Docket No. 50-271
BVY 04-058

Attachment 4

Vermont Yankee Nuclear Power Station

Proposed Technical Specification Change No. 263 – Supplement No. 8

Extended Power Uprate

Response to Request for Additional Information

EXHIBITS

Docket No. 50-271
BVY 04-058

Exhibit 1

Vermont Yankee Nuclear Power Station

Proposed Technical Specification Change No. 263 – Supplement No. 8

Extended Power Uprate

Response to Request for Additional Information

VYNPS Calculation VYC-0808 Revision 6 and CCN's 01, 03, 04 and 05
CS and RHR Pump NPSH Margin Following a LOCA or ATWS

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VY CALCULATON TITLE PAGE

VYC-808	6	NA	NA
VY Calculation Number	Revision #	Vendor Calculation #	Revision #

Title: Core Spray and Residual Heat Removal Pump Net Positive Suction Head Margin following a Loss of Coolant Accident With Fibrous Debris on the Intake Strainers

QA Status: ☒ SC ☐ NNS ☐ OQA Operating Cycle Number* NA

Calculation Supports A Design Change/Specification? ☐ Yes ☒ No NA (VYDC/MM/TM/Spec. No.)

Implementation Required? ☐ Yes ☒ No

Calculation Done as a Study Only? ☐ Yes ☒ No

Safety Evaluation Number: N/A

Superseded Calculation Number, Title, Revision: ① VYC-808, Core Spray and Residual Heat Removal Pump Net Positive Suction Head Margin following a Loss of Coolant Accident With Fibrous Debris on the Intake Strainers, Revision 5; ② VYC-1751, Core Spray and Residual Heat Removal Pump Strainer Loss following a Loss of Coolant Accident with Fibrous Debris on the New Intake Strainer, Revision 0. ③ VYC-1678, Limiting Debris Split Fraction for RHR & CS Suction Strainer Design, Rev. 0.

For Revisions: List CCns, IIJs, or SAs incorporated/superseded by this revision: CCN1, CCN2, CCN3, and VYS 60/97

Computer Code(s): None

Review and Approval: (Print and Sign Name)

Preparer: B. C. Slifer *B C Slifer* Date: 9/19/00

Interdiscipline Reviewer(s): NA Date: NA

Independent Reviewer(s): W. TIMOFEEV Date: 12/13/00

Approved: CARL D. FANO Date: 2/13/01

Installation Verification / Final Turnover to DCC:

Open Items Associated with Calculation? ☐ Yes ☒ No ☐ Closed (Section 2.3.2)

Total No. Pages in Package (including all attachments): 78

Installation Verification (Section 2.3.4)

☒ Calculation accurately reflects plant as-built configuration, OR

☐ N/A, calculation does not affect plant configuration

Resolution of documents identified in the Design Output Documents Section of VYAPF 0017.07 initiated (Section 2.3.6)

CARL D. FANO	/		/	2/13/01
Printed Name		Signature		Date

BCS 2/13/01

VY CALCULATION DATABASE INPUT FORM

VYC-808	6	NA	NA
VY Calculation/CCN #	Revision #	Vendor Calculation #	Revision #

Vendor Name: NA PO Number: NA

Originating Department: Fluid Systems

Critical References Impacted: ☐ FSAR ☐ DBD ☐ Reload "Check" the appropriate box if any critical document is identified in the tables below.

EMPAC Asset/Equipment ID Number(s): P-10-1A, P-10-1B, P-10-1C, P-10-1D, P-46-1A, P-46-1B

EMPAC Asset/System ID Number(s): 10, 14

Keywords: Residual Heat Removal (RHR), Core Spray (CS), Net Positive Suction Head (NPSH), Strainer, Pump

For Revision/CCN only: Are deletions to General References, Design Input Documents or Design Output Documents required?

☒ Yes† ☐ No

General References

*Reference #	** DOC #	REV #	*** Reference Title (including Date, if applicable) (See App. A, Section 3.2.7 for Guidance)	**** Affected Program	Critical Reference (√)
1			American National Standard for Centrifugal Pumps, ANSI/HI 1.1-1.5-1994.		
16	BVY 97-138	N/A	Letter, VYNPC to USNRC, "Reply to Inspection Report No. 50-271/97-201," (Appendix B, IFI 97-201-04), dated 10/27/97.		
(c) Attachments 6 and 7			Technical Paper No. 410, "Flow of Fluids Through Valves Fittings and Pipe," Crane Co., 24th Printing, 1988.		
(l) Attachment 6 and (m) Attachment 7			Hydraulic Institute Engineering Data Book, 1st Edition		
(k) Attachment 7			Handbook of Hydraulic Resistance, I. E. Idelchik, 2nd Edition, Hemisphere Publishing Co., New York, 1986.		

