EA-07-047

Response to Open Issues from HCV-345 Regulatory Conference

The attachments address the three open issues that were raised during the HCV-345 regulatory conference on April 16, 2007. The issues related to: (1) use of cognitive events for the quantification of the human failure events; (2) additional bases for some of the performance shaping factors associated with the human failure events; and, (3) the fire risk assessment methodology, particularly the treatment of hot shorts.

One attachment is a revised Scientech report, prepared in collaboration with OPPD PRA staff, addressing the first two issues. Two human failure events were presented at the regulatory conference: HPSIFLOW, "Human Failure to Increase HPSI Flow on Loss of RCS Inventory", and XSPRAYVALVE, "Operator Fails to Respond to Open CS Valve". There was discussion during the conference regarding dependency between the two human failure events, and regarding the use of a common cognitive analysis applicable to both. As is typically the case with human reliability analysis (HRA), there is more than one valid analytical approach. Using more than one approach also helps to bracket the uncertainty associated with HRA. The recommended human error probability from this report is 1.63E-05, compared with 3.37E-05 that was presented at the regulatory conference.

The other attachment addresses the third issue regarding fire. It provides additional information concerning fire methodology and the treatment of hot shorts.

Please contact Alan Hackerott at (402)533-7276 if you would like more information.

Additional Fire Perspectives for HCV-345 Containment Spray Valve
{Provided by OPPD}

April 23, 2007

A white paper entitled "External Event Perspective Regarding Improper Positioning of Containment Spray Header Isolation Valve HCV-345" was provided for consideration during the April 16, 2007 regulatory conference. The following information addresses questions raised at the regulatory conference with regard to fire methodology and the treatment of hot shorts.

IPEEE Fire PRA Methodology

The fire areas in Table 5 of the white paper were based on a review of fire initiating events that fail component cooling water, but result in the survival of systems required to achieve cold shutdown (e.g., instrument air, residual heat removal, and raw water). The methodology chosen for the IPEEE fire analysis follows the EPRI Report, Project 3385-01, Fire Risk Analysis Implementation Guide (DRAFT), January 1994, which consists of a sequential approach involving increasingly detailed analysis to identify significant fire areas. The process provides focus on the significant fire areas and issues through a graded approach. The criteria for screening as provided by the EPRI Fire Risk Analysis Implementation Guide are:

1. The impact of a fire in a particular area would not result in a plant trip
2. The total core damage frequency is less than 1.0E-7
3. The conditional core damage probability is less than 1.0E-4 (For conservatism, OPPD chose to use 1.0E-5)

Initially, the FCS Fire PRA conservatively assumed that all postulated fire events result in complete failure of all equipment and circuits located within their respective fire area. Screening criteria was applied and additional refinements including the crediting of hot shorts at values of less than 1.0, human recovery analysis, and, in a few cases, the performance of detailed fire impact analysis for a particular fire area were performed until the fire area either screened, or until unreasonably large results were eliminated in an effort to discover the true fire insights for our station.

Determination of Fire Areas Involving Loss of CCW

Hot shorts were modeled in the IPEEE using a value of 0.06 from the EPRI Fire Risk Analysis Implementation Guide. Fire scenarios were screened if they had a conditional core damage probability of less than 1.0E-5 or a core damage frequency of less than 1.0E-7. The quantification of these fire area scenarios included random failures, fire induced failures and normal maintenance unavailabilities. Based on this methodology only the scenarios identified in the Table 5 of the white paper resulted in a loss of component cooling water without impacting raw water, residual heat removal, or instrument air.

Determination of Impact on CDF

The CDF contribution from fires in Table 5 gives no credit to hot short probabilities nor to the random failures of components not affected by the fire. It is simply a compilation

of the sum of the initiating event frequencies for the fire areas where component cooling water could be lost by a fire without affecting raw water, residual heat removal, or instrument air. It is assumed that CCW failure by hot short or other fire induced failure occurs at 100% likelihood. The human failure probability was raised by a factor of 10 in this simple relationship in order to account for an additional burden brought on by a fire. This presents a reasonable and conservative estimate of the impact of fire on this scenario.

SCIENTECH®

REF: SEA-JFG-07-005
April 23, 2007

Mr. Alan Hackerott
Mail Stop FC-2-4
Omaha Public Power District
444 So. 16th Street Mall
Omaha, NE 68102-2247

Subject: **HRA Review Comments and Recommendations on OPPD HCV-345 Mispositioning SDP, Revision 1**

Dear Mr. Hackerott,

Please find attached a letter report documenting a revised review of the Human Reliability Analysis aspects of the Significance Determination Process case for the Ft. Calhoun HCV-345 valve mispositioning event.

An initial review was provided in SEA-JFG-07-004. However, in response to discussions between OPPD and the NRC, the human reliability analysis was updated to address the NRC's request for additional information. In particular, this report adds individual diagnoses for the XSPRAYVALVE and HPSIFLOW human failure events, expands discussion on the basis for PSFs assigned and revisits the dependency analysis. This review resulted in improved estimates of the joint human error probabilities.

It has been a pleasure working with you and your staff on this task. I look forward to working with you on future projects.

Sincerely,

Jan F. Grobbelaar
Senior Consulting Engineer

Attachment

1 Purpose and Scope

This report documents the review of the significance determination process (SDP) case [2, 3] for the Ft. Calhoun HCV-345 valve mispositioning event [1] with specific reference to the human reliability analysis (HRA) aspects. The objectives of the review are:

- Review of OPPD worksheets (mostly HRA worksheets) and making recommendations to improve the SPAR-H [6] worksheets, if appropriate
- Providing a separate analysis (documented) regarding alternative success paths (closing valves or initiating flow) and dependency between the actions that would be required
- Providing a final, independent conclusion that supports the OPPD position, if possible.

The scope of the review is to consider the major elements of the HRA in the SDP case. The review will apply the SPAR-H [6] methodology, which would facilitate interpretation and comparison by the NRC. SPAR-H [6] is understood to be a simplified method that provides conservative results, which would be bounding. Should a less conservative analysis be required, this could be accomplished using the EPRI methods [7] and THERP [8].

The HEPs in this report are point estimates and the number of reported digits is for traceability only and should not be regarded as significant figures.

Thermal-hydraulic analyses and timing analyses are excluded from the review. The review does not focus on format, typography etc.

2 Conclusions and Recommendations

1. A joint human error probability (HEP), with due consideration for dependencies, of 1.63E-05 is recommended as a reasonable and defensible HEP for LOCA initiators.
2. A joint human error probability (HEP), with due consideration for dependencies, of 1.79E-08 is recommended as a reasonable and defensible HEP for transient initiators. The difference between the transient and the LOCA HEPs is due to the fact that with transient initiators, the operators would have an opportunity to detect the flow diversion prior to opening the SDC suction isolation valves and could therefore avoid causing a LOCA.

3. The initial OPPD submittal to the NRC was based on a single operator action and a single human error probability (HEP). It is important to distinguish that there are more than one success path and therefore more than one operator error is required for overall failure. Given the time available for recovery, more than one operator action can be credited with due regard for dependency.
4. The individual HEP analyses were reviewed and are presented in revised form in this report.
5. A new HEP analysis was performed for early detection of the flow diversion during filling and venting of the SDC system.
6. The OPPD analyses contain all the required HRA elements, except for the integration of the HEPs into a joint HEP and a dependency analysis, which is presented in this report.

3 Introductory Overview

The "Severe Accident Perspective" OPPD analysis [2] credits an operator action (XSPRAYVALVE) for success based on recognizing the symptoms of a loss of coolant accident (LOCA) and closing the SDC isolation valve HCV-348 or HCV-347, or HCV-335 upstream of the SDC heat exchangers. The closing of these SDC isolation valves is a recovery action which is appropriate in terms of the ASME PRA Standard [4] supporting requirements HR-H1 and HR-H2. The initial OPPD evaluation of the HEP for this action is 6E-05 per Attachment D of Ref 2. The NRC evaluation of this HEP is 4.1E-04 per Attachment A2 of Ref. 1. The "HCV-345 Mispositioning Event" OPPD analysis of the HEP for this action is 4E-05 per Appendix A of Ref. 3. This OPPD evaluation also includes an evaluation of an HEP of 4E-05 for failing to increase HPSI flow on loss of RCS inventory (HPSIFLOW). The event tree in Figure 3 of Ref. 3 shows that both operator actions (isolate SDC, increase HPSI flow) must fail to lead to core damage (CD), which is appropriate. However, the conclusion in Ref. 3 "*...HRA numbers show that the total probability is on the order of 1.00E-5 when all successful end states and parallel operator actions are accounted...*" needs to be supported by calculations with due consideration for dependencies.

4 Success Paths

For transient initiators, there is an opportunity for the operators to detect and diagnose the flow diversion path before opening of the SDC suction isolation valves HCV-347 and HCV-348. During filling and venting of the SDC system, a LPSI pump taking suction from the SIRWT is started and run for approximately 10 minutes to fill the SDC system piping. The flow diversion via HCV-345 will become evident due to containment sump high level alarms and SIRWT low level

alarms. For transient initiators, there should not be any coolant in the sumps and the SIRWT would be at nominal level, so these alarms would be clear cues that coolant is being transferred from the SIRWT to the containment sump following startup of the LPSI pump. Should the operators fail to detect and diagnose the flow diversion path prior to SDC suction alignment from the RCS, a LOCA will be caused when they perform the alignment, with consequences similar to a LOCA initiator in terms of mitigating actions required as discussed in the following paragraphs.

There are two success paths following a LOCA initiator namely:

1. Operators detect and diagnose a LOCA and close either HCV-348, HCV-347, or HCV-335. Although these three valves are in series and would therefore provide equipment redundancy to achieve isolation, the closing of one or more of these valves is considered to be a single operator action due to the common cognitive element. SPAR-H [6] is also not a sufficiently detailed method to credit redundant execution actions in the same human failure event (HFE). The closing of the SDC valve/s is a recovery action without any specific procedural guidance.

