

Calculation No. NED-M-MSD-43  
Dresden LPCI Pumps NPSHA Evaluation- Post DBA-LOCA

| Case | Total Flow (gpm) | Single Pump Flow (gpm) | Torus Temp (F) | Torus Pressure (psia) | Static Head (ft) | Specific Volume (ft <sup>3</sup> /lb) | Vapor Pressure (psia) | Suction Piping Losses (ft) | NPSHA (ft) | NPSHR (ft) | Margin (ft) |
|------|------------------|------------------------|----------------|-----------------------|------------------|---------------------------------------|-----------------------|----------------------------|------------|------------|-------------|
| 3    | 10000            | 5000                   | 168            | 18.7                  | 13.32            | 0.01644                               | 5.7223                | 4.72                       | 39.32      | 30.00      | 9.32        |
| 3A   | 8916             | 4458                   | 171            | 19.1                  | 13.32            | 0.016457                              | 6.1318                | 3.75                       | 40.30      | 26.90      | 13.40       |
| 4    | 5000             | 5000                   | 180            | 19.9                  | 13.32            | 0.01651                               | 7.511                 | 3.77                       | 39.00      | 30.00      | 9.00        |
| 4A   | 3881             | 3881                   | 186            | 20.6                  | 13.32            | 0.016547                              | 8.568                 | 2.27                       | 39.72      | 25.70      | 14.02       |

TABLE 1

QJ-61.D  
EXHIBIT B  
REV. 3

Purpose/Objective:

Calculate the Net Positive Suction Head Available (NPSHA) for the LPCI pumps at Dresden Station under post-accident conditions as outlined in Reference 2, and compare with NPSH required (NPSHR) to ensure pump protection.

Assumptions/Inputs:

The NPSHA is calculated for each of the four cases analyzed by General Electric in Reference 2. Inputs to this calculation were taken from Tables 3, 4 and B.2 of Reference 2 and are summarized in Table 1 below:

| Case | LPCI Pumps /Loop | Total Flow (gpm) | Maximum Suppression Pool Temp(F) | Reduced Suppression Chamber Pressure(psia) |
|------|------------------|------------------|----------------------------------|--|
| 3    | 2                | 10000            | 168                              | 18.7                                       |
| 3A   | 2                | 8916             | 171                              | 19.1                                       |
| 4    | 1                | 5000             | 180                              | 19.9                                       |
| 4A   | 1                | 3881             | 186                              | 20.6                                       |

Table 1

These calculations include the following assumptions:

- 1) An even split of flow is assumed between two pumps operating in parallel.
- 2) Suction piping losses based on calculations in References 1 and 5.
- 3) NPSHR values taken from Reference 1 (Table 2 - no temperature correction). For cases 3A and 4A, NPSHR values were obtained through linear interpolation.

References:

- 1) R. Kolflat letter report titled "Alternate Shutdown Cooling Core Spray and LPCI pumps", Chron #841425 dated April 23, 1984
- 2) General Electric Report No. GENE-770-26-1092 "Dresden Nuclear Power Station Units 2 & 3 LPCI/Containment Cooling System Evaluation," November, 1992
- 3) S. Eldridge letter to C. Schroeder titled "Submergence of LPCI Discharge Line Post LOCA Dresden Units 2 and 3" dated September 29, 1992, chron# 0115532
- 4) ASME Steam Tables, 1967
- 5) Alternate Shutdown Cooling Core Spray and LPCI pump notes and back-up calculations for Reference 1, R. Kolflat, circa 4/89

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Equations:

Net Positive Suction Head Available (NPSHA) is determined using the following equation (Reference 1):

$$\begin{array}{rcll} \text{NPSHA} & = & \text{Torus} & \text{Static} & \text{Vapor} & \text{Suction} & (1) \\ (\text{ft}) & & \text{Pressure} & + & \text{Head} & - & \text{Pressure} & - & \text{Losses} \end{array}$$

where: Torus Pressure = given in Table 1 (psia); converted to feet using specific volume

Static Head = the minimum water elevation expected above the LPCI pump suction as calculated below:

Minimum Torus water level elevation 491.5'  
(including maximum post-LOCA draw  
down as discussed in Reference 3)

LPCI pump suction elevation - 478.13'

Static Head ----- 13.32'

Vapor Pressure = from Reference 4, in psia; converted to feet using specific volume

Suction Losses = piping losses in feet  
=  $K * Q^2$ , K calculated at  $Q = 5000$  gpm  
using suction losses from References  
1 and 5. (Tables 2 and 3)

LPCI NPSHA Calculations:

Using Equation 1 and the inputs provided above, the NPSHA is calculated for each of the four cases (Table 4). The required NPSH is also provided and the difference between the two is calculated.

Summary/Conclusions:

Post DBA-LOCA torus conditions were determined in Reference 2 and were used to calculate the available NPSH for the LPCI pumps at Dresden Station. The results in Table 4 indicate that the available NPSH is greater than the NPSH required (with margin) for all four cases, and therefore adequate to protect the pump under these conditions.

FLOW DEPENDENT TERM -  $f(Q)$   
SCALE Q

| Q    | NPSHR | $h_L$ | $NPSHR + h_L - 0.87$ |
|------|-------|-------|----------------------|
| 3500 | 25    | 1.89  | 26.02                |
| 3800 | 25.5  | 2.21  | 26.84                |
| 4000 | 26    | 2.44  | 27.57                |
| 4300 | 26.5  | 2.81  | 28.44                |
| 4500 | 27.0  | 3.07  | 29.2                 |
| 4600 | 27.6  | 3.21  | 29.74                |
| 4700 | 28.2  | 3.35  | 30.68                |
| 4800 | 28.8  | 3.49  | 31.42                |
| 4900 | 29.4  | 3.63  | 32.16                |
| 5000 | 30.0  | 3.77  | 32.9                 |
| 5100 | 31.0  | 3.92  | 34.05                |
| 5200 | 32    | 4.07  | 35.2                 |
| 5300 | 33    | 4.23  | 36.36                |
| 5400 | 34    | 4.39  | 37.52                |
| 5500 | 35    | 4.55  | 38.68                |
| 5600 | 36.1  | 4.71  | 39.94                |
| 5700 | 37.2  | 4.87  | 41.2                 |
| 5800 | 38.4  | 5.04  | 42.57                |
| 5900 | 39.5  | 5.21  | 43.84                |
| 6000 | 40.6  | 5.39  | 45.12                |

AT 95° - NO TEMPERATURE CORRECTION

TABLE 2  
(REFERENCE 1)

