September 8, 2003

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SUBJECT: RESULTS OF THE DUANE ARNOLD ENERGY CENTER SDP PHASE 2 NOTEBOOK BENCHMARKING VISIT

During June, 2003, NRC staff and contractors visited the Duane Arnold Energy Center in Cedar Rapids, IA, to compare the Significance Determination Process (SDP) Phase 2 notebook and licensee's risk model results. In addition, the results from analyses using the NRC's draft Revision 3i Standard Plant Analysis Risk (SPAR) model for Duane Arnold 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 Duane Arnold Phase 2 notebook was generally more conservative in comparison to the licensee's PSA. The revision 1 SDP notebook will capture 95% of the risk significance of inspection findings. A summary of the results of comparisons of hypothetical inspection findings between SDP notebook and the licensee's PSA are as follows.

5%	Underestimates Risk Significance
55%	Match Risk Significance
28%	Overestimates Risk Significance by 1 Order of Magnitude
12%	Overestimates Risk Significance by 2 Orders of Magnitude

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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 Duane Arnold SDP Phase 2 Notebook and the licensee's PSA.

Attachments: As stated

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Attachments: As stated

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SUMMARY REPORT ON RISK-INFORMED BENCHMARKING TRIP

TO THE DUANE ARNOLD ENERGY CENTER (DAEC)

(JUNE 7, 2003)

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August, 2003

ATTACHMENT A

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List of Tables

1 INTRODUCTION

On June 7, 2003, the NRC conducted an SDP Benchmarking visit with the Duane Arnold PRA staff. The purpose of this visit was to validate the underlying assumptions of the updated Rev. 0 SDP Phase 2 Notebook. The validation was conducted by soliciting comments from the licensee's PRA staff; reviewing differences between the underlying assumptions of the notebook and the licensee's PRA; and comparing the safety significance of hypothetical inspection findings using both the notebook and the licensee's PRA. The outcome of this SDP Benchmarking visit is the issuance of Rev. 1 of the SDP notebook. The SDP notebook is used by inspectors to determine the safety significance of inspection findings.

The Duane Arnold SDP notebook was originally prepared in early 2001. The Duane Arnold 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. The licensee's comments were received on the Rev. 0 notebook around July 2002. These comments, along with other changes deemed necessary, were incorporated in the updated SDP notebook prior to the benchmarking visit.

2 SUMMARY RESULTS FROM BENCHMARKING

The benchmarking visit identified that the results obtained using the Duane Arnold notebook is generally consistent with the risk significance calculated by the Duane Arnold PRA. As expected, in some cases conservative results were obtained by the Duane Arnold SDP notebook. 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 is as follows.

2 Cases (5%)	Underestimates Risk Significance
24 Cases (55%)	Match Risk Significance
12 Cases (28%)	Overestimates Risk Significance by 1 Order of Magnitude
5 Cases (12%)	Overestimates Risk Significance by 2 Orders of Magnitude
2 Cases (----%)	Unable to compare with the licensee's PRA.

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 Revision 4, January 1998 version of the Duane Arnold PRA. This PRA has an internal events CDF of 1.18E-5 events/reactor-year, including internal flooding which accounts for less than 1% of the total contribution.

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 Duane Arnold.

Non-conservative Benchmarking Results

There were two cases where the SDP underestimated the plant's PRA. These cases are discussed below:

1. Loss of 4160 VAC Bus 1A4: The Duane Arnold PRA currently models bus 1A4 as the bus that would become available if one EDG is available after LOOP or if one EDG is recovered after initial SBO. As a result of this asymmetric assumption, the risk significance associated with failing bus 1A4 would be significantly overestimated. On the contrary, the risk significance associated with failing bus 1A3 would be significantly underestimated. This effect was observed in the plant RAW values. The RAW associated with buses 1A4 and 1A3 were 127 and 4.8 respectively. The true RAW value should be somewhere between 60 to 80; that is, the failure of any emergency AC bus should be "Red (R4)" and the SDP should score one match and one overestimate. However, the approach taken at the site, albeit conservative, was to assume that the RAW associated with each bus is 127 or "Double Red (R3)". This resulted in one match and one underestimate.

