December 22, 2003

MEMORANDUM TO: Michael D. Tschiltz, Chief
Probabilistic Safety Assessment Branch
Division of Systems Safety and Analysis
Office of Nuclear Reactor Regulation

FROM: F. Mark Reinhart, Chief /**RA/**
Operations Support and Licensing Section
Probabilistic Safety Assessment Branch
Division of Systems Safety and Analysis
Office of Nuclear Reactor Regulation

SUBJECT: PUBLIC MEETING TO DISCUSS THE PROPOSED SHUTDOWN SIGNIFICANCE DETERMINATION PROCESS WITH INDUSTRY REPRESENTATIVES

DATE AND TIME: Thursday, January 15, 2004
8:30 a.m. - 4.30 p.m.

LOCATION: U.S. Nuclear Regulatory Commission
One White Flint North
Room OWFN 10 B-4
11555 Rockville Pike
Rockville, Maryland

PURPOSE: To discuss and to respond to stakeholder comments on the proposed shutdown Significance Determination Process (SDP).

CATEGORY: The public is invited to participate in this meeting providing comments and asking questions throughout the meeting.

BACKGROUND: Under the NRC new Reactor Oversight Process, the staff developed phase 2 shutdown risk templates for BWRs and PWRs. These templates are to be used to determine the risk significance of shutdown inspection findings and shutdown performance deficiencies. The staff also developed Appendix H which is used to assess the risk significance of performance deficiencies using the large early release frequency (LERF) risk metric.

AGENDA TOPICS: The staff will discuss the Basis document for the phase 2 BWR and PWR templates. The Basis document defines the shutdown PRA model used in the phase 2 templates. The staff will also discuss Appendix H.

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(301) 415-1846

PARTICIPANTS:

NRC	INDUSTRY
M. Pohida	T. Houghton et al.
R. Palla	
A. El-Bassioni	
G. Parry	
F. Reinhart	
P. Koltay	

Attachments:
1. Risk-Informed Inspection Template for a PWR During Shutdown
2. Risk-Informed Inspection Template for a BWR During Shutdown
3. BWR Event Trees
4. PWR Event Trees

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ATTACHMENT 1

RISK-INFORMED INSPECTION TEMPLATE FOR A PWR DURING SHUTDOWN

U. S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation

POINT OF CONTACT FOR ASSISTANCE/COMMENTS
Marie Pohida NRR/DSSA/SPSB
301-415-1846

December 18, 2003

Table of Contents

1.0 ENTRY CONDITIONS AND APPLICABILITY

As directed in the SRM to SECY 97-168, the staff is inspecting and monitoring licensee performance at shutdown to ensure that the licensees are maintaining a mitigation capability (equipment, instrumentation, policies, procedures, and training) consistent with the staff's estimate of industry shutdown risk presented to the Commission in SECY 97-168 (the proposed shutdown rule). In the Reactor Oversight Process (ROP), the significance of such inspection findings is assessed, using a Risk Informed process, called the Significance Determination Process (SDP). The shutdown SDP consists of three phases: Phase 1, Definition and Initial Screening of Findings; Phase 2, Initial Risk Significance Approximation and Basis; and Phase 3, Risk Significance Finalization and Justification. IMC 0609 Appendix G, Shutdown Operations Significance Determination Process is used to conduct the phase 1 screening analysis. This template is used to perform phase 2 analyses for certain PWR shutdown findings discussed below.

1.1 Entry Conditions

1.1.1 SDP-related Inspection Finding

This SDP provides a simplified risk-informed framework to estimate the increase in core damage frequency during shutdown operations due to conditions which contribute unintended risk increases caused by deficient licensee performance. Conditions which do NOT represent deficient licensee performance, as determined by the staff, are considered part of the acceptable plant normal operating risk, and are NOT candidates for SDP evaluation. The entry conditions for the shutdown SDP described in this document are degraded plant equipment, functions, or processes affecting initiating event frequency, mitigation system availability/reliability, or RCS barrier integrity that result from deficient licensee performance.

Concurrent performance deficiencies should be assessed collectively if they resulted from a closely-tied common cause. If causes are independent, each performance deficiency should be assigned a color individually. See IMC 0609, Appendix A for more detailed guidance.

1.1.2 MD 8.3 Entry

Procedures are given in Chapter 4 for using this template to perform quantitative assessment of shutdown events to satisfy Management Directive 8.3.

1.2 Applicability

The process in this SDP is designed to provide Senior Reactor Analysts a simple scrutable probabilistic risk framework for use in identifying potentially risk-significant shutdown issues within the initiating events, mitigation systems, and barriers cornerstones. The results from this SDP tool are intended to facilitate communication on the basis of risk significance between the NRC and licensees.

2.0 LIMITS AND PRECAUTIONS

2.1 Limits

The template is a simplified tool that generates an order-of-magnitude assessment of the risk significance of inspection findings during shutdown.

2.2 Precautions

2.2.1 The analyst should consider each evaluated Core Damage sequence using the event trees to ensure that the scenario makes sense for the deficiency. The variability of plant configurations at shutdown and timing issues may result in performance deficiencies which do not directly map on the event trees. See Headquarters for assistance if needed.

2.2.2 The analyst must understand: (1) the differences between precursor and condition findings, (2) the definitions of the plant operational states, and (3) the definitions of the shutdown initiating events.

2.2.3 The availability of standby RCS injection along with operator error drives shutdown risk. As long as standby injection is available, in most cases, standby injection buys time for other operator recovery actions such as: leak path termination and RHR recovery. If there are factors that could render the standby RCS injection unavailable such as: gas intrusion or support system unavailability, then these factors (assumptions) become risk significant and should be assessed carefully.

2.2.4 Upon RWST depletion and long term failure of RHR, recirculation of RCS inventory from the sump is not credited in this phase 2 model, since: (1) for many licensees, the low pressure injection pumps that are necessary for recirculation are the same pumps used for RHR, and (2) there is a high likelihood that trash accumulated during the outage could block the sump screens.

2.2.5 Some findings are not covered by these templates and go directly to Headquarters for Phase 3 analysis. Examples of such findings are as follows:

- Potential over-pressurization of low -pressure piping and deficiencies associated with maintaining low temperature over pressure protection.

- Use of Nozzle Dams without an adequate RCS vent path that would prevent the RCS from re-pressurizing above 25 psig following an extended loss of RHR (25 psi represents an approximate differential pressure capability for the nozzle dams)

- Findings that increase the likelihood of having a boron dilution event such as the source range monitors being inoperable or the RWST having boron concentrations lower than Technical Specifications prescribed values.

- Findings that involve containment closure are assessed using IMC 0609 Appendix H.

3.0 ABBREVIATIONS AND DEFINITIONS

3.1 Abbreviations

CETs	Core Exit Thermocouples
CD	Core Damage
High Decay Heat	Decay heat of early time window
Low Decay Heat	Decay heat of late time window
CCW	Component Cooling Water
DHR	Decay Heat Removal
ECCS	Emergency Core Cooling System
INDIC.	Indication
IMC	Inspection Manual Chapter
LOI	Loss of Reactor Inventory Initiating Event
LER	Licensee Event Report
LOOP	Loss of Offsite Power
LORHR	Loss of RHR Initiating Event
OP.	Operator
POS	Plant Operational State
PRA	Probabilistic Risk Assessment
RCS	Reactor Coolant System
RHR	Residual Heat Removal
ROP	Reactor Oversight Process
SDP	Significance Determination Process
SG	Steam Generator
SG PORV	Steam Generator Power Operated Relief Valve
SRW	Site Raw Water
SSW	Standby Service Water
TBB	Time to Boiling
TW	Time Window
TW-E	Early Time Window, before refueling operation
TW-L	Late Time Window, after refueling operation

3.2 Definitions

Phases of a Significance Determination

Phase 1 -Characterization and Initial Screening of Findings: Precise characterization of the finding and an initial screening of very low-significance findings for disposition by the licensee's corrective action program.

Phase 2 - Initial Risk Significance Approximation and Basis**:** Initial approximation of the risk significance of the finding and development of the basis for this determination for those findings that are not screened out in Phase 1 screening.

Phase 3 - Risk Significance Finalization and Justification: Review and as-needed refinement of the risk significance estimation results from Phase 2, or development of any risk analysis outside of this guidance, by an NRC risk analyst (any departure from the guidance provided in this document or IMC 609 Appendix G for Phase 1 or Phase 2 constitutes a Phase 3 analysis and must be performed by an NRC risk analyst).

Types of Shutdown Performance Deficiencies

Precursor Finding - Inspection findings that have the potential to cause a loss of the operating train of RHR.

Condition findings - Inspection findings that only involve a degradation of the licensee's mitigation capability.

Shutdown Initiating Events

Loss of RHR (LORHR) - Includes losses of RHR resulting from failures of the RHR system (such as RHR pump failure) or failures of the RHR support systems other than offsite power.

Loss of Offsite Power (LOOP) - Includes losses of offsite power which cause a loss of RHR.

Loss of Reactor Inventory (LOI) - Includes losses of RCS inventory that lead to a loss of RHR due to loss of RHR pump suction.

Loss of Level Control (LOLC) - This initiating event category includes: (1) the operator overdrains the RCS to reach midloop conditions such that RHR is lost, and (2) the operator fails to maintain level or flow control while in midloop such that the RHR function is lost.

Plant Operational States (POSs)

POS 1 - This POS starts when the RHR system is put into service. The RCS is closed such that a steam generator could be used for decay heat removal, if the secondary side of a steam generator is filled. The RCS may have a bubble in the pressurizer. This POS ends when the RCS is vented such that the steam generators cannot sustain core heat removal. This POS typically includes Mode 4 (hot shutdown) and portions of Mode 5 (cold shutdown).

POS 2 - This POS starts when the RCS is vented such that: (1) the steam generators cannot sustain core heat removal and (2) a sufficient vent path exists for feed and bleed. This POS includes portions of Mode 5 (cold shutdown) and Mode 6 (refueling). Reduced inventory operations and midloop operations with a vented RCS are subsets of this POS. Note: performance deficiencies occurring during a vacuum refill of the RCS require use of the POS 1 event trees.

POS 3 - This POS represents the shutdown condition when the refueling cavity water level is at or above the minimum level required for movement of irradiated fuel assemblies within containment as defined by Technical Specifications. This POS occurs during Mode 6.

Time Windows

Early Time Window (TW-E)- This time widow represents the time before POS 3 is entered. The decay heat is relatively high. The reactor is either in POS 1 or 2.

Late Time Window (TW-L)- This time window represents the time after POS group 3. The decay heat is relatively low. The reactor is either in POS 1, 2, or 3.

Other Key Shutdown Definitions

Available - A piece of equipment is considered available if it can be put into service quickly enough to meet its function need and all necessary supporting systems are functional (such as AC power, cooling water, and DC control power)

Gravity Feed - Gravity feeding to the RCS may be credited if Gravity Feed is expected to be available AFTER RCS boiling initiates. To credit Gravity Feed, the analyst needs to consider the following factors that can negate the elevation head provided by the RWST or other sources of RCS inventory: (1) pressure drops in the surge line, (2) entrained water accumulating in the pressurizer, (3) RCS vent paths that are restricted (to control loose parts or control off gassing)

Mid Loop - As defined in Generic Letter 88-17, a mid-loop condition exists whenever the RCS water level is below the top of the flow area of the hot legs at the junction with the reactor vessel.

RCS Vented - RCS vented with such that(1) SG heat removal cannot be sustained, and (2) the vent path is large enough to support feed and bleed. Examples of vent paths include: open pressurizer manways, safety relief valve removal, or vessel head removal.

Reduced Inventory Operations - As defined in Generic Letter 88-17, Reduced inventory operation exists whenever the reactor vessel water level is lower than 3 feet below the reactor vessel flange.

RWST Depletion - RWST level reaches the level that requires makeup or recirculation to continue injection to RCS

Shutdown Operations - Shutdown Operation exists during hot shutdown, cold shutdown, and refueling when more than one fuel assembly is in the reactor vessel and the decay heat removal system is in operation.

4.0 PROCEDURE FOR SIGNIFICANCE DETERMINATION

Step 4.1 **Use the Information Gathered in the Phase 1 process to identify the set of equipment that the licensee planned to meet the following safety functions: Standby RCS injection, RCS pressure control, and Steam generator cooling if applicable.**

Note: Equipment is considered available if it can be put into service quickly enough to meet its functional need, and all necessary supporting systems are functional (such as AC power, cooling water and DC control power).

Step 4.2 **Determine if the finding is a precursor to an initiating event (a loss of the DHR function) or a condition finding.**

Note: Precursor findings: (1) have the potential to: cause a loss of the operating train of RHR, or (2) increase the likelihood that the operating RHR train could be lost, or (3) result in a shutdown event - cause a loss/interruption of the operating train of RHR. Condition findings only involve a degradation of the licensee's capability to mitigate an event if an event were to occur. Findings only affecting the standby train of RHR are condition findings. The templates treats precursor and condition findings differently.

Go To Step 4.3 for Precursor Findings

OR

Go To Step 4.4 for Condition Findings

NOTE: If this tool is being used to assess a shutdown event under Management Directive 8.3, Go to Step 4.5

4.3 Procedure for Assessing Precursor Findings

Step 4.3.1 Identify **each** TW and POS where the finding could have occurred.

Step 4.3.2 Determine the IEL rating. The IEL rating is the conditional likelihood of having a loss of the RHR function given the occurrence of the performance deficiency.

- IF a finding increases the likelihood of a loss of level control (LOLC) or actually caused a LOLC, THEN LOLC is the applicable initiating event. Use Table 1 to determine the IEL. Go to Step 4.2.3.

- IF a finding increases the likelihood of a loss of offsite power (LOOP) or actually caused a LOOP, THEN LOOP is the applicable initiating event. Use Table 2 to determine the IEL. Go to Step 4.2.3.

- IF a finding increases the likelihood of a loss of reactor inventory (LOI) or actually caused a LOI, THEN LOI is the applicable initiating event. Use Table 3 to determine the IEL. Go to Step 4.2.3

- IF a finding increases the likelihood of a loss of the operating train of RHR (LORHR) or actually caused a LORHR (except for LOOP and LOI), THEN LORHR is the applicable initiating event. Use Table 4 to determine the IEL. Go to Step 4.2.3

- IF a finding involves the RHR support systems (except for LOOP and LOI), THEN LORHR is the applicable initiating event. Use Table 4 to determine the IEL. Go to Step 4.2.3

Step 4.3.3 Use the SDP Worksheet that contains the POS and initiating event that were determined to be applicable in Step 4.2.2.

EXCEPTIONS:

(1) For LOI Phase 1 if RCS < 200F, use the POS 1 LOLC worksheets and event trees.

(2) If failure of the cavity seal could occur following LOOP or SBO, use the LOOP POS 2 worksheet

Step 4.3.4 Enter the time to RCS boiling and an approximate time to core uncovery/core damage in the first line of the Worksheet.

Table 8 can be used to estimate time to core damage from hot leg midplane conditions.

Step 4.3.5 Label the IEL in each row of the lower section of the worksheet.

Step 4.3.6 Determine Credit for each top event function.

A. Verify that the licensee has the instrumentation referenced for the top event function.

NOTE If the licensee does not have the referenced instrumentation available or the referenced instrumentation is not reflective of RCS conditions, then the default operator credit MUST by decreased by 2.

B. To obtain the equipment credit, credit each **available** system that is (1) capable of maintaining the top event function and (2) is not impacted by the finding. Use the Event Tree associated with the Worksheet to help understand the successes and failures associated with each accident sequence. Use guidance in Tables 6 and 7 to determine equipment credits. Document key assumptions.

C. To obtain the Operator Credit. **Use the default operator credit unless any of the following four conditions are applicable :**

1. The referenced instrumentation is missing or misleading, Then decrease the operator credit by two.
2. The default time is incorrect and significantly reduced. If the diagnoses time is less than 20 minutes OR the time to perform the action is approximately the time required, then decrease the operator credit by 1.
3. The action is complicated by missing equipment, unaccessible equipment, steam or high radiation, or loop seals for venting pumps, then decrease the operator credit by two.
4. If the procedures are not complete for the shutdown plant configuration, then the operator credit is decreased by one.

NOTE: If the default operator credit is changed and results in a negative operator credit, then the operator credit is zero.

B. Determine the Credit for Function for each Top Event Function needed. Select the lower of Equipment Credit and Operator Credit, and enter the value in this column.

Step 4.3.7. Quantification of Core Damage Scenarios

Quantify each accident scenario by adding the credits for IEL + Mitigation Credit. Enter the sum in the Result column.

Note, For phase 2 analyses, the recovery credit is not used.

Step 4.3.8. Identifying the Frequency of Finding Occurrence.

The color of the finding is determined similar to the process using the guidance in IMC 0609 Appendix A. However, this color is based on the finding being assessed as a conditional core damage probability. The analyst now must estimate how frequently per calender year can this performance deficiency would result in the finding occurrence, so that a delta initiating event frequency can be obtained.

Rather than providing method to develop initiating event frequencies (that will not cover all findings and may lead to errors), examples were providing to assist the analyst.

A. Deficiencies involving faulty test procedures or fault equipment that results in a precursor event during test or maintenance.

For a faulty test procedure, the initiating event frequency becomes: (1 test / outage)*(1 outage/outage frequency (e.g.18 months) = .67 per year.

EXAMPLE: A mechanic incorrectly re-assembled a CCW relief valve such that the relief valve would not reseat as quickly as intended. This deficiency was revealed during an containment isolation valve test which is performed once per outage. CCW relief valve lift is anticipated during performance of the test. A stuck open relief valve would lead to a potential loss of CCD and result in a potential loss of the RHR function.

Frequency of the deficiency becomes:

(1 outage /18month period)*(12 months/calender year*(1 relief valve lift /outage)*(1.0 relief valve fails to reseat/ relief valve lift)

B. Deficiencies that are revealed through random events (such that the event could have occurred in POS 1, POS 2, POS 3 or full power) that lead to a precursor event - The analyst needs to perform an SDP analysis for POS 1, POS2, POS 3, and full power for time window 1. The analyst can assumed that the risk is bounded by Time Window 1.

Based on a representative 35 day outage, the duration of POS 1, POS 2, and POS 3 during time window one is given at 2 days, 6 days, and 10 days per outage respectively.

EXAMPLE - A licensee had a single cable that carried protective relays for the offsite power supplies and the safety-related buses which were underground and outside the licensee's protected area. The cable was damaged during the installation of a sign post in the parking lot which damaged the cable The damage caused a LOOP while the licensee was in POS 2.

The analyst has to assess the risk of this specific performance deficiency in POS 1 and POS 2 and full power (using the full power SDP tools). This specific deficiency does not need to be assessed for POS 3. As explained in the Basis Document, LOOP events are not assessed in POS 3 since, the time to core uncovery is assumed to be greater than 24 hours.

For example, the frequency for the occurrence of this deficiency for POS 2 Time Window One becomes:

(Deficiency manifested once/ 32 calender years of plant operation)*(1 outage /18 month)*(12 months/ calender year)*(6 days of POS 2 operation/outage) (1 calender year/8760 days) =

Once the annual frequency is determined, the color is reduced by one if the frequency is estimated between .1 and 1. The color is reduced by two is the frequency is estimated between .01 and .1

4.4 Process for Assessing SDP Condition Findings

NOTE: Only the core damage scenarios impacted by the finding are quantified.

Step 4.4.1 Select the applicable initiating events (LOLC, LORHR, LOOP and/or LOI) by identifying the equipment or safety functions affected and determine the initiating event scenarios that must be evaluated (i.e., the affected function plays some role in mitigating the initiating event scenario).

Step 4.4.2 Determine the exposure times for the degraded condition in the mitigating system. A separate exposure time must be determined for each POS for findings that span one or more POS. Using Table 5, determine an IEL for each applicable initiating event in each applicable POS.

Step 4.4.3 Use the SDP Worksheet(s) that contain the POSs and initiating events that were determined to be applicable in Step 4.2. Perform the following steps on the Worksheet for each applicable POS and initiating event.

Step 4.4.4 Enter the time to RCS boiling and an approximate time to core uncovery/core damage in the first line of the Worksheet.

Table 8 can be used to estimate time to core damage from hot leg midplane conditions.

Step 4.4.5 Label the IEL in each row of the lower section of the worksheet.

Step 4.4.6 Determine Revised Credit for each top event function Impacted by the Finding

A. Verify that the licensee has the instrumentation referenced for the top event function.

NOTE: If the licensee does not have the referenced instrumentation available or the referenced instrumentation is not reflective of RCS conditions, then the default operator credit must be decreased by two.

B. To obtain the equipment credit, credit each **available** system that is (1) capable of maintaining the top event function and (2) is not impacted by the finding. Use the Event Tree associated with the Worksheet to help understand the successes and failures associated with each accident sequence. Use guidance in Tables

6 and 7 to determine equipment credits. Document key assumptions.

NOTE: Each top event has a equipment credit and an operator credit, only the equipment credit **change** or the operator credit **change** is propagated through the worksheets. See the following examples

Example: if the licensee has a finding that changes the FEED equipment credit from 5 to 3, then the revised credit for the FEED&BLEED FUNCTION becomes 3, regardless of the BLEED credit or the operator credit.

