March 21, 2003

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

SUBJECT: RESULTS OF THE THREE MILE ISLAND UNIT 1 SDP PHASE 2 NOTEBOOK BENCHMARKING VISIT

During October, 2002, NRC staff and contractors visited the Exelon East corporate office in Kennet Square, Pennsylvania to compare the Three Mile Island (TMI), Unit 1 Significance Determination Process (SDP) Phase 2 notebook and licensee's risk model results to ensure that the SDP notebook was generally conservative. TMI's 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 TMI were also 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 good correlation between the Phase 2 SDP Notebook and the licensee's PSA. The results indicate that the TMI Phase 2 notebook was generally more conservative in comparison to the licensee's PSA. The SDP Rev. 1 notebook when issued should provide similar or slightly more conservative results than the licensee's PSA in 89% of the cases.

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

A summary of the results of comparisons of hypothetical inspection findings between SDP notebook and the licensee's PSA are as follows.

11%	Notebook predicted the risk an order of magnitude less than the licensee's PSA Significance
71%	Notebook and licensee's PSA results matched within an order of magnitude
13%	Notebook predicted the risk an order of magnitude greater than the licensee's PSA.
5%	Notebook predicted the risk two orders of magnitude greater than the licensee's PSA.

The Rev-1 SDP notebook has been greatly improved as a result of the benchmarking activity. Number of underestimates was significantly reduced (from 15 to 5). Number of cases that Rev-1 SDP would match that of the updated licensee's PSA has increased from 20 to 32. Finally, some reduction is gained for the number of overestimates.

The licensee's PSA staff was very knowledgeable of the plant model and provided very helpful comments during the benchmark visit.

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

Attachments: As stated

A summary of the results of comparisons of hypothetical inspection findings between SDP notebook and the licensee's PSA are as follows.

11% Notebook predicted the risk an order of magnitude less than the licensee's PSA Significance

71% Notebook and licensee's PSA results matched within an order of magnitude

13% Notebook predicted the risk an order of magnitude greater than the licensee's PSA.

5% Notebook predicted the risk two orders of magnitude greater than the licensee's PSA.

The Rev-1 SDP notebook has been greatly improved as a result of the benchmarking activity. Number of underestimates was significantly reduced (from 15 to 5). Number of cases that Rev-1 SDP would match that of the updated licensee's PSA has increased from 20 to 32. Finally, some reduction is gained for the number of overestimates.

The licensee's PSA staff was very knowledgeable of the plant model and provided very helpful comments during the benchmark visit.

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

Attachments: As stated

Accession # ML030800607
G:\SPSB\wilson\TMIBENCH.wpd

OFFICE	SPSB	SC:SPSB	SPSB:RGN-1
NAME	PWilson:nxh2	FMReinhart/**RA/**	ECobey
DATE	03/20/03	03/21/03	03/20/03

OFFICIAL RECORD COPY

SUMMARY REPORT ON BENCHMARKING TRIP

TO THE THREE MILE ISLAND NUCLEAR GENERATING STATION

UNIT 1

Mohamad A. Azarm (BNL)

Energy Sciences and Technology Department
Brookhaven National Laboratory
Upton, N.Y. 11973-5000

November 2002

Attachment A

Table of Contents

List of Tables

1 INTRODUCTION

A benchmarking meeting took place at the Exelon east headquarter at Kenneth Square Pennsylvania for Three Mile Island (TMI), unit 1 on October 27, 2002. P. Wilson and E. Cobey from NRC, along with M.A. Azarm from BNL, and R. Buell from INEEL participated in this benchmarking exercise. This benchmarking report documents the overall results and insights from the benchmarking trip.

In preparation of the meeting, BNL staff reviewed the SDP notebook for Three Mile Island, evaluated the coloring results of the Rev. 0 SDP worksheets, and collected system diagrams and information. In addition, a copy of the meeting protocol was sent to the licensee by E. Cobey of the NRC prior to the meeting.

