ATTACHMENT 1

Limerick Generating Station
Unit 1

NPSH Analysis
Residual Heat Removal System

Effective Date: 8-19-96

Exhibit NE-C-420-6, Rev. 2
Page 1 of 1
RAS/mak

CONTROLLED COPY

PORC	NO
SQR	NO
QR	NO
50.59	NO
RESP MGR	YES

Source Calc. # M-51-62 Rev. 4

ECR # LG 97-03058 Rev. 0

CALCULATION REVISION SHEET

☒ INTERIM REVISION ☐ MARGIN REVISION

THIS CALCULATION HAS BEEN IMPACTED PER THIS REVISION SHEET AS FOLLOWS:

THIS REVISION IS APPLICABLE TO UNIT 1 ONLY. THIS CALCULATION IS REVISED TO DETERMINE THE WORST CASE RHR SYSTEM NPSHA AND TO CALCULATE NPSHA MARGIN AS A RESULT OF THE INSTALLATION OF NEW LARGE CAPACITY PASSIVE STRAINERS ON THE RHR SUCTION PIPING. PER PECO DIRECTION THE ANALYSIS PERFORMED BY REVISION 4 WILL BE DELETED AND THE MODE A-1, MODE A-2, AND MODE B ANALYSIS WILL BE RESTORED, INCORPORATING THE NEW STRAINER PRESSURE DROPS.

PAGES REVISED: 2b, 2a, 3, 4, 8, 11, 13, 15-20

PAGES ADDED: 3A, 21-31

Prepared By: Joseph T. Schill (SWEC) Date: 1/13/98

Reviewed By: M O'Hagan (SWEC) Date: 1/13/98

Approved By: [illegible] for N.B. Crosby Date: 1/15/98

Effective Date: 8-19-96

Exhibit NE-C-420-3, Rev. 2
Page 1 of 1
RAS/mak

CONTROLLED COPY

PORC	NO
SQR	NO
QR	NO
50.59	NO
RESP MGR	YES

Source Calc. # M-51-62 Rev. 4

ECR # LG 9703058 Rev. 0

CALCULATION REVIEW CHECKLIST

MANUAL CALC.	COMPUTER CALC.		YES or N/A
X	X	Calculation is the appropriate basis for the activity	Yes
X	X	Calculation assumptions, considerations, and methodology conform to applicable design requirements	Yes Yes
X	X	Sources of data and formulas were reviewed and verified to be correct and complete	Yes
X	X	Input data is correct and used properly	Yes
X		The analytical method used in the calculation has been considered and is proper for the intended use	Yes Yes
X		Mathematical accuracy has been checked and is correct (indicate method used)	Yes
		a) Complete check of each calculation	Yes
		b) Spot check of selected calculations	N/A
		c) Performance of alternate or approximation calculation (attached)	N/A
X	X	Calculation results were checked against applicable design criteria and were found to be in compliance	Yes
X	X	Existing calculations requiring revision as a result of this calculation have been identified and documented	N/A
	X	The analytical methods described in the computer calculation summary are proper for the intended use	N/A
X	X	All system and topic numbers associated with the calculation are listed	Yes
	X	Computational accuracy has been checked and is correct (indicate method used)	N/A
		a) Check sample calculation using data other than that used in the sample	N/A
		b) Performance of alternate or approximation calculation (attached)	N/A
		c) Describe other method used: ______	N/A
	X	Program used is appropriate, input is valid, and output is reasonable considering the input	N/A
X	X	Base calculation has been reviewed against current drawing revisions and posted DCDs to identify significant differences	Yes *

The criteria listed above are the minimum criteria to be considered and are not intended to limit the initiative of the reviewer to consider other criteria.

Attributes applicable to manual and computer calculations are noted by an "X" in the appropriate column.

List the documents used to support this review. * Drawings/documents not affected by MOD P0028 are not reviewed to verify if their revisions are current.

Prepared By: M Dhasan (SWEC) Date: 1/13/98

Exhibit NE-C-420-1, Rev. 1
Effective Date: 9/4/94

NUCLEAR
GROUP

DOCTYPE 061

CALCULATION COVER SHEET

1. Calculation No. M-51-62

Page 1 FOLLOWED BY Pg 1a.

2. ☒ LGS
☐ PBAPS

3. UNIT(S) 1+2

4. MOD/NCR/ECR No.:
Other: PEP I0004457

5. Responsible Branch: SEEM

6. Last Page No: 20

7. ☒ Safety Related
☐ Non-Safety Related

8. Description: RHR SYSTEM NPSHA FROM S.P. 4

9. System/Topic No.: 051, 111 4
Structure: NA
Component: NA

RECORD OF REVISIONS

10. Rev. No.	11. Description of Revision	12. Vendor Calc. Number	Rev.	13. Assumptions Yes	No	14. Signatures Preparer	Reviewer	Approver/Date
4	CHANGE MAX ALLOWABLE SUCTION STRAINER dP FROM 2.0 PSID TO 5.0 PSID. CALC WORST-CASE NPSHA FROM S.P. ALSO PROVIDE 'ACTION' VALUE FOR SYSTEM TEST. RENUMBERED PAGES AND ADDED PAGES 15-20. SEE PAGE 15 FOR SUMMARY OF RESULTS. REVISION 4 DOES NOT IMPACT POWER RERATE OR PERFORM. REVISION 4 DOES NOT IMPACT STATION ADMIN + IMPLEM. PROCEDURES. REV 4 DOES IMPACT SURVEILLANCE TESTS, THE RHR DBD (L-S-9), AND THE LGS SAR.	NA			X	(SKIP DEWITT)	(C. [illegible])	11/1/95

15. Related Calc. Numbers

Provides Info to:	LM-0571				
Receives Info from:	MISC-62			4	

16. ☒ Manual
☐ Computer
Computer program and version

17. Provides Info to UFSAR/ Tech. Spec.:	UFSAR 6.3	T.S. 3/4.5.1	T.S. 3/4.5.2	T.S. 3/4.6.2.2	3/4.6.2.3

18. Total Pages: (DS Use) 1

CALCULATION COVER SHEET ~~12~~ 20

△4

PROJECT Limerick Gen. Station Unit 1 & 2 JOB NO. 8031 DISCIPLINE Mechanical

SUBJECT RHR SYSTEM NPSH

~~FILE NO.~~ Page 1b Followed by Pg 1a

CALC. NO. M-51-62

NO. OF SHEETS ~~15+20~~ ~~(14+1A)~~ ~~COVER SHEETS 20~~

RECORD OF ISSUES

NO.	[illegible]IPTION	BY	DATE	CHKD	DATE	APPRD	DATE	
△								
△								
△								
△								
△4	See new cover sheet							
△3	Final calc. Revised for calc. screening only. Added sheet 1A, list of MDCPs, DCPs etc. reviewed. Added New Cover Sheet		1/31/90	SSK	2/1/90		2/3/90	2-15-91 91-9058

△4

CALCULATION SCREENING FOR THE AS-BUILT DESIGN

The purpose of this calculation revision is to document that the calculation results and conclusions are still applicable to the as-built design of the plant, including modifications.

☒ Reviewer has determined the calculation results and conclusions are applicable to the as-built design of the plant because:

- ___ the original design margin was large and subsequent modifications have had little or no impact on the design margin.
- ✓ there have been no modifications to the system which affect this calculation.
- ___ the pre-op test results (as adjusted to agree with calculation assumptions, where appropriate) are consistent with the calculation and subsequent mods have not significantly affected the calculation results.
- ___ Other:

☐ Reviewer has determined the calculation results and conclusions are no longer applicable to the as-built design of the plant because:

- ___ the calculation design margin has already been exceeded.
- ___ Other:

☐ Reviewer cannot determine that the calculation results and conclusions are applicable to the as-built design of the plant in the time available. Further technical evaluation is recommended.

Refer to Sheet ~~1A~~ 20 for a list of MDCPs, DCPs, design documents and pre-op test results that were reviewed during the calculation screening review.

