September 5, 2003

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

SUBJECT: RESULTS OF THE LIMERICK GENERATING STATION UNITS 1 & 2 SDP PHASE 2 NOTEBOOK BENCHMARKING VISIT

During November, 2002, NRC staff and two contractors visited with the Limerick PRA staff in the Exelon Corporate Office, Kennett Square, Pennsylvania to compare the Limerick Generating Station (LGS) Units 1 & 2 Significance Determination Process (SDP) Phase 2 notebook and the licensee's risk model results to ensure that the SDP notebook was generally conservative. Since the updated LGS PRA did not have a quantitative external events model at the time of the benchmarking visit, the benchmarking team did not perform sensitivity analyses to assess the 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 LGS Units 1 & 2 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.

The benchmarking visit identified that there was adequate correlation between the Phase 2 SDP Notebook and the licensee's PRA model. The results indicate that the LGS Units 1 & 2 SDP Phase 2 notebook has about 37 percent matching of the hypothetical cases, and 63 percent more conservative in comparison to the licensee's PRA model. Prior to benchmarking, the revision 0 SDP notebook has about 25 percent matching of the hypothetical cases, and 69 percent more conservative in comparison to the licensee's PRA model. A summary of the results of comparisons of hypothetical inspection findings between the Revision 1SDP notebook and the licensee's PRA model are as follows:

Attachments: As stated

CONTACT: S. Wong, SPSB/DSSA/NRR
301-415-1125

- 0% Notebook predicted the risk significance by one order of magnitude less than the licensee's PRA model,
- 37% Notebook and licensee's PRA results matched within an order of magnitude,
- 32% Notebook predicted the risk significance by one order of magnitude greater than the licensee's PRA,
- 24% Notebook predicted the risk significance by two orders of magnitude greater than the licensee's PRA, and
- 7% Notebook predicted the risk significance by three orders of magnitude greater than the licensee's PRA.

At LGS Unit 1, the CDF contribution from internal events was 4.4E-6/yr, and the CDF contribution from internal flooding events was 1.1E-7/yr. The CDF contribution from internal events for LGS Unit 2 was 4.5E-6/yr.

Since the updated LGS Probabilistic Risk Assessment (PRA) model did not include a quantitative external events model at the time of the benchmarking visit, the benchmarking team was unable to perform sensitivity analyses to assess the impact of external event initiators on SDP color determinations, or to determine the importance of certain risk-significant systems/components and operator actions if the impact of external events were included in the risk significance determination.

The licensee's PRA 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 LGS Units 1 & 2 SDP Phase 2 Notebook and the licensee's PRA.

If you have any questions regarding this effort, please contact See-Meng Wong.

Attachments: As stated

CONTACT: S. Wong, SPSB/DSSA/NRR
301-415-1125

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- 7% Notebook predicted the risk significance by three orders of magnitude greater than the licensee's PRA.

At LGS Unit 1, the CDF contribution from internal events was 4.4E-6/yr, and the CDF contribution from internal flooding events was 1.1E-7/yr. The CDF contribution from internal events for LGS Unit 2 was 4.5E-6/yr.

Since the updated LGS Probabilistic Risk Assessment (PRA) model did not include a quantitative external events model at the time of the benchmarking visit, the benchmarking team was unable to perform sensitivity analyses to assess the impact of external event initiators on SDP color determinations, or to determine the importance of certain risk-significant systems/components and operator actions if the impact of external events were included in the risk significance determination.

The licensee's PRA 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 LGS Units 1 & 2 SDP Phase 2 Notebook and the licensee's PRA.

If you have any questions regarding this effort, please contact See-Meng Wong.

Attachments: As stated

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|---|---|---|---|
| **NAME** | PWilson:nxh2 | MReinhart /***RA/*** P. Wilson for | WSchmid |
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# SUMMARY REPORT ON BENCHMARKING TRIP

# TO THE LIMERICK GENERATING STATION

# UNITS 1 & 2

# (November 18 - 19, 2002)

J. C. Higgins

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

**July 22, 2003**

ATTACHMENT A

# TABLE OF CONTENTS



## List of Tables

# 1 Introduction

On November 18 & 19, 2002, the NRC conducted an SDP Benchmarking visit with the Limerick PRA staff in the Kennett Square, PA corporate offices of Exelon (Attachment 1 provides a list of participants). The purpose of this visit was to validate the underlying assumptions of the draft Revision 1, SDP Phase 2 Notebook. The validation was conducted by soliciting comments from the licensee's PRA staff; reviewing differences between the underlying assumption of the notebook and the licensee's PRA; and comparing the safety significance of hypothetical inspection findings using both the notebook and PRA. The outcome of this SDP Benchmarking visit is the issuance of Revision 1 of the SDP notebook. The SDP notebook is used by inspectors to determine the safety significance of inspection findings.