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Design Input Documents – The following documents provide design input to this calculation. (Refer to Appendix A, section 4)

*Reference #	** DOC #	REV #	*** Reference Title (including Date, if applicable) (See App. A, Section 3.2.7 for Guidance)	**** Affected Program	Critical Reference (√)
5	VYC-1628F	0	Limiting Torus Temperature Response, Million Second Run		
6	VYC-1919	0	DE&S Calc:DC-A34600-01, "RHR and CS Suction Strainer Assembly Clean Strainer Head Loss"		
2	VYC-1924	0	DE&S Calc:DC-A43600.006, "Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment, RHR and CS Debris Head Loss Calculation"		

Design Output Documents – **This calculation provides output to the following documents.** (Refer to Appendix A, section 5)

*Reference #	** DOC #	REV #	Document Title (including Date, if applicable)	**** Affected Program	Critical Reference (√)
3	VYC-1677	0	Debris Source Terms for Sizing of Replacement RHR and CS Strainers		

* Reference # - Assigned by preparer to identify the reference in the body of the calculation.
** Doc # - Identifying number on the document, if any (e.g. 5920-0264, G191172, VY6-1286)
*** Reference Title - List the specific documentation in this column. "See attached list" is not acceptable. Design Input/Output Documents should identify the specific design input document used in the calculation or the specific document affected by the calculation and not simply reference the document (e.g., VYDC, MM) that the calculation was written to support.
**** Affected Program - List the affected program or the program that reference is related to or part of. If the reference is FSAR, DBD or Reload (IASD or OPL), check Critical Reference column and check FSAR, DBD or Reload, as appropriate, on this form (above).
† If "yes", attach a copy of "VY Calculation Data" marked-up to reflect deletion (See Section 3.1.8 for Revision and 5.2.3.18 for CCNs).

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VY Calculation Data

VYC-1868

VY Calculation Number

Vendor Calculation Numbe

☑ CCNs

Rev No.	Revision Title	Rev Dat	Preparer	Rev Status	Microfilm
0	NPSH MARGIN FOR RHR + CORE SPRAY PUMPS AT DESIGN FLOW RATE FIBROUS INSULATION DEBRIS ON INTAKE STRAINERS FROM A DESIGN BASIS LOCA	03/31/1989	L. TREMBLAY	Superseded	1477-1902
1	NPSH MARGIN FOR RESIDUAL HEAT REMOVAL RHR + CORE SPRAY PUMPS AT DESIGN FLOW RATE INCLUDING FIBROUS INSULATION DEBRIS ON INTAKE STRAINERS FROM A DESIGN BASIS LOCA	10/19/1993	R SWENSON	Superseded	1835-0657
2	NPSH MARGIN FOR RHR RESIDUAL HEAT REMOVAL + CORE SPRAY PUMPS AT DESIGN FLOW RATE INCLUDING FIBROUS INSULATION DEBRIS ON INTAKE STRAINERS FROM A DESIGN BASIS LOCA	12/06/1995	R SWENSON	Superseded	2011-0423
3	CORE SPRAY AND RESIDUAL HEAT REMOVAL PUMP NET POSITIVE SUCTION HEAD MARGIN FOLLOWING A LOSS OF COOLANT ACCIDENT WITH FIBROUS DEBRIS ON THE INTAKE STRAINER	01/13/1998	B SLIFER	Superseded	DCC
4	CORE SPRAY + RESIDUAL HEAT REMOVAL RHR PUMP NET POSITIVE SUCTION HEAD MARGIN FOLLOWING A LOSS OF COOLANT ACCIDENT WITH FIBROUS DEBRIS ON THE INTAKE STRAINERS	05/14/1998	B SLIFER	Superseded	2427-0209
5	CORE SPRAY + RESIDUAL HEAT REMOVAL RHR PUMP NET POSITIVE SUCTION HEAD MARGIN FOLLOWING A LOSS OF COOLANT ACCIDENT LOCA WITH FIBROUS DEBRIS ON THE INTAKE STRAINERS	07/31/1998	B SLIFER	Active	2427-0300
6	CORE SPRAY + RESIDUAL HEAT REMOVAL RHR PUMP NET POSITIVE SUCTION HEAD MARGIN FOLLOWING A LOSS OF COOLANT ACCIDENT LOCA WITH FIBROUS DEBRIS ON THE INTAKE STRAINERS	08/22/2000	B SLIFER	Pending	null

