August 25, 2003

NOTE TO: Stuart Richards, 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, Section Chief /***RA***/
Licensing Section
Probabilistic Safety Assessment Branch
Division of Systems Safety and Analysis
Office of Nuclear Reactor Regulation

SUBJECT: RESULTS OF THE JOSEPH M. FARLEY NUCLEAR PLANT UNITS 1 AND 2 SDP PHASE 2 NOTEBOOK BENCHMARKING VISIT

During March, 2003, NRC staff and contractors visited the Southern Nuclear Company in Birmingham, Al to compare the Joseph M. Farley Nuclear Plant Units 1 and 2 Significance Determination Process (SDP) Phase 2 notebook and licensee's risk model results to ensure that the SDP notebook was generally conservative. The Farley PSA did not include external initiating events; so 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 Farley were compared with the licensee's risk model. The results of the SPAR model benchmarking effort will be documented in next revision of the SPAR (revision 3) model documentation.

The benchmarking visit identified that there was a good correlation between the Phase 2 SDP Notebook and the licensee's PSA. The results indicate that the Farley Phase 2 notebook was generally more conservative in comparison to the licensee's PSA. The revision 1 SDP notebook will capture about 86% (results matched or overestimated the licensee's PSA by one order of magnitude) of the risk significance of inspection the findings. A summary of the results of comparisons of hypothetical inspection findings between the SDP notebook and the licensee's PSA are as follows. The results from Unit 1 differ slightly from those of Unit 2. The reason for these differences is that the service water system (SW) of Unit 2 requires the use of Service Water lube and cooling pumps for its main pumps. The Unit 1's SW pumps do not require Service Water lube and cooling pumps.

CONTACT: Peter Wilson, SPSB/DSSA/NRR
301-415-1114

Unit 1

- 3% Underestimates Risk Significance
- 38% Match Risk Significance
- 49% Overestimates Risk Significance by 1 Order of Magnitude
- 5% Overestimates Risk Significance by 2 Orders of Magnitude
- 5% Overestimates Risk Significance by 3 Orders of Magnitude

Unit 2

- 3% Underestimates Risk Significance
- 40% Match Risk Significance
- 46% Overestimates Risk Significance by 1 Order of Magnitude
- 8% Overestimates Risk Significance by 2 Orders of Magnitude
- 3% Overestimates Risk Significance by 3 Orders of Magnitude

The Rev-1 SDP notebook was improved as a result of the benchmarking activity. For Unit 1, the number of cases that the Rev-1 SDP would match that of the updated licensee's PSA has increased from 11 to 14. The number of over estimations dropped from 26 to 22 cases. However, the number of underestimations increased from 0 to 1. For Unit 2, the number of cases that the Rev-1 SDP would match that of the updated licensee's PSA has increased from 12 to 15. The number of over estimations dropped from 25 to 21 cases. However, the number of underestimations increased from 0 to 1.

The benchmarking effort at Farley was more difficult than most benchmarking efforts due some of the unique design features of the units. The success of the visit was due in a large part to the licensee's very knowledgeable and helpful PSA staff.

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

Attachments: As stated

Unit 1

3% Underestimates Risk Significance
38% Match Risk Significance
49% Overestimates Risk Significance by 1 Order of Magnitude
5% Overestimates Risk Significance by 2 Orders of Magnitude
5% Overestimates Risk Significance by 3 Orders of Magnitude

Unit 2

3% Underestimates Risk Significance
40% Match Risk Significance
46% Overestimates Risk Significance by 1 Order of Magnitude
8% Overestimates Risk Significance by 2 Orders of Magnitude
3% Overestimates Risk Significance by 3 Orders of Magnitude

The Rev-1 SDP notebook was improved as a result of the benchmarking activity. For Unit 1, the number of cases that the Rev-1 SDP would match that of the updated licensee's PSA has increased from 11 to 14. The number of over estimations dropped from 26 to 22 cases. However, the number of underestimations increased from 0 to 1. For Unit 2, the number of cases that the Rev-1 SDP would match that of the updated licensee's PSA has increased from 12 to 15. The number of over estimations dropped from 25 to 21 cases. However, the number of underestimations increased from 0 to 1.

The benchmarking effort at Farley was more difficult than most benchmarking efforts due some of the unique design features of the units. The success of the visit was due in a large part to the licensee's very knowledgeable and helpful PSA staff.

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

Attachments: As stated

Distribution: SPSB: r/f P. Wilson M. Reinhart W. Rogers/RIII

Accession#ML032390222
G:\SPSB\wilson\farleybench.wpd NRR-096

| **OFFICE** | SPSB | SPSB:SC | SPSB:RIII |
|---|---|---|---|
| **NAME** | PWilson:nxh2 | MReinhart | WRogers |
| **DATE** | 05/21/03 | 08/25/03 | 08/22/03 |

**OFFICIAL RECORD COPY**

# SUMMARY REPORT ON BENCHMARKING TRIP

# TO JOSEPH M. FARLEY NUCLEAR PLANT

# UNITS 1 AND 2

**G. Martinez-Guridi**

**Brookhaven National Laboratory (BNL)**
**Energy Sciences and Technology Department**
**Upton, NY 11973**

**May 7, 2003**

Attachment A

# Table of Contents



# List of Tables

# 1. INTRODUCTION

A benchmarking of the Joseph M. Farley Nuclear Plant, Units 1 and 2, Significance Determination Process (SDP) Risk-Informed Inspection Notebook was conducted during a visit to the Southern Nuclear Company in Birmingham, Al between March 10-12, 2003. Rudolph Bernhard and Peter Wilson (NRC), supported by Gerardo Martinez-Guridi (BNL), participated in this benchmarking exercise.

In preparation for the plant site visit, BNL staff reviewed the Rev. 0 Farley SDP notebook and evaluated a set of hypothetical inspection findings using the Rev. 0 SDP notebook, plant system diagrams and information in the licensee's updated PRA.

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 (hypothetical inspection findings) for the benchmarking exercise.