C. To obtain, a **revised** <u>Operator Credit,</u> **use the following guidance:**

1. The referenced instrumentation is missing or misleading, Then decrease the operator credit by two.
2. The default time is incorrect and significantly reduced. If the diagnoses time is less than 20 minutes OR the time to perform the action is approximately the time required, then decrease the operator credit by 1.
3. The action is complicated by missing equipment, unaccessible equipment, steam or high radiation, or loop seals for venting pumps, then decrease the operator credit by two.
4. If the procedures are not complete for the shutdown plant configuration, then the operator credit is decreased by one.

NOTE: If the default operator credit is changed and results in a negative operator credit, then the operator credit is zero.

Example: if the licensee has a finding that changes the operator credit from a 5 to a 3 due to a loss of instrumentation, then the revised credit for the FEED&BLEED FUNCTION becomes 3, regardless of the equipment FEED&BLEED equipment credit.

B. Determine the <u>Credit for Function</u> for each <u>Top Event Function</u> needed. Select the lower of <u>Equipment Credit</u> and <u>Operator Credit</u>, and enter the value in this column.

Step 4.4.7. Quantification of Core Damage Scenarios

Quantify each accident scenario that is impacted by the finding adding the credits for <u>IEL</u> + <u>Mitigation Credit.</u> Enter the sum in the <u>Result</u> column.

Note, For phase 2 analyses, the recovery credit is not used.

Step 4.4.8 Go to the next applicable Worksheet and begin at Step 4.3.1 or, if all Worksheets are completed, continue to Step 4.3.9.

Step 4.4.9 Estimating the Risk Significance of the Inspection Finding

The risk significance of an inspection finding is determined in the same manner as for at-power findings. Use IMC 0609, Appendix A, Step 2.4 - "Estimating the Risk Significance of Inspection Findings" to determine the risk significance of a finding.

4.5 Process for Assessing Events Under Management Directive 8.3

Step 4.5.1 Identify the TW and POS where the shutdown event occurred.

Step 4.5.2 Identify the appropriate shutdown initiating event.

Use an IEL = 1.0 if the event caused a loss of interruption of the RHR function.

OR

Determine the IEL rating. Evaluate the each question in order, one will apply:

- IF a finding increases the likelihood of a loss of level control (LOLC) or actually caused a LOLC, THEN LOLC is the applicable initiating event. Use Table 1 to determine the IEL. Go to Step 4.4.3.
- IF a finding increases the likelihood of a loss of offsite power (LOOP) or actually caused a LOOP, THEN LOOP is the applicable initiating event. Use Table 2 to determine the IEL. Go to Step 4.4.3.
- IF a finding increases the likelihood of a loss of reactor inventory (LOI) or actually caused a LOI, THEN LOI is the applicable initiating event. Use Table 3 to determine the IEL. Go to Step 4.4.3
- IF a finding increases the likelihood of a loss of the operating train of RHR (LORHR) or actually caused a LORHR (except for LOOP and LOI), THEN LORHR is the applicable initiating event. Use Table 4 to determine the IEL. Go to Step 4.4.3
- IF a finding involves the RHR support systems (except for LOOP and LOI), THEN LORHR is the applicable initiating event. Use Table 4 to determine the IEL. Go to Step 4.4.3

Step 4.5.3 Use the SDP Worksheet that contains the POS and initiating event that were determined to be applicable in Step 4.4.1

EXCEPTIONS: (1) For LOI POS 1 if RCS < 200F, use the POS 1 LOLC worksheets and event trees.

(2) If failure of the cavity seal could occur following LOOP or SBO, use the LOOP POS 2 worksheet

Step 4.5.4 Enter the time to RCS boiling and an approximate time to core uncovery/core damage in the first line of the Worksheet.

Table 8 can be used to estimate time to core damage from hot leg midplane conditions.

Step 4.5.5 Label the IEL in each row of the lower section of the worksheet.

Step 4.5.6 Determine the revised Credit for each top event function impacted by the finding for the **as found condition during the event.**

A. Verify the licensee has the instrumentation referenced for the top event function.

NOTE If the licensee does not have the referenced instrumentation available or the referenced instrumentation is not reflective of RCS conditions, then the default operator credit MUST be reduced by two.

B. To obtain the equipment credit, credit each **available** system that is (1) capable of maintaining the top event function and (2) is not impacted by the finding. Use the Event Tree associated with the Worksheet to help understand the successes and failures associated with each accident sequence. Use guidance in Tables 7 and 8 to determine equipment credits. Document key assumptions.

C. To obtain, the Operator Credit. **Use the default operator credit unless any of the following four conditions are applicable:**

1. The referenced instrumentation is missing or misleading, Then decrease the operator credit by two.
2. The default time is incorrect and significantly reduced. If the diagnoses time is less than 20 minutes OR the time to perform the action is approximately the time required, then decrease the operator credit by 1.
3. The action is complicated by missing equipment, unaccessible equipment, steam or high radiation, or loop seals for venting pumps, then decrease the operator credit by two.

4. If the procedures are not directed for shutdown configuration that the plant is in, then the operator credit is decreased by one.

NOTE: If the default operator credit is changed and results in a negative operator credit, then the operator credit is zero.

D. Determine the Credit for Function for each Top Event Function needed. Select the lower of Equipment Credit and Operator Credit, and enter the value in this column.

Step 4.5.7. Quantification of Core Damage Scenarios

Quantify each accident scenario by adding the credits for IEL + Mitigation Credit. Enter the sum in the Result column.

Note, For phase 2 analyses, the recovery credit is not used.

5.0 FIGURES, TABLES, WORKSHEETS AND EVENT TREES

5.1 Figures

5.2 Tables

5.3 Worksheets and Event Trees

Figure 1 Determination of Applicable POSs and Time Windows - PWRs

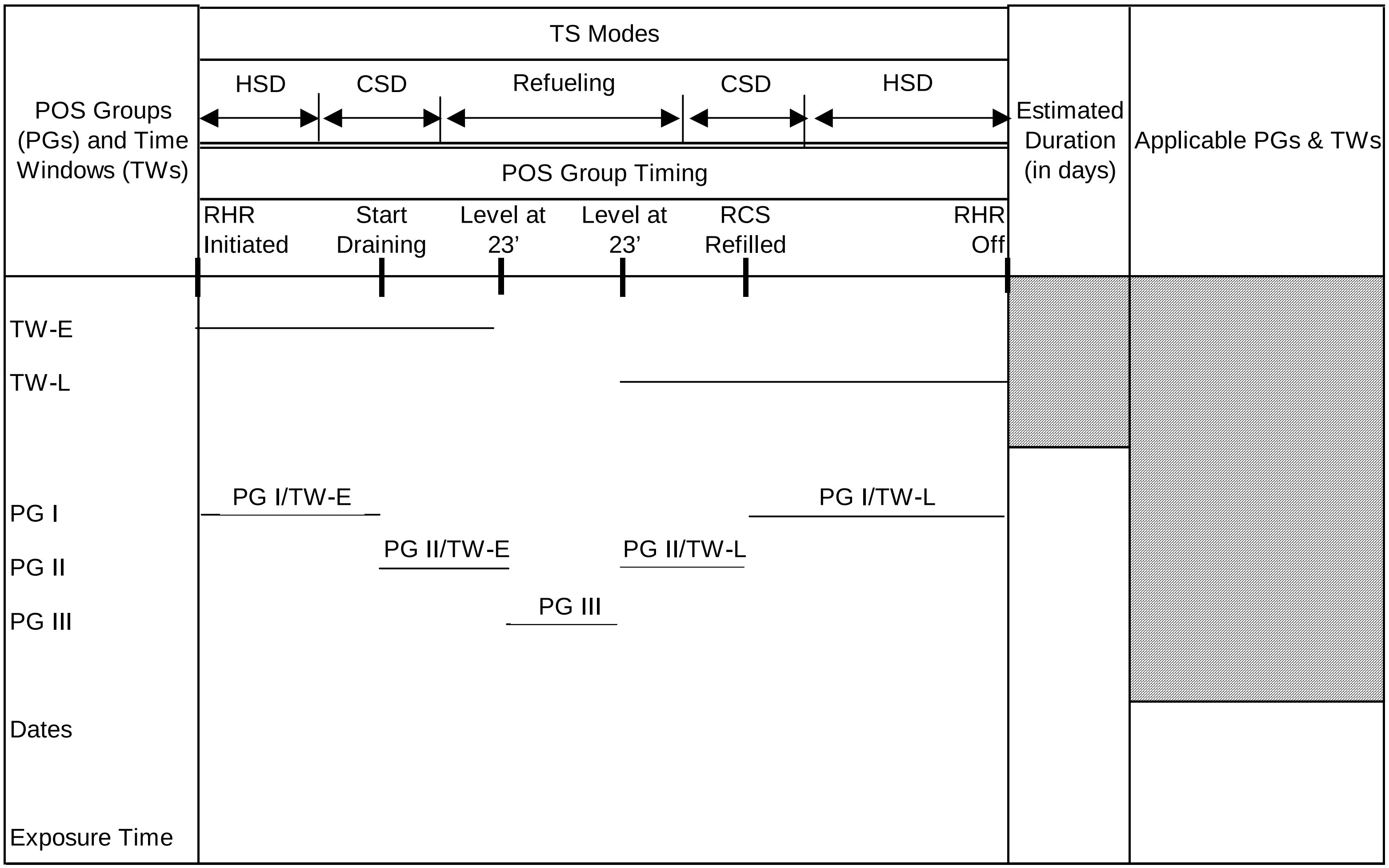

Table 1 - Initiating Event Likelihood (IELs) For LOLC Precursors

Time to RHR loss due to loss of RHR function due to loss of NPSH or vortexing assuming no successful operator action	Was RCS Level Indic.. Reasonable Reflection of RCS level ? AND Is DHR flow indic. & DHR motor current available	Can Action to Recover RHR be identified within ½ time to RHR loss? Eg. Decrease RHR pump flow rate or increase RCS level	Can Action to Recover RHR be performed within ½ time to RHR loss?	Estimated IEL
LOLC occurred OR X<20 min.	N/A	N/A	N/A	0
20<x< 40 min.	YES	YES	YES	1
20<x< 40min.	NO	N/A	N/A	0
20<X <40min.	YES	NO	N/A	0
20<x< 40 min.	YES	YES	NO	0
40<x< 60 min.	YES	YES	YES	2
40<x< 60min.	NO	N/A	N/A	0
40<X <60min.	YES	NO	N/A	0
40<X<60 min.	YES	YES	NO	0
1HR<X<2HR	YES	YES	YES	3
1HR<X<2HR	NO	Yes	Yes	1
1HR<X<2HR	YES	NO	N/A	0
1HR<X<2HR	YES	Yes	NO	0
X>2HR	YES	YES	YES	4
X>2HR	NO	Yes	Yes	1
X> 2HR	YES	NO	N/A	0
X> 2 HR	YES	Yes	NO	0

Table 2 - Initiating Event Likelihoods (IELs) for LOOP Precursors

Type of LOOP precursor	Estimated Initiator Rating
Actual LOOP occurred	0
Work Activities have the potential to affect existing power supplies (example: crane operating close to a Reserve Auxiliary Transformer supplying power to RHR without adequate controls on its movement)	1

Table 3 - Initiating Event Likelihood (IELs) For LOI Precursors

Time to RHR loss due to loss of RHR pump suction Given no successful operator action (X = time to loss of RHR pump suction)	Was RCS Level Indic.. Reasonable Reflection of RCS level ? AND Is DHR flow indic. & DHR motor current available (LOLC events only)	Can leak path be readily identified within ½ time to loss of RHR	Can drain path be isolated by at least one functional valve such that a train of RHR can be re-started (e.g. not RHR suction valves)	Estimated IEL
LOI occurred X<20 min.	N/A	N/A	N/A	0
20<x< 40 min.	YES	YES	YES	1
20<x< 40min.	NO	N/A	N/A	0
20<X <40min.	YES	NO	N/A	0
20<x< 40 min.	YES	YES	NO	0
40<x< 60 min.	YES	YES	YES	2
40<x< 60min.	NO	N/A	N/A	0
40<X <60min.	YES	NO	N/A	0
40<X<60 min.	YES	YES	NO	0
1HR<X<2HR	YES	YES	YES	3
1HR<X<2HR	NO	YES	YES	1
1HR<X<2HR	YES	NO	N/A	0
1HR<X<2HR	YES	YES	NO	0
X>2HR	YES	YES	YES	4
X>2HR	NO	YES	YES	1
X> 2HR	YES	NO	N/A	0
X> 2 HR	YES	YES	NO	0

TABLE 4 - INITIATING EVENT LIKELIHOODS (IELs) FOR LORHR PRECURSORS

Time to RHR loss given no successful operator action	Trouble Alarms Present for Finding AND Core Exit Thermocouples (CETs) Ex. DHR high temp. DHR low flow Support System Trouble Alarms Ex. CCW low flow	Can Action to Recover RHR be identified within ½ time to RHR loss? Eg. RHR recovery procedures, Support System Recovery procedures,	Can Action to Recover RHR be performed within ½ time to RHR loss?	Estimated IEL
LORHR occurred OR< 20 minutes	N/A	N/A	N/A	0
20<X<40 min.	Yes	Yes	Yes	1
20<X< 40 min.	No	N/A	N/A	0
20 <X< 40min.	Yes	No	N/A	0
20<X< 40 min.	Yes	Yes	NO	0
40<X< 60min.	Yes	Yes	Yes	2
40<X< 60min.	No	N/A	N/A	0
40<X< 60min.	Yes	No	N/A	0
40>X < 60min.	Yes	Yes	NO	0
1hr< X<2 hr.	Yes	Yes	Yes	3
1hr <X< 2 hr.	No	Yes	Yes	1
1 hr <X<2 hr.	Yes	No	N/A	0
1hr <X < 2 hr.	Yes	Yes	No	0
X > 2 hr	Yes	Yes	Yes	4
X > 2 hr	No	Yes	Yes	1
X> 2 hr	Yes	No	N/A	0
X> 2 hr	Yes	Yes	NO	0

Table 5 - Initiating Event Likelihoods (IELs) for Condition Findings - PWRs

Row	Approximate Conditional Frequency	Example Event Type	IEL		
I	> 1 per 1-10 yr	Loss of offsite power (LOOP), Loss of RHR (LORHR)	**1**	**2**	**3**
II	1 per 10-10^2 yr	Loss of Inventory (LOI)	**2**	**3**	**4**
III	1 per 10-10^2 yr	Loss of Level Control (LOLC)[1]	**2**	**2**	**2**
			> 30 days	**3-30 days**	**< 3 days**
			Exposure Time for Degraded Condition		

LOLC is only applicable to POS group II.
LORHR and LOI are not applicable to POS group III.

[1]Loss of level control failure is dominated by likelihood of overdraining to reach midloop conditions (this is a demand failure)

Table 6 - Mitigation Capability Credits for Installed Equipment

Type of Remaining Capability	**Remaining Capability Rating**
Recovery of Failed Train Operator action to recover failed equipment that is capable of being recovered after an initiating event occurs. Action may take place either in the control room or outside the control room and is assumed to have a failure probability of approximately 0.1 when credited as “Remaining Mitigation Capability.” Credit should be given only if the following criteria are satisfied: (1) sufficient time is available; (2) environmental conditions allow access, where needed; (3) procedures exist; (4) training is conducted on the existing procedures under similar conditions; and (5) any equipment needed to perform these actions is available and ready for use.	1
1 Automatic Steam-Driven (ASD) Train A collection of associated equipment that includes a single turbine-driven component to provide 100% of a specified safety function. The probability of such a train being unavailable due to failure, test, or maintenance is assumed to be approximately 0.1 when credited as “Remaining Mitigation Capability.”	1
1 Train A collection of associated equipment (e.g., pumps, valves, breakers, etc.) that together can provide 100% of a specified safety function. The probability of this equipment being unavailable due to failure, test, or maintenance is approximately 1E-2 when credited as “Remaining Mitigation Capability.”	2
1 Multi-Train System A system comprised of two or more trains (as defined above) that are considered susceptible to common cause failure modes. The probability of this equipment being unavailable due to failure, test, or maintenance is approximately 1E-3 when credited as “Remaining Mitigation Capability,” regardless of how many trains comprise the system.	3
2 Diverse Trains A system comprised of two trains (as defined above) that are not considered to be susceptible to common cause failure modes. The probability of this equipment being unavailable due to failure, test, or maintenance is approximately 1E-4 when credited as “Remaining Mitigation Capability.”	4 (=2+2)

TABLE 7 - CREDIT FOR TEMPORARY EQUIPMENT

Mitigation Capability	Credits
Equipment available during power operation and available during shutdown operation	Use credit similar to at-power SDP; manual alignment and actuation may be needed limiting the credit to the credit for operator action
Temporary Equipment (e.g. skid mounted diesel) that is available during shutdown; equipment and tools needed are staged for quick hookup	Use credit of 1

TABLE 8 - Definitions and Characterizations of Time Windows from the Surry Shutdown PRA (NUREG/CR-6144 Table 5.4-20) assuming a vented RCS (RCS temperature initially 140F)

Time Post Shutdown	< 75 hrs	75 hrs < X <240 hrs	240 hrs <X < 32 days	32 days < X
Decay Heat	13MW (2 days)	10 MW (5 days)	7 MW (12 days)	5 MW (32 days)
TBB (from midloop)	15 min.	20 min.	27 min.	37 min.
Time to Core Uncovery	120 min.	157 min.	209 min.	273 min.
Time to Core Damage	219 min.	297 min.	411 min.	557min.

Worksheet 1. SDP for a Westinghouse 4-Loop Plant — Loss Level Control in POS 1 (LOLC - POS 1)

FILL IN: TIME TO BOILING _________ TIME TO CORE UNCOVERY __________ TIME TO CORE DAMAGE __________
(NOTE: losses of inventory shorten time to core uncovery and core damage)

Top Event Function:	Success Criteria and Important Instrumentation:	Equip. Credit	Operator Credit	Credit for Function
SG Cooling (SG)	Operator maintains SG cooling by: (1) maintaining adequate level for 24 hours and (2) venting steam from SGs, and (3) keeping RCS closed. Operator needs SG level and pressure indication and CETs		Credit = 3 if supported by procedures and analyses	
RCS Injection And Bleed Before Core Damage **(FEED& BLEED)**	Operator initiates RCS injection before CD requires: 1standby ECCS train or injection train capable of keeping core covered. Operator needs RCS level indication and CETs. AND Operator opens a RCS vent path (ex PORV) for RCS pressure control.,		Credit = 2, CD assumed >3 hrs w/o injection	
DHR Recovery Before RWST Depletion and CD (RHR-R)	Operator vents RHR pumps and restarts RHR before RWST depletion or Initiates an alternate DHR path other than FEED&BLEED. Operator needs RHR inlet/outlet temp indic. and RHR flow indic. w/low alarm		Credit = 3 time until RWST depletion assumed > 10 hrs	
Borated Water Makeup before CD (RWSTMU)	Operator initiates RWST makeup before RWST depletion and core damage. Operator needs RWST level indic. w/low level alarm		Credit = 2, time to RWST depletion and CD > 13 hours	

Circle Affected Functions	IEL	Mitigation Credit	Recovery	Result
LOLC - SG - RHR-R - RWSTMU (4)				

LOLC - SG - FEED&BLEED (5)				

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:

If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

Notes: Failure to recover RHR before RWST depletion is assumed to fail recirculation from the sump since the RHR pumps are also used to perform the recirculation function. Recovery of RHR does not guarantee available recirculation since the sump may be unavailable due to trash..

Worksheet 2. SDP for a Westinghouse 4-Loop Plant — Loss Level Control in POS 2 (LOLC - POS 2)

FILL IN: TIME TO BOILING _________ TIME TO CORE UNCOVERY _______ TIME TO CORE DAMAGE ________
(NOTE: losses of inventory shorten time to core uncovery and core damage)

Top Event Function:	**Success Criteria and Important Instrumentation:**	**Equip. Credit**	**Operator Credit**	**Credit for Function**
RCS injection before Core Damage (FEED)	Operator initiates RCS injection before CD requires: 1standby ECCS train or injection train capable of keeping core covered Operator needs RCS level indication and CETs		Credit = 4 CD assumed >3 hrs w/o injection	
DHR Recovery Before RWST depletion and CD (RHR-R)	Operator vents RHR pumps, and restarts RHR before RWST depletion. Operator needs RHR inlet/outlet temp indic. and RHR flow indic. w/low alarm	N/A	Credit = 3 time to RWST depletion >10hrs	
Borated Water Makeup before CD (RWSTMU)	Operator initiates RWST makeup before RWST depletion and core damage. Operator needs RWST level indic w/ low level alarm		Credit = 2 time to RWST depletion and CD > 13 hours	

Circle Affected Functions	**IEL**	**Mitigation Credit**	**Recovery**	**Result**
LOI - RHR-R-RWSTMU (3)				
LOI -FEED (4)				

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:

If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

Notes: Failure to recover RHR before RWST depletion is assumed to fail recirculation from the sump since the RHR pumps are also used to perform the recirculation function. Recovery of RHR does not guarantee available recirculation since the sump may be unavailable due to trash..