# SINGLE PUMP

# 2 PUMP

| Q    | NPSHR | $h_L$ | $NPSHR + h_L - 0.87$ | FEET  | $h_L$ | $NPSHR + h_L - 0.87$ | FEET  |
|------|-------|-------|----------------------|-------|-------|----------------------|-------|
| 3500 | 25    | 1.89  | 26.02                | 0     | 2.36  | 26.49                |       |
| 3800 | 25.5  | 2.21  | 26.84                | 0.82  | 2.77  | 27.4                 | .91   |
| 4000 | 26    | 2.44  | 27.57                | 1.55  | 3.06  | 28.19                | 1.7   |
| 4300 | 26.5  | 2.81  | 28.44                | 2.42  | 3.52  | 29.15                | 2.66  |
| 4500 | 27.0  | 3.07  | 29.2                 | 3.18  | 3.85  | 29.98                | 3.49  |
| 4600 | 27.6  | 3.21  | 29.94                | 3.92  | 4.02  | 30.75                | 4.26  |
| 4700 | 28.2  | 3.35  | 30.68                | 4.66  | 4.19  | 31.52                | 5.03  |
| 4800 | 28.8  | 3.49  | 31.42                | 5.4   | 4.36  | 32.29                | 5.8   |
| 4900 | 29.4  | 3.63  | 32.16                | 6.14  | 4.54  | 33.07                | 6.58  |
| 5000 | 30.0  | 3.77  | 32.9                 | 6.88  | 4.72  | 33.85                | 7.36  |
| 5100 | 31.0  | 3.92  | 34.05                | 8.03  | 4.91  | 35.04                | 8.55  |
| 5200 | 32    | 4.07  | 35.2                 | 9.18  | 5.10  | 36.23                | 9.74  |
| 5300 | 33    | 4.23  | 36.36                | 10.34 | 5.29  | 37.42                | 10.93 |
| 5400 | 34    | 4.39  | 37.52                | 11.5  | 5.49  | 38.62                | 12.13 |
| 5500 | 35    | 4.56  | 38.68                | 12.66 | 5.69  | 39.82                | 13.33 |
| 5600 | 36.1  | 4.71  | 39.94                | 13.52 | 5.89  | 41.12                | 14.63 |
| 5700 | 37.2  | 4.87  | 41.2                 | 15.18 | 6.10  | 42.43                | 15.94 |
| 5800 | 38.4  | 5.04  | 42.57                | 16.55 | 6.31  | 43.84                | 17.35 |
| 5900 | 39.5  | 5.21  | 43.84                | 17.82 | 6.52  | 45.15                | 18.66 |
| 6000 | 40.6  | 5.39  | 45.12                | 19.1  | 6.74  | 46.47                | 19.96 |

\* AT 85°F - NO CORRECTION FOR TEMPERATURE

TABLE 3  
(REFERENCE 5)

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| Case | Total Flow (gpm) | Single Pump Flow (gpm) | Torus Temp (F) | Torus Pressure (psia) | Static Head (ft) | Specific Volume (ft <sup>3</sup> /lb) | Vapor Pressure (psia) | Suction Piping Losses (ft) | NPSHA (ft) | NPSHR (ft) | Margin (ft) |
|------|------------------|------------------------|----------------|-----------------------|------------------|---------------------------------------|-----------------------|----------------------------|------------|------------|-------------|
| 3    | 10000            | 5000                   | 168            | 18.7                  | 13.32            | 0.01644                               | 5.7223                | 4.72                       | 39.32      | 30.00      | 9.32        |
| 3A   | 8916             | 4458                   | 171            | 19.1                  | 13.32            | 0.016457                              | 6.1318                | 3.75                       | 40.30      | 26.90      | 13.40       |
| 4    | 5000             | 5000                   | 180            | 19.9                  | 13.32            | 0.01651                               | 7.511                 | 3.77                       | 39.00      | 30.00      | 9.00        |
| 4A   | 3881             | 3881                   | 186            | 20.6                  | 13.32            | 0.016547                              | 8.568                 | 2.27                       | 39.72      | 25.70      | 14.02       |

Table 4



## REVIEW CHECKLIST

|                                     |               |                           |
|-------------------------------------|---------------|---------------------------|
| CALCULATION NO: <i>NED-M-MSD-43</i> | REV. <i>0</i> | PAGE <i>7</i> OF <i>7</i> |
| REVIEWED BY: <i>ROLF S. KOLFLAT</i> |               | DATE: <i>11/30/92</i>     |

| YES                                 | NO                                  |  | REMARKS |
|-------------------------------------|-------------------------------------|--|---------|
| <input checked="" type="checkbox"/> | <input type="checkbox"/>            | 1. IS THE OBJECTIVE OF THE ANALYSIS CLEARLY STATED?  |         |
| <input checked="" type="checkbox"/> | <input type="checkbox"/>            | 2. ARE ASSUMPTIONS AND ENGINEERING JUDGEMENTS VALID AND DOCUMENTED?                              |         |
| <input type="checkbox"/>            | <input checked="" type="checkbox"/> | 3. ARE THERE ASSUMPTIONS THAT NEED VERIFICATION?   |         |
| <input checked="" type="checkbox"/> | <input type="checkbox"/>            | 4. ARE THE REFERENCES (I.E. DRAWINGS, CODES, STANDARDS) LISTED BY REVISION EDITION, DATE, ETC.?  |         |
| <input checked="" type="checkbox"/> | <input type="checkbox"/>            | 5. IS THE DESIGN METHOD CORRECT AND APPROPRIATE FOR THIS ANALYSIS?                               |         |
| <input checked="" type="checkbox"/> | <input type="checkbox"/>            | 6. IS THE CALCULATION IN COMPLIANCE WITH DESIGN CRITERIA, CODES, STANDARDS, AND REG. GUIDES?     |         |
| <input checked="" type="checkbox"/> | <input type="checkbox"/>            | 7. ARE THE UNITS CLEARLY IDENTIFIED, AND EQUATIONS PROPERLY DERIVED AND APPLIED?                 |         |
| <input checked="" type="checkbox"/> | <input type="checkbox"/>            | 8. ARE THE DESIGN INPUTS AND THEIR SOURCES IDENTIFIED AND IN COMPLIANCE WITH UPBAR & TECH SPECS? |         |
| <input checked="" type="checkbox"/> | <input type="checkbox"/>            | 9. ARE THE RESULTS COMPATIBLE WITH THE INPUTS AND RECOMMENDATIONS MADE?                          |         |

*Computer software (spreadsheet) used for simple operations (addition, multiplication, etc.). Checked/verified by hand calc*

