August 28, 2003

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SUBJECT: RESULTS OF THE WATTS BAR SDP PHASE 2 NOTEBOOK BENCHMARKING VISIT

During January 2003, NRC staff and contractors visited the Tennessee Valley Authority (TVA) corporate offices in Chattanooga, Tennessee to compare the Watts Bar Nuclear (WBN) plant Significance Determination Process (SDP) Phase 2 notebook and licensee's risk model results to ensure that the SDP notebook was generally conservative. The current plant probabilistic safety assessment's (PSA's) internal event core damage frequency was 2.17 E-5/reactor-year excluding internal flood events. The WBN PSA did not include an integrated PSA model with external initiating events and therefore sensitivity studies were not performed to determine any impact of external event 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 WBN were also compared with the licensee's risk model. The results of the SPAR model benchmarking effort will be documented in the next revision of the SPAR (revision 3) model documentation.

In the review of the WBN SDP notebook for the benchmark efforts, the team determined that some changes to the SDP notebook were needed to reflect how the WBN plant is currently designed and operated. Forty two hypothetical inspection findings were processed through the SDP notebook and compared with the licensee's related importance measures. Using the Revision 0 SDP notebook, the team determined that 14 percent of the cases were less conservative, 24 percent of the cases were more conservative, 50 percent were consistent, and 12 percent were not comparable with the licensee's results. Of the conservative cases, 3 cases were two colors greater than the results obtained using the licensee's model. Consequently, 30 changes were made to the SDP notebook.

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Using the Revision 1 SDP notebook, the team determined that 9 percent of the cases were less conservative, 34 percent were more conservative, 57 percent of the cases were consistent with the licensee's results, and zero percent were not comparable with the licensee's results. Of the conservative cases, all but 2 cases were one order of magnitude greater than the results obtained with the licensee's model and as such are generally consistent with the expectation that the notebooks should be slightly conservative when compared to the licensee's model.

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

Attachment: As stated

Using the Revision 1 SDP notebook, the team determined that 9 percent of the cases were less conservative, 34 percent were more conservative, 57 percent of the cases were consistent with the licensee's results, and zero percent were not comparable with the licensee's results. Of the conservative cases, all but 2 cases were one order of magnitude greater than the results obtained with the licensee's model and as such are generally consistent with the expectation that the notebooks should be slightly conservative when compared to the licensee's model.

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

Attachment: As stated

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SUMMARY REPORT ON BENCHMARKING TRIP

TO THE WATTS BAR NUCLEAR PLANT

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Table of Contents

List of Tables

1 INTRODUCTION

A benchmarking meeting took place for the Watts Bar Nuclear Plant (WBNP) at the TVA office at Chattanoga (TN) on January 13-17, 2003. Mr. Michael Franovich and R. Bernhard from USNRC, along with M.A. Azarm from BNL, and Mr. John Poloski from INEEL participated in this benchmarking exercise. This benchmarking report documents the overall results and insights from the benchmarking trip.

In preparation for the meeting, BNL staff reviewed the SDP notebook for Watts Bar, evaluated the coloring of the Rev. 0 SDP worksheets, and collected the system diagrams and information. In addition, a copy of the meeting protocol, table of the target lists, and a set of questions were sent to the licensee by Mr. Franovich prior to the meeting.

The major milestones achieved during this meeting were as follows:

1. The licensee submitted a file containing the RAW values for the equipment and human errors (basic events) identified in the target list. The RAW values were based on an average maintenance model of the internal events excluding the internal flood scenarios.

2. The licensee calculated the RAW values for each basic event through a complete run of the model with the modified input and logic as necessary. This is done since the licensee uses a large event tree approach with many support states utilizing the Riskman computer code. Therefore, identification of PSA basic event names for each run is not appropriate and they were not provided.

3. The licensee's staff provided comments on the Rev. 0 notebook and provided updated dependency information for the fluid support systems and electrical systems to facilitate evaluation of the hypothetical inspection findings as a part of the benchmarking exercise.

