*BWR DRAFT*
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# 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 an adequate mitigation capability (equipment, instrumentation, policies, procedures, and training). 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: Phase 1, Definition and Initial Screening of Findings 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 for performing phase 3 analyses for certain BWR shutdown findings discussed below.

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### 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 issue 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 issue screens as minor this SDP should not be entered.

#### 1.1.2 MD 8.3 Entry

This tool is used when a finding has been identified as requiring quantitative assessment from the phase 1 shutdown SDP screening tool (IMC 0609 Appendix G)..

### 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 CD 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. Before using Worksheets, users should review attached event trees to ensure that Worksheet entries are consistent with the sequence logic in the event trees.

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. These definitions can be found in Chapter 6.4 , Procedure for Significance Determination.

2.2.3 The SDP is constructed for a BWR-4. It can be used for other BWR product lines acknowledging that different systems may be used to maintain the safety functions listed in the worksheets.

2.2.4 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 with 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 deficiencies

## 3.0 ABBREVIATIONS AND DEFINITIONS



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### 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 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)..

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.

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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 isolation of RHR on Level 3 or loss of RHR due to loss of RHR pump suction.

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 starts when the vessel head is removed and RCS level is less than 23' above the reactor vessel flange. This POS includes portions of Mode 5 (Refueling). Conservatively, events that occur during transition between POS 2 and POS 3 are modeled as occurring in POS 2.

POS 3 - This POS represents the shutdown condition with the refueling cavity filled to 23 feet above the reactor vessel flange. A very large amount of coolant inventory is available. This POS occurs 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.

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.

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## 4.0 PROCEDURE FOR SIGNIFICANCE DETERMINATION

### Step 4.1 Initiating Event Characterization

Detailed guidance for initiating event characterization can be found in Sections 6.2 through 6.5 of the Basis Document.

**Step 4.1.1** Determine if the finding is a precursor to a loss of RHR or a condition finding. Note: Precursor findings have the potential to cause a loss of the operating train of RHR or actually caused the loss of the RHR function. Condition findings only involve a degradation of the licensee's capability to mitigate an event if an event were to occur. The SDP is significantly different for these two different types of findings.

**Step 4.1.2** Go to Step 4.1.2.1 for Precursor Findings or Step 4.1.2.2 for Condition Findings.

**Step 4.1.2.1** *Precursor Findings* - Determine the IEL rating. Evaluate the following 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 4.1.2.1.1.
- 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 4.1.2.1.1.
- 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 4.1.2.1.1.
- 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 4.1.2.1.1.

**Step 4.1.2.1.1** Determine the POS and TW in which the precursor occurred. Figure 3 defines the POSs used in the SDP. Go to Step 4.2.

**Step 4.1.2.2** *Condition Findings* - Select the applicable initiating events (LORHR, LOOP and/or LOI) by identifying the equipment or safety functions affected and

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determine the initiating event scenarios that must be evaluated (i.e., the affected function plays some role in mitigating the initiating event scenario). Tables provided in the plant-specific full power SDP notebooks provide useful information, as do the SDP worksheets in this document.

**Step 4.1.2.2.1** 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 4, determine an IEL for each applicable initiating event in each applicable POS. Go to Step 4.3.

**Step 4.2 Evaluation of Mitigation Capability for Precursor Findings**

Use the SDP Worksheet that contains the POS and initiating event that were determined to be applicable in Step 4.1. Detailed guidance for initiating event characterization can be found in Sections 6.6 of the Basis Document. Underlined phrases are Worksheet column headings.

**Step 4.2.1** Enter the time to boiling and time to core damage in the first line of the Worksheet and the IEL in each row of the lower section of the worksheet. Below the safety function section of the Worksheet is a listing of core damage sequences associated with the initiating event being evaluated. Evaluate all sequences for the applicable initiating event in the applicable POS.

**Step 4.2.2** Determine the remaining creditable mitigation capability for each safety function assuming the occurrence of the initiating event, and using the reported status of plant equipment and the times to boiling and core damage. The various Safety Functions Needed to mitigate the specific initiating event are listed in the first column of the SDP Worksheet. The creditable plant-specific capability that is potentially available to satisfy the safety function is described in the second column, entitled Success Criteria and Important Instrumentation. Use the Event Tree associated with the Worksheet to help understand the successes and failures associated with each accident sequence.

**Step 4.2.2.1** Determine the Equipment Credit based on the remaining equipment capability for each affected safety function. Use guidance in Tables 6 and 7, and notes in the Worksheet to enter the Equipment Credit in the third column of the Worksheet. Document key assumptions.

**Step 4.2.2.2** Determine the Operator Credit based on the time and complexity of operator actions to use the available equipment to achieve each safety function. Take into account the availability of instrumentation, alarms, time and procedures for the operator. Table 5 provides general guidance for operator credits and the Worksheets contain sequence specific guidance. Document key assumptions.

**Step 4.2.2.3** Determine the Credit for Function for each Safety Function Needed. Select the lower of Equipment Credit and Operator Credit, and enter the value in this column.

**Step 4.2.3** Working in the lower section of the Worksheet, determine the risk increase for the Finding. Use the Event Tree associated with the Worksheet to help understand the successes and failures associated with each accident sequence.