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FILL IN: TIME TO BOILING _________ TIME TO CORE UNCOVERY __________ TIME TO CORE DAMAGE __________
(NOTE: losses of inventory shorten time to core uncovery and core damage)

Top Event Function:	**Success Criteria and Important Instrumentation:**	**Equip. Credit**	**Operator Credit**	**Credit for Function**
Emergency AC starts and loads (EAC)	One EDG or alternate AC source [2]	N/A		
SG Cooling (SGSBO)	Operator maintains SG cooling by: (1) maintaining adequate level for 24 hours and (2) venting steam from SGs, and (3) keeping RCS closed. Operator needs SG level and SG pressure indication and CETs		Credit = 3 if supported by procedures and analyses	
Operator recovers offsite power before CD (RLOOP3)	Recovery of offsite power before core damage given SGSBO failed	Credit = 1 (assumes CD = 3 hours)	N/A	

Circle Affected Functions	**IEL**	**Mitigation Credit**	**Recovery**	**Results**
LOOP-EAC-SGSBO-RLOOP3 (3)				

[2]If time to CD minus time to actuate AC source > 1 hr then equipment limited, else credit for alternate source = 0

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event: If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

FILL IN: TIME TO BOILING _________ TIME TO CORE UNCOVERY __________ TIME TO CORE DAMAGE _________

Top Event Function:	Success Criteria and Important Instrumentation:	Equip. Credit	Operator Credit	Credit for Function
Emergency AC starts and loads (EAC)	One EDG or alternate AC source [1]	N/A		
Gravity Feed (GRAVITY) before CD	Operator initiates Gravity Feed assuming SBO before core damage. Requires an available flow path, procedures, supporting analyses, and CETs. Gravity feeding to the RCS may be credited if Gravity Feed is expected to be available AFTER RCS boiling initiates. To credit Gravity Feed, the analyst needs to consider the following factors that can negate the elevation head provided by the RWST or other sources of RCS inventory: (1) pressure drops in the surge line (2) entrained water accumulating in the pressurizer (3) RCS vent paths that are restricted (to control loose parts or control off gassing) .		Credit = 3	
Operator recovers offsite power before CD (RLOOP4)	Recovery of offsite power before core damage given unsuccessful gravity feed (CD assumed at 4 hours)	Credit = 1	N/A	

[1]If time to CD minus time to actuate AC source > 1 hr then equipment limited, else credit for alternate source = 0

Operator recovers offsite power before CD (RLOOP18)	Recovery of offsite power before core damage given successful gravity feed (CD assumed at 18 hours)	Credit = 2	N/A	

<u>**Circle Affected Functions**</u>	<u>**IEL**</u>	<u>**Remaining Mitigation Capability Rating for Each Affected Sequence**</u>	<u>**Recovery**</u>	<u>**Result**</u>
LOOP-EAC-RLOOP18 (3)				
LOOP-EAC-GRAVITY-RLOOP4 (5)				

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:

If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

Worksheet 5. SDP for a Westinghouse 4-Loop Plant — Loss of Inventory in POS I (LOI - POS I)

FILL IN: TIME TO BOILING _________ TIME TO CORE UNCOVERY _________ TIME TO CORE DAMAGE __________
(NOTE: losses of inventory shorten time to core uncovery and core damage)

Top Event Function:	**Success Criteria and Important Instrumentation:**	**Equip. Credit**	**Operator Credit**	**Credit for Function**
RCS injection (FEED)	Operator initiates RCS injection before CD requires: 1standby ECCS train or injection train capable of keeping core covered Operator needs RCS level indic and CETs,		Credit = 4, CD assumed >3 hrs w/o injection	
Leak Path Terminated before RWST depletion (LEAK-STOP)	Operator isolates leak before RWST depletion, requires: one available valve such that RHR can be restarted (not RHR isolation valves) Operator needs RCS level indic.		Credit = 3 (assumed >10 hrs to RWST depletion)	
Leak Path Terminated before core uncovery given no FEED (LEAK-STOP2)	Operator isolates leak before core uncovery, requires: one available valve such that RHR can be restarted (not RHR isolation valves), Operator needs RCS level indic.		Credit = 2	
SG Cooling (SG)	Operator maintains SG cooling by: (1) maintaining adequate level for 24 hours, (2) venting steam from SGS, and (3) keeping the RCS closed. Operator needs SG level and SG pressure indic. and CETs		Credit = 3, if supported by procedures and analyses	
RCS Vent path for Feed and Bleed (BLEED)	Operator opens a PORV or vent path large enough to remove decay heat		Credit = 4	

DHR recovery before RWST depletion and CD (RHR-R)	Operator vents RHR pumps and restarts RHR before RWST depletion. Operator needs RHR inlet/outlet temp indic. and RHR flow indic. w/low alarm	N/A	Credit = 3 (assumed time until RWST depletion > 10 hrs)	
Borated Water Makeup before CD(RWSTMU)	Operator initiates RWST makeup before RWST depletion and core damage. Operator needs RWST level indication with low level alarm		Credit = 2 time to RWST depletion and CD > 13 hours	

Circle Affected Functions	**IEL**	**Mitigation Credit**	**Recovery**	**Result**
LOI - SG - RHR-R - RWSTMU (4)				
LOI-SG-BLEED (5)				
LOI- LEAKSTOP-RWSTMU (7)				
LOI - FEED - SG - (9)				
LOI - FEED - LEAKSTOP2 (10)				

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:

If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

Notes: Failure to recover RHR before RWST depletion is assumed to fail recirculation from the sump since the RHR pumps are also used to perform the recirculation function. Recovery of RHR does not guarantee available recirculation since the sump may be unavailable due to trash..

Worksheet 6. SDP for a Westinghouse 4-Loop Plant — Loss of Inventory in POS 2 (LOI - POS 2)

FILL IN: TIME TO BOILING _________ TIME TO CORE UNCOVERY __________ TIME TO CORE DAMAGE __________
(NOTE: losses of inventory shorten time to core uncovery and core damage)

Top Event Function:	Success Criteria and Important Instrumentation:	Equip. Credit	Operator Credit	Credit for Function
RCS injection before CD (FEED)	**Operator initiates RCS injection before CD requires: 1standby ECCS train or injection train capable of keeping core covered** **Operator needs RCS level indication and CETs.**		**Credit = 4, CD assumed >3 hrs w/o injection**	
Leak Path Terminated before RWST depletion (LEAK-STOP)[2]	**Operator isolates leak before RWST depletion, requires: one available valve such that RHR can be restarted (not RHR isolation valves)** **Operator needs RCS level indication.**		**Credit = 3 (assumed >10 hrs to depletion)**	
DHR recovery before RWST depletion and CD (RHR-R)	**Operator vents RHR pumps and restarts RHR before RWST depletion.** **Operator needs RHR inlet/outlet temp indic. and RHR flow indic. w/low alarm**	**N/A**	**Credit = 3 time to RWST depletion >10hrs**	
Borated Water Makeup before CD(RWSTMU)	**Operator initiates RWST makeup before RWST depletion and core damage.** **Operator needs RWST level indication with low level alarm**		Credit = 2 time to RWST depletion and CD > 13 hours	

[2]If leak path is back to the RWST , then use operator credit = 5 to account that RWST will not deplete but will heat up without cooling.

Circle Affected Functions	IEL	Mitigation Credit	Recovery	Result
LOI - RHR-R-RWSTMU (3)				
LOI- LEAK-ST-RWSTMU (5)				
LOI -FEED (6)				

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:

If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

Notes: Failure to recover RHR before RWST depletion is assumed to fail recirculation from the sump since the RHR pumps are also used to perform the recirculation function. Recovery of RHR does not guarantee available recirculation since the sump may be unavailable due to trash..

Worksheet 7. SDP for a Westinghouse 4-Loop Plant — Loss of Inventory in POS 3 (LOI - POS 3)

FILL IN: TIME TO BOILING _________ TIME TO CORE UNCOVERY __________ TIME TO CORE DAMAGE _________
(NOTE: losses of inventory shorten time to core uncovery and core damage)

Top Event Function	Success Criteria and Important Instrumentation:	Equip. Credit	Operator Credit	Credit for Function
RCS injection before CD (FEED)	Operator initiates RCS injection before CD requires: 1 standby ECCS train or injection train capable of keeping core covered, a source of borated water Operator needs RCS level indic. and CETs,		Credit = 4, CD assumed >3 hrs w/o injection	
Leak terminated before RCS injection cannot be sustained and CD occurs (LEAK-STOP)	Operator isolates drain path using at least one functional valve such that RHR can be restarted.		Credit = 3 time to CD assumed > 4 hours	
DHR recovery before RCS injection cannot be sustained and CD results (RHR-R)	Operator vents RHR pumps and restarts RHR system. Operator needs RHR inlet/outlet temp and RHR flow indic. w/low alarm.		Credit = 3 time to CD assumed > 4 hours	

Circle Affected Functions	IEL	Mitigation Credit	Recovery	Sequence Color
LOI - RHR-R- (2)				
LOI - LEAK-STOP (3)				
LOI -FEED (4)				

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:

If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

Worksheet 8. SDP for a Westinghouse 4-Loop Plant — Loss of RHR in POS I (LORHR - POS I)

FILL IN: TIME TO BOILING _________ TIME TO CORE UNCOVERY ___________ TIME TO CORE DAMAGE ___________
(NOTE: losses of inventory shorten time to core uncovery and core damage)

Top Event Function:	Success Criteria and Important Instrumentation:	Equip. Credit[1]	Operator Credit[2]	Credit for Function
DHR recovery before RCS boiling (RHR-S)	Operator a train of RHR before RCS boiling. Operator needs RHR inlet/outlet temp indic. and RHR flow indic. w/low alarm AND IF APPLICABLE[3] Operator recovers failed RHR support systems before RCS boiling (SEE FOOT NOTE 3)		Credit = 0 if TBB <20 minutes IF RHR recovery action can be identified within ½ TBB AND RHR recovery action can be performed within ½ TBB AND Trouble alarms are available. THEN CREDIT = 1 if 20 min. < TBB < 40 min. CREDIT = 2 if 40 min. <TBB < 1 hour CREDIT = 3 if TBB > 1 hour	

[1]If performance deficiency is being transferred from LOOP tree, analyst must consider if the front line systems and necessary support systems are supported from successful EAC.

[2]For the safety function RHR-S, when being transferred from LOOP tree, if TBB < 10 minutes and re-start of RHR requires operator action outside the control room, then operator credit = 0. Otherwise, operator credit = 1.

[3]If this worksheet is being used to assess a RHR support system deficiency that could cause a loss of the operating train of RHR, then the equipment credit and operator credit is determined by the operator's ability to recover the support system before RCS boiling.

SG Cooling (SG)	**Operator maintains SG cooling by: (1) maintaining adequate level for 24 hours, (2) venting steam from SGS, and (3) keeping the RCS closed. Operator needs SG level and pressure indic. and CETs**		**Credit = 3, if supported by procedures and analyses**	
RCS Injection AND Bleed Before Core Damage (FEED&BLEED)	**Operator initiates RCS injection before CD requires: 1standby ECCS train or injection train capable of keeping core covered** **Operator needs RCS level indic. and CETs,** **AND** **Operator also opens a RCS vent path (ex PORV) to control RCS pressure**		**Credit = 2, CD assumed >3 hrs w/o injection**	
DHR recovery before RWST depletion and CD (RHR-R)	**Operator vents RHR pumps and restarts RHR before RWST depletion.** **Operator needs RHR inlet/outlet temp indic. and RHR flow indic. w/low alarm**	**Consider Equip. Failures in RHR-S that could impact this equip. credit**	**Credit = 2 time until RWST depletion > 10 hrs.**	
Borated Water Makeup before CD(RWSTMU)	**Operator initiates RWST makeup before RWST depletion and core damage.** **Operator needs RWST level indication with low level alarm**		Credit = 2 time to RWST depletion and CD > 16 hours	

Circle Affected Functions	**IEL**	**Mitigation Credit**	**Recovery**	**Result**

LORHR - RHR-S - SG - RHR-R-RWSTMU (5)				
LORHR - RHR-S - SG - FEED&BLEED (6)				

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:

If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

Notes: Failure to recover RHR before RWST depletion is assumed to fail recirculation from the sump since the RHR pumps are also used to perform the recirculation function. Recovery of RHR does not guarantee available recirculation since the sump may be unavailable due to trash..

Worksheet 9. SDP for a Westinghouse 4-Loop Plant — Loss of RHR in POS 2 (LORHR - POS 2)

FILL IN: TIME TO BOILING _________ TIME TO CORE UNCOVERY _________ TIME TO CORE DAMAGE _____________
(NOTE: losses of inventory shorten time to core uncovery and core damage)

Top Event Function:	Success Criteria and Important Instrumentation:	Equip. Credit [1]	Operator Credit[2]	Credit for Function
DHR recovery before RCS boiling (RHR-S)	Operator a train of RHR before RCS boiling. Operator needs RHR inlet/outlet temp indic. and RHR flow indic. w/low alarm AND IF APPLICABLE[3] Operator recovers failed RHR support systems before RCS boiling (SEE FOOT NOTE 3)	N/A	Credit = 0 if TBB <20 minutes IF RHR recovery action can be identified within ½ TBB AND RHR recovery action can be performed within ½ TBB AND Trouble alarms are available. THEN CREDIT = 1 if 20 min. < TBB < 40 min. CREDIT = 2 if 40 min. <TBB < 1 hour CREDIT = 3 if TBB> 1 hour	

[1]If performance deficiency is being transferred from LOOP tree, analyst must consider if the front line systems and necessary support systems are supported from successful EAC.

[2]For the safety function, RHR-S, when being transferred from LOOP tree, if TBB < 10 minute and re-start of RHR requires operator action outside the control room, then operator credit = 0. Otherwise, operator credit = 1.

[3]If this worksheet is being used to assess a RHR support system deficiency that could cause a loss of the operating train of RHR, then the equipment credit and operator credit is determined by the operator's ability to recover the support system before RCS boiling.

RCS injection before CD	**Operator initiates RCS injection before CD requires: 1standby ECCS train or injection train capable of keeping core covered, RCS level indic., CETs,**		**Credit = 4, CD assumed >3 hrs w/o injection**	
DHR recovery before RWST depletion (RHR-R)	**Operator fills RCS, vents RHR pumps, and restarts RHR before RWST depletion, requires: CET w/hi alarm, RHR inlet/outlet temp indic., RHR flow indic. w/low alarm**	**Consider Equip. Failures in RHR-S that could impact this equip. credit**	**Credit = 2 time to RWST depletion >10hrs**	
Borated Water Makeup before CD(RWSTMU)	**Operator initiates RWST makeup before RWST depletion with boric acid transfer pumps and primary grade water,** **Operator needs RWST level indic and low level alarm**		**Credit = 2 time to RWST and CD assumed > 13 hours**	

Circle Affected Functions	IEL	Mitigation Credit	Recovery	Result
LORHR - RHR-S - RHR-R - RWSTMU (4)				
LORHR - RHR-S - FEED (5)				

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:

If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

Notes: Failure to recover RHR before RWST depletion is assumed to fail recirculation from the sump since the RHR pumps are also used to perform the recirculation function. Recovery of RHR does not guarantee available recirculation since the sump may be unavailable due to trash..

PWR Basis Document for Appendix G

Table of Contents

1. 0bjective

The objective of this basis document is to define the PRA model used to develop Appendix G for BWR and PWRs and the BWR and PWR Shutdown Templates.

2.0 Introduction

2.1 Model Scope

This low power and shutdown PRA model focuses on shutdown operations when more than one fuel assembly in the reactor vessel. This PRA specifically covers shutdown operations-initiating when the licensee has met the entry conditions for RHR and RHR cooling has been initiated and ending when the licensee is heating up and RHR had been secured.

Once the plant is above the RHR entry conditions, a severe accident during this configuration is expected to produce a plant response that is bounded by the plant response to full power initiating events. For deficiencies occurring above the RHR entry conditions, the full power SDP tools should be used acknowledging: (1) decay heat is less compared to full power, potentially allowing more time for operator recovery (2) some mitigating systems may require manual operation versus automatic operation, and (3) some containment systems may not be required to be operable potentially increasing the likelihood of containment failure.

2.2 Limitations of the PRA model

The template is a simplified tool that generates an order-of-magnitude assessment of the risk significance of the inspection findings during a shutdown. This template is developed for a PWR plant, considering the features of a Westinghouse 4-loop plant. However, it can be used for different plant classes as long as the analyst considers each system and strategy that can be used to maintain the shutdown key safety functions such as the ability to: maintain/recover DHR heat removal, maintain RCS level control, maintain RCS pressure control, and maintain a containment closure capability.

This generic tool could not include plant specific mitigating features because they vary between licensees and outages. Therefore, the analyst has to consider the licensee's outage-specific mitigation capability.

Since the template was developed based on maintaining key shutdown safety functions, this template does not provide any information on frontline system dependencies. The analyst is to refer to the system-dependency table provided in the at-power Notebooks. The analyst has to consider additional dependencies for additional systems/functions not needed at full power (e.g., AC power for containment closure). The analyst also has to consider whether a support system is needed for the frontline system at shutdown. For example, CCW may not be required for high pressure injection pump bearing and motor cooling if the pump is pumping cool water (< 120F).

3.0 Characterization of Shutdown Operations

The risk significance of an inspection finding at shutdown depends on the plant configuration. To account for the plant's changing configuration and decay heat level during shutdown, this PRA model parses an outage into plant operational states (POSs) and time windows (TWs). The plant response to the a loss or interruptions of RHR is assumed to remain constant during a given POS. Time Windows are used to separate POSs occurring early in the outage when decay heat is high to POSs occurring late in the outage when decay heat is low.

For this template, Figure 1 defines the POSs and time windows for a PWR plant. It also shows the relationship between the POSs and the modes defined in the Technical Specifications (TSs). We now describe the POSs and Time Windows (TWs).

POS 1- This POS starts when the RHR system is put into service. The RCS is closed such that the steam generators could be used for decay heat removal, if the secondary side of a steam generator is filled. The RCS may have a bubble in the pressurizer. This POS ends when the RCS is vented such that the steam generators cannot sustain core head removal. This POS typically includes Mode 4 (hot shutdown) and portions of Mode 5 (cold shutdown).

POS 2- This POS starts when the RCS is vented such that: (1) the steam generators cannot sustain core heat removal and (2) a sufficient vent path exists for feed and bleed. This POS includes portions of Mode 5 (cold shutdown) and Mode 6 (refueling). Reduced inventory conditions and midloop operations with a vented RCS are subsets of this POS. Note: performance deficiencies occurring during a vacuum refill of the RCS require use of the POS 1 event trees.

POS 3- This POS represents the shutdown condition when the refueling cavity water level is at or above the minimum level required for movement of irradiated fuel assemblies within containment as defined by Technical Specifications. This POS occurs during Mode 6.

Early Time Window (TW-E)- This time widow represents the time before POS 3 is entered. The decay heat is relatively high. The reactor is either in POS 1 or 2.

Late Time Window (TW-L)- This time window represents the time after POS group 3. The decay heat is relatively low. The reactor is either in POS 1, 2, or 3

The above definitions of the POSs and Time Windows can be used to address different types of plant shutdowns, i.e., refueling outage, planned maintenance outage, and an unplanned outage. Depending on the type of outage and its duration, the POSs and TWs can be identified from the above list. For example, all POSs and both TWs will apply to a refueling outage. Only POS 1 and the early Time Window (TW-E) may apply to an unplanned outage.

NOTE: The operator credits in the SDP worksheets are given for Time Window 1. The same worksheets can be used for Time Window 2 except the credits for operator response may need to be changed to account for the longer operator's response time. Detailed instructions are given in Chapter 6.0 of this template

4.0 Shutdown Initiating Events

An initiating event at shutdown is defined as an event that causes a loss or interruption of the decay heat removal function. This template considers the four internal initiators known to dominate the internal-event shutdown risk based on the Surry Shutdown PRA (NUREG/CR 6144).

The following are the initiating events considered, with their applicability to the POS groups.

Loss of RHR (LORHR) - This initiating event category includes losses of RHR resulting from failures of the RHR system (such as RHR pump failure) or failures of the RHR support systems such as loss of CCW, loss of SRW, loss of vital AC, and loss of DC power. (Loss of offsite power is treated as a separate category.) This category also includes interruptions of RHR caused by spurious ESFAS signals such as RHR suction valve closure. This initiating event category is considered for POS 1 and POS 2 . This category is not considered necessary to POS 3, since the time to core uncovery is assumed to be greater than 24 hours.

Loss of Offsite Power (LOOP) - This initiating event category covers losses of offsite power at shutdown which cause an interruption in DHR. This initiator category is considered for all POSs. For POS 3, if a LOOP or SBO could cause a loss of the refueling cavity seal to due a loss of support systems, then this issue is evaluated by using the POS 2 LOOP worksheets.

Loss of Reactor Inventory (LOI) - This initiating event category includes losses of RCS inventory that lead to a loss of RHR due to loss of RHR pump suction. Many of these flow diversions are caused from improper alignment of valves. This initiator category is considered for all POSs.

Loss of Level Control (LOLC) - This initiating event category includes: (1) the operator overdrains the RCS to reach midloop conditions such that the RHR function is lost, and (2) the operator fails to maintain level control and/or RHR flow control while in midloop such that the RHR function is lost. This initiator is considered for midloop operations only.

Other initiators that merit consideration include those events that challenge low-temperature over pressure protection (LTOP), and findings that increase the likelihood of a reactivity transient. In Surry Shutdown PRA (NUREG/CR 6144), these two initiators were found to make a smaller contribution to the core damage frequency than the four initiators discussed above. For some inspection findings, their contribution may become significant. Therefore, they will go directly to Headquarters for Phase 3 analysis.

5.0 Shutdown Initiating Event Frequencies

Initiating-event frequencies were estimated by searching LERs from 1992 to 1998[4] and the totaling the number of refueling hours.

