RISK-INFORMED INSPECTION NOTEBOOK FOR

BROWNS FERRY NUCLEAR POWER STATION

UNIT 2 & 3

BWR-4, GE, WITH MARK I CONTAINMENT

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NOTICE

This notebook was developed for the NRC's inspection teams to support risk-informed inspections. The "Reactor Oversight Process Improvement," SECY-99-007A, March 1999 discusses the activities involved in these inspections. The user of this notebook is assumed to be an inspector with an extensive understanding of plant-specific design features and operation. Therefore, the notebook is not a stand-alone document, and may not be suitable for use by non-specialists. It will be periodically updated with new or replacement pages incorporating additional information on this plant. All recommendations for improvement of this document should be forwarded to the Chief, Probabilistic Safety Assessment Branch, NRR, with a copy to the Chief, Inspection Program Branch, NRR.

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ABSTRACT

This notebook contains summary information to support the Significance Determination Process (SDP) in risk-informed inspections for the Browns Ferry Nuclear Power Station, Unit 2 and 3.

The information includes the following: Categories of Initiating Events Table, Initiators and System Dependency Table, SDP Worksheets, and SDP Event Trees. This information is used by the NRC's inspectors to identify the significance of their findings, i.e., in screening risk-significant findings, consistent with Phase-2 screening in SECY-99-007A. The Categories of Initiating Event Table is used to determine the likelihood rating for the applicable initiating events. The SDP worksheets are used to assess the remaining mitigation capability rating for the applicable initiating event likelihood ratings in identifying the significance of the inspector's findings. The Initiators and System Dependency Table and the SDP Event Trees (the simplified event trees developed in preparing the SDP worksheets) provide additional information supporting the use of SDP worksheets.

The information contained herein is based on the licensee's Individual Plant Examination (IPE) submittal, the updated Probabilistic Risk Assessment (PRA), and system information obtained from the licensee during site visits as part of the review of earlier versions of this notebook. Approaches used to maintain consistency within the SDP, specifically within similar plant types, resulted in sacrificing some plant-specific modeling approaches and details. Such generic considerations, along with changes made in response to plant-specific comments, are summarized.

CONTENTS

TABLES

FIGURES

Page

1. INFORMATION SUPPORTING SIGNIFICANCE DETERMINATION PROCESS (SDP)

SECY-99-007A (NRC, March 1999) describes the process for making a Phase-2 evaluation of the inspection findings. In Phase 2, the first step is to identify the pertinent core damage scenarios that require further evaluation consistent with the specifics of the inspection findings. To aid in this process, this notebook provides the following information:

1. Estimated Likelihood Rating for Initiating Events Categories
2. Initiator and System Dependency Table
3. Significance Determination Process (SDP) Worksheets
4. SDP Event Trees.

Table 1, Categories of Initiating Events, is used to obtain the estimated likelihood rating for applicable initiating events for the plant for different exposures times for degraded conditions. This Table follows the format of the Table 1 contained in SECY-99-007A. Initiating events are grouped in frequency bins covering one order of magnitude. The table includes the initiating events that should be considered for the plant and for which SDP worksheets are provided. Categorization of the following initiating events is based on industry-average frequency: transients (Reactor Trip) (TRANS); transients without power conversion system (TPCS); large, medium, and small loss of coolant accidents (LLOCA, MLOCA, and SLOCA); inadvertent or stuck open relief valve (IORV or SORV); anticipated transients without scram (ATWS); interfacing systems LOCA (ISLOCA) and LOCA outside containment (LOC). The frequency of the remaining initiating events vary significantly from plant to plant, and accordingly, they are categorized using the plant-specific frequency obtained from the licensee. These initiating events include loss of offsite power (LOOP) and special initiators caused by loss of support systems.

The Initiator and System Dependency Table shows the major dependencies between frontline and support systems, and identifies their involvement in different types of initiators. This table identifies the most risk-significant systems; it is not an exhaustive nor comprehensive compilation of the dependency matrix, as shown in Probabilistic Risk Assessments (PRAs). This table is used to identify the SDP worksheets to be evaluated, corresponding to inspection findings on systems and components.

To evaluate the impact of an inspection finding on the core-damage scenarios, we developed the SDP worksheets. They contain two parts. The first part identifies the functions, the systems, and the combinations thereof that can perform mitigating functions, the number of trains in each system, and the number of trains required (success criteria) for each the initiator. It also characterizes the mitigation capability in terms of the available hardware (e.g., 1 train, 1 multi-train system) and the operator action involved. The second part of the SDP worksheet contains the core-damage accident sequences associated with each initiator; these sequences are based on SDP event trees. In the parentheses next to each of the sequences the corresponding event tree branch number(s) representing the sequence is included. Multiple branch numbers indicate that the different accident sequences identified by the event tree are merged into one through the Boolean reduction.

SDP worksheets are developed for each initiating event, including "Special Initiators," which are typically caused by complete or partial loss of support systems. A special initiator typically leads to a reactor scram and degrades some front-line or support systems (e.g., Loss of Service water in BWRs). The SDP worksheets for initiating events that directly lead to core damage are different. Of this type of initiating events, only the interfacing system LOCA (ISLOCA) and LOCA outside containment (LOC) are included. This worksheet identifies the major consequential leak paths and the number of barriers that may fail to cause the initiator to occur.

For the special initiators, we considered those plant-specific initiators whose contribution to the plant's core damage frequency (CDF) is non-negligible and/or have the potential to be a significant contributor to CDF given an inspection finding on system trains and components. We defined a set of criteria for their inclusion to maintain some consistency across the plants. These conditions are as follows:

1. The special initiator should degrade at least one of the mitigating safety functions changing its mitigation capability in the worksheet. For example, a safety function with two redundant trains, classified as a multi-train system, degrades to an one-train system, to be classified as 1 Train, due to the loss of one of the trains as a result of the special initiator.

2. The special initiators, which degrade the mitigation capability of the accident sequences associated with the initiator from comparable transient sequences by two and higher orders of magnitude, must be considered.

Following the above considerations, the classes of initiators that we consider in this notebook are:

1. Transients with power conversion system (PCS)available, called Transients (Reactor trip) (TRANS),
2. Transients without PCS available, called Transients w/o PCS (TPCS),
3. Small Loss of Coolant Accident (SLOCA),
4. Inadvertent or Stuck-open Power Operated Relief Valve (IORV or SORV),
5. Medium LOCA (MLOCA),
6. Large LOCA (LLOCA),
7. Loss of Offsite Power (LOOP)
8. Anticipated Transients Without Scram (ATWS).

Section 1.3 lists the plant-specific special initiators addressed in this notebook. Examples of special initiators are as follows:

1. LOOP with failure of 1 Emergency AC (LEAC) bus or associated EDG (LEAC),
2. LOOP with stuck open SORV (LORV),

3. Loss of 1 DC Bus (LDC),
4. Loss of component cooling water (LCCW),
5. Loss of instrument air (LOIA),
6. Loss of service water (LSW).

The worksheet for the LOOP may include LOOP with emergency AC power (EAC) available and LOOP without EAC, i.e., Station Blackout (SBO). LOOP with partial availability of EAC, i.e., LOOP with loss of a bus of EAC, is covered in a separate worksheet to avoid making the LOOP worksheet too large. LOOP with stuck open SORV is also covered in a separate worksheet, when applicable. In some plants, LOOP with failure of 1 EAC bus and LOOP with stuck-open SORV are large contributors to the plant's core damage frequency (CDF).

Following the SDP worksheets, the SDP event trees corresponding to each of the worksheets are presented. The SDP event trees are simplified event trees developed to define the accident sequences identified in the SDP worksheets. For special initiators whose event tree closely corresponds to another event tree (typically, the Transient(Reactor trip) or Transients w/o PCS event tree) with one or more functions eliminated or degraded, a separate event tree may not be drawn.

We considered the following items in establishing the SDP event trees and the core-damage sequences in the SDP worksheets; Section 2.1 gives additional guidelines and assumptions.

1. Event trees and sequences were developed such that the worksheet contains all the major accident sequences identified by the plant-specific IPEs or PRAs. The special initiators modeled for a plant is based on a review of the special initiators included in the plant IPE/PRA and the information provided by the licensee.

2. The event trees and sequences for each plant took into account the IPE/PRA models and event trees for all similar plants. Any major deviations in one plant from similar plants typically are noted at the end of the worksheet.

3. The event trees and the sequences were designed to capture core-damage scenarios, without including containment-failure probabilities and consequences. Therefore, branches of event trees that are only for the purpose of a Level II PRA analysis are not considered. The resulting sequences are merged using Boolean logic.

4. The simplified event-trees focus on classes of initiators, as defined above. In so doing, many separate event trees in the IPEs often are represented by a single tree. For example, some IPEs define four or more classes of LOCAs rather than the three classes considered here. The sizes of LOCAs for which high-pressure injection is not required are some times divided into two classes; the only difference between them being the need for reactor scram in the smaller break size. Some consolidation of transient event tree may also be done besides defining the special initiators following the criteria defined above.

5. Major actions by the operator during accident scenarios are credited using four categories of Human Error Probabilities (HEPs). They are termed operator action =1 (representing an error probability of 5E-2 to 0.5), operator action=2 (error probability of 5E-3 to 5E-2), operator action=3 (error probability of 5E-4 to 5E-3), and operator action=4 (error probability of 5E-5 to 5E-4). An human action is assigned to a category bin, based on a generic grouping of similar actions among a class of plants. This approach resulted in designation of some actions to a higher bin, even though the IPE/PRA HEP value may have been indicative of a lower category. In such cases, it is noted at the end of the worksheet. On the other hand, if the IPE/PRA HEP value suggests a higher category than that generically assumed, the HEP is assigned to a bin consistent with the IPE/PRA value in recognition of potential plant-specific design; a note is also given in these situations. Operator's actions belonging to category 4, i.e., operator action=4, may only be noted at the bottom of worksheet because, in those cases, equipment failures may have the dominating influence in determining the significance of the findings.

The four sections that follow include the Categories of Initiating Events Table, Initiators and System Dependency Table, SDP Worksheets, and the SDP Event Trees for the Browns Ferry Nuclear Power Station, Unit 2 and 3.

1.1 INITIATING EVENT LIKELIHOOD RATINGS

Table 1 presents the applicable initiating events for this plant and their estimated likelihood ratings corresponding to the exposure time for degraded conditions. The initiating events are grouped into rows based on their frequency. As mentioned earlier, loss of offsite power and special initiators are assigned to rows using the plant-specific frequency obtained from individual licensees. For other initiating events, industry-average values are used, as per SECY-99-007A.

Table 1 Categories of Initiating Events for Browns Ferry Nuclear Power Station, Unit 2 and 3

Row	Approximate Frequency	Example Event Type	Estimated Likelihood Rating		
I	> 1 per 1-10 yr	Reactor Trip, Loss of Power Conversion System (Loss of condenser, Closure of MSIVs, Loss of feedwater)	**A**	**B**	**C**
II	1 per 10-10^2 yr	Inadvertent or stuck open SRVs	**B**	**C**	**D**
III	1 per 10^2 - 10^3 yr	Loss of offsite power, Loss of Raw Cooling Water (LRCW)	**C**	**D**	**E**
IV	1 per 10^3 - 10^4 yr	Small LOCA (RCS rupture), Medium LOCA (RCS rupture)	**D**	**E**	**F**
V	1 per 10^4 - 10^5 yr	Large LOCA (RCS rupture), ATWS	**E**	**F**	**G**
VI	less than 1 per 10^5 yr	ISLOCA, Vessel rupture	**F**	**G**	**H**
			> 30 days	**3-30 days**	**< 3 days**
			Exposure Time for Degraded Condition		

Notes:

1. The SDP worksheets for ATWS core damage sequences assume that the ATWS is not recoverable by manual actuation of the reactor trip function or by ARI (for BWRs). Thus, the ATWS frequency to be used by these worksheets must represent the ATWS condition that can only be mitigated by the systems shown in the worksheet (e.g., boration).