2. Operators detect and diagnose a LOCA and either restart HPSI or increase HPSI flow rate. This action is sufficient to guarantee success until switchover to recirculation ("RAS") is required. The restart of HPSI or throttling of flow is a proceduralized action.

Both success paths need to fail to result in core damage. The operator actions in both success paths therefore have to fail to result in core damage. As operator failures are intrinsically not as independent as equipment failures, the operator failure probabilities should not simply be multiplied without considering dependencies.

An operator action event tree for this scenario is presented in Table 1. The early diagnosis node asks whether operators detect and diagnose the flow diversion path prior to opening the SDC isolation valves. For a LOCA initiator, this is not credited and the lower branch is to be followed with a probability of 1.0. For transient initiators, successful detection and diagnosis leads to success via sequence # 1. If early detection and diagnosis fail, the next node asks for LOCA diagnosis, which is the common cognitive element for the LOCA mitigating actions. If the operators do not detect and diagnose a LOCA, they will not perform any of the mitigating actions i.e they will neither close the required SDC valves nor increase HPSI flow rate. These mitigating actions are said to be completely dependent on the detection and diagnosis of the LOCA. This is represented by top event "COMCOG" and sequence # 5. If the LOCA detection and diagnosis is successful, the next node "XSPRAYVALVE" asks if the

operators successfully close the SDC valve/s. If successful, sequence # 2 leads to success. If unsuccessful, the next node "HPSIFLOW" asks if operators were successful in starting/increasing HPSI flow rate. If successful, sequence # 3 leads to success. If unsuccessful, sequence # 4 leads to core damage (CD).

Table 1: Operator Action Tree for Closing SDC Valve/s First

Top Event	Early Cognition	Open SDC Valve/s	LOCA Cognition	Close SDC Valve/s	Increase HPSI	Seq #	Outcome
BE ID	COGEARLY		COMCOG	XSPRAYVALVE	HPSIFLOW		
	No					1	Success
Yes						2	Success
No						3	Success
	Yes					4	CD
						5	CD

As dependencies generally manifest in successive failure events, the chronological order of the events needs to be considered. As the two LOCA mitigation success paths are not based on proceduralized instructions in a specific order, the operators may choose either of the mitigating strategies, following successful diagnosis of the LOCA. If the operators first respond by increasing HPSI flow, the sequence of events in Table 2 applies. As in Table 1 above, the early diagnosis node asks whether operators detect and diagnose the flow diversion path prior to opening the SDC isolation valves. For a LOCA initiator, this is not credited and the lower branch is to be followed with a probability of 1.0. For transient initiators, successful detection and diagnosis leads to success via sequence # 1. If early detection and diagnosis fail, the next node asks for LOCA diagnosis, which is the common cognitive element for the LOCA mitigating actions. If cognition is successful, node "HPSIFLOW" asks for HPSI restart/throttling. If successful, sequence # 2 leads to success. If HPSI is unsuccessful, the next node "XSPRAYVALVE" asks for SDC valve closure. If successful, sequence # 3 leads to success. If unsuccessful, sequence # 4 leads to CD.

Table 2: Operator Action Event Tree for Increasing HPSI Flow First

Top Event	Early Cognition	Open SDC Valve/s	LOCA Cognition	Increase HPSI	Close SDC Valve/s	Seq #	Outcome
BE ID	COGEARLY		COMCOG	HPSIFLOW	XSPRAYVALVE		
	No					1	Success
Yes						2	Success
No						3	Success
	Yes					4	CD
						5	CD

5 Human Error Probabilities

The HEPs were quantified using the SPAR-H [6] method. The HEPs are summarized in Table 3. The individual analyses are presented in the following sections. The number of reported digits in the HEPs and other numbers in the analyses are for traceability only and should not be regarded as significant figures.

Table 3: Summary of HEP Results

BE ID	Description	Diag. HEP	Action HEP	Total HEP	Comments
COGEARLY	Operators fail to detect flow diversion via HCV-345 given dry sump initially	1E-03	1E-04	1.1E-03	New HFE based on annunciator response.
COMCOG	Operators fail to detect or diagnose LOCA	5E-06		5E-06	This is based on the Diagnosis part of the OPPD HPSIFLOW analysis, with some modifications and additions.
HPSIFLOW	Human Failure to Increase HPSI Flow on Loss of RCS Inventory	5E-06	1E-05	1.5E-05	This is based on the Action part of the OPPD HPSIFLOW analysis, with some modifications and additions.

Table 3: Summary of HEP Results

BE ID	Description	Diag. HEP	Action HEP	Total HEP	Comments
XSPRAYVALVE	Operator fails to respond to open CS valve	1E-05	4E-04	4.1E-04	This is based on the Action part of the OPPD XSPRAYVALVE analysis, with some modifications and additions

5.1 COGEARLY, Operators Fail to Detect and Diagnose Flow Diversion via HCV-345 Given Dry Sump Initially

Cognitive Method	Date	Analyst
SPAR-H	03/30/07	Jan Grobbelaar
Analysis File	**File Date**	**File Size (Bytes)**
HCV345.HRA	03/30/07	401408

HEP Summary		
	Failure Probability	Total HEP
Diagnosis	1E-03	
Action	1E-04	1.1E-03

Plant	Fort Calhoun Unit 1
Initiating Event	Transients resulting in a dry sump prior to initiation of SDC

Basic Event Context

INITIAL CONDITIONS

At power. The plant has experienced one of several transients. The containment sumps are dry.

PRECEDING FAILURES AND SUCCESSES

Operators completed EOP-00. Cooldown and depressurization to SDC entry conditions successful. SDC entry conditions are:

PZR level is greater than or equal to 45% and constant or rising
RCS subcooling is greater than or equal to 20°F
RCS pressure is less than or equal to 250 psia.
RCS TC between 250 and 300°F

The operators entered Attachment 4 to place SDC in service.

SCENARIO DESCRIPTION

Basic Event Context
Operating crew is utilizing EOP Attachment 4 (SDC without RAS). Operator performs step 18 of EOP attachment 4 (R22): Start selected LPSI pump. SUCCESS CRITERION Identify rising containment sump level or lowering SIRWT level, and suspend efforts to initiate shutdown cooling before creating the diversion flow path. CONSEQUENCES OF FAILURE If the operators do not detect and diagnose the flow diversion during SDC system filling and venting, they will proceed to implement SDC. CUES AND INDICATIONS Containment sump level hi: Panel: AI-65A Annunciator: A65A Window: 13 SIRWT level hi-lo: Panel: AI-30A Annunciator: A33-1 Window: B-6. PROCEDURES AND TRAINING ARP-AI-65A/A65A (13) CONTAINMENT SUMP LEVEL HI (Setpoint > 25 inches) ARP-AI-65B/A65B (13) CONTAINMENT SUMP LEVEL HI (Setpoint > 25 inches) IF level does not decrease or continues to increase, THEN check the following systems for indication of leakage inside Containment: • Reactor Coolant • Charging and Letdown • Safety Injection • Component Cooling Water ARP-AI-30A/A33-1 (B-6), SAFETY INJECTION REFUELING WATER STORAGE TANK LEVEL HIGH OR LOW, Setpoint LO 185 inches

Timing Analysis	
T_{sw}	10.00 Minutes
T_{delay}	1.00 Minutes
$T_{1/2}$	1.00 Minutes
T_M	1.00 Minutes
Time available for recovery	7.00 Minutes
SPAR-H Available time (cognitive)	8.00 Minutes
SPAR-H Available time (execution) ratio	8.00
Minimum level of dependence for recovery	HD

Notes
The system time window, Tsw is based on the time that the LPSI pump is typically run for in performing step 18 of EOP Attachment 4. This is based on operator interviews conducted in

Notes
March 2007. The delay time, Tdelay, is a conservative estimate for reaching the containment sump 25" level or the SIRWT level decreasing below 185".(see notes below) The median response time, $T_{1/2}$ is assumed to be 1 minute to respond to an annunciator while the plant is in a stable condition. The manipulation time, Tm, is assumed to be one minute for a simple control room action. Notes: There is approximately 160 gallons level difference between hi-lo level alarms for the containment sump. Therefore with approximately 2000 gpm diversion flow (approx.) it should take less than a minute for the sump alarms to actuate even counting time for some drainage. Secondly, the SIRWT level is approximately 1200 gallons per inch for the levels we are talking about. Average maintained level in the SIRWT is approximately 188" over an operating cycle. The hard alarm comes in at 185" and an ERF alarms comes in at 186". Taking the 3" difference that corresponds to approximately 3600 gallons. All water taken out will be from the SIRWT so therefore using the same estimate of 2000 gallons diversion flow it should only take approximately 2 minutes to reach SIRWT lo level alarm.

