Reference 2

DRE97-0012 Dresden LPCI/Core Spray NPSH Analysis Post DBA-LOCA: Short Term - Design Basis/GE SIL 151, Rev 0.

Calculation Title Page

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☒ Safety Related ☐ Regulatory Related ☐ Non-Safety Related

Calculation Title:

Dresden LPCI/Core Spray NPSH Analysis
Post-DBA LOCA: Short-Term
Design Basis

Station/Unit: Dresden Units 2 and 3 System Abbreviation: LPCI/CS

Equipment No.: 2(3)-1502A/B/C/D
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Do any assumptions in this calculation require later verification? ☐ Yes ☒ No

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Calculation Revision Page

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1.0 PURPOSE/OBJECTIVE

The purpose of this calculation is to determine if sufficient Net Positive Suction Head (NPSH) is available to the Dresden LPCI and Core Spray (CS) pumps following a DBA-LOCA. This will be accomplished by developing a time-dependent set of curves comparing the available containment pressure versus the pressure required to satisfy LPCI/CS pump NPSH requirements. The most limiting single failure (SF) scenarios will be evaluated, encompassing the various LPCI/CS pump combinations that are possible post-LOCA. This calculation is limited in scope to the first 600 seconds following the accident, during which no credit is taken for operator action. The results of this calculation will be used to support a Dresden License Amendment request. Upon approval of this request, this calculation will represent a Design Basis Document.

2.0 METHODOLOGY AND ACCEPTANCE CRITERIA

The most limiting single failures with respect to Peak Clad Temperature (PCT) are (Ref. 1):

1) SF-LPCI: Failure of a LPCI Injection Valve
This case results in two (2) Core Spray pumps injecting at maximum flow with four (4) LPCI pumps running on minimum flow only.

2) SF-DG: Loss of a Diesel Generator
This case results in two (2) LPCI pumps and one (1) Core Spray pump injecting at maximum flow (Design Input 1).

The most limiting single failure with regards to LPCI/CS pump NPSH, however, is failure of the LPCI Loop Select Logic (SF-LSL). This scenario involves the LPCI pumps injecting into a broken reactor recirculation loop and is discussed in detail in GE SIL 151. From a PCT perspective, this case is identical to the SF-LPCI case since the net result of each scenario is two Core Spray pumps injecting into the core with no contribution from the LPCI pumps. SF-LSL is the NPSH limiting scenario due to the LPCI/CS pumps operating at the highest achievable flow rates, resulting in the maximum pump suction losses and NPSH requirements. Both the SF-LSL and SF-DG single failure cases will be evaluated in this calculation. The SF-LPCI case is bounded by the SF-LSL case and is not included.

The minimum suppression pool pressure required to meet LPCI/CS pump NPSH requirements will be determined for both the SF-LSL and SF-DG single failure cases. The minimum pool pressure required will be compared to the minimum pool pressure available post-LOCA for both cases (Refs. 2, 4). If the pressure available is greater than the pressure required, then adequate NPSH exists. If the available pressure is less than the pressure required, then the potential exists for the pumps to cavitate, resulting in reduced flows. Cavitation tests performed by the vendor indicate the LPCI/CS pumps can run at least one hour in full cavitation without incurring damage to the pump internals or resulting in any pump performance degradation (Ref. 23). Therefore, LPCI/CS pump cavitation for a period up to one hour is acceptable.

LPCI/CS pump flow requirements are as follows:

SF-LSL

- For the SF-LSL (SF-LPCI) case, a two-pump CS flow of ≥11,300 gpm results in a PCT of ≤2030°F, which occurs ~170 seconds post-accident (Refs. 6, 22). For the purposes of this calculation, a two-pump CS flow of ≥11,300 gpm for the first 200 seconds is required.
- After PCT has been achieved, a two-pump CS flow of ≥9000 gpm (nominal flow) is required for reflooding purposes (Ref. 7, Section 9.0).

SF-DG

- For the SF-DG case, a two-pump LPCI flow of ≥9000 gpm and a single Core Spray pump flow of ≥5650 gpm are required for the first 200 seconds post-LOCA (Ref. 7, Table 4.4).
- After PCT has been achieved, the flow entering the core is needed only for reflood (level) purposes. Therefore, the SF-DG case has the same total ECCS flow requirement as the SF-LSL case above, which is a combined LPCI/CS flow of ≥9000 gpm (Ref. 7, Section 9.0).

This calculation is conservative due to use of the following inputs:

- Maximum suppression pool temperature response - References 2 and 4 determine maximum suppression pool temperatures post-LOCA, thus maximizing the vapor pressure and minimizing NPSH margin.
- Minimum suppression pool pressure response - References 2 and 4 utilize inputs that minimize suppression pool pressures, thus minimizing overpressure credit and minimizing NPSH margin.
- Technical Specifications minimum suppression pool level including maximum drawdown, minimizing elevation head and minimizing NPSH margin
- Maximum LPCI and Core Spray pump flow conditions (unthrottled system, reactor pressure at 0 psid), maximizing suction piping friction losses and NPSH Required (NPSHR).
- Increased clean, commercial steel suction piping friction losses by 15% to account for potential aging effects, thus maximizing suction losses.

3.0 ASSUMPTIONS

1. LPCI/CS pump suction piping friction losses (excluding strainer losses) were developed for a single flow case using a FLO-SERIES model of the Dresden ECCS ring header and pump suction piping (Ref. 8). This piping model was then run at the various LPCI/CS pump combinations and flows as required to support the cases evaluated in this calculation (Attachment A). The model that was developed uses clean, commercial steel pipe. In order to compensate for the increased loss due to the potential effects of aging, the resulting friction losses from the model were increased by 15%. This is consistent with discussions provided in References 9 and 10.

2. To account for strainer plugging, one of the four torus strainers is assumed 100% blocked, while the remaining three strainers are assumed clean. While the torus strainers are not included in the FLO-SERIES model discussed in Assumption 1, blocking a strainer translates to blocking a torus-to-ring header entrance leg. This is accomplished in the model by closing one of the torus legs (Torus 1-4). Based on previous sensitivity analyses, Torus-4 was chosen for maximum effect on both LPCI and Core Spray suction losses for all pump combinations.

3. Reference 11 developed LPCI system resistance curves and expected maximum operating flows for Unit 2. It is assumed that the Unit 3 results are similar based on identical pumps and elevations, and similar discharge piping layouts.

4. Reference 12 developed Core Spray system resistance curves and expected maximum operating flows utilizing actual Core Spray pump performance. For the Core Spray loop with the least system resistance, the original vendor pump curve (Ref. 13) was plotted with the system curve developed in Reference 12. The operating point was determined to be the same as that developed in the calculation. Therefore, the maximum Core Spray system flow of 5800 gpm used in Design Input 1 is appropriate.

5. GE SIL 151 includes a case of all 4 LPCI pumps injecting into both reactor recirculation loops simultaneously, with one loop broken. While it is expected that this case may result in slightly higher LPCI pump flow rates than the case being evaluated, a significant amount of water will be injected into the reactor through the intact loop. Therefore, any reduction in Core Spray system flow due to cavitation below the minimum required flow will be made up by the LPCI flow injecting into the reactor. Therefore, it is expected that the PCT will not be challenged in this case and it will not be explored in this calculation.