4. We obtained and the licensee provided the updated HEPs used in the WBNP PSA and files containing the summary description of the PSA method, application, results, and system information.

5. We conducted a detailed benchmarking of the elements within the target set using the Rev. 0 SDP notebook and compared the results with the RAW values from the licensee's PSA.

6. We also carried out the on-site modifications to the Rev. 0 SDP notebook per the licensee's comments. The modified notebook (a draft of what would become Rev. 1 SDP notebook) then was used to conduct benchmarking of the elements within the target set and the results were compared with the RAW values from the licensee's PSA.

7. We requested a few runs from the licensee to determine the dominant contributors to the RAW values, and compared them with the contributors captured by either the Rev. 0 or draft Rev. 1 notebooks. This was mainly done for those cases where the draft Rev.

1 SDP resulted in a SDP color that either underestimated by one color or overestimated by two or more orders of magnitude the color determined based on the licensee's RAW values.

8. Additional modifications were proposed based on the identified root causes and the results from the case runs in step 5 above to enhance the Rev. 1 notebook.

The utility's staff provided extensive comments that were resolved and will be incorporated in the SDP Rev. 1 notebook.

The Rev. 0 SDP notebook for WBNP was reviewed, modified as necessary, and the sequences were solved prior to the site visit based on the current SDP generic guidelines. A total of 42 hypothetical inspection findings were examined during the site visit. Table 1 lists these items along with the associated risk significance based on the RAW values from the licensee's PSA and the SDP notebook.

The summary results from benchmarking are shown in Table 2. The Rev. 1 SDP notebook when issued should provide similar or slightly more conservative results (by one color) than the licensee's PSA in about 86% of the cases. In 9% of the cases (4 cases) the SDP underestimated the PSA by one order of magnitude (one color), and in 5% of the cases (2 cases) the SDP overestimated the licensee's results by two colors. The reason for the four cases of underestimates and the two cases of overestimates by two colors were investigated and determined. The specific reasons for these cases are discussed in detail in Section 2 below.

2. SUMMARY RESULTS FROM BENCHMARKING

This section provides the results of the benchmarking exercise. The results of the benchmarking analyses are summarized in Table 1. Table 1 consists of seven column headings. In the first column, the out-of-service components, human actions, or recovery actions are identified for the case analyses. The second column shows the colors assigned for significance characterization from using the Rev. 0 SDP notebook. The third and fourth columns show the conditional CDF and the associated RAW value. The significant determination color determined based on the licensee's PSA for internal event initiators is shown in the fifth column under the heading of "Site Color". The sixth column shows the assigned colors that are expected to be obtained from the Rev. 1 SDP notebook when the licensee's comments are incorporated and the report is issued. This column also indicates whether the Rev. 1 SDP would match, overestimate by one color, overestimate by two colors, or underestimate the site color based on the licensee's RAW values. It should be noted that the internal RAW values are determined based on a PSA model that excludes the flood contribution. Finally, the last column provides some comments clarifying how the SDP rules were applied as a part of the SDP evaluation process and if any changes to the SDP notebook resulted from a detailed case run.

The specific cases of underestimates and overestimates by two colors could be identified in Table 1. Summary reasons for these cases where the SDP notebook and the PSA did not agree are also provided in Table 1. Further elaboration of these cases is provided below:

Cases of Underestimates

- CCS Pump 1A-A fail to run, the RAW indicates “R” where the SDP notebook indicates “Y”. The RAW value for Train A is 56.1. The RAW for a pump then should be around 5.6 rather than 17.88 as reported (about an order of magnitude less). The RAW value may be artificially high due to CCF modeling. Therefore, the potential reason could be due to asymmetric CCF modeling. It will be considered as a true underestimate.

- Primary PORV Block valve FTC. RAW indicates “Y” where the SDP notebook indicates “W”. Main reason is the high HEP for RWSTCS action. It will be considered as true underestimate.