**Step 4.2.3.1** Enter the Mitigation Credit in the form of a additive equation of Credit for Functions from the upper section of the worksheet for each Core Damage Sequence. For example, take the Core Damage Sequence is LOI-RHRREC-CV. If the Credit for Function for RHRREC is 2 and for CV is 3, enter 2+3 into the Mitigation Credit column.

**Step 4.2.3.2** Enter the Recovery credit and document the value in the box provided at the bottom of the Worksheet.

**Step 4.2.3.3** Sum these credit values (IEL + Mitigation Credit + Recovery) for each sequence and enter the value in the Result column. Go to Step 4.4.

**Step 4.3 Evaluation of Mitigation Capability for Condition Findings**

Use the SDP Worksheet(s) that contain the POSs and initiating events that were determined to be applicable in Step 4.2. Detailed guidance for initiating event characterization can be found in Sections 6.6 of the Basis Document. Perform the following steps on the Worksheet for each applicable POS and initiating event.

**Step 4.3.1** Enter the time to boiling and time to core damage in the first line of the Worksheet.

**Step 4.3.2** Determine which Core Damage Sequences are affected by the finding. Circle the affected safety function(s) in the Core Damage Sequences in the lower area of the Worksheet. Write the IEL in each row of the lower section of the worksheet that corresponds to an affected sequence.

**Step 4.3.2** Determine the remaining creditable mitigation capability for safety functions assuming the occurrence of the initiating event, and using the reported status of plant equipment and the times to boiling and core damage. The various Safety Functions Needed to mitigate the specific initiating event are listed in the first column of the SDP Worksheet. This step only needs to be done for safety functions that appear in affected sequences, as identified in Step 4.3.1. The creditable plant-specific capability that is potentially available to satisfy the safety function is described in the second column, entitled Success Criteria and Important Instrumentation. Pay particular attention to the

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safety functions affected by the finding. Use the Event Tree associated with the Worksheet to help understand the successes and failures associated with each accident sequence.

**Step 4.3.2.1** Determine the Equipment Credit based on the remaining equipment capability for each affected safety function. Use guidance in Tables 6 and 7, and notes in the Worksheet to enter the Equipment Credit in the third column of the Worksheet. Document key assumptions.

**Step 4.3.2.2** Determine the Operator Credit based on the time and complexity of operator actions to use the available equipment to achieve the each safety function. Table 5 provides general guidance for operator credits and the Worksheets contain sequence specific guidance. Document key assumptions.

**Step 4.3.2.3** Determine the Credit for Function for each Safety Function Needed. Select the lower of Equipment Credit and Operator Credit, and enter the value in this column.

**Step 4.3.3** Working in the lower section of the Worksheet, determine the risk increase for the Finding. Use the Event Tree associated with the Worksheet to help understand the successes and failures associated with each accident sequence.

**Step 4.3.3.1** Enter the Mitigation Credit in the form of a additive equation of Credit for Functions from the upper section of the worksheet for each Core Damage Sequence. For example, take the Core Damage Sequence is LOI-RHRREC-CV. If the Credit for Function for RHRREC is 2 and for CV is 3, enter 2+3 into the Mitigation Credit column.

**Step 4.3.3.2** Enter the Recovery credit and document the value in the box provided at the bottom of the Worksheet.

**Step 4.3.3.3** Sum these credit values (IEL + Mitigation Credit + Recovery) for each affected sequence and enter the value in the Result column.

**Step 4.3.3.4** Go to the next applicable Worksheet and begin at Step 4.3.1 or, if all Worksheets are completed, continue to Step 4.4.

**Step 4.4 Estimating the Risk Significance of Inspection Findings**

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.