6. The calculations in References 2 and 4 have been performed to minimize the extent of overpressure that would exist post-LOCA, and are more appropriate with respect to the prediction of minimum containment pressure than are the original design basis calculations. While different decay heat standards are applied in these calculations, the peak containment temperatures being predicted are consistent with the original design basis temperature predictions. The pressure response is not a function of decay heat models, but is primarily only affected by the pool temperature. The new calculations incorporate analysis assumptions to minimize overpressure that are consistent with NRC Information Notice 96-55. The use of this data is thus conservative with respect to overpressure and minimizes NPSH margin.

4.0 DESIGN INPUTS

1. a. Maximum LPCI and Core Spray pump flows used are as follows:

CASE SF-LSL	Maximum Flow (gpm)	
CS 1-pump	5800	Ref. 12
LPCI 3-pump (flow split)	16,750 (5610/11,140)	Ref. 11 Att. T
LPCI 4-pump	20,600	Ref. 11 Att. S

CASE SF-DG	Maximum Flow (gpm)	
CS 1-pump	5800	Ref. 12
LPCI 2-pump	11,600	Ref. 11 Att. R

2. Initial suppression pool temperature is 95°F, the maximum allowable pool temperature under normal operating conditions (Ref. 15). This value is used as the initial pool temperature in References 2 and 4 to maximize pool peak temperature, and is used as a minimum temperature during the LOCA in Reference 8 to maximize piping friction losses (maximum viscosity).

3. Numerous short-term suppression pool temperature and pressure responses were generated in Reference 2 based on a containment model developed by General Electric. These cases consisted of 2 LPCI pumps and 1 Core Spray pump operating under maximum flow conditions, which defines the SF-DG case. The intent of these cases was to determine not only the maximum pool temperatures expected post-LOCA, but to vary the inputs in such a way as to produce a coupled minimum pool pressure response. In this manner, the temperature-pressure combination that is bounding for NPSH was determined to be Case 2A1 - 100% mixing. A tabular representation of the suppression pool temperature and pressure responses is provided in Reference 3 and is included in Table 3 of this calculation.

4. An additional suppression pool response case was generated in Reference 4 consisting of 4 LPCI pumps and 2 Core Spray pumps operating under maximum flow conditions. To simulate the SF-LSL case, the LPCI pump flow out of the broken reactor recirculation loop was modelled similar to a containment spray, thus reducing containment and suppression pool pressure below that determined in previous cases. This bounding case is Case 6A2 - 60% mixing, and is included in Table 2 of this calculation.

5. LPCI/CS pump suction piping friction losses were developed for a single flow case using a FLO-SERIES Version 4.11 model of the Dresden ECCS ring header and LPCI/CS pump suction piping (Ref. 8). This piping model was then utilized for the various LPCI/CS pump combinations and flows as required to support the cases evaluated in this calculation (Attachment A).

6. The minimum suppression pool level elevation using a maximum drawdown of 2.1 ft. is 491' 5", or 491.4 ft. (Ref. 16).

7. The suppression pool strainers have a 100% clean head loss of 5.8 ft. @10,000 gpm (Ref. 17).

8. LPCI and Core Spray pump centerline elevation is 478.1 ft. (Refs. 18, 19).

9. NPSH Available (NPSHA) is calculated using the following equation:

$$\text{NPSHA} = 144\,V\,(P_t - P_v) + Z - h_L - h_{strain} \quad \text{(based on Ref. 20, p. 2.216)}$$

where:
P_t = suppression pool pressure in psia
P_v = saturation pressure in psia
V = specific volume in ft^3/lb
h_L = suction friction losses in feet
h_{strain} = head loss across strainer in feet
Z = static head of water above pump inlet in feet

10. NPSHR values at various LPCI/CS pump flows are taken from the published NPSHR curves developed by the original equipment manufacturer and provided in References 13 and 14. These values are summarized in the table below:

Pump Flow (gpm)	NPSHR (ft.)
5100	31.0
5150	31.5
5570	35.8
5800	38.5
6100	42.0*

*extrapolated

11. Saturation pressures and specific volumes at various temperatures are taken from Reference 21 and are included in Tables 1 and 2.

5.0 REFERENCES

1. "Impact of Reduced LPCS Runout Flow on the Limiting Dresden LOCA Analysis", Siemens Power Corp. letter JHR:96:446 from J. H. Riddle to R. J. Chin dated November 5, 1996.
2. "Dresden Units 2 and 3 Containment Analyses of the DBA-LOCA Based on Long-Term LPCI/Containment Cooling System Configuration of One LPCI/Containment Cooling System Pump and 2 CCSW Pumps", GE report GE-NE-T2300740-2, December 1996
3. "Transmittal of Digitized Suppression Pool Temperature and Suppression Chamber Pressure Time Histories", GE letter from S. Mintz to J. Nash dated February 5, 1997
4. "Dresden Containment Analyses for Limiting Short-Term LOCA Event", GE letter from S. Mintz to J. Nash dated January 28, 1997
5. "Transmittal of Digitized Suppression Pool Temperature and Suppression Chamber Pressure Time Histories", GE letter from S. Mintz to J. Nash dated January 28, 1997
6. "Dresden LOCA PCT Impact of NPSH Limiting ECCS Flow", letter NFS:BSA:96-165 from R. Tsai to R. Freeman dated December 20, 1996
7. EMF-95-140(P) Rev. 1, "LOCA Break Spectrum Analysis for Dresden Units 2 and 3", Siemens Power Corporation (Proprietary), September 1996
8. "ECCS Suction Hydraulic Analysis without the Strainers", Duke Engineering & Services Calculation Number DRE96-0241 dated December 20, 1996
9. Hydraulic Institute Engineering Data Book, Second Edition, 1990
10. Cameron Hydraulic Data, 17th Edition, Ingersoll-Rand Company, 1988
11. "LPCI System Derivation of System Resistance Curves, Pump Curves, and Comparison to LOCA Analysis - Unit 2", Dresden Calculation No. DRE96-0211, Rev. 2, January 29, 1997
12. "Evaluation of Core Spray Capabilities and Surveillance Basis", Dresden Calculation No. DRE96-0207, dated December 17, 1996
13. Bingham Pump Curve Nos. 25213 (2A), 25243 (2B), 25231 (3A) and 25242 (3B) for Model 12x16x14.5 CVDS, Dresden Station Core Spray pumps
14. Bingham Pump Curve Nos. 25355-7, 27367-8, 27383, 25384-5 for Model 12x14x14.5 CVDS, Dresden Station LPCI pumps
15. Dresden Unit 2 Technical Specifications, DPR-19, Section 3.7.A.1.c.1
16. "Submergence of LPCI Discharge Line Post LOCA - Dresden Units 2 & 3", letter from S. Eldridge to C. Schroeder dated September 29, 1992, CHRON# 0115532
17. "Supporting Calculations for the ECCS Suction Strainer Modification", Nutech File No. 64.313.3119 Rev. 1, dated June 22, 1983
18. Sargent & Lundy Drawing M-547, LPCI pump suction
19. Sargent & Lundy Drawing M-549, Core Spray pump suction
20. "Pump Handbook", 2nd Edition, Karassik, Igor et. al., 1986
21. ASME Steam Tables, 1967
22. "Dresden Units 2 and 3 LOCA-ECCS Analysis MAPLHGR Results for ANF 9x9 Fuel", ANF-88-191, Supplement 4, Siemens Power Corporation, dated November 1996.
23. "Cavitation Test Report - 12x14x14-1/2 CVDS Pump", Bingham Pump Co., May 22, 1969