2. Based on the site visit by the NRC, the only special initiator added was Loss of RCW (5.7% of CDF). Three internal flooding sequences contribute 4.9% to CDF. All other special initiators are less than 1% of internal events CDF.

1.2 INITIATORS AND SYSTEM DEPENDENCY

Table 2 provides the list of the systems included in the SDP worksheets, the major components in the systems, and the support system dependencies. The system involvement in different initiating events are noted in the last column.

Table 2 Initiators and System Dependency for Browns Ferry Nuclear Power Station, Unit 2 and 3

Affected System		Major Components	Support Systems	Initiating Event Scenarios
Code	**Name**			
PCS	Power Conversion System	6 MDP, 3 TDP, MOV, 4 TBV, 8 MSIV, condenser	AC, RCW, DC	Transient (Rx Trip), SLOCA, SORV
HPCI	High Pressure Coolant Injection	1 TDP, MOV	DC, Act	All but MLOCA & LLOCA
RCIC	Reactor Core Isolation Cooling	1 TDP, MOV	DC, Act	Transient (Rx Trip), TPCS, SLOCA, LOOP, ATWS, LRCW
SRVs	Safety Relief Valves	13 SRV, Accumulators	DC, DWCA, CAD	All but LLOCA
LPCI	Low Pressure Coolant Injection	4 MDP, MOV	AC, DC, EECW, Act, HVAC	All
RHR	Residual Heat Removal	4 MDP, MOV, 4 HX	AC, DC, RHRSW, EECW, HVAC	All
CS	Core Spray	4 MDP, MOV	AC, DC, EECW, Act, HVAC	All
AC	AC Power (non-EDG)	Breakers, Transformers	AC, DC	All
EDGs	AC Power (EDGs)	4 Engine-Generators	DC, EECW, HVAC, FO xfer	LOOP
FO xfer	Fuel Oil Transfer	2 MDP	AC, DC, Act	LOOP
DC	DC Power, 125 V and 250 V	5 Batteries, Battery Chargers	None (Short term - 4 hours) Chargers and AC (long term)	All
RHR SW	RHR Service Water	12 MDP, MOV	AC, DC	All
CRD	Control Rod Drive Hydraulic System	2 MDP, MOV	AC, DC, PCA, RCW	Transient (Rx Trip), TPCS, SORV

Table 2 (Continued)

Affected System		Major Components	Support Systems	Initiating Event Scenarios
Code	**Name**			
Act	Shared Actuation Instrumentation (SAI)	Instruments, Relays	AC, DC	All
PCA	Plant Control Air	4 Air Compressors, Valves	AC, DC, RCW (EECW)	All but LLOCA
DWCA	Drywell Control Air	2 Compressors, Valves	AC, PCA, RBCCW	All but LLOCA
SLC	Standby Liquid Control	2 MDP, MOV, 2 Explosive Valves	AC, DC	ATWS
RBCCW	Reactor Building Closed Cooling Water	2 MDP, MOV, 2 HX	AC, DC, RCW (EECW), PCA	All but LLOCA
EECW	Emergency Equipment Cooling Water System	4 MDP, MOV, Heat Exchanger	AC, DC, Act	All
RCW	Raw Cooling Water	6 MDP, MOV, Heat Exchanger	AC, DC	LRCW
CV	Containment Vent or Hard Wet Well Vent	AOV	DC, PCA, CAD	All
FP	Firewater Injection Pump	MDP, Diesel-driven Pump	None	None
CAD	Containment Atmosphere Dilution	SOV	AC	All but LLOCA
HVAC	Heating, Ventilation and Air Conditioning	Coolers, Dampers	AC, DC, EECW	All

Notes:

1. Information herein was initially developed from the BF-2 IPE dated Sept. 1, 1992 and RAI responses dated 9/21/93 & 12/23/93. Modifications were made based on licensee input received during a site visit on May 24, 2000 that included information from the updated Browns Ferry PRA

Table 2 (Continued)

2. The baseline BF-2 IPE core damage frequency (CDF) from internal events was 4.5 x 10^{-5} events/Reactor year and the Large Early Release Frequency (LERF) was 2.2 x 10^{-5} events/Reactor year. For the PRA, Unit 2 internal events CDF is 5.4 x 10^{-6} events/Reactor year. For the PRA, Unit 3 internal events CDF is 9.2 x 10^{-6} events/Reactor year. BF-2 internal floods (in the Unit 2 Reactor Building) constitute about 2% of CDF in the PRA.

3. The 'Initiating Event Scenarios' column provides a guide as to which worksheets contain credit for a particular system. The ISLOCA/LOC worksheet is not referenced in this column.

4. For Unit 2, the crossties are generally available from both Unit 1 and Unit 3; however, for Unit 3, the crossties are available only from Unit2. For example, for Unit 2, LPI can be cross-tied to both Units 1 & 3; however for Unit 3 LPI can be cross-tied only to Unit 2. The same is true for CHR.

5. Where we have indicated AC in the Support system column, this means that power can be supplied by one or both of the EDG System or the non-EDG AC power system. Typically for BF-2 the safety-related AC equipment can be supplied by either, while the non-safety can only be supplied by non-EDG power. The EDGs are only specifically credited in the LOOP Event Tree.

6. There are two divisions of emergency power at Browns Ferry Unit 2 and 4 EDGs (A, B, C, &D) for Units 1 & 2. For Unit 3 there are four EDGs (3A through 3D), for a total of 8 EDGs on the site.

7. For BF-2 a stuck open relief valve is treated as equivalent to a small break steam LOCA. A separate worksheet is included for an SORV.

8. SRVs: There are 13 SRVs, of which 6 are used for ADS. All 13 can be used for manual DEP, provided the Plant Control Air System/Drywell Control Air System are operable. If not, then only 6 can be used for DEP via their accumulators.

9. PCS: At BF-2, the TBVs have 25 % bypass capacity.

10. DC Power: On an SBO, the DC batteries fail at four hours, causing a loss of HPCI & RCIC.

11. RHR System: both RHR and CS Systems have pump room coolers (HVAC), supplied by EECW; there are RHR cross-ties between U1 and U2 for suppression pool cooling.

12. HPCI and RCIC are both located in very large rooms and thus do not require HVAC for room cooling.

Table 2 (Continued)

13. In the RHRSW System, there are 12 RHRSW pumps - 4 for RHRSW, 4 for EECW, and 4 swing pumps. RHRSW can be cross-tied to RHR for late injection (LI). No credit was taken in the IPE for this action, but the licensee has stated during the site visit that it is now credited in the PRA for LI.

14. RCW normally cools Plant Control Air, RBCCW, and CRD. During an accident/transient RCW cooling is replaced by the safety-related EECW system for selected components. This is indicated in the above Table by RCW (EECW). There are three Unit 1 RCW pumps and three Unit 2 RCW pumps. Any one of the six can cool the Unit 2 loads.

15. In their 12/23/93 response letter to RAIs, TVA notes that they installed a hardened vent after the IPE was submitted and that updates to the PRA will take credit for the vent, that were not credited in the IPE.

16. BF-2 does not take credit for late injection, with a fire pump or cross connect from RHR SW. The NRC SER on the BF-2 IPE questioned this and TVA responded in their 4/14/95 submittal of their multi-unit PRA. They stated that sensitivity studies showed that use of the fire pump for late injection had a relatively small impact on CDF. They also noted that use of the fire pump and the hardened wetwell vent was discussed in the BF emergency procedures. BF does take credit for LPI with condenser and hotwell makeup or CRD flow. We have provided this credit in the LI function here to be consistent with other BWR plant worksheets.

17. The CRD System can provide HPI for the reactor. When used in place of HPCI or RCIC, this would typically require enhanced CRD flow. As described in the IPE, this consists of starting the 2nd CRD pump and maximizing the flow to the Reactor Vessel from the CRD system . The source of suction water is from the CST. Also, if the HPCI or RCIC systems operate for 4 to 6 hours and then fail, the CRD system can provide adequate flow with only one CRD pump. In the worksheets, the need for the enhanced flow mode is noted by an acceptance criteria of 2/2 pumps.

18. BF has 12 drywell to suppression pool downcomers, with two vacuum breakers for each downcomer. These two vacuum breakers are a 10 inch and a two inch valve and are arranged in parallel.

1.3 SDP WORKSHEETS

This section presents the SDP worksheets to be used in the Phase 2 evaluation of the inspection findings for the Browns Ferry Nuclear Power Station, Unit 2. The SDP worksheets are presented for the following initiating event categories:

1. Transients (Reactor Trip) (TRANS)
2. Transients without PCS (TPCS)
3. Small LOCA (SLOCA)
4. Stuck Open Relief Valve (SORV)
5. Medium LOCA (MLOCA)
6. Large LOCA (LOCA)
7. Loss of Offsite Power (LOOP)
8. Anticipated Transients Without Scram (ATWS)
9. Loss of Raw Cooling Water (LRCW)
10. ISLOCA and LOCA Outside Containment (LOC)

Table 3.1 SDP Worksheet for Browns Ferry Nuclear Power Station — Transients (Reactor Trip) (TRANS)

Estimated Frequency (Table 1 Row) __________ **Exposure Time** __________ **Table 1 Result (circle): A B C D E F G H**

Safety Functions Needed:	Full Creditable Mitigation Capability for Each Safety Function:
Power Conversion System (PCS)	1/4 steam lines, condenser, TBVs, 1/3 circ. water pump, 1/3 condensate pumps, 1/3 cond. booster pumps, 1/3 reactor feed pumps (operator action = 3)
High Pressure Injection (HPI)	HPCI (1 ASD train) or RCIC (1 ASD train) or 2/2 CRD pumps (1 single train system)
Depressurization (DEP)	2/13 SRVs manually opened (operator action = 2)
Low Pressure Injection (LPI)	1/4 RHR pumps in 1/2 trains in LPCI Mode (1 multi-train system); or 1/2 CS trains with 1/2 pumps per train (1 multi-train system)
Containment Heat Removal (CHR)	1/4 RHR pumps and 1/4 RHR heat exchangers in 1/2 trains, plus 1/4 RHRSW pumps in either the suppression pool cooling (SPC) mode or the shutdown cooling (SDC) mode (1 multi-train system)
Containment Venting (CV)	Hardened Wet Well Vent (operator action = 2)
Late Inventory, Makeup (LI)	1/2 CRD pumps or LI crosstie to other BF Units (operator action = 2); or 1/4 RHRSW pumps aligned for RPV injection through the RHR system (operator action = 1)

Circle Affected Functions	Recovery of Failed Train	Remaining Mitigation Capability Rating for Each Affected Sequence	Sequence Color
1 Trans - PCS - CHR - LI (4, 8)			
2 Trans - PCS - CHR - CV (5, 9)			
3 Trans - PCS - HPI - LPI (10)			

4 Trans - PCS - HPI - DEP (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.

<u>Notes</u>:

1. We have grouped together with Reactor Scram any transients that do not involve a loss of offsite power or the PCS.

2. Transients (with the reactor not isolated), such as in this worksheet, constitute 29% of CDF in the BF-2 PRA.

3. The licensee has indicated that no operator action is required for PCS due to an unspecified modification. We have kept this as an operator action that is equal to 3 for the current version of the SDP worksheets.

4. BF also credits PCS for the DEP & CHR functions and the condensate pumps for LI. However, this worksheet only credits these in the PCS function.

5. Unit 2 can crosstie LPI, CHR, and RHR SW with Unit 1 and Unit 3. Unit 3 can only crosstie with Unit 2. These crosstie activities can be used to backup the LPI, CHR, and LI functions, but are only specifically credited in the worksheets for LI.

6. In the BF PRA, the HEP for DEP is 4 E-3 and for CV is 3.7 E-5.

7. When using CRD for HPI, operator action is needed to start the second CRD pump and to maximize flow in the system. The HEP for these operator actions is 1.3 E-3.