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## 5.0 FIGURES, TABLES, WORKSHEETS AND EVENT TREES

### 5.1 Figures



### 5.2 Tables



### 5.3 Worksheets and Event Trees



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

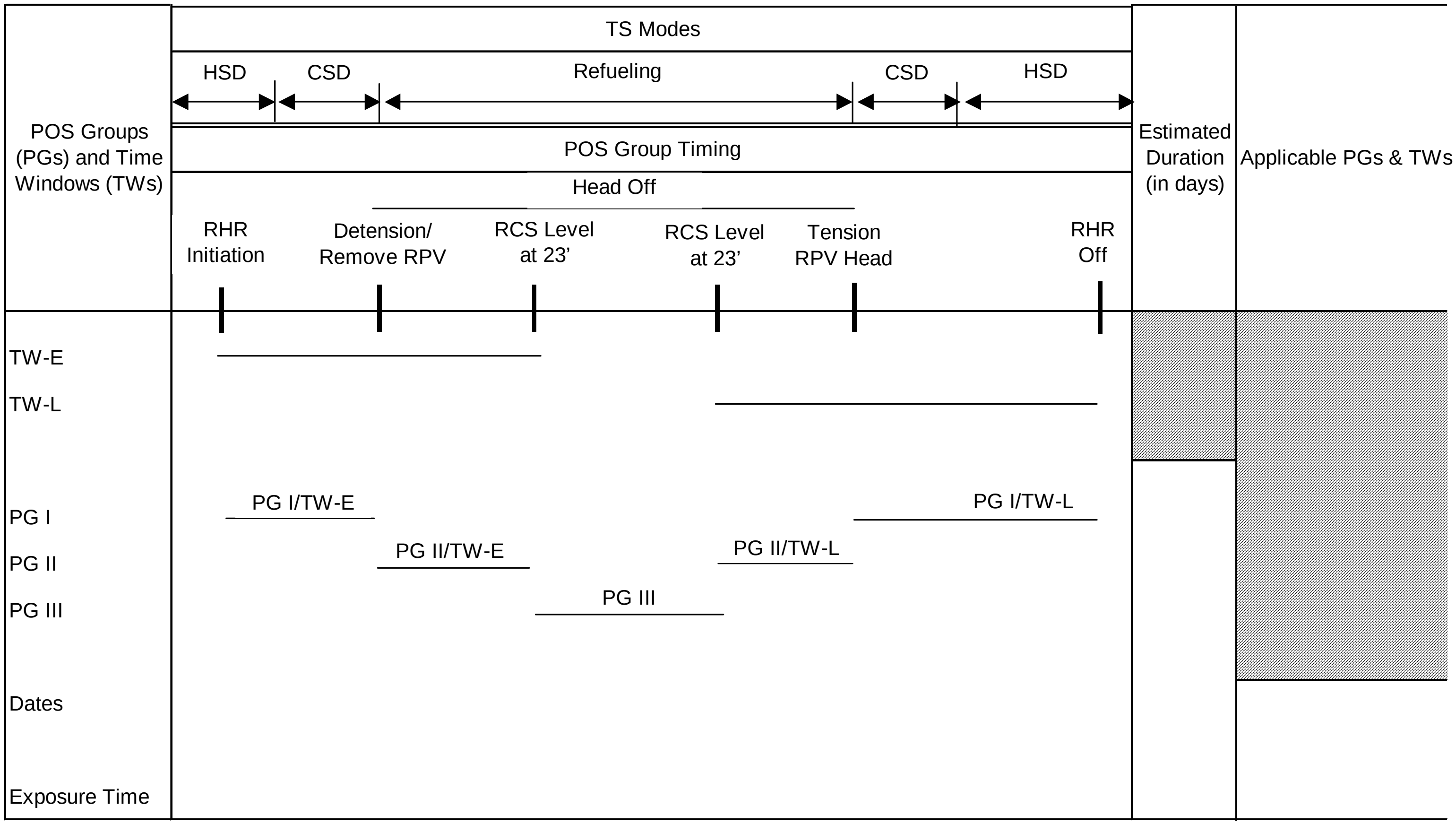

**Table 1 - Initiating Event Likelihoods (IELs) for LOOP Precursors**

| 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 |

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## 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<10 min. | N/A | N/A | N/A | 0 |
| 10<X<30 min. | YES | YES | YES | 1 |
| 10<X<30 min. | NO | N/A | N/A | 0 |
| 10<X<30 min. | YES | NO | N/A | 0 |
| 10<X<30 min. | YES | YES | NO | 0 |
| 30<X<60 min. | YES | YES | YES | 2 |
| 30<X<60 min. | NO | YES | YES | 0 |
| 30<X<60 min. | YES | NO | N/A | 0 |
| 30<X<60 min. | YES | YES | NO | 0 |
| 1<X<4 hours | YES | YES | YES | 3 |
| 1<X<4 hours | NO | YES | YES | 1 |
| 1<X<4 hours | YES | NO | N/A | 0 |
| 1<X<4 hours | YES | YES | NO | 0 |
| X>4 hours | YES | YES | YES | 3 |
| X>4 hours | NO | YES | YES | 1 |
| X>4 hours | YES | NO | N/A | 0 |
| X>4 hours | YES | YES | NO | 0 |

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## 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**<br><br>**Ex.**<br>**DHR high temp.**<br>**DHR low flow**<br><br>**Support System Trouble Alarms**<br>**Ex. SSW low flow** | **Can Action to Recover RHR be identified within ½ time to RHR loss?**<br><br>**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 < 10 minutes | N/A | N/A | N/A | 0 |
| 10<X<30 min. | YES | YES | YES | 1 |
| 10<X<30 min. | NO | N/A | N/A | 0 |
| 10 <X<30min. | Yes | NO | N/A | 0 |
| 10<X<30 min. | YES | YES | NO | 0 |
| 30<X<60min. | YES | YES | YES | 2 |
| 30<X<60min. | NO | N/A | N/A | 0 |
| 30<X<60min. | YES | NO | N/A | 0 |
| 30>X<60min | YES | YES | NO | 0 |
| 1<X<4 hours | YES | YES | YES | 3 |
| 1<X<4 hours | NO | YES | YES | 1 |
| 1<X<4 hours | YES | NO | N/A | 0 |
| 1<X<4 hours | YES | YES | NO | 0 |
| X>4 hour | YES | YES | YES | 3 |
| X>4 hour | NO | YES | YES | 1 |
| X>4 hour | YES | NO | N/A | 0 |
| X> 4 hour | YES | YES | NO | 0 |

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**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.

