NRR-PMDAPEm Resource

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Sent: Wednesday, September 14, 2016 10:17 AM
To: Regner, Lisa; Klos, John
Subject: [External_Sender] DRAFT Supplemental Response to SSIB Follow up to RAI 34
Attachments: Supplement F2009 RAI-34 (002).pdf

Lisa, John,

Here is draft supplemental response to Follow up SSIB 34 for Steve Smith and our public call today.

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This supplemental response was written to provide further clarification and analysis to support follow up to RAI-34 response (2016). Follow-up to RAI-34 provided analysis of degasification for bounding temperature conditions from STP's design basis accident analysis [1]. For all analyzed temperatures above 212 F overpressure was credited to prevent boiling in the pool or a calculated void fraction of less than 2%. This overpressure credit was intended to be applied in accordance with RG 1.82 [2], which states that additional pressure credit should not be taken above what is needed to prevent a failing NPSH value; where boiling conditions and a void fraction >2% were treated as NPSH failure. This previous degasification analysis in the follow-up RAI-34 response, however, did not directly analyze the effect of the calculated void fraction on net positive suction head required (NPSHR) and calculated net positive suction head margin (NPSHM). This supplemental response provides NPSHM, as well as comparison to head loss, analysis to support the follow-up RAI-34 analysis. Additionally this supplement provides results for a best estimate LBLOCA temperature case. Results from the follow-up to RAI-34 analysis are provided below for convenience in Table 1; including an additional Case "1N" representing a best estimate LBLOCA evaluation with cool water conditions.

Table 1: Results from 2016 Follow-Up to RAI-34 Analysis

Case #	Temperature at Sump [°F]	Head Loss (ft)	Accident Analysis Contain ment Pressure (psia)	$P_{Containment}$ Analyzed Pressure (psia)			
				Pressure value used to yield non-boiling pool conditions / unchallenged conditions		Pressure value used to yield passing void fraction (<=0.02)	
				$P_{Containment}$ (psia)	Void Fraction	$P_{Containment}$ (psia)	Void Fraction
**1	269.8	0.497	43.3	*41.9	0.000		
**2	273.6	0.488	44.9	*44.5	0.000		
3	266.9	3.757	45.6			*41.3	0.020
4	213.6	4.946	29.0			*17.5	0.019
5	144.0	7.994	18.3	14.7	0.004		
6	144.0	1.071	18.3	14.7	0.000		
7	121.0	9.8780	16.9	14.7	0.006		
1N	190	5.716	~16	14.7	0.007		

*Smallest pressure above saturation pressure credited to achieve passing degasification scenarios

**No debris bed head loss is used for these cases – only clean strainer head loss is considered. These cases occur less than 5 minutes after the start of recirculation so there will be less than a third of a full sump pool volume turnover. Chemical debris is not expected at this early time post-LOCA. Thus there will not be sufficient debris accumulated on thestrainer to have an impact on head loss at the time of this case.

The best estimate case (Case 1N) utilized temperature and pressure from MELCOR-RELAP 5 sump temperature sensitivity analysis [3] modelling a DEGB break on a 27.5" CL. The highest temperature achieved after the initiation of recirculation was found to be 190F, and this single case is evaluated as bounding of the nominal temperature analysis. Results for this case will be provided along with the Follow-up to RAI-34 cases throughout this supplement.

NPSHM for a given pump can be calculated by taking the difference between the available head of water (NPSHA), adjusted by major and minor flow losses in system piping, and the NPSHR; defined by the pump manufacturer with testing corresponding to the centerline of the pump impeller or calculated with flow rate and geometry at the pump inlet nozzle depending on which case is limiting. The vertical pumps installed at STP, are limited by NPSHM calculated at the pump inlet nozzle in the design basis NPSH calculation [3], however adjustments of NPSHR for air ingestion, following RG 1.82, are made to the impeller centerline test defined NPSHR value. Therefore calculation of adjusted NPSHR, and resultant NPSHM in this supplemental evaluation will be based on the test specified NPSHR value at the pump impeller centerline.

The use of NPSHR found from the empirical examination of pump performance at the impeller centerline should not be confused with the calculation vertical datum. Because design basis analysis used a vertical datum at the pump inlet nozzles, all hydraulic head values in this supplemental evaluation will also be referenced from the elevation at the pump inlet nozzle. The equation for NPSHM is provided below for reference.

$$NPSHM = NPSHA - NPSHR \quad \text{Equation 1}$$

Values of NPSHA and NPSHR from the NPSHm design basis [3] evaluation were used as inputs for this evaluation and are provided below in Table 2 below.