The Limerick SDP Notebook was originally prepared in 2000. The Limerick notebook was reviewed prior to this benchmarking visit in order to identify potential changes that may be needed in order to address generic NRC changes for the Rev. 1 notebook update. These questions and a summary of the changes (see Attachment 2) were provided to the licensee prior to the benchmarking visit.

# 2 Summary of Results from Benchmarking

The benchmarking visit identified that the notebook is conservative compared to the licensee's PRA. The comparison of the significance between the licensee's PRA and the SDP Phase 2 notebook for hypothetical inspection findings is provided in Table 1. A summary of the results of the risk characterization of hypothetical findings by the SDP notebook are as follows.

| | |
|---|---|
| 0% | Underestimates Risk Significance (non-conservative) |
| 37% | Match Risk Significance |
| 32% | Overestimates Risk Significance by 1 Order of Magnitude |
| 24% | Overestimates Risk Significance by 2 Orders of Magnitude |
| 7% | Overestimates Risk Significance by 3 Orders of Magnitude |
| 63% | Total overestimation (1, 2, or 3 Orders ) |

The benchmarking team noted several reasons why the notebook is more conservative than the Limerick Generating Station (LGS) PRA. The principal reasons for the differences are as follows:

- On failure of containment heat removal (CHR) and containment venting (CV), Limerick credits success of late injection (LI) to prevent core damage (with a 25% probability, due to harsh environment in Reactor Building). This is not credited in the notebook.

- The PRA credits certain recovery actions that are not included in the notebook.

- The notebook is not able to model the very detailed electrical distribution system at Limerick for the LOOP worksheet.

- Limerick has four electrical trains yet the most credit we give is 3 for a multi-train system.

- Limerick has four electrical and safety trains (for certain systems). This is modeled and

credited in the LGS PRA. However, the notebook provides only a multi-train system credit of 3 for the four trains (the same as if it were two trains).

# 3 Modifications to SDP Worksheets

## 3.1 Benchmarking Details

Benchmarking Methodology

The licensee's PRA information used during this benchmarking visit was based on the updated November 2002 version of the Limerick PRA. The baseline PRA core damage frequency (CDF) for Unit 1 from internal events was 4.5E-6 core damage events/reactor-year, including internal flooding which is 1.08E-7 events per RY (about 2.4% of CDF). Unit 2's CDF was 4.54E-6 core damage events/reactor-year. If the internal flooding contribution is removed, the Unit 1's CDF was 4.39E-6 core damage events/reactor-year.

During the beginning of the benchmarking visit, the team reviewed the notebook with the licensee's staff and obtained comments from the licensee. These comments were incorporated, as appropriate, into the notebook prior to the onsite benchmarking.

The team computed the break points in RAW values for the different SDP colors based upon a current PRA total internal events CDF of 4.39E-6 core damage events/reactor-year. The team pre-selected components and human actions, as listed in Table 1, that would be evaluated for the effect of having the component or human action fail. The team developed the color corresponding to failure of each item. The latest revised version of the notebook was used to develop the color corresponding to failure of each item and compared that to the color that would be implied by the item's RAW value from the PRA. Table 1 tabulates the results of the benchmarking of both the Rev. 0 and the modified Rev. 1 worksheets that are contained in the risk-informed inspection notebook for Limerick.

