April 12, 2002

Mr. Gary Van Middlesworth
Site General Manager
Duane Arnold Energy Center
Nuclear Management Company, LLC
3277 DAEC Road
Palo, IA 52324-0351

SUBJECT: DUANE ARNOLD ENERGY CENTER - SITE-SPECIFIC PHASE 2 WORKSHEETS FOR USE IN THE NUCLEAR REGULATORY COMMISSION'S SIGNIFICANCE DETERMINATION PROCESS (TAC NO. MA6544)

Dear Mr. Van Middlesworth:

Enclosed please find the Risk-Informed Inspection Notebook which incorporates the updated Significance Determination Process (SDP) Phase 2 Worksheets that inspectors are using to characterize and risk-inform inspection findings. This document is one of the key implementation tools of the reactor safety SDP in the reactor oversight process.

Following initial implementation of the revised reactor oversight process, site visits were conducted by the U.S. Nuclear Regulatory Commission (NRC) to verify and update plant equipment configuration data and to collect site-specific risk information from your staff. The enclosed document reflects the results of this visit and updates the site-specific worksheets forwarded to you by our letter of March 27, 2000.

The enclosed Phase 2 Worksheets have incorporated much of the information we obtained during our site visits. The staff encourages further licensee comments where it is identified that the Worksheets give inaccurately low significance determinations. Any comments should be provided to the NRC's Document Control Desk, with a copy to the Chief, Probabilistic Safety Assessment Branch, Nuclear Reactor Regulation. We will continue to assess SDP accuracy and update the document based on continuing experience.

While the enclosed Phase 2 Worksheets have been verified by our staff to include the site-specific data, we will continue to assess its accuracy throughout implementation and update the document based on comments by our inspectors and your staff.

Sincerely,

/RA/

Darl S. Hood, Senior Project Manager, Section 1
Project Directorate III
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket No. 50-331

Enclosure: Risk-Informed Inspection Notebook for DAEC

cc w/o encl: See next page

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RISK-INFORMED INSPECTION NOTEBOOK FOR

DUANE ARNOLD ENERGY CENTER

BWR-4, GE, WITH MARK I CONTAINMENT

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ENCLOSURE

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 Duane Arnold Energy Center.

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.

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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 Duane Arnold Energy Center.

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 Duane Arnold Energy Center

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	Loss of offsite power, Inadvertent or stuck open SRVs	B	C	D
III	1 per 10^{2} - 10^{3} yr	Loss of one Division of DC Power	C	D	E
IV	1 per 10^{3} - 10^{4} yr	Small LOCA (RCS rupture), Medium LOCA (RCS rupture), Loss of River Water	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. The initiating event frequency for Loss of 125 VDC is 1 E-3 events per reactor-year and for Loss of River Water is 7.5 E-4 events per reactor-year.

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 involvements in different initiating events are noted in the last column.

Table 2 Initiators and System Dependency Table for Duane Arnold

Affected System		Major Components	Support Systems	Initiating Event Scenarios
Code	Name			
PCS	Power Conversion System	4 MDPs, MOVs, 8 MSIVs, 2 TBVs, Condenser	Division I, II 125 V-DC , 4160 V Normal AC , 480 VAC, 120 VAC, Circulating Water, IA, GSW	All but TPCS, IORV/SORV, & ATWS
HPCI	High Pressure Coolant Injection	1 TDP, MOV	Division II 125 V-DC, 250 V-DC, HVAC, Act	All except LLOCA & LODCII
RCIC	Reactor Core Isolation Cooling	1 TDP, MOV	Division I 125 V-DC, HVAC, Act	TRANS, TPCS, SLOCA, IORV, LOOP, LODCII, LORW
SRVs/ADS	Safety Relief Valves	6 SRVs (4 ADS & 2 RVs), Accumulators	Division I, II 125 V-DC , 480 VAC, Essential AC, N_2, Act	All except LLOCA
N_2	Instrument N_2 System	Accumulators, valves	AC	All except LLOCA
LPCI	Low Pressure Coolant Injection	4 MDPs, MOVs	4160 V Essential AC, 480 VAC, Div I, II 125 V-DC , Act	All
RHR	Residual Heat Removal	4 MDPs, MOVs, 2 HXs	4160 V Essential AC, 480 VAC, Div I, II 125 V-DC , RHRSW	All but LORW
CS	Core Spray	2 MDPs, MOVs	4160 V Essential AC, Div I, II 125 V-DC , ESW (pump motor), Act	All but LORW
AC	AC power (non-EDG)	Auxiliary and startup transformers, buses	125 VDC	All
EDGs	AC power (EDGs)	2 EDGs, 1A3 & 1A4 Essential buses	Division I, II 125 V-DC , ESW, HVAC, Act	LOOP

Table 2 (Continued)

Affected System		Major Components	Support Systems	Initiating Event Scenarios
Code	**Name**			
FO transfer	EDG fuel oil transfer	MDPs, valves	AC	LOOP
DFP	Diesel Fire Pump	1 diesel-driven pump	None	LOOP
DC	DC Power	3 Batteries, 5 Chargers 125 & 250 VDC buses	Essential AC, 480 VAC	All
Act	Instrumentation System	Sensors, Relays	Division I, II 125 V-DC	All but LODCI, LODCII, & LORW
CRD	Control Rod Hydraulic System	2 MDPs, Valves	Division I, II 125 V-DC (1D13, 1D23) , RBCCW, Essential AC (1A3,4), CST, IA	None
IA	Instrument Air	Compressors, valves	AC, WW or ESW	All but TPCS, IORV/SORV, & ATWS
HVAC	Heating, Ventilation, & Air Conditioning	Room coolers, fans	Essential AC, AC, WW or ESW	All except LLOCA
RBCCW	Reactor Building Closed Cooling Water	MDPs, valves, HXs	AC, DC, GSW	None
RHRSW	RHR Service Water	4 MDPs, MOVs	4160 V Essential AC , Division I, II 125 V-DC, RW, ESW (pump motor cooling)	All but LORW
GSW	General Service Water	3MDPs, MOVs, HXs	4160 V Essential AC , 480 VAC, Non-essential Division I, II 125 V-DC , Act, RW or WW	All except ATWS, LLOCA, & LODCII

Table 2 (Continued)

Affected System		Major Components	Support Systems	Initiating Event Scenarios
Code	Name			
ESW	Emergency Service Water	2 MDPs, MOVs	4160 V Essential AC , Division I, II 125 V-DC, RW, Act	All but LORW
RW	River Water	4 MDPs, Control valves	4160 V Essential AC , Division I, II 125 V-DC, Act	LORW
W W	Well Water	4 MDPs, MOVs	Essential AC , Non-essential AC, Division I, II 125 V-DC	LORW
SLC	Standby Liquid Control	2 MDPs, MOV, 2 Explosive valves	480 V Essential AC, Act, RWCU isolation	ATWS
RPT	Recirculation pump trip	RPT Breakers	Division I, II 125 V-DC, Act	ATWS
CV	Containment Venting	Torus hard pipe vent path and drywell path, Control Valves, Rupture disk, and accumulators	Division I, II 125 V-DC , AC, IA (with accumulator backup)	All

Notes:

1. Information herein was developed from the Duane Arnold (DA) IPE, the licensee's responses to the NRC requests for additional information, and the licensee's comments on the draft risk-informed inspection notebook (see references). The licensee's comments were based on the updated DAEC PRA, Rev. 4.

2. The baseline IPE core damage frequency (CDF) from internal events was 7.8 x 10^{-6} events/Rx year. The PSA update, Rev. 4, 1998 has a baseline CDF of 1.1 x 10^{-5} events/Rx year. Duane Arnold IPE's top sequence (at 13% of total internal CDF) is a total loss of DC power. The contribution from internal flooding were determined to be negligible. High, early release frequency (also termed LERF) is 8.6 E-7 events per reactor year in the PSA update.

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.

Table 2 (Continued)

4. One train of feedwater/condensate must be available for long term operation of the condenser. There are two turbine bypass valves (TBVs) in the PCS at DA.

5. Emergency DC power has two 125 V divisions and a 250 V system that primarily supports HPCI operation. Initial conservative calculations showed a battery life of 4 hours. Updated calculations for the PRA showed 5 hour battery life for HPCI and RCIC without load shedding and an 8 hour life with load shedding.
6. The control rod hydraulic system is not credited as a source of RPV makeup in the Duane Arnold IPE. The IPE notes that in the 4 to 8 hour period of the accident would require 2/2 CRD pumps and support of AC/DC power, RBCCW, and IA.

7. The Diesel Fire Pump (DFP) is credited as a low pressure injection source on a LOOP scenario. It is located in the safety related pump house and takes a suction from the stilling basin. Injection with the DFP requires DEP and cross connection to the RHR injection pathway.

8. Failure of primary system pressure control (failure of SRVs to reclose) will challenge primary system integrity and can be captured in the LOCA trees.

9. RHR Shutdown Cooling is not credited in the Duane Arnold IPE as a mode of containment heat removal (CHR).

10. In the IPE, HVAC cooling is required for: Essential and non-essential switchgear, HPCI (or alternatively open doors), RCIC (or alternatively open doors), but HVAC is not required for: CRD, CS, LPCI, RHR, RHRSW.

11. Duane Arnold has a large variety of cooling water systems. The next five notes discuss these systems.

12. Emergency Service Water (ESW) provides cooling for: ECCS HVAC, EDGs, RHR pumps, CS pumps, RHRSW pumps, control building chiller, and essential compressors. Success requires 2/2 ESW pumps and makeup from 1/4 RW pumps.

13. RHRSW can be cross-connected to RHR for post-accident flooding of the reactor vessel or containment. For success of RHRSW injection also need 1/4 RW pumps to provide suction water for RHRSW and 1/2 ESW pumps for RHRSW pump cooling.

14. The Circulating Water wet pit is the water source for the General Service Water (GSW) System. Makeup to the pit is by the river water system or the Well Water System. GSW can also provide alternate injection as follows: supply from 1/4 RW pumps or 1/4 WW pumps to 1/3 GSW pumps to the RHRSW flow path into the reactor or containment.

15. The RW system supplies makeup water from the Cedar River to the CWS, GSW, RHRSW, and ESW systems via the stilling basin. The first priority is for the RHRSW & ESW pit. From there the water overflows into the CW pit, which supplies the CW and the GSW systems.

Table 2 (Continued)

16. The Well Water (WW) system provides cooling to some HVAC, and makeup to: demineralizer, potable water system, and fire protection system. WW can also provide a backup to the RW system, but is not credited for this function in the IPE.

