June 11, 2002

NOTE TO: Cynthia Carpenter, Chief
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Licensing Section
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SUBJECT: RESULTS OF THE QUAD CITIES UNIT 1 AND 2 SDP PHASE 2 NOTEBOOK BENCHMARKING VISITS

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

In the review of the QC SDP notebook for the benchmark efforts, it was found that some changes to the SDP worksheets were needed to reflect how the QC units plant are currently designed and operated. Twenty nine hypothetical inspection findings were processed through the SDP notebook. Results from this effort indicated that the total risk impacts modeled in the SDP notebook were underestimated by 7 percent, overestimated by 55 percent, and adequately estimated by 38 percent. The reviewers found that if ten fixes were made to the SDP notebook, the results would be 7 percent underestimation and 45 percent overestimation of risk impacts.

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

If you have any questions regarding this effort, please contact Peter Wilson.

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

Attachments: As stated

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SUMMARY REPORT ON BENCHMARKING TRIP

to the Quad Cities Nuclear Generating Station

(November 28-29, 2001)

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Energy Sciences and Technology Department
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December 2001

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1. Introduction

A benchmarking of the Risk-Informed Inspection Notebook for Quad Cities Nuclear Generating Station was conducted during a plant site visit on November 28-29, 2001. NRC staff (M. Franovich, M. Parker and P. Wilson) and BNL staff (P. Samanta) participated in this Benchmarking exercise.

In preparation for the meeting, BNL staff reviewed the SDP notebook for Quad Cities and evaluated a set of hypothetical inspection findings using the Rev 0 SDP worksheets. In addition, a copy of the meeting protocol was sent to the licensee by P. Wilson of the NRC prior to the meeting.

The major milestones achieved during this meeting were as follows:

1) Licensee's comments on the Rev 0 SDP notebook were discussed and applicable modifications are considered in the benchmarking exercise.

2) Importance measures including the risk achievement worths (RAWs) for the basic events in the internal event model for average maintenance was obtained from the licensee.

3. Benchmarking was conducted using the Rev 0 SDP model and the revised SDP model considering the licensee inputs and other modifications that were judged necessary based on comparison of the SDP model and the licensee's detailed model.

4) For cases where the color evaluated by the SDP notebook differed from that determined based on the RAW values generated by the updated licensee's PSA, results of the licensee's model including the detailed minimal cutsets were requested from the licensee. The cutsets were reviewed to understand the reason for the differences. Applicable changes were defined for the SDP model.

Following the modifications to the Quad Cities SDP model, it is observed that 2 out of 29 cases, i.e., 7% of the cases show underestimation and the remaining 93% of the cases show similar or more conservative colors. Of the 29 cases analyzed, similar color was obtained for 14 cases, conservative color by one order of magnitude was obtained for 11 cases, and conservative color by two orders of magnitude was obtained for 2 cases.

Analyses into the potential causes for the differences between the SDP worksheets and the updated PSA identified the differences in assumptions between the SDP models and the Licensee's updated PSA. These differences and recommendations for handling them in improving SDP models and/or in using the SDP models for Phase 2 evaluations are discussed in this report. Overall, the benchmarking exercise has resulted in improvements to the SDP model facilitating its use of Phase 2 evaluations.

2. Summary Results from Benchmarking

This Section describes the results of the benchmarking exercise. The results are summarized in Table 1. Table 1 consists of six columns. The first column identifies the components or the case runs. The assigned colors from the SDP Rev 0 worksheets without incorporating any modification from the benchmarking exercise are shown in the second column. The third column shows the internal RAW and the fourth column shows the associated colors estimated based on the Licensee generated RAW values from the latest PSA model. The fifth column presents the colors for the inspection findings based on the revisions of the SDP Rev 0 worksheets judged applicable during benchmarking. The last column provides comments explaining the differences between the SDP and plant PSA colors.

The colors for inspection findings obtained using the SDP model were found to be underestimated in 2 cases (out of 29 cases evaluated), but otherwise are generally conservative compared to that obtained using the plant-specific PSA. Conservative results are expected since SDP model is a simplified tool and is intended to provide conservative colors. However, the reason for the differences are analyzed using the minimal cutsets for the cases where differences in colors are observed. These cases are discussed below.