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## Table 5 - Adjustment to Credits for Operator Actions

To Use:

Take operator action from work sheet and adjust credits using rows 1, 2, and 3.

| ROW | **Factors Affecting Operator Action Credit** | **Impact of Inspection Findings on the Factors** | **Adjustment to Operator Action Credit** |
|---|---|---|---|
| 1 | TIME TO COMPLETE OPERATOR ACTION | Half of the assumed available time in the worksheet | Reduce credit by 1 |
| | | Same as that assumed available time in the worksheets | No change in credit |
| | | Twice as that assumed in the worksheet | Increase credit by 1 |
| 2 | COMPLEXITY OF ACTION<br><br>Additional Complicating Factors (list not exhaustive)<br><br>Poor Environment (ex. Steam or Hi. Rad.)<br><br>Procedures are incorrect, unavailable or ambiguous for the HEP | Additional Complicating Factors | Reduce credit by 1 or by 2 (depending on severity) |
| | | No Additional Complexities | No change |
| 3 | AVAILABILITY OF INSTRUMENTATION | Unavailable or Providing Indication not reflective of RCS conditions | Reduce credit by 2 |
| | | Same as worksheet | No change |

## Table 6 - Mitigation Capability Credits for Installed Equipment

| Type of Remaining Capability | Remaining Capability Rating |
|---|---|
| Recovery of Failed Train<br><br>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<br><br>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<br><br>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<br><br>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<br><br>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 - 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 |

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**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<br>------------------- -------------------------<br>Losses from lower plenum | Credit = 3<br>---------------------<br>Unisolable leak (lower plenum) - 0 | N/A<br>---------- -----------<br>Credit = 0 | |
| **Early Automatic ECCS (AECCS)** | 1 low pressure ECCS pump train in automatic | | N/A | |
| **Early injection by operator - 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<br><br>Operator needs Vessel level indic. W/low level alarms | | Credit = 4<br>(Assumes time to RHR shutoff head > 1hr). | |
| **Early injection by operator - Leak not isolated (MINJX)** | Reconfigure RHR to ECCS injection or other high flow rate source essentially equivalent in capability to ECCS injection.<br><br>Operator needs Vessel level indication w/low level alarms | | Credit = 4<br>(Assumed time to CD >3hours w/o leak path isolation) | |

| | | | | |
|---|---|---|---|---|
| **DHR Recovery before RCS pressure control needed. Leak Isolated. (RHRREC)** | Operator restarts RHR before RCS pressure control needed.<br>OR<br>Operator initiates an alternate, diverse, DHR path such as CRD and RWCU.before RCS pressure control is needed. | | Credit = 3<br>(Time to RHR shutoff head >1 hr.) | |
| **DHR Recovery before RCS pressure control needed. Leak not isolated. (RHRRECX)** | Operator restarts RHR before RCS pressure control is needed.<br>OR<br>Operator initiates an alternate, diverse, DHR path such as CRD and RWCU. before RCS pressure control is needed.<br><br>Caution: One train of equipment is required for injection and cannot be credited for RHR. Operator also needs to replace or recover lost inventory. | | Credit = 3<br>(Operator manages injection and RHR, time to shutoff head > 1 hr) | |
| **Safety Relief Valves before CD (SRV)** | Operator opens 1 SRV[1] to control pressure.<br><br>Operator needs RCS pressure indication. | | Credit = 3 | |
| **Manual Injection after SRV lift before CD (MINJY)** | Operator injects following auto-isolation of RHR on high pressure or SRVs lifting.<br>using high pressure pumps such as Control Rod Drive pumps or HPCI. | | Credit = 1 | |
| **Containment Venting (CV)** | Operator opens available vent paths.<br>Additionally, long term make-up water must be provided to the injection source. | | Credit = 3 | |

| **Core Damage Sequences**<br>(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 - RHRRECX - CV (10) | | | | |
| LOI - ISOL - RHRRECX - SRV (11) | | | | |
| LOI - ISOL - AECCS - CV (13) | | | | |
| LOI - ISOL - AECCS - SRV (14) | | | | |
| LOI-ISOL-AECCS-MINJX (15) | | | | |

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 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.
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.
6. 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 _____________**<br>(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<br>------------------- -------------------------<br>Losses from lower plenum | Credit = 3<br>---------------------<br>--<br>Unisolable leak (lower plenum) - 0 | N/A<br>---------- -----------<br>Credit = 0 | |
| **Early Automatic ECCS (AECCS)** | 1 low pressure ECCS pump train in automatic | | N/A | |
| **Early 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<br><br>Operator needs Vessel level indic. W/low level alarms | | Credit = 5<br>Visible boiling/steam<br>(Time to CD > 3 hrs. w/o injection) | |

| | | | | |
|---|---|---|---|---|
| **Early injection by operator - 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.<br><br>Operator needs Vessel level indic. W/ low level alarms | | Credit = 5<br>(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<br>OR<br>Operator initiates an alternate, diverse DHR path such as CRD and RWCU before Long Term Cooling is needed. | | Credit = 3<br>(assumes operator has several hours to perform task) | |
| **DHR Recovery before Long Term Cooling needed. Leak not isolated. (RHRRECX)** | Operator restarts RHR before Long Term Cooling needed<br>OR<br>Operator initiates an alternate, diverse DHR path such as CRD and RWCU before Lont Term Cooling is needed.<br><br>Caution: One train of equipment is required for injection and cannot be credited for RHR. Operator also needs to make-up lost inventory in long term. | | Credit = 3<br>(assumes operator has several hours to perform task) | |
| **Long Term Cooling** | Operator maintains long term inventory source | | Credit = 2 | |

| **Core Damage Sequences** (Circle Affected Functions) | **IEL** | **Mitigation Credit** | **Recovery** | **Result** |
|---|---|---|---|---|
| LOI-RHRREC-LCOOL (3) | | | | |
| LOI-MINJ (4) | | | | |
| LOI -ISOL-RHRRECX-LCOOL (7) | | | | |
| LOI - ISOL-AECCS - RHRRECX-LCOOL (10) | | | | |
| LOI-ISOL-AECCS-MINJX (11) | | | | |

