April 29, 2002

NOTE TO: Cynthia Carpenter, Chief
Inspection Program Branch
Division of Inspection Program Management
Office of Nuclear Reactor Regulation

Patrick D. O'Reilly
Operating Experience Risk Applications Branch
Division of Risk Analysis and Applications
Office of Nuclear Regulatory Research

FROM: Mark F. Reinhart, Chief**/Signed by M. Caruso for**
Licensing Section
Probabilistic Safety Assessment Branch
Division of Systems Safety and Analysis
Office of Nuclear Reactor Regulation

SUBJECT: RESULTS OF THE ARKANSAS NUCLEAR ONE UNIT 2 SDP PHASE 2 NOTEBOOK BENCHMARKING VISIT

During November, 2001, NRC staff and a contractor visited the Arkansas Nuclear One (ANO) Plant site to compare the ANO Unit 2 Significance Determination Process (SDP) Phase 2 notebook and licensee's risk model results to ensure that the SDP notebook was generally conservative. ANO Unit 2's PSA did not include external initiating events; and therefore, no sensitivity studies were performed to assess the impact of these initiators on SDP color determinations. In addition, the results from analyses using the NRC's draft Revision 3i Standard Plant Analysis Risk (SPAR) model for ANO Unit 2 were also compared with the licensee's risk model. The results of the SPAR model benchmarking effort will be documented in a separate a trip report to be prepared by the Office of Nuclear Regulatory Research.

In the review of the ANO Unit 2 SDP notebook, it was found that some changes to the SDP worksheets were needed to reflect how the plant is currently designed and operated. Forty-one hypothetical inspection findings were processed through the SDP notebook. Results from this effort indicated that the total risk impacts modeled in the SDP notebook were underestimated by 17 percent, overestimated by 49 percent, and adequately estimated by 34 percent. The reviewers found that if fourteen fixes were made to the SDP notebook, the results would be 14 percent underestimation, 42 percent overestimation, and 44 percent adequate estimation of risk impacts.

Attachment A describes the process and results of the comparison of the ANO Unit 2 SDP Phase 2 Notebook and the licensee's PSA.

If you have any questions regarding this effort, please contact See-Meng Wong.

CONTACT: S. Wong, SPSB/DSSA/NRR
301-415-1125

Attachments: As stated

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SUMMARY REPORT ON BENCHMARKING TRIP TO

Arkansas Nuclear One Unit-2 (Nov 27-29, 2001)

M. A. AZARM (BNL)
T. PRUETT (NRC)
S. M. WONG (NRC)

December 2001

Attachment A

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1. Introduction

A benchmarking of the Arkansas Nuclear One Unit 2 (ANO-2) SDP Risk-Informed Inspection Notebook was conducted during a plant site visit on November 27-29, 2001. NRC staff (Troy Pruett and See Meng Wong) supported by BNL staff (M. A. Azarm) participated in this benchmarking exercise.

In preparation of the plant site visit, BNL staff reviewed the ANO-2 SDP notebook and evaluated a set of hypothetical inspection findings using the Rev 0 SDP worksheets, plant system diagrams and information in the licensee's updated PSA. A copy of the site visit agenda was sent to the licensee by NRC staff prior to the meeting.

The major activities performed during this plant site visit were:

1. Discussed licensee's comments on the Rev 0 SDP notebook.

2. Obtained listings of the Risk Achievement Worth (RAW) values for basic events for of the internal event PRA model for average maintenance at model.

3. Identified a target set of basic events for the benchmarking exercise.

4. Performed benchmarking of the Rev 0 SDP worksheets with considerations of the licensee's proposed modifications to the SDP notebook.

5. Identified areas of discrepancies and reviewed the licensee's PSA model to determine the underlying reasons. Proposed additional changes to the SDP notebook, if appropriate.