Table 5 - Initiating Event Likelihoods (IELs) for Condition Findings - PWRs

Row	Approximate Conditional Frequency	Example Event Type	IEL		
I	> 1 per 1-10 yr	Loss of offsite power (LOOP), Loss of RHR (LORHR)	**1**	**2**	**3**
II	1 per 10-10^2 yr	Loss of Inventory (LOI)	**2**	**3**	**4**
III	1 per 10-10^2 yr	Loss of Level Control (LOLC)[5]	**2**	**2**	**2**
			> 30 days	**3-30 days**	**< 3 days**
			Exposure Time for Degraded Condition		

LOLC is only applicable to POS group II.
LORHR and LOI are not applicable to POS group III.

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[4] Loss of Shutdown Cooling Initiating Events Data Summary (1992-1998), Jim Houghton, RES, Internal Report

[5] Loss of level control failure considers two events during midloop operation: (1) the operator overdrains the RCS to reach midloop conditions such that the RHR function is lost, and (2) the operator fails to maintain level control and/or RHR flow control while in midloop such that the RHR function is lost. Loss of level control failure is dominated by likelihood of overdraining to reach midloop condition given that the licensee entered midloop conditions which is a demand failure and not time dependent.

6.0 Event Trees Models

6.1 Overview

For each event tree, there is an associated worksheet that defines each top event function in the event tree by:

❑ Top Event Function - A key safety function that is necessary to restore core cooling given a loss or interruption of the RHR function (e.g. the operator initiates RCS injection before core damage).

❑ Success Criteria - The minimum set of equipment that can be used to fulfill the top event function.

❑ Instrumentation - The minimum set of instrumentation needed by the operator to fulfill the top event function.

❑ Equipment Credit - The credit given to the top event function by the analyst based on all available systems able to fulfill the top event function. The equipment credit used in the worksheets are similar to the equipment credits used in the full power SDP worksheets. Temporary equipment credit is obtained using Table 6.

❑ Operator Credit - The credit given for the operator to perform the corresponding top event function. The default operator credit for performing the top event assumes that: (1) the success criteria for the top event function has been met, and (2) the minimum set of instrumentation needed by the operator is available and providing reliable indication. Operator Credits were developed using the SPAR-H methodology developed by INEL (ADAMS Accession number ML031540084)

NOTE: The analyst must adjust the default operator credits in the worksheets if:

- **If the referenced instrumentation if missing or misleading, then the operator credit is decreased by two or becomes zero, if the operator credit becomes negative.**

  Referring to the SPAR-H LP&SD worksheets, the PSF level for stress is now considered to be high, and the PSF level for ergonomics is now considered missing/misleading. Using the SPAR-H LP&SD worksheets, this condition results in an HEP multiplier of 100.

- **The default time is incorrect and significantly reduced. If the diagnoses time is less than 20 minutes, OR the time to perform the action is approximately the time required, then decrease the operator credit by one or becomes zero, if the operator credit becomes negative.**

  Referring to the SPAR-H LP&SD worksheets, the PSF level for available time for diagnoses becomes barely adequate and has a multiplier of 10. The PSF level for available time for the action portion of the task has a PSF multiplier of 10.

- **If the action is complicated by missing equipment, unaccessible equipment, steam or high radiation, or Loop seals for pump venting, then the operator credit is decreased by two or becomes zero, if the operator credit becomes negative.**

  Referring to the SPAR-H LP&SD worksheets, the PSF level for stress is now considered to be high, and the PSF level for ergonomics is now considered to be missing/misleading. Using the SPAR-H worksheets, this results in an HEP multiplier of 100.

- **If the procedure are not complete for the shutdown plant configuration, then the operator credit is decreased by one or becomes zero, fit he operator credit becomes negative.**

  Referring to the SPAR-H LP&SD worksheets, the PSF level for procedures is considered as incomplete. The HEP multiplier was assigned a factor of 20.

❑ Function Credit - The lower of <u>Equipment Credit</u> and <u>Operator Credit.</u>

6.2 Event Tree Success Criteria

The Success Criteria for the PWR Shutdown Template is based on the Byron Units 1 and 2 LP&SD success criteria shown in referenced 1. As shown,

Initiator: LOOP, LORHR, LOI, LOLC	13 MW (2 days)	10MW (5 days)	7 MW (12 days)	5 MW (32 days)
FEED	1 of 2 LPI OR 1 of 2 HPSI OR 1 of 2 CVCS	1 of 2 LPI OR 1 of 2 HPSI OR 1 of 2 CVCS	1 of 2 LPI OR 1 of 2 HPSI OR 1 of 2 CVCS	1 of 2 LPI OR 1 of 2 HPSI OR 1 of 2 CVCS
RHR-R	Operator to recover 1 of 2 RHR trains	Operator to recover 1 of 2 RHR trains	Operator to recover 1 of 2 RHR trains	Operator to recover 1 of 2 RHR trains
Reflux Cooling (SG)	2 SG (available short-term cooling). Makeup FW to 2 SG (long term)	1 SG (available short-term cooling). Makeup FW to 1 SG (long term)	1 SG (available short-term cooling). Makeup FW to 1 SG (long term)	1 SG (available short-term cooling). Makeup FW to 1 SG (long term)
BLEED	1PORV or safety valve removed or RCS opening of equivalent size	1PORV or safety valve removed or RCS opening of equivalent size	1PORV or safety valve removed or RCS opening of equivalent size	1PORV or safety valve removed or RCS opening of equivalent size

Gravity Feed	1 SV removed and LPI flow path (provides 4.3 hours for operator actions)	1 SV removed and LPI flow path (provides 6.5 hrs for operator actions)	1 SV removed and LPI flow path (provides 12 hrs for operator actions)	1 SV removed and LPI flow path (provides 24 hrs for operator actions)

6.3 General Description/Philosophy for Event Trees

6.3.1 LOLC Event Trees

The LOLC event trees is defined as (1) the operator overdrains the RCS to reach midloop conditions such that the RHR function is lost, and (2) the operator fails to maintain level control and/or RHR flow control while in midloop such that the RHR function is lost. The LOLC does not require termination of the RCS leak path since it is assume to terminate without operation action at the bottom of the hot leg. If the event occurs in POS 1, then secondary reflux cooling can be used. Successful RCS injection is required to restore RCS level such that RHR can be recovered and provide for core cooling if SG cooling is not available. Failure to recover RHR before RWST depletion is assumed to fail recirculation from the sump since the RHR pumps are assumed to also perform the recirculation function. Recovery of RHR does not guarantee available recirculation since the sump may be unavailable due to trash.

6.3.2 LOI Event Trees

The LOI event trees evaluate losses of RCS inventory that lead to a loss of RHR due to loss of RHR pump suction that do not involve a loss of level control at midloop (LOLC events). Many of these flow diversions are caused from improper alignment of valves. This initiator category is considered for all POSs. In POS 1, since the RCS may be pressurized, a LOI may lead to losses of inventory below the hotleg due to RCS de-pressurization. In POS 2, LOI events do not require termination of the RCS leak path since it is assume to terminate without operation action at the bottom of the hot leg. If the event occurs in POS 1, then secondary reflux cooling can be used as long as the core is covered. Successful RCS injection is required to restore RCS level such that RHR can be recovered. Failure to recover RHR before RWST depletion is assumed to fail recirculation from the sump since the RHR pumps are assumed to also perform the recirculation function. Recovery of RHR does not guarantee available recirculation since the sump may be unavailable due to trash.

6.3.3LORHR Event Trees

The LORHR event trees evaluate losses of the operating train of RHR that result from failures of the RHR system itself or from failures of the RHR support systems. These failures could also cause failure of the standby RHR system. The analyst is asked to consider whether RHR can be recovered prior to boiling to account for the possibility of voids being swept into the RHR pumps, necessitating that the RHR pumps be vented. Failure to recover RHR before RWST depletion is assumed to fail recirculation from the sump since the RHR pumps are assumed to also perform the recirculation function. Recovery of RHR does not guarantee available recirculation since the sump may be unavailable due to trash.

6.3.4LOOP Event Trees

The LOOP event trees evaluate loss of offsite power that result in a loss or interruption of the operating train of RHR. For POS 1, reflux cooling is considered if sufficient inventory exist until offsite power is recovered. For POS 2, gravity feed may be recited if gravity feed is expected to be available after RCS boiling initiates. To credit gravity feed, the licensee should have considered:

- ❑ pressure drops in the surge line
- ❑ entrained water accumulating in the pressurizer
- ❑ RCS vent paths that are restricted (to control loose parts or control off gassing)

7.0 Human Error Probabilities

7.1 Basis for HEPS used in the IEL Tables

If a licensee has a finding that increases the likelihood of a loss of RHR, IEL tables were created to estimate the new conditional likelihood that a loss of RHR will occur due to the performance deficiency given the occurrence of the performance deficiency and/or condition.

The following HEP tables were used in the PWR Shutdown template. The tables for LOI, LORHR, and LOLC are constructed suing the same format. The first column is used to estimate the time to loss of the RHR function from the specific initiating event . The second column determines the availability of key instrumentation that would help the operator to: (1) diagnose that a potential problem exists with maintaining the RHR function and (2) diagnose how to recover from the potential problem such that an interruption or loss of the RHR function is prevented.

From the first column, the time to loss of the RHR function was then divided by two to determine how long the operator had to (1) diagnose the specific action needed to prevent RHR from being interrupted and (2) perform the specific action needed to prevent RHR from being interrupted. (The factor of two was used to keep this phase 2 model simple.) The third and fourth columns ask if (1) the specific action to recover RHR can be identified within ½ time to loss of the RHR function and (2) if action to recover RHR can be performed within ½ time to loss of the RHR function.

It was assumed that failure of the operator to diagnose the tasks needed to be performed to prevent a loss of the RHR function would dominant the IEL rather than failure of the operator to perform the necessary physical manipulations of the task.

The IELs corresponding to ½ time to loss of the RHR function come from "Nominal Model of estimated HEPs and EFs within time for diagnosis within time T by control room personnel of an abnormal event annunciated closely in time." Table 12-4, in NUREG/CR 1278. The median joint HEP curve was used assuming the operator had key instrumentation referenced in the IEL tables.

If the licensee did not have the key instrumentation referenced in the IEL tables, then the IEL was assessed a multiplier of 100 based on the SPAR-H methodology. Referring to the LP&SD SPAR-H worksheets, if the licensee has missing/misleading instrumentation, the PSF multiplier is assessed as 50. This loss of instrumentation will result in the task complexity changing from nominal to moderately complex, resulting in an additional multiplier of 2.

7.2 Basis for HEPs used in the Worksheets

SPAR-H methodology developed by INEL was used to derive the HEPs for the worksheets (ADAMS accession number ML031540084). Since every interruption of RHR requires a successful operator response to prevent core damage, operator error is a key contributor to shutdown risk. Operator error appears in almost every top event/mitigation path in the shutdown event trees.

The SPAR-H LP&SD worksheets were used to develop a diagnosis probability. for each safety function that has an operator credit. Using the SPAR-H method given a similar set of PSFs, the diagnosis probability dominates the action probability. Therefore, to simplify the model for phase 2 analysis , the diagnosis probability defines the operator credits used in the worksheets. The first safety function does not include dependence in the operator credit estimate. The second and succeeding safety functions include an estimate of dependence.

The inferred definition of diagnosis is any cognitive decision making that is necessary to perform a task. This definition includes all cognitive tasks ranging from responding to annunciators to recognizing what is necessary to recover a failed RHR system. The inferred definition of action is any manipulation is involved in performing the task.

The analyst must recognize that the impact of various PSFs may overlap each other. For example, if the procedures are poor, the time available to perform an action may be decreased if the operator is following the procedures step-by-step.

In the following sections, each default operator credit referenced in the worksheets is derived in the following sections using the SPAR-H methodology.

Referring to the SPAR-H LP&SD worksheets, for each operator credit, the available time was evaluated. This is defined the time that the action must be completed (often in terms of several hours) minus the time it takes to perform the action (often in terms of minutes) plus the time it takes to receive the first cue. The definitions for nominal time, extra time, and expansive time are given in the worksheets.

7.2.1 HEPs for the POS 1 and POS 2 LOLC Worksheets

LOLC POS 1 Worksheet

SG Cooling (SG): Operator acknowledges a loss of RHR function and maintains SG cooling by: (1) maintaining adequate level for 24 hours and (2) venting steam from SGs and (3) keeping the RCS closed. It is assumed that the operators have CETs and SG level and pressure indication. It is also assumed that the operator have procedures which are supported by analysis for shutdown conditions. Using the SPAR-H LP&SD diagnosis worksheets, the PSF level for time is considered expansive. The experience/training in these procedures is considered to be low for shutdown conditions when the RCS may not be full.. All other PSF levels are considered nominal. The default operator credit is assumed to be 1E-3.

FEED&BLEED: Operator initiates RCS injection and RCS bleed before core damage. It is assumed that the operator has RCS level indication and CETs with a CET hi alarm setpoint. It is assumed that the operator have procedures for this action as recommended by NUMARC 91-06.

Time is to core damage is assumed to occur after 3 hours. The time to manually initiate injection is assumed to take minutes to perform. Rising CET values and the CET hi alarm would be received well before RCS boiling. Therefore, using the SPAR-H LP&SD worksheets, the PSF level for time is considered to be expansive. All other PSF levels are considered nominal, since FEED &BLEED is a common recovery procedure for an extended loss of RHR and is performed similar to the full power procedures. The default operator credit is estimated to be 1E-4.

Considering dependence, if the operator failed to maintain SG cooling, the PORVs and/or the RHR relief valves would lift providing the operator additional cues that RHR cooling is interrupted. The actions to initiate FEED&BLEED would be performed by the same crew, but not close in time. Thus, the dependency between the two actions was determined to be low. Using the SPAR-H worksheets, the task failure with dependence was estimated as 5E-2. Since the SDP uses operator credits in multiplies of ten, the revised operator default credit is 2.

RHR-R - Given a loss of RHR due to loss of level/flow control, the operator can recover one of two operable trains of RHR before RWST depletion. It was assumed that the operators had at least 10 hours to repair/recover one operable train of RHR before RWST depletion based on a full RWST. The operator may need to fill the RCS and vent the RHR pumps. As recommended in GL 88-17, the licensees should have procedures for this recovery action. Using the SPAR-H LP&SD worksheets, the PSF level for time was considered extra not expansive since action outside the control is required. All other PSF levels were considered nominal. The default operator credit was estimated as 1E-3.

RWSTMU - It was assumed that the licensee could makeup to the RWST if long term RHR recovery failed. The time to perform this action was considered expansive. It was assumed that the licensee has procedures for this action, and the operator has RWST level indication with a low level alarm. Using the SPAR-H LP&SD worksheets, the PSF level for time is considered expansive. The stress was assumed to be high and the complexity was assumed to be high, the operators would be simultaneously trying to recover RHR. All other PSF levels were assumed to be nominal. The default HEP was estimated as 1E-3.

Considering dependence with RHR-R, an additional shift would be available due to the long time duration. The timing of both actions is simultaneous but not close in time. The operators would receive the additional cue of the RWST level alarm Thus, the dependency between the two actions was believed to be low. Using the SPAR-H worksheets, the task failure with dependence was estimated as 5E-2. Since the SDP uses operator credits in multiplies of ten, the revised operator default credit is 2.

LOLC POS 2 WORKSHEET

FEED: Operator initiates RCS injection before core damage. It is assumed that the operator has RCS level indication and CETs. It is assumed that the operator have procedures for this action as recommended by NUMARC 91-06.

Core damage is assumed to occur after 3 hours without FEED. The time to manually initiate injection is assumed to take minutes to perform. Rising CET values and the CET hi alarm would be received well before RCS boiling. Also, since the RCS is open, steam would be an additional visual cue. Therefore, using the SPAR-H LP&SD worksheets, the PSF level for time is considered to be expansive. All other PSF levels are considered nominal, since FEED is a common recovery procedure for an extended loss of RHR and is performed similar to the full power procedures. The default operator credit is estimated to be 1E-4.

RHR-R - Given a loss of RHR due to loss of level/flow control, the operator can recover one of two operable trains of RHR before RWST depletion. It was assumed that the operators had at least 10 hours to repair/recover one operable train of RHR before RWST depletion based on a full RWST. The operator may need to fill the RCS and vent the RHR pumps. As recommended in GL 88-17, the licensees should have procedures for this recovery action. Using the SPAR-H LP&SD worksheets, the PSF level for time was considered extra not expansive since operator action outside the control room is required.. All other PSF levels were considered nominal. The default operator credit was estimated as 1E-3.

RWSTMU - It was assumed that the licensee could makeup to the RWST if long term RHR recovery failed. The time to perform this action was considered expansive. It was assumed that the licensee has procedures for this action, and the operator has RWST level indication with a low level alarm. Using the SPAR-H LP&SD worksheets, the PSF level for time is considered expansive. The stress was assumed to be high and the complexity was assumed to be high, the operators would be simultaneously trying to recover RHR.   All other PSF levels were assumed to be nominal. The default HEP was estimated as 1E-3.

Considering dependence with RHR-R, an additional shift would be available due to the long time duration. The timing of both actions is simultaneous but not close in time. The operators would receive the additional cue of a low RWST level alarm. Thus, the dependency between the two actions was believed to be low. Using the SPAR-H worksheets, the task failure with dependence was estimated as 5E-2. Since the SDP uses operator credits in multiplies of ten, the revised operator default credit is 2.

7.2.2 HEPs for the POS 1 and POS 2 LOOP Worksheets

SGSBO: Operator acknowledges a LOOP and maintains SG cooling by: (1) maintaining adequate SG level for 24 hours and (2) venting steam from SGs and (3) keeping the RCS closed.   It is assumed that the operators have CETs and SG level and pressure indication. It is also assumed that the operator have procedures which are supported by analysis for shutdown conditions.   Using the SPAR-H LP&SD diagnosis worksheets, the PSF level for time is considered expansive.   The experience/training in these procedures is considered to be low. All other PSF levels are considered nominal. The default operator credit is assumed to be 1E-3.

GRAVITY: Operator initiates Gravity Feed assuming SBO before core damage. Requires an available flow path, procedures, and supporting analyses.

Gravity feeding to the RCS may be credited if Gravity Feed is expected to be available AFTER RCS boiling initiates. To credit Gravity Feed, the analyst needs to consider the following factors that can negate the elevation head provided by the RWST or other sources of RCS inventory: (1) pressure drops in the surge line (2) entrained water accumulating in the pressurizer (3) RCS vent paths that are restricted (to control loose parts or control off gassing) .

Using the SPAR-H LP&SD diagnosis worksheets, the PSF level for time is considered expansive.   The experience/training in these procedures is considered to be low. All other PSF levels are considered nominal. The default operator credit is assumed to be 1E-3.

7.2.3 HEPs for the POS 1 and POS 2 LOI Worksheets

LOI POS 1 Worksheet

FEED: Operator acknowledges a loss of inventory and initiates RCS injection before core damage. It is assumed that the operator has RCS level indication and CETs. It is assumed that the operator have procedures for this action as recommended by NUMARC 91-06. Using the SPAR-H LP&SD worksheets, the PSF level for time is considered exapansive. All other PSF levels are considered nominal, since FEED is a common recovery procedure for any type of loss of RCS inventory and is similar response to the full power procedures. The default operator credit is estimated to be four.

LEAK-STOP: Operator isolates leak before RWST depletion given successful FEED. Using the SPAR-H LP&SD worksheets, the PSF level for available time is considered to be expansive. However, the diagnoses on the operator's part to locate the source of the leak and isolate is considered to be highly complex and high stress. All other PSFs were considered to be nominal. The default operator credit was estimated as three (1E-3). **The time assumption assumes that the leak does not impact the availability of the standby injection pumps (e.g. Wolf Creek draindown event in 1994).**

LEAK-STOP2: The operator isolates the leak before core uncovery at which point the SG cooling is no longer considered to prevent core damage given unsuccessful FEED.

Using the SPAR-H LP&SD worksheets, the PSF level for time is considered to be extra not expansive. The diagnoses on the operator's part to locate the source of the leak and isolate is considered to be highly complex and high stress. All other PSFs were considered to be nominal. Thus, the default failure probability was estimated as 1E-2. Considering dependence, both the FEED task and the LEAK-STOP task occur using the same crew and an not close in time. However, additional cues would be provided to the operator indicating the location of an LOI such as sump level alarms, tank level alarms, visible flooding , etc. The dependency was believed to be low. The revised operator credit considering dependence was estimated as 2 (.01)

SG Cooling (SG): Operator successfully isolates the leak before core uncovery and maintains SG cooling by: (1) maintaining adequate level for 24 hours and (2) venting steam from SGs and (3) keeping the RCS closed. It is assumed that the operators have CETs and SG level and pressure indication. It is also assumed that the operator have procedures which are supported by analysis for shutdown conditions. Using the SPAR-H LP&SD diagnosis worksheets, the PSF level for time is considered expansive. The experience/training in these procedures is considered to be low. All other PSF levels are considered nominal. The default operator credit is assumed to be 1E-3.

BLEED: The operator opens a PORV or vent path large enough to remove decay heat by FEED&BLEED. This tasks assumes that the operators already have successfully isolated the leak and started RCS injection. It is assumed that the operator have procedures for FEED&BLEED as recommended by NUMARC 91-06. Using the SPAR-H LP&SD worksheets, the PSF level for time is considered expansive. All other PSF levels are considered nominal, since FEED&BLEED PORV is a common recovery procedure an extended loss of RHR. The default operator credit is estimated to be four.

