August 5,2002

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

Patrick D. O'Reilly
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Office of Nuclear Regulatory Research

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

SUBJECT: RESULTS OF THE PALISADES NUCLEAR PLANT SDP PHASE 2 NOTEBOOK BENCHMARKING VISITS

During December, 2001, NRC staff and a contractor visited the Palisades site to compare the Palisades Significance Determination Process (SDP) Phase 2 notebook and licensee's risk model results to ensure that the SDP notebook was generally conservative. The Palisades PSA did not include external initiating events so no sensitivity studies were performed to determine any 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 Palisades were also compared with the licensee's risk model. The results of the SPAR model benchmarking effort will be documented in a separate trip report to be prepared by the Office of Research.

In the review of the Palisades SDP notebook for the benchmark efforts, it was determined that some changes to the SDP worksheets were needed to reflect how the Palisades plant is currently designed and operated. Thirty 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 10 percent, overestimated by 39 percent, and adequately estimated by 52 percent. The reviewers found that if 24 fixes were made to the SDP notebook, the results would be 3 percent underestimation and 32 percent overestimation of risk impacts.

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

CONTACT: M. Franovich, SPSB/DSSA/NRR
301-415-3361

Attachments: As stated

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Attachments: As stated
G://SPSB/Franovich/PAlisadesbench.wpd

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SUMMARY REPORT ON BENCHMARKING TRIP TO PALISADES NUCLEAR PLANT (Dec. 11-12, 2001)

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June 17, 2002

Attachment A

Table of Contents

Page

List of Tables

Page

1. Introduction

A benchmarking of the Palisades Nuclear Plant (PNP) Significance Determination Process (SDP) Risk-Informed Inspection Notebook was conducted during a plant site visit on December 11-12, 2001. NRC staff (Sonia Burgess, Mike Franovich and See Meng Wong) supported by BNL staff (G. Martinez-Guridi) participated in this benchmarking exercise.

In preparation of the plant site visit, BNL staff reviewed the Rev-0 PNP 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.

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 of the internal events PRA 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.

The benchmarking exercise provided insights for significant improvement to the SDP notebook. In 29 of the 31 cases evaluated, the revised SDP notebook should obtain either a match or one order of magnitude (color) higher than the licensee's PSA. As described below, in one of the two remaining cases (failure of one MSIV), the revised SDP notebook correctly obtains more than one order of magnitude (color) difference than the licensee's PSA. In the other remaining case (Diesel generator 1-1 fails to start), the revised SDP notebook underestimates by one color. A brief description of these two cases follows:

1. Failure of one MSIV. We initially obtained a red color because the SDP's worksheet for Main Steam Line Break (MSLB) Outside Containment considers that 2/2 MSIVs are required to close to prevent pressurized thermal shock (PTS); the SDP worksheet assumes that PTS leads to core damage. The licensee is currently analyzing MSIV failures and their potential to cause PTS. Currently, the licensee's PRA model does not include PTS due to MSIV failures. Therefore, the failure of an MSIV is currently evaluated as a green by the licensee. Subsequent to the benchmark trip, the SDP MSLB worksheet and event tree were revised to make the sequence that could lead to PTS similar and consistent with the SDP notebook treatment of PTS for other affected Combustion Engineering plants. This change resulted in a yellow color.

2. Diesel generator 1-1 fails to start. The licensee's PRA model obtained a red color, while the SDP notebook got a yellow. The cause of the difference is the rounding error that is

inherent in SDP's evaluations. This error is discussed in detail in the next chapter. Similar underestimations when evaluating a diesel generator have been observed in other benchmarking exercises, and a solution will be considered.

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 six column headings. In the first column, the out-of-service components, including human errors are identified for the case analyses. The second column contains the basic event(s) selected to model the failure in the first column. The third and fourth columns show 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 fifth column. Finally, the colors assigned for significance characterization from using the SDP worksheets after incorporation of the licensee's comments are shown in the sixth column.

Table 1 is divided into three sections. The first section, titled "No match," contains the two events for which a match could not be obtained; they are discussed next.