17. CV: The CV system has a moderate amount of redundancy. There are both drywell and torus vent paths. The drywell vent path is non-hardened and uses AC powered control valves. The torus vent path goes through an inboard torus purge and vent valve (CV-4300) which is operated by IA. IA has an accumulator backup and the IA to CV-4300 is controlled by redundant AC and DC Div. I solenoid valves. After CV-4300, the vent line splits into two vent paths, a hardened path to the offgas stack and a non-hardened path to the standby gas treatment system. The hardened vent path goes through an outboard valve controlled by IA and a DC Div. II solenoid, then through a rupture disk. The non-hardened path goes through an outboard valve controlled by IA and a DC Div. I solenoid.

1.3 SDP WORKSHEETS

This section presents the SDP worksheets to be used in the Phase 2 evaluation of the inspection findings for the Duane Arnold Energy Center. 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. Inadvertent Open Relief Valve (IORV)
5. Medium LOCA (MLOCA)
6. Large LOCA (LLOCA)
7. Loss of Offsite Power (LOOP)
8. Anticipated Transients Without Scram (ATWS)
9. Loss of Div. I DC Power (LODCI)
10. Loss of Div. II DC Power (LODCII)
11. Loss of River Water (LORW)
12. Interfacing System LOCA (ISLOCA) and LOCA Outside Containment (LOC)

Table 3.1 SDP Worksheet for Duane Arnold — Transient (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, 2/2 TBVs, Condenser, 1/2 Steam jet air ejectors, 1/2 Circulation Water pumps, 1/2 Condensate pumps, 1/2 Reactor feedwater pumps (operator action = 3)
High Pressure Injection (HPI)	HPCI (1 ASD train) or RCIC (1 ASD train)
Depressurization (DEP)	3/6 valves (4 ADS and 2 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 pump in 1/2 trains (1 multi-train system)
Containment Heat Removal (CHR)	1/4 RHR pumps and 1/2 RHR HXs in 1/2 trains aligned in torus cooling or containment spray mode plus 1/4 RHRSW pumps and 1/4 RW pumps (1 multi-train system)
Containment Venting (CV)	CV through hardened torus vent path or 1/2 non-hardened paths (one torus and one drywell) (operator action = 2)
Late Inventory Makeup (LI)	1/4 RHRSW pumps aligned for RPV injection (requires 1/4 RW pumps and 1/2 ESW pumps for RHRSW pump cooling); or 1/2 ESW pumps aligned for RPV injection (requires 1/4 RW pumps); or 1/3 GSW pumps aligned for RPV injection (requires 1/4 RW pumps)] (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) Transients in the Duane Arnold (DA) IPE pertinent to this worksheet include turbine trip, electrical load rejection, reactor trip, and recirculation pump trip.

(2) The Duane Arnold IPE also credits feedwater as a source of HPI and condensate for LI. These systems are included in the PCS for the SDP methodology and are not credited separately here. For use of PCS in the HPI function, DAEC needs 1/2 condensate pumps and 1/2 feedwater pumps. For use of PCS in the LI function at low pressures, DAEC needs only 1/2 condensate pumps.

(3) The PSA update uses two HEP values for DEP, 2.1 E-4 and 0.3.

(4) The PSA update uses two HEP values for CV 2.3 E-3 and 0.1.

(5) The PSA update uses several HEP values for alternate injection (or late injection - LI) varying from 0.14 to 0.54. The DAEC event trees in the PRA take credit for both LPI and LI systems early in the event tree (before CHR). Thus, they are precluding sequences such as sequence 10 on our ET. We have given credit for the LI systems only after successful CV. This maintains similarity with other BWRs. Further, loss of LPI will generally cause a loss of CHR as well, necessitating the use CV anyway.

Table 3.2 SDP Worksheet for Duane Arnold — Transient without PCS (TPCS)

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)	3/6 valves (4 ADS and 2 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 pump in 1/2 trains (1 multi-train system)
Containment Heat Removal (CHR)	1/4 RHR pumps and 1/2 RHR HXs in 1/2 trains aligned in torus cooling or containment spray mode plus 1/4 RHRSW pumps and 1/4 RW pumps (1 multi-train system)
Containment Venting (CV)	CV through hardened torus vent path or 1/2 non-hardened paths (one torus and one drywell) (operator action = 2)
Late Inventory Makeup (LI)	[1/4 RHRSW pumps aligned for RPV injection (requires 1/4 RW pumps and 1/2 ESW pumps for RHRSW pump cooling); or 1/2 ESW pumps aligned for RPV injection (requires 1/4 RW pumps); or 1/3 GSW pumps aligned for RPV injection (requires 1/4 RW pumps)] (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). TPCS includes MSIV closure, turbine trip without bypass, loss of vacuum, and loss of feedwater. 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) The PSA update uses two HEP values for DEP, 2.1 E-4 and 0.3.

(3) The PSA update uses two HEP values for CV 2.3 E-3 and 0.1.

(4) The PSA update uses several HEP values for alternate injection (or late injection - LI) varying from0.14 to 0.54.

Table 3.3 SDP Worksheet for Duane Arnold — 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:**
Early Containment Control (EC)	Passive operation of Suppression Pool, 7/7 vacuum breakers remain closed at onset of LOCA (1 single train system)
Power Conversion System (PCS)	1/4 Steam lines, 2/2 TBVs, Condenser, 1/2 Steam jet air ejectors, 1/2 Circulation Water pumps, 1/2 Condensate pumps, 1/2 Reactor feedwater pumps (operator action = 3)
High Pressure Injection (HPI)	HPCI (1 ASD train) or RCIC (1 ASD train)
Depressurization (DEP)	3/6 valves (4 ADS and 2 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 pump in 1/2 trains (1 multi-train system)
Containment Heat Removal (CHR)	1/4 RHR pumps and 1/2 RHR HXs in 1/2 trains aligned in torus cooling or containment spray mode plus 1/4 RHRSW pumps and 1/4 RW pumps (1 multi-train system)
Containment Venting (CV)	CV through hardened torus vent path or 1/2 non-hardened paths (one torus and one drywell) (operator action = 2)
Late Inventory Makeup (LI)	[1/4 RHRSW pumps aligned for RPV injection (requires 1/4 RW pumps and 1/2 ESW pumps for RHRSW pump cooling); or 1/2 ESW pumps aligned for RPV injection (requires 1/4 RW pumps); or 1/3 GSW pumps aligned for RPV injection (requires 1/4 RW pumps)] (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)			
4 SLOCA - PCS - HPI - DEP (11)			
5 SLOCA - EC (12)			
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) The Small Break LOCA is defined by the Duane Arnold IPE as a leak that exceeds the makeup capacity of the Control Rod Drive pumps (409 gpm). Reactor pressure remains high unless manual depressurization occurs.

(2) Per the IPE, the SLOCA accident progression is similar to that of a turbine trip with bypass initiator (shown in Table 3.1 here).

(3) EC: There are seven torus-to-drywell vacuum breaker control valves CV-4327A, C, D, F, G, & H. Per the licensee’s comment, all seven must remain closed on an SLOCA to preserve the pressure suppression and containment function of the torus.

(4) The Duane Arnold IPE also credits condensate as a source for LI. This system is included in the PCS for the SDP methodology and is not credited separately here.

Table 3.4 SDP Worksheet for Duane Arnold — Inadvertently Open Relief Valve/Stuck Open Relief Valve (IORV)

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>
Power Conversion System (PCS)	No credit for PCS on IORV/SORV
High Pressure Injection (HPI)	HPCI (1 ASD train) or RCIC (1 ASD train)
Depressurization (DEP)	3/6 valves (including the IORV) 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 pump in 1/2 trains (1 multi-train system)
Containment Heat Removal (CHR)	1/4 RHR pumps and 1/2 RHR HXs in 1/2 trains aligned in torus cooling or containment spray mode plus 1/4 RHRSW pumps and 1/4 RW pumps (1 multi-train system)
Containment Venting (CV)	CV through hardened torus vent path or 1/2 non-hardened paths (one torus and one drywell) (operator action = 2)
Late Inventory Makeup (LI)	[1/4 RHRSW pumps aligned for RPV injection (requires 1/4 RW pumps and 1/2 ESW pumps for RHRSW pump cooling); or 1/2 ESW pumps aligned for RPV injection (requires 1/4 RW pumps); or 1/3 GSW pumps aligned for RPV injection (requires 1/4 RW pumps)] (operator action = 1); or 1/2 condensate pumps (operator action = 2)

<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 IORV - CHR - LI (3, 7, 12)			
2 IORV - CHR - CV (4, 8, 13)			
3 IORV - PCS - HPI - LPI (9, 14)			

4 IORV - PCS - HPI - DEP (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) This worksheet applies to both an IORV and a stuck open relief valve (SORV). One IORV is approximately the same size as an MLOCA at DA. This initiating event accounts for 10% of the internal events CDF in the PSA update for DA. For conservatism we have modeled the portion of the DAEC event tree that assumes that the IORV does not reclose at lower pressures.

(2) While we have maintained a record of PCS in the worksheet and the event tree, to match the licensee's modeling, no credit should be given in performing evaluations. This is due to a generic NRC position that an SORV typically results from transients caused by a loss of the turbine, TBVs, or MSIVs. We have provided credit for the condensate pumps in LI to match the licensee's modeling.

(3) For the DEP function need a total of 3 SRVs, including the IORV. DEP is also successful with 2/2 TBVs steaming to the condenser in the PRA, but this is not credited here.

(4) The Duane Arnold IPE also credits condensate as a source for LI.

Table 3.5 SDP Worksheet for Duane Arnold — 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 torus with 6/7 vacuum breakers remaining closed (1 multi-train system)
Power Conversion System (PCS)	1/2 Condensate pumps and 1/2 Reactor Feedwater pumps (operator action = 3)
High Pressure Injection (HPI)	HPCI (1 ASD train)
Depressurization (DEP)	3/6 valves (4 ADS and 2 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 pump in 1/2 trains (1 multi-train system)
Containment Heat Removal (CHR)	1/4 RHR pumps and 1/2 RHR HXs in 1/2 trains aligned in torus cooling or containment spray mode plus 1/4 RHRSW pumps and 1/4 RW pumps (1 multi-train system)
Containment Venting (CV)	CV through hardened torus vent path or 1/2 non-hardened paths (one torus and one drywell) (operator action = 2)
Late Inventory Makeup (LI)	[1/4 RHRSW pumps aligned for RPV injection (requires 1/4 RW pumps and 1/2 ESW pumps for RHRSW pump cooling); or 1/2 ESW pumps aligned for RPV injection (requires 1/4 RW pumps); or 1/3 GSW pumps aligned for RPV injection (requires 1/4 RW pumps)] (operator action = 1)

Circle Affected Functions	**Recovery or Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Sequence**	**Sequence Color**
1 MLOCA - CHR - LI (3, 7, 12)			
2 MLOCA - CHR - CV (4, 8, 13)			
3 MLOCA - PCS - LPI (9, 14)			

4 MLOCA - PCS - HPI - DEP (15)			
5 MLOCA - EC (16)			

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 Medium Break LOCA is defined by the Duane Arnold IPE as a leak that exceeds the makeup capacity of the RCIC system. DAEC also considers one SORV as within the range of an MLOCA.

