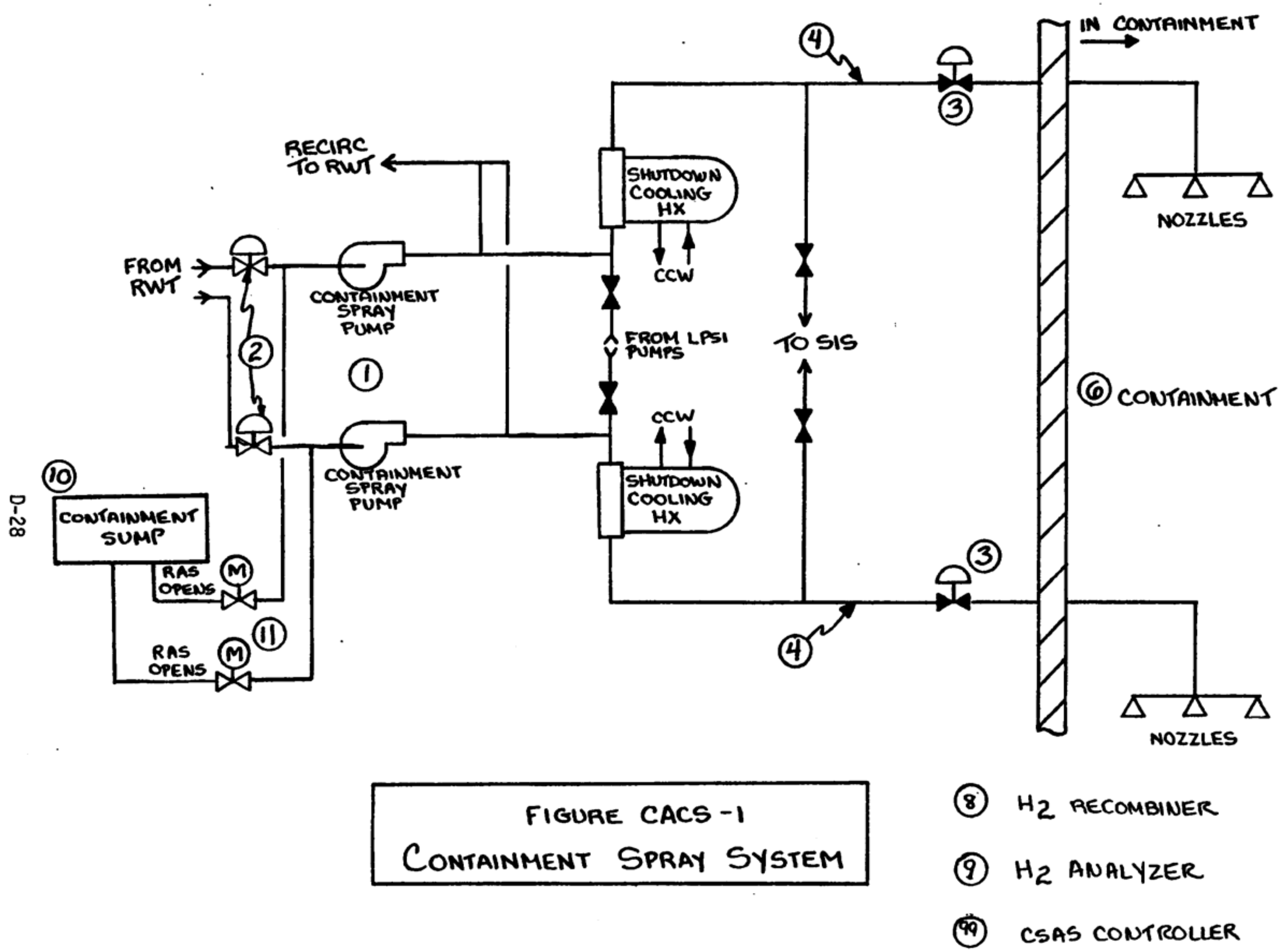

Figure 2.1-2 Containment Spray System (System #06)

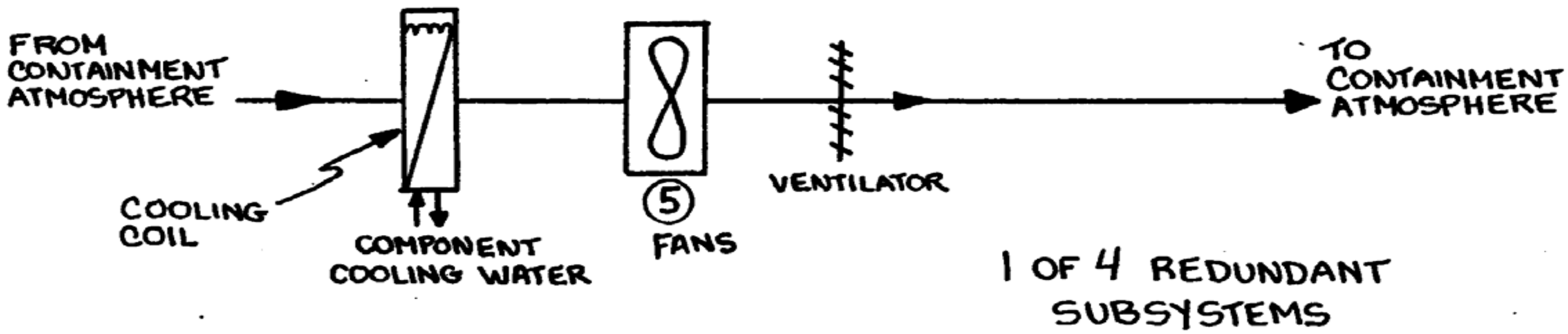

Figure 2.1-3 Containment Cooling System (System #06)

2.2 WESTINGHOUSE REFERENCE PLANT

The reference plant for Westinghouse-designed plants is described in the ERG Executive Volume and in Background Information for the individual guidelines. The ERGs were developed in high-pressure and low-pressure versions to address the most significant difference in plant design configuration with respect to plant response to emergency transients, specifically, the maximum shutoff pressure of the safety injection system. Each version of the ERGs is based on a generic reference plant configuration, sufficiently defined to enable the development of generic technical guidance while maximizing the applicability of the guidance. The high-pressure reference plant is essentially a 4-loop plant with system design features similar to current Westinghouse-designed plants. The low-pressure plant is essentially an "n-loop" plant with system design features similar to earlier Westinghouse-designed 2-loop plants. Below are descriptions of selected systems and equipment important to the mitigation of recirculation sump blockage. The index on the last page of this section identifies the ERG document location for more detailed descriptions of selected systems and equipment.

2.2.1 Safety Injection (SI) System

A safety injection system diagram for the high-pressure reference plant is shown in Figure 2.2-1. The major components of this system for the high-pressure (HP) plant are the refueling water storage tank, two charging/SI pumps, two high-head SI pumps, two low-head SI pumps, two RHR heat exchangers, one boron injection tank, four SI accumulators, nine high-pressure injection valves and five low-pressure injection valves. A safety injection system diagram for the low-pressure reference plant is shown in Figure 2.2-2. The major components of this system for the low-pressure (LP) plant are the refueling water storage tank, two high-head SI pumps, two low-head SI pumps, two RHR heat exchangers, one boric acid tank, two SI accumulators, four high-pressure injection valves and four low-pressure injection valves.

Following an incident that generates a Safety Injection (SI) signal, the safety injection pumps automatically start and high- and low-pressure injection valves automatically open. If the incident results in a containment pressure increase sufficient to initiate a containment spray signal, the containment spray pumps are automatically started. The specific pumps and valves that operate depend on the available power source. If standby (offsite) power is available, all safeguards equipment will operate. If standby power is not available, safeguards loads are divided between the two plant emergency diesel-generators and will sequentially operate after the associated emergency diesel-generator starts.

During the injection mode of operation the safety injection pumps take suction from the Refueling Water Storage Tank (RWST) and inject borated water into the Reactor Coolant System (RCS). If the RCS pressure drops below approximately 650 psig for the HP plant or 750 psig for the LP plant the SI accumulators will discharge borated water into the RCS cold legs. The SI accumulators are a passive injection means since no electrical signal, operator action or outside power source is required for their successful operation.

When the RWST level reaches the "low" ("switchover") setpoint, the SI system is aligned for cold leg recirculation. When the "low" level setpoint is reached an adequate liquid inventory should exist in the containment recirculation sump to support SI pump operation. During switchover to recirculation, the Low-Head Safety Injection (LHSI) pump suction is realigned from the RWST to the containment recirculation sump and the High-Head Safety Injection (HHSI) pump suction is realigned from the RWST to the LHSI pump discharge. For HP plants, the Charging/SI pump suction is also realigned from the RWST to the LHSI pump discharge. The SI system pumps will inject into the RCS cold legs whenever RCS pressure is below the pump shutoff pressure. When the RWST level reaches the “low-low” setpoint, the containment spray system is aligned for recirculation with the containment spray pumps taking suction from the containment recirculation sump. At a predetermined time after event initiation, based on boron concentration approaching the solubility limit in the vessel/core region, hot leg recirculation is established by realigning the HHSI pump discharge (and LHSI pump discharge if appropriate) to the RCS hot legs. Hot leg recirculation continues until terminated or modified by operator action.

The RHR heat exchangers and low-head safety injection (RHR) pumps are also used during plant cooldown to remove core decay heat and reactor coolant system sensible heat. Following cooldown they are used to maintain a stable reactor coolant system temperature while the plant is at cold shutdown. Component cooling water is the heat exchanger cooling medium.

The LHSI pumps are centrifugal pumps with a shutoff pressure of 200 psig (HP plant) or 250 psig (LP plant) and a run out flow of approximately 4800 gpm (HP plant) or 2500 gpm (LP plant). The HHSI pumps are centrifugal pumps with a shutoff pressure of 1500 psig (LP plant) or 1600 psig (HP plant) and a run out flow of approximately 600 gpm. The charging/SI pumps (HP plant) are centrifugal pumps with a shutoff pressure greater than 2335 psig and a run out flow of approximately 550 gpm.

Safety Injection Accumulators

The SI accumulators will inject borated water into the RCS following any emergency transient that depressurizes the RCS below the accumulator pressure. Each accumulator is connected to a cold leg of the RCS via an injection line shared with the SI pumps. A single isolation valve is provided in each accumulator injection line. During normal plant operation, the isolation valve is de-energized open and the accumulator is isolated from the RCS by two check valves in series. The accumulators automatically discharge if RCS pressure decreases below the nitrogen gas cover pressure of approximately 650 psig (HP plant) to 750 psig (LP plant).

Refueling Water Storage Tank (RWST)

The RWST is an atmospheric tank containing water borated to at least 2000 ppm boron. The RWST is sized to contain sufficient water to fill the refueling water canal, transfer tube and the refueling cavity to a depth of at least 23 feet above the reactor vessel flange for refueling operations.

The RWST also provides the reservoir of borated water for the injection mode of operation for the high-head SI pumps, low-head SI pumps and charging/SI pumps, and supplies the containment spray pumps. Per Westinghouse Standard Technical Specifications, the RWST minimum water volume and boron concentration ensure that:

1. Sufficient water is available within containment to permit recirculation cooling flow to the core.

2. The reactor will remain subcritical in the cold condition following mixing of the RWST and RCS water volumes with all control rods inserted except for the most reactive control assembly.

The minimum water volume includes an allowance for water not usable because of tank discharge line location or other physical characteristics.

Boron Injection Tank (BIT)

The BIT is a tank within the charging/SI system of the HP plant containing water borated to approximately 21000 ppm boron. The BIT is provided to inject negative reactivity into the core to counter the positive reactivity caused by an RCS cooldown due to events such as a LOCA, steam line break or inadvertent depressurization. During normal plant operation, the BIT contents are isolated from the charging/SI injection line by parallel sets of inlet and outlet valves; these valves open upon receipt of a SI signal. The BIT minimum water volume and boron concentration ensure that the assumptions used in the steam line break analysis are met.

Boric Acid Tank (BAT)

The BAT is a tank within the high-head SI system of the LP plant containing water borated to approximately 21000 ppm boron. The BAT is provided to inject negative reactivity into the core to counter the positive reactivity caused by an RCS cooldown due to events such as a LOCA, steam line break or inadvertent depressurization. During normal plant operation, the BAT contents are isolated from the charging/SI injection line by parallel sets of outlet valves. Upon receipt of a SI signal, the high-head SI pumps take suction from the BAT and discharge to the RCS cold legs. High-head SI pump suction is automatically transferred to the RWST on low BAT level. The BAT minimum water volume and boron concentration ensure that the assumptions used in the steam line break analysis are met.

(Note: The Westinghouse reference plant designs currently assume a 21000 ppm boron concentration for the BIT and BAT consistent with the original design of most Westinghouse plants. It is acknowledged that more recent steam line break analyses require a reduced boron concentration in the injection water at many plants, for example, 2400 ppm to 2500 ppm.)

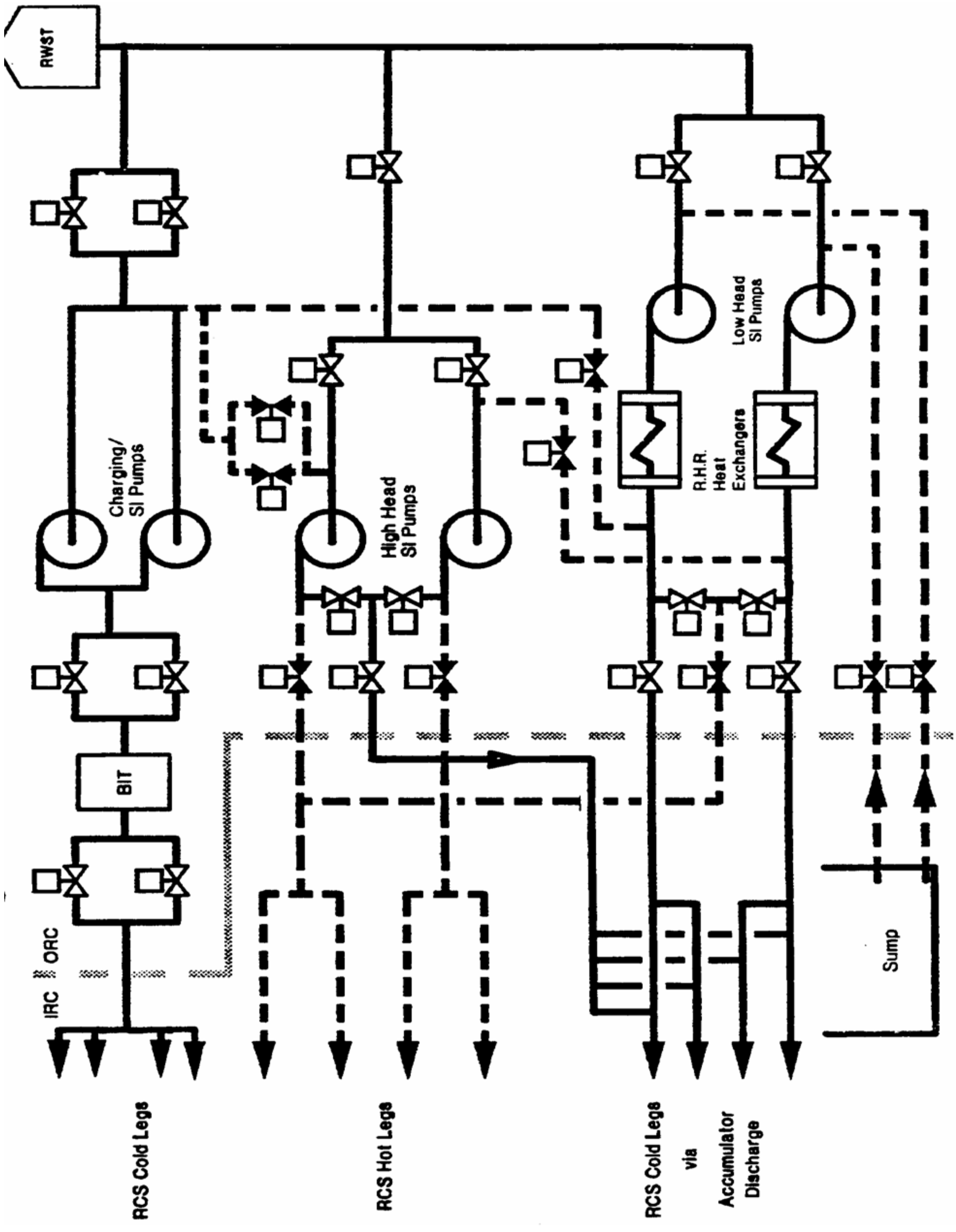

Figure 2.2-1 Safety Injection System – High-Pressure Reference Plant

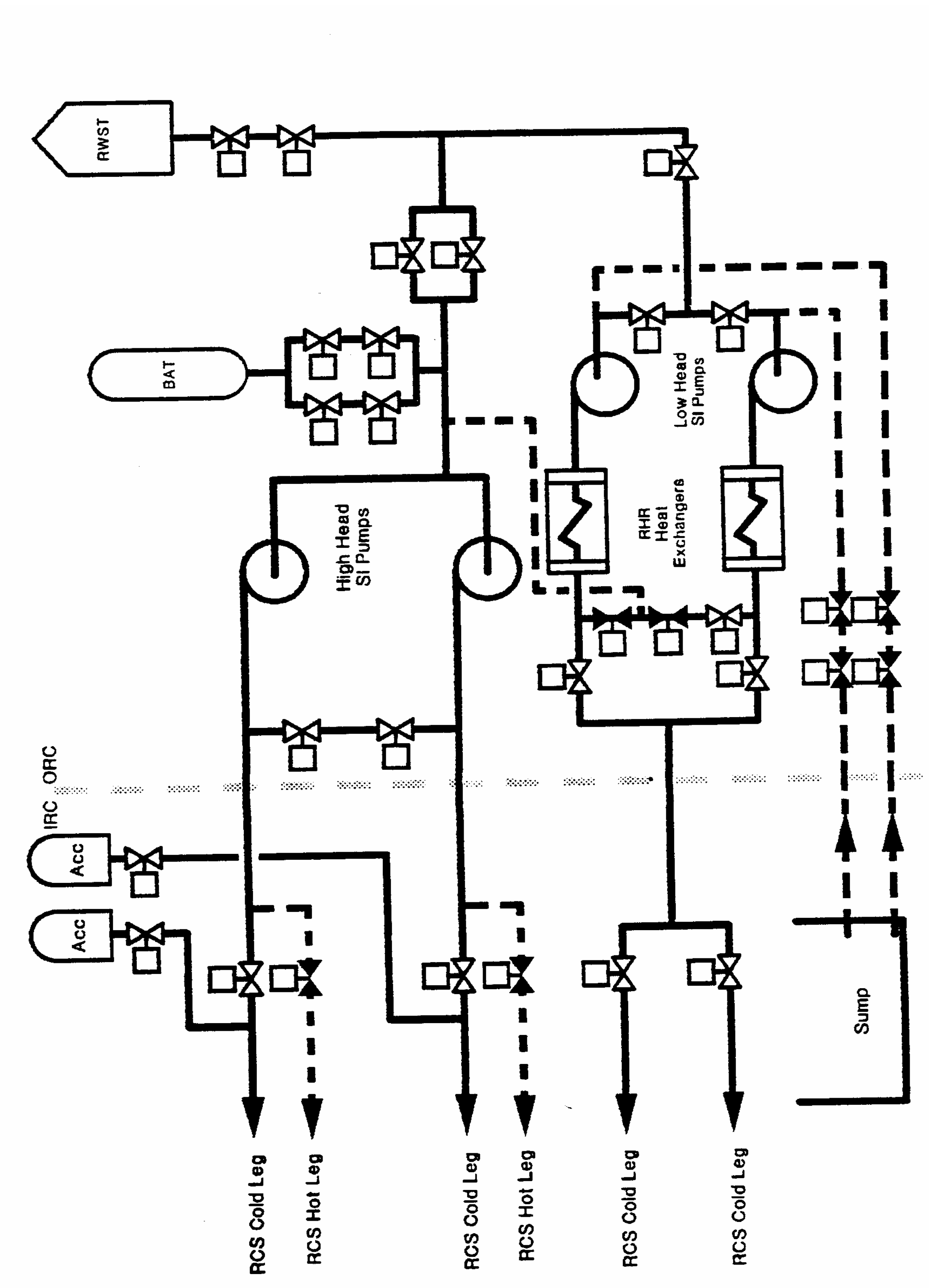

Figure 2.2-2 Safety Injection System – Low Pressure Reference Plant

Component List for
Safety Injection System

Refueling Water Storage Tank
RWST Isolation Valves
Charging/SI Pumps (HP only)
Low-head SI Pumps
High-head SI Pumps
HHSI, Charging/SI and LHSI Miniflow Isolation Valves (not shown)
RHR Heat Exchangers
RHR Heat Exchanger Bypass Flow Control Valves (not shown)
RHR Heat Exchanger Outlet Valves
HHSI Cold Leg Injection Isolation Valves
HHSI Hot Leg Injection Isolation Valves
BIT Isolation Valves (HP only)
BAT Isolation Valves (LP only)
LHSI Sump Suction Isolation Valves
LHSI Cold Leg Isolation Valves
LHSI Hot Leg Isolation Valves (HP only)
LHSI to HHSI Crossover Isolation Valves
LHSI to Charging/SI Crossover Isolation Valves (HP only)
Accumulators (not shown on HP)
Accumulator Isolation Valves (not shown on HP)
Hot Leg and Cold Leg Injection Headers

2.2.2 Containment Spray System

The containment spray system provides containment pressure suppression, heat removal and airborne fission product removal following an accident. The system contains two separate trains; each train consists of a centrifugal spray pump, spray header and nozzles, spray additive tank and eductor, and the necessary piping and valves as shown in Figure 2.2-3. The spray additive tank (SAT) contains a sodium hydroxide solution for removal of radioiodines from the containment atmosphere and control of the containment sump pH. The system has two modes of operation:

1. The injection mode, during which the system draws water from the RWST.

2. The recirculation mode, during which the system takes suction from the containment sump for long-term cooling.

Containment spray is automatically initiated by a containment spray signal, generated by "High-3" containment pressure. Upon receipt of the containment spray signal, the containment spray pumps are started and the isolation valves are opened. The containment spray pumps take suction from the RWST and spray directly into the containment atmosphere via the spray nozzles. The injection mode is terminated before the RWST is emptied to ensure the system piping remains full of water and adequate NPSH for the spray pumps is maintained.

The recirculation mode is initiated by the operator upon receipt of an RWST "low-low" level alarm by manually shifting containment spray pump suctions from the RWST to the containment recirculation sump. The spray pump discharge paths are the same as in the injection mode. Containment spray in the recirculation mode is continued to maintain an equilibrium temperature between the containment atmosphere and the recirculation sump. The piping and valves which connect the containment recirculation sump to the containment spray system are separate from the piping and valves which connect the containment recirculation sump to the low-head SI subsystem.

The containment spray pumps are centrifugal pumps with a discharge capacity of approximately 2800 gpm.

2.2.3 Containment Atmosphere Control System

The containment atmosphere control system provides containment atmosphere heat removal, filtration and combustible gas mixture control. This system includes the containment fan coolers, containment electric hydrogen recombiners and containment ventilation equipment. The containment filtration subsystem and electric hydrogen recombiners are not pertinent to sump blockage mitigation and are not discussed here.

Containment Fan Coolers

The containment fan coolers provide cooling of the containment atmosphere to limit containment pressure, temperature and humidity during accident conditions. Upon receipt of a safety injection signal, the containment fans start automatically in the emergency mode (low speed) or shift to the emergency mode if already running to prevent motor overload due to high containment pressure. Emergency mode fan operation provides an alternate heat removal means to the containment spray system. Component cooling water is supplied to the cooling coils of each fan cooler.

The Westinghouse reference plant design uses containment fan coolers (in the emergency mode) and containment spray pumps for containment heat removal under accident conditions. Any one of the following combinations of fan coolers and spray pumps provides the design basis heat removal capability:

1. 4 fan coolers and 0 spray pumps, or
2. 2 fan coolers and 1 spray pump, or
3. 0 fan coolers and 2 spray pumps

Additionally, a "best estimate" (non-design basis) calculation was used to determine the required non-design basis containment heat removal capability. For the Westinghouse reference plant design, based upon this best estimate calculation, either three fan coolers or one spray pump will maintain pressure below the containment design pressure.

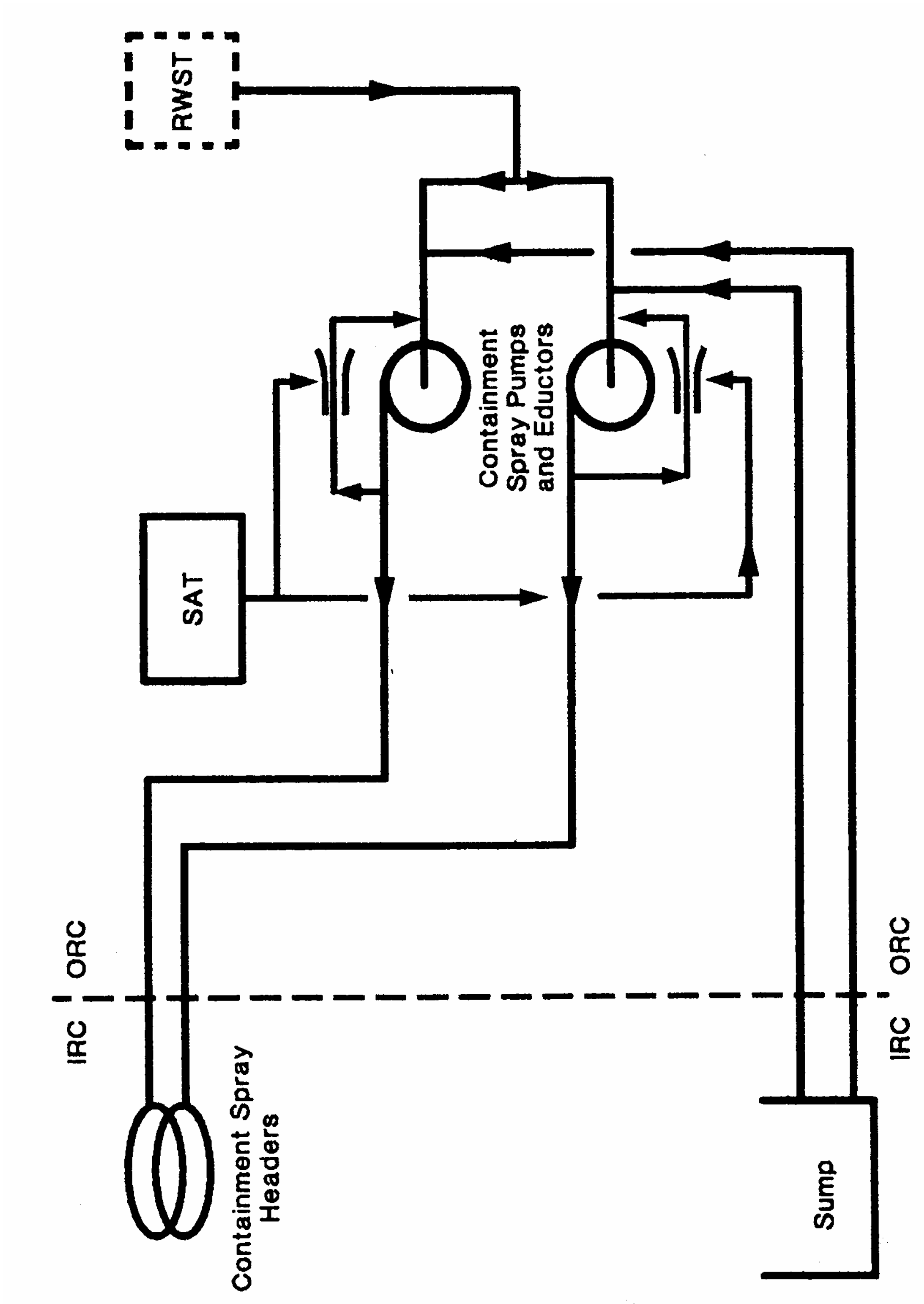

Figure 2.2-3 Containment Spray System

Component List for
Containment Spray System

Containment Spray Pumps
Spray Additive Tank
Containment Spray Eductors
Containment Spray Headers
Containment Sump
Containment Spray Header Isolation Valves (not shown)
Containment Spray Sump Suction Isolation Valves (not shown)
Containment Spray RWST Suction Isolation Valves (not shown)

Component List for
Containment Atmosphere Control System
(not shown)

Containment Cooling Fans
Hydrogen Recombiners
Hydrogen Analyzers
Containment Ventilation Fans
Containment Ventilation Filters

2.2.4 Containment Isolation System

The containment isolation system provides the means of isolating fluid systems that pass through containment penetrations to confine any radioactivity that may be released into the containment atmosphere following a postulated Design Basis Accident (DBA). There is no one particular system for complete containment isolation, but isolation design is provided by applying acceptance criteria common to penetrations in many different fluid systems. Two distinct phases of containment isolation are provided.

Containment Isolation Phase A

The containment isolation Phase A signal automatically isolates non-essential containment penetrations to prevent or minimize the release of radioactive material outside containment. This signal closes valves in specific plant systems that penetrate containment. The containment isolation Phase A signal automatically actuates when a Safety Injection (SI) signal is generated, or when containment pressure reaches the “High-1” setpoint.

Containment Isolation Phase B

The containment isolation Phase B signal automatically isolates essential containment penetrations (not required for operation of the ESF systems) to prevent the release of radioactive material outside containment. This signal automatically closes the containment isolation valves in the component cooling water lines to the reactor coolant pumps. The containment isolation Phase B signal automatically actuates when containment pressure reaches the “High-3” setpoint. (Note that Main Steamline Isolation occurs on “High-2” containment pressure.)

The containment isolation system is designed so that no single active failure (in conjunction with a loss of offsite power) could result in offsite doses or doses to operators in the control room in excess of 10 CFR 100 and General Design Criteria 19, respectively. Containment isolation valves on lines serving ESF systems are not closed automatically by the containment isolation system, but may be closed by remote manual operation from the control room.

Component List for
Containment Isolation System

Containment Isolation Valves (applicable to many systems)

ERG Reference Document Index

	High-Pressure Plant	Low-Pressure Plant
Safety Injection System		
Components/Design	EV HPRPD Pages 13-21	EV LPRPD Pages 15-20
	HPBD ES-1.2 Pages 3-5	LPBD ES-1.2 Pages 3-6
	HPBD ECA-1.1 Page 12	
Recirculation Mode	EV HPRPD Pages 15, 16, 19	EV LPRPD Pages 15, 16, 18
	HPBD ES-1.3 Pages 2-6, 18	LPBD ES-1.3 Pages 2-5, 18
Containment Spray System		
Components/Design	EV HPRPD Pages 27, 28	EV LPRPD Pages 23, 23A, 27
	HPBD ECA-1.1 Page 12	
Recirculation Mode	EV HPRPD Page 27	EV LPRPD Page 23A
Containment Fan Coolers		
Components/Design.	EV HPRPD Pages 24, 28A	EV LPRPD Pages 23, 23B
Heat Removal Assumptions	EV HPRPD Page 28A	EV LPRPD Page 23B
	HPBD ECA-1.1 Page 26	LPBD ECA-1.1 Page 22
Containment Design		
Structural Type	EV HPRPD Pages 46, 47	EV LPRPD Page 45, 46
Design Pressure, Temp	EV HPRPD Page 46	EV LPRPD Page 45
Sump Configuration	EV HPRPD Page 27	EV LPRPD Page 23A
	HPBD ECA-1.1 Page 3	LPBD ECA-1.1 Page 3
Refueling Water Storage Tank		
Refill Assumptions	HPBD ECA-1.1 Page 15	LPBD ECA-1.1 Page 11
	DW-99-056, DW-93-039	DW-99-056, DW-93-039
Instrumentation		
ESFAS.	EV HPRPD Pages 5-11, 37	EV LPRPD Pages 5-11, 36
	HPBD FR-Z.1 Page 2	LPBD FR-Z.1 Page 2
Qualification	EV GINSTR Pages 2, 20-22B	EV GINSTR Pages 2, 20-22B
Sump Blockage Indications	EV HPRPD Pages 12, 40-42	EV LPRPD Pages 12, 39-41
Uncertainties	EV GINSTR 18-23	EV GINSTR 18-23
	DW-95-024	DW-95-024
Containment Flooding		
Water Source Assumptions	HPBD FR-Z.2 Pages 2, 7	LPBD FR-Z.2 Pages 2, 7
Equipment Assumptions	EV PES Page 44	EV PES Page 44
	EV GINSTR Page 16	EV GINSTR Page 16

Reference Document Key

EV – ERG Executive Volume, Rev. 1C
HPRPD – High Pressure Reference Plant Description (section in EV)
LPRPD – Low Pressure Reference Plant Description (section in EV)
GINSTR – Generic Instrumentation (generic issue in EV)
PES – Evaluations by Plant Engineering Staff (generic issue in EV)
HPBD – High-Pressure ERG Background Information, Rev. 1C (one for each guideline)
LPBD – Low-Pressure ERG Background Information, Rev. 1C (one for each guideline)
DW – ERG Direct Work Request (ERG Maintenance Item)

2.3 OPERATOR ACTION TIMES

2.3.1 Operator Actions With Time Assumptions

The operator action times assumed in the evaluations address proposed operator actions taken before diagnosis of a sump blockage condition. These actions prevent, reduce or delay the effects of sump blockage on ECCS and/or CSS operation in a recirculation mode. The specific actions included are:

- Stopping one train of CS pumps after verifying two trains in operation but before transfer to a recirculation mode (Part of COA-1)
- Stopping one train of CS pumps after transfer to a recirculation mode (part of COA-9)
- Stopping one train of ECCS pumps after verifying two trains in operation but before transfer to a recirculation mode (COA-4, COA-10)
- Stopping one train of ECCS pumps after transfer to a recirculation mode (COA-3, part of COA-9)
- Early termination of CS flow after verifying criteria (part of COA-1)
- Early termination of ECCS after verifying criteria (part of COA-9)
- Restoration of CS flow following recognition of changed plant conditions or incorrect reduction/termination of flow (contingency following COA-1 or COA-9)
- Restoration of ECCS flow following recognition of changed plant conditions or incorrect reduction/termination of flow (contingency following COA-3, COA-4, COA-9 or COA-10)

This evaluation did not consider opera action times for transferring one train of ECCS to recirculation suction before the normal transfer criteria (COA-2). The operator manipulations performed to accomplish this action depend strongly on plant-specific characteristics. For the Westinghouse high-head ECCS design, operators cannot establish a system alignment that has one entire train with suction from the RWST and one entire train with suction from the recirculation sump.

This evaluation did not consider operator action times for refilling the RWT/RWST (COA-5) or to inject more than one RWT/RWST (COA-6). The operator manipulations performed to accomplish these actions depend strongly on plant-specific characteristics and event-specific conditions.

This evaluation did not assume operator action times for all the actions taken in response to a diagnosed sump blockage condition (COA-8 and COA-9). The highly variable time sequence of a developing sump blockage condition made such assumptions highly speculative. In addition, no acceptance criteria exist for such a beyond-design-basis sequence.

This evaluation did not consider operator action times for preventing or delaying CSS actuation for small LOCAs in ice-condenser plants. The analysis identified no specific operator manipulations to perform this action.

2.3.2 Standards Employed

ANSI/ANS-58.8-1994, "Time Response Design Criteria for Safety-Related Operator Actions," provides guidance for establishing timing requirements to be used in the design of safety-related systems for nuclear power plants. Although not directly applicable to the evaluation of potential ERG/EPG changes[1], ANSI/ANS-58.8 provides conservative criteria for this evaluation.

WCAP-14996, "ERG Operator Response Time Assessment Program Final Report," discusses issues associated with prolonged operator action times. The specific events evaluated in WCAP-14996 do not include issues of sump blockage. However, WCAP-14996 does include times associated with actions similar to those considered in the present evaluation.

2.3.3 Times Assumed

2.3.3.1 Stopping one train of CS after verifying that two trains are in operation but before transfer to a recirculation mode

Existing procedures already include verification of CS pump operation. Therefore, the only additional time involves the actual operator actions: (1) Reset containment spray signal and (2) Stop one containment spray pump. Although resetting the containment spray signal involves two separate controls, operators usually operate these simultaneously, so this evaluation treats it as a single manipulation.

ANSI/ANS 58.8 Table 2 suggests allowing one minute for each discrete manipulation. Therefore, stopping one train of CS pumps should take less than two minutes. Practical experience suggests approximately two minutes to perform such a step, including communication time.

2.3.3.2 Stopping one train of CS after transfer to a recirculation mode

Performing this step requires a second verification that two trains are in operation. This requires time in addition to the discrete manipulations. Since the verification is simple in nature and identical in content to existing verifications, this should be treated as a manipulation rather than a diagnoses, which would take from 5 to 20 minutes based on ANSI/ANS 58.8. After transfer to a recirculation mode, the SI signal should already have been reset. We assume that stopping one train of CS after transfer to a recirculation mode involves two operator actions: (1) Verify two trains of CSS are in operation and (2) Stop one containment spray pump. Therefore, based on ANSI/ANS 58.8 methods, stopping one train of CS pumps should take less than two minutes.

Practical experience suggests approximately two minutes to perform such a step, including communication time.

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[1] ANSI/ANS 58.8, Section 1.2, "The criteria are not intended to serve as a basis for determining actual operator action times in procedures or training, nor do they set requirements for operator staffing or qualification."

2.3.3.3 Stopping one train of ECCS pumps after verifying that two trains are in operation but before transfer to a recirculation mode

Existing procedures already include verification of ECCS pump operation. Therefore, the only additional time involves the actual operator actions. The number of actions involved depends on the plant-specific design of the ECCS. For a Westinghouse-type high-head ECCS design, the discrete operator manipulations are: (1) Reset SI, (2) Stop one low-head SI pump, (3) Stop one high-head SI pump and (4) Stop one charging/SI pump. Although resetting SI involves two separate controls, operators usually operate these simultaneously, so it should be considered a single manipulation. Therefore, based on ANSI/ANS 58.8 methods, stopping one train of ECCS pumps should take less than four minutes.

Practical experience suggests approximately three minutes to perform such a step, including communication time.

2.3.3.4 Stopping one train of ECCS pumps after transfer to a recirculation mode

Performing this step requires a second verification that two trains are in operation, with a separate verification for each type of ECCS pump. However, existing procedures already include steps such as, "Stop all but one charging/SI pump." Therefore, a reasonable application of discrete operator actions to stop one train of ECCS pumps for a high-head plant would be: (1) Reset SI, (2) Stop all but one low-head SI pump, (3) Stop all but one high-head SI pump, and (4) Stop all but one charging/SI pump. ANSI/ANS 58.8 methods indicate stopping one train of ECCS pumps should take less than four minutes.

Practical experience suggests approximately three minutes to perform such a step, including communication time.

Best estimate analyses have been performed to determine the time after trip when the decay heat level is low enough, such that, failure of "the one" running high pressure injection pump will result in approximately 15 minutes of reaction time before core temperature begins to rise. Fifteen minutes was selected so that loss of the one remaining high pressure injection pump will allow one Safety Function Status Check interval for the operator to recognize the loss of injection flow and take corrective action to restore core cooling.

Best estimate analyses show that at 40 minutes after trip there is approximately 15 minutes of operator reaction time before core temperatures begin to rise. Details of this analysis are contained in Appendix B. Since 40 minutes is an approximate value, each plant should complete a similar plant specific best estimate analysis.

2.3.3.5 Early termination of CS flow after verifying criteria

Existing procedures already include identical actions. This evaluation considers performing these actions at an earlier time. Verifying the criteria is simple in nature and should be treated as a single discrete manipulation. The existing step to terminate CS flow includes the following actions: (1) Check spray pumps –RUNNING, (2) Check Containment pressure – LESS THAN [ACTUATION SETPOINT], (3) Reset containment spray signal, (4 and 5) Stop containment spray pumps and place in standby [two discrete manipulations for two separate pumps]. ANSI/ANS 58.8 methods indicate termination of CS flow should take less than five minutes.

Practical experience suggests approximately three minutes to perform such a step, including communication time.

2.3.3.6 Early termination of ECCS after verifying criteria

Existing procedures already include identical actions. This evaluation considers performing these actions at an earlier time.

WCAP 14996 evaluates operator response times to verify criteria and terminate ECCS injection flow. The times ranged from less than three minutes to over thirteen minutes, with an average of about nine minutes. Therefore, ten minutes is a reasonable time to complete this action.

2.3.3.7 Restoration of CS flow following recognition of changed plant conditions or incorrect reduction/termination of flow

ANSI/ANS 58.8 Table 1 provides minimum times for diagnosis of a plant condition based on the best-estimate frequency of occurrence: five minutes for frequency greater than 0.1 per reactor year, ten minutes for frequency between 0.1 and 0.01 per reactor year and twenty minutes for frequency less than 0.01 per reactor year.

Operator actions to restore CS flow involve only a single discrete manipulation – starting a spray pump.

For the purposes of this analysis, we assumed ten minutes from the occurrence of a plant condition requiring restoration of CS flow until restoration of flow.

2.3.3.8 Restoration of ECCS flow following recognition of changed plant conditions or incorrect reduction/termination of flow

ANSI/ANS 58.8 Table 1 provides minimum times for diagnosis of a plant condition based on the best-estimate frequency of occurrence: five minutes for frequency greater than 0.1 per reactor year, ten minutes for frequency between 0.1 and 0.01 per reactor year and twenty minutes for frequency less than 0.01 per reactor year.

Operator actions to restore SI flow involve only a single discrete manipulation – starting one charging/SI pump, one high-head SI pump or one low-head SI pump.

For the purposes of this analysis, we assumed ten minutes from the occurrence of a plant condition requiring restoration of ECCS flow until restoration of flow.

3 TASK B1/B13 – IDENTIFY UFSAR SECTIONS AFFECTED BY RECOMMENDED CHANGES

3.1 TASK OBJECTIVE

This section addresses Tasks B1 and B13 from PA-SEE-0085.

Task B1 – UFSAR ECCS Cold And Hot Leg Recirculation Design Basis Review

This task will evaluate the impact of throttling flow for adequate heat removal in the recirculation modes on the ECCS Cold and Hot Leg Recirculation Design Basis. This task will identify the UFSAR sections that will be considered for review and revision, as necessary, to address a change in cold leg and hot leg recirculation alignments in a reduced flow operating mode.

For plants with individual sumps per ECCS/CSS train, this review will identify considerations for the limits on throttling flow for adequate heat removal in the recirculation modes.

NOTE: There are two components to this task, one review before any ERG/EPG changes are processed to ensure that other current licensing basis are not violated, and a second review after the ERG/EPG changes are identified and prior to their approval.

Task B13 – Identify UFSAR Sections Affected by Recommended Changes

After the recommended changes to the ERGs and EPGs are identified, this task will review the UFSAR and identify the sections that will need to be considered for revision by individual plants due to the proposed changes to the ERGs/EPGs.

A review of the Candidate Operator Actions (COA) in Appendix A indicates that explicit realignments of recirculation flow paths have not been considered. The COA dealt with more generic potential operator actions like securing an operating pump. This approach was taken because it appears that securing a pump would envelop throttling flow in that train and that the opportunities for recirculation realignment are plant specific.

3.2 IMPACT OF THROTTLING FLOW IN RECIRCULATION MODES ON DESIGN BASIS

Some plants can throttle flow without securing pumps or realigning recirculation. This type of throttling action would not require UFSAR changes as long as two conditions can be shown for a given plant. First, the throttled flow with all pumps still operating must be greater than the analyzed case that assumes the failure of one train. Having met this condition, the plant must show that the operators can, upon the subsequent loss of one running train, restore full (unthrottled) flow to the remaining train in the time necessary to maintain temperatures and pressures below that determined by the Chapter 15 safety analyses. This conclusion applies for both single and multiple sump plants. It is based upon the recommendation that any operational changes to the safety injection or recirculation lineup be made only after it is confirmed that all (both trains) of the expected flow paths are running as expected. Manual operations to modify the operation of a train at this point are assumed to be reversible upon loss of the other train. As shown in other sections of this report, generic analysis shows that there is adequate time for operator reaction after securing a pump, so there should be adequate time to unthrottle a throttled train.

For some plants throttling flow of the LHSI pumps should also consider FSAR analysis covered in Chapter 6. In particular, decreasing flow may affect long-term containment pressure and temperature (P-T) curves used for Equipment Qualification programs. See Section 6 of this report for more detailed information on the effect of throttling on Equipment Qualification programs.

For plants with multiple sumps, manually securing one train is considered to impose less risk of ultimate long-term sump blockage than throttling both trains. There will be no, or very little, flow through the secured sump allowing debris to settle while the other sump is operating. If the operating sump becomes blocked, restart of the secured train should provide a longer overall time to its subsequent blockage, if this occurs at all.

3.3 UFSAR SECTIONS TO BE CONSIDERED FOR REVIEW OR REVISION

The Vogtle FSAR was reviewed to determine potential changes required to implement any of the COA identified in Appendix A. Implementation of Candidate Operator Actions (COA) A5, A7, A8, and A9 in Appendix A will likely require no change to an FSAR since none of them impact design basis assumptions. However, each plant must review their Current Licensing Basis (CLB) to ensure no impact. The balance of the Candidate Operator Actions may impact some FSAR sections and may require FSAR revisions. The necessity for revision will be determined by the results of the 10 CFR 50.59 safety screening and evaluation, and a review of other specific regulations such as 10 CFR 50.46 (ECCS rule), to support implementation of each change. To provide more definitive guidance, the plant Vogtle FSAR has been reviewed to identify specific sections that may require revision if the applicable COA are adopted. Changes to other plants' FSARs may be in different sub-subsections (since they are numbered differently) but the concepts below should apply.

The majority of any potential changes will be in Chapter 6 of the FSAR and the Technical Specifications. Chapter 15 may require minor revisions. Changes to the Technical Specifications are addressed in Chapter 14 of this report. Example portions of the Vogtle FSAR requiring revision are Sections 6.2 and 6.3. It is expected that similar sections will require revision in other plant FSARs. The nature and extent of FSAR revisions are also dependent upon the COA chosen for implementation. For the examples shown below, all relevant COA are assumed to be implemented. In general, the changes are those that modify the description and use of the plant's single failure criteria.

Section 6.2.1.3.3 (Application of Single Failure Criteria) of the Vogtle FSAR states:

> In the case of minimum safeguards, the single failure postulated to occur is the loss of an emergency diesel generator. This results in the loss of one pumped safety injection train and the containment safeguards components on that diesel . . .

For any of the COA that include securing a safety injection pump, this section (6.2.1.3.3) would need to include a statement similar to:

> To reduce the probability and consequence of clogging the sump recirculation screens after switchover to recirculation, the operator is instructed to manually secure one ____ pump. This is performed after the operator has determined that all ECCS and CSS trains and equipment are operating. Following the manual stopping of the ____ pump, the single failure assumed is the loss of the remaining, running pump. The safety injection function is assumed to be lost for the time it takes to restart the secured pump (__ minutes). The secured pump is assumed to start since it was running when manually shut down. This transient has been shown to be less severe than the single train only running case discussed above.

Another change to Section 6.2.1.3.3 may be:

> . . manual actions for switchover. Adequate transfer allowance is provided to allow the operator to perform the switchover sequence without securing the **operating** containment spray pump~~s~~. The total . . .

Section 6.2.2.2.2.3.2 (Containment Spray Pumps) includes a discussion of the determination of adequacy of available NPSH for the containment spray pumps. It is based upon a single spray pump operating, so no changes are required for that reason. However, it includes a value of head loss based upon debris transport calculated in a Reference to the UFSAR. The debris transport and deposition model would have to be revised based upon the securing of one spray pump and the deposition models developed by others.

Section 6.2.2.2.2.4 (System Operation) describes the operation of the containment spray system. It requires additional text to describe the manual securing of one containment spray pump after the operator has determined that all safety injection equipment is operating as designed. If the plant in question has sufficient containment fan cooler capacity, the securing of an operating spray pump can be performed before the switchover to recirculation.

Section 6.2.2.2.2.5 (pH Control) describes containment pH conditions and operations. The summary of procedural requirements for containment spray operation should include recognition that one pump can be secured before recirculation if that COA is chosen. If the COA to inject more than one refueling water storage tank volume of water is chosen, the summary of procedural requirements should recognize the impact on refill time, in containment chemistry and water level and cleanup required.

Section 6.3.1 (Design Basis) of Section 6.3 (Emergency Core Cooling System) should be revised to state:

> . . The subsystem functional parameters are selected so that, when integrated, the Appendix K requirements are met over the range of anticipated accidents and single failure assumptions. **This includes the case where one ECCS pump is manually secured to reduce the probability for and consequences of debris transport to the containment sump. For this case, the single failure is assumed to be loss of the remaining operating pump until the secured pump can be restarted.**
>
> Portions of the ECCS . . .

In addition, plant specific analyses are required to justify the assertion above.

Section 6.3.2.2.9.1 (Injection Mode Allowance) describes the calculation of the minimum (shortest) injection mode operation time. It is based upon all (both of each type) safety injection pumps operating at design flow. Additional text is required to indicate which COA has been selected to reduce the probability for and the consequences of debris transport to the containment sump and the impact of that selection on the minimum injection operation time.

Section 6.3.2.2.9.2 (Transfer Allowance) describes the calculation of the time for operator transfer from the injection mode to the recirculation mode. It is based upon all (both of each type) safety injection pumps operating at design flow. Additional text is required to indicate which COA has been selected to reduce the probability for and the consequences of debris transport to the containment sump and the impact of that selection on the transfer operation time.

Section 6.3.2.5.1 (Active Failure Criteria) describes the analysis performed to characterize active failures in the ECCS. It includes a reference to FSAR Table 6.3.2-5. This table includes the ECCS failure modes and effects analysis (FMEA). It must be revised to reflect any selected COA and the resultant securing of a redundant operating pump with the subsequent loss of the running pump and restart of the secured pump. The section conclusions should remain unchanged, but the supporting analysis and table will change.

Section 6.3.2.5.2 (Passive Failure Criteria) describes the analysis performed to characterize passive failures in the ECCS. It includes a reference to FSAR Table 6.3.2-6. This table demonstrates that the ECCS can sustain a single passive failure during the long-term phase and still retain an intact flowpath to the core to supply sufficient flow to keep the core covered and to effect the removal of decay heat. The text of 6.3.2.5.2 and Table 6.3.2-6 must be revised to reflect any selected COA and the resultant securing of a redundant operating pump with the subsequent loss of the running pump and restart of the secured pump. The section conclusions should remain unchanged, but the supporting analysis and table will change.

Section 6.3.2.8 (Manual Actions) will require any of a number of revisions based upon the COA selected for a specific plant. All COA are initiated manually based upon defined indications to the operator. For the selected COA, the indications and manual actions require definition and discussion in this section. In addition, the description of the conditions and actions required to reverse the selected COA should also be described.

3.4 CONCLUSION

This section outlines and provides examples of FSAR changes required to implement the COA in Appendix A. Most changes will be required within Chapter 6 of the FSAR (Chapter 5 for older plants) and the Technical Specification bases. Technical Specification changes are included in Section 14 of this report. FSAR changes, like the COA selection, are plant specific. Any of the COA addressing securing a redundant operating pump will require UFSAR changes.

4 TASK B2 – IDENTIFICATION OF MANUAL OPERATOR ACTIONS ASSOCIATED WITH THE TERMINATION OF ECCS/CSS

4.1 INTRODUCTION/TASK OBJECTIVE

Several COA consider termination of Emergency Core Cooling System (ECCS) and/or Containment Spray System (CSS). This evaluation identifies manual operator actions associated with the termination of ECCS/CSS. Since the specific actions performed depend on the plant-specific design characteristics of the systems, this analysis assumes the following characteristics:

- The CSS consists of two independent trains, each with one spray pump
- For high-head plants, the ECCS consists of two independent trains, each with one low-head SI pump, one high-head SI pump and one charging/SI pump
- For low-head plants, the ECCS consists of two independent trains, each with one low-head SI pump and one high-head SI pump

As performed in Westinghouse Owners Group (WOG) Emergency Response Guidelines (ERGs), ECCS termination involves more than just stopping ECCS pumps. The specific actions performed depend on the circumstances (i.e., the actions taken to terminate ECCS flow following spurious actuation differ from the actions taken to terminate ECCS flow in response to a steam generator tube rupture). Manual operator actions associated with the termination of ECCS/CSS should also include those actions needed to determine that conditions require ECCS/CSS termination. The conditions requiring ECCS termination vary, depending on the circumstances. The requirements for ECCS termination include verifying at least two criteria but never more than four criteria. This evaluation considers the 'standard' ECCS termination requirement, which includes four criteria. For simplicity, this evaluation uses the actions of ES-1.1, SI TERMINATION. In all cases, this evaluation assumes that equipment operates as expected and that circumstances require no contingency actions.

