August 28, 2003

MEMORANDUM TO: Stuart Richards, Chief
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FROM: Mark F. Reinhart, Chief **/RA/**
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SUBJECT: RESULTS OF THE SEQUOYAH 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 Sequoyah Nuclear (SQN) 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 1.23 E-5/reactor-year excluding internal flood events. The SQN 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 SQN 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 SQN SDP notebook for the benchmark efforts, the team determined that some changes to the SDP notebook were needed to reflect how the SQN plant is currently designed and operated. Forty 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 concluded that 7.5 percent of the cases were less conservative, 40 percent of the cases were more conservative, and 52.5 percent of the cases were consistent with the licensee's results. Of the conservative cases, 4 cases were two colors greater than the results obtained using the licensee's model. Consequently, 28 changes were made to the SDP notebook.

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Using the Revision 1 SDP notebook, the team determined that 5 percent of the cases were less conservative, 25 percent were more conservative, and 70 percent of the cases were consistent with the licensee's results. Of the conservative cases, all but one case 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 SQN SDP Phase 2 Notebook and the licensee's PSA.

Attachment: As stated

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

Attachment: As stated

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SUMMARY REPORT ON BENCHMARKING TRIP

TO THE SEQUOYAH NUCLEAR PLANT

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ATTACHMENT A

Table of Contents

List of Tables

1 INTRODUCTION

A benchmarking meeting took place for the Sequoyah Nuclear Plant (SEQH) at the TVA office at Chattanooga (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 Sequoyah, 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 a 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. The team obtained and the licensee provided the updated HEPs used in the SEQH PSA and files containing the summary description of the PSA method, application, results, and system information.

5. The team 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. The team also carried out the on-site modifications to the SDP notebook Rev. 0 per the licensee's comments. The modified notebook (a draft of what would become SDP notebook Rev. 1) 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. The team 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 SDP Rev. 1 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 the step 5 above, to enhance the Rev. 1 notebook.

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

The Rev. 0 SDP notebook for Sequoyah 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 40 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 SDP Rev. 1 notebook ed provides similar or slightly more conservative results than the licensee's PSA in about 92.5% of the cases. In 5% of the cases the SDP underestimated the PSA by one order of magnitude (one color), and in 2.5% of the cases the SDP may overestimate the licensee's results by two colors. The reason for two cases of underestimates was attributed to the types and the frequency of the ATWS modeled in the licensee's PSA. This point requires additional discussion which has been provided in both Chapter 2 and Section 3.3 of this benchmarking report.

There was one case that the SDP overestimated the licensee's results by two orders of magnitude. This case deals with the failure of one MSIV to close when demanded. The SDP significant determination is dominated by the PTS issues which is not yet fully modeled and incorporated in the licensee's PSA models.

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 the "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. The last column indicates whether the SDP Rev. 1 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 also 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 detail case run. The basic event names are not included in the last column to avoid complexities usually caused by those plant models which utilize the large event tree approach.

A total of 40 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.

Initial review of Table 1 indicated that there are several cases related to the mitigation capabilities associated with the SGTR initiator that SDP slightly underestimates the licensee's RAW values. The SGTR initiator frequency in the licensee's PSA is set at 6.41E-3 per reactor year whereas it is assigned to Row III of the initiator table in the SDP notebook. This would cause an underestimation by a factor of six for all mitigation capabilities for SGTR. Both BNL and NRC representative decided to move SGTR to Row II consistent with the licensee's PSA and the SDP update construction rule. Subsequent to the visit, SGTR was returned to Row III since the under estimations were also attributed to operator dependencies which were not appropriately adjusted. The team limited operator credit for some of these sequences.