In developing the colors from the notebooks, the team evaluated all sequences in each worksheet that contained the item (component or human action). A number was obtained for each re-evaluated sequence. We then used a "counting rule" to cascade lower value sequences to higher value ones as follows. For example, three sequences of value 8 (shorthand for an estimated sequence frequency of 1E-8 events/reactor-year) were equivalent to one sequence of value 7. Likewise, 3 sequences of value 7 (3-7s) were equivalent to one sequence of value 6 (1-6). Also, 3-6s were equal to 1-5, and so on. Colors were developed as follows:

| | |
|---|---|
| Sequences of value 7, 8, and higher | Green |
| Sequences of value 6 | White |
| Sequences of value 5 | Yellow |
| Sequences of value 4 or less | Red. |

*Key Limerick PRA Assumption*

On failure of CHR and CV, Limerick credits success of LI to prevent core damage (the PRA models failure of LI, due to harsh environment in the Reactor Building with a PRA event OENVIRON =

0.25). This is not credited in this notebook due to uncertainty of the needed equipment surviving the steam environment. In the event of SPC (CHR) failure, on an LOIA, the LGS PRA credits DEP and use of LI to prevent core damage. One of the methods of LI credited in the PRA is LI with 1/2 CRD pumps, for which the PRA uses a failure probability of 1E-2. Since the notebook does not credit this as a success path, there are some important implications for the SDP notebook. One item is that there is a CHR - CV failure path in each notebook, that does not exist in the PRA. In the PRA those sequences end with CHR - CV - LI, or CHR - CV - OENVIRON. Further, for initiators that fail Instrument Air (IA) and/or CV (such as LOIA and LOTECW), these sequences in the notebook are merely (LOIA - CHR and LOTECW - CHR). Thus, the notebook has sequences with two term cutsets, which are notably high in frequency (close to Red). This will make the notebook evaluation of any component associated with these sequences conservative (closer to Red). It can also make items credited in the PRA (e.g., injection pumps for the LI pathway used after CV failure) to be more important in the PRA. These injection pumps (e.g., CRD) could in turn be potentially non-conservative in the notebook.

This key PRA assumption will also potentially lead to discrepancies and/or disagreements during future SDP Phase III analyses.

Modeling Issue # 1

Limerick has a unique electrical distribution system with 4 EDGs per unit, but the loads are not fully symmetrical. Only 1 EDG is needed for success, if it is EDG 11 or 12; but if it is EDG 13 or 14, some cross-connection of loads from Buses 11 and 12 is also needed. Some detail on this is given below, as quoted from footnote 4 of Table 3.7 (LOOP worksheet) from the notebook.

> If both EDGs 11 and 12 fail (event EAC1/2), then we are left with the possibility that either EDG 13 can power Bus D13 or EDG 14 can power Bus D14. Either one of these cases is not quite sufficient to prevent core damage. One also needs an ESW pump, an RHRSW pump, and a 480 VAC MCC to power valves. These can be powered by: (1) circuit breaker switching in Unit 1 to cross-tie the A or B train loads onto the running EDG 13 or 14, or (2) circuit breaker switching to power the A or B train loads from a Unit 2 EDG. In this case, for example, EDG 13 would run its own loads plus the ESW pump, the RHRSW pump and the valve's MCC.

The PRA models this in great detail with separate ET branches for each possible combination of the 4 EDGs. This large level of detail could not be duplicated in the notebook. Thus, our simplification results in some conservatism in the LOOP worksheet.

Modeling Issue # 2

Limerick has four electrical and safety trains (for certain systems – LPCI, LPCS, & the pump portion of RHR SPC). This is modeled and credited in the LGS PRA. However, the notebook provides only a multi-train system credit of 3 for the four trains (the same as if it were two trains).

*Non-conservative Benchmarking Results*

None.

*Conservative Benchmarking Results*

As stated above in the paragraph "Key Limerick PRA Assumption," there were many items that benchmarked as conservative (notebook gave a color closer to Red than the PRA RAW value) due to Limerick crediting success after failure of CHR and CV. There were also some other aspects of the modeling (issues #1 and # 2 above) versus the notebook that contributed to the large number of conservative items. Some specifics are provided below, based upon best judgements. An analysis of the PRA modeling and cutsets for each conservative item was not able to be performed in the time period available during the benchmarking.

*3 orders conservative*

DC Buses C & D and DC chargers A & B benchmark as Red while the PRA gives a Green (3 orders conservative). We get 1 Red from the LOIA - CHR (5) sequence that is discussed above in the "Key Limerick PRA assumption." We also get 2 Yellows from TPCS and LOTECW. Then there are many other sequences that cascade down to 2 more Yellows. This conservatism is a combination of the Key PRA assumption and the two modeling issues noted above.