QA Status ☑ SC ☐ NNS ☐ OQA

Operating Cycle No

Supports a Design Change/Spec? ☐

Done as a Study Only? ☐

Related Design Changes:
EDCR 85-01
DCR 98-005

Safety Evaluation:

DBD: ☑

Superseded Calculations: VYC-1685

Superseded by:

Open Items Associated with Calculation ☐

Vender Name: VY

Originating Department: Fluid Systems

Equipment:

P-10-1A
P-10-1B
P-10-1C
P-10-1D
P-46-1A
P-46-1B
P10-1A-D (RHR PUMPS)
P46-1A,B (CS PUMPS)

Systems:

10 Residual Heat Removal System RHR
14 Core Spray System CS

Keywords:

VY Calculation Data

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[redacted]

☑ CCNs

VY Calculation Number | Vendor Calculation Numbe

NPSH
RESIDUAL
HEAT
CORE
SPRAY
PUMP
NEGATIVE
SUCTION
HEAD
MARGIN
FLOW
INSULATION
DEBRIS
INTAKE
STRAINER
COOLANT
E7014
CHEMICAL
VOLUME
EMERGENCY
COOLING
NET
POSITIVE
REMOVAL
FIBROUS
CS
RHR
NET POSITIVE SUCTION HEAD
STRAINER
LOCA

General References:

BMO 96-05

BVY 97-138

CSN 1034

CSN 4805

CSN 5268

CSN 5610

Document E12.5.522 Dated 5/26/98

GE Data Sh Doc 22A1440AB

GE Data Sh Doc 22A2806AB

HANDBOOK OF HYDRAULIC RESISTANCE I E IDELCHIK 2 ED

HYDRAULIC INST. ENG DATA BOOK 1ST ED

NVY 97-130

NVY 98-043

TECH PAPER NO 410 CRANE CO 24TH PRINTING 1988

THSAG VY 98-064

VYS 95-109

Input Documents:

5920-9209 PART 3	4
5920-9284 PART 5	3
Drawing 6202-1	1
FSAR — Delete	14
G-191168	38
G-191172	57
G-191207	10
G-191211	16

VY Calculation Data

9.6

[redacted]

☑ CCNs

VY Calculation Number	Vendor Calculation Numbe
Letter Sulzer Bingham Pumps to D Yasi 3/26/1999 Delete	
Memo THASG-VY 98-064 Fago to Hoffman 4/27/1998	
ON-3164 Delete	1
OP-2124	43
VYC-0018	
VYC-0019 Delete	
VYC-0417	0,1
VYC-0717B	
VYC-0808 Delete	2
VYC-1254	2
VYC-1290	0,2
VYC-1388 Delete	1,0
VYC-1389	0
VYC-1442	
VYC-1628	0
VYC-1685	
VYC-1751 Delete	
VYS 98/58	
VYS 98/97	

Output Documents:

CORE SPRAY DESIGN BASIS DOC
DBD CS
DBD RHR
RESIDUAL HEAT REMOVAL DESIGN BASIS
VYC-0019
VYC-0417 Delete
VYC-1628
VYC-1670
VYC-1678
VYC-1685 Delete
VYC-1751
VYC-1803
VYPC 96-015

Related Programs:

Comments

Outstanding VYDEP 022 memo VYS 97/60 Delete (incorporated in Revision 6)

TABLE OF CONTENTS

VY CALCULATON TITLE PAGE

VY CALCULATION DATABASE INPUT FORM

1.0 OBJECTIVE

2.0 METHOD OF SOLUTION

3.0 INPUTS AND ASSUMPTIONS

4.0 CALCULATION

5.0 SUMMARY & CONCLUSIONS

6.0 REFERENCES

ATTACHMENTS

Attachment 1 Derivation of Strainer Debris Accumulation Equation (2 pages)

Attachment 2, Innovative Technology Solutions Corporation, "Revised ECCS Suction Strainer Head Loss Assessment for Vermont Yankee," ITS/VY-00-001, Rev. 0. (3 pages)

Attachment 3, Available NPSH for Most Limiting Torus Temperature Transient (10 pages)

~~Attachment 4, Vermont Yankee Strainer/Torus Design Change Overview (1 page)~~

Attachment 5, Sulzer Bingham Pumps Inc. Document E12.5.561, NPSH/Minimum Flow Study-Summary Report, dated May 26, 1998. (19 pages)

Attachment 6, Core Spray NPSH Evaluation (4 pages)

Attachment 7, Residual Heat Removal (LPCI) NPSH Evaluation (12 pages)

Attachment 8, Review Form (1 page)

1.0 OBJECTIVE

1.1 To determine the NPSH margin for the Core Spray and Residual Heat Removal (RHR) pump taking suction from the Torus (1) at maximum run out flow during the first 10 minutes following a LOCA, (2) at design flow at the maximum peak post-LOCA suppression pool temperature, and (3) over the long-term post-accident suppression pool heatup and cooldown transient.