△4

BECHTEL

CALCULATION COVER SHEET

~~[illegible]~~
~~[illegible]~~
~~F00 18240 Ω~~ 4

PROJECT LIMERICK UNIT 1 & 2 JOB NO. 8031* DISCIPLINE MECH

SUBJECT RHR SYSTEM NPSH ~~FILE NO.~~ PAGE 1a FOLLOWED BY PG 2 4

CALC. NO. M-51-62

ORIGINATOR R.M. VITANGCOL DATE 10/4/88

CHECKER KRIS H NARAYAN DATE 10/5/88 NO. OF SHEETS ~~14~~ ~~20~~ 8 4

RECORD OF ISSUES								
NO.	DESCRIPTION	BY	DATE	CHKD	DATE	APPRD	DATE	DATE FILMED
0	FINAL CALC	RMV	10/4/88	Kris Narayan	10/5/88	[illegible]	11/1/88	[illegible]
1	REVISED TO REFLECT LOWEST SP W.L. PER CALC. # MISC.-62 REV. 1 (REF. 2)	RMV	11/30/88	Kris Narayan	12/1/88	[illegible]	12/16/88	
↓	FINAL	↓	↓	↓	↓	↓	↓	
2	REVISED TO REFLECT CALC #MISC-62 REV. 3 (REF. 2) REVISED PAGE 2 - FINAL	RMV	12/29/88	Kris Narayan	12/29/88	[illegible]	1/3/89	[illegible]
	New Calc Cover Sheet							

PRELIMINARY CALC. ☐ COMMITTED PRELIMINARY DESIGN CALC. ☐

SUPERSEDED CALC. ☐ FINAL CALC. ☒

NOTE: THIS CALC. SUPERSEDES CALCULATION NO. 8031-M-51-9, Rev. 2 AND NO. 8031-M-51-10, Rev. 2.

Effective Date: 9/4/94

Exhibit NE-C-420-3, Rev. 1
Page 1 of 1
RAS/kmm

CALC. # M-51-62 REV. 4
PAGE ~~DCD~~ → 2 FOLLOWED ~~DATE:~~ BY PAGE 2b

CALCULATION REVIEW CHECKLIST

MANUAL CALC.	COMPUTER CALC.		YES or N/A
X	X	CALCULATION IS THE APPROPRIATE BASIS FOR THE ACTIVITY	Y
X	X	CALCULATION ASSUMPTIONS, CONSIDERATIONS, AND METHODOLOGY CONFORM TO APPLICABLE DESIGN REQUIREMENTS	Y
X	X	SOURCES OF DATA AND FORMULAS WERE REVIEWED AND VERIFIED TO BE CORRECT AND COMPLETE	Y
X	X	INPUT DATE IS CORRECT AND USED PROPERLY	Y
X		THE ANALYTICAL METHOD USED IN THE CALCULATION HAS BEEN CONSIDERED AND IS PROPER FOR THE INTENDED USE	Y
X		MATHEMATICAL ACCURACY HAS BEEN CHECKED AND IS CORRECT (INDICATE METHOD USED)	Y
		A) COMPLETE CHECK OF EACH COMPUTATION	Y
		B) SPOT CHECK OF SELECTED COMPUTATIONS	NA
		C) PERFORMANCE OF ALTERNATE OR APPROXIMATION CALCULATION (ATTECHED)	NA
X	X	CALCULATION RESULTS WERE CHECKED AGAINST APPLICABLE DESIGN CRITERIA AND WERE FOUND TO BE IN COMPLIANCE	Y
X	X	EXISTING CALCULATIONS REQUIRING REVISION AS A RESULT OF THIS CALCULATION HAVE BEEN IDENTIFIED & DOCUMENTED	
	X	THE ANALYTICAL METHODS DESCRIBED IN THE COMPUTER CALCULATION SUMMARY IS PROPER FOR THE INTENDED USE	NA
X	X	ALL SYSTEM AND TOPIC NUMBERS ASSOCIATED WITH THE CALCULATION ARE LISTED	Y
	X	COMPUTATIONAL ACCURACY HAS BEEN CHECKED AND IS CORRECT (INDICATE METHOD USED)	NA
		A) CHECK SAMPLE CALCULATION USING DATA OTHER THAN THAT USED IN THE SAMPLE	NA
		B) PERFORMANCE OF ALTERNATE OR APPROXIMATION CALCULATION (ATTACHED)	NA
		C) DESCRIBE OTHER METHOD USED:	NA
	X	PROGRAM USED IS APPROPRIATE, INPUT IS VALID, AND OUTPUT IS REASONABLE CONSIDERING THE INPUT	NA
X	X	BASE CALCULATION HAS BEEN REVIEWED AGAINST CURRENT DRAWING REVISIONS AND POSTED DCDs TO IDENTIFY SIGNIFICANT DIFFERENCES	NA

The criteria listed above are the minimum criteria to be considered and are not intended to limit the initiative of the reviewer to consider other criteria.

Attributes applicable to manual and computer calculations are noted by an "X" in the appropriate column.

List the documents used to support this review. Crane Technical paper 410
Pump Curves M1-E11-C002-J-12 to 19, System Flow Diagram M1-E11-1020-G002

REVIEWED BY: DATE: 10-25-95

Checker's Note: Methodology used to combine 24" and 30" piping losses slightly overstates piping losses. The result is conservative and acceptable.

CALCULATION SHEET

CALC. NO. M-51-62 REV. NO. 3
ORIGINATOR W.E. Purcell DATE 1-31-90
CHECKED SSkalch DATE 2/1/90
PROJECT LGS Units 1 & 2
JOB NO. 8031
SUBJECT RHR System NPSH
SHEET NO. 2c Followed by pg 2b | 4

The Following MDCPs, DCPs, Design Documents, and Pre-Op Test Results Were Reviewed.

Circled items relate specifically to this calculation.

MDCP			DCP		PCR/PCN		
UNIT 1		UNIT 2	UNIT 1	UNIT 2	UNIT 1	UNIT 2	
0024-1	0815-1	5579-2	68	2006	5	1115	6878
0035-1	0831-1	6006-2	76	2014	80	5006	6995
0047-1	5010-1		78	2015	84	5012	8203
0133-1	5042-1		81	2021	86	5013	8455
0171-1	5054-1		109	2044	116	5022	8466
0176-1	5178-1		115	2083	121	5042	8468
0193-1	5228-1		117	2088	248	5510	8477
0302-1	5261-1		139	2092	620	5562	8595
0303-1	5579-1		156	2095		6005	20173
0363-1	5650-1		239	2103		6080	20176
0397-1	5658-1		289			6084	20179
0494-1	5663-1		367			6116	20181
0522-1	5716-1		493			6121	20216
0680-1	5770-1		558			6171	20319
0696-1	5709-1		559			6208	20321
0793-1	5791-1		563			6240	20329
0801-1	5906-1		2014			6241	20383
			2015			6306	20405
			2021			6331	20423
			2083			6354	20477
			2088			6373	20562
			2092			6494	20580
			2095			6569	20739
			2103			6620	20886

Other Design Documents

CALCULATION SHEET

RMV 11/30/88 △1
CALC. NO. M-51-62 REV. NO. ~~0~~ 1
ORIGINATOR R. M. VITANGCOL DATE 10/4/88
CHECKED Kris Narayan DATE 10/5/88
PROJECT LIMERICK UNIT 1 & 2
JOB NO. 8031
SUBJECT RHR SYSTEM NPSH
SHEET NO. 2b FOLLOWS BY PG 2a △4

checked by. Kris Narayan △1
12/1/88

PURPOSE

The purpose of this calculation is to determine whether an adequate NPSH is available in the RHR system during Post Accident operating MODES A-1, A-2 and B (Ref. 1) when the suppression pool water level drops to EL. 199'-11½" (SP Depth = 18.04') (REF 2) from the current design minimum level at elev. 203'-11" (SP Depth = 22'-0"), REF 8. IN ADDITION, THE NPSHA MARGIN FOR MODE B IS CALCULATED BASED ON THE ACTUAL DIRTY STRAINER PRESSURE DROP. △1 THIS ECR

ASSUMPTIONS

1. The suppression pool water level is at minimum level elevation of 203'-11" at the time of the accident. Since the downcomers are raised above the drywell floor, the water level in the suppression pool may drop to EL 199'-11½" △1 before recirculation is achieved.

2. The longest suction pipe routing (Unit 1 & 2) is considered in this calculation i.e suction piping of Pump 2AP202 or 2BP202 which are identical

3. Pipe lengths are gross distance between fitting centerlines. Fitting dimensions were not deducted.

THIS ECR

4. Maximum suppression pool suction strainer losses of 2.0* psid as specified in Ref 9 is used. △4

* THE ORIGINAL PURCHASE ORDER SPECIFIED A MAX dP ACROSS A SINGLE STRAINER @ FULL FLOW OF NO MORE THAN 2.0 PSID. FOR REV 4 OF THIS CALC A MAX dP OF 5.0 PSID IS USED TO ESTABLISH OPERABILITY CRITERIA. SEE REV 4 PAGES 15-20. △4

BECHTEL

CALCULATION SHEET

R. Vitangcol △2 12/29/88 RMV 11/30/88 △1

CALC. NO. M-51-62 REV. NO. ~~0~~ ~~1~~ 2

ORIGINATOR R.M. VITANGCOL DATE 10/4/88

CHECKED Kris Narayan DATE 10/~~12~~5/88

PROJECT LIMERICK UNIT 1&2

JOB NO. 8031

SUBJECT RHR SYSTEM NPSH

SHEET NO. 2a FOLLOWED BY PG 3 △4

checked by: Kris Narayan 12/1/88 △1

Kris Narayan 12/29/88 △2

ASSUMPTIONS (CONT.)