4.2 SUMMARY OF CHANGES TO MANUAL OPERATOR ACTIONS

- CSS Termination

  Several existing procedures include action steps to terminate CSS operation. These action steps typically have the following form and content:

  Check If Containment Spray Should Be Stopped:

  a. Spray pumps – RUNNING
  b. Containment pressure – LESS THAN (T.04) PSIG
  c. Reset containment spray signal
  d. Stop containment spray pumps and place in standby:

  [Enter plant-specific means]

The manual operator actions associated with this action step are:

1) Determine that spray pumps are running

2) Determine that containment pressure is less than (T.04) psig

3) Reset containment spray signal (Although resetting the containment spray signal involves two separate controls (one for each train), operators usually operate these simultaneously, so this should be considered as a single manipulation)

4) Stop the containment spray pump in one train and place in standby (For most plants, releasing the control switch places the spray pump in standby, so this is not considered a separate manipulation)

5) Stop the containment spray pump in the other train and place in standby

The proposed ERG changes do not change the operator actions associated with CSS termination. The proposed changes only relocate these actions.

- ECCS Termination (High-head)

Several existing procedures include transition to ES-1.1, SI TERMINATION. Beginning with the determination that operators should terminate SI, the action steps typically have the following form and content:

RCS subcooling based on core exit TCs – GREATER THAN (R.01) °F [(R.02) °F FOR ADVERSE CONTAINMENT]

Check If SI Flow Should Be Reduced:

a. RCS subcooling based on core exit TCs – GREATER THAN (R.01) °F [(R.02) °F FOR ADVERSE CONTAINMENT]

b. Secondary heat sink:
   - Total feed flow to intact SGs – GREATER THAN (S.02) GPM

     - OR –

   - Narrow range level in at least one intact SG – GREATER THAN (M.02)% [(m.03)% FOR ADVERSE CONTAINMENT]

c. RCS pressure – STABLE OR INCREASING:

d. PRZR level – GREATER THAN (D.04)% [(D.05)% FOR ADVERSE CONTAINMENT]

e. Go to ES-1.1, SI TERMINATION, Step 1

1 **Reset SI**

2 **Reset Containment Isolation Phase A And Phase B**

3 **Establish Instrument Air To Containment**

4 **Stop All But One Charging/SI Pump And Place In Standby**

5 **Check RCS Pressure – STABLE OR INCREASING**

6 **Isolate BIT:**

a. Check charging/SI pump – SUCTION ALIGNED TO RWST

b. Check charging/SI pump miniflow isolation valves – OPEN

c. Close BIT inlet isolation valves

d. Close BIT outlet isolation valves

7 **Establish Charging Flow:**

a. Close charging line hand control valve

b. Open charging line isolation valves

c. Establish desired charging flow using charging flow control valve and charging line hand control valve

8 **Control Charging Flow To Maintain PRZR Level**

9 **Check If High-Head SI Pumps Should Be Stopped:**

a. Check RCS pressure:

- Pressure – STABLE OR INCREASING
- Pressure – GREATER THAN (B.05) PSIG [(B.06) PSIG FOR ADVERSE CONTAINMENT]

b. Stop high-head SI pumps and place in standby

10 **Check If Low-Head SI Pumps Should Be Stopped:**

a. Low-head SI pumps – ANY RUNNING WITH SUCTION ALIGNED TO RWST

b. Stop low-head SI pumps and place in standby

The manual operator actions associated with these steps are:

1) Determine if 'adverse containment' exists

2) Determine that RCS subcooling based on core exit TCs is greater than (R.01) °F [(R.02) °F]

3) Determine that secondary heat sink exists (This may involve determining up to four separate feed flow values, adding the values and comparing the values to the specified action setpoint. In other cases, this involves only comparing a single SG level to the specified action setpoint. Despite the range of possible sequences, we consider this a single operator action.)

4) Determine that RCS pressure is stable or increasing

5) Determine that PRZR level is greater than (D.04)% [(D.05)%]

6) Go to ES-1.1 (Since this involves at least opening the procedures to a new page, we consider this an operator action. Specific plants may require additional administrative tasks at this time, such as explicit reading of purpose, entry conditions, foldout page items, etc. We do not consider these as separate operator actions.)

7) Reset SI (Although resetting the SI signal involves two separate controls (one for each train), operators usually operate these simultaneously, so we consider it as a single manipulation)

8) Reset Containment Isolation Phase A (Although resetting the Containment Isolation Phase A signal involves two separate controls (one for each train), operators usually operate these simultaneously, so we consider it as a single manipulation)

9) Reset Containment Isolation Phase B (Although resetting the Containment Isolation Phase B signal involves two separate controls (one for each train), operators usually operate these simultaneously, so we consider it as a single manipulation)

10) Establish Instrument Air to containment (The number of operator actions varies with plant-specific design properties. In some cases, this may involve only opening a single valve. In other cases, operators may have to start air compressors or perform multiple valve manipulations. We consider this as a single manipulation.)

11) Determine if more than one charging/SI pump is running

12) Stop all but one charging/SI pump and place in standby. (The reference plant design has only two charging/SI pumps. Therefore, stopping all but one charging/SI pump involves, at the most, stopping one pump. For most plants, releasing the control switch places the pump in standby, so we do not consider this a separate manipulation.)

13) Check RCS pressure – stable or increasing

14) Check charging/SI pump – suction aligned to RWST (Although this involves checking the position indication of two valves, we consider this a single action)

15) Check charging/SI pump miniflow isolation valves – open (Although this involves checking the position indication of two valves, we consider this a single action.)

16) Close (one of two) BIT inlet isolation valve

17) Close (the second) BIT inlet isolation valve

18) Close (one of two) BIT outlet isolation valve

19) Close (the second) BIT outlet isolation valve

20) Close charging line hand control valve

21) Open (one of two charging line isolation valves

22) Open (the second) charging line isolation valve

23) Establish desired charging flow using charging flow control valve and charging line hand control valve (Although this may involve manipulation of more than one valve, we consider this a single operator action. In practice, this can involve iterative adjustment of valve position, waiting for flow to stabilize, and comparing indicated flow to desired values.)

24) Control charging flow to maintain PRZR level (This is a continuous action step that may involve iterative monitoring of PRZR level and adjustment of valve position.)

25) Check RCS pressure – stable or increasing

26) Check RCS pressure – greater than (B.05) psig [(B.06) psig]

27) Stop (one of two) high-head SI pumps and place in standby (For most plants, releasing the control switch places the pump in standby, so we do not consider this a separate manipulation.)

28) Stop (the second) high-head SI pump and place in standby

29) Determine if low-head SI pumps are running with suction aligned to RWST (Although this involves checking the position of two valves, we consider this a single action.)

30) Stop (one of two) low-head SI pumps and place in standby (For most plants, releasing the control switch places the pump in standby, so we do not consider this a separate manipulation.)

31) Stop (the second) low-head SI pump and place in standby

The proposed ERG changes do not change the operator actions associated with ECCS termination. The proposed changes only relocate these actions.

- ECCS Termination (Low-head)

Several existing procedures include transition to ES-1.1, SI TERMINATION. Beginning with the determination that operators should terminate SI, the action steps typically have the following form and content:

Check If SI Flow Should Be Terminated:

a. RCS subcooling based on core exit TCs – GREATER THAN (R.01) °F [(R.02) °F FOR ADVERSE CONTAINMENT]

b. Secondary heat sink:
   - Total feed flow to intact SGs – GREATER THAN (S.02) GPM

     - OR –
   - Narrow range level in at least one intact SG – GREATER THAN (M.02)% [(m.03)% FOR ADVERSE CONTAINMENT]

c. RCS pressure:
   - Pressure – GREATER THAN (B.05) PSIG [(B.06) PSIG FOR ADVERSE CONTAINMENT]
   - Pressure – STABLE OR INCREASING

d. PRZR level – GREATER THAN (D.04)% [(D.05)% FOR ADVERSE CONTAINMENT]

e. Go to ES-1.1, SI TERMINATION, Step 1

1 Reset SI

2 Reset Containment Isolation Phase A And Phase B

3 Establish Instrument Air To Containment

4 Align High-Head SI Pump Suction From BAT To RWST

[Enter plant-specific means]

5 Stop SI Pumps And Place In Standby:

a. Stop high-head SI pumps and place in standby

b. Low-head SI pumps – ANY RUNNING WITH SUCTION ALIGNED TO RWST

c. Stop low-head SI pumps and place in standby

Check If Charging Flow Has Been Established:

a. Charging pumps – AT LEAST ONE RUNNING

b. Establish flow as necessary: [Enter plant-specific means]

The manual operator actions associated with these steps are:

1) Determine if 'adverse containment' exists

2) Determine that RCS subcooling based on core exit TCs is greater than (R.01) °F [(R.02) °F]

3) Determine that secondary heat sink exists (This may involve determining up to four separate feed flow values, adding the values and comparing the values to the specified action setpoint. In other cases, this involves only comparing a single SG level to the specified action setpoint. Despite the range of possible sequences, we consider this a single operator action.)

4) Determine that RCS pressure is greater than (B.05) psig [(B.06) psig]

5) Determine that RCS pressure is stable or increasing

6) Determine that PRZR level is greater than (D.04)% [(D.05)%]

7) Go to ES-1.1 (Since this involves at least opening the procedures to a new page, we consider this an operator action. Specific plants may require additional administrative tasks at this time, such as explicit reading of purpose, entry conditions, foldout page items, etc. We do not consider these as separate operator actions.)

8) Reset SI (Although resetting the SI signal involves two separate controls (one for each train), operators usually operate these simultaneously, so we consider it as a single manipulation)

9) Reset Containment Isolation Phase A (Although resetting the Containment Isolation Phase A signal involves two separate controls (one for each train), operators usually operate these simultaneously, so we consider it as a single manipulation)

10) Reset Containment Isolation Phase B (Although resetting the Containment Isolation Phase B signal involves two separate controls (one for each train), operators usually operate these simultaneously, so we consider it as a single manipulation)

11) Establish Instrument Air to containment (The number of operator actions varies with plant-specific design properties. In some cases, this may involve only opening a

single valve. In other cases, operators may have to start air compressors or perform multiple valve manipulations. We consider this as a single manipulation.)

12) Open (one of two) high-head SI pump suction valves from RWST (Aligning high-head SI pump suction from BAT to RWST typically involves opening two valves from RWST to pump suction and closing two valves from BAT to pump suction. We consider these valve manipulations as four separate actions.)

13) Open (second of two) high-head SI pump suction valves from RWST

14) Close (one of two) high-head SI pump suction valves from BAT

15) Close (second of two) high-head SI pump suction valves from BAT

16) Stop (one of two) high-head SI pumps and place in standby. (For most plants, releasing the control switch places the pump in standby, so we do not consider this a separate manipulation.)

17) Stop (second of two) high-head SI pumps and place in standby

18) Determine if low-head SI pumps are running with suction aligned to RWST (Although this involves checking the position of two valves, we consider this a single action.)

19) Stop (one of two) low-head SI pumps and place in standby (For most plants, releasing the control switch places the pump in standby, so we do not consider this a separate manipulation.)

20) Stop (the second) low-head SI pump and place in standby

21) Determine if at least one charging pump is running

22) Establish flow as necessary (This is not a single action. The plant-specific design of the Chemical and Volume Control System determines the operator actions involved. Typically, this involves about ten separate operator actions. Because of the significant differences between plants, we do not identify these individual actions.)

The proposed ERG changes do not change the operator actions associated with ECCS termination. The proposed changes only relocate these actions.

- Proposed new procedure to address diagnosed recirculation sump blockage (assuming high-head ECCS design)

  The proposed new procedure to addressed diagnosed recirculation sump blockage includes several new steps that are different from existing action steps in intent and/or content. The following evaluation looks at the section of the draft proposal for this proposed new procedure that includes new operator actions.

1	**Monitor Low-Head SI Pump Suction Conditions – NO INDICATION OF CAVITATION:**	1. Perform the following: a. Stop any containment spray pump(s) taking suction from sump. b. IF indications of cavitation continue, THEN reduce RHR flow using flow control valves until cavitation stops. c. IF indications of cavitation continue, THEN close associated RHR injection isolation valve(s). d. IF indications of cavitation continue, THEN perform the following: i. Stop any charging/SI pump(s) and high-head SI pump(s) supplied from affected low-head SI pump(s). ii. Stop affected low-head SI pump(s).
2	**Verify Containment Fan Coolers – RUNNING IN EMERGENCY MODE**	
3	**Monitor RWST Level – GREATER THAN (U.03)**	Stop pumps taking suction from RWST and go to Step 5
4	**Determine Containment Spray Requirements With Suction From RWST**	
	a. Spray pump suction – ALIGNED TO RWST	
	b. Determine number of spray pumps required from table (based on containment pressure and number of fan coolers running in emergency mode)	
	c. Spray pumps running – EQUAL TO NUMBER REQUIRED	c. Manually operate pumps as necessary.
5	**Establish SI Recirculation Suction:**	
	a. Any low-head SI pump – RUNNING WITH SUCTION FROM SUMP	a. Perform the following: 1) Start one low-head SI pump. 2) IF indications of cavitation continue, THEN stop the pump and start the other low-head SI pump.

	b. Running low-head SI pump(s) – NO INDICATION OF CAVITATION	b. Perform the following: 1) Stop any charging/SI pump(s) and high-head SI pump(s) supplied from affected low-head SI pump(s). 2) Stop affected low-head SI pump(s).
	c. Any low-head SI pump – RUNNING	c. Go to Step 7.
	d. Low-head SI pumps – ONLY ONE RUNNING	d. Operate low-head SI pumps to obtain one pump running.
	e. RCS pressure – LESS THAN (B.07) PSIG [(B.08) PSIG FOR ADVERSE CONTAINMENT]	e. Go to Step 6.
	f. Manually align valves to establish low-head SI flow without indication of cavitation.	f. IF low-head SI flow can not be established without indication of cavitation, THEN go to Step 6.
	g. Low-head SI pump flow indicators – FLOW INDICATED	g. Go to Step 6.
	h. Go to Step 8	
6	**Establish High-Head ECCS In Recirculation Mode:**	
	a. High-head SI pump and charging/SI pump – SUCTIONS ALIGNED TO RUNNING LOW-HEAD SI PUMP	a. Align high-head SI pump and charging/SI pump suctions to running low-head SI pump. [Enter plant-specific means]
	b. High-head SI pumps and charging/SI pumps – ONLY ONE RUNNING	b. Operate pumps to obtain one high-head SI pump or charging/SI pump running in recirculation alignment.
	c. High-head SI pump or charging/SI pump – RUNNING IN RECIRCULATION ALIGNMENT	c. Go to Step 7.
	d. Go to Step 8	
8	**Check If Containment Spray Should Be Aligned For Recirculation:**	
	a. Recirculation sump level – GREATER THAN (T.O8)	
	b. Align spray for recirculation: [Enter plant-specific means]	
9	**Determine Spray Requirements With Suction From Recirculation Sump:**	

a. Determine number of spray pumps required from table (based on containment pressure and number of fan coolers running in emergency mode)	
b. Spray pumps running – EQUAL TO NUMBER REQUIRED	b. Manually operate spray pumps as necessary.

The manual operator actions associated with these steps are:

1) Determine if Train A low-head SI pump is operating without indications of cavitation

2) Determine if Train B low-head SI pump is operating without indications of cavitation

3) (If required) Stop Train A CS pump

4) (If required) Stop Train B CS pump

5) Determine if Train A low-head SI pump continues to indicate cavitation

6) Determine if Train B low-head SI pump continues to indicate cavitation

7) (If required) Reduce Train A RHR flow using flow control valves until cavitation stops (This may involve iterative throttling followed by check for continued cavitation. We consider this as a single operator manipulation.)

8) (If required) Reduce Train B RHR flow using flow control valves until cavitation stops

9) Determine if Train A low-head SI pump continues to indicate cavitation

10) Determine if Train B low-head SI pump continues to indicate cavitation

11) (If required) Close Train A RHR injection isolation valve

12) (If required) Close Train B RHR injection isolation valve

13) Determine if Train A low-head SI pump continues to indicate cavitation

14) Determine if Train B low-head SI pump continues to indicate cavitation

15) (If required) Stop Train A charging/SI pump

16) (If required) Stop Train B charging/SI pump

17) (If required) Stop Train A high-head SI pump

18) (If required) Stop Train B high-head SI pump

19) (If required) Stop Train A low-head SI pump

20) (If required) Stop Train B low-head SI pump

21) Verify containment fan coolers operating in emergency mode

22) Monitor RWST level – GREATER THAN (U.03) (The contingency actions for this step may include stopping low-head SI pumps, high-head SI pumps, charging/SI pumps and/or containment spray pumps. Since a previous step may have already stopped these pumps, we do not repeat operator actions to stop these pumps.)

23) Determine if Train A spray pump is aligned to RWST

24) Determine if Train B spray pump is aligned to RWST

25) Determine containment pressure

26) Determine number of fan coolers running in emergency mode

27) Determine number of spray pumps required from table

28) Determine if number of spray pumps running is equal to number required

29) Manually operate Train A spray pump as necessary (The maximum number of manipulations involved is two – stopping both spray pumps if both are running with suction from the RWST)

30) Manually operate Train B spray pump as necessary.

31) Determine if any low-head SI pump is running with suction from the sump

32) (If required) start one low-head SI pump

33) Determine if running low-head SI pump displays indication of cavitation

34) (If required) stop the low-head SI pump

35) (If required) start the other low-head SI pump

36) Determine if running low-head SI pump displays indication of cavitation

37) Determine if any low-head SI pump is running

38) Determine that only one low-head SI pumps is running

39) Determine if containment conditions are adverse

40) Determine if RCS pressure is less than (B.07) [(B.08)]

41) Manually align RHR injection isolation valve(s) to establish low-head SI flow without indication of cavitation

42) Manually align RHR flow control valve to establish low-head SI flow without indication of cavitation

43) Determine if low-head SI pump flow indicators indicate flow

44) Determine if high-head SI pump suction is aligned to running low-head SI pump

45) (If required) align high-head SI pump suction to running low-head SI pump

46) Determine if charging/SI pump suction is aligned to running low-head SI pump

47) (If required) align charging/SI pump suction to running low-head SI pump

48) Determine if only one high-head SI pump or charging/SI pump is running (This requires checking the status of four pumps. We consider this as a single operator action.)

49) (If required) Operate pumps to obtain one high-head SI pump or charging/SI pump running in recirculation mode (This may require manipulation of up to three controls – stopping three pumps if four pumps are running. Since previous steps included stopping pumps under different circumstances, we treat this as a single manipulation.)

50) Determine if high-head SI pump or charging/SI pump is running in recirculation mode.

51) Determine if recirculation sump level is greater than (T.08)

52) Align spray for recirculation (This step may require several separate manipulations. Since the exact number of manipulations depends on plant-specific characteristics and event-specific conditions, we treat this as a single manipulation.)

53) Determine containment pressure

54) Determine number of fan coolers operating in emergency mode

55) Determine number of spray pumps required

56) Determine if number of spray pumps running is equal to the number required

57) Manually operate spray pumps as necessary (This step may require zero, one or two separate manipulations, depending on plant conditions and the number of pumps running. We treat this as a single manipulation.)

4.3 CONCLUSIONS

- With respect to ECCS/CSS termination, the proposed ERG changes do not introduce any new operator actions (different in intent or action) from existing ERGs.

- With respect to ECCS/CSS termination, the proposed ERG changes do not change the intent or action of any existing operator actions.

- The proposed ERG changes do relocate some actions associated with ECCS/CSS termination within existing procedures.

- The proposed ERG changes include a proposed new procedure that addresses operator responses to diagnosed recirculation sump blockage. This proposed new procedure includes operator actions associated with ECCS/CSS termination. The specific list of operator actions depends strongly on the plant-specific design characteristics and event-specific conditions. The list above provides the operator actions associated with the reference plant and the most extreme accident circumstances.

5 TASK B3 – REVIEW DESIGN BASIS ACCIDENT DOSE ANALYSIS

5.1 INTRODUCTION/TASK OBJECTIVE

The standard radiological consequences analysis for the large break Loss-of-Coolant Accident (LOCA) assumes that there has been a single failure at the beginning of the accident that leaves only one containment spray pump operable. If there is no initial single failure and there are two containment spray pumps in operation following a large break LOCA, it is possible to stop one of the pumps and remain within the design basis analysis unless there is a delayed single failure that stops the operating pump during the relatively short period of time when spray removal of airborne activity is credited. However, when the single failure assumption is applied to the operating spray pump after the intentional stopping of one spray pump, there will be a period of time when no spray pumps are in operation. This period of no spray will result in an increase in the calculated doses. The objective of this task is to first determine the time of pump failure that would have the greatest impact on doses and then to define the magnitude of the impact of the loss of sprays.

It is noted that for each plant it is required to perform an analysis to demonstrate that, in the event of a postulated large break LOCA, core cooling is maintained and that severe damage of the reactor core will not occur (the limits of 10 CFR 50.46 are met). Thus, even greater core protection exists for the case in which there is no initial single failure. In the absence of severe core damage there is no need for containment sprays to remove airborne activity and, as long as containment pressure concerns are addressed, there would be no need for any containment spray. The review of the radiological consequences of the large break LOCA utilizes the presumption of severe core damage without any defined causation path.

5.2 SOURCE TERM METHODOLOGY

The evaluation is based on use of the alternate source term methodology which is defined in Regulatory Guide 1.183 (Reference 1). In this source term model the release of core activity takes place in two stages over a period of 1.8 hours. The first stage is the gap release phase which has a 0.5 hour duration and is followed by the core melt phase which has a duration of 1.3 hours.

Because of the duration of releases to the containment, spray operation is required for a period of time significantly greater than when it is assumed that the release of activity to the containment atmosphere occurs at the beginning of the accident.

5.3 EVALUATION APPROACH

A benchmark LOCA analysis was first performed using a reference plant based on the 4-Loop design. This benchmark analysis assumed the failure of a single electrical train at the beginning of the event. This results both in the loss of one spray pump and in a reduction in the number of fan cooler units in operation. Thus, not only is there a reduced ability to remove airborne activity but there is also a reduction in the recirculation between the spray and unsprayed regions of the containment.

A series of sensitivity cases were run in which there was no initial single failure assumed and one spray pump was assumed to be removed from service at the beginning of the event. All fan coolers were assumed to be in operation. The sensitivity cases were run to calculate the doses due to only the iodine nuclide group in order to identify the time at which the loss of containment spray would have the greatest impact. The single failure was assumed to be the loss of an electrical train resulting in loss of the spray pump and in loss of half the fan cooler units. The loss of sprays is assumed to last for ten minutes and then credit is taken for the operator returning the stopped pump into operation. The ten minute interval of spray loss is considered to be conservative.

Lastly, the benchmark case was revised to incorporate the single failure and resulting loss of containment sprays for a ten-minute period into the dose calculations for all eight nuclide groups.

5.4 RESULTS SUMMARY

The analysis shows that the worst time for the loss of sprays is 0.8 hr and that the impact on the offsite and control room doses is to increase them by less than ten percent.

The need for spray to remove airborne activity ceases after less than three hours.

5.5 IMPACT ON PLANT LICENSING BASIS

The postulated operator action to stop one of two operating spray pumps in order to reduce the rate of flow out of the refueling water storage tank and to reduce the sump recirculation flow rate could result in the situation where containment spray is interrupted for a short period of time. For most plants the interruption of containment sprays due to a delayed single failure would be a justifiable difference from the licensing basis. Some plants already have an interruption of containment spray as part of their licensing basis. This occurs during the switchover from injection to containment recirculation.

5.6 CONCLUSIONS

The interruption of containment sprays for a period of ten minutes results in an impact on calculated doses that has a good probability of being acceptable at most plants. Due to the variation in plant designs (e.g., fan cooler flow rate, spray flow rate, etc.) and site meteorology, specific plant evaluations are required.

5.7 REFERENCES

1. Regulatory Guide 1.183, “Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors,” July 2000.

6 TASK B4 – IMPACT ON THE LOCA M&E ANALYSIS FOR LARGE DRY CONTAINMENTS

6.1 INTRODUCTION & TASK OBJECTIVE

The uncontrolled release of pressurized high temperature reactor coolant, termed a Loss-of-Coolant Accident (LOCA), will result in release of steam and water into the containment. This, in turn, will result in increases in the global containment pressure and temperature. The LOCA mass and energy releases are analyzed to approximately 10^6 seconds and are utilized as input to the containment integrity analysis, which demonstrates the acceptability of the containment safeguards systems to mitigate the consequences of a hypothetical large break LOCA. The containment safeguards systems must be capable of limiting the peak containment pressure to less than the design pressure and to limit the temperature excursion to less than the Environmental Qualification (EQ) acceptance limits. Generally, the loss of one train of ECCS and containment pressure reducing equipment combined with a loss of offsite power is shown to result in the most limiting containment pressure and temperature transient. These assumptions are based on the NRC's NUREG-0800, Section 6.2.1.3, "Mass and Energy Release Analysis for Postulated Loss-of-Coolant Accidents" subsection II for design basis analysis for LOCAs on containment response. In order to determine if there are operator actions that can delay the onset of ECCS recirculation and/or reduce the recirculation flow rates through the sump screens, the analysis assumptions must be reconsidered.

6.2 LOCA MASS AND ENERGY RELEASE ANALYSES

The LOCA mass and energy release analyses performed for Westinghouse designed PWRs analyze two single failure scenarios. Both scenarios are analyzed assuming a loss off-site power. The first scenario assumes that a diesel generator fails to start which results in losing one-half of the ECCS pumps and containment pressure reducing equipment (i.e., Minimum ECCS case). The second scenario assumes that both diesels start but that a containment spray pump fails to start (i.e., Maximum ECCS case). Both of these scenarios have only one spray pump in operation and thus any operator action to minimize spray flow in order to increase the RWST drain down time or reduce sump flow during recirculation will have negative effect on the calculated containment peak pressure (Note: Ice Condenser plants are an exception during this early period, since the ice is providing for steam condensation and controlling containment pressure). Further, LOCA containment analyses do not make assumptions with regard to ECCS equipment availability or operator actions associated with the ECCS pumps, other than the switchover to ECCS recirculation. Assumptions for the ECCS pumps are based on the LOCA 10 CFR 50.46 analyses which set minimum requirements for ECCS performance. Thus, from the containment integrity analysis view point, only accident scenarios that initiate with two (or all) spray pumps running can be considered in developing operator actions to delay the onset of ECCS recirculation and/or reduce sump flows during ECCS recirculation. A scenario with two spray pumps running is less limiting than analyzed in the plants UFSAR and thus is not normally analyzed. LOCA scenarios that could result in two (or all) spray pumps running will have all diesel generators running and thus all ECCS equipment and containment pressure reducing equipment could be expected to operate. Thus, there is no single failure as required by design criteria. However, this scenario has been generally considered to be the most probable condition following a postulated LOCA and would result in early RWST draindown and entry into ECCS recirculation. Thus, this scenario was considered to present the most difficulty with respect to sump debris blockage and the associated issue with ECCS recirculation. Therefore, to support the WOG efforts in addressing NRC Bulletin 2003-01, the following scenario was considered. A LOCA with a loss of offsite power followed by both diesel generators starting and accepting all loads such that two trains of ECCS equipment, all Reactor Containment Fan Coolers (RCFCs) and all Containment Spray (CS) pumps are operating was analyzed.

6.3 CONTAINMENT ANALYSIS RESULTS

Given a LOCA with no single failure, the operator has options to reduce the safety equipment to the minimum assumed in the UFSAR analysis without creating an accident different than previously analyzed. However, once operator action is taken, the accident progression will be different than previously analyzed, but if it can be shown that the result is bounded by the licensing basis analysis, then an unanalyzed condition would not exist. Thus, in the case analyzed to support the WOG program to review potential changes to the ERGs, the operator was assumed to secure one CS pump 10 minutes following the LOCA. To address the requirement to account for a single active failure, the remaining CS pump was assumed to fail simultaneously with the operator action to secure a CS pump. This was followed by a 10 minute period with no CS in operation, however, all RCFCs will be operating. At 20 minutes after the LOCA, the operator was credited with re-starting the secured CS pump. This scenario was applied to several Westinghouse designed PWRs and depending upon the heat removal capacity of the RCFCs, there was a potential to calculate a containment peak pressure less than the FSAR limiting case. Because of the variation in containment design within the Westinghouse designed PWRs, generic statements can not be supported. A plant specific evaluation would be needed to determine the acceptability of this scenario and the associated operator actions.

6.4 CONCLUSIONS

The potential for operator action to delay entry into ECCS recirculation and reduce sump recirculation flows was reviewed as applied to LOCA containment integrity analyses. Only one LOCA scenario was identified as providing the potential for beneficial operator action. This was a scenario without an active single failure, but with a loss of offsite power. This scenario is generally accepted as being a more probable scenario than analyzed in the UFSAR where a single active failure is assumed to occur early in the accident. Given the higher level of probability and higher RWST and sump recirculation flows due to no equipment failures, this scenario was considered to be potentially the most limiting with respect to early entry into ECCS sump recirculation and sump recirculation flow rates. LOCA mass and energy releases and containment pressure calculations were performed which showed that if the relationship between RCFC and CS heat removal was such that an RCFC was a near equivalent to a CS, then acceptable results could be expected. However, due to the variation in containment design within the Westinghouse designed PWRs, generic statements could not be developed. A plant specific evaluation would be needed to determine the acceptability of this scenario and the associated operator actions to a given plant.

7 TASK B5 – IMPACT ON THE LOCA M&E ANALYSIS FOR ICE CONDENSER CONTAINMENT

7.1 INTRODUCTION/TASK OBJECTIVE

The purpose of this report is to evaluate the feasibility and appropriateness of preventing or delaying automatic actuation of the containment spray system for ice condenser plants. The intent of this change is to delay ECCS suction switch over from the refueling water storage tank to the containment sump.

Securing containment spray (one or both trains) once it is actuated is addressed in COA 1(Task B10). The COA 1 evaluation would appropriately apply to both large dry and ice condenser containments with the only caveat being that ice condenser containment designs may require more attention by the operators since there may be a containment pressure increase following depletion of the ice condenser heat removal capability.

7.2 IMPACT TO CONTAINMENT PRESSURE M&E ANALYSIS FOR ICE CONDENSER CONTAINMENT

Upon completion of the COA 11 evaluation, it was determined that the prevention or delay of containment spray for Ice Condenser plants would not be recommended as a potential compensatory action. Consequently there was no analysis initiated to specifically evaluate containment response to the prevention/delay of containment spray. It should be noted that although this action is not a recommended compensatory action, the potential exists that ice condenser plant design changes may incorporate this action as a part of the final GSI 191 resolution. Plant specific analysis would be required to support this prospect.

7.3 STRATEGIES FOR DELAYING CONTAINMENT SPRAY ACTUATION

Upon completion of the COA 11 evaluation it was determined that the prevention or delay of containment spray for Ice Condenser plants would not be recommended as a potential compensatory action.

7.4 IMPACT ON PLANT LICENSING CRITERIA

Blocking the automatic safeguards actuation or a revision to the current design basis actuation logic would be considered to be a change to the licensing basis. Revision of the actuation setpoints requires a technical specification change, a 10 CFR 50.59 evaluation, and reanalysis of containment transients with the new actuation setpoint included.

The termination of a single train of containment spray can be done within the current licensing basis. Justification may be required in the event of the failure of the single operating pump or termination of both containment spray pumps evaluated in COA 1.

7.5 CONCLUSIONS

Implementation is not recommended due to the need for logic changes. No further generic work is required. Licensees may determine based upon the potential for debris related concerns, that it may be advisable to implement logic changes to prevent automatic initiation of containment spray until the ice has melted. Detailed plant specific analysis and changes to the licensing basis would be required.

8 TASK B6 – IMPACT ON CONTAINMENT SUMP CHEMISTRY

8.1 OBJECTIVE

All plants are designed to protect the core following a LOCA by providing a continuous supply of cooling water to the core following the event. In the long term, the RWT/RWST inventory will be depleted and core heat removal is accomplished via recirculation of water previously injected into the RCS and collected in the containment sump. If sump recirculation is lost due to screen blockage, water for continued injection could be provided from a refilled RWT/RWST or from an alternate water source. This evaluation will consider the impact of such actions on sump pH control, on the radioactive iodine removal process, on maintaining the core subcritical, and on boron precipitation within the core region.

This evaluation applies only to scenarios in which additional water – with or without boron – is introduced into containment during or after the LOCA event, so that the total inventories of water or boron are greater than the amounts assumed in the Tri-Sodium Phosphate (TSP) or sodium hydroxide calculations of record. If the response to loss of sump recirculation uses only water already in containment, this water and the boric acid it contains have already been accounted for in the TSP or sodium hydroxide calculations of record, and there will be no impact on the containment sump chemistry.

8.2 IMPACT ON SUMP PH AND IODINE REMOVAL

In a post-LOCA environment, the pH of the containment sump must be kept at or above pH 7.0 in order to control the volatility of species containing radioactive iodine. This requirement is driven by the need to control the long-term (weeks or months) volatility of iodine-containing species dissolved in the containment sump solution. Post-accident sump pH must be maintained at or above 7.0 so that iodine – released from a damaged core and washed into the sump water – will remain in solution and not enter the gas phase. There is no requirement to control the pH of the initial containment spray during the LOCA event, since the spray will effectively remove volatile iodine species from the containment atmosphere regardless of the pH of the spray. This allows some PWRs to control sump pH with baskets of TSP pre-staged in the containment sump. This TSP dissolves in the containment sump solution in the hours and days after the LOCA event. Other PWRs neutralize the boric acid with sodium hydroxide (NaOH) injected directly into the containment spray during the LOCA event.

8.2.1 Addition of Water Without Boron

If the additional water introduced into containment from outside sources contains no boron or boric acid, the impact on long-term sump pH will be negligible. Regardless of whether the sump pH is controlled by sodium hydroxide or by TSP, dilution of the sump solution by the addition of water without boric acid will result in a slight increase in the pH of the solution, raising the long-term pH above the required minimum of 7.0 (Reference 1).

However, ensuring that the core does not become critical requires that borated water be maintained in the core to control reactivity. Before unborated water can be injected into the core, it must be mixed with borated water already in containment to achieve some minimum boron concentration for reactivity control. Minimum boron requirements for reactivity control are plant specific, and must be calculated on a plant-by-plant basis.

8.2.2 Addition of Water With Boron

Addition of water containing additional boric acid will impact the pH of the containment sump solution. Surprisingly, the addition of water containing boric acid at a lower concentration than the average boric acid concentration of the sump solution will initially raise the pH of the sump (Reference 1). For example, in a sump buffered to pH 7.0 by TSP, the sump pH will remain above 7.0 during the addition of more than three times the initial sump volume (i.e., quadrupling the sump water volume) if the additional water has a boric acid concentration that is 40% of the average initial sump concentration (Reference 1). Results for plants using sodium hydroxide are similar. Continued addition of this dilute boric acid will eventually drive the sump pH below 7.0, and increasing the boric acid concentration will reduce the volume of water that can be added. But it is noteworthy that significant volumes of boric acid solution with high enough boron concentrations to control core reactivity and prevent criticality can be introduced into containment without bringing long-term sump pH below 7.0. Calculation of the exact liquid volumes and boric acid concentrations that can be added while remaining above pH 7.0 is plant specific, and must be performed on a plant-by-plant basis.

If, because of high boron concentrations or large volumes of water, it proves to be desirable to neutralize the boric acid solution introduced into containment, several chemical additives are available. Additional TSP or sodium hydroxide can be added along with the water. The volume of TSP necessary for neutralization can be reduced by substituting Tri-Sodium Phosphate Dodecahydrate, ¼ Sodium Hydroxide, a commercially available material. Alternatively, borated water can be prepared with borax (sodium tetraborate decahydrate, $Na_2B_4O_7{\cdot}10H_2O$) instead of boric acid. Borax is a commonly available chemical, readily soluble in water, with a solution pH above 9, so that no other neutralization would be necessary.

8.3 CONSIDERATION OF SAFETY INJECTION FLOW REQUIREMENTS

Plant-specific calculations must be performed to determine the minimum required flowrate from the Safety Injection (SI) system, as a function of time, to 1) maintain adequate RCS inventory and 2) prevent precipitation of boric acid within the reactor vessel. Flowrate must be high enough to match the decay heat output of the core and to prevent core uncover. Additional SI flow is required to flush the highly concentrated boric acid from the core in order to prevent the precipitation of boron within the core that could adversely impact core cooling Simultaneous hot leg and cold leg injection of SI water is used to provide this capability.

8.4 CONCLUSIONS

This evaluation applies only to scenarios in which additional water is introduced into containment during or after the LOCA event. If the additional water is unborated, the impact on long-term sump pH will be negligible. If the additional water is borated, significant volumes of solution with a high enough boron concentration to prevent criticality can be introduced into containment without bringing long-term sump pH below 7.0. If it proves desirable to neutralize the boric acid solution introduced into containment, several chemical additives are available, including the use of borax instead of boric acid. Plant-specific calculations must be performed to determine the minimum required flowrate from the Safety Injection system as a function of time during the LOCA event.

8.5 REFERENCES

1. DAR-OA-03-16, Revision 0, "Evaluation of Emergency Core Cooling by Alternate Water Sources in the Absence of Sump Recirculation," November 2003.

9 TASK B7 – DETERMINE THE OPTIMAL RATE OF ADDITION (CE PLANT ONLY)

9.1 INTRODUCTION/TASK OBJECTIVE

"This task is intended to provide guidance to support the technical bases for possible operator instructions to inject additional water from a refilled RWST or from an alternate source bypassing the RWST.

Questions to be answered:

1. How does the operator determine the optimal addition rate?

   Develop a tool for a reference plant (for proof of principle) that shows the required minimum flow for heat removal based on time in core life and time after shutdown. May be answered using CENTS code. Level of effort will depend on number of break locations and sizes analyzed."

9.2 DISCUSSION

This task is not only plant specific, but dependent on the time in core life and break size specific. In the limit, the minimum addition rate is that just greater than the rate where the indicated core temperature is rising. This scenario is discussed in Appendix A, Candidate Operator Action A6. As shown in Sections 10, 11 and 12, one train of injection with the throttle valves open is more than sufficient to provide adequate cooling. There is no real advantage in throttling flow when injecting additional water from the RWST because injection is directly to the reactor coolant system since the recirculation flow is already stopped.

9.3 CONCLUSION

See Appendix A, Candidate Operator Action A6. The minimum practical flow should be one pump with the throttle valves open.

10 TASK B8 – SECURING ONE TRAIN OF HPSI BEFORE AND AFTER TRANSFER TO RECIRCULATION

10.1 INTRODUCTION

COA-10 – Secure One (out of 2) HPSI Pumps Before Transfer To Recirculation (CE Plants)

The purpose of this COA is to evaluate an EPG change for early termination of HPSI (High-Head Injection) prior to containment sump recirculation alignment (RAS). This change is being evaluated to determine whether it can be used as an acceptable method to delay the Recirculation Actuation Signal ("RAS" CE-NSSS) and thereby limit risk of containment sump blockage.

COA 3A – Secure One (out of 2) HPSI Pumps After Transfer To Recirculation Actuation (CE Plants)

The purpose is to evaluate an EPG strategy change to terminate one train of HPSI injection following containment sump recirculation alignment, assuming two trains of HPSI are in operation after Recirculation Actuation Signal (RAS) and are running normally. Currently the EPGs/ERGs have one standard set of HPSI Stop/Throttle or SI termination criteria criterion. The existing HPSI Stop/Throttle criteria are:

- RCS Subcooling equal to or greater than the minimum required
- Pressurizer level greater than the minimum level for verification of inventory control
- At least one steam generator available for RCS heat removal and SG level being maintained or restored
- Reactor Vessel level greater that the top of the hot legs

Although all the above conditions may not be met after RAS, it may still be risk beneficial to stop/throttle HPSI pumps to reduce the probability and severity of containment sump blockage. Since most plants only require one HPSI pump to meet licensing requirements, securing all but one HPSI pump after RAS still provides adequate core cooling consistent with the licensing bases.

COA 3B – Secure One (out of 2) SI Pump Trains After Transfer To Recirculation (Westinghouse Plants)

The purpose of this document is to evaluate an ERG change to terminate one train of SI injection following containment sump recirculation, assuming two trains of SI are in operation after transfer to recirculation and are running normally. Currently the ERGs have one standard set of SI Stop/Throttle or SI termination criteria that may not be satisfied post-recirculation depending on the size of the break. The SI Stop/Throttle criteria are:

- RCS subcooling equal to or greater than the minimum required

- Pressurizer level greater than the minimum level for verification of inventory control
  - At least one steam generator available for RCS heat removal and SG level being maintained or restored
  - Reactor vessel level greater than the top of the hot legs

During a large break LOCA, all of the above conditions may not be met after transfer to recirculation. Yet, depending on containment sump blockage risk, it may still be advantageous to stop/throttle SI pumps to lower containment sump blockage risk. Since most plants only require one train of SI pumps to satisfy the licensing bases, securing all but one SI train after transfer to recirculation still provides adequate core cooling consistent with the licensing basis.

10.2 CRITERIA FOR SECURING ONE TRAIN

COA-10 (CE NSSS) – Secure One (out of 2) HPSI Pumps Before Transfer To Recirculation

Not applicable. Securing one HPSI before transfer to recirculation is not considered risk beneficial due to the risk of core damage upon single failure loss of the–*one*–operating HPSI pump during a small break LOCA. Failure of the operating HPSI pump during small break LOCA may result in core voiding since RCS pressure may be greater than the shutoff head of the low pressure safety injection pump(s). See COA-10 in "Appendix, Engineering Evaluations and Analyses" for more detailed discussion.

CAO 3A (CE NSSS) – Post RAS HPSI Stop Criteria ***(proposed draft EPG change)***

IF RAS is present,

AND ALL of the following conditions exist,

- **BOTH** HPSI trains are in operation,
- HPSI flow rate is within the [SI flow delivery curves], REFER TO Figure 13.13. SI Flow Delivery Curves
- Representative CET Temperature less than [superheat],
- Reactor Vessel level greater than [top of active fuel].

THEN stop one HPSI pump at a time until only one pump is in operation.

a) Stop one HPSI pump.

b) Verify SI flowrate greater than [SI flow delivery curves], REFER TO Figure 13.13. SI Flow Delivery Curves

c) Verify Representative CET Temperature less than [superheat] and not rising,

d) Verify Reactor Vessel level greater than [top of active fuel] and not lowering.

CAO 3B (Westinghouse NSSS) – After Transfer To Recirculation SI Train Stop Criteria *(proposed draft ERG change)*

IF transfer to recirculation has occurred,

AND ALL of the following conditions exist,

- **BOTH** SI trains (2 RHR/LHSI, 2 SI and 2 HHSI/Charging Pumps) are in operation,
- SI flow rate is within the [SI flow delivery curves], REFER TO Figure SI Flow Delivery Curves
- Representative CET Temperature less than [superheat] and not rising,
- Reactor vessel level greater than [top of active fuel] and not lowering.

THEN stop one SI pump train at a time until only one train is in operation.

a) Stop one HHSI/charging pump.

b) Verify SI flowrate greater than [SI flow delivery curves], REFER TO Figure SI Flow Delivery Curves.

c) Verify Representative CET Temperature less than [superheat] and not rising,

d) Verify Reactor Vessel level greater than [top of active fuel] and not lowering.

e) Stop one RHR/LHSI pump.

f) Verify SI flowrate greater than [SI flow delivery curves], REFER TO Figure SI Flow Delivery Curves

g) Verify Representative CET Temperature less than [superheat] and not rising,

h) Verify Reactor Vessel level greater than [top of active fuel] and not lowering.

i) Stop one RHR/LHSI pump.

j) Verify SI flowrate greater than [SI flow delivery curves], REFER TO Figure 13.13. SI Flow Delivery Curves.

k) Verify Representative CET Temperature less than [superheat] and not rising,

l) Verify Reactor vessel level greater than [top of active fuel] and not lowering.

10.3 RESTART CRITERIA

COA-10 (CE NSSS) – Secure One (out of 2) HPSI Pumps Before Transfer To Recirculation

Not applicable. Securing one HPSI before RAS is not considered risk beneficial.

CAO 3A (CE NSSS) – Post RAS HPSI Stop Criteria *(proposed draft EPG change)*

IF ANY of the HPSI Stop criteria can **NOT** be maintained,

THEN:

a. Start HPSI pumps as necessary.
b. Raise HPSI flow, as necessary.

CAO 3B (Westinghouse NSSS) – After Transfer To Recirculation SI Train Stop Criteria *(proposed draft ERG change)*

IF ANY of the SI Stop criteria can **NOT** be maintained,

THEN:

a. Start the secured RHR/LHSI pump as necessary with delivery to cold legs closed.
b. Start SI pump with suction provided by the RHR/LHSI pump and delivery to the cold legs

IF ANY of the SI Stop criteria can **NOT** be maintained,

THEN:

c. Start SI pump with suction provided by the RHR/LHSI pump and delivery to the cold legs

IF ANY of the SI Stop criteria can **NOT** be maintained,

THEN:

d. Open the RHR/LHSI pump delivery to the cold legs

10.4 IMPACT ON CORE COOLING OF A SINGLE FAILURE AFTER SECURING ONE TRAIN

COA-10 (CE NSSS) – Secure One (out of 2) HPSI Pumps Before Transfer To Recirculation

Securing one HPSI before transfer to recirculation is not considered risk beneficial due to the risk of core damage upon single failure loss of the–*one*–operating HPSI pump during a small break LOCA. Failure of the operating HPSI pump during small break LOCA may result in core voiding since RCS pressure may be greater than the shutoff head of the low pressure safety injection pump(s). See COA-10 in "Appendix A, Engineering Evaluations and Analyses" for more detailed discussion.

CAO 3A (CE NSSS) – Post RAS HPSI Stop Criteria *(proposed draft EPG change)*

Preliminary best estimate analyses indicate that decay heat after recirculation is low enough to allow the operator to recover from loss of the running HPSI pump and restart the standby pump without core damage. Therefore, pending consideration of other factors, this COA is acceptable with respect to single failure.

CAO 3B (Westinghouse NSSS) – After Transfer To Recirculation SI Train Stop Criteria *(proposed draft ERG change)*

Preliminary best estimate analyses indicate that decay heat after recirculation is low enough to allow the operator to recover from loss of the running HPSI pump and restart the standby pump without core damage. Therefore, pending consideration of other factors, this COA is acceptable with respect to single failure.

10.5 IMPACT ON EPG SER COMMITMENTS AND NUREG 0737 REQUIREMENTS

CEN-152, Revision 3 (issued in 1987), is the last revision that has been reviewed by the NRC. The NRC has since indicated they no longer intend to review and approved subsequent changes to generic emergency procedure guidelines (EPGs). Instead, the NRC will review the generic guidelines within the context of plant specific EOP inspections, reviews, or audits conducted at the utility. While this policy is in force, the owners group has adopted a policy of providing the NRC with a copy of each new revision of the EPGs. Consistent with the current policy, a copy of EPG changes will be sent to the NRC "For Information Only."

In support of this project, the CEN-152 revision 3 SER was reviewed to determine if there were any RAI commitments that were impacted by any of the proposed changes. None were found. In addition, NUREG 0737 requirements were reviewed to determine if any of the proposed changes negatively impacted any requirement therein. None were found.

10.6 CONCLUSIONS

COA-10 (CE NSSS) – Secure One (out of 2) HPSI Pumps Before Transfer To Recirculation

Not Risk Beneficial – Securing one HPSI before transfer to recirculation is not considered risk beneficial due to the risk of core damage upon single failure loss of the–*one*–operating HPSI pump during a small break LOCA. However, each plant must consider the advantages and disadvantages as they apply to their plant specific design and incorporate interim compensatory measures accordingly. See COA-10 in "Appendix A, Engineering Evaluations and Analyses" for more detailed discussion.

CAO 3A (CE NSSS) – Post RAS HPSI Stop Criteria *(proposed draft EPG change)*

Risk Beneficial – Securing one (out of 2) HPSI pump after recirculation actuation is considered risk beneficial. However, each plant must consider the advantages and disadvantages as they apply to their plant specific design and incorporate interim compensatory measures accordingly. See COA-3 in "Appendix A, Engineering Evaluations and Analyses" for more detailed discussion.

CAO 3B (Westinghouse NSSS) – After Transfer To Recirculation SI Train Stop Criteria *(proposed draft ERG change)*

Risk Beneficial – Securing one (out of 2) HPSI pump after recirculation actuation is considered risk beneficial. However, each plant must consider the advantages and disadvantages as they apply to their plant specific design and incorporate interim compensatory measures accordingly. See COA-3 in "Appendix A, Engineering Evaluations and Analyses" for more detailed discussion.

11 TASK B9 – SECURING ONE TRAIN OF LPSI BEFORE AND AFTER RECIRCULATION ACTUATION (CE NSSS ONLY)

11.1 INTRODUCTION

The purpose of this task is to evaluate early termination of one (1) LPSI pump prior to recirculation alignment (see COA 4-CE). The intent of this change is to delay ECCS suction switch over from the refueling water tank to containment sump suction mode.

Current licensing bases analyses assume one train of LPSI pump operation from time of SIAS until RAS. The principal function of LPSI pumps is to provide high volume and low head cooling water to the core during a large break LOCA. LPSI pumps are most effective during the interval between Safety Injection Tank (SIT) dump and RAS, after which, one pump HPSI flow is sufficient to provide core cooling.

Preliminary indications show stopping one LPSI pump before recirculation is not risk beneficial due to the risk of core damage upon single failure loss of the–*one*–operating LPSI pump.

11.2 PROCEDURE CHANGES

Not applicable. COA 4 is not considered risk beneficial.

11.3 IMPACT ON CORE COOLING OF A SINGLE FAILURE AFTER SECURING ONE TRAIN

Preliminary best estimate analyses show that securing one LPSI pump before transfer to recirculation is not risk beneficial due to the risk of core damage upon single failure loss of the–*one*–operating LPSI pump during large break LOCA.

Best estimate analyses show rise in core temperature approximately 10 minutes after the interruption of all LPSI flow due to single failure loss of the one operating LPSI pump.

Analyses Sequence of Events		
	Time (sec.)	Event
1.	0	a) large break LOCA b) Rx Trip, SIAS and Containment Spray Actuation
2.	600	manually stop one of two running LPSI pumps
3.	601	single failure event: a) the only running LPSI pump stops (total LPSI flow interruption), b) one of two running HPSI pumps stop, c) one HPSI pump continues to run
4.	1200	600 seconds after loss of all LPSI flow, upper node core temperature begins to rise (departs from saturation temperature, begin superheat)

The implication here is that one HPSI pump is not sufficient to maintain adequate core cooling during early stage of large break LOCA event (less than 20 min. post trip, prior to recirculation). See COA-4 in "Appendix A, Engineering Evaluations and Analyses" for more detailed discussion.

11.4 IMPACT ON EPG SER COMMITMENTS AND NUREG 0737 REQUIREMENTS

CEN-152, Revision 3 (issued in 1987), is the last revision that has been reviewed by the NRC. The NRC has since indicated they no longer intend to review and approved subsequent changes to generic emergency procedure guidelines (EPGs). Instead, the NRC will review the generic guidelines within the context of plant specific EOP inspections, reviews, or audits conducted at the utility. While this policy is in force, the owners group has adopted a policy of providing the NRC with a copy of each new revision of the EPGs. Consistent with the current policy, a copy of EPG changes will be sent to the NRC "For Information Only."

In support of this project, the CEN-152 Revision 3 SER was reviewed to determine if there were any RAI commitments that were impacted by any of the proposed changes. None were found. In addition, NUREG 0737 requirements were reviewed to determine if any of the proposed changes negatively impacted any requirement therein. None were found.

11.5 CONCLUSIONS

COA 4 (CE NSSS) – Secure One (out of 2) LPSI Pump Before Transfer To Recirculation

Not Risk Beneficial – Securing one LPSI pump before transfer to recirculation is not considered risk beneficial due to the risk of core damage upon single failure loss of the–*one*–operating LPSI pump during large break LOCA. However, each plant must consider the advantages and disadvantages as they apply to their plant specific design and incorporate interim compensatory measures accordingly. See COA-4 in "Appendix A, Engineering Evaluations and Analyses" for more detailed discussion.