*2 orders conservative*

An IA compressor is conservative due to: conservatism in the IA worksheet from the key PRA assumption noted above, modeling issue #2, and due to the manner in which we increase the initiating event frequency (ief) of LOIA for the loss of only one compressor.

The conservatism in RHR pump A and RHRSW pump B primarily come from the LOIA - CHR (5) sequence that is discussed above in the "Key Limerick PRA assumption." Also contributing to the conservatism is modeling issue # 2.

All four of the 4160 VAC buses benchmark as Red. The Red benchmark color of these buses comes primarily from the LOIA - CHR (5) sequence. However, the licensee's RAW gives Yellow to Buses A, B, & C and White to Bus D. Thus, Bus D is two orders conservative and the other three buses are one order conservative. Bus D has a lower RAW value because there are less important loads on Bus D.

Also for similar reasons as the AC buses, the DC buses A & B, the two DC batteries (A & B) and the two DC chargers color as Red. The batteries are colored the same as the DC buses and the chargers are also colored the same as the buses and batteries. Thus, DC Buses A & B, and DC batteries A & B are 2 orders conservative due to modeling issues 1 & 2 above.

The PRA model does not appear to have sequences that go directly to CD on failure of 2 SP vacuum breakers, but the notebook does. This makes the two vacuum breakers Red in the notebook, whereas the RAW only gives a White. Hence the notebook is conservative by 2 orders.

ATWS related items and operator actions are conservative since (as noted in footnote 5 of Table 1 of the notebook) the ATWS ief is about 3E-7 which is almost two orders of magnitude lower than the E-5 assumed by the notebook. As a result, Inhibit on ATWS is 2 orders conservative.

OPESW is Red by the notebook but colors as White based on the PRA RAW. We were not able

to identify specific reasons for this mismatch during the site visit.

The operator action for CV is conservative by two orders since its failure does not lead directly to core damage in the PRA, but does in the notebook (Key assumption above).

*1 order conservative*

HPCI & RCIC are conservative by 1 order due to a TPCS worksheet sequence and the SORV, LOOP, and LOIA sequences. The TPCS ief is 0.14 which is just into Row I and also the PRA credits recovery of PCS which is not credited in the notebook. Also, the SORV (both the fto and the ftc modes) is generally conservative because we combine IORV and SORV, but do not credit PCS. LOOP is conservative as discussed above. Also, LOIA is conservative for reasons noted in the key PRA assumption.

PCS steam and one SRV fto are conservative by one order due to the same TPCS issues noted just above.

One SRV ftc is conservative because we evaluate this by setting the SORV frequency to zero, which is somewhat of a conservative method.

One RHR HX is conservative from the LOIA - CHR (5) sequence that is discussed above in the "Key Limerick PRA Assumption."

One CV valve failure causes a loss of one of the two CV paths but not all CV. Hence it is only one order conservative as opposed to the two orders noted above for the operator action CV.

ATWS related items and operator actions are conservative since (as noted in footnote 5 of Table 1 of the notebook) the ATWS ief is about 3E-7 which is almost two orders of magnitude lower than the E-5 assumed by the notebook. As a result, Recirculation Pump Trip (RPT) and reactor vessel overfill on ATWS are one order conservative.

The 4160 VAC Buses A, B, & C are one order conservative. See the discussion of 4160 VAC Bus D above under the 2 orders conservative section.

ESW loop A is one order conservative based on the LOOP worksheet, which we noted was conservative due to the key PRA assumption and modeling issue # 1.

TECW colors as Yellow using rule 1.3. This is conservative by one order. This is a result of one sequence (LOTECW - CHR) on the LOTECW worksheet, which has a base case value of 6. The PRA gives higher credit due to the key PRA assumption.

LI with the RHRSW cross tie is one order conservative based mainly on the TPCS worksheet. See discussion HPCI and RCIC above. Also LI with the condensate or RWST transfer is likewise conservative based on the TPCS worksheet.

## 3.2 Specific Changes to the Rev. 0 SDP Notebook for Limerick

A number of changes were made to the Limerick Rev. 0 notebook in the process of developing the Rev. 1 notebook. Some of these were made prior to the onsite benchmarking effort. Additionally,

at the conclusion of the benchmarking, further changes were made to the notebook in order to minimize the differences between the notebook and the licensee's PRA, while maintaining consistency with the NRC notebook construction rules. Refer to Attachment 2 for a summary of the changes.