6. Performed a benchmarking exercise using the Revision 3i SPAR model for the ANO Unit 2 plant

The benchmarking exercise provided insights for significant improvement to the SDP notebook. The revised SDP notebook should provide either similar or more conservative significance characterization (i.e., color) than the licensee's PRA model in about 86% (i.e. 14% underestimation) of the cases analyzed. Further investigation into those cases of underestimation revealed that some of the cases could be explained by different assumptions between the SDP worksheets and the updated PSA. Two out of the six cases that were underestimated resulted from a very conservative assumption in the licensee's PSA. Two more cases of the underestimation might have resulted in a way the RAW values for the recovery actions are calculated (i.e., the RAW values could be high). The remainder two cases could not have been explained. For these two cases, similar accident sequences were modeled in both SDP worksheets and the plant PSA. The PSA generated a large number of cutsets, which when added resulted in bigger RAW values (PSA level of detail). Therefore, we assume that these two cases are true underestimations of the risk significance by the SDP notebook. However, it should be noted that for the two cases in question, the SDP notebook resulted in a "Green next to White" and "Green" instead of the PSA equivalent of "White" and "White", respectively.

The SDP benchmarking also identified two cases, for the turbine bypass valve failure to open and ISO/EQ function in SGTR worksheet, where the SDP worksheet overestimated the risk significance by two orders of magnitude. Further investigation into the underlying reason for this overestimation indicated some differences between the SDP worksheet and that of the licensee's PSA. Most importantly, the licensee's PSA credit both the turbine bypass valves and the ADVs for the intact Steam Generator for the purpose of ISO/EQ function and cool down in the Steam Generator Tube rupture scenarios. The SDP currently credits only the turbine bypass valves. The appropriate modifications in SDP worksheet, as will be discussed in the next Section, would eliminate this highly conservative color estimation.

2. Summary Results from Benchmarking

This Section provides the results of the benchmarking exercise. The results of benchmarking analyses are summarized in Table 1. Table 1 consists of five column headings. In the first column, the out-of-service components (human and recovery actions) are identified for the case analyses. The second and the third column shows the RAW values and the associated colors based on the licensee's latest PSA model. The colors assigned for significance characterization from using the Rev 0 SDP worksheets, before incorporation of the licensee's comments, are shown in the fourth column. Finally, the colors assigned for significance characterization from using the SDP worksheets after incorporation of the licensee's comments, are shown in the fifth column. Review of the differences in the assigned colors shown in the third and fifth columns were performed to identify the underlying reasons for these differences. These reasons are:

1. The ANO1 Unit 2 is equipped with both inboard and out board ADVs. The ADVs are normally isolated during operation and require operator action to open. The Main Steam Safety valves (MSSVs) are the first to respond to a transient. The success criteria is 1/10 MSSVs. The operation of ADVs can be credited as a back up to safety valves. Per SDP rule, an inspection finding on ADVs would require that all sequences involving the steam relief to be counted. Since failure of all 10 MSSVs to close is a very unlikely event, the SDP rule for this case would result in an unnecessary overestimation of the significance characterization involving ADVs. This SDP rule may be revised to account for the sequences only if the remaining mitigation capability is a redundancy of two or less (i.e., the success criteria can be satisfied with half of the equipment available).

2. In SGTR, when the operator fails to isolate and equalize the affected SG, he will attempt to conduct cool down using secondary and establish the SDC mode through 1/2 LPI system. This operator action is currently credited as “1" in the SDP worksheet. The licensee's PSA models this action through four distinct events, with the sum total of all operator actions of about 8.5 E-4. It is proposed that an operator action credit of “2" to be given to SDC function in SGTR. This would result in a Yellow color determination for the event ISO/EQ rather than Red.

3. In SGTR, the operation of turbine bypass valves is required for ISO/EQ function in the SDP worksheet. Comparison of the licensee's PSA models and discussion with the licensee staff indicated that if the turbine bypass valves were not available, the operator would use ADVs to conduct the ISO/EQ function. Incorporation of this modification to the SDP notebook would result in a Green next to White (G/W) for turbine bypass valve rather than the current Red color.