12 TASK B10 – SECURING CSS PRIOR TO AND AFTER RECIRCULATION ALIGNMENT

12.1 INTRODUCTION/ TASK OBJECTIVE

A reduction in the rate of recirculation flow to the containment sump can be a positive influence the amount of debris that may collect on the sump screen. Reduced recirculation flow will also reduce the pressure differential that may build up across the screen if debris does build up. Stopping containment spray will reduce the flow in a portion of the recirculation path suction lines. This has the potential to improve the NPSH to the SI pumps.

Reducing or stopping containment spray flow prior to the time of recirculation, can delay the onset of ECCS recirculation. However, as the LOCA break size increases, the delay becomes less significant. This Task determine the feasibility of reducing or stopping containment spray pumps as a means to delay the onset of ECCS recirculation and/or reduce the recirculation flow rates through the sump screens.

12.2 CRITERIA FOR REDUCING/SECURING SPRAY AND THE IMPACT OF MISDIAGNOSIS

The criteria for reducing/securing containment spray will be dependent on the results of the plant specific containment analysis for an interruption of all spray flow (see Section 6.2). The design of the containment heat removal system and the capacity of the containment fan coolers, will dictate the ability to reduce or stop containment spray flow.

The Safety Function accomplished by the containment spray pumps and containment fan coolers is to reduce containment pressure following a high energy line break in containment. The rate of containment pressure reduction is dependent on how much of the equipment actuates. The analysis for a complete interruption of spray flow is dependent on the containment pressure at the time the spray flow interruption occurs. Prior to turning off any spray pumps, the operator must verify that the minimum heat removal equipment assumed in the interruption of flow analysis is operating. This is accomplished by verifying a specific number of spray pumps and containment fan coolers are operating (See Appendix A1, Section 1.0). The operator should also verify that the equipment has performed its Safety Function. This is accomplished by verifying containment pressure and temperature are no longer increasing. Plants that credit containment spray in their dose analysis need to confirm that no core damage has occurred by confirming safety injection has actuated properly. This can be done by verifying Safety injection actuation and SI flow have remained within the values bounded by the delivery curves.

The only other event that requires containment spray is a Main Steam Line Break (MSLB). The containment pressurization portion of this event is over when the affected steam generator is blown dry. During large MSLBs, the affected steam generator will reach dry out within minutes. The operator will not have time to affect the containment heat removal system. Smaller breaks will take longer to reach steam generator dry out, but the demand on the containment heat removal systems is less. Verifying that the containment heat removal system has accomplished its Safety Function prior to shutting off any containment spray pumps and verifying no increase in containment pressure and temperature, will keep a misdiagnosed small MSLB within the defined limits of the MSLB Record of Analysis.

12.3 APPROPRIATE RESTART CRITERIA

This step in the Emergency Operating Procedure should have the operator verify that containment pressure and temperature are not increasing each time a containment spray pump is stopped. Failure to meet this criteria should result in restarting the secured pump. An indication of increasing containment pressure or temperature should continue to be a criterion to start an idle containment spray pump.

12.4 IMPACT ON CONTAINMENT PRESSURE/TEMPERATURE RESULTS

(See Section 5.3 of this report.)

12.5 IMPACT ON OFF-SITE DOSE OF A SINGLE FAILURE AFTER SECURING SPRAY

Safety systems are designed to assure that the core is protected from significant damage in the event of a postulated large-break LOCA. In the absence of significant core damage, containment spray operation is not required to mitigate the radiological consequences of the event. It is important to note that, if there is no initial single failure, the postulated core melt is not credible. Even with a single failure, core melt is not expected to occur. Major core damage would not be anticipated unless there was a combination of failures that deprived the core of adequate cooling. Plants that credit containment spray to reduce the dose source term during a LOCA need to verify the absence of significant core damage. This can be accomplished by verifying that the Safety Injection equipment has actuated properly.

12.6 IMPACT ON PLANT LICENSING BASES

See Section 5.5 of this analysis.

12.7 IMPACT ON EPG SER COMMITMENTS AND NUREG 0737 REQUIREMENTS

The only SER for the Combustion Engineering Emergency Procedure Guidelines (CEN-152) is for Revision 3. The SER has no specific requirements related to the operation of the containment spray pumps. The intent of the current containment spray termination step in CEN-152 is to “secure containment spray flow as soon as it can be determined that it is no longer required.” The list of criteria in the current step is very conservative because no analysis was done to define “no longer required” conditions. The revised step, constructed to address the sump blockage issue, is consistent with the current EPG logic but includes analysis and parameter evaluation to better define when containment spray is no longer required. The intentions currently in CEN-152 on when to secure containment spray pumps can be maintained with revised instructions that will result in securing containment spray sooner.

12.8 CONCLUSIONS

Implementing a step in the emergency operating procedures to stop one or more containment spray pump prior to RAS is possible if the plant specific containment analysis demonstrates that the containment fan coolers will provide ample time to start an idle containment spray pump and appropriate stop/restart criteria are implemented. (See Section 5.2) The step should include verification than a minimum number of containment fan coolers and spray pumps actuated properly. The step should also evaluate the containment pressure and temperature prior to stopping any containment spray pumps and after the containment spray pumps are stopped. The ability to stop all spray will depend on the required analysis (See Section 5.0) and current EQ limitations.

13 TASK B11 – EVALUATE THE IMPACT ON OPERATOR RESPONSE TIMES

13.1 INTRODUCTION/TASK OBJECTIVE

Several proposed changes to the ERG/EPG to address NRC Bulletin 2003-01 involve operator actions to secure one train of the Emergency Core Cooling System (ECCS) and/or Containment Spray System (CSS). The objective of this task is to evaluate the impact of these actions on operator response times.

13.2 OPERATOR RESPONSE TIME OF SECURING ONE TRAIN (HPSI, LPSI, OR CS) EARLY

Section 2.1 evaluates operator action times assumed for stopping one train of safeguards equipment. This evaluation considers termination of one entire train (both high-pressure and low-pressure) of ECCS at one time, we do not consider separate times for securing one train of HPSI and one train of LPSI. Since identical operator manipulations occur, the combined time for securing one train of HPSI and separately securing one train of LPSI should not differ significantly from that of securing one entire train of ECCS. Subsection 2.1.3 provides the following assumed operator response times:

- Stopping one train of CS pumps after verifying two trains in operation but before transition to a recirculation mode:

  Existing procedures already include verification of CS pump operation. Therefore, the only additional time involves the actual operator actions: (1) Reset containment spray signal and (2) Stop one containment spray pump. Although resetting the containment spray signal involves two separate controls, operators usually operate these simultaneously, so it should be considered as a single manipulation.

  ANSI/ANS 58.8 Table 2 suggests allowing one minute for each discrete manipulation. Therefore, stopping one train of CS pumps should take less than two minutes.

  Practical experience suggests approximately two minutes to perform such a step, including communications time.

- Stopping one train of CS pumps after transition to a recirculation mode:

  Performing this step requires a second verification that two trains are in operation. This requires time in addition to the discrete manipulations. Since the verification is simple in nature and identical in content to existing verifications, this should be treated as a manipulation rather than a diagnoses, which would take from 5 to 20 minutes based on ANSI/ANS 58.8. Therefore, based on ANSI/ANS 58.8 methods, stopping one train of CS pumps should take less than three minutes.

  Practical experience suggests approximately two minutes to perform such a step, including communications time.

- Stopping one train of ECCS pumps after verifying two trains in operation but before transition to a recirculation mode:

  Existing procedures already include verification of ECCS pump operation. Therefore, the only additional time involves the actual operator actions. The number of actions involved depends on the plant-specific design of the ECCS. For a Westinghouse-type high-head ECCS design, the discrete operator manipulations are: (1) Reset SI, (2) Stop one low-head SI pump, (3) Stop one high-head SI pump and (4) Stop one charging/SI pump. Although resetting SI involves two separate controls, operators usually operate these simultaneously, so it should be considered a single manipulation. Therefore, based on ANSI/ANS 58.8 methods, stopping one train of ECCS pumps should take less than four minutes.

  Practical experience suggests approximately three minutes to perform such a step, including communications time.

- Stopping one train of ECCS pumps after transition to a recirculation mode:

  Performing this step requires a second verification that two trains are in operation, with a separate verification for each type of ECCS pump. However, existing procedures already include steps such as, "Stop all but one charging/SI pump." Therefore, a reasonable application of discrete operator actions to stop one train of ECCS pumps for a high-head plant would be: (1) Reset SI, (2) Stop all but one low-head SI pump, (3) Stop all but one high-head SI pump and (4) Stop all but one charging/SI pump. ANSI/ANS 58.8 methods indicate stopping one train of ECCS pumps should take less than four minutes.

  Practical experience suggests approximately three minutes to perform such a step, including communications time.

13.3 IMPACT ON OPERATOR RESPONSE TIME EVALUATIONS

The proposed changes have the following impacts on the evaluation of operator response times:

- Some time-critical operator actions may be delayed by the time required to secure one train of ECCS/CSS. The time to secure one train of CSS is about two minutes. The time to secure one train of ECCS is about three minutes. The time to secure both one train of CSS and one train of ECCS is about five minutes. The specific time-critical operator actions affected by the proposed changes depend on the location at which the guideline incorporates the proposed changes.

- Securing one train of ECCS increases the time available for operators to terminate ECCS injection flow in response to a spurious SI signal or steamline break accident before filling the pressurizer. For those plants in which operators must terminate ECCS injection flow before pressurizer level reaches a specified value, this provides a benefit. Conversely, the time required to secure one train of ECCS/CSS increases the time required for operators to terminate injection flow. The net effect depends on plant-specific characteristics and event-specific conditions, but should be beneficial or neutral.

- Securing one train of ECCS increases the time available for operators to terminate ECCS injection flow in response to a steam generator (SG) tube rupture before filling the ruptured SG. For those plants in which operators must terminate ECCS injection flow before ruptured SG level reaches a specified value, this provides a benefit. For those plants that impose a specific time limit (rather than a ruptured SG level limit) on ECCS termination, securing one train of ECCS has a negative impact on the ability of operators to complete the actions within the specified limit.

- Securing one train of ECCS/CSS before the transition to a recirculation mode increases the time available for operators to perform those actions that must be completed before the transition. The specific time effect depends on plant-specific design characteristics and the specific event in progress. Therefore, this evaluation can not provide numerical values for this effect. This effect should have no significant benefit on overall risk.

- Securing one train of ECCS/CSS before the transition to a recirculation mode may reduce the time required to perform the transition. For some plants, the process of transitioning from the injection mode to the recirculation mode includes stopping and restarting pumps. Operators do not have to perform these actions if the pumps have already been stopped. However, the valve alignments should still be performed on the secured train. Since this is a plant-specific characteristic, this evaluation does not provide numerical values for this effect.

13.4 CONCLUSIONS

The proposed changes can increase the time required to perform certain time-critical actions. While this time is relatively short (on the order of five minutes), it has a negative impact on times assumed in the safety analysis.

Guidelines should not incorporate actions to secure one train of ECCS/CSS before verifying automatic actions necessary to protect the integrity of the fission product barriers.

Guidelines should not incorporate actions to secure one train of ECCS/CSS before performing operator actions with restrictive time limits, such as tripping Reactor Coolant Pumps.

For plants with restrictive time limits for ECCS termination in response to a SG tube rupture, guidelines should not incorporate actions to secure one train of ECCS/CSS before addressing the SG tube rupture.

For most other events, the proposed changes are beneficial or neutral with respect to operator response time. Individual plants must evaluate assumptions made in the safety analysis and assumed times for operator responses in existing guidelines before incorporating the proposed changes.

14 TASK B12 – REVIEW THE NUREG-1431 AND 1432, STANDARD TECHNICAL SPECIFICATIONS FOR WESTINGHOUSE AND COMBUSTION ENGINEERING PLANTS BASES

14.1 INTRODUCTION/TASK OBJECTIVE

The stated task objective is:

> After the recommended changes to the ERG and EPS are identified, this task will review the Bases in NUREG-1431/1432 for potential impact due to the proposed changes to the ERGs/EPGs.
>
> Recommended Bases changes, if necessary, will be identified in a letter report. Refer to Section C, Part D, Task 4 and Section D.4 for additional details on the how this will be included in the final deliverable.

The following sections provide a preliminary identification of recommended changes to Technical Specification Bases for Combustion Engineering plants related to each of the Candidate Operator Actions described in Appendix A. Changes to Bases for Westinghouse plants will be similar for each COA selected. All Bases changes will be plant specific based upon the COA chosen for implementation.

14.2 SECURE ONE OR TWO CONTAINMENT SPRAY PUMP(S) BEFORE RECIRCULATION ALIGNMENT

14.2.1 TS 3.6.6 (A and B) Containment Spray and Cooling Systems

14.2.1.1 ERG/EPG CHANGE

This strategy involves securing one containment spray pump after it has been verified that the containment spray system has performed its design function and containment pressure has peaked and is reduced to less than containment design pressure. This action is taken prior to initiating containment sump recirculation to extend the time to recirculation and lower recirculation flow rate once the switch to cold leg recirculation has occurred. Prior to stopping a containment spray pump, adequate heat removal should exist to allow the operator time to start the idle spray pump if the running pump fails. The operator must verify that the number of operating containment fan coolers are consistent with the design basis for no containment spray.

Securing one containment spray pump has the potential to introduce a complete interruption of spray flow. This is a new event that assumes one spray pump has been turned off and a loss of the operating pump occurs. Analysis must define how much time is available to restart the secured spray pump if the operating spray pump fails while remaining under the licensing basis analysis results of only one train operating.

14.2.1.2 TS BASES

"The Containment Spray System and Containment Cooling System limit the temperature and pressure that could be experienced following a DBA. The limiting DBAs considered relative to containment temperature and pressure are the loss of coolant accident (LOCA) and the main steam line break (MSLB). The DBA LOCA and MSLB are analyzed using computer codes designed to predict the resultant containment pressure and temperature transients. No DBAs are assumed to occur simultaneously or consecutively. The postulated DBAs are analyzed with regard to containment ESF systems, assuming the loss of one ESF bus, which is the worst case single active failure, resulting in one train of the Containment Spray System and one train of the Containment Cooling System being rendered inoperable."

The BASES statement must be expanded to identify the time an operator has to restart a manually secured pump following the loss of the operating pump from a condition with all safety injection and decay heat removal equipment operating.

14.2.2 TS 3.6.7 Spray Additive System (Atmospheric and Dual)

14.2.2.1 ERG/EPG CHANGE

Securing one containment spray pump early may impact this Bases discussion because a containment spray train is secured before the RWT/RWST and spray additive tank contents have been completely transferred to the containment sump. Therefore, the assumed amount of spray additive may not be transferred. This applies only to those plants where pH control is provided by the spray. Recognize that for these plants, this Candidate Operator Action may not be selected.

14.2.2.2 TS BASES

The Spray Additive System is essential to the effective removal of airborne iodine within containment following a Design Basis Accident (DBA). Following the assumed release of radioactive materials into containment, the containment is assumed to leak at its design value following the accident.

The BASES statement for plants using this Candidate Operator Action and spray additive for sump pH control must address the minimum volume of spray required for pH control. This volume may need to be added with the secured pump if the operating pump fails.

14.3 MANUALLY ESTABLISH ONE TRAIN OF CONTAINMENT SUMP RECIRCULATION PRIOR TO AUTOMATIC ACTUATION

14.3.1 TS3.3.4 ESFAS Instrumentation Recirculation Actuation Signal

14.3.1.1 ERG/EPG CHANGE

This strategy involves a staggered recirculation actuation. One ECCS train would be placed on sump recirculation early, when adequate inventory has been transferred to the containment sump to support one train of ECCS operation. The other ECCS train remains aligned to the RWT/RWST as a backup. If this strategy were to be adopted, a new actuation setpoint may have to be developed and current setpoint reevaluated. The large break LOCA analysis and the ECCS NPSH analysis would have to be reviewed and possibly reevaluated.

14.3.1.2 TS BASES

At the end of the injection phase of a LOCA, the refueling water storage tank (RWT/RWST) level will be very low. Continued cooling must be provided by the ECCS to remove decay heat. The source of water for the ECCS pumps is automatically switched to the containment recirculation sump. Switchover from the RWT/RWST to containment sump must occur before the RWT/RWST empties to prevent damage to the ECCS pumps and a loss of core cooling capability. For similar reasons, switchover must not occur before there is sufficient water in the containment sump to support pump suction. Furthermore, early switchover must not occur to ensure sufficient borated water is injected from the RWT/RWST to ensure the reactor remains shut down in the recirculation mode. An RWT/RWST Level – Low signal initiates the transfer or switchover to recirculation (RAS).

14.4 TERMINATE ONE TRAIN OF HPSI/HIGH-HEAD INJECTION AFTER RECIRCULATION ALIGNMENT

No Impact.

14.5 TERMINATE LPSI/RHR PUMP PRIOR TO RECIRCULATION ALIGNMENT

Action not recommended, therefore, no impact.

14.6 REFILL REFUELING WATER STORAGE TANK

No Impact.

14.7 INJECT MORE THAN ONE RWT/RWST VOLUME FROM REFILLED RWT/RWST OR BY BYPASSING RWT/RWST

14.7.1 TS 3.3.11 PAM Instrumentation

14.7.1.1 ERG/EPG CHANGE

Injecting more than one RWT/RWST volume may result in the water level inside of containment exceeding the analyzed maximum flood plane. Consequently, the operability of some PAM instrumentation may be negatively impacted. The specific instruments affected must be determined on a plant specific basis depending on the projected water elevation and PAM instrument equipment locations and vulnerabilities.

14.7.1.2 BASES

The PAM instrumentation ensures the OPERABILITY of Regulatory Guide 1.97 Type A variables, so that the control room operating staff can:

- Perform the diagnosis specified in the emergency operating procedures. These variables are restricted to preplanned actions for the primary success path of DBAs and

- Take the specified, preplanned, manually controlled actions, for which no automatic control is provided, that are required for safety systems to accomplish their safety functions.

The PAM instrumentation also ensures OPERABILITY of Category I, non-Type A variables. This ensures the control room operating staff can:

- Determine whether systems important to safety are performing their intended functions,

- Determine the potential for causing a gross breach of the barriers to radioactivity release,

- Determine if a gross breach of a barrier has occurred, and

- Initiate action necessary to protect the public as well as to obtain an estimate of the magnitude of any impending threat.

Performing this refill action is expected only in the event that recirculation flow is lost. As a result not all instrumentation is required at this point since the accident has progressed beyond the design basis. The BASES should be revised to recognize those instruments required to perform their PAM function of core temperature and containment integrity and indicate the maximum containment water level which preserves the minimum number of required instruments.

14.8 PROVIDE MORE AGGRESSIVE COOLDOWN AND DEPRESSURIZATION FOLLOWING A SMALL BREAK LOCA

14.8.1 TS 3.4.3 RCS Pressure and Temperature (P/T) Limits

14.8.1.1 ERG/EPG CHANGE

One of the contingency actions in NRC Bulletin 2003-01 suggested following a loss of the ECCS pumps due to sump blockage has the operator perform a rapid cooldown in an effort to get on SDC as soon as possible. In this situation, cooling down at the maximum achievable rate is permissible, considering the alternatives. Consequently the ASME Section XI Appendix G cooldown limits (controlled cooldown TS limits) may be exceeded. However, it is unlikely that this action would exceed the Appendix E limits (uncontrolled cooldown).

14.8.1.2 BASES

The P/T limits are not derived from Design Basis Accident (DBA) Analyses. They are prescribed during normal operation to avoid encountering pressure, temperature, and temperature rate of change conditions that might cause undetected flaws to propagate and cause nonductile failure of the reactor coolant pressure boundary (RCPB), an unanalyzed condition. The FSAR establishes the methodology for determining the P/T limits. Since the P/T limits are not derived from any DBA, there are no acceptance limits related to the P/T limits. Rather, the P/T limits are acceptance limits themselves since they preclude operation in an unanalyzed condition.

14.9 PROVIDE GUIDANCE ON SYMPTOMS AND IDENTIFICATION OF CONTAINMENT SUMP BLOCKAGE

No impact.

14.10 DEVELOP CONTINGENCY ACTIONS IN RESPONSE TO: CONTAINMENT SUMP BLOCKAGE, LOSS OF SUCTION, AND CAVITATION

Addressed in various other sections. See above.

14.11 TERMINATE ONE TRAIN OF HPSI/HIGH-HEAD INJECTION PRIOR TO RECIRCULATION ALIGNMENT

Action not recommended, therefore, no impact.

14.12 DELAY CONTAINMENT SPRAY ACTUATION FOR SMALL BREAK LOCA IN ICE CONDENSER PLANTS

Action not recommended, therefore, no impact.

14.13 CONCLUSION

This section outlines examples of Technical Specification (TS) Bases that are impacted by various proposed EPG/ERG changes listed in Appendix A. The fact that it is listed here does not imply that the TS Bases will have to be changed in order to implement the COA. Changes may be required within Chapters 6 and 15 of the FSER as indicated in Section 3 of this report. The nature and extent of such changes are plant specific pending completion of plant specific 10 CFR 50.59 reviews and risk reviews for proposed changes at each plant.

15 TASK C1 – IDENTIFY RISK IMPACT OF ERG/EPG CHANGES (PRA EVALUATION)

15.1 PROVIDE GUIDANCE ON SYMPTOMS AND IDENTIFICATION OF CONTAINMENT SUMP BLOCKAGE AND DEVELOP CONTINGENCY ACTIONS (COA 8 AND 9)

The basic risk assessment for each of these COA is provided under the discussion of the respective COA (See Appendix A). As identified in the COA 8 risk assessment, the benefits associated with timely and accurate diagnosis of sump blockage can only be realized if other procedures and guidance are available to describe alternate strategies that can be implemented when sump blockage occurs. COA 9 provides the alternate strategies. From a risk perspective, COA 8 needs at least COA 9 follow-on guidance to be effective. These strategies provide a risk benefit for post-sump blockage core damage mitigation, but provide no risk benefit for prevention of sump blockage. However, additional strategies to provide additional assurance that a method of injecting to the RCS is preserved (e.g., COA 3, 4 or 10) and for providing alternate injection capability prior to sump blockage (e.g., COA 5 and 6) would further enhance the risk benefits of these strategies. In addition, strategies to minimize debris transport (e.g., COA 1) would also provide added benefits for prevention of sump blockage.

Risk Measure	Sump Blockage	
	Early	**Late**
Reduce Potential for Sump Blockage:	→	→
Increase Capability to Diagnose Sump Blockage:	↑	↑
Increase Potential for Injection After Sump Blockage:	→	→
Legend: → signifies risk neutral ↑ signifies risk beneficial		

There is not a significant difference in the risk impacts for accidents requiring the use of ECC recirculation, between the low probability DBA large break LOCAs and the more probable small break LOCAs. In both cases, this strategy combination provides for effective diagnosis of sump blockage, but has no other benefits.

Risk Measure	Accident Sequence	
	DBA Large LOCA	**Small LOCA**
Reduce Potential for Sump Blockage:	→	→
Increase Capability to Diagnose Sump Blockage:	↑	↑
Increase Potential for Injection After Sump Blockage:	→	→

15.2 PROVIDE GUIDANCE ON SYMPTOMS AND IDENTIFICATION OF CONTAINMENT SUMP BLOCKAGE AND DEVELOP CONTINGENCY ACTIONS AND TERMINATE ONE TRAIN OF INJECTION AFTER RECIRCULATION ALIGNMENT (COA 3, 8 AND 9)

The basic risk assessment for each of these COA is provided under the discussion of the respective COA (See Appendix A). This combination of CAO provides additional assurance that alternate RCS injection capabilities are available by securing one train of injection capability after switchover to recirculation is achieved. In this way, a sudden sump blockage episode would not damage both trains of RCS injection capability. From a risk perspective, this combination is risk beneficial. However, if there are concerns about sump blockage in the immediate time frame following switchover to recirculation, then a more effective combination might include also terminating one train of HPSI prior to switchover (COA 10) or terminating one train of LPSI prior to switchover (e.g., COA 4, 8 and 9). However, this strategy could be further enhanced by providing alternate injection capability prior to sump blockage (e.g., COA 5 and 6). In addition, strategies to minimize debris transport (e.g., COA 1) would also provide added benefits.

Risk Measure	Sump Blockage	
	Early	**Late**
Reduce Potential for Sump Blockage:	→	↑
Increase Capability to Diagnose Sump Blockage:	↑	↑
Increase Potential for Injection After Sump Blockage:	→	↑

There is not a significant difference in the risk impacts for accidents requiring the use of ECC recirculation, between the low probability DBA large break LOCAs and the more probable small break LOCAs. In both cases, this strategy combination provides for effective diagnosis of sump blockage. In addition, termination of one train of recirculation after recirculation alignment has similar benefits for both large and small LOCAs.

Risk Measure	Sump Blockage	
	DBA Large LOCA	**Small LOCA**
Reduce Potential for Sump Blockage:	↑	↑
Increase Capability to Diagnose Sump Blockage:	↑	↑
Increase Potential for Injection After Sump Blockage:	↑	↑

15.3 TERMINATE ONE TRAIN OF INJECTION AFTER RECIRCULATION ALIGNMENT, REFILL THE REFUELING WATER STORAGE TANK, AND INJECT MORE THAN ONE VOLUME RWST VOLUME (COA 3, 5, AND 6)

The basic risk assessment for each of these COA is provided under the discussion of the respective COA (See Appendix A). This combination of CAO provides strategies to pre-plan for continued injection capabilities in the event of sump blockage such that the strategies can be implemented in a timely manner to preclude core damage. From a risk perspective, this combination helps assure that a source of injection to the RCS is available (COA 5 and 6) and a means to inject is preserved (COA 3) for cases in which the sump blockage occurs in a late time frame after switchover to recirculation. However, this strategy combination could be further enhanced by providing a means of diagnosing sump blockage (COA 8), thereby potentially preserving multiple means of injection into the RCS. Additionally, strategies to prevent the loss of an injection source for cases with sump blockage at the time of switchover to recirculation would also provide additional benefits. Finally, strategies to minimize debris transport (e.g., COA 1) would also provide added benefits.

Risk Measure	Sump Blockage	
	Early	Late
Reduce Potential for Sump Blockage:	→	↑
Increase Capability to Diagnose Sump Blockage:	→	→
Increase Potential for Injection After Sump Blockage:	↑	↑↑

There is not a significant difference in the risk impacts for accidents requiring the use of ECC recirculation, between the low probability DBA large break LOCAs and the more probable small break LOCAs. In both cases, this strategy combination provides for effective preparation for alternate injection capability in the event of sump blockage. In addition, termination of one train of recirculation after recirculation alignment has similar benefits for both large and small LOCAs.

Risk Measure	Sump Blockage	
	DBA Large LOCA	Small LOCA
Reduce Potential for Sump Blockage:	↑	↑
Increase Capability to Diagnose Sump Blockage:	→	→
Increase Potential for Injection After Sump Blockage:	↑↑	↑↑

15.4 TERMINATE ONE TRAIN OF INJECTION PRIOR TO RECIRCULATION ALIGNMENT, REFILL THE REFUELING WATER STORAGE TANK, AND INJECT MORE THAN ONE VOLUME RWST VOLUME (COA 10, 5, AND 6)

The basic risk assessment for each of these COA is provided under the discussion of the respective COA (See Appendix A). This combination of CAO provides strategies to pre-plan for continued injection capabilities in the event of sump blockage such that the strategies can be implemented in a timely manner to preclude core damage. From a risk perspective, this combination helps assure that a source of injection to the RCS is available (COA 5 and 6) and a means to inject is preserved (COA 10) for cases in which the sump blockage occurs in an early or a late time frame after switchover to recirculation. However, this strategy combination could be further enhanced by providing a means of diagnosing sump blockage

(COA 8), thereby potentially preserving multiple means of injection into the RCS. Finally, strategies to minimize debris transport (e.g., COA 1) would also provide added benefits.

Risk Measure	Sump Blockage	
	Early	**Late**
Reduce Potential for Sump Blockage:	↑	↑
Increase Capability to Diagnose Sump Blockage:	→	→
Increase Potential for Injection After Sump Blockage:	↑↑	↑↑

There is not a significant difference in the risk impacts for accidents requiring the use of ECC recirculation, between the low probability DBA large break LOCAs and the more probable small break LOCAs. In both cases, this strategy combination provides for effective preparation for alternate injection capability in the event of sump blockage. In addition, termination of one train of recirculation prior to recirculation alignment probably has a larger benefit for the DBA large break LOCA because the flows to the sump (debris transport) are reduced much more that for small LOCAs.

Risk Measure	Sump Blockage	
	DBA Large LOCA	**Small LOCA**
Reduce Potential for Sump Blockage:	↑↑	↑
Increase Capability to Diagnose Sump Blockage:	→	→
Increase Potential for Injection After Sump Blockage:	↑↑	↑↑

15.5 MANUAL TRANSFER OF ONE ECCS TO THE CONTAINMENT SUMP PRIOR TO AUTOMATIC RECIRCULATION ALIGNMENT, REFILL THE REFUELING WATER STORAGE TANK, AND INJECT MORE THAN ONE VOLUME RWST VOLUME (COA 2, 5, AND 6)

The basic risk assessment for each of these COA is provided under the discussion of the respective COA (See Appendix A). This combination of CAO provides strategies to pre-plan for continued injection capabilities in the event of sump blockage such that the strategies can be implemented in a timely manner to preclude core damage. From a risk perspective, this combination helps assure that a source of injection to the RCS is available (COA 5 and 6) and a means to inject is preserved (COA 2) for cases in which the sump blockage occurs in an early time frame after switchover to recirculation. However, this strategy combination could be further enhanced by providing a means of diagnosing sump blockage (COA 8), thereby potentially preserving multiple means of injection into the RCS. If the second train of ECC is not aligned to recirculation after RAS or if the second train is secured after RAS, protection against long term loss of injection capability would be enhanced. Finally, strategies to minimize debris transport (e.g., COA 1) would also provide added benefits.

Risk Measure	Sump Blockage	
	Early	Late
Reduce Potential for Sump Blockage:	→	→
Increase Capability to Diagnose Sump Blockage:	→	→
Increase Potential for Injection After Sump Blockage:	↑	↑

There is not a significant difference in the risk impacts for accidents requiring the use of ECC recirculation, between the low probability DBA large break LOCAs and the more probable small break LOCAs. In both cases, this strategy combination provides for effective preparation for alternate injection capability in the event of sump blockage. In addition, transfer of one train to recirculation prior to the normal has no significant difference in impact between the DBA large break LOCA and the small LOCAs.

Risk Measure	Sump Blockage	
	DBA Large LOCA	Small LOCA
Reduce Potential for Sump Blockage:	→	→
Increase Capability to Diagnose Sump Blockage:	→	→
Increase Potential for Injection After Sump Blockage:	↑	↑

15.6 SECURE ONE CONTAINMENT SPRAY PUMP BEFORE RECIRCULATION ALIGNMENT, PROVIDE GUIDANCE ON SYMPTOMS AND IDENTIFICATION OF CONTAINMENT SUMP BLOCKAGE, TERMINATE LPSI/RHR PUMP PRIOR TO RECIRCULATION ALIGNMENT, REFILL THE REFUELING WATER STORAGE TANK, AND INJECT MORE THAN ONE VOLUME RWST VOLUME (COA 1, 4, 8, 5, AND 6)

The basic risk assessment for each of these COA is provided under the discussion of the respective COA (See Appendix A). This combination of CAO provides strategies to reduce the potential for sump blockage (COA 1 and 4) increase the potential for timely diagnosis of sump blockage (COA 8), prevent the loss of injection capability in the event of rapid sump blockage (COA 4), and pre-plan for continued injection capabilities in the event of sump blockage such that the strategies can be implemented in a timely manner to preclude core damage (COA 5 and 6). From a risk perspective, this combination provides the maximum level of assurance that core cooling can be continued if sump blockage occurs.

Risk Measure	Sump Blockage	
	Early	**Late**
Reduce Potential for Sump Blockage:	↑↑	↑↑
Increase Capability to Diagnose Sump Blockage:	↑	↑
Increase Potential for Injection After Sump Blockage:	↑↑	↑↑

There is not a significant difference in the risk impacts for accidents requiring the use of ECC recirculation, between the low probability DBA large break LOCAs and the more probable small break LOCAs. In both cases, this strategy combination provides for effective reduction in sump blockage potential, diagnosis of sump blockage, optimized preservation of injection capability and efficient preparation for alternate injection capability in the event of sump blockage.

Risk Measure	Sump Blockage	
	DBA Large LOCA	**Small LOCA**
Reduce Potential for Sump Blockage:	↑↑	↑↑
Increase Capability to Diagnose Sump Blockage:	↑	↑
Increase Potential for Injection After Sump Blockage:	↑↑	↑↑

This combination provides the most effective overall protection because it minimizes the potential for sump blockage by reducing flows to the containment sump (debris transport) and reducing containment spray flow (debris generation). These actions to prevent sump blockage are the most effective because once sump blockage occurs, the subsequent actions all have significant uncertainties regarding their effectiveness. RWST refill or continued injection with alternate sources to the loop level may be an effective long term strategy IF debris clogging of the break location or the core does not occur. Sump backwash may be an effective strategy if it works and if it is not required to be performed on a short time interval basis.

16 TASK D3 – IMPACT ON EOP SETPOINTS

16.1 INTRODUCTION/TASK OBJECTIVE

PA-SEE-0085 was initiated in response to NRC Bulletin 2003-01, "Potential Impact of Debris Blockage on Emergency Sump Recirculation at Pressurized-Water Reactors." Per PA-SEE-0085, Task D3 was established to provide guidance relative to the potential impact on EOP setpoints that may occur because of changes to ERG requirements or as a result of changes to the uncertainties used to determine the setpoints. Changes to the ERGs and EOP setpoints may be necessary to provide the operators with additional means to detect possible containment flooding or sump recirculation flow path blockage. Additionally, EOP setpoints that have been determined based on explicit uncertainty calculations may be affected by changes in the environmental allowance factors used in the uncertainty calculations as a result of a change in the containment environment profile.

16.2 IDENTIFY IMPACTS TO EOP SETPOINTS AS A RESULT OF ERG CHANGES

On a generic basis, the ERG Maintenance Core Group and Westinghouse ERG personnel are currently developing guidance to address the sump blockage issue. Additionally, several Candidate Operator Actions under evaluation may result in ERG changes such as early reduction of containment spray flow and RWST refill. In general the approach being used is to rely on existing instrumentation to provide indications of potential recirculation path blockage and containment conditions during recovery from the blockage event. This may require a change to the ERGs to monitor additional, but available, instrumentation that currently is not required by the ERGs, or this may entail an increased frequency in the surveillance interval for existing indications (e.g., containment sump level, pump flow, pump current, discharge pressure). Therefore no guidance on changes to EOP setpoints as a result of changes to the ERGs is available at this time.

16.3 GENERIC EVALUATION OF IMPACT ON SETPOINT UNCERTAINTIES

As a part of this task, a generic evaluation of the impact on setpoint uncertainties is being provided. It should be understood that this generic evaluation is limited in nature because those uncertainties which may be affected by this program are dependent on plant specific instrumentation, sump configuration, containment configuration, containment and instrument location environmental profiles, and assumptions/allowances in the uncertainty calculations of record. The ERGs require explicit uncertainty calculations for a limited number of EOP applications. A typical list of functions requiring uncertainty calculations is provided below. However, a review of the key parameters and the application for each plant based on the ERGs should be performed to determine a complete list. On a plant specific basis, this list may be different and some plants may have more calculations to determine EOP setpoints.

1. RCS Wide Range hot and cold leg temperature
2. RCS Wide Range pressure
3. Core exit thermocouples (CETCs) temperature
4. RCS subcooling based on CETCs and RCS Wide Range pressure
5. Narrow Range S/G level
6. Wide Range S/G level
7. Pressurizer level

8. Steam Line pressure
9. Auxiliary Feedwater flow
10. Containment pressure
11. Containment (RHR) Sump level
12. RVLIS

The impact of this program on uncertainties should be limited to changes in the containment environment as a result of potential containment flooding, and the impact this may have on environmental allowance terms included in the uncertainty calculations.

An obvious concern would be submergence of instrumentation, cables, or level channel reference legs/sensing lines and the impact this would have on the indication parameter. Plant specific evaluations will be required to determine what instrumentation used for EOP setpoints may be submerged and how submergence will affect the instrument performance. Some instruments may be qualified for submergence, but others may not have a demonstrated performance during or after submergence. In addition to the instrument itself, cables, connectors, and reference legs for level channels will need to be assessed if it is determined that they will be submerged. Cables and connectors may be prone to electrical failures and become unreliable when submerged. Also, the temperature used to determine insulation resistance degradation errors may change. Sensing line temperatures may change in vertical runs that may affect indicated level due to uneven heating, or due to changes in ambient temperatures assumed in the uncertainty calculations.

In addition to submergence, environmental allowance terms used in the uncertainty calculations should be reviewed to determine if there would be any changes due to an overfill event. For example some environmental allowance terms, such as elevated temperature effects on transmitters, or insulation resistance degradation, may have been based on plant specific containment profiles instead of a generic qualification program. The calculations may also have been performed based on a location specific ambient temperature during the accident scenario. It is possible that actions such as early termination of containment spray could change the short-term and/or long-term containment pressure-temperature profile. If such actions are recommended for implementation, a review of the containment profiles used to determine environmental allowance terms would be required. This may also affect a return to a "normal containment" condition because temperature and/or humidity levels may remain elevated for longer time periods which may change the uncertainties. These conditions must be considered on a plant specific basis to determine if there is any impact on the uncertainty calculations.

16.4 CONCLUSIONS

Based on the program evaluation to date, no EOP setpoint changes have been identified. As the evaluation continues, some changes may be required. However, an attempt is being made to consider changes within the context of currently available instrumentation indication to not impose new instrumentation installation requirements. Relative to the impact on EOP setpoint uncertainties, an assessment must be performed on a plant-specific basis. Each plant should review the instrumentation required for EOP setpoints that may become submerged during the overfill event and determine the continued validity of the indication and/or what affect submergence may have on the uncertainties. In addition to submergence, each plant should review their calculations of record to determine the basis for assumptions relative to environmental allowance terms. The basis of the environmental allowance terms (i.e., containment temperature, radiation, and humidity) should be reviewed to determine if that basis remains valid in the event of a containment sump overfill condition.

17 TASK E3 – DEVELOP THE TECHNICAL BASES FOR ANY NEW EPG ACTION VALUES THAT MAY BE REQUIRED

See Volume 3 of this report.

18 TASK E4 – CONDUCT TABLE-TOP REVIEW

See Volume 3 of this report.

19 TASK E5 – CONDUCT VALIDATION ON FULL SCOPE SIMULATOR

See Volume 2 of this report for Westinghouse-type plants and Volume 3 for CE-type plants.

APPENDIX A
CANDIDATE OPERATOR ACTION (COA) EVALUATIONS

A1a-CE – Candidate Operator Action 1A – Combustion Engineering Plants
Operator Action to Secure One Spray Pump

1.0 INTRODUCTION

NRC Bulletin 2003-01 requires that the utilities evaluate and implement compensatory measures to reduce the potential risk due to post-accident debris blockage as evaluations to determine compliance proceed. The bulletin directed utilities to consider a range of possible interim compensatory measures. Utilities may elect to implement those compensatory actions they deem appropriate, based upon the specific conditions associated with their plants. One possible interim compensatory measure included in the bulletin was, "procedural modifications, if appropriate, that would delay switchover to containment sump recirculation (e.g., shutting down redundant pumps that are not necessary …"

The purpose of this report is to evaluate actions to secure one containment spray pump prior to initiating containment sump recirculation for Combustion Engineering (CE) designed plants. This action would be part of the Loss of Coolant Accident (LOCA) Guideline. The following describes the steps that would be necessary to accomplish this action.

1. It should be verified that both containment spray pumps are operating. If this can not be confirmed no action should betaken to stop a containment spray pump.

2. Prior to stopping a containment spray pump, it should be confirmed that the spray pumps have completed their safety function by confirming the following:

    a. Containment pressure is less than [Containment Design Pressure] and NOT increasing.
    b. Containment temperature is less than [EQ requirement] °F and NOT increasing.

3. Prior to stopping a containment spray pump, adequate heat removal should exist to allow the operator time to start the idle spray pump if the running pump fails. Verify [two] containment fan coolers per train are operating.

4. Plants that credit containment spray in their dose analysis need to confirm that no core damage has occurred by confirming safety injection has actuated properly. This can be done by verifying safety injection (SI) actuated and SI flow has remained within the values bounded by the delivery curves.

5. Having met the above criteria, stop one containment spray pump

6. Confirm one spray pump is adequate by verifying containment pressure and temperature are not increasing.

Bases:

The step is intended to do the following:

- Reduce the flow rate to the sump when containment recirculation begins
- Reduce the pressure differential across the emergency sump cage if there is a build up of debris.
- Provide a modest time delay to the start of containment recirculation during small breaks.

A large break LOCA will reach peak containment pressure and temperature within 5 minutes. As the break size decreases the time to peak conditions will increase but the peaks will decrease in magnitude. This makes it easier for the active heat removal systems to accomplish their safety functions. The step is placed in the LOCA procedures because securing one spray pump has virtually no effect on the time to start containment recirculation during a large break LOCA. Small break LOCAs by definition have already increased the time to containment recirculation and a rush to implement this step will only change the delay time to containment recirculation by minutes. Verifying the decrease in containment temperature and pressure will make sure enough time has elapsed to accomplish the containment safety function prior to securing a spray pump.

Verifying proper safety injection confirms no core damage has occurred. Containment spray is not required to meet the dose source term assumptions if no core damage has occurred. This step confirms that a complete interruption of spray flow, resulting from securing one containment spray pump and assuming a loss of the other pump's electrical train, will not affect the analysis of record for dose calculation. This is a plant specific step and only required for plants that need spray to meet their dose source term assumptions.

2.0 QUALITATIVE EVALUATION SUMMARY

2.1 Advantages

The step can reduce the flow rate demand on the refueling water storage tank (RWST) inventory. This has potential to delay the initiation of containment sump recirculation. The step will have a negligible effect on large breaks but will provide a modest effect to extend the time to containment recirculation during smaller breaks. See Section 3.1 for an evaluation of the time to containment recirculation.

Once recirculation has occurred, running one spray pump can reduce flow through the sump screen/cage anywhere from 15% to 35% depending on the design of the plant. This will reduce the flow rate to the sump and the pressure differential across the sump cage/screen if excessive debris buildup on the cage/screen does occur. This is the real benefit by implementing this preemptive clogged sump step.

Securing one pump has no effect on sump water chemistry because the same amount of water is eventually transferred into containment from the RWST by the time containment sump recirculation actuates.

Securing one spray pump produces results that are less restrictive than the current analysis of record with a failed spray pump. This is because both spray pumps function up to the time one is stopped.

Containment pressure, temperature, pH and iodine control should remain within the analyzed bounds of the current analysis of record.

2.2 Disadvantages/Potential Issues

The step will have virtually no effect on delaying containment recirculation during large break LOCAs.

Depending on the plant design, stopping one CS pump could introduce a total interruption of spray flow upon the loss of the operating CS pump. This event has not been analyzed. However, because full actuation of the Engineering Safety Features is credited up to the time of interrupted spray flow, it may be possible to demonstrate that ample time exists to start the idle spray pump and containment temperature and pressure will remain bounded by the current analysis of record. Implementation of this step should include analysis verifying containment pressure and temperature will remain below the current peak values during the time delay to start the secured spray pump on a loss of the operating pump. If adequate time is not available to start the idle spray pump, this step should not be implemented.

3.0 REFERENCE PLANT ANALYSES/EVALUATIONS

3.1 Summary of Analyses Performed

The CE Reference plant has two trains of forced cooling to carry out the containment safety function. Each train includes one spray pump and two containment fan coolers. The design of the system is such that two containment spray pumps, or four containment fan coolers or one cooling train will provide enough heat removal to accomplish the containment safety function. At the time containment sump recirculation actuates, two spray pumps and two high head injection pumps will transfer the suction from the Refueling Water Tank to the containment sump.

The current Analyses of Record (AOR) for containment response to LOCA was evaluated for the effect of stopping one spray pump. The following items were reviewed:

- Impact on the current AOR methodology
- Impact on the current AOR results
- Loss of the operating spray pump (complete interruption of spray flow)
- Potential to delay the time to reach containment recirculation

Securing one containment spray pump has the potential to introduce a complete interruption of spray flow. This is a new event that assumes one spray pump has been turned off and a loss of vital bus occurs. The containment fan coolers (CFC) effectiveness defines how much time is available to restart the secured spray pump if the operating spray pump fails. For the Reference CE Plant time is infinite because soon after blowdown 2 of 4 CFCs can continue to reduce containment pressure and temperature after switching to containment recirculation. Figures 1 and 2 show the results of the current LOCA Analysis of Record (AOR) for the Reference CE Plant. All containment spray is secured at 10 minutes into the event (assumed to be the earliest stopping a spray pump would occur). The results show that the CFCs will maintain containment pressure and temperature control. Failure of the operating containment spray (CS) pump and half the CFCs (loss of a vital bus) does not introduce a potential to challenge the containment pressure and temperature safety functions. The step to confirm that each train has [two] CFCs ensures that adequate time is available to start the standby spray pump if there is a loss of electrical power to the buss with the operating spray pump. Implementation of this step should include running the complete interruption of spray flow due to a loss of the electrical bus. The results should demonstrate there is adequate time to start the secured spray pump and maintain the pressure and temperature below the current peak values in the AOR.

To demonstrate the maximum delay to the onset of containment recirculation by securing one spray pump, assume the spray pumps are the only pumps using water from the RWST. The maximum time delay to containment recirculation that can be achieved by stopping one spray pump is equal to (RWST volume)/1 spray flow – (RWST volume)/2 spray flow. For the Reference CE Plant this is about 1.5 hours. Due to the fact that full spray will actuate for some time and injection pumps will also draw from the RWST, only a fraction of the maximum available delay can be obtained. The best estimate analyses, which include injection flow, demonstrated that securing a spray pump during .01 ft^2 or .03 ft^2 breaks could delay the time to containment recirculation by about 40 minutes (see Figures 3 and 4). The delay to the time recirculation begins is affected by the break size and plant design, but the delay in time to recirculation due to securing one spray pump will be tens of minutes not hours.

The amount of water transferred from the RWST to the containment prior to containment recirculation is unchanged. The acceptability of iodine control, sump chemistry and available net positive suction head (NPSH) in the emergency sump is not affected.

3.2 Risk Assessment

Effective CFCs will minimize any risk associated with this step. The improvement in reducing the time to containment recirculation is small but the reduction to the pressure differential across the sump cage after recirculation is initiated could reduce the potential for clogging the screen or for clogging the pumps due to a structural failure of the sump cage.

Containment spray is not a risk significant system. Containment design pressure is conservative and some margin exists in probabilistic risk assessment (PRA) space. Pressure will not increase to containment failure in the event of an accident. Due to Containment Spray being a non-risk significant system, any change in procedures will not have a significant impact on plant risk. However, benefits will be achieved, particularly for small breaks, by increasing the time for manual actions at recirculation actuation signal (RAS). With larger break sizes the time to recirculation is already short; thus, time for manual actions is short, with an insignificant increase due to securing one train of containment spray. In conclusion, while some risk benefit may be gained for small break (or equivalent) accidents, because containment spray is a non-risk significant system the overall assessment is that this candidate operator action (COA) is risk neutral.

3.3 Human Factors

When applicable event conditions have stabilized or improved, it is a familiar operator task to secure CS pump(s) after automatic actuation. However, early in a LOCA, the probability of human error on any given task is assumed to be raised by stress. Also, added manual actions will delay downstream EPG steps (nominally 1 minute per manipulation, per ANSI/ANS-58.8, with the number of manipulations TBD). However, since the proposed COA may only be plausible for smaller LOCAs, more time may be available for manual action when this operator action is actually relevant. To detect failure of the running CS pump and then to restart the available pump also adds some operator burden and another error opportunity (however the risk is mitigated by non-safety containment fan coolers and by Safety Function Status Checks; a standby pump control circuit may also be feasible.)

In summary, from an human factors perspective, changes to the timing or criteria for securing CS pumps are reasonable, since the task is already familiar, and since compensating factors may exist for any increased demands on the operator.

4.0 CONCLUSIONS/RECOMMENDATIONS

Each plant must consider the advantages and disadvantages as they apply to their plant specific design and incorporate this action if it is determined to be risk beneficial with respect to containment sump blockage.

However, in general, implementation of this step is recommended for plants with containment fan coolers capable of removing significant heat loads for the following reasons:

- There is potential for a modest increase in the time to initiate containment recirculation during small break LOCAs. However, the step will have a negligible effect on the plant response to large break LOCAs.
- The step has the ability to reduce the flow and the potential pressure differential across the emergency sump cage by the time containment recirculation begins.
- Little analysis is necessary to implement the step into the current emergency procedures.