Revision 6 differs from Revision 5 as follows:

a) CCN 1 incorporated
b) CCN 2 incorporated
c) CCN 3 incorporated
d) Assesses NPSH margins under minimum flow conditions.
e) Incorporates results of VYC-1919 (Reference 6) and VYC-1924 (Reference 2).

The RHR and Core Spray Systems are Safety Class 2.

2.0 METHOD OF SOLUTION

2.1 Required NPSH can be obtained from the pump curves based on witnessed tests performed by the pump vendor. There is a separate set of test data for each of the two Core Spray pumps and the four RHR pumps delivered to Vermont Yankee. A curve fit bounding the required NPSH data was developed for each pump type. The required NPSH for the RHR pumps is based on the data labeled "Minimum Operable NPSH @ Reduced Head". (The basis for the RHR required NPSH was reviewed during the AE Inspection (Reference 4)).

At Vermont Yankee's request, the pump vendor performed additional NPSH evaluations for the RHR and Core Spray pumps in order to provide a more rigorous basis for interpolating between and extrapolating beyond the NPSH data base provided with the pumps. The pump vendor supplemented the data supplied for each pump with additional and more extensive data for the same or similar pumps obtained from their archives. The pump vendor used these data, adjusted as necessary using pump affinity laws, to develop characteristic NPSH curves that complement the original witnessed test data. When pumps have been NPSH tested over a small flow range and NPSH data are required outside of this range, the NPSH curves have to be extrapolated. Only NPSH tests of pumps of similar style, design, specific speed, suction specific speed, number of impeller vanes and suction vane angles can be used for this purpose.

The pump vendor also provided additional information to define allowable times of operation and minimum allowable NPSH for minimum flow conditions and at higher flow rates. The vendor report is included as Attachment 5.

2.1.1 RHR Pumps

The original witnessed test data for the four (4) RHR pumps covered a flow range of 6,300 gpm to slightly less than 9,000 gpm. This range is adequate for the RHR pumps since the expected maximum flow rates following a LOCA are between 7,100 gpm and 7,400 gpm.

NPSH tests were also performed on one of the four RHR pumps, prior to the final impeller trimming, at 6300, 8065, and 9502 gpm. Five (5) to eight (8) test points were taken at each of the above capacities to establish the slope and shape of NPSH vs. Total Dynamic Head (TDH) curve. These tests established that the so-called knee of the NPSH vs. TDH curve is gradual, i.e. there is no rapid drop in TDH for a relatively small reduction in NPSH. Data points were taken at TDH reductions of up to 8% relative to the values obtained at higher values of available NPSH. These data were used to develop a family of curves of NPSH vs. flow for TDH drops of 1%, 3%, and 6%. The witnessed test data compared to these curves fell somewhere between 3% and 6% lines, and slightly below the 6% line for flow rates above 7,000 gpm for the data points labeled "Minimum Operable NPSH @ Reduced Head". The vendor concluded that the pumps, if operated with the minimum NPSH, are within acceptable limits of the NPSH knee.

Extrapolation of required NPSH to flow rates less than 6,300 gpm was based on data from tests on similar pump designs, but of different sizes (18x24x28 CVIC and 8x10x21 CVIC vs. 16x18x26 CVIC). Similar pumps are of the same suction specific speed, number of vanes and suction vane angle. The extrapolation is based on estimation and experience from NPSH tests on other styles of pumps performed in recent years, when more detailed NPSH tests were required. NPSH at lower flow rates is of less importance than at higher flow rates since available NPSH will always be higher at lower flow rates because of lower head loss due to flow, and also since core and containment cooling requirements dictate flow rates higher than 6,300 gpm when reactor water level is below the elevation of the top of the active fuel. The extrapolated NPSH at flow rates less than 6,300 gpm is not used for the evaluation of design NPSH margins. The required NPSH at low flow rates is mainly of interest in evaluating operating characteristics under minimum flow conditions, when the pumps are operating with the minimum flow bypass valves in their open position until reactor pressure drops low enough to allow the injection valves to open.