- Failure to restore MFW is colored “Y” by the RAW and “W” by the SDP notebook. The potential reason is the round-off error. In all reactor trips the MFW would trip and needs to be recovered. The frequency of all trips is about 3.06 per reactor-year in the PSA. A frequency of 0.1 (or Row I) is used in SDP. It will be considered as a true underestimate.

- AMSAC is colored “W” by the RAW and “G” by the SDP notebook. The licensee’s PSA models all ATWS scenarios with an order of magnitude higher frequency, whereas the SDP notebook only models the non-recoverable ATWS due to mechanical failures. It will be considered as a true underestimate.

Cases of Overestimates by Two Colors

- CCF of both PORVs FTO was colored “W” by the RAW and “R” by the SDP notebook. The potential reason for this discrepancy could be the use of an inappropriate RAW value. The RAW for two PORVs to fail open cannot be below the failure of feed and bleed. We, therefore, do not consider this as a true overestimate by two orders of magnitude.

- MSIV FTC was colored as “G” by the RAW value and “Y” by the SDP notebook. The reason for this difference is exclusion of PTS scenarios in the licensee’s PSA model. We, therefore, do not consider this as a true overestimate by two orders of magnitude.

The benchmarking site visit and the incorporation of the licensee’s comments significantly improved the SDP notebook and allowed the modeling of the additional five cases which was not possible with the Rev. 0 SDP notebook. Furthermore, as expected, the benchmarking results for the Rev. 1 SDP notebook showed both an increase in number of matches and a reduction in the number of underestimates compared to the Rev. 0 SDP notebook.

Table 1: Summary of Benchmarking Results for Watts Bar
Internal Events CDF is 2.17E-5/reactor-year (revision 3) at a 1.0E-13 truncation limit [(1)]

RAW Thresholds were W = 1.046, Y = 1.46, and R = 5.61

Unavailable system or component	SDP Worksheet Results (Before)	Case CDF	Internal RAW	Site Color	SDP Worksheet Results (After)	Comments
One cold leg accumulator fails to inject	Y	2.49E-5	1.147	W	Y (over by 1)	Can use outlet check valve failure as surrogate. CV 63-622, 63-23, 63-24, or 63-25.
Emergency DG 1A-A FTR	Y	5.88E-05	2.7	Y	Y (match)	Run case without onsite AC/EDG recovery.
	Y	5.03E-5	2.32	Y	Y (match)	Run case with EDG recovery model with 1 of 2 EDGs potentially recovered.
EDG fuel oil transfer pump FTS	NA	2.23E-5	1.027	G	W (over by 1)	
6.9 kV bus 1A-A failure (safeguards)	R	9.64E-3	444	R	R (match)	
MDAFW pump >A= FTS	Y	4.82E-5	2.22	Y	Y (match)	
Both MDAFW pumps FTR (common-cause failure)	R	1.49E-4	6.86	R	R (match)	
TD AFW pump FTS	Y	2.29E-4	3.92	Y	Y (match)	Licensee provided a RAW of 10.55 which appears to be in error. The RAW provided in the table prior to the site visit was 3.92 which is more appropriate since it should be Yellow, similar to TDAFW trip and Throttle valve FTO (see next item).