Table 2: NPSHR and NPSHA Values from Design Basis Calculation

Pump	NPSHR Pump Impeller (ft).	NPSHA 2015 Calc (ft) T>212 F	NPSHA 2015 Calc (ft) T=190 F	NPSHA 2015 Calc (ft) T<171 F
LHSI	13	7.5	20.1	27.9
HHSI	11	7.4	20.2	28
CS	12	7.2	19.8	27.6

To perform the NPSHM and head loss difference evaluation, first NPSHR from Table 2 was adjusted by the calculated void fraction (Table 1above) from the follow-up to RAI-34 response utilizing the adjustment provided in RG 1.82 Rev. 4 [2] shown in the equation below; where α is the void fraction applied as the percentage value and not as a fraction.

$$NPSHR_{Adj} = NPSHR * (1 + 0.5 * \alpha) \quad \text{Equation 2}$$

Adjusted (RG 1.82) NPSHR values utilizing the void fractions calculated in Follow-Up RAI-34 are given in Table 3 below.

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Table 3: Void Fraction Adjusted NPSH Values

Case #	Void Fraction	LHSI NPSHR Pump CL (ft)	HHSI NPSHR Pump CL (ft)	CS NPSHR Pump CL (ft)	LHSI $NPSHR_{Adj}$ @ Pump CL (ft)	HHSI $NPSHR_{Adj}$ @ Pump CL (ft)	CS $NPSHR_{Adj}$ @ Pump CL(ft)
1	0.000	13	11	12	13.00	11.00	12.00
2	0.000	13	11	12	13.00	11.00	12.00
3	0.020	13	11	12	26.00	22.00	24.00
4	0.019	13	11	12	25.35	21.45	23.40
5	0.004	13	11	12	15.89	13.45	14.67
*6	0.000	13	11	12	13.00	11.00	12.00
7	0.006	13	11	12	16.68	14.11	15.40
1N	0.007	13	11	12	17.55	14.85	16.20

* Case 6 is a half full flow condition however full flow NPHSR values were used in this evaluation.

Next void adjusted NPSHR values, representing adjustment to tested values at the center line of the pump impeller, were related to the datum at the vertical pump inlet datum; which is 15-feet above the centerline of the pump impeller. This relation subtracts 15-feet from the adjusted NPSHR value to account for the 15-feet of water head gained by relating values to the pump inlet datum. Results of this NPSHR relation as well as NPSHM calculated using Equation 1 are provided below in Table 4; noting that NPSHA is related to case temperatures using the rules in Table 2.

Table 4: Follow-Up to RAI-34 Void Adjusted NPSHM

Case #	Void Fraction	LHSI $NPSHR_{Adj}$ @ Pump Inlet (ft)	HHSI $NPSHR_{Adj}$ @ Pump Inlet (ft)	CS $NPSHR_{Adj}$ @ Pump Inlet (ft)	Void Adjusted NPSHM LHSI (ft)	Void Adjusted NPSHM HHSI (ft)	Void Adjusted NPSHM CS (ft)
1	0.000	-2.00	-4.00	-3.00	9.5	11.4	10.2
2	0.000	-2.00	-4.00	-3.00	9.5	11.4	10.2
3	0.020	11.00	7.00	9.00	-3.5	0.4	-1.8
4	0.019	10.35	6.45	8.40	-2.9	1.0	-1.2
5	0.004	0.60	-1.80	-0.60	27.3	29.8	28.2
6	0.000	-2.00	-4.00	-3.00	29.9	32.0	30.6
7	0.006	1.90	-0.70	0.60	26.0	28.7	27.0
1N	0.007	2.55	-0.15	1.20	17.6	20.4	18.6

Utilizing the void adjusted NPSHM (Table 4) values the difference between adjusted NPSHM and head loss (Table 1) is now evaluated.

Table 5: Head Loss Differences for Follow-up tor RAI-34 Cases

Case #	Temp (F)	Head Loss (ft)	Void Adjusted NPSHM LHSI (ft)	Void Adjusted NPSHM HHSI (ft)	Void Adjusted NPSHM CS (ft)	LHSI Difference [NPSHM-HL] (ft)	HHSI Difference [NPSHM-HL] (ft)	CS Difference [NPSHM-HL] (ft)
1	269.8	0.497	9.5	11.4	10.2	9.0	10.9	9.7
2	273.6	0.488	9.5	11.4	10.2	9.0	10.9	9.7
3	266.9	3.757	-3.5	0.4	-1.8	-7.3	-3.4	-5.6
4	213.6	4.946	-2.9	1.0	-1.2	-7.8	-4.0	-6.1
5	144	7.994	27.3	29.8	28.2	19.3	21.8	20.2
6	144	1.071	29.9	32.0	30.6	28.8	30.9	29.5
7	121	9.878	26.0	28.7	27.0	16.1	18.8	17.1
1N	190	5.716	17.6	18.6	13.9	11.8	14.6	12.9