1. Failure of one MSIV. As mentioned in the previous chapter, we obtained a Yellow color for this failure because the SDP's event tree logic and worksheet for Main Steam Line Break (MSLB) Outside Containment considers that 2/2 MSIVs are required to close or isolation of feedwater to the affected steam generator to prevent pressurized thermal shock (PTS); the SDP worksheet assumes that PTS leads to core damage. The licensee is currently analyzing MSIV failures and their potential to cause PTS. Currently, the licensee's PRA model does not include PTS due to MSIV failures. Therefore, the failure of an MSIV is currently evaluated as a green by the licensee.

2. Diesel generator 1-1 fails to start. The licensee's PRA model obtained a red color, while the SDP notebook got a yellow. The cause of the difference is the rounding error that is inherent in SDP's evaluations. For example, a station blackout sequence consists of

   LOOP * EAC * REC4

   where LOOP is the initiating event, EAC is Emergency AC Power (diesel generators), and REC4 is Recovery of AC Power in < 4 hrs. Assuming the probabilistic values for these elements of the sequence are as follows:

Element	Licensee	SDP
LOOP	3 E-2	2
EAC (given one diesel generator is unavailable)	2.5 E-2	2
REC4	2.0 E-1	1
Total	1.5 E-4	5

From this table, the licensee's estimate is about one order of magnitude larger than the SDP's.

Similar underestimations when evaluating a diesel generator have been observed in other benchmarking exercises, and a solution will be considered.

Table 1's second section is entitled "Match or SDP one magnitude higher than licensee's PSA: Hardware failures," contains 24 hardware failures for which the revised SDP notebook obtained either a match or one order of magnitude (color) higher than the licensee's PSA. Table 1's third section is entitled "Match or SDP one magnitude higher than licensee's PSA: Human Errors," and contains five Human Errors for which the revised SDP notebook obtained either a match or one order of magnitude (color) higher than the licensee's PSA.

To evaluate a failure in the CCW system, a new worksheet was developed before the visit, and it was revised during the visit.

At the beginning of the visit, we also intended to evaluate the unavailability of the turbine bypass valve (TBV) and one Steam Generator safety valve. However, due to the redundancy available for steam relief from the steam generators, we decided to remove these components from the worksheets.

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, or the SDP matched the outcome from the licensee's PRA model. The associated percentage of differences found for the 31 analyzed cases are also shown on Table 2. It is concluded that the pre-visit SDP Notebook could capture at least 90% of the significant inspection findings (see Table 2 summation of the cases matched and overestimated). The revised SDP notebook captured 97% of the true significance of inspection findings (either true color or more conservative).

Table 1 Comparison of Sensitivity Calculations
Between SDP Phase 2 Worksheets and Palisades RAWs

CDF = 6.16E-5 / year, White = 1.02, Yellow = 1.16, Red = 2.61
TRUNCATION=1E-9 / year

Description	Basic Event Name	RAW	Plant CDF & Color	SDP Before	SDP After
No match					
1 MSIV	M-AVMB-CV-0501 (SGA)	1.01	Green	Red	Yellow
Diesel generator 1-1 fails to start	E-DGME-K-6A	3.11	Red	Yellow	Yellow
Match or SDP one magnitude higher than licensee's PSA: Hardware failures					
Diesel generator 1-2 fails to start	E-DGME-K-6B	3.56	Red	Yellow	Red
Battery charger	D-BCMT-ED-15 D-BCMT-ED-16 D-BCMT-ED-17 D-BCMT-ED-18	1.88	Yellow	Yellow	Yellow
EDG1-1 and EDG1-2 common cause fail to start	E-DGCC-K-6AB-ME	21.3	Red	Red	Red
Compressor C-2B fails to start	I-CMME-C-2B	1.02	White	Red	Yellow
Charging pump P-55A fails to start	G-PMME-P-55A	1.07	White	Green	White
AFW pump P-8C fails to start	A-PMME-P-8C	1.21	Yellow	Red	Red
AFW turbine pump P-8B fails to start	A-PMME-P-8B	1.19	Yellow	Red	Red
Loss of Condensate pump P-2A	IE-LOCPA	1.0	Green	Green	Green
P-54A Containment Spray pump fails to start	S-PMME-P-54A	2.17	Yellow	Yellow	Yellow