PART I. DIAGNOSIS			
PSFs	**PSF Levels**		**Multiplier for Diagnosis**
Available Time (recommended choice based on timing information in bold)	Inadequate Time		P(failure) = 1.0
	Barely adequate time (~ 2/3 x nominal)		10
	Nominal time	X	1
	Extra time (between 1 and 2 x nominal and > 30 min)		0.1
	Expansive time (> 2 x nominal and > 30 min)		0.01
	Insufficient Information		1
	See TIMING ANALYSIS above. The time window is limited to 10 minutes, which is the approximate time that the LPSI pump would be run in practice for filling and venting operations. Limiting the time window to 10 minutes avoids timing dependency issues with other human failure events following the LOCA initiator, so that the post-initiator HFEs can be deemed independent of the pre-initiator HFEs.		
Stress/Stressors	Extreme		5
	High	X	2
	Nominal		1
	Insufficient Information		1
	Although nominal stress is typically assumed for scenarios following successful cooldown and depressurization with the plant under control and in a stable state, high stress is selected to reflect the unexpected alarms received following LPSI start.		
Complexity	Highly complex		5
	Moderately complex		2
	Nominal		1

PART I. DIAGNOSIS			
PSFs	**PSF Levels**		**Multiplier for Diagnosis**
	Obvious diagnosis	X	0.1
	Insufficient Information		1
	Validating and/or convergent information becomes available to the operator due to sump high level alarms, SIWRT low level alarms following LPSI startup.		
Experience/Training	Low		10
	Nominal		1
	High	X	0.5
	Insufficient Information		1
	The operating crews are highly experienced with many crew members having 10 years or more experience.		
Procedures	Not available		50
	Incomplete		20
	Available, but poor		5
	Nominal	X	1
	Diagnostic/symptom oriented		0.5
	Insufficient Information		1
	Although the operators are still performing the EOPs, which are diagnostic/symptom oriented, the ARPs are considered to be nominal procedures.		
Ergonomics/HMI	Missing/Misleading		50
	Poor		10
	Nominal	X	1
	Good		0.5
	Insufficient Information		1
	The control room is compact and well designed. All alarms, indications, and controls are located within the front panels of the control room necessary for diagnosis and action. Redundant channels and associated alarms are grouped together. Control rooms in general are designed to promote excellent HMI. The FCS control room is no different and has undergone HMI improvements over the years. SPAR-H discusses this as a possible "Good" rating. This PSF could have been assigned a positive number but was left as nominal		
Work Process	Poor		2
	Nominal	X	1
	Good		0.8
	Insufficient Information		1
	ARP's are used during normal conditions, which is appropriate for this scenario since initiation of shutdown cooling is a planned evolution following stabilization of the plant. Operating crew interaction is stressed during training and has been the focus of specific training sessions.		
Diagnosis HEP	1E-03		

PART II. ACTION			
PSFs	**PSF Levels**		**Multiplier for Diagnosis**

PART II. ACTION			
PSFs	**PSF Levels**		**Multiplier for Diagnosis**
Available Time (recommended choice based on timing information in bold)	Inadequate Time		P(failure) = 1.0
	Time available is ~ the time required		10
	Nominal time		1
	Time available >= 5x the time required	X	0.1
	Time available >= 50x the time required		0.01
	Insufficient Information		1
	Note that given a successful diagnosis, there is no limit on the time window for the required actions. Following the stopping of the LPSI pump run after 10 minutes, the plant is in a stable, controlled state and does not require any immediate operator actions (within the 10 minute time window for diagnosis). The operators have several alternatives to isolating the containment spray line before continuing with SDC. The timing PSF is therefore really not applicable to this action, so the value of 0.1 is retained as representative of the fact that there is no time limitation.		
Stress/Stressors	Extreme		5
	High	X	2
	Nominal		1
	Insufficient Information		1
	Although nominal stress is typically assumed for scenarios following successful cooldown and depressurization with the plant under control and in a stable state, high stress is selected to reflect the unexpected alarms received following LPSI start.		
Complexity	Highly complex		5
	Moderately complex		2
	Nominal	X	1
	Insufficient Information		1
	Stopping the LPSI pump is a very simple action.		
Experience/Training	Low		3
	Nominal		1
	High	X	0.5
	Insufficient Information		1
	The operating crews are highly experienced with many crew members having 10 years or more experience.		
Procedures	Not available		50
	Incomplete		20
	Available, but poor		5
	Nominal	X	1
	Insufficient Information		1
	Although the operators are still performing the EOPs, which are diagnostic/symptom oriented, the ARPs are considered to be nominal procedures. The closing of the containment spray manual isolation valve is not in the EOP, but in the normal shutdown procedure.		
Ergonomics/HMI	Missing/Misleading		50
	Poor		10
	Nominal	X	1
	Good		0.5
	Insufficient Information		1

PART II. ACTION			
PSFs	**PSF Levels**		**Multiplier for Diagnosis**
	The LPSI pump to be stopped is easily identified, especially since it is the pump that was started only minutes ago.		
Fitness for Duty	Unfit		P(failure) = 1.0
	Degraded Fitness		5
	Nominal	X	1
	Insufficient Information		1
	Due to the duration of the event (entire operating cycle) an average crew (nominal) crew has to be assumed.		
Work Process	Poor		5
	Nominal	X	1
	Good		0.5
	Insufficient Information		1
	Operating crew interaction is stressed during training and has been the focus of specific training sessions. Additionally, basic operator training emphasizes verification of expected response following an action. Rising containment sump level and low SIRWT level alarms are not expected responses.		
Action Probability	1E-04		

5.2 COMCOG, Operators fail to detect or diagnose LOCA

Cognitive Method	Date	Analyst
SPAR-H	03/27/07	Jan Grobbelaar
Analysis File	**File Date**	**File Size (Bytes)**
HCV345.HRA	03/27/07	397312

HEP Summary	
Diagnosis Failure Probability	**Total HEP**
5.0e-06	5.0E-06

Plant	Fort Calhoun Unit 1
Initiating Event	SLOCA, I3Q, MSLB

Basic Event Context

INITIAL CONDITIONS

At power. The plant has experienced one of several initiating events, SLOCA, I3Q, MSLB. A SLOCA (< 200 gpm) is chosen as the representative initiating event, as no RAS would be required before the plant reaches SDC conditions.

PRECEDING FAILURES AND SUCCESSES

Operators completed EOP-00, diagnosed LOCA correctly and transferred to EOP-03. Cooldown and depressurization to SDC entry conditions successful. SDC entry conditions are:

Basic Event Context

PZR level is greater than or equal to 45% and constant or rising
RCS subcooling is greater than or equal to 20°F
RCS pressure is less than or equal to 250 psia.
RCS TC between 250 and 300°F

The operators proceeded to EOP-03 step 65 and enter Attachment 4 to place SDC in service.

SCENARIO DESCRIPTION

Operating crew is utilizing EOP Attachment 4 (SDC without RAS). Operator performs step 18 of EOP attachment 4 (R22): Start selected LPSI pump. Operator has a potential at this time to catch open CS valve due to lowering SIRWT level and possible containment sump level alarms, however due to previous sequences it is unlikely that the operator will be able to easily diagnose this due to no audible cues and therefore given limited success is not credited. Operator performs step 22: Stops LPSI pump that was started in step 18 (Diversion of flow to thru the CS valve is terminated at that time). Operator performs step 24: Open HCV-347 and HCV-348, SDC suction valves from RCS, which creates a diversion flowpath via HCV-345.

SUCCESS CRITERION

Detect and diagnose LOCA

CUES AND INDICATIONS

Possible annunciators: Prz. level hi-lo channel x/y, Pzr. level lo-lo channel x/y, containment sump level hi, SIRWT level hi-lo

ARP-CB-1,2,3/A4 (A-8) PRESSURIZER LEVEL HI-LO CHANNEL X (Setpoint Hi = 56% Lo= 42%, setpoint derived from > 8% or < 6% level from programmed level (48%).
ARP-CB-1,2,3/A4 (B-8) PRESSURIZER LEVEL HI-LO CHANNEL Y (Setpoint Hi = 56% Lo= 42%, setpoint derived from > 8% or < 6% level from programmed level (48%).
ARP-CB-1,2,3/A4 (C-8) PRESSURIZER LEVEL LO-LO CHANNEL X (Setpoint < 41.5%)
ARP-CB-1,2,3/A4 (D-8) PRESSURIZER LEVEL LO-LO CHANNEL Y (Setpoint < 41.5%)
ARP-AI-65A/A65A (13) CONTAINMENT SUMP LEVEL HI (Setpoint > 25 inches)
ARP-AI-65B/A65B (13) CONTAINMENT SUMP LEVEL HI (Setpoint > 25 inches)

PROCEDURES AND TRAINING

In EOP-03 Step 4, the operators are instructed to "Monitor the Floating Steps".

Floating Step A "HPSI STOP AND THROTTLE CRITERIA" includes the following CAUTIONS before Step 1:

3. Reducing SI flow should be approached cautiously.
4. The purpose of HPSI stop and throttle is to prevent an over pressurization of the RCS and a solid PZR, however, maintaining RCS inventory is more important than pressure control.

Floating Step A "HPSI STOP AND THROTTLE CRITERIA" Step 1 provides the HPSI stop and throttling criteria:

Verify ALL of the following stop and throttle criteria are satisfied:

Basic Event Context

- RCS subcooling is greater than or equal to 20°F
- PZR level is greater than or equal to 10% and not lowering
- At least one S/G is available for RCS heat removal
- RVLMS indicates level is at or above the top of the Hot Leg (43%, ERF "I" display)

Floating Step A "HPSI STOP AND THROTTLE CRITERIA" includes the following CAUTION before Step 4:

1. LOCAs pose a significant threat to RCS subcooling. Therefore, full SI Flow should be maintained until subcooled margin is stable and natural circulation has developed.

Floating Step A "HPSI STOP AND THROTTLE CRITERIA" step 4 instructs:

IF a LOCA or SGTR is in progress, THEN maintain RCS pressure control by performing the following:

a. Ensure at least one HPSI Pump is operating.
b. Throttle HPSI Loop Injection Valves.

Floating Step A "HPSI STOP AND THROTTLE CRITERIA" step 5 instructs:

IF HPSI stop and throttle criteria can NOT be maintained, THEN raise HPSI flow by performing the
following steps:
a. Start either HPSI Pumps, SI-2A/B or SI-2B/C, as necessary.
b. Open HPSI Loop Injection Valves, as necessary.

In EOP-03 Step 65, the operators are instructed to implement SDC using EOP Attachment 4, given that no RAS has occurred. The operators would remain in EOP-03, while performing Attachment 4 and would return to the EOP-03 Section 8 "Exit Conditions" following implementation of Attachment 04.

The operators are well trained in recognizing the symptoms of a LOCA and requirement for safety injection. They are well trained in monitoring the HPSI stop and initiation criteria; subcooling, pressurizer level and S/G heat removal are some of the most fundamental parameters monitored continuously by operators during cooldown and depressurization, especially following an accident.

ASSUMPTIONS

During the fill of the SDC system piping, there is an opportunity for detecting the flow diversion path, but this is not credited, which is conservative.

RAS has not occurred. However, containment spray may have been initiated early in the event and successfully terminated using EOP floating step for reset of safeguards or containment spray termination. If spray did occur it is possible that the crew has recognized that there is a problem with a spray valve not operating correctly. This HFE however does not credit such early detection or diagnosis.