4. Performed benchmarking of the Rev. 0 SDP notebook considering the licensee's proposed modifications to this notebook.

5. Identified overestimates and reviewed the licensee's PRA model to determine the underlying reasons. Additional changes to the SDP notebook were proposed, as appropriate.

The licensee's core damage frequencies (CDFs) for Units 1 and 2 are 3.19E-5/year and 5.06E-5/year, respectively. These values do not include flooding. The reason for the difference in these values is that the service water system (SW) of Unit 2 requires the use of SW lube and cooling pumps for its main pumps. The Unit 1's SW pumps do not require SW lube and cooling pumps. Despite these different values, the benchmarking results are very similar for both units, so the results discussed in this report are applicable to both, except when unit-specific results are obtained.

Chapter 2 presents a summary of the results obtained during benchmarking, Chapter 3 discusses the proposed revisions to the Rev. 0 SDP notebook, and Chapter 4 discusses the results from both internal and external events. Finally, Attachment 1 shows a list of the participants in the benchmarking activities.

## 2. SUMMARY RESULTS FROM BENCHMARKING

Summary of Benchmarking Results

Benchmarking of the SDP Notebook for the Joseph M. Farley Nuclear Plant Units 1 and 2 was conducted comparing the risk significance of the inspection findings obtained using the notebook with that obtained using the plant PRA. The benchmarking identified the hypothetical inspection findings for which the results of the evaluation using the notebook were under or overestimations compared to the plant PRA.

Thirty-seven cases of hypothetical findings were evaluated. A summary of the results of the risk characterization of hypothetical inspection findings for Unit 1 is as follows:

| | | |
|---|---|---|
| 2.7% | (1 of 37 cases) | Non-conservative; underestimation of risk significance (by one order of magnitude) |
| 5.4% | (2 of 37 cases) | Conservative; overestimation of risk significance (by three orders of magnitude) |
| 5.4% | (2 of 37 cases) | Conservative; overestimation of risk significance (by two orders of magnitude) |
| 48.6% | (18 of 37 cases) | Conservative; overestimation of risk significance (by one order of magnitude) |
| 37.8% | (14 of 37 cases) | Consistent risk significance |

A summary of the results of the risk characterization of hypothetical inspection findings for Unit 2 is as follows:

| | | |
|---|---|---|
| 2.7% | (1 of 37 cases) | Non-conservative; underestimation of risk significance (by one order of magnitude) |
| 2.7% | (1 of 37 cases) | Conservative; overestimation of risk significance (by three orders of magnitude) |
| 8.1% | (3 of 37 cases) | Conservative; overestimation of risk significance (by two orders of magnitude) |
| 45.9% | (17 of 37 cases) | Conservative; overestimation of risk significance (by one order of magnitude) |
| 40.5% | (15 of 37 cases) | Consistent risk significance |

Detailed results of Benchmarking are summarized in Tables 1 and 2 for Units 1 and 2, respectively. These tables consist of eight column headings: in the first two columns, the out-of-service components, including human errors, are identified for the case analyses. The colors assigned for significance characterization from using the Rev. 0 SDP notebook before incorporation of the licensee's comments are shown in the third column. The licensee's basic event or component for which the RAW was found, representing the hypothetical finding, is presented in the fourth column. The fifth and sixth columns show the RAW values and the associated colors, respectively, based on the licensee's latest PRA model. The colors assigned for significance characterization from using the SDP notebook after incorporation of the licensee's comments and the outcome of comparing the results between the SDP Rev. 1 notebook and the plant PRA are shown in the seventh column. Finally, the eighth column presents some comments about the evaluations.

A comparative summary of the benchmarking results is provided in Tables 3 and 4 for Units 1 and 2, respectively. These tables show the number of cases where the SDP was more or less conservative, the SDP matched the outcome from the licensee's PRA model, and the cases not modeled by the licensee.

Observations on the Licensee's PRA

One characteristic of the licensee's PRA contributes to the relatively large percentage of overestimates obtained by the Rev. 1 SDP notebook. The licensee's frequencies of several LOCAs are smaller than those of the Rev. 1 SDP notebook. For example, the licensee's frequencies for small LOCA and medium LOCA are 4.96E-4/year and 3.98E-5/year, while the notebook's "credits" for them are 3 and 4, respectively.

Discussion of Non-conservative Results by the Notebook

The Rev. 1 notebook yielded one underestimate out of the 37 hypothetical findings evaluated: operator fails to recover AC power in less than 1 hour after a LOOP. The licensee's model gives white, and the notebook gives green. The licensee's model considers that after the loss of cooling to the RCP seals due to a station blackout, RCP seal LOCA has a probability of 0.19 of occurring with a leak rate larger than 21 gpm. The licensee's calculations actually assumed a leak rate equal to 480 gpm, so core uncovery follows in about an hour, regardless of whether the turbine-driven pump of AFW provides secondary cooling or not. On the other hand, the SDP notebook considers that on loss of cooling to the RCP seals, RCP seal LOCA occurs with a probability of one, but with a smaller leak rate than 480 gpm, so the notebook assumes that time available before the core uncovers is about 5 hours after the onset of loss of RCP seal cooling. Hence, the licensee's model yields an order of magnitude larger than the notebook because on failure to recover AC power in less than 1 hour after a LOOP, the licensee models a scenario that is more severe than the one modeled by the notebook.

Discussion of Conservative Results by the Notebook

For Unit 1, the Rev. 1 notebook produced 22 overestimates, 2 by three orders of magnitude, 2 by two orders of magnitude, and eighteen overestimates by one order of magnitude. For Unit 2, the Rev. 1 notebook produced 21 overestimates, 1 by three orders of magnitude, 3 by two orders of magnitude, and seventeen overestimates by one order of magnitude. The four overestimates by more than one order of magnitude are the same for Unit 1 and Unit 2: battery charger of bus B fails, failure of battery charger of SW Intake Structure DC feeding the "on-service" train of SW, one safety valve of a steam generator fails to open, and operator fails to switchover in LPR. These four overestimates are discussed next.