The major milestones achieved during this meeting were as follows:

1. Obtained the Risk Achievement Worth (RAW) values for basic events for the internal event model for average maintenance based on internal event model including internal flooding (6% contribution).

2. Identified a target set for the basic events for the benchmarking exercise.

3. Performed benchmarking of a subset of the target set of basic events using the Rev. 0 SDP notebook with the licensee's staff participating and providing comments on the notebooks.

4. Requested some PSA model results from the licensee to determine the dominant contributors to the RAW values and to compare with the contributors captured by the notebook.

5. Obtained updated HEPs used in the TMI PSA.

6. Obtained 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.

7. Carried out the benchmarking and on-site modifications to the SDP notebook

8. Rev-0 per licensee's comments.

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

The Rev. 0 SDP notebook for TMI was updated and the sequences were solved prior to the site visit based on the current SDP generic guidelines. A total of 46 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 when issued should provide similar or slightly more conservative results than the licensee's PSA in 85% of the cases. In the 11% of cases where the SDP underestimated the PSA, the main reason was attributed to round off errors. Round off errors refer to the results of a case run when the following two conditions exist:

1. The SDP notebook captures all pertinent sequences affected and identified by PSA for the specific case run (e.g. when a given component is removed from service).

2. The resulting RAW value from the PSA for the specific case run is at proximity of the assigned color threshold.

All cases where the SDP underestimated the PSA or overestimated by two orders of magnitude were examined during the site visit and they are discussed below:

- There are dedicated cooling water systems for LPI/LPR trains through the decay heat river water system (DHRW) and decay heat closed cooling water system (DHCCW). Therefore, operation of one train of LPR would require availability of the associated train of DHRW and DHCCW in addition to the availability of the LPI pump, valves, and heat exchanger. Therefore, the PSA's credit for one train of LPR when the other train is assumed not to be available would be less than the SDP credit of one train. Since the support systems for LPR is a unique plant feature in TMI, generic credit in SDP was not changed and the case was recorded as an underestimate.

- Round off error was identified as a main reason for the SDP notebook to underestimate the seal injection crossconnect, the operator failure to pin the seal injection valves, and the recovery of offsite power in 1 and 4 hours. Examination of the PSA output for the above cases showed that the SDP rev. 1 notebook will captured all relevant sequences.

- The emergency boration is shown as a match in both Tables 1 and 2 . The PSA RAW value for this case includes sequences from other initiators besides ATWS due to the way the human errors are modeled in the PSA. The specific action for emergency boration only applies to ATWS scenarios. The equivalent contribution from ATWS scenarios was re-estimated using the licensee PSA and resulted in an increase in CDF of about 2E-6 per reactor year, consistent with the results from the SDP notebook. This case was, therefore, recorded as a match.

- For HPSI pump A or B, the SDP estimated a "Red" and a "Yellow" respectively, where the PSA assigned a "White" color. The RAW values from the PSA were judged to be not appropriate due to effects of various levels of CCF that are modeled in the PSA. The CCF modeling technique used in the licensee's PSA has impacted the RAW values in two ways: (1) the failure probability associated with the remaining two pumps when either pumps A or B is unavailable are estimated without CCF contribution (independently), and (2) the failure probability associated with the remaining two pumps when pump C is unavailable is estimated accounting for full CCF contribution. Therefore, this treatment has resulted in artificially lower RAW values for pumps A or B but slightly higher RAW value (approximately a factor of 3) for pump C.

- There were also three cases where the SDP notebook overestimated the PSA results by two orders of magnitude. The case of HPSI pump A was just discussed and it was shown that it is not a true overestimation by two orders of magnitude. The other two cases were the failures of a SRV or a PORV to reclose. Failure of a SRV to re-close was treated in the SDP notebook as an occurrence of SLOCA with a probability of one. Failure of a PORV to re-close was treated by the SDP notebook as an occurrence of SORV with a probability of one. The PSA assumes that the SRVs/PORVs will only be demanded in a small fraction of the initiators (less than 1 in 10 reactor years). The PSA, therefore, treated this case as a SLOCA or SORV; however, with a frequency estimated by the SRV/PORV demand probability for all initiators. This frequency was estimated to be less than 1 in 10 years. Therefore, these cases were recorded in Table 2 as overestimates.