Of the head loss difference [NPSHM-HL] values calculated above further analysis is only needed for cases 3 and 4 (highlighted yellow) which yielded negative head loss differences when considering the void fractions calculated in follow-up RAI-34. For these cases (3 and 4) the void fraction was decreased in (0.001) increments, while updating NPSHR adjustments as performed in Table 3 and Table 4, until positive head loss difference was realized. This iteration yielded void fraction 0.008 and 0.006 for Case3 and 4 respectively, which were the first void fraction values found by decreasing in 0.001 increments to yield a positive head loss difference value. Results of this iteration are shown in Table 6 which follow the same calculation methodology used for Table 3 through Table 5.

Table 6: Results of Incremental Void Fraction Iteration for Positive HLoss Difference

Case #	Temp (F)	Head Loss (ft)	Analyzed Pressure (psia)	Void Fraction	LHSI Difference [NPSHM-HL] (ft)	HHSI Difference [NPSHM-HL] (ft)	CS Difference [NPSHM-HL] (ft)
3	266.9	3.757	*??	0.0080	0.5	3.2	1.6
4	213.6	4.946	*??	0.0060	0.7	3.2	1.7

* ?? denotes that this iteration was performed to find a void fraction that would yield a positive head loss difference. Analyzed pressure is found the next step.

In Table 6 the calculated head loss differences including NPSHR adjustment are shown in Columns 6 through 8, increasing the void fraction in Column 5 by 0.001 and redoing calculations would yield a negative number for the head loss difference; ie this is the first positive head loss difference value found with the void fraction incremental iteration. To complete the evaluation the void fraction values for Case 3 and 4 in Table 6 were used as targets, and the CASA Grande degasification model was run by incrementally increasing containment pressure by 0.1 psia until void fraction values equal to or smaller than the respective fractions in Table 6 were found; doing this finds the lowest containment pressure needed to guarantee positive head loss difference utilizing RG 1.82 adjustments for voiding. Note that all degasification inputs except for the containment pressure and the void fraction found in Table 6 were held constant to their assignments defined in the follow-up to RAI-34 response. Results of this incremental pressure iteration analysis are provided below in Table 7.

Table 7: Results for Lowest Containment Pressure to Satisfy Positive HLoss Difference

Case #	Temp (F)	Head Loss (ft)	Analyzed Pressure (psia)	Void Fraction	LHSI Difference [NPSHM-HL] (ft)	HHSI Difference [NPSHM-HL] (ft)	CS Difference [NPSHM-HL] (ft)
3	266.9	3.757	42.4	0.0077	0.7	3.4	1.8
4	213.6	4.946	19.8	0.0059	0.7	3.2	1.7

The results of Table 7 were substituted for the original Follow-up to RAI-34 results in Table 5 to form the updated final results (Table 8).

Table 8: Updated Final Results - Degasification Implications on Head Loss Difference

Case #	Temp (F)	Head Loss (ft)	Design Basis Calc Pressure (psia)	Analyzed Pressure (psia)	Pressure Difference [DBA-Analyzed] (psia)	Void Fraction	LHSI Difference [NPSHM-HL] (ft)	HHSI Difference [NPSHM-HL] (ft)	CS Difference [NPSHM-HL] (ft)
1	269.8	0.497	43.3	41.9	1.4	0.0000	9.0	10.9	9.7
2	273.6	0.488	44.9	44.5	0.4	0.0000	9.0	10.9	9.7
3	266.9	3.757	45.62	42.4	3.22	0.0077	0.7	3.4	1.8
4	213.6	4.946	29	19.8	9.2	0.0059	0.7	3.2	1.7
5	144	7.994	18.3	14.7	3.6	0.0040	19.3	21.8	20.2
6	144	1.071	18.3	14.7	3.6	0.0000	28.8	30.9	29.5
7	121	9.878	16.9	14.7	2.2	0.0060	16.1	18.8	17.1
1N	190	5.716	~16	14.7	1.3	0.007	11.8	14.6	12.9

The results in Table 8 show that positive head loss difference has been achieved for all cases while analyzed pressure remained below DBA accident analysis pressures. In accordance with RG 1.82 only over pressure needed in excess of vapor pressure was credited, and the difference between DBA calculated pressure and analyzed pressure has been tabulated.