Failure of battery charger of SW Intake Structure DC feeding the "on-service" train of SW: licensee's color is green and notebook is red (4). Similar to the above explanation, this difference is because of different assumptions in treating this failure by the notebook and the licensee. The SDP evaluation rules assume that without the battery charger the associated battery will discharge under normal loads and result in a loss of the associated DC bus. On the other hand, the licensee considers that the loss of the battery charger would initiate alarms in the control room and cause entry into a 2 hour LCO. Therefore, the licensee assumes that actions would be taken to align another battery charger or the plant would be shut down before a loss of bus of SW Intake Structure DC would occur. If the standby pump of SW is needed after the loss of the battery

charger, it can be started using battery power. Accordingly, the loss of the battery charger does not cause the initiating event "Loss of On-Service Train of SW," so the licensee does not model this loss as a contributor to this initiating event.

Battery charger of bus B fails: licensee's color is yellow, and notebook is red (2). This difference is because of different assumptions in treating this failure by the notebook and the licensee. The SDP evaluation rules assume that without the battery charger the associated battery will discharge under normal loads and result in a loss of the DC bus. On the other hand, the licensee considers that the loss of the battery charger would initiate alarms in the control room and cause entry into a 2 hour LCO. Therefore, the licensee assumes that actions would be taken to align the standby ("swing") battery charger or the plant would be shut down before a loss of DC bus would occur. In other words, the loss of the battery charger does not cause the initiating event "Loss of a DC Bus," so the licensee does not model this loss as a contributor to this initiating event.

One safety valve of a steam generator fails to open: licensee's model gives green, and notebook gives yellow. The SG safety valves are used for steam relief from the SGs. Since there is ample redundancy to satisfy this function (1/15 SG safety valves for most scenarios and 6/15 for the most severe ATWS event, or the ARVs), the licensee's model gives green for the loss of a single SG safety valve. On the other hand, the current SDP evaluation requires counting the base case of every sequence where this valve appears. Thus, while all these sequences are of value 7 or less, the counting rule used by the current SDP evaluation produces a yellow.

Operator fails to switchover in LPR: licensee's color is yellow, and notebook is red (3). This difference is because of two main reasons: 1) the licensee's frequencies of several LOCAs are smaller than those of the Rev. 1 SDP notebook, 2) in all scenarios leading to a small LOCA, the notebook gives credit to LPR after both success and failure of high-pressure injection; on the other hand, the licensee uses LPR only after such failure. This treatment by the licensee of LPR in all scenarios leading to a small LOCA causes LPR to have a lower risk importance in the licensee's model.

The reasons causing the overestimates by one color were not further investigated per the benchmarking process for this kind of estimate. However, we note that two significant factors contributing to the overestimates are:

1. As mentioned above, the licensee's frequencies of several LOCAs are smaller than those of the Rev. 1 SDP notebook.

2. Several conservative assumptions implemented while developing the Rev. 1 worksheets. Two examples are the worksheets for "Loss of 4160 V Bus F or G (When Aligned to On-service Train of Cooling) (LBACON)" and for "Loss of 4160 V Bus F or G (When Aligned to Off-service Train of Cooling) (LBACOFF)." These worksheets were developed assuming the "worst case" scenario, so neither the TDAFW pump nor the ARVs are credited.

Unit 1's eighteen overestimates by one color are: Class 1E AC bus 1G fails, Class 1E AC bus 1F fails, Vital 125 VDC bus 1B fails, failure of battery of SW Intake Structure DC feeding the "on-service" train of SW, one accumulator fails, AMSAC fails, one MDP of AFW fails, TDP of AFW fails, pump in the "off-service train" (standby) of CCW fails, CVCS centrifugal charging pump in the "off-service train" fails, one Atmospheric Relief Valve (ARV) fails to open, one primary block valve fails to close, one primary safety valve fails to open, one RHR pump fails, one running SW pump

in on-service train fails, operator fails to conduct Feed/Bleed, operator fails to conduct emergency boration after ATWS, and operator fails to align mitigating equipment to the off-service train after loss of on-service train of cooling.

Unit 2's seventeen overestimates by one color are: Class 1E AC bus 2G fails, Class 1E AC bus 2F fails, Vital 125 VDC bus 2B fails, one accumulator fails, AMSAC fails, one MDP of AFW fails, TDP of AFW fails, pump in the "non-onservice train" (standby) of CCW fails, CVCS centrifugal charging pump in the "non-onservice train" fails, one Atmospheric Relief Valve (ARV) fails to open, one primary block valve fails to close, one primary safety valve fails to open, one RHR pump fails, one running SW pump in on-service train fails, operator fails to conduct Feed/Bleed, operator fails to conduct emergency boration after ATWS, and operator fails to align mitigating equipment to the off-service train after loss of on-service train of cooling.

Changes Incorporated Following Benchmarking Resulting in Updating of Benchmarking Results

Following benchmarking, we incorporated some additional changes to the Rev. 1 notebook as follows:

1. To better model the alignments of the 4160 V safety buses, the worksheets for "Loss of 4160 V Bus F" and "Loss of 4160 V Bus G" were changed to the worksheets "Loss of 4160 V Bus F or G (When Aligned to On-service Train of Cooling) (LBACON)" and "Loss of 4160 V Bus F or G (When Aligned to Off-service Train of Cooling) (LBACOFF)."

2. Loss of Instrument Air (LIA). The ARVs fail closed on LIA. They can receive air from emergency air compressors, and manual operation is possible. However, since steam relief can be provided by the steam generator safety valves, the ARVs were removed as a path of steam relief.

3. Loss of Instrument Air (LIA). AFW flow control valves fail open, which requires manual control of the valves. Accordingly, we changed the credit of the function "Secondary Heat Removal (MDAFW)" from 1 multi-train system to operator action = 3. We added footnotes with this information.