6.0 CALCULATIONS

The equation presented in Design Input 9 can be rewritten to solve for the minimum suppression pool pressure required to meet pump NPSH requirements by setting the NPSHA equal to the NPSHR as follows:

$$P_{t,\,min} = \frac{(NPSHR - Z + h_{total})}{144 \times V} + P_v \qquad (1)$$

where h_{total} = friction (h_L) + strainer (h_{strain}) loss (Attachment A)

h_{strain} = 5.8 ft. @ 10,000 gpm clean (Design Input 7)

Z = 491.4 ft. - 478.1 ft. = 13.3 ft. (Design Inputs 6, 8)

NPSHR = various (Design Input 10)

Solving Equation 1, the minimum suppression pool pressure required to meet LPCI and Core Spray pump NPSH requirements for the SF-LSL case is calculated (Table 1). Similarly, the minimum pool pressure required to meet LPCI and Core Spray pump NPSH requirements for the SF-DG case is calculated (Table 2). These results are plotted in Figure 1 and 2, along with the available suppression pool pressure (Refs. 2, 4).

It can be seen that for the SF-DG case (Table 2, Figure 2), adequate suppression pool pressure is available to satisfy LPCI/CS pump NPSH requirements for the entire 10 minute period. That is, no LPCI/CS pump cavitation will occur, nor will any flow reduction take place.

For the SF-LSL case (Table 1, Figure 1), no cavitation is expected to occur for the first 290 seconds post-LOCA. During this time, the LPCI and CS pumps will deliver maximum flow (Design Input 1). Since PCT occurs at < 200 seconds, the CS pumps will deliver adequate flow to ensure no impact on PCT. After 290 seconds, the LPCI and CS pumps may cavitate, resulting in reduced flows. The CS pump NPSH deficit reaches a maximum of 10.0 feet at 533 seconds, and is 9.8 feet at the 600 second mark. In order to estimate the reduced flow at which the CS pumps will operate under these conditions, a flow estimate of 5100 gpm per CS pump is used in conjunction with Equation 1:

Time (sec)	CS Flow Per Pump (gpm)	Pool Temp (°F)	Total CS Suction Loss h_{total} (ft)	LPCI Flow Per Pump (gpm)	Static Head (ft)	Vapor Pressure (psia)	Specific Volume (ft^3/lb)	CS Pump NPSHR (ft)	Required Torus Pressure (psia)	Available Torus Pressure (psia)	CS NPSH Margin (ft)
533	5800	147.8	17.90	5150	13.3	3.52	0.01633	38.5	21.85	17.61	-10.0
533	5100	147.8	15.57	5150	13.3	3.52	0.01633	31.0	17.68	17.67	-0.1
600	5800	148.7	17.90	5150	13.3	3.60	0.01634	38.5	21.92	17.76	-9.8
600	5100	148.7	15.57	5150	13.3	3.60	0.01634	31.0	17.74	17.76	0.0

Since the NPSH margin at 5100 gpm is essentially 0 feet, it is at this flow that the NPSHA equals the vendor published NPSHR. Under this NPSH condition, the pump exhibits incipient cavitation but is not yet in the full cavitation stage. As full cavitation and total head collapse have not yet been achieved, pump flow will continue to increase, i.e. the pump is expected to operate above 5100 gpm. It is therefore conservative to use the flow at which NPSHA equals NPSHR to bound the minimum flow rate at which the CS pump will operate. Thus, under the most limiting scenario for NPSH, Core Spray pump flow will reduce from a flow of 5800 gpm at ≤ 290 seconds to a minimum flow of about 5100 gpm at ≥ 533 seconds post-LOCA.

7.0 SUMMARY AND CONCLUSIONS

An NPSH analysis was performed for the LPCI/CS pumps under short-term post-accident conditions as outlined in References 2 and 4. Specifically, the limiting single failure scenarios of SF-LSL and SF-DG were examined. Selecting inputs to minimize NPSH margin, it was determined that no pump cavitation will occur in the SF-DG case. Therefore, all flow requirements described in Section 2.0 are met.

For the SF-LSL case, no CS pump cavitation is predicted for the first 290 seconds post-LOCA, thus ensuring adequate flow for PCT considerations. After 290 seconds, the CS pumps may cavitate; however, a minimum flow of 5100 gpm per CS pump is expected in the 290-600 second time period, greater than the required flows as described in Section 2.0. The total time the CS pumps may cavitate is approximately 5 minutes, significantly less than the one hour allowed in Section 2.0.

Therefore, it is concluded that adequate NPSH exists to ensure the LPCI/CS pumps can perform their safety function under all accident scenarios.