Unavailable system or component	SDP Worksheet Results (Before)	Case CDF	Internal RAW	Site Color	SDP Worksheet results (After)	Comments
TD AFW trip and throttle valve FTO FCV 1-51	Y	1.05E-4	4.84	Y	Y (match)	
ERCW (service water) pump J-A FTS	W	2.71E-5	1.25	W	W (match)	Increase IEL by one order and solve LERCW worksheet.
CCS pump 1A-A FTR	R	3.88E-4	17.88	R	Y (under by 1)	Increase IEL by one order for LCCW and solve base case of systems affected on other worksheets. The RAW value for Train A is 56.1. The RAW for a pump then should be around 5.6. The RAW value may be artificially high due to CCF modeling.
CS pump FTR Shared CCS Train	NA	4.6E-4	21.2	R	R (match)	Value was found under Train B of CCS (shared) in information provided prior to site visit.
CVCS centrifugal charging pump "A" FTR	Y	7.26E-5	3.34	Y	Y (match)	
CVCS centrifugal charging pump "B" FTR	NA	6.1E-5	2.81	Y	R (over by 1)	
MOV FCV 63-25 FTO (CCP discharge to cold legs on safety injection signal)	Y	2.17E-5	1.0	G	W (match)	Becomes a match when inspector applies manual recovery credit.
HHSI pump A (intermediate SI) FTS	Y	2.57E-5	1.27	W	Y (over by 1)	
RHR pump A FTR	Y	7.87E-5	3.6	Y	Y (match)	

Unavailable system or component	SDP Worksheet Results (Before)	Case CDF	Internal RAW	Site Color	SDP Worksheet results (After)	Comments
RHR Pump B	Y	8.36E-5	3.95	Y	Y (match)	
Containment recirculation sump valve Train B (63-73) FTO	Y	8.73E-5	4.0	Y	Y (match)	Only HPR and LPR (not Cont spray makeup to RWST, has separate sump valve unlike SQN).
Failure of RWST level lo 4/4 instruments	R	6.2E-4	28	R	R (match)	SDP assumed total loss of RWST, otherwise it is a White for one channel.
ECCS LPI/HPI piggy back valve FCV 63-8 FTO	W	2.19E-5	1.009	G	W (over by 1)	
One primary PORV PCV 68-334 FTO	Y	2.36E-5	1.087	W	Y (over by 1)	See concern in the CCF for both PORVs FTO (below). The RAW value for one PORV to open and re-close is given as 2.21 (Yellow) in the table provided before the site visit.
Common cause both primary PORVs FTO	R	2.70E-5	1.24	W	R (over by 2)	The RAW should be higher than the RAW for feed and bleed which is reported as yellow later on in the table. Therefore, the RAW value is suspect and may only be showing the contribution from ATWS for pressure relief.
Primary PORV block valve FCV-68-333 FTC on demand (hardware)	W	3.61E-5	1.66	Y	W (under by 1)	The SDP resulted in 2 “whites” whereas the PSA assigned threshold yellow. The cause may be attributed to a round-off error. The HEP for RWSTCs is 4.4E-1 and the worksheet credits it as 0.1 (credit of 1).

Unavailable system or component	SDP Worksheet Results (Before)	Case CDF	Internal RAW	Site Color	SDP Worksheet results (After)	Comments
Primary Safety Valve 68-563 FTO	G	2.34E-5	1.078	W	W (match)	
AMSAC circuit failure	G	2.34E-5	1.078	W	G (under by 1)	The licensee models all causes of ATWS, not just mechanical failure; therefore, AMSAC would be credited in all ATWS scenarios which have an order of magnitude higher frequency.
125 VDC vital bus 1-1 failure	Y	6.62E-4	12.26	R	R (match)	
125 VDC vital battery failure	Y	2.18E-5	1.004	G	W (over by 1)	Assuming battery charger can carry SI loads without battery.
Vital battery charger failure	Y	2.17E-5	1.00	G	W (over by 1)	Swing charger can be manually aligned.
One MSIV FTC on demand (FCV 1-22)	Y	2.17E-5	1.00	G	Y (over by 2)	
One SG PORV fails to open PCV 1-5	W	2.90E-5	1.34	W	W (match)	
Standby air compressor FTS on demand	NA	2.18E-5	1.004	G	W (over by 1)	
Containment spray pump A FTS	W	2.27E-5	1.046	W	W (match)	
Containment spray pump B FTS	W			W	W (match)	
Operator Actions						
Fail to establish Feed & Bleed	Y	9.73E-5	4.48	Y	R (over by 1)	
Fail to emergency borate (Long-term shutdown)	W	2.43E-5	1.12	W	W (match)	
Fail to HPR	R	5.78E-5	2.66	Y	R (over by 1)	