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 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<br>------------------ ------------------------<br>Losses from lower plenum | Credit = 3<br>----------------------<br>Unisolable leak (lower plenum) - 0 | N/A<br>---------- -----------<br>Credit = 0 | |
| **Early 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<br><br>Operator needs Vessel level indic. W/low level alarms | | Credit = 5<br>(Time to CD > 3 hrs. w/o injection) | |
| **Early injection by operator - 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<br><br>Operator needs Vessel level indic. W/ low level alarms | | Credit = 5<br>(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.<br>OR<br>Operator initiates an alternate, diverse DHR path such as CRD and RWCU before Long Term Cooling is needed. | | Credit = 3 | |
| **DHR Recovery before Long Term Cooling is needed. Leak not isolated. (RHRRECX)** | Operator restarts RHR before Long Term Cooling is needed..<br>OR<br>Operator initiates an alternate, diverse, DHR path such as CRD and RWCU.<br><br>Caution: One train of equipment is required for injection and cannot be credited for RHR. Operator also needs to make-up lost inventory in long term. | | Credit = 3 | |
| **Long Term Cooling** | Operator maintains long term inventory source | | Credit = 3 | |

| **Core Damage Sequences** (Circle Affected Functions) | **IEL** | **Mitigation Credit** | **Recovery** | **Result** |
|---|---|---|---|---|
| LOI-RHRREC-LCOOL (3) | | | | |
| LOI - MINJ (4) | | | | |
| LOI-ISOL-RHRRECX-LCOOL (7) | | | | |
| LOI-ISOL-MINJX (8) | | | | |

| 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 (LORHR-1)**

**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 RHR shutoff head reached** | Operator restores a train of RHR, RHR HX I/O temp., RHR flow, and vessel pressure indic. w/alarms<br>OR<br>Operator initiates an alternate, diverse DHR path such as CRD and RWCU . | | Credit = 3 (assumed 2 hrs to shutoff head) | |
| **Short Term Water Injection by Operator (MINJ)** | Operator uses a LPCS pump, or a condensate pump or another low pressure non-ECCS pump capable of keeping the core covered<br><br>Operator needs Vessel level indic. w/ low level alarms | | Credit = 4 (Time to reliefs lifting > 3hrs) | |
| **Pressure Control (SRV) before CD** | Operator opens 1 SRV with vessel pressure indic. (check to ensure 1 SRV is sufficient)<br><br>Operator needs RCS pressure indication. | | Credit = 3 | |

[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.

| | | | | |
|---|---|---|---|---|
| **Manual Injection after SRV lift before CD (MINJY)** | Operator injects following auto-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 vents containment and provides long term inventory for injection system | | Credit = 3 (LC needed > 10 hrs.) | |

| **Core Damage Sequences** (Circle Affected Functions) | **IEL** | **Mitigation Credit** | **Recovery** | **Result** |
|---|---|---|---|---|
| LORHR - RHRREC - CV (3) | | | | |
| LORHR - RHRREC - SRV (4) | | | | |
| LORHR - RHRREC - MINJ - CV (6) | | | | |
| LORHR - RHRREC - MINJ - MINJY | | | | |

| |
|---|
| Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:<br><br><br><br>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 Level 3 reached** | Operator restores a train of RHR, RHR HX I/O temp., RHR flow, and vessel level indic. w/alarms<br>OR<br>Operator initiates an alternate, diverse, DHR path such as CRD and RWCU. | | Credit = 3 | |
| **Short Term Water Injection by Operator before CD (MINJ)** | Operator actuates LPCS pump, or actuates 1 non-ECCS pump capable of keeping core covered.<br><br>Operator needs Vessel level indic. w/ low level alarms | | Credit = 5<br>(Time to CD > 3hrs) | |
| **Long Term Cooling (LC)** | Operator maintains long term inventory source | | Credit = 3<br>(LC needed > 10 hrs) | |

[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.

| **Core Damage Sequences** | **IEL** | **Mitigation Credit** | **Recovery** | **Result** |
|---|---|---|---|---|
| LORHR -RHRREC-LC (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 [2] | | Credit = 2 (assumed 2 hrs to shutoff head) | |
| **AC-Independent injection before core damage (ACI)** | Operator actuates 1 AC independent pump,<br><br>Operator needs vessel level indic. w/alarms | | Credit =3 (Time to CD w/o injection > 3hrs) | |
| **RCS pressure control before CD (SRV)** | Operator opens 1 SRV (check if one SRV is sufficient and availability of $N_2$ bottles),<br><br>Operator needs RCS pressure indication. | | Credit = 3 (Time to CD > 3hrs) | |
| **Recovery of LOOP in 2 hours (RLOOP2)** | Offsite power recovered in two hours before RHR shutoff head reached | Credit = 1 | | |

[2]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 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-SRV-RLOOP2 (5) | | | | |
| LOOP-EAC-ACI-RLOOP8 (7) | | | | |
| LOOP-EAC-ACI-SRV-RLOOP2 (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:

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 [3] | | Credit = 2 | |
| **AC-Independent injection before core damage (EAC-AIC)** | Operator actuates 1 AC independent pump,<br><br>Operator needs Vessel level indication w/low level alarms | | Credit =3<br>(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 | | |

| **Core Damage Sequences** (Circle Affected Functions) | **IEL** | **Mitigation Credit** | **Recovery** | **Result** |
|---|---|---|---|---|
| LOOP - EAC-ACI - RLOOP8 | | | | |

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

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.