5. Pump suction nozzle ℄ elevation is assumed to be the same as the pump impeller eye ℄. △4

6. Flow is assumed to be thru one suction leg only.

7. Velocity head is not considered.

8. MAXIMUM ALLOWABLE DIRTY STRAINER PRESSURE DROP IS 12 ft H_2O AT 212.5°F AS SPECIFIED IN REFERENCE 11 AND REFERENCE 13. THIS ECR

REFERENCES

1. G.E. Process Diagrams for Residual Heat Removal System.
   - a). Dwg. No. 761E292AD Sh. 1, Rev. ~~7~~ 10, Bechtel No. 8031-M-1-E11-1020-G-002(1) ~~1~~ 4 THIS ECR
   - b). Dwg. No. 761E292AD Sh. 3, Rev. 7, Bechtel No. 8031-M-1-E11-1020-G-002(3). 1

2. Calculation No. 8031-MISC-62, Rev. 3 (Intermediate Break Accident, IBA at 600 seconds, Worst Case) △2

3. Bechtel Drawings, Piping Isometric

HBB-117-1, Rev. 16
HBB-118-4, Rev. 13
HBB-117-2, Rev. 16
HBB-118-5, Rev. 11
HBB-117-3, Rev. 17
HBB-118-6, Rev. 11

CALCULATION SHEET

CALC. NO. M-51-62 REV. NO. 0
ORIGINATOR R. M. VITANGCOL DATE 10/4/88
CHECKED Kris Naveyo DATE 10/5/88
PROJECT LIMERICK UNIT 1 & 2
JOB NO. 8031
SUBJECT RHR SYSTEM NPSH
SHEET NO. 3 ~~OF 142~~ △4

REFERENCES (CON'T)

3. HBB-117-4, Rev. 15
HBB-118-7, Rev. 11
HBB-217-1, Rev. 14
HBB-218-4, Rev. 9
HBB-217-2, Rev. 14
HBB-218-5, Rev. 8
HBB-217-3, Rev. 12
HBB-218-6, Rev. 8
HBB-217-4, Rev. 13
HBB-218-7, Rev. 8

4. Bechtel Drawings, Piping Spools marked as follows:
HBB-117-1-1, Rev. 2
HBB-117-2-1, Rev. 2
HBB-117-3-1, Rev. 2
HBB-117-4-1, Rev. 2
HBB-217-1-1, Rev. 0
HBB-217-2-1, Rev. 5
HBB-217-3-1, Rev. 4
HBB-217-4-1, Rev. 5

5. Crane Technical Paper #410, Sixth Printing
6. Crane Technical Paper #410, 1982 Printing
7. Cameron Hydraulic Data, IR, Sixteenth Edition
8. Bechtel Dwg. 8031-M-247, Rev. 23
9. ~~Specification No. 8031-M-162, Rev. 3~~ | THIS ECR
10. RHR Pump Performance Test Curve, IR No. N-693, Rev. 0 FOR 0BP202; Bechtel No. 8031-M1-E11-C002-J-18.1.

ALL PUMP CURVES WERE CONSIDERED. E11-C002-J-12 THROUGH J-19. △4

REFERENCES CONTINUED ON PAGE 3A

| THIS ECR

SFP-20769 Rev. (6/76)

ED-69 (5/76)

REFERENCES (CONTINUED)

11. Specification No. NE-265, Revision 1, Specification for ECCS Suction Strainers.

12. Bechtel Drawing 8031-M-277, Revision 66.

13. SDOC NE-265-00037, Revision ~~0~~ 1: ABB Calculation 599-PENG-CALC-060, Revision 0, Limerick ECCS Strainer Sizing for Debris Loading and Pressure Drops.

14. SDOC NE-265-18, Revision 0: ABB Calculation MISC-PENG-CALC-062, Revision 0, Evaluation of Predictions and Data for Prototype Strainer.

CALCULATION SHEET

RMV 11/30/88 △1

CALC. NO. M-51-62 REV. NO. ~~0~~ 1

ORIGINATOR R. M. VITANGCOL DATE 10/4/88

CHECKED Kris Narayan DATE 10/5/88

PROJECT LIMERICK UNIT 1 & 2

JOB NO. 8031

SUBJECT RHR SYSTEM NPSH

SHEET NO. 4 ~~OF 140~~ △4

Checked by: Kris Narayan 12/1/88 △1

SUMMARY OF RESULTS*

MODE	NPSHA	NPSHR	REF. SH. NO
A-1	35.44 ~~38.14 FT~~	5 FT.	23 ~~10~~
A-2	25.72 ~~34.17 FT~~	6 FT	25 ~~12~~
B	10.62 ~~17.54 FT.~~	5 FT**	27 ~~14~~

△4 THIS ECR △1

** SEE PAGE 27 FOR ADDITIONAL DISCUSSION REGARDING NPSH REQUIREMENTS SPECIFIED BY REFERENCE 1. SEE PAGE 30 FOR NPSHA MARGIN FOR MODE B BASED ON ACTUAL DIRTY STRAINER ΔP

CONCLUSION*

~~The calculated NPSHA shows that the system provides sufficient margin over the required NPSH during accident modes at a lower suppression pool water level as stated in assumption 1. A higher NPSH margin is expected in the actual operation due to conservatism included in the calc. as stated in assumptions 3, 4, 6 and 7.~~ △4

~~* THESE RESULTS ARE BASED ON THE ORIGINAL DESIGN BASIS FOR THE SUCTION STRAINERS OF NO MORE THAN 2.0 PSID ACROSS ONE STRAINER AT FULL FLOW (THE OTHER STRAINER FULLY FOULED, I.E., THE UNIT BEING 50% FOULED). IN REV 4 OF THIS CALC, THE DESIGN BASIS FOR THE SYSTEM IS CHANGED TO ALLOW A MAXIMUM OF 5.0 PSID ACROSS THE STRAINER. ADEQUATE NPSHA IS PROVEN IN REV 4 PAGES 15 - 20. THE RESULTS AND CONCLUSIONS ON THIS PAGE ARE THEREFORE NO LONGER VALID.~~ △4 THIS ECR

* SEE PAGES 24, 26, 29 and 31. NOTE RESULTS FOR MODE A-2 & B ARE BASED ON MAXIMUM ALLOWABLE DIRTY STRAINER ΔP.

CALCULATION SHEET

BECHTEL

ORIGINATOR R. M. VITANGCOL DATE 10/4/88
CALC. NO. M-51-62 REV. NO. 0
CHECKED Kris Narayan DATE 10/5/88
PROJECT LIMERICK UNIT 1 & 2
JOB NO. 8031
SUBJECT RHR SYSTEM NPSH
SHEET NO. 5 ~~of 10~~ 4

RHR PUMP SUCTION MATERIAL TAKE-OFF

(REFERENCES 3 and 4)

PUMP NOS.

24" LINE	1AP202	1BP202	1CP202	1DP202	2AP202	2BP202	2CP202	2DP202
STR. PIPE	49.5'	49.5'	49.0'	49.0'	53.0'	53.0'	48.5'	48.5'
90° Elbow	3	3	3	3	4	4	3	3
Tee, Br	1	1	1	1	1	1	1	1
Tee FT	1	1	1	1	1	1	1	1
Gate Valve	1	1	1	1	1	1	1	1
24"× 30" Exp	1	1	1		1	1	1	1

30" LINE								
Str. Pipe	5.25'	5.25'	5.25	5.25	5.25	5.25	5.25	5.25
90° ELBow	2	2	2	2	2	2	2	2.

BASED ON THE ABOVE, THE LONGEST SUCTION LINE IS EITHER PUMP #2AP202 OR 2BP202. THIS WILL BE USED AS THE BASIS FOR THIS NPSHA CALCULATION.