Figure 1 - Containment Pressure with Failure of CSP at Time of Stopping a CSP

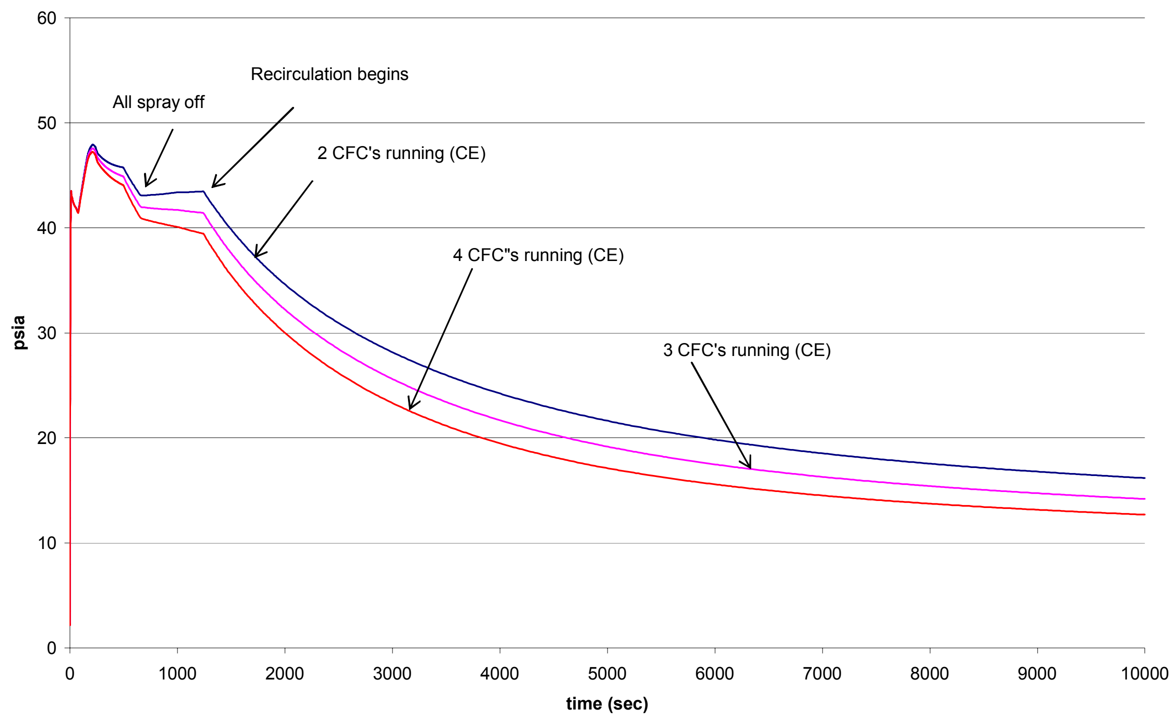
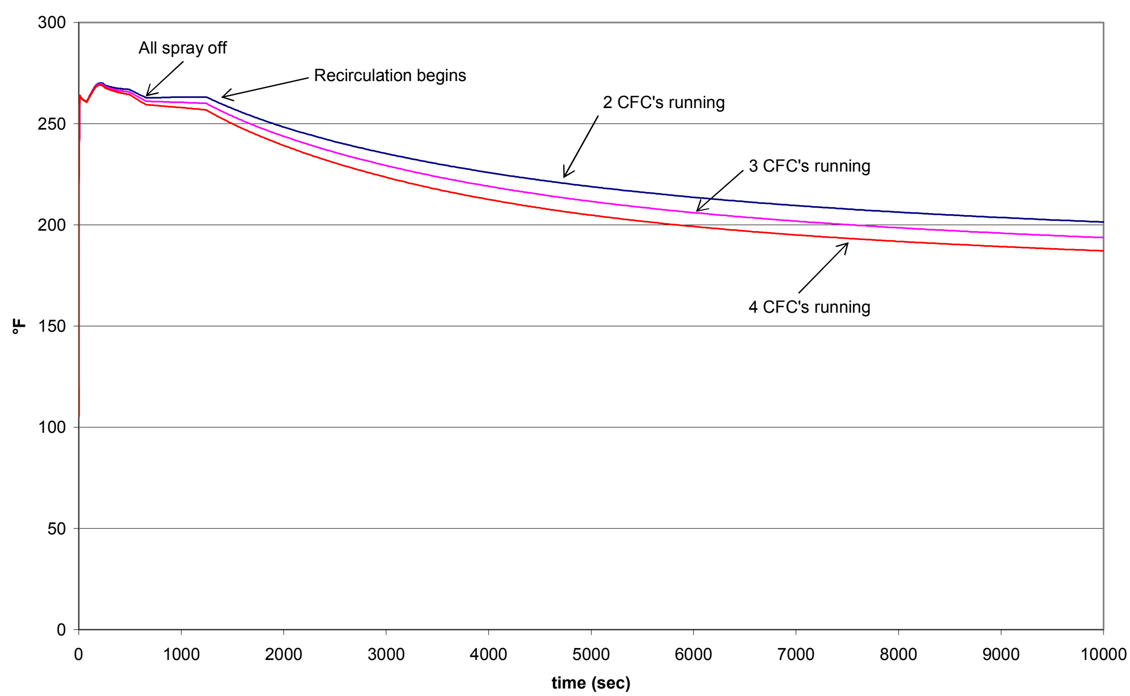


Figure 2 - Containment Temperature with Failure of CSP at Time of Stopping a CSP



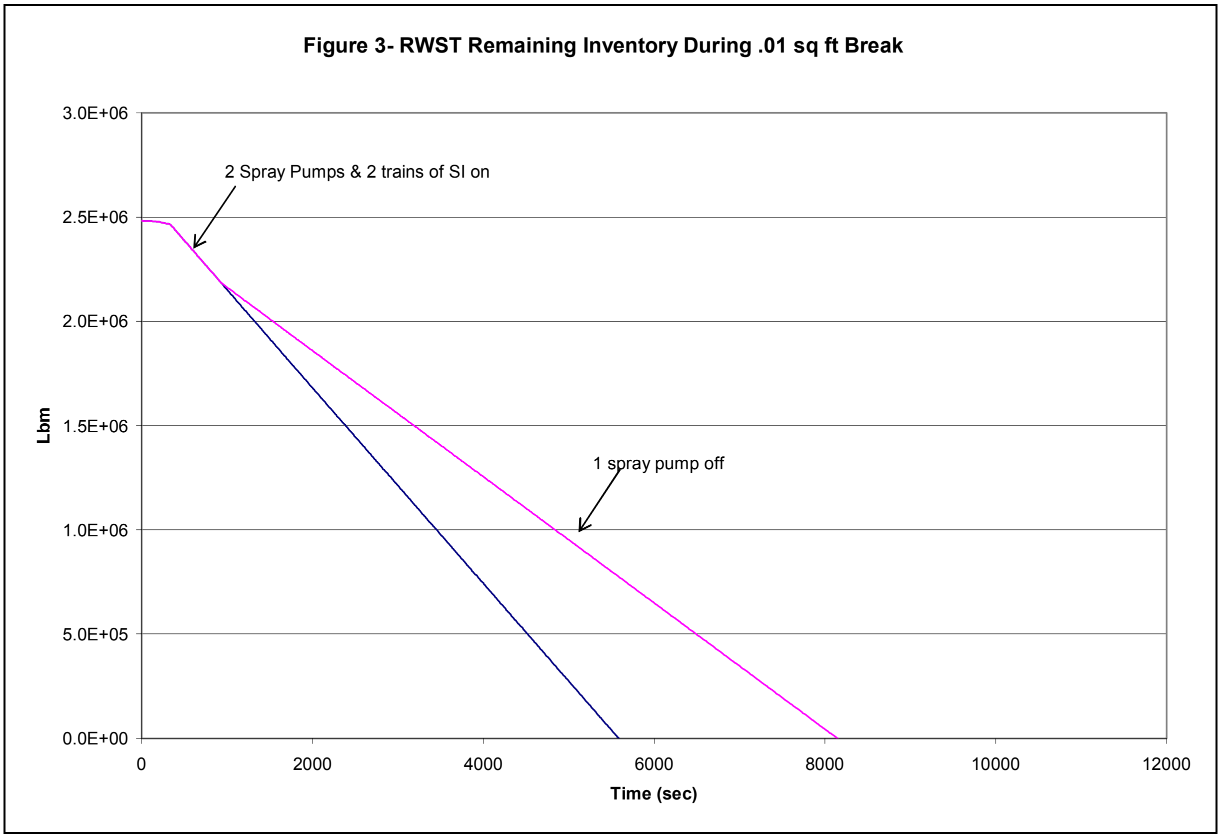


Figure 3- RWST Remaining Inventory During .01 sq ft Break
2 Spray Pumps & 2 trains of SI on
1 spray pump off
Lbm
3.0E+06
2.5E+06
2.0E+06
1.5E+06
1.0E+06
5.0E+05
0.0E+00
0
2000
4000
6000
8000
10000
12000
Time (sec)

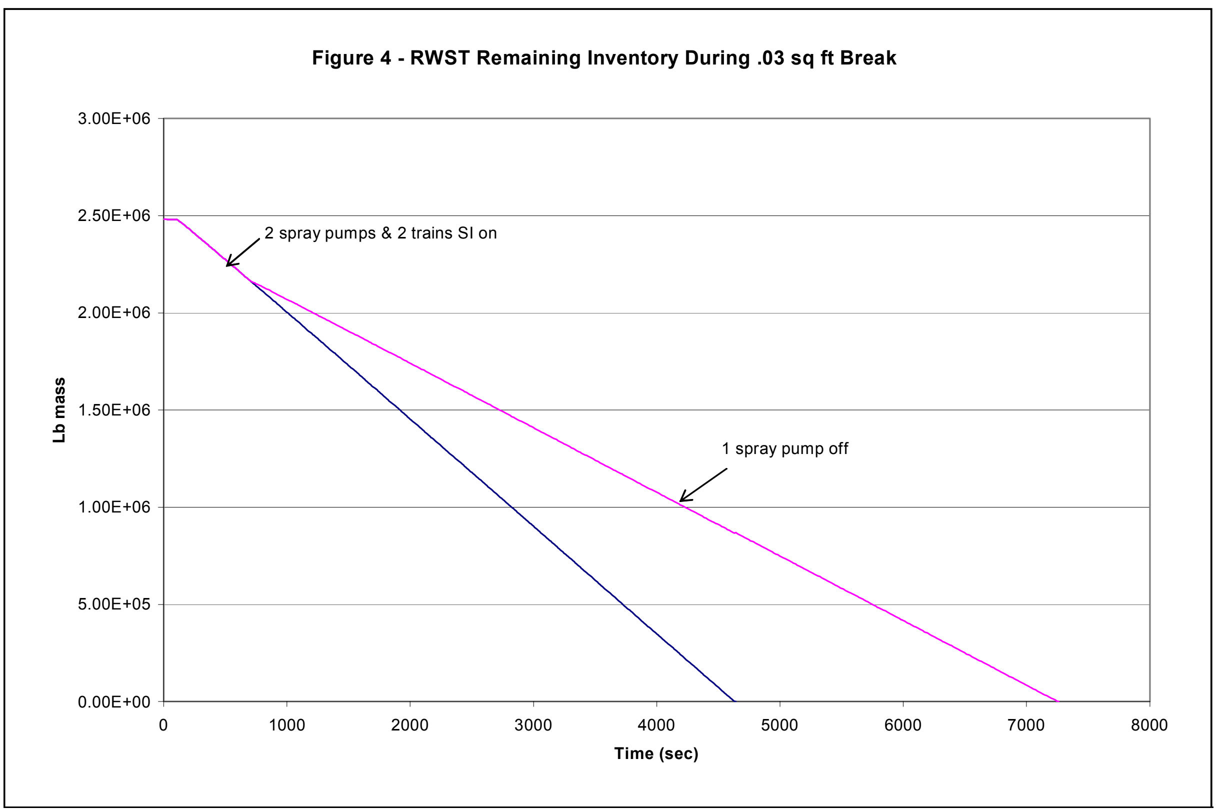


Figure 4 - RWST Remaining Inventory During .03 sq ft Break
2 spray pumps & 2 trains SI on
1 spray pump off
Lb mass
3.00E+06
2.50E+06
2.00E+06
1.50E+06
1.00E+06
5.00E+05
0.00E+00
0
1000
2000
3000
4000
5000
6000
7000
8000
Time (sec)

A1a-W – Candidate Operator Action 1A – Westinghouse Plants
Operator Action to Secure One Spray Pump

1.0 INTRODUCTION

NRC Bulletin 2003-01 requires that the utilities evaluate and implement compensatory measures to reduce the potential risk due to post-accident debris blockage as evaluations to determine compliance proceed. The bulletin directed utilities to consider a range of possible interim compensatory measures. Utilities may elect to implement those compensatory actions they deem appropriate, based upon the specific conditions associated with their plants. One possible interim compensatory measure included in the bulletin was, “procedural modifications, if appropriate, that would delay switchover to containment sump recirculation (e.g., shutting down redundant pumps that are not necessary …”

The purpose of this report is to evaluate actions to secure one containment spray pump prior to initiating containment sump recirculation for Westinghouse designed plants. This action would be part of the Loss of Coolant Accident (LOCA) Guideline. The following describes the steps that would be necessary to accomplish this action.

1. It should be verified that both containment spray pumps are operating. If this can not be confirmed no action should be taken to stop a containment spray pump.

2. Prior to stopping a containment spray pump, it should be confirmed that the spray pumps have completed their safety function by confirming the following:

    a. Containment pressure is less than [Containment Design Pressure] and NOT increasing.
    b. Containment temperature is less than [EQ requirement] °F and NOT increasing.

3. Prior to stopping a containment spray pump, adequate heat removal should exist to allow the operator time to start the idle spray pump if the running pump fails. Verify that two or more containment fan coolers are operating.

4. Plants that credit containment spray in their dose analysis need to confirm that no core damage has occurred by confirming safety injection has actuated properly. This can be done by verifying safety injection (SI) actuated and SI flow has remained within the values bounded by the delivery curves.

5. Having met the above criteria, stop one containment spray pump.

6. Confirm one spray pump is adequate by verifying containment pressure and temperature are not increasing.

Bases:

The step is intended to do the following:

- Reduce the flow rate to the sump when containment recirculation begins.
- Reduce the pressure differential across the emergency sump screen if there is a build up of debris.
- Provide a modest time delay to the start of containment recirculation during small breaks.

A large break LOCA will reach peak containment pressure and temperature prior to Emergency Core Cooling System (ECCS) recirculation. As the break size decreases the time to peak conditions will increase but the peaks will decrease in magnitude. This makes it easier for the active heat removal systems to accomplish their safety functions. The step is placed in the LOCA procedures because securing one spray pump has virtually no effect on the time to start containment recirculation during a large break LOCA. Small break LOCAs by definition have already increased the time to containment recirculation and a rush to implement this step will only change the delay time to containment recirculation by minutes. Verifying the decrease in containment temperature and pressure will make sure enough time has elapsed to accomplish the containment safety function prior to securing a spray pump.

Verifying proper safety injection confirms no core damage has occurred. Containment spray is not required to meet the dose source term assumptions if no core damage has occurred. This step confirms that a complete interruption of spray flow, resulting from securing one containment spray pump and assuming a loss of the other pump, will not affect the analysis of record for dose calculation. This is a plant specific step and only required for plants that need spray to meet their dose source term assumptions.

2.0 QUALITATIVE EVALUATION SUMMARY

2.1 Advantages

The step can reduce the flow rate demand on the refueling water storage tank (RWST) inventory. This has potential to delay the initiation of containment sump recirculation. The step will have a negligible effect on large breaks but will provide a modest effect to extend the time to containment recirculation during smaller breaks. Due to the fact that full spray will actuate for some time and injection pumps will also draw from the RWST, only a fraction of the maximum available delay can be obtained. The delay to the time recirculation begins is affected by the break size and plant design, but the delay in time to recirculation due to securing one spray pump will be tens of minutes not hours.

Once recirculation has occurred, running one spray pump can reduce flow through the sump screen anywhere from 15% to 35% depending on the design of the plant. This will reduce the flow rate to the sump and the pressure differential across the sump screen if excessive debris buildup on the screen does occur. This is the real benefit by implementing this preemptive clogged sump step.

Securing one pump may have an effect on sump water chemistry. Westinghouse designs that use a spray additive tank with eductor may lose some spray additive addition due to the period of time when no spray has been postulated due to a single failure. Since there is a step to check the sump pH in the Westinghouse Emergency Response Guidelines (ERGs), no additional evaluations should be needed.

Securing one spray pump produces results that are less restrictive than the current analysis of record with a failed spray pump. This is because both spray pumps function up to the time one is stopped. Containment pressure, temperature, pH and iodine control should remain within the analyzed bounds of the current analysis of record.

2.2 Disadvantages/Potential Issues

The step will have virtually no effect on delaying containment recirculation during large break LOCAs.

Stopping one CS pump could introduce a total interruption of spray flow upon the loss of the operating CS pump. However, because full actuation of the Engineering Safety Features is credited up to the time of interrupted spray flow, it may be possible to demonstrate that ample time exists to restart the idle spray pump and containment temperature and pressure will remain bounded by the current analysis of record. Implementation of this step should include analysis verifying containment pressure and temperature will remain below the current peak values during the time delay to start the secured spray pump on a loss of the operating pump. If adequate time is not available to start the idle spray pump, this step should not be implemented.

3.0 REFERENCE PLANT ANALYSES/EVALUATIONS

3.1 Summary on Analyses Performed

The Westinghouse reference plant has a two train system consisting of one set of high and low pressure ECCS pumps, one spray pump and one CFC, each train has a dedicated electrical train including an emergency diesel generator. Each train is considered to be a 100% train in that all design and licensing criteria can be met with only one train in operation. Further, the specification for the spray and CFC systems is such that any combination of sprays and CFCs can accomplish all required safety functions. At the time of ECCS recirculation the suction of the low head SI will be switched over to the containment sump followed by aligning the suction of the high pressure pumps to the discharge of the low pressure pump. Later, at the RWST Lo-Lo alarm, the suction of the spray pump(s) will be switched over to the containment sump.

Securing one containment spray pump has the potential to introduce a complete interruption of spray flow. This is a new event that assumes one spray pump has been turned off and later the active spray pump is lost. The containment fan coolers (CFC) effectiveness defines how much time is available to restart the secured spray pump if the operating spray pump fails. Analysis of the Westinghouse reference plant (see Figures 1 & 2) demonstrated that containment pressure will continue to decrease with only fan coolers running. The Westinghouse analysis stopped both spray pumps at 10 minutes and restarted the idle pump at 20 minutes. The graph shows there is more than ample time to restart the idle spray pump if it becomes necessary to do so. The results show that the CFCs will maintain containment pressure and temperature control. Failure of the operating containment spray (CS) pump does not introduce a potential to challenge the containment pressure and temperature safety functions. The step to confirm that two or more CFCs are operating ensures that adequate time is available to start the idle spray pump if there is a loss of the operating spray pump. Implementation of this step should include analyzing the complete interruption of spray flow due to a failure of the active spray pump. The results should demonstrate there is adequate time to start the idle spray pump and maintain the pressure and temperature below the current peak values in the analysis of record (AOR) for containment response to LOCA.

The amount of water transferred from the RWST to the containment prior to containment recirculation is unchanged. The acceptability of iodine control, sump chemistry and available NPSH in the emergency sump is not affected.

3.2 Risk Assessment

Effective CFCs will minimize any risk associated with this step. The improvement in reducing the time to containment recirculation is small but the reduction to the pressure differential across the sump screen after recirculation is initiated could reduce the potential for clogging the screen and for clogging the pumps due to a structural failure of the sump screen.

Containment spray is not a risk significant system. Containment design pressure is conservative and some margin exists in probabilistic risk assessment (PRA) space. Pressure will not increase to containment failure in the event of an accident. Due to Containment Spray being a non-risk significant system, any change in procedures will not have a significant impact on plant risk. However, benefits will be achieved, particularly for small breaks (small LOCA, stuck open power operated relief valve (PORV), steam generator tube rupture (SGTR), main steam line break (MSLB) inside containment), by increasing the time for manual actions at recirculation actuation signal (RAS). With larger break sizes the time to RAS is already short; thus, time for manual actions is short, with an insignificant increase due to securing one train of containment spray. In conclusion, while some risk benefit may be gained for small break (or equivalent) accidents, because containment spray is a non-risk significant system the overall assessment is that this candidate operator action (COA) is risk neutral.

3.3 Human Factors

When applicable event conditions have stabilized or improved, it is a familiar operator task to secure CS pump(s) after automatic actuation. However, early in a LOCA, the probability of human error on any given task is assumed to be raised by stress. Also, added manual actions will delay downstream ERG steps (nominally 1 minute per manipulation, per ANSI/ANS-58.8, with the number of manipulations TBD). However, since the proposed COA may only be plausible for smaller LOCAs, more time may be available for manual action when this operator action is actually relevant. To detect failure of the running CS pump and then to restart the available pump also adds some operator burden and another error opportunity (however the risk is mitigated by non-safety containment fan coolers and by Safety Function Status Checks; a standby pump control circuit may also be feasible.)

In sum, from an human factors perspective, changes to the timing or criteria for securing CS pumps are reasonable, since the task is already familiar, and since compensating factors may exist for any increased demands on the operator.

4.0 CONCLUSIONS/RECOMMENDATIONS

Each plant must consider the advantages and disadvantages as they apply to their plant specific design and incorporate this action if it is determined to be risk beneficial with respect to containment sump blockage.

However, in general, implementation of this step is recommended for plants with containment fan coolers capable of removing significant heat loads for the following reasons:

- There is potential for a modest increase in the time to initiate containment recirculation during small break LOCAs. However, the step will have a negligible effect on the plant response to large break LOCAs.

- The step has the ability to reduce the flow and the potential pressure differential across the emergency sump screen by the time containment recirculation begins.

- Minimal analysis is necessary to implement the step into the current emergency procedures.

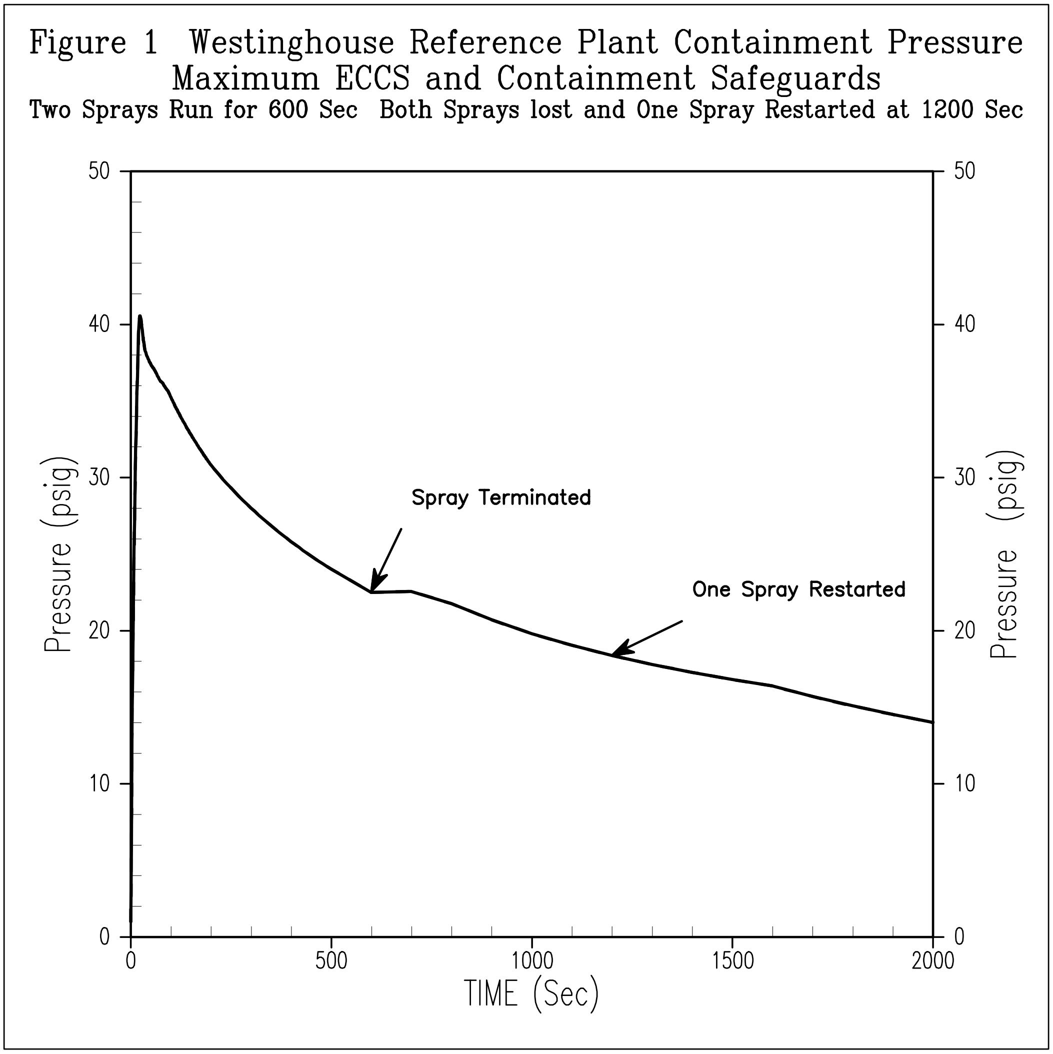
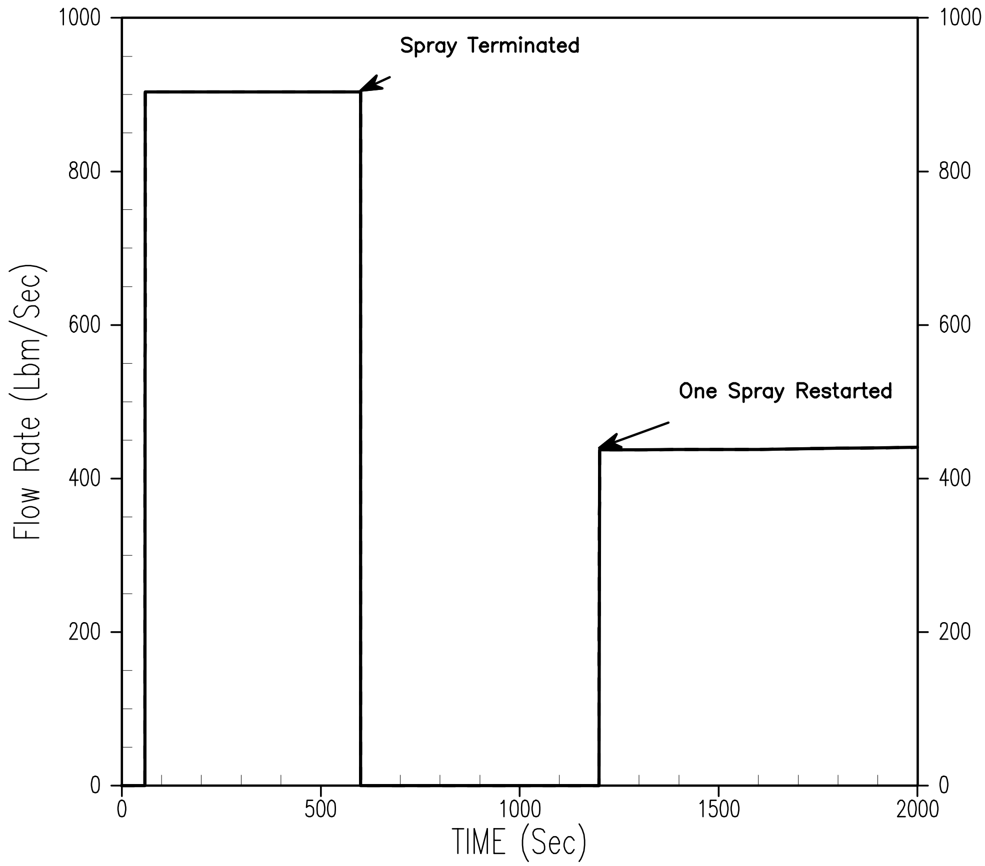


Figure 1 Westinghouse Reference Plant Containment Pressure
Maximum ECCS and Containment Safeguards
Two Sprays Run for 600 Sec Both Sprays lost and One Spray Restarted at 1200 Sec
Spray Terminated
One Spray Restarted
Pressure (psig)
TIME (Sec)
0
10
20
30
40
50
0
500
1000
1500
2000

Figure 2 Westinghouse Reference Plant Containment Spray Flow
Maximum ECCS and Containment Safeguards
Two Sprays Run for 600 Sec Both Sprays lost and One Spray Restarted at 1200 Sec



A1a-Ice Addendum – Candidate Operator Action 1A – Westinghouse Ice Condenser Plants Operator Action to Secure One Spray Pump

1.0 INTRODUCTION

NRC Bulletin 2003-1 requires that the utilities evaluate and implement compensatory measures to reduce the potential risk due to post-accident debris blockage as evaluations to determine compliance proceed. The bulletin directed utilities to consider a range of possible interim compensatory measures. Utilities may elect to implement those compensatory actions they deem appropriate, based upon the specific conditions associated with their plants. One possible interim compensatory measure included in the bulletin was, "procedural modifications, if appropriate, that would delay switchover to containment sump recirculation (e.g., shutting down redundant pumps that are not necessary …)".

The purpose of this report is to evaluate actions to secure one containment spray pump prior to initiating containment sump recirculation for Westinghouse-designed ice condenser containment plants. This action would be part of the Loss of Coolant Accident (LOCA) Guideline. The following describes the steps that would be necessary to accomplish this action.

1. It should be verified that both containment spray pumps are operating. If this cannot be confirmed, no action should be taken to stop a containment spray pump.

2. Prior to stopping a containment spray pump, it should be confirmed that the spray pumps have completed their safety function by confirming the following:

   – Containment pressure is less than [Containment Design Pressure] and NOT increasing.
   – Containment temperature is less than [EQ requirement] °F and NOT increasing.

3. Prior to stopping a containment spray pump, adequate heat removal must exist to allow the operator time to start the idle spray pump if the running pump fails at any time during accident mitigation. This step is particularly critical for ice condenser containments due to the lower containment design pressure, smaller containment volume, nonoperable containment fan coolers in an accident environment, and depletion of the ice condenser cooling capacity. These factors significantly reduce the ability to control containment pressure without adequate containment spray.

   The following ensures adequate heat removal capability following ice bed depletion:

   – Operation of RHR spray. (At the point when RHR spray is initiated, approximately 3600 seconds, if RHR spray cannot be established, the idle spray pump must be restarted.)

   – Confirmation that the LOCA is a small-break, thus moving ice depletion out in time such that decay heat levels are reduced and that either RHR or containment spray will provide adequate time to respond to a single failure. A small-break for the purposes of this candidate operation action (COA), can be based on the RCS pressure remaining above

900 psia at 10 minutes after event initiation (or, alternatively the SI accumulators have not discharged 15 minutes after event initiation).

4. Plants that credit containment spray in their dose analysis need to confirm that no core damage has occurred by confirming safety injection has actuated properly. This can be done by verifying safety injection (SI) actuated and SI flow has remained within the values bounded by the delivery curves.

5. Having met the above criteria, stop one containment spray pump.

6. Confirm one spray pump and RHR spray is adequate by verifying and continuously monitoring that containment pressure and temperature are not increasing.

Bases:

The step is intended to do the following:

- Reduce the flow rate to the sump when containment recirculation begins.
- Reduce the pressure differential across the emergency sump screen if there is a buildup of debris.
- Provide a modest time delay to the start of containment recirculation during small breaks.

A large-break LOCA will reach peak containment pressure and temperature following the depletion of heat removal capability by the ice condenser. As the break size decreases, the time to peak conditions will increase, but the peaks will decrease in magnitude. This makes it easier for the active heat removal systems to accomplish their safety functions. The step is placed in the LOCA procedures because securing one spray pump has virtually no effect on the time to start containment recirculation during a large-break LOCA. Small-break LOCAs by definition have already increased the time to containment recirculation and a rush to implement this step will change only the delay time to containment recirculation by minutes and not permit adequate consideration of break size indicators. Atypical of the reference plant design, the ice condenser designs incorporate provision to switch over the containment spray pumps from the RWST to the containment sump prior to the time of earliest ice bed depletion. This action prevents any potential loss of spray flow at the time of ice depletion. Also prior to ice bed depletion, the RHR spray is initiated to provide for additional spray capability in anticipation of the loss of the ice condenser capability.

In order to accommodate the potential loss of the operating spray pump after terminating the operation of one pump, adequate heat removal must be assured. It is essential that the RHR spray capability is active and that ice melt occurs at a period in time when decay heat is reduced to provide time for operator response to the single failure of the operating spray pump.

Verifying proper safety injection confirms no core damage has occurred. Containment spray is not required to meet the dose source term assumptions if no core damage has occurred. This step confirms that a complete interruption of spray flow, resulting from securing one containment spray pump, will not affect the analysis of record for dose calculation (provided containment integrity is maintained). This is a plant-specific step and only required for plants that need spray to meet their dose source term assumptions.

2.0 QUALITATIVE EVALUATION SUMMARY

2.1 Advantages

The step can reduce the flow rate demand on the refueling water storage tank (RWST) inventory. This has the potential to delay the initiation of containment sump recirculation. The step would have a negligible effect on large breaks (and as discussed above is not intended to be implemented for large breaks), but will provide a modest effect to extend the time to containment recirculation during smaller breaks. Due to the fact that full spray will actuate for some time and injection pumps will also draw from the RWST, only a fraction of the maximum available delay can be obtained. The delay to the time recirculation begins is affected by the break size and plant design, but the delay in time to recirculation due to securing one spray pump will be tens of minutes, not hours.

Once recirculation has occurred, running one spray pump can reduce flow through the sump screen anywhere from 15 to 35 percent depending on the design of the plant. This will reduce the flow rate to the sump and the pressure differential across the sump screen if excessive debris buildup on the screen does occur. This is the real benefit of implementing this preemptive clogged sump step.

Securing one pump may have an effect on sump water chemistry for plants with a spray additive system. Westinghouse designs that use a spray additive tank with eductor may lose some spray additive addition due to the period of time when no spray has been postulated due to a single failure. Since there is a step to check the sump pH in the Westinghouse Emergency Response Guidelines (ERGs), no additional evaluations should be needed.

Securing one spray pump produces results that are less restrictive than the current analysis of record with a failed spray pump. This is because both spray pumps function up to the time one is stopped. Containment pressure, temperature, pH, and iodine control should remain within the analyzed bounds of the current analysis of record.

2.2 Disadvantages/Potential Issues

The step will have virtually no effect on delaying containment recirculation during large-break LOCAs.

Stopping one CS pump could introduce a total interruption of spray flow upon the loss of the operating CS pump. If this loss of spray occurs after the depletion of the ice condenser heat removal capability, the potential exists for a large-break LOCA to rapidly exceed containment design pressure. Further, it is likely that insufficient time would be available for the operators to restore the idle pump under these conditions to preclude exceeding design pressure. Implementation of this step must, therefore, include analysis verifying that containment pressure and temperature will remain below the current peak values during the time delay to start the secured spray pump on a loss of the operating pump. If adequate time is not available to start the idle spray pump, this step should not be implemented.

Limiting this action to only small-break LOCAs reduces the COA's applicability to the events with limited potential for recirculation blockage. The amount of debris generated from a small-break LOCA is by definition less than for large breaks. Further, the potential for debris transport to the sump, the differential pressure across the sump screens, and finally the SI pumps required NPSH demands are all reduced with the lower recirculation flow rates associated with small breaks.

3.0 REFERENCE PLANT ANALYSES/EVALUATIONS

3.1 Summary on Analyses Performed

The Westinghouse ice condenser design has a similar ECCS system design to the reference plant with a two train system consisting of a set of high- and low-pressure ECCS pumps. The containment heat removal system includes the ice condenser system supplemented by two trains of containment spray pumps and post-recirculation spray provided by the RHR pumps. Each train has a dedicated electrical train, including an emergency diesel generator. Each train is considered to be a 100-percent train in that all design and licensing criteria can be met with only one train in operation. Further, the specification for the containment systems is such that the ice condenser system, in combination with a single train of the spray system, can accomplish all required safety functions. At the time of ECCS recirculation, the suction of the low-head SI will be switched over to the containment sump followed by aligning the suction of the high-pressure pumps to the discharge of the low-pressure pump. Later, at the RWST Lo-Lo alarm, the suction of the spray pump(s) will be switched over to the containment sump, or alternatively, to preclude the potential for switchover of spray coincidently with depletion of ice condenser heat removal, the spray pumps suction may be switched to the containment sump earlier.

Westinghouse ice condenser containment designs warrant special consideration for this COA due to their particular sensitivity to the loss of containment spray unique to their containment cooling system design. Ice condenser containment plants are more sensitive to the loss of containment spray flow due to their lower containment design pressure, smaller containment volume, and eventual depletion of ice condenser heat removal capability (approximately 1 hour following in a large-break LOCA). As such, if a spray pump is stopped and the operating pump fails following depletion of the ice beds, it is likely that insufficient time would be available to reactivate the idle pump. Depending on the operating heat removal systems, the containment pressure may approach design pressure in an estimated time of 2 to 5 minutes (assuming no RHR spray). Therefore, it is essential, prior to implementing this procedure revision, that each plant performs the necessary containment pressure sensitivity analysis considering the variety and quantity of containment heat removal mechanisms that may be available and, thus, determine the prerequisites that would prevent or preclude implementation of the COA.

For a small break (less than 4 inches), the time for ice melt is extended by approximately 2.5 to 3 hours. At this point, with reduced decay heat levels and assuming the operation of RHR spray, it is probable that sufficient time would be available for the operator to reactivate the idle spray pump upon failure of the operating unit. Although decay heat continues to exceed RHR spray heat removal at this point, the repressurization of containment is sufficiently slow to permit operator response.

The amount of water transferred from the RWST to the containment prior to containment recirculation is unchanged. The acceptability of iodine control, sump chemistry, and available NPSH in the emergency sump is not affected.

3.2 Risk Assessment

The improvement in reducing the time to containment recirculation is small, but the reduction to the pressure differential across the sump screen after recirculation is initiated could reduce the potential for clogging the screen and for clogging the pumps due to a structural failure of the sump screen.

Containment spray on the ice condenser plant is a risk-significant system. Although, containment design pressure is conservative and some margin exists in probabilistic risk assessment (PRA) space, it is likely containment pressure would exceed design pressure without spray. However, benefits will be achieved, particularly for small breaks (small LOCA, stuck open power-operated relief valve [PORV], steam generator tube rupture [SGTR], main steam line break [MSLB] inside containment), by increasing the time for manual actions at recirculation actuation signal (RAS). With larger break sizes, the time to RAS is already short; thus, time for manual actions is short, with an insignificant increase due to securing one train of containment spray. In conclusion, while some risk benefit may be gained for small-break (or equivalent) accidents, because containment spray is a risk-significant system, the overall assessment is that this COA is risk negative.

3.3 Human Factors

Based on plant-specific containment analysis, it must be demonstrated that sufficient time is available for the operator to reactivate the idle spray pump to recover from a single failure. Only after this is demonstrated, can this COA be justified and considered.

For those ice condenser plants that can justify termination of a spray pump, when applicable event conditions have stabilized or improved, it is a familiar operator task to secure CS pump(s) after automatic actuation. However, early in a LOCA, the probability of human error on any given task is assumed to be raised by stress. Also, added manual actions will delay downstream ERG steps (nominally 1 minute per manipulation, per ANSI/ANS-58.8, with the number of manipulations to be determined). However, since the proposed COA may be plausible only for smaller LOCAs, more time may be available for manual action when this operator action is actually relevant. To detect failure of the running CS pump and then to restart the available pump (provided sufficient time can be allotted) also adds some operator burden, another error opportunity (however, the risk is mitigated by Safety Function Status Checks; a standby pump control circuit may also be feasible.)

In summary for applicable plants, from a human factors perspective, changes to the timing or criteria for securing CS pumps are reasonable since the task is already familiar and compensating factors may exist for any increased demands on the operator.

4.0 CONCLUSIONS/RECOMMENDATIONS

Each plant must consider the advantages and disadvantages as they apply to its plant-specific design and incorporate this action if it is determined to be risk beneficial with respect to containment sump blockage.

However, in general, implementation of this step is not recommended for plants with ice condenser containment cooling systems for the following reasons:

- The Westinghouse ice condenser containment plants are especially sensitive to the single failure of the operating spray pump once ice condenser heat removal capability is exhausted. The sensitivity is driven by containment size, lower containment design pressure, and available containment heat removal systems.

- For a large-break LOCA, preliminary evaluations indicate that the insufficient time would be available for the operator to respond to the loss of the operating containment spray following the exhaustion of heat removal capability by the ice condenser system.

- For a small-break LOCA, preliminary evaluations indicate sufficient time would be available for the operator to respond to the loss of the operating spray pump. This condition, however, drives the applicability of this COA to only small-break LOCA, events that are not as challenging from the perspective of debris generation, transport, and differential pressure.

A1b – Candidate Operator Action 1B
Operator Action to Secure Both Spray Pumps

1.0 INTRODUCTION

NRC Bulletin 2003-01 requires that the utilities evaluate and implement compensatory measures to reduce the potential risk due to post-accident debris blockage as evaluations to determine compliance proceed. The bulletin directed utilities to consider a range of possible interim compensatory measures. Utilities may elect to implement those compensatory actions they deem appropriate, based upon the specific conditions associated with their plants. One possible interim compensatory measure included in the bulletin was, "procedural modifications, if appropriate, that would delay switchover to containment sump recirculation (e.g., shutting down redundant pumps that are not necessary …"

The purpose of this report is to evaluate actions to secure all containment spray prior to initiating containment sump recirculation. This action would be part of the Loss of Coolant Accident (LOCA) Guideline. The following describes the steps that would be necessary to accomplish this action.

1. It should be verified that at least one containment spray pump is operating.

2. Prior to stopping any containment spray pump, it should be confirmed that the operating spray pumps have completed their safety function by confirming the following:

    a. Containment pressure is less than [Containment Design Pressure] and NOT increasing.
    b. Containment temperature is less than [EQ requirement] °F and NOT increasing.

3. Verify [two] containment fan coolers per train are operating.

4. Plants that credit containment spray in their dose analysis need to confirm that no core damage has occurred by confirming safety injection has actuated properly. This can be done by verifying safety injection (SI) actuated and SI flow has remained within the values bounded by the delivery curves.

5. Having met the above criteria, stop one containment spray pump.

6. Confirm containment pressure and temperature is not increasing.

7. If a second pump is running and containment pressure and temperature are not increasing, stop the second containment spray pump.

8. Confirm that containment pressure and temperature are not increasing.

Bases:

The step is intended to do the following:

- Reduce the flow rate to the sump when containment recirculation begins
- Reduce the pressure differential across the emergency sump cage if there is a build up of debris.
- Delay the time to the start of containment recirculation during small breaks.

A large break LOCA will reach peak containment pressure and temperature within 5 minutes. As the break size decreases the time to peak conditions will increase but the peaks will decrease in magnitude. This makes it easier for the active heat removal systems to accomplish their safety functions. The step is placed in the LOCA procedures because securing the spray pumps has only a small effect on the time to start containment recirculation during a large break LOCA. Small break LOCAs by definition have already increased the time to containment recirculation and a rush to implement this step will only change the delay time to containment recirculation by minutes. Verifying the decrease in containment temperature and pressure will make sure enough time has elapsed to accomplish the containment safety function prior to securing the spray pumps.

Verifying proper safety injection confirms no core damage has occurred. Containment spray is not required to meet the dose source term assumptions. Securing the containment spray pumps will not affect the analysis of record dose calculation. This is a plant specific step and only required for plants that need spray to meet their dose source term assumptions.

2.0 QUALITATIVE EVALUATION SUMMARY

2.1 Advantages

The step can significantly reduce the flow rate demand on the refueling water storage tank (RWST) inventory. This can delay the time to initiate containment sump recirculation. The step will have a negligible effect on delaying the time to containment recirculation during large breaks but has the potential to extend the time of containment recirculation by hours during smaller breaks.

Once recirculation has occurred, running without spray pumps can reduce flow through the sump screen/cage anywhere from 25% to 65% depending on the design of the plant. This will reduce the flow rate to the sump and the pressure differential across the sump cage/screen if excessive debris buildup on the cage/screen does occur.

For plants using trisodium phosphate pH control, securing both spray pumps has no effect on sump water chemistry, because the same amount of water is eventually transferred into containment through safety injection.

Following containment recirculation, the injection pumps are the only pumps taking suction on the emergency sump. An injection only line up can increase the available net positive suction head (NPSH) at the emergency sump.

2.2 Disadvantages/Potential Issues

The step will have virtually little effect on time to containment recirculation during large break LOCAs.

Plants using spray injection for pH control would be required to continue spray until pH control was established. Securing a second spray pump would not be an option until containment recirculation is initiated.

Stopping the CS pumps could introduce a probability of losing half the fan coolers if the electrical bus is lost. This event has not been analyzed. However, because full actuation of the Engineering Safety Features is credited up to the time spray flow is secured, it may be possible to demonstrate that ample time exists to start the idle spray pump and containment temperature and pressure will remain bounded by the current analysis of record. Implementation of this step should include plant specific analysis verifying containment pressure and temperature will remain below the current peak values during the time delay to start the secured spray pump if power is lost to one of the vital buses. If adequate time is not available to start the idle spray pump, this step should not be implemented.

Plants required to continue operating a containment spray pump in order to meet environmental qualification requirements may not be able to secure all spray. Such a condition may require implementing this action much later into the event or not at all.

3.0 REFERENCE PLANT ANALYSES/EVALUATIONS

3.1 Summary of Analyses Performed

The current Analyses of Record (AOR) for containment response to LOCA and main steam line break (MSLB) were evaluated for the effect of stopping both spray pumps at 10 minutes into the event. The following items were reviewed:

- Impact on the current AOR methodology
- Impact on the current AOR results
- Loss of containment fan coolers
- Potential to improve the time to reach containment recirculation

The current AOR does not secure both spray pumps. However, the spray pumps are not secured until well after the time of peak pressure and temperature. The requirement to verify pressure and temperature are decreasing confirms the containment active heat removal systems have completed their safety function prior to stopping any spray flow.

Securing all the containment spray pumps leaves the containment fan coolers (CFCs) as the only active containment heat removal system. A loss of an electrical bus has the potential to reduce the containment heat removal capability by half. The CFC effectiveness defines how much time is available to restart the idle spray pump. For the Reference CE Plant time is infinite because soon after blowdown 2 of 4 CFCs can continue to reduce containment pressure and temperature after switching to containment recirculation. Figures 1 and 2 show the results of the current LOCA Analysis of Record (AOR) for the Reference CE Plant. All containment spray is secured at 10 minutes into the event (assumed to be the earliest this event would occur). The results show that the CFCs will maintain containment pressure and temperature control. Failure of half the CFCs does not introduce a potential to challenge the containment pressure and temperature safety functions. Implementation of this step should include loss of one train of CFCs while containment spray pumps are secured. The results demonstrate there is adequate time to start an idle spray pump and maintain the pressure and temperature below the current peak values in the AOR.

The analysis of the Reference CE Plant indicates loss of one vital bus while CFCs are providing the containment heat removal, allows the time necessary to start the available containment spray pump.

Analyses of LOCAs smaller than those in the AOR were evaluated using best estimate methodology to evaluate the potential to increase the time to containment recirculation. Figures 3 and 4 show the depletion of the RWST during two small break LOCAs. The pump configurations are with all spray and injection, half spray and all injection and injection only. The plots are based on the pumps being turned off at 10 minutes. However, following the "all pumps on" line to the desired time of stopping spray pumps and continuing at the slope of the "no spray" line allows estimating how long containment recirculation can be delayed. The plots show that stopping all spray has the potential to delay the time to containment recirculation by hours.

Stopping all spray may require verifying that no core damage has occurred. Containment spray may be credited in reducing the source term during core damage scenarios. If safety analyses show that proper actuation of Safety Injection will avoid core damage, than verification of proper SI actuation can be used to confirm there is no core damage. If spray must continue for dose considerations, steps stopping all spray can not be implemented.

The amount of water transferred from the RWST to the containment prior to containment recirculation is unchanged. For plants using trisodium phosphate for pH control, acceptability of water chemistry is maintained.

The available NPSH at the emergency sump may increase due to the flow reduction in the lines between the sump and pumps.

3.2 Risk Assessment

Effective CFCs will minimize any risk associated with this step. The improvement in reducing the time to containment recirculation is small but the reduction to the pressure differential across the sump cage after recirculation is initiated could reduce the potential for clogging the screen or for clogging the pumps due to a structural failure of the sump cage.

Containment spray is not a risk significant system. Containment design pressure is conservative and some margin exists in probabilistic risk assessment (PRA) space. Pressure will not increase to containment failure in the event of an accident. Due to Containment Spray being a non-risk significant system, any change in procedures will not have a significant impact on plant risk. However, benefits will be achieved, particularly for small breaks, by increasing the time for manual actions when recirculation begins. With larger break sizes the time to recirculation is already short; thus, time for manual actions is short, with an insignificant increase due to securing one train of containment spray. In conclusion, while some risk benefit may be gained for small break (or equivalent) accidents, because containment spray is a non-risk significant system the overall assessment is that this candidate operator action (COA) is risk neutral.

3.3 Human Factors

When applicable event conditions have stabilized or improved, it is a familiar operator task to secure CS pump(s) after automatic actuation. However, early in a LOCA, the probability of human error on any given task is assumed to be raised by stress. Also, added manual actions will delay downstream EPG steps (nominally 1 minute per manipulation, per ANSI/ANS-58.8, with the number of manipulations TBD). However, since the proposed COA may only be plausible for smaller LOCAs, more time may be available for manual action when this operator action is actually relevant. To detect failure of the running CS pump and then to restart the available pump also adds some operator burden and another error opportunity (however the risk is mitigated by non-safety containment fan coolers and by Safety Function Status Checks; a standby pump control circuit may also be feasible.)

In summary, from an human factors perspective, changes to the timing or criteria for securing CS pumps are reasonable, since the task is already familiar, and since compensating factors may exist for any increased demands on the operator.

4.0 CONCLUSIONS/RECOMMENDATIONS

Implementation of this step requires effective CFCs and minimal or no requirement for iodine or pH control with spray. This action will reduce the flow through the emergency sump cage at the time of containment recirculation and post containment recirculation operations. The step will have a negligible effect on the time to containment recirculation during large break LOCAs but has the potential to significantly increase the time to containment recirculation during small break LOCAs.

Implementation of this step is only recommended for plants with containment fan coolers that can remove 100% of the decay heat load when spray is stopped and spray is not required for iodine removal or pH control.

Each plant must consider the advantages and disadvantages as they apply to their plant specific design and incorporate this action if it is determined to be risk beneficial with respect to containment sump blockage.