Subsequent to the onsite benchmarking the LOOP event tree and worksheet were simplified in order to maintain better consistency with notebook construction conventions and to obtain a better match with the licensee's PRA RAW values.

### 3.3 Generic Changes in IMC 0609 for Guidance to NRC Inspectors

None.

### 3.4 Generic Changes to the SDP Notebooks

Limerick has four electrical trains yet the most credit we give is 3 for a multi-train system. We should consider whether there should be more credit given for a three or four train system.

## 4 Discussion on External Events

The licensee's updated PRA does not have an quantitative external events model.

## 5 References

1. Limerick PRA, LGS101R1 for Unit 1 and LGS201R1 for Unit 2, both dated November 2002.

2. Risk-informed Inspection Notebook for Limerick Generating Station, Revision 1.

## Table 1: Summary of Benchmarking Results for Limerick Units 1 & 2

**Internal Events CDF is 4.39E-6 events/reactor-year excluding internal flooding at a 1E-11 truncation limit**
**RAW thresholds are W = 1.23, Y = 3.28, R = 23.77**

| Component Out of Service or Failed Operator Action | SDP Worksheet Results (Before) | Limerick Basic Event | Limerick RAW ratio | Color by Limerick RAW | SDP Worksheets Results (After) | Comments |
|---|---|---|---|---|---|---|
| **Component** | | | | | | |
| HPCI | R | HTU002DWI | 2.64 | W | Y | conservative |
| RCIC | R | RTU002DWI | 2.46 | W | Y | conservative |
| PCS steam | R | FMOD032 | 1.5 | W | Y | conservative |
| PCS feed | Y | All condensate pumps | 12.0 | Y | Y | |
| 1 SRV fto | Y | AAD100DPI | 1.0 | G | W | conservative |
| 1 SRV ftc | Y | PTT | 1.44 | W | Y | conservative |
| CS pump A | G | LPM01ADWI | 1.0 | G | G | |
| RHR pump A | W | DPM02ADSI by CDF calculation | 1.21 | G | Y | conservative 2 orders |
| RHR HX A | R | DHX01AE31 | 7.95 | Y | R | conservative |
| RHR HX B | R | DHX01BE31 | 7.84 | Y | R | conservative |
| Condensate transfer pump | G | YPM15ADWIO | 1.0 | G | G | |
| RWST transfer pump | G | YPM17ADWIO | 1.0 | G | G | |
| 1 CV valve (SP path) | W | VAV104DPI or VMV112DPI | 1.0 | G | W | conservative |
| 1 DD fire pump | G | FSSFTOO | 1.2 | G | G | By Table 2 of notebook |
| 1 Condensate pump | G | FPM02AEWI | 1.0 | G | G | |

| Component Out of Service or Failed Operator Action | SDP Worksheet Results (Before) | Limerick Basic Event | Limerick RAW ratio | Color by Limerick RAW | SDP Worksheets Results (After) | Comments |
|---|---|---|---|---|---|---|
| SBLC pump | G | SPM01ADSI | 1.02 | G | G | |
| RPT 1 train (RRCS) | G | XMOD02A | 1.01 | G | G | |
| RPT both trains (RRCS) | Y | XCCFRPTB | 2.01 | W | Y | conservative |
| EDG Div I | Y | EDGD11DSI | 1.30 | W | W | |
| EDG Div II | Y | EDGD12DSI | 1.24 | W | W | |
| EDG Div III | Y | EDGD13DSI | 1.82 | W | W | |
| EDG Div IV | Y | EDGD14DSI | 1.74 | W | W | |
| 4160 VAC Bus A | R | EBSD11DWI | 9.96 | Y | R | conservative |
| 4160 VAC Bus B | R | EBSD12DWI | 9.96 | Y | R | conservative |
| 4160 VAC Bus C | R | EBSD13DWI | 7.68 | Y | R | conservative |
| 4160 VAC Bus D | R | EBSD14DWI | 2.29 | W | R | conservative 2 orders |
| CRD pump A | G | BPM58AHRI | 1.16 | G | G | |
| IA compressor | - | ICMPIADWI | 1.15 | G | Y | conservative 2 orders |
| ESW Loop A | R | WESWAXTM | 6.58 | Y | R | conservative [7] |
| RHRSW pump B | Y | JPM01BDWIO | 1.01 | G | Y | conservative 2 orders |
| RECW pump | W | MPM21ADRI | 1.0 | G | G | Based on notebook Table 2 |
| SW pump | R | WPM50ADRI | 1.11 | G | Y | conservative 2 orders |
| TECW pump A | R | TPM13ADWI | 2.05 | W | Y | conservative |
| DC Div A panel | R | EBS25ADWI | 1.31 | W | R | conservative 2 orders |
| DC Div B panel | R | EBS25BDWI | 1.31 | W | R | conservative 2 orders |
| DC Div C panel | R | EBS25CDWI | 1.0 | G | R | conservative 3 orders |

