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 (ft3/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



TITLE PAGE

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

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 3A 4 4A	2 2 1	10000 8916 5000 3881	168 171 180 186	18.7 19.1 19.9 20.6

Table 1

These calculations include the following assumptions:

- An even split of flow is assumed between two pumps operating in parallel.
- 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:

- 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
- Alternate Shutdown Cooling Core Spray and LPCI pump notes and back-up calculations for Reference 1, R. Kolflat, circa 4/89

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

Equations:

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

NPSHA = (ft)	Torus Static Vapor Suct Pressure + Head - Pressure - Loss	ion (1) es
where:	Torus Pressure = given in Table 1 (psia); to feet using specific vo	converted
	Static Head = the minimum water elevati above the LPCI pump sucti calculated below:	on expected
	Minimum Torus water level elevation (including maximum post-LOCA draw down as discussed in Reference 3)	491.5'
	LPCI pump suction elevation	- 478.13'
	Static Head	13.32'
	Vapor Pressure = from Reference 4, in psiz to feet using specific vo	; converted
	Suction Losses = piping losses in feet = K * Q ² , K calculated at Q using suction losses from 1 and 5. (Tables 2 and 3)	≈ 5000 gpm n References

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.

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MBHR + 4 - 0.87 he NPSHE 0 26.02 1.89 25 3500 26.84 2.21 3800 25.5 27.57 2.44 4000 26. 28.44 2.81 4300 26.5 29.2 3.07 4500 27.0 29.74 3.21 4600 27.6 30.68 3.35 4700 28.2 31.42 3.49 28.8 4800 32.16 3.63 29.4 4900 32.9 3.77 5000 30.0 \$4.05 1.92 31.0 5100 35.2 4.07 32 5200 36.36 4.25 33 5300 37.52 4.59 34 5400 38.68 4.55 35 5500 39.94 4.71 36.1 5600 41.2 4.87 37.2 5700 42.57 5.04 5800 38.4 45.84 5.21 5:00 39.5 45.12 5.39 10.6 6000 LERE B LTIDA

TABLE 2 (REFERENCE 1

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4300	26.5	2.81	28.44	2.42	3.52		1 49
4500	27.0	3.07	29.2	318	3.85	39.30	3.77
4400	276	3.21	29.74	3.92	apro 2	30.75	4.26
10000	28.7	3 35	30.68	466	4.19	3.52	5.03
4/00	20.6	749	31.42	5.4	4.36	3z.29	5.8
4800	28.0	3.40	#2.16	6.14	4.54	33.07	6.58
4900	29.4	3.63	27 4	688	4.72	33.85	7.36
5000	30.0	3.77	36.5	803	4.91	35.04	8.55
5100	31.0	3.92	\$4.05	610	5.10	36.23	9.74
5200	32	4.07	35.2	10 24	529	37.42	10.93
5300	33	4.25	36.36	10.54	- 49	39 42	1213
5400	34	4.59	37.52	11.5	5.40	29 9.7	18.33
5500	0 35	4.56	38.68	12.66	3.00	1117	14.63
51.00	36.1	4.71	39.94	13.52	5.57	42.43	1<94
5700	372	4.8	7 41.2	15.11	B 6.10	76.70	17 25
5700		6 500	42.57	16.5	5 6.31	43.84	81.00
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TABLE 3 (REFERENCE 5)

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 (ft3/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

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CALCULATION NO. NE	D-M-MSD-43	I	PAGE 1 01	F 13
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EQUIP NUMBER(S)	STATION/UNIT	SYSTEM		
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QE-51.D EXHIBIT B REV. 3

TABLE OF CONTENTS

CALCULATIC	ON NO: NED-M-MED-43	REV 1	PAGE 2	OF 13
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2.	TITLE PAGE			1
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3	REVISION SUMMARY			3
4	CALCULATION SHEET(S)			4-12
5	REVIEW CHECKLIST			13
	Attachments			
	APPENDIX A			A.1-A.
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QE-51.D EXHIBIT C REV. 3

REVISION SUMMARY

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do	cument. nsitivi	In addition, Core Spray ity analysis on NPSH is inc	added to	scope and a
	1	AFFECTED PAGE	ES	
PAGES	REV.	DESC	CRIPTION	
1	1	Changed Title and Equipme Core Spray	ent Nos./S	ystem to include
2	1	Added Table of Contents		
4	1	Changed Purpose/Objective	e to inclu	ide Core Spray
4,5	1	Added assumptions regard calculations and addition	ing hydrau n of Core	lic loss Spray pps to scope
5	1	Removed two R. Kolflat r for hydraulic loss calcu	eferences; lations ar	added references nd Core Spray
6	1	Added equation for hydra	ulic loss	calculations
7-9	1	Added calculations for h	ydraulic 1	losses
9	1	Included discussion of N increased temperature	PSHR reduc	ction due to
10	1	Added sensitivity analys	is to NPSH	HA calculations
10	1	Added Core Spray to Summ	ary/Conclu	usions
11	1	Added Table 2 - NPSHR va Updated Table 3 for new	lues suction lo	oss values
12	1	Added Figure 1 - NPSHR r	eduction	vs. temperature
A.1-A.3	1	New NPSH sensitivity ana	lysis	
B.1	1	New calculation of resis 24 x 14 reducer	stance coe	fficient for a