10. INDICATE TYPE OF CALCULATION (HAND-PREPARED AND/OR COMPUTER-AIDED) AND METHOD OF REVIEW:

☒ HAND PREPARED DESIGN CALCULATION

THE REVIEW OF THE HAND-PREPARED DESIGN CALCULATION WAS ACCOMPLISHED BY ONE OR A COMBINATION OF THE FOLLOWING (AS CHECKED):

☒ A DETAILED REVIEW OF THE ORIGINAL CALCULATION  
☐ A REVIEW BY AN ALTERNATE, SIMPLIFIED OR APPROXIMATE METHOD OF CALCULATION  
☐ A REVIEW OF A REPRESENTATIVE SAMPLE OF REPETITIVE CALCULATIONS  
☒ A REVIEW OF THE CALCULATION AGAINST A SIMILAR CALCULATION PREVIOUSLY PERFORMED

☐ COMPUTER AIDED DESIGN CALCULATION

| YES                      | NO                       |  | YES                      | NO                       |   |
|--------------------------|--------------------------|--|--------------------------|--------------------------|---|
| <input type="checkbox"/> | <input type="checkbox"/> | 11. IS THE PROGRAM APPLICABLE TO THIS PROBLEM?   | <input type="checkbox"/> | <input type="checkbox"/> | 16. ARE THE RESULTS CONSISTENT WITH THE ASSUMPTIONS AND THE INPUT DATA?                         |
| <input type="checkbox"/> | <input type="checkbox"/> | 12. IS THE COMPUTER PROGRAM VALIDATED PER QP 3-647   | <input type="checkbox"/> | <input type="checkbox"/> | 18. IS A LIST OF THE PROGRAMS USED AND DATE OF EACH COMPUTER RUN REFERENCED IN THE CALCULATION? |
| <input type="checkbox"/> | <input type="checkbox"/> | 13. IS THE COMPUTER PROGRAM VALIDATED BY OTHER A/E'S / ORGANIZATIONS AND HAS IT BEEN PREVIOUSLY APPLIED TO NUCLEAR PROJECTS? | <input type="checkbox"/> | <input type="checkbox"/> | 17. IS THE PROGRAM VERSION AND IT'S REVISION IDENTIFIED ON THE COMPUTER RUN?                    |
| <input type="checkbox"/> | <input type="checkbox"/> | 14. IS THE INPUT DATA IN CONFORMANCE WITH THE DESIGN INPUTS?   |                          |                          |   |



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## TITLE PAGE

|   |         |   |                           |                |          |                     |          |
|---|---------|---|---------------------------|----------------|----------|---------------------|----------|
| CALCULATION NO. NED-M-MSD-43  |         | PAGE 1 OF 13                                |                           |                |          |                     |          |
| <input checked="" type="checkbox"/> SAFETY RELATED  |         | <input type="checkbox"/> NON-SAFETY RELATED |                           |                |          |                     |          |
| <u>CALCULATION TITLE</u><br><br>Dresden LPCI/Core Spray Pumps NPSHA Evaluation<br>Post DBA-LOCA |         |   |                           |                |          |                     |          |
| EQUIP NUMBER(S)<br>2(3) - 1502A/B/C/D<br>2(3) - 1401A/B   |         | STATION/UNIT<br>Dresden 2 & 3               | SYSTEM<br>LPCI/Core Spray |                |          |                     |          |
| REV.  | CHRON # | PREPARER                                    | DATE                      | REVIEWER       | DATE     | APPROVER            | DATE     |
| 0   | 194745  | H. Palas                                    | 11/30/92                  | R. Kolflat     | 11/30/92 | P. Dietz            | 11/30/92 |
| 1   | 198391  | <i>Henry Palas</i>                          | 2/11/93                   | <i>Don Lee</i> | 2/11/93  | <i>Paul E Dietz</i> | 2/11/93  |

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## REVISION SUMMARY

| CALCULATION NO: NED-M-MSD-43  |      | REV 1  | PAGE 3 OF 13 |
|---|------|--|--------------|
| DESCRIPTION OF REVISIONS/REASON FOR CHANGE  |      |  |              |
| Calculation revised to eliminate non-QA references and inputs and to incorporate the calculation of these inputs into this document. In addition, Core Spray added to scope and a sensitivity analysis on NPSH is included. |      |  |              |
| AFFECTED PAGES  |      |  |              |
| PAGES   | REV. | DESCRIPTION  |              |
| 1   | 1    | Changed Title and Equipment Nos./System to include Core Spray                                      |              |
| 2   | 1    | Added Table of Contents  |              |
| 4   | 1    | Changed Purpose/Objective to include Core Spray  |              |
| 4,5   | 1    | Added assumptions regarding hydraulic loss calculations and addition of Core Spray pps to scope    |              |
| 5   | 1    | Removed two R. Kolflat references; added references for hydraulic loss calculations and Core Spray |              |
| 6   | 1    | Added equation for hydraulic loss calculations   |              |
| 7-9   | 1    | Added calculations for hydraulic losses  |              |
| 9   | 1    | Included discussion of NPSHR reduction due to increased temperature                                |              |
| 10  | 1    | Added sensitivity analysis to NPSHA calculations   |              |
| 10  | 1    | Added Core Spray to Summary/Conclusions  |              |
| 11  | 1    | Added Table 2 - NPSHR values<br>Updated Table 3 for new suction loss values                        |              |
| 12  | 1    | Added Figure 1 - NPSHR reduction vs. temperature   |              |
| A.1-A.3   | 1    | New NPSH sensitivity analysis  |              |
| B.1   | 1    | New calculation of resistance coefficient for a 24 x 14 reducer                                    |              |

Purpose/Objective:

Calculate the Net Positive Suction Head Available (NPSHA) for the LPCI and Core Spray pumps at Dresden Station under post-accident conditions as outlined in Reference 2, and compare with NPSH required (NPSHR) to ensure pump protection.