| Component Out of Service or Failed Operator Action | SDP Worksheet Results (Before) | Limerick Basic Event | Limerick RAW ratio | Color by Limerick RAW | SDP Worksheets Results (After) | Comments |
|---|---|---|---|---|---|---|
| DC Div D panel | R | EBS25DDWI | 1.0 | G | R | conservative 3 orders |
| DC Battery A | R | EBY1A1EWI | 1.85 | W | R | conservative 2 orders |
| DC Battery B | R | EBY1B1EWI | 1.92 | W | R | conservative 2 orders |
| DC Charger A | R | EBCCA1DWI | 1.05 | G | R | conservative 3 orders |
| DC Charger B | R | EBCCB1DWI | 1.14 | G | R | conservative 3 orders |
| 2 SP vac. bkrs | G | VBOUNDEV | 1.69 | W | R | conservative 2 orders |
| 1 SP vac. bkr | G | not modeled | - | G | G | |
| 1 CS room cooler | - | - | - | - | G | |
| 1 RHR room cooler | - | - | - | - | G | |
| **Failed Operator Actions** | | | | | | |
| PCS | - | - | - | - | Y | |
| DEP | R | AHUXTE (LOOP) | 199.31 | R | R | |
| | | AHUXTR (non-LOOP) | 110.94 | R | R | |
| RHR SPC mode | R | DHURHR4 | 61.69 | R | R | |
| LI with RHRSW cross-tie | W | JHU073DXI | 1.08 | G | W | conservative |
| LI with 1/2 CRD pumps | G | BHU8ABDXI | 3.9 | Y | Y | |
| LI with condensate transfer or RWST transfer | G | OHURFCDX10 | 1.0 | G | W | conservative |
| INH for ATWS | Y | DHU01XDX | 1.12 | G | Y | conservative 2 orders |

| Component Out of Service or Failed Operator Action | SDP Worksheet Results (Before) | Limerick Basic Event | Limerick RAW ratio | Color by Limerick RAW | SDP Worksheets Results (After) | Comments |
|---|---|---|---|---|---|---|
| OP-ESW | R | WESWINT | 1.39 | W | R | conservative 2 orders |
| Overfill for ATWS | Y | UP16 | 1.51 | W | Y | conservative |
| CV | R | VHUVENTH | 1.9 | W | R | conservative 2 orders |
| RLOOP5HR | G | NOOOSP5 | 2.26 | W | W | |

**Notes:**

1. Limerick RAW for internal events, average maintenance case.

2. The ΔCDF used in RAW value calculations represented the change in CDF due to the component being out of service for 1 year.

3. For a component such as a pump, the basic events include both for "failure to start" and "failure to run." We selected either selected the highest (more conservative) RAW value for the pump, or used a synthesized RAW value separately calculated by the licensee that included all failure modes. Where the basic event column indicates "by CDF calculation," the licensee separately calculated a RAW by setting all the appropriate system events to true (or failed) and resolving the model to obtain the new higher CDF.

4. For the item where the basic event column is noted as "not modeled," the PRA did not separately model the item and so a PRA RAW value was not available. For the item where the basic event column has a dash (-), an appropriate basic event could not be identified (for a variety of different reasons) or the RAW could not readily be determined.

5. When comparing the modified SDP worksheet color to the color by the Limerick RAW, we found many that were conservative. Each color of conservatism represents approximately one order of magnitude in ΔCDF. In the comments column, we indicate how by many orders of magnitude the item is conservative.

6. On failure of CHR and CV, Limerick credits success of LI to prevent core damage (the PRA models failure of LI, due to harsh environment in the Reactor Building with a PRA event OENVIRON = 0.25). This is not credited in this notebook due to uncertainty of the needed equipment surviving the steam environment. In the event of SPC (CHR) failure, on an LOIA, the LGS PRA credits DEP and use of LI to prevent core damage.