Table 1 - SF-LSL

Case 6A2 - 60% Mixing						SF Loop Select Logic - 4/2 5150 gpm/LPCI - 5800 gpm/CS								SF Loop Select Logic - 3/2 5570 gpm/LPCI (5610 gpm for single LPCI) 5800 gpm/CS							
Time (sec)	Pool Press (psig)	Pool Temp (°F)	Specific Volume (ft^3/lb)	Pv (psia)	Static Head (feet)	LPCI NPSHR (feet)	LPCI Total Loss (feet)	LPCI Preqd (psig)	LPCI NPSH Margin (feet)	CS NPSHR (feet)	CS Total Loss (feet)	CS Preqd (psig)	CS NPSH Margin (feet)	LPCI NPSHR (feet)	LPCI Total Loss (feet)	LPCI Preqd (psig)	LPCI NPSH Margin (feet)	CS NPSHR (feet)	CS Total Loss (feet)	CS Preqd (psig)	CS NPSH Margin (feet)
16	21.67	105.8	0.01615	1.13	13.3																
31	23.14	116.6	0.01619	1.54	13.3																
44	24.00	123.7	0.01622	1.87	13.3	31.5	18.68	2.96	**49.1**	38.5	17.90	5.63	**42.9**	35.8	17.21	4.18	**46.3**	38.5	15.31	4.52	**45.5**
51	24.25	126.7	0.01623	2.03	13.3	31.5	18.68	3.11	**49.4**	38.5	17.90	5.77	**43.2**	35.8	17.21	4.32	**46.6**	38.5	15.31	4.66	**45.8**
59	24.36	128.7	0.01624	2.15	13.3	31.5	18.68	3.21	**49.5**	38.5	17.90	5.88	**43.2**	35.8	17.21	4.43	**46.6**	38.5	15.31	4.77	**45.8**
79	24.48	131.2	0.01625	2.30	13.3	31.5	18.68	3.35	**49.4**	38.5	17.90	6.01	**43.2**	35.8	17.21	4.56	**46.6**	38.5	15.31	4.90	**45.8**
105	24.50	132.3	0.01626	2.36	13.3	31.5	18.68	3.42	**49.4**	38.5	17.90	6.07	**43.1**	35.8	17.21	4.63	**46.5**	38.5	15.31	4.97	**45.7**
134	23.30	133.7	0.01626	2.45	13.3	31.5	18.68	3.50	**46.4**	38.5	17.90	6.16	**40.2**	35.8	17.21	4.71	**43.5**	38.5	15.31	5.05	**42.7**
161	20.64	135.7	0.01627	2.58	13.3	31.5	18.68	3.62	**39.9**	38.5	17.90	6.28	**33.7**	35.8	17.21	4.83	**37.0**	38.5	15.31	5.17	**36.2**
188	16.29	137.6	0.01628	2.72	13.3	31.5	18.68	3.74	**29.4**	38.5	17.90	6.40	**23.2**	35.8	17.21	4.95	**26.6**	38.5	15.31	5.29	**25.8**
223	11.68	139.4	0.01629	2.84	13.3	31.5	18.68	3.87	**18.3**	38.5	17.90	6.52	**12.1**	35.8	17.21	5.07	**15.5**	38.5	15.31	5.41	**14.7**
254	8.93	140.7	0.01630	2.94	13.3	31.5	18.68	3.96	**11.7**	38.5	17.90	6.61	**5.4**	35.8	17.21	5.16	**8.8**	38.5	15.31	5.50	**8.0**
290	6.70	142.1	0.01630	3.05	13.3	31.5	18.68	4.06	**6.2**	38.5	17.90	6.71	**0.0**	35.8	17.21	5.26	**3.4**	38.5	15.31	5.60	**2.6**
337	5.14	143.6	0.01631	3.17	13.3	31.5	18.68	4.17	**2.3**	38.5	17.90	6.82	**-3.9**	35.8	17.21	5.37	**-0.5**	38.5	15.31	5.71	**-1.3**
385	4.34	144.9	0.01632	3.27	13.3	31.5	18.68	4.27	**0.2**	38.5	17.90	6.92	**-6.1**	35.8	17.21	5.47	**-2.7**	38.5	15.31	5.81	**-3.5**
442	3.83	146.3	0.01632	3.39	13.3	31.5	18.68	4.38	**-1.3**	38.5	17.90	7.03	**-7.5**	35.8	17.21	5.58	**-4.1**	38.5	15.31	5.92	**-4.9**
497	3.13	147.3	0.01633	3.48	13.3	31.5	18.68	4.46	**-3.1**	38.5	17.90	7.11	**-9.4**	35.8	17.21	5.66	**-6.0**	38.5	15.31	6.00	**-6.8**
533	2.91	147.8	0.01633	3.52	13.3	31.5	18.68	4.50	**-3.7**	38.5	17.90	7.15	**-10.0**	35.8	17.21	5.71	**-6.6**	38.5	15.31	6.05	**-7.4**
600	3.06	148.7	0.01634	3.60	13.3	31.5	18.68	4.58	**-3.6**	38.5	17.90	7.22	**-9.8**	35.8	17.21	5.78	**-6.4**	38.5	15.31	6.12	**-7.2**

Table 2 - SF-DG

Case 2A1 - 100% Mixing						**SF Diesel Generator - 2/1 5800 gpm/LPCI - 5800 gpm/CS**							
Time (sec)	Pool Press (psig)	Pool Temp (°F)	Specific Volume (ft^3/lb)	Pv (psia)	Static Head (feet)	LPCI NPSHR (feet)	LPCI Total Loss (feet)	LPCI Preqd (psig)	LPCI NPSH Margin (feet)	CS NPSHR (feet)	CS Total Loss (feet)	CS Preqd (psig)	CS NPSH Margin (feet)
19	23.84	121.3	0.01621	1.75	13.3								
34	24.47	130.5	0.01625	2.25	13.3								
50	24.28	132.5	0.01626	2.38	13.3	38.5	12.28	3.69	**48.2**	38.5	9.31	2.42	**51.2**
70	24.05	133.0	0.01626	2.41	13.3	38.5	12.28	3.71	**47.6**	38.5	9.31	2.44	**50.6**
101	24.06	134.5	0.01627	2.50	13.3	38.5	12.28	3.81	**47.4**	38.5	9.31	2.54	**50.4**
155	23.90	136.7	0.01628	2.65	13.3	38.5	12.28	3.94	**46.8**	38.5	9.31	2.67	**49.8**
182	22.87	137.9	0.01628	2.74	13.3	38.5	12.28	4.02	**44.2**	38.5	9.31	2.75	**47.2**
254	19.17	139.6	0.01629	2.86	13.3	38.5	12.28	4.14	**35.3**	38.5	9.31	2.87	**38.2**
304	15.69	140.9	0.01630	2.96	13.3	38.5	12.28	4.23	**26.9**	38.5	9.31	2.96	**29.9**
367	11.86	142.7	0.01631	3.10	13.3	38.5	12.28	4.36	**17.6**	38.5	9.31	3.09	**20.6**
402	10.17	143.7	0.01631	3.18	13.3	38.5	12.28	4.43	**13.5**	38.5	9.31	3.17	**16.4**
438	8.81	144.8	0.01632	3.27	13.3	38.5	12.28	4.52	**10.1**	38.5	9.31	3.25	**13.1**
506	6.96	146.6	0.01633	3.42	13.3	38.5	12.28	4.66	**5.4**	38.5	9.31	3.40	**8.4**
551	6.18	147.6	0.01633	3.50	13.3	38.5	12.28	4.74	**3.4**	38.5	9.31	3.48	**6.4**
597	5.55	148.6	0.01634	3.59	13.3	38.5	12.28	4.83	**1.7**	38.5	9.31	3.56	**4.7**