Assumptions/Inputs:

The NPSHA is calculated for each of the four cases analyzed by General Electric in Reference 2. Inputs to this calculation for the LPCI pumps were taken from Tables 3, 4 and B.2 of Reference 2 and are summarized in Table 1 below:

| Case | LPCI Pumps /Loop | Total Flow (gpm) | Maximum Suppression Pool Temp(F) | Reduced Torus Pressure(psia) |
|------|------------------|------------------|----------------------------------|------------------------------|
| 3    | 2                | 10000            | 168                              | 18.7                         |
| 3A   | 2                | 8916             | 171                              | 19.1                         |
| 4    | 1                | 900              | 180                              | 19.9                         |
| 4A   | 1                | 881              | 186                              | 20.6                         |

Table 1

In addition to the assumptions made in Reference 2, the following assumptions are also made in this calculation:

- 1) An even split of flow is assumed between two pumps operating in parallel; frictional losses to each pump assumed similar.
- 2) Suction piping losses determined at 90 deg F, 5000 gpm (one pump) and 10000 gpm (two pumps). Assumed lower temperature than Table 1 for higher kinematic viscosity and conservatively higher suction losses.
- 3) Strainer losses assumed to be 0.8 ft @ 5000 gpm and entrance losses assumed 0.6 ft @ 5000 gpm, 1.8 ft @ 10000 gpm (Used Reference 11 as basis; extrapolated values provided for 5750 and 11620 gpm to 5000 and 10000 gpm respectively using quadratic relationship between flow and friction losses).
- 4) NPSHR values (Table 2) are developed based on the NPSHR curves for the LPCI and Core Spray pumps (References 5 and 6). NPSHR not reduced for higher temperatures.
- 5) Minimum torus level (including maximum drawdown) assumed as provided in Reference 3.

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- 6) Assumed roughness factor,  $e$ , for clean commercial steel pipe ( $e = 0.00015$ ).
- 7) Assumed turbulent flow through fittings.
- 8) Core Spray and LPCI pump suction losses similar. Also, Unit 3 LPCI/Core Spray suction losses assumed similar.
- 9) Core Spray case bounded by LPCI case due to similar suction losses, similar NPSHR curves, and identical pump centerline elevations; also, Core Spray runs at a lower flow than LPCI, therefore operating at a lower NPSHR condition than LPCI.
- 10) Assumed all gate valves to be fully open.

References:

- 1) "Flow of Fluids Through Valves, Fittings, and Pipe", Crane Technical Paper No. 410, 24th Printing, 1988
- 2) General Electric Report No. GENE-770-26-1092 "Dresden Nuclear Power Station Units 2 & 3 LPCI/Containment Cooling System Evaluation," November, 1992
- 3) S. Eldridge letter to C. Schroeder titled "Submergence of LPCI Discharge Line Post LOCA Dresden Units 2 and 3" dated September 29, 1992, chron# 0115532
- 4) ASME Steam Tables, 1967
- 5) Bingham Pump Curve No. 25355 for 12x14x14.5 CVDS, Dresden Station LPCI Pump
- 6) Bingham Pump Curve No. 25231 for 12x16x14.5 CVDS, Dresden Station Core Spray Pump
- 7) Sargent & Lundy drawing M-547, LPCI pump suction
- 8) Sargent & Lundy drawing M-549, Core Spray pump suction
- 9) "Cameron Hydraulic Data," Ingersoll-Rand Co., 16th Edition, 2nd Printing, 1984
- 10) "Dresden LPCI/Containment Cooling System," GE Nuclear Energy letter from S. Mintz to T. L. Chapman dated January 27, 1993
- 11) "Dresden Station Units 2 and 3, Quad-Cities Station Units 1 and 2, NRC Docket Nos. 50-237, 50-249, 50-254, and 50-265," letter from G. J. Pliml to D. L. Ziemann dated September 27, 1976
- 12) "Centrifugal Pump Clinic," Karassik, Igor J., second edition, Marcel Dekker, Inc., New York, 1989

Equations:

Suction Losses

Straight piping and fitting losses are determined using the following equation (Reference 1, page 3-4):

$$hL = \frac{0.00259 * K * Q^2}{d^4} \quad (1)$$

where:  $hL$  = frictional losses (ft)

$K$  = resistance coefficient

$Q$  = flow (gpm)

$d$  = inner diameter of pipe (in)

The resistance coefficient,  $K$ , is the sum of the resistance coefficient for the fittings,  $K_f$ , and the resistance coefficient for the straight pipe,  $K_p$ .  $K_f$  can be obtained directly from applicable tables (Reference 9). For straight pipe,  $K_p$  is defined as:

$$K_p = f \frac{L}{D} \quad (2)$$

where:  $f$  = friction factor

$L$  = length of pipe (ft)

$D$  = inner diameter of pipe (ft)

The friction factor,  $f$ , is dependent upon the pipe diameter, Reynold's number, and pipe roughness, and can be determined using the Moody diagram (Reference 1). Reynold's number,  $Re$ , is determined using the following equation (Reference 1, page 3-2):

$$Re = \frac{50.6 * Q * \rho}{d * \mu} \quad (3)$$

where:  $\rho$  = density, lb/ft<sup>3</sup>

$\mu$  = dynamic viscosity (centipoise)

### Net Positive Suction Head

Net Positive Suction Head Available (NPSHA) is determined using the following equation:

$$NPSHA = 144 * \frac{(P_t - P_v)}{S} + Z - h_L \quad (4)$$

where:  $P_t$  = Torus Pressure given in Table 1 (psia)

$P_v$  = Vapor Pressure from Reference 4 (psia)

$Z$  = Static Head, the minimum water elevation expected above the LPCI/Core Spray pump suction as calculated below:

Minimum Torus water level elevation 491.42'  
(including maximum post-LOCA draw down as discussed in Reference 3)

LPCI/CS pump suction elevation - 478.13'

Static Head 13.29'

$h_L$  = suction losses in feet

### Calculations:

#### Suction Losses - One Pump

The suction piping for LPCI pump 2A is shown in Reference 7 and is made up of the following components:

| Line                      | Component                      | No. | $K_f^a$           | L/D  | Loss(ft) |
|---------------------------|--------------------------------|-----|-------------------|------|----------|
| 2-1502-24"<br>ID= 23.25"  | Entrance loss                  | -   | -----             |      | 0.6      |
|                           | 90 deg elbow (LR) <sup>b</sup> | 1   | 0.19              |      |          |
|                           | 45 deg elbow                   | 1   | 0.19              |      |          |
|                           | gate valve                     | 1   | 0.10              |      |          |
|                           | reducing tee (thru)            | 1   | 0.24              |      |          |
|                           | 16' straight pipe <sup>d</sup> | -   |                   | 8.26 |          |
|                           | Total                          |     | 0.72              | 8.26 | 0.6      |
| 2-1502A-14"<br>ID= 13.25" | reducer, 24x14                 | 1   | 0.07 <sup>c</sup> |      |          |
|                           | 90 deg elbow                   | 2   | 0.78              |      |          |
|                           | 45 deg elbow                   | 1   | 0.21              |      |          |
|                           | gate valve                     | 1   | 0.10              |      |          |
|                           | strainer                       | 1   | -----             |      | 0.8      |
|                           | 4' straight pipe <sup>d</sup>  | -   |                   | 3.62 |          |
|                           | Total                          |     | 1.16              | 3.62 | 0.8      |