## 6.0 BASIS DOCUMENT

### 6.0.1 Abstract

This report provides a template for assessing the risk significance of the inspection findings for a General Electric Boiling Water Reactor 4 (BWR) plant during shutdown conditions. This template is intended for use in the Significance Determination Process (SDP) for shutdown operations under the US NRC's Risk-Informed Reactor Oversight Process. It supplements the at-power SDP by considering shutdown conditions when the residual heat removal (RHR) system is the normal means of removing decay heat. In considering the plant's characteristics at shutdown, we define the plant operational state (POS) groups and time windows (TWs) (considering the elapsed time from a shutdown), similar to probabilistic risk assessments (PRAs) for shutdown, that influence the significance of the inspection findings. Because an order-of-magnitude impact on risk is assessed in the SDP for determining a color (to represent the risk significance) for the inspection findings, shutdown characteristics are defined in terms of fewer POS groups and time windows than they are in a shutdown PRA. Additional assumptions also are made to allow inspectors to quickly assess the inspection findings. The approach used is similar to that used for an at-power SDP so that the assessment process remains comparable and inspection findings are treated similarly. In addition, the way in which the at-power and shutdown findings are determined remains conceptually similar, facilitating their use by the inspectors.

This template is a generic BWR 4 template and accordingly, plant-specific characteristics or differences are not included. Plant-specific features and outage-specific information will be collected by the user who then can use this template to evaluate the findings of the inspection. Guidance is given on using the template. It covers the adjustment of the initiating event ratings for inspection findings which increase the likelihood of initiating event occurring, adjustment of credit for the operator's actions considering the changes in the time available and the limitations in the available instrumentations, and also, adjustment of mitigation credit considering the temporary equipment that may be used as part of the contingency measures implemented.

### 6.0.2 OVERVIEW OF THE SHUTDOWN SDP PROCESS

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 an adequate mitigation capability (equipment, instrumentation, policies, procedures, and training). 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). Similar to an at-power SDP, a shutdown SDP consists of two phases: Phase 1, Definition and Initial Screening of Findings and Phase 3, Risk Significance Finalization and Justification. IMC 0609 Appendix G, Shutdown Operations Significance Determination Process, has guidance for conducting a significance determination for the inspection findings during a shutdown.

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These templates have been developed for conducting Phase 3 assessment in the SDP for shutdown operations. The templates supplement the at-power notebooks for addressing the inspection findings identified during a plant shutdown. They use a similar conceptual approach to that of at-power Phase 2 SDP and assume that the analyst is familiar with the ideas used in the at-power notebooks. This report is the template for a Boiling Water Reactor (BWR) plant, developed considering a GE BWR/4 design. A companion template also was made for a Pressurized Water Reactor (PWR) plant, considering a Westinghouse 4 loop design.

## 6.1 ENTRY CONDITIONS AND APPLICABILITY

### 6.1.1 Entry Condition and Definition of Inspection Findings

Inspection Manual Chapter (IMC) 0612 specifies the evaluation process that is used to determine if an inspection observation should be subjected to the SDP process. The shutdown SDP provides a graded risk-informed process to estimate the increase in core damage frequency during shutdown operations from conditions which contribute to unintended increases in risk caused by a licensee's deficient performance. Conditions which do NOT represent such a deficiency, as determined by the staff, are considered part of the acceptable normal shutdown risk, and are NOT candidates for SDP evaluation. Hence, the entry conditions for the Reactor Safety SDP described in this template include any degraded equipment, functions, or processes affecting the frequency of initiating events, the availability/ reliability of mitigation systems, or the integrity of the RCS barrier arising from deficiencies in the licensee's performance.

### 6.1.2 Phase 1 - Definition and Initial Screening of the Findings

In Phase 1, the Shutdown Screening tool presented in IMC 0609 Appendix G is used to characterize shutdown findings and determine if the finding should be screened out, or further evaluated in a Phase 3 analysis. The impact of the finding on the ability of a licensee to maintain the five key shutdown safety functions (decay heat removal, inventory control, power availability, reactivity control and containment) is evaluated. These safety functions impact the initiating events cornerstone, the mitigating systems cornerstone, and the barrier integrity cornerstone. Findings with low significance are forwarded to the licensee's corrective action program.

### Special Findings Not Covered by This Template

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 with 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 deficiencies

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### 6.1.3 Phase 3 Refined Risk Assessment

Phase 3 conducts an order-of magnitude evaluation of the risk significance of a BWR inspection finding using this template. It is anticipated that the SRAs would perform the Phase 3 analyses with assistance from staff at headquarters.

## 6.2 SCOPE AND LIMITATIONS OF THE CURRENT TEMPLATE

The template is a simplified tool that generates an order-of-magnitude assessment of the risk significance of the inspection findings during a shutdown. Our intent in formulating the template is to define a tool that NRC inspectors can easily use to obtain a quick assessment of the risk significance.