EQUIVALENT PIPE LENGTHS (REF. 5)

24" LINE	ID	L/D	EQ. L. (FT)
STR. PIPE	23.25"	—	53
4-90° ELBOW	↓	30	233.0
1-Tee Br		60	116.0
1-Tee F.T.		20	39.0
1-Gate Va		13	25.0
1- 24"×30" EXP.		4.35	8.5 (SEE SH. 7)
TOTAL EQ. L			474.5

CALCULATION SHEET

RMV 11/30/88 △1

CALC. NO M-51-62 REV. NO. 01

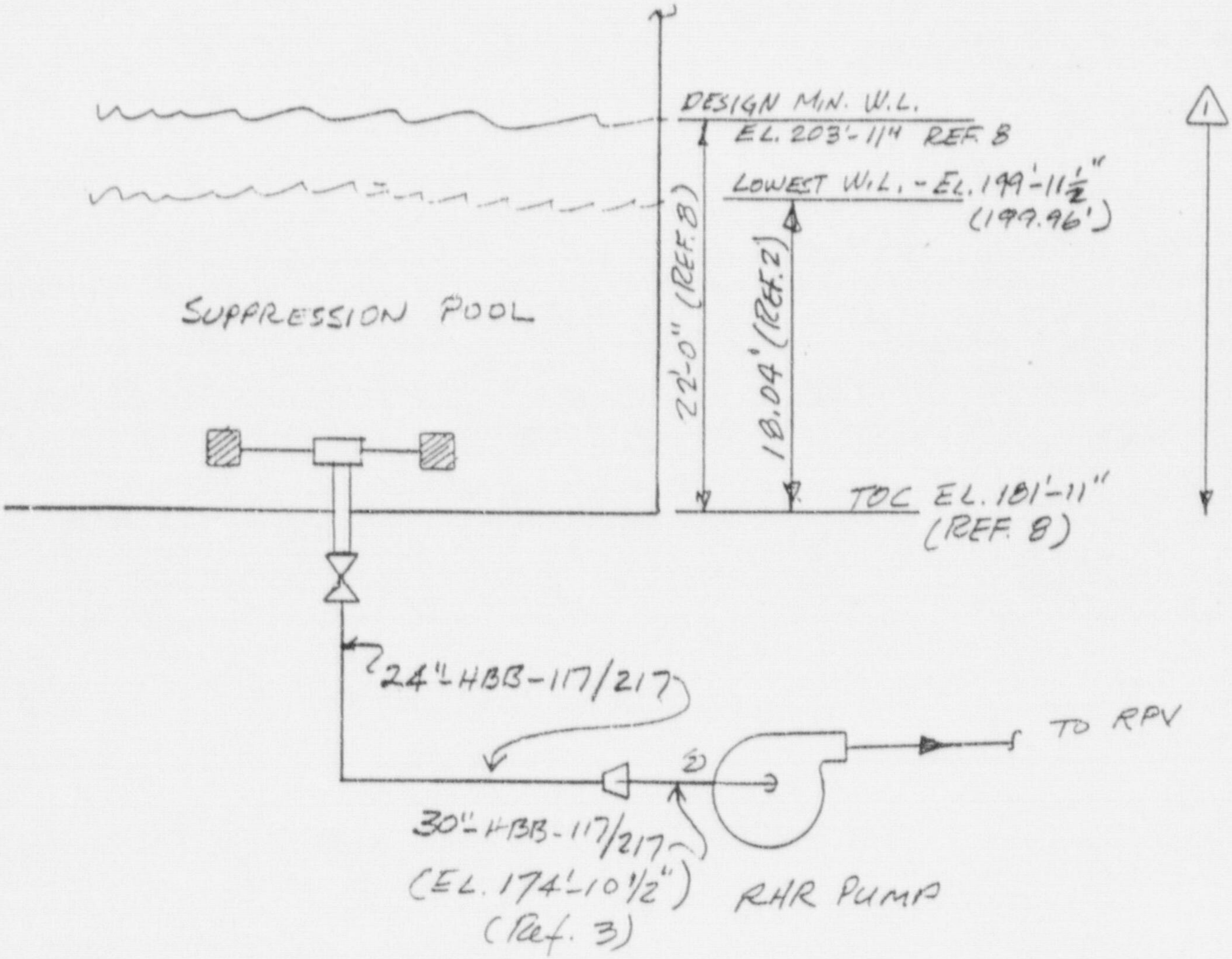
ORIGINATOR R. M. VITANGCOL DATE 10/4/88 CHECKED Kris Narayan DATE 10/5/88

PROJECT LIMERICK UNIT 1 & 2 JOB NO. 8031

SUBJECT RHR SYSTEM NPSH SHEET NO. 6 ~~OF 14~~ △1

Checked by: Kris Narayan 12/1/88 △1

30" LINE	ID	L/D	EQ. L.
STR. PIPE	29.25"	—	5.25
2 - 90° ELBOW	29.25	30	146.25
TOTAL EQ. L.			151.50'
		SAY	152'



SFP-20768 Rev (6/76)

ED-69 (5/76)

BECHTEL

CALCULATION SHEET

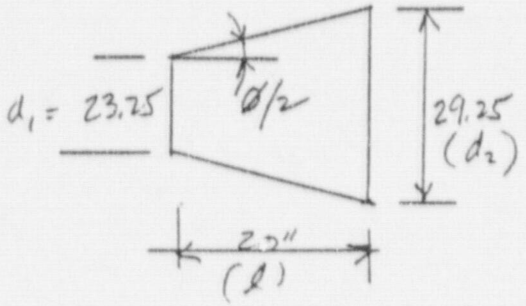
CALC. NO. M-51- REV. NO. 0

ORIGINATOR R. M. VITANGCOL DATE 10/4/88 CHECKED KNS Narayan DATE 10/5/88

PROJECT LIMERICK UNIT 1 & 2 JOB NO. 8031

SUBJECT RHR SYSTEM NPSH SHEET NO. 7 ~~OF 142~~ △4

CALCULATE L/D FOR 24" x 30" INCREASER (Ref 6)



$K = 2.6 \sin \phi/2 \, (1-\beta^2)^2$ (smaller pipe dia. is referenced)

$\beta = \frac{d_1}{d_2} = \frac{23.25}{29.25} = 0.795$

$\phi/2 = \tan^{-1}\left[\frac{(d_2-d_1)\frac{1}{2}}{\ell}\right] = \tan^{-1}\left[\frac{(29.25-23.25)}{2 \times 20}\right] = 8.53°$

$K = 2.6 \, (\sin 8.53) \, (1-.795^2)^2$

$= 0.0522$

$h_f = \left(f \frac{L}{D}\right) \frac{V^2}{2g} \quad K = f \, L/D$

$L/D = \frac{K}{f}$ where f = 0.012 (for 18"-24 pipe) (Ref. 6)

$= \frac{0.0522}{.012} = 4.35$

SFP-20768 Rev. (6/76) ED-69 (5/76)

CALCULATION SHEET

RMV 11/30/88 △1

CALC. NO. M-51-62 REV. NO. ~~Ø~~ 1

ORIGINATOR R.M. VITANGCOL DATE 10/14/88 CHECKED Kris Narayan DATE 10/15/88

PROJECT LIMERICK UNIT 1 & 2 JOB NO. 8031

SUBJECT RHR SYSTEM NPSH SHEET NO. 8 ~~OF 12~~ △4

checked by: Kris Narayan 12/1/88 △1

CALCULATE NPSHA FOR MODE "A-1" (REF. 1)

→ SEE PAGE 21 FOR MODE A-1

MODE A-1 IS NOT NPSH LIMITING, AND IS NOT RECALCULATED FOR REV 4 CHANGES △4

OPERATING CONDITIONS

FLOW - 10,150 GPM

TEMPERATURE - 170 °F

Specific Wt @ 170°F(ρ) = 60.79 #/FT3 (ρ) (REF. 7)

Min. SUPP. POOL W.L. Depth = 18.04' } REF. 2

ELEV. = 199'-11 1/2" }

△1

Pressure @ SUPPRESSION Pool = 14.7 psia (Ref 1)

Vapor pressure @ 170°F - 5.99 psia (Ref. 7)

Pump Suction Elevation — 174'-10 1/2" or 174.875' (Ref.

$$NPSH = h_a - h_{vpa} + h_{st} - h_{fs} \quad (Ref\ 7)$$

where h_a = absolute pressure (in ft of liquid) on the surface of liquid supply level

△4

h_{vpa} = head (in feet) corresponding to to the vapor pressure of the liquid being pumped.

h_{st} = Static head (in feet) of liquid above centerline of impeller eye.

h_{fs} = Suction line friction losses. (in feet)

SFP 20768 Rev. (6/76) ED-69 (5/76)

CALCULATION SHEET

CALC. NO. M-51-62 REV. NO. 0

ORIGINATOR R. M. VITANGCOL DATE 10/4/88 CHECKED Krishnaswamy DATE 10/5/88

PROJECT LIMERICK UNIT 1 & 2 JOB NO. 8031

SUBJECT RHR SYSTEM NPSH SHEET NO. 9 ~~OF 142~~ △4

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Calculate suction line losses (ΔP)

$$\Delta P = 0.000216 \frac{f L \rho Q^2}{d^5}$$ (Ref 5)

△4

where ΔP = friction losses in psi.
Q = Flow in gpm
L = Length of pipe in ft
d = Internal diameter of pipe, inches
ρ = Wt density of fluid, #/FT³
f = friction factor.