Unavailable system or component	SDP Worksheet Results (Before)	Case CDF	Internal RAW	Site Color	SDP Worksheet results (After)	Comments
Fail to refill RWST SGTR	Y	9.55E-5	4.4	Y	Y (match)	
Fails to depressurize RCS in SLOCA with PORVs or sprays when secondary heat removal is available	Y	2.18E-5	1.005	G	W (over by 1)	This slight overestimate is caused since the SDP gives a credit of 3 or 1 multi-train system to EIHP (1/2 CCPs and 1/2 SI trains).
Fail to isolate faulted steam generator	W	2.47E-5	1.14	W	W (match)	
Fail to RCS cooldown & Depressurize in SGTR event	W	1.52E-4	7.0	R	R (match)	Kill EQ and SDC cool.
Fail to restore Main Feedwater	W	3.52E-5	1.62	Y	W (under by 1)	Set TPCS initiator to zero and solve. Note that the sum of all causes for trips (WBN PSA) is 3.06.

<u>Note</u>:

1. The truncation limit is not applicable since the PSA was modeled using the Riskman Code. The equivalent truncation limit for the CDF estimation is about 1.0E-13.

Table 2. Comparative Summary of the Benchmarking Results

Total Number of Cases Compared	SDP Notebook Before (draft Rev. 1)		SDP Notebook After (Rev. 1)	
	Number of Cases (42)	**Percentage**	**Number of Cases (42)**	**Percentage**
SDP: Less Conservative	6	14	4	9
SDP: More Conservative				
Over by 1	7	17	12	29
Over by 2	3	7	2	5
SDP: Matched	21	50	24	57
Not modeled	5	12	0	0

3. PROPOSED REVISIONS TO REV. 0 SDP NOTEBOOK

A set of modifications were proposed for the Rev. 0 SDP notebook as a result of the site visit. These proposed modifications are driven by the licensee's comments on the Rev. 0 SDP notebook, better understanding of the current plant design features, allowance for additional recovery actions, revised Human Error Probabilities (HEPs), updated frequencies of the initiating events, and the results of benchmarking.

3.1 Specific Changes to the Rev. 0 SDP Notebook for Watts Bar

The earlier version of the notebook was reviewed by the utility on May 26, 2000. The resolution of the utility's comments is included in the notebook. Additional comments were received during the benchmarking site visit. These comments were reviewed and incorporated into the SDP notebook and are listed below.

Table 1:

1. Moved LVDC1 to Row II.
2. Removed LASD from Row III.
3. Moved SGTR from Row III to Row II. Added a footnote stating that the IE frequency of SGTR is 1.9E-2 per reactor-year.
4. Moved SORV to Row II and added a footnote describing the reason. The footnote stated that: SORV frequency calculated by taking PORV FTC/demand as 0.0259 multiplied by the conditional probability of challenge (e.g. LOOP, loss of condenser vacuum, MSIV closure). SORV frequency is 1.149E-2 per reactor-year.
5. Added LIA to Row III. Stated that this is total loss of air including loss of ACAS compressors. The IE frequency is not explicitly modeled in the licensee's PSA but was estimated by the licensee to be around 1.0E-3 per reactor-year.
6. Added a footnote indicating the licensee's IE frequencies for MLOCA and LLOCA are 2.67E-5 and 2.67E-6 per reactor-year respectively.