4. Licensee's PSA assumes that if the MSSV fails to re-close when demanded, the affected SG cannot be used for cooling and it would be isolated. This is a conservative assumption in a part of the licensee's PSA, which significantly affect the mitigation credit for EFW and PCS. As a result, the Feed and Bleed operation would be required more frequent than expected. This has resulted in the licensee's high RAW values for feed and bleed function, MSSVs fail to re-close, and PCS function. The SDP worksheet will

not be modified to be consistent with the licensee's PSA, since this assumption appears to be unnecessary restrictive.

5. The time dependent recovery and operator actions are modeled in licensee's PSA in a dynamic manner, accounting for the sequences of the failures in the associated minimal cutsets. The number of run failures of the components in the minimal cutset would have a major impact on the time available for the recovery and/or the manual actions. Therefore, there is no single event that can be explicitly assigned to the probability of a recovery/manual action. The licensee PSA uses an implicit quantification routine, which is triggered by a screening value for the associated operator/recovery action. SDP worksheet, on the other hand, uses a simple fixed time recovery action model. Therefore, there is no one-to-one correspondence between such basic events in licensee's PSA and the SDP notebook. This is the case for REC1 and REC10 basic events in the Table 2. The slight underestimation presented in the table could have resulted from the selection of the associated basic events, which does not reflect the complexity of the calculations used in the PSA model.

6. Loss of Nuclear side of CCW will result in a transient with the potential of a catastrophic RCP seal failure if the operator fails to trip the pumps. This event should be treated as a special initiator and an associated worksheet and event tree should be added.

In addition to the above items, the licensee's PSA currently does not use a logic model for evaluating the frequency of the special initiators. Therefore, some SDP overestimation could result; since per SDP rule, the special initiator frequency would be raised by one or two order of magnitude depending on the inspection finding on the related systems.

A comparative summary of the benchmarking results is provided on Table 2. Table 2 shows the number of cases where the SDP was more or less conservative, i.e., the SDP matched the outcome from the licensee's PRA model. The associated percentage of differences found for the 43 analyzed cases are also shown on Table 2. It is concluded that the SDP Notebook could capture at least 86% of the significant inspection findings (see Table 2 summation of the cases matched and overestimated). This conclusion should be tempered by the discussions above. The final version of the revised SDP notebook should capture at least 94% of the true significance of inspection finding (either true color or more conservative).

Table 1: Comparison of Sensitivity Calculations between SDP Phase 2 Worksheets and ANO-2 RAWs

CDF 1.1E-5, W= 1.09, Y= 1.91, R= 10.1
TRUNCATION=1E-9

Basic Event Name	RAW	Plant CDF & Color	SDP Before	SDP After	Comments
4160 A3 %T12	15.61	R	R-M	R-M	
4160 A4 %T13	1.03	G	W-O	W-O	
4160 A1 NONSAFETY ETM2A1XXXX	1.7	W	W-M	W-M	
ACW SMM2LSWACW	1.09	W	G/W-U	G/W-U	True underestimate. The SDP rule for evaluating PCS is currently under consideration.
ADV PCC2DADVFC	1.02	G	Y-O	Y-O	High redundancy of the MSSVs should be considered and SDP rule may be changed. This would result in G/W for ADVs fail to open (See note 1 in Section 2). (G/W-M)
AFWMD ZHF2AFWMSP	4.0	Y	R-O	R-O	
BATT 1 DMM202D11F	29	R	R-M	R-M	
BATT 2 DTM2002D12	2.28	Y	Y-M	Y-M	
NON NUCLEAR CCW XMM22E22BK	1.03	G	N/A	G/W-M	
CHARGER 2 DMM2D031AF	1.0	G	Y-O	W-O	
CHARGER 1 DMM2D031AF	1.0	G	Y-O	W-O	