RHR-R - Given a loss of RHR function due to an LOI, the operator can recover one of two operable trains of RHR before RWST depletion. It was assumed that the operators had at least 10 hours to repair/recover one operable train of RHR before RWST depletion based on a full RWST. The operator may need to fill the RCS and vent the RHR pumps. As recommended in GL 88-17, the licensees should have procedures for this recovery action. Using the SPAR-H LP&SD worksheets, the PSF level for time was considered extra not expansive. All other PSF levels were considered nominal. The default operator credit was estimated as 1E-3.

RWSTMU - It was assumed that the licensee could makeup to the RWST if long term RHR recovery failed. The time to perform this action was considered expansive. It was assumed that the licensee has procedures for this action, and the operator has RWST level indication with a low level alarm. Using the SPAR-H LP&SD worksheets, the PSF level for time is considered expansive. The stress was assumed to be high and the complexity was assumed to be high, the operators would be simultaneously trying to recover RHR. All other PSF levels were assumed to be nominal. The default HEP was estimated as 1E-3.

Considering dependence with RHR-R, an additional shift would be available due to the long time duration. The timing of both actions is simultaneous but the close in time. The operators would receive the additional cue of a low RWST level RWST alarm. Thus, the dependency between the two actions was believed to be low. Using the SPAR-H worksheets, the task failure with dependence was estimated as 5E-2. Since the SDP uses operator credits in multiplies of ten, the revised operator default credit is 2.

LOI POS 2 Worksheet

FEED: Operator initiates RCS injection before core damage. It is assumed that the operator has RCS level indication and CETs. It is assumed that the operator have procedures for this action as recommended by NUMARC 91-06.

Core damage is assumed to occur after 3 hours without FEED. The time to manually initiate injection is assumed to take minutes to perform. Rising CET values and the CET hi alarm would be received well before RCS boiling. Also, since the RCS is open, steam would be an additional visual cue. Therefore, using the SPAR-H LP&SD worksheets, the PSF level for time is considered to be expansive. All other PSF levels are considered nominal, since FEED is a common recovery procedure for an extended loss of RHR and is performed similar to the full power procedures. The default operator credit is estimated to be 1E-4.

RHR-R - Given a loss of RHR due to loss of level/flow control, the operator can recover one of two operable trains of RHR before RWST depletion. It was assumed that the operators had at least 10 hours to repair/recover one operable train of RHR before RWST depletion based on a full RWST. The operator may need to fill the RCS and vent the RHR pumps. As recommended in GL 88-17, the licensees should have procedures for this recovery action. Using the SPAR-H LP&SD worksheets, the PSF level for time was considered extra not expansive since operator action outside the control room is required.. All other PSF levels were considered nominal. The default operator credit was estimated as 1E-3.

RWSTMU - It was assumed that the licensee could makeup to the RWST if long term RHR recovery failed. The time to perform this action was considered expansive. It was assumed that the licensee has procedures for this action, and the operator has RWST level indication with a low level alarm. Using the SPAR-H LP&SD worksheets, the PSF level for time is considered expansive. The stress was assumed to be high and the complexity was assumed to be high, the operators would be simultaneously trying to recover RHR. All other PSF levels were assumed to be nominal. The default HEP was estimated as 1E-3.

Considering dependence with RHR-R, an additional shift would be available due to the long time duration. The timing of both actions is simultaneous but the close in time. The operators would receive the additional cue of a RWST low level alarm. Thus, the dependency between the two actions was believed to be low. Using the SPAR-H worksheets, the task failure with dependence was estimated as 5E-2, Since the SDP uses operator credits in multiplies of ten, the revised operator default credit is 2.

7.2.4 HEPs for the POS 1 and POS 2 LORHR Worksheets

LORHR POS 1 Worksheet

RHR-S: The operators ability to quickly recover the alternate train of RHR from the control room before boiling given a loss or interruption of the operating train

of RHR. Using the operator response curves in NUREG 1278 Table 12-4, it was assumed if RHR recovery action can be identified within ½ TBB AND RHR recovery action can be performed within ½ TBB.
AND
Trouble alarms are available.
THEN
CREDIT = 1 if 10 min. < TBB < 30 min.
CREDIT = 2 if 30 min. <TBB < 1hour
ELSE, Credit = 0

SG Cooling (SG): Operator acknowledges a loss of RHR function and maintains SG cooling by: (1) maintaining adequate level for 24 hours and (2) venting steam from SGs and (3) keeping the RCS closed. It is assumed that the operators have CETs and SG level and pressure indication. It is also assumed that the operator have procedures which are supported by analysis for shutdown conditions. Using the SPAR-H LP&SD diagnosis worksheets, the PSF level for time is considered expansive. The experience/training in these procedures is considered to be low. All other PSF levels are considered nominal. The default operator credit is assumed to be 1E-3.

FEED&BLEED: Operator initiates RCS injection and RCS bleed before core damage. It is assumed that the operator has RCS level indication and CETs. It is assumed that the operator have procedures for this action as recommended by NUMARC 91-06. Using the SPAR-H LP&SD worksheets, the PSF level for time is considered exapansive. All other PSF levels are considered nominal, since FEED &BLEED is a common recovery procedure for an extended loss of RHR and is similar to the full power procedures. The default operator credit is estimated to be 1E-4.

Considering dependence, if the operator failed to maintain SG cooling, the PORVs and/or the RHR relief valves would lift providing the operator additional cues the RHR cooling is interrupted. The actions would be performed by the same crew, but not close in time. Thus, the dependency between the two actions was believed to be low. Using the SPAR-H worksheets, the task failure with dependence was estimated as 5E-2. Since the SDP uses operator credits in multiplies of ten, the revised operator default credit is 2.

RHR-R - Given that RHR could not be recovered before boiling, the operators can recover/repair one of two operable trains of RHR before RWST depletion. It was assumed that the operators had at least 10 hours to repair/recover one operable train of RHR before RWST depletion based on a full RWST. The level of diagnoses to recover/repair the RHR system is considered to be highly complex and high stress. The PSF level for time is considered extra not expansive since operator action outside the control room is necessary. All other

PSFs were considered to be nominal. Using the SPAR-H LP&SD worksheets, the default HEP was estimated as 1E-2.

RWSTMU - It was assumed that the licensee could makeup to the RWST if long term RHR recovery failed. The time to perform this action was considered expansive. It was assumed that the licensee has procedures for this action, and the operator has RWST level indication with a low level alarm. Using the SPAR-H LP&SD worksheets, the PSF level for time is considered expansive. The stress was assumed to be high and the complexity was assumed to be high, the operators would be simultaneously trying to recover RHR. All other PSF levels were assumed to be nominal. The default HEP was estimated as 1E-3.

Considering dependence with RHR-R, an additional shift would be available due to the long time duration. The timing of both actions is simultaneous but the not close in time. The operators would receive the additional cue of a RWST low level alarm. Thus, the dependency between the two actions was believed to be low. Using the SPAR-H worksheets, the task failure with dependence was estimated as 5E-2. Since the SDP uses operator credits in multiplies of ten, the revised operator default credit is 2. .

LORHR POS 2 Worksheet

RHR-S: The operators ability to quickly recover the alternate train of RHR from the control room before boiling given a loss or interruption of the operating train of RHR. Using the operator response curves in NUREG 1278 Table 12-4, it was assumed if RHR recovery action can be identified within ½ TBB AND RHR recovery action can be performed within ½ TBB.
AND
Trouble alarms are available.
THEN
CREDIT = 1 if 10 min. < TBB < 30 min.
CREDIT = 2 if 30 min. <TBB < 1hour
ELSE, Credit = 0

FEED: Operator initiates RCS injection before core damage. It is assumed that the operator has RCS level indication and CETs. It is assumed that the operator have procedures for this action as recommended by NUMARC 91-06.

Core damage is assumed to occur after 3 hours without FEED. The time to manually initiate injection is assumed to take minutes to perform. Rising CET values and the CET hi alarm would be received well before RCS boiling. Also, since the RCS is open, steam would be an additional visual cue. Therefore, using the SPAR-H LP&SD worksheets, the PSF level for time is considered to be expansive.   All other PSF levels are considered nominal, since FEED is a common recovery procedure for an extended loss of RHR and is performed similar to the full power procedures.   The default operator credit is estimated to be 1E-4.

RHR-R - Given that RHR could not be recovered before boiling, the operators can recover/repair one of two operable trains of RHR before RWST depletion.   It was assumed that the operators had at least 10 hours to repair/recover one operable train of RHR before RWST depletion based on a full RWST.   The level of diagnoses to recover/repair the RHR system is considered to be highly complex and high stress. The PSF level for time is considered extra not expansive since operator action outside the control room may be required. All other PSFs were considered to be nominal. Using the SPAR-H LP&SD worksheets, the default HEP was estimated as 1E-2.

RWSTMU - It was assumed that the licensee could makeup to the RWST if long term RHR recovery failed. The time to perform this action was considered expansive. It was assumed that the licensee has procedures for this action, and the operator has RWST level indication with a low level alarm. Using the SPAR-H LP&SD worksheets, the PSF level for time is considered expansive. The stress was assumed to be high and the complexity was assumed to be high, the operators would be simultaneously trying to recover RHR.   All other PSF levels were assumed to be nominal. The default HEP was estimated as 1E-3.

Considering dependence with RHR-R, an additional shift would be available due to the long time duration. The timing of both actions is simultaneous but the not close in time. The operators would receive the additional cue of a RWST low level alarm. Thus, the dependency between the two actions was believed to be low. Using the SPAR-H worksheets, the task failure with dependence was estimated as 5E-2. Since the SDP uses operator credits in multiplies of ten, the revised operator default credit is 2.

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ATTACHMENT 2

RISK-INFORMED INSPECTION TEMPLATE FOR A

BWR DURING SHUTDOWN

U. S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation

POINT OF CONTACT FOR ASSISTANCE/COMMENTS
Marie Pohida NRR/DSSA/SPSB
301-415-1846

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1.0 ENTRY CONDITIONS AND APPLICABILITY

As directed in the SRM to SECY 97-168, the staff is inspecting and monitoring licensee performance at shutdown to ensure that the licensees are maintaining a mitigation capability (equipment, instrumentation, policies, procedures, and training) consistent with the staff's estimate of industry shutdown risk presented to the Commission in SECY 97-168 (the proposed shutdown rule). In the Reactor Oversight Process (ROP), the significance of inspection findings is assessed, using a Risk Informed process, called the Significance Determination Process (SDP). The Shutdown SDP consists of: Phase 1, Definition and Initial Screening of Findings; Phase 2, Initial Risk Significance Approximation and Basis; and Phase 3, Risk Significance Finalization and Justification. IMC 0609 Appendix G, Shutdown Operations Significance Determination Process is used to conduct the phase 1 screening analysis. This phase 2 template is used for performing phase 2 analyses for certain BWR shutdown performance deficiencies discussed below.

1.1 Entry Conditions

1.1.1 SDP-related Inspection Finding

This SDP provides a simplified risk-informed framework to estimate the increase in core damage frequency during shutdown operations due to conditions which contribute unintended risk increases caused by deficient licensee performance. Conditions which do NOT represent deficient licensee performance, as determined by the staff, are considered part of the acceptable plant normal operating risk, and are NOT candidates for SDP evaluation. The entry conditions for the shutdown SDP described in this document are degraded plant equipment, functions, or processes affecting initiating event frequency, mitigation system availability/reliability, or RCS barrier integrity that result from deficient licensee performance.

Concurrent performance deficiencies should be assessed collectively if they resulted from a closely-tied common cause. If causes are independent, each performance deficiency should be assigned a color individually. See IMC 0609, Appendix A for more detailed guidance.

Each performance deficiency should first be screened by using IMC 0612 (formerly 0610*), Appendix B to determine whether or not the issue is a minor issue. If the deficiency screens as minor this SDP should not be entered.

1.1.2 MD 8.3 Entry

Procedures are given in Chapter 4 for using this template to perform quantitative assessment of shutdown event to satisfy management Directive 8.3.

1.2 Applicability

The process in this SDP is designed to provide Senior Reactor Analysts a simple scrutable probabilistic risk framework for use in identifying potentially risk-significant shutdown issues within the initiating events, mitigation systems, and barriers cornerstones. The results from this SDP tool are intended to facilitate communication on the basis of risk significance between the NRC and licensees.

2.0 LIMITS AND PRECAUTIONS

2.1 Limits

The template is a simplified tool that generates an order-of-magnitude assessment of the risk significance of inspection findings during shutdown operation.

2.2 Precautions

2.2.1 The analyst should consider each evaluated core damage sequence using the event trees to ensure that the scenario makes sense for the deficiency. The variability of plant configurations at shutdown and timing issues may result in performance deficiencies which do not directly map on the event trees. See HQs for assistance if needed.

2.2.2 The analyst must understand: 1) the differences between precursor and condition findings, (2) the definitions of the plant operational states (POSs), and (3) the definitions of the shutdown initiating events.

2.2.3 The availability of standby RCS injection along with operator error drives shutdown risk. As long as standby injection is available, in most cases, standby injection buys time for other operator recovery actions such as: leak path termination and RHR recovery. If there are factors that could render the standby RCS injection unavailable such as: gas intrusion or support system unavailability, then these factors (assumptions) become risk significant and should be assessed carefully.

2.2.5 Some findings are not covered by these templates and go directly to Headquarters for Phase 3 analysis. Examples of such findings are as follows:

- Findings that involve freeze seals that are installed in systems connected to the RCS where failure could lead to a loss of inventory.

- Findings that involve containment closure are assessed using IMC 0609 Appendix H

3.0 ABBREVIATIONS AND DEFINITIONS

3.1 Abbreviations

CD	Core Damage
CCW	Component Cooling Water
DHR	Decay Heat Removal
ECCS	Emergency Core Cooling System
INDIC.	Indication
IMC	Inspection Manual Chapter
LOI	Loss of Reactor Inventory Initiating Event
LER	Licensee Event Report
LOOP	Loss of Offsite Power
LORHR	Loss of RHR Initiating Event
OP.	Operator
POS	Plant Operational State
PRA	Probabilistic Risk Assessment
RCS	Reactor Coolant System
RHR	Residual Heat Removal
ROP	Reactor Oversight Process
SDP	Significance Determination Process
SRW	Site Raw Water
SSW	Standby Service Water
TW	Time Window
TW-E	Early Time Window, before refueling operation
TW-L	Late Time Window, after refueling operation

3.2 Definitions

Phases of a Significance Determination

Phase 1 -Characterization and Initial Screening of Findings: Precise characterization of the finding and an initial screening of very low-significance findings for disposition by the licensee's corrective action program.

Phase 2- Initial Risk Significance Approximation and Basis: Initial approximation of the risk significance of the finding and development of the basis for this determination for those findings that are not screened out in Phase 1 screening.

Phase 3 - Risk Significance Finalization and Justification: Assessment of the risk significance of a shutdown finding as directed from the Phase 1 analysis (IMC 0609 Appendix G).

Types of Shutdown Performance Deficiencies

Precursor Finding - Inspection findings that have the potential to cause a loss or interruption of the DHR function.

Condition findings - Inspection findings that only involve a degradation of the licensee's mitigation capability.

Shutdown Initiating Events

Loss of RHR (LORHR) - Includes losses of RHR resulting from failures of the RHR system (such as RHR pump failure) or failures of the RHR support systems other than offsite power.

Loss of Offsite Power (LOOP) - Includes losses of offsite power which cause a loss of the DHR function.

Loss of Reactor Inventory (LOI) - Includes losses of RCS inventory that lead to a loss of the DHR function due to isolation of RHR on Level 3 or loss of RHR due to loss of RHR pump suction.

Plant Operational States (POSs)

POS 1 - This POS starts when the RHR system is put into service. The vessel head is on. This POS covers part of Hot Shutdown (Mode 3) and Cold Shutdown (Mode 4) of the TS Modes.

POS 2 - This POS represents the shutdown condition when the vessel head is removed and reactor pressure vessel water level is less than the minimum level required for movement of irradiated fuel assemblies within the reactor pressure vessel as defined by Technical Specifications. This POS occurs during Mode 5.

POS 3 - This POS represents the shutdown condition when the reactor pressure vessel water level is equal or greater than the minimum level required for movement of irradiated fuel assemblies within the reactor pressure vessel as define by Technical Specifications. This POS occurs during Mode 5. .

Time Windows

Early Time Window (TW-E)- This time widow represents the time before POS 3 is entered. The decay heat is relatively high. The reactor is either in POS 1 or 2.

Late Time Window (TW-L)- This time window represents the time after POS group 3. The decay heat is relatively low. The reactor is either in POS 1, 2, or 3.

Other Key Shutdown Definitions

Available - A piece of equipment is considered available if it can be put into service quickly enough to meet its function need and all necessary supporting systems are functional (such as AC power, cooling water, and DC control power)

Shutdown Operations - Shutdown Operation exists during hot shutdown, cold shutdown, and refueling when more than one fuel assembly is in the reactor vessel and the decay heat removal system is in operation.

4.0 PROCEDURE FOR SIGNIFICANCE DETERMINATION

Step 4.1 Use the Information Gathered in the Phase 1 process to identify the set of equipment that the licensee planned to achieve the following safety functions: Standby RCS injection and RCS pressure control, if applicable.

Note: Equipment is considered available if it can be put into service quickly enough to meet its functional need, and all necessary supporting systems are functional (such as AC power, cooling water and DC control power).

Step 4.2 Determine if the finding is a precursor to an initiating event (a loss of the DHR function) or a condition finding.

Note: Precursor findings: (1) have the potential to: cause a loss of the operating train of RHR, or (2) increase the likelihood that the operating RHR train could be lost, or (3) result in a shutdown event - cause a loss/interruption of the operating train of RHR. Condition findings only involve a degradation of the licensee's capability to mitigate an event if an event were to occur. Findings only affecting the standby train of RHR are condition findings. The templates treats precursor and condition findings differently.

Go To Step 4.3 for Precursor Findings

OR

Go To Step 4.4 for Condition Findings

NOTE: If this tool is being used to assess a shutdown event under Management Directive 8.3, Go to Step 4.5

Step 4.3 Procedure for Assessing SDP Precursor Findings

Step 4.3.1 Identify **each** TW and POS where the finding could have occurred.

Step 4.3.2 Determine the IEL rating. The IEL rating is the conditional likelihood of having a loss of the RHR function given the occurrence of the performance deficiency.

- IF a finding increases the likelihood of a loss of offsite power (LOOP) or actually caused a LOOP, THEN LOOP is the applicable initiating event. Use Table 1 to determine the IEL. Go to Step 4.3.3.

- IF a finding increases the likelihood of a loss of reactor inventory (LOI) or actually caused a LOI, THEN LOI is the applicable initiating event. Use Table 2 to determine the IEL. Go to Step 4.3.3

- IF a finding increases the likelihood of a loss of the operating train of RHR (LORHR) or actually caused a LORHR (except for LOOP and LOI), THEN LORHR is the applicable initiating event. Use Table 3 to determine the IEL. Go to Step 4.3.3

- IF a finding involves the RHR support systems (except for LOOP and LOI), THEN LORHR is the applicable initiating event. Use Table 3 to determine the IEL. Go to Step 4.3.3

Step 4.3.3 Use the SDP Worksheet that contains the POSs and initiating events that were determined to be applicable in Step 4.3.2.

Step 4.3.4 Enter the time to RCS boiling and an approximate time to core uncovery/core damage in the first line of the Worksheet.

Step 4.3.5 Label the <u>IEL</u> in each row of the lower section of the worksheet.

Step 4.3.6 Determine Credit for each top event function.

A. Verify that the licensee has the instrumentation referenced for the top event function.

NOTE If the licensee does not have the referenced instrumentation available or the referenced instrumentation is not reflective of RCS conditions, then the default operator credit MUST by decreased by 2.

B. To obtain the <u>equipment credit</u>, credit each **available** system that is (1) capable of maintaining the top event function and (2) is not impacted by the finding. Use the Event Tree associated with the Worksheet to help understand the successes and failures associated with each accident sequence. Use guidance in Tables 6 and 7 to determine equipment credits. Document key assumptions.

C. To obtain the <u>Operator Credit.</u> **Use the default operator credit unless any of the following four conditions are applicable:**

1. The referenced instrumentation is missing or misleading, then decrease the operator credit by two.
2. The default time is incorrect and is significantly reduced. If the diagnoses time is less than 20 minutes, OR the time required to perform the action is approximately the time available, then decrease the operator credit by one.
3. The action is complicated by missing equipment, unaccessible equipment, steam or high radiation, or loop seals for pump venting, then decrease the operator credit by two.
4. If the procedures are incomplete for the shutdown configuration, then the operator credit is decreased by one.

NOTE: If the default operator credit is changed and results in a negative operator credit, then the operator credit is zero.

B. Determine the <u>Credit for Function</u> for each <u>Top Event Function</u> needed. Select the lower of <u>Equipment Credit</u> and <u>Operator Credit</u>, and enter the value in this column.

Step 4.3.7. Quantification of Core Damage Scenarios

Quantify each accident scenario by adding the credits for <u>IEL</u> + <u>Mitigation Credit.</u> Enter the sum in the <u>Result</u> column.

Note, For phase 2 analyses, the recovery credit is not used.

Step 4.3.8. Identifying the Frequency of Finding Occurrence.