2. Failure of two or more Suppression Pool Vacuum Breakers: The failure of vacuum breaker to remain closed is modeled under the heading EC in the Large LOCA worksheet. The success criteria in Duane Arnold is success of 6 out of 7 vacuum breakers. The main reason for this underestimate stems from the licensee's frequency for the LLOCA initiating event which is about 3.0E-4, an order of magnitude higher than the generic values used in the SDP notebook.

Even though the reason for this underestimate was trivial, it revealed some modeling assumptions in the Duane Arnold PRA which may have generic implications. The failure of vacuum breaker to remain closed is modeled in the Duane Arnold PRA for SLOCA, MLOCA, and LLOCA with success criteria of 7/7, 7/7, and 6/7. The more forgiving criteria for LLOCA is because the higher pressure in drywell will push some steam through the wetwell, therefore, reducing the bypass flow. In all cases, if the success criteria is not met, the Suppression pool will fail at some high point (typically due to leakage) after a short period of time (in about 1/2 hour). The licensee assumes that in SLOCA and MLOCA the water in the pool would remain cool and will not impact the operation of the injection systems. In LLOCA, however, the water is assumed to heat up rapidly, therefore causing the injection pumps to fail, and core damage is conservatively assumed. Therefore, the inclusion of the EC in SLOCA and MLOCA is mainly considered in Duane Arnold from the LERF issue assuming core damage has occurred due to other reasons. Since the SDP notebook is designed to capture core damage scenarios, it has only modeled EC in the LLOCA initiator.

Conservative Benchmarking Results

There was a total of seventeen cases of overestimation (five cases by two colors and twelve cases by one color) which were noted during Benchmarking. We first make some general observations regarding the overestimations by the SDP notebook and then discuss the overestimations by more than one color.

Overestimations by the SDP notebook for the Duane Arnold Energy Center compared to the results obtained using the plant-specific PRA were mostly caused by the differences in SDP assumptions compared to the assumptions made in the plant PRA. One of the main PRA assumptions that had profound impact on the differences is discussed below:

The licensee assumes that after containment venting the ECCS has a high failure probability and the core inventory control will be achieved with sources outside the reactor building (late Injection). Example of these sources include Condensate, feedwater, CRD, and other sources connecting to loop A of the RHR system. The licensee assumes that after containment venting the late injection will be very redundant and reliable, therefore they are not modeled in the PRA (e.g., CRD is not in the model). In reality, depending on the initiators, credit for these sources can vary from 1 to 5 (i.e., failure probabilities from 0.1 to 1.E-5 per demand). The SDP, therefore, adhered to its construction rule and credited these sources appropriately for each core damage sequence. The results of this licensee assumption will make containment venting exactly equivalent to CHR (suppression pool cooling). This makes the licensee's importance for CHR components to be low and CV paths to be high compared to the SDP evaluation. This same licensee assumption will make the PCS steam which can be considered as a redundant system to CHR and CV not to be as important as the SDP denotes.

Another PRA assumption that is different than the SDP notebook is related to survivability of injection after containment failure or venting. The PRA credits the survivability of injection after containment failure at 0.66. With such a high probability of failure, we felt there is no need to credit any form of injection after containment failure in the SDP notebook and we adhered to the SDP construction rule. The minor conservatism caused by this difference in assumptions between the SDP and plant PRA would be similar to round off errors.

Overestimations by two colors were noted for the Steam condensing function of PCS, the feedwater portion of PCS, suppression pool cooling function, and the battery chargers associated with Divisions 1&2.

1. The overestimation of the risk significance of the PCS-Steam was expected since the PRA assumes that there are three equivalent means of removing the heat from the reactor and/or suppression pool; PCS-Steam, RHR in Suppression Pool Cooling Mode, and Containment Venting

as discussed before. The SDP notebook, however, does not consider that the CV is equivalent to the other two systems. Therefore, failure of PCS-Steam in the SDP notebook would have higher impact on loss of CHR and would be more important.