Re (Reynolds No. of Flow in Pipe) (Ref 5)

$$R_e = 50.6 \frac{Q\rho}{d\mu}$$

μ = absolute (dynamic) viscosity, in Centipoise.
= 0.4 @ 170°F (Ref 5)

ΔP @ 24" Line

$$R_e = \frac{50.6 \times 10{,}150 \times 60.79}{23.25 \times 0.4} = 3.35 \times 10^6$$

$\frac{e}{D}$ (Relative pipe roughness) 24"ϕ, commercial steel pipe (Ref 5)

$= 0.000072$

$f = 0.0115$ (REF 5)

$$\Delta P_{24"\phi} = \frac{2.16 \times 10^{-4} \times 0.0115 \times 474.5 \times 60.79 \times (10{,}150)^2}{(23.25)^5}$$

$= 1.09$ PSI ✓

SFP-20768 Rev. (6/76)

ED-69 (5/76)

CALCULATION SHEET

RMV 11/30/88 △1

ORIGINATOR R. M. VITANGCOL DATE 10/4/88

CALC. NO. M-51-62 REV. NO. ~~0~~ 1

CHECKED Kris Narayan DATE 10/5/88

PROJECT LIMERICK UNIT 1 & 2

JOB NO. 8031

SUBJECT RHR SYSTEM NPSH

SHEET NO. 10 ~~OF 14~~ △4

Checked by: Kris Narayan △1
12/1/88

△4

ΔP @ 30" LINE

$$R_e = \frac{52.6 \times 10,150 \times 60.79}{29.25 \times .4} = 2.66 \times 10^6$$

e/D (30" Comm. Steel Pipe) = 0.00006 (Ref 5)

$$f = 0.0118$$

$$\Delta P = \frac{2.16 \times 10^{-4} \times 0.0118 \times 152 \times 60.79 \times (10,150)^2}{(29.25)^5}$$

$$= 0.113 \text{ psi}$$

$$h_{fs} = \Delta P_{24''} + \Delta P_{30''} + \Delta P_{STRAINER} \text{ (Ref. 9)}$$

$$= (11.09 + 0.113 + 2.0)\frac{144}{60.79}$$

$$= 7.58 \text{ ft}$$

h_{ST} = Min. W.L. @ Suppression Pool − Elev. @ ℄ of Pump Suction Nozzle.

$$= 199.96 - 174.875$$

$$= 25.085 \text{ ft} ✓$$

△1

$$\text{NPSHA (MODE A-1)} = \frac{144}{60.79}(14.7-\overset{5.71}{5.99}) + 25.085 - 7.58$$

$$= \underline{\underline{38.137}} \text{ ft. SAY } 38.14$$

RHR PUMP TYPICAL NPSHR @ 10,150 gpm = 5 ft. (Ref 10)

SFP-20768 Rev. (6/76)

ED-69 (5/76)

CALCULATION SHEET

RMV 11/30/88 △1

ORIGINATOR R. M. VITANGCOL DATE 10/4/88

CALC. NO. M-51-62 REV. NO. ~~0~~ 1

CHECKED Kris Narayan DATE 10/5/88

PROJECT LIMERICK UNIT 1 & 2

JOB NO. 8031

SUBJECT RHR SYSTEM NPSH

SHEET NO. 11 ~~of 14~~ △4

Checked by: Kris Narayan △1
12/11/88

CALCULATE NPSHA FOR MODE A-2 (Ref. 1)

TMS
ECF

→ See Pg 25 for Mode A-2

Mode A-2 is not NPSH limitting and is not re-calc'd for Rev 4.

△4

~~OPERATING CONDITIONS~~

~~Flow – 11,000 gpm~~

~~Temperature – 180°F~~

~~Sp. Wt. @ 180°F (ρ) = 60.57 #/FT3 (Ref. 7)~~

~~Vapor Pressure @ 180°F = 7.511 psia (Ref. 7)~~

~~Pressure @ Suppression Pool – 14.7 psia (Ref. 1)~~

~~Min. W.L. @ Suppression Pool – EL 199'-11½" (Ref 2)~~ △1

~~Pump Suction ℄ elevation – EL. 174-10½" (Ref 3)~~

~~NOTE: Use Equations in Mode A-1~~

~~ΔP @ 24" LINE~~

$$R_e = \frac{50.6 \times 11{,}000 \times 60.57}{23.25 \times .35}$$

μ = 0.35 centipois. @ 180°F (Ref. 5)

$$= 4.14 \times 10^6$$

$$e/D = 0.000072 \text{ (Ref. 5)}$$

$$f = 0.0113 \text{ (Ref. 5)}$$

$$\Delta P_{24''\phi} = \frac{2.16 \times 10^{-4} \times .0113 \times 474.5 \times 60.57\,(11{,}000)^2}{(23.25)^5}$$

$$= 1.25 \text{ psi}$$

△4

SFP-20768 Rev. (6/76)

ED-69 (5/7

CALCULATION SHEET

RMV 11/30/88 △1

CALC. NO. M-51-62 REV. NO. ~~0~~ 1

ORIGINATOR R. M. VITANGCOL DATE 10/4/88 CHECKED Kris Narayan DATE 10/5/88

PROJECT LIMERICK UNIT 1 & 2 JOB NO. 8031

SUBJECT RHR SYSTEM NPSH SHEET NO. 12 ~~OF 14~~ △4

checked by. Kris Narayan △1
12/1/88

ΔP @ 30" LINE

$$R_e = \frac{50.6 \times 11{,}000 \times 60.57}{29.25 \times .35} = 3.29 \times 10^6$$

e/D (30" Comm. Stl. Pipe) = 0.00006 (Ref. 5)

$$f = 0.0113$$

$$\Delta P = \frac{2.16 \times 10^{-4} \times .0113 \times 152 \times 60.57 \times (11{,}000)^2}{(29.25)^5}$$

$$= 0.127 \text{ PSI}$$

$$h_{fs} = \Delta P_{24''\phi} + \Delta P_{30''\phi} + \Delta P_{STRAINER} \text{ (Ref. 9)}$$

$$= (1.25 + 0.127 + 2.0)\frac{144}{60.57}$$

$$= \underline{\underline{8.0 \text{ ft}}}$$

$$h_{ST} = 199.96 - 174.875 = 25.085 \text{ ft}$$

$$\text{NPSHA (MODE A-2)} = \frac{144}{60.57}(14.7 - 7.511) + 25.085 - 8.0$$

$$= \underline{34.17} \text{ ft}$$

△1

RHR PUMP TYPICAL NPSHR @ 11,000 gpm = 6 ft (Ref. 10)

△4

CALCULATION SHEET

BECHTEL

RMV 11/30/88 △1

CALC. NO. M-51-62 REV. NO. ~~0~~ 1

ORIGINATOR R.M. VITANGCOL DATE 10/4/88

CHECKED Kris Narayan DATE 10/5/88

PROJECT LIMERICK UNIT 1 & 2

JOB NO. 8031

SUBJECT RHR SYSTEM NPSH

SHEET NO. 13 ~~OF 142~~ △4

checked by: Kris Narayan △1 12/1/88

CALCULATE NPSHA FOR MODE "B" (Ref 1)

→ SEE Pg 27 For MODE B | THIS EER

MODE B IS NPSH LIMITTING AND IS RECALC'D ON PAGES 15-20 FOR REV 4. △4

OPERATING CONDITIONS

Flow — 10,000

Temperature — 212 °F

Sp. wt (ρ) @ 212°F = 59.81 (Ref 7)

Vapor Pressure @ 212°F = 14.696 say 14.7 " (Ref. 7)

Pressure @ Suppression Pool = 14.7 psia (Ref. 1)

Min. W.L. @ " " = EL. 199'-11½" (Ref. 2) △1

Pump Suction ℄ Elevation = EL. 174'-10½" (Ref 3)

NOTE: EQUATIONS USED AS IN MODE A-1

ΔP @ 24" LINE

$$R_e = \frac{50.6 \times 10{,}000 \times 59.81}{23.25 \times 0.29}$$

$\mu = 0.29$ @ 212°F (Ref 5)

$$= 4.49 \times 10^6$$

$e/D = 0.000072$ (Ref 5)