2. SUMMARY RESULTS FROM BENCHMARKING

This section provides the results of the benchmarking exercise. A total of 46 hypothetical inspection findings were examined during the site visit. The results of the benchmarking analyses are summarized in Table 1. Table 1 consists of seven columns. 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 column shows the RAW values based on the licensee's PSA for internal event initiators. The fourth 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 fifth column shows the results from comparison of the third and fourth columns. The results shown in fifth column are categorized in the sixth column into three groups: O, M, and U which stand for Overestimated, Matched, and Underestimated, respectively. If an item in this column is categorized as "M", it indicates that the color that will be obtained from the SDP Rev. 1 notebook will match the risk significance color obtained from the current licensee's PSA model. Items categorized by "O" and "U" should also be interpreted similarly. Finally, the last column provides some comments for clarification of the SDP evaluation process, and the underlying reasons for any differences that might have occurred. The basic event names were not available and not incorporated in the last column since this plant uses the large event tree approach. In this approach RAW calculations may require changes to be done to several basic or top events, therefore identification of one basic event name may not be possible.

Table-2 shows the summary statistics of the benchmarking results for the Rev-0 SDP notebook and what would be the expected results for the Rev-1 SDP notebook. This table shows that the Rev-1 SDP notebook has been greatly improved as a result of the benchmarking activity. Number of underestimates has significantly reduced (from 15 to 5). Number of cases that Rev-1 SDP would match that of the updated licensee's PSA has increased from 20 to 32. Finally, some reduction is gained for the number of overestimates.

Table 1: Summary of Benchmarking Results for Three Mile Island Unit 1

Internal Events' CDF is 4.02E-5 per reactor-year; therefore,
RAW thresholds are: W = 1.02, Y = 1.25 , and R = 3.49
External Events CDF is 1.4 E-4 per reactor-year

Component Out-of-Service or Human Actions or Recovery Actions	SDP Worksheet Results (Before) (Internal only)	Internal RAW (1)	SDP Worksheet Results (After)	PSA/SDP	Categorization of the Results	Comments (1)
HPSI Pump C	Y (1Y+5W)	29	R	R/R	M	
HPSI Pump A	Y	1.01	R	W/R	O	The SDP assigns a red to pumps A. The PSA's RAW are Biased by the CCF Modeling. The more appropriate color for PSA should be a yellow at minimum. This case is considered as an over estimate by one color.
HPSI Pump B	Y	1.07	Y	W/Y	O	The SDP assigns yellow to pumps B. The PSA's RAW are Biased by CCF Modeling.
LPI Pump	R	8.9	Y	R/Y	U	Under: Case Run was Examined
TDEFW Pump	Y	1.3	Y	Y/Y	M	
MDEFW Pump	Y	1.7	Y	Y/Y	M	

Component Out-of-Service or Human Actions or Recovery Actions	SDP Worksheet Results (Before) (Internal only)	Internal RAW [1]	SDP Worksheet Results (After)	PSA/SDP	Categorization of the Results	Comments [1]
1 MFW Pump	G	1.06	W	W/W	M	
PCS (Initiator)	W	1.1 (3.91E-6)	W	W/W	M	
PCS (Initiator + Mitigation)	W	NA[2]	W	NA	NA	
EDG	W	1.2 (EDG-A) 1.1 (EDG-B)	W	W/W	M	
SBO DG	G	1.08	W	W/W	M	
Battery Charger	R	38	R	R/R	M	Bravo side assuming that, PCS is not lost
Battery Charger Alpha side	R	38	R	R/R	M	
Battery (B SIDE)	W (Take SI) R(Not Take SI)	38	R	R/R	M	
1 SRV Fails to Open (FTO)	W	1.028	W	W/W	M	
PZR vent line FTO	G	1.01	W	G/W	O	
PZR PORV FTO	G	1.2	W	W/W	M	
Block Valve Fails to Close (FTC)	W	1.02	W	W/W	M	
PSV FTC	R	1.07	R	W/R	O	Demand