Table 3.2 SDP Worksheet for Browns Ferry Nuclear Power Station — Transients (without PCS)

Estimated Frequency (Table 1 Row) __________ **Exposure Time** __________ **Table 1 Result (circle): A B C D E F G H**

Safety Functions Needed:	**Full Creditable Mitigation Capability for Each Safety Function:**
High Pressure Injection (HPI)	HPCI (1 ASD train) or RCIC (1 ASD train) or 2/2 CRD pumps (1 single train system)
Depressurization (DEP)	2/13 SRVs manually opened (operator action = 2)
Low Pressure Injection (LPI)	1/4 RHR pumps in 1/2 trains in LPCI Mode (1 multi-train system); or 1/2 CS trains with 1/2 pumps per train (1 multi-train system)
Containment Heat Removal (CHR)	1/4 RHR pumps and 1/4 RHR heat exchangers in 1/2 trains, plus 1/4 RHRSW pumps in either the suppression pool cooling (SPC) mode or the shutdown cooling (SDC) mode (1 multi-train system)
Containment Venting (CV)	Hardened Wet Well Vent (operator action = 2)
Late Inventory, Makeup (LI)	1/2 CRD pumps or LI crosstie to other BF Units (operator action = 2); or 1/4 RHRSW pumps aligned for RPV injection through the RHR system (operator action = 1)

Circle Affected Functions	**Recovery of Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Sequence**	**Sequence Color**
1 TPCS - CHR - LI (3, 7)			
2 TPCS - CHR - CV (4, 8)			
3 TPCS - HPI - LPI (9)			
4 TPCS - HPI - DEP (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:

1. This event tree and worksheet is for Transient (without PCS). It includes Main steam line break, Loss of FW, and loss of main condenser. These initiating events at BF-2 constitute about 9% total CDF. It is assumed that no aspects of the PCS are available for safety functions during the transients evaluated in this event tree and worksheet.

2. Unit 2 can crosstie LPI, CHR, and RHR SW with Unit 1 and Unit 3. Unit 3 can only crosstie with Unit 2. These crosstie activities can be used to backup the LPI, CHR, and LI functions, but are only specifically credited in the worksheets for LI.

3. In the BF PRA, the HEP for DEP is 4 E-3 and for CV is 3.7 E-5.

4. When using CRD for HPI, operator action is needed to start the second CRD pump and to maximize flow in the system. The HEP for these operator actions is 1.3 E-3.

Table 3.3 SDP Worksheet for Browns Ferry Nuclear Power Station — Small LOCA (SLOCA)

Estimated Frequency (Table 1 Row) __________ Exposure Time __________ Table 1 Result (circle): A B C D E F G H

Safety Functions Needed:	**Full Creditable Mitigation Capability for Each Safety Function:**
Power Conversion System (PCS)	1/4 steam lines, condenser, TBVs, 1/3 circ. water pump, 1/3 condensate pumps, 1/3 cond. booster pumps, 1/3 reactor feed pumps (operator action = 3)
High Pressure Injection (HPI)	HPCI (1 ASD train) or RCIC (1 ASD train)
Depressurization (DEP)	2/13 SRVs manually opened (operator action = 2)
Low Pressure Injection (LPI)	1/4 RHR pumps in 1/2 trains in LPCI Mode (1 multi-train system); or 1/2 CS trains with 1/2 pumps per train (1 multi-train system)
Containment Heat Removal (CHR)	1/4 RHR pumps and 1/4 RHR heat exchangers in 1/2 trains, plus 1/4 RHRSW pumps in either the suppression pool cooling (SPC) mode or the shutdown cooling (SDC) mode (1 multi-train system)
Containment Venting (CV)	Hardened Wet Well Vent (operator action = 2)
Late Inventory, Makeup (LI)	1/2 CRD pumps or LI crosstie to other BF Units (operator action = 2); or 1/4 RHRSW pumps aligned for RPV injection through the RHR system (operator action = 1)

Circle Affected Functions	**Recovery of Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Sequence**	**Sequence Color**
1 SLOCA - PCS - CHR - LI (4, 8)			
2 SLOCA - PCS - CHR - CV (5, 9)			
3 SLOCA - PCS - HPI - LPI (10)			

<table>
<tr><td>4 SLOCA - PCS - HPI - DEP (11)</td><td></td><td></td><td></td></tr>
<tr><td colspan="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.</td></tr>
</table>

Notes:

1. All LOCAs constitute 12% of the total internal events CDF in the BF PRA.

2. In the BF PRA, the HEP for DEP is 4 E-3 and for CV is 3.7 E-5.

3. Unit 2 can crosstie LPI, CHR, and RHR SW with Unit 1 and Unit 3. Unit 3 can only crosstie with Unit 2. These crosstie activities can be used to backup the LPI, CHR, and LI functions, but are only specifically credited in the worksheets for LI.

4. BF also credits PCS for the DEP & CHR functions and the condensate pumps for LI. However, this worksheet only credits these in the PCS function.

Table 3.4 SDP Worksheet for Browns Ferry Nuclear Power Station — Stuck Open Relief Valve (SORV)

Estimated Frequency (Table 1 Row) __________ Exposure Time __________ Table 1 Result (circle): A B C D E F G H

Safety Functions Needed:	**Full Creditable Mitigation Capability for Each Safety Function:**
Power Conversion System (PCS)	1/4 steam lines, condenser, TBVs, 1/3 circ. water pump, 1/3 condensate pumps, 1/3 cond. booster pumps, 1/3 reactor feed pumps (No credit)
High Pressure Injection (HPI)	HPCI (1 ASD train)
Depressurization (DEP)	2/13 SRVs manually opened (operator action = 2)
Low Pressure Injection (LPI)	1/4 RHR pumps in 1/2 trains in LPCI Mode (1 multi-train system); or 1/2 CS trains with 1/2 pumps per train (1 multi-train system)
Containment Heat Removal (CHR)	1/4 RHR pumps and 1/4 RHR heat exchangers in 1/2 trains, plus 1/4 RHRSW pumps in either the suppression pool cooling (SPC) mode or the shutdown cooling (SDC) mode (1 multi-train system)
Containment Venting (CV)	Hardened Wet Well Vent (operator action = 2)
Late Inventory, Makeup (LI)	1/2 CRD pumps or LI crosstie to other BF Units (operator action = 2); or 1/4 RHRSW pumps aligned for RPV injection through the RHR system (operator action = 1)

Circle Affected Functions	**Recovery of Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Sequence**	**Sequence Color**
1 SORV - PCS - CHR - LI (4, 8)			
2 SORV - PCS - CHR - CV (5, 9)			
3 SORV - PCS - HPI - LPI (10)			

4 SORV - PCS - HPI - DEP (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. Per licensee comments, RCIC is not credited for HPI in an SORV event. Further, HPCI will only function for about one hour in this event, but we have kept credit in HPI in this worksheet for HPCI for the one hour.

2. In the BF PRA, the HEP for DEP is 4 E-3 and for CV is 3.7 E-5.

3. Unit 2 can crosstie LPI, CHR, and RHR SW with Unit 1 and Unit 3. Unit 3 can only crosstie with Unit 2. These crosstie activities can be used to backup the LPI, CHR, and LI functions, but are only specifically credited in the worksheets for LI.

4. BF also credits PCS for the DEP & CHR functions and the condensate pumps for LI. However, this worksheet only credits these in the PCS function.

5. SRVs may fail to reclose when demanded in transients such as MSIV closure or turbine trip without bypass. In such transients, the PCS function could not be credited. Considering such scenarios, this SDP worksheet conservatively does not credit PCS.

Table 3.5 SDP Worksheet for Browns Ferry Nuclear Power Station — Medium LOCA (MLOCA)

Estimated Frequency (Table 1 Row) __________ Exposure Time __________ Table 1 Result (circle): A B C D E F G H

Safety Functions Needed:	**Full Creditable Mitigation Capability for Each Safety Function:**
Early Containment Control (EC)	Passive operation of SP with all vacuum breakers closed (1 train system)
High Pressure Injection (HPI)	No credit for HPI in MLOCA.
Depressurization (DEP)	2/13 SRVs manually opened or HPCI operation (operator action = 2)
Low Pressure Injection (LPI)	1/4 RHR pumps in 1/2 trains in LPCI Mode (1 multi-train system); or 1/2 CS trains with 1/2 pumps per train (1 multi-train system)
Containment Heat Removal (CHR)	1/4 RHR pumps and 1/4 RHR heat exchangers in 1/2 trains, plus 1/4 RHRSW pumps in either the suppression pool cooling (SPC) mode (1 multi-train system)
Containment Venting (CV)	Hardened Wet Well Vent (operator action = 2)
Late Inventory, Makeup (LI)	1/4 RHRSW pumps aligned for RPV injection through the RHR system (operator action = 1); or LI crosstie to other BF Units (operator action = 1)

Circle Affected Functions	**Recovery of Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Sequence**	**Sequence Color**
1 MLOCA - CHR - LI (3)			
2 MLOCA - CHR - CV (4)			
3 MLOCA - LPI (5)			
4 MLOCA - DEP (6)			

<table>
<tr><td>5 MLOCA - EC (7)</td><td></td><td></td><td></td></tr>
<tr><td colspan="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.</td></tr>
</table>

Notes:

1. In their MLOCA analysis, BF takes credit for HPCI assisting the LOCA in depressurization, but does not credit HPCI or RCIC for high pressure injection. Thus (similar to the LLOCA) there is no credit for any HPI in the MLOCA scenario.

2. All LOCAs constitute 12% of the total internal events CDF in the BF PRA.

3. Unit 2 can crosstie LPI, CHR, and RHR SW with Unit 1 and Unit 3. Unit 3 can only crosstie with Unit 2. These crosstie activities can be used to backup the LPI, CHR, and LI functions, but are only specifically credited in the worksheets for LI.

4. In the BF PRA, the HEP for DEP is 4 E-3 and for CV is 3.7 E-5.

Table 3.6 SDP Worksheet for Browns Ferry Nuclear Power Station — Large LOCA (LLOCA)

Estimated Frequency (Table 1 Row) __________ **Exposure Time __________** **Table 1 Result (circle): A B C D E F G H**

Safety Functions Needed:	**Full Creditable Mitigation Capability for Each Safety Function:**
Early Containment Control (EC)	Passive operation of SP with all vacuum breakers closed (1 train system)
Low Pressure Injection (LPI)	1/4 RHR pumps in 1/2 trains in LPCI Mode (1 multi-train system); or 1/2 CS trains with 2/2 pumps per train (1 multi-train system)
Containment Heat Removal (CHR)	1/4 RHR pumps and 1/4 RHR heat exchangers in 1/2 trains, plus 1/4 RHRSW pumps in either the suppression pool cooling (SPC) mode (1 multi-train system)
Containment Venting (CV)	Hardened Wet Well Vent (operator action = 2)
Late Inventory, Makeup (LI)	1/4 RHRSW pumps aligned for RPV injection through the RHR system (operator action = 1); or LI crosstie to other BF Units (operator action = 1)

Circle Affected Functions	**Recovery of Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Sequence**	**Sequence Color**
1 LLOCA - CHR - LI (3)			
2 LLOCA - CHR - CV (4)			
3 LLOCA - LPI (5)			
4 LLOCA - EC (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. All LOCAs constitute 12% of the total internal events CDF in the BF PRA.

2. Unit 2 can crosstie LPI, CHR, and RHR SW with Unit 1 and Unit 3. Unit 3 can only crosstie with Unit 2. These crosstie activities can be used to backup the LPI, CHR, and LI functions, but are only specifically credited in the worksheets for LI.