The major differences between the SDP model and the plant-specific PSA resulting in conservative estimate by the SDP model are as follows:

1) In the SDP model, the credit for operator action to depressurize following failure of Isolation condenser and high pressure injection sources is 2, which is equivalent to human error probability (HEP) of 1.0E-02. The HEP for the corresponding operator action in the PSA is assigned an error probability of 7E-04.

2) In the SDP model, it is assumed that core damage will occur if containment heat removal fails due to failure of both suppression pool cooling and containment venting. Late injection is not credited. In the Quad Cities PSA model, it is assumed that in 94% of such cases the drywell failure will be favorable allowing late injection. The situation corresponding to the SDP model is assigned a probability of 6E-02 where late injection is not feasible.

The (two) cases where SDP underestimates compared to the licensee PSA are analyzed and are explained as follows:

1. In cases of failure of all MFW pumps, the SDP color is white compared to an yellow color from the licensee RAW. This difference is attributed to the licensee IE frequency of 2 per year for turbine trip and manual reactor shutdown. In the SDP the comparable frequency from industry average data is 1E-01 per year.

2. For failure of both the SBO diesels, SDP estimate is an underestimate by one order of magnitude. This is due to the difference in the EDG unavailability used in the licensee PSA compared to the credit of 1 train used in the SDP.

The specific cases where differences are observed and the reason for the differences are as follows:

1. Failure of 1 MS/FW pump and 1 condensate pump evaluation showed that the SDP model is two orders of magnitude conservative. The SDP evaluation rule increase the TPCS frequency by resulting in a reactor trip event with the loss of power conversion system. A review of SDP rules for these cases may be necessary.

2. For HPCI and SSMP, the difference is due the credit for the DEP function used in the SDP. The SDP credit for DEP is 2 compared to the licensee value of 7E-04.

3. For CV, 1 SRV failing to close, and 1 LPCI train, the difference is attributed to the assumption of favorable drywell failure. In these cases, the scenarios or cutsets that contributed to the higher color in the SDP is reduced to lower contributor in the PSA model because of the assumption mentioned above. The SDP assumption is consistent with the SDP approach used for all BWR plants. A review of the SDP assumption in this regard may be undertaken if similar inconsistencies are observed in many BWRs.

4. Other differences in colors are noted for inspection findings for 1 SLC pump, 1 EDG, 1 IA compressor, and operator failure to Inhibit in an ATWS. These differences are due to SDP modeling approaches and usage rule and are consistent with the expectations for SDP models.

Table 1. Comparison Table for Quad Cities Benchmarking
CDF = 4.47 E-6, W = 1.22 (RAW), Y = 3.24 (RAW), R = 23.4 (RAW)

Basic Event Name	Before	RAW	Plant CDF Color	After	Comments
RCIC FTS/FTR	Yellow	1.35/1.34	White	White	Match
HPCI FTS/FTR	Yellow	1.43/1.44	White	Yellow	SDP color is conservative by one order of magnitude. Yellow is obtained by counting rule. The difference is attributed to assigning a credit of 2 for DEP in the SDP. PSA HEP is 7E-04.
One SRV FTC (trans)	Green	1.03	Green	White	SDP color is conservative by one order of magnitude. This difference is attributed to the assumption of favorable drywell failure.
All ADS/SRVs FTO for ATWS challenge	Yellow	6	Yellow	Yellow	Match
PCS (trip of all 3 FW pumps due to pressure switch)	Yellow	4.02	Yellow	White	SDP underestimated by one order of magnitude. The initiating event frequency for reactor trip in the PSA is estimated at 2 per year. SDP rating corresponds to a frequency of 1E-01 per year.
MS/FW 1 pump	Red	1.58	White	Yellow	SDP is conservative by one order of magnitude. SDP is evaluated by increasing the TPCS IELR by 1, as per the usage rule. A review of the usage rule may apply.
1 condensate pump	Red	1.0	Green	Yellow	SDP is conservative by one order of magnitude. SDP is evaluated by increasing the TPCS IELR by 1, as per the usage rule. A review of the usage rule may apply.