$f = 0.0115$ (Ref 5)

$$\Delta P_{24''\phi} = \frac{2.16 \times 10^{-4} \times .0115 \times 474.5 \times 59.81 \times (10{,}000)^2}{(23.25)^5}$$

$$= 1.03 \text{ psi}$$

△4

CALCULATION SHEET

BECHTEL

RMV 11/30/88 △1

CALC. NO. M-51-62 REV. NO. ~~0~~ 1

ORIGINATOR R. M. VITANGCOL DATE 10/4/88

CHECKED Kris Narayan DATE 10/5/88

PROJECT LIMERICK UNIT 1 & 2

JOB NO. 8031

SUBJECT RHR SYSTEM NPSH

SHEET NO. 14 ~~OF 14~~e △4

Checked by: Kris Narayan △1
12/1/88

ΔP @ 30" LINE

$$R_e = \frac{50.6 \times 10{,}000 \times 59.81}{29.25 \times 0.29} = 3.57 \times 10^6$$

e/D (30" Comm. stl. pipe) = 0.00006 (Ref. 5)

$$f = 0.0113$$

$$\Delta P_{30"\phi} = \frac{2.16 \times 10^{-4} \times .0113 \times 152 \times 59.81 \times (10{,}000)^2}{(29.25)^5}$$

$$= 0.103 \text{ psi}$$

$$h_{fs} = \Delta P_{24"\phi} + \Delta P_{30"\phi} + \Delta P_{STRAINER} \text{ (Ref. 9)}$$

$$= (1.03 + 0.103 + 2.0)\frac{144}{59.81}$$

$$= 7.54 \text{ ft.}$$

$$h_{ST} = 199.96 - 174.875 = 25.085 \text{ ft}$$

$$\text{NPSHA (MODE B)} = \frac{144}{59.81}\overset{0}{(14.7-14.7)} + 25.085 - 7.54$$

$$= \underline{\underline{17.54}} \text{ ft}$$

RHR PUMP TYPICAL NPSHR @ 10,000 gpm = 5 ft. (Ref 10

△4

SFP-20768 Rev. (6/76)

THIS ECR

REVISION 4

Purpose

To re-evaluate the net positive suction head available (NPSHA) for the residual heat removal (RHR) system with suction aligned from the suppression pool (SP) under the worst expected conditions and with an increase in the maximum allowable differential pressure across the suction strainer of 5.0 psid (the original design was 2.0 psid).

During the regular pump valve and flow tests, measurements will be taken of the pressure at the pump suction (PP-51-102A-D and PP-51-202A-D) with suction aligned to the SP and with no flow (static) and with design rated (10,000 gpm) flow (dynamic). The purpose of these measurements is to show loop capability for LGS Technical Specification requirements. An additional purpose of this calculation is to establish the maximum value for the difference between these two measured pressures beyond which the loop may not satisfy its safety function.

Results

With suction aligned from the SP, under worst expected conditions (212°F and 1 atm), with a pump flow rate of 11,000 gpm, a SP level of 199' 11½", and a maximum allowable differential pressure across the suction strainer of 5.0 psid, the calculated net positive suction head available is

NPSHA = **7.97** feet

The margin to the net positive suction head required by the pump is,

Margin = **2.0** feet

With a system test (SP to SP) flow rate of 10,000 gpm, the maximum allowed change in suction pressure measured at PP-51-1(2)02A(-D) is 6.3 psid.

$P_{static} - P_{dynamic} > 6.3$ psid **Max. Allowed**

These results are applicable to both LGS Unit 1 and Unit 2.

Inputs

T = 212 °F
P = 45 psia (only used to determ ρ and μ)
ρ = 59.81992 lbm/cuft
μ = 0.28222 cp

P_a = 1 atm
P_v = 1 atm

Q = 11,000 gpm
d = 23.25 inches

$L_{eq}(24")$ = 474.5 feet
$L_{eq}(30")$ = 151.5 feet

Z_{SP} = 199.95833 feet
Z_{pump} = 174.87500 feet

NPSHR = 6.0 feet @ 11,000 gpm

Calculations

NET POSITIVE SUCTION HEAD AVAILABLE

Flow losses (not including strainer, from page 3-2 of References 5 & 6,

$$Re = 50.65929 \frac{Q \rho}{\mu d}$$

$$= 5.08 \text{ E+06}$$

To account for 40 year life, assume a roughness factor of 0.00085 feet (equivalent to cast iron)

From page A-24 of References 5 & 6,

$f = 0.0163351$.

From page 3-2 Equation 3-5 of Reference 5 & 6,

$$\Delta P_f = 2.161037233E\text{-}4 \frac{f \rho Q^2}{d^5} L_{eq}$$

$$L_{eq} = 474.5 + 151.5 \times \left(\frac{23.25}{29.25}\right)^5$$

$$= 522.57 \text{ feet}$$

$$\Delta P_f = 2.161037233E\text{-}4 \frac{(0.0163351)(59.81992)(522.57)(11000)^2}{(23.25)^5}$$

$$= 1.965 \text{ psid}$$

THIS
ECR

Calculations (Cont'd)

This ECR

Calculating the NPSHA, with $P_a = P_v$,

$$NPSHA = \frac{144}{\rho}(P_a - P_v - \Delta P_f - \Delta P_{strainer}) + Z_{SP} - Z_{pump}$$

$$= 199.95833 - 174.875 - \frac{144}{59.81992}(1.965 + 5.0)$$

$$= 8.317 \text{ feet @ } \rho = 59.81992 \text{ lbm/cuft}$$

$$= 8.317 \times \frac{59.81992}{62.4}$$

$$= 7.97 \text{ feet @ } \rho = 62.4 \text{ lbm/cuft}$$

Thus,

NPSHA = **7.97** feet

NPSHR = 6.00 feet (@ 11,000 gpm. Ref 10)

Margin = **2.00** feet

THIS ECR

Calculations (Cont'd)

MAXIMUM VALUE

The pressure loss due to flow calculated above considered the longest suction line from the SP and assumed a roughness factor of 0.00085 to account for a 40 year life. The equivalent length calculated is therefore conservative for the calculation of NPSHA, but should not be used to evaluate a maximum value for a measured difference in suction pressure between static and dynamic conditions because it would attribute more measured flow dP to the line itself and less to the strainer. Thus a conservatively LOW value of equivalent length should be used for this part of the calculation.

It is conservative to assume the hotest SP temperature expected during the test, that of the maximum SP temperature allowable by Technical Specification during normal plant operation, 95°F.

T = 95 °F
P = 45 psia
ρ = 62.06687 lbm/cuft
μ = 0.71955 cp

Q = 10,000 gpm

Calculating the Reynold's Number for these input parameters yields,

$$Re = 50.65929 \frac{Q \rho}{\mu d}$$

$$= 1.88 \text{ E+06}$$

and using clean pipe with a roughness factor of 0.00015, we get a friction factor of,

$$f = 0.0124405$$

Re-evaluating the a total equivalent line length using shorter line lengths of,

$L_{eq}(24")$ = 450 feet
$L_{eq}(30")$ = 100 feet

$$L_{eq} = 450 + 100 \times \left(\frac{23.25}{29.25}\right)^5$$

$$= 481.73 \text{ feet}$$

THIS ECR

Calculations (Cont'd)

Evaluating the line losses (not including the suction strainer),

$$\Delta P_f = 2.161037233E-4 \frac{(0.0124405)(62.06687)(481.73)(10000)^2}{(23.25)^5}$$

$$= 1.183 \text{ psid}$$

The difference between the pressure at the pump suction (PP) at static conditions and at dynamic conditions can be expressed as,

$$\Delta P = P_{static} - P_{dynamic}$$

$$= \Delta P_f + \Delta P_v + \Delta P_{strainer}$$

where,

P_{static} = pressure at the pump suction with no flow
$P_{dynamic}$ = pressure at the pump suction with flow
ΔP_f = pressure loss due to flow (not including the suction strainer)
ΔP_v = pressure loss due to velocity (i.e. the velocity head in psid)
$\Delta P_{strainer}$ = maximum allowable pressure drop across the strainer (5.0 psid)

The pressure loss due to velocity is evaluated, using the 30" suction pipe (since the pressure tap is in the 30" portion of the suction line) as,

$$\Delta P_v = 1.80086E-5 \frac{\rho Q^2}{d^4}$$

$$= 1.80086E-5 \frac{(62.06687)(10000)^2}{(29.25)^4}$$

$$= 0.1527 \text{ psid}$$

TMS
ECR

Calculations (Cont'd)