<sup>a</sup> from Reference 9

<sup>b</sup> from Reference 11

<sup>c</sup> see Appendix B

<sup>d</sup> Total straight pipe length determined as the sum of all straight pipe lengths minus the length of all fittings



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The Reynold's number for each piping run is determined using Equation 3 (@ 90 deg F):

$$Re_{24} = \frac{50.6 * (5000) * (62.116)}{(23.25) * (0.75)} = 9.0 \times 10^5$$

$$Re_{14} = \frac{50.6 * (5000) * (62.116)}{(13.25) * (0.75)} = 1.6 \times 10^6$$

The friction factor for each piping run can then be determined using the Moody diagram for clean commercial steel pipe (Reference 1: A-25):

$$f_{24} = 0.0132$$

$$f_{14} = 0.0134$$

The resistance coefficient, K, is now be determined for each piping run utilizing Equation 2 for the straight pipe portion:

$$\begin{aligned} K_{24} &= K_f + K_p \\ &= 0.72 + (0.0132) * (8.26) \\ &= 0.83 \end{aligned}$$

$$\begin{aligned} K_{14} &= 1.16 + (0.0134) * (3.62) \\ &= 1.21 \end{aligned}$$

Using Equation 1, the friction loss for each piping run and total suction friction losses can be determined as follows:

$$\begin{aligned} hL_{24} &= 0.6' + \frac{0.00259 \times 0.83 \times (5000)^2}{(23.25)^4} \\ &= 0.78 \text{ feet} \end{aligned}$$

$$\begin{aligned} hL_{14} &= 0.8' + \frac{0.00259 \times 1.21 \times (5000)^2}{(13.25)^4} \\ &= 3.34 \text{ feet} \end{aligned}$$

$$\begin{aligned} hL_{tot} &= 0.78 + 3.34 \\ &= 4.12 \text{ feet @ 5000 gpm} \end{aligned}$$

To determine frictional losses at any flow, the quadratic relationship between hL and Q establishes the following:

$$hL_2 = hL_1 \times (Q_2/Q_1)^2 \quad (5)$$

Suction Losses - Two Pumps

For two pump operation, most of the 24" line (assume all) sees full flow (10000 gpm), while each of the 14" lines that branch off of it see one-half full flow (5000 gpm). Since the 14" line was previously analyzed at 5000 gpm, only the 24" line at 10000 gpm needs to be analyzed.

The Reynold's number and friction factor for the 24" line at 10000 gpm are:

$$Re_{24} = \frac{50.6 \times 10000 \times 62.116}{23.25 \times 0.75} = 1.8 \times 10^6$$

$$f_{24} = 0.0125$$

The resistance coefficient and frictional losses for the 24" pipe at 10000 gpm are then calculated as:

$$\begin{aligned} K_{24} &= K_f + K_p \\ &= 0.72 + (0.0125) \times (8.26) \\ &= 0.82 \end{aligned}$$

$$\begin{aligned} hL_{24} &= 1.8' + \frac{0.00259 \times 0.82 \times (10000)^2}{(23.25)^4} \\ &= 2.53 \text{ feet} \end{aligned}$$

The suction friction losses for each pump with two pumps running is:

$$\begin{aligned} hL_{tot} &= 2.53 + 3.34 \\ &= 5.87 \text{ feet @ 10000 gpm total flow} \end{aligned}$$

NPSHA Calculations:

Using Equation 4 and the inputs provided in Table 1 and Equation 5, the NPSHA is calculated for each of the four cases (Table 3). The required NPSH is also provided and the difference between the two is calculated. The NPSHR provided is for cold water and is not adjusted for the increased temperatures expected in the torus. This adjustment would have taken the form of a NPSHR reduction and resulted in a greater margin for NPSHA over NPSHR. From Figure 1 (Ref. 12), the reduction at 170 deg F (Cases 3 and 3A) would be about 0.3 feet, and at 180 deg F (Cases 4 and 4A) would be about 0.4 feet.

The margin between available and required NPSH in Table 3 is given in feet. In order to better understand the significance of this margin, a sensitivity analysis was performed (Appendix A) based on each of the following:

- A1) torus temperature increase (Cases 3 and 4)
- A2) torus pressure decrease (Cases 3 and 4)
- A3) CCSW initiation time increase (All cases)

In preparing this sensitivity analysis, the following conservative assumptions were made:

- A1) As torus temperature increases, torus pressure remains constant.
- A2) Torus temperature remains unchanged for lower torus pressures.
- A3) Higher temperatures produced by delaying the initiation of CCSW will not be accompanied by higher pressures.

Summary/Conclusions:

Post DBA-LOCA torus conditions were determined in Reference 2 and were used to calculate the available NPSH for the LPCI and Core Spray pumps at Dresden Station. The results in Table 3 indicate that the available NPSH is greater than the required NPSH (with margin) for all four cases, and therefore adequate to protect the pumps under these conditions. While the calculations performed were for the LPCI 2A pump, the results bound the remaining LPCI pumps as well as the Core Spray pumps for both Units based on similar suction losses, required NPSH and pump elevations.

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| Flow<br>(gpm) | NPSHR<br>(ft) | Flow<br>(gpm) | NPSHR<br>(ft) |
|---------------|---------------|---------------|---------------|
| 3500          | 25.0          | 5500          | 35.0          |
| 3800          | 25.5          | 5600          | 36.1          |
| 4000          | 26.0          | 5700          | 37.2          |
| 4500          | 27.0          | 5800          | 38.4          |
| 5000          | 30.0          | 5900          | 39.5          |
| 5300          | 33.0          | 6000          | 40.6          |

Table 2

| Case | Total<br>Flow<br>(gpm) | Single<br>Pump<br>Flow (gpm) | Torus<br>Temp<br>(F) | Torus<br>Pressure<br>(psia) | Static<br>Head (ft) | Specific<br>Volume<br>(ft <sup>3</sup> /lb) | Vapor<br>Pressure<br>(psia) | Suction<br>Losses<br>(ft) | NPSHA<br>(ft) | NPSHR<br>(ft) | Margin<br>(ft) |
|------|------------------------|------------------------------|----------------------|-----------------------------|---------------------|---|-----------------------------|---------------------------|---------------|---------------|----------------|
| 3    | 10000                  | 5000                         | 168                  | 18.7                        | 13.29               | 0.01644                                     | 5.722                       | 5.87                      | 38.14         | 30.00         | 8.14           |
| 3A   | 8916                   | 4458                         | 171                  | 19.1                        | 13.29               | 0.016457                                    | 6.132                       | 4.67                      | 39.35         | 26.90         | 12.45          |
| 4    | 5000                   | 5000                         | 180                  | 19.9                        | 13.29               | 0.01651                                     | 7.511                       | 4.12                      | 38.62         | 30.00         | 8.62           |
| 4A   | 3881                   | 3881                         | 186                  | 20.6                        | 13.29               | 0.016547                                    | 8.568                       | 2.48                      | 39.48         | 25.70         | 13.78          |