This template is developed for a BWR/4 plant. The template is a generic one and was developed based on maintaining key safety functions such as the ability to: provide RCS injection; recover RHR if has been interrupted; and maintain containment closure. This generic tool could not include plant specific mitigating features because they vary between licensees and outages. Therefore, the inspector has to consider the licensee's outage-specific mitigation capability. For example, a licensee may have the ability to add fire water following a station blackout, thereby reducing the core damage frequency from a loss of an offsite power initiator.

Developing a simple, easy-to-use process for assessing the risk significance of inspection findings during a shutdown required many assumptions and approximations. During a shutdown, the plant's configuration changes as time progresses; there are differences in the availability of equipment and in the time spent in different configurations from one shutdown to another. Our intent in making the assumptions is to capture the changes and discriminate different findings within an order of magnitude.

We used information from shutdown risk assessments and past shutdown events (including past Phase 3 shutdown SDP evaluations) to make assumptions and approximations, especially in the assessment of human error. 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. To simplify the shutdown event trees, the event trees treat each operator error in each of the top events independently. In reality, the operator error events can be dependent; they share a cognitive error that is based on the operators failure to understand the plant conditions and required actions. This cognitive error is the failure of the operator to diagnose that a loss of shutdown cooling has taken place and action is needed to prevent core damage. The cognitive element was not explicitly treated in the event trees. The operator error included in the event trees is failure for the operator to execute each top event in the core damage scenario.

When the operator has: (1) RCS level indication that is reflective of plant conditions and (2) RCS low level alarms, the failure of the operator to acknowledge that a shutdown event occurred and action is required before core damage is not perceived as a dominant contributor to shutdown risk.



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This error probability is also reduced during shutdown since (1) the RCS may be open and RCS boiling would be observed well before core damage, and (2) the licensee has many personnel performing maintenance and testing around the plant and may be observing adverse conditions such as inventory losses.

If a finding is identified and the inspector concludes that RCS level instrumentation was not available or key trouble alarms were not available or bypassed, then a set of tables was developed to allow the inspector to scale up each operator error in the event trees. In this situation, the execution failure probability for each mitigation path would be increased to account for the reduced ability for the operator to diagnose a loss of RHR.

Since the template was developed based on maintaining key shutdown safety functions, this template does not provide any information on frontline system dependencies. We ask the user to refer to the system-dependency table provided in the at-power 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.

## 6.3 DEFINITIONS

Additional definitions are provided in IMC 0612-03, “Power Reactor Inspection Reports.”

## 6.4 PROCEDURE FOR SIGNIFICANCE DETERMINATION

### 6.4.1 Initiating Event Characterization

**Determining Whether the Finding is a Precursor to a loss of RHR or a Condition Finding**

Once a finding has been identified by the inspector as requiring Phase 3 analysis, the inspector must determine whether the finding represents a precursor to a loss of RHR or the finding represents a condition finding. These two findings are evaluated differently in the SDP process.

Precursors to a loss of RHR include inspection findings that have the potential to cause a loss of the operating train of RHR. These findings increase the likelihood of an initiating event, i.e., they are precursors to the initiating event or they define a condition which makes the initiating event more likely. Examples of such findings include:

- Losses of inventory that are terminated before RHR is isolated on level 3.

- Switchyard activities that increase the likelihood of a loss of offsite power, such as a crane operating too close to a reserve auxiliary transformer.



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- Level instrumentation that does not reflect plant conditions and the licensee plans to initiate RCS draining. This type of finding increases the likelihood of a loss of inventory event.

Condition findings include findings that ONLY involve a degradation of the licensee's mitigation capability. For example, during POS 1 and POS 2, the licensee planned to have two EDG's available, but both were found to have coolant in the cylinders. Clearly, a loss of offsite power initiating event is no more likely, but the plant's ability to successfully mitigate a loss of offsite power initiating event is reduced.

**Initiating Event Descriptions**

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.

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## Guidance for Assessing Precursor and Condition Findings

The tables in Chapters 5 are based on estimates of initiating event frequencies from the best available data. Initiating-event frequencies were estimated by searching LERs from 1992 to 1998. They represent the frequencies conditional on the plant being in a shutdown. Accordingly, the same tables can be used with any combination of POSs and time windows. The estimated duration of the degraded condition in such a combination is used to determine the likelihood rating. The likelihood ratings of the applicable categories of initiating events are employed in evaluating the core-damage sequences in the worksheets of the applicable combinations of POSs and time windows.

For precursor findings, findings involving an actual loss of RHR, or findings that involve level instrumentation that is not representative of plant conditions, use Tables 1, 2 or 3 for estimating the initiator rating. Then, use the guidance in this Chapter for filling in the worksheets.

For condition findings, use Table 4 for estimating the initiating event rating. The ratings correspond to the duration of exposure to the degraded conditions identified by the inspector. Then use the guidance in this Chapter for filling in the worksheets.

## Definitions of the POSs and Time Windows

The risk significance of an inspection finding depends on the associated shutdown condition. A unique aspect in assessing the risk significance of a finding during a shutdown is the consideration of the plant's changing configuration and level of decay heat. During development of a shutdown PRA, the plant's changing configuration and decay heat level are taken into account by dividing the shutdown into plant operational states (POSs) and time windows (TWs). The plant's response to the initiating events and success criteria for mitigation functions are considered to remain unchanged during a given POS. From one time window to another, the decay heat can be substantially different, such that the time available for the operator's actions is different, and the credit given for them may vary.