3. In the BF PRA, the HEP for DEP is 4 E-3 and for CV is 3.7 E-5.

Table 3.7 SDP Worksheet for Browns Ferry Nuclear Power Station — Loss of Offsite Power (LOOP)

Estimated Frequency (Table 1 Row) __________ Exposure Time __________ Table 1 Result (circle): A B C D E F G H

Safety Functions Needed:	**Full Creditable Mitigation Capability for Each Safety Function:**
Emergency Power (EAC)	1/4 EDGs (1 multi-train system); or 1/4 EDGs via cross tie to other Unit (operator action = 2)
Recovery of LOOP in 30 min (RLOOP30M)	Operator action = 1
Recovery of LOOP in 6 hours (RLOOP6H)	Operator action = 1
High Pressure Injection (HPI)	HPCI (1 ASD train) or RCIC (1 ASD train)
Depressurization (DEP)	2/13 SRVs manually opened (operator action = 2)
Low Pressure Injection (LPI)	1/4 RHR pumps in 1/2 trains in LPCI Mode (1 multi-train system); or 1/2 CS trains with 1/2 pumps per train (1 multi-train system) - requires AC power
Containment Heat Removal (CHR)	1/4 RHR pumps and 1/4 RHR heat exchangers in 1/2 trains, plus 1/4 RHRSW pumps in either the suppression pool cooling (SPC) mode or the shutdown cooling (SDC) mode (1 multi-train system)
Containment Venting (CV)	Hardened Wet Well Vent (operator action = 2)
Late Inventory, Makeup (LI)	1/4 RHRSW pumps aligned for RPV injection through the RHR system (operator action = 1); or LI crosstie to other BF Units (operator action = 1)

Circle Affected Functions	**Recovery of Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Sequence**	**Sequence Color**
1 LOOP - CHR - LI (1, 2, 5)			
2 LOOP - CHR - CV (1, 2, 6)			
3 LOOP - HPI - LPI (1, 2)			
4 LOOP - HPI - DEP (1, 2)			

5 LOOP - EAC - RLOOP30M - HPI (7)			
6 LOOP - EAC - RLOOP6H (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. There are two divisions of emergency power at Browns Ferry Unit 2 and 4 EDGs (A, B, C, &D) for Units 1 & 2, and four EDGs (3A through 3D) at Unit 3, for a total of 8 EDGs on the site.

2. In the BF-2 IPE, a LOOP (non SBO) constitutes 42% of total CDF, while a LOOP (SBO) constitutes 27% of total CDF. Together LOOP is 69% of CDF. At BF the LOOP initiating event frequency in the PRA is 7.15 E-3 events per reactor year. In the BF PRA the CDF contribution from LOOP is 28% to 29%.

3. BF-2 models two recovery times (30 min and 6 hours). The non-recovery probabilities are RLOOP30M = 0.5 and RLOOP6H = 0.13.

4. On an SBO, HPCI and RCIC can last for 4 hours. After this time they are assumed to fail due to battery depletion and loss of control power. However, Core Damage (CD) does not occur until after 6 hours, thus allowing added time for recovery of LOOP. BF-2 does not credit recovery of failed EDGs.

5. In the BF PRA, the HEP for DEP is 4 E-3 and for CV is 3.7 E-5.

6. Unit 2 can crosstie LPI, CHR, and RHR SW with Unit 1 and Unit 3. Unit 3 can only crosstie with Unit 2. These crosstie activities can be used to backup the LPI, CHR, and LI functions, but are only specifically credited in the worksheets for LI.

7. For sequences in the above worksheet, the numbers in parentheses refer to the corresponding sequence in the ETs. For the LOOP ET there are some transfers to the TPCS ET. These are indicated by (1), and (2). All of the sequences in the TPCS event tree apply here, i.e., LOOP-CHR-LI, LOOP-CHR-CV, LOOP-HPI-DEP, and LOOP-HPI-LPI.

Table 3.8 SDP Worksheet for Browns Ferry Nuclear Power Station — Anticipated Transients Without Scram (ATWS)

Estimated Frequency (Table 1 Row) __________ **Exposure Time** __________ **Table 1 Result (circle): A B C D E F G H**

<u>Safety Functions Needed</u>:	**<u>Full Creditable Mitigation Capability for Each Safety Function</u>:**
Overpressure Protection (OVERP)	9/13 SRVs (1 multi-train system)
Recirculation Pump Trip (RPT)	Automatic trip of recirculation pumps (1 multi-train system)
Standby Liquid Control (SLC)	Manual initiation of SLC plus mechanical operation 1/2 SLC pumps plus isolation of RWCU valve (operator action = 2)
Inhibit ADS (INH)	Operator inhibits automatic ADS actuation (operator action = 2)
High Pressure Injection (HPI)	HPCI (1 ASD train) or RCIC (1 ASD train)
Depressurization (DEP)	2/13 SRVs manually opened (operator action = 2)
Low Pressure Injection (LPI)	1/4 RHR pumps in 1/2 trains in LPCI Mode (1 multi-train system); or 1/2 CS trains with 1/2 pumps per train (1 multi-train system)
Overfill (OVERFL)	Operator prevents overfill by LPI (operator action = 2)
Containment Heat Removal (CHR)	1/4 RHR pumps and 1/4 RHR heat exchangers in 1/2 trains, plus 1/4 RHRSW pumps in either the suppression pool cooling (SPC) mode or the shutdown cooling (SDC) mode (1 multi-train system)
Containment Venting (CV)	Hardened Wet Well Vent (operator action = 2)
Late Inventory, Makeup (LI)	1/4 RHRSW pumps aligned for RPV injection through the RHR system (operator action = 1); or LI crosstie to other BF Units (operator action = 1)

<u>Circle Affected Functions</u>	**<u>Recovery of Failed Train</u>**	**<u>Remaining Mitigation Capability Rating for Each Affected Sequence</u>**	**<u>Sequence Color</u>**
1 ATWS - CHR - LI (3, 7)			
2 ATWS - CHR - CV (4, 8)			

3 ATWS - HPI - OVERFL (9)			
4 ATWS - HPI - LPI (10)			
5 ATWS - HPI - DEP (11)			
6 ATWS - INH (12)			
7 ATWS - SLC (13)			
8 ATWS - RPT (14)			
9 ATWS - OVERP (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. In the IPE, ATWS scenarios at BF-2 constitute about 3% of CDF. None of the top 10 IPE sequences are ATWS sequences. In the PRA BF lists ATWS as constituting about 40% of the dominant functional failure groups from both Unit 2 and Unit3.

2. In this worksheet we have combined the ATWS initiator with failure of Alternate Rod Insertion (ARI) and Manual Rod Insertion (MRI). Also, this worksheet conservatively assumes that a loss of PCS transient initiated the ATWS. Therefore, due to these generic NRC assumptions, no credit should be given to the PCS in evaluating findings on this worksheet. The licensee does however take credit for use of PCS for HPI in the IPE.

3. BF-2 assumes that failure of operators to manually initiate SLC, within two minutes of a transient with MSIVs closed, implies failure of other operator actions (lowering Reactor level and controlling level at the TAF) and leads to CD. However, if SLC fails mechanically (SLC), they still allow operator actions to limit reactivity by controlling reactor level (LC)and inhibiting ADS (INH). This worksheet has been simplified by combining the operator action and the mechanical operation of SLC.

4. BF has a 600 gpm capacity RCIC system and they credit both HPCI and RCIC for HPI during an ATWS event.

5. The BF IPE seems to imply that failure to inhibit ADS by itself will not lead to CD. This has not been clearly justified and is different than most BWRs. This worksheet assumes that INH will lead to CD.

6. Although not clearly stated, the IPE implies that reactor vessel level control (LC) is not needed if SLC is successful. We have agreed with the implied success and have not included a CD sequence for ATWS - LC.

7. Operator action to inject boron at BF-2 with the SLC system has different HEPs depending on the scenario. The HEPs involved vary from a value of 6E-3 to 1.2E-2.

8. Other HEPs in the IPE are as follows: controlling RPV level using LPCI or CS to prevent overfill has an HEP of 1.5E-3; operator action to inhibit ADS has an HEP of 1.5E-3; lowering RPV level to the TAF has an HEP range of 1 to 3 E-4; emergency depressurization has an HEP range of 2E-4 to 1E-2. In the BF PRA, the HEP for DEP is 4 E-3 and for CV is 3.7 E-5.

9. Unit 2 can crosstie LPI, CHR, and RHR SW with Unit 1 and Unit 3. Unit 3 can only crosstie with Unit 2. These crosstie activities can be used to backup the LPI, CHR, and LI functions, but are only specifically credited in the worksheets for LI.

Table 3.9 SDP Worksheet for Browns Ferry Nuclear Power Station — Loss of Raw Cooling Water (LRCW)

Estimated Frequency (Table 1 Row) __________ **Exposure Time** __________ **Table 1 Result (circle): A B C D E F G H**

Safety Functions Needed:	**Full Creditable Mitigation Capability for Each Safety Function:**
High Pressure Injection (HPI)	HPCI (1 ASD train) or RCIC (1 ASD train)
Depressurization (DEP)	2/13 SRVs manually opened (operator action = 2)
Low Pressure Injection (LPI)	1/4 RHR pumps in 1/2 trains in LPCI Mode (1 multi-train system); or 1/2 CS trains with 1/2 pumps per train (1 multi-train system)
Containment Heat Removal (CHR)	1/4 RHR pumps and 1/4 RHR heat exchangers in 1/2 trains, plus 1/4 RHRSW pumps in either the suppression pool cooling (SPC) mode or the shutdown cooling (SDC) mode (1 multi-train system)
Containment Venting (CV)	Hardened Wet Well Vent (operator action = 2)
Late Inventory, Makeup (LI)	1/4 RHRSW pumps aligned for RPV injection through the RHR system (operator action = 1); or LI crosstie to other BF Units (operator action = 1)

Circle Affected Functions	**Recovery of Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Sequence**	**Sequence Color**
1 LRCW - CHR - LI (3, 7)			
2 LRCW - CHR - CV (4, 8)			
3 LRCW - HPI - LPI (9)			
4 LRCW - HPI - DEP (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:

1. A loss of RCW causes a loss of cooling to the condensate and feedwater systems and hence the PCS. This results in a turbine trip and reactor trip and hence is a TPCS type transient. Additionally RCW cooling is lost to the CRD, PCA, RHR and RBCCW systems. This is discussed in Section 3.1.4.3 of the IPE. However, all of these (except CRD) are backed up automatically by the EECW system. Thus, this transient acts like a TPCS with an added loss of CRD. The initiating event frequency for LRCW in the IPE is 3 to 5 x 10^{-3} events per reactor year. In the Browns Ferry PRA, the LRCW event constitutes 3% to 6% of total internal events CDF.

2. This worksheet can be used with the event tree for TPCS, since it causes a loss of the PCS and behaves similarly.

3. Unit 2 can crosstie LPI, CHR, and RHR SW with Unit 1 and Unit 3. Unit 3 can only crosstie with Unit 2. These crosstie activities can be used to backup the LPI, CHR, and LI functions, but are only specifically credited in the worksheets for LI.

4. In the BF PRA, the HEP for DEP is 4 E-3 and for CV is 3.7 E-5.

Table 3.10 SDP Worksheet for Browns Ferry Nuclear Power Station — Interfacing System LOCA (ISLOCA) and LOCA Outside Containment (LOC)

Estimated Frequency (Table 1 Row) ________ Exposure Time __________ Table 1 Result (circle): A B C D E F G H

Initiation Pathways:	**Mitigation Capability: Ensure Component Operability for Each Pathway**
ISLOCA PATHWAYS:	
LPCI Injection Lines	Two lines each with 1 NO MOV, 1 NC MOV, and 1 testable check valve (e.g., line B has FCV 74-66, FCV 74-67, & FCV 74-68)
Core Spray Injection Lines	Two lines each with 1 NO MOV, 1 NC MOV, and 1 testable check valve (e.g., line B has FCV 75-51, FCV 75-53 and FCV 75-54)
RHR Drop Line	One line with two NC MOVs, FCV 74-48 and FCV 74-47.
LOC PATHWAYS:	
HPCI steam Line	One line with two NO MOVs, FCV 73-2 and 73-3, but the system is high pressure design up to turbine.
RCIC steam Line	One line with two NO MOVs, FCV 71-2 and 71-3, but the system is high pressure design up to turbine.
RWCU System Lines	Not analyzed
Feedwater Lines	Two lines each with two check valves and a NO manual valve
Main Steam Lines	Four 26" steam lines with 2 MSIVs per line

Circle Affected Component in Pathways	**Recovery of Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Pathway**	**Sequence Color**

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: (One of first three notes may apply)

1. The initiation pathways and the applicable components in the pathways are based on licensee inputs supplemented by generic insights based on NRC studies on ISLOCA.