The licensee's PSA assigns initiating event frequencies of 2.7E-5 and 2.7E-6 for Medium (2 to 6 inches) and Large (greater than 6 inches) LOCAs respectively. These values are a factor of 3 below the assigned Rows for these initiators in the SDP notebook. Per the SDP construction rule these values are generic and cannot be changed. The colors assigned to the mitigation capabilities of medium and large LOCAs were examined to understand the impact of such a differences in the initiating event frequencies. Accumulators were found to be overestimated by one color as expected. The charging pumps were matched at low yellow, and an increase by a factor of 3 of the RAW values would not have changed the assigned color. The HHSI pumps are overestimated by one color driven by medium LOCA. The RHR pump is a match; however, the dominant contributors (SLOCA and LCCSA) are independent of the initiating event frequency of medium and large LOCAs. Therefore, it was concluded that maintaining the current initiating event frequencies and the logic structure for MLOCA and LLOCA in the SDP notebook is appropriate.

In one case; failure of one MSIV to close, the SDP overestimated site color based on the RAW values obtained from the licensee's PSA by two colors (i.e., two orders of magnitude). The significance determination color in the SDP notebook is driven by PTS concern, where the licensee PSA currently lacks the needed modeling.

There were two cases where the SDP notebook underestimated the site color based on the RAW values obtained from the licensee's PSA by one color (one order of magnitude). These were failure of a safety valve to open and operator failure to emergency borate. Both of these cases relate to the ATWS scenarios. 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 other hand models all ATWS scenarios, i.e., both electrical and mechanical with a total frequency of 3.29E-5 per reactor year. This frequency is about a factor of 30 over the SDP assigned frequency. It is therefore expected that the SDP notebook will underestimate some of the ATWS mitigation capabilities. As an example, the safety valves are required to open under any type of ATWS scenario; therefore, they would be much more important per the licensee's model. 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.

The summary results from benchmarking of the SDP notebook before and after benchmarking are shown in Table 2. The large conservatism in the SDP Rev. 0 notebook is expected to be reduced significantly by issuance of the SDP Rev. 1 notebook. The percentage of conservatism by two colors would be reduced from 10% to 2.5%. The percentage of conservatism by one color would be reduced from 30% to 22.5%. The percentage of matched cases would increase from 50% to 70%. More importantly, the SDP Rev. 1 models would be more justifiable and reflective of the latest PSA information and insights.

Table 1: Summary of Benchmarking Results for Sequoyah

Internal Events CDF is 1.23E-5 per reactor-year (Rev. 2 without floods)
at a 1E-13 Truncation limit
RAW Thresholds are W = 1.08, Y = 1.8 , and R = 9.1

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	YELLOW	1.50E-05	1.220	WHITE	YELLOW	*(Over by one color)*
Emergency DG 1A-A FTR	YELLOW	4.29E-05	3.488	YELLOW	YELLOW	*(Matched) Run a case without EDG recovery*
		1.69E-05	1.374	WHITE	N/A	*Run case with EDG recovery model with 1 of 2 EDGs recovered*
EDG fuel oil transfer pump FTS	WHITE	1.24E-05	1.008	GREEN	WHITE	*(Over by one color)*
6.9kV bus 1A-A failure (safeguards)	RED	7.89E-03	641.46	RED	RED	*(Matched)*
MDAFW pump 'A' FTS	YELLOW	1.67E-05	1.358	WHITE	YELLOW	*(Over by one color)*
Both MDAFW pumps FTR (common-cause failure)	RED	6.64E-04	53.984	RED	RED	*(Matched)*
TD AFW pump FTS	YELLOW	2.92E-05	2.374	YELLOW	YELLOW	*(Matched)*
TDAFW trip and throttle valve FTO FCV 1-51	Yellow	1.91E-05	1.553	WHITE	WHITE	*(Matched) manual recovery applied (local valve operation)*