Component Out-of-Service or Human Actions or Recovery Actions	SDP Worksheet Results (Before) (Internal only)	Internal RAW [(1)]	SDP Worksheet Results (After)	PSA/SDP	Categorization of the Results	Comments [(1)]
PORV FTC	Y	1.015	Y	G/Y	O	Demand
LIA (Initiator)	R	19 (8.01E-4)	R	R/R	M	
1 Air Compressor	W	P1 (1.4) P2 (1.2)	Y	Y/Y	M	Under: Round off for P2 and match for P1
LNSRW (initiator)	W	35 (1.4E-3)	R	R/R	M	
Loss of 1 NSRW pump	G	2.5	Y	Y/Y	M	
LRW (Initiator)	R	~250 (2.27E-2)	R	R/R	M	
1 train of RW	Y	2.5	Y	Y/Y	M	
1 DHCCW pump	W	19 (A) 11 (B)	R	R/R	M	
1 DHRW pump	W	12 (A) 8.6 (B)	R	R/R	M	
ADV FTO	G	1.08	W	W/W	M	
1 MSIV FTC	Y(1Y+2W)	1.01	G	G/G	M	
1 SSCW pump (TPCS)	W	1.09	W	W/W	M	
1 SSRW pump (TPCS)	W	1.0	W	G/W	O	

Component Out-of-Service or Human Actions or Recovery Actions	SDP Worksheet Results (Before) (Internal only)	Internal RAW [(1)]	SDP Worksheet Results (After)	PSA/SDP	Categorization of the Results	Comments [(1)]
HPR operator action	R	14.2	R	R/R	M	
FB operator action	R	2.2	Y	Y/Y	M	
LPR operator action	R	1.08 (LLOCA) 14.2 (MLOCA)	R	R/R	M	
RCS Cooldown and Depress. (SGTR/EQ)	R	18.4	R	R/R	M	
Emergency Boration (ATWS)	W	2.2	W	Y/W	M (see the note column for reasons not being an under)	The emergency boration is the same event as manual initiation of HPI in the PSA. Contribution from ATWS scenarios which is appropriate for this entry is about 2E-6 (W). This case therefore is considered as a match.
RCP Trip	R	3.14	R	Y/R	O	
Seal injection by X-connect pump C	W	1.26 1.94	W	Y/W	U	Under Round Off Error
Operator pins seal injection valves (LIA)	W	1.36	W	Y/W	U	Under Round Off Error

Component Out-of-Service or Human Actions or Recovery Actions	SDP Worksheet Results (Before) (Internal only)	Internal RAW (1)	SDP Worksheet Results (After)	PSA/SDP	Categorization of the Results	Comments (1)
Align fire service water to decay heat river water to restore seal injection (LRW)	R	2.25	R	Y/R	O	
Isolate SG and control SI flow (FWIC)	Y	1.76	Y	Y/Y	M	
Recovery of Power in 1 hr (REC1)	G	1.03	G	W/G	U	Under Round off
Recovery of Power in 4 hrs (REC4)	W	1.28	W	Y/W	U	Under Round off
Local manual control of EFW flow (LIA)	W	1.94	Y	Y/Y	M	
Failure to ISOSG (SGTR)	NA	1.12	W	W/W	M	

(1) The RAW values obtained are based on the internal event model, including flood (about 6% contribution). The truncation limit was about 1.E-8 within the Riskman approach with residue bin calculated. The surrogate basic event names are not provided due to difficulties in extracting such information from a large event tree approach.

- NA stands for not available or not modeled.