2. This worksheet contains pathways for both ISLOCA and LOC. Licensees typically analyze these events separately. These sequences constitute less than 1% of internal events CDF in the BF IPE. They are discussed in section 3.3.9 and App. E2. The principle contributors were the CS and LPCI injection lines.

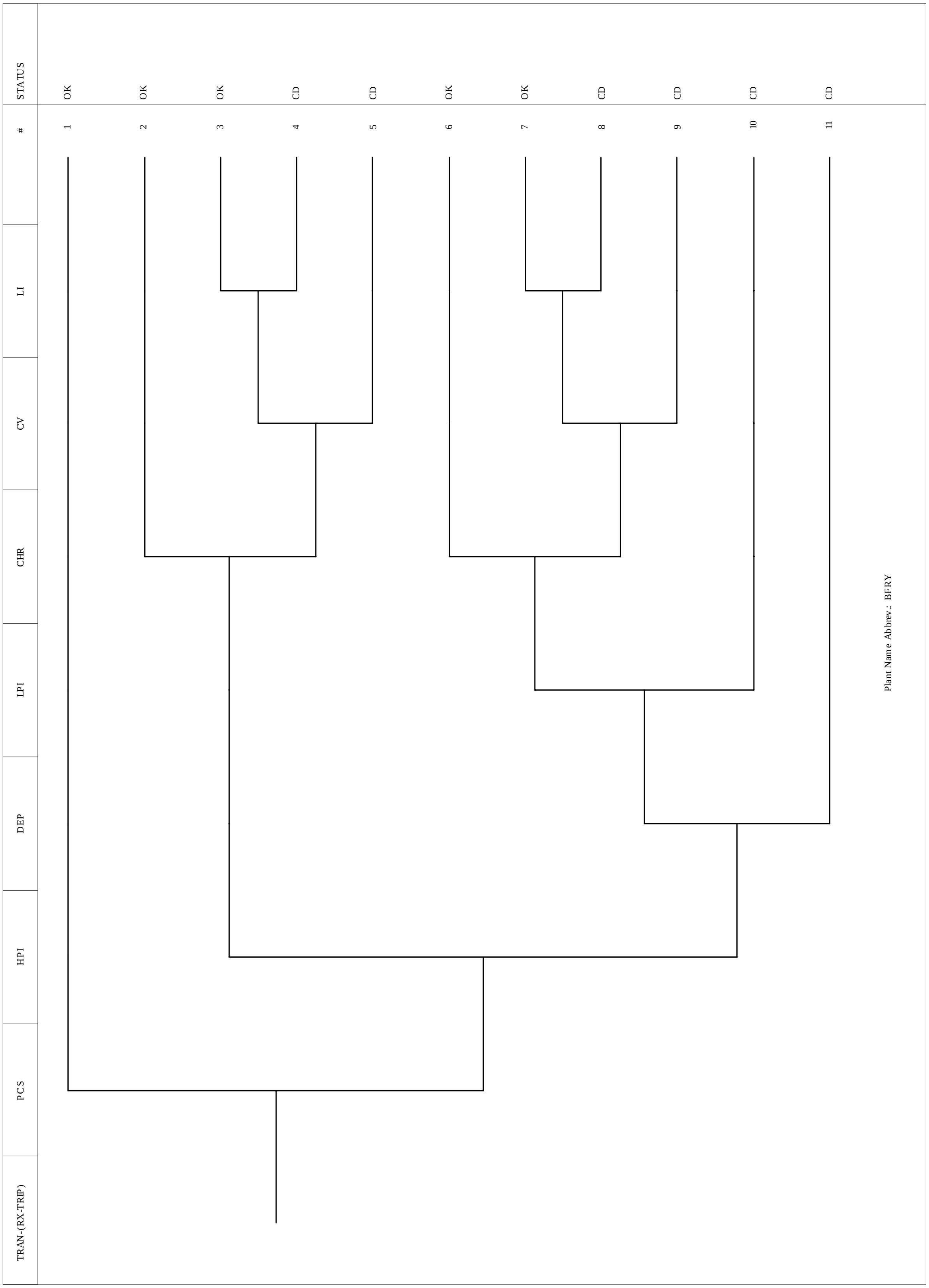
3. This worksheet is different from the other worksheets, in that ISLOCA is typically an unmitigated initiating event in most PRAs. Therefore the right side of the worksheet contains valves, whose failure may lead to an ISLOCA or LOC rather than mitigating systems to address an event in progress. As such, it is not intended to be referenced by the last column of Table 2, Initiators and System Dependency Table.

1.4 SDP EVENT TREES

This section provides the simplified event trees called SDP event trees used to define the accident sequences identified in the SDP worksheets in the previous section. The event tree headings are defined in the corresponding SDP worksheets.

The following event trees are included:

1. Transients (Reactor Trip) (TRANS)
2. Transients without PCS (TPCS)
3. Small LOCA (SLOCA)
4. Stuck Open Relief Valve (SORV)
5. Medium LOCA (MLOCA)
6. Large LOCA (LLOCA)
7. Loss of Offsite Power (LOOP)
8. Anticipated Transients Without Scram (ATWS)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PCS
HPI
DEP
LPI
CHR
CV
LI
#
STATUS
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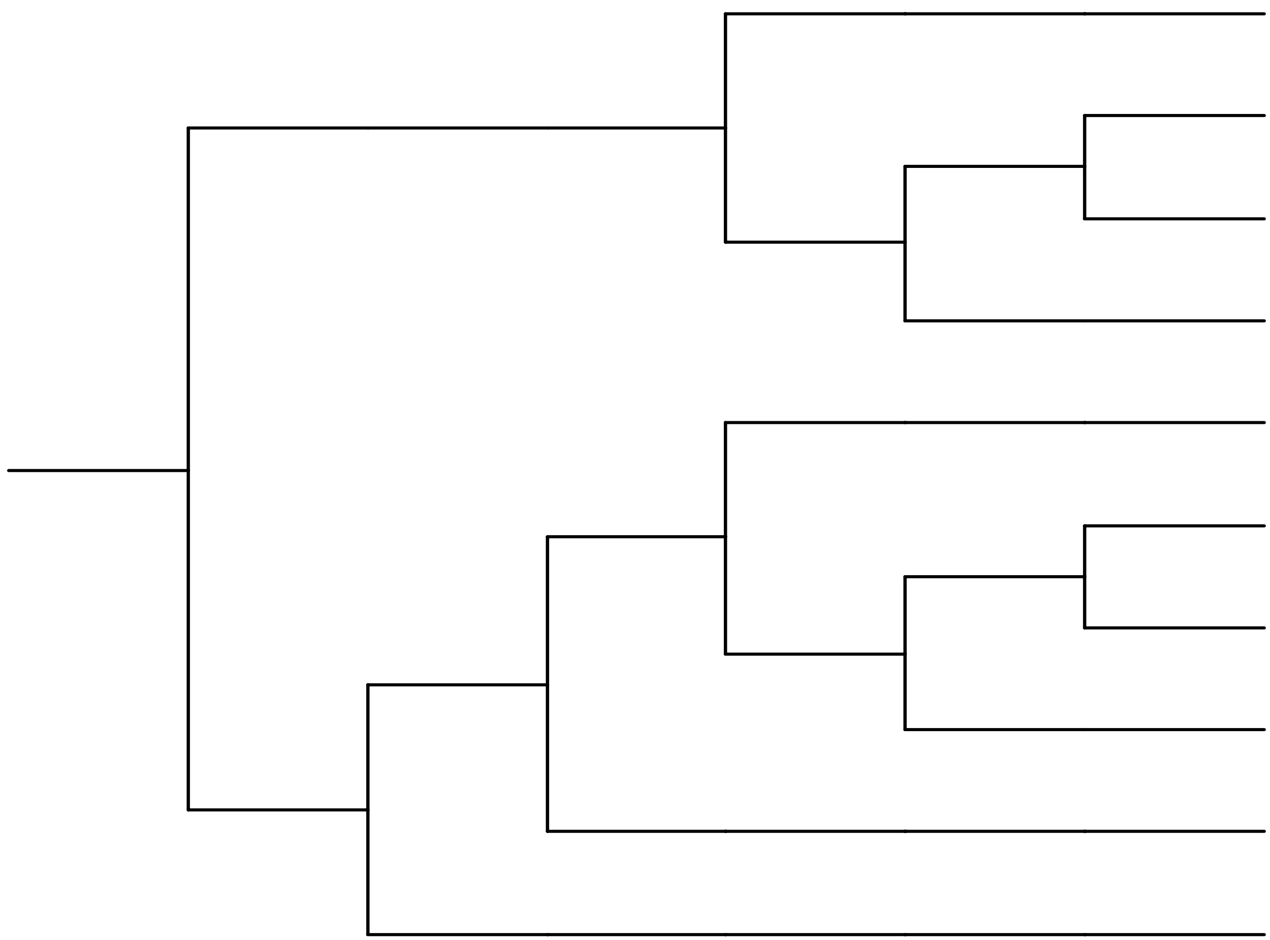
2 OK
3 OK
4 CD
5 CD
6 OK
7 OK
8 CD
9 CD
10 CD
11 CD
Plant Name Abbrev: BFRY

TPCS	HPI	DEP	LPI	CHR	CV	LI	#	STATUS



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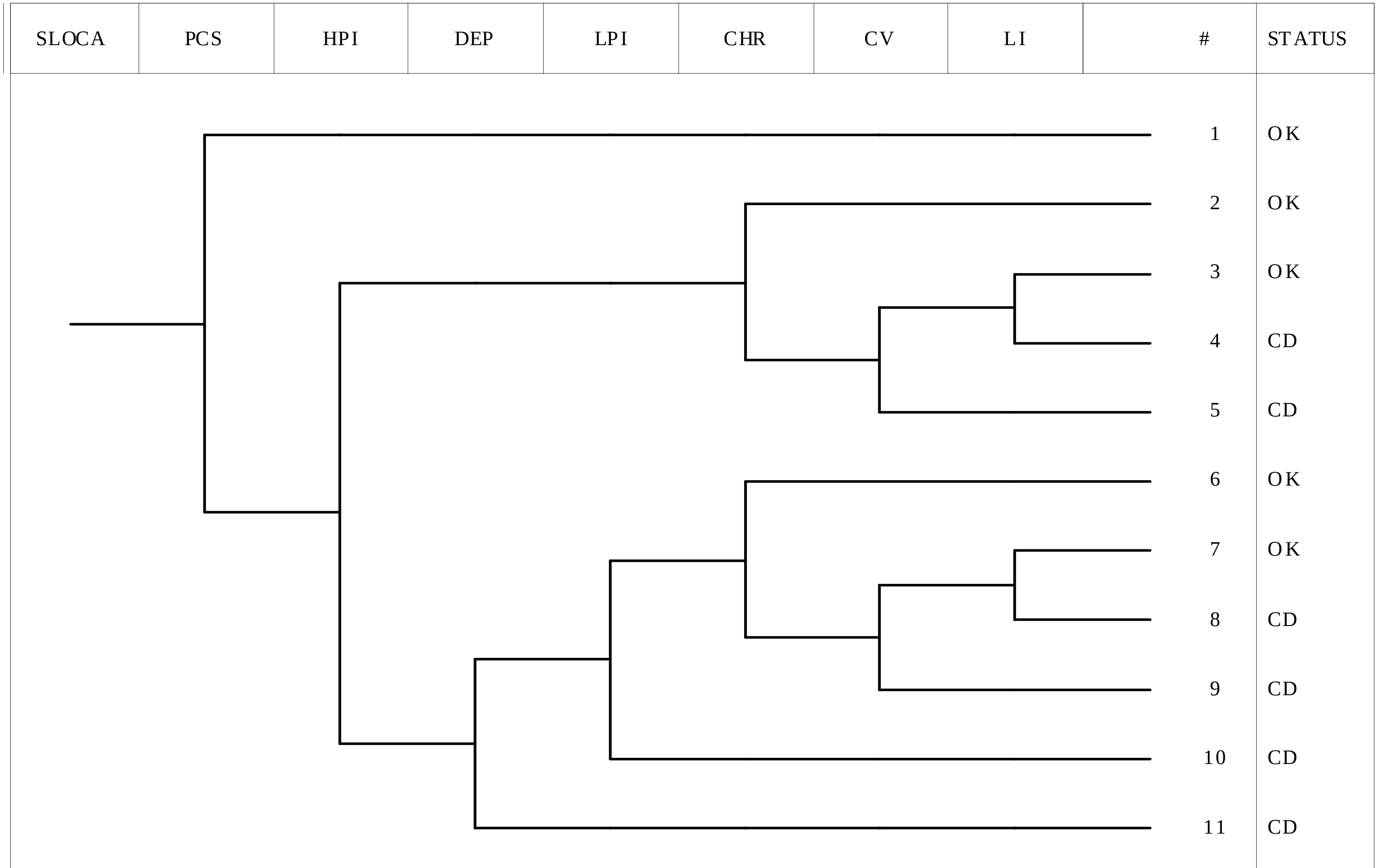
Plant Name Abbrev.: BFRY