The color of the finding is determined similar to the process using the guidance in IMC 0609 Appendix A. However, this color is based on the finding being assessed as a conditional core damage probability. The analyst now must estimate how frequently per calender year can this performance deficiency would result in the finding occurrence, so that a delta initiating event frequency can be obtained.

Rather than providing method to develop initiating event frequencies (that will not cover all findings and may lead to errors), examples were providing to assist the analyst.

A. Deficiencies involving faulty test procedures or faulty equipment that results in a precursor event during test or maintenance.

For a fault test procedure, the initiating event frequency becomes: (1 test / outage)*(1 outage/outage frequency (e.g.18 months) = .67 per year.

EXAMPLE: A mechanic incorrectly re-assembled a CCW relief valve such that the relief valve would not reseat as quickly as intended. This deficiency was revealed during an containment isolation valve test which is performed once per outage. CCW relief valve lift is anticipated during performance of the test. A stuck open relief valve would lead to a loss of CCW and result in a loss of the DHR function.

Frequency of the deficiency becomes:

(1 outage /18month period)*(12 months/calender year*(1 relief valve lift /outage)*(1.0 relief valve fails to reseat/ relief valve lift)

B. Deficiencies that are revealed through random events (such that the event could have occurred in POS 1, POS 2, POS 3 or full power) that lead to a precursor event - The analyst needs to perform an SDP analysis for POS 1, POS2, POS 3, and full power for time window 1. The analyst can assumed that the risk is bounded by Time Window 1.

Based on a representative 35 day outage, the duration of POS 1, POS 2, and POS 3 during time window one is given at 2 days, 6 days, and 10 days per outage respectively.

EXAMPLE - A licensee had a single cable that carried protective relays for the offsite power supplies and the safety-related buses which were underground and outside the licensee's protected area. The cable was damaged during the installation of a sign post in the parking lot which damaged the cable The damage caused a LOOP while the licensee was in POS 2..

The analyst has to assess the risk of this specific performance deficiency in POS 1 and POS 2 and full power (using the full power SDP tools). This specific deficiency does not need to be assessed for POS 3. As explained in the Basis Document, LOOP events are not assessed in POS 3, since the time to core uncovery is assumed to be greater than 24 hours.

For example, the frequency for the occurrence of this deficiency for POS 2 Time Window One becomes:

(Deficiency manifested once/ 32 calender years of plant operation)*(1 outage /18 month)*(12 months/ calender year)*(6 days of POS 2 operation/outage) (1 calender year/8760 days) =

Once the annual frequency is determined, the color is reduced by one if the frequency is estimated between .1 and 1. The color is reduced by two is the frequency is estimated between .01 and .1

4.4 Process for Assessing SDP Condition Findings

NOTE: Only the core damage scenarios impacted by the finding are quantified.

Step 4.4.1 Select the applicable initiating events (LOOP. LOI, and/or LOI) by identifying the equipment or safety functions affected and determine the initiating event scenarios that must be evaluated (i.e., the affected function plays some role in mitigating the initiating event scenario).

Step 4.4.2 Determine the exposure times for the degraded condition in the mitigating system. A separate exposure time must be determined for each POS for findings that span one or more POS. Using Table 5, determine an IEL for each applicable initiating event in each applicable POS.

Step 4.4.3 Use the SDP Worksheet(s) that contain the POSs and initiating events that were determined to be applicable in Step 4.4.2. Perform the following steps on the Worksheet for each applicable POS and initiating event.

Step 4.4.4 Enter the time to RCS boiling and an approximate time to core uncovery/core damage in the first line of the Worksheet.

Step 4.4.5 Label the IEL in each row of the lower section of the worksheet.

Step 4.4.6 Determine Revised Credit for each top event function Impacted by the Finding

A. Verify that the licensee has the instrumentation referenced for the top event function.

NOTE: If the licensee does not have the referenced instrumentation available or the referenced instrumentation is not reflective of RCS conditions, then the default operator credit must be decreased by two.

B. To obtain the equipment credit, credit each **available** system that is (1) capable of maintaining the top event function and (2) is not impacted by the finding. Use the Event Tree associated with the Worksheet to help understand the successes and failures associated with each accident sequence. Use guidance in Tables

6 and 7 to determine equipment credits. Document key assumptions.

NOTE: Each top event has a equipment credit and an operator credit, only the equipment credit **change** or the operator credit **change** is propagated through the worksheets. See the following examples

Example: if the licensee has a finding that changes the MINJ equipment credit from 5 to 3, then the revised credit for the MINJ&SRV becomes 3, regardless of the SRV credit or the operator credit.

C. To obtain, the **revised** <u>Operator Credit,</u> **use the following guidance:**

1. The referenced instrumentation is missing or misleading, then decrease the operator credit by two.
2. The default time is incorrect and is significantly reduced. If the diagnoses time is less than 20 minutes, OR the time required to perform the action is approximately the time available, then decrease the operator credit by one.
3. The action is complicated by missing equipment, unaccessible equipment, steam or high radiation, or loop seals for pump venting, then decrease the operator credit by two.
4. If the procedures are incomplete for the shutdown configuration, then the operator credit is decreased by one.

NOTE: If the default operator credit is changed and results in a negative operator credit, then the operator credit is zero.

Example: if the licensee has a finding that changes the operator credit from a 5 to a 3 due to a loss of instrumentation, then the revised credit for the MINJ&SRV becomes 3, regardless of the equipment MINJ&SRV equipment credit.

B. Determine the <u>Credit for Function</u> for each <u>Top Event Function</u> needed. Select the lower of <u>Equipment Credit</u> and <u>Operator Credit</u>, and enter the value in this column.

Step 4.4.7. Quantification of Core Damage Scenarios

Quantify each accident scenario that is impacted by the finding adding the credits for <u>IEL</u> + <u>Mitigation Credit.</u> Enter the sum in the <u>Result</u> column.

Note, For phase 2 analyses, the recovery credit is not used.

Step 4.4.8 Go to the next applicable Worksheet and begin at Step 4.4.1 or, if all Worksheets are completed, continue to Step 4.4.9.

Step 4.4.9 Estimating the Risk Significance of the Inspection Finding

The risk significance of an inspection finding is determined in the same manner as for at-power findings. Use IMC 0609, Appendix A, Step 2.4 - “Estimating the Risk Significance of Inspection Findings” to determine the risk significance of a finding.

4.5 Process for Assessing Events Under Management Directive 8.3

Step 4.5.1 Identify the TW and POS where the shutdown event occurred.

Step 4.5.2 Identify the appropriate shutdown initiating event.

Use an IEL = 1.0 if the event caused a loss of interruption of the RHR function.

OR

Determine the IEL rating. Evaluate the each question in order, one will apply:

- IF a finding increases the likelihood of a loss of offsite power (LOOP) or actually caused a LOOP, THEN LOOP is the applicable initiating event. Use Table 1 to determine the IEL. Go to Step 4.5.3.
- IF a finding increases the likelihood of a loss of reactor inventory (LOI) or actually caused a LOI, THEN LOI is the applicable initiating event. Use Table 2 to determine the IEL. Go to Step 4.5.3
- IF a finding increases the likelihood of a loss of the operating train of RHR (LORHR) or actually caused a LORHR (except for LOOP and LOI), THEN LORHR is the applicable initiating event. Use Table 3 to determine the IEL. Go to Step 4.5.3
- IF a finding involves the RHR support systems (except for LOOP and LOI), THEN LORHR is the applicable initiating event. Use Table 3 to determine the IEL. Go to Step 4.5.3

Step 4.5.3 Use the SDP Worksheet that contains the POS and initiating event that were determined to be applicable in Step 4.5.1

Step 4.5.4 Enter the time to RCS boiling and an approximate time to core uncovery/core damage in the first line of the Worksheet.

Step 4.5.5 Label the <u>IEL</u> in each row of the lower section of the worksheet.

Step 4.5.6 Determine the revised Credit for each top event function impacted by the finding for the **as found condition during the event.**

A. Verify the licensee has the instrumentation referenced for the top event function.

NOTE If the licensee does not have the referenced instrumentation available or the referenced instrumentation is not reflective of RCS conditions, then the default operator credit MUST be reduced by two.

B. To obtain the equipment credit, credit each **available** system that is (1) capable of maintaining the top event function and (2) is not impacted by the finding. Use the Event Tree associated with the Worksheet to help understand the successes and failures associated with each accident sequence. Use guidance in Tables 7 and 8 to determine equipment credits. Document key assumptions.

C. To obtain, the Operator Credit. **Use the default operator credit unless any of the following four conditions are applicable:**

1. The referenced instrumentation is missing or misleading, then decrease the operator credit by two.
2. The default time is incorrect and is significantly reduced. If the diagnoses time is less than 20 minutes, OR the time required to perform the action is approximately the time available, then decrease the operator credit by one.
3. The action is complicated by missing equipment, unaccessible equipment, steam or high radiation, or loop seals for pump venting, then decrease the operator credit by two.
2. If the procedures are incomplete for the shutdown configuration, then the operator credit is decreased by one.

NOTE: If the default operator credit is changed and results in a negative operator credit, then the operator credit is zero.

D. Determine the Credit for Function for each Top Event Function needed. Select the lower of Equipment Credit and Operator Credit, and enter the value in this column.

Step 4.5.7. Quantification of Core Damage Scenarios

Quantify each accident scenario by adding the credits for IEL + Mitigation Credit. Enter the sum in the Result column.

Note, For phase 2 analyses, the recovery credit is not used.

5.0 FIGURES, TABLES, WORKSHEETS AND EVENT TREES

5.1 Figures

5.2 Tables

5.3 Worksheets and Event Trees

Figure 1 Determination of Applicable POS Groups and Time Windows - BWRs

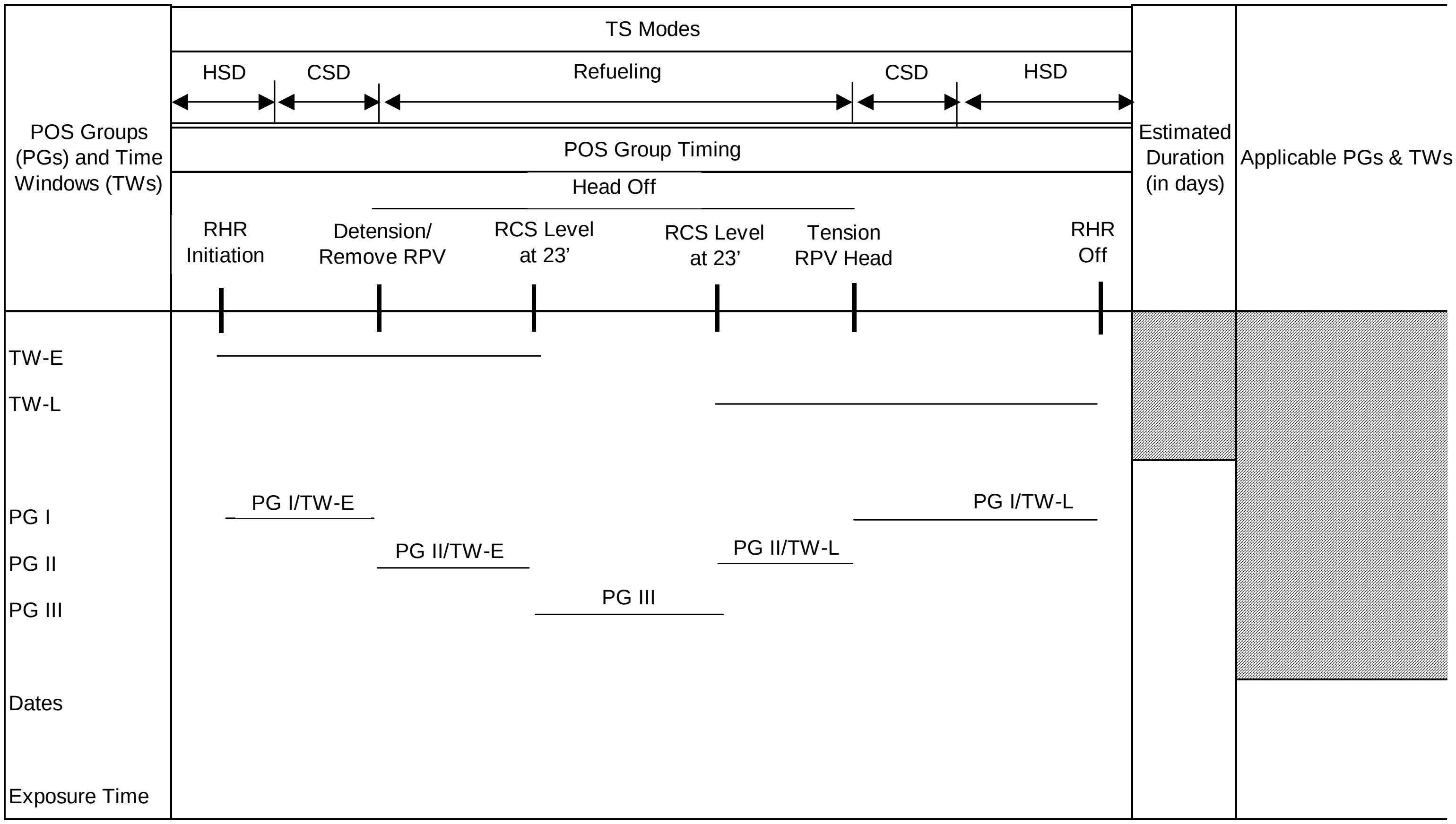

Table 1 - Initiating Event Likelihoods (IELs) for LOOP Precursors

Type of LOOP precursor	**Initiating Event Likelihood (IEL)**
Actual LOOP occurred	0
Work Activities have the potential to affect existing power supplies (example: crane operating close to a Reserve Auxiliary Transformer supplying power to RHR without adequate controls on its movement)	1

Table 2 - Initiating Event Likelihoods (IELs) for LOI Precursors

Time to RHR loss due to isolation of RHR on level 3 given no operator action	Is RCS Level Indication a reasonable reflection of RCS level	Can leak path be readily identified within ½ time to loss of RHR	Can drain path be isolated by at least one functional valve such that a train of RHR can be re-started (e.g. not RHR suction valves)	Estimated IEL
loss of RHR occurred or X<20 min.	N/A	N/A	N/A	0
20<X<40 min.	YES	YES	YES	1
20<X<40 min.	NO	N/A	N/A	0
20<X<40 min.	YES	NO	N/A	0
20<X<40 min.	YES	YES	NO	0
40<X<60 min.	YES	YES	YES	2
40<X<60 min.	NO	YES	YES	0
40<X<60 min.	YES	NO	N/A	0
40<X<60 min.	YES	YES	NO	0
1<X<2 hours	YES	YES	YES	3
1<X<2 hours	NO	YES	YES	1
1<X<2 hours	YES	NO	N/A	0
1<X<2 hours	YES	YES	NO	0
X>2 hours	YES	YES	YES	4
X>2 hours	NO	YES	YES	1
X>2 hours	YES	NO	N/A	0
X>2 hours	YES	YES	NO	0

Table 3 - Initiating Event Likelihoods (IELs) for LORHR Precursors

Note: For findings affecting Loss of the Operating Train of RHR and RHR Supports System Including SSW, AC and DC components

Time to RHR loss given no successful operator action	**Trouble Alarms Present for Finding** **Ex.** **DHR high temp.** **DHR low flow** **Support System Trouble Alarms** **Ex. SSW low flow**	**Can Action to Recover RHR be identified within ½ time to RHR loss?** **Eg. RHR recovery procedures, Support System Recovery procedures,**	**Can Action to Recover RHR be performed within ½ time to RHR loss?**	**Estimated IEL**
Loss of RHR occurred OR < 20 minutes	N/A	N/A	N/A	0
20<X<40 min.	YES	YES	YES	1
20<X<40 min.	NO	N/A	N/A	0
20 <X<40min.	Yes	NO	N/A	0
20<X<40 min.	YES	YES	NO	0
40<X<60min.	YES	YES	YES	2
40<X<60min.	NO	N/A	N/A	0
40<X<60min.	YES	NO	N/A	0
40>X<60min	YES	YES	NO	0
1<X<2 hours	YES	YES	YES	3
1<X<2 hours	NO	YES	YES	1
1<X<2 hours	YES	NO	N/A	0
1<X<2 hours	YES	YES	NO	0
X>2 hour	YES	YES	YES	4
X>2 hour	NO	YES	YES	1
X>2 hour	YES	NO	N/A	0
X> 2 hour	YES	YES	NO	0

Table 4 - Initiating Event Likelihoods (IELs) for Condition Findings - BWRs

Row	Approximate Conditional Frequency	Example Event Type	Estimated IEL[1]		
0	> 1 per yr	Loss of a Operating Train of RHR (LORHR)	**0**	**1**	**2**
I	1 per 1-10 yr	Loss of offsite power (LOOP)	**1**	**2**	**3**
II	1 per 10-10^2 yr	Loss of Inventory (LOI)	**2**	**3**	**4**
			> 30 days	**3-30 days**	**< 3 days**
			Exposure Time for Degraded Condition		

1. The likelihood ratings are presented in terms of 0, 1, 2, etc. A rating of 0 is comparable to a frequency of 1 per year, a rating of 1 is comparable to a frequency of 1E-1 per year, and similarly, a rating of 2 is comparable to a frequency of 1E-2 per year.

Table 5 - Mitigation Capability Credits for Installed Equipment

Type of Remaining Capability	Remaining Capability Rating
Recovery of Failed Train Operator action to recover failed equipment that is capable of being recovered after an initiating event occurs. Action may take place either in the control room or outside the control room and is assumed to have a failure probability of approximately 0.1 when credited as "Remaining Mitigation Capability." Credit should be given only if the following criteria are satisfied: (1) sufficient time is available; (2) environmental conditions allow access, where needed; (3) procedures exist; (4) training is conducted on the existing procedures under similar conditions; and (5) any equipment needed to perform these actions is available and ready for use.	1
1 Automatic Steam-Driven (ASD) Train A collection of associated equipment that includes a single turbine-driven component to provide 100% of a specified safety function. The probability of such a train being unavailable due to failure, test, or maintenance is assumed to be approximately 0.1 when credited as "Remaining Mitigation Capability."	1
1 Train A collection of associated equipment (e.g., pumps, valves, breakers, etc.) that together can provide 100% of a specified safety function. The probability of this equipment being unavailable due to failure, test, or maintenance is approximately 1E-2 when credited as "Remaining Mitigation Capability."	2
1 Multi-Train System A system comprised of two or more trains (as defined above) that are considered susceptible to common cause failure modes. The probability of this equipment being unavailable due to failure, test, or maintenance is approximately 1E-3 when credited as "Remaining Mitigation Capability," regardless of how many trains comprise the system.	3
2 Diverse Trains A system comprised of two trains (as defined above) that are not considered to be susceptible to common cause failure modes. The probability of this equipment being unavailable due to failure, test, or maintenance is approximately 1E-4 when credited as "Remaining Mitigation Capability."	4 (=2+2)

Table 6 - Credits for Temporary Equipment

Mitigation Capability	Credits
Equipment available during power operation and available during shutdown operation	Use credit similar to at-power SDP; manual alignment and actuation may be needed limiting the credit to the credit for operator action
Temporary Equipment (e.g. skid mounted diesel) that is available during shutdown; equipment and tools needed are staged for quick hookup	Use credit of 1

Worksheet 1. SDP Worksheet for a BWR/4 Plant — Loss of Inventory in POS 1

FILL IN: TIME TO BOILING _________ TIME TO CORE DAMAGE _____________
(NOTE: losses of inventory shorten time to core damage)

Safety Functions Needed:	**Success Criteria and Important Instrumentation:**	**Equip. Credit**	**Operator Credit**	**Credit for Function**
Isolation of the loss (ISOL)	Downcomer losses: Auto isolation of RHR on Low Vessel Level W/low level alarm ------------------- ------------------------- Losses from lower plenum	Credit = 3 --------------------- Unisolable leak (lower plenum) - 0	N/A ---------- ----------- Credit = 0	
Early Automatic ECCS (AECCS)	1 low pressure ECCS pump train in automatic		N/A	
Manual Low Pressure Injection - Leak isolated (MINJ)	Reconfigure RHR to ECCS injection, or LPCS, or a condensate pump or another low pressure non-ECCS pump capable of keeping the core covered Operator needs Vessel level indic. W/low level alarms		Credit = 4 (Assumes time to RHR shutoff head > 1hr).	
Manual Low Pressure Injection - Leak not isolated (MINJX)	Reconfigure RHR to ECCS injection or other high flow rate source essentially equivalent in capability to ECCS injection. Operator needs Vessel level indication w/low level alarms		Credit = 4 (Assumed time to CD >2hours w/o leak path isolation)	

DHR Recovery before RCS pressure control needed. Leak Isolated. (RHRREC)	Operator restarts RHR before RCS pressure control needed. OR Operator initiates an alternate, diverse, DHR path such as CRD and RWCU before RCS pressure control is needed.		Credit = 4 (Time to RHR shutoff head >1 hr.)	
RCS Pressure Control **(SRV)**	Operator opens A RCS vent path (e.g. SRV) to control RCS pressure. Operator needs RCS pressure indication.		Credit = 2	
Manual High Pressure Injection at Pressure (MINJY)	Operator injects following isolation of RHR on high pressure or SRVs lifting. using high pressure pumps such as Control Rod Drive pumps or HPCI.		Credit = 1	
Containment Venting (CV)	Operator opens available vent paths. Additionally, long term make-up water must be provided to the injection source.		Credit = 3	

Core Damage Sequences (Circle Affected Functions)	**IEL**	**Mitigation Credit**	**Recovery**	**Result**
LOI - RHRREC- CV (3)				
LOI - RHRREC - SRV (4)				
LOI - MINJ - CV (6)				
LOI - MINJ - MINJY(7)				
LOI - ISOL - CV (9)				

LOI - ISOL - SRV (10)				
LOI - ISOL - AECCS - CV (12)				
LOI - ISOL - AECCS - SRV (13)				
LOI-ISOL-AECCS-MINJX (14)				

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:

If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

Notes:

2. Different non-ECCS sources may apply for different plants. Examples include: firewater and high pressure service water.
3. Failure of ECCS and alternate injection sources is assumed to fail the ability of the operator to recover RHR and is assumed to fail suppression pool cooling and makeup.
4. Failure to isolate the leak reduces the ability to recover RHR.
5. Non-ECCS systems are not assumed to be able to keep core covered if leak path is not isolated.
6. If a leak is isolated by the operator, it is assumed that ECCS will not automatically be activated.
7. Actions to steam the core at high or low pressure to prevent core damage are treated as recovery actions.