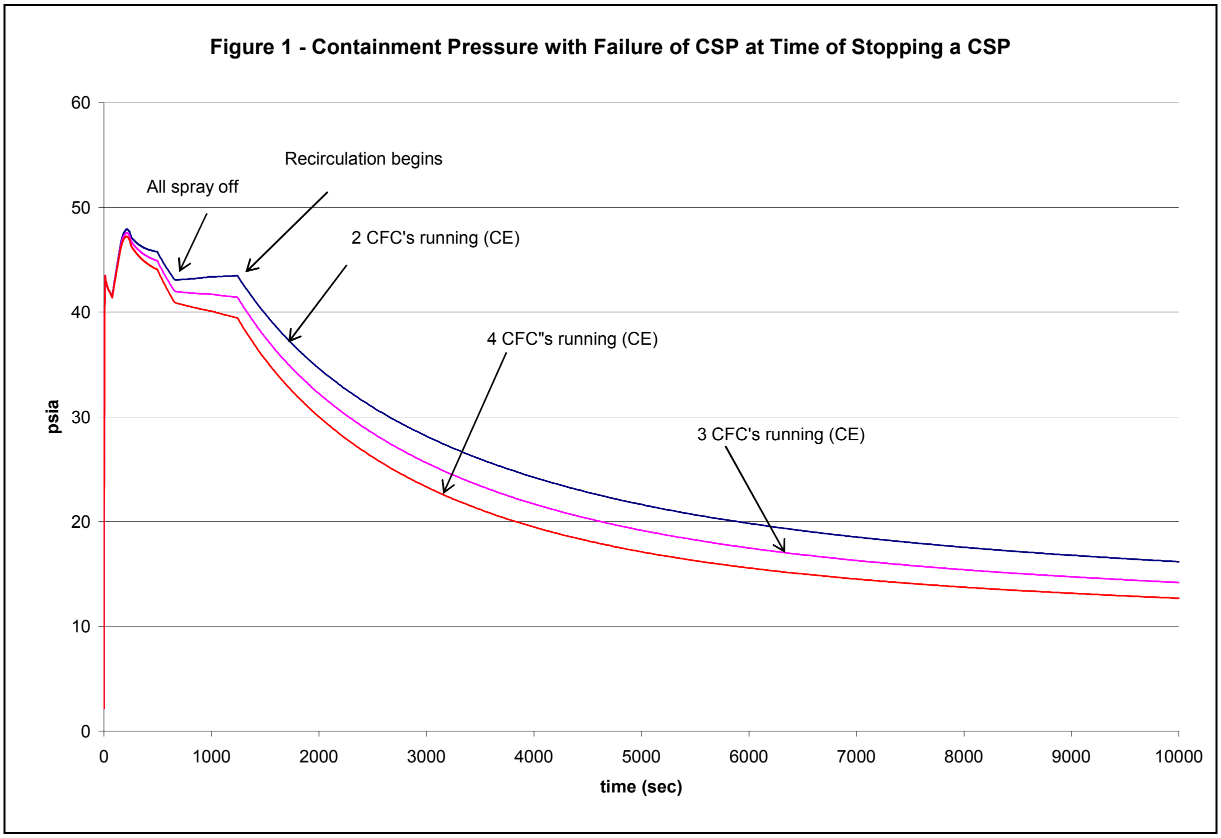


Figure 1 - Containment Pressure with Failure of CSP at Time of Stopping a CSP
Recirculation begins
All spray off
2 CFC's running (CE)
4 CFC"s running (CE)
3 CFC's running (CE)
psia
0
10
20
30
40
50
60
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
time (sec)

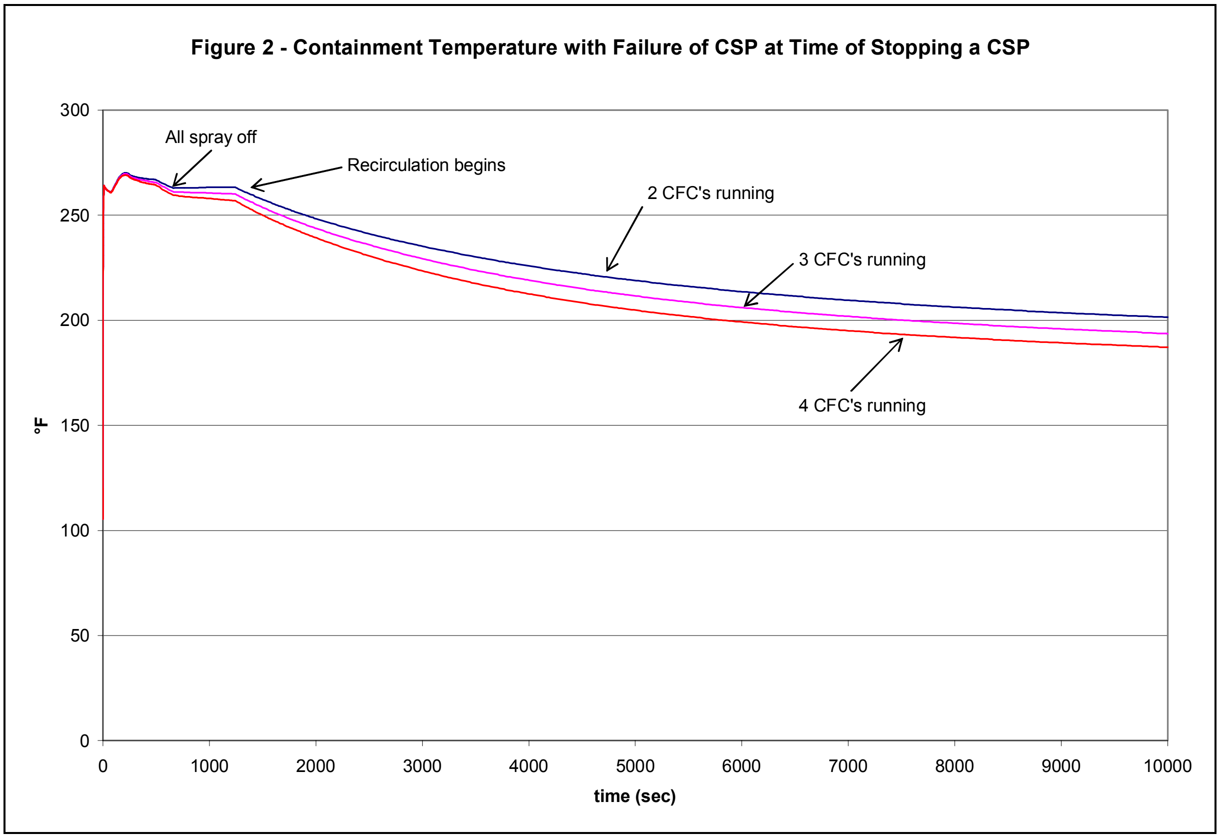


Figure 2 - Containment Temperature with Failure of CSP at Time of Stopping a CSP
All spray off
Recirculation begins
2 CFC's running
3 CFC's running
4 CFC's running
°F
0
50
100
150
200
250
300
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
time (sec)

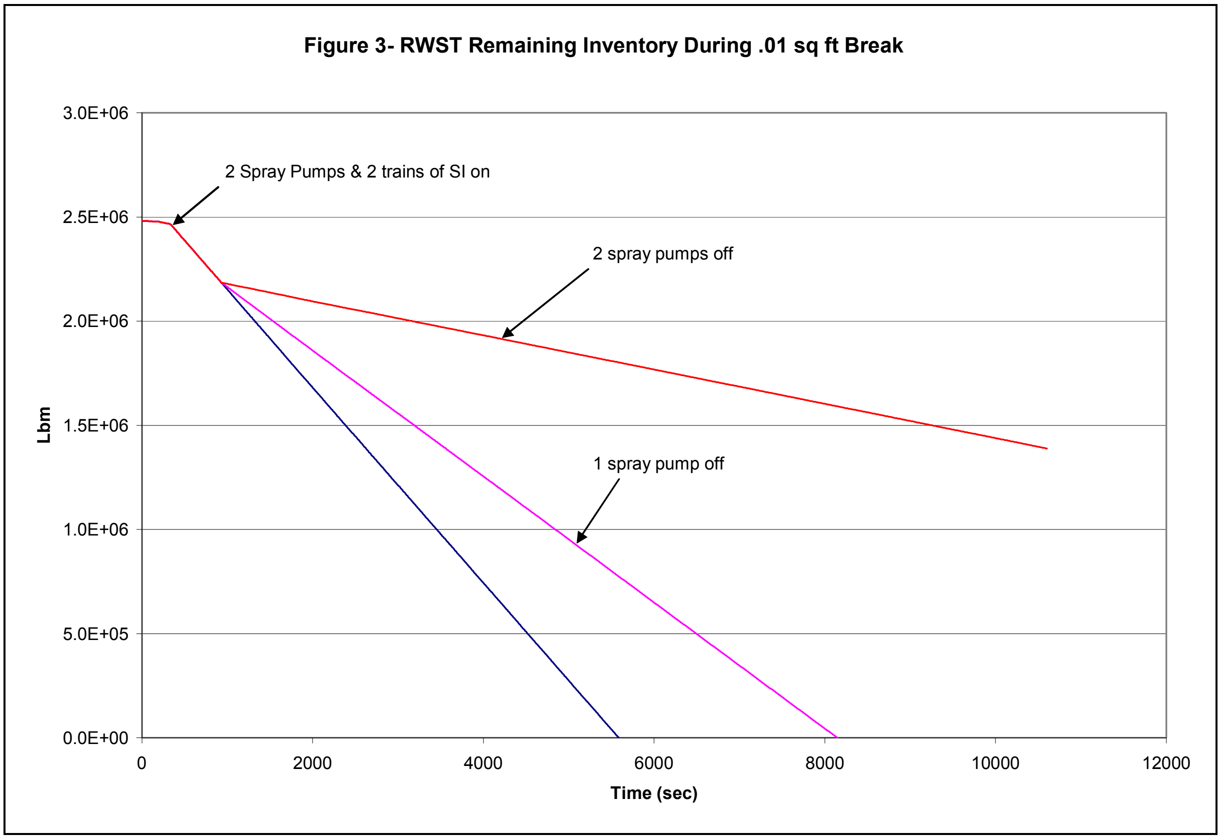


Figure 3- RWST Remaining Inventory During .01 sq ft Break
3.0E+06
2.5E+06
2.0E+06
1.5E+06
1.0E+06
5.0E+05
0.0E+00
Lbm
2 Spray Pumps & 2 trains of SI on
2 spray pumps off
1 spray pump off
0
2000
4000
6000
8000
10000
12000
Time (sec)

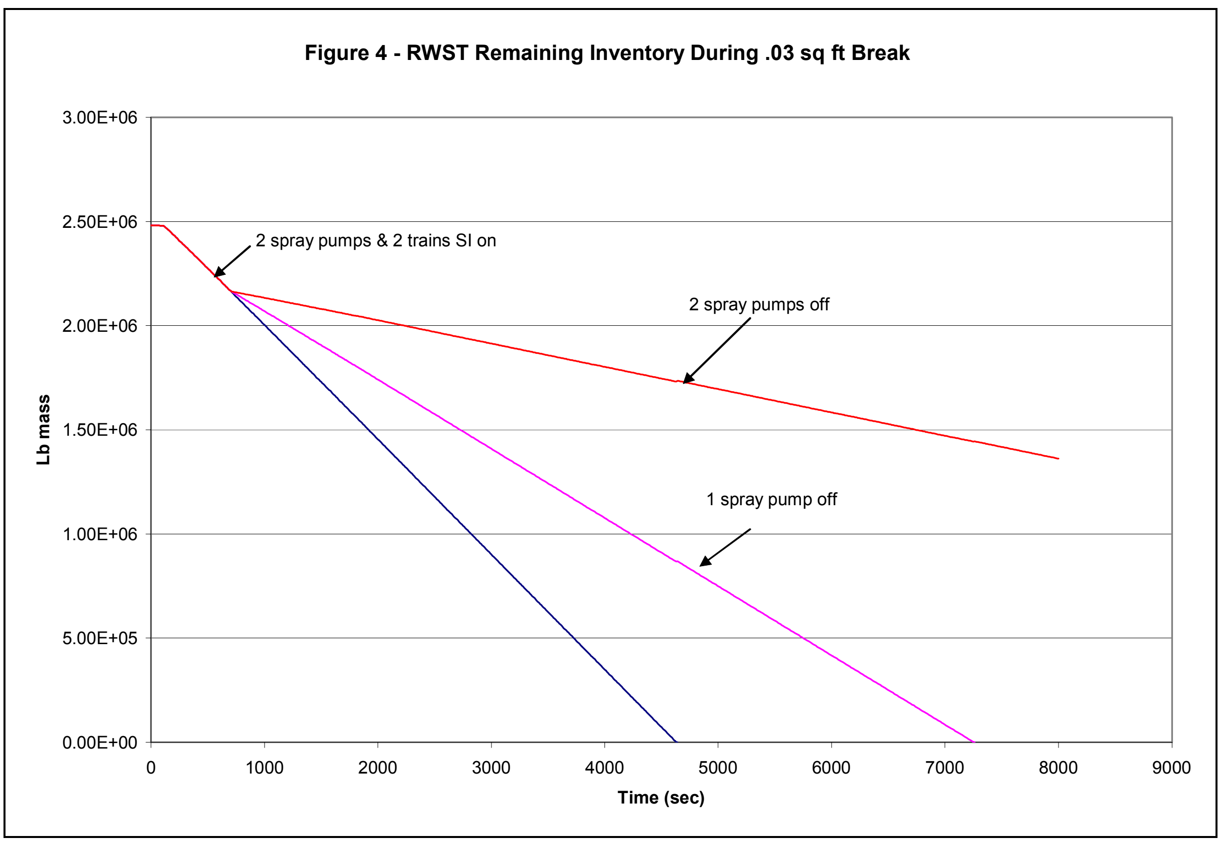


Figure 4 - RWST Remaining Inventory During .03 sq ft Break
3.00E+06
2.50E+06
2.00E+06
1.50E+06
1.00E+06
5.00E+05
0.00E+00
Lb mass
2 spray pumps & 2 trains SI on
2 spray pumps off
1 spray pump off
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
Time (sec)

A2 – Candidate Operator Action 2
Manually Establish One Train of Containment Sump Recirculation Prior to Automatic Actuation

1.0 INTRODUCTION

NRC Bulletin 2003-01 requires that the utilities evaluate and implement compensatory measures to reduce the potential risk due to post-accident debris blockage as evaluations to determine compliance proceed. The bulletin directed utilities to consider a range of possible interim compensatory measures. Utilities may elect to implement those compensatory actions they deem appropriate, based upon the specific conditions associated with their plants. One possible interim compensatory measure developed as a possible response to the bulletin was “to manually establish one train of containment sump recirculation prior to automatic actuation.”

This document provides the evaluation of the manually transfer of the suction of one safety injection train to the containment sump prior to automatic actuation. One train of safety injection and containment spray remains lined up to the Refueling Water Storage Tank (RWST). If meeting Net Positive Suction Head (NPSH) requirements necessitates using the full volume of the RWST, an alternative would be to allow normal containment sump recirculation to initiate. Add water to the RWST. Transfer the suction of one injection train back to the RWST when adequate water inventory has been restored to the RWST.

A NPSH calculation will define the amount of water that needs to be transferred to containment to support operating the necessary pumps. When RWST level is below [15%] line up injection pump [1] and containment spray (CS) pump [1] to take suction from the containment sump.

Manually:

- Open train [1] sump suction valve
- Verify proper injection flow
- Close train [1] RWST suction line valve
- Verify proper injection flow
- Stop high pressure safety injection (HPSI) pump [2]
- [Stop CS pump 2]

Close RWST re-circulation valve

Or Automatically:

- Actuate train one for containment recirculation.

Bases:

The intention is to start containment recirculation while usable inventory remains available in the RWST. This step is intended to provide a backup injection path independent of the containment sump. The injection pump and spray pump on the suction line connected to the RWST are secured and are available as a backup if the operating pumps experiences excessive sump clogging. A NPSH calculation will provide the earliest RWST level that will support operating in the containment recirculation mode.

2.0 QUALITATIVE EVALUATION SUMMARY

2.1 Advantages

This will eliminate the common cause failure of both injection pumps from clogged strainer issues. One injection pump remains lined up to the RWST.

This action decreases flow through the containment sump screen compared to automatic initiation with two trains operating. The lower flows through the sump reduce the potential for screen clogging at the time of initiation of containment recirculation.

2.2 Disadvantages/Potential Issues

In order to implement this step a plant must have existing NPSH margin or be able to demonstrate operating only one train of injection in the recirculation mode will improve NPSH requirements to allow manual transfer to containment sump recirculation while significant inventory remains in the RWST. Operating with one train of injection means steps to stop all spray must be implemented and steps to stop one injection train must be implemented. If meeting NPSH requirements necessitates using the full volume of the RWST, the plant would have to be able to implement RWST refill steps. Due to the relatively short time to initiate recirculation flow during a large break LOCA, establishing early recirculation may only occur during smaller breaks. However, there should be analyses to verify component cooling water will adequately handle all heat loads at the earliest time recirculation could be established.

This is only a temporary reprieve unless adequate makeup to the RWST is available.

3.0 REFERENCE PLANT ANALYSES/EVALUATIONS

3.1 Summary of Analyses Performed

No analysis is specific to this candidate operator action (COA). However implementation of this step requires that other sump clogging preventive steps have been implemented. Only one train of safety injection and spray will be lined up to the containment sump. As a minimum, implementing the steps to secure one train of injection and spray is necessary. Depending on the available NPSH following an early transfer to containment recirculation, it may be necessary to implement the steps to secure one train of injection and all spray. The ability to refill the RWST improves the longevity of the standby pump and steps to implement RWST refill should be implemented. Implementing this COA requires a plant to have favorable analysis to stop one injection train, one or both spray pumps and refill the RWST.

3.2 Risk Assessment

In the event sump blockage does occur, by transferring only one train of emergency core cooling system (ECCS) to recirculation at a given time, the impact on the system due to the sump blockage will only affect the transferred train. Thus, one train of ECCS will still be available for injection from either the RWST or any other coolant source. However, for small loss-of-coolant accidents (LOCAs) and accidents requiring feed and bleed, the accident may be adequately mitigated without recirculation if the reactor coolant system is depressurized to residual heat removal (RHR) pressure. Therefore, the operator must be aware of the situation and not transfer to recirculation too early, as there is no existing procedure to secure recirculation and initiate normal RHR. Overall, this COA provides a risk benefit because of the potential to protect one train of ECCS from the consequences of sump blockage.

3.3 Human Factors

The staggered recirculation strategy is proposed to make technical sense only when it follows COA 1 (Securing Spray Pump(s) Before Recirculation) within the interval available, so that comments on COA 1 are also relevant. It is assumed that the proposed task is either already routine in some other context, or if not could be made routine in the present context by training. Thus, the main questions for anticipated circumstances are whether or not:

1. Time is available to effectively perform the COA

2. Additional risk-significant errors are permitted by the COA (e.g., failure to secure CS pumps causing cavitation/damage to realigned HPSI pump)

3. Expected downstream delays from added upstream manual actions are worth the wait

4. Burden of added manual actions will add stress or otherwise degrade overall operator performance

COA 2 is infeasible for large break LOCA because of the short time available before the RWST empties and containment recirculation is automatically actuated. Smaller breaks (i.e., slower LOCAs) thus increase the likelihood that COA 2 will be applicable, and in turn that it can be performed successfully (more time available, moderated stress, etc.) In sum, from the human factors perspective, COA 2 seems reasonable if it can be easily skipped by procedure when it is not applicable.

4.0 CONCLUSIONS/RECOMMENDATIONS

Each plant must consider the advantages and disadvantages as they apply to their plant specific design and incorporate interim compensatory measures that are risk beneficial with respect to containment sump blockage.

As general guidance, implementation of this operator action is recommended only for plants that:

- Have margin in their containment sump NPSH calculation
- Have the ability to secure one injection train
- Have the ability to secure one or both spray pumps
- Can refill the RWST

The advantage of this operator action is that while safety injection and possibly spray are being supplied from the containment sump, the backup source of injection and spray is completely independent of the sump and potential clogging issues.

A3-CE – Candidate Operator Action 3 – Combustion Engineering Plants Terminate One Train of HPSI/High-Head Injection After Recirculation Alignment

1.0 INTRODUCTION

NRC Bulletin 2003-01 requires that the utilities evaluate and implement compensatory measures to reduce the potential risk due to post-accident debris blockage as evaluations to determine compliance proceed. The bulletin directed utilities to consider a range of possible interim compensatory measures. Utilities may elect to implement those compensatory actions they deem appropriate, based upon the specific conditions associated with their plants. One possible interim compensatory measure developed as a possible response to the bulletin was "to terminate one train of high-head injection after recirculation alignment."

The purpose of this document is to evaluate a Combustion Engineering Emergency Procedure Guidelines (EPG) strategy change to terminate one train of high pressure safety injection (HPSI) injection following containment sump recirculation alignment, assuming two trains of HPSI are in operation after Recirculation Actuation Signal (RAS) and are running normally. Currently the EPGs have one standard set of HPSI Stop/Throttle or SI termination criteria criterion. The existing HPSI Stop/Throttle criteria are:

- Reactor coolant system (RCS) subcooling equal to or greater than the minimum required
- Pressurizer level greater than the minimum level for verification of inventory control
- At least one steam generator available for RCS heat removal and SG level being maintained or restored
- Reactor vessel level greater that the top of the hot legs

During a large break loss-of-coolant accident (LOCA), all of the above conditions may not be met after RAS. Yet, depending on containment sump blockage risk, it may still be advantageous to stop/throttle HPSI pumps to lower containment sump blockage risk. Since most plants only require one HPSI pump to meet licensing requirements, securing all but one HPSI pump after RAS still provides adequate core cooling consistent with the licensing bases.

This evaluation examines the advantages and disadvantages of stop/throttle all but one HPSI after RAS. The EPG LOCA strategy is unchanged, that is, to ensure sufficient RCS inventory and maintain core heat removal.

2.0 QUALITATIVE EVALUATION SUMMARY

2.1 Assumed Plant Conditions

1. LOCA in progress.
2. Reactor is tripped.
3. Standard Post Trip Actions complete.

4. LOCA Emergency Operating Procedure in use.
5. RAS has occurred and suction for all HPSI pumps is aligned to the containment sump.

2.2 Assumed Operator Actions for Proposed Compensatory Interim Measure

1. Verify two HPSI pumps in operation taking suction from containment sump.

2. Verify representative core exit thermocouple (CET) temperature less than superheated.

3. Verify reactor vessel level measurement system (RVLMS) indicates greater than the top of the active fuel.

4. Stop one HPSI pump.

5. Monitor Core heat removal based on:

   a. CET temperature not superheated.
   b. RVLMS indicates core is covered.

6. Monitor running HPSI pump to ensure nominal performance.

2.3 Advantages

2.3.1 <u>Reduce Debris Transport</u>

Securing one HPSI pump reduces the total flow through the sump screens and thereby reduces the rate of debris transport to the screen surface and reduces the risk of blockage. The amount and size of debris collected at the containment sump screens is a function of screen size, the flow volume through the screens and the overall inflow to the containment sump. Greater volumetric flow is more likely to "sweep" debris to the containment sump screens and thereby increase the risk of blockage. The flow contribution of one HPSI pump is relatively small compared to containment spray pump (less that 1/10). However, any flow reduction should reduce the risk of blockage.

2.3.2 <u>Reduce Risk of Screen Failure</u>

PWR sump screens were typically designed assuming relatively small structural loads from the differential pressure associated with 50% debris blockage. Consequently, PWR sump screens may not be capable of accommodating the substantial structural loadings that may occur due to debris beds that cover the entire screen surface. Inadequate structural reinforcement of a sump screen may result in its deformation, damage, or failure, which could allow large quantities of debris to be ingested into the HPSI and Containment Spray System piping, pumps, and other components, potentially leading to clogging and failure. Reducing both the risk and rate of sump blockage lowers the risk of containment sump screen failure and potential failure of operating HPSI and Containment Spray pumps.

2.3.3 Preserve Operable HPSI Pump

Securing one HPSI pump post RAS provides additional assurance that the secured pump will not be damaged due to debris ingestion or loss of net positive suction head (NPSH), thereby preserving one operable HPSI pump for later use.

2.3.4 Preserving One Sump Screen Enclosure (Dual-Sump plants)

Some plants have separate sumps for each ECCS train. In this case securing flow from one train will preserve one sump for use in the event that the in-service sump screens become blocked. In addition, operation of the single screen might reduce the amount of free debris available to block the other screen. Therefore, if the first screen becomes blocked, it is more likely to remain unblocked.

2.4 Disadvantages

2.4.1 Revise HPSI Stop Throttle Criteria

Typical PWR LOCA safety analysis assumes failure of one diesel generator and therefore relies on one train of HPSI to show adequate core cooling. However, if both HPSI trains are operating, the current EPGs provide "HPSI Stop Throttle Criteria" that must be met before securing one of the operating HPSI pumps. Current EPGs provide "HPSI Stop Throttle Criteria" that must be met before securing one of the operating HPSI pumps. Current EPGs provide the following guidelines:

HPSI Stop Throttle Criteria
IF HPSI pumps are operating,
AND ALL of the following conditions are satisfied:

1) RCS subcooling is greater than [minimum RCS subcooling]

2) Pressurizer level is greater than [minimum level for inventory control] and NOT lowering

3) At least one steam generator is available for RCS heat removal with level being maintained or restored to [normal control band]

4) Reactor vessel level is greater than the [top of the hot leg nozzles]

THEN throttle HPSI flow or stop **ONE** HPSI pump at a time.

Current guidelines will not permit securing one HPSI pump unless all the above conditions are met. Conditions 1, 2, and 4 may not be met during a large break LOCA. Therefore, the current HPSI Stop Throttle Criteria must be revised in order to permit securing one HPSI pump post RAS.

2.4.2 HPSI Pump NPSH

Stopping one (1) HPSI pump during recirculation mode may slightly increase the required NPSH for the remaining running HPSI pump due to the increase in flow through the running pump. During two pump operation all HPSI flow must pass through common loop headers into the cold leg. When one HPSI pump is stopped, the reduction in overall flow also reduces the line-loss to the cold leg and thus flow will increase slightly for the remaining running HPSI pump. This increase in flow will result in a slight increase in required NPSH. This should not present a problem since the required NPSH for one HPSI pump operation is already accounted for in system design. This item is presented here to provide a comprehensive listing of all factors that should be considered on a plant specific basis before implementing an interim compensatory measure.

2.4.3 Single Failure

Typical plant licensing bases show adequate core cooling with one HPSI pump after recirculation actuation. However, since deliberate manual securing of one HPSI pump is not considered a "failure," licensees may be required to show acceptable consequences with failure of the running HPSI pump after manually stopping one of two HPSI pumps. This would mean an interruption of HPSI flow until the operator could restart the previously secured HPSI pump. Since current licensing analysis does not account for an interruption in HPSI flow due to single failure, plant specific 10 CFR 50.59 evaluation may be required to determine the acceptability of securing one HPSI pump after recirculation actuation.

Best estimate analyses have been performed to determine the time after trip when the decay heat level is low enough, such that, failure of "the one" running high pressure injection pump will result in approximately 15 minutes of reaction time before core temperature begins to rise. Fifteen minutes was selected so that loss of the one remaining high pressure injection pump will allow one Safety Function Status Check interval for the operator to recognize the loss of injection flow and take corrective action to restore core cooling.

Best estimate analyses show that at 40 minutes after trip there is approximately 15 minutes of operator reaction time before core temperatures begin to rise. Details of this analysis are contained in Appendix B. Since 40 minutes is an approximate value, each plant should complete a similar plant specific best estimate analysis.

2.4.4 Low Volume Pump

Since HPSI pumps are low volume pumps compared to low pressure safety injection (LPSI) and Containment Spray pumps, the benefit of reduced flow through the sump screens is limited.

2.4.5 Instrument Readability and Uncertainties

At the point in the event (up to 1 hour post event) when the operator would likely be ready to take the proposed action, the injection flow required for decay heat removal may only be 200 – 300 gpm. Therefore it will be difficult for him to balance the required flow between the four injection points (50 – 75 gpm each). SI cold leg injection flow instrument uncertainties for a harsh containment typically are more than this amount. This reality supports adopting a stop a pump strategy as opposed to a throttle flow to match decay heat strategy.

2.4.6 Throttling Limitations on SI Injection Valves (throttling vs. stopping one pump)

Some plants may have restrictions on how much they can throttle the SI injection valves because of the potential for valve seat blockage from small debris particles that make it through the sump screens.

3.0 REFERENCE PLANT ANALYSES/EVALUATION

3.1 Summary of Evaluations Performed

1. What is the impact of shutting off one ECCS train on the LOCA analysis?

   Response:

   If plant specific safety analysis assumes only (1) HPSI pump post RAS, there should be no impact on existing LOCA analysis. Confirm current LOCA analysis assumes only one (1) HPSI pump operable post RAS.

2. How does the operator determine the rate of addition? Develop tool that shows required minimum flow for heat removal based on core life and time after shutdown. ERG personnel must review and modify as appropriate for the Westinghouse guidelines.

   Response:

   This evaluation suggests that guidance for post RAS HPSI flow control should be changed from the existing “flow monitoring” (via ECCS pump flow vs. RCP Pressure curves) to “core condition monitoring.” Where, instead of using total ECCS header flow to the reactor vessel as the initial indicator of adequate core cooling, the operator would instead, throttle HPSI based on real time core conditions and trends, i.e., core exit thermocouples, reactor vessel level, etc.

   This is a significant change in strategy, in that, the existing initial mitigating action to ensure adequate core cooling, monitor HPSI flow, would be removed. This would leave little recovery time to adjust for worsening core conditions. The elimination of HPSI flow monitoring may increase the risk of core damage due to lack of sufficient operator response time.

   Recommend continue using existing “HPSI flow monitoring” strategy.

3. Does changing HPSI/high-head injection reduction criteria, post recirculation alignment, conflict with any commitments, NUREG 0737 or other licensing requirements? ERG personnel and must review and modify as appropriate for the Westinghouse guidelines and licensing commitments.

   Response:

   If current licensing bases assumes only one (1) train of SI pumps is operable post RAS, then, there should be no impact.

4. How does securing one train impact NPSH of pumps remaining in operation?

Response:

For containment sump configurations with a common suction line from the containment sump to the HPSI pumps (reference plant SONGS), operating only one (1) HPSI pump during recirculation mode will slightly reduce the line-loss from the sump to the HPSI pump suction since the total flow in the suction line has decreased. This should provide a slight increase in HPSI pump suction pressure and thereby increase the available NPSH. However, the slight increase in available NPSH may be offset by the slight increase in required NPSH of the remaining running HPSI pump due to increased flow in the single pump configuration. The net effect must be calculated on a plant specific bases.

5. Determine specific criteria for flow reduction and document bases.

Response:

Since the reduction of HPSI flow post RAS is a preventative measure intended to slow the accumulation of debris and subsequent sump blockage, this action should be taken for any LOCA inside containment after RAS has occurred. In addition, since the rate of sump blockage is unknown (time from first indication of sump blockage to complete blockage), waiting for specific indications of sump blockage may reduce the beneficial effect of reduced HPSI flow and increase the risk of complete sump blockage.

6. Determine specific criteria requiring flow restoration and document bases.

Response:

If core conditions indicate inadequate core cooling (via loss of subcooling by CET), then, maximum core cooling flow should be restored, i.e., start idle HPSI pumps.

3.2 Comparison to Licensing Requirements

Reference: NRC Memorandum to File, “Revised NRC Staff Responses To Three Industry Questions On Bulletin 2003-01 Submitted Prior To The June 30, 2003, Public Meeting,” date: August 7, 2003

Prior NRC Review and Approval

A change to a facility, as defined by 10 CFR 50.59, must be evaluated against certain criteria enumerated in 10 CFR 50.59 to determine whether NRC review and approval is necessary prior to its implementation. The NRC staff believes that interim measures, such as securing a train of safety injection, may be risk beneficial for certain PWRs with potentially degraded recirculation sump performance. If a particular licensee finds that such an interim measure is risk beneficial for its facility and plans to implement the measure, the licensee is responsible for evaluating whether or not the criteria for prior NRC review in 10 CFR 50.59 are met. Whether or not a licensee determines that criteria in 10 CFR 50.59 are met depends on plant- specific configurations and analyses.

Consistency with Licensing Bases

Bulletin 2003-01 does not intend for licensees to implement compensatory measures that invalidate their safety analyses. If an interim measure is inconsistent with safety analyses, licensees should either: (1) not implement the measure, or (2) revise the safety analysis (including NRC review and approval if required) and then implement the measure. To provide further clarification, a specific discussion of preemptive and responsive compensatory measures follows.

Preemptive compensatory measures are actions to reduce the risk of sump failure that would be taken prior to indications of degraded sump performance. This category includes actions that may be taken during the injection phase and/or recirculation phase (prior to indications of degraded sump performance) of an accident, such as reducing ECCS flows to values that remain above analyzed minimum rates, terminating high- pressure injection if not required, and shutdown of redundant equipment. Some preemptive measures may be consistent with the licensing basis for certain licensees. The implementation of other preemptive measures that may not be analyzed in the current licensing basis would require a revision to the licensing basis (and potentially NRC review and approval) prior to implementation. For any proposed change (as defined in 10 CFR 50.59), licensees are required to address the criteria in 10 CFR 50.59.

Responsive compensatory measures are actions taken to reduce the risk of sump failure or its consequences (e.g., loss of core cooling and/or loss of containment cooling) during the recirculation phase of an accident following indications of degraded sump performance and/or impending sump failure. As sump failure is not considered in plants' current licensing bases, it may be warranted for licensees to take appropriate actions in response to indications of likely sump failure, even if the actions are not analyzed in the current licensing basis. An example of such a responsive measure would be switching back to ECCS/CSS injection following sump failure. The implementation of responsive measures may involve revisions to emergency procedures or guidelines, but it is not necessary to revise the Final Safety Analyses Report to include responsive measures for beyond- design- basis occurrences such as sump failure. Although licensees should evaluate any changes for risk benefit, this type of action typically does not require prior NRC approval.

3.3 Risk Assessment

If the sump is diagnosed to be blocked, the operators are trained not to initiate recirculation. Therefore this candidate operator action (COA) provides no benefit to risk if the sump is blocked. However, plants that are highly susceptible to sump blockage may achieve some benefit due to slightly reduced debris transport. In addition, if it is necessary to restart the secured pump, an additional "pump fail to start" failure mode is introduced to the probabilistic risk assessment (PRA) model. From a success criteria perspective, only one out of two HPSI pumps are required for some accident sequences. Therefore, as long as one pump is available the risk of this COA will not be impacted. Damage to the secured HPSI may be prevented if sump blockage were to occur in the longer term following RAS; the HPSI pump would be available for injection to the RCS from other sources if it is saved from damage at sump blockage. In conclusion, this COA can provide a benefit to plant risk.

3.4 Human Performance Evaluation

No general means has been identified to unclog containment sump strainers during an event. Realignment to alternative sources, if at all feasible, is time consuming. If a HPSI pump begins to cavitate, there is insufficient time (potentially much less than one minute) to respond manually before catastrophic pump failure occurs. Preemptive measures are thus necessary.

When applicable criteria are met, it is a familiar operator task to throttle/stop and subsequently restart HPSI pump(s) after automatic actuation (LOCA 18/19). To do so following RAS should not be more error-prone or time-consuming than usual, since RAS during LOCA is neither early nor unpredictable. In fact, securing one pump may slow the course of some scenarios, though there is some question about worst-case time margins to core uncovery if both pumps are erroneously secured. But since there is seemingly little change in the operators' overall responsibilities, from a human factors perspective, this action is recommended for further consideration.

4.0 CONCLUSIONS/RECOMMENDATIONS

Preliminary indications show stopping one HPSI pump after recirculation actuation may be risk beneficial. However, each plant must consider the advantages and disadvantages as they apply to their plant specific design and incorporate interim compensatory measures that are risk beneficial with respect to containment sump blockage.

A3-W – Candidate Operator Action 3 – Westinghouse Plants
Terminate One Train of Safety Injection After Recirculation Alignment

1.0 INTRODUCTION

NRC Bulletin 2003-01 requires that the utilities evaluate and implement compensatory measures to reduce the potential risk due to post-accident debris blockage as evaluations to determine compliance proceed. The bulletin directed utilities to consider a range of possible interim compensatory measures. Utilities may elect to implement those compensatory actions they deem appropriate, based upon the specific conditions associated with their plants. One possible interim compensatory measure developed as a possible response to the bulletin was "to terminate one train of safety injection after recirculation alignment."

The purpose of this document is to evaluate a Westinghouse Emergency Response Guidelines (ERG) strategy change to terminate one train of safety injection (SI) following containment sump recirculation alignment, assuming two trains of SI are in operation after initiation of recirculation and are running normally. Currently the ERGs have one standard set of SI termination criteria that may not be satisfied post-recirculation depending on the size of the break. The SI termination criteria is:

- Reactor coolant system (RCS) subcooling equal to or greater than the minimum required
- Pressurizer level greater than the minimum level for verification of inventory control
- At least one steam generator available for RCS heat removal and steam generator level being maintained or restored
- RCS pressure stable or increasing

During large break loss-of-coolant accident (LOCA), all of the above conditions may not be met after the initiation of recirculation. Yet, depending on containment sump blockage risk, it may still be advantageous to stop/throttle SI pumps to lower containment sump blockage risk. If plants only require one train of SI pumps to meet licensing requirements, securing all but one SI train after switchover to recirculation still provides adequate core cooling consistent with the licensing bases.

This evaluation examines the advantages and disadvantages of stop/throttle all but one SI train after initiation of recirculation. The ERG LOCA strategy is unchanged, that is, to ensure sufficient RCS inventory and maintain core heat removal.

2.0 QUALITATIVE EVALUATION SUMMARY

2.1 Assumed Plant Conditions

1. LOCA in progress.

2. Reactor is tripped.

3. Standard Post Trip Actions complete (Actions of E-0 complete).

4. LOCA Emergency Operating Procedure in use (E-1 has been entered).

5. Switchover to recirculation has occurred and suction for the SI system and all containment spray pumps is aligned to the containment sump.

2.2 Assumed Operator Actions for Proposed Compensatory Interim Measure

1. Verify core cooling and both SI trains are in operation taking suction from containment sump.

2. Verify reactor vessel level measurement system (RVLMS) indicates greater than the top of the active fuel.

3. Stop one charging/SI pump.

4. Monitor Core heat removal based on:

   a. Core exit thermocouple (CET) temperature not superheated.
   b. RVLMS indicates core is covered.

5. Monitor running pumps performance to ensure nominal operation.

6. Stop one SI pump.

7. Monitor core heat removal based on:

   a. CET temperature not superheated.
   b. RVLMS indicates core is covered.

   Monitor running pumps performance to ensure nominal operation.

   Stop one RHR/LHSI pump.

   Monitor core heat removal based on:

   a. CET temperature not superheated.
   b. RVLMS indicates core is covered.

2.3 Advantages

2.3.1 <u>Reduce Debris Transport</u>

Securing one train of SI pumps reduces the total flow through the sump screens and thereby reduces the rate of debris transport to the screen surface and reduces the risk of blockage. The amount and size of debris collected at the containment sump screens is a function of screen size, the flow volume through the screens and the overall inflow to the containment sump. Greater volumetric flow is more likely to "sweep" debris to the containment sump screens and thereby increase the risk of blockage. The flow contribution of one train of SI pumps is approximately equivalent to a containment spray pump, and any flow reduction should reduce the risk of blockage.

2.3.2 Reduce Risk of Screen Failure

PWR sump screens were typically designed assuming relatively small structural loads from the differential pressure associated with 50% debris blockage. Consequently, PWR sump screens may not be capable of accommodating the substantial structural loadings that may occur due to debris beds that cover the entire screen surface. Inadequate structural reinforcement of a sump screen may result in its deformation, damage, or failure, which could allow large quantities of debris to be ingested into the low head safety injection (LHSI) and Containment Spray System piping, pumps, and other components, potentially leading to clogging and failure. Reducing both the risk and rate of sump blockage lowers the risk of containment sump screen failure and potential failure of operating SI and Containment Spray pumps.

2.3.3 Preserve Operable SI Train

Securing one train of SI pumps after switchover to recirculation provides additional assurance that the secured pump will not be damaged due to debris ingestion or loss of net positive suction head (NPSH), thereby preserving one operable set of SI pump for later use.

2.3.4 Preserving One Sump Screen Enclosure (Dual-Sump plants)

Some plants have separate sumps for each Emergency Core Cooling System (ECCS) train. In this case securing flow from one train will preserve one sump for use in the event that the in-service sump screens become blocked. In addition, operation of the single screen might reduce the amount of free debris available to block the other screen. Therefore, if the first screen becomes blocked, it is more likely to remain unblocked.

2.4 Disadvantages

2.4.1 Revise HHSI Termination Criteria

Typical PWR LOCA safety analysis assumes failure of one diesel generator and therefore relies on one train of SI to show adequate core cooling. However, if both SI trains are operating, the current ERGs provide "SI Termination Criteria" that must be met before securing one of the operating high head safety injection (HHSI) pumps. Current ERGs provide the following guidance:

SI Termination Criteria
IF HHSI pumps are operating,
AND ALL of the following conditions are satisfied:

1) RCS subcooling is greater than [minimum RCS subcooling]

2) Pressurizer level is greater than [minimum level for inventory control]

3) At least one steam generator is available for RCS heat removal with level greater than [on span] or total feed flow greater than [minimum for heat removal]

4) RCS pressure stable or increasing

THEN stop **ONE** HHSI pump at a time.

Current guidelines will not permit securing one HHSI pump unless all the above conditions are met. Conditions 1, 2, and 4 may not be met during a large break LOCA. Therefore, the current SI Termination Criteria must be revised in order to permit securing one HHSI pump after switchover to recirculation.

2.4.2 SI Pump NPSH

Stopping one (1) train of SI pumps during recirculation mode may slightly increase the required NPSH for the remaining running RHR/LHSI pump due to the increase in flow through the running pump. During two train operation all SI flow must pass through common loop headers into the cold leg. When one SI train is stopped, the reduction in overall flow also reduces the line-loss to the cold leg and thus flow will increase slightly for the remaining running SI pump. This increase in flow will result in a slight increase in required NPSH. This should not present a problem since the required NPSH for one SI train operation is already accounted for in system design. This item is presented here to provide a comprehensive listing of all factors that should be considered on a plant specific basis before implementing an interim compensatory measure.

2.4.3 Single Failure

Current plant licensing bases show adequate core cooling with the loss of one SI train (due to single failure) and one SI train remaining operable through out the event. Generally, the loss of one SI train is due to failure of one diesel generator. However, since deliberate manual securing of one SI train is not considered a "failure," the plant may be required to show acceptable consequences with a failure of the remaining running train after manually stopping one SI train. This would mean an interruption of SI flow until the operator could start the standby SI pumps. Since current licensing analysis does not account for interruption in SI flow during single failure, reanalysis and a licensing amendment may be required.

3.0 REFERENCE PLANT ANALYSES/EVALUATION

3.1 Summary of Evaluations Performed

1. What is the impact of shutting off one ECCS train on the LOCA analysis?

   Response:

   If plant specific safety analysis assumes only (1) set of SI pumps post RAS, there should be no impact on existing LOCA analysis.

2. How does the operator determine the rate of addition? Develop tool that shows required minimum flow for heat removal based on core life and time after shutdown.

   Response:

   The ERGs use core exit thermocouples and reactor vessel level values to indicate adequate/ inadequate core cooling. These would be monitored, as well as the performance of the SI pumps after recirculation is established.

   ERG ECA-1.1 currently provides an operator aid to determine the amount of SI flow necessary to remove core decay heat, based on time after the reactor trip. This aid is used to determine the minimum SI flow to be established from the RWST when recirculation capability is lost.

3. Does changing/high-head injection reduction criteria, post recirculation alignment, conflict with any commitments, NUREG 0737 or other licensing requirements?

   Response:

   The licensing design basis of the SI system requires that minimum safeguards be met with either a single active failure or a single passive failure during the cold leg recirculation mode (assuming no failure occurred during the injection mode). For the reference plant, the minimum safeguards requirements are two high pressure pumps (HHSI or Charging/SI) and one low-head SI pump.

4. How does securing one train impact NPSH of pumps remaining in operation?

   Response:

   For containment sump configurations with a common suction line from the containment sump to the RHR/LHSI pumps (reference plant: Westinghouse Standard 412), operating only one train (1 RHR/LHSI, 1 SI pump and 1 HHSI/charging pump) during recirculation mode will slightly reduce the line-loss from the sump to the RHR/LPSI pump suction since the total flow in the suction line has decreased. This should provide a slight increase in pump suction pressure and thereby increase the available NPSH. However, the slight increase in available NPSH may be offset by the slight increase in required NPSH of the remaining running RHR/LPSI pump due to increased flow in the single pump configuration. The net effect must be calculated on a plant specific basis.

5. Determine specific criteria for flow reduction and document bases.

   Response:

   Since the reduction of SI flow after initiation of recirculation is a preventative measure intended to slow the accumulation of debris and subsequent sump blockage, this action should be taken for any LOCA inside containment after recirculation has occurred. In addition, since the rate of sump blockage is unknown (time from first indication of sump blockage to complete blockage), waiting for specific indications of sump blockage may reduce the beneficial effect of reduced SI flow and increase the risk of complete sump blockage.

6. Determine specific criteria requiring flow restoration and document bases.

   Response:

   If core conditions indicate inadequate core cooling (via loss of subcooling by CET), then, maximum core cooling flow should be restored, i.e., start idle SI pumps.

3.2 Comparison to Licensing Requirements

Typical licensing bases show adequate core cooling with one high-head safety injection pump after recirculation is initiated. However, since manually securing a high-head pump is not considered a failure, consideration must be given to the consequences of a failure of the running high-head pump after manually stopping one pump. A plant-specific 10 CFR 50.59 evaluation may be required to determine the acceptability of securing one high-head pump after recirculation initiation.

3.3 Risk Assessment

If the sump is diagnosed to be blocked, the operators are trained not to initiate recirculation. Therefore this candidate operator action (COA) provides no benefit to risk if the sump is blocked. However, plants that are highly susceptible to sump blockage may achieve some benefit due to slightly reduced debris transport. In addition, if it is necessary to restart the secured pumps, an additional "pump fail to start" failure mode is introduced to the probabilistic risk assessment (PRA) model. From a success criteria perspective, only one out of two trains of SI pumps are required for accident sequences. Therefore, as long as one train of SI pumps is available the risk of this COA will not be impacted. Damage to the secured SI pumps may be prevented if sump blockage were to occur in the longer term following initiation of recirculation; the secured SI pumps would be available for injection to the RCS from other sources if the pumps are saved from damage at sump blockage. In conclusion, this COA can provide a benefit to plant risk.

3.4 Human Performance Evaluation

No general means has been identified to unclog containment sump strainers during an event. Realignment to alternative sources, if at all feasible, is time consuming. Depending on the pump design, if a SI pump begins to cavitate, there may be insufficient time (potentially much less than one minute) to respond manually before catastrophic pump failure occurs. Preemptive measures are thus necessary.

When applicable criteria are met, it is a familiar operator task to stop and subsequently restart SI pump(s) after automatic actuation. To do so following switchover to recirculation should not be more error-prone or time-consuming than usual, since recirculation initiation during LOCA is neither early nor unpredictable. In fact, securing one pump may slow the course of some scenarios, though there is some question about worst-case time margins to core uncovery if both pumps are erroneously secured. But since there is seemingly little change in the operators' overall responsibilities, from a human factors perspective, this action is recommended for further consideration.

4.0 CONCLUSIONS/RECOMMENDATIONS

Each plant must consider the advantages and disadvantages as they apply to their plant specific design and incorporate interim compensatory measures that are risk beneficial with respect to containment sump blockage.

A4 – Candidate Operator Action 4
Early Termination of One LPSI/RHR Pump Prior to Recirculation Alignment

1.0 INTRODUCTION

NRC Bulletin 2003-01 requires that the utilities evaluate and implement compensatory measures to reduce the potential risk due to post-accident debris blockage as evaluations to determine compliance proceed. The bulletin directed utilities to consider a range of possible interim compensatory measures. Utilities may elect to implement those compensatory actions they deem appropriate, based upon the specific conditions associated with their plants. One possible interim compensatory measure included in the bulletin was, "procedural modifications, if appropriate, that would delay switchover to containment sump recirculation (e.g., shutting down redundant pumps that are not necessary …"

The purpose of this document is to evaluate early termination of one (1) low pressure safety injection (LPSI)/residual heat removal (RHR) pump prior to recirculation alignment. The intent of this change is to delay Emergency Core Cooling System (ECCS) suction switch over from the refueling water tank to containment sump suction mode.

This evaluation is performed for the Combustion Engineering (CE) designed plants only. In the CE design the low pressure and high pressure pumps are independent, and thus a low pressure pump can be shut down while the high pressure pump in that train continues to operate. In the Westinghouse designed plants, however, the low pressure pumps provide suction for the high pressure pumps. Therefore, if a low pressure pump is shut down, the entire train of safety injection would be lost because the associated high pressure pump would have to be shut down also.

Current licensing bases analyses assume one train of LPSI pump operation from time of safety injection actuation signal (SIAS) until after transfer to recirculation. The principal function of LPSI pumps is to provide high volume and low head cooling water to the core during a large break LOCA. LPSI pumps are most effective during the interval between Safety Injection Tank (SIT) dump and recirculation actuation signal (RAS), after which high pressure safety injection (HPSI) flow is sufficient to provide core cooling.

Generic evaluations show stopping one LPSI pump before recirculation is not risk beneficial due to the risk of core damage upon single failure loss of the one operating LPSI pump.

2.0 QUALITATIVE EVALUATION SUMMARY

2.1 Advantages

2.1.1 <u>Delay Switch Over To Containment Sump Recirculation Mode</u>

Post LOCA time to reach RAS is a function of the refueling water tank depletion rate; i.e., reducing the refueling water tank depletion rate will prolong time to RAS. Therefore, if reactor coolant system (RCS) pressure is below HPSI shutoff head, stopping one (1) LPSI pump will delay RAS in proportion to the change in depletion rate of refueling water tank inventory.

Delaying time to RAS will result in a lower decay heat at time of switch over to containment sump recirculation mode. Lower decay heat is a mitigating effect if the containment sump becomes blocked since the rate of core boil-off is slower and thus more time is available for recovery actions.

2.1.2 Reduce Debris Transport

The amount and size of debris collected at the containment sump is, in part, a function of the total flow volume to the containment sump. Greater volumetric flow is more likely to "sweep" debris to the containment sump screens and thereby increase the risk of blockage. Securing LPSI pump(s) prior to RAS may have a slight mitigating effect in reducing the total flow to the sump and thereby reduce debris transport to the containment sump.

2.2 Disadvantages/Potential Issues

2.2.1 Revise LPSI Stop Criteria

Typical PWR LOCA safety analysis assumes failure of one diesel generator and therefore relies on only one LPSI pump to show adequate core cooling. However, if both LPSI trains are operating, the current Emergency Procedure Guidelines (EPGs) does not permit securing LPSI pumps unless RCS pressure is greater than LPSI shutoff head and pressure is controlled. The applicable steps follow:

Existing LOCA Step 20
IF pressurizer pressure is greater than
[LPSI pump shutoff head] and controlled,
THEN:
a. Stop the LPSI pumps.
b. Close the LPSI injection valves.

Existing LOCA Step 21
IF pressurizer pressure lowers to less than
[LPSI pump shutoff head],
AND BOTH of the following conditions are satisfied:
a. LPSI pumps have been stopped,
b. RAS has **NOT** occurred
THEN:
a. Start LPSI pumps as necessary.
b. Open the LPSI injection valves.

The existing strategy must be revised to permit securing one (1) LPSI pump prior to RAS.

2.2.2 Single Failure

Typical plant licensing bases show adequate core cooling with one LPSI pump and one HPSI pump before recirculation actuation. However, since deliberate manual securing of one LPSI pump is not considered a "failure," licensees may be required to show acceptable consequences with failure of the running LPSI pump after manually stopping one of two LPSI pumps. Failure of the only running

LPSI pump would mean an interruption of LPSI flow until the operator could restart the previously secured LPSI pump. Since current licensing analysis does not account for an interruption in LPSI flow due to single failure, plant specific 10 CFR 50.59 evaluation may be required to determine the acceptability of securing one LPSI pump after recirculation actuation.

3.0 REFERENCE PLANT ANALYSES/EVALUATION

3.1 Summary of Analyses Performed

Best estimate analyses were performed to determine the rise in core temperature approximately 10 minutes after the interruption of all LPSI flow due to single failure. It was assumed that one LPSI pump was secured 10 minutes into a large break LOCA, and that the single failure (loss of one train of electrical power) occurs immediately after. The analysis sequence of events is shown in the table below.

Analyses Sequence of Events		
	Time (sec.)	Event
1.	0	a) Large break LOCA b) Rx Trip, SIAS and Containment Spray Actuation
2.	600	Manually stop one of two running LPSI pumps
3.	601	Single failure event: a) The only running LPSI pump stops (total LPSI flow interruption) b) One of two running HPSI pumps stop c) One HPSI pump continues to run
4.	1200	Upper node core temperature begins to rise (departs from saturation)

The event sequence shows that one HPSI pump is not sufficient to maintain adequate core cooling early in a large break LOCA event (less than 20 minutes post trip).

Interruption/loss of all LPSI flow due to single failure may present an unreviewed safety question since mitigation is dependent on prompt operator action to recognize the problem and restart the standby LPSI pump within 10 minutes of the loss. In general, use of time critical operator actions in Emergency Operating Procedures should be limited due to the high stress human factors environment.

3.2 Comparison to Licensing Requirements

Reference: NRC Memorandum To File, "Revised NRC Staff Responses To Three Industry Questions On Bulletin 2003-01 Submitted Prior To The June 30, 2003, Public Meeting," date: August 7, 2003

Prior NRC Review and Approval

A change to a facility, as defined by 10 CFR 50.59, must be evaluated against certain criteria enumerated in 10 CFR 50.59 to determine whether NRC review and approval is necessary prior to its implementation. The NRC staff believes that interim measures, such as securing a train of safety injection, may be risk beneficial for certain PWRs with potentially degraded recirculation sump performance. If a particular licensee finds that such an interim measure is risk beneficial for its facility and plans to implement the measure, the licensee is responsible for evaluating whether or not the criteria for prior NRC review in 10 CFR 50.59 are met. Whether or not a licensee determines that criteria in 10 CFR 50.59 are met depends on plant- specific configurations and analyses.

Consistency with Licensing Bases

Bulletin 2003-01 does not intend for licensees to implement compensatory measures that invalidate their safety analyses. If an interim measure is inconsistent with safety analyses, licensees should either: (1) not implement the measure, or (2) revise the safety analysis (including NRC review and approval if required) and then implement the measure. To provide further clarification, a specific discussion of preemptive and responsive compensatory measures follows.

Preemptive compensatory measures are actions to reduce the risk of sump failure that would be taken prior to indications of degraded sump performance. This category includes actions that may be taken during the injection phase and/or recirculation phase (prior to indications of degraded sump performance) of an accident, such as reducing ECCS flows to values that remain above analyzed minimum rates, terminating high- pressure injection if not required, and shutdown of redundant equipment. Some preemptive measures may be consistent with the licensing basis for certain licensees. The implementation of other preemptive measures that may not be analyzed in the current licensing basis would require a revision to the licensing basis (and potentially NRC review and approval) prior to implementation. For any proposed change (as defined in 10 CFR 50.59), licensees are required to address the criteria in 10 CFR 50.59.

Responsive compensatory measures are actions taken to reduce the risk of sump failure or its consequences (e.g., loss of core cooling and/or loss of containment cooling) during the recirculation phase of an accident following indications of degraded sump performance and/or impending sump failure. As sump failure is not considered in plants' current licensing bases, it may be warranted for licensees to take appropriate actions in response to indications of likely sump failure, even if the actions are not analyzed in the current licensing basis. An example of such a responsive measure would be switching back to ECCS/CSS injection following sump failure. The implementation of responsive measures may involve revisions to emergency procedures or guidelines, but it is not necessary to revise the Final Safety Analyses Report to include responsive measures for beyond- design- basis occurrences such as sump failure. Although licensees should evaluate any changes for risk benefit, this type of action typically does not require prior NRC approval.

3.3 Risk Assessment

By securing 1 train of LPSI prior to transfer to recirculation, the flow required from the RWST will be greatly reduced, resulting in a longer time before transfer to recirculation would be implemented and reduced debris transport to the containment sump screens. As a result, the probability of sump blockage may be decreased. However, this is only applicable during Large and Medium Break LOCA situations. LPSI is not required to mitigate a smaller break accident. Therefore, there is no benefit to risk from this COA for smaller break LOCAs, or transients requiring feed and bleed from the perspective of the RWST drain-down time or debris transport. The addition of procedure steps may decrease the time available for the operator to perform other manual actions, which may provide a slight negative risk impact. Therefore, overall this COA is considered to be risk beneficial.

3.4 Human Performance Evaluation

During a LOCA following RAS, it is a familiar and relatively simple operator task to secure LPSI pumps after automatic actuation. To secure one pump sooner (adding the potential need for restart) adds some delay for downstream EPG steps (nominally 1 minute per manipulation, per ANSI/ANS-58.8). Possibly mitigating these delays is the fact that securing the redundant LPSI pump prior to RAS may postpone RAS and slow the course of the event in more severe LOCAs.