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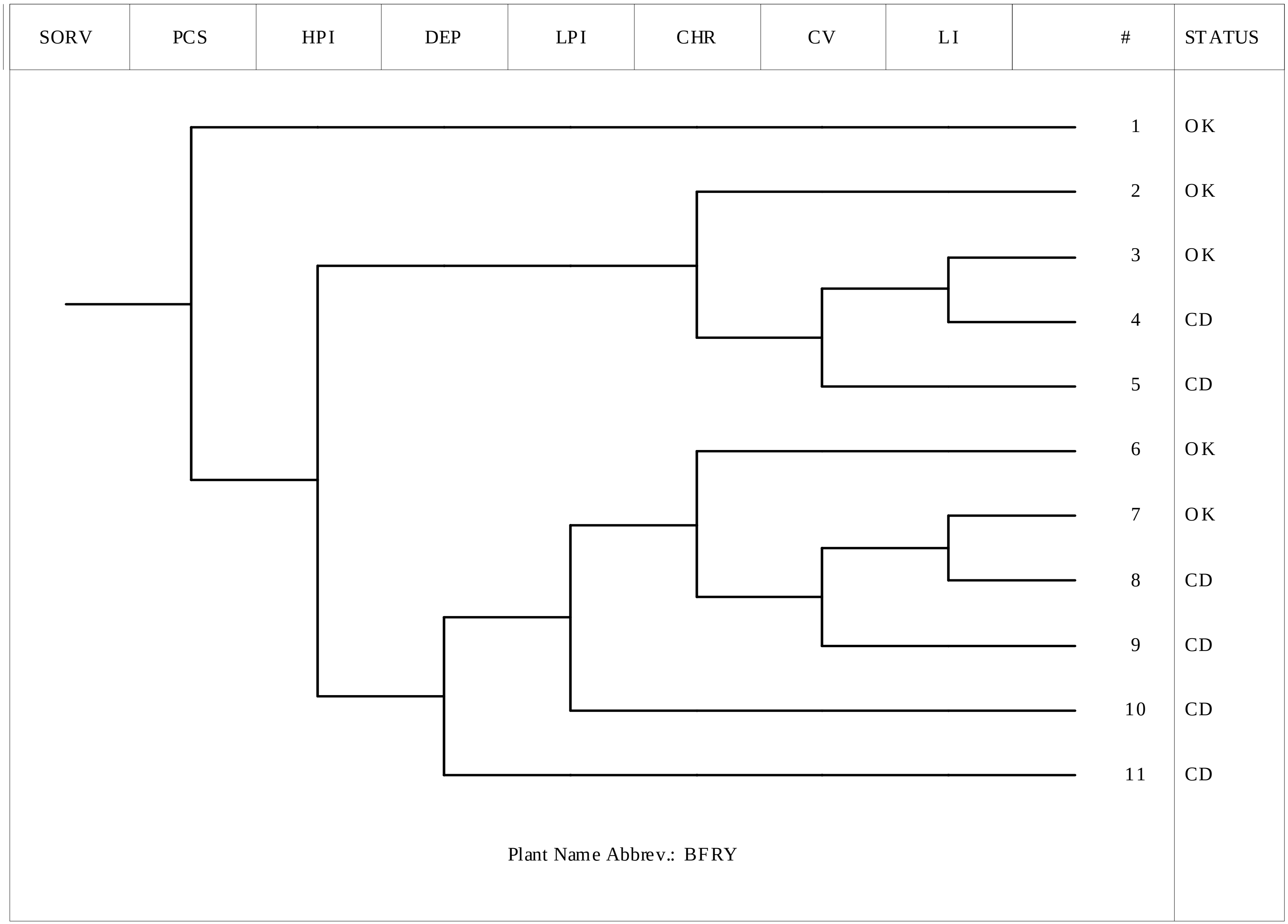
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HPI
DEP
LPI
CHR
CV
LI
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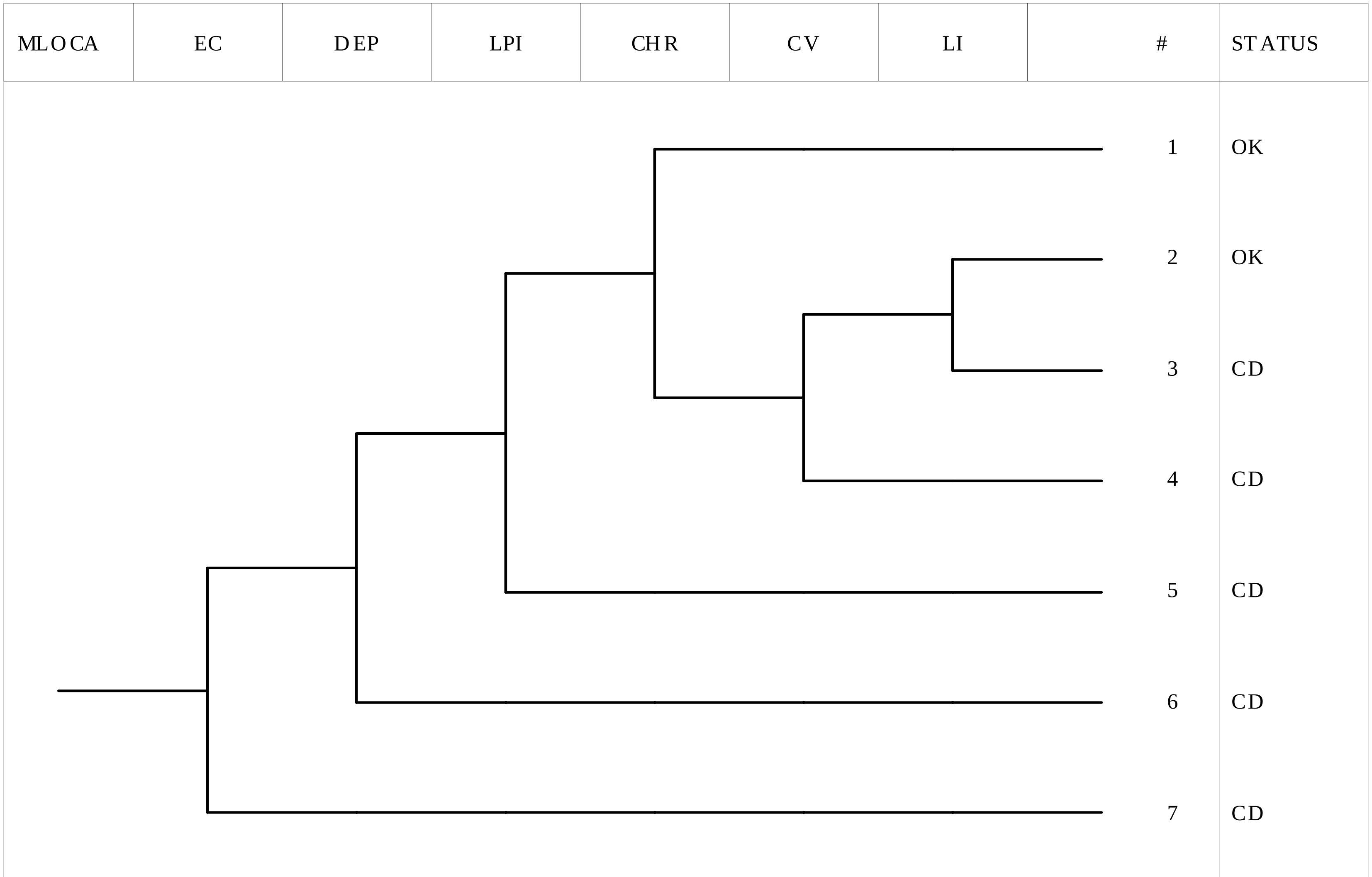
11 CD
Plant Name Abbrev.: BFRY



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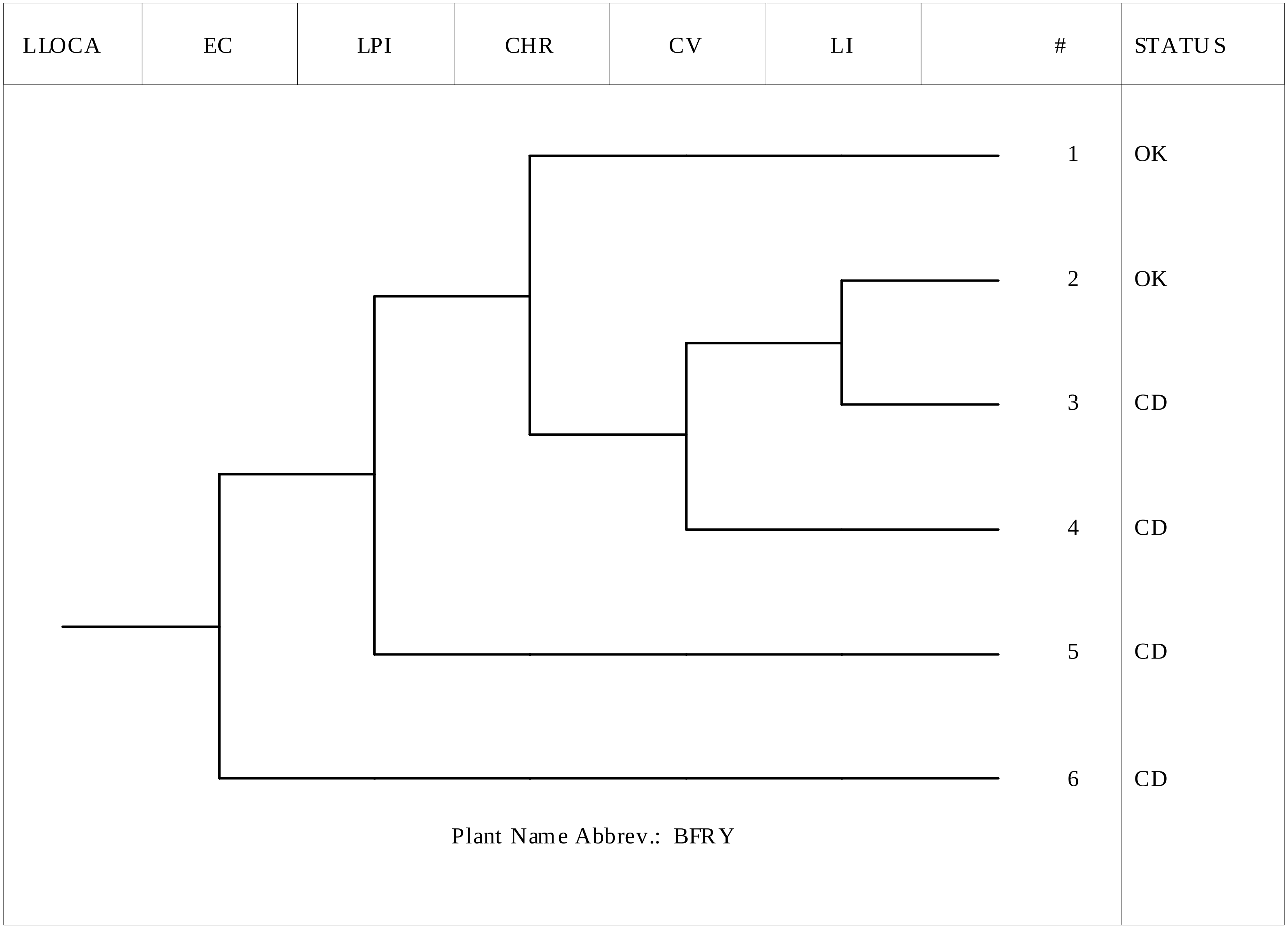