4. LOOP with Loss of 4160 V Bus F or G (LEAC). The event tree and worksheet were modified so that the function "Low Pressure Recirculation (LPR)" is questioned after depressurization of the RCS. Two depressurization functions are now implemented: 1) "RCS Cooldown/Depressurization (DEP1)," used when EIHP and AFW are successful, and 2) "RCS Cooldown/Depressurization (DEP2)," used when EIHP fails but AFW is successful, to reach the conditions of low pressure injection.

## Table 1 Summary of Benchmarking Results for Farley Unit 1

### Internal Events CDF is 3.19E-5/year
### RAW Thresholds are W = 1.03, Y = 1.32, and R = 4.14

| No. | Component Out of Service or Failed Operator Action | SDP Worksheet Results (Before) (1) | Basic Event Name (3) | Internal RAW (Highest) | Plant CDF Color (2) | SDP Worksheet Results (After) (1) | Comments |
|---|---|---|---|---|---|---|---|
| | ***Component*** | | | | | | |
| 1 | Class 1E AC bus 1G fails | Red (1) (over by 1) | 1ACBSR15A007BF | 324 | Red (2) | Red (1) (over by 1) | |
| 2 | Diesel generator 1B fails | Red (4) (over by 1) | 1DGGER43A502BAL 1DGGER43A502BXL | 1.95 | Yellow | Yellow (match) | |
| 3 | Class 1E AC bus 1F fails | Red (1) (over by 1) | 1ACBSR15A006AF | 347 | Red (2) | Red (1) (over by 1) | |
| 4 | Diesel generator 1-2A fails | Red (4) (over by 1) | BDGGER43A501AAL BDGGER43A501AXL | 3.99 | Yellow | Yellow (match) | |
| 5 | Vital 125 VDC bus 1B fails | Red (2) (over by 1) | 1DCBSR42B001BF 1DCBSB001BDGSF 1DCBSB001B-I1F | 94 | Red (3) | Red (2) (over by 1) | SDP evaluation assumes that the bus is aligned to off-service train of cooling. |
| 6 | Vital 125 VDC bus 1A fails | Red (3) (match) | 1DCBSR42B001AF 1DCBSB001ADGSF 1DCBSB001A-I1F | 83 | Red (3) | Red (3) (match) | SDP evaluation assumes that the bus is aligned to on-service train of cooling. |
| 7 | Battery of bus 1B fails | Red (4) (match) | 1DCBYR42E002BF 1DCBYE002BDGSF | 6.73 | Red (4) | Red (4) (match) | Battery charger capacity is adequate to start and carry the SI loads. |
| 8 | Battery charger of bus 1B fails | Red (2) (over by 3) | 1DCBCE001B-I1F 1DCBCR42E001BF | 1.47 | Yellow | Red (2) (over by 3) | |
| 9 | Failure of bus of SW Intake Structure DC feeding the "on-service" train of SW | Red (2) (over by 2) | BDCBSR41L505BF | 6.22 | Red (4) | Red (4) (match) | |

| No. | Component Out of Service or Failed Operator Action | SDP Worksheet Results (Before) [1] | Basic Event Name [3] | Internal RAW (Highest) | Plant CDF Color [2] | SDP Worksheet Results (After) [1] | Comments |
|---|---|---|---|---|---|---|---|
| 10 | Failure of battery of SW Intake Structure DC feeding the "on-service" train of SW | Red (4) (over by 1) | BDCBYR42B523CF<br>BDCBYR42B523DF | 3.19 | Yellow | Red (4) (over by 1) | |
| 11 | Failure of battery charger of SW Intake Structure DC feeding the "on-service" train of SW | Red (2) (over by 5) | BDCBCR42B526AF<br>1DCBCR42B526BF | 1.02 | Green | Red (4) (over by 3) | |
| 12 | One accumulator fails | Yellow (over by 1) | 1ATCV8948A---D<br>1ATCV8948B---D<br>1ATCV8948C---D | 1.11 | White | Yellow (over by 1) | |
| 13 | AMSAC fails | White (over by 1) | AM_A_1 | 1.00 | Green | White (over by 1) | |
| 14 | One MDP of AFW fails | Red (4) (match) | 1AFPM001B----A<br>1AFPM001B----X<br>1AFPM001B-SL-X | 10.47 | Red (4) | Red (3) (over by 1) | |
| 15 | TDP of AFW fails | Yellow (match) | 1AFPT002-----A<br>1AFPT002-----X<br>1AFPT002-SL--X | 2.04 | Yellow | Red (4) (over by 1) | |
| 16 | Pump in the "off-service train" (standby) of CCW fails | Red (2) (over by 2) | 1CCPM001A----A<br>1CCPM001A----X<br>1CCPM001AI---X<br>1CCPM001AI2---X | 9.67 | Red (4) | Red (3) (over by 1) | |
| 17 | One condensate pump fails | Green (match) | 1CDPMP001A---A<br>1CDPMP001A---X | 1.00 | Green | Green (match) | |
| 18 | One SGFP fails | Green (match) | 1MFPTSGFPA---A<br>1MFPTSGFPA---X | 1.01 | Green | Green (match) | |

| No. | Component Out of Service or Failed Operator Action | SDP Worksheet Results (Before) [1] | Basic Event Name [3] | Internal RAW (Highest) | Plant CDF Color [2] | SDP Worksheet Results (After) [1] | Comments |
|---|---|---|---|---|---|---|---|
| 19 | CVCS centrifugal charging pump in the "non-onservice train" fails | Red (4) (over by 1) | 1HHPMP002C---A<br>1HHPMP002C---X | 3.48 | Yellow | Red (4) (over by 1) | |
| 20 | One boric acid transfer pump fails | Green (match) | 1VCPMP005A---A<br>1VCPMP005A---X | 1.00 | Green | Green (match) | |
| 21 | One air compressor of IA fails | Red (3) (over by 3) | 1IACMC001A---A<br>1IACMC001A---X<br>1IACMC001A-I1X<br>1IACMC001A-I2X | 1.14 | White | White (match) | |
| 22 | One Atmospheric Relief Valve (ARV) fails to open | White (match) | 1MSAVPV3371A-D | 1.06 | White | Yellow (over by 1) | |
| 23 | One SG safety valve fails to open | Red (4) (over by 3) | 1MSRVQV010A—D<br>1MSRVQV010B—D<br>1MSRVQV010C—D<br>1MSRVQV010D—D<br>1MSRVQV010E—D | 1.00 | Green | Yellow (over by 2) | |
| 24 | One Main Steam Isolation Valve (MSIV) fails to close | White (over by 1) | 1MSHV3369A---K<br>1MSHV3369B---K<br>1MSHV3369C---K | 1.00 | Green | Green (match) | |
| 25 | One PORV fails to open | Red (4) (over by 1) | 1PZAV444B-----D | 1.50 | Yellow | Yellow (match) | |
| 26 | One primary block valve fails to close | White (over by 1) | 1PZMV8000A---K | 1.00 | Green | White (over by 1) | |
| 27 | One primary safety valve fails to open | White (over by 1) | 1PZRV8010A---D | 1.00 | Green | White (over by 1) | |