Following ECCS actuation, the benefit of this COA is maximized if it is performed before LPSI shutoff head is reached; benefits decline beyond this point. The probability of human error on any task is assumed raised by stress and by more severe or infrequent accidents (e.g., LBLOCA). Also, the need to detect failure of the running LPSI pump and then to restart the standby pump adds some operator burden and opportunity for human error. Added human error risks here are somewhat mitigated by running redundant HPSI pumps prior to RAS and by normal performance of Safety Function Status Checks. Plant-specific risk analysis should confirm that no unacceptable failure modes are introduced by this COA.

In summary, assuming that at least one HPSI pump runs continuously after LOCA and prior to RAS, then from an human factors perspective, changes to the timing, strategy, and criteria for securing and restarting LPSI pumps are reasonable, since:

- the elements of the task are relatively simple and already familiar,

- compensating factors may exist for added demands and possible errors (e.g., failure to restart the secured LPSI pump following loss of opposite/running ECCS pump train.)

4.0 CONCLUSIONS/RECOMMENDATIONS

Preliminary indications show stopping one LPSI pump before recirculation may result in core damage and therefore is not be risk beneficial. However, each plant must consider the advantages and disadvantages as they apply to their plant specific design and incorporate interim compensatory measures that are risk beneficial with respect to containment sump blockage.

A5 – Candidate Operator Action 5
Refill of Refueling Water Storage Tank

1.0 INTRODUCTION

NRC Bulletin 2003-01 requires that the utilities evaluate and implement compensatory measures to reduce the potential risk due to post-accident debris blockage as evaluations to determine compliance proceed. The bulletin directed utilities to consider a range of possible interim compensatory measures. Utilities may elect to implement those compensatory actions they deem appropriate, based upon the specific conditions associated with their plants. One possible interim compensatory measure included in the bulletin was, "Ensure that alternative water sources are available to refill the refueling water storage tank (RWST) or otherwise provide inventory to inject into the reactor core and spray into the containment atmosphere." The purpose of this report is to evaluate the following set of proposed Westinghouse Emergency Response Guidelines (ERG)/Combustion Engineering Emergency Procedures Guidelines (EPG) changes to preemptively prepare to refill the RWST or lineup an alternate makeup source, bypassing the RWST in anticipation of possible sump blockage following the initiation of recirculation:

1. Make preparations and line up to refill the RWST.

2. Make preparations and line up to inject to the reactor coolant system (RCS) or containment sump from an alternate source (bypassing RWST).

3. Initiate RWST refill after initiating sump recirculation/recirculation actuation signal (RAS).

4. Initiate RWST refill before completely transferring the design volume to the containment sump.

For those proposals that are found to be acceptable, Westinghouse will develop generic strategies along with the technical bases and implementation guidance. The utilities may use this information to implement the change in their Emergency Operating Procedures (EOPs) as they deem appropriate, based upon the specific conditions associated with their plants.

Combustion Engineering (CE) Designed Plants

Refilling the RWST post loss-of-coolant accident (LOCA) is not a design requirement for CE plants. However, typically it is a significant operator action in the Probabilistic Risk Assessment (PRA) to prevent core damage. This is primarily for interfacing system LOCA (LOCA outside Containment) and steam generator tube ruptures where RCS inventory losses are outside containment and there is no sump level to support sump recirculation. The EPGs currently contain instructions to prepare to refill the RWST if the LOCA is determined to be out side of containment, but not for a loss of recirculation.

The EPGs typically do not address specific beyond design basis events. However, the safety function based structure of the EPGs does provide the necessary general guidance to respond to and mitigate beyond design base events. The EPGs, in coordination with the Severe Accident Management Guidelines (SAMGs) provide operator guidance for recovering all safety functions and to support long-term accident recovery.

Westinghouse-Designed Plants

Similarly, Westinghouse plants do not have refilling the RWST post-LOCA as a design requirement. However, the ERGs address loss of emergency coolant recirculation in ECA-1.1. Although this guideline addresses loss of recirculation capability due to valve or pump failure explicitly, many parts of it apply equally to loss of suction due to sump blockage. One step of this guideline (HP Step 8, LP Step 6) instructs the operators to, “Add Makeup to RWST as Necessary: [Enter plant-specific means].” A subsequent step (HP Step 29, LP Step 28) instructs the operators to, “Try to Add Makeup to RCS from Alternate Sources: [Enter plant-specific means].” The background document description of this step specifies that, in case of a conflict, supplying water to the RCS has precedence over supplying water to the RWST.

2.0 QUALITATIVE EVALUATIONS

2.1 Make Preparations and Line Up To Refill the RWST

The available sources for refilling the RWST, priority and associated line up are plant specific. The possible sources of borated water include:

- Normal make up water via plant specific chemical addition system
- Reprocessed reactor coolant via plant specific liquid waste processing and recovery system
- Spent Fuel Pool
- Adjacent unit RWST
- Other available sources

The prerequisites will also be plant specific. Detailed plant specific guidance should be preplanned and available in an appropriate plant procedure or guideline. Prerequisites may include such things as getting support from other organizations (Chemistry, Maintenance, Health Physics, Security etc.), sampling, removing flanges or installing other mechanical modifications, staging temporary pumps and hoses, staging and mixing solutions of borated water, flushing lines, valve line ups, etc.

Including this guidance in the EPGs/ERGs ensures that starting the prerequisites and line up for refill will occur as soon as circumstances allow and resources are available because accomplishing this may take significant time.

For the Westinghouse plants, normal RWST refill is a relatively simple evolution and preparations for refill do not require much time. If normal refill means are not available when refill is desired, then alternate alignments can be performed as needed after time critical operator actions are completed. Actions to begin the actual refill would not occur until after transfer to recirculation, therefore, these actions would be located toward the end of ES-1.3, TRANSFER TO COLD LEG RECIRCULATION, if included in the ERG set.

For the CE plants, if this change is adopted for the EPGs, it would likely be located as early as possible in the LOCA Optimal Recovery Guidelines (ORG) (after step 21, low pressure safety injection (LPSI) Restart Criteria) and in a similar location in the Functional Recovery Guidelines (FRG).

2.2 Make Preparations and Line Up to Inject to the RCS or Containment Sump from an Alternate Source (Bypassing RWST)

The sources, priority and associated line up are plant specific and similar to those that operators could use to refill the RWST. The possible sources of borated water include:

- Normal make up water via plant specific chemical addition system
- Reprocessed reactor coolant via plant specific liquid waste processing and recovery system
- Spent Fuel Pool
- Adjacent unit RWST
- Other available sources

The prerequisites will be plant specific. Detailed guidance must be preplanned and available in an appropriate plant procedure or guideline. Prerequisites will include such things as getting support from other organizations (Chemistry, Maintenance, Health Physics, Security etc.), sampling, removing flanges or installing other mechanical modifications, staging temporary pumps and hoses, staging and mixing solutions of borated water, flushing lines, valve line ups, etc.

Including this guidance in the EPGs/ERGs ensures starting the prerequisites and line up as soon as circumstances allow and resources are available, because accomplishing this may take significant time.

For the Westinghouse plants, normal RWST refill is a relatively simple evolution and preparations for refill do not require much time. If normal refill means are not available when refill is desired, then alternate alignments can be performed as needed after time critical operator actions are completed. Actions to begin the actual refill would not occur until after transfer to recirculation, therefore, these actions would be located toward the end of ES-1.3, TRANSFER TO COLD LEG RECIRCULATION, if included in the ERG set.

For the CE plants, if this change is adopted for the EPGs, it would likely be located as early as possible in the LOCA ORG (after step 21, LPSI Restart Criteria) and in a similar location in the FRG.

2.3 Initiate RWST Refill After Initiating Sump Recirculation/RAS

This option addresses initiating RWST refill after the design RWST volume is completely transferred to the containment sump. It is assumed that a source of borated water will be used for refill. For the Westinghouse reference plant used to develop the ERGs, the inventory (level) required to support operation of the SI system (low-head SI pumps) on recirculation will be available in the recirculation sump when RWST level reaches the “low” level value. This same is true for the Combustion Engineering plants with the exception that the high-head SI pumps are operated on recirculation and the low-head pumps are secured. Thus, the “design volume” or “minimum recirculation volume” has been transferred into the containment sump when RWST switchover is initiated.

Note that individual plants have different methods for performing switchover to recirculation. Switchover may occur automatically, manually, or a combination of both (semi-automatically). Switchover may occur in stages, where each stage actuates a group of valves and/or pumps. The impact of RWST refill is affected by the timing of the actual start of refill; for example, it may occur very early in the transient when a LOCA is diagnosed, or after reaching a pre-recirculation alignment setpoint (if used), or when the first stage of a multi-stage recirculation alignment starts.

2.3.1 Advantages

Post recirculation/RAS refill does not impact a design requirement that [plant specific number] gallons of borated water be transferred to the containment sump prior to recirculation actuation/RAS. ECCS pump NPSH requirements and containment sump chemistry requirements are thus assured.

This approach will not add additional operator burden prior to recirculation/RAS.

This approach will not increase the probability of a Boron dilution event associated with refill before the initial volume is transferred to the containment sump, which may increase rather than reduce overall risk.

2.3.2 Disadvantages/Potential Issues

The RWST may not be refilled by the time it is needed should sump blockage occur soon after initiating recirculation.

Regardless of the time RWST refill is initiated, the injection of greater than one RWST volume into containment may exceed the containment flood plane, with the potential for submergence of equipment and instrumentation inside containment that may be required for the recovery.

Some dilution of the long-term recirculation sump water supply can occur if the boron concentration of the RWST makeup water is less than the original RWST boron concentration.

Some plants may have an issue with leakage by the RWST outlet valves after switchover to recirculation. If the RWST outlet valves leak by, the RWST inventory may be discharged to the RCS as level is raised during the refill. This would improperly raise sump level before it was needed or wanted. Utilities with this problem may have to implement a compensatory strategy such as maintaining a slightly higher containment pressure to prevent leakage and/or repair the RWST outlet valves prior to implementing this COA. The generic recommendation to initiate RWST refill after switchover assumes that the RWST is effectively isolated during the refill process.

2.4 Initiate RWST Refill Before Initiating Sump Recirculation/RAS

This option addresses initiating RWST refill before the design RWST volume is completely transferred to the containment sump. It is assumed that a source of borated water will be used.

2.4.1 Advantages

Initiating RWST refill before recirculation switchover occurs will extend the time to recirculation switchover, which is a key goal of the interim compensatory measures to be considered. The benefit of RWST refill is best realized by having refill in progress when switchover occurs, especially if refill rate is relatively low (for example, 100 gpm). This provides the maximum extension of time the RWST is available as a viable suction source.

2.4.2 Disadvantages/Potential Issues

Starting refill prior to switchover may interfere with more important operator actions. Normal makeup is a simple evolution. More drastic measures, outside our normal methods, may take more time and could impact the important operator actions that need to be performed, in a timely manner, for the existing design basis event.

It is difficult to assure complete mixing in the RWST if a different concentration of borated water is used (see Chemistry Assessment, subsection 3.1.1).

Regardless of the time RWST refill is initiated, the injection of greater than one RWST inventory into containment may exceed containment flooding limit, with the potential for submergence of equipment and instrumentation inside containment that may be required for the recovery.

Some dilution of the long-term recirculation sump water supply can occur if the boron concentration of the RWST makeup water is less than the original RWST boron concentration.

Some plants may have an issue with leakage by the RWST outlet valves after switchover to recirculation. If the RWST outlet valves leak by, the RWST inventory may be discharged to the RCS as level is raised during the refill. This would improperly raise sump level before it was needed or wanted. Utilities with this problem may have to implement a compensatory strategy such as maintaining a slightly higher containment pressure to prevent leakage and/or repair the RWST outlet valves prior to implementing this COA. The generic recommendation to initiate RWST refill after switchover assumes that the RWST is effectively isolated during the refill process.

3.0 ANALYSES AND EVALUATIONS

3.1 Chemistry Assessment

This assessment of RCS/containment makeup options considers both borated and unborated water sources. The candidate operator action (COA) addresses RWST refill in EPG/ERG space using borated water only. The use of unborated water for makeup is limited to extreme accident conditions. It should only be done when directed by plant emergency management organization using guidance provided in the SAMGs. The following information applies primarily to unborated water makeup sources.

3.1.1 Adding Water to the RWST from Alternate Source (Option 1)

- Can be done prior to or after recirculation initiation.
- Can be done with borated water or un-borated water.

  - Un-borated water has the advantage of not needing to be chemically neutralized with trisodium phosphate (TSP) or other means.

  - If un-borated water is used, then incomplete mixing with water already in the RWST is an issue.

- Un-borated water is less dense than borated water, so the un-borated water will tend to float on the borated water. If the RWST is then pumped directly into the reactor vessel, this would create the potential for a reactivity event.

- Thorough, and time consuming, agitation or recirculation of the RWST would be required to assure complete mixing.

– Water can be borated with borax (sodium tetraborate decahydrate, $Na_2B_4O_7 \cdot 10H_2O$) instead of boric acid. The pH would then be above 7, and complete mixing with water already in the RWST would not be necessary because the boration would remove the potential for a reactivity event.

- Minimum boron concentration to control reactivity needs to be calculated on plant-specific basis.

- Method must be devised to disburse the borax in the water and to assure that the minimum boron concentration is met.

– Water can be borated with boric acid, but it will eventually have to be neutralized by TSP or some other means to maintain sump pH.

3.1.2 Add Water from an Alternate Source Directly into the Containment Sump (Option 2)

- Could be used to increase suction head for recirculation pumps.
- Can be done with borated water or un-borated water.

– Minimum sump boron concentration to control reactivity needs to be calculated on plant-specific basis,

– Un-borated water has the advantage of not needing to be chemically neutralized with TSP or other means,

– Water could be borated with borax, as in Option 1,

– If boric acid is used, it will eventually have to be neutralized by TSP or some other means.

3.1.3 Add Water from an Alternate Source Directly into the RCS (via cold leg or hot leg injection paths), Bypassing the RWST (Option 3)

- Borated water must be used to control reactivity.

– Minimum boron concentration to control reactivity needs to be calculated on plant-specific basis.

– Water could be borated with borax, as in Option 1.

– If boric acid is used, it will eventually have to be neutralized by TSP or some other means.

– Method must be devised to disburse the borax or boric acid in the water and to assure that the minimum boron concentration is met.

3.2 Summary of Analyses Performed

None

3.3 Risk Assessment

If containment flooding to the RCS loop level is not done, then RWST refill is only a temporary measure and not a successful end state.

RWST refill or alternate refill bypassing the RWST will provide an alternate success path for large and medium LOCAs only if SAMG guidance is provided to permit filling containment above the elevation of the RCS loops. With the loops covered to at least the mid-plane and normal RHR initiated, and then any make-up to the RCS can be via reverse break flow. Once adequate level is established in the RCS, normal RHR can be used for decay heat removal.

For small break LOCAs, this success path is more difficult to achieve since the RCS has to be significantly depressurized to permit reverse flow and there may be a short term problem with counter-current flow through the small break area if a secondary side heat sink is not available to establish and maintain subcooling in the RCS. Thus this COA is likely to provide little risk benefit for Small LOCAs/Transients. However, PRA currently credits RWST refill during Steam Generator Tube Ruptures, and Inter-system LOCAs based on current ERG/EPG guidance. Current PRAs show that this is a large risk benefit for these events. The current benefit could be increased if containment flooding guidelines were better developed.

This COA is expected to provide a significant positive risk impact.

3.4 Human Performance Evaluation

The following statement should be considered in light of plant-specific information and overall impact on plant risk. Analysis of operator response times and error probabilities requires more detailed information than is presently available. Further evaluation is needed to confirm the conclusions below, and also to determine that the net effect of other COAs on plant risk is favorable, including the effect of revised manual actions.

This COA suggests a wide array of plant-specific options and combinatorial possibilities. As a result, one general HF assessment can not be provided. Pending more specific guidance as to individual strategies, the following comments are offered.

While the benefits of this action decline with time, prerequisites for action may be time-consuming and require coordinated support. Given this conflict, the level and type of this support should be assessed, and preparations should ensure that additional staff will be available when needed.

The technical implications of using different sources vary widely. Use of an adjacent unit RWST, for example, increases risk for the adjacent (presumably shutdown) unit.

Certain strategies may increase the probability of a Boron dilution event, which may increase rather than reduce overall risk.

Complex or ad hoc realignments during accident conditions may be error prone, particularly as stress and burden increase. The impact of each possible failure path should be evaluated.

4.0 CONCLUSIONS/RECOMMENDATIONS

Each plant must consider the advantages and disadvantages as they apply to their plant specific design and incorporate this action if it is determined to be risk beneficial with respect to containment sump blockage.

Implementation of ERG/EPG changes to initiate early action to line up to refill the RWST or bypass it to support using an alternate makeup source, if needed, are generally recommended. Actual refill is not generally recommended until after switchover has occurred.

A6 – Candidate Operator Action 6
Inject More Than One RWST Volume From a Refilled RWST or by Bypassing the RWST

1.0 INTRODUCTION

NRC Bulletin 2003-01 requires that the utilities evaluate and implement compensatory measures to reduce the potential risk due to post-accident debris blockage as evaluations to determine compliance proceed. The bulletin directed utilities to consider a range of possible interim compensatory measures. Utilities may elect to implement those compensatory actions they deem appropriate, based upon the specific conditions associated with their plants. This candidate operator action (COA) addresses the NRC Bulletin 2003-1 recommended interim compensatory measure, "Ensure that alternative water sources are available to refill the RWST or otherwise provide inventory to inject into the reactor core and spray into the containment atmosphere."

This COA evaluates possible operator actions to re-initiate RCS injection, i.e., restore inventory control, if screen blockage causes loss of sump recirculation capability. Proposed actions provide water for re-injection from a refilled refueling water storage tank (RWST) or from an alternate source, bypassing the RWST. The evaluation considers the advantages, benefits, limitations, issues, cautions and procedural questions associated with this action.

Note that COA 5 evaluated the preparations for and initiation of RWST refill, and the preparations for line up to inject to the RCS or containment sump from an alternate source (bypassing RWST).

The Combustion Engineering (CE) plant design provides for transferring one RWST volume to the containment sump prior to the initiation of the sump recirculation actuation signal (RAS). There is one RAS setpoint that automatically opens containment sump isolation valves. The operator then closes the RWST outlet valves and secures the low-head SI pumps.

Westinghouse plants are designed for the transfer of one RWST volume to the containment sump via safety injection flow (through the reactor coolant system) and containment spray. Most of the RWST volume is transferred to the containment sump prior to initiation of sump recirculation switchover. For the Westinghouse reference plant used to develop the Emergency Response Guidelines (ERGs), recirculation switchover occurs in two distinct stages – Safety Injection (SI) system switchover on "low" RWST level, and containment spray system switchover on "low-low" RWST level. The containment spray pumps will continue to transfer RWST inventory to containment after recirculation switchover is initiated until the RWST is essentially empty.

The inventory (level) required to support operation of the Emergency Core Cooling System (ECCS) pumps on recirculation will be available in the recirculation sump when RWST level reaches the "low" level value (RAS setpoint). This amount of RWST inventory has been analyzed as sufficient to provide adequate net positive suction head (NPSH) for the ECCS pumps, to provide adequate shutdown margin via sump boron concentration, and support Long Term Cooling via Cold and Hot Leg Injection. The transfer of greater than one RWST volume to containment is outside the design bases of the plant, and may exceed the containment flooding limit with the potential for submergence of equipment and instrumentation inside containment that may be required for the recovery. Thus, the use of an alternate injection source beyond the RWST is considered a last resort means to cool the core.

The overall objective of reinitiating reactor coolant system (RCS) injection is to regain RCS inventory control, to prevent loss of or regain core heat removal. With RCS inventory control lost and while attempting to restore it, it is very important to maintain RCS heat removal via the steam generators to support single or two-phase natural circulation (i.e., core heat removal) and to maintain containment cooling.

The results of this evaluation will be used to determine if and when alternate injection should be included in the Emergency Procedures Guidelines (EPG)/ERGs as a response to recirculation sump blockage. If this action is appropriate, it will be included in the EPG/ERG technical bases to assist utilities in implementing the change in their Emergency Operating Procedures (EOPs) as they deem appropriate. For the CE fleet, it will also consider the possibility or relying on the Severe Accident Management Guidelines (SAMGs) to provide this guidance.

2.0 QUALITATIVE EVALUATIONS

There are significant differences between ERGs and the EPG philosophies when it comes to the level of detail included to address beyond design base events in the generic guidelines.

CE Fleet

For the CE fleet, guidance for injecting alternate water sources (non-RWST) into the reactor core in the event that safety injection flow to the RCS is not adequate is addressed in the EPG Functional Recovery Guideline (FRG). The details as to how to accomplish this are addressed on a plant-specific basis. Supporting guidance is included in the SAMGs. The objective of SAMG Candidate High Level Action (CHLA-1), INJECT TO THE RCS, is to cool the reactor core materials and thereby regain the core/RCS heat removal safety function. The ultimate goal is to restore water inventory to RCS in order to provide the most effective medium to cool the reactor core. In addition SAMG CHLA-10, FLOOD REACTOR CAVITY, provides additional guidance to provide alternate sources of water to the flood the reactor cavity to regain core heat removal and prevent core damage.

Since the RWST may not be refilled and available in the early stages of a sump blockage event, bypassing the RWST using an existing plant specific source may be the preferred success path. Success of the RWST refill method depends on preserving the availability of the safety injection or charging pumps by securing them prior to damage following screen blockage and subsequent loss of suction (refer to COA 8, Provide Guidance on Symptoms And Identification of Containment Sump Blockage and COA 9, Develop Contingency Actions in Response to: Containment Sump Blockage, Loss of Suction, and Cavitation). Success of the RWST bypass method depends on aligning an alternate source as soon as possible such that it is available when needed. In both cases, it is assumed that electrical power to the pumps and valves is available and that the appropriate lineup can be performed.

If Core Heat Removal Safety Function Status Check (SFSC) (Representative CET temperature is greater than superheated), the operator would continue using the FRG Heat Removal Continuing Actions to regain control of the safety function. If core cooling cannot be restored the operator continues to implement the EPGs as best he can and looks to the technical support center (TSC) for additional guidance using the SAMGs to limit the extent of core damage. These guidelines consider any viable source of RCS injection to restore core cooling. The suction sources, pumps and necessary alignments identified by individual plants to support the actions of these guidelines should contribute to the success of the RWST bypass method. This information can be adapted for recovery from a sump blockage event.

Westinghouse Fleet

For the Westinghouse fleet, alternate RCS injection, similar to what is proposed here, is addressed in the ERGs (ECA-1.1, FR-C.1 and FR-C.2) and in the SAMGs (SAG-3 and SAG-4). Guidance for injecting alternate water sources (non-RWST) into the reactor core is included in ECA-1.1 under the high level operator action “Try to add makeup to RCS from alternate source.” This action is intended to provide cooling water to the RCS when the RWST is empty and no recirculation capability exists. FR-C.1 and FR-C.2 provide a contingency action “Try to establish flow from any other form of RCS injection available” (note that this wording reflects the changes resulting from DW-98-006). This action is intended to provide cooling water to the RCS using any source of makeup flow available, when core cooling is lost and SI flow is not verified. The SAMGs provide high level guidance for identifying and aligning equipment for RCS and containment injection in SAG-3, INJECT INTO THE RCS and SAG-4, INJECT INTO CONTAINMENT. Note that each of these guidelines direct recovery from events beyond the design basis.

In the event that sump recirculation capability has been lost and core cooling is still maintained, ECA-1.1 provides the appropriate actions to restore RCS inventory control through RWST refill or alternate RCS injection. These actions are intended to maintain core cooling by injection into the RCS until recirculation capability is restored. Since the RWST may not be refilled and available in the early stages of a sump blockage event, bypassing the RWST using an existing plant specific source may be the preferred success path. Success of the RWST refill method depends on preserving the availability of the safety injection or charging pumps by securing them prior to damage following screen blockage and subsequent loss of suction (refer to COA 8 and 9). Success of the RWST bypass method depends on aligning an alternate source as soon as possible such that it is available when needed. In both cases, it is assumed that electrical power to the pumps and valves is available and that the appropriate lineup can be performed.

If core cooling becomes degraded (core exit temperatures greater than 700°F) or inadequate (core exit temperatures greater than 1200°F), FR-C.2 or FR-C.1, respectively, would be used for recovery. If core cooling cannot be restored through the actions of FR-C.1, the operator will transition to the SAMGs to limit the extent of core damage. These guidelines consider any viable source of RCS injection to restore core cooling. The suction sources, pumps and necessary alignments identified by individual plants to support the actions of these guidelines should contribute to the success of the RWST bypass method. This information can be adapted for recovery from a sump blockage event.

The RWST may not be refilled and available in the early stages of the event. Therefore bypassing the RWST using an existing plant specific source may be the preferred success path. Success of using the RWST method depends on preserving the availability of the safety injection or charging pumps by securing them prior to damage following screen blockage and subsequent loss of suction (COA 8, Provide Guidance on Symptoms And Identification of Containment Sump Blockage and COA 9, Develop Contingency Actions in Response to: Containment Sump Blockage, Loss of Suction, and Cavitation, include discussion of these actions). Success of the bypass method depends on lining up an alternate source as soon as possible such that it is available when needed.

2.1 Injection from a Refilled RWST

A refilled RWST could be injected into the RCS by any available charging pump via the normal charging line (or alternate charging line, if applicable), or a charging/SI pump, high-head SI (HHSI) pump or low-head SI (LHSI)/RHR pump using the cold/hot leg injection lines. Consider the following:

2.1.1 Equipment Required

- LPSI/RHR pump
- Charging/SI pump
- HPSI pump
- Charging pump (non-safeguards)
- Electrical power to pump and motor operated valves
- Appropriate system alignment

2.1.2 Plant Initial Conditions

1. Unisolable loss-of-coolant accident (LOCA) in progress

2. RWST level lowered to recirculation actuation setpoint and subsequently partially or fully refilled per COA 5, Refilling of Refueling Water Storage Tank

3. Beyond-design-basis blockage of containment sump screens

4. Sump Recirculation was in progress, but is now secured due to inadequate suction

5. Containment Spray System (CSS), HPSI, LPSI/Residual Heat Removal (RHR) and charging pumps secured

6. RCS pressure less than injection pump shutoff head

7. RCS heat removal via steam generators

8. Containment heat removal via all available normal and emergency fan coolers

2.1.3 Likely Sequence of Actions

1. Verify all ECCS pumps aligned to sump are stopped.
2. Close suction from containment sump.
3. Align LPSI/low-pressure SI/RHR pump to RWST and open RWST outlet.
4. Vent LPSI/RHR pump, if radiological conditions permit.
5. Verify RCS pressure less that LPSI/RHR pump shutoff head.
6. Start LPSIR pump.
7. Throttle open the LPSI/RHR pump flow control valve to full open position.

8. Injection flow may be throttled based on the following criteria:

   a. Avoiding pump runout, cavitation or vortexing.
   b. Core exit thermocouple (CET) temperature not superheated.
   c. Reactor vessel level measurement system (RVLMS) indicates core is covered.

2.1.4 Expected Plant Response

- Increasing reactor vessel water level
- Decreasing core exit temperature
- Possible RCS pressure spike
- Possible increasing RCS and/or containment hydrogen concentration
- Possible increasing containment pressure

Ideally, RCS injection flow will maintain water level above the core and preclude excessive core temperatures. Initiating injection flow to an overheated core will cause rapid steam production and an RCS pressure spike, which may cause creep rupture failure of the RCS (including steam generator tubes). Creep rupture failure is caused by excessive metal temperature combined with excessive pressure. Injection flow should be reintroduced gradually to minimize the RCS pressure spike.

2.1.5 Final Plant Conditions

- Reactor vessel water level greater than the top of active fuel or higher
- Core exit temperature not superheated
- RCS pressure stable less than pump discharge pressure
- Containment hydrogen concentration being monitored
- Containment pressure and temperature controlled and stable
- RCS heat removal via steam generators effective

2.2 Injection from Alternate Source (Bypassing RWST)

The sources, priority and associated line up using an alternate source (Bypassing the RWST) are plant specific and similar to those that could be used to refill the RWST. Possible sources include:

- Spent Fuel Pool
- Adjacent unit RWST
- Condensate
- Fire service
- Other available sources

2.2.1 Equipment Required (plant specific)

- Pump (or series of pumps)
- Temporary piping/hoses
- Electrical power to pump and motor operated valves
- Appropriate system alignment

2.2.2 Plant Initial Conditions

1. Unisolable LOCA in progress

2. RWST level lowered to recirculation actuation setpoint and RWST bypass line up initiated per COA 5

3. Beyond-design-basis blockage of containment sump screens

4. Sump Recirculation was in progress, but is now secured due to inadequate suction

5. CSS, HPSI, LPSI/RHR and charging/SI pumps secured

6. RCS pressure less than injection pump shutoff head

7. RCS heat removal via steam generators

8. Containment heat removal via all available normal and emergency fan coolers

2.2.3 Likely Sequence of Actions

1. Verify all ECCS pumps aligned to sump - STOPPED.
2. Close suction from containment sump.
3. Align injection pump from source to RCS leaving pump discharge closed.
4. Fill and vent system, if radiological conditions permit
5. Verify RCS pressure less than pump shutoff head.
6. Start injection pump.
7. Throttle open pump discharge valve to full open position.
8. Injection flow may be throttled based on the following criteria:

    a. Avoiding pump runout, cavitation and vortexing.
    b. CET temperature not superheated.
    c. RVLMS indicates core is covered.

2.2.4 Expected Plant Response

- Increasing reactor vessel water level
- Decreasing core exit temperature
- Possible RCS pressure spike
- Possible increasing RCS and/or containment hydrogen concentration
- Possible increasing containment pressure

Ideally, RCS injection flow will maintain water level above the core and preclude excessive core temperatures. Initiating injection flow to an overheated core will cause rapid steam production and an RCS pressure spike, which may cause creep rupture failure of the RCS (including steam generator tubes).

Creep rupture failure is caused by excessive metal temperature combined with excessive pressure. Injection flow should be reintroduced gradually to minimize the RCS pressure spike.

2.2.5 Final Plant Conditions

- Reactor vessel water level greater that the top of active fuel or higher
- Core exit temperature not superheated
- RCS pressure stable less than pump discharge pressure
- Containment hydrogen concentration being monitored
- Containment pressure and temperature controlled and stable
- RCS heat removal via steam generators effective

2.3 Advantages

1. This action may mitigate the consequences of a loss of safety injection. In the event of a loss of recirculation capability (sump blockage), this action provides alternate sources of borated water to the RCS to restore inventory control and a medium that can transfer heat from the core which consequently helps maintain existing core geometry.

2. Possible sources of water larger than one RWST volume potentially provide unlimited makeup.

3. Actions to refill the RWST and inject into the RCS/containment from alternate sources are consistent with existing ERG/SAMG guidance.

2.4 Disadvantages/Potential Issues and Cautions

1. This is a near term fix unless there is sufficient water available to ultimately flood to above the hot leg nozzles, if necessary. Long term actions required for when makeup water source is depleted.

2. Westinghouse best-estimate analyses indicate that, with no injection following recirculation actuation, the inventory boils off at decay heat levels. The amount of inventory available above the top of the active fuel depends on the location of the break and, to a lesser extent, the size of the break. In the most limiting case, there will be approximately 10 minutes to uncovery and another 10 to 20 minutes until core overheating begins (See Section 3.2).

3. RCS pressurization analyses performed in support of the SAMGs should be reviewed prior to RCS injection after any interruption of flow, due to the large RCS pressure spike that may be generated when water is added to a potentially overheated core. If the estimated pressure spike exceeds [3000 psia], depressurization of the RCS should be considered prior to RCS injection. Also, the measured RCS pressure spike provides input to the RCS/SG tube creep rupture failure analysis. After recovery of reactor vessel water level, maintaining the water level above the top of the hot legs (via RVLIS) eliminates creep failure considerations for reactor vessel, hot legs, and surge line. Maintaining adequate steam generator wide range level eliminates creep rupture failure considerations for the steam generator tubes.

4. A large rate of water injection may not result in removing more heat from the core. Depending on the existing core characteristics if core damage has occurred (e.g., compaction, porosity, etc.), the amount of heat that can be removed from the damaged core may be limited. Hence, large rates of water injection may be wasteful and could result in not being able to control the course of the accident at some point in the future (due to lack of a water source). Although it is generally not recommended that safety injection be throttled until the inventory is restored to a condition where flow through the vessel/core is sufficient to provide flushing flow, the rate of water injection should be monitored to ensure that it is being effectively used.

5. If core damage occurs, hydrogen may be generated as a result of the zirconium-water reaction. Accumulation of hydrogen in the steam generator tubes may reduce or eliminate natural circulation. For a LOCA inside containment, the hydrogen gas concentrations in containment may increase.

6. Injection of unborated water could lead to a return to criticality. The potential increases with increasing flow rate. Monitor the ex-core detectors for power spikes. If fission power spikes occur, decrease the rate of safety injection to eliminate power spikes and take actions to restore borated water to the RCS.

7. The solubility limit of boric acid should be considered to avoid boron precipitation in the core. Safety injection flow in excess of the core boil-off flow rate (core flushing flow) prevents boron precipitation in the core, if the inventory has been restored to a level where water is flowing out of the reactor vessel. If possible, use a simultaneous hot leg/cold leg injection strategy.

8. Cool ECCS water may cause thermal shock to fuel pins and result in more fuel damage. It is possible that a slower rate of injection may be better.

9. The accumulation of water in containment basement may:

   a. Flood and thereby reduce or eliminate containment heat removal equipment.
   b. Flood and thereby reduce or eliminate containment venting capability.
   c. Submerge equipment and/or instrumentation desired to mitigate or monitor the event.

10. Use of external water sources (other than the RWST and accumulators) may reduce pH of the containment sump/recirculated water which could cause increased corrosion of piping systems and materials in containment. Adding a pH buffer, via the charging pumps, to the containment sump should be considered in order to maintain long term pH control. This may also be required for those plants that use hydrazine for iodine removal from the containment atmosphere.

11. Higher level of flooding in the containment may render needed instrumentation inoperable.

12. The containment water level instrumentation may not have the required range to monitor the rise associated with the volume of additional water.

13. Containment sump level instrumentation should be evaluated and a graph of containment water level versus equipment/instrumentation elevations inside containment should be made for use in

the TSC. This may be available from the plant specific SAMGs. If the level instrumentation is not adequate, then use of SI suction pressure (if available) should be evaluated for use in obtaining the same information.

14. If injection pump suction is transferred from the recirculation sump to the RWST, fluid in the piping systems may contaminate other sections of the plant.

3.0 REFERENCE PLANT ANALYSES AND OTHER EVALUATIONS

3.1 Chemistry Assessment

This assessment of RCS/containment makeup options considers both borated and unborated water sources. The COA addresses RWST refill in EPG/ERG space using borated water only. The use of unborated water for makeup is limited to extreme accident conditions. It should only be done when directed by plant emergency management organization using guidance provided in the SAMGs. The following information applies primarily to unborated water makeup sources.

3.1.1 Adding Water to the RWST from Alternate Source (Option 1)

- Can be done prior to or after recirculation initiation.
- Can be done with borated water or un-borated water.
  - Un-borated water has the advantage of not needing to be chemically neutralized with TSP or other means.
  - If un-borated water is used, then incomplete mixing with water already in the RWST is an issue.
    - Un-borated water is less dense than borated water, so the un-borated water will tend to float on the borated water. If the RWST is then pumped directly into the reactor vessel, this would create the potential for a reactivity event.
    - Thorough, and time consuming, agitation or recirculation of the RWST would be required to assure complete mixing.
  - Water can be borated with borax (sodium tetraborate decahydrate, $Na_2B_4O_7 \cdot 10H_2O$) instead of boric acid. The pH would then be above 7, and complete mixing with water already in the RWST would not be necessary because the boration would remove the potential for a reactivity event.
    - Minimum boron concentration to control reactivity needs to be calculated on plant-specific basis.
    - Method must be devised to disburse the borax in the water and to assure that the minimum boron concentration is met.

- Water can be borated with boric acid, but it will eventually have to be neutralized by trisodium phosphate (TSP) or some other means to maintain sump pH.

3.1.2 Add Water from an Alternate Source Directly into the Containment Sump (Option 2)

- Could be used to increase suction head for recirculation pumps.
- Can be done with borated water or un-borated water.

  - Minimum sump boron concentration to control reactivity needs to be calculated on plant-specific basis.

  - Un-borated water has the advantage of not needing to be chemically neutralized with TSP or other means.

  - Water could be borated with borax, as in Option 1.

  - If boric acid is used, it will eventually have to be neutralized by TSP or some other means.

3.1.3 Add Water from an Alternate Source Directly into the RCS (via cold leg or hot leg injection paths), bypassing the RWST (Option 3)

- Borated water must be used to control reactivity.

  - Minimum boron concentration to control reactivity needs to be calculated on plant-specific basis.

  - Water could be borated with borax, as in Option 1.

  - If boric acid is used, it will eventually have to be neutralized by TSP or some other means.

  - Method must be devised to disburse the borax or boric acid in the water and to assure that the minimum boron concentration is met.

3.2 Summary of Analyses Performed

When considering taking action to line up for RWST refill or to use an alternate source to inject into the RCS in the event of a loss of recirculation (sump blockage, it is useful to have an idea of how much time to the operators have to respond before core uncovery and subsequently overheating the core. If after successfully switching to a sump recirculation line up, it suddenly fails, there is a credible accident sequence with loss of core cooling.

Using the information in the Vogtle PRA Success Criteria Notebook – a Westinghouse 4-loop 1100 MWe plant that is typical of the Westinghouse fleet:

- For the large break LOCA, switchover is started at about 20 minutes and it takes 5 to 10 minutes to complete the transfer.

- Decay heat at 30 minutes is about 1.8%.
- The volume of water from mid-loop (estimated mixture level for LB LOCA) to the top of the core is about 775 ft^3 assuming a 40% void fraction (actual volume is 1290 ft^3).
- This yields 11.8 minutes to core uncovery – approximately 10 minutes for generic applications.
- The time from core uncovery to the beginning of core overheating (defined as 1200 degree F core exit thermocouple indication) for LBLOCA is 0.2 hours (12 minutes) based on MAAP3b analyses in the "Vogtle Source Term Notebook") – approximately 10 minutes also.

So for the LBLOCA with a recirculation failure, there is about 10 minutes between loss of RCS injection and the time of core uncovery and another 10 minutes to core overheating. For any other event, there is additional time due to:

- Decreased decay heat levels.
- Increased water volume for boil-off after injection is stopped. The LBLOCA assumed the mixture level was at mid-loop. For smaller LOCAs, there is additional water in the loops and in the vessel upper plenum.

From PRA success criteria analyses for other plants, there is not much difference in these times for 2-loop, 3-loop or 4-loop plants. These numbers are representative of the entire Westinghouse fleet.

Considering the scenario above, if recirculation capability is lost at the time when you switch the first train to recirculation, then according to the Vogtle Success Criteria Notebook, there is 18.1 minutes until the RWST is emptied (assuming 2 spray trains and 1 ECC train drawing from the RWST – the failed recirculation train was not switched back to injection). Adding the 11.8 minutes to boil-off the RCS inventory to core uncovery, there is close to 30 minutes for this case.

The most limiting case is when recirculation is not lost until the second train is lined up for recirculation. In this case, there is about 10 minutes to re-establish RCS injection before core uncovery and another 10 minutes until core overheating begins. In DBA space, core overheating can probably be used as the "success" criterion (i.e., 20 minutes to re-establish RCS make-up) since the 1200 degree core exit temperature is equivalently less than the Appendix K limit for peak clad temperature of 2200 degrees.

3.3 Risk Assessment

If containment flooding to the RCS loop level is not done, then RWST refill is only a temporary measure and not a successful end state.

RWST refill or alternate refill bypassing the RWST will provide an alternate success path for large and medium LOCAs only if SAMG guidance is provided to permit filling containment above the elevation of the RCS loops. With the loops covered to at least the mid-plane and normal RHR initiated, and then any make-up to the RCS can be via reverse break flow. Once adequate level is established in the RCS, normal RHR can be used for decay heat removal.

For small break LOCAs, this success path is more difficult to achieve since the RCS has to be significantly depressurized to permit reverse flow and there may be a short term problem with counter-current flow through the small break area if a secondary side heat sink is not available to establish and maintain subcooling in the RCS. Thus this COA is likely to provide little risk benefit for Small LOCAs/Transients. However, probabilistic risk assessment (PRA) currently credits RWST refill during Steam Generator Tube Ruptures, and Inter-system LOCAs based on current ERG/EPG guidance. Current PRAs show that this is a large risk benefit for these events. The current benefit could be increased if containment flooding guidelines were better developed.

This COA is expected to provide a significant positive risk impact.

3.4 Human Performance Evaluation

The following statement should be considered in light of plant-specific information and overall impact on plant risk. Analysis of operator response times and error probabilities requires more detailed information than is presently available. Further evaluation is needed to confirm the conclusions below, and also to determine that the net effect of other COAs on plant risk is favorable, including the effect of revised manual actions.

This COA suggests a wide array of plant-specific options and combinatorial possibilities. As a result, one general human factors assessment can not be provided. Pending more specific guidance as to individual strategies, the following comments are offered.

- While the benefits of this action decline with time, prerequisites for action may be time-consuming and require coordinated support. Given this conflict, the level and type of this support needed should be assessed, and preparations should ensure that additional staff will be available when needed.

- The technical implications of using different sources vary widely. Use of an adjacent unit RWST, for example, increases risk for the adjacent (presumably shutdown) unit.

- Certain strategies may increase the probability of a Boron dilution event, which may increase rather than reduce overall risk.

- Complex or ad hoc realignments during accident conditions may be error prone, particularly as stress and burden increase. The impact of each possible failure path should be evaluated.

4.0 CONCLUSIONS/RECOMMENDATIONS

Each plant must consider the advantages and disadvantages as they apply to their plant specific design and incorporate this action if it is determined to be risk beneficial with respect to containment sump blockage.

Incorporating new guidance or modifying existing ERG/EPG guidance to inject water into the RCS from a refilled RWST or from an alternate source bypassing the RWST will likely be addressed differently between the two sets of guidelines as was discussed above. This action would only be taken after aligning for recirculation and a subsequent loss of recirculation capability due to sump blockage. This is clearly a beyond design bases situation. Therefore, these actions must be coordinated by the TSC and in accordance with the SAMGs.

A7 – Candidate Operator Action 7
Provide More Aggressive Cooldown and Depressurization Following A Small Break LOCA

1.0 INTRODUCTION

NRC Bulletin 2003-01 requires that the utilities evaluate and implement compensatory measures to reduce the potential risk due to post-accident debris blockage as evaluations to determine compliance proceed. The bulletin requires consideration of a range of possible interim compensatory measures. Utilities may implement recommended compensatory actions they deem appropriate, based upon the specific conditions associated with their plants.

The purpose of this evaluation is to review the current guidance in the EPGs for cooldown and depressurization following a loss-of-coolant accident (LOCA) to determine if it is adequately implements the desired strategy. A preliminary review indicates that terms such as ‘controlled cooldown’, ‘aggressive cooldown’ and ‘rapid cooldown’ may not be adequately defined. Therefore, the optimal strategy may not be clear to the operator.

This evaluation applied only to the Combustion Engineering Emergency Procedure Guidelines (EPGs). The Westinghouse Emergency Response Guidelines (ERGs) already address maximizing the cooldown rate up to the Technical Specification limit.

2.0 QUALITATIVE EVALUATIONS

The intent of this step is to initiate a ‘rapid’ cooldown of the RCS at the maximum allowed rate. This action will reduce the pressure and temperature of the plant. In the case of a LOCA, steam generator tube rupture (SGTR), or ESDE, this limits the associated break flow by reducing the stored energy in the plant.

During a large break LOCA, break flow cools the core. Steam generators are not the primary means of core cooling. This means the operator has little control over reactor vessel cooldown rate since cold emergency core cooling system (ECCS) in-flow down the vessel wall is the dominant cooling mechanism. During a small or medium size LOCA, rapid cooldown is important to lower Pressurizer pressure to ensure that the high pressure safety injection (HPSI) pumps are able to inject into the reactor coolant system (RCS). If a smaller break size holds pressurizer pressure above HPSI shutoff head, it is important to maintain RCS heat removal via the steam generators, and to maintain forced circulation, if possible, using the reactor coolant pump trip two/leave two strategy.

A plant cooldown will change the reactivity conditions in the reactor core. Therefore, whenever a cooldown is performed the crew must consider the effects of the cooldown on reactivity control and take appropriate actions to maintain the reactor shutdown. This may include borating and sampling the RCS, both, prior to and during the cooldown. This step assumes that emergency boration will be in progress due to safety injection actuation signal (SIAS) and therefore no direction is given to commence boration.

2.1 Proposed Clarifications in Cooldown Definitions

2.1.1 Controlled Cooldown

The LOCA strategy currently refers to using a 'controlled' cooldown and depressurization after the break has been isolated. The introduction for the LOCA strategy directs that a 'rapid' cooldown and depressurization be performed if the break can not be isolated. The distinction between 'controlled' and 'rapid' is not explained or used in the bases of the guideline. For consistency, the term 'controlled' cooldown was adopted by the PWG in the past to be used throughout the EPGs. The case of LOCA, ESDE and SGTR are mention briefly in the bases as an exception when the cooldown should be more aggressive to limit inventory losses. The EPG definition for a 'controlled' cooldown implies that the operator is in control of the cooldown, i.e., the cooldown is within the designed reset capabilities of MSIS and SIAS, or the operator has the ability to stop or maintain a given pressure and temperature band.

2.1.2 Rapid Cooldown

A 'rapid' cooldown as defined here is a controlled cooldown performed at or as close to the Tech Spec limit as can be achieved for the current plant conditions, that is, at the maximum allowed cooldown rate.

As mentioned in 2.1.1, 'rapid cooldown' is not well defined in the EPGs. When used in the EPGs, a 'rapid' cooldown implies that the operator cooldown as fast as possible without exceeding the 'maximum allowed' TS cooldown rates, i.e., [<100°F/Hr]. It is suggested that in LOCA, SGTR and ESDE (unisolable leaks), 'controlled' cooldown be changed to 'rapid' cooldown and the bases changed accordingly.

2.2 Applications and Uses of each Cooldown Definition

There are basically two types of cooldown addressed in the EPGs currently; 'controlled' and 'rapid.' In an effort to promote consistency throughout the EPGs, 'controlled' was used everywhere. This may not be the best approach. A 'rapid' cooldown should be used in the case of a LOCA, SGTR, or ESDE because the cooldown limits the associated break flow by reducing the stored energy in the plant.

2.2.1 Current Uses and Suggested Changes to Bases

The following describes the circumstances when each type of cooldown would be recommended.

LOCA Step 15 – LOCA not isolated, the operator is directed to cooldown. Current Step 15 bases refers to a 'controlled' cooldown, it should be a 'rapid' cooldown. Bypassing MSIS (Step 17) refers to controlled. This should also be changed.

LOCA Step 61 – LOCA isolated, is correct as it is. The operator is directed to cooldown. The bases refer to a 'controlled' cooldown.

SGTR Step 8 – The operator is directed to cooldown to below the relief valve setpoint. Step 24 does a 'controlled' cooldown to SDC entry conditions. It should be a 'rapid' cooldown.

ESDE Step 38 – The operator is directed to cooldown. Current Step 38 bases refer to a 'controlled' cooldown. It should be a 'rapid' cooldown.

The same changes would apply to the FRG.

The associated instructions should be changed from a 'controlled' to 'rapid' cooldown and the bases changes to define 'rapid' and explain the importance of an aggressive cooldown in these circumstances.

3.0 REFERENCE PLANT ANALYSES/EVALUATION

3.1 Summary of Analyses Performed

None required.

3.2 Risk Assessment

Current procedures refer to a 'controlled' cooldown. For accidents such as LOCA, SGTR, and ESDE, specific guidance may be added to the EPGs to address a 'rapid' cooldown. Since no specific guidance currently exists for 'rapid' cooldown, any additional guidance will improve the probability of the operator correctly performing the procedure. The probability of success of an Operator action, with guidance, generally is an order of magnitude greater than the probability of success of an Operator action, without guidance. Part of the purpose of this COA is to limit inventory loss by introducing guidance for a more aggressive cooldown. The reduction in inventory loss may result in reduced debris transport to the sump screens during LOCA accident sequences; therefore, reducing the probability of sump blockage. Overall, this COA provides risk benefit primarily by improving cooldown and depressurization guidance.

3.3 Human Performance Evaluation

From an human factors standpoint, refining this guidance is generally recommended. Neither the difference between a controlled and a rapid cooldown, nor the cues to indicate that a rapid cooldown is needed are presently clear in the EPGs. The net impact of any such strategies on event mitigation and plant risk are plant specific.

4.0 CONCLUSIONS/RECOMMENDATIONS

It is recommended that the EPG terminology and usage of 'controlled cooldown' and 'rapid cooldown' be clarified and EPG changes incorporated.

A8-CE – Candidate Operator Action 8 – Combustion Engineering Plants Provide Guidance on Symptoms and Identification of Containment Sump Blockage

1.0 INTRODUCTION

NRC Bulletin 2003-01 requires that the utilities evaluate and implement compensatory measures to reduce the potential risk due to post-accident debris blockage as evaluations to determine compliance proceed. The bulletin directed utilities to consider a range of possible interim compensatory measures. Utilities may elect to implement those that they deem appropriate, based upon the specific conditions associated with their plants. One possible interim compensatory measure included in the bulletin is "operator training on indications of and responses to sump clogging."

The PWR Template for Responding to NRC Bulletin 2003-01, "Potential Impact of Debris Blockage on Emergency Sump Recirculation at Pressurized-Water Reactors" states, "The [current] operator training includes the monitoring of operating ECCS and CSS pumps for indications of pump distress or loss of NPSH, such as erratic current, flow or discharge pressure. Utilizing all available instrumentation to identify symptoms of containment sump blockage or degraded ECCS pump performance may enhance the current training. For example, high sump screen differential pressure (if available) is a definitive indicator of containment sump screen blockage. General symptoms of pump distress (erratic current, flow or discharge pressure) could be used in combination with sump level to determine sump blockage."

The same document lists the following specific parameters that operators could monitor as indications of sump blockage:

- Containment recirculation sump level
- Residual heat removal (RHR) (low-head safety injection (SI)) pump flow
- Containment Spray pump flow
- RHR (low-head SI) pump vibration
- Containment Spray pump vibration
- RHR (low-head SI) pump current
- RHR (low-head SI) pump discharge pressure
- Containment Spray pump current
- Charging/SI pump discharge pressure
- Charging/SI pump flow
- Charging/SI pump current
- SI pump discharge pressure
- SI pump flow
- SI pump current
- Containment sump screen delta p (if available)
- [Identify other plant specific indications that may be available]

In addition to the list of parameters given in NRC Bulletin 2003-01, annunciator alarms associated with pump suction pressure (if available) could alert operators to problems with pump suction.

Existing operator training programs include generic training on indications and responses to loss of suction for pumps.

Typical indications of loss of suction include:

- Reduced/erratic flow
- Reduced/erratic discharge pressure
- Reduced/erratic motor current
- Low suction pressure alarm (if available)

Previously, operator training programs have not addressed explicit concerns of recirculation sump blockage because it was considered an incredible and beyond design bases event. Few, if any, plants have instrumentation providing direct indication of sump blockage (such as differential pressure across the sump screen). Therefore, operators can not observe symptoms of sump blockage itself, only symptoms of pump distress resulting from the sump blockage.

Therefore, the Combustion Engineering Emergency Procedure Guidelines (EPGs) do not include explicit steps to monitor for or address the inability to establish or maintain recirculation from the containment sump. If sump blockage were to occur, as evident by the inability to satisfy the SFSCs, the operators would transition from the LOCA Optimal Recovery Guideline (ORG) to the Functional Recovery Guideline (FRG) and continue to monitor/restore the Safety Functions as best they could. In parallel, management (i.e., the Technical Support Center (TSC) would be called on to provide additional guidance and recommendations. The Accident Management Guidelines (AMGs) would be opened and used in parallel with the EPGs to attempt to restore core cooling and RCS inventory control.

The purpose of this report is to evaluate the appropriateness of adding more explicit guidance to the EPGs to monitor ECCS pump performance post recirculation actuation signal (RAS) for indications of sump screen clogging.

For those proposals that are found to be acceptable, the program will develop generic technical information and implementation guidance to support preparation of the EPG technical bases and to assist the utility in implementing the guidance in their Emergency Operating Procedures (EOPs) as they deem appropriate, based upon the specific conditions associated with their plants. Implementation of the EOPs includes training of the operators in use of the modified EOPs.