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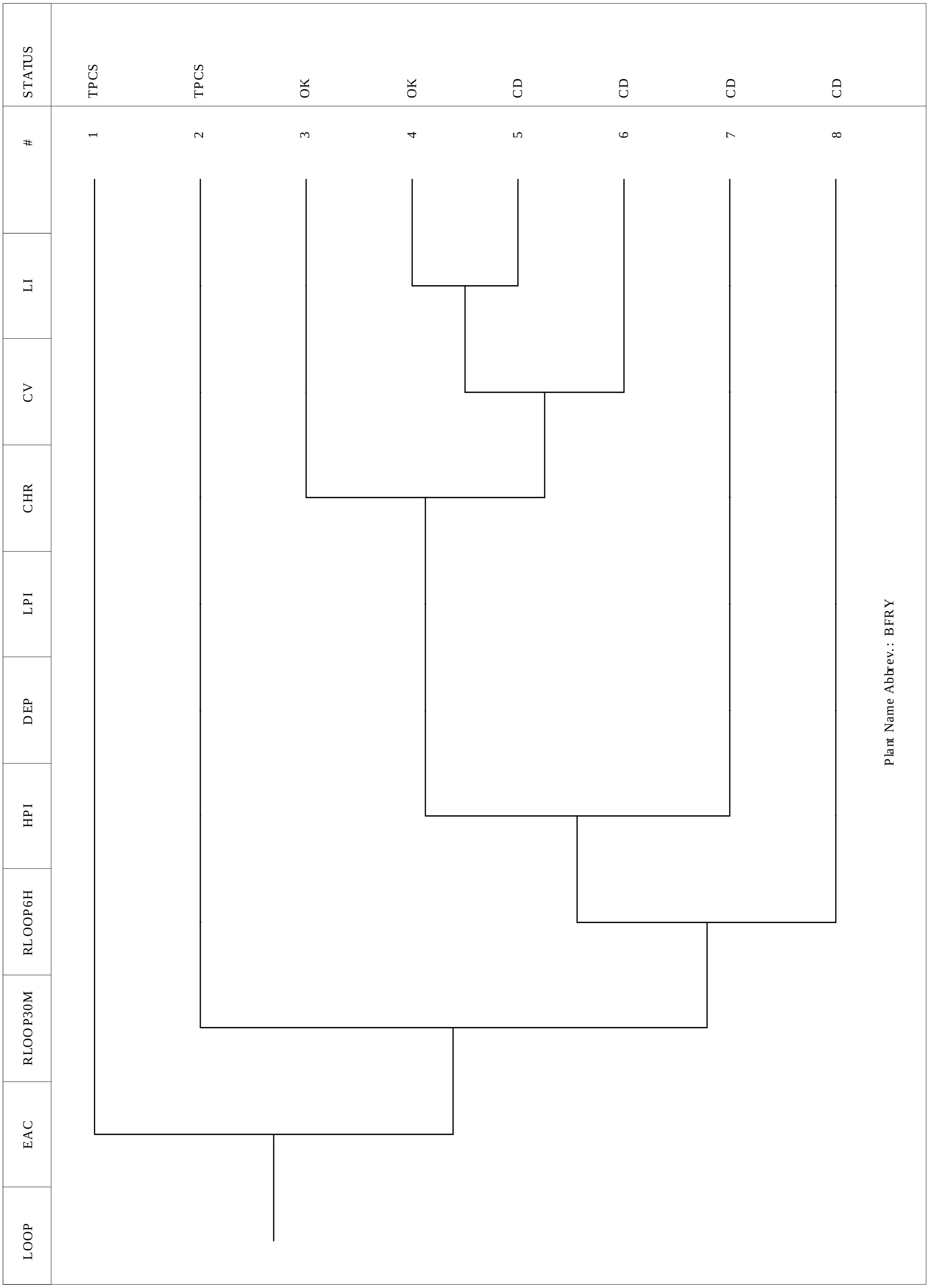
LOOP
EAC
RLOOP30M
RLOOP6H
HPI
DEP
LPI
CHR
CV
LI
#
STATUS
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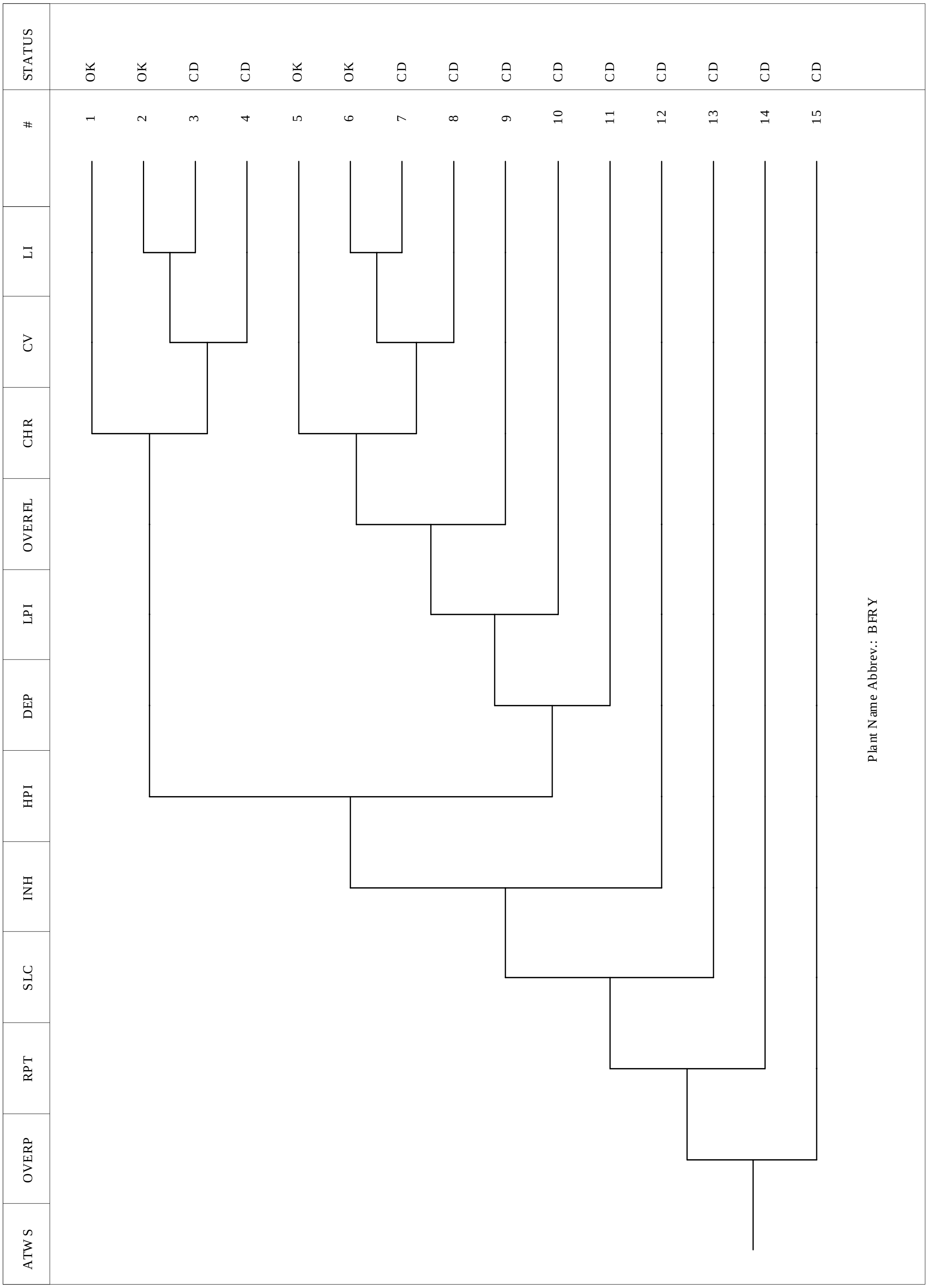
2 TPCS
3 OK
4 OK
5 CD
6 CD
7 CD
8 CD
Plant Name Abbrev.: BFRY



STATUS
#
ATWS
OVERP
RPT
SLC
INH
HPI
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LPI
OVERFL
CHR
CV
LI
1 OK
2 OK
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Plant Name Abbrev.: BFRY

2. RESOLUTION AND DISPOSITION OF COMMENTS

This section is composed of two subsections. Subsection 2.1 summarizes the generic assumptions that were used for developing the SDP worksheets for the BWR plants. These guidelines were based on the plant-specific comments provided by the licensee on the draft SDP worksheets and further examination of the applicability of those comments to similar plants. These assumptions which are used as guidelines for developing the SDP worksheets help the reader better understand the worksheets' scope and limitations. The generic guidelines and assumptions for BWRs are given here. Subsection 2.2 documents the plant-specific comments received on the draft version of the material included in this notebook and their resolution.

2.1 GENERIC GUIDELINES AND ASSUMPTIONS

Initiating Event Likelihood Rating Table

1. Assignment of plant-specific IEs into frequency rows:

Transient (Reactor trip) (TRANS), transients without PCS (TPCS), small, medium, and large LOCA (SLOCA, MLOCA, LLOCA), inadvertent or stuck-open SRVs (IORV), anticipated transients without scram (ATWS), interfacing system LOCA (ISLOCA), and LOCA outside containment (LOC) are assigned into rows based on consideration of industry-average frequency. Plant-specific frequencies can be different, but are not considered. Plant-specific frequencies for LOOP and special initiators are used to assign these initiating events.

2. Inclusion of special initiators:

The special initiators included in the worksheets are those applicable for the plant. A separate worksheet is included for each of the applicable special initiators. The applicable special initiators are primarily based on the plant-specific IPEs. In other words, the special initiator included are those modeled in the IPEs unless it is shown to be a negligible contributor. In some cases, in considering plants of similar design, a particular special initiator may be added for a plant even if it is not included in the IPE if such an initiator is included in other plants of similar design and is considered applicable for the plant. Except for the interfacing system LOCA (ISLOCA) and LOCA outside containment (LOC), if the occurrence of the special initiator results in a core damage, i.e., no mitigation capability exists for the initiating event, then a separate worksheet is not developed. For such cases, the inspection focus is on the initiating event and the risk implication of the inspection finding can be directly assessed. For ISLOCA and LOC, a separate worksheet is included noting the pathways that can lead to these events.

3. Inadvertent or stuck open relief valve as an IE in BWRs:

Many IPEs/PRAs model this event as a separate initiating event. Also, the failure of the SRVs to re-close after opening can be modeled within the transient tree. In the SDP worksheet, these events are modeled in a separate worksheet (and, are not included in the transient worksheets) considering both inadvertent opening and failure to re-close. We typically consider a single valve is stuck or inadvertently open. The frequency of this initiator is generically estimated for all BWR plants. This IE may behave similar to a small or medium LOCA depending on the valve size, and the mitigation capability is addressed accordingly.