Timing Analysis	
T_{sw}	90.00 Minutes
T_{delay}	1.00 Minutes
$T_{1/2}$	1.00 Minutes
T_M	1.00 Minutes
Time available for recovery	87.00 Minutes
SPAR-H Available time (cognitive)	88.00 Minutes
SPAR-H Available time (execution) ratio	88.00
Minimum level of dependence for recovery	ZD

Notes

Tsw = 90 minutes. Initial RCS inventory will be at nominal operating level. Shutdown cooling can not be placed into service leading to this event unless that level has been obtained. Using analysis document (WEC T-H Analysis for Flow Diversion.doc) with a partially open CS valve, the loss of inventory due to opening of HCV-347 and HCV-348 SDC isolation valves resulted in core uncovery in 90 minutes without operator action to close the valve(s).

Tdelay = 1 minute. After the opening of the SDC isolation valves initiating the loss of inventory, immediate audible and visual cues will be available to the operator that a loss of inventory is occurring. One minute is a conservative number.

$T_{1/2}$ = 1 minute. After visual cues operators and diagnosis completed, direction from CRS would be to immediately close the SDC isolation valves

Tm = One switch operation for one operator to perform to terminate loss of inventory.

DIAGNOSIS			
PSFs	**PSF Levels**		**Multiplier for Diagnosis**
Available Time (recommended choice based on timing information in bold)	Inadequate Time		P(failure) = 1.0
	Barely adequate time (~ 2/3 x nominal)		10
	Nominal time		1
	Extra time (between 1 and 2 x nominal and > 30 min)		0.1
	Expansive time (> 2 x nominal and > 30 min)	X	0.01
	Insufficient Information		1
	See TIMING ANALYSIS above. Expansive time exists for the operator to complete diagnosis and take action. The T-H analysis shows that at least 90 minutes are available. The indications of rapid inventory loss would be present immediately to allow for a quick and easy diagnosis, leaving most of the 90 minutes for action.		
Stress/Stressors	Extreme		5
	High	X	2
	Nominal		1
	Insufficient Information		1

DIAGNOSIS			
PSFs	**PSF Levels**		**Multiplier for Diagnosis**
	Plant is stabilized. No preceding operator or functional failures. Normal control room environment. Work load normal. High stress is conservatively selected due to unexpected plant response when placing SDC in service.		
Complexity	Highly complex		5
	Moderately complex		2
	Nominal		1
	Obvious diagnosis	X	0.1
	Insufficient Information		1
	They are well trained in monitoring the HPSI stop and initiation criteria; subcooling, pressurizer level and S/G heat removal are some of the most fundamental parameters monitored continuously by operators during cooldown and depressurization, especially following an accident.		
Experience/Training	Low		10
	Nominal		1
	High	X	0.5
	Insufficient Information		1
	The operators are well trained in recognizing the symptoms of a LOCA and requirement for safety injection. LOCA scenarios are routinely practiced on the simulator during operator training.		
Procedures	Not available		50
	Incomplete		20
	Available, but poor		5
	Nominal		1
	Diagnostic/symptom oriented	X	0.5
	Insufficient Information		1
	Ft. Calhoun EOPs are symptom-based.		
Ergonomics/HMI	Missing/Misleading		50
	Poor		10
	Nominal	X	1
	Good		0.5
	Insufficient Information		1
	The control room is compact and well designed. All alarms, indications, and controls are located within the front panels of the control room necessary for diagnosis and action. Redundant channels and associated alarms are grouped together. Control rooms in general are designed to promote excellent HMI. The FCS control room is no different and has undergone HMI improvements over the years. SPAR-H discusses this as a possible "Good" rating. This PSF could have been assigned a positive number but was left as nominal.		
Fitness for Duty	Unfit		P(failure) = 1.0
	Degraded Fitness		5
	Nominal	X	1
	Insufficient Information		1
	Due to the duration of the event (entire operating cycle) an average crew (nominal) crew has to be assumed.		
Work Process	Poor		2

DIAGNOSIS			
PSFs	**PSF Levels**		**Multiplier for Diagnosis**
	Nominal	X	1
	Good		0.8
	Insufficient Information		1
	Operating crew interaction is stressed during training and has been the focus of specific training sessions. However, an argument could be made that with the emergency response organization (ERO) structure that would be present in these events, and the multiple layers of defense that the ERO system provides, the value could be more positive and as such be lowered to smaller values in both the diagnosis and action areas.		
Diagnosis HEP	5.0e-06		

5.3 HPSIFLOW, Human Failure to Increase HPSI Flow on Loss of RCS Inventory

Cognitive Method	**Date**	**Analyst**
SPAR-H	**03/27/07**	**Jan Grobbelaar**
Analysis File	**File Date**	**File Size (Bytes)**
HCV345.HRA	**03/27/07**	**397312**

HEP Summary		
	Failure Probability	**Total HEP**
Cognitive	5.0e-06	
Action	1.0e-05	1.5E-05

Plant	Fort Calhoun Unit 1
Initiating Event	SLOCA, I3Q, MSLB

Basic Event Context
INITIAL CONDITIONS At power. The plant has experienced one of several initiating events, SLOCA, I3Q, SGTR, MSLB. A SLOCA (< 200 gpm) is chosen as the representative initiating event, as no RAS would be required before the plant reaches SDC conditions. PRECEDING FAILURES AND SUCCESSES Operators completed EOP-00, diagnosed LOCA correctly and transferred to EOP-03. Cooldown and depressurization to SDC entry conditions successful. SDC entry conditions are: PZR level is greater than or equal to 45% and constant or rising RCS subcooling is greater than or equal to 20°F RCS pressure is less than or equal to 250 psia. RCS TC between 250 and 300°F The operators proceeded to EOP-03 step 65 and enter Attachment 4 to place SDC in service.

Basic Event Context

SCENARIO DESCRIPTION

Operating crew is utilizing EOP Attachment 4 (SDC without RAS). Operator performs step 18 of EOP attachment 4 (R22): Start selected LPSI pump. Operator has a potential at this time to catch open CS valve due to CS flow indication, lowering SIRWT level, and rising containment sump level; however due to previous sequences it is unlikely that the operator will be able to easily diagnose this due to no audible cues and therefore given limited success is not credited. Operator performs step 22: Stops LPSI pump that was started in step 18 (Diversion of flow to thru the CS valve is terminated at that time). Operator performs step 24: Open HCV-347 and HCV-348, SDC suction valves from RCS, which creates a diversion flowpath via HCV-345.

SUCCESS CRITERION

Detect and diagnose LOCA and increase HPSI flow per EOP-03 floating step "A" Step 5: If HPSI stop and throttle criteria can not be maintained then start HPSI pumps and open HPSI loop injection valves. This action will restore operating level to RCS.

CUES AND INDICATIONS

Possible annunciators: Pzr. level hi-lo channel x/y, Pzr. level lo-lo channel x/y, containment sump level hi, SIRWT level hi-lo

ARP-CB-1,2,3/A4 (A-8) PRESSURIZER LEVEL HI-LO CHANNEL X (Setpoint Hi = 56% Lo= 42%, setpoint derived from > 8% or < 6% level from programmed level (48%).
ARP-CB-1,2,3/A4 (B-8) PRESSURIZER LEVEL HI-LO CHANNEL Y (Setpoint Hi = 56% Lo= 42%, setpoint derived from > 8% or < 6% level from programmed level (48%).
ARP-CB-1,2,3/A4 (C-8) PRESSURIZER LEVEL LO-LO CHANNEL X (Setpoint < 41.5%)
ARP-CB-1,2,3/A4 (D-8) PRESSURIZER LEVEL LO-LO CHANNEL Y (Setpoint < 41.5%)
ARP-AI-65A/A65A (13) CONTAINMENT SUMP LEVEL HI (Setpoint > 25 inches)
ARP-AI-65B/A65B (13) CONTAINMENT SUMP LEVEL HI (Setpoint > 25 inches)
Possible indications: lowering pressurizer level on multiple recorders and indicators, lowering pressurizer level on computer displays (in control room and in emergency response facilities), containment spray flow indication (in control room and in emergency response facilities)

PROCEDURES AND TRAINING

In EOP-03 Step 4, the operators are instructed to "Monitor the Floating Steps".

Floating Step A "HPSI STOP AND THROTTLE CRITERIA" includes the following CAUTIONS before Step 1:

3. Reducing SI flow should be approached cautiously.
4. The purpose of HPSI stop and throttle is to prevent an over pressurization of the RCS and a solid PZR, however, maintaining RCS inventory is more important than pressure control.

Floating Step A "HPSI STOP AND THROTTLE CRITERIA" Step 1 provides the HPSI stop and throttling criteria:

Verify ALL of the following stop and throttle criteria are satisfied:

o RCS subcooling is greater than or equal to 20°F

Basic Event Context
o PZR level is greater than or equal to 10% and not lowering o At least one S/G is available for RCS heat removal o RVLMS indicates level is at or above the top of the Hot Leg (43%, ERF "I" display) Floating Step A "HPSI STOP AND THROTTLE CRITERIA" includes the following CAUTION before Step 4: 1. LOCAs pose a significant threat to RCS subcooling. Therefore, full SI Flow should be maintained until subcooled margin is stable and natural circulation has developed. Floating Step A "HPSI STOP AND THROTTLE CRITERIA" step 4 instructs: IF a LOCA or SGTR is in progress, THEN maintain RCS pressure control by performing the following: a. Ensure at least one HPSI Pump is operating. b. Throttle HPSI Loop Injection Valves. Floating Step A "HPSI STOP AND THROTTLE CRITERIA" step 5 instructs: IF HPSI stop and throttle criteria can NOT be maintained, THEN raise HPSI flow by performing the following steps: a. Start either HPSI Pumps, SI-2A/B or SI-2B/C, as necessary. b. Open HPSI Loop Injection Valves, as necessary. In EOP-03 Step 65, the operators are instructed to implement SDC using EOP Attachment 4, given that no RAS has occurred. The operators would remain in EOP-03, while performing Attachment 4 and would return to the EOP-03 Section 8 "Exit Conditions" following implementation of Attachment 04. The operators are well trained in recognizing the symptoms of a LOCA and requirement for safety injection. They are well trained in monitoring the HPSI stop and initiation criteria; subcooling, pressurizer level and S/G heat removal are some of the most fundamental parameters monitored continuously by operators during cooldown and depressurization, especially following an accident. ASSUMPTIONS During the fill of the SDC system piping, there is an opportunity for detecting the flow diversion path, but this is not credited, which is conservative. RAS has not occurred. However, containment spray may have been initiated early in the event and successfully terminated using EOP floating step for reset of safeguards or containment spray termination. If spray did occur it is possible that the crew has recognized that there is a problem with a spray valve not operating correctly. This HFE however does not credit such early detection or diagnosis.