Worksheet 2 SDP Worksheet for a BWR/4 Plant — Loss of Inventory in POS 2

FILL IN: TIME TO BOILING _________ TIME TO CORE DAMAGE _____________
(NOTE: losses of inventory shorten time to core damage)

Safety Functions Needed:	Success Criteria and Important Instrumentation:	Equip. Credit	Operator Credit	Credit for Function
Isolation of the loss (ISOL)	Downcomer losses: Auto isolation of RHR on Low Vessel Level W/low level alarm ------------------- ------------------------- Losses from lower plenum	Credit = 3 ----------------------- Unisolable leak (lower plenum) - 0	N/A ---------- ----------- Credit = 0	
Early Automatic ECCS (AECCS)	1 low pressure ECCS pump train in automatic		N/A	
Manual RCS Injection by operator - Leak isolated (MINJ)	Reconfigure RHR to ECCS injection, or manual CRD, or HPCS, or LPCS, or LPCI, or condensate pump or CRD or other non-ECCS before Core Damage Operator needs Vessel level indic. W/low level alarms		Credit = 4 (Time to CD > 3 hrs. w/o injection)	
Manual RCS Injection -- Leak not isolated (MINJX)	Reconfigure RHR to ECCS injection or other high flow rate source essentially equivalent in capability to ECCS injection before core damage. Operator needs Vessel level indic. W/ low level alarms		Credit = 4 (Time to CD > 3 hrs w/o injection.)	

DHR Recovery before Long Term Cooling needed **Leak Isolated.** **(RHRREC)**	Operator restarts RHR before Long Term Cooling needed OR Operator initiates an alternate, diverse DHR path such as CRD and RWCU before Long Term Cooling is needed.		Credit = 4	
Long Term Cooling (LCOOL)	Operator maintains long term inventory source		Credit = 4	

Core Damage Sequences (Circle Affected Functions)	**IEL**	**Mitigation Credit**	**Recovery**	**Result**
LOI-RHRREC-LCOOL (3)				
LOI-MINJ (4)				
LOI -ISOL-LCOOL (6)				
LOI - ISOL-AECCS - LCOOL (8)				
LOI-ISOL-AECCS-MINJX (9)				

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:

If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

Notes:

ATTACHMENT 2

1. Different non-ECCS sources may apply for different plants. Examples include: firewater and high pressure service water.
2. Failure of ECCS and alternate injection sources is assumed to fail the ability of the operator to recover RHR
3. Failure to isolate the leak reduces the ability to recover RHR.
4. Non-ECCS systems are not assumed to be able to keep core covered if leak path is not isolated.
5. If a leak is isolated by the operator, it is assumed that ECCS will not automatically be activated.

Worksheet 3 SDP Worksheet for a BWR/4 Plant — Loss of Inventory in POS 3

FILL IN: TIME TO BOILING _________ TIME TO CORE DAMAGE _____________
(NOTE: losses of inventory shorten time to core damage)

Safety Functions Needed:	**Success Criteria and Important Instrumentation:**	**Equip. Credit**	**Operator Credit**	**Credit for Function**
Isolation of the loss (ISOL)	Downcomer losses: Auto isolation of RHR on Low Vessel Level W/low level alarm ------------------- ------------------------ Losses from lower plenum	Credit = 3 ---------------------- Unisolable leak (lower plenum) - 0	N/A ---------- ----------- Credit = 0	
Manual RCS Injection - Leak isolated (MINJ)	Reconfigure RHR to ECCS injection, or manual CRD, or HPCS, or LPCS, or LPCI, or condensate pump or CRD or other non-ECCS before Core Damage Operator needs Vessel level indic. W/low level alarms		Credit = 4 (Time to CD > 3 hrs. w/o injection)	
Manual RCS Injection - Leak not isolated (MINJX)	Reconfigure RHR to ECCS injection or other high flow rate source essentially equivalent in capability to ECCS injection before Core Damage Operator needs Vessel level indic. W/ low level alarms		Credit = 4 (Time to CD > 3 hrs. w/o injection.)	

DHR Recovery before Long Term Cooling needed. (RHRREC)	Operator restarts RHR before Long Term Cooling is needed. OR Operator initiates an alternate, diverse DHR path such as CRD and RWCU before Long Term Cooling is needed.		Credit = 4	
Long Term Cooling	Operator maintains long term inventory source		Credit = 4	

Core Damage Sequences (Circle Affected Functions)	**IEL**	**Mitigation Credit**	**Recovery**	**Result**
LOI-RHRREC-LCOOL (3)				
LOI - MINJ (4)				
LOI-ISOL-LCOOL (6)				
LOI-ISOL-MINJX (7)				

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:

If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

Notes:

1. Different non-ECCS sources may apply for different plants. Examples include: firewater and high pressure service water.
2. Failure to isolate the leak reduces the ability to recover RHR.
3. Non-ECCS systems are not assumed to be able to keep core covered if leak path is not isolated.

Worksheet 4 SDP Worksheet for a BWR/4 Plant — Loss of Operating Train of RHR (LORHR) in POS 1

FILL IN: TIME TO BOILING ____________________ TIME TO CORE DAMAGE ____________

Safety Functions Needed:	**Success Criteria and Important Instrumentation:**	**Equip. Credit** [6]	**Operator Credit**	**Credit for Function**
DHR Recovery (RHRREC) before RHR shutoff head reached	Operator restores a train of RHR or Alternate DHR path before RHR shutoff head (Tshut) is reached Operator needs RHR inlet/outlet temp indic. and RHR flow indic. with low flow alarm **OR IF APPLICABLE**[7] Operator recovers failed RHR support systems before RHR shutoff head (Tshut) is reached .		Credit = 0 if Tshut <20 min If recovery action can be identified within ½ time to Tshut AND recovery action can be performed within ½ Tshut , then: Credit = 1, if 20<Tshut <40min. Credit = 2, if 40min<Tshut <1 hr Credit = 3, if Tshut > 1 hr.	

[6] If performance deficiency is being transferred from LOOP tree, analyst must consider if the front line systems and necessary support systems are supported from successful EAC.

[7] If this worksheet is being used to assess a RHR support system deficiency that could cause a loss of the operating train of RHR, the equipment credit and operator credit is determined by the operator's ability to recover the support system before the RHR shutoff head is reached.

Manual Low Pressure Injection & RCS Pressure Control **(MINJ&SRV)**	Operator uses a LPCS pump, a condensate pump or another low pressure pump capable of keeping the core covered, in addition to the RHR pumps which are assumed to be failed. Operator needs RCS pressure indication and RCS level indication with low level alarm AND Operator opens a RCS vent a path to control RCS pressure (e.g SRV).		Credit = 2	
Manual High Pressure Injection at Pressure (MINJY)	Following isolation of RHR on high pressure, operator injects using high pressure pumps such as Control Rod Drive pumps or HPCI and steaming out the SRVs at their safety setpoint.		Credit = 1	
Containment Venting (CV)	Operator vents containment and provides long term inventory for injection system		Credit = 3	

Core Damage Sequences (Circle Affected Functions)	**IEL**	**Mitigation Credit**	**Recovery**	**Result**
LORHR - RHRREC - CV (3)				
LORHR - RHRREC - MINJ&SRV- CV (5)				
LORHR-RHRREC-MINJ&SRV-MINJY(6)				

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:

If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

Notes:

1. Failure to recover RHR before RHR shutoff head is reached is assumed to fail short term injection using LPCI.
2. Actions to prevent core damage by steaming the core at high or low pressure are treated as recovery actions.

Worksheet 5 SDP Worksheet for a BWR/4 Plant — Loss of Operating Train of RHR in POS 2

FILL IN: TIME TO BOILING ____________________ TIME TO CORE DAMAGE ____________

Safety Functions Needed:	**Success Criteria and Important Instrumentation:**	**Equip. Credit**[1]	**Operator Credit**	**Credit for Function**
DHR Recovery (RHRREC) before RCS Level 3 reached and RHR automatically isolates	Operator restores a train of RHR or Alternate DHR path before RCS Level 3 (Tisol) reached Operator needs RHR inlet/outlet temp indic. and RHR flow indic. with low flow alarm **OR IF APPLICABLE**[2] Operator recovers failed RHR support systems before RCS Level 3 (Tisol) is reached .		Credit = 0 if Tisol <20 min If recovery action can be identified within ½ time to Tisol AND recovery action can be performed within ½ Tisol , then: Credit = 1, if 20<Tisol <40min. Credit = 2, if 40min<Tisol <1 hr Credit = 3, if Tisol > 1 hr.	

[1]If performance deficiency is being transferred from LOOP tree, analyst must consider if the front line systems and necessary support systems are supported from successful EAC.

[2]If this worksheet is being used to assess a RHR support system deficiency that could cause a loss of the operating train of RHR, the equipment credit and operator credit is determined by the operator's ability to recover the support system before the RHR shutoff head is reached.

Manual RCS Injection before CD (MINJ)	Operator actuates LPCS pump, or another high pressure or low pressure pump capable of keeping core covered, in addition to the RHR pumps which are assumed to be failed Operator needs Vessel level indic. with low level alarms		Credit = 2	
Long Term Cooling (LCOOL)	Operator maintains long term inventory source		Credit = 4	

Core Damage Sequences	**IEL**	**Mitigation Credit**	**Recovery**	**Result**
LORHR -RHRREC-LCOOL (3)				
LORHR-RHRREC-MINJ (4)				

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:

If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

Worksheet 6 SDP Worksheet for a BWR/4 Plant — Loss of Offsite Power in POS 1

FILL IN: TIME TO BOILING _________ TIME TO CORE DAMAGE _____________

Safety Functions Needed:	**Success Criteria and Important Instrumentation:**	**Equip. Credit**	**Operator Credit**	**Credit for Function**
Emergency AC before RHR pump shutoff head reached (EAC)	1 EDG or 1 alternate on-side AC power source [3]		Credit = 3 (assumed 2 hrs to shutoff head)	
AC-Independent injection and RCS Pressure Control (ACI&SRV)	Operator actuates 1 AC independent pump (.e.g Firewater) Operator needs RCS pressure indication and RCS level indication with low level alarm AND Operator opens a RCS vent path to control RCS pressure (e.g. SRV)		Credit =3 (Time to CD w/o injection > 3hrs)	
Recovery of LOOP in 8 hours (RLOOP8)	Offsite power recovered before core damage with no RCS makeup (assumed 8 hours)	Credit = 1		

[3] Alternate AC source can be credited if can be tied in to 4KV buses at least 1hour before RHR pump shutoff head reached.

Recovery of LOOP in 20 hours (RLOOP20)	Offsite power recovered after battery depletion but before core damage (12 hours to depletion + 8 hours to core damage)	Credit = 2		

Core Damage Sequences (Circle Affected Functions)	**IEL**	**Mitigation Credit**	**Recovery**	**Result**
LOOP-EAC-RLOOP20 (3)				
LOOP-EAC-ACI&SRV-RLOOP8 (5)				

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:

If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

Notes:

1. Different non-ECCS sources may apply for different plants. Examples include: firewater and high pressure service water.
2. In sequence 1, LOOP followed by successful start of a EDG or EAC source, analyze the Loss of RHR sequences. The IEL for the Loss of RHR analysis should the LOOP IEL. The analysis must take into account the complexities of recovering RHR with specific deficiencies of the electrical system.

Worksheet 7 SDP Worksheet for a BWR/4 Plant — Loss of Offsite Power in POS 2 (LOOP-2)

FILL IN: TIME TO BOILING _________ TIME TO CORE DAMAGE _____________
(NOTE: losses of inventory shorten time to core damage)

Safety Functions Needed:	Success Criteria and Important Instrumentation:	Equip. Credit	Operator Credit	Credit for Function
Emergency AC (EAC)	1 EDG or 1 alternate on-side AC power source [4]		Credit = 3	
AC-Independent injection before core damage (EAC-AIC)	Operator actuates 1 AC independent pump (e.g. fire water) Operator needs Vessel level indication w/low level alarms		Credit =3 (Time to CD w/o injection > 3hrs)	
Recovery of LOOP in 8 hours (RLOOP8)	Offsite power recovered before core damage with no RCS makeup (assumed 8 hours)	Credit = 1		
Recovery of LOOP in 20 hours (RLOOP20)	Offsite power recovered after battery depletion but before core damage (12 hours to depletion + 8 hours to core damage)	Credit = 2		

Core Damage Sequences (Circle Affected Functions)	IEL	Mitigation Credit	Recovery	Result
LOOP - EAC- RLOOP20 (3)				
LOOP - EAC-ACI - RLOOP8 (5)				

[4]Alternate AC source can be credited if can be tied in to 4KV buses at least 1hour before RHR pump shutoff head reached.

ATTACHMENT 2

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:

If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

Notes:

1. Different non-ECCS sources may apply for different plants. Examples include: firewater and high pressure service water.
2. In sequence 1, LOOP followed by successful start of a EDG or EAC source, analyze the Loss of RHR sequences. The IEL for the Loss of RHR analysis should the LOOP IEL. The analysis must take into account the complexities of recovering RHR with specific deficiencies of the electrical system.

BWR Basis Document for Appendix G

Table of Contents

1.0 Objective

The objective of this basis document is to define the PRA model used to develop Appendix G for BWR and PWRs and the BWR and PWR Shutdown Templates.

2.0 Introduction

2.1 Model Scope

This low power and shutdown PRA model focuses on shutdown operations when more than one fuel assembly in the reactor vessel. This PRA specifically covers shutdown operations-initiating when the licensee has met the entry conditions for RHR and RHR cooling has been initiated and ending when the licensee is heating up and RHR had been secured.

Once the plant is above the RHR entry conditions, a severe accident during this configuration is expected to produce a plant response that is bounded by the plant response to full power initiating events. For deficiencies occurring above the RHR entry conditions, the full power SDP tools should be used acknowledging: (1) decay heat is less compared to full power, potentially allowing more time for operator recovery (2) some mitigating systems may require manual operation versus automatic operation, and (3) some containment systems may not be required to be operable potentially increasing the likelihood of containment failure.

2.2 Limitations of the PRA model

The template is a simplified tool that generates an order-of-magnitude assessment of the risk significance of the inspection findings during a shutdown. This template is developed for a BWR plant, considering the features of a General Electric /4 -Mark I plant. However, it can be used for different plant classes as long as the analyst considers each system and strategy that can be sued to maintain the shutdown key safety functions such as the ability to: maintain/recover DHR heat removal, maintain RCS level control, and maintain RCS pressure control.

This generic tool could not include plant specific mitigating features because they vary between licensees and outages. Therefore, the analyst has to consider the licensee's outage-specific mitigation capability.

Since the template was developed based on maintaining key shutdown safety functions, this template does not provide any information on frontline system dependencies. The analyst should refer to the system-dependency table provided in the full-power phase 2 Notebooks. However, the inspector has to consider additional dependencies for additional systems/functions not needed at full power (e.g., AC power for containment closure). The inspector also has to consider whether a support system is needed for the frontline system at shutdown.

3.0 Characterization of Shutdown Operations

The risk significance of an inspection finding at shutdown depends on the plant configuration. To account for the plant's changing configuration and decay heat level during shutdown, this PRA model parses an outage into plant operational states (POSs) and time windows (TWs). The plant response to the a loss or interruptions of RHR is assumed to remain constant during a given POS. Time Windows are used to separate POSs occurring early in the outage when decay heat is high to POSs occurring late in the outage when decay heat is low.

For this template, Figure 1 defines the POSs and time windows for a BWR plant. It also shows the relationship between the POSs and the modes laid down in the Technical Specifications (TSs). We now describe the POSs and Time Windows (TWs).

POS 1- This POS starts when the RHR system is put into service and the vessel head is on. This POS covers part of Hot Shutdown (Mode 3) and Cold Shutdown (Mode 4) of the TS Modes.

POS 2- This POS represents the shutdown condition when the vessel head is removed, and the reactor pressure vessel water level is less than the minimum level required for movement of irradiated fuel assemblies within the reactor pressure vessel as defined by Technical Specifications. This POS occurs during Mode 5.

POS 3- This POS represents the shutdown condition when the reactor pressure vessel water level is equal or greater than the minimum level required for movement of irradiated fuel assemblies within the reactor pressure vessel as defined by Technical Specifications. This POS occur during Mode 5.

Early Time Window (TW-E)- This time widow represents the time before POS 3 is entered. The decay heat is relatively high. The reactor is either in POS 1 or 2.

Late Time Window (TW-L)- This time window represents the time after POS group 3. The decay heat is relatively low. The reactor is either in POS 1, 2, or 3

The above definitions of the POSs and Time Windows can be used to address different types of plant shutdowns, i.e., refueling outage, planned maintenance outage, and an unplanned outage. Depending on the type of outage and its duration, the POSs and TWs can be identified from the above list. For example, all POSs and both TWs will apply to a refueling outage. Only POS 1 and the early Time Window (TW-E) may apply to an unplanned outage.

NOTE: The operator credits in the SDP worksheets are given for Time Window 1. The same worksheets can be used for Time Window 2 except the credits for operator response may need to be changed to account for the longer operator's response time. Detailed instructions are given in Chapter 6.0 of this template.

4.0 Shutdown Initiating Events

An initiating event at shutdown is defined as an event that causes a loss or interruption of the decay heat removal function. This template considers the three internal initiators known to dominate the internal-event shutdown risk based on the Grand Gulf Shutdown PRA (NUREG/CR 6143).

The following are the initiating events considered, with their applicability to the three POSs.

Loss of RHR (LORHR) - This initiating event category includes losses of RHR resulting from failures of the RHR system (such as RHR pump failure) or failures of the RHR support systems such as loss of RBC, loss of SRW, loss of vital AC, and loss of DC power (Loss of offsite power is treated as a separate category.) This category also includes interruptions of RHR caused by spurious ESFAS signals such as RHR suction valve closure. This initiating event category is considered for POS 1 and POS 2. This category is not considered applicable to POS 3, since the time to core uncovery is assumed to be greater than 24 hours.

Loss of Offsite Power (LOOP) - This initiating event category covers losses of offsite power at shutdown which cause a loss of RHR, and operator action is needed to restore RHR. This initiator category is considered for only POS 1 and POS 2. This category is not considered applicable to POS 3, since the time to core uncovery is assumed to be greater than 24 hours.

Loss of Reactor Inventory (LOI) - This initiating event category includes losses of RCS inventory that lead to a loss of RHR due to isolation of RHR on Level 3 or loss of RHR due to loss of RHR pump suction. Many of these flow diversions are caused from improper alignment of valves. This initiator category is considered for all POS groups.

5.0 Shutdown Initiating Event Frequencies

Initiating-event frequencies were estimated by searching LERs from 1992 to 1998[5] and the totaling the number of refueling hours.

Row	Approximate Conditional Frequency	Example Event Type	Estimated IEL(1)		
0	> 1 per yr	Loss of a Operating Train of RHR (LORHR)	**0**	**1**	**2**
I	1 per 1-10 yr	Loss of offsite power (LOOP)	**1**	**2**	**3**
II	1 per 10-10^2 yr	Loss of Inventory (LOI)	**2**	**3**	**4**
			> 30 days	**3-30 days**	**< 3 days**
			Exposure Time for Degraded Condition		

1. The likelihood ratings are presented in terms of 0, 1, 2, etc. A rating of 0 is comparable to a frequency of 1 per year, a rating of 1 is comparable to a frequency of 1E-1 per year, and similarly, a rating of 2 is comparable to a frequency of 1E-2 per year.

[5] Loss of Shutdown Cooling Initiating Events Data Summary (1992-1998), Jim Houghton, RES , NRC Internal Report

6.0 Event Trees Models

6.1 Overview

For each event tree, there is an associated worksheets that defines each top event function in the event tree by:

- ❏ Top Event Function - A key safety function that is necessary to restore core cooling given a loss or interruption of the RHR function (e.g. the operator initiates RCS injection before core damage).

- ❏ Success Criteria - The minimum set of equipment that can be used to fulfill the top event function.

- ❏ Instrumentation - The minimum set of instrumentation needed by the operator to fulfill the top event function.

- ❏ Equipment Credit - The credit given to the top event function by the analyst based on all available systems able to fulfill the top event function. The equipment credit used in the worksheets are similar to the equipment credits used in the full power SDP worksheets. Temporary equipment credit is obtained using Table 6.