CHARGING PUMP NOT MODELED	N/A	N/A	G-	G-	
CSS TRAIN ETM2B6XXXX	2.39	Y	R-O	R-O	
DC 1 %T10	11.62	R	R-M	R-M	
DC 2 %T11	6.32	Y	R-O	R-O	
EDG ALT ZHF2AACSTP	1.59	W	G/W-U	Y-O	
EDG EDG2DG2XXA	1.16	W	Y-O	Y-O	
EFWMD Train B QTM2EFWTBF	4.29	Y	R-O	Y-M	
EFWTD Train A QTM2EFWTAF	1.38	W	Y-O	Y-O	
HPI TRAIN HMM2ACTMPB	4.35	Y	R-O	R-O	
HPR TRAIN YMM2CSTRAK	1.98	Y	R-O	R-O	
IA ICC2IASCMF	1.03	G	G/W-M	G/W-M	
ISO/EQ ZHF2MSSVGP	1.15	W	R-O	R-O	Modification proposed in note 2 of Section 2 would result in Yellow color for this event. (Y-O)
FEED AND BLEED FUNCTION	100	R	Y-U	Y-U	Per discussion provided in note 4 of Section 2, the assignment of Yellow color is appropriate (Y-M).
LPI TRAIN	1.03	G	G/W-M	G/W-M	
LSWP4A SERVICE WATER 1 %T8	1.79	W	W-M	W-M	

LSWP4C SERVICE WATER 2 %T9	1.66	W	R-O	W-M	
LSW %T‘	76	R	R-M	R-M	
LTOP/ECCS VENT LINE 1 RMM2LTOPL1	1.66	W	W-M	W-M	
MSIV 2 FTC FUNCTION (ONE VALVE FAILS)	1.11	W	G-U	G-U	Reason not known for the discrepancy. It is currently considered to be a true underestimation.
MSIV 1 FTC FUNCTION (2 VALVES FAIL) PCC2MSIVFO	25.36	R	R-M	R-M	
PCS %T2	1.69	W	G/W-U	G/W-U	The result of two effects. Per discussion provided in note 4 of Section 2, the assignment of the color by the licensee's PSA is conservative. Proposed modification in SDP rule for evaluating PCS, which is currently under consideration, could also impact the color determined by the SDP notebook.
PSV FTC RCSRV	26.51	R	R-M	R-M	
PSV FTO NOT MODELED	N/A	N/A	W-	W-	
RAS ACC2RAS24A	917	R	R-M	R-M	
1 TRAIN CFC (RBC) GMM2SWVL2M	1.0	G	Y-O	W-O	
RCP TRIP 2HF2RCPTRP	8.07	Y	R-O	R-O	
REC 10 ZHF2LOSPBP	3.31	Y	W-U	W-U	Per discussion of note 5 of Section 2, the SDP color may be appropriate for this event.

REC 1 ZBN1RUNF	1.17	W	G/W-U	G/W-U	Per discussion of note 5 of Section 2, the SDP color may be appropriate for this event.
SDCHX YMM2SWHXAF	1.0	G	W-O	W-O	
SIT	1.0	G	G/W-M	G/W-M	
MSSV FTC PRY201052T	10.37	R	N/A	N/A	
MSSV FTO PRY2V1002N	1.0	G	N/A	G/W-M	
TURBINE BYPASS VALVES PMM2TBV302	1.0	G	R-O	R-O	Per discussion of note 2 of Section 2, failure of TBVs will not result in failure of ISO/EQ function. Incorporation of this change to Rev 1 notebook would result in G/W-M.
TURBINE TRIP NOT MODELED	N/A	N/A	W-	W-	
XFER A3 TO A1 ZHF2LOSPXP	1.13	W	Y-O	Y-O	
XFER A4 TO A2 ZHF2LOSPXP	1.13	W	Y-O	Y-O	
NUCLEAR CCW PUMP XMP22P33A	1.34	W	N/A	N/A	Addition of LNCCW special tree to Rev 1 SDP as it will be discussed in Section 3 would result in a Yellow color from 3 Whites (Y-O).

Table 2: Comparative Summary of the Benchmarking Results

Total Number of Cases Compared	**SDP Notebook Before (Rev 0)**		**SDP Notebook After (Rev 1)**	
	Number of Cases (41)	Percentage	Number of Cases (43)	Percentage
SDP: Less Conservative	7	17%	6	14%
SDP: More Conservative	20	49%	18	42%
SDP: Matched	14	34%	19	44%

3. Proposed Revisions to Rev 0 SDP Notebook

Based on insights gained from the plant site visit, a set of revisions is proposed for the Rev 0 SDP notebook. The proposed revisions are based on licensee comments on the Rev 0 SDP notebook, better understanding of the current plant design features, consideration of additional recovery actions, use of revised Human Error Probabilities (HEPs) and initiator frequencies, and the results of benchmarking.