(2) The Duane Arnold IPE credits the use of the PCS on an MLOCA (feedwater and condensate) for injection. With success of FW and condensate, LPI is not required since condensate is available.

(3) When using HPCI for HPI, reactor pressure will slowly decrease due to the LOCA and the use of steam for the HPCI turbine, but manual depressurization is still required for low pressure injection system operation. Further, with success of only HPCI for HPI, LPI is required due to eventual loss of HPCI due to reactor depressurization.

Table 3.6 SDP Worksheet for Duane Arnold — 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 torus with 6/7 vacuum breakers remaining closed (1 multi-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 pump in 1/2 trains (1 multi-train system); or 1/2 condensate pumps (operator action = 2)
Containment Heat Removal (CHR)	1/4 RHR pumps and 1/2 RHR HXs in 1/2 trains aligned in torus cooling or containment spray mode plus 1/4 RHRSW pumps and 1/4 RW pumps (1 multi-train system)
Containment Venting (CV)	CV through hardened torus vent path or 1/2 non-hardened paths (one torus and one drywell) (operator action = 2)
Late Inventory, Makeup (LI)	1/2 condensate pumps (operator action = 2)

Circle Affected Functions	**Recovery or Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Sequence**	**Sequence Color**
1 LLOCA - CHR - LI (3)			
3 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.

<u>Notes</u>:

(1) Failure of EC/ Suppression Pool (SP) could be due to downcomer vent pipe failures, vacuum breaker failures, or inadequate Torus level. A malfunction of two vacuum breaker assemblies will fail this function (6 of 7 must remain closed).

(2) The Duane Arnold IPE credits the condensate system for LPI and LI because it can be aligned from the control room. RHRSW takes longer to align and therefore is not credited in LI.

Table 3.7 SDP Worksheet for Duane Arnold — 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)	1/2 EDGs (1 multi-train system)
Recovery of LOOP in 30 min (RLOOP30M)	Operator action = 1
Recovery of LOOP in 6 hours (RLOOP6H)	Operator action = 1
Recovery of LOOP in 9 hours (RLOOP9H)	Operator action = 2
Ventilation actions (OP-VENT)	Operator opens doors to HPCI and RCIC rooms, and bypasses room high temperature trips (operator action = 2)
DC Load Shed on SBO (LD-SHED)	Operator action to shed DC loads (operator action = 2)
High Pressure Injection (HPI)	HPCI (1 ASD train) or RCIC (1 ASD train)
Depressurization (DEP)	3/6 valves (4 ADS and 2 SRVs) manually opened (operator action = 2)
Diesel Fire Pump Injection (DFP)	Operator injects at low pressure with the Diesel Fire pump (no credit)
Low Pressure Injection (LPI)	1/4 RHR pumps in 1/2 trains in LPCI Mode (1 multi-train system); or 1/2 CS pump in 1/2 trains (1 multi-train system)
Containment Heat Removal (CHR)	1/4 RHR pumps and 1/2 RHR HXs in 1/2 trains aligned in torus cooling or containment spray mode plus 1/4 RHRSW pumps and 1/4 RW pumps (1 multi-train system)
Containment Venting (CV)	CV through hardened torus vent path or 1/2 non-hardened paths (one torus and one drywell) (operator action = 2)
Late Inventory Makeup (LI)	[1/4 RHRSW pumps aligned for RPV injection (requires 1/4 RW pumps and 1/2 ESW pumps for RHRSW pump cooling); or 1/3 GSW pumps aligned for RPV injection (requires 1/4 RW pumps) (operator action = 1); or 1/2 condensate pumps] (operator action = 1)

Circle Affected Functions	**Recovery or Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Sequence**	**Sequence Color**
1 LOOP - CHR - LI (1, 2, 5, 11)			

2 LOOP - CHR - CV (1, 2, 6, 12)			
3 LOOP - HPI - DEP (1, 2)			
4 LOOP - HPI - LPI (1, 2)			
5 LOOP - EAC - RLOOP30M - HPI (7, 13) [SBO sequence]			
6 LOOP -EAC - RLOOP30M - (OP-VENT)(8) [SBO sequence]			
7 LOOP - EAC - RLOOP6H - (LD-SHED) (14) [SBO sequence]			
8 LOOP - EAC - RLOOP9H (15) [SBO sequence]			

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. We have constructed this worksheet based on information from the licensee based on Rev. 4 of the DAEC PRA, the LOOP event trees dated 6/4/97 (20 pages), and the LOOP/SBO Event Tree Notebook dated August 1994 (provided by the licensee in March 2001).

2. LOOP/SBO at DAEC is 54% of the total internal events CDF. LOOP/IORV is 8.3% of CDF, but these notebooks typically do not have a separate worksheet just for LOOP/SORV.

3. The first two sequences in the LOOP ET (sequences 1 and 2) have transfers from the LOOP event tree to the TPCS event tree in order to simplify the LOOP event tree.

4. For this worksheet we have included in RLOOP actions the recovery of either offsite power or an EDG. The failure events imply failure to recover either offsite power or an EDG. The DAEC PRA values for cumulative probability of failure to recover offsite power are as follows:
   RLOOP30M = 0.39
   RLOOP6H = 0.06
   RLOOP9H = 0.029

5. In the event tree and sequences, we assume that a failure to recover LOOP in 9 hours implies a failure at all earlier hours (e.g., 6 hours). Thus we have subsumed and not presented some sequences that would be redundant.

6. Given early failure of HPI (e.g., HPCI & RCIC fail to start) on an SBO, a source of AC power must be recovered in 30 minutes to prevent core damage.

7. On an SBO the temperature in the HPCI room increases quickly in 30 to 45 minutes time. The operators need to open the doors to the room to allow natural circulation cooling per AOP-301. This has an HEP of 3.1 E-3 in the DAEC IPE. They also must bypass the room high temperature trips for both HPCI and RCIC in order to assure continued system operation. Both of these actions are grouped together in the worksheet above as OP-VENT. Failure to successfully accomplish OP-VENT will result in failure of HPI with a high likelihood at about 2 hours.

8. On an SBO, without any DC load shedding, the HPCI system can last about 5 hours and RCIC about 5.4 hours. The consequent failure of HPI would then lead to core damage at 6 hours. With effective DC load shedding HPCI & RCIC both can last about 8 hours. If power is not recovered, this would lead to loss of all HPI and core damage at about 9 hours. The HEP for failure to load shed (LD-SHED) that is used in the IPE is 5 E-2.

9. The DAEC PRA does not treat the HPCI and RCIC time dependencies as absolute, but rather vary the failure probabilities depending on the time without AC power recovery, bypassing of high temperature trips and DC load shedding. We have simplified these dependencies as described above.

10. On the SBO sequences with successful HPI, the DAEC event trees do not question LPI. We have maintained this assumption here.

11. The DAEC PRA credits the use of the Diesel Fire pump at 9 hours into a LOOP, after failure of all HPI, in order to extend the time available for recovery of the LOOP from 9 hours to 15 hours. The PRA also credits the DFP at some other locations in the 20 page LOOP ET on failure of other injection sources. However, the failure probability for the Diesel Fire pump in the DAEC PRA is 0.9, therefore no credit is given in this worksheet for its use, and failure to recover power in 9 hours is assumed to lead to core damage. We have thus also not included RLOOP15H in this worksheet.

12. The DAEC PRA does not require LI upon successful CV, but we have included it for consistency with other plants' SDP worksheets.

13. If AC power is not recovered, 1 of the 2 non-hardened containment ventilation vent paths is lost.

Table 3.8 SDP Worksheet for Duane Arnold — Anticipated Transients Without Scram (ATWS)

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:**
Recirculation Pump Trip (RPT)	Automatic trip of 2/2 recirculation pumps and automatic runback of 2/2 reactor feedwater pumps (1 multi-train system)
Overpressure Protection (OVERP)	7/8 valves automatically open (4 ADS, 2 SRVs, and 2 SVs) (1 multi-train system)
Inhibit ADS (INH)	Operator inhibits ADS (operator action = 2)
Standby Liquid Control (SLC)	Manual initiation of 2/2 SLC pumps (operator action = 2)
High Low Pressure Injection (HPI)	HPCI (1 ASD train)
Depressurization (DEP)	3/6 valves manually opened (4 ADS and 2 SRVs) (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 pump in 1/2 trains (1 multi-train system)
Overfill/ Level Control (OVERFL/LC)	Operator prevents overfill and controls reactor water level in order to provide adequate power control (operator action = 1)
Containment Heat Removal (CHR)	1/4 RHR pumps and 1/2 RHR HXs in 1/2 trains aligned in torus cooling or containment spray mode plus 1/4 RHRSW pumps and 1/4 RW pumps (1 multi-train system)
Containment Venting (CV)	CV through hardened torus vent path or 1/2 non-hardened paths (one torus and one drywell) (operator action = 2)
Late Inventory Makeup (LI)	[1/4 RHRSW pumps aligned for RPV injection (requires 1/4 RW pumps and 1/2 ESW pumps for RHRSW pump cooling); or 1/3 GSW pumps aligned for RPV injection (requires 1/4 RW pumps) (operator action = 1)

Circle Affected Functions	**Recovery or Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Sequence**	**Sequence Color**
1 ATWS - CHR - LI (3, 8)			
2 ATWS - CHR - CV (4, 9)			

3 ATWS - OVERFL/LC (5, 10)			
4 ATWS - HPI - LPI (11)			
5 ATWS - HPI - DEP (12)			
6 ATWS - INH (13)			
7 ATWS - SLC (14)			
8 ATWS - OVERP (15)			
9 ATWS - RPT (16)			

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 DAEC PRA ATWS constitutes 18% of the internal events core damage frequency.

(2) DAEC has 4 ADS SRVS, 2 non-ADS SRVs, and 2 safety valves.

(3) 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 (FW and condensate) for HPI in the IPE.

(4) This SDP assumes that the SLC system success criteria requires two out of two pumps, although the Duane Arnold IPE gives limited credit for 1 pump operation. Additionally, the DAEC PRA separates SLC into early SLC and late SLC and models these separately in the ATWS ET. Nonetheless , if both early and late SLC fail in the PRA, core damage ensues. Thus, we have maintained the typical presentation ere of only one SLC event that leads to CD if it fails.

(5) The Duane Arnold IPE does not credit RCIC for ATWS mitigation.

(6) We have combined prevention of overfill on use of LPI with properly controlling reactor water level and reactor power (OVERFL/LC). The DAEC IPE notes that on an ATWS, operators must avoid uncontrolled injection of LPI, which can cause: dilution of boron with cold boron-free water, and flushing out of boron through the SRVs. These situations can cause a recriticality. The operator is also directed to lower reactor water level to minimize power generation in the core, typically to the top of the active fuel, but sometimes as low as 1/3 core height (which still permits adequate steam cooling of the fuel).