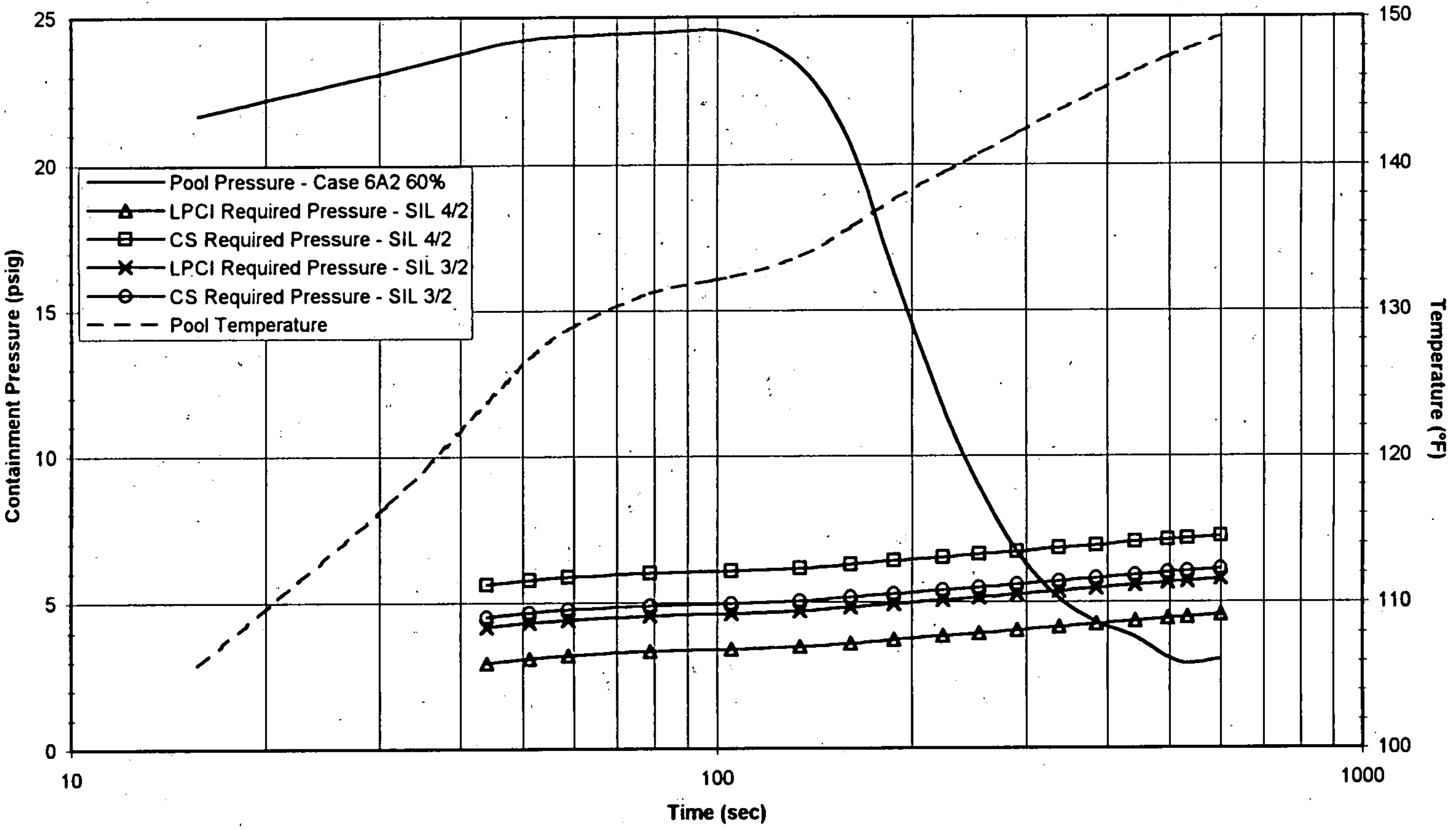

Figure 1 - SF-LSL

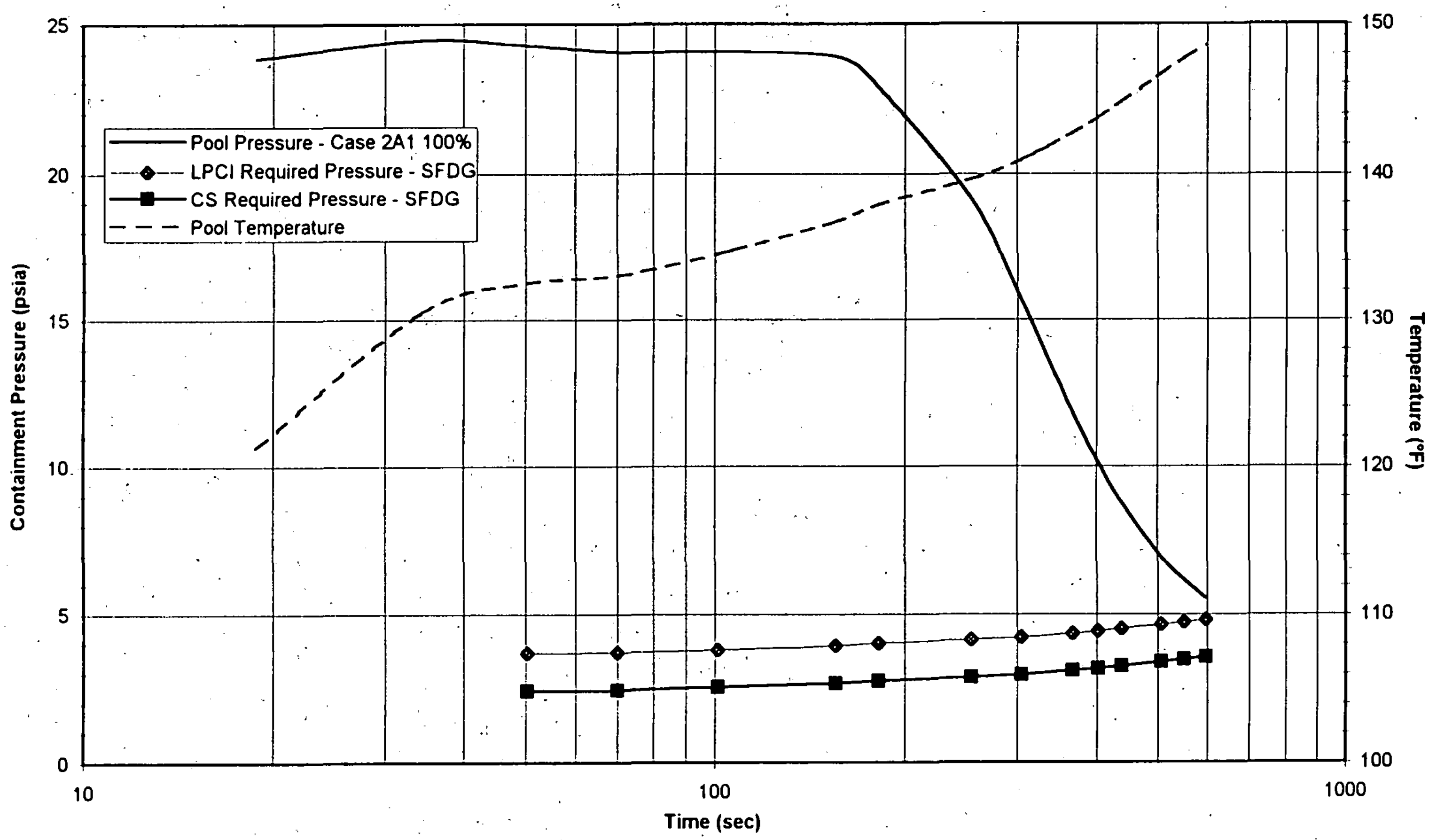

Figure 2 - SF-DG

ATTACHMENT A

LPCI/Core Spray Suction Friction Losses FLO-SERIES Model

LPCI/Core Spray pump suction piping friction losses were developed using a FLO-SERIES model of the Dresden ECCS ring header and pump suction piping (Ref. 8). The nodal diagram of the piping model is included as Figure A1. The model was run at the various LPCI and Core Spray pump combinations and flows listed below as required to support the cases evaluated in this calculation. The input and output of the FLO-SERIES runs are included in this Attachment.