| No. | Component Out of Service or Failed Operator Action | SDP Worksheet Results (Before) (1) | Basic Event Name (3) | Internal RAW (Highest) | Plant CDF Color (2) | SDP Worksheet Results (After) (1) | Comments |
|---|---|---|---|---|---|---|---|
| 28 | One RHR pump fails | Red (3) (over by 1) | 1LHPMP001B---A<br>1LHPMP001B---X | 13.55 | Red (4) | Red (3) (over by 1) | |
| 29 | One running SW pump in on-service train fails | Red (2) (over by 3) | 1SWPM1C------A<br>1SWPM1C------X<br>1SWPM1C1-----X<br>1SWPM1C2-----X | 1.41 | Yellow | Red (4) (over by 1) | |
| | ***Operator Actions*** | | | | | | |
| 30 | Operator fails to conduct Feed/Bleed | Red (4) (over by 1) | OAB_A_1------H<br>OAB_A_5------H<br>OAB_AZFA1----H<br>OAB_AZFB1----H<br>OAB_C_1------H<br>OAB_C_2------H<br>OAB_SB-------H | 3.01 | Yellow | Red (4) (over by 1) | |
| 31 | Operator fails to switchover in HPR | Red (4) (match) | OAR_B_1------H<br>OAR_BH------H<br>OAR_BXCB-----H<br>OAR_BXDA-----H<br>OAR_BXTC1----H<br>OAR_BZDA-----H<br>OAR_BZTC1----H | 22.5 | Red (4) | Red (4) (match) | |
| 32 | Operator fails to switchover in LPR | Red (3) (over by 2) | OAR_A_1------H<br>OAR_AH-------H<br>OAR_BH-------H<br>OAR_BXNA-----H<br>OAR_BXTB-----H | 3.44 | Yellow | Red (3) (over by 2) | |
| 33 | Operator fails to recover AC power in < 1 hour after a LOOP | White (match) | 1HR_A_1-F | 1.11 | White | Green (under by 1) | |

| No. | Component Out of Service or Failed Operator Action | SDP Worksheet Results (Before) (1) | Basic Event Name (3) | Internal RAW (Highest) | Plant CDF Color (2) | SDP Worksheet Results (After) (1) | Comments |
|---|---|---|---|---|---|---|---|
| 34 | Operator fails to recover AC power in < 5 hours after a LOOP | Yellow (over by 1) | XHR_A_1-F | 1.08 | White | White (match) | |
| 35 | Operator fails to depressurize RCS using SGs to less than setpoint of relief valves of SG after SGTR | White (match) | OAD_B_1------H | 1.16 | White | White (match) | |
| 36 | Operator fails to conduct emergency boration after ATWS | White (over by 1) | OBR_A_1------H<br>OBR_A_2------H | 1.00 | Green | White (over by 1) | |
| 37 | Operator fails to align mitigating equipment to the off-service train after loss of on-service train of cooling | Red (2) (over by 3) | OMH_B_1------H | 2.36 | Yellow | Red (4) (over by 1) | |

**Notes**:

1. When the color of the result of the SDP notebook is red, the number in parenthesis after the word “Red” is the order of magnitude yielded by the SDP notebook.

2. When the color corresponding to the plant’s CDF is red, the number in parenthesis after the word “Red” is the order of magnitude obtained from the following calculation: (Base-case CDF) * RAW.

3. When information about several similar components in a system, such as pumps in redundant trains, is available, the one with the highest impact on CDF was selected for inclusion in this table.

## Table 2 Summary of Benchmarking Results for Farley Unit 2

### Internal Events CDF is 5.06E-5/year
### RAW Thresholds are W = 1.02, Y = 1.20, and R = 2.98

| No. | Component Out of Service or Failed Operator Action | SDP Worksheet Results (Before) (1) | Component Name (2, 4) | Internal RAW | Plant CDF Color (3) | SDP Worksheet Results (After) (1) | Comments |
|---|---|---|---|---|---|---|---|
| | ***Component*** | | | | | | |
| 1 | Class 1E AC bus 2G fails | Red (1) (over by 1) | Q2R15A0007 | 296.9 | Red (2) | Red (1) (over by 1) | |
| 2 | Diesel generator 2B fails | Red (4) (over by 1) | Q2R43A0505 | 1.32 | Yellow | Yellow (match) | |
| 3 | Class 1E AC bus 2F fails | Red (1) (over by 1) | Q2R15A0006 | 363.64 | Red (2) | Red (1) (over by 1) | |
| 4 | Diesel generator 1-2A fails | Red (4) (over by 1) | QSR43A0501 | 1.45 | Yellow | Yellow (match) | |
| 5 | Vital 125 VDC bus 2B fails | Red (2) (over by 1) | Q2R42B0001B | 129.58 | Red (3) | Red (2) (over by 1) | SDP evaluation assumes that the bus is aligned to off-service train of cooling. |
| 6 | Vital 125 VDC bus 2A fails | Red (3) (match) | Q2R42B0001A | 122.37 | Red (3) | Red (3) (match) | SDP evaluation assumes that the bus is aligned to on-service train of cooling. |
| 7 | Battery of bus 2B fails | Red (4) (match) | Q2R42E0002B | 7.25 | Red (4) | Red (4) (match) | Battery charger capacity is adequate to start and carry the SI loads. |
| 8 | Battery charger of bus 2B fails | Red (2) (over by 3) | Q2R42E0001B | 1.7 | Yellow | Red (2) (over by 3) | |
| 9 | Failure of bus of SW Intake Structure DC feeding the "on-service" train of SW | Red (2) (over by 2) | Q2R41L0508 | 11.09 | Red (4) | Red (4) (match) | |