4. LOCA outside containment (LOC):

A LOCA outside of containment (LOC) can be caused by a break in a few types of lines such as Main Steam or Feedwater. LOC is treated differently among the IPEs. Separate ETs are usually not developed in the IPEs for LOCs. Thus, credit is usually not taken for mitigating actions. LOC sequences typically have a core damage frequency in the E-8 range. As such, LOCs are included together with ISLOCAs in a separate summary type SDP worksheet. Plant specific notes are included to explain how the particular IPE has addressed LOCs.

Initiating Event and System Dependency Table

1. Inclusion of systems under the support system column:

This table shows the support systems for the support and frontline systems. Partial dependency, which usually is a backup system, is not expected to be included. If included, they should be so noted. The intent is to include only the support system and not the systems supporting the support system, i.e., those systems whose failure will result in failure of the system being supported. Sometimes, some subsystems on which inspection findings may be noted have been included as a support system, e.g., EDG fuel oil transfer pump as a support system for EDGs.

2. Coverage of system/components and functions included in the SDP worksheets:

The Initiators and System Dependency Table includes systems and components which are included in the SDP worksheets and those which can affect the performance of these systems and components. One to one matching of the ET headings/functions to that included in the Table was not considered necessary.

SDP Worksheets and Event Trees

1. Crediting of non-safety related equipment:

SDP worksheets credit or include safety-related equipment and also, non-safety related equipment as used in defining the accident sequences leading to core damage. In defining the success criteria for the functions needed, the components included are typically those covered under the Technical Specifications (TS) and the Maintenance Rule (MR). No evaluation was performed to assure that the components included in the worksheets are covered under TS or MR. However, if a component was included in the worksheet, and the licensee requested its removal, it may not have been removed if it is considered that the components is included in either TS or MR.

2. No credit for certain plant-specific mitigation capability:

The significance determination process (SDP) screens inspection findings for Phase 3 evaluations. Some conservative assumptions are made which result in not crediting some plant-specific features. Such assumptions are usually based on comparisons with plants of similar design and to maintain consistency across the SDP worksheets of similar plant designs.

3. Crediting system trains with high unavailability

Some system component/trains may have unavailability higher than 1E-2, but they are treated in a manner similar to other trains with lower unavailability in the range of 1E-2. In this screening approach, this is considered adequate to keep the process simple. An exception is made for steam-driven components which are designated as automatic steam driven (ASD) train with a credit of 1, i.e., an unavailability in the range of !E-1.

4. Treating passive components (of high reliability) same as active components:

Passive components, namely isolation condensers in some BWRs, are credited similar to active components. The reliability of these components are not expected to differ (from that of active components) by more than an order of magnitude. Pipe failures have been excluded in this process except as part of initiating events where appropriate frequency is used. Accordingly, a separate designation for passive components was not considered necessary.

5. Defining credits for operator actions:

The operator's actions modeled in the worksheets are categorized as follows: operator action=1 representing an error probability of 5E-2 to 0.5; operator action=2 representing an error probability of 5E-3 to 5E-2; operator action=3 representing an error probability of 5E-4 to 5E-3; and operator action=4 representing an error probability of 5E-5 to 5E-4. Actions with error probability > 0.5 are not credited. Thus, operator actions are associated with credits of 1, 2, 3, or 4. Since there is large variability in similar actions among different plants, a survey of the error probability across plants of similar design was used to categorize different operator actions. From this survey, similar actions across plants of similar design are assigned the same credit. If a plant uses a lower credit or recommends a lower credit for a particular action compared to our assessment of similar action based on plant survey, then the lower credit is assigned. An operator's action with a credit of 4, i.e., operator action=4, is noted at the bottom of the worksheet; the corresponding hardware failure, e.g., 1 multi-train system, is defined in the mitigating function.

6. Difference between plant-specific values and SDP designated credits for operator actions:

As noted, operator actions are assigned to a particular category based on review of similar actions for similar design plants. This results in some differences between plant-specific HEP values and credit for the action in the worksheet. The plant-specific values are usually noted at the bottom of the worksheet, when available.

7. Dependency among multiple operator actions:

IPEs or PRAs, in general, account for dependencies among multiple operator actions that may be applicable. In this SDP screening approach, if multiple actions are involved in one function, then the credit for the function is designated as one operator action considering the dependency involved.

8. Crediting late injection (LI) following failure of containment heat removal (CHR), i.e., suppression pool cooling:

Following successful high or low pressure injection, suppression pool cooling is modeled. Upon failure of suppression pool cooling, containment venting (CV) is considered followed by late injection. Late injection is credited if containment venting is successful. Further, LI is required following CV success. The suction sources for the LI systems credited are different from the suppression pool. HPCI, LPCI, and CS are not credited in late injection. No credit is given for LI following failure of CV. The survival probability is low and such details are not considered in the screening approach here.

9. Combining late injection (LI) with low pressure injection (LPI) or containment venting (CV):

In some modeling approaches, LI is combined with LPI or CV. In the SDP worksheet approach here, these functions are separate. As discussed above, LPI and LI use different suction sources, and CV and LI may be two different categories of operator actions. In these respects, for some plants, SDP event trees may be different than the plant-specific trees.

10. Crediting condensate trains as part of multiple functions: power conversion system (PCS), low pressure injection (LPI), and late injection (LI):

Typically, condensate trains can be used as an LPI and LI source in addition to its use as part of the power conversion system. However, crediting the same train in multiple functions can result in underestimation of the risk impact of an inspection finding in the SDP screening approach since it does not account for these types of dependencies in defining the accident sequences. To simplify the process and to avoid underestimation, condensate train is not credited in LPI, but may be credited in LI.

11. Modeling vapor suppression success in different LOCA worksheets:

Vacuum breakers typically must remain closed following a LOCA to avoid containment failure and core damage. Some plants justify that vapor suppression is not needed for SLOCA. These sequences typically have low frequency and are not among the important contributors. However, an inspection finding on these vacuum breakers may make these sequences a dominant contributor. Accordingly, success of vapor suppression is included in the SDP worksheets. It is included for all three LOCA worksheets (LLOCA, MLOCA, and SLOCA); for plants presenting justification that they are not needed in a SLOCA appropriate modifications are made.

12. ATWS with successful PCS as a stable plant state:

Some plants model a stable plant state when PCS is successful following an ATWS. Following our comparison of similarly designed plants, such credits are not given.

13. Modeling different EDG configurations, SBO diesel, and cross-ties:

Different capabilities for on-site emergency AC power exist at different plant sites. To treat them consistently across plants, they are typically combined into a single emergency AC (EAC) function. The dedicated EDGs are credited following the standard convention used in the worksheets for equipment (1 dedicated EDG is 1 train; 2 or more dedicated EDGs is 1 multi-train system). The use of the swing EDG or the SBO EDG requires operator action. The full mitigating capability for emergency AC could include dedicated Emergency Diesel Generators (EDG), Swing EDG, SBO EDG, and finally, nearby fossil-power plants. The following guidelines are used in the SDP modeling of the Emergency AC power capability:

1. Describe the success criteria and the mitigation capability of dedicated EDGs.

2. Assign a mitigating capability of “operator action=1" for a swing EDG. The SDP worksheet assumes that the swing EDG is aligned to the other unit at the time of the LOOP (in a sense a dual unit LOOP is assumed). The operator, therefore, should trip, transfer, re-start, and load the swing EDG.

3. Assign a mitigating capability of “operator action=1" for an SBO EDG similar to the swing EDG. Note, some of the plants do not take credit for an SBO EDG for non-fire initiators. In these cases, credit is not given.

4. Do not credit the nearby power station as a backup to EDGs. The offsite power source from such a station could also be affected by the underlying cause for the LOOP. As an example, overhead cables connecting the station to the nuclear power plant also could have been damaged due to the bad weather which caused the LOOP. This level of detail should be left for a Phase 3 analysis.

14. Recovery of losses of offsite power:

Recovery of losses of offsite power is assigned an operator-action category even though it is usually dominated by a recovery of offsite AC, independent of plant activities. Furthermore, the probability of recovery of offsite power in “X” hours (for example 4 hours) given it is not recovered earlier (for example, in the 1st hour) would be different from recovery in 4 hours with no condition. The SDP worksheet uses a simplified approach for treating recovery of AC by denoting it as an operator action=1 or 2 depending upon the HEP used in the IPE/PRA. A footnote highlighting the actual value used in the IPE/PRA is provided, when available.

15. Mitigation capability for containment heat removal:

The mitigation capability for containment heat removal (CHR) function is considered dominated by the hardware failure of the RHR pumps. The applicable operator action is categorized as an operator action with a credit 4, i.e., operator action=4. For this situation, the function is defined as 1 multi-train system since the operator action involved is considered routine and reliable, and is assigned a credit of 4. No other operator action in the worksheets is generically assigned this high credit.

16. Crediting CRD pumps as an alternate high pressure injection source:

In many plants, CRD pumps can be used as a high pressure injection source following successful operation of HPCI or RCIC for a period of time, approximately 1 to 2 hours. In some plants, CRD system is enhanced where it can be directly used and does not need the successful operation of other HPI sources. In the worksheets, if the CRD pumps require prior successful operation of HPCI or RCIC as a success criteria, then CRD is not credited as a separate high pressure injection source. If the CRD can be used and does not require successful operation of HPCI or RCIC, then it is credited as a separate success path within the HPI function.

2.2 RESOLUTION OF PLANT-SPECIFIC COMMENTS

This section documents the comments received on the material included in this report and their resolution.

The NRC met with Browns Ferry (BF) personnel on May 24, 2000 and received a set of written comments. The licensee provided overall comments, specific comments on the individual SDP worksheets and ETs, and a set of revised SDP worksheets and ETs. These were discussed with the licensee personnel and addressed as indicated below.

Overall Comments

Initiating Event and System Dependency Table

Added numbers of major components.

Revised acronyms per BF comments.

Added fuel oil transfer system for the EDGs.

SDP Worksheets and Event Trees

Changed the CRD system success criteria from 1/2 to 2/2 pumps.

Changed the TBV success criteria from 9/9 to 5/9 TBVs.

Changed the CS system success criteria from 1/2 trains with 2/2 pumps to 1/2 trains with 1/2 pumps (except for the LLOCA which stays at 2/2 pumps).

Moved credit for condensate pumps and CRD pumps from LPI to LI and dropped mention of hotwell makeup.

Added worksheets for Loss of Raw Cooling Water (LRCW) and for ISLOCA/LOC. LRCW at Bf constitutes 5.7% of total internal events CDF. Internal flooding, which is not addressed in these worksheets, constitutes 4.9% of CDF. All other special initiators constitute less than 1% of CDF, therefore no other worksheets for special initiators have been developed.

Simplified the LOOP event tree by providing transfers to the TPCS event tree.

Clarified the use of cross-connected EDGs in the LOOP worksheet.

Changed the use RHR for the CHR function from an operator action to a multi-train system in some worksheets.

For the ATWS worksheet, combined the mechanical failures and operator action failures for SLC into one function. Also for ATWS, removed credit for PCS per generic NRC resolution.

REFERENCES

1. NRC SECY-99-007A, Recommendations for Reactor Oversight Process Improvements (Follow-up to SECY-99-007), March 22, 1999.

2. Tennessee Valley Authority, "Browns Ferry Nuclear Power Station, Unit 2, Individual Plant Examination Transmittal Report," dated September 1, 1992.

3. Tennessee Valley Authority, Browns Ferry Nuclear Plant Unit 2 Responses to NRC RAIs dated 9/21/93 and 12/23/93

4. Tennessee Valley Authority, Browns Ferry Nuclear Plant - Multi-Unit Probabilistic Risk Assessment (PRA), submitted to NRC via letter dated April 14, 1995

5. Licensee comment package on draft version of Inspection Notebook contained in memo from Ian Jung to Jose Ibarra dated June 16, 2000 and based on site visit to Browns Ferry on May 24, 2000.