Table 3

## Dresden LPCI/Core Spray Pumps NPSHA Evaluation - Post DBA LOCA

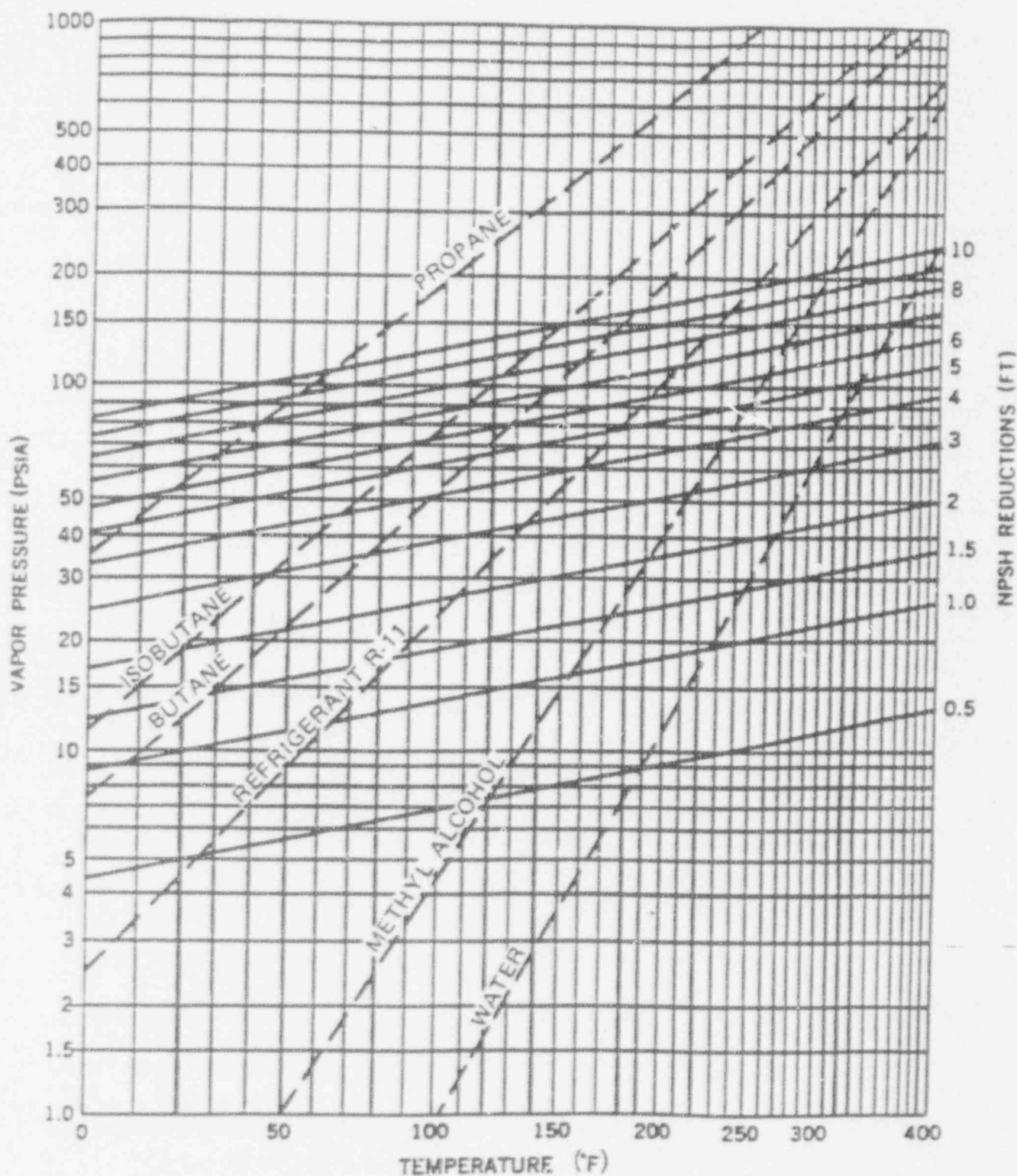


Figure 1.29 NPSH reductions for pumps handling hydrocarbon liquids and high-temperature water (Courtesy Hydraulic Institute Standards of 1975.)

FIGURE 1 (Ref. 11, p. 56)

## REVIEW CHECKLIST

|                                |        |                      |
|--------------------------------|--------|----------------------|
| CALCULATION NO: NEO-M-MSD-43   | REV. 1 | PAGE 13 OF 13        |
| REVIEWED BY: <u>Dan K. Lee</u> |        | DATE: <u>2/11/93</u> |

| YES                                 | NO                                  |  | <u>REMARKS</u> |
|-------------------------------------|-------------------------------------|--|----------------|
| <input checked="" type="checkbox"/> | <input type="checkbox"/>            | 1. IS THE OBJECTIVE OF THE ANALYSIS CLEARLY STATED?  |                |
| <input checked="" type="checkbox"/> | <input type="checkbox"/>            | 2. ARE ASSUMPTIONS AND ENGINEERING JUDGEMENTS VALID AND DOCUMENTED?                              |                |
| <input type="checkbox"/>            | <input checked="" type="checkbox"/> | 3. ARE THERE ASSUMPTIONS THAT NEED VERIFICATION?   |                |
| <input checked="" type="checkbox"/> | <input type="checkbox"/>            | 4. ARE THE REFERENCES (I.E. DRAWINGS, CODES, STANDARDS) LISTED BY REVISION EDITION, DATE, ETC.?  |                |
| <input checked="" type="checkbox"/> | <input type="checkbox"/>            | 5. IS THE DESIGN METHOD CORRECT AND APPROPRIATE FOR THIS ANALYSIS?                               |                |
| <input checked="" type="checkbox"/> | <input type="checkbox"/>            | 6. IS THE CALCULATION IN COMPLIANCE WITH DESIGN CRITERIA, CODES, STANDARDS, AND REG. GUIDES?     |                |
| <input checked="" type="checkbox"/> | <input type="checkbox"/>            | 7. ARE THE UNITS CLEARLY IDENTIFIED, AND EQUATIONS PROPERLY DERIVED AND APPLIED?                 |                |
| <input checked="" type="checkbox"/> | <input type="checkbox"/>            | 8. ARE THE DESIGN INPUTS AND THEIR SOURCES IDENTIFIED AND IN COMPLIANCE WITH UFSAR & TECH SPECS? |                |
| <input checked="" type="checkbox"/> | <input type="checkbox"/>            | 9. ARE THE RESULTS COMPATIBLE WITH THE INPUTS AND RECOMMENDATIONS MADE?                          |                |
|                                     |                                     |  |                |
|                                     |                                     |  |                |