| No. | Component Out of Service or Failed Operator Action | SDP Worksheet Results (Before) [1] | Component Name [2, 4] | Internal RAW | Plant CDF Color [3] | SDP Worksheet Results (After) [1] | Comments |
|---|---|---|---|---|---|---|---|
| 10 | Failure of battery of SW Intake Structure DC feeding the “on-service” train of SW | Red (4) (match) | QSR42B0523A | 3.13 | Red (4) | Red (4) (match) | |
| 11 | Failure of battery charger of SW Intake Structure DC feeding the “on-service” train of SW | Red (2) (over by 4) | QSR42B0526A | 1.03 | White | Red (4) (over by 2) | |
| 12 | One accumulator fails | Yellow (over by 1) | Q2E21V0032A | 1.07 | White | Yellow (over by 1) | |
| 13 | AMSAC fails | White (over by 1) | N2C31NFAMS2627 | 1.0 | Green | White (over by 1) | |
| 14 | One MDP of AFW fails | Red (4) (match) | Q2N23P0001B | 5.01 | Red (4) | Red (3) (over by 1) | |
| 15 | TDP of AFW fails | Yellow (match) | Q2N23P0002 | 2.69 | Yellow | Red (4) (over by 1) | |
| 16 | Pump in the "non-onservice train" (standby) of CCW fails | Red (2) (over by 2) | Q2P17P0001C | 5.44 | Red (4) | Red (3) (over by 1) | |
| 17 | One condensate pump fails | Green (match) | N2N21P0001A | 1.0 | Green | Green (match) | |
| 18 | One SGFP fails | Green (match) | N2N21P0002A | 1.01 | Green | Green (match) | |
| 19 | CVCS centrifugal charging pump in the "non-onservice train" fails | Red (4) (over by 1) | Q2E21P0002C | 2.59 | Yellow | Red (4) (over by 1) | |

| No. | Component Out of Service or Failed Operator Action | SDP Worksheet Results (Before) (1) | Component Name (2, 4) | Internal RAW | Plant CDF Color (3) | SDP Worksheet Results (After) (1) | Comments |
|---|---|---|---|---|---|---|---|
| 20 | One boric acid transfer pump fails | Green (match) | Q2E21P0005A | 1.0 | Green | Green (match) | |
| 21 | One air compressor of IA fails | Red (3) (over by 3) | N2P19C0001A | 1.07 | White | White (match) | |
| 22 | One Atmospheric Relief Valve (ARV) fails to open | White (match) | Q2N11PV3371A | 1.05 | White | Yellow (over by 1) | |
| 23 | One SG safety valve fails to open | Red (4) (over by 3) | Q2N11V0010A | 1.0 | Green | Yellow (over by 2) | |
| 24 | One Main Steam Isolation Valve (MSIV) fails to close | White (over by 1) | Q2N11HV3369A(FTC) | 1.0 | Green | Green (match) | |
| 25 | One PORV fails to open | Red (4) (over by 1) | Q2B31PCV0444B | 1.45 | Yellow | Yellow (match) | |
| 26 | One primary block valve fails to close | White (over by 1) | Q2B31MOV8000A(FTC) | 1.0 | Green | White (over by 1) | |
| 27 | One primary safety valve fails to open | White (over by 1) | Q2B13V0031A | 1.0 | Green | White (over by 1) | |
| 28 | One RHR pump fails | Red (3) (over by 1) | Q2E11P0001B | 9.43 | Red (4) | Red (3) (over by 1) | |
| 29 | One running SW pump in on-service train fails | Red (2) (over by 3) | Q2P16P0001C | 1.23 | Yellow | Red (4) (over by 1) | |
| | ***Operator Actions*** | | | | | | |

| No. | Component Out of Service or Failed Operator Action | SDP Worksheet Results (Before) [1] | Component Name [2, 4] | Internal RAW | Plant CDF Color [3] | SDP Worksheet Results (After) [1] | Comments |
|---|---|---|---|---|---|---|---|
| 30 | Operator fails to conduct Feed/Bleed | Red (4) (over by 1) | OAB | 1.72 | Yellow | Red (4) (over by 1) | |
| 31 | Operator fails to switchover in HPR | Red (4) (match) | OAR-HPR | 13.09 | Red (4) | Red (4) (match) | |
| 32 | Operator fails to switchover in LPR | Red (3) (over by 2) | OAR-LPR | 2.97 | Yellow | Red (3) (over by 2) | |
| 33 | Operator fails to recover AC power in < 1 hour after a LOOP | White (match) | 1HR | 1.14 | White | Green (under) | |
| 34 | Operator fails to recover AC power in < 5 hours after a LOOP | Yellow (over by 1) | XHR | 1.10 | White | White (match) | |
| 35 | Operator fails to depressurize RCS using SGs to less than setpoint of relief valves of SG after SGTR | White (match) | OAD_B_1 | 1.06 | White | White (match) | |
| 36 | Operator fails to conduct emergency boration after ATWS | White (over by 1) | OBR | 1.0 | Green | White (over by 1) | |

| No. | Component Out of Service or Failed Operator Action | SDP Worksheet Results (Before) (1) | Component Name (2, 4) | Internal RAW | Plant CDF Color (3) | SDP Worksheet Results (After) (1) | Comments |
|---|---|---|---|---|---|---|---|
| 37 | Operator fails to align mitigating equipment to the off-service train after loss of on-service train of cooling | Red (2) (over by 3) | OMH | 1.63 | Yellow | Red (4) (over by 1) | |

**Notes:**

1. When the color of the result of the SDP notebook is red, the number in parenthesis after the word "Red" is the order of magnitude yielded by the SDP notebook.