2.0 QUALITATIVE EVALUATIONS

2.1 Proposed EPG Enhancement

The overall goal of the proposed instruction is to prevent failure, and minimize interruption of emergency core cooling system (ECCS) flow when these systems are required to be in operation. It is assumed that the operator has previously secured unneeded pumps taking suction from the containment sump. The intent of this step is to:

1. Monitor key parameters associated with containment sump blockage.

2. Identify symptoms indicative of degraded ECCS pump performance.

3. Implement a preemptive strategy to minimize the risk of a loss of core cooling.

4. Provide compensatory actions to respond to a single pump failure.

5. Provide compensatory actions to restore core cooling in the event of loss of ECCS sump as a viable suction source.

2.1.1 Parameters to be Monitored

- Containment wide range level indication
- *Cold leg high pressure safety injection (HPSI) flowrate
- *Low pressure safety injection (LPSI) pump flowrate
- *Containment spray (CS) pump flowrate
- *HPSI pump discharge pressure
- *CS pump discharge pressure
- HPSI, LPSI and CS pump motor current
- HPSI, LPSI and CS pump suction pressure
- Other plant specific indications

* Key parameters: Establish trending and alarms to alert operators to deviations from nominal performance. Alarm setpoints should be determined on a plant specific basis. The intent is to provide notification of off-normal ECCS performance.

2.1.2 Expected Trends and Possible Anomalies

Normal Trend

Once in service, a baseline 'normal' trend for each pump should be established. Assuming no changes in system configuration, expect all parameters to be similarly affected by changes in containment pressure and sump water temperature. Containment water level should remain relatively constant after the refueling water storage tank (RSWT) is transferred to containment. Unexpected increase in sump level may indicate in-leakage from component cooling water or essential service water systems. Lowering sump level may indicate an ECCS leakage outside containment, or pooling inside containment due to blocked chokepoints along the return path to the containment sump.

Degradation of Single Pump

Individual pump mechanical degradation would be indicated by unexpected reduction or erratic behavior in pump flowrate, discharge pressure and motor current. Concurrently, other pumps operating on the same suction source would continue to trend as expected.

Blockage of Sump Screens

The containment sump screens are designed to filter out debris and provide adequate suction flow to the ECCS pumps. Debris buildup on sump screens will impair suction flow return to the ECCS pumps. Typical containment sump screens are designed for 50% debris blockage and still deliver design rated flow. Debris blockage in excess of design (50% screen area) will adversely affect ECCS pump performance and may result in loss of net positive suction head (NPSH), severe cavitation, and potential pump failure. All ECCS pumps taking suction directly from a common sump will be affected. (If ECCS pumps are connected in series, the pump taking suction directly on the containment sump will be affected before the downstream pump.) Minor Head loss (3 to 5%) should have minimal affect on pump performance. Moderate Head loss (10 to 20%) may be accompanied by noticeable reductions in flow and discharge pressure. A large Head loss (25% and more) will result in significant flow reduction, unstable pump operation and eventually cavitation will occur. Cavitation will be result in increased pump noise.

Failure of Sump Screens

If the sump screens experience a large buildup of debris, a high differential pressure may result in screen failure. If the screens fail, the pumps will ingest debris. Blockage of small internal passages and mechanical binding may occur. The pump will behave erratically, performance will decline and it will ultimately fail. Multi-stage, high pressure injection pumps are more susceptible to damage from debris ingestion than low pressure single stage pumps. Ingested debris may also cause downstream valves to fail due to blockage between the valve disc and seat.

2.2 Advantages

These monitoring actions can not reduce the probability of sump blockage. However, early recognition of abnormal ECCS pump behavior can lower the possibility of experiencing pump damage and possibly delay the consequences or sump blockage, giving the operator more time to perform mitigative actions in response to the condition.

2.3 Disadvantages/Potential Issues

In most cases, the instrumentation readily available to monitor sump blockage is limited to sump level, discharge pressure, flow and motor current. These parameters indicate pump operating conditions rather than sump blockage itself. If individual plants have direct indication of sump blockage, such as differential pressure across the sump screen or pump suction pressure, these parameters should be included in the guidance.

In most cases, the instrumentation available to monitor for sump blockage is not qualified to Regulatory Guide 1.97 standards. This is not a significant issue because repeated NRC guidance states that it is acceptable to use all available means, including non-Regulatory Guide 1.97 instrumentation, to respond to and mitigate the consequences of an accident.

Any addition to the EPGs increases operator response time. This presents a particular concern when operators are performing time-critical tasks, such as manual realignment for emergency coolant recirculation. Using instrumentation readily available in the control room and simplifying the diagnostic actions as much as possible minimizes the impact on operator response time.

No single parameter provides adequate indication of sump blockage. Consider a typical plant with two trains of containment spray, two low-head ECCS pumps, two high-head ECCS pumps and two charging/SI pumps, each with indication of motor amps, header pressure and flow. This represents a total of twenty-four indications. Typical plants may have these indications widely separated. This diversity of indications complicates operator evaluation and requires more time.

The diagnostic actions must be as simple as possible. The guidelines should use the most useful and reliable parameters in a corroborative way to make a decision.

The diagnostic actions should be conservative with respect to RCS inventory control, core cooling, containment temperature and pressure control and limiting radiation releases. At the same time, the diagnostic actions should be proactive with respect to preserving the integrity of the safeguards pumps. These two goals may be contradictory. Proactive pump protection requires stopping any pump experiencing loss of suction as soon as possible. Demands for RCS makeup flow and containment spray flow require operators to keep pumps running as long as possible.

Indications of sump blockage do not have specific action setpoints. Instead, operators must evaluate indications as being “reduced” or “erratic.” Operators require significant additional time to perform this action and are more likely to make errors. The guidelines should minimize subjectivity and ambiguity. Any new guidance should be “operator friendly” to be beneficial or risk neutral.

If operators incorrectly diagnose sump blockage, actions taken to mitigate the perceived problem may increase the consequences of the actual event in progress. For example, operators may stop high-head ECCS pumps to protect the pumps from a perceived loss of suction condition when in fact continued pump operation is required to prevent core damage.

The relative priority of symptoms must be determined. For example, the relative priority of indication of sump blockage compared to Critical Safety Functions.

3.0 REFERENCE PLANT ANALYSES/EVALUATION

3.1 Summary of Analyses Performed

None.

3.2 Risk Assessment

Any increase in risk is expected to be minimal. The additional procedure steps to monitor and diagnose sump blockage may potentially slow operator response to the event. This may impact risk for accident sequences where other time critical procedures and diagnoses are being performed at the time that sump blockage is being monitored. However, guidance for increased ECCS pump monitoring post RAS should increase the probability of timely detection, which may provide additional time for the operator to take compensatory actions. In addition, specific EPG guidance and training for monitoring ECCS pump performance post RAS decrease the chances of the operator misdiagnosing the situation. Therefore, from a risk perspective, it is beneficial to implement this candidate operator action.

3.3 Human Performance Evaluation

As long as there is no direct indication or definitive check for sump blockage, real-time diagnosis of this condition by human operators in the midst of a LOCA event is not practical. While not impossible, human action should not presently be relied on or be credited for doing so. It is easy (i.e., low cost) to commend that, “indications of possible sump blockage and corresponding contingency actions should be specified and applied where appropriate" and so it should be done (based on a plant-specific evaluation). However, when sump blockage occurs, such actions offer little if any compensatory risk reduction. In contrast, preemptive manual actions prior to symptoms of cavitation (e.g., early termination of unneeded CS and ECCS pumps) may offer the most benefit, though not without added analytic cost.

In summary, from an human factors perspective, operators should not be relied on or directed to diagnose multiple indications for a blocked sump, since:

1. With the present indications available to them and the associated uncertainties, it has a low probability of being diagnosed correctly or in time.

2. Incorrect conclusions may complicate an event and worsen its consequences.

3. The activity may divert the operators' attention from their principal responsibilities in the event.

4. Turning pumps off after the sump is clogged does not necessarily unclog sump, save the pump, or save screen.

Preferred responses to symptoms that may occur during a LOCA recovery or functional recovery are desirable and are consistent with continued refinement of existing emergency procedures. However, this action cannot be relied upon as an effective compensatory action.

4.0 CONCLUSIONS/RECOMMENDATIONS

Each plant must consider the advantages and disadvantages as they apply to their plant specific design and incorporate this action if it is determined to be risk beneficial with respect to containment sump blockage.

A8-W – Candidate Operator Action 8 – Westinghouse Plants
Provide Guidance on Symptoms and Identification of Containment Sump Blockage

1.0 INTRODUCTION

NRC Bulletin 2003-01 requires that the utilities evaluate and implement compensatory measures to reduce the potential risk due to post-accident debris blockage as evaluations to determine compliance proceed. The bulletin directed utilities to consider a range of possible interim compensatory measures. Utilities may elect to implement those that they deem appropriate, based upon the specific conditions associated with their plants. One possible interim compensatory measure included in the bulletin is "operator training on indications of and responses to sump clogging."

The PWR Template for Responding to NRC Bulletin 2003-01, "Potential Impact of Debris Blockage on Emergency Sump Recirculation at Pressurized-Water Reactors" states, "The [current] operator training includes the monitoring of operating ECCS and CSS pumps for indications of pump distress or loss of NPSH, such as erratic current, flow or discharge pressure. Utilizing all available instrumentation to identify symptoms of containment sump blockage or degraded ECCS pump performance may enhance the current training. For example, high sump screen differential pressure (if available) is a definitive indicator of containment sump screen blockage. General symptoms of pump distress (erratic current, flow or discharge pressure) could be used in combination with sump level to determine sump blockage."

The same document lists the following specific parameters that operators could monitor as indications of sump blockage:

- Containment recirculation sump level
- RHR (low-head SI) pump flow
- Containment Spray pump flow
- RHR (low-head SI) pump vibration
- Containment Spray pump vibration
- RHR (low-head SI) pump current
- RHR (low-head SI) pump discharge pressure
- Containment Spray pump current
- Charging/SI pump discharge pressure
- Charging/SI pump flow
- Charging/SI pump current
- SI pump discharge pressure
- SI pump flow
- SI pump current
- Containment sump screen delta p (if available)
- [Identify other plant specific indications that may be available]

Existing operator training programs include generic training on indications and responses to loss of suction for pumps.

Typical indications of loss of suction include:

- Reduced/erratic flow
- Reduced/erratic discharge pressure
- Reduced/erratic motor current

Previously, operator training programs have not addressed explicit concerns of recirculation sump blockage. Few, if any, plants have instrumentation providing direct indication of sump blockage (such as differential pressure across the sump screen). Therefore, operators can not observe symptoms of sump blockage itself, only symptoms of pump distress resulting from the sump blockage.

The Westinghouse Owners Group (WOG) Emergency Response Guidelines (ERGs) explicitly address inability to establish or maintain recirculation from the containment sump. ES-1.3, TRANSFER TO COLD LEG RECIRCULATION, Step 3, RNO contains the only explicit instructions associated with sump blockage: "IF at least one flow path from the sump to the RCS can NOT be established or maintained {italics added}, THEN go to ECA-1.1, LOSS OF EMERGENCY COOLANT RECIRCULATION. Since this is not a continuous action step, it is unlikely to provide appropriate diagnosis of sump screen clogging that occurs after establishing the recirculation alignment.

The purpose of this report is to evaluate the feasibility and appropriateness of adding procedural guidance on recognition of sump clogging to the ERGs.

For those proposals that are found to be acceptable, the program will develop generic technical information and implementation guidance to support preparation of the ERG technical bases and to assist the utility in implementing the guidance in their Emergency Operating Procedures (EOPs) as they deem appropriate, based upon the specific conditions associated with their plants. Implementation of the EOPs includes training of the operators in use of the modified EOPs.

2.0 QUALITATIVE EVALUATIONS

2.1 Advantages

This action can not reduce the probability of sump blockage. Proper identification of sump blockage can reduce the consequences associated with sump blockage. Identification of sump blockage allows operators to perform mitigative actions in response to the condition. ERGs must contain guidance on the identification of sump blockage to make possible actions in response to this condition.

Specific ERG changes associated with this action are:

- Add a continuous-action procedure step to ES-1.3, TRANSFER TO COLD LEG RECIRCULATION, immediately after verifying or establishing recirculation flow instructing operators to check for indications of sump screen clogging with instructions to transition to the appropriate guideline (modified ECA-.1, LOSS OF EMERGENCY COOLANT RECIRCULATION, proposed new ECA-1.3, RECIRCULATION SUMP BLOCKAGE), or proposed new SUMP BLOCKAGE CONTROL ROOM GUIDELINE (SBCRG) if blockage occurs. This continuous-action step would continue to apply for any subsequent guideline entered.

- Add to ECA-1.1, LOSS OF EMERGENCY COOLANT RECIRCULATION, guidance that, if loss of emergency coolant recirculation is due to sump blockage, then the sump blockage guideline applies.

- Add continuous-action steps to guidelines intended for response to sump blockage (modified ECA-1.1, proposed new ECA-1.3, or proposed new SBCRG) instructing operators to monitor for changes in sump blockage indications and adjusting actions as required.

2.2 Disadvantages/Potential Issues

- In most cases, the instrumentation readily available to monitor sump blockage is limited to sump level, discharge pressure, flow and motor current. These parameters indicate pump operating conditions rather than sump blockage itself. If individual plants have direct indication of sump blockage, such as differential pressure across the sump screen or pump suction pressure, these parameters should be included in the guidance.

- In most cases, the instrumentation available to monitor sump blockage is not qualified to Regulatory Guide 1.97 standards. This is not a significant issue because repeated NRC guidance states that it is acceptable to use non-Regulatory Guide 1.97 instrumentation.

- Any addition to ERGs increases operator response time. This presents a particular concern when operators are performing time-critical tasks, such as manual realignment for emergency coolant recirculation.

- No single parameter provides adequate indication of sump blockage. Consider a typical plant with two trains of containment spray, two low-head emergency core cooling system (ECCS) pumps, two high-head ECCS pumps and two charging/safety injection (SI) pumps, each with indication of motor amps, header pressure and flow. This represents a total of twenty-four indications. Typical plants may have these indications widely separated. This diversity of indications complicates operator evaluation and requires more time.

- Indications of sump blockage do not have specific action setpoints. Instead, operators must evaluate indications as being “reduced” or “erratic.” Operators require significant additional time to perform this action and are more likely to make errors.

- If operators incorrectly diagnose sump blockage, actions taken to mitigate the perceived problem may increase the consequences of the actual event in progress. For example, operators may stop high-head ECCS pumps to protect the pumps from a perceived loss of suction condition when in fact continued pump operation is required to prevent core damage.

The relative priority of symptoms requires must be determined. For example, the relative priority of indication of sump blockage compared to Critical Safety Functions.

3.0 REFERENCE PLANT ANALYSES/EVALUATION

3.1 Summary of Analyses Performed

None.

3.2 Risk Assessment

Any increase in risk is expected to be minimal. The additional procedure steps to diagnose sump blockage may potentially slow the process of diagnosing the situation. This may impact risk for accident sequences where other time critical procedures and diagnoses are being performed at the time that sump blockage is diagnosed. However, guidance for detecting sump blockage will increase the probability of timely detection, which would provide additional time for the Operator to align alternative RCS makeup sources. In addition, specific procedures for diagnosing sump blockage decrease the chances of the Operator misdiagnosing the situation. Therefore, from a risk perspective, it is beneficial to implement this candidate operator action.

3.3 Human Performance Evaluation

The addition of procedural steps to check for indications of sump blockage may add to operator response times, in particular for manual actions to realign for cold leg recirculation before refueling water storage tank (RWST) level decreases below the minimum level for pump operation.

Addition of procedural steps to check for indication of sump blockage does not change overall ERG strategies and involves only minor revision of instructions. Contingency actions associated with sump blockage may require new or significantly revised instructions. These contingency actions may also affect overall ERG strategies.

The large number of individual indications that operators must monitor for sump blockage considerations aggravates both the operator response times and the potential for misdiagnosis.

The fact that there are no explicit action setpoints for sump blockage also aggravates both operator response times and the potential for misdiagnosis.

4.0 CONCLUSIONS/RECOMMENDATIONS

In general the proposed change is advantageous to all/most plants, however each plant must consider the advantages and disadvantages as they apply to their plant specific design and incorporate this action if it is determined to be risk beneficial with respect to containment sump blockage.

A9-CE – Candidate Operator Action 9 – Combustion Engineering Plants Develop Contingency Actions in Response to: Containment Sump Blockage, Loss of Suction, and Cavitation

1.0 INTRODUCTION

NRC Bulletin 2003-01 requires that the utilities evaluate and implement compensatory measures to reduce the potential risk due to post-accident debris blockage as evaluations to determine compliance proceed. They were directed to consider a range of possible interim compensatory measures and may elect to implement those, which they deem appropriate, based upon the specific conditions associated with their plants. One possible interim compensatory measure included in the bulletin was, "operator training on indication of and responses to sump clogging."

Training operators to recognize and respond to sump clogging requires identifying appropriate responses before such an event occurs. Identifying appropriate responses to credible events properly belongs in the procedure development and maintenance process. Therefore, developing contingency actions in response to containment sump blockage represents a fundamental part of "operator training on … responses to sump clogging." Existing operator training programs capture changes to emergency procedures and provide the actual training.

This report evaluates developing comprehensive Combustion Engineering Emergency Procedure Guidelines (EPG) strategies to respond to indications of sump blockage, loss of pump suction and pump cavitation. Based on available indications, no set of symptoms provides unique and absolute diagnosis of sump blockage. Directing operator actions based on possible, rather than confirmed, sump blockage requires considering the consequences of misdiagnosis. This report evaluates the following list of possible contingency actions and focuses on the best options. Note that the last item added in response to possible vortexing induced by partial sump blockage:

1. Stop pumps experiencing loss of suction to prevent permanent pump damage.

2. Reduce recirculation flow to the minimum required to support design basis or critical safety functions.

3. Ensure all available normal and emergency containment cooling units are in operation to minimize cooling demand for containment spray flow and support core heat removal later in the event by indirect heat removal.

4. Establish alternate water sources to inject into the reactor core and spray into the containment.

5. Optimize use of available water sources for injection into the reactor core and spray into the containment.

6. Cool-down and depressurize the reactor coolant system (RCS) using the secondary system to reduce required injection flow to the RCS and allow placing the RHR system in service.

7. Backflush the recirculation flow path to remove blocking material from sump screens (if applicable).

8. Vent pumps that have become air-bound.

Previously, operator training programs have not addressed explicit concerns of recirculation sump blockage because it was considered an incredible and beyond design bases event. Few, if any, plants have instrumentation providing direct indication of sump blockage (such as differential pressure across the sump screen). Therefore, operators can not observe symptoms of sump blockage itself, only symptoms of pump distress resulting from the sump blockage.

Therefore, the EPGs do not include explicit steps to monitor for or address the inability to establish or maintain recirculation from the containment sump. The fundamental EPG strategy focuses the operators' attention on the status of critical safety functions, not specific events. If sump blockage were to occur, as evident by the inability to satisfy the SFSCs, the operators would transition from the LOCA Optimal Recovery Guideline (ORG) to the Functional Recovery Guideline (FRG) and continue to monitor/restore the Safety Functions as best they could. In parallel, management (i.e., the Technical Support Center (TSC)) would be called on to provide additional guidance and recommendations. The Accident Management Guidelines (AMGs) would be opened and used in parallel with the EPGs to attempt to restore core cooling and RCS inventory control.

The purpose of this report is to evaluate the appropriateness of adding more explicit contingency actions to the EPGs that would be taken in response to indications of degraded ECCS pump performance post recirculation actuation signal (RAS) and indications of sump screen clogging.

For those proposals that are found to be acceptable, the program will develop generic technical information and implementation guidance to support preparation of the EPG technical bases and to assist the utility in implementing the guidance in their Emergency Operating Procedures (EOPs) as they deem appropriate, based upon the specific conditions associated with their plants. Implementation of the EOPs includes training of the operators in use of the modified EOPs.

2.0 QUALITATIVE EVALUATION OF POSSIBLE COMPENSATORY ACTIONS

The best overall strategy to reduce the risk of sump screen blockage, loss of all Emergency Core Cooling System (ECCS) pump capability and loss of core cooling, is to stop unneeded high pressure safety injection (HPSI), low pressure safety injection (LPSI) and containment spray (CS) pumps as soon as possible and place them in standby. To the extent possible, this should have been done prior to getting to this point in the procedure. When unneeded pumps are secured, system alignment should not be changed (unless there is a compelling reason to do so), so that the possibility of realignment failures is avoided. This strategy reduces the demand on the containment sump and establishes reliable backup capability. If this strategy is used, the post RAS lineup would then consist of one operating HPSI pump aligned to inject to the RCS, and possibly one CS pump operating in recirculation mode to remove heat from the containment sump water.

Following RAS the operator should intensify monitoring of all available ECCS pump performance indications for signs of blockage or reduced net positive suction head (NPSH) at the containment sump screen. If any of the following conditions exist, the pump may be experiencing a reduction in NPSH (see Candidate Operator Action 8, Provide Guidance on Symptoms and Identification of Containment Sump Blockage). They are listed in order of likely occurrence:

1. Unstable or lower than expected SI or CS flow
2. Unstable or lower than expected HPSI or CS pump discharge pressure
3. Lower than expected HPSI or CS pump suction pressure, low suction pressure alarm
4. Unstable or lower than expected HPSI or CS pump motor current
5. Increased HPSI or CS pump noise
6. Other plant specific indications

If there are signs of a reduction in NPSH, the operator would then evaluate trends of these indications and attempt to diagnose what is happening. These symptoms could mean a variety of things such as: an individual pump in distress, a valve/piping failure or sump screen failure. Accurate diagnosis of these occurrences under accident conditions is difficult and will require the operator to rely heavily on knowledge, experience and training. None of the available indications will provide a 100% conclusive diagnoses. Nevertheless, time is of the essence. If the operator is fairly certain that a loss of suction is taking place, he must act quickly if he is to avert equipment damage and still assure adequate core cooling.

Based on the diagnoses of the situation, the operator would then initiate various actions to help protect the pumps, ensure continued core heat removal and avert potential core damage. For example: reduce demand on the sump by securing unneeded pumps in order of priority, evaluate system response, accelerate plant cooldown using the steam generators, place all available containment cooling units into service, attempt to transition to shutdown cooling (SDC) and inject from a refilled RWT or from an alternate source by bypassing the RWT. Alternate injection may use any of the following methods:

- From a refilled RWT using all available charging pumps
- From a refilled RWT using a LPSI pump
- Bypassing the RWT using all available charging pumps
- Bypassing the RWT using a LPSI pump
- Other plant specific methods

2.1 Actions to Avert ECCS Pump Damage

Based on the diagnoses of the situation, the operator would then initiate various actions to help protect the pumps. Stop all operating CS pumps and observe if HPSI pump performance improves. If HPSI pump performance does not improve, then the operator would take any of the following actions: throttle safety injection (SI) flow, stop the running HPSI pump.

This action reduces the demand on the sump to a minimum (securing containment spray) and focuses on protecting the HPSI pump from damage. Reduced total recirculation flow raises the available net positive suction head for pumps operating in the recirculation mode.

For conditions of partial sump blockage, reduced flow minimizes additional transport of material to the sump screen.

2.2 Actions to Restore ECCS Flow in the Event of ECCS Pump Failure

With the preemptive strategy discussed above in use, if an individual ECCS pump fails or is diagnosed to be seriously degraded, the pump should be stopped and the standby pump placed in service after performing the necessary verifications to avoid a possible common cause failure.

2.3 Actions to Mitigate Increasing Screen Blockage

If there are indications of increasing sump screen blockage, consider reducing the flow demand through the sump screens to as little as possible consistent with adequate core cooling demands. Also, consider going to a piggy back alignment (if possible) in order to insulate the HPSI pump from damage due to possible head loss. Throttle HPSI flow or intermittently operate the HPSI pump as needed to maintain core heat removal, until an alternate RCS injection source is available. Note that it may be difficult to provide the operator with clear threshold values to trigger ‘intermittent” ECCS pump operation.

2.4 Additional Actions to Maintain or Restore Core Cooling if the Containment Sump is Inoperable (blocked)

Based on the diagnoses of the situation, the operator initiates various actions to ensure continued core heat removal. For example: accelerate plant cooldown using the steam generators, place all available containment cooling units into service, attempt to transition to SDC and inject from a refilled RWT or from an alternate source by bypassing the RWT. Alternate injection may use any of the following methods:

- From a refilled RWT using all available charging pumps
- From a refilled RWT using a LPSI pump
- Bypassing the RWT using all available charging pumps
- Bypassing the RWT using a LPSI pump
- Other plant specific methods

Containment: Ensure all available normal and emergency containment cooling units are in operation to maximize containment heat removal and support indirect cooling of the RCS and reactor core. Without spray and SDC heat exchangers, water in the sump will reach saturated conditions and create steam. Steam energy is removed by the CFCs and transferred to CCW. Thus decay heat is removed without spray and heat exchangers.

Steam Generators: Take maximum advantage of steam generators as a heat sink. RCS heat removal can be accomplished via single phase heat transfer to the steam generators or two phase reflux cooling. Ensure adequate steam generator level and control steam flow to maintain steam generator temperature lower than the RCS, i.e., ensure steam generator is heat sink, not heat source. Continue rapid cooldown and depressurize the RCS using the secondary system to reduce break flow (RCS mass loss), and thereby reduce the need for ECCS makeup flow. In addition, RCS depressurization may facilitate SIT injection if they have not yet discharged to the RCS.

Shutdown Cooling: If RCS conditions permit, consider placing the SDC system in service as follows. The reactor vessel level must be stable and equal or greater than mid-level on the hot leg to ensure adequate pump suction. It is not necessary that pressurizer level be above the heaters. The RCS will likely be saturated, so care must be taken to initiate flow slowly and minimize pump cavitation.

Borated Water alternate Source: Commence RCS injection of borated water from an alternate source (non-RWST). Since the RWST may still be empty in the early stages of a sump blockage event, bypassing the RWST using an existing plant specific source may be the preferred success path. Success of refilling and using a refilled RWST requires that a HPSI, LPSI or charging pump be available. The suction sources, pumps and necessary alignments are plant specific.

2.5 Advantages and disadvantages

Most of the contingency actions addressed hear have been evaluated separately in other Candidate Operator Action (COA) evaluations. Refer to the applicable COA evaluation for a discussion of advantages and disadvantages. See especially COA 8, Provide Guidance on Symptoms and Identification of Containment Sump Blockage.

3.0 REFERENCE PLANT ANALYSES/EVALUATION

3.1 Summary of Analyses Performed

None.

3.2 Risk Assessment

No significant risk impact is expected due to any of these contingency actions. Explicit guidance for contingency actions in the event of sump blockage will increase the probability of establishing alternate RCS makeup sources and using the available sources wisely. Any additional contingency actions may decrease the time available for the operator to perform other tasks. However, the delay in time available is expected to be short. In conclusion, guidance for contingency actions will be beneficial to risk in terms of priorities of actions and available alternatives.

3.3 Human Performance Evaluation

Following RAS, if cavitation of either HPSI pump is detected, immediate securing of both pumps should be considered, and any contingencies pursued from there. Regardless of the cause, cavitating HPSI pumps give little time for manual response (potentially much less than one minute) before catastrophic pump failure occurs. From an HF perspective, securing cavitating pumps has a better probability of timely performance right after RAS than later in the event (without a corresponding cue to watch the pumps). Adding a dedicated "containment blockage" observer during HPSI operation post RAS may not greatly improve things, since:

1. Watching for unlikely events leads to inattention

2. Contingent responses will be delayed by verbal communication to the operators (unless the observer also takes the action – not recommended)

3. Staffing is already at a premium

Thus, this COA can be recommended, primarily in association with RAS, preceded by additional preemptive actions addressed by other COAs.

4.0 CONCLUSIONS/RECOMMENDATIONS

Each plant must consider the advantages and disadvantages as they apply to their plant specific design and incorporate any or all of these actions if it is determined to be risk beneficial with respect to containment sump blockage.

A9-W – Candidate Operator Action 9 – Westinghouse Plants
Develop Contingency Actions in Response to: Containment Sump Blockage, Loss of Suction, and Cavitation

1.0 INTRODUCTION

NRC Bulletin 2003-01 requires that the utilities evaluate and implement compensatory measures to reduce the potential risk due to post-accident debris blockage as evaluations to determine compliance proceed. They were directed to consider a range of possible interim compensatory measures and may elect to implement those, which they deem appropriate, based upon the specific conditions associated with their plants. One possible interim compensatory measure included in the bulletin was, "operator training on indication of and responses to sump clogging."

Training operators on responses to sump clogging requires identifying appropriate responses before such an event occurs. Identifying appropriate responses to credible events properly belongs in the procedure development and maintenance process. Therefore, developing contingency actions in response to containment sump blockage represents a fundamental part of "operator training on … responses to sump clogging." Existing operator training programs capture changes to emergency procedures and provide the actual training.

This report evaluates the feasibility and appropriateness of the following proposals related to responses to sump clogging, loss of suction and cavitation. Note the last item added in response to possible vortexing induced by partial sump blockage:

1. Stop pumps experiencing loss of suction to prevent permanent pump damage.

2. Reduce recirculation flow to the minimum required to support design basis or critical safety functions.

3. Verify containment cooling unit operation to minimize cooling demand for containment spray flow.

4. Establish alternate water sources to inject into the reactor core and spray into the containment.

5. Optimize use of available sources of flow for injection into the reactor core and spray into the containment.

6. Cool-down and depressurize the reactor coolant system (RCS) using the secondary system to reduce required injection flow to the RCS and allow placing the residual heat removal (RHR) system in service.

7. Backflush the recirculation flow path to remove blocking material from sump screens.

8. Vent pumps that have become air-bound.

Existing operator training programs address concerns of loss of suction and cavitation. This training begins in generic fundamental training, which includes training on indications of these conditions and actions taken in response to them.

Existing Westinghouse Owners Group (ORG) Emergency Response Guidelines (ERGs) address loss of suction, although not explicitly containment sump blockage. For example, ECA-1.1, LOSS OF EMERGENCY COOLANT RECIRCULATION, Caution preceding Step 1 states, "If suction source is lost to any SI or spray pump, the pump should be stopped." The same procedure includes action steps that are consistent with several of the proposed actions in response to sump clogging (Items 1, 3, 4, and 5 in the list above).

For those proposals that are found to be acceptable, generic technical information and implantation guidance will be developed to support preparation of the ERG technical bases and to assist the utility in implementing the guidance in their Emergency Operating Procedures (EOPs) as they deem appropriate, based upon the specific conditions associated with their plants.

2.0 QUALITATIVE EVALUATIONS

One fundamental issue involves the appropriate placement of contingency responses to sump blockage. Possibilities include the development of a new guideline (proposed ECA-1.3, RECIRCULATION SUMP BLOCKAGE), including the guidance as a modification of existing procedures (in particular, ECA-1.1, LOSS OF EMERGENCY COOLANT RECIRCULATION) or providing guidance in the form of a SUMP BLOCKAGE CONTROL ROOM GUIDELINE (SBCRG). This SBCRG would be similar in format and usage to the existing SEVERE ACCIDENT CONTROL ROOM GUIDELINES.

The initial approach involved parallel development of a new procedure optimized for response to sump blockage with that of a modified ECA-1.1 that includes specific additions to address sump blockage. The most recent evaluation favors the SBCRG, since this allows introduction of interim guidelines with minimum intrusion into the existing ERG system.

2.a. Stop Pumps Experiencing Loss Of Suction To Prevent Permanent Pump Damage

2.a.1 Advantages/Benefits

This action is consistent with existing guidance. Within limits of Optimal Recovery Guidelines (ORGs), this action best maintains the ability to operate pumps in the future if required for more extreme actions to support design-basis operation and Critical Safety Functions (CSFs).

2.a.2 Disadvantages/Potential Issues

- If operators incorrectly diagnose loss of suction, they might stop all containment spray and Emergency Core Cooling System (ECCS) pumps. This places the plant in a condition outside the design basis.

- The existing FR-C.1, RESPONSE TO INADEQUATE CORE COOLING, does not include guidance on operating ECCS pumps that have lost suction. FR-C.1 has priority over ECA-1.1

with no reference to ECA-1.1. The existing FR-Z.1, RESPONSE TO HIGH CONTAINMENT PRESSURE, does not include guidance on operating spray pumps that have lost suction. FR-Z.1 has priority over ECA-1.1 but includes the following Caution preceding Step 3, "If ECA-1.1, LOSS OF EMERGENCY COOLANT RECIRCULATION, is in effect, containment spray should be operated as directed in ECA-1.1 rather than Step 3 below.

- Determine need for explicit instructions in the guidelines on restarting pumps after they have been stopped because of loss of suction.

2.b Reduce Recirculation Flow To The Minimum Required To Support Design Basis Or Critical Safety Functions

2.b.1 Advantages/Benefits

- Reduced total recirculation flow raises the margin of net positive suction head for pumps operating in the recirculation mode.

- For conditions of partial sump blockage, reduced flow minimizes additional transport of material to the sump screen.

- In general, actions to minimize flow while supporting design basis or critical safety functions are consistent with existing guidance in ECA-1.1. Specific parts of ECA-1.1 addressing this action include Step 6, Determine Containment Spray Requirements, Step 12, Establish One Train of SI Flow, Steps 15 through 20, beginning with Check If SI Can Be Terminated, and Step 21, Verify Adequate RCS Makeup Flow.

2.b.2 Disadvantages/Potential Issues

- Operator error in reducing flow could create a condition outside plant design basis.

- Operator error in reducing flow could create a condition challenging Critical Safety Functions.

- The existing FR-C.1 does not provide guidance on restricting ECCS flow. The existing FR-Z.1 includes the following Caution preceding Step 3, "If ECA-1.1, LOSS OF EMERGENCY COOLANT RECIRCULATION, is in effect, containment spray should be operated as directed in ECA-1.1 rather than Step 3 below.

- Existing guidance on reducing core injection flow includes only stopping pumps and restoring normal charging flow. Determine if closing injection line isolation valves and/or throttling RHR flow control valves should be included in responses to sump clogging.

- There can be a conflict between providing containment spray flow at the values required by existing procedures and maintaining injection flow to the reactor core. In general, the ERGs give core cooling priority over containment concerns.

- If an ORG instructs operators to stop containment spray flow to support continued injection to the core, then FR-Z.1 must include explicit instructions that spray pumps should be operated as directed in the ORG rather than in FR-Z.1.

- The concept also applies to FR-C.1. This procedure would be modified to instruct operators to reduce or stop containment spray flow if necessary to support core cooling in the recirculation mode.

2.c. Verify Containment Cooling Unit Operation To Minimize Cooling Demand For Containment Spray Flow

2.c.1 Advantages/Benefits

This action is consistent with existing guidance. It achieved the desired result with minimum impact on existing analyses.

2.c.2 Disadvantages/Potential Issues

- For facilities in which containment cooling units are not safeguards equipment, operation of the cooling units during accident conditions may violate the design basis.

- Containment cooling unit operation does not perform other functions assumed for containment spray operation, such as removal of iodine from containment atmosphere.

2.d Establish Alternate Water Sources To Inject Into The Reactor Core And Spray Into The Containment

2.d.1 Advantages/Benefits

- If successful, this action provides the desired safety function.

- This action is consistent with existing guidance in ECA-1.1. Specific steps addressing this action include Step 8, Add Makeup To RWST As Necessary; and Step 29, Try To Add Makeup To RCS From Alternate Source.

2.d.2 Disadvantages/Potential Issues

- Use of unborated alternate water sources could create an unacceptable positive reactivity insertion.

- Use of demineralized alternate water sources could create an unacceptable chemistry condition in the recirculation sump for iodine retention or corrosion limitation.

- If pumps have been in a recirculation mode and operators subsequently restore RWST level, pump suction will have to be returned to the RWST to make use of this additional water in the RWST.

- If pump suction is transferred from recirculation to RWST, fluid in the piping systems could contaminate other sections of the plant.

2.e Optimize Use Of Available Sources Of Flow For Injection Into The Reactor Core And Spray Into The Containment

2.e.1 Advantages/Benefits

- Under conditions of reduced safeguards equipment availability, any actions to optimize use of available equipment provides a benefit.

2.e.2 Disadvantages/Potential Issues

- Determining optimum alignment of core injection flow and containment spray for beyond-design-basis sump blockage presents a challenge. Any attempt to define optimum alignments in anticipation of such an occurrence would produce a very long and complicated procedure step. Determining an optimum alignment on an ad hoc basis (for example, "Consult Plant Engineering Staff") require significant time during a transient that poses an immediate challenge to critical safety functions.

- Options for flow optimization could include closing injection line isolation valves and/or throttling RHR flow control valves.

- Conflicts in the options for flow optimization could occur between reducing containment spray flow below values required by existing procedures and maintaining injection flow to the reactor core.

- Determine whether optimization actions should be restricted to ORGs or applied to both ORGs and FRs.

2.f Cool-Down And Depressurize The RCS Using The Secondary System To Reduce Required Injection Flow To The RCS And Allow Placing The RHR System In Service

2.f.1 Advantages/Benefits

- If successful, this action minimizes required injection to the reactor core and heat input to the containment atmosphere.

- This action is consistent with existing guidance in ECA-1.1. Specific steps addressing this action include "Check Intact SG Levels;" "Initiate RCS Cooldown To Cold Shutdown;" "Depressurize RCS To Decrease RCS Subcooling;" "Check If RHR System Should Be Placed In Service;" "Check If All Intact SGs Should Be Depressurized To (O.06) PSIG;" "Depressurize All Intact SGs To Inject Accumulators As Necessary;" "Depressurize All Intact SGs To Atmospheric Pressure;" and "Maintain RCS Heat Removal."

2.f.2 Disadvantages/Potential Issues

- If the cool-down and depressurization actions taken in response to sump blockage are the same as those in the existing ECA-1.1, no new disadvantages or potential issues occur.

- Any cool-down or depressurization actions beyond those in the existing ECA-1.1 would present issues associated with positive reactivity insertion, core cooling, secondary heat sink, and pressurized thermal shock.

2.g Backflush The Recirculation Flow Path To Remove Blocking Material From Sump Screens

2.g.1 Advantages/Benefits

- This action may reduce or remove sump blockage. This would allow improved core injection flow and containment spray flow to support safety objectives.

- NUREG/CR-6808, Knowledge Base for the Effect of Debris on Pressurized Water Reactor Emergency Core Cooling Sump Performance states, “Strainer clogging due to reflective metallic insulation debris was effectively mitigated by backflushing. … Backflushing was also effective for removing fibrous debris from the strainers. In this case, fibrous debris fell off in chunks and some of the debris did not accumulate back onto the strainers …”

2.g.2 Disadvantages/Potential Issues

- The ability to backflush depends on plant-specific characteristics.

- The only credible source of water for backflushing depletes the available RWST water inventory that could support injection to the reactor core or containment spray.

- Preparation for backflushing requires significant evaluation of plant conditions and manual valve realignment.

- NUREG/CR-6808 states, “[for reflective metal insulation debris] Soon after completing the backflush procedure, the pressure differential was nearly zero but it steadily increased again as the freed debris gradually accumulated back onto the strainer subsequently reaching the original differential pressure. … “Backflushing systems were not very effective where beds of mixed fibrous and RMI or fibrous and particulate debris were present. … “It was also observed that the debris tended to accumulate once again on the strainer surface, and this accumulated debris caused a higher head loss than did the original bed.”

2.h Vent Pumps That Have Become Air-Bound

2.h.1 Advantages/Benefits

Venting a pump that has become air-bound may restore the pump to an operable condition.

2.h.2 Disadvantages/Potential Issues

- If a pump has been in recirculation flow, radiation levels may be too high to allow personnel access to the pump.
- If a pump has been in recirculation flow, venting it may release radioactive materials.
- Venting requires time and personnel resources that may not be available.

3.0 REFERENCE PLANT ANALYSES/EVALUATION

3.1 Summary of Analyses Performed

No generic plant analyses have been performed. Potential plant specific evaluations that should be considered are:

1. Stop Pumps Experiencing Loss of Suction to Prevent Permanent Pump Damage

   Risk analysis should compare potential for operator error that improperly stops pumps to the challenge imposed by continuing to operate pumps without suction, resulting in permanent loss of pumping capability.

2. Reduce Recirculation Flow To The Minimum Required To Support Design Basis Or Critical Safety Functions

   Risk analysis should compare potential for operator error that improperly reduces flow to less than that required to the challenge imposed by excessive flow with sump clogging. This analysis does not need to cover actions already included in the existing ECA-1.1. Reducing containment spray flow below design basis requirements or to levels that challenge the containment CSF (in order to support core cooling) require evaluation of the relative risks.

   Analysis required to support use of ECCS injection line isolation valves or RHR throttling valves to reduce flow. Analysis required to support reducing containment spray flow in favor of core injection flow within ORGs.

3. Verify Containment Cooling Unit Operation To Minimize Cooling Demand For Containment Spray Flow

   No analysis required. Existing guidelines already address the actions and issues.

4. Establish Alternate Water Sources To Inject Into The Reactor Core And Spray Into The Containment

   Transfer of pump suction from recirculation sump back to RWST should be evaluated for potential failure paths and radiation releases. Evaluation performed for existing guidelines should already cover other issues.

5. Optimize Use Of Available Sources Of Flow For Injection Into The Reactor Core And Spray Into The Containment

   Evaluation required to define appropriate mechanism for determining optimum alignment – pre-defined procedural step or evaluation by Plant Engineering Staff. Evaluation required to determine if these actions would apply only to ORG or to both ORG and FR guidelines.

   Analysis required to support use of ECCS injection line isolation valves or RHR throttling valves to reduce flow. Analysis required to support reducing containment spray flow in favor of core injection flow within ORGs.

6. Cool-Down And Depressurize The RCS Using The Secondary System To Reduce Required Injection Flow To The RCS And Allow Placing The RHR System In Service

   No evaluation or analysis required if the actions conform to those already existing in ECA-1.1, as expected.

7. Backflush The Recirculation Flow Path To Remove Blocking Material From Sump Screens

   No evaluation or analysis required. The information contained in NUREG/CR-6808 provides adequate information to determine that this action should not be included in ERGs.

8. Vent Pumps That Have Become Air-Bound

   No advance analysis required. Plant Engineering Staff should perform ad hoc evaluations (based on existing radiation levels and availability of personnel) before venting pumps. Evaluate if specific instructions should be included in ERGs or added to evaluations performed by the Plant Engineering Staff.

3.2 Comparison to Licensing Requirements

3.2.a Stopping SI pumps may adversely affect fuel temperature limits. Stopping containment spray pumps may adversely affect containment pressure. Either action may adversely affect dose equivalents.

3.2.b Reducing recirculation flow by reducing SI flow may adversely affect fuel temperature limits. Reducing recirculation flow by stopping spray pumps may adversely affect containment pressure and the concentration of radioactive materials in containment. Either action may adversely affect dose equivalents.

3.2.c For applicable plants, use of non-safety-grade containment cooling units may violate equipment qualification limits. Actions already included in ECA-1.1 do not create any new challenges.

3.2.d Reducing spray flow in favor of core injection flow may adversely affect containment pressure and the concentration of radioactive materials in the containment. Non-standard sources of suction may challenge assumptions regarding reactivity control, iodine retention and corrosion conditions. Actions already included in ECA-1.1 do not create any new challenges.

3.2.e Actions to optimize available sources of flow create no challenges beyond those addressed in the items above.

3.2.f Actions to cool-down and depressurize the RCS have already been evaluated for ECA-1.1 and should not create any new issues with respect to licensing.

3.2.g Establishing an open path between the containment sump and the RWST presents a potential release path for radioactive materials. This potentially challenges offsite and operator dose equivalent standards.

3.2.h Venting pumps present a possibility of operator over-exposure and increased radiation releases. Plant Engineering Staff must evaluate these possibilities on an ad-hoc basis. This requires no advance evaluation against licensing requirements.

3.3 Risk Assessment

These actions are all contingent upon the operator diagnosing sump blockage. Therefore, instances where the operator does not diagnose sump blockage, he will not perform these actions.

There are eight contingency actions presented. Risk assessment of each is below.

1. Stop Pumps Experiencing Loss of Suction to Prevent Permanent Pump Damage

   This action is consistent with existing guidance. Additional operator actions will not be necessary. However, two situations exist. If the operator improperly diagnoses loss of suction, he may secure a normally operating pump. If the pumps are to be restarted then the risk of pump failure increases (pump failure to start is approximately an order of magnitude greater than failure to run over a given period of time). On the other hand, if the operator allows a pump to run while experiencing loss of suction, the pumps may be damaged, resulting in loss of core cooling. The impact on risk is expected to be highly negative.

2. Reduce Recirculation Flow to the Minimum Required to Support Design Basis or Critical Safety Functions

   Optimizing use of available sources of flow may increase RWST drain down time. However, alternate cooling systems may not be as reliable as ECCS. In addition, if the operator improperly reduces flow to less than that required to mitigate the accident, some success accident sequences in the PRA may result in failures. Thus, having a negative impact on PRA results.

3. Verify Containment Cooling Unit Operation to Minimize Cooling Demand for Containment Spray Flow

   Existing guidelines already address the actions and issues.

4. Establish Alternate Water Sources to Inject Into the Reactor Core and Spray Into Containment

   Alternate cooling systems may not be as reliable as ECCS for core cooling. It is assumed that pumps will be aligned for recirculation and switched over to draw from the RWST once an alternate cooling source has been aligned. This action will introduce a “pump fail to start” failure mode into the PRA model.

5. Optimize Use of Available Sources of Flow for Injection Into the Reactor Core and Spray Into the Containment

   Optimizing use of available sources of flow may increase RWST drain down time. However, if alternate cooling systems are used, they may not be as reliable as ECCS. In cases where flow throttling is considered, as long as thermal-hydraulic analyses support the use of throttling valves to reduce flow, there will be small impact on risk.

6. Cool-Down and Depressurize the RCS Using the Secondary System to Reduce Required Injection Flow to the RCS and Allow Placing the RHR System in Service

   Existing guidelines already address the actions and issues.

7. Backflush the Recirculation Flow Path to Remove Material From Sump Screens

   No evaluation required. The information contained in NUREG/CR-6808 provides adequate information to determine that this action should not be included in ERGs.

8. Vent Pumps That Have Become Air-Bound. Additional operator actions may decrease operator time to perform other actions

   Venting a pump may release radioactive materials. In a situation where containment pressure is high, LERF may increase.

The majority of the contingency actions are consistent with current procedure tasks (ECA-1.1 for Westinghouse, Monroeville plants). Explicit procedures for contingency actions in the event of sump blockage will increase the probability of establishing alternate RCS makeup sources and using the available sources wisely. Any additional procedure steps may decrease the time available for the operator to perform other tasks. In conclusion, guidance for contingency actions will be beneficial to risk in terms of priorities of actions and available alternatives.

3.4 Human Performance Evaluation

Human factors considerations dominate the decision to incorporate actions in response to sump blockage in existing procedures (ECA-1.1) or create a new procedure specifically for sump blockage (proposed ECA-1.3).

3.4.a Incorrect operator action may unnecessarily stop pumps needed to perform safeguards functions. The large number of parameters available to monitor for symptoms of loss of suction may increase operator response times, especially for completing manual actions for realignment to cold leg recirculation. Location and sequencing are important because operators must stop pumps for pump protection in a short time, especially for multi-stage high-head pumps.

3.4.b Incorrect operator actions may reduce flow below values required for safeguards functions. Since these actions are similar to those already included in ECA-1.1, the human performance should be similar.

3.4.c Existing procedures already include actions to verify containment cooling unit operation. Therefore, no new human performance issues arise.

3.4.d Existing procedures already include actions to establish alternate water sources. However, actions in response to sump blockage may differ from those of existing procedures (for example, spray pump suction from the sump and charging/SI pump suction from a refilled RWST). Therefore, human factors should be evaluated for potential errors in establishing or maintaining highly unusual system alignments.

3.4.e. Optimizing use of available sources of flow involves either complicated procedural evaluations or consultation with Plant Engineering Staff. Either process may produce highly unusual system alignments. Therefore, this action requires human performance evaluation.

3.4.f Existing procedures (especially ECA-1.1) already include actions that are identical or very similar to the proposed cool-down and depressurization. Therefore, no further human performance evaluation should be required.

3.4.g Backflushing the recirculation flow path is an action unique to these circumstances and different from any existing procedural guidance. Therefore, if ERGs contain this action, human factor performance evaluation should be required.

3.4.h Venting an air-bound pump requires restricted space entry to a potential very high radiation area and airborne contamination area. This requires significant preparation time and imposes high stress on personnel involved.

4.0 CONCLUSIONS/RECOMMENDATIONS

Continue current program for development of new generic guidance in response to sump blockage. This document does not specify the format for implementing responses to sump blockage (changes to existing ERGs, addition of new ERG, or new SBCRG outside the existing ERG system). The majority of the development group favors guidance outside the ERG system, since this enables implementation of interim guidance with minimum long-term changes to the ERG system. However, individual facilities should retain the option of placing this guidance within their Emergency Operating Procedures. In particular, facilities that have already implemented changes to their procedures should not be penalized for their proactive approach to this issue.

Each plant must consider the advantages and disadvantages as they apply to their plant specific design and incorporate any or all of these actions if it is determined to be risk beneficial with respect to containment sump blockage.

In general, the following contingency actions in response to sump blockage were determined to be advantageous:

a. Stop Pumps Experiencing Loss of Suction to Prevent Permanent Pump Damage

b. Reduce Recirculation Flow to the Minimum Required to Support Design basis or Critical Safety Functions

c. Verify Containment Cooling Unit Operation to Minimize Cooling Demand for Containment Spray Flow

d. Establish Alternate Water Sources to Inject Into the Reactor Core and Spray Into the Containment

e. Optimize Use of Available Sources of Flow for Injection Into the Reactor Core and Spray Into the Containment

f. Cool-down and Depressurize the RCS Using the Secondary System to Reduce Required Injection Flow to the RCS and Allow Placing the RHR System in Service

It is recommended that Item g (Backflush the Recirculation Flow Path to Remove Blocking Material From Sump Screens) not be implemented and no further work be performed.

Based on information in NUREG/CR-6808, backflushing the sump has significant negative impacts that may outweigh any potential benefits. Therefore, consideration of any such action properly belongs in Severe Accident Mitigation Guidelines rather than in Emergency Response Guidelines.

Item h (Vent Pumps That Have Become Air-Bound) is judged to be advantageous to most plants, but not appropriate for inclusion in the ERGs. This more appropriately belongs in the Plant Engineering Staff document or in background for Severe Accident Mitigation Guidelines.

A10 – Candidate Operator Action 10
Early Termination of One Train of HPSI/High-Head Injection Prior to Recirculation Alignment (RAS)

1.0 INTRODUCTION

NRC Bulletin 2003-01 requires that the utilities evaluate and implement compensatory measures to reduce the potential risk due to post-accident debris blockage as evaluations to determine compliance proceed. The bulletin directed utilities to consider a range of possible interim compensatory measures. Utilities may elect to implement those compensatory actions they deem appropriate, based upon the specific conditions associated with their plants. One possible interim compensatory measure included in the bulletin was, "procedural modifications, if appropriate, that would delay switchover to containment sump recirculation (e.g., shutting down redundant pumps that are not necessary …"

The purpose of this document is to evaluate an Emergency Procedure Guidelines (EPG) strategy change for early termination of high pressure safety injection (HPSI) prior to containment sump recirculation alignment. This evaluation is performed for the Combustion Engineering-designed plants only. This change is being evaluated to determine whether it can be used as an acceptable method to delay recirculation actuation signal (RAS) and thereby limit risk of containment sump blockage.

1.1 Related Existing Steps and Bases

CEN–152 Emergency Procedure Guidelines
Two major steps are affected:
1. Optimize SI (LOCA Step 5)
2. HPSI Throttle Criteria (LOCA Step 18)

As CEN-152 is currently written, the two major steps indicated above will not permit early termination of HPSI pumps prior to containment sump recirculation.

2.0 QUALITATIVE EVALUATION SUMMARY

2.1 Event Overview

2.1.1 Initial Plant Conditions

1. Unisolable LOCA in progress.

2. SIAS (Safety Injection Actuation Signal) has occurred, all systems respond as expected.

3. Refueling water tank (RWT) level has NOT lowered to recirculation actuation setpoint.

2.1.2 Sequence of Operator Actions if the Interim Compensatory Measure is Implemented

Not applicable. Preliminary determination is that this compensatory measure is not risk beneficial.