Case	LPCI Pumps	Flow Per LPCI Pump (gpm)	CS Pumps	Flow Per CS Pump (gpm)	Strainer Loss[#] h_{strain} (ft)	LPCI Friction Loss (ft)	LPCI Loss +15% h_L (ft)	Total LPCI Suction Loss* h_{total} (ft)	CS Friction Loss (ft)	CS Loss +15% h_L (ft)	Total CS Suction Loss* h_{total} (ft)	FLO-SERIES Line-up Filename
2/1	2	5800	1	5800	1.95	8.98	10.33	**12.28**	6.40	7.36	**9.31**	2L581C58.PLU
4/2SIL	4	5150	2	5800	6.68	10.43	11.99	**18.68**	9.76	11.22	**17.90**	4L512C58.PLU
3/2SIL 1-pp	3	5610	2	5800	5.18	9.10	10.46	**15.64**	8.81	10.13	**15.31**	3L2CSIL1.PLU
3/2SIL 2-pp	3	5570	2	5800	5.18	10.46	12.03	**17.21**	8.57	9.85	**15.03**	3L2CSIL2.PLU
4/2SIL	4	5150	2	5100	6.11	10.07	11.58	17.68	8.22	9.46	**15.57**	4L512C51.PLU

[#] **Strainer Loss = (Flow per strainer/10,000 gpm)^2 x 5.8 ft.**

* **Total Loss = (Loss +15%) + Strainer Loss**

Table A-1

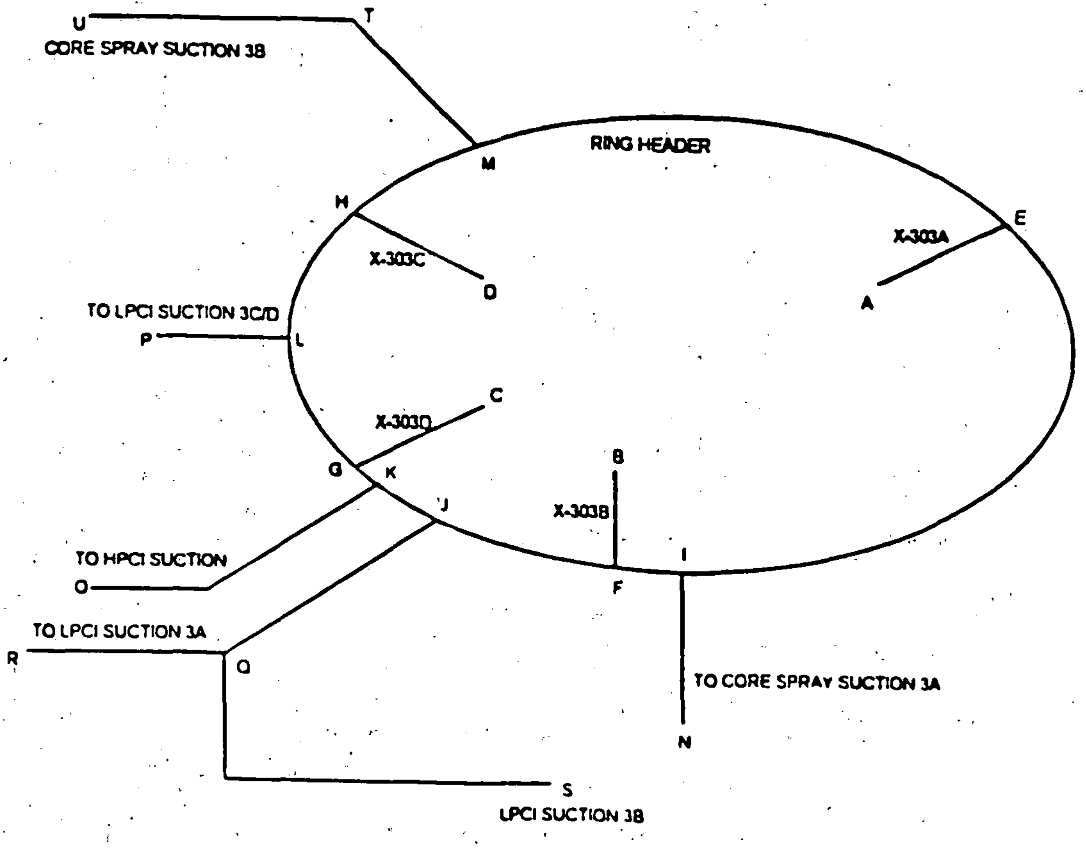

Figure A1: ECCS Suction Nodal Diagram including the Ring Header

```
Company: comed                                          2L581C58
Project:                                                02/03/97
     by: palas

                     LINEUP REPORT   rev: 01/02/97

LINELIST: RING                                 DEVIATION: 1.15 %
   dated: 12/18/96                                 after: 4 iterations

      2 LPCI @5800 and 1 CS @5800 Injecting. One blocked strainer
Volumetric flow rates require constant fluid properties in all pipelines.
          Fluid properties in the first specification were used.

     NODE                DEMAND            NODE               DEMAND
                         gpm                                  gpm

     R           >>>     5800              S          >>>     5800
     U           >>>     5800

                                               FLOWS   IN: 0 gpm
                                               FLOWS  OUT: 17400    gpm

                                           NET FLOWS  OUT: 17400    gpm


     PIPELINE                   FLOW            PRESSURE          SET
                                gpm             SOURCE            psig

     Torus-1             <<<    5611      <<<   A                 0
     Torus-2             <<<    5686      <<<   B                 0
     Torus-3             <<<    6103      <<<   C                 0

                                               FLOWS   IN: 17400    gpm
                                               FLOWS  OUT: 0 gpm

                                           NET FLOWS   IN: 17400    gpm
```

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LINEUP NODES

NODE	ELEVATION ft	DEMAND gpm	PRESSURE psi g	H GRADE ft
A	0		p 0	0
B	0		p 0	0
C	0		p 0	0
E	0		* -0.497	-1.153
F	0		* -0.510	-1.184
G	0		* -0.588	-1.364
H	0		* -0.599	-1.389
I	0		* -0.508	-1.179
J	0		* -0.642	-1.491
K	0		* -0.622	-1.444
L	0		* -0.592	-1.374
M	0		* -0.601	-1.396
Q	0		* -1.465	-3.399
R	0	> 5800	* -2.194	-5.094
S	0	> 5800	* -3.87	-8.983
T	0		* -1.025	-2.38
U	0	> 5800	* -2.756	-6.397

```
                              LINEUP PIPELINES                       2L581C58
                                                                   02/03/97

PIPELINE       FROM          TO       FLOW       VEL      dP        Hl
                                      gpm        ft/sec   psi g     ft

CS-3A          I             N        closed     0        0         0
CS3B-16        T             U        5800       10.2     1.73      4.016
CS3B-18        M             T        5800       8.086    0.424     0.984
HPCI           K             O        closed     0        0         0
LPCI3A         Q             R        5800       13.51    0.730     1.694
LPCI3A/B       J             Q        11600      8.773    0.822     1.909
LPCI3B         Q             S        5800       13.51    2.405     5.583
LPCI3C/D       L             P        closed     0        0         0
Ring-1         E             I        1327       1.004    0.011     0.026
Ring-2         I         <-> F        1327       1.004    0.002     0.005
Ring-3         F             J        7014       5.304    0.132     0.307
Ring-4         K             J        4586       3.469    0.020     0.046
Ring-5         G             K        4586       3.469    0.035     0.080
Ring-6         G             L        1516       1.147    0.004     0.010
Ring-7         L         <-> H        1516       1.147    0.007     0.015
Ring-8         H             M        1516       1.147    0.003     0.007
Ring-9         E             M        4284       3.24     0.105     0.243
Torus-1        A             E        5611       6.793    0.497     1.153
Torus-2        B             F        5686       6.884    0.510     1.184
Torus-3        C             G        6103       7.388    0.588     1.364
Torus-4        D             H        closed     0        0         0
```

```
Company: comed                                          4L512C58
Project:                                                02/03/97
     by: palas

                    LINEUP REPORT    rev: 01/28/97

LINELIST: RING                              DEVIATION: 0.00898 %
   dated: 01/08/97                              after: 5 iterations

     4 LPCI @5150 and 2 CS @5800 Injecting. Nearest torus leg blocked
Volumetric flow rates require constant fluid properties in all pipelines.
       Fluid properties in the first specification were used.

     NODE            DEMAND          NODE            DEMAND
                     gpm                             gpm

     N        >>>    5800            O        >>>    0.0001
     P        >>>    10300           R        >>>    5150
     S        >>>    5150            U        >>>    5800

                                         FLOWS   IN: 0 gpm
                                         FLOWS  OUT: 32200    gpm

                                     NET FLOWS  OUT: 32200    gpm


     PIPELINE               FLOW          PRESSURE       SET
                            gpm           SOURCE         psig

     Torus-1        <<<     10501   <<<   A              0
     Torus-2        <<<     10632   <<<   B              0
     Torus-3        <<<     11068   <<<   C              0

                                         FLOWS   IN: 32201    gpm
                                         FLOWS  OUT: 0 gpm

                                     NET FLOWS   IN: 32201    gpm
```