Basic Event Name	Before	RAW	Plant CDF Color	After	Comments
1 LPCI pump FTS	Yellow	1.0	Green	Yellow	SDP is conservative by two orders of magnitude. Yellow is obtained through the counting rule. The difference is attributed primarily to the favorable drywell failure assumption.
1 LPCI train with 1 train CHR affected	Red	3.58	Yellow	Red	SDP is conservative by one orders of magnitude. Red is obtained through the counting rule. The difference is attributed primarily to the favorable drywell failure assumption
SSMP pump fail/ (cooling unit FTS)	Red	2.02/1.8	White	Yellow	SDP is conservative by one order of magnitude. Yellow is obtained through counting rule. The difference is due to the assignment of a credit of 2 for the DEP function.
Operator fails to realign FP to SSMP room coolers (LOSW only initiator)	Yellow	1.24	White	White	Match
RHR & RHRSW Outlet MOVs 1001-5A and 5B FTO	Red	327	Red	Red	Match
IA (one compressor fails)	Yellow	1.0	Green	Yellow	SDP is conservative by two orders of magnitude. The difference is attributed to the usage rule where the IELR is increased by 1.
DGCW pumps 1, 2 and 1/ 2 swing	Red	8.64	Yellow	Yellow	Match

Basic Event Name	Before	RAW	Plant CDF Color	After	Comments
All EDGs & 1,2 & 1/2 (swing FTS/FTR	Red	8.49/7.52	Yellow	Yellow	Match
SBO diesels FTR/FTS	White	5.2	Yellow	White	SDP underestimates by one order of magnitude. Multiple cutsets incrementally contribute to the higher RAW.
1 SBO DG	Green	1.18	Green	Green	Match
1 EDG	Yellow	1.11	Green	White	SDP is conservative by one order of magnitude. Plant-specific EDG unavailability contributed to this difference.
1 swing EDG	White	1.08	Green	Green	Match
failure to recover from LOOP within 4hrs	White	1.46	White	White	Match.
SBLC pump 1-A FTS	Green	2.47	White	Yellow	SDP is conservative by one order of magnitude. SDP requires 2 out of 2 SBLC pumps as success criteria in ATWS.
SBLC explosive valves FTO	Yellow	6.18	Yellow	Yellow	Match
CV AOV 1601-24 FTO/FTC	Red	5/5	Yellow	Red	SDP is conservative by one order of magnitude. This difference is attributed to favorable drywell failure assumption in the licensee PSA.

Basic Event Name	Before	RAW	Plant CDF Color	After	Comments
DEP HEP set to one (all but MLOCA/MLOCA)	Red	5.28/37	Yellow/red	Red	Match. Licensee RAWs corresponds to two different cases, as indicated. Match (by counting rule) when you combine licensee cases.
Operator fails to INH	Yellow	6.17	Yellow	Yellow	Match
Operator FTS CRD (one pump)	White	1.01	Green	White	SDP is conservative by one order of magnitude. This difference is attributed to the favorable drywell failure assumption in the licensee PSA.
1 SW pump FTS/FTR	White	1.02/1.78	Green/white	White	Match. In the licensee modeling, different SW pumps have different RAWs because of the modeling needs and assumptions.
Bus 13-1	Red	3E-5 delta CDF run (7.7)	Yellow	Red	SDP is conservative by one order of magnitude.
Bus 14-1	Red	1E-4 delta CDF based (RAW = 23.4	Red	Red	Match.

Table 2: Comparative Summary of the Benchmarking Results

Total Number of Cases Compared = 23	SDP Notebook		Considering the Issues Raised for the Differences Implemented	
	Number of Cases	**Percentage**	**Number of Cases**	**Percentage**
SDP: Less Conservative	2	7%	2	7%
SDP: More Conservative	16	55%	13	45%
SDP: Matched	11	38%	14	48%

3. Proposed Modifications 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), modified initiator frequencies, and the results of benchmarking.

3.1 Specific Changes to the Rev 0 SDP Notebook for Quad Cities

The licensee provided comments in the Rev 0 SDP notebook, most of these comments clarify the detail design, procedure, and operational features in the plant and they will be incorporated in the next revision of the SDP. The following comments were considered to be important for the Benchmarking exercise and were considered for color determination.

1. For the late inventory function only 1 of 2 CRD pumps is required, as per the QC PSA. This change applies to all worksheets where use of CRD is credited.