(7) The DAEC PRA does not require LI upon successful CV, but we have included it for consistency with other plants' SDP worksheets.

Table 3.9 SDP Worksheet for Duane Arnold — Loss of Div. I DC Power (LODCI)

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, 2/2 TBVs, Condenser, 1/2 Steam jet air ejectors, 1/1 Circulation Water pumps, 1/1 Condensate pumps, 1/1 Reactor feedwater pumps (1 single train system)
High Pressure Injection (HPI)	HPCI (1 ASD train)
Depressurization (DEP)	3/6 valves (4 ADS and 2 SRVs) manually opened (operator action = 2)
Low Pressure Injection (LPI)	1/2 RHR pumps in 1/1 trains in LPCI Mode (1 single train system); or 1/2 CS pump in 1/1 trains (1 single train system)
Containment Heat Removal (CHR)	1/2 RHR pumps and 1/1 RHR HXs in 1/1 trains aligned in torus cooling or containment spray mode plus 1/2 RHRSW pumps and 1/2 RW pumps (1 single train system)
Containment Venting (CV)	CV through hardened torus vent path or the (1/1) drywell non-hardened vent path (operator action = 2)
Late Inventory Makeup (LI)	1/2 RHRSW pumps aligned for RPV injection (requires 1/2 RW pumps and 1/1 ESW pumps for RHRSW pump cooling); or 1/1 ESW pumps aligned for RPV injection (requires 1/2 RW pumps); or 1/3 GSW pumps aligned for RPV injection (requires 1/2 RW pumps)] (operator action = 1)

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

4 LODCI - 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) Loss of a 125 VDC bus at DAEC has an initiating event frequency of 1 E-3 events per reactor-year. This event contributes 4% to internal events core damage frequency. There is no direct tie between loss of a single 125 VDC bus and a reactor scram. However, historical evidence at DAEC indicates that faults on a single bus combined with latent random failures existing in the plant will result in an automatic protection action such as a scram or MSIV closure. Furthermore, Technical Specification Section 3.8.4 requires DAEC to be in the hot shutdown mode within 12 hours of losing either division of 125 VDC. As such, the PRA model assumes reactor shutdown will result from 125 VDC bus failures.

(2) Loss of the bus also results in a loss of: RCIC; 1 EDG; Train A of condensate, FW, & circulating water; and Div. I of CRD, CS, LPCI, RHR, RHRSW, and ESW. Also, loss of a DC bus causes a loss of DC control power to breakers 1A101 and 1A102 that transfer non-essential power from the main generator to the startup transformer. Also, loss of a DC bus reduces reliability by removing one of the control power sources from ADS/SRV valves, CV torus inboard vent valve, and the MSIVs. Also loss of Div I DC causes a loss of the non-hardened torus vent path due to loss of the torus outboard vent valve.

(3) Both LODCI and LODCII use the same event tree.

(4) The PSA update uses two HEP values for DEP, 2.1 E-4 and 0.3.

(5) The PSA update uses two HEP values for CV 2.3 E-3 and 0.1.

(6) The PSA update uses several HEP values for alternate injection (or late injection - LI) varying from 0.14 to 0.54.

Table 3.10 SDP Worksheet for Duane Arnold — Loss of Div. II DC Power (LODCII)

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, 2/2 TBVs, Condenser, 1/2 Steam jet air ejectors, 1/1 Circulation Water pumps, 1/1 Condensate pumps, 1/1 Reactor feedwater pumps (1 single train system)
High Pressure Injection (HPI)	RCIC (1 ASD train)
Depressurization (DEP)	3/6 valves (4 ADS and 2 SRVs) manually opened (operator action = 2)
Low Pressure Injection (LPI)	1/2 RHR pumps in 1/1 trains in LPCI Mode (1 single train system); or 1/2 CS pump in 1/1 trains (1 single train system)
Containment Heat Removal (CHR)	1/2 RHR pumps and 1/1 RHR HXs in 1/1 trains aligned in torus cooling or containment spray mode plus 1/2 RHRSW pumps and 1/2 RW pumps (1 single train system)
Containment Venting (CV)	CV through 1/2 non-hardened vent paths (one torus and one drywell) (operator action = 2)
Late Inventory Makeup (LI)	1/2 RHRSW pumps aligned for RPV injection (requires 1/2 RW pumps and 1/1 ESW pumps for RHRSW pump cooling); or 1/1 ESW pumps aligned for RPV injection (requires 1/2 RW pumps) (operator action = 1)

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

<table>
<tr><td>4 LODCII - 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) Loss of a 125 VDC bus at DAEC has an initiating event frequency of 1 E-3 events per reactor-year. This event contributes 4% to internal events core damage frequency. There is no direct tie between loss of a single 125 VDC bus and a reactor scram. However, historical evidence at DAEC indicates that faults on a single bus combined with latent random failures existing in the plant will result in an automatic protection action such as a scram or MSIV closure. Furthermore, Technical Specification Section 3.8.4 requires DAEC to be in the hot shutdown mode within 12 hours of losing either division of 125 VDC. As such, the PRA model assumes reactor shutdown will result from 125 VDC bus failures.

(2) Loss of the bus also results in a loss of: HPCI; 1 EDG; Train B of condensate, FW, & circulating water; and Div. II of CRD, CS, LPCI, RHR, RHRSW, and ESW. Also, loss of a DC bus causes a loss of DC control power to breakers 1A101 and 1A102 that transfer non-essential power from the main generator to the startup transformer. Also, loss of a DC bus reduces reliability by removing one of the control power sources from ADS/SRV valves, CV torus inboard vent valve, and the MSIVs. Also, loss of Div. II DC causes a loss of the hardened torus vent path due to loss of the torus outboard vent valve.

(3) Both LODCI and LODCII use the same event tree.

(4) The PSA update uses two HEP values for DEP, 2.1 E-4 and 0.3.

(5) The PSA update uses two HEP values for CV 2.3 E-3 and 0.1.

(6) The PSA update uses several HEP values for alternate injection (or late injection - LI) varying from 0.14 to 0.54.

Table 3.11 SDP Worksheet for Duane Arnold — Loss of River Water (LORW)

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:**
Safety Functions Needed:	**Full Creditable Mitigation Capability for Each Safety Function:**
Power Conversion System (PCS)	1/4 Steam lines, 2/2 TBVs, Condenser, 1/2 Steam jet air ejectors, mechanical vacuum pump, 1/4 WW pumps, 1/2 Condensate pumps, 1/2 Reactor feedwater pumps (operator action = 2)
High Pressure Injection (HPI)	HPCI (1 ASD train) or RCIC (1 ASD train)
Depressurization (DEP)	3/6 valves (4 ADS and 2 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)
Containment Heat Removal (CHR)	No Credit
Containment Venting (CV)	CV through hardened torus vent path or 1/2 18" containment vent valves (operator action = 2)
Late Inventory Makeup (LI)	1/3 GSW pumps aligned for RPV injection (with 1/4 WW pumps) (operator action = 1)

Circle Affected Functions	**Recovery of Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Sequence**	**Sequence Color**
1 LORW - PCS - LI (3, 6)			
2 LORW - PCS - CV (4, 7)			
3 LORW - PCS - HPI - LPI (8)			
4 LORW - PCS - HPI - DEP (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.

<u>Notes</u>:

(1) A Loss of River Water has an initiating event frequency of 7.5 E-4 events per reactor-year. Operators are directed to manually scram the reactor on a LORW due to the significance of the event.

(2) LORW causes a loss of: circulating water makeup (and a subsequent loss of the main condenser), ESW, and RHRSW. The Well Water (WW) System is a possible backup to the RW System but requires operator action per the AOPs. In order to remove decay heat, the operators have the option for: some initial cooldown with the main condenser, some possible later use of the main condenser (with operator action to run the mechanical vacuum pump and to maximize WW), and use of CV. Also lost with the LORW are: EDGs (due to no ESW), the SP cooling mode of RHR (due to no RHRSW), and the CS pumps (due to no ESW). There is a possibility of still using the containment spray mode of the RHR System for the CHR function, but credit is not given in the PRA for this.

(3) The DAEC PRA gives credit for recovery of the RW System (0.1 probability of failure to recover).

(4) The PSA update uses two HEP values for DEP, 2.1 E-4 and 0.3.

(5) The PSA update uses two HEP values for CV 2.3 E-3 and 0.1.

Table 3.12 SDP Worksheet for Duane Arnold — 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 LPCI lines: Train A has check valve V20-0082 and 2 MOVs 2003 & 2004. Train B has check valve V19-0149 and 2 MOVs , MO-1905 & 1904.
Core Spray Injection Lines	Two CS lines: Train A has check valve V21-0072 and 2 MOVs MO-2115 & 2117. Train B has check valve V21-0073 and 2 MOVs MO-2135 & 2137.
RHR Shutdown Cooling Suction Line	One line with two NC MOVs, MO-1908 & 1909
LOC PATHWAYS:	
HPCI steam Line	One line with two NO MOVs, MO-2238 & 2239, but the steam line is high pressure design up to the turbine.
RCIC steam Line	One line with two NO MOVs, MO-2400 & 2401, but the steam line is high pressure design up to the turbine.
RWCU System Lines	Not discussed in IPE
Feedwater Lines	Two lines each with a check valve, a stop check valve, and a NO manual isolation valve
Main Steam Lines	Four steam lines, each with two MSIVs

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.

<u>Notes</u>:

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 is different from the other worksheets, in that an 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.