LINEUP NODES

NODE	ELEVATION ft	DEMAND gpm	PRESSURE psi g	H GRADE ft
A	0		p 0	0
B	0		p 0	0
C	0		p 0	0
E	0		* -1.739	-4.037
F	0		* -1.783	-4.138
G	0		* -1.932	-4.484
H	0		* -2.052	-4.763
I	0		* -1.792	-4.16
J	0		* -1.948	-4.521
K	0		* -1.942	-4.507
L	0		* -2.06	-4.782
M	0		* -2.049	-4.755
N	0	> 5800	* -2.209	-5.127
O	0	> 0.0001	* -1.942	-4.507
P	0	> 10300	* -2.341	-5.433
Q	0		* -2.596	-6.026
R	0	> 5150	* -3.172	-7.362
S	0	> 5150	* -4.493	-10.43
T	0		* -2.473	-5.74
U	0	> 5800	* -4.203	-9.756

LINEUP PIPELINES

4L512C58
02/03/97

PIPELINE	FROM	TO	FLOW gpm	VEL ft/sec	dP psi g	Hl ft
CS-3A	I	N	5800	8.086	0.417	0.967
CS3B-16	T	U	5800	10.2	1.73	4.016
CS3B-18	M	T	5800	8.086	0.424	0.984
HPCI	K	O	0	0	0	0
LPCI3A	Q	R	5150	11.99	0.576	1.336
LPCI3A/B	J	Q	10300	7.79	0.649	1.506
LPCI3B	Q	S	5150	11.99	1.897	4.404
LPCI3C/D	L	P	10300	7.79	0.281	0.651
Ring-1	E	I	3020	2.284	0.053	0.124
Ring-2	F	I	2780	2.103	0.010	0.022
Ring-3	F	J	7852	5.938	0.165	0.383
Ring-4	K	J	2448	1.852	0.006	0.013
Ring-5	G	K	2448	1.852	0.010	0.023
Ring-6	G	L	8619	6.519	0.128	0.298
Ring-7	H	L	1681	1.271	0.008	0.019
Ring-8	M	<-> H	1681	1.271	0.004	0.008
Ring-9	E	M	7481	5.658	0.310	0.719
Torus-1	A	E	10501	12.71	1.739	4.037
Torus-2	B	F	10632	12.87	1.783	4.138
Torus-3	C	G	11068	13.4	1.932	4.484
Torus-4	D	H	closed	0	0	0

```
Company: comed                                              3L2CSIL1
Project:                                                    02/03/97
    by: palas

                   LINEUP REPORT   rev: 01/29/97

LINELIST: RING                                   DEVIATION: 0.0161 %
   dated: 01/08/97                                   after: 6 iterations

     2 LPCI @5570, 1 LPCI @5610, 2 CS @5800. One Blocked strainer.
                          Single pp loss

Volumetric flow rates require constant fluid properties in all pipelines.
      Fluid properties in the first specification were used.

     NODE           DEMAND           NODE           DEMAND
                    gpm                             gpm

     N       >>>    5800             O       >>>    0.0001
     P       >>>    11140            S       >>>    5610
     U       >>>    5800

                                        FLOWS  IN: 0 gpm
                                        FLOWS OUT: 28350   gpm
                                    NET FLOWS OUT: 28350   gpm


     PIPELINE            FLOW          PRESSURE       SET
                         gpm           SOURCE         psig

     Torus-1       <<<   9309    <<<   A              0
     Torus-2       <<<   9365    <<<   B              0
     Torus-3       <<<   9675    <<<   C              0

                                        FLOWS  IN: 28349   gpm
                                        FLOWS OUT: 0 gpm
                                    NET FLOWS  IN: 28349   gpm
```

LINEUP NODES

NODE	ELEVATION ft	DEMAND gpm	PRESSURE psi g	H GRADE ft
A	0		p 0	0
B	0		p 0	0
C	0		p 0	0
E	0		* -1.367	-3.173
F	0		* -1.383	-3.211
G	0		* -1.476	-3.427
H	0		* -1.642	-3.811
I	0		* -1.398	-3.246
J	0		* -1.476	-3.427
K	0		* -1.476	-3.427
L	0		* -1.646	-3.821
M	0		* -1.64	-3.807
N	0	> 5800	* -1.815	-4.213
O	0	> 0.0001	* -1.476	-3.427
P	0	> 11140	* -1.974	-4.583
Q	0		* -1.669	-3.875
S	0	> 5610	* -3.92	-9.099
T	0		* -2.064	-4.791
U	0	> 5800	* -3.794	-8.808

LINEUP PIPELINES

3L2CSIL1
02/03/97

PIPELINE	FROM	TO	FLOW gpm	VEL ft/sec	dP psi g	Hl ft
CS-3A	I	N	5800	8.086	0.417	0.967
CS3B-16	T	U	5800	10.2	1.73	4.016
CS3B-18	M	T	5800	8.086	0.424	0.984
HPCI	K	O	0	0	0	0
LPCI3A	Q	R	closed	0	0	0
LPCI3A/B	J	Q	5610	4.243	0.193	0.449
LPCI3B	Q	S	5610	13.06	2.251	5.224
LPCI3C/D	L	P	11140	8.425	0.328	0.762
Ring-1	E	I	2295	1.736	0.031	0.073
Ring-2	F	I	3505	2.651	0.015	0.035
Ring-3	F	J	5860	4.432	0.093	0.216
Ring-4	J	<-> K	250.1	0.189	0	0
Ring-5	K	<-> G	250.1	0.189	0	0
Ring-6	G	L	9925	7.506	0.170	0.394
Ring-7	H	L	1215	0.919	0.004	0.010
Ring-8	M	<-> H	1215	0.919	0.002	0.004
Ring-9	E	M	7015	5.305	0.273	0.634
Torus-1	A	E	9309	11.27	1.367	3.173
Torus-2	B	F	9365	11.34	1.383	3.211
Torus-3	C	G	9675	11.71	1.476	3.427
Torus-4	D	H	closed	0	0	0

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```
Company: comed                                                  3L2CSIL2
Project:                                                        02/03/97
     by: palas

                    LINEUP REPORT   rev: 01/29/97

LINELIST: RING                                    DEVIATION: 0.771 %
   dated: 01/08/97                                    after: 3 iterations

     2 LPCI @5570, 1 LPCI @5610, 2 CS @5800. One Blocked strainer.
                              2-pp loss

Volumetric flow rates require constant fluid properties in all pipelines.
       Fluid properties in the first specification were used.