2. In the LOSW worksheet, HPCI and RCIC are available since they do not have dependency on SW. Similarly CS can be credited in the LPI function since it also does not have dependency on SW. The worksheet and the event tree is modified removing the prior assumption where HPCI, RCIC, and CS were assumed to be dependent on SW. Containment venting is credited as an operator action = 1.

3. In the LOIA worksheet, containment venting is assumed to be a recovery action with a credit of 1, similar to the LOSW worksheet. The CV valves have no air accumulators requiring a recovery action to use. However, a long time for recovery is available.

4. In the LAC worksheet, the mitigation capability of the LPI and the CHR function is changed to include both trains of LPCI, LPCS, and SPC mode. The loss of 4 kV buses 13-1 and 14-1 do not result in loss of 1 train as assumed in the worksheet. Also, 1/1 CRD pump is credited in the late inventory function.

5. In the LOCA worksheets, the number of suppression pool-to-drywell vacuum breakers is corrected to 12 from 8. QC requires 12/12 to remain closed for IORV, small LOCA, and medium LOCA, and 11/12 to remain closed for large LOCA.

6. In the IORV worksheet, credit for PCS is removed. This is consistent with changes being made in other BWRs.

7. In the MLOCA worksheet, use of condensate pump is credited as an operator action credit of 2 in the LPI function.

8. In the LOOP worksheet, the EAC function is defined to include separate credit of 1 for each of the two SBO diesels and for cross-tie of the swing EDG. Both the SBO diesels can be used to power both the trains in the unit.

9. In the ATWS worksheet, the success criteria for standby liquid control system (SBLC) is changed to 2/2 pumps from 1/ 2 pumps. Use of 1 pump is adequate if the operator acts within 15 minutes.

10. IA is removed as support system for ADS. Target rock SRV requires no air and other relief valves have accumulators.

3.2 Generic Change in 0609 for Inspectors

A generic change relating to the evaluation of 1 MS/FW or 1 condensate pump may be considered. A finding relating to a single pump is evaluated as “green” by the PSA, but is evaluated as a “yellow” in the Quad Cities SDP. It is judged that the SDP finding is unnecessarily conservative and can not be supported in a detailed evaluation. The SDP color is obtained because of the usage rule of increasing the initiating event likelihood rating. A change in the usage rule or in the way the SDP Phase 1 screening should be used can be considered to avoid this overestimation.

3.3 Generic Change to the SDP Notebook

Some of the modifications made to the SDP notebook and some of the differences in colors noted in this benchmarking provide input for considering some generic changes to BWR SDP notebooks. If similar observations are made in other BWR benchmarking, then some generic changes will apply and can be considered.

1. Operator action credit for depressurization for failure of high pressure injection sources: A generic value of 2 is assigned based on a survey of the HEP value used in BWRs. The survey of the BWR plants may need to be revisited considering the revised HEP values being used by plants. The generic HEP value may be a source of overestimation in a number of cases. A evaluation of multiple BWR worksheets may need to be undertaken to assure that any change in this aspect will not result in additional underestimation in other areas.

2. Crediting late injection sources following failure to remove heat from containment because of failure of the suppression pool cooling and containment venting: Current SDP model do not credit late injection in such situation resulting in core damage unless the containment is designed such to avert failures in such situations. A favorable containment/drywell failure, as assumed in Quad Cities, may have been considered in other BWR plants. Conditions for accepting or rejecting the detailed PSA models may need to be better defined.

3. In analyzing the stuck-open relief valve, a modification is made in the LOOP worksheet to include LOOP with SORV scenarios. Current SORV work does not include these scenarios resulting in underestimation. This may apply to other BWRs. A separate LOOP with SORV worksheet may also be considered.

4. Discussion on External Events

Integrated external event PSA model was not available for the Quad Cities plant. No evaluations was conducted for the external event risk during the benchmarking exercise.

5. List of Participants

Peter Wilson	USNRC - NRR
Mike Franovich	USNRC - NRR
Michael Parker	USNRC - RIII
Robert Buell	INEEL
Pranab Samanta	BNL
Eric Jebsen	Quad Cities
Xavier Polanski	Quad Cities/MWROG