Description	Basic Event Name	RAW	Plant CDF & Color	SDP Before	SDP After
Common cause 3 Containment Spray pumps fail to start	S-PMCC-P54ABC-ME	42.3	Red	Red	Red
Battery D02 fails to discharge on demand	D-BYMB-ED-02	3.73	Red	Red	Red
HPSI pump P-66A fails to start	H-PMME-P-66A	3.44	Red	Red	Red
1 pump of LPSI	L-PMME-P67A	1.01	Green	Yellow	Green
Common cause failure of both PORVs to not open	O-RVCC-PORVS-MA	2.4	Yellow	Red	Red
Turbine fails to trip with ATWS	TTF	1.0	Green	White	White
Primary Safety Relief Valves FTO	RVO	1.0	Green	White	White
Loss of Service Water System	IE-LOSWS	5.12	Red	Red	Red
Loss of 2400V bus 1D	IE-LOBUS1D	1.14	White	White	White
ARS: Failure of SIS(X) signal to even-numbered relays	R-REMB-SIS-X2 R-REMB-SIS-X4 R-REMB-SIS-X6 R-REMB-SIS-X8	1.29	Yellow	Red	Red
1 ADV (FTO)	B-AVMA-CV-0780	1.09	White	Yellow	Yellow
1 Fan cooler	V-FNME-V-1A	1.0	Green	Green	Green
1 SIT	T-CVMA-CK-ES3117	1.0	Green	Green	Green
Pump 7B of SW	U-PMME-P-7B	2.02	Yellow	Yellow	Yellow
1 pump of CCW	C-PMME-P-52B	1.01	Green	White	Green
Match or SDP one magnitude higher than licensee's PSA: Human Errors					
Fails to makeup to CST	A-OOOT-CSTMKUP	5.56	Red	Red	Red
Operator fails to depressurize PCS with Pzr Spray / Aux Spray	W-AVOA-PZR-SPRAY	22.7	Red	Red	Red

Description	**Basic Event Name**	**RAW**	**Plant CDF & Color**	**SDP Before**	**SDP After**
Fails to initiate once through cooling	H-ZZOA-OTC-INIT	2.67	Red	Red	Red
Recovery of AC Power in < 1 hr (REC1)	R2H	1.0	Green	White	White
Recovery of AC Power in < 4 hrs (REC4)	R4H	1.23	Yellow	Yellow	Yellow

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	Percentage	Number of Cases	Percentage
SDP: Less Conservative	3	10%	1	3%
SDP: More Conservative	12	39%	10	32%
SDP: Matched	16	52%	20	65%
Total	31	100%	31	100%

3. Proposed Revisions to Rev-0 SDP Notebook

Based on insights gained from the plant site visit, a set of revisions are 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 the Palisades Nuclear Plant

The licensee provided several comments on the Rev-0 SDP Notebook. 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 suggested changes that had an impact on the evaluation of the worksheets were incorporated during the visit, including revised HEPs and initiator frequencies. The remaining changes dealt mainly with updated footnotes to the dependency matrix and the worksheets. The proposed revisions are discussed below:

1. Loss of CCW (LCCW) was added to row II of Table 1, "Categories of Initiating Events for Palisades Power Plant." A worksheet for Loss of CCW also was developed, and Table 2, "Initiators and System Dependency for Palisades Nuclear Power Plant" was updated to indicate the new worksheet to be used for CCW failures.

   On loss of CCW, the RCPs must be tripped by the operators within 10 minutes after the onset of the loss of cooling to the RCPs, but this event is not currently included in the licensee's PRA model. However, after the benchmarking visit, and per SDP assumptions, we included this event in the SDP's worksheet and event tree, with the generic credit = 3, and leading to a small LOCA.

2. A generic change for all worksheets and associated event trees, except LOOP and LIA, was to remove the safety function "Make Up to CST (MUCST)" because this make up is provided automatically, and no operator action is required. In the LOOP and LIA scenarios the make up requires operator actions.

3. A generic change for many worksheets and associated event trees is that, since the plant can achieve decay heat removal using AFW during the mission time of 24 hours, it is not necessary to ask for shutdown cooling (SDC) once AFW was successful. The worksheets and associated event trees were revised, and the dependencies for "LPSI/SDC" in Table 2, "Initiators and System Dependency for Palisades Nuclear Power Plant," were updated.