## BWR POSs and Time Windows for Phase 3 Assessment

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 starts when the vessel head is removed and RCS level is less than 23' above the reactor vessel flange. This POS includes portions of Mode 5

(Refueling). Conservatively, events that occur during transition between POS 2 and POS 3 are modeled as occurring in POS 2.

POS 3- This POS represents the shutdown condition with the refueling cavity filled to 23 feet above the vessel flange and the spent fuel storage pool gates are removed. A very large amount of coolant inventory is available. This POS occurs 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

**Determining Applicable POSs and Time Windows for Inspection Findings**

Figure 1 is used to determine the applicable POSs and time windows relevant to an inspection finding. The inspector then notes the estimated time when the identified degraded condition started and when it was resolved. The time-line of the degraded condition then is matched with the POS and TW time-lines to identify the applicable POSs and TWs. For example, a degraded condition lasting the entire refueling outage will involve five combinations of POSs and Time Windows. Similarly, a forced outage may only cover POS 1 and TW-E. As discussed, using the outage plan or description and the assumptions of the inspection finding, the inspector delineates the estimated duration of the degraded condition and the applicable POSs and TWs.

**Selecting Applicable Table to Precursor Findings**

This section provides guidance for estimating the initiating event likelihood (IEL) for precursor findings. This chapter consists of tables that the analyst uses to estimate the initiator rating depending on the type of precursor that occurred.

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- ❏ IF a finding increases the likelihood of a loss of offsite power (LOOP) or actually caused a LOOP, THEN use Table 1

- ❏ IF a finding increases the likelihood of a loss of reactor inventory (LOI) or actually caused a LOI, THEN use Table 2

- ❏ 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 use Table 3.

- ❏ IF a finding involves the RHR support systems (except for LOOP and LOI), THEN also use Table 3

**Condition Findings**

For condition findings, the analyst must obtain an initiating event likelihood for EACH POS that the condition finding occurred in. Table 4 is used in the same manner as the full power notebooks. Then, the analyst enters the initiating event likelihood in the shutdown worksheets in the same manner as the full power worksheets.

### 6.4.2 Evaluation of Mitigation Capability

The SDP worksheets for shutdown are based on guidance in IMC 0609 and used in the same manner as the full power worksheets using the following specific guidance:

- ❏ The success criterion of a safety function specifies what is needed, not what might be available. Therefore, the inspector should use the outage plan to determine what equipment to credit for each safety function.

- ❏ A frontline system or piece of equipment is considered available if all support systems that are necessary to support the function of the frontline system are available (such as AC power, cooling, instrument air, etc.). If manual action is required, there must be enough time to: (1) recognize that manual action is needed and (2) execute the manual action after recognizing that manual action is needed. To credit system availability, these two tasks should be able to be completed reliably within ½ the time that the equipment must actuate.

- ❏ If the performance deficiency involves a support system, the analyst must consider the impact of potential loss of the system for each safety function specified in the worksheets.

- ❏ Installed equipment is credited similar to the full power worksheets. Use Table 6 for guidance.

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❑ Temporary equipment can be credited. Use Table 7 for guidance.

❑ Operator action drives shutdown risk. Almost every function in the worksheets (almost every top event in the event trees) has an operator action. Often the operator credit defines the credit given to the mitigating function (operator limited). Nominal operator credits are specified in the worksheets based on: (1)
In the worksheets, almost all mitigating functions includes a manual action. Often the manual action defines the credits given to the mitigating function. The **nominal** credit for each operator action is based on: (1) the time available to perform the action and (2) the assumed instrumentation available to the operator as specified in the worksheets.

**THE ANALYST MUST ADJUST EACH OPERATOR CREDIT IN THE WORKSHEETS USING TABLE 5 IF:**

✓ If the time available to perform the action is too short or too long by greater than a factor of 2 (.e.g the finding occurs in Time Window 2)

**OR**

✓ The assumed instrumentation specified in the worksheet is not available/not reflective of plant conditions

**OR**

✓ There are significant, finding specific, negative performance shaping factors for the operator action. Examples include (not limited to): (1) RHR venting cannot be accomplished easily because the scaffolding needed to access the vents is not staged, (2) the ability to vent the RHR pipes is limited by loop seals, (3) the operator needs to enter an area that has high steam or radiation levels, (4) the operator needs special equipment to open a valve that is not staged. .

❑ The inspector should write down any unique assumptions that significantly influence the credit given to the mitigating function at the bottom of the worksheet. These assumptions are critical to performing the Phase 3 analysis and these assumptions are critical to understanding plant specific risk of the finding. For example, if cooling water is not needed to support low pressure injection when the ECCS pump is pumping water cooler than 120F, that assumption should be written at the bottom of the worksheet.

❑ This template does not provide any information on system dependency or alignment during shutdown. We refer the user to the system-dependency tables of at-power plant-



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specific SDP 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 the support system is needed for the frontline system at shutdown. For example, for some licensees, SRW may not be required for low pressure safety injection pump bearing and motor cooling if the pump is pumping cool water (< 120F).

❑ Finally, 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.

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