2. The overestimation of the risk significance of the PCS-feedwater was expected since the PCS-feedwater (or condensate) is one means of providing late injection (LI function in the SDP notebook). The plant PRA assumes that CRD will always be available after CV; therefore, there would be no need for LI function in many scenarios unless containment fails. Furthermore, the plant PRA provides small credit for survivability of the injection sources after containment failure (about 0.4 probability of survival). The combined impact of these two modeling assumptions in the plant PRA would result in questioning the LI function only after CV and CHR have failed and the injection systems did not survive after containment failure. The SDP notebook on the contrary would require LI even after successful CV. The higher demand for the LI function as modeled in the SDP would make LI much more important than the plant PRA results. Since the feedwater and condensate system is one means for conducting LI function, they would be considered significantly more important in the SDP than in the plant PRA.

3. The overestimation of the risk significance of the CHR function results from the PRA assumption that CHR and CV are equivalent as discussed before. So, lower risk significance for CHR is expected when evaluated using the plant's PRA compared to the SDP notebook.

4&5. The overestimation of the risk significance of the battery chargers (for Div. 1&2) results from the conservatism that is built in the SDP evaluation rules. Modifications to these evaluation rules would be necessary in order to provide a more realistic estimate of the risk significance associated with a battery charger (see Section 3.3).

3.2 Specific Changes to the Rev. 0 SDP Worksheets for Duane Arnold

A number of changes were made to the Duane Arnold worksheets. Refer to Attachment 2 for a detailed list of changes. These changes will be included in Rev. 1 of the Duane Arnold SDP notebook.

Table 1:

1. Moved LOOP to Row I and added a footnote that the IE frequency is 0.08 in the PRA.
2. Moved LORW from Row IV to Row III. Added a footnote that the IE frequency is 7.5E-4 per reactor-year and the Recovery of LORW is now explicitly modeled in the worksheet.
3. Removed LIA from the table.
4. Changed IORV to SORV (Globally). Added a footnote saying that IE frequency for SORV is 6.2E-2 per reactor-year and it is composed of IORV with a frequency of 0.05 per reactor-year and SORV which is estimated at .012 per reactor-year by the licensee's PRA.
5. Added a footnote saying that the SLOCA, MLOCA, and LLOCA initiating event frequencies in the licensee's PRA are 1.0E-2, 3E-3, 3E-4 respectively.

Table 2:

- Removed 480VAC essential AC from support column for SRVs and added it as a support to N_2.
- Added a footnote for SRVs to clarify that there are two additional spring loaded relief valves that discharge to drywell.
- Added a footnote that LPCI/RHR pumps can operate for an extended period of time (beyond the PRA's mission time) without ESW for seal cooling, therefore the ESW is not modeled in the PRA.
- Removed diesel fire pump from the table.
- Clarified that the GSW pump C is fed from non-essential bus 1A2.
- Added a footnote that the day tank capacity is sufficient for four hours.
- Added a footnote stating that the battery chargers cannot take the SI loads.

Table 3.1:

1. Simplified the PCS description to "1/2 condensate pumps, 1/2 reactor feedwater pumps, and CST". This is a Global change all through the worksheets.
2. Globally added when applicable "through Loop A of RHR through a single valve" to the description of LI.
3. Globally credited 1 CRD pump for LI as an operator action with a credit of 1.
4. Globally changed the credit for LPI for LPCI to one train to account for the Loop Selection Logic.

Table 3.3: SLOCA

1. Identified the size of break in the footnote.
2. Removed EC function and modified the event tree accordingly.
3. Credited CRD for LI.

Table 3.4: SORV

1. Modified similar to SLOCA.

Table 3.5: MLOCA

1. Identified the size of break in the footnote.
2. Removed EC function and modified the event tree accordingly.

Table 3.6: LLOCA

1. Changed the success criteria for EC from 7/7 to 6/7 Vacuum breakers with a credit of 1 multi-train system.

Table 3.7: LOOP

1. Removed condensate as a means for LI.

Tables 3.9 and 3.10: Loss of Div. I & II DC

1. Credited 1/1 remaining CRD for LI function.

Table 3.11: LORW

1. Added a heading for recovery of RW by maximizing WW makeup to basin (RRW). Modified the event tree and the worksheet sequences accordingly.