3.1 Specific Changes to the Rev 0 SDP Notebook for ANO Unit 2

The licensee provided several comments for minor revisions to the SDP Notebook. The suggested changes mainly dealt with the dependency matrix, updated footnotes associated with the worksheets, and revised HEP values. All of these changes will be incorporated in the SDP worksheets. In addition, several major revisions that directly impacted the color assignments by the SDP evaluation were discussed with the licensee and their resolutions were identified in the meeting. The proposed revisions are discussed below:

1. Either loss of Loop 1 or loss of Loop 2 service water is to be considered special initiators. The frequency of these special initiators including the recovery credit is currently assigned to ROW III of Table 1. Per licensee's PSA, these two initiators should be moved to Row II. This is based on the hardware failure frequency of 1.38E-1 per year per loop, and a recovery action credit of 1 for aligning the standby pump.

2. The special initiator of LOOP1EDG should be moved from Row IV to Row V and it should be defined as the most conservative case of extended loop with loss of "red" EDG and the alternate EDG. The worksheet should be modified to properly account for the impact (e.g., MDEFW train should not be credited).

3. Add a footnote in Table 1 indicating that the loss of ACW and IA should be treated as TPCS. Divide CCW to nuclear (loop 2) and non-nuclear (loop 2) in Table 2. Indicate in the footnote of Table 1 indicate that loss of non-nuclear side of CCW should be treated similarly to TPCS. Add a special initiator for LNCCW (loss of nuclear side of CCW) in ROW III of Table 1. Develop the event tree and the worksheet for the LNCCW.

4. Table 2 should indicate that the preferred feed path for MDAFW pump is through EFW header A or B, with MFW header as the back up option. Therefore, the MDAFW pump could be credited in scenarios where the MFW header may not be available such as LOOP scenarios.

5. Table 2 should indicate that there are two battery chargers per battery; one charger is normally aligned and the backup charger is manually aligned if needed. Furthermore, the licensee's PSA assumes that the battery charger is capable of taking the starting loads during safety injection actuation. In reality, there is about two seconds during a DBA that the starting loads exceed the charger capability and the charger would enter a current limiting mode. Therefore, the SDP would credit the chargers for picking up the starting loads consistent with the licensee's PSA.

6. Make a note in Table 2 that ADVs are normally isolated and require operator action. The preferred path for steam relief is through main steam safety valves. Globally change the worksheet to show main steam safety valves as the preferred path.

7. Globally change the worksheet to show that CSR is auto-aligned by RAS.

8. In the Loop worksheet, credit the MDAFW pump and footnote that it requires the availability of the alternate EDG.

9. In SGTR worksheet, explicitly add ADVs as a backup steam relief path for ISO/EQ function. Change the operator action for PCS to 1. Change operator action for SDC to 2.

10. In ATWS worksheet, do not credit the manual operation of MDAFW pump and modify the success criteria for steam relief to 8/10 MSSVs.

11. In LSW, change the credit for RCPTRIP to 3 to be more consistent with the licensee's PSA and the generic operator credit for CE plants.

12. For loss of DC bus 2D01 and similarly for 2D02, change the credit for XFER to 2 and add a footnote saying that this accounts for three potential manual transfer to alternate EDG, offsite power, or cross over 2A4 to 2A3. Indicate that about one hour is available for such a recovery action. Modify footnote 1 to state that loss of DC bus may not result in a plant trip but it is currently assumed as a special initiator in the licensee's PSA.

13. Remove RCPTRIP from loss of loop 2 of SW and the associated sequences. The nuclear side CCW can be fed from either SW loop.

14. Add a footnote in Table 2 stating that the swing HPSI pumps require room cooling in both injection and recirculation but not the dedicated pumps.