Table 2:

1. Footnoted that each EDG is equipped with two fuel transfer pumps and a dedicated DC for starting.
2. Added a footnote stating that long term operation of TDAFW requires room cooling which is provided by a DC fan fed from DC board III, or an AC fan fed from 120 VAC instrument power distribution 1-A (no HVAC required). It also depends on both trains of air; each train of air supplies 2/4 control valves. There is also nitrogen backup.
3. Added a footnote that the MFW pumps trip on reactor trip. The SBMFP has a 18% capacity and can be credited as a manual start after reactor trip as long as there is a hot well pump available. The SBMFP auto starts during normal operation (no reactor trip) when Feed flow is degraded.
4. Added a footnote that on total loss of CCS, but availability of ERCW, a charging pump could operate by cross-connecting the ERCW flow for room cooling for pump lube oil cooling.
5. Added a footnote that there is nitrogen backup for the SG ARVs. The SG ARVs could be locally operated manually either with connecting nitrogen backup or hand wheels.

6. Removed HVAC as a support to CCS.
7. Added the swing manual charger as a major component to DC power system.
8. Indicated that the RCP seals are high temperature seals on both units.
9. Modified footnote 1 reflecting the current CDF per the Rev. 3 PSA is 2.3E-5 per reactor-year for internal events excluding floods. Also indicated that the flood contribution is 5.0E-6 per reactor-year.

All tables in Section 1.3:

1. Updated the credit for manual actions and the associated footnotes per the updated PSA human error probability values.

Table 3.3:

1. Combined worksheet sequence 6 with worksheet sequence 1.

Table 3.7:

1. Changed REC6 to REC4 and reduced the credit to 1.

2. Added a footnote stating that even though backfeed from the other unit's EDGs is possible, it is not credited in either the PSA or the SDP notebook.

Table 3.8:

1. Included a new event tree and worksheet for the SGTR per the licensee's input.

Table 3.9:

1. Changed the success criteria for AFW to 2/2 MDAFW trains or 1/1 TDAFW train.

Table 3.11

1. Changed the description of ERCWB to state 2/4 remaining ERCW pumps.

Table 3.12

1. Changed the description of CS to state continued operation of normally running C-S pump.

2. Added the function (SINJ) describing operator action for connecting ERCW to CCP lube oil cooling.

Table 3.13

1. Removed LASD worksheet and inserted a new worksheet for loss of IA (LIA).

2. LIA should behave similar to TPCS; however, the operation of AFW would be manual (credit of 2).

3. Assigned a frequency consistent to Row III (Credit = 3) to LIA.

Table 3.14:

- Changed the frequency of LVDC1 to 3.8E-3 per each division and gave it a credit of 2 in the worksheet for any of the four divisions.

- Changed the credit of EIHP from 1 train to 1 multi-train system.

Table 3.15:

- Changed the credit of EIHP from 1 train to 1 multi-train system.

3.2 Generic Changes in IMC 0609 for Guidance to NRC Inspectors

No changes were identified from this site visit.

3.3 Generic Changes to the SDP Notebook

None.

3.3.1 Generic Insights for SDP Evaluation Process

The SDP notebook currently models the mechanical failure of scram rods as the ATWS initiating event with a frequency assigned to Row VI. Such ATWS scenarios are not recoverable and delayed manual scram cannot be credited. The licensee's PSA, on the contrary, models all ATWS scenarios, i.e., both electrical and mechanical. The overall ATWS frequency from all causes is about a factor of 10 to 30 over the SDP assigned frequency. It is, therefore, expected that the SDP notebook will underestimate some of the ATWS mitigation capabilities, e.g., AMSAC. These underestimates, therefore, are a direct result of the simplified modeling and assumptions that are utilized in the generic development of the ATWS worksheet in the SDP notebooks for PWRs. One remedy to this problem is to also develop the ATWS worksheet for the "electrical ATWS" as well.

4. DISCUSSION ON EXTERNAL EVENTS

There was little or no discussion on the external events. The Watts Bar PSA addresses the risk from internal fire using FIVE (Fire Induced Vulnerability Evaluation) methodology. Seismic risk is addressed through qualitative seismic margin approach. The RAW values for internal events could not be easily compared to those of internal plus external events since the PSA models are not currently integrated.

5. LIST OF PARTICIPANTS

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