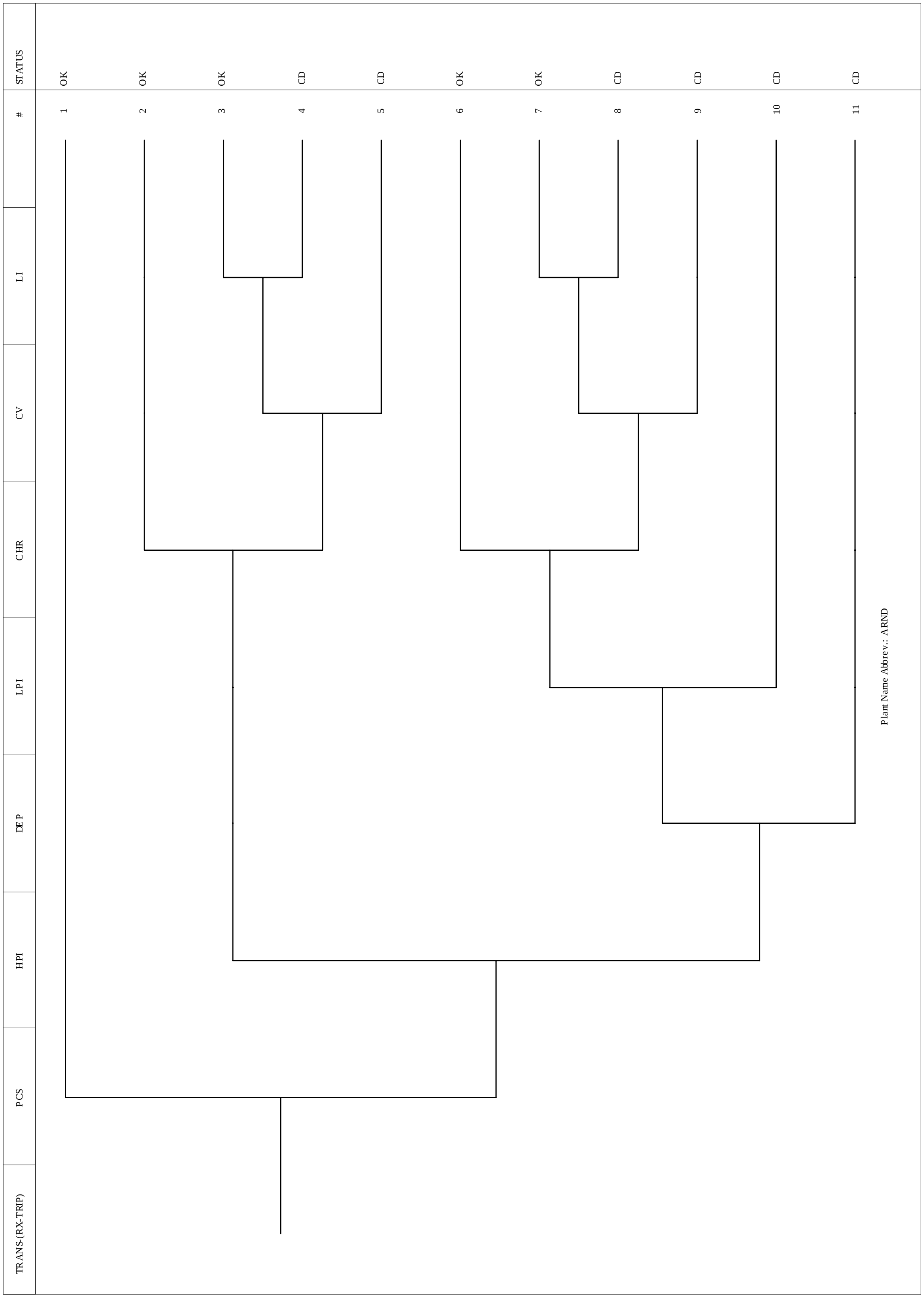
3. This worksheet contains pathways for both ISLOCA and LOC. Licensees typically analyze these events separately. In their IPE, DAEC analyzed ISLOCAs using an event tree and did not assume that all ISLOCAs lead directly to core damage. However, for the updated PRA the licensee stated that they no longer specifically model ISLOCAs in event trees. For the PRA ISLOCAs constitute less than 1% of total internal events CDF. For the IPE analysis LOCs are included within the LLOCA and MLOCA initiators. The updated PRA models LOC in a separate event tree (with a CDF of 5 E-8). The total of all classes of LOCAs constitutes 5% of total internal events CDF.