Since loss of the nuclear side of CCW is not currently a special initiator in the licensee's PSA, there is no information available on the frequency of such initiator. To estimate the initiator frequency for the purpose of the SDP worksheets, the following assumptions were made. The system was treated as one running pump and one standby pump. It is assumed that the standby pump referred here is the swing pump that is administratively aligned to the nuclear side of CCW. Therefore, it is assumed that the system is composed of one running and one standby train. This would result in an annual frequency of failure in the order of 1E-2 to 1E-3. Therefore, this special initiator is assigned to ROW III. Attachment 1 provides the new worksheet and the event tree for this initiator.

3.2 Generic Change in IMC 0609 for Guidance to NRC Inspectors

No specific recommendation for changes to IMC 0609 was identified as a result of this benchmarking exercise. However, three items were identified that can further improve the process. These are:

1. Additional training may be required for NRC inspectors to effectively use the SDP evaluation rules and a greater set of examples, could be provided.

2. Guidance is needed on how to evaluate the inspection finding relating to feed water and power conversion system. Two possible approaches can be considered: (a) set the TPCS initiator credit to zero and re-evaluate that worksheet, or (b) set a credit of zero for PCS as a mitigation capability. A third possibility is the combination of the earlier two possibilities. The power conversion system is a large system, and evaluation of inspection finding on this system needs further guidance. For the purpose of benchmarking the first option, i.e., setting the TPCS credit to zero is utilized.

3. The current counting rule allows the folding of green next to white and green-green next to white to arrive at a higher color. This practice appears sometimes to be useful in cases where the component has a marginal importance (i.e., at lower level of the white threshold). However, in general it results in a more conservative color. Since the SDP note book for ANO1 unit 2 has relatively larger number of sequences than other SDP notebooks, the degree of conservatism resulting from the counting rule is more magnified. One solution to this problem might be modifying the rules such that to reduce conservatism (e.g., considering 5 G/W s to be equivalent to one White instead of current 3 G/W s).

3.3 Generic Change to the SDP Notebook

No generic change was identified. The NRC participants strongly emphasized that the format of the Rev 1 SDP notebooks should be carefully designed incorporating all insights gained so far prior to issuance of a Rev 1 notebook.

4. Discussion on External Events

The PSA for ANO1 Unit 2 currently does not include the external events. Therefore, no activity was performed on this item during the benchmarking site visit.

Attachment 1

The Worksheet and the Event Tree for LNCCW to be Incorporated in Rev 1 SDP Notebook