7. ESW is a split train and cools ECCS HVAC, EDGs, RHR, and LPCI. The SW system can act as a back up to ESW. The EDGs are supplied by both loop A & B of ESW, but operator actions is needed if one loop fails. Thus, to benchmark ESW we evaluate LOOP and LOSW worksheets. On a LOOP with loss of ESW loop A, you lose EAC1/2 and the A train of RHR, LPCI and CS.

8. The 4 items that were 3 orders of magnitude conservative were: DC Div C & D panels, and DC chargers A & B.

9. The 13 items that were 2 orders of magnitude conservative were: an IA compressor, an RHR pump, RHRSW pump B, SW pump, 4160 VAC Bus D, DC Div. A & B panels, DC batteries A & B, 2 SP vacuum breakers, inhibit for ATWS, OP-ESW, and CV.

10. The 17 items that were 1 order of magnitude conservative were: HPCI, RCIC, PCS steam, 1 SRV ftc or fto, RHR HX A or B, 1 CV valve, 2 trains of RPT, 4160 VAC Bus A, B, or C, ESW Loop A, TECW pump A, LI with RHRSW, LI with condensate transfer or RWST transfer, and overfill on ATWS.

## Table 2: Comparative Summary of the Benchmarking Results

| | Rev. 0 SDP Worksheets | | Rev. 1 SDP Worksheets, as Modified | |
|---|---|---|---|---|
| | **Number of Cases** | **Percentage** | **Number of Cases** | **Percentage** |
| SDP: Non-Conservative | 3 | 6 | 0 | 0 |
| SDP: Conservative | (36) | (69) | (34) | (63) |
| by one order | 17 | 32 | 17 | 32 |
| by two orders | 14 | 27 | 13 | 24 |
| by three orders | 5 | 10 | 4 | 7 |
| SDP: Matched | 13 | 25 | 20 | 37 |
| Total | 52 | 100 | 54 | 100 |

**Notes**:

1. Before the benchmarking, there were 3 non-conservative items. After the benchmarking, there were no non-conservative items.

2. Before the benchmarking, there were 36 conservative items. After the benchmarking, there were 34 conservative items, 17 by one order, 13 by two orders, and 4 by 3 orders of magnitude. These conservative items are discussed in Section 3.1 above.

# ATTACHMENT 1

## List of Participants

| | |
|---|---|
| See-Meng Wong | NRC/NRR |
| Gene Cobey | NRC/Region I |
| James Higgins | BNL |
| Edward Grove | BNL |
| John Schroeder | INEEL |
| Vickie Warren | Limerick |
| Alex Knoll | Limerick |
| Phil Tarpinian | Limerick |
| Gary Krueger | Peach Bottom |

# ATTACHMENT 2

## Changes to Notebook

### Notebook Changes Prior to Onsite Visit

- Changed IORV/SORV title to SORV.
- Dropped credit for PCS from the SORV worksheet.
- Dropped credit in DEP for stuck-open SORV.
- Dropped credit for condensate from LI on TRANS, SLOCA, & SORV.
- Editorial changes.
- Added base case credits to the worksheet sequences.

### Notebook Changes Made During & After Benchmarking Visit

- Updated initiating event frequencies in the notes to Table 1.
- Updated Table 2 equipment, support systems, and footnotes.
- Added worksheets for LODCI, LODCII, LOIA, & LOTECW.
- Updated description of PCS in worksheets.
- Updated operator action credits in worksheets based upon current PRA HEPs: DEP credit changed from 2 to 3 for most worksheets, total credit for LI limited to a maximum of 3.
- CHR information amplified to include detailed train information.
- Modified CV to include both SP and DW paths.
- Amplified the RHRSW cross-tie description in worksheets.
- Updated the footnotes to all worksheets.
- Modified event trees (ETs) for SORV & LLOCA to more closely agree with PRA.
- Changed Early Containment Control (EC) to require 4/4 vacuum breaker paths to be closed.
- Completely revised the LOOP ET and worksheet to better match the PRA modeling.
- Dropped HPI and RHRSW cross-tie from the ATWS worksheet.
- Added operator action to LOSW for starting ESW. Added credit for CV and LI to LOSW.
- Added credit for cross tie of IA from the opposite unit.