Thus the difference between the measured suction pressure at static conditions and at dynamic conditions becomes,

$$\Delta P = \Delta P_f + \Delta P_v + \Delta P_{strainer}$$

$$= 1.18 + 0.15 + 5.00$$

$= 6.3$ psid Max. Allowed

1. CALCULATE NPSHA FOR MODE "A-1" (REF. 1)

Operating Conditions

Flow = 10,150 gpm
Temperature = 170 °F
Specific Weight @ 170 °F = 60.79 lb/ft^3 (Ref 7)
Minimum Suppression Pool W.L. Depth = 18.04 ft (Ref 2)
Minimum Suppression Pool W.L. Elevation = 199'-11½" (Ref 2)
Pressure @ Suppression Pool = 14.7 psia (Ref 1)
Vapor Pressure @ 170 °F = 5.99 psia (Ref 7)
Pump Suction Elevation = 174.875 ft (Ref 3)

NPSHA = $h_a - h_{vpa} + h_{st} - h_{fs}$

where,

h_a = absolute pressure (in feet of liquid) on the surface of liquid supply level

h_{vpa} = head (in feet) corresponding to the vapor pressure of the liquid being pumped

h_{st} = static head (in feet) of liquid above centerline of impeller eye

h_{fs} = suction line friction losses (in feet)

Calculate Suction Line Losses (ΔP)

$$\Delta P = 0.000216 \frac{f\ L\rho\ Q^2}{d^5} \qquad \text{(Ref 5)}$$

where,

ΔP = friction losses, psi
Q = flow, gpm
L = length of pipe, ft
d = internal diameter of pipe, inches
ρ = weight density of fluid, lb/ft^3
f = friction factor

Reynolds Number of Flow in Pipe

$$\mathrm{Re} = 50.6\frac{Q\,\rho}{d\;\mu} \qquad \text{(Ref 5)}$$

where,

μ = absolute (dynamic) viscosity in centipoise = 0.4 @ 170 °F (Ref 5)

ΔP @ 24" Line

$$\mathrm{Re} = \frac{(50.6)(10{,}150)(60.79)}{(23.25)(0.4)} = 3.35x10^{6}$$

ε/D (Relative Pipe Roughness)
Use Cast Iron Pipe to account for Pipe Aging
24" DIA, Cast Iron Pipe = 0.0004 (Ref 5)

f = 0.016 (Ref 5)

$$\Delta P_{24"} = 0.000216\frac{(0.016)(474.5)(60.79)(10150)^{2}}{(23.25)^{5}}$$

$$= 1.51 \text{ psi}$$

ΔP @ 30" Line

$$\mathrm{Re} = \frac{(50.6)(10{,}150)(60.79)}{(29.25)(0.4)} = 2.66x10^{6}$$

ε/D (Relative Pipe Roughness)
Use Cast Iron Pipe to account for Pipe Aging
30" DIA, Cast Iron Pipe = 0.00034 (Ref 5)

f = 0.015 (Ref 5)

$$\Delta P_{30"} = 0.000216\frac{(0.015)(152)(60.79)(10150)^{2}}{(29.25)^{5}}$$

$$= 0.144 \text{ psi}$$

ΔP of Suction Strainer

Dirty ΔP @ 11,000 gpm @ 180°F = 7.11 ft (Ref 13)

For Mode A-1 the strainer ΔP @ 10,150 gpm @ 170°F is needed.

The 10°F difference in temperature between Mode A-1 conditions and Reference 13 is addressed in the note on page 24.

The dirty strainer ΔP given in Reference 13 consists of normal system losses and bed losses (the layer of debris consisting of fiber and corrosion products). When adjusting the ΔP for various flow rates the system losses are proportional to the square of the flow rates , while the bed losses have a linear relationship to the flow rates (Reference 14).

From Reference 13 the actual system losses are 2.85 ft and the bed losses are 4.26 ft @ 11,000 gpm @ 180°F.

Therefore, the dirty ΔP @ 10,150 gpm @ 180°F is:

$$(2.85\ ft)\left(\frac{10{,}150}{11{,}000}\right)^2 + (4.26\ ft)\left(\frac{10{,}150}{11{,}000}\right) = 6.36\ ft\ H_2O$$

Total Suction Line Friction Losses

$h_{fs} = \Delta P_{24"} + \Delta P_{30"} + \Delta P_{STRAINER}$

$h_{fs} = (1.51 + 0.144)(144/60.79) + 6.36 = 10.28$ ft H_2O

Static Head

h_{st} = Min W.L. @ Suppression Pool - Elevation @ Center Line of Pump Suction Nozzle

h_{st} = 199.96 ft - 174.875 ft = 25.085 ft

MODE A-1 NPSHA

$NPSHA = h_a - h_{vpa} + h_{st} - h_{fs}$

$NPSHA = (14.7 - 5.99)(144/60.79) + 25.085 - 10.28 = 35.44$ ft H_2O

RHR Pump NPSHR @ 10,150 gpm = 5 ft H_2O (Ref 10)

NPSHA > NPSHR

NOTE - the dirty strainer ΔP used is for 180°F. Based on Reference 14 the strainer ΔP will be slightly greater at 170°F (from 180°F to 100°F the strainer ΔP only increases by approximately 2 ft). Since the NPSHA @ 180°F is greater than the NPSHR by approximately 30 ft the slight increase in strainer ΔP from 180°F to 170°F will not result in the NPSHA being less than the NPSHR for Mode A-1.

2. CALCULATE NPSHA FOR MODE "A-2" (REF. 1)

Operating Conditions

Flow = 11,000 gpm
Temperature = 180 °F
Specific Weight @ 180 °F = 60.57 lb/ft^3 (Ref 7)
Specific Weight @ 212 °F = 59.81 lb/ft^3 (Ref 7)
Minimum Suppression Pool W.L. Depth = 18.04 ft (Ref 2)
Minimum Suppression Pool W.L. Elevation = 199'-11½" (Ref 2)
Pressure @ Suppression Pool = 14.7 psia (Ref 1)
Vapor Pressure @ 180 °F = 7.511 psia (Ref 7)
Pump Suction Elevation = 174.875 ft (Ref 3)

NOTE: Equations for NPSHA, ΔP, and Reynolds Number are defined in the section of this calculation evaluating Mode A-1 (see page 21 and page 22).

ΔP @ 24" Line

μ = absolute (dynamic) viscosity in centipoise = 0.35 @ 180 °F (Ref 5)

$$\mathrm{Re} = \frac{(50.6)(11{,}000)(60.57)}{(23.25)(0.35)} = 4.14x10^{6}$$

ε/D (Relative Pipe Roughness)
Use Cast Iron Pipe to account for pipe aging.
24" DIA, Cast Iron Pipe = 0.0004 (Ref 5)

f = 0.016 (Ref 5)

$$\Delta P_{24"} = 0.000216\frac{(0.016)(474.5)(60.57)(11000)^2}{(23.25)^5}$$

$$= 1.77 \text{ psi}$$

ΔP @ 30" Line

$$\mathrm{Re} = \frac{(50.6)(11{,}000)(60.57)}{(29.25)(0.35)} = \text{[illegible]}9x10^{6}$$

ε/D (Relative Pipe Roughness)
Use Cast Iron Pipe to account for pipe aging.
30" DIA, Commercial Steel Pipe = 0.00034 (Ref 5)

f = 0.015 (Ref 5)

$$\Delta P_{30"} = 0.000216 \frac{(0.015)(152)(60.57)(11000)^2}{(29.25)^5}$$

$$= 0.169 \text{ psi}$$

ΔP of Suction Strainer

Actual Dirty ΔP @ 11,000 gpm @ 180 °F = 7.11 ft H_2O (Ref 13)

Maximum Allowable Dirty ΔP @ 11,000 gpm @ 212 °F = 12 ft H_2O (Ref 11 and Ref 13)
Converted to 180 °F = (12)(59.81/60.57) = 11.85 ft H_2O

Total Suction Line Friction Losses

$h_{fs} = \Delta P_{24"} + \Delta P_{30"} + \Delta P_{STRAINER}$

Based on Actual Strainer Dirty ΔP:
$h_{fs} = (1.77 + 0.169)(144/60.57) + 7.11 = 11.72$ ft H_2O

Based on Maximum Allowable Strainer Dirty ΔP:
$h_{fs} = (1.77 + 0.169)(144/60.57) + 11.85 = 16.46$ ft H_2O