Unavailable System or Component	SDP Worksheet Results (Before)	Case CDF	Internal RAW	Site Color	SDP Worksheet Results (After)	Comments
ERCW (service water) pump J-A FTS	WHITE [GREEN]	1.22E-05	1.00	GREEN	GREEN	*(Matched) Only solve base case LERCW sheet (loss of 1 of 4 pumps)*
CCS pump 1A-A FTR	RED	2.58E-05	2.098	YELLOW	YELLOW	*(Matched)*
CVCS centrifugal charging pump ‘A’ FTR	YELLOW	2.77E-05	2.252	YELLOW	YELLOW	*(Matched)*
CVCS centrifugal charging pump ‘B’ FTR	YELLOW	2.93E-05	2.38	YELLOW	YELLOW	*(Matched)*
MOV FCV 63-25 FTO (CCP discharge to cold legs on safety injection signal)	YELLOW	1.24E-05	1.008	GREEN	WHITE	*(Matched) Consider matched when you apply recovery credit*
HHSI pump A (intermediate SI) FTS	YELLOW	1.23E-05	1.000	GREEN	WHITE	*(Over by one color)*
RHR pump A FTR	YELLOW	4.92E-05	4.000	YELLOW	YELLOW	*(Matched)*
RHR pump B FTR	YELLOW	7.22E-05	5.87	YELLOW	YELLOW	*(Matched)*
Containment recirculation sump valve FCV 63-73 (Train B) FTO	YELLOW	6.86E-05	5.577	YELLOW	YELLOW	*(Matched)*

Unavailable System or Component	SDP Worksheet Results (Before)	Case CDF	Internal RAW	Site Color	SDP Worksheet Results (After)	Comments
Failure of RWST level lo 4/4 instruments	RED	2.43E-03		RED	RED	*(Matched)*
ECCS LPI/HPI piggy back valve FCV 63-8 FTO	WHITE	1.23E-05	1.000	GREEN	WHITE	*(Matched) match with credit for operator recovery*
One primary PORV PCV 68-334 FTO	YELLOW	1.47E-05	1.195	WHITE	WHITE	*(Matched)*
Common cause both primary PORVs FTO	YELLOW	2.63E-05	2.138	YELLOW	RED	*(Over by one color)*
Primary PORV block valve FCV-68-333 FTC on demand (hardware)	WHITE	1.65E-05	1.341	WHITE	WHITE	*(Matched)*
Primary Safety Valve 68-563 FTO	GREEN	2.53E-05	2.057	YELLOW	WHITE	*(Under by one color) ATWS frequency 3.29E-5*
AMSAC circuit failure	GREEN	1.24E-05	1.008	GREEN	GREEN	*(Matched)*
125 VDC vital bus 1-1 failure	YELLOW [RED WITH MITIG]	6.15E-04	50.000	RED	RED	*(Matched)*
125 VDC vital battery failure	YELLOW	1.23E-05	1.000	GREEN	GREEN	*(Matched) dedicated batteries for EDGs*, also we assumed battery charger can carry SI loads

Unavailable System or Component	SDP Worksheet Results (Before)	Case CDF	Internal RAW	Site Color	SDP Worksheet Results (After)	Comments
Vital battery charger failure	YELLOW	1.23E-05	1.000	GREEN	GREEN	*(Matched)*
One MSIV FTC on demand (FCV 1-22)	YELLOW	1.23E-05	1.000	GREEN	YELLOW	*(Over by two colors) PTS sequence driven (direct yellow)*
One SG PORV fails to open PCV 1-5	WHITE	N/A, currently only models one PORV, the operator would use another for depressur-ization	1.000	GREEN	WHITE	*(Over by one color)*
Standby air compressor FTS on demand	WHITE	1.23E-05	1.000	GREEN	GREEN	*(Matched)*
Containment spray pump A FTS	WHITE	1.23E-05	1.000	GREEN	GREEN	*(Matched)*
Containment spray pump B FTS	WHITE	1.23E-05	1.00	GREEN	WHITE	*(Over by one color)*
Operator Action						
Fail to establish Feed & Bleed	YELLOW	1.59E-05	1.293	WHITE	YELLOW	*(Over by one color)*
Fail to emergency borate (Long-term shutdown)	WHITE	4.62E-05	3.756	YELLOW	WHITE	*(Under by one color) ATWS frequency driven (3.29E-5)*
Fail to HPR	RED	2.41E-03	195.94	RED	RED	*(Matched)*