2.2 Advantages

2.2.1 Delay Recirculation Alignment

Recirculation alignment is automatically actuated at a specific low level setpoint as the RWT inventory is pumped into containment via the emergency core cooling system pumps and the containment spray pumps. The depletion rate of the RWT is a direct function of volume flow rate through the Emergency Core Cooling System (ECCS) pumps and containment spray pumps. Stopping one HPSI/High-Head Injection pump will delay recirculation actuation in direct proportion to the amount ECCS flow rate is lowered (i.e., RWT depletion rate lowered).

Current safety analyses assume only one operable HPSI pump throughout the loss-of-coolant accident (LOCA) event. Therefore, time to RAS will not change from significantly from current assumptions.

2.2.2 Reduce Debris Transport

The amount and size of debris collected at the containment sump screens is a function of screen size, the flow volume through the screens and the overall inflow to the containment sump. Greater volumetric flow is more likely to “sweep” debris to the containment sump screens and thereby increase the risk of blockage. Securing one HPSI pump reduces the total flow through the sump screens and thereby reduces the rate of debris transport to the screen surface and may reduce the risk of blockage. The flow contribution of one HPSI pump is relatively small compared to that of a containment spray pump (less that 1/10). However, any flow reduction may reduce the overall risk of sump blockage.

2.2.3 Preserve Operable HPSI Pump

Securing one HPSI pump provides additional assurance that the secured pump will not be damaged due to debris ingestion or loss of NPSH post RAS, thereby preserving one operable HPSI pump for later use.

2.3 Disadvantages/Potential Issues

2.3.1 Single Failure

Current safety analyses assume loss of one HPSI pump due to a failure of one diesel generator. The assumed failed diesel generator accounts for a “single active failure” as required by 10 CFR 50, Appendix A, General Design Criteria for Nuclear Power Plants.

Typical plant licensing bases show adequate core cooling with one LPSI pump and one HPSI pump before recirculation actuation. However, since deliberate manual securing of one HPSI pump is not considered a “failure,” licensees may be required to show acceptable consequences with failure of the running HPSI pump after manually stopping one of two HPSI pumps before recirculation actuation. Failure of the only running HPSI pump would mean an interruption of HPSI flow until the operator could restart the previously secured HPSI pump. Since current licensing analysis does not account for an interruption in HPSI flow due to single failure, plant specific 10 CFR 50.59 evaluation may be required to determine the acceptability of securing one HPSI pump after recirculation actuation.

2.3.2 Revise HPSI Stop Throttle Criteria and Bases

A significant change in the existing HPSI stop/throttle criteria and bases would be required In order to implement stopping one HPSI pump prior to RAS.

Typical PWR LOCA safety analysis assumes failure of one diesel generator and therefore relies on one train of HPSI to show adequate core cooling. However, if both HPSI trains are operating, the current EPGs provide "HPSI Stop Throttle Criteria" that must be met before securing one of the operating HPSI pumps. Current EPGs provide the following guidelines:

HPSI Stop Throttle Criteria
IF HPSI pumps are operating,
AND ALL of the following conditions are satisfied:

1) RCS subcooling is greater than [minimum RCS subcooling]

2) Pressurizer level is greater than [minimum level for inventory control] and NOT lowering

3) At least one steam generator is available for RCS heat removal with level being maintained or restored to [normal control band].

4) Reactor vessel level is greater than the [top of the hot leg nozzles]

THEN throttle HPSI flow or stop **ONE** HPSI pump at a time.

Current guidelines will not permit securing one HPSI pump unless all the above conditions are met. Conditions 1, 2, and 4 may not be met during a large break LOCA. Therefore, the current HPSI Stop Throttle Criteria must be revised in order to permit securing one HPSI pump prior RAS.

2.3.3 Throttling limitations on SI Injection Valves (Throttling vs. stopping one pump)

Some plants may have restrictions on how much they can throttle the SI injection valves because of the potential for valve seat blockage from small debris particles that make it through the sump screens.

3.0 REFERENCE PLANT ANALYSES/EVALUATION

3.1 Summary of Evaluation

Evaluations and Engineering Support

1. How does securing one train impact NPSH of pumps remaining in operation?

   Response:

   Securing one HPSI/High-Head Injection pump will have little effect on NPSH since pump suction is from the refueling water tank prior to recirculation alignment.

2. How does the proposed change impact operator response time evaluations?

Response:

In order for this action to be effective, the operator would have to secure one HPSI pump in the early stages of the event, prior to RAS. In general, the first 10-20 minutes of a significant LOCA event are dedicated to standard post trip actions, confirming emergency safety features actuations, and diagnosis of the event. In addition, plant conditions are changing at rapid rate as the event progresses. This is not a good time to secure an emergency core cooling pump (HPSI) until plant conditions are more stable and predictable.

3.2 Comparison to Licensing Requirements

Reference: NRC Memorandum To File, "Revised NRC Staff Responses To Three Industry Questions On Bulletin 2003-01 Submitted Prior To The June 30, 2003, Public Meeting," date: August 7, 2003

Prior NRC Review and Approval

A change to a facility, as defined by 10 CFR 50.59, must be evaluated against certain criteria enumerated in 10 CFR 50.59 to determine whether NRC review and approval is necessary prior to its implementation. The NRC staff believes that interim measures, such as securing a train of safety injection, may be risk beneficial for certain PWRs with potentially degraded recirculation sump performance. If a particular licensee finds that such an interim measure is risk beneficial for its facility and plans to implement the measure, the licensee is responsible for evaluating whether or not the criteria for prior NRC review in 10 CFR 50.59 are met. Whether or not a licensee determines that criteria in 10 CFR 50.59 are met depends on plant-specific configurations and analyses.

Consistency with Licensing Bases

Bulletin 2003- 01 does not intend for licensees to implement compensatory measures that invalidate their safety analyses. If an interim measure is inconsistent with safety analyses, licensees should either: (1) not implement the measure, or (2) revise the safety analysis (including NRC review and approval if required) and then implement the measure. To provide further clarification, a specific discussion of preemptive and responsive compensatory measures follows.

Preemptive compensatory measures are actions to reduce the risk of sump failure that would be taken prior to indications of degraded sump performance. This category includes actions that may be taken during the injection phase and/or recirculation phase (prior to indications of degraded sump performance) of an accident, such as reducing ECCS flows to values that remain above analyzed minimum rates, terminating high- pressure injection if not required, and shutdown of redundant equipment. Some preemptive measures may be consistent with the licensing basis for certain licensees. The implementation of other preemptive measures that may not be analyzed in the current licensing basis would require a revision to the licensing basis (and potentially NRC review and approval) prior to implementation. For any proposed change (as defined in 10 CFR 50.59), licensees are required to address the criteria in 10 CFR 50.59.

Responsive compensatory measures are actions taken to reduce the risk of sump failure or its consequences (e.g., loss of core cooling and/or loss of containment cooling) during the recirculation phase of an accident following indications of degraded sump performance and/or impending sump failure. As sump failure is not considered in plants' current licensing bases, it may be warranted for licensees to take appropriate actions in response to indications of likely sump failure, even if the actions are not analyzed in the current licensing basis. An example of such a responsive measure would be switching back to ECCS/containment spray system (CSS) injection following sump failure. The implementation of responsive measures may involve revisions to emergency procedures or guidelines, but it is not necessary to revise the Final Safety Analyses Report to include responsive measures for beyond- design- basis occurrences such as sump failure. Although licensees should evaluate any changes for risk benefit, this type of action typically does not require prior NRC approval.

3.3 Risk Assessment

Securing one HPSI pump may not significantly reduce coolant flow to the containment sump, due to the small flowrate from the pump. Therefore, debris transport to the sump screens may not significantly decrease. For the same reasons, RWST drain down time may not be significantly impacted. If it is required to restart the secured pump, an additional pump failure mode "pump fail to start" will be introduced in place of "pump fails to run." The probability of pump failure to start is approximately an order of magnitude higher than the probability of pump failure to run. Success accident sequences where one HPSI pump is available may become failure sequences if the running pump fails and the operator fails to start the secured pump. However, risk benefit may be achieved in situations where sump blockage occurs early in the sequence. Damage is prevented to one HPSI pump by securing the pump early, thus preserving a potential injection path for alternate cooling sources. Therefore, this operator action is expected to provide an overall risk benefit to the plant by preserving a HPSI pump.

3.4 Human Performance Evaluation

Early in a LOCA this action is thought to be counterintuitive. More generally, early in a major event, human performance is relatively error-prone. For this reason, automatic protection and plant design normally have been credited as adequate for maintaining plant safety without operator response in the first [20] minutes of design basis events. This reduces the probability of operator errors contributing to accident consequences. Thus, 10 CFR 50.54(x) notwithstanding, to add routine manual control actions early in an accident is generally not recommended.

The question about interruption in ECCS flow which may occur if one train is manually secured and the other train is lost through single failure results in a 50.59 concern and warrants safety analysis to ensure that the plant would remain protected (uninterrupted flow is now credited). In addition to the concern for the physical plant response, it should be noted that the need to manually restore the injection lineup delays downstream tasks and adds stress, contributing to error, and may worsen the original problem. Therefore, risk analysis also is needed to evaluate the impact of the proposed changes.

4.0 CONCLUSIONS/RECOMMENDATIONS

Securing on HPSI pump before transfer to recirculation is not considered risk beneficial due to the risk of core damage upon single failure loss of the one operating HPSI pump during a small break LOCA.

However, each plant must consider the advantages and disadvantages as they apply to their plant specific design and incorporate interim compensatory measures accordingly.

A11 – Candidate Operator Action 11
Prevent or Delay Containment Spray for
Small Break LOCAs (<1.0 Inch Diameter) in Ice Condenser Plants

1.0 INTRODUCTION

NRC Bulletin 2003-01 requires that the utilities evaluate and implement compensatory measures to reduce the potential risk due to post-accident debris blockage as evaluations to determine compliance proceed. The bulletin directed utilities to consider a range of possible interim compensatory measures. Utilities may elect to implement those that they deem appropriate, based upon the specific conditions associated with their plants. One possible interim compensatory measure included in the bulletin is "procedural modifications, if appropriate, that would delay the switchover to containment sump recirculation (e.g., shutting down redundant pumps that are not necessary to provide required flows to cool the containment and reactor core, and operating CSS intermittently)."

This candidate operator action (COA) proposes to prevent or delay the initiation of containment spray for ice condenser plants. Securing containment spray (one or both trains) once it is actuated is addressed in COA 1. The COA 1 evaluation would appropriately apply to both dry and ice condenser containments, with the only caveat that ice condenser containment designs may require more attention by the operators since there may be a containment pressure increase following depletion of ice condenser heat removal capability.

The purpose of this report is to evaluate the feasibility and appropriateness of preventing or delaying automatic actuation of the containment spray system for ice condenser plants.

For those proposals that are found to be acceptable, the program will develop generic technical information and implantation guidance to support preparation of the Emergency Response Guidelines (ERG) technical bases and to assist the utility in implementing the guidance in their Emergency Operating Procedures (EOPs) as they deem appropriate, based upon the specific conditions associated with their plants. Implementation of the EOPs includes training of the operators in use of the modified EOPs.

2.0 QUALITATIVE EVALUATIONS

2.1 Advantages

This action can reduce the probability of sump blockage. The step will reduce the flow rate demand on the refueling water storage tank (RWST) inventory and thereby both delay recirculation actuation signal (RAS) and, once switchover has occurred, reduce recirculation flow rate as long as spray is secured. The delay to the onset of RAS by preventing spray is expected to be several hours. This delay permits greater debris settling within containment and also represents a lower decay heat level at the time of RAS, thus reducing risk. Additionally, should spray not be subsequently required based on adequate heat removal via the ice condenser system, fan coolers or decay heat removal via steam generators or residual heat removal (RHR), then the debris that may normally have been transported to the sump via the spray flow drainage paths would be excluded from the debris volume.

Once RAS has occurred, if containment spray remains secured, the flow through the containment sump will be dramatically less (in excess of a factor of 10 for a small break). This will reduce the differential pressure across the sump cage resulting from debris buildup on the cage and increase net positive suction head (NPSH) available to safety injection pumps.

2.2 Disadvantages/Potential Issues

Preventing or delaying containment spray by revising plant logic or actuation setpoint (for example changing actuation logic or using rate of containment pressure increase) requires not only changes to licensing documentation including technical specification but also physical changes to the plant. In particular reanalysis of containment response to design basis events both in the short and long term. This action has potential for success in the short term, however, subsequent actuation of the spray system upon ice depletion requires plant specific analysis based on the capacity of the operating heat removal systems. A revision to plant logic and/or actuation setpoints to effect blocking of spray actuation is considered beyond the scope of the ERG compensatory actions, but may be considered as a component of the licensee's response to NRC Bulletin 2003-1 with plant specific analysis. Such a change requires either a complete revision of the analysis of record within the licensing documentation or a violation of the current licensing design basis. The first is beyond the scope of this program and the second is contrary to the program criteria.

If the break is small, yet the automatic actuation of spray occurs early in the event (setpoints are very low for ice condenser spray systems – 2.0 to 3.0 psi), then the operator will not have time to prevent or delay actuation. In this scenario, the best approach is implementation of COA 1 "Secure one or two containment spray pumps before recirculation alignment."

If the break is sufficiently small to allow the operator time to assess the need for spray and allow time to prevent or delay containment spray, the effect of the actions required are again essentially the same as COA 1. It is however likely a conflict of licensing criteria to preclude or block automatic actuation of safeguards function.

Actuation logic for containment spray is potentially designed such that once the actuation setpoints are attained, the operator cannot prevent actuation from the control board. Once actuated however, the operator is likely able to reset containment spray actuation and then proceed in a manner consistent with COA 1. Logic must be reviewed on plant specific basis.

For a small break in this range the most likely scenario is that SI termination would be met prior RWST switchover (1 to 2 hours) and the heat removal would continue via the steam generators and subsequently via normal RHR operation.

3.0 REFERENCE PLANT ANALYSES/EVALUATION

3.1 Summary of Analyses Performed

No generic analyses have been performed. Plant specific analysis would be required to evaluate the potential for the delay of spray start given available specific containment heat removal mechanism but equally as critical incorporating plant specific instrumentation or actuation logic or time available for operator response to initiate spray upon ice melt.

3.2 Comparison to Licensing Requirements

Blocking automatic safeguards actuation or revision of actuation logic under existing design basis documentation would be considered a violation of licensing criteria. Revision of the actuation setpoints requires revision to licensing documentation and a 10 CFR 50.59 evaluation with accompanying reanalysis of containment transients with the new actuation setpoint included.

There is no conflict with existing licensing criteria for termination of a single train of containment spray. Justification may be required in the event of the failure of the single operating pump or termination of both containment spray pumps under COA 1.

3.3 Risk Assessment

Containment spray is not a risk significant system. Containment design pressure is conservative and some margin exists in PRA space. Pressure will not increase to containment failure in the event of an accident. Due to Containment Spray being a non-risk significant system, any change in procedures will not have a significant impact on plant risk. However, benefits will be achieved, particularly for small breaks (small loss-of-coolant accident (LOCA), stuck open power operated relief valve (PORV), steam generator tube rupture (SGTR), main steam line break (MSLB) Inside Containment), by increasing the time for manual actions at RAS. With larger break sizes the time to RAS is already short; thus, time for manual actions is short, with an insignificant increase due to securing one train of containment spray. In conclusion, while some risk benefit may be gained for small break (or equivalent) accidents, because containment spray is a non-risk significant system the overall assessment is that this COA is risk neutral.

3.4 Human Performance Evaluation

From an human factors perspective, changes to the timing or criteria for securing CS pumps are reasonable, since the task is already familiar, and since compensating factors may exist for any increased demands on the operator. This is similar to COA 1 and is unchanged for COA 11. When applicable event conditions have stabilized or improved, it is a familiar operator task to secure CS pump(s) after automatic actuation. However, early in a LOCA, the probability of human error on any given task is assumed to be raised by stress. Also, added manual actions will delay downstream ERG steps (nominally 1 minute per manipulation, per ANSI/ANS-58.8, with the number of manipulations TBD). However, since the proposed action may only be plausible for smaller LOCAs, more time may be available for manual action. To detect failure of the running CS pump and then to restart the available pump also adds some operator burden and another error opportunity (though the risk is mitigated by non-safety containment fan coolers and by Safety Function Status Checks.)

4.0 CONCLUSIONS/RECOMMENDATIONS

Implementation is not recommended as a change to the Emergency Response Guidelines and no further generic work is required. Licensees may determine based upon the potential for debris related concerns, as well as enhancing the Ice Condenser Plant’s response to smaller break LOCA, that it is advisable to implement logic changes to prevent automatic initiation of containment spray until ice melt. In depth plant specific analysis and licensing reviews would be required.

COA 1 provides appropriate response to small break LOCAs without plant specific analysis for actuation blockage.

APPENDIX B
LOCA ANALYSES IN SUPPORT OF RESOLUTION OF THE SUMP BLOCKAGE ISSUE

B.1 INTRODUCTION

Best estimate LOCA analysis was performed using the RELAP5 computer code to determine the impact of potential actions aimed at minimizing debris generation within the containment and delaying the switchover to containment sump recirculation following a LOCA. These actions include shutting down redundant safety injection (SI) pumps that are not necessary to provide the required flows for the cooldown of the reactor core.

The objective of the analysis is to quantify the impact on the LOCA consequences of shutting down selected number of high pressure (HP) and low pressure (LP) SI pumps, including shutting down of all HPSI and LPSI pumps. Shutdown of all SI pumps is postulated for those scenarios for which the operator shuts off flow from one train of the SI system and a single failure causes the shutdown of SI flow from the other SI pumps as well.

B.2 RELAP5 DATABASE

Best estimate assumptions are used in setting up the RELAP5 database. Of primary importance to the LOCA event are: (1) the safety injection flow rate as a function of RCS pressure, and (2) the decay heat level. Unlike the Appendix K LOCA analysis, the best estimate analysis uses the maximum available SI flow rates and realistic decay heat levels as proposed by the ANS 1979 Standard.

Values for other plant design and operating parameters are assumed to be the same as those for the licensing analysis, since the impact of these changes are not expected to be as large as for the SI flow rates and the decay heat levels.

The 2700 MWt Millstone Unit 2 plant was modeled in the analysis. The plant was modeled using the node/flow path arrangement in RELAP5. Normal initial plant operating conditions (i.e., no conservative biases on parameter values) were assumed in the analysis.

B.3 ACCIDENT SCENARIOS ANALYZED

The following LOCA scenarios were analyzed using the RELAP5 computer code in support of the resolution of the sump blockage issue.

- Case 1: Large break LOCA with full SI flow (both trains operating, no single failure) analyzed for a 1500 seconds duration to generate baseline LOCA results using RELAP5.

- Case 2: Large break LOCA with full SI flow (both trains operating) and shutoff of all SI flow at 10 minutes. This case simulates the LOCA scenario for which operator shuts off SI flow from one SI train (1 HPSI and 1 LPSI pump) with a single failure causing a loss of the SI flow from the other train as well.

- Case 3: Large break LOCA with manual shutoff of one LPSI pump in one SI train at 10 minutes with a single failure causing SI flow from the other SI train (1 HPSI and 1 LPSI pump) to be shutoff. Effectively, after 10 minutes flow from only one HPSI pump is available to the RCS for this scenario.

- Case 4: Large break LOCA with manual shutoff of one HPSI pump in one SI train at 10 minutes with a single failure causing SI flow from the other SI train (1 HPSI and 1 LPSI pump) to be shutoff. Effectively, after 10 minutes flow from only one LPSI pump is available to the RCS for this scenario.

- Case 5: Large break LOCA with SI flow from only one SI train (1 HPSI and LPSI pump) from the start of the event under the assumption of a single failure (Diesel generator failure) that shuts off flow from one SI train. At 20 minutes, flow from the LPSI pump is turned off and at the same time the HPSI pump is assumed to have failed, leading to no safety injection flow to the RCS. The objective of the case is to determine the time available to the operator to restore SI flow using the LPSI pump that was manually shut off.

- Case 6: Large break LOCA with SI flow from only one SI train (1 HPSI and LPSI pump) from the start of the event under the assumption of a single failure (Diesel generator failure) that shuts off flow from one SI train. At 30 minutes, flow from the LPSI pump is turned off and at the same time the HPSI pump is assumed to have failed, leading to no safety injection flow to the RCS. The objective of the case is to determine the time available to the operator to restore SI flow using the LPSI pump that was manually shut off. Case 6 is similar to Case 5, except that the LPSI pump is shutoff at 30 minutes instead of at 20 minutes.

- Case 7: Large break LOCA with SI flow from both SI trains (2 HPSI and 2 LPSI pumps providing flow) from the start of the event under best estimate assumption. At 25 minutes a recirculation actuation signal (RAS) is assumed to be generated on low refueling water storage tank (RWST) level. At this time SI flows from both LPSI pumps and one HPSI pump are assumed to be terminated per emergency operating procedures (EOPs). Flow from the remaining HPSI pump is assumed to be delivering SI flow to the RCS. This flow is assumed to be terminated at about 15 minutes from the time of RAS generation (total of 40 minutes from the initiation of the LOCA event). This action would stop all SI flow into the RCS. The objective of the case is to determine the time available to the operator to restore SI flow to preclude the clad temperature turn around due to the core heatup from decay heat.

B.4 LOCA ANALYSIS RESULTS

The results of the preliminary analysis are provided in terms of the core temperatures. These temperatures are calculated for the clad surface in four separate regions of the core. The bottom most region temperature is designated as “Temp 1,” with the top most region having a designation of “Temp 4.” In between region temperatures are marked as “Temp 3” and “Temp 4”.

Typical clad temperature variation for the base case (Case 1) is shown in Figure B-1. It shows blowdown and reflood peak temperatures for the top most (Temp 4) region. Following the occurrence of the peak values the clad temperature reaches an asymptotic value that is less than 400°F as the core region is fully covered by the SI fluid and the decay heat that decreases with time as well as sensible heat is removed via the break.

Graphical results for Case 2 are provided in Figure B-2. It shows the variation of the clad surface temperatures from 800 seconds to about 1280 seconds after the initiation of the event. Within this time frame the higher elevation region temperatures (Temp 2, Temp 3, and Temp 4) sharply increase due to the lack of SI flow. For region 3 (Temp 3) the temperature rises to about 1500°F within this period. Since these temperatures are rising very rapidly, it is expected that the clad temperature could exceed the acceptance criterion for licensing analysis within a few minutes, thus significantly compromising the capability of the operators to take timely mitigative actions.

Clad temperature variation for Case 3 is shown in Figure B-3. For this case, all SI flow except that from one HPSI pump was shutoff at 10 minutes. It shows that the clad temperature for the top most region sharply increases at about 1160 seconds. This indicates insufficient SI flow to the RCS as a result of the use of only one HPSI pump.

Case 4 results provide the clad temperature impact for all SI flow shutoff scenario except that from one LPSI pump at 10 minutes. Figure B-4 shows that the clad temperature continues to decrease in the long term with no sharp increases or decreases. The SI flow from one LPSI pump appears to be more than adequate to keep the core covered and remove the decay heat and sensible heat. Note that the SI flow from one LPSI pump is significantly larger than that from the HPSI pump.

The results for Cases 5 and 6 show the impact of the timing of LPSI pump shutoff on the peak clad temperature. LPSI shutoff at 20 minutes into the event provides only about 400 seconds time span before the clad temperature begins to increase due to the absence of SI flow as shown in Figure B-5. Results of Case 6, for which SI flow is shutoff at 30 minutes, indicate that the clad temperature does not increase for up to 600 seconds (10 minutes) as seen from Figure B-6. Thus, it appears that the time available for operator action (to restart one LPSI pump) increases considerably by delaying the shutoff of the SI pump by 10 minutes.

The results of Case 7 show the impact of the HPSI flow shutoff 40 minutes (15 minutes after RAS generation) after the initiation of the LOCA event. Figure B-7 illustrates the clad temperature variation at the limiting axial location (region 4) for this case. It shows that following the blowdown and reflood peaks, the clad temperature settles around 280°F due to the significant SI flow to the RCS and the decreasing core decay heat. The core is covered with coolant at this time (either single phase liquid or two phase mixture). Subsequent to shutoff of SI flow from both LPSIs and one HPSI (leaving one HPSI to provide injection flow) on RAS, the void fraction slightly increases. However, the clad temperature continues to decrease due to: (1) decreasing decay heat levels, and (2) higher heat transfer coefficient due to increased nucleate boiling. This behavior continues even after all SI flow is shutoff at 40 minutes from event initiation. However, with no SI flow, the upper regions of the core begins to experience core uncovery and liquid deficient heat transfer. This leads to rapid increase in the clad temperature at about 15 minutes after the shutoff of all SI flow (55 minutes after the initiation of the LOCA event) as seen from Figure B-7. If all SI flow were to be shut off later than the 40 minutes used for Case 7, it is anticipated that the rapid rise in clad temperature would probably take place later than the 15 minute time interval realized for this case, due to the decreasing core decay heat with time.

B.5 CONCLUSIONS

The clad surface temperatures would reach unacceptable values if all SI flow is shutoff for about 10 minutes and is not turned back on within this time frame. This is a very short time for relying on plant operators under stressful conditions to restart the SI flow so as to bring the core temperatures down to acceptable values.

A better approach may be to shut off one HPSI or one LPSI pump flow to gain some benefit from the reduced SI flow on delayed recirculation and debris generation. Results of Case 3 and Case 4 indicate that the preferred approach would be to turn off the HPSI pump as this leaves on LPSI pump to provide adequate SI flow and leads to no increase in the clad temperature.

Shutting off all SI flow immediately prior to the generation of the RAS leads to an increase in the clad temperature with time. However, delaying the SI shutoff time appears to yield longer operator action time (to restart LPSI pump) before the clad temperature begins to turn around and rise.

Results of Case 7 support the conclusion that as much as 15 minutes operator action time is available to restore SI flow for the best estimate case that uses both SI trains initially, uses only one HPSI following RAS, and shuts off all SI flow at 40 minutes into the transient. This time is expected to be longer if shutoff of all SI flow occurs later than this time, due to the decreasing time dependent decay heat levels.

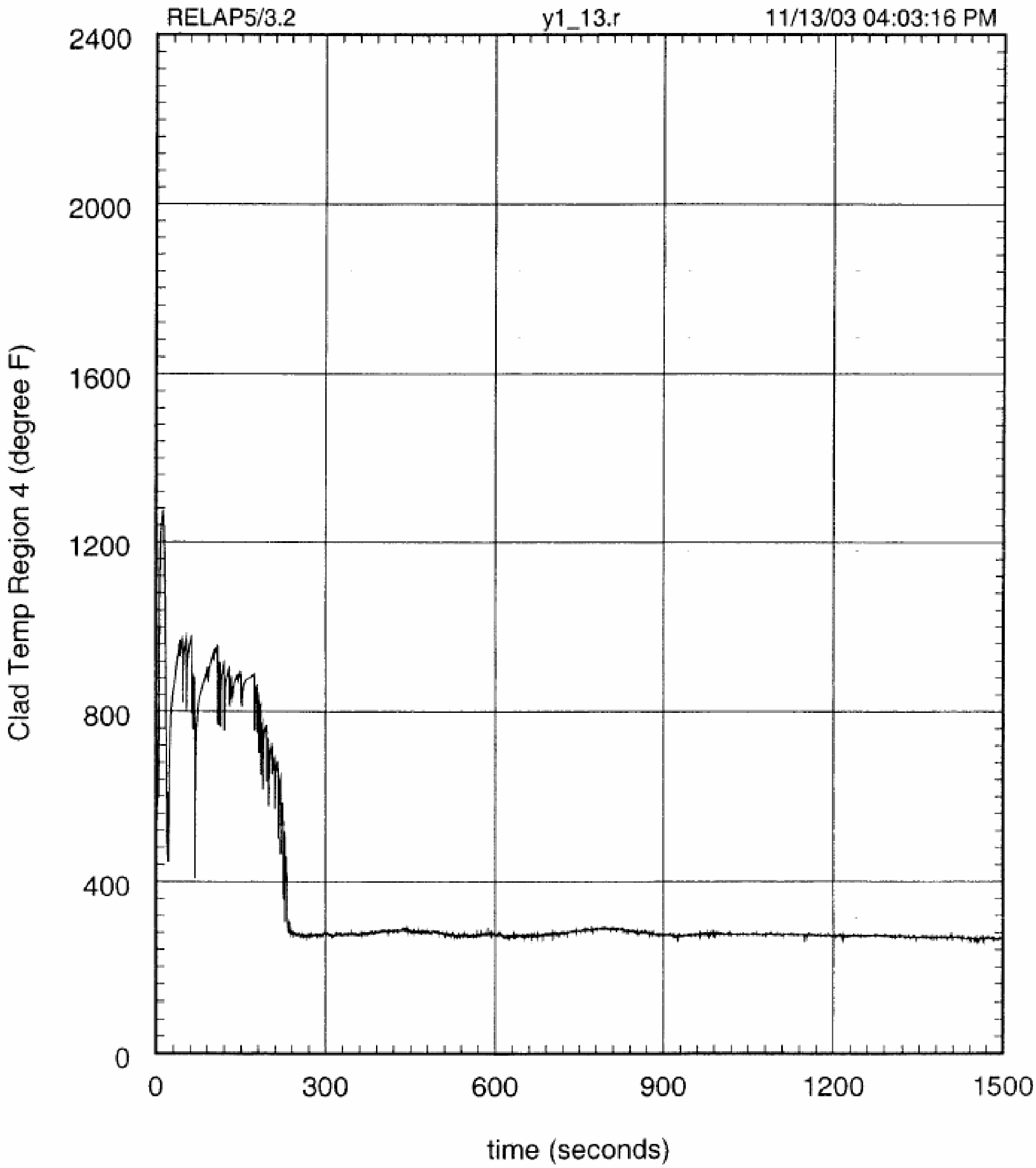


Figure B-1 Clad Temperature Variation for the Base Case (Case 1)

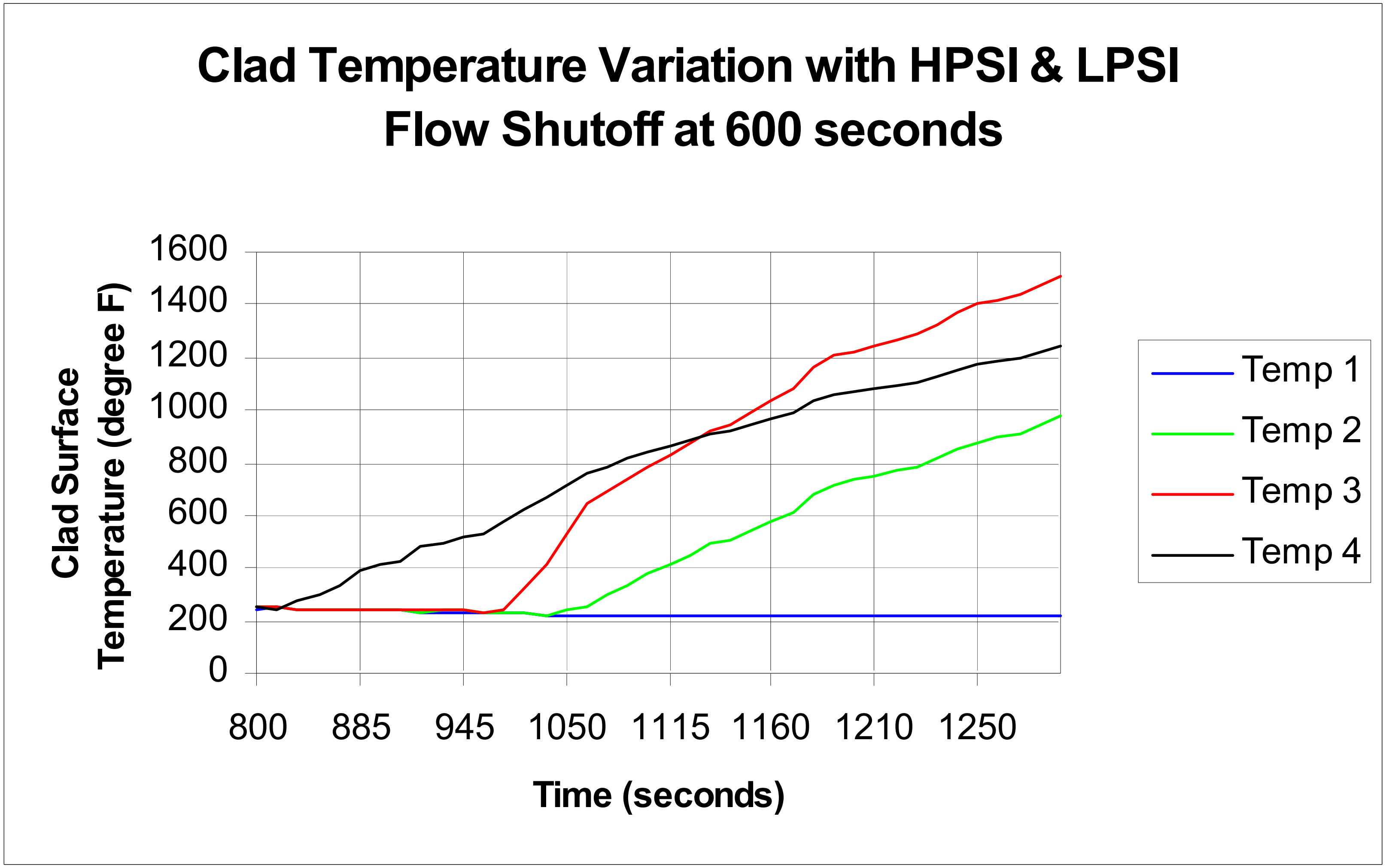


Figure B-2 Clad Temperature Variation for Case 2

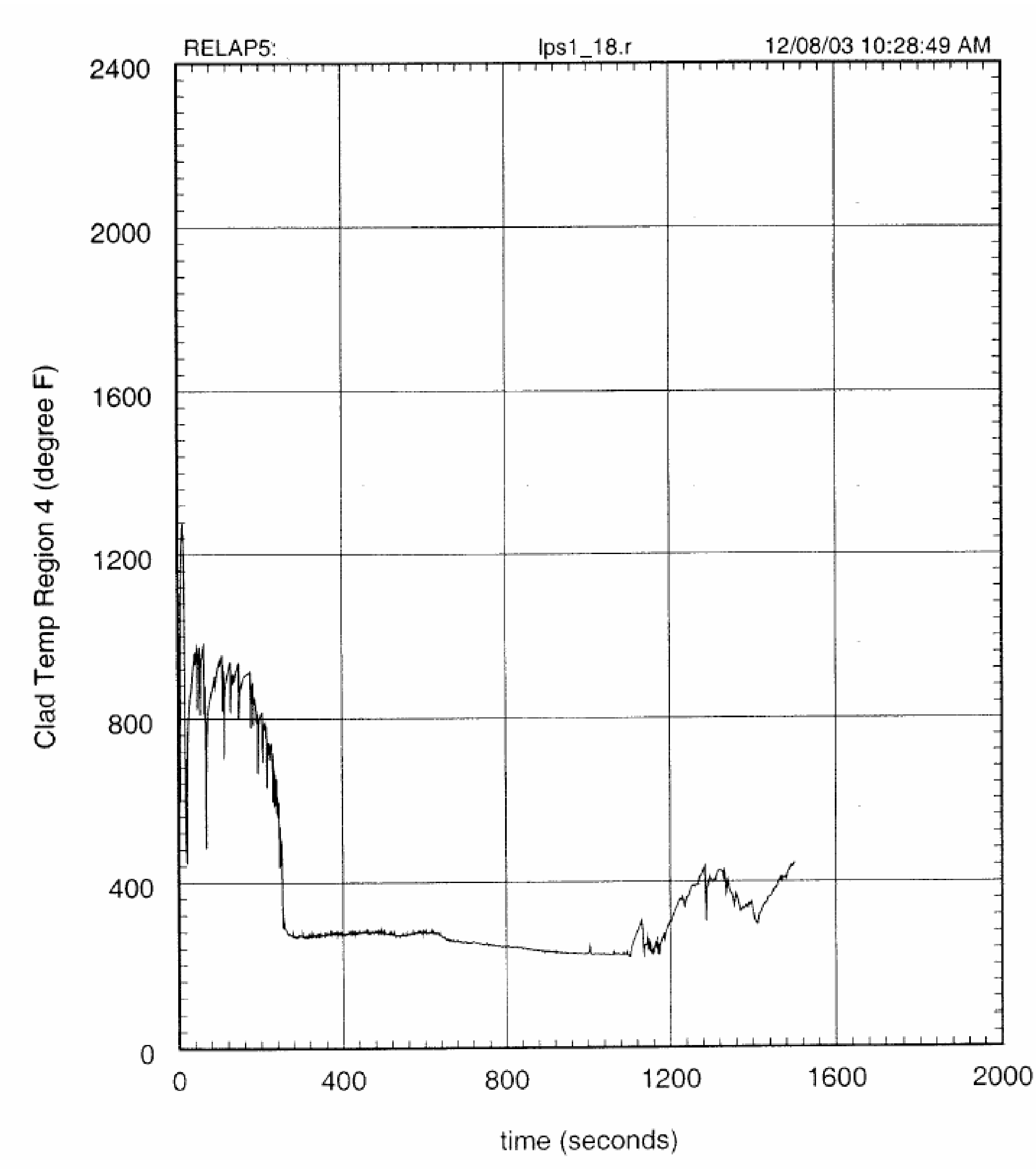


Figure B-3 Clad Temperature Variation for Case 3

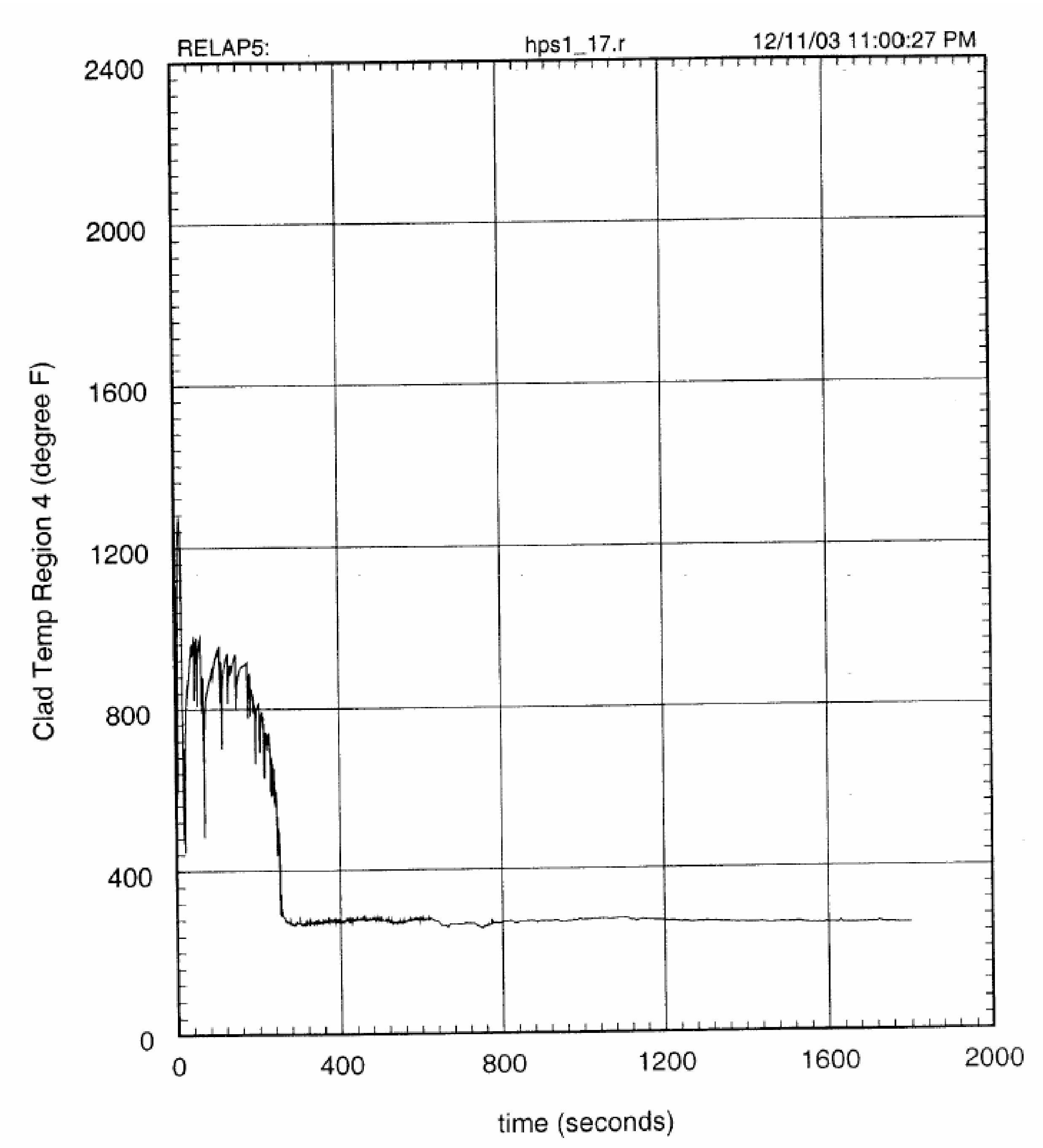


Figure B-4 Clad Temperature Variation for Case 4

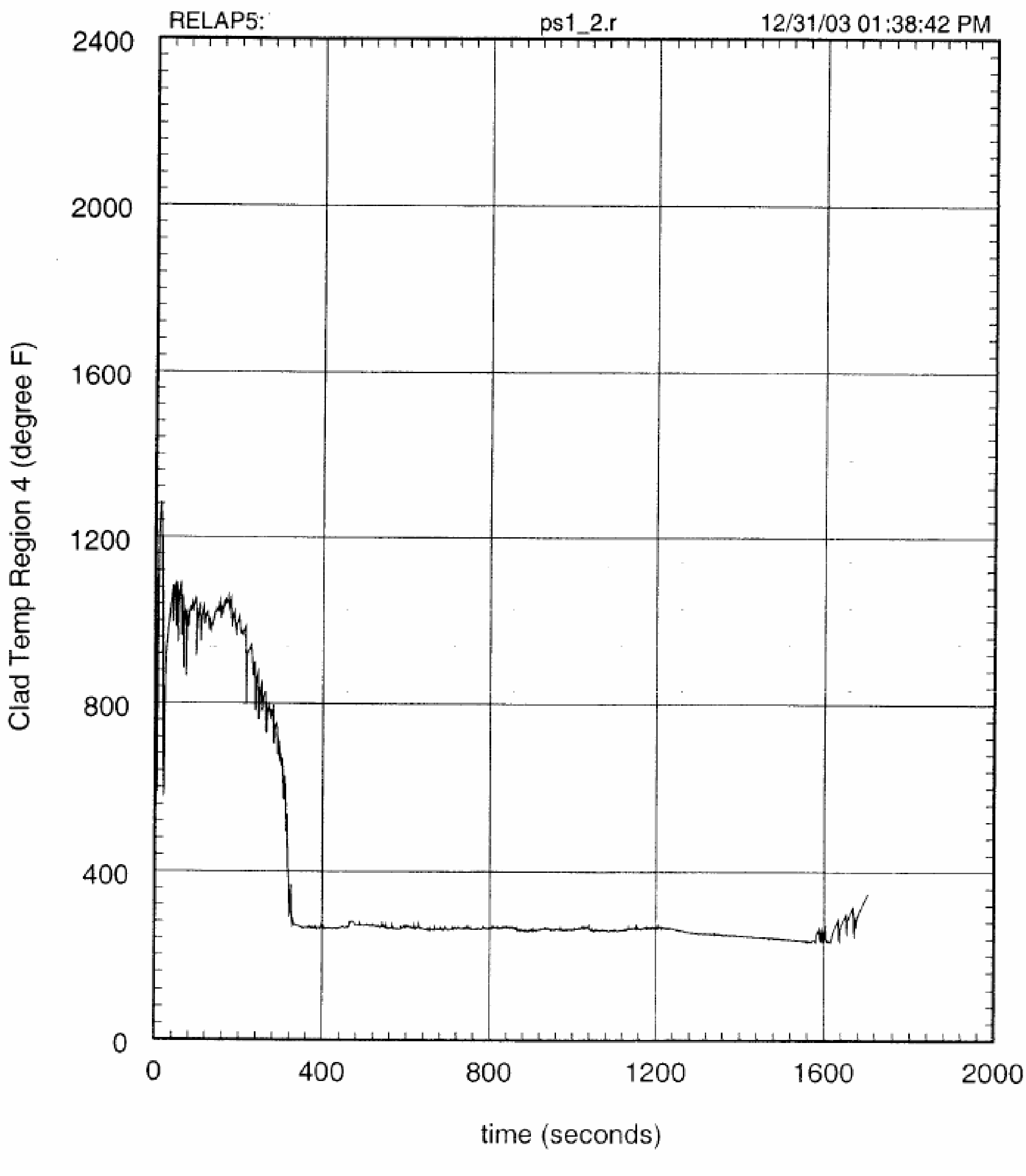


Figure B-5 Clad Temperature Variation for Case 5

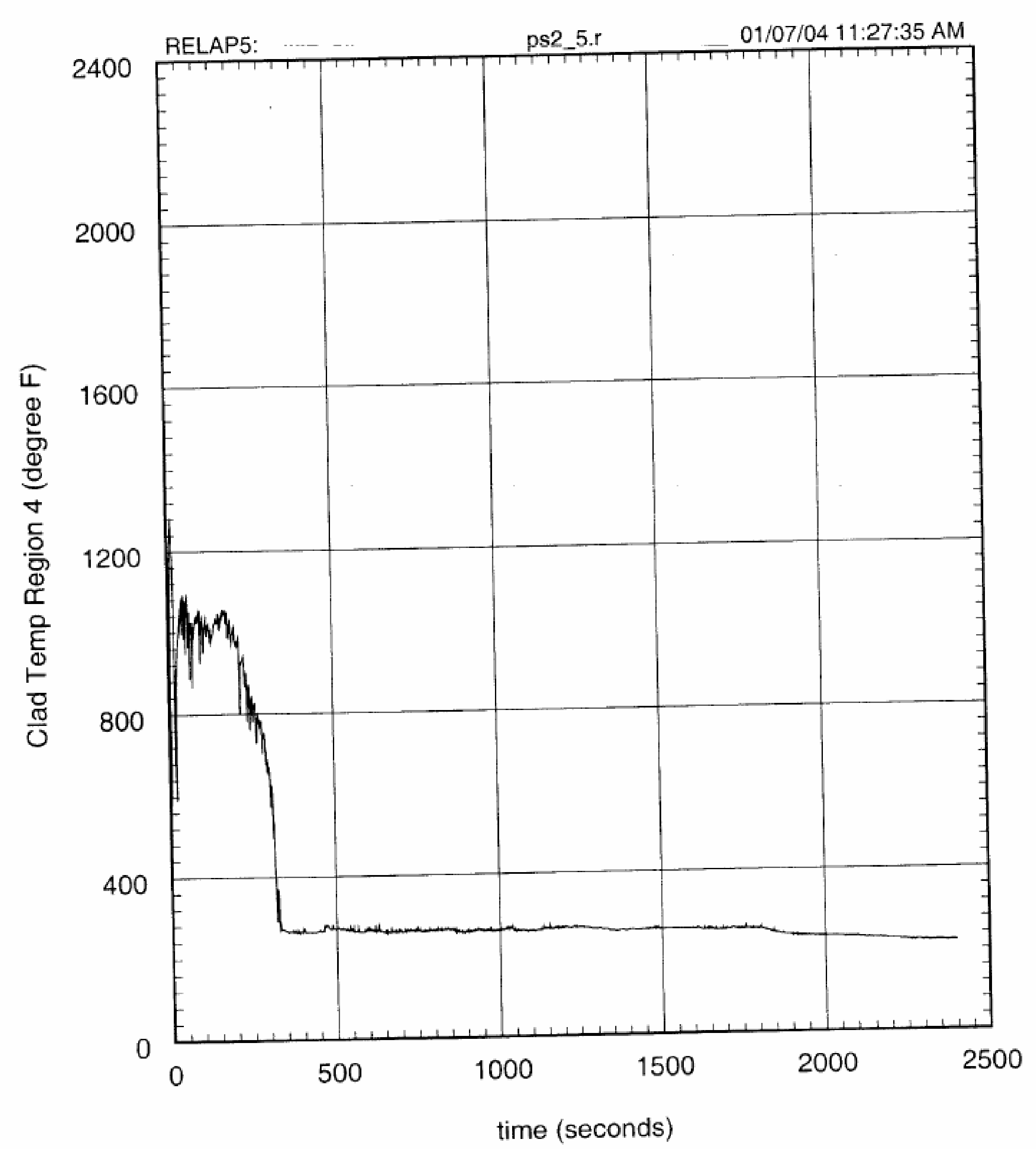


Figure B-6 Clad Temperature Variation for Case 6

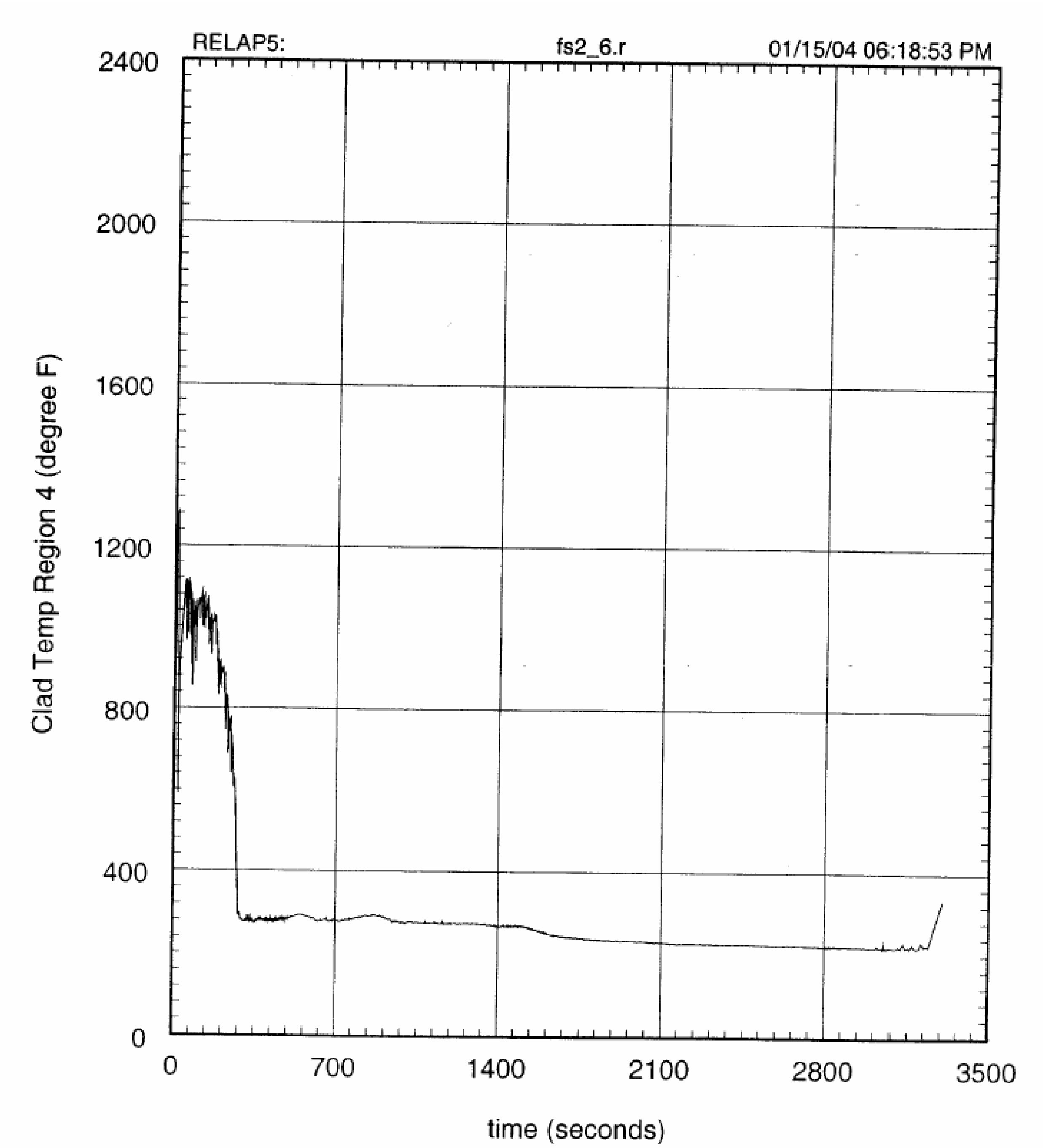


Figure B-7 Clad Temperature Variation for Case 7