Timing Analysis	
T_{sw}	90.00 Minutes
T_{delay}	1.00 Minutes
$T_{1/2}$	1.00 Minutes
T_M	1.00 Minutes
Time available for recovery	87.00 Minutes
SPAR-H Available time (cognitive)	88.00 Minutes
SPAR-H Available time (execution) ratio	88.00
Minimum level of dependence for recovery	ZD

Notes

Tsw = 90 minutes. Initial RCS inventory will be at nominal operating level. Shutdown cooling can not be placed into service leading to this event unless that level has been obtained. Using analysis document (WEC T-H Analysis for Flow Diversion.doc) with a partially open CS valve, the loss of inventory due to opening of HCV-347 and HCV-348 SDC isolation valves resulted in core uncovery in 90 minutes without operator action to close the valve(s).

Tdelay = 1 minute. After the opening of the SDC isolation valves initiating the loss of inventory, immediate audible and visual cues will be available to the operator that a loss of inventory is occurring. One minute is a conservative number.

$T_{1/2}$ = 1 minute. After visual cues operators and diagnosis completed, direction from CRS would be to immediately increase HPSI flow rate.

Tm = 1 minute. One switch to start a HPSI pump, and one switch to open a HPSI loop injection valve. There are 3 HPSI pumps and 8 HPSI valves. On the simulator, it was observed (04/20/2007) that the operators would start all 3 HPSI pumps and open all 8 HPSI valves, within 1 minute.

DIAGNOSIS			
PSFs	**PSF Levels**		**Multiplier for Diagnosis**
Available Time (recommended choice based on timing information in bold)	Inadequate Time		P(failure) = 1.0
	Barely adequate time (~ 2/3 x nominal)		10
	Nominal time		1
	Extra time (between 1 and 2 x nominal and > 30 min)		0.1
	Expansive time (> 2 x nominal and > 30 min)	X	0.01
	Insufficient Information		1
	See TIMING ANALYSIS above. Expansive time exists for the operator to complete diagnosis and take action. The T-H analysis shows that at least 90 minutes are available. The indications of rapid inventory loss would be present immediately to allow for a quick and easy diagnosis, leaving most of the 90 minutes for action.		
Stress/Stressors	Extreme		5

DIAGNOSIS			
PSFs	**PSF Levels**		**Multiplier for Diagnosis**
	High	X	2
	Nominal		1
	Insufficient Information		1
	Plant is stabilized. No preceding operator or functional failures. Normal control room environment. Work load normal. High stress is conservatively selected due to unexpected plant response when placing SDC in service.		
Complexity	Highly complex		5
	Moderately complex		2
	Nominal		1
	Obvious diagnosis	X	0.1
	Insufficient Information		1
	They are well trained in monitoring the HPSI stop and throttle criteria; subcooling, pressurizer level and S/G heat removal are some of the most fundamental parameters monitored continuously by operators during cooldown and depressurization, especially following an accident.		
Experience/Training	Low		10
	Nominal		1
	High	X	0.5
	Insufficient Information		1
	The operators involved hold NRC Senior Reactor Operator of Reactor Operator licenses, and have many years of FCS experience. The operators are well trained in recognizing the symptoms of a LOCA and requirement for safety injection. LOCA scenarios are routinely practiced on the simulator during operator training.		
Procedures	Not available		50
	Incomplete		20
	Available, but poor		5
	Nominal		1
	Diagnostic/symptom oriented	X	0.5
	Insufficient Information		1
	Ft. Calhoun EOPs are symptom-based.		
Ergonomics/HMI	Missing/Misleading		50
	Poor		10
	Nominal	X	1
	Good		0.5
	Insufficient Information		1
	The control room is compact and well designed. All alarms, indications, and controls are located within the front panels of the control room necessary for diagnosis and action. Redundant channels and associated alarms are grouped together. Control rooms in general are designed to promote excellent HMI. The FCS control room is no different and has undergone HMI improvements over the years. SPAR-H discusses this as a possible "Good" rating. This PSF could have been assigned a positive number but was left as nominal.		
Fitness for Duty	Unfit		P(failure) = 1.0

DIAGNOSIS			
PSFs	**PSF Levels**		**Multiplier for Diagnosis**
	Degraded Fitness		5
	Nominal	X	1
	Insufficient Information		1
	Due to the duration of the event (entire operating cycle) an average crew (nominal) crew has to be assumed.		
Work Process	Poor		2
	Nominal	X	1
	Good		0.8
	Insufficient Information		1
	Operating crew interaction is stressed during training and has been the focus of specific training sessions. However, an argument could be made that with the emergency response organization (ERO) structure that would be present in these events, and the multiple layers of defense that the ERO system provides, the value could be more positive and as such be lowered to smaller values in both the diagnosis and action areas.		
Diagnosis HEP	5.0e-06		

ACTION			
PSFs	**PSF Levels**		**Multiplier for Diagnosis**
Available Time (recommended choice based on timing information in bold)	Inadequate Time		P(failure) = 1.0
	Time available is ~ the time required		10
	Nominal time		1
	Time available >= 5x the time required		0.1
	Time available >= 50x the time required	X	0.01
	Insufficient Information		1
	See TIMING ANALYSIS above. Expansive time exists for the operator to complete diagnosis and take action. The T-H analysis shows that at least 90 minutes are available. The indications of rapid inventory loss would be present immediately to allow for a quick and easy diagnosis, leaving most of the 90 minutes for action. The action to mitigate the loss of inventory consists of one or two steps completed from the control room.		
Stress/Stressors	Extreme		5
	High	X	2
	Nominal		1
	Insufficient Information		1
	Plant is stabilized. No preceding operator or functional failures. Normal control room environment. Work load normal. High stress is conservatively selected due to unexpected plant response when placing SDC in service.		
Complexity	Highly complex		5
	Moderately complex		2
	Nominal	X	1
	Insufficient Information		1
	A nominal PSF value was assigned due to the simple and uncomplicated sequence to stop the loss of inventory. For both		

ACTION			
PSFs	**PSF Levels**		**Multiplier for Diagnosis**
	HPSIFLOW and XSPRAYVALVE each action is only one or two steps. In HPSIFLOW the operator starts the HPSI pump and opens a valve. In XSPRAYVALVE the operator uses only one switch to close a valve (HCV-348). There is little ambiguity, and only a single pertinent variable – lowering pressurizer level – is involved.		
Experience/Training	Low		3
	Nominal		1
	High	X	0.5
	Insufficient Information		1
	A positive PSF was assigned for HPSIFLOW due to the rigorous training of all reactor operators and control room personnel. Loss of inventory simulator scenarios are practiced routinely along with HPSI Stop and Throttle criteria being met or not met and as such was rated as a positive PSF. Training records for simulator exercises were obtained. The Loss of Coolant Accident scenarios were run at least once every other training cycle (6 week cycle) for the past two years. The event takes place in the control room along with mitigation steps required. Experience level is high with shift manager and control room supervisor present as well as evenly balanced crews (each year Operations realigns crews) ensuring a high experience level mix exists within each crew for the reactor operators		
Procedures	Not available		50
	Incomplete		20
	Available, but poor		5
	Nominal	X	1
	Insufficient Information		1
	The EOP structure allows flexibility to the operating crew to perform steps necessary to mitigate many different scenarios that could be presented. The structure contains floating steps that are continuously monitored for applicability. When conditions are met, the floating step is implemented and the actions carried out. Also, the EOP has safety function status checklists performed every 10 minutes as verification that safety functions (RCS inventory is one of the safety functions) are being met. While the HRA analysis varies slightly for procedure use for the two human failure events analyzed, in either case the same EOP is being utilized. With the floating steps specifically applying to raising HPSI flow, the PSF for HPSIFLOW was assigned the nominal value.		
Ergonomics/HMI	Missing/Misleading		50
	Poor		10
	Nominal	X	1
	Good		0.5
	Insufficient Information		1
	A nominal value for this PSF was assigned. The control room is compact and well designed. All alarms, indications, and controls are located within the front panels of the control room necessary for diagnosis and action. Redundant channels and associated alarms are grouped together. Control rooms in general are designed to promote excellent HMI. The FCS control room is no different and		

ACTION			
PSFs	**PSF Levels**		**Multiplier for Diagnosis**
	has undergone HMI improvements over the years. SPAR-H discusses this as a possible "Good" rating. This PSF could have been assigned a positive number but was left as nominal.		
Fitness for Duty	Unfit		P(failure) = 1.0
	Degraded Fitness		5
	Nominal	X	1
	Insufficient Information		1
	A nominal value for this PSF was assigned. Due to the duration of the event (entire operating cycle) any crew and time of day could be used that could either negatively or positively impact behavior.		
Work Process	Poor		5
	Nominal	X	1
	Good		0.5
	Insufficient Information		1
	A nominal value for this PSF was assigned. Operating crew interaction is stressed during training and has been the focus of specific training sessions. However, an argument could be made that with the emergency response organization (ERO) structure that would be present in these events, and the multiple layers of defense that the ERO system provides, the value could be more positive and as such be lowered to smaller values in both the diagnosis and action areas.		
Action Probability	1.0e-05		

5.4 XSPRAYVALVE, Operator fails to respond to open CS valve

Cognitive Method	**Date**	**Analyst**
SPAR-H	**03/27/07**	
Analysis File	**File Date**	**File Size (Bytes)**
HCV345.HRA	**03/27/07**	**397312**

HEP Summary		
	Failure Probability	**Total HEP**
Diagnosis	1.0e-05	
Action	4.0e-04	4.1e-04

Plant	Ft Calhoun Unit 1
Initiating Event	SLOCA, I3Q, MSLB

Basic Event Context
INITIAL CONDITIONS At power. The plant has experienced one of several initiating events, SLOCA, I3Q, SGTR, MSLB. A SLOCA (< 200 gpm) is chosen as the representative initiating event, as no RAS would be required before the plant reaches SDC conditions.