2. A component can be interpreted as a group of basic events modeling the failure of one "real" component, such as a pump or a valve.

3. When the color corresponding to the plant's CDF is red, the number in parenthesis after the word "Red" is the order of magnitude obtained from the following calculation: (Base-case CDF) * RAW.

4. When information about several similar components in a system, such as pumps in redundant trains, is available, the one with the highest impact on CDF was selected for inclusion in this table.

**Table 3: Comparative Summary of the Benchmarking Results - Farley Unit 1**

| SDP Notebook is... | SDP Notebook Before (Rev. 0) | | SDP Notebook After (Rev. 1) | |
|---|---|---|---|---|
| | Number of Cases | Percentage | Number of Cases | Percentage |
| Less conservative | 0 | 0 | 1 | 2.7 |
| More conservative by one color | 17 | 45.9 | 18 | 48.6 |
| More conservative by two colors | 3 | 8.1 | 2 | 5.4 |
| More conservative by three colors | 5 | 13.5 | 2 | 5.4 |
| More conservative by four colors | 0 | 0 | 0 | 0 |
| More conservative by five colors | 1 | 2.7 | 0 | 0 |
| Matched | 11 | 29.7 | 14 | 37.8 |
| Total | 37 | 100 | 37 | 100 |

**Table 4: Comparative Summary of the Benchmarking Results - Farley Unit 2**

| SDP Notebook is... | SDP Notebook Before (Rev. 0) | | SDP Notebook After (Rev. 1) | |
|---|---|---|---|---|
| | Number of Cases | Percentage | Number of Cases | Percentage |
| Less conservative | 0 | 0 | 1 | 2.7 |
| More conservative by one color | 16 | 43.2 | 17 | 45.9 |
| More conservative by two colors | 3 | 8.1 | 3 | 8.1 |
| More conservative by three colors | 5 | 13.5 | 1 | 2.7 |
| More conservative by four colors | 1 | 2.7 | 0 | 0 |
| Matched | 12 | 32.4 | 15 | 40.5 |
| Total | 37 | 100 | 37 | 100 |

# 3. PROPOSED REVISIONS TO THE 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 the licensee's 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 Joseph M. Farley Nuclear Plant, Units 1 and 2

The NRC staff participating in the benchmarking and 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. Several significant changes that had an impact on the evaluation of the notebook were incorporated during the visit, including revised HEPs and initiator frequencies. The proposed revisions are discussed below:

1. Table 1. The "Loss of 4160 V Bus F or G (When Aligned to On-service Train of Cooling) (LBACON)" and "Loss of 4160 V Bus F or G (When Aligned to Off-service Train of Cooling) (LBACOFF)" were added to row IV.

2. Table 2. The column "Initiating Event" was updated to incorporate the changes to the notebook.

3. Table 2. We added footnotes to indicate the systems/components for which the notebook will result in an under or overestimate. We identified cases that will be conservative by one color or by more than one color.

4. Table 2. We updated the internal event CDF value, excluding internal flooding, for both units.

5. Table 2. HVAC is not required to support the AC Power system, so it was removed from the list of support systems.

6. Table 2. The support system of AMSAC was changed to 120 VAC.

7. Table 2. The major components of Instrument Air were changed to 3 air compressors per unit. One of them is swing because it can be manually connected to the other unit.

8. Table 2. We added footnotes to the RCP seals indicating that 1) manual realignment is necessary to recover cooling to the RCP's thermal barrier after loss of the on-service train of cooling, and 2) the RCP seals have high-temperature o-rings.

9. Table 2. We added a footnote indicating that the AFW's valves fail open on loss of instrument air. After this loss, manual flow control of AFW pumps is required.

10. Transients with PCS Available (Reactor Trip) (TRANS). We changed the credit of the function "Power Conversion System (PCS)" from operator action = 2 to operator action = 1 because the licensee's HEP for this action is 8E-2 and, hence, it has a credit = 1.

11. Transients with PCS Available (Reactor Trip) (TRANS), Transients with Loss of PCS (TPCS), Small LOCA (SLOCA), Stuck-open PORV (SORV), and Loss of Offsite Power (LOOP). We added the number of steam generators to which AFW is provided: 1/3 SGs.

12. Transients with Loss of PCS (TPCS). 1/3 ARVs were included as a path for steam relief.

13. Stuck-open PORV (SORV). We added an event tree for this initiator.

14. Medium LOCA (MLOCA). The success criteria for the function "RCS Depressurization (DEP1)" was changed from 2/3 ARVs to 1/3 ARVs. The credit for this function was changed from operator action = 1 to operator action = 3 because the licensee's HEP for this action is 1.09E-3 and, hence, it has a credit = 3.

15. Medium LOCA (MLOCA). The credit for the function "RCS Depressurization (DEP2)" was changed from operator action = 3 to operator action = 2 because the licensee's HEP for this action is 7.16E-3 and, hence, it has a credit = 2.

16. Medium LOCA (MLOCA). To be consistent with the two previous changes, the headings DEP1 and DEP2 in the event tree were swapped, i.e., DEP1 became DEP2, and vice versa.

17. Medium LOCA (MLOCA). We added a footnote to indicate that secondary heat removal is not required due to the cooldown provided by the break. AFW is used for depressurization.

18. Medium LOCA (MLOCA). The function "Low Head Injection (LHI)" was changed to "Low Pressure Injection (LPI)" to use a consistent name across the notebook for similar functions.

19. Large LOCA (LLOCA). The function "Early Inventory, Low Pressure Injection (EILP)" was changed to "Low Pressure Injection (LPI)" to use a consistent name across the notebook for similar functions.

20. Loss of Offsite Power (LOOP). The function "Emergency AC Power (EAC)" was changed to 1/2 EDGs (1 multi-train system) or 1/1 swing EDG (to train B) (operator action =1).