Unavailable System or Component	**SDP Worksheet Results (Before)**	**Case CDF**	**Internal RAW**	**Site Color**	**SDP Worksheet Results (After)**	**Comments**
Fail to refill RWST during SGTR	YELLOW	2.27E-05	1.846	YELLOW	YELLOW	*(Matched)*
Fail to depressurize RCS in SLOCA with PORVs or sprays when secondary heat removal is available	WHITE	1.23E-05	1.000	GREEN	WHITE	*(Over by one color)*
Fail to isolate faulted steam generator	YELLOW	7.41E-05	6.024	YELLOW	YELLOW	*(Matched) SGTR frequency should set in Row II consistent with the licensee's value*
Fail to RCS cooldown & depressurize in SGTR event	YELLOW	1.61E-03	130.89	RED	RED	*(Matched) Killed EQ and SDC cool*
Fail to restore Main Feedwater	WHITE	1.37E-05	1.114	WHITE	WHITE	*(Matched) Set TPCS initiator to zero and solve. The SQN frequency of all causes of transients in their model is 1.206.*

Table 2: Summary Comparative Results from the Sequoyah Benchmarking Activity

Total Number of Cases Compared	SDP Notebook Before (Rev. 0)		SDP Notebook After (Rev. 1)	
	Number of Cases (40)	**Percentage**	**Number of Cases (40)**	**Percentage**
SDP: Less Conservative	3	7.5	2	5
SDP: More Conservative - One Color	12	30	9	22.5
SDP More Conservative - Two Colors	4	10	1	2.5
SDP: Matched	21	52.5	28	70

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 Sequoyah

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. The following items list major comments that were incorporated.

Table 1:

1. Moved LVDC1 to Row III.
2. Removed LASD from Row III.
3. Added LIA in Row IV. 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-4 per reactor year.
4. Added a footnote indicating licensee's IE frequencies for MLOCA and LLOCA.

Table 2:

1. Indicated that there are two fuel transfer pumps per each EDG.
2. Added a footnote stating that flow control valves for AFWTDP fails open on a loss of DC. Air accumulators on the valve operators allow for AFWTDP flow control on loss of air. The accumulators have sufficient capacity to allow valve operation until TDAFW flow can be locally controlled.
3. Added a footnote that ERCW is needed for room cooling of HHSI and that HHSI shutoff head is 1600 psi.
4. For ERCW stated that 1 pump per train is normally running. Added a footnote stating that each train is cross-tied between the units with locked open valves, therefore requiring no additional alignment.
5. Added a footnote that the SG PORV on SGs 1 and 4 can be manually operated by a hand wheel.
6. Split the Row for PORV/Block Valve. Added a footnote stating the size of the PORV piping is 3" diameter.
7. Added a footnote for the air system stating that during normal operation, normal air feeds everything. Upon failure of normal air, indicated by low pressure in the receiver tank, the emergency air takes over.
8. Indicated that the RCP seals are high temperature seals on all units.
9. Added a footnote that the MFW pumps would trip on any turbine trip.
10. Removed the original footnotes 5 and 7. Modified footnote 1 reflecting the current CDF and LERF contributions. Stated that the PSA is Rev.2 and the HEPs are not yet updated.

Table 3.3:

1. Removed worksheet sequence 6 and subsumed it to the worksheet sequence 1.

Table 3.7:

1. In REC2 removed the cross-tie in 2 hrs.
2. Changed REC6 to REC4 and gave it a credit of 1.

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 ERCW-B pumps available.

Table 3.12

1. Changed the description of CCSB to state that 1/1 CCS pump train or alignment of 1/1 pump from 2B train to A train.
2. Added the function (SINJ) described as 1/2 charging pumps available for maintaining seal injection.

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 IV (Credit = 4) to LIA.

Table 3.14:

- Changed the frequency of the LVDC1 to 2.62E-3 per each division and gave it a credit of 3 in the worksheet.
- 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. 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. As an example, the safety valves are required to open under any type of ATWS scenario; therefore, it would be much more important per the licensee's model. 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 a little or no discussion on the external events. The Sequoyah 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 PRA models are not currently integrated.

5. LIST OF PARTICIPANTS

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