Basic Event Context

PRECEDING FAILURES AND SUCCESSES

Operators completed EOP-00, diagnosed LOCA correctly and transferred to EOP-03. Cooldown and depressurization to SDC entry conditions successful. SDC entry conditions are:

PZR level is greater than or equal to 45% and constant or rising
RCS subcooling is greater than or equal to 20°F
RCS pressure is less than or equal to 250 psia.
RCS TC between 250 and 300°F

The operators proceeded to EOP-03 step 65 and enter Attachment 4 to place SDC in service. Operator performed step 18 of EOP attachment 4 (R22): "Start selected LPSI pump". Operator had an opportunity to detect and diagnose the open CS valve due to CS flow indication, lowering SIRWT level, and rising containment sump level ; however due to previous sequences, it is unlikely that the operator would have been able to easily diagnose this and therefore it is not credited. Operator performed step 22: Stopped LPSI pump that had been started in step 18 (Diversion of flow to thru the CS valve was terminated at that time). Operator performed step 24: Opened HCV-347 and HCV-348, SDC suction valves from RCS, which creates a diversion flowpath via HCV-345. Operators successfully detected and diagnosed LOCA symptoms immediately following opening of HCV-347 and HCV-348.

SUCCESS CRITERION

Diagnose loss of reactor coolant was caused by initiating shutdown cooling, and close the SDC isolation valve that had just been opened.

CUES AND INDICATIONS

Possible annunciators due to LOCA: Pzr. level hi-lo channel x/y, Pzr. level lo-lo channel x/y, containment sump level hi, SIRWT level hi-lo

ARP-CB-1,2,3/A4 (A-8) PRESSURIZER LEVEL HI-LO CHANNEL X (Setpoint Hi = 56% Lo= 42%, setpoint derived from > 8% or < 6% level from programmed level (48%).
ARP-CB-1,2,3/A4 (B-8) PRESSURIZER LEVEL HI-LO CHANNEL Y (Setpoint Hi = 56% Lo= 42%, setpoint derived from > 8% or < 6% level from programmed level (48%).
ARP-CB-1,2,3/A4 (C-8) PRESSURIZER LEVEL LO-LO CHANNEL X (Setpoint < 41.5%)
ARP-CB-1,2,3/A4 (D-8) PRESSURIZER LEVEL LO-LO CHANNEL Y (Setpoint < 41.5%)
ARP-AI-65A/A65A (13) CONTAINMENT SUMP LEVEL HI (Setpoint > 25 inches)
ARP-AI-65B/A65B (13) CONTAINMENT SUMP LEVEL HI (Setpoint > 25 inches)

Containment spray flow indications labeled as Spray flow FI-342 (HCV-344) on AI-30-30A ESF and Spray Flow FI-343 (HCV-345) on AI-30B ESF.

PROCEDURES AND TRAINING

Operators are required to undergo extensive human performance training prior to obtaining a NRC reactor operator license. As part of this human performance training and station procedures operators are trained to perform certain required actions whenever operating a component or manipulating a switch. FCSG-7 (Fort Calhoun Station Guidelines) states the following:

> *Self-checking is an attention-management technique to help focus the performer's attention on the appropriate component, to think about the intended action and its expected outcome before acting, and to verify results achieved after the action. Attention varies. Error is a specific act. Therefore,*

Basic Event Context
attention must peak when the risk is greatest—altering a component's status. Consequently, rigor and care using self-checking is essential. This technique helps prevent errors when touching and altering equipment or related documentation. But, it is particularly effective for skilled, repetitive tasks, which people can perform without conscious thought. If used correctly, self-checking boosts attention just before performing a physical action. Once the performer pauses to focus his or her attention, the individual takes a moment to reflect on the intended action, the component, and its expected outcome. If uncertain, the performer resolves questions or concerns before proceeding. When the performer is prepared, the individual takes the action, followed by a review of the results of the action. 1. **Stop** – Pause. • Focus attention on the task, the immediate objective. • Eliminate distractions. 2. **Think** – Focus attention on the correct action and component. • Verify the action is appropriate for equipment/system status. • Anticipate and understand expected result(s) of the action. • Consider contingency if an unexpected results occur. • If uncertain, apply the questioning-attitude tool. 3. **Act** – Perform the correct action on the correct component. • Without losing eye contact, read out loud and touch the component label. • Compare component label, etc., with guiding document. • Without losing physical contact, perform the action. 4. **Review** – Verify anticipated result obtained. • Perform the contingency, if expected result does not occur. • Notify supervisor, as needed. Obviously the review step is the critical step in this procedure/guideline for this event. Once the operator opens HCV-348, plant response will not be as expected. This will require him to reverse the step he just did to eliminate the undesired response. This is an operator basic fundamental step. ASSUMPTIONS During the fill of the SDC system piping, there is an opportunity for detecting the flow diversion path, but this is not credited, which is conservative. RAS has not occurred. However, containment spray may have been initiated early in the event and successfully terminated using EOP floating step for reset of safeguards or containment spray termination. If spray did occur it is possible that the crew has recognized that there is a problem with a spray valve not operating correctly. This HFE however does not credit such early detection or diagnosis.

Timing Analysis	
T_{sw}	90.00 Minutes
T_{delay}	1.00 Minutes
$T_{1/2}$	1.00 Minutes
T_M	1.00 Minutes
Time available for recovery	87.00 Minutes
SPAR-H Available time (cognitive)	88.00 Minutes
SPAR-H Available time (execution) ratio	88.00
Minimum level of dependence	ZD

for recovery	
Notes	
Tsw = 90 minutes. Initial RCS inventory will be at nominal operating level. Shutdown cooling can not be placed into service leading to this event unless that level has been obtained. Using analysis document (WEC T-H Analysis for Flow Diversion.doc) with a partially open CS valve, the loss of inventory due to opening of HCV-347 and HCV-348 SDC isolation valves resulted in core uncovery in 90 minutes without operator action to close the valve(s). Tdelay = 1 minute. After the opening of the SDC isolation valves initiating the loss of inventory, immediate audible and visual cues will be available to the operator that a loss of inventory is occurring. One minute is a conservative number. $T_{1/2}$ = 1 minute. After visual cues operators and diagnosis completed, direction from CRS would be to immediately close the SDC isolation valves Tm = One switch operation for one operator to perform to terminate loss of inventory.	

DIAGNOSIS			
PSFs	**PSF Levels**		**Multiplier for Diagnosis**
Available Time (recommended choice based on timing information in bold)	Inadequate Time		P(failure) = 1.0
	Barely adequate time (~ 2/3 x nominal)		10
	Nominal time		1
	Extra time (between 1 and 2 x nominal and > 30 min)		0.1
	Expansive time (> 2 x nominal and > 30 min)	X	0.01
	Insufficient Information		1
	See TIMING ANALYSIS above. Expansive time exists for the operator to complete diagnosis and take action. The T-H analysis shows that at least 90 minutes are available. The indications of rapid inventory loss would be present immediately to allow for a quick and easy diagnosis, leaving most of the 90 minutes for action.		
Stress/Stressors	Extreme		5
	High	X	2
	Nominal		1
	Insufficient Information		1
	Plant is stabilized. No preceding operator or functional failures. Normal control room environment. Work load normal. High stress is conservatively selected due to unexpected plant response when placing SDC in service.		
Complexity	Highly complex		5
	Moderately complex		2
	Nominal		1
	Obvious diagnosis	X	0.1
	Insufficient Information		1
	The cause and effect in this situation are not difficult to ascertain. Pressurizer level was constant until HCV-348 was opened. It is NOT necessary for the operator to determine the exact diversion flow path, only that opening HCV-348 caused lowering of pressurizer level. The obvious reaction is to close HCV-348 again.		

DIAGNOSIS			
PSFs	**PSF Levels**		**Multiplier for Diagnosis**
Experience/Training	Low		10
	Nominal	X	1
	High		0.5
	Insufficient Information		1
	Experience level is high with shift manager and control room supervisor present as well as evenly balanced crews (each year Operations realigns crews) ensuring a high experience level mix exists within each crew for the reactor operators. However, since the LOCA diversion was not practiced specifically for HCV-345 diversion, the experience/training value for XSPRAYVALVE was left a nominal value.		
Procedures	Not available		50
	Incomplete		20
	Available, but poor		5
	Nominal		1
	Diagnostic/symptom oriented	X	0.5
	Insufficient Information		1
	The EOP structure allows flexibility to the operating crew to perform steps necessary to mitigate many different scenarios that could be presented. The structure contains safety function status checks that are reviewed by the Shift Technical Advisor every 10 minutes. The safety function status check for inventory control includes pressurizer level. In the unlikely event that the primary system operator did not immediately detect lowering level, it would be caught by the safety function status check.		
Ergonomics/HMI	Missing/Misleading		50
	Poor		10
	Nominal	X	1
	Good		0.5
	Insufficient Information		1
	The control room is compact and well designed. All alarms, indications, and controls are located within the front panels of the control room necessary for diagnosis and action. Redundant channels and associated alarms are grouped together. Control rooms in general are designed to promote excellent HMI. The FCS control room is no different and has undergone HMI improvements over the years. SPAR-H discusses this as a possible "Good" rating. This PSF could have been assigned a positive number but was left as nominal.		
Fitness for Duty	Unfit		P(failure) = 1.0
	Degraded Fitness		5
	Nominal	X	1
	Insufficient Information		1
	Due to the duration of the event (entire operating cycle) an average crew (nominal) crew has to be assumed.		
Work Process	Poor		2
	Nominal	X	1
	Good		0.8
	Insufficient Information		1