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. Transient (Reactor Trip) (TRANS)
2. Transients without PCS (TPCS)
3. Inadvertent Opening of Relief Valve (IORV)
4. Small LOCA (SLOCA)
5. Medium LOCA (MLOCA)
6. Large LOCA (LLOCA)
7. Loss of Offsite Power (LOOP)
8. Anticipated Transients Without Scram (ATWS)
9. Loss of DC Power (LODC)
10. Loss of River Water (LORW)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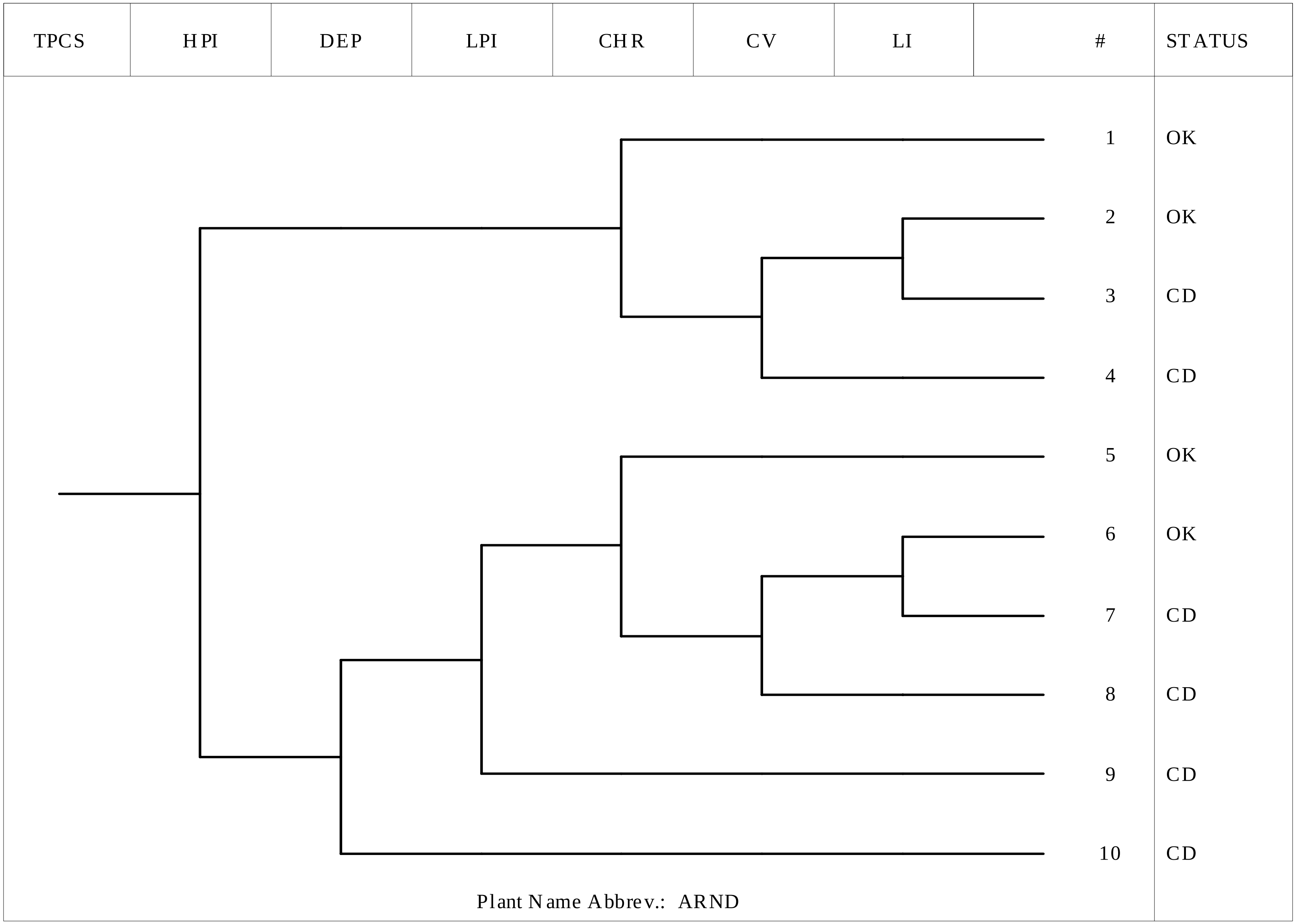
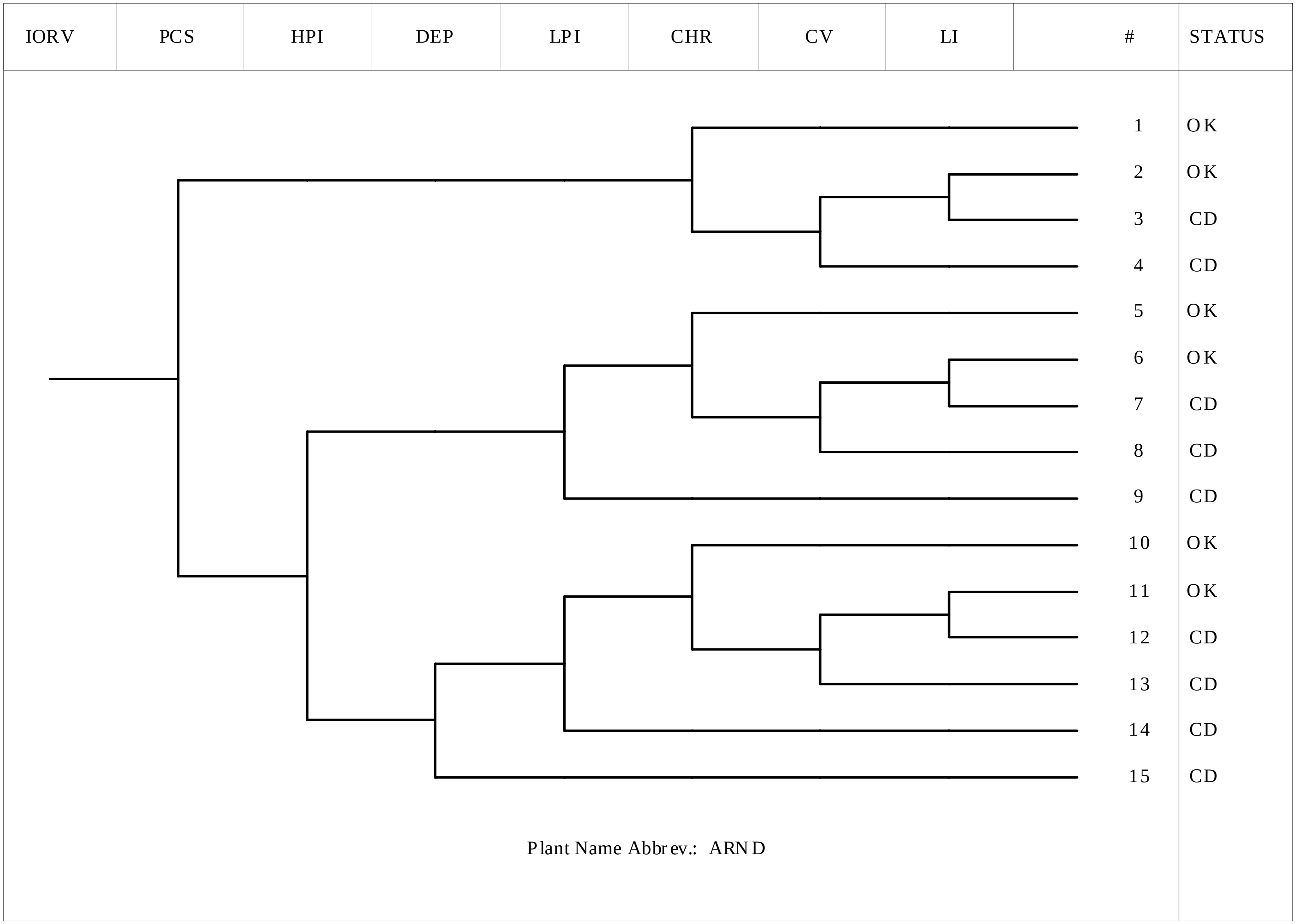
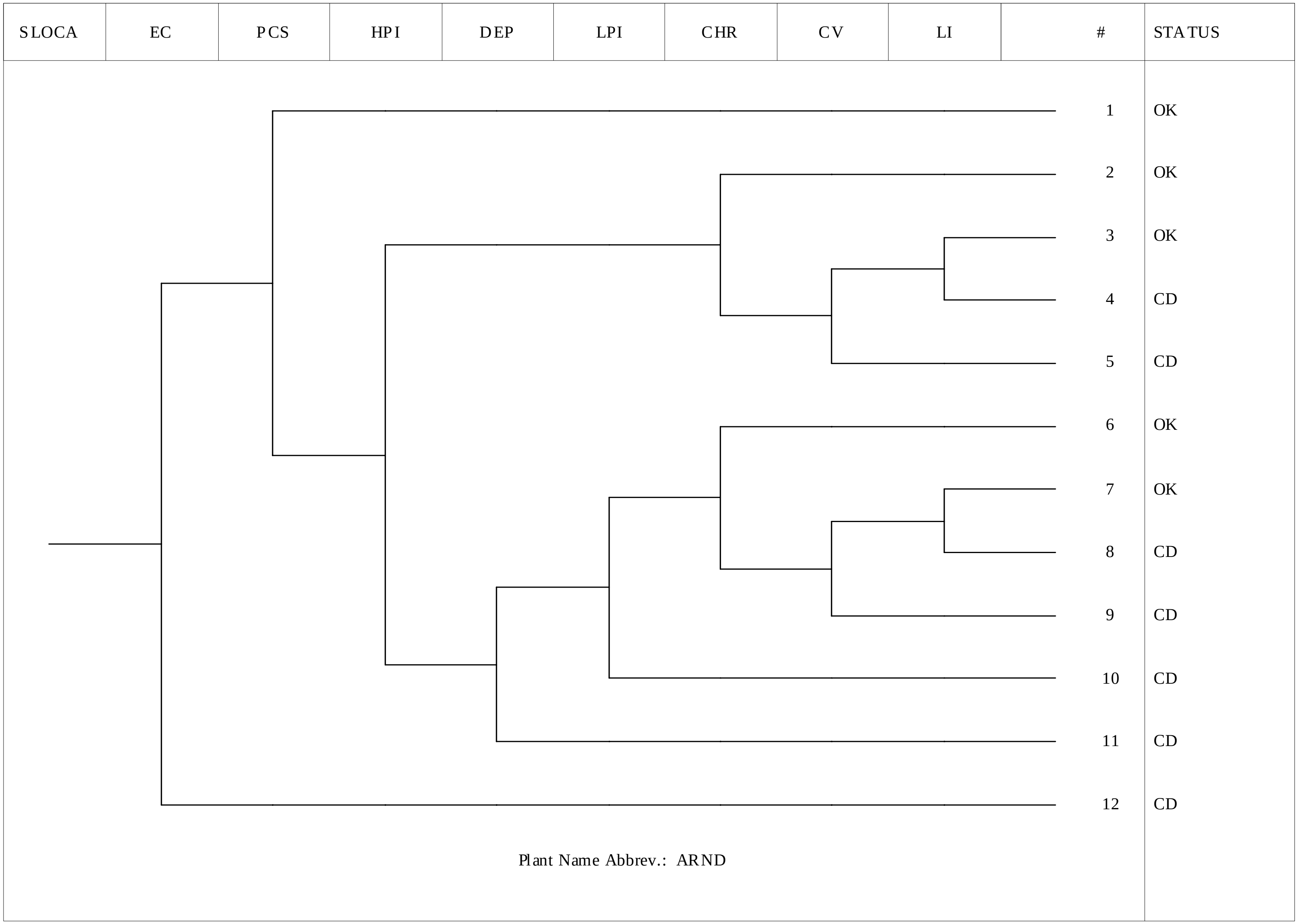
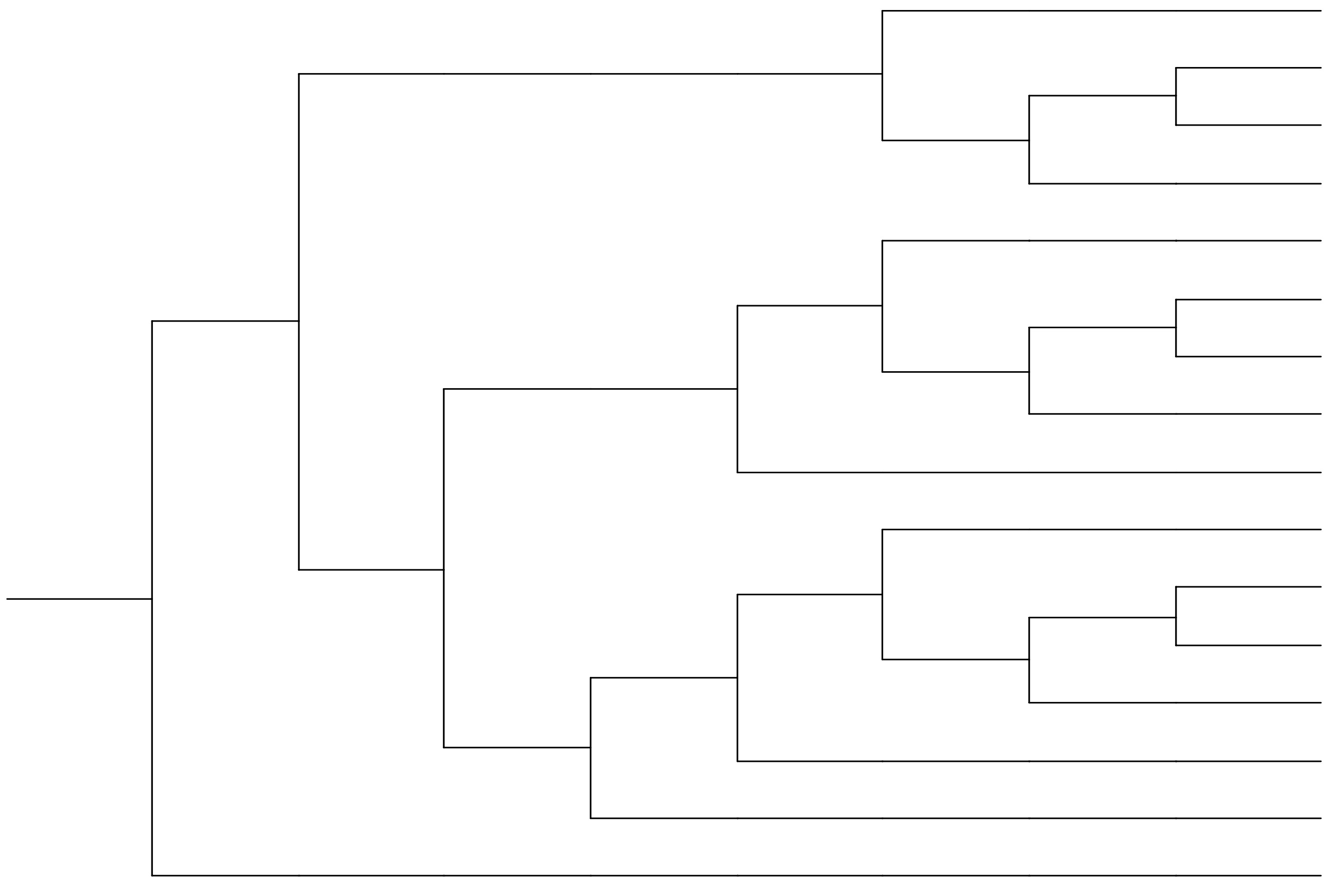
#
LI
CV
CHR
LPI
DEP
HPI
PCS
TRANS-(RX-TRIP)
1 OK
2 OK
3 OK
4 CD
5 CD
6 OK
7 OK
8 CD
9 CD
10 CD
11 CD
Plant Name Abbrev.: ARND


TPCS
HPI
DEP
LPI
CHR
CV
LI
#
STATUS
1 OK
2 OK
3 CD
4 CD
5 OK
6 OK
7 CD
8 CD
9 CD
10 CD
Plant Name Abbrev.: ARND


IORV
PCS
HPI
DEP
LPI
CHR
CV
LI
#
STATUS
1 OK
2 OK
3 CD
4 CD
5 OK
6 OK
7 CD
8 CD
9 CD
10 OK
11 OK
12 CD
13 CD
14 CD
15 CD
Plant Name Abbrev.: ARND


SLOCA
EC
PCS
HPI
DEP
LPI
CHR
CV
LI
#
STATUS
1 OK
2 OK
3 OK
4 CD
5 CD
6 OK
7 OK
8 CD
9 CD
10 CD
11 CD
12 CD
Plant Name Abbrev.: ARND