     NODE              DEMAND          NODE              DEMAND
                       gpm                               gpm

     N          >>>    5800            O          >>>    0.0001
     P          >>>    5610            R          >>>    5570
     S          >>>    5570            U          >>>    5800

                                          FLOWS   IN: 0 gpm
                                          FLOWS  OUT: 28350    gpm

                                       NET FLOWS OUT: 28350    gpm


     PIPELINE               FLOW           PRESSURE        SET
                            gpm            SOURCE          psig

     Torus-1           <<<  9227     <<<   A               0
     Torus-2           <<<  9418     <<<   B               0
     Torus-3           <<<  9705     <<<   C               0

                                          FLOWS   IN: 28350    gpm
                                          FLOWS  OUT: 0 gpm

                                       NET FLOWS  IN: 28350    gpm
```

```
                          LINEUP NODES                          3L2CSIL2
                                                              02/03/97

NODE       ELEVATION      DEMAND          PRESSURE         H GRADE
           ft             gpm             psi g            ft


A          0                            p  0               0
B          0                            p  0               0
C          0                            p  0               0
E          0                            * -1.343           -3.117
F          0                            * -1.399           -3.247
G          0                            * -1.486           -3.448
H          0                            * -1.537           -3.568
I          0                            * -1.407           -3.266
J          0                            * -1.529           -3.549
K          0                            * -1.514           -3.515
L          0                            * -1.539           -3.572
M          0                            * -1.537           -3.568
N          0              > 5800        * -1.824           -4.234
O          0              > 0.0001      * -1.514           -3.515
P          0              > 5610        * -1.622           -3.765
Q          0                            * -2.287           -5.309
R          0              > 5570        * -2.96            -6.872
S          0              > 5570        * -4.506           -10.46
T          0                            * -1.961           -4.553
U          0              > 5800        * -3.692           -8.569
```

LINEUP PIPELINES

3L2CSIL2
02/03/97

PIPELINE	FROM	TO	FLOW gpm	VEL ft/sec	dP psi g	Hl ft
CS-3A	I	N	5800	8.086	0.417	0.967
CS3B-16	T	U	5800	10.2	1.73	4.016
CS3B-18	M	T	5800	8.086	0.424	0.984
HPCI	K	O	0	0	0	0
LPCI3A	Q	R	5570	12.97	0.673	1.563
LPCI3A/B	J	Q	11140	8.425	0.758	1.761
LPCI3B	Q	S	5570	12.97	2.219	5.15
LPCI3C/D	L	P	5610	4.243	0.083	0.193
Ring-1	E	I	3333	2.52	0.064	0.150
Ring-2	F	I	2467	1.866	0.008	0.017
Ring-3	F	J	6951	5.257	0.130	0.301
Ring-4	K	J	4189	3.168	0.017	0.039
Ring-5	G	K	4189	3.168	0.029	0.067
Ring-6	G	L	5516	4.172	0.053	0.124
Ring-7	H	L	94.28	0.071	0	0
Ring-8	M	<-> H	94.28	0.071	0	0
Ring-9	E	M	5894	4.458	0.195	0.452
Torus-1	A	E	9227	11.17	1.343	3.117
Torus-2	B	F	9418	11.4	1.399	3.247
Torus-3	C	G	9705	11.75	1.486	3.448
Torus-4	D	H	closed	0	0	0

```
Company: comed                                                4L512C51
Project:                                                      02/03/97
     by: palas

                    LINEUP REPORT   rev: 02/03/97

LINELIST: RING                                     DEVIATION: 0.0117 %
   dated: 01/08/97                                     after: 5 iterations

     4 LPCI @5150 and 2 CS @5100 Injecting. Nearest torus leg blocked
Volumetric flow rates require constant fluid properties in all pipelines.
        Fluid properties in the first specification were used.

    NODE              DEMAND          NODE              DEMAND
                      gpm                               gpm

    N          >>>    5100            O          >>>    0.0001
    P          >>>    10300           R          >>>    5150
    S          >>>    5150            U          >>>    5100
                                         FLOWS  IN: 0 gpm
                                         FLOWS OUT: 30800    gpm
                                     NET FLOWS OUT: 30800    gpm


    PIPELINE                FLOW            PRESSURE       SET
                            gpm             SOURCE         psig

    Torus-1          <<<    10030     <<<   A              0
    Torus-2          <<<    10156     <<<   B              0
    Torus-3          <<<    10615     <<<   C              0
                                         FLOWS  IN: 30801    gpm
                                         FLOWS OUT: 0 gpm
                                     NET FLOWS  IN: 30801    gpm
```

LINEUP NODES

4L512C51
02/03/97

NODE	ELEVATION ft	DEMAND gpm	PRESSURE psi g	H GRADE ft
A	0		p 0	0
B	0		p 0	0
C	0		p 0	0
E	0		* -1.587	-3.683
F	0		* -1.627	-3.776
G	0		* -1.777	-4.125
H	0		* -1.88	-4.365
I	0		* -1.633	-3.791
J	0		* -1.792	-4.161
K	0		* -1.787	-4.148
L	0		* -1.893	-4.394
M	0		* -1.875	-4.352
N	0	> 5100	* -1.955	-4.539
O	0	> 0.0001	* -1.787	-4.148
P	0	> 10300	* -2.174	-5.045
Q	0		* -2.441	-5.666
R	0	> 5150	* -3.017	-7.002
S	0	> 5150	* -4.338	-10.07
T	0		* -2.203	-5.113
U	0	> 5100	* -3.542	-8.222

LINEUP PIPELINES

PIPELINE	FROM	TO	FLOW gpm	VEL ft/sec	dP psi g	Hl ft
CS-3A	I	N	5100	7.11	0.322	0.748
CS3B-16	T	U	5100	8.965	1.339	3.109
CS3B-18	M	T	5100	7.11	0.328	0.761
HPCI	K	O	0	0	0	0
LPCI3A	Q	R	5150	11.99	0.576	1.336
LPCI3A/B	J	Q	10300	7.79	0.649	1.506
LPCI3B	Q	S	5150	11.99	1.897	4.404
LPCI3C/D	L	P	10300	7.79	0.281	0.651
Ring-1	E	I	2817	2.131	0.047	0.108
Ring-2	F	I	2283	1.726	0.006	0.015
Ring-3	F	J	7873	5.954	0.166	0.385
Ring-4	K	J	2427	1.835	0.006	0.013
Ring-5	G	K	2427	1.835	0.010	0.023
Ring-6	G	L	8188	6.192	0.116	0.269
Ring-7	H	L	2112	1.598	0.013	0.029
Ring-8	M	<-> H	2112	1.598	0.006	0.013
Ring-9	E	M	7212	5.455	0.288	0.669
Torus-1	A	E	10030	12.14	1.587	3.683
Torus-2	B	F	10156	12.3	1.627	3.776
Torus-3	C	G	10615	12.85	1.777	4.125
Torus-4	D	H	closed	0	0	0