DIAGNOSIS			
PSFs	**PSF Levels**		**Multiplier for Diagnosis**
	Operating crew interaction is stressed during training and has been the focus of specific training sessions. However, an argument could be made that with the emergency response organization (ERO) structure that would be present in these events, and the multiple layers of defense that the ERO system provides, the value could be more positive and as such be lowered to smaller values in both the diagnosis and action areas.		
Diagnosis HEP	1E-05		

ACTION			
PSFs	**PSF Levels**		**Multiplier for Diagnosis**
Available Time (recommended choice based on timing information in bold)	Inadequate Time		P(failure) = 1.0
	Time available is ~ the time required		10
	Nominal time		1
	Time available >= 5x the time required		0.1
	Time available >= 50x the time required	X	0.01
	Insufficient Information		1
	See TIMING ANALYSIS above. Expansive time exists for the operator to complete diagnosis and take action. The T-H analysis shows that at least 90 minutes are available. The indications of rapid inventory loss would be present immediately to allow for a quick and easy diagnosis, leaving most of the 90 minutes for action. The action to mitigate the loss of inventory consists of one or two steps completed from the control room.		
Stress/Stressors	Extreme		5
	High	X	2
	Nominal		1
	Insufficient Information		1
	A negative PSF value was assigned due to the unexpected nature of the loss of inventory after the plant had been stabilized, and the activation of numerous annunciators indicating degrading plant conditions. However, the level of disruptive stress would be insufficient to cause substantial performance deterioration		
Complexity	Highly complex		5
	Moderately complex		2
	Nominal	X	1
	Insufficient Information		1
	A nominal PSF value was assigned due to the simple and uncomplicated sequence to stop the loss of inventory. For both HPSIFLOW and XSPRAYFLOW each action is of only one or two steps. In HPSIFLOW the operator starts the HPSI pump and opens a valve. In XSPRAYVALVE the operator uses only one switch to close a valve (HCV-348). There is little ambiguity, and only a single pertinent variable – lowering pressurizer level – is involved		
Experience/Training	Low		3
	Nominal	X	1
	High		0.5

ACTION			
PSFs	**PSF Levels**		**Multiplier for Diagnosis**
	Insufficient Information		1
	Experience level is high with shift manager and control room supervisor present as well as evenly balanced crews (each year Operations realigns crews) ensuring a high experience level mix exists within each crew for the reactor operators. However, since the LOCA diversion was not practiced specifically for HCV-345 diversion, the experience/training value for XSPRAYVALVE was left a nominal value of 1.		
Procedures	Not available		50
	Incomplete	X	20
	Available, but poor		5
	Nominal		1
	Insufficient Information		1
	Neither Attachment 4 nor EOP-03 contains specific instructions for closing the SDC isolation valves following a flow diversion on the implementation of SDC. Therefore, the assigned value was raised to incomplete, with a value of 20. However, it is standard practice for operators to verify expected response after each action. If the response were not as expected in this situation, it is expected that the operation is reversed. Step-by-step procedural guidance would not be necessary.		
Ergonomics/HMI	Missing/Misleading		50
	Poor		10
	Nominal	X	1
	Good		0.5
	Insufficient Information		1
	A nominal value for this PSF was assigned. The control room is compact and well designed. All alarms, indications, and controls are located within the front panels of the control room necessary for diagnosis and action. Redundant channels and associated alarms are grouped together. Control rooms in general are designed to promote excellent HMI. The FCS control room is no different and has undergone HMI improvements over the years. SPAR-H discusses this as a possible "Good" rating. This PSF could have been assigned a positive number but was left as nominal.		
Fitness for Duty	Unfit		P(failure) = 1.0
	Degraded Fitness		5
	Nominal	X	1
	Insufficient Information		1
	A nominal value for this PSF was assigned. Due to the length of event (entire operating cycle) any crew and time of day could be used that could either negatively or positively impact behavior		
Work Process	Poor		5
	Nominal	X	1
	Good		0.5
	Insufficient Information		1
	A nominal value for this PSF was assigned. Operating crew interaction is stressed during training and has been the focus of specific training sessions. However, an argument could be made		

ACTION			
PSFs	**PSF Levels**		**Multiplier for Diagnosis**
	that with the emergency response organization (ERO) structure that would be present in these events, and the multiple layers of defense that the ERO system provides, the value could be more positive and as such be lowered to smaller values in both the diagnosis and action areas		
Action Probability	4.0e-04		

6 Dependency Analysis

The SPAR-H dependency analysis considers the following dependency factors:

- Crew. Decide whether the crew performing the basic event is the same crew that failed the previous basic event in the sequence. Same crew (relates to similar mindset, use of similar heuristics, tendencies to tunnel vision, recent effects, etc.).

- Time. Decide whether the basic event is close in time to the previous failed basic event in the sequence. This range extends from a few seconds to a few minutes. Close succession of the next action/reaction (from within seconds to a few minutes).

- Location. Decide whether the basic event takes place in the same location as the previous failed basic event in the sequence. Same location (the control, display or piece of equipment must be the same or located within the same relatively restricted area, such as the same panel).

- Cues. Decide (if not close in time) whether additional cues were available following the previous failed basic event in the sequence. These cues can be additional parameter displays, alarms or procedures and procedural steps providing guidance to the operator. Lack of additional cues (additional cues exist if there is a specific procedural call out or a different procedure is used, or additional alarm(s) or display(s) are present).

The above dependency factors were considered in the subsequent dependency analyses.

6.1 COGEARLY, Operators Fail to Detect and Diagnose Flow Diversion via HCV-345 Given Dry Sump Initially

COGEARLY is the first HFE in the sequence of events. The first HFE in a sequence is always independent as it is not preceded by any HFE. COGEARLY is therefore independent, by definition.

6.2 COMCOG, Operators fail to detect or diagnose LOCA

The detection and diagnosis of a LOCA following opening of the SDC suction isolation valves are considered independent of the early detection and diagnosis of a flow diversion during the venting and filling of the SDC system (*COGEARLY*). Should the operators fail the early detection and diagnosis of the flow diversion, they will continue with the procedure and proceed to the step before opening the SDC suction valves. Continuing with the procedure constitutes operator successes as they are performing procedural steps correctly. Intervening successes are deemed to decouple failure events occurring before and after the successes from a dependency point-of-view. When they reach the step prior to opening the SDC suction isolation valves, they will be in exactly the same situation as had there been an initial LOCA: the plant is in a stable state with some coolant in the containment sump. The fact that they had previously not diagnosed the flow diversion has no impact on the probability of failure to diagnose a LOCA.

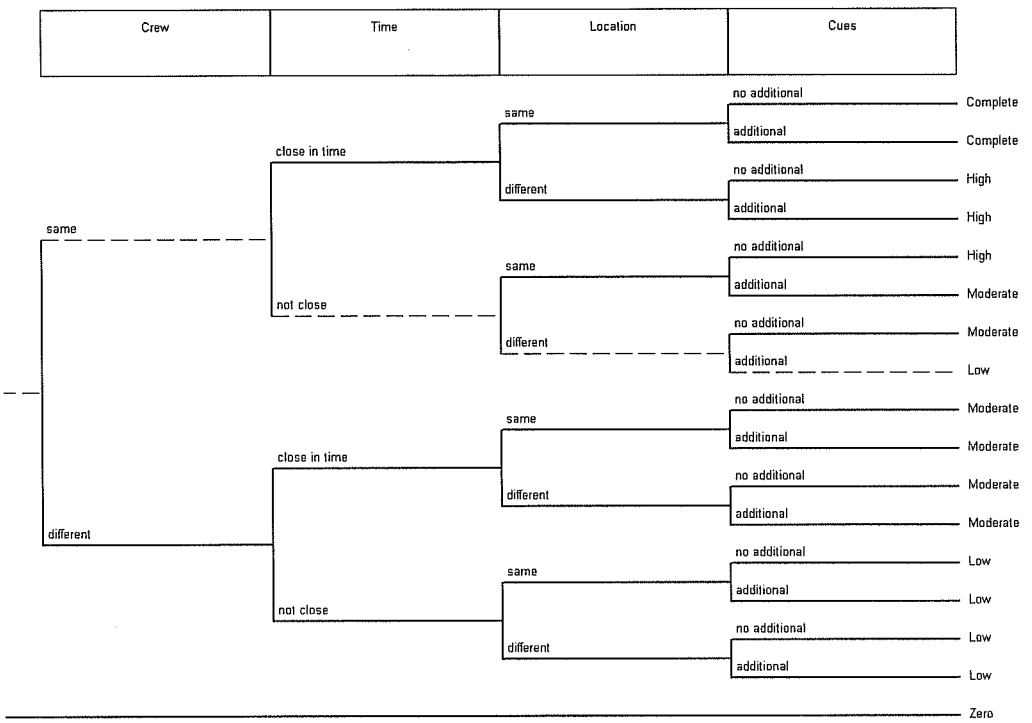
The occurrence of a LOCA is an initiating event because of the requirement for safety injection. The flow diversion that would have occurred during system filling and venting would have had no impact on RCS parameters and would therefore not be an initiating event. In dependency analysis, events following an initiating event are usually considered independent of events that preceded the initiating event in power operating states, because the initiating event is so compelling. The operators are well trained to stop what they are doing and focus exclusively on entering and performing the EOPs – the initiating event is a clear demarcation that decouples the preceding and subsequent events. The operators will not continue with their routine activities following an initiating event, thereby making all their resources available to respond to the initiating event. This is reflected in only allowing 10 minutes for detection and diagnosis of the flow diversion during the running of the LPSI pump, instead of allowing the full 90 minutes.