QE-51.D EXHIBIT D REV. 3

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Purpose/Objective:

Calculate the Net Positive Suction Head Available (NPSHA) for the LPCI and Core Spray pumps at Dresden Station under postaccident 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	Total	Maximum	Reduced
	Pumps	Flow	Suppression	Torus
	/Loop	(gpm)	Pool Temp(F)	Pressure(psia)
3	2	10000	168	18.7
3A	2	8916	171	19.1
4	1	000	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:

- 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 guadratic 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.
- Minimum torus level (including maximum drawdown) assumed as provided in Reference 3.

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

- 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:

- "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

0/13

(2)

Equations:

Suction Losses

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

$$hL = \frac{0.00259 * K * Q^2}{d^4}$$
(1)
here: $hL = frictional losses (ft)$
 $K = resistance coefficient$
 $Q = flow (gpm)$
 $d = inner diameter of pipe (in)$

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

$$x_p = f \frac{L}{D}$$

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):

$$Re = \frac{50.6 * Q * g}{d * y}$$
(3)

where:
$$\beta = \text{density}$$
, lb/ft^3
 $\mu = \text{dynamic viscosity (centipoise)}$

Net Positive Suction Head

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

NPSHA = $144 * (Pt - Pv) + Z - hL$						(4)
where:	Pt	355	Torus	Pressure	given in Table 1 (psia)	
	PV		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)

13

LPCI/CS pump suction elevation - 478.13' Static Head 13.29'

hL = 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.	Kf ^a	L/D	Loss(ft)
2-1502-24" ID= 23.25"	Entrance loss 90 deg elbow (LR) ^b 45 deg elbow gate valve reducing tee (thru) 16' straight pipe		0.19 0.19 0.10 0.24	8.26	0.6
	Total		0.72	8.26	0.6
2-1502A-14" ID= 13.25"	reducer, 24x14 90 deg elbow 45 deg elbow gate valve strainer 4' straight pipe ^d	1 2 1 1 1	0.07 ^c 0.78 0.21 0.10	3.62	0.8
	Total		1.16	3.62	0.8
and all shares and shares and			and the second secon	and a state of the later of the state	1

å from Reference 9
b from Reference 11

c see Appendix B

d Total straight pipe length determined as the sum of all straight pipe lengths minus the length of all fittings

The Reynold's number for each piping run is determined using Equation 3 (0 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:

 $K_{24} = Kf + Kp$ = 0.72 + (0.0132)*(8.26) = 0.83 $K_{14} = 1.16 + (0.0134)*(3.62)$ = 1.21

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

 $hL_{24} = 0.6^{\circ} + \frac{0.00259 \times 0.83 \times (5000)^2}{(23.25)^4}$ = 0.78 feet $hL_{14} = 0.8^{\circ} + \frac{0.00259 \times 1.21 \times (5000)^2}{(13.25)^4}$ = 3.34 feet

hLtot = 0.78 + 3.34 = 4.12 feet @ 5000 gpm

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

 $hL2 = hL1 \times (Q2/Q1)^2$

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(5)

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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:

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

 $f_{24} = 0.0125$

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

 $K_{24} = Kf + Kp$ = 0.72 + (0.0125)*(8.26) = 0.82

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

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

hLtot = 2.53 + 3.34 = 5.87 feet @ 10000 gpm total flow

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.

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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.

Calculation No. NED-M-MSD-43 Rev 1 Dresden LPCI/Core Spray Pumps NPSHA Evaluation - Post DBA LOCA

Flow (gpm)	NPSHR (ft)	Flow (gpm)	NPSHR (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 Flow (gpm)	Single Pump Flow (gpm)	Torus Temp (F)	Torus Pressure (psia)	Static Head (ft)	Specific Volume (ft3/lb)	Vapor Pressure (psia)	Suction Losses (ft)	NPSHA (ft)	NPSHR (ft)	Margin (ft)
3	10000	5000	168	18.7	13.29	0.01644	5.722	5.87	38.14	30.00	8.14
34	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

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

TEMPERATURE ("F)

100

1.5

1.0

0

50

FIGURE 1 (Ref. 11, p. 56)

150

200

250

300

400

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Calc. No. NED-M-MSD-43 Rev1



REVIEW CHECKLIST

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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 (ft3/ib)	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
34'	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
44'	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

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Appendix A





Figure A-1

Page A.3 of A.3

Appendix A





Figure A-2

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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:

 $K = 0.8 \sin (a/2) (1 - b^2)$ (B-1) where $a = 2 \tan^{-1} \left[\frac{(d2 - d1)}{2L} \right]$ b = d1/d2d1 = 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 in L = assume d1 + d2d2 = 23.25 in = 36.5 in

Therefore,

b = 0.57 and a = 15.6 deg

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

K = 0.07