21. Loss of Offsite Power (LOOP). 1/3 ARVs were credited as a steam relief path.

22. Steam Generator Tube Rupture (SGTR). The success criteria for the function "Secondary Heat Removal (AFW)" was changed from "(1/2 MDPs of AFW or 1/1 TDP of AFW) (operator action = 3)" to "[1/2 MDAFW trains (1 multi-train system) or 1/1 TDAFW train (1 ASD train)] to 1/2 SGs with (1/5 SG safety valves or 1/3 ARVs)"

23. Steam Generator Tube Rupture (SGTR). The Rev. 0 function "Pressure Equalization (EQ)" was split into two functions: 1) "Isolation of Affected SG (ISOL)": Operator isolates the affected SG by using flow control valves and steam flow isolated by (1/2 MSIVs and bypass valves on ruptured SG) or (1/2 MSIVs and bypass valves on both intact SGs closed) (operator action = 2).

2) "Pressure Equalization (EQ)": Operator depressurizes RCS by using 1/1 ARV on 2 of 2 intact SGs to less than setpoint of relief valves of SG (operator action = 2).
The SGTR's event tree was modified to include the new function "Isolation of Affected SG (ISOL)."

24. Main Steam Line Break Outside Containment (MSLB). The event tree and worksheet were modified according to the "standard" SDP model for MSLB in Westinghouse plants. Also, for the functions related to the MSIVs, the success criteria was changed to "1/2 MSIVs close on x/y steam paths," where x is the number of paths necessary out of y available paths.

25. Main Steam Line Break Outside Containment (MSLB). The credit for the function "Stop Injection (STIN)" was changed from operator action = 2 to operator action = 3 because the licensee estimated a HEP = 3.39E-3 for this action and, hence, it has a credit = 3.

26. The Rev. 0 worksheet "Loss of On-Service Train of Cooling (LOTC)" was divided into two worksheets: "Loss of On-Service Train of CCW (LCCW)" and "Loss of On-Service Train of SW (LOSW)."

27. The event tree for the initiators causing a loss of the on-service train of cooling, with the initiating event LOTC, was modified to take into account that:
1) if the operator trips the RCPs, then if the operator fails to provide RCP seal cooling, an RCP seal LOCA occurs (heading OFST of event tree). After the loss of the on-service train of cooling, this LOCA can only be mitigated with the off-service train of cooling.
2) On loss of the on-service train, cooling to the RCPs is lost, and the operator must trip the RCPs in less than 3 minutes after loss of cooling. If the operator fails, we assume that a small LOCA occurs (heading RCPT of event tree). The licensee (and the event tree) assume that if the operator fails to trip the RCPs, the leakage will be large enough to automatically initiate SI which will start the standby train of cooling prior to starting the SI mitigation equipment in the standby train.

28. Loss of On-Service Train of CCW (LCCW) and Loss of On-Service Train of SW (LOSW). 1/3 ARVs were credited as a steam relief path.

29. Loss of Instrument Air (LIA). Credit was given to an emergency air compressor. If this compressor fails, the TDAFW pump is not available.

30. Loss of Instrument Air (LIA). Credit was given to Feed/Bleed because the pressurizer PORVs can be manually aligned to backup $N_2$.

31. Loss of a DC Bus (LBDC). Loss of 125 VDC bus causes a transient with loss of PCS with loss of automatic start of one train of mitigating equipment and of one PORV. Hence the event tree and worksheet were modified to model this scenario.

32. Loss of a DC Bus (LBDC). On loss of 125 VDC bus A, the ARVs fail closed. Since we modeled the worst case, we removed the ARVs from this worksheet.

20. Loss of a DC Bus (LBDC). We changed the success criteria of the function "Primary Heat Removal, Feed/Bleed (FB)" from "1/1 remaining PORV open for Feed/Bleed (operator action = 2)" to "Operator restores IA to the containment and opens 1/1 remaining PORV for

Feed/Bleed (operator action = 1)."  The licensee estimated a HEP = 6.58E-2 for this operator action.  Hence, it has a credit = 1.

## 3.2 Generic Change in IMC 0609 for Guidance to NRC Inspectors

Based on the lessons from this benchmarking, a recommendation for improving 0609 is as follows:

For the loss of a battery charger of a DC bus, including the battery charger of SW Intake Structure DC, the rule for SDP evaluation assumes that the associated DC bus will be lost as a result of the failure of the battery charger because the associated battery will discharge under normal loads. On the other hand, the loss of the charger at Farley is annunciated in the main control room and cause entry into a 2 hour LCO.  Therefore, the licensee assumes that actions would be taken to align another battery charger or the plant would be shut down before a loss of DC bus would occur. Accordingly, it is recommended that the rule for SDP evaluation of a battery charger be revised to account for the possibility that the associated DC bus will not be lost as a result of the failure of the battery charger.  This issue also was observed while benchmarking the Seabrook Station.

## 3.3 Generic Change to the SDP Notebook

No generic change to the SDP notebook was identified.

# 4. DISCUSSION ON EXTERNAL EVENTS

The licensee does not have a PRA model for external events. Unit 1's CDF due to internal floods is 7.24 E-6/year, and Unit 1's total CDF including both internal events and internal floods is 3.92 E-5/year. Unit 2's CDF due to internal floods is 6.82 E-6/year, and the Unit 2's total CDF including both internal events and internal floods is 5.74 E-5/year.

The licensee's PRA for both Unit 1 and Unit 2 models what were used for the benchmarking is Revision level 5 with a calculation sign off date of 12/31/01.

# 5. LIST OF PARTICIPANTS

| | |
|---|---|
| Rudolph Bernhard | Nuclear Regulatory Commission/Region II |
| Peter Wilson | Nuclear Regulatory Commission/Office of Nuclear Reactor Regulation |
| David E. McCoy | Southern Company |
| John A. Schroeder | Idaho National Engineering and Environmental Laboratory |
| Gerardo Martinez-Guridi | Brookhaven National Laboratory |