6.3 HPSIFLOW, Human Failure to Increase HPSI Flow on Loss of RCS Inventory

The dependency factors for *HPSIFLOW* are as follows:

Factor	Determination
Crew	Same crew as the probability of a shift change for 12 hour shifts during the 90 minute time window is small (0.125)
Time	Not close in time as the time available for recovery is 88 minutes and each action, which takes less than a minute each, can be performed more than an hour apart. Even though the initial responses may be a few minutes apart, time is not a restrictive driving factor as there is sufficient time for multiple recoveries.
Location	Different location as the controls for HPSI are on the A33-1, A33-2, A34-1 and A34-2 panels, while the HCV-347 and HCV-348 controls are on the CB1, 2, 3 panels on different sides in the control room.
Cues	Additional cues that can be credited are the Reactor Vessel Level Monitoring System (RVLMS) indications, which are monitored by the STA as part of the safety function monitoring every 10 minutes. So, should the operators initially fail to diagnose LOCA based upon lowering of pressurizer level, RCS pressure and subcooling, the LOCA will manifest due to lowering of reactor vessel level. The STA also reviews SI flow requirements per Attachment 3 as part of the safety function monitoring, which can be credited as a cue for recovery of HPSI.

Given the dependency factors above, the SPAR-H dependency decision tree evaluates to "Low" as show below:



Given the "Low" level of dependence, the conditional HEP evaluates to 0.05, based on the THERP dependency formulas used in SPAR-H.

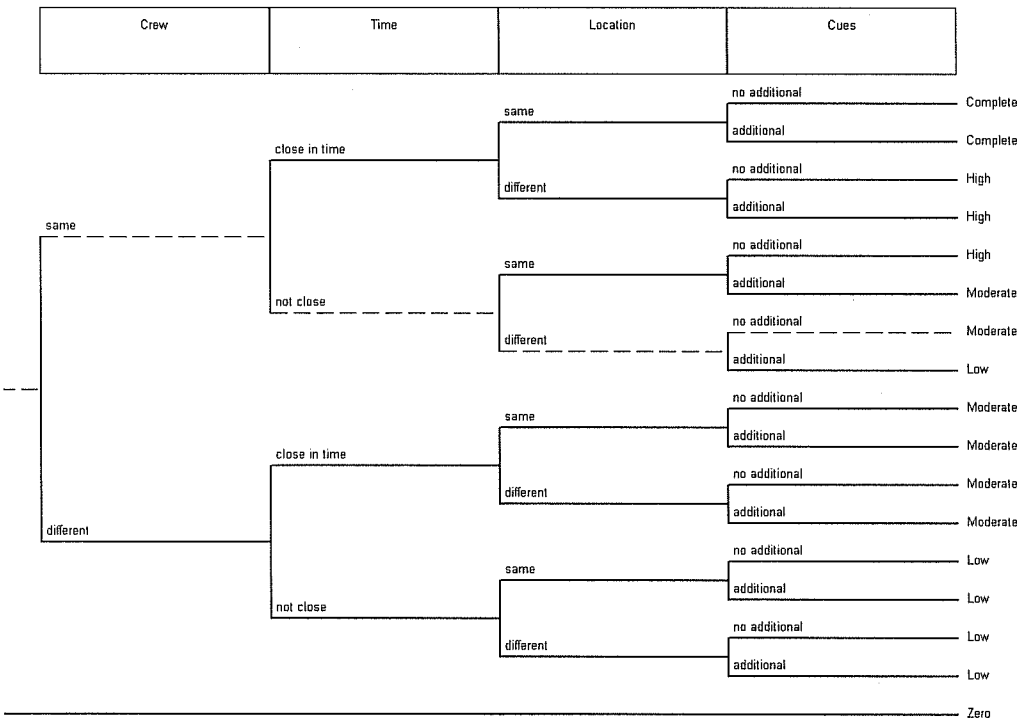
6.4 XSPRAYVALVE, Operator fails to respond to open CS valve

The dependency factors for *XSPRAYVALVE* are as follows:

Factor	Determination
Crew	Same crew as the probability of a shift change for 12 hour shifts during the 90 minute time window is small (0.125)
Time	Not close in time as the time available for recovery is 88 minutes and each action, which takes less than a minute each, can be performed more than an hour apart. Even though the initial responses may be a few minutes apart, time is not a restrictive driving factor as there is sufficient time for multiple recoveries.

Factor	Determination
Location	Different location, as the controls for HPSI are on the A33-1, A33-2, A34-1 and A34-2 panels, while the HCV-347 and HCV-348 controls are on the CB1, 2, 3 panels on different sides in the control room.
Cues	No additional cues are credited.

Given the dependency factors above, the SPAR-H dependency decision tree evaluates to "Moderate" as show below:



Given the "Moderate" level of dependence, the conditional HEP evaluates to 0.14, based on the THERP dependency formulas used in SPAR-H.

7 Results

For transient initiators, Table 5 shows that the joint HEP - associated with the strategy where the operators first attempt to close the SDC valves - is 2.81E-08. The *COGEARLY* HEP is 1.1E-03 as calculated in Section 5.1. The *COMCOG* HEP is 5.00E-06 as calculated in Section 5.2. The *XSPRAYVALVE* HEP of 4.10E-04 is the independent HEP calculated in Section 5.4. The *HPSIFLOW* HEP of 0.05 is the conditional HEP calculated in Section 6.3.

For transient initiators, Table 6 shows that the joint HEP associated with the strategy where the operators first attempt to increase HPSI flow is 7.81E-09. The *COGEARLY* HEP is 1.1E-03 as calculated in Section 5.1. The *COMCOG* HEP is 5.00E-06 as calculated in Section 5.2. The *HPSIFLOW* HEP of 1.5E-05 is the independent HEP calculated in Section 5.3. The *XSPRAYVALVE* HEP of 4.10E-04 following successful HPSI is the independent HEP calculated in Section 5.4. The *XSPRAYVALVE* HEP of 0.14 following failure of HPSI is the conditional HEP calculated in Section 6.4.

For LOCAs, Table 7 shows that the joint HEP - associated with the strategy where the operators first attempt to close the SDC valves - is 2.55E-05. The *COGEARLY* HEP is 1.0 as this is not credited for LOCA scenarios. The *COMCOG* HEP is 5.00E-06 as calculated in Section 5.2. The *XSPRAYVALVE* HEP of 4.10E-04 is the independent HEP calculated in Section 5.4. The *HPSIFLOW* HEP of 0.05 is the conditional HEP calculated in Section 6.3.

For LOCAs, Table 8 shows that the joint HEP associated with the strategy where the operators first attempt to increase HPSI flow is 7.1E-06. The *COGEARLY* HEP is 1.0 as this is not credited for LOCA scenarios. The *COMCOG* HEP is 5.00E-06 as calculated in Section 5.2. The *HPSIFLOW* HEP of 1.5E-05 is the independent HEP calculated in Section 5.3. The *XSPRAYVALVE* HEP of 4.10E-04 following successful HPSI is the independent HEP calculated in Section 5.4. The *XSPRAYVALVE* HEP of 0.14 following failure of HPSI is the conditional HEP calculated in Section 6.4.

Although it could be more defensible to argue that the operators would be more likely to follow the proceduralized instructions i.e. to increase HPSI flow as an immediate response to the flow diversion, it is quite likely that they would respond by first closing the SDC valves. By assigning each mitigating scenario a weighting factor of 0.5, the overall joint HEPs for transient and LOCA scenarios are summarized in Table 4.

Table 4: Summary of Joint HEP Results

	Close SDC	WF	HPSI	WF	Joint HEP
Transient	2.81E-08	0.5	7.81E-09	0.5	1.79E-08
LOCA	2.55E-05	0.5	7.10E-06	0.5	1.63E-05

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Table 5: Joint HEP for Failure to Close SDC Valves and Failure to Start HPSI for Transients

Top Event	Early Cognition	Open SDC Valve/s	LOCA Cognition	Close SDC Valve/s	Start HPSI	Seq #	Outcome	Prob
BE ID	COGEARLY		COMCOG	XSPRAYVALVE	HPSIFLOW			
		No				1	Success	
Yes						2	Success	
No						3	Success	
					0.95			
		Yes		4.10E-04		4	CD	2.26E-08
	1.1E-03				0.05			
			5.00E-06			5	CD	5.50E-09
						Total:		2.81E-08

Table 6: Joint HEP for failure to Start HPSI and Failure to Close SDC Valve/s for Transients

Top Event	Early Cognition	Open SDC Valve/s	LOCA Cognition	Start HPSI	Close SDC Valve/s	Seq #	Outcome	Prob
BE ID	COGEARLY		COMCOG	HPSIFLOW	XSPRAYVALVE			
		No				1	Success	
Yes						2	Success	
No						3	Success	
					0.86			
		Yes		1.5E-05		4	CD	2.31E-09
	1.1E-03				0.14			
			5.00E-06			5	CD	5.5E-09
						Total:		7.81E-09

Table 7: Joint HEP for Failure to Close SDC Valves and Failure to Start HPSI for LOCAs

Top Event	Early Cognition	Open SDC Valve/s	LOCA Cognition	Close SDC Valve/s	Start HPSI	Seq #	Outcome	Prob
BE ID	COGEARLY		COMCOG	XSPRAYVALVE	HPSIFLOW			
		No				1	Success	
Yes						2	Success	
No					0.95	3	Success	
		Yes		4.10E-04		4	CD	2.05E-05
	1.00E+00				0.05	5	CD	5.00E-06
			5.00E-06				**Total:**	2.55E-05

Table 8: Joint HEP for failure to Start HPSI and Failure to Close SDC Valve/s for LOCAs

Top Event	Early Cognition	Open SDC Valve/s	LOCA Cognition	Start HPSI	Close SDC Valve/s	Seq #	Outcome	Prob
BE ID	COGEARLY		COMCOG	HPSIFLOW	XSPRAYVALVE			
		No				1	Success	
Yes						2	Success	
No						3	Success	
					0.86			
		Yes		1.50E-05		4	CD	2.1E-06
	1.00E+00				0.14			
			5.00E-06			5	CD	5.00E-06
							Total:	7.1E-06

8 References

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