- ❏ Operator Credit - The credit given for the operator to perform the corresponding top event function. The default operator credit for the performing the top event assumes that: (1) the success criteria for the top event function has been met and (2) the minimum set of instrumentation needed by the operator is available and providing reliable indication. Operator credits were developed using the SPAR-H methodology developed by INEL (ADAMS Accession number ML031540054).

  NOTE: **The analyst must adjust the default operator credits in the worksheets using the following table if:**

  - **If the referenced instrumentation is missing or misleading, then the operator credit is decreased by two or becomes zero, if the operator credit becomes negative.**

    Referring to the SPAR-H LP&SD worksheets, the PSF level for stress is now considered to be high, and the PSF level for ergonomics is now considered missing/misleading. Using the SPAR-H worksheets, this condition results in an HEP multiplier of 100.

- **The default time is incorrect and is significantly reduced. If the diagnosis time is less than 20 minutes, OR the time necessary to perform the action is approximately the available time, then the operator credit is decreased by two or becomes zero, if the operator credit becomes negative.**

  Referring to the SPAR-H LP&SD worksheets, the PSF level for available time for diagnosis becomes barely adequate and has a multiplier of ten. The PSF level for available time for the action portion of the task has a PSF multiplier of 10.

- **If the operator action is complicated by missing equipment, unaccessible equipment, steam or high radiation, or loop seals for pumps that must be vented, then the operator credit is decreased by two or becomes zero, if the operator credit becomes negative.**

  Referring to the SPAR-H LP&SD worksheets, the PSF level for stress is now considered to be high, and the PSF level for ergonomics is now considered to be missing/misleading. Using the SPAR-H LP&SD worksheets, this condition results in an HEP multiplier of 100.

- **If the procedure is not complete for the shutdown plant configuration, then the operator credit is decreased by one or becomes zero, if the operator credit becomes negative.**

  Referring to the SPAR-H LP&SD worksheets, the PSF level for procedures is considered as incomplete. The HEP multiplier is assigned a factor of 20.

- Function Credit - The lower of <u>Equipment Credit</u> and <u>Operator Credit.</u>

6.2 Event Tree Success Criteria

The Success Criteria for the BWR Shutdown Template is based on the RES Grand Gulf PRA referenced in Table 5.1.1 of NUREG/CR-6143 Vol 2. Part 1A.

6.3 General Description/Philosophy for Event Trees

6.3.1. LOI Event Trees

POS 1- Head on

The LOI event trees are defined as a losses of RCS inventory such that DHR should have isolated on low level (Level 3). Losses though the downcomer can be isolated by the automatic isolation of DHR on low level. Losses from the bottom head (such as through a breached RWCU drain line) are not assumed to be isolable for phase 2 analysis. For phase 2 analysis, the break size is assumed not be large enough to be able to remove decay head, so RCS pressure control is necessary. Should the operator fail to manually inject early, the possibility of manual high pressure injection with the SRVs steaming at their safety setpoint is considered.

POS 2- Head off

The LOI event trees are defined as a losses of RCS inventory such that DHR should have isolated on low level (Level 3). Losses though the downcomer can be isolated by the automatic isolation of DHR on low level. Losses from the bottom head (such as through a breached RWCU drain line) are not assumed to be isolable for phase 2 analysis.

6.3.2 LORHR Event Trees

The LORHR event trees are defined as losses or interruptions of the RHR system due failures of the RHR system and/or its support systems (such as SSW or DC power). Recovery of DHR must take place before (1) RHR shutoff head is reached in POS 1 or (2) low RCS level is reached in POS 2 when RHR is automatically isolated, else RCS injection is required to prevent core damage. It is assumed that automatic ECCS via a LPCI train is not available since the LPCI train would have been re-configure for RHR recovery.

6.3.3 LOOP Event Trees

The LOOP event trees evaluate loss of offsite power that result in a loss or interruption of the operating train of RHR. For POS 1, AC independent injection and RCS pressure control is assumed to be sufficient until battery depletion. Based on the RES Grand Gulf Shutdown PRA (NUREG/CR-6143 Vol 2, Part 1 , page 8-49), each ESF battery bank can supply the required DC loads for 11 hours after a loss of AC power if unnecessary loads are shed.

7.0 Human Error Probabilities

7.1 Basis for HEPS used in the IEL Tables

If a licensee has a finding that increases the likelihood of a loss of RHR, IEL tables were created to estimate the new conditional likelihood that a loss of RHR will occur due to the performance deficiency given the occurrence of the performance deficiency and/or condition.

The following HEP tables were used in the BWR Shutdown template. The tables for LOI and LORHR are constructed using the same format. The first column is used to estimate the time to loss of the RHR function from the specific initiating event. The second column determines the availability of key instrumentation that would help the operator to: (1) diagnose that a potential problem exists with maintaining the RHR function and (2) diagnose how to recover from the potential problem such that an interruption or loss of the RHR function is prevented.

From the first column, the time to loss of the RHR function was then divided by two to determine how long the (1) operator had to diagnose the specific action needed to recover RHR and (2) the operator had to perform the specific action needed to recover RHR. (The factor two was used to keep this phase 2 model simple.) Then, the third and fourth columns ask if (1) the specific action to recover RHR can be identified within ½ time to loss of the RHR function and (2) if action to recover RHR can be performed within ½ time to loss of the RHR function.

It was assumed that failure of the operator to diagnose the tasks needed to be performed to prevent a loss of the RHR function would dominant the IEL rather than failure of the operator to perform the necessary physical manipulations of the task.

The IELs corresponding to ½ time to loss of the RHR function come from "Nominal Model of estimated HEPs and EFs within time for diagnosis within time T by control room personnel of an abnormal event annunciated closely in time." Table 12-4, in NUREG/CR 1278. The median joint HEP curve was used assuming the operator had key instrumentation referenced in the IEL tables.

If the licensee did not have the key instrumentation referenced in the IEL tables, then the IEL was assessed a multiplier of 100 based on the SPAR-H methodology. Referring to the LP&SD SPAR-H worksheets, if the licensee has missing/misleading instrumentation, the PSF multiplier is assessed as 50. This loss of instrumentation will result in the task complexity changing from nominal to moderately complex, resulting in an additional multiplier of 2.

7.2 Basis for HEPs used in the Worksheets

SPAR-H methodology developed by INEL was used to derive the HEPs for the worksheets (ADAMS accession number ML031540084). Since every interruption of RHR requires a successful operator response to prevent core damage, operator error is a key contributor to shutdown risk. Operator error appears in almost every top event/mitigation path in the shutdown event trees.

The SPAR-H LP&SD worksheets were used to develop a diagnosis probability. for each safety function that has an operator credit. Using the SPAR-H method given a similar set of PSFs, the diagnosis probability dominates the action probability. Therefore, to simplify the model for phase 2 analysis , the diagnosis probability defines the operator credits used in the worksheets. The first safety function does not include dependence in the operator credit estimate. The second and succeeding safety functions include an estimate of dependence.

The inferred definition of diagnosis is any cognitive decision making that is necessary to perform a task. This definition includes all cognitive tasks ranging from responding to annunciators to recognizing what is necessary to recover a failed RHR system. The inferred definition of action is any manipulation involved in performing the task.

The analyst must recognize that the impact of various PSFs may overlap each other. For example, if the procedures are poor, the time available to perform an action may be decreased if the operator is following the procedures step-by-step.

In the following sections, each default operator credit referenced in the worksheets is derived in the following sections using the SPAR-H methodology.

Referring to the SPAR-H LP&SD worksheets, for each operator credit, the available time was evaluated. This is defined the time that the action must be completed (often in terms of several hours) minus the time it takes to perform the action (often in terms of minutes) plus the time it takes to receive the first cue. The definitions for nominal time, extra time, and expansive time are given in the worksheets.

7.2.1 HEPs for the POS 1 and POS 2 for Loss of Inventory Events

LOI POS 1 Worksheet

MINJ: Operator manually initiates low pressure injection before RHR shutoff head is reached given the leak path has been isolated. For cues, it is assumed that the operator has received the automatic isolation of RHR on Level III alarm. As an additional cue, if RCS injection is delayed, the operators would see rising RCS pressure. It is also assumed that the operators have procedures for this action at shutdown as recommended by NUMARC 91-06.

Time to RHR shutoff head is assumed to occur after 1 hour. The time to manually initiate RCS injection is assumed to take minutes to perform. Thus, using the SPAR-H LP&SD worksheets, the PSF level for time is considered to be expansive. All other PSF levels are considered nominal. The default operator credit is estimated to be 1E-4 or an operator credit of 4.

MINJX Operator manually initiates low pressure injection before RCS pressure control is needed or core damage given the leak path has **not** been isolated. For cues, it is assumed that the operator has received the automatic isolation of RHR on Level III alarm. Also, the operators would receive a RCS low low level alarm (level 2). It is also assumed that the operators have procedures for this action at shutdown as recommended by NUMARC 91-06. Time to RHR shutoff head is assumed to be greater than 1 hour. Time to core damage given the leak is assumed to occur greater than 2 hours. The time to manually initiate injection is assumed to take minutes to perform. Using the SPAR-H LP&SD worksheets, the PSF level for time is considered to be expansive. All other PSF levels are considered nominal, the default operator credit is estimated to be 1E-4.

RHRREC: Operator recovers RHR before RCS pressure control is needed given the leak path has been isolated, and the operators successfully initiated RCS injection. Time to RHR shutoff head is assumed to be greater than 1 hour. For cues, it is assumed that the operator has received the automatic isolation of RHR on Level III alarm. It is also assumed that the operators have procedures for this action as recommended by NUMARC 91-06. The time to recover RHR from the control room is assumed to take minutes. The time to RHR shutoff head is assumed to be greater than 1 hour. Using the SPAR-H LP&SD worksheets, the PSF level for time is considered to be expansive. All other PSF levels are considered nominal, the default operator credit is estimated to be 1E-4.

SRV: Operator controls RCS pressure using an SRV or other means so that core heat removal can be sustained, given the operators successful initiated RCS injection but failed to restore RHR. This action has to be performed before core damage. For cues, the operator has increasing RCS pressure and the alarm associated with automatic isolation of shutdown cooling suction valves above 135 psig. The time needed to open the SRVs is assumed to take minutes; the time to core damage is assumed to be greater than 3 hour with injection. Using the SPAR-H LP&SD worksheets, the PSF level for time is considered to be expansive. All other PSF levels are considered nominal, the default operator credit is estimated to be 1E-4.

Considering dependence with RHRREC, the timing of both actions is simultaneous but not close in time. For this event, the operators have successfully initiated RCS injection. Now, the operators have failed to recover RHR before RCS pressure control is needed but must control RCS pressure to allow low pressure injection to continue. For cues, the operator has increasing RCS pressure. The dependency between RHRREC and SRV is believed to be low. Using the SPAR-H worksheets, the task failure with dependence was estimated as .05, so the revised HEP credit is 2.

MINJY Operator initiates high pressure injection given complete failure of the operator to manually inject at low pressure (MINJ). Failure of MINJ includes equipment failure and operator failure. This action has to be performed before core damage. For cues, the operator has increasing RCS pressure, automatic isolation of the shutdown cooling suction valves at 135 psig, and possibly the SRVs lifting. The time needed to open the SRVs and initiate high pressure injection is assumed to take minutes. Using the SPAR-H LP&SD worksheets, the time to perform the action is considered nominal. All other PSF levels are considered nominal, the default operator credit is estimated to be 1E-2.

Considering dependence with MINJ, the timing of both actions is not close in time. The operators have additional cues increasing RCS pressure, automatic isolation of the shutdown cooling suction valves at 135 psig, and possibly the SRVs lifting. Thus, the dependency between the two actions was believed to be moderate.. Using the SPAR-H worksheets, the task failure with dependence was estimated as 1E-1 or an operator credit of 1.

CV: Operator successfully initiates containment venting and/or makeup water to the suppression pool for long term cooling given the operator successfully initiated RCS injection. It is assumed that the operator has hours to this action. For cues, the operator may have increasing suppression pool temperature; however suppression pool temperatures are not required to be monitored at shutdown. Suppression pool level is required to be monitored at shutdown to support ECCS operability. Using the SPAR-H LP&SD worksheets, the time to perform the action versus the time to perform the action is considered expansive. However, the stress level for this action is perceived to be extreme, and it is assumed that training for this scenario is low. Regarding the ergonomics PSF level, if the suppression pool level temperature is available, then all other PSF levels (other than stress and training) are considered nominal, the default operator credit is rounded to 1E-3.

LOI POS 2 and POS 3 WORKSHEET

MINJ Operator manually initiates low pressure injection before core damage given the leak path has been isolated. For cues, it is assumed that the operator has received the automatic isolation of RHR on Level III alarm. It is also assumed that the operators have procedures for this action at shutdown as recommended by NUMARC 91-06. Time to core damage is assumed to occur after 3 hours. The time to manually initiate injection is assumed to take minutes to perform. As an additional cue, if RCS injection is delayed, the operators would encounter steaming from the top of the open vessel. Using the SPAR-H LP&SD worksheets, the PSF level for time is considered to be expansive since initiating injection is assumed to take minutes. All other PSF levels are considered nominal, the default operator credit is estimated to be 1E-4.

MINJX: Operator manually initiates low pressure injection before core damage given the leak path has **not** been isolated and automatic ECCS injection has failed. For cues, it is assumed that the operator has received the automatic isolation of RHR on Level III alarm. Also, the operators would receive a RCS low low level alarm (level 2). It is also assumed that the operators have procedures for this action at shutdown as recommended by NUMARC 91-06. Using the SPAR-H LP&SD worksheets, the PSF level for time is considered to be expansive since the time to initiate RCS injection is assumed to take minutes and core damage is assumed to occur after 2 hours given the leak. All other PSF levels are considered nominal, the default operator credit is estimated to be 1E-4.

RHRREC: Operator recovers RHR before long term makeup to the suppression pool is needed given successful manual injection. For cues, it is assumed that the operator has received the automatic isolation of RHR on Level III alarm. It is also assumed that the operators have procedures for this action as recommended by NUMARC 91-06. The time to recover RHR from the control room is assumed to take minutes. Using the SPAR-H LP&SD worksheets, the PSF level for time is considered to be expansive. All other PSF levels are considered nominal, the default operator credit is estimated to be 1E-4.

LCOOL: Operator successfully initiates makeup water to the suppression pool for long term cooling given the operator successfully initiated RCS injection. It is assumed that the operator has hours to this action. For cues, suppression pool level is required to be monitored at shutdown to support ECCS operability. Using the SPAR-H LP&SD worksheets, the time to perform the action versus the time to perform the action is considered expansive. All other PSF levels are considered nominal, the default operator credit is estimated as 1E-4

Given successfully RCS injection, it was assumed that there is no dependence between restoration of RHR and the operator failing to continue long term makeup

LOOP POS 1 and POS 2 Worksheet

ACI&SRV: Operator manually initiates AC independent low pressure injection (e.g. fire water) and initiates RCS pressure control (e.g. opens SRVs) before core damage. For cues, it is assumed that the operator has received indication that a total loss of AC power occurred via alarms. Time to core damage is assumed to occur after 3 hours. The time to manually initiate AC independent injection is assumed to be completed under 1 hour. Therefore, using the SPAR-H LP&SD worksheets, the PSF level for time is considered to be expansive. The PSF level for stress is assumed to be extreme, and the level of training for this situation is assumed to be low. All other PSF levels are considered nominal. Using the SPAR-H LP&SD worksheets, the default HEP is rounded to 1E-3.

ACI: Operator manually initiates AC independent low pressure injection (e.g. fire water) before core damage. For cues, it is assumed that the operator has received indication that a total loss of AC power occurred via alarms. Time to core damage is assumed to occur after 3 hours. The time to manually initiate AC independent injection is assumed to be completed under 1 hour. Therefore, using the SPAR-H LP&SD worksheets, the PSF level for time is considered to be expansive. The PSF level for stress is assumed to be extreme, and the level of training for this situation is assumed to be low. All other PSF levels are considered nominal. Using the SPAR-H LP&SD worksheets, the default HEP is rounded to 1E-3.

LORHR POS 1 Worksheet

RHRREC: Operator recovers a train of RHR before RHR shutoff head is reached and RCS pressure control is needed. The time to RHR shutoff head is assumed to be greater than 1 hour. Using the operator response curves in NUREG 1278 Table 12-4, the operator credit is 3, if each of the following statements are true.

A. There are trouble alarms present for the finding.
B. The action to recover RHR can be identified (diagnosed) within ½ the time to RHR shutoff head
C. The action to recover RHR can be performed within ½ the time to RHR shutoff head

If the time to RHR shutoff head is between 30 minutes and 1 hour, and statements 1, 2, and 3 are true, then the default operator credit is 2.

MINJ&SRV: Operator manually (1) initiates RCS injection using another standby low pressure injection pumps in addition to the two LPCI pumps that are being used to satisfy the RHR function and (2) initiates RCS pressure control (e.g. opens an SRV) before RHR shutoff head is reached It is assumed that the operators have received trouble alarms for the RHR system. It is assumed that the operator must perform this action before core damage which is assumed to occur after 3 hours. Using the SPAR-H LP&SD worksheets, the PSF level for time is considered to be expansive since initiating RCS injection and pressure control is assumed to require minutes. It is assumed that the operators have procedures for this action at shutdown as recommended by NUMARC 91-06. Thus, all other PSF levels are considered nominal. Using the SPAR-H LP&SD worksheets, the default HEP is rounded to 1E-4.

Considering dependence between RHRREC and MINJ&SRV, the dependence is assumed to be low. The timing of both actions is not close in time. Also, the operators will receive additional cues such as increasing RCS pressure and the automatic isolation of RHR at 135 psig. Using the SPAR LP&SD worksheets, considering low dependence the revised HEP is 1 E-2 or an operator credit of 2.

MINJY Operator initiates high pressure injection given complete failure of the operator to manually inject at low pressure (MINJ). Failure of MINJ includes equipment failure and operator failure. This action has to be performed before core damage. For cues, the operator has increasing RCS pressure, automatic isolation of the shutdown cooling suction valves at 135 psig, and possibly the SRVs lifting. The time needed to open the SRVs and initiate high pressure injection is assumed to take minutes. Using the SPAR-H LP&SD worksheets, the time to perform the action is considered nominal. All other PSF levels are considered nominal, the default operator credit is estimated to be 1E-2.

Considering dependence with MINJ, the timing of both actions is not close in time. The operators have additional cues increasing RCS pressure, automatic isolation of the shutdown cooling suction valves at 135 psig, and possibly the SRVs lifting. Thus, the dependency between the two actions was believed to be moderate. Using the SPAR-H worksheets, the task failure with dependence was estimated as 1E-1 or an operator credit of 1.

CV: Operator successfully initiates containment venting and/or makeup water to the suppression pool for long term cooling given the operator successfully initiated RCS injection but fails to recover RHR. It is assumed that the operator has hours to this action. For cues, the operator may have increasing suppression pool temperature; however suppression pool temperatures are not required to be monitored at shutdown. Suppression pool level is required to be monitored at shutdown to support ECCS operability. Using the SPAR-H LP&SD worksheets, the time to perform the action versus the time to perform the action is considered expansive. However, the stress level for this action is perceived to be extreme, and it is assumed that training for this scenario is low. Regarding the ergonomics PSF level, if the suppression pool level temperature is available, then all other PSF levels (other than stress and training) are considered nominal, the default operator credit is rounded to 1E-3.

LORHR POS 2 Worksheet

RHRREC: Operator recovers a train of RHR before low RCS level is reach (level 3), and RHR is automatically isolated. The time to RHR reach RCS low level is assumed to be greater than 1 hour. Using the operator response curves in NUREG 1278 Table 12-4, the operator credit is 3, if each of the following statements are true.

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1. There are trouble alarms present for the finding.

2. The action to recover RHR can be identified (diagnosed) within ½ the time to RHR shutoff head
3. The action to recover RHR can be performed within ½ the time to RHR shutoff head

If the time to low RCS level is between 30 minutes and 1 hour, and statements 1, 2, and 3 are true, then the default operator credit is 2.

MINJ : Operator manually initiates RCS injection using another standby high or low pressure injection pumps in addition to the two LPCI pumps that are being used to satisfy the RHR function before core damage is reached. It is assumed that the operators have received trouble alarms for the RHR system. It is assumed that the operator must perform this action before core damage which is assumed to occur after 3 hours. Using the SPAR-H LP&SD worksheets, the PSF level for time is considered to be expansive since initiating RCS injection is assumed to require minutes. It is assumed that the operators have procedures for this action at shutdown as recommended by NUMARC 91-06. Thus, all other PSF levels are considered nominal. Using the SPAR-H LP&SD worksheets, the default HEP is rounded to 1E-4.

Considering dependence between RHRREC and MINJ, the dependence is assumed to be low. The timing of both actions is not close in time. Also, the operators will receive additional cues such as decreasing RCS level and the RCS low low level alarms. Using the SPAR LP&SD worksheets, considering low dependence the revised HEP is 1 E-2 or an operator credit of 2.

LCOOL: Operator successfully initiates makeup water to the suppression pool for long term cooling given the operator successfully initiated RCS injection. It is assumed that the operator has hours to this action. For cues, suppression pool level is required to be monitored at shutdown to support ECCS operability. Using the SPAR-H LP&SD worksheets, the time to perform the action versus the time to perform the action is considered expansive. All other PSF levels are considered nominal, the default operator credit is estimated as 1E-4.