10. INDICATE TYPE OF CALCULATION (HAND-PREPARED AND/OR COMPUTER-AIDED) AND METHOD OF REVIEW:

☒ HAND PREPARED DESIGN CALCULATION

THE REVIEW OF THE HAND-PREPARED DESIGN CALCULATION WAS ACCOMPLISHED BY ONE OR A COMBINATION OF THE FOLLOWING (AS CHECKED):

☒ A DETAILED REVIEW OF THE ORIGINAL CALCULATION

☐ A REVIEW BY AN ALTERNATE, SIMPLIFIED OR APPROXIMATE METHOD OF CALCULATION

☐ A REVIEW OF A REPRESENTATIVE SAMPLE OF REPETITIVE CALCULATIONS

☒ A REVIEW OF THE CALCULATION AGAINST A SIMILAR CALCULATION PREVIOUSLY PERFORMED

☐ COMPUTER AIDED DESIGN CALCULATION

| YES                      | NO                       |   |   |
|--------------------------|--------------------------|---|---|
| <input type="checkbox"/> | <input type="checkbox"/> | 11. IS THE PROGRAM APPLICABLE TO THIS PROBLEM?  | <input type="checkbox"/> <input type="checkbox"/> 15. ARE THE RESULTS CONSISTENT WITH THE ASSUMPTIONS AND THE INPUT DATA?                         |
| <input type="checkbox"/> | <input type="checkbox"/> | 12. IS THE COMPUTER PROGRAM VALIDATED PER QP 3-54?  | <input type="checkbox"/> <input type="checkbox"/> 16. IS A LIST OF THE PROGRAMS USED AND DATE OF EACH COMPUTER RUN REFERENCED IN THE CALCULATION? |
| <input type="checkbox"/> | <input type="checkbox"/> | 13. IS THE COMPUTER PROGRAM VALIDATED BY OTHER AE'S / ORGANIZATIONS AND HAS IT BEEN PREVIOUSLY APPLIED TO NUCLEAR PROJECTS? | <input type="checkbox"/> <input type="checkbox"/> 17. IS THE PROGRAM VERSION AND IT'S REVISION IDENTIFIED ON THE COMPUTER RUN?                    |
| <input type="checkbox"/> | <input type="checkbox"/> | 14. IS THE INPUT DATA IN CONFORMANCE WITH THE DESIGN INPUTS?  |   |



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Appendix A

NPSH Margin CCSW Initiation Time Sensitivity  
Increase from 600 to 1800 Seconds

| Case | Total Flow (gpm) | Single Pump Flow (gpm) | Torus* Temp (F) | Torus Pressure (psia) | Static Head (ft) | Specific Volume (ft <sup>3</sup> /lb) | Vapor Pressure (psia) | Suction Losses (ft) | NPSHA (ft) | NPSHR (ft) | 1800 s Margin (ft) | 600 s Margin (ft) |
|------|------------------|------------------------|-----------------|-----------------------|------------------|---------------------------------------|-----------------------|---------------------|------------|------------|--------------------|-------------------|
| 3'   | 10000            | 5000                   | 172             | 18.7                  | 13.29            | 0.016463                              | 6.274                 | 5.87                | 36.88      | 30.00      | 6.88               | 8.14              |
| 3A'  | 8916             | 4458                   | 174             | 19.1                  | 13.29            | 0.016474                              | 6.566                 | 4.67                | 38.35      | 26.90      | 11.45              | 12.45             |
| 4'   | 5000             | 5000                   | 182             | 19.9                  | 13.29            | 0.016522                              | 7.851                 | 4.12                | 37.84      | 30.00      | 7.84               | 8.62              |
| 4A'  | 3881             | 3881                   | 188             | 20.6                  | 13.29            | 0.016559                              | 8.947                 | 2.48                | 38.60      | 25.70      | 12.90              | 13.78             |