MLOCA	EC	PCS	HPI	DEP	LPI	CHR	CV	LI	#	STATUS



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2	OK
3	CD
4	CD
5	OK
6	OK
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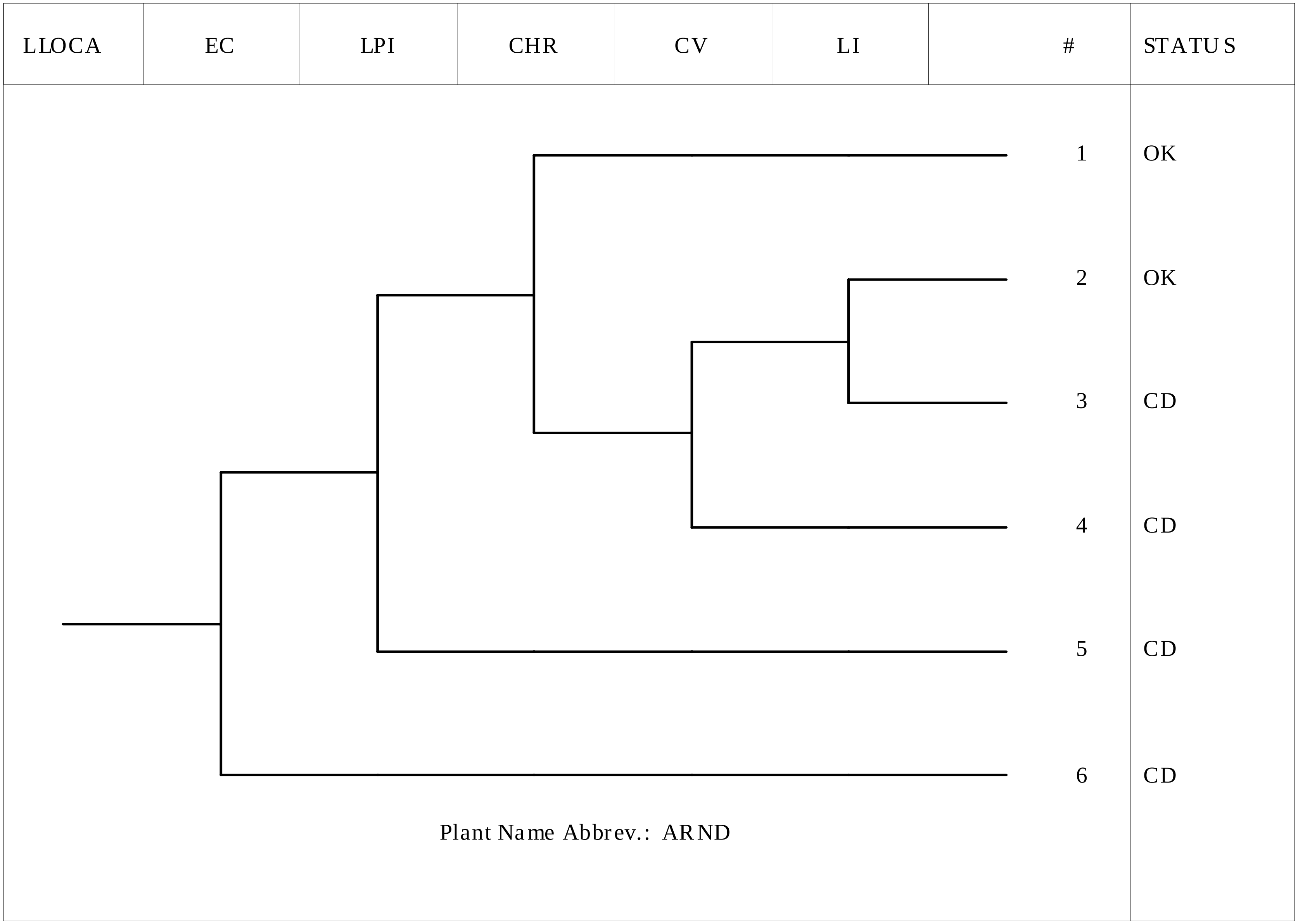
10	OK
11	OK
12	CD
13	CD
14	CD
15	CD
16	CD

Plant Name Abbrev.: ARND


LLOCA
EC
LPI
CHR
CV
LI
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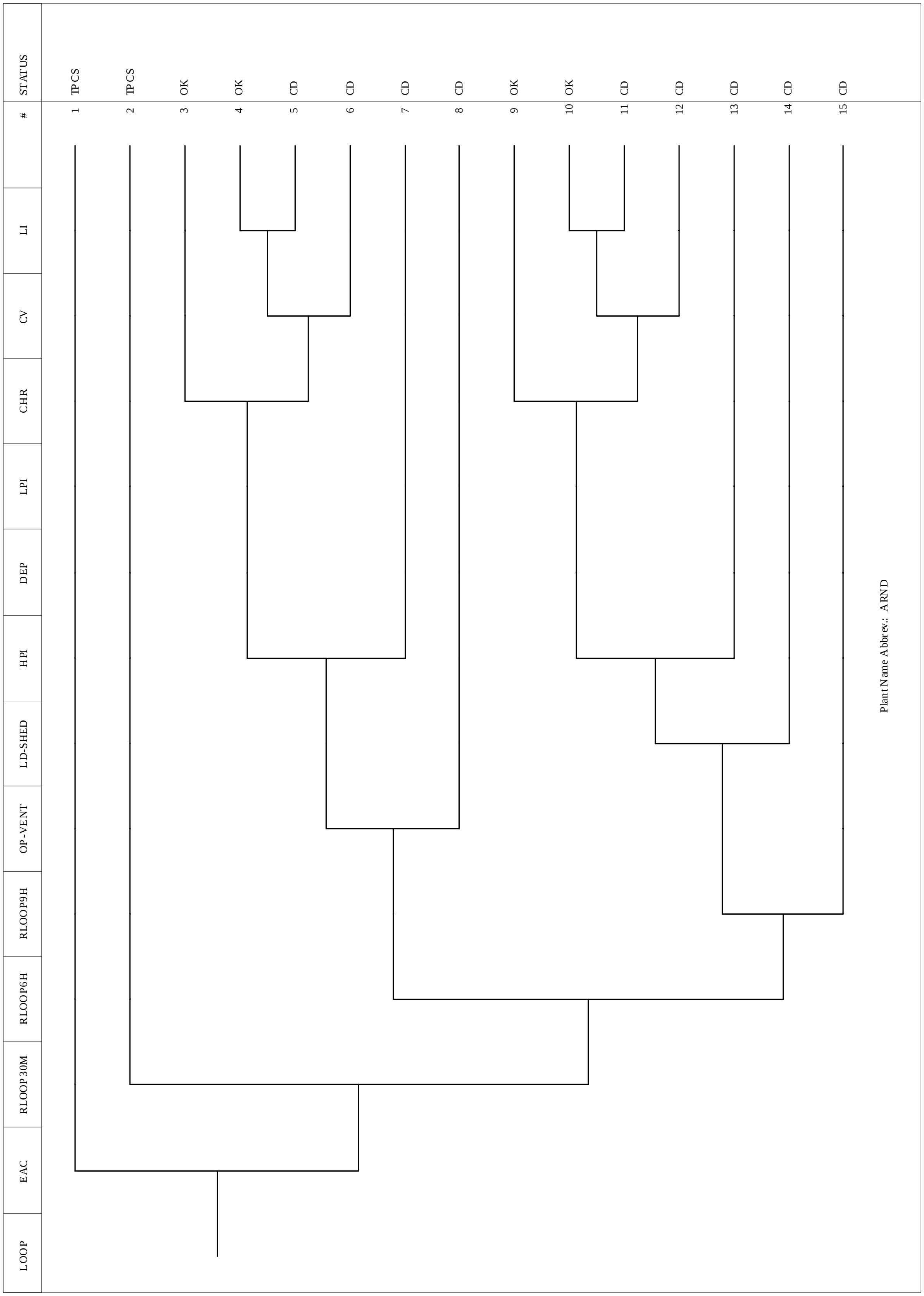
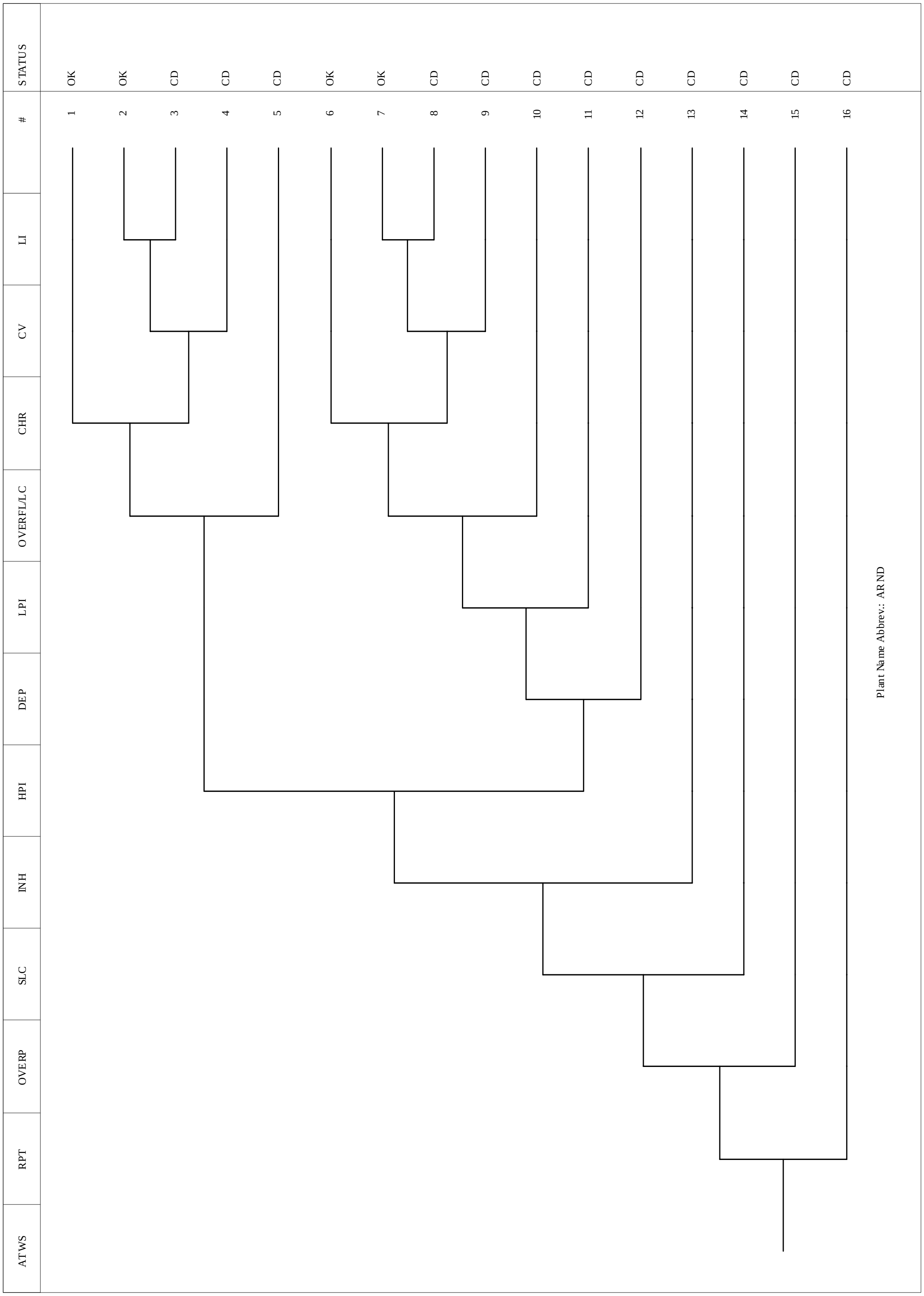
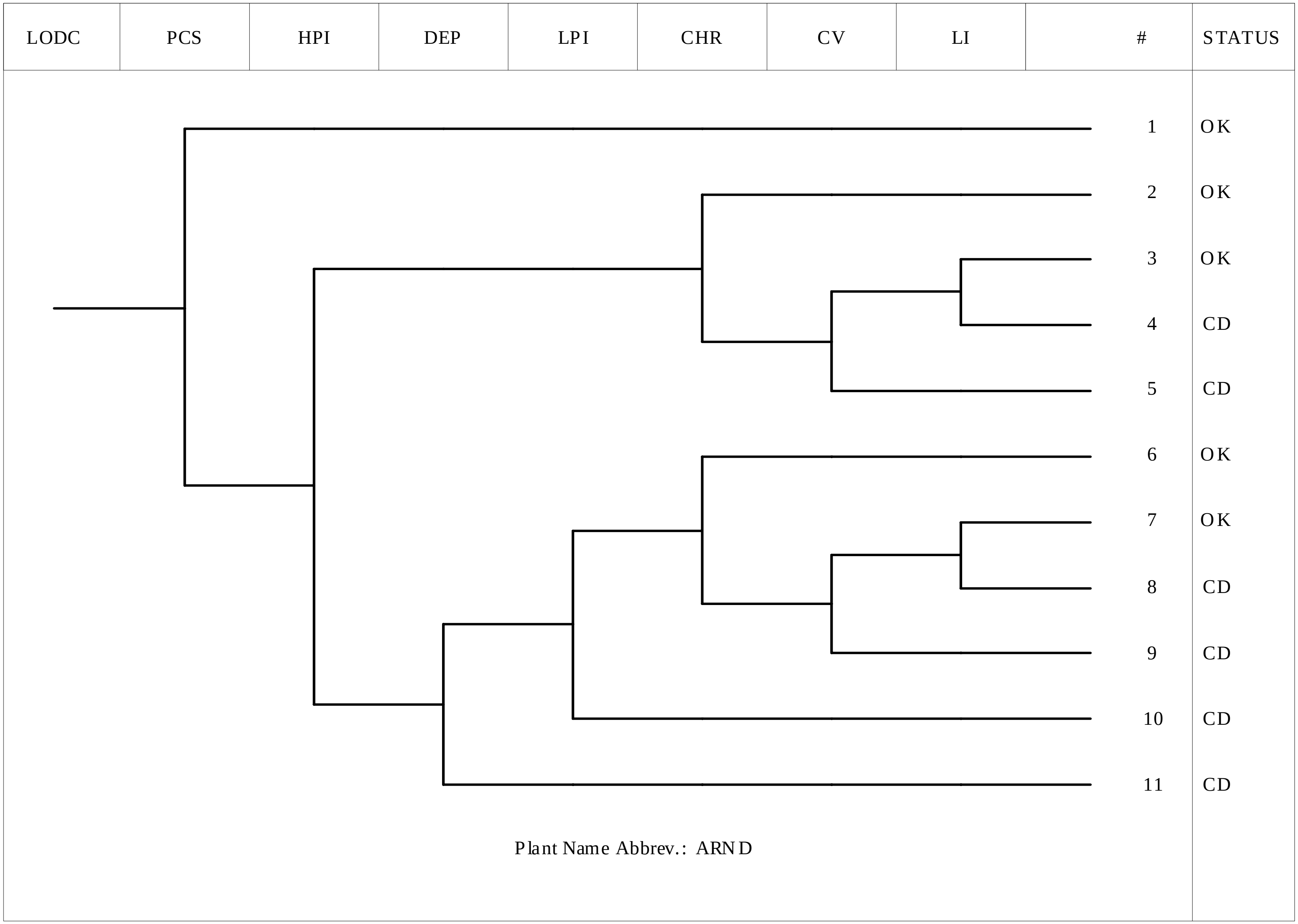
6 CD
Plant Name Abbrev.: ARND