2. Added 1/2 CRD for LI when at least 1/4 WW is available.

3.3 Generic Changes in IMC 0609 for Guidance to NRC Inspectors

1. The evaluation rules for battery charger should be modified to prevent unnecessary overestimations in the SDP notebook. One approach may be to assume that prolonged loss of a battery charger can lead to the loss of the associated DC bus if no recovery action is taken. The resulting color then should be reduced by a proper credit for the recovery actions. The credit for the recovery action should be based on the design. A credit of 1 may be assigned when there is one swing charger available for manual alignment, 2 when there is one swing charger that could be automatically aligned. For evaluating the inspection findings on swing charger utilizing the SDP notebook, the frequency of the associated loss of DC buses could be raised by one order of magnitude without any base case evaluation.

2. The evaluation rule may credit recovery of AC power for LOOP sequences that involves failure of CHR with CV or LI. Such sequences are not expected to result in CDF until the very late stages of accidents when there would be a high recovery probability of offsite AC.

3.4 Generic Changes to the SDP Notebooks

1. Technical basis document could further clarify the role of EC for both core damage as well as LERF.

4 DISCUSSION ON EXTERNAL EVENTS

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

Table 1: Summary of Benchmarking Results for Duane Arnold

Internal Events CDF is 1.18E-5 events/reactor-year including internal flooding at a 1E-10 truncation limit
RAW thresholds are W = 1.08, Y = 1.85, R4 = 9.47, R3 = 85.75, R2 = 849, R1 = 8500

Component Out of Service or Failed Operator Action	SDP Worksheet Results (Before)	Duane Arnold Basic Event	Duane Arnold RAW Ratio	Color by Duane Arnold RAW	SDP Worksheet Results (After)	Comments
Component						
HPCI	Y	h-hpcimaint-	2.3	Y	Y	MATCH (M)
RCIC	Y	r-rcicinmnt-	2.9	Y	Y	(M)
PCS steam	R3		1.59	W	R4	Over by 2 (O2)
PCS feed	R4		1.2	W	R4	(O2)
1 SRV fto	W	o-rvpsv4407p	1	G	W	Over by 1 (O1)
1 SRV ftc	Y	o-rvanysrvtt	1.9	Y	R4	(O1): PRA credits closure of the valve once reactor depressurized
1 CS pump	G	s-csmta-----	1.2	W	W	(M)
1 RHR pump	Y	l-rhramaint	1.32	W	Y	(O1)
RHR HX A or B	R4	l-rhrbdmaint	2.1	Y	R4	(O1)
1 CV path	Y	v-avcv4300-p	1.03	G	W	(O1)

Component Out of Service or Failed Operator Action	SDP Worksheet Results (Before)	Duane Arnold Basic Event	Duane Arnold RAW Ratio	Color by Duane Arnold RAW	SDP Worksheet Results (After)	Comments
1 condensate pump	Y	c-mpmt1p08a	1.1	W	W	(M) Contribution for PCS/LI is used consistent with PRA's RAW value.
1SBLC pump(1) 2 SBLC pumps	Y Y	bslcatest	2.1 2.8	Y Y	Y Y	(M) (M)
RP Trip (2/2)	Y	FTPE-C2-C2-	6.3	Y	Y	(M)
EDG (Div I)	Y	P-DGMT1G31--	6.4	Y	Y	(M)
EDG (Div II)	Y	P-DGMT1G21–	5.4	Y	Y	(M)
EDG Fuel Transfer pump train	Y				Y	Not Modeled (NM) Treated like EDG.
4160 AC (Bus 1A3)	R3	P-AB1A3----A	127 (4.8)	R3	R3	(M)TRUE RAW cannot be estimated since the recovery of one bus is hardwired in LOOP.
4160 AC (Bus 1A4)	R3	P-AB1A4----A	127	R3	R4	(U) True RAW should be less than Div 1.
1 GSW pump	Y	G-MPMTA-----	1.1	W	W	(M)