Table A-1

\* Increased Values of Torus Temperature from Reference 10



## Appendix A

### NPSH Margin Temperature Sensitivity

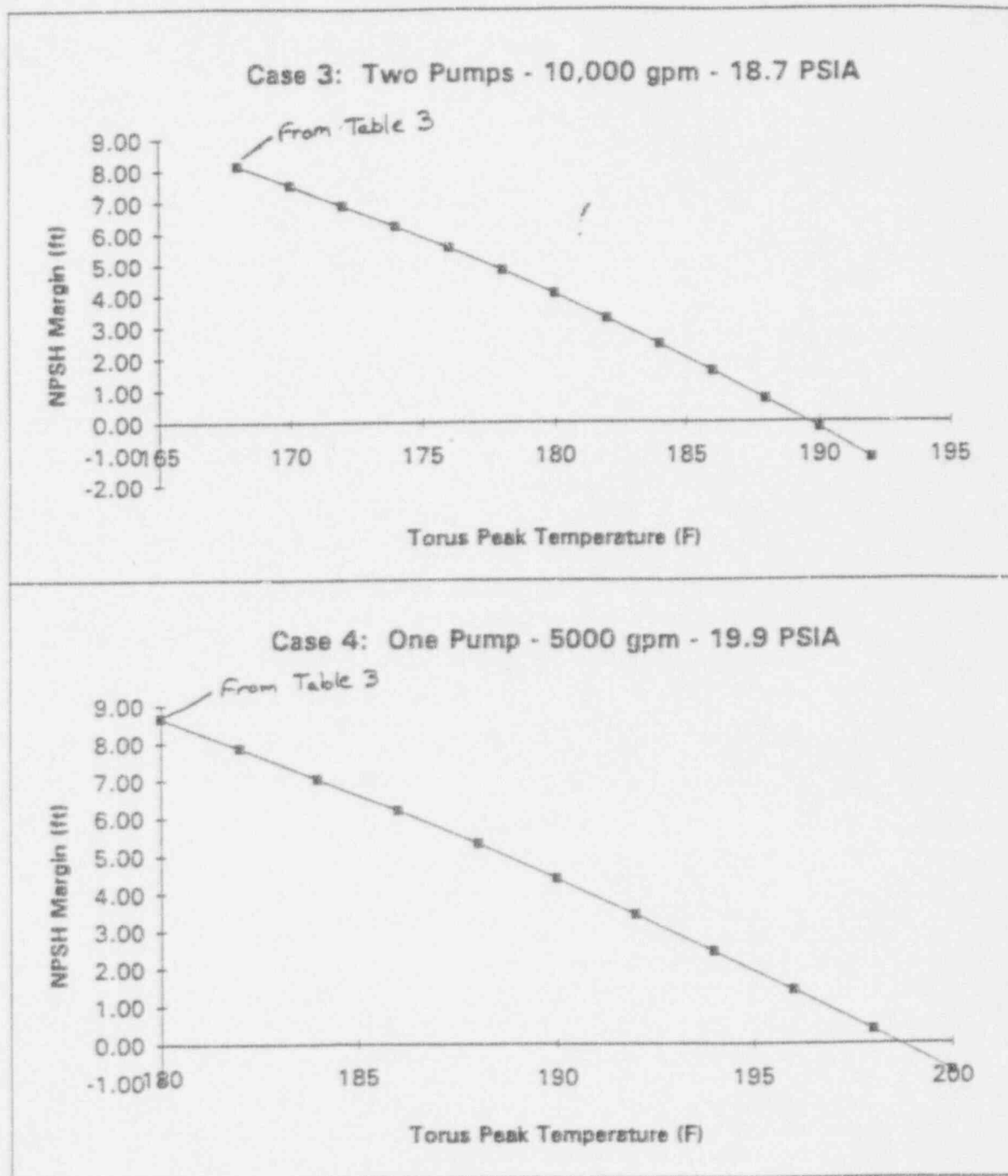


Figure A-1

Appendix A

NPSH Margin Pressure Sensitivity

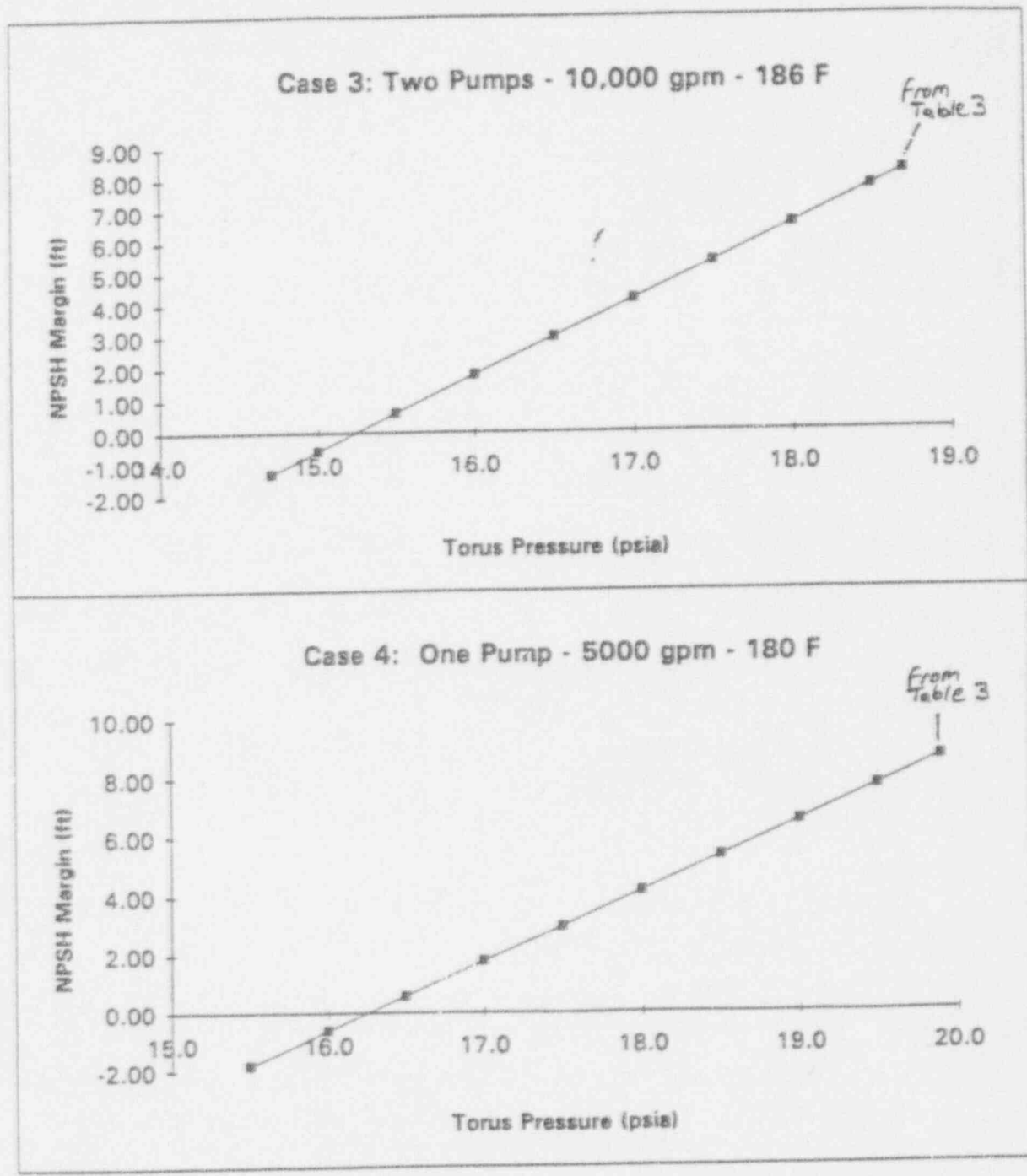


Figure A-2

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Dresden LPCI/Core Spray Pumps NPSHA Evaluation - Post DBA-LOCA

#### APPENDIX B

##### Calculation of Resistance Coefficient of 24 x 14 Reducer

From Reference 1 (A-26), the equation for the resistance coefficient of a reducer is given by:

$$K = 0.8 \sin (a/2) (1 - b^2) \quad (B-1)$$

$$\text{where } a = 2 \tan^{-1} \left[ \frac{(d2 - d1)}{2L} \right]$$

$$b = d1/d2$$

d1 = small diameter of reducer (in)

d2 = large diameter of reducer (in)

L = length of reducer (in)

For a 24 x 14 reducer, the above parameters are defined as:

$$d1 = 13.25 \text{ in}$$

$$L = \text{assume } d1 + d2$$

$$d2 = 23.25 \text{ in}$$

$$= 36.5 \text{ in}$$

Therefore,

$$b = 0.57$$

and

$$a = 15.6 \text{ deg}$$

Substituting into Equation A-1, the resistance coefficient for the reducer is:

$$K = 0.07$$