Table 2: Comparative Summary of the Benchmarking Results

Total Number of Cases Compared	SDP Notebook Before (Rev 0)		SDP Notebook After (Rev 1)	
	Number of Cases (46)	Percentage	Number of Cases (46)	Percentage
SDP: Less Conservative	15	32.6	5	10.9
SDP: More Conservative	7 (O1)	15.2	6 (O1)	13.0
	2 (O2)	4.4	2 (O2)	4.4
SDP: Matched	20	43.4	32	69.5
not modeled	2	4.4	1	2.2

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 Three Mile Island

The earlier version of the notebook was reviewed by the utility on May 26-27, 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 to the extent possible. The following items list major comments that were incorporated.

Table 1:

3. Add the initiator for NSCCW to Row III.

4. Remove L4KV Bus from Row III.

Table 2:

1. Add a footnote on battery duration of 2 hrs without load shedding and 6 hours with load shedding.

2. Add a footnote that PCS is automatically controlled by ICS.

3. Add a footnote for PORV size (0.939 inch squared), PSV size (2.5 inches squared), and vent line (1 inch squared).

4. Add 3 condensate booster pumps to condensate/MFW row.

5. Remove all references to L4KVBUS in the initiating event column.

6. Add a row for BWST makeup from spent fuel pool through spent fuel pumps with AC and DC as support system.

7. Add a footnote that all inspection findings associated with ICCW should be colored as "green". Total loss of ICCW would behave similar to a transient.

8. Note that there are 16 air bottles for EFW flow control valves that would be sufficient for 2 hours for backup air supply.

Table 3.1:

1. Change the credit for PCS to 1 train globally. The MFW ramps back and SG level would be maintained and controlled automatically by the Integrated Control System (ICS) which should be credited as a single train.

Table 3.4:

1. Remove PSV from the title.

Table 3.5:

1. Put a footnote that the PSA HEP value for LPR is 1.7E-3.

Table 3.6:

1. Put a footnote that the PSA HEP value for LPR is 8.7E-3.

Table 3.8:

1. Change the event tree and sequences for SGTR such that it captures the licensee's major sequences.

Table 3.9:

1. Change the credit and the success criteria for MDEFW for ATWS from 1/2 to 2/2 MDEFW.

2. Change the HEP value for emergency boration to 5.2 E-3.

Table 3.10:

1. The Function RCPSEAL should be credited as one train, since it is limited by a train of seal injection.

2. Change the sequence "LNSRW - RCPSEAL - EIHP" to "LNSRW - EIHP", since the failure of EIHP implies the failure of RCP seal. Modify the event tree to explicitly show that.

Table 3.11:

1. Add explicitly to the success criteria for "SEALINJ" or the operator pins the ICCW containment isolation valve.

Table 3.12:

1. Change the title to say " Loss of all River Water". Show in footnote 1 that the screen plugging is a major contributor to this event.

Table 3.13:

1. Add a footnote to say that MSIV isolation is not important for preventing PTS in MSLB in TMI. State that there is no equalizing line for the steam lines. It takes about 2 minutes for MSIVs to close. As long as turbine stop valves are closed, at most one SG will be emptied. The PTS is mainly prevented by termination of feed to SG or controlling SI flow.

2. Redraw the event tree and sequences for MSLB consistent with the licensee's assumption on PTS.

Table 3.14:

3. Remove the worksheet for L4KV bus and substitute it with a worksheet for loss of NSCCW (LNSCCW). The loss of the 4KV bus does not cause an initiating event.

4. Draw the event tree for LNSCCW and substitute it for the event tree for loss of 4KV bus.

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

None.

3.3.2 Generic Insights for B&W Plants

No new generic insight for B&W plants was identified in Three Mile Island.

4. DISCUSSION ON EXTERNAL EVENTS

In TMI, the CDF contribution from internal events is 4.0E-5 per reactor-year, seismic 3E-5 per reactor-year, fire 2E-5 per reactor-year, high winds 8E-7 per reactor-year, and aircraft crash 4E-7 per reactor-year. The CDF contribution from internal floods is 2.5E-6 per reactor-year.

5. LIST OF PARTICIPANTS

P. Wilson, NRC/NRR
G. Cobey, SRA/Region I
M.A. Azarm, BNL
R. Buel, INEEL
C. Pupek, Exelon
C. Adams, Exelon