Static Head

h_{st} = Min W.L. @ Suppression Pool - Elevation @ Center Line of Pump Suction Nozzle

h_{st} = 199.96 ft - 174.875 ft = 25.085 ft

MODE A-2 NPSHA

$NPSHA = h_a - h_{vpa} + h_{st} - h_{fs}$

NPSHA Based on Actual Strainer Dirty ΔP=
(14.7 - 7.511)(144/60.57) + 25.085 - 11.72 = 30.46 ft H_2O

NPSHA Based on Maximum Allowable Strainer Strainer Dirty ΔP=
(14.7 - 7.511)(144/60.57) + 25.085 - 16.46 = 25.72 ft H_2O

RHR Pump NPSHR @ 11,000 gpm = 6 ft H_2O (Ref 10)

NPSHA > NPSHR

3. CALCULATE NPSHA FOR MODE "B" (REF. 1)

Operating Conditions

Flow = 10,000 gpm
Temperature = 212 °F
Specific Weight @ 212 °F = 59.81 lb/ft^3 (Ref 7)
Minimum Suppression Pool W.L. Depth = 18.04 ft (Ref 2)
Minimum Suppression Pool W.L. Elevation = 199'-11½" (Ref 2)
Pressure @ Suppression Pool = 14.7 psia (Ref 1)
Vapor Pressure @ 212 °F = 14.696 psia (Ref 7)
Pump Suction Elevation = 174.875 ft (Ref 3)

NOTE: Equations for NPSHA, ΔP, and Reynolds Number are defined in the section of this calculation evaluating Mode A-1 (see page 21 and page 22).

ΔP @ 24" Line

μ = absolute (dynamic) viscosity in centipoise = 0.29 @ 212 °F (Ref 5)

$$Re = \frac{(50.6)(10,000)(59.81)}{(23.25)(0.29)} = 4.49x10^{6}$$

ε/D (Relative Pipe Roughness)
Use Cast Iron Pipe to account for pipe aging.
24" DIA, Cast Iron Pipe = 0.0004 (Ref 5)

f = 0.016 (Ref 5)

$$\Delta P_{24"} = 0.000216 \frac{(0.016)(474.5)(59.81)(10,000)^2}{(23.25)^5}$$

$$= 1.44 \text{ psi}$$

ΔP @ 30" Line

$$Re = \frac{(50.6)(10,000)(59.81)}{(29.25)(0.29)} = 3.57x10^{6}$$

ε/D (Relative Pipe Roughness)
Use Cast Iron Pipe to account for pipe aging.
30" DIA, Commercial Steel Pipe = 0.00034 (Ref 5)

f = 0.015 (Ref 5)

$$\Delta P_{30''} = 0.000216\frac{(0.015)(152)(59.81)(10{,}000)^2}{(29.25)^5}$$

$$= 0.138 \text{ psi}$$

ΔP of Suction Strainer

Maximum Allowable Dirty ΔP @ 212.5 °F @ 11,000 gpm = 12 ft H_2O (Ref 11 and Ref 13)

For Mode B the strainer pressure drop @ 212 °F @ 10,000 gpm is needed.

The ΔP associated with the strainer consists of normal system losses and bed losses (the layer of debris consisting of fiber and corrosion products). When adjusting the ΔP for various flow rates the system losses are proportional to the square of the flow rates while the bed losses have a linear relationship to the flow rates (Ref 14).

From Reference 13 the actual system losses are 2.85 ft @ 213 °F @ 11,000 gpm. Therefore it is assumed the maximum specified dirty ΔP of 12 ft from Reference 11 allows for 9.15 ft for bed losses.

Therefore the Maximum Dirty ΔP @ 212 °F @ 10,000 gpm is:

$$(2.85\ ft)\left(\frac{10{,}000}{11{,}000}\right)^2 + (9.15\ ft)\left(\frac{10{,}000}{11{,}000}\right) = 10.67\ ft\ H_2O$$

NOTE: The strainer ΔP obtained from Reference 11 is based on 212.5 °F and 11,000 gpm. The actual system losses obtained from Reference 13 is based on 213 °F and 11,000 gpm. The Mode B operating temperature is 212 °F (Reference 1). The difference in temperature is considered negligible based on the insignificant change in water properties between 212 °F, 212.5 °F, and 213 °F which would have no impact on NPSHA.

Total Suction Line Friction Losses

$h_{fs} = \Delta P_{24''} + \Delta P_{30''} + \Delta P_{STRAINER}$

$h_{fs} = (1.44 + 0.138)(144/59.81) + 10.67 \text{ ft} = 14.47 \text{ ft } H_2O$

Static Head

h_{st} = Min W.L. @ Suppression Pool - Elevation @ Center Line of Pump Suction Nozzle

h_{st} = 199.96 ft - 174.875 ft = 25.085 ft

MODE B NPSHA

NPSHA = $h_a - h_{vpa} + h_{st} - h_{fs}$

NPSHA = (14.7 - 14.7)(144/59.81) + 25.085 - 14.47 = 10.62 ft H_2O

RHR Pump NPSHR @ 10,000 gpm = 5 ft H_2O (Ref 10)

NPSHA > NPSHR

The GE RHR Process Diagram (Reference 1) requires the NPSHA at the pump suction nozzle to be ≥ 10.3 ft plus the difference in elevation between a reference location and the centerline of the pump suction nozzle. Reference 1 defines the reference location as 2 ft above the pump mounting flange. From Reference 12, the RHR pump mounting flange is at Elevation 177 ft. Therefore, based on the requirements of Reference 1, the NPSHA must be ≥ 14.43 ft (177 + 2 -174.875 + 10.3). From above, the RHR piping arrangement only provides 10.62 ft. Although the NPSHA does not meet the generic design requirements specified in Reference 1, NPSHA is considered acceptable based on the actual as-built pump vendor requirements in accordance with Reference 10.

4. NPSHA Margin For Mode B Based On Actual Dirty Strainer ΔP

The RHR System operating in Mode B is the limiting accident mode for NPSH, therefore the NPSHA margin based on the Actual dirty strainer ΔP will be based on Mode B conditions.

RHR Mode B NPSHA = 10.62 ft H_2O @ 10,000 gpm @ 212 °F (page 29 of this calculation)

The above NPSHA is based on the maximum allowable ΔP for the new large capacity passive strainers. The purpose of this calculation is to determine the NPSH margin based on the actual dirty strainer ΔP. Therefore, the above NPSHA will be adjusted to obtain the NPSHA based on the actual dirty strainer ΔP:

$$NPSHA_{Actual\ Dirty} = NPSHA_{Page\ 29} + \text{Maximum Allowable Dirty Strainer } \Delta P - \text{Actual Dirty Strainer } \Delta P$$

Maximum Allowable Dirty Strainer ΔP @ 10,000 gpm @ 212 °F = 10.67 ft H_2O (Page 28)

The Actual Dirty Strainer ΔP is obtained from Table 3 of Reference 11:

Actual Dirty Strainer ΔP @ 11,000 gpm @ 213 °F = Strainer System Losses + StrainerBed Losses

Actual Dirty Strainer ΔP @ 11,000 gpm @ 213 °F = 2.85 ft + 3.75 ft = 6.60 ft H_2O

NOTE: The Actual Dirty Strainer ΔP obtained from Reference 13 is based on 213 °F, however the actual Mode B temperature is 212 °F. This 1 °F difference is considered to have an insignificant affect on the strainer ΔP based on the insignificant change in water properties from 212 °F to 213 °F.

Adjusting Actual Dirty Strainer ΔP adjusted to 10,000 gpm:

As previoulsy stated the actual dirty strainer ΔP consists of strainer system losses and strainer bed losses. From Reference 14 the system losses are proportional to the square of the flow rates while the bed losses have a linear relationship to the flow rates. Therefore the Actual Dirty Strainer ΔP adjusted to 10,000 gpm:

$$(2.85\ ft)\left(\frac{10,000}{11,000}\right)^2 + (3.75\ ft)\left(\frac{10,000}{11,000}\right) = 5.76\ ft\ H_2O$$

Therefore,

$$NPSHA_{Actual\ Dirty} = 10.62\text{ ft} + 10.67\text{ ft} - 5.76\text{ ft} = 15.53\text{ ft } H_2O$$

Determine NPSHA Margin:

$$\text{NPSHA Margin} = \text{NPSHA}_{\text{Actual Dirty}} - \text{NPSHR}$$

NPSHR = 5 ft H_2O @ 10,000 gpm (Reference 10)

Therefore,

$$\text{NPSHA Margin} = 15.53 \text{ ft} - 5 \text{ ft} = 10.53 \text{ ft } H_2O$$

Therefore, there is sufficient margin between the RHR Pump NPSHA and the NPSHR when considering the actual dirty strainer ΔP of the new large capacity passive strainers.