Component Out of Service or Failed Operator Action	SDP Worksheet Results (Before)	Duane Arnold Basic Event	Duane Arnold RAW Ratio	Color by Duane Arnold RAW	SDP Worksheet Results (After)	Comments
1 ESW pump	R3	E-ESWAMAINT–	5.6	Y	R4	(O1) Recovery from WW and potential ESW cross-tie not credited.
1 RHRSW pump	Y	W-RIMTC---- Case run delta CDF 1.1E-6	1.09	W	Y	(O1)
1 RW pump	W	W-MP1P022A-R	1.03	G	G	(M) Increased the LORW IE by one order
All WW pumps (system not available)	W	W-MPMT1P058A,B,C,D	1.1	W	W	(M) Major impact on LORW
DC Div 1 (125VDC)	R3	P-DB1010TO-A P-DB1D10–-A	99.8	R3	R3	(M)
DC Div 2 (125VDC)	R3	P-DB1D20TO-A P-DB1D20–A	87.1	R3	R3	(M)
One DC division (250 VDC)	Y	P-BTMT1D4–C	1.5	W	Y	(O1)
125 VDC battery Bank (Div 1)	Y	P-BTMT1D1–C	20.7	R4	R4	(M)
125 VDC battery bank (Div 2)	Y	P-BTMT1D2–C	17.6	R4	R4	(M)

Component Out of Service or Failed Operator Action	SDP Worksheet Results (Before)	Duane Arnold Basic Event	Duane Arnold RAW Ratio	Color by Duane Arnold RAW	SDP Worksheet Results (After)	Comments
Charger Div 1	G	P-BCMT1D12--	1.22	W	R4	(O2)
Charger Div 2	G	P-BCMT1D22–	1.52	W	R4	(O2)
Charger Spare	W	P-BCMT1D120-	2.16	Y	R4	(O1)
IA compressor	R4	A-INST-N2-C	1.	G	G	(M)
2 SP vac. bkr	R4	T-VVA-------A,N	26.4	R4	Y	(U) Frequency for LLOCA is 3.0E-4 in PRA rather than Row V in SDP
Failed Operator Actions						
DEP	R3	O-OPMANDEP-V	77.3	R4	R3	(O1)
RHR suppression cooling mode	R2	CASE RUN	21.6	R4	R2	(O2)
INH for ATWS	Y	FTPE-X—X--	1.8	W	Y	(O1)
SBLC for ATWS	Y	CASE RUN	2.8	Y	Y	(M)
Overfill/LC for ATWS	Y	FTPE-L1–L1-	1.92	Y	Y	(M)
DC load shed during SBO	W	FTPE-SH–SH-	1.51	W	Y	(O1)

Component Out of Service or Failed Operator Action	SDP Worksheet Results (Before)	Duane Arnold Basic Event	Duane Arnold RAW Ratio	Color by Duane Arnold RAW	SDP Worksheet Results (After)	Comments
CV	R4	V-OPTORVENTV	21.8	R	R	(M)
RLOOP 30min	G	FTRE-I—I–	1.84	W	W	(M)
RLOOP 6 hours	G	FTPE-I06-I06	1.32	W	W	(M)
RLOOP 9 hours	Y	estimated	11	R	R	(M) PRA is only for conditional to six hours failed
HPCI/RCIC alternate room cooling	W	P-OOPALTCLNGU	2.7	Y	Y	(M)
Both CRD pumps/operator fail to maximize the CRD flow for LI	G				Y	(NM)

<u>Note</u>:

1. The licensee's PRA considers operation of 1 SBLC pump if started early as a success path for ATWS. The SDP notebook conservatively requires the operation of both pumps. The benchmarking results shows that the risk significance of the inspection finding for one SBLC pump is consistent between the licensee's PRA and the SDP notebook, and that the effect of this conservative assumption in the SDP notebook will not bias the results.

Table 2: Comparative Summary of the Benchmarking Results

	Rev. 0 SDP Worksheets		**Rev. 1 SDP Worksheets, as Modified**	
	Number of Cases (45)	**Percentage**	**Number of Cases (45)**	**Percentage**
SDP: Non-Conservative	10	23	2	5
SDP: Conservative				
by one order	8	19	12	28
by two orders	5	12	5	12
by three orders	2	5	0	0
SDP: Matched	18	41	24	55
RAW values not available	2	NA	2	NA
Total	45/43*	100	45/43*	100

Note:

* There are 43 cases that RAW values are available. The percentages are estimated based on these 43 cases.

ATTACHMENT 1

List of Participants

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