4. The licensee clarified that to implement once-through-cooling (feed and bleed), the operators open the block valves by turning a control switch in the control room. The PORVs are opened by putting them in the OPEN position from the control room, causing a DC relay to energize. The licensee's HEP for this action is 2.9E-3, and we assigned a credit = 3. The worksheets containing feed and bleed were updated, as well as their footnotes.

5. The licensee models high-pressure recirculation using two human actions: failure to align subcooling valves (HEP = 4.8E-3, event H-AVOA-HISUBCLG), and failure to enable ESS recirc valves (HEP = 2.6E-4, event Y-AVOB-RAS-VLVS). We assigned a credit of an operator action = 2.

6. Power Conversion System (PCS). One change implemented for the worksheets using the PCS was a success criteria of "(½ MFW trains with ½ condensate trains) or (½ condensate trains with 1/4 ADVs)." In Table 2, "Initiators and System Dependency for Palisades Nuclear Power Plant," the "Initiating Event" column for the ADVs was updated according to the modifications to several worksheets. The footnote for the ADVs was modified to indicate that Nitrogen provides a supply to operate the ADVs.

7. Table 2, "Initiators and System Dependency for Palisades Nuclear Power Plant." Footnote 1 was updated with the plant internal event CDF = 6.16E-5 / year.

8. Table 2, "Initiators and System Dependency for Palisades Nuclear Power Plant." A new footnote was added to indicate the subsystems comprising the Actuating Relays System (ARS).

9. Table 2, "Initiators and System Dependency for Palisades Nuclear Power Plant." The turbine bypass valve (TBV) and Steam Generator safety valves were removed because the safety functions containing these components were deleted.

10. Table 2, "Initiators and System Dependency for Palisades Nuclear Power Plant." The "Support Systems" column for AFW was updated to include the Condensate Storage Tank (CST) instead of the Demineralized water storage tank. The CST is the primary suction source for the auxiliary feedwater (AFW) system. The demineralized water storage tank is the primary makeup source for the CST.

11. Table 2, "Initiators and System Dependency for Palisades Nuclear Power Plant." A new row for Condensate Storage Tank (CST) was created to show its dependency on the Demineralized water storage tank and backup sources of water: the primary system makeup tank, fire protection system, and the service water system. The SW can provide suction water for only one (motor-driven) AFW pump (P-8C).

12. Table 2, "Initiators and System Dependency for Palisades Nuclear Power Plant." The "Initiating Event" column for AFW was updated to "All except MLOCA, LLOCA."

13. Table 2, "Initiators and System Dependency for Palisades Nuclear Power Plant." Added a footnote for HPSI indicating that, according to the licensee, HPSI pumps only need CCW cooling when the temperature of the pumped water is higher than 325 degrees F.

14. Medium LOCA (MLOCA). The licensee's PRA model credits Low Pressure Injection (LPI) if "Early Inventory, HP Injection (EIHP)" failed and PCS/AFW is successful to depressurize to the LPI's injection pressure. High Pressure Recirculation (HPR) is the preferred path for recirculation. Therefore, we conservatively did not give credit to the mitigation strategy of depressurizing to the LPI's pressure and using LPI. Hence, we removed the safety

functions “RCS Depressurization (RCSDEP), Low Pressure Injection (LPI), and Low Pressure Recirculation (LPR).

15. Large LOCA (LLOCA). The licensee indicated that it will use High Pressure Recirculation (HPR), as opposed to Low Pressure Recirculation (LPR). The safety function Low Pressure Recirculation (LPR) was removed.

16. Loss of Offsite Power (LOOP). The licensee indicated that the HEP for “Recovery of AC Power in < 4 hrs (REC4)” is larger than 0.05, so we changed the credit to operator action = 1, instead of 2.

    The licensee’s PRA model credits the MDAFW pumps if AC power is recovered within 30 minutes.