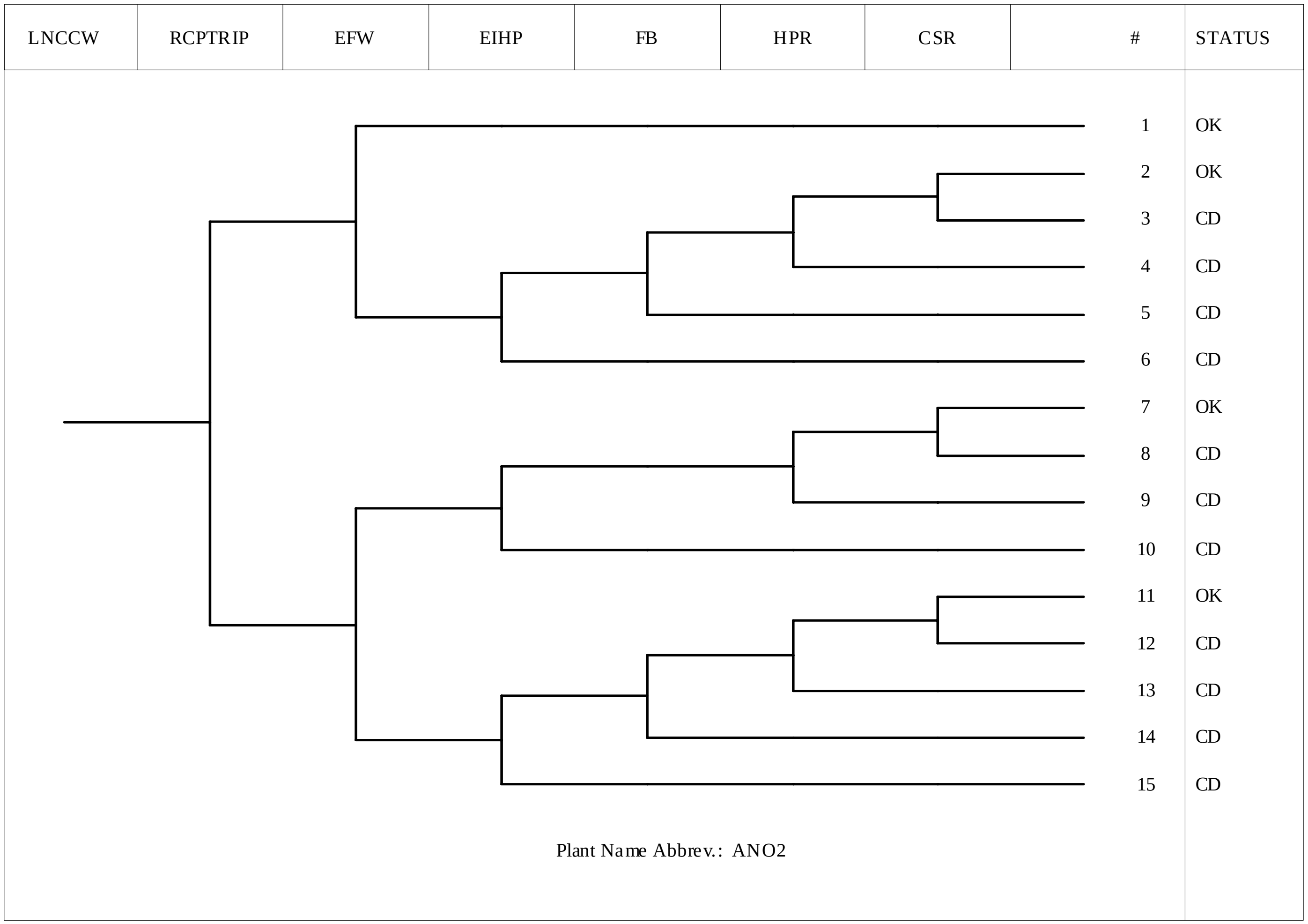

Table 3.19 SDP Worksheet for Arkansas Nuclear One, Unit 2 C Loss of Nuclear side of CCW (LNCCW)

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>:**
Early Inventory, HP Injection (EIHP)	1/2 HPSI trains or operator starts and aligns the third pump (1 multi-train systems)
RCP Seal LOCA (RCPTRIP)	operator trips the RCP in 40 minutes (operator action = 3)
Secondary Heat Removal (EFW)	1/1 MDEFW trains (1 train) or 1 TDEFW train (1 ASD train) or manual alignment of AFWMDP (operator action = 2) and steam relief through 1/10 safety valves or manual operation of 1/2 ADVs
Primary Bleed (FB)	1/2 LTOP vent paths or 1/1 ECCS vent path to open for Feed/Bleed and initiate HPSI injection (operator action = 2) [5]
Containment Spray in Recirc. (CSR)	1/2 CSS including the associated SDC HX. auto-actuated by RAS or 1/2 CSS trains with 2/4 CFCs (1 multi-train system)
High Pressure Recirc (HPR)	1/2 HPSI trains taking suction from containment sump and auto-aligned by RAS or operator starts and aligns the third pump (1 multi-train system)

<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 LNCCW - EFW - CSR (3)			
2 LNCCW - EFW - HPR (4)			
3 LNCCW - EFW - FB (5,15)			
4 LNCCW - EFW - EIHP (6)			

5 LNCCW - RCPTRIP - CSR (9,13)			
6 LNCCW - RCPTRIP - HPR (10,14)			
7 LNCCW - RCPTRIP - EIHP (11,16)			

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.

Attachment 2

List of Participants

See Meng Wong (NRC/NRR)
Troy Pruett (NRC/Region IV)
Mike Cooper (ANO Licensing)
Richard Harris (Entergy/PSA)
Jessica Walker (Entergy/PSA)
Thom Robinson (Engineering/Fire Protection)
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