LOOP
EAC
RLOOP30M
RLOOP6H
RLOOP9H
OP-VENT
LD-SHED
HPI
DEP
LPI
CHR
CV
LI
#
STATUS
1 TPCS
2 TPCS
3 OK
4 OK
5 CD
6 CD
7 CD
8 CD
9 OK
10 OK
11 CD
12 CD
13 CD
14 CD
15 CD
Plant Name Abbrev.: ARND



ATWS
RPT
OVERP
SLC
INH
HPI
DEP
LPI
OVERFL/LC
CHR
CV
LI
#
STATUS
1 OK
2 OK
3 CD
4 CD
5 CD
6 OK
7 OK
8 CD
9 CD
10 CD
11 CD
12 CD
13 CD
14 CD
15 CD
16 CD
Plant Name Abbrev.: ARND


LODC
PCS
HPI
DEP
LPI
CHR
CV
LI
#
STATUS
1 OK
2 OK
3 OK
4 CD
5 CD
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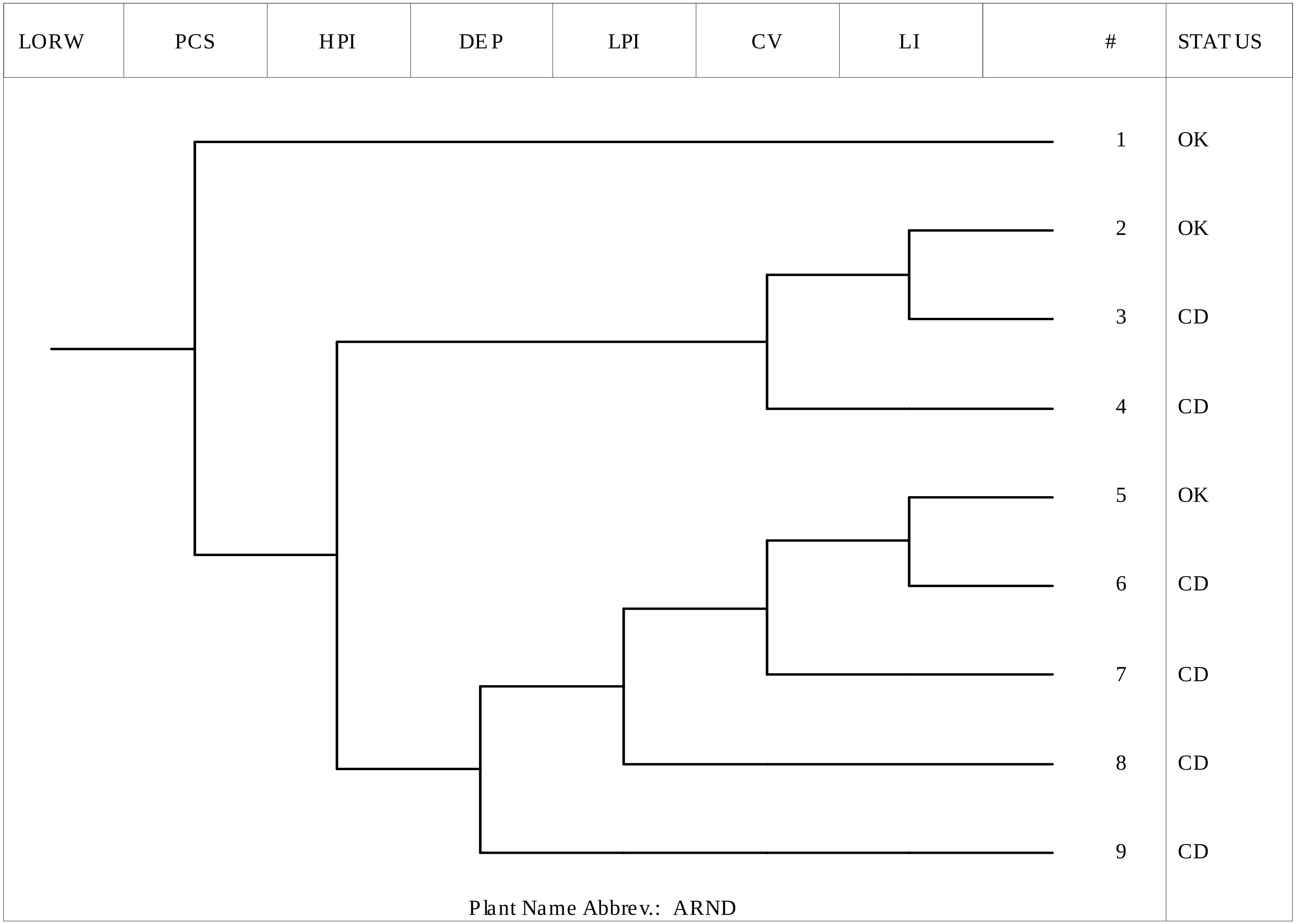
10 CD
11 CD
Plant Name Abbrev.: ARND


LORW
PCS
HPI
DEP
LPI
CV
LI
#
STATUS
1 OK
2 OK
3 CD
4 CD
5 OK
6 CD
7 CD
8 CD
9 CD
Plant Name Abbrev.: ARND

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 (BWRs)

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

The present update addresses both generic resolution of comments received from across the industry, general changes in format, and plant specific comments. Below, are summarized the important plant-specific comments.

Initiating Event Table and System Dependency Table:

The format was changed to the new standard format. Added plant specific IE frequency for loss of a DC bus and loss of River Water. The numbers of major components was added. Lines were added for Fuel Oil Transfer, Nitrogen System, Instrument Air, RBCCW, and HVAC. Coverage of HVAC was expanded. The support systems were updated. Clarified the cooling water system arrangements in notes. Additional explanatory notes were added the table. The initiating event scenarios were updated. Added RWCU isolation to the support systems for SLC. Changed to include only direct dependencies on a given system's line.

SDP Worksheets:

A worksheet was added for IORV. Also added the special initiator worksheets LORW, and LODCI and LODCII. Added a new worksheet for ISLOCA and LOC.

The components for PCS were expanded. Changed the treatment of alternate injection sources to correlate more closely with that of other BWR-4 plants. For example injection with RHRSW and GSW was moved to the LI function rather than the LPI function. These would correspond to the VI and QUV functions of the DAEC updated PSA. Changed the characterization of torus and drywell spray cooling for the CHR function from a high stress operator action to a multi-train system. Added more descriptive information to the CV function. Changed the number of SRVs required for DEP from 2 to 3.

Added early containment control (EC) function to the SLOCA. Clarified the number of vacuum breakers required for successful EC. Added the relation between a SORV and LOCA size. Added RW as required for CHR.

Clarified the credited mitigation capability as far as trains are concerned. Completely redid the LOOP worksheet and ET, based upon information from the licensee based on Rev. 4 of the DAEC PRA, the LOOP event trees dated 6/4/97 (20 pages), and the LOOP/SBO Event Tree Notebook dated August 1994 (provided by the licensee in March 2001). Redid the ATWS ET and worksheet based upon the DAEC provided information and the latest standard BWR worksheet methods.

Developed the LODC worksheet and ET based on excerpts from the 125 VDC Event Tree Notebook, and a list of systems supported by 125 VDC provided by the licensee on 3/28/01.

REFERENCES

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

2. Iowa Electric Light & Power Co., Duane Arnold Energy Center (DAEC) – Individual Plant Examination Report, dated November, 1992.

3. IES Utilities Inc. Response to Request for Additional Information on IPE, with letter from IES to NRC dated June 26, 1995.

4. SDP Worksheet Comments for Duane Arnold in memo from Mike Parker, SRA, Region III to Jose Ibarra, RES dated April 24, 2000 based on site visit to Duane Arnold. Contains information from Rev. 4 of DAEC PRA.

5. LOOP/SBO Event Tree Notebook dated August 1994.

6. Excerpts from the 125 VDC Event Tree Notebook, C1249309-080995.