17. Steam Generator Tube Rupture (SGTR). The licensee indicated that when Secondary Heat Removal (AFW) and Pressure Equalization (EQ) are successful, water makeup still has to be provided to the vessel. For this makeup, the plant can use either the HPSI pumps or 3/3 charging pumps. A new safety function, “Charging Pumps (CHAPUM),” was added to give credit to the charging pumps for this purpose. The licensee’s HEP for aligning charging is 2.5E-4. Therefore, it is an operator action limited by hardware failure.

    For Pressure Equalization (EQ), the licensee indicated that auxiliary spray can also be used.

    The licensee indicated that the HEP for RCS Depressurization (RCSDEP) corresponds to a credit = 3, instead of 1.

18. Anticipated Transients without Scram (ATWS). The licensee indicated that the HEP for Emergency Boration (CVCS) corresponds to a credit = 1, instead of 2.

    The licensee’s current analysis indicates that after the charging system injects sufficient boron to shutdown the reactor, one AFW pump is sufficient to remove decay heat. When new information on secondary heat removal requirements is available, the worksheet will be revised per communication to Regional SRA.

19. Main Steam Line Break (MSLB) Outside Containment. The licensee is currently analyzing MSIV failures and their potential to cause pressurized thermal shock (PTS). Currently, the licensee’s PRA model does not include PTS due to MSIV failures. During the visit, we considered that both MSIVs have to close to prevent PTS, and this success criteria was consolidated in the safety function “Closure of Both MSIVs (MSIV)”; PTS could also be prevented by isolation of feedwater to the affected SG and hence the event tree logic and worksheet were revised.

20. Loss of SW (LSW). The RCPs must be tripped by the operators within 10 minutes after the onset of the loss of cooling to the RCPs, but this event is not currently included in the licensee’s PRA model. However, after the benchmarking visit, and per SDP assumptions, we included this event in the SDP’s worksheet and event tree, with the generic credit = 3, and leading to a small LOCA.

21. Loss of IA (LIA). Loss of motive air fails the AFW injection valves open. The valves of pumps P-8A (motor-driven pump) & B (steam-driven pump) have nitrogen backup, which lasts for at least 8 hours. During these 8 hours the plant has three alternatives: 1) recover Instrument Air, 2) the valves can be operated manually, or, 3) the licensee considers that the plant can reach entry conditions to SDC; operator actions are then needed to align SDC. Accordingly, the TDP of AFW was credited; it requires operator action (credit = 1), which is limited by hardware failure, 1 ASD train.

    Loss of IA also fails CV-3025 closed, and the SDC mode of heat removal requires operator actions. Loss of IA also fails the turbine bypass valve closed. Nitrogen provides a supply to operate the ADVs.

    Make up water to CST can be provided from (1) demineralized water storage tank, (2) primary system makeup tank, (3) Service water, or (4) fire protection water. However, the valves of these sources of water to the CST are supported by instrument air, or can be locally manually operated, or are manual valves. On loss of instrument air, all valves can be locally manually operated, but the human actions required to provide make up to the CST are expected to be more involved since there is no automatic capability to open the valves. Hence, the safety function "Make Up to CST (MUCST)" was kept in this worksheet. The licensee's HEP is 2.6E-3.

22. Loss of One DC Bus (LDCB). CV-3025 fails closed and the shutdown heat exchangers cannot be used for heat removal. However, manual operation of this valve is possible, enabling the SDC mode of heat removal.

    There are two battery chargers in each DC train. One charger is active, and the other is in standby. The licensee is currently analyzing whether a battery charger is capable of handling the starting of all safety loads. A footnote was added in Table 2, "Initiators and System Dependency for Palisades Nuclear Power Plant."

23. Loss of One Engineered Safeguards AC Bus (LACB). In addition to the equipment lost that was identified in the Rev-0 SDP Notebook, two SW pumps are lost. Operator action is needed to reduce SW loads, so there is enough flow of SW to support SDC. SDC is not modeled because AFW can provide decay heat removal during the mission time of 24 hours.

24. Other footnotes containing minor clarifications were added or updated in Tables 1 and 2 and in the worksheets.

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, the following item was identified that can further streamline the process:

1. Additional training may be required for NRC inspectors to clarify the SDP evaluation rules and present to them a more complete set of examples.

3.3 Generic Change to the SDP Notebook

No generic change was identified.

Attachment 1

List of Participants

Sonia Burgess	(NRC/Region III)
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