The pump vendor also provided an assessment of the potential for permanent pump damage due to cavitation at the minimum NPSH. Their assessment required input from Vermont Yankee on the durations of operation at minimum NPSH conditions. Vermont Yankee provided this information in the form of predicted suppression pool temperature and available NPSH vs. time for the LOCA. Relative to the RHR pumps, when operating for seven (7) hours at 7,000 gpm with an available NPSH of 23 to 24 feet, the pump vendor concluded that, "Depending on water temperature and

water chemistry there can be some "frosting (e.g. light pitting) on the impeller suction vanes, but there will be no detrimental pump damage due to cavitation when operating at minimum NPSH for the specified hours of operation." The vendor extended this assessment beyond the seven (7) hours at 23 to 24 feet of NPSH to define the NPSH required based on an impeller life of 8,000 hours. This information is compared to the expected decrease in suppression pool temperature following the peak, and subsequent increase in available NPSH, and it shows that the RHR pump will always operate within the acceptable bounds defined by the vendor.

The vendor recommended minimum flow requirements were given as $\leq$ 4 hours at 350 gpm and $\geq$ 4 hours at 2700 gpm. The corresponding required NPSH values were 30 ft at 350 gpm and 26 ft at 2700 gpm (page 5, Attachment 5).

2.1.2 CS Pumps

The original witnessed test data for the CS pumps covered a flow range of 3,000 gpm to slightly more than 3,800 gpm. The expected maximum flow rates following a LOCA are between 3,000 gpm and 4,600 gpm.

More comprehensive NPSH tests were performed on an identical pump for a different customer. These tests were performed at approximately 1780 rpm. Converted to 3582 rpm using affinity laws, the flow rates were 3005, 4037, 5038, 5120, 6000, 6020, and 6524 gpm, thus bounding the flow range of interest. Four (4) to ten (10) test points at each of the above capacities established the slope and shape of the NPSH vs. TDH characteristic curve. Differences in impeller trim diameter were also factored into the developed required NPSH curves. The vendor concluded that these tests were sufficient to develop NPSH characteristics for the pump and are representative of the pumps delivered to Vermont Yankee. The vendor also concluded that Vermont Yankee's pumps, if operated with the minimum NPSH, are within acceptable limits of the NPSH knee.

Extrapolation of required NPSH to flow rates less than 3,000 gpm was based on data from tests on similar pump design, but of different size (12x14x14 ½ CVDS and 14x16x23 CVDS vs. 12x16x14 CVDS). Similar pumps are of the same suction specific speed, number of vanes and suction vane angle. The extrapolation is based on estimation and experience from NPSH tests on other styles of pumps performed in recent years, when more detailed NPSH tests were required. NPSH at lower flow rates is of less importance than at higher flow rates since available NPSH will always be higher at lower flow rates because of lower head loss due to flow, and also since core cooling requirements dictate flow rates higher than 3,000 gpm when reactor water level is below the elevation of the top of the active fuel. The extrapolated NPSH at flow rates less than 3,000 gpm is not used for the evaluation of design NPSH margins. The required NPSH at low flow rates is mainly of interest in evaluating operating characteristics under minimum flow conditions, when the pumps are operating with the minimum flow bypass valves in their open position until reactor pressure drops low enough to allow the injection valves to open.

The pump vendor also provided an assessment of the potential for permanent pump damage due to cavitation at the minimum NPSH. Their assessment required input from Vermont Yankee on the durations of operation at minimum NPSH conditions. Vermont Yankee provided this information in the form of predicted suppression pool temperature and available NPSH vs. time for the LOCA. The vendor concluded that the CS pumps have more margin than the RHR pumps relative to potential damage from cavitation at the minimum available NPSH predicted for the LOCA. The vendor developed a curve of allowable hours of operation vs. available NPSH for the CS pump similar to that developed for the RHR pump. Comparison of predicted minimum available NPSH for the CS pumps vs. time for the LOCA shows that the CS pump will always operate within the acceptable bounds defined by the vendor based on an 8,000 hour impeller life.

The vendor recommended minimum flow requirements were given as $\leq$ 4 hours at 300 gpm and $\geq$ 4 hours at 1250 gpm. The corresponding required NPSH values were 32.5 ft at 300 gpm and 27 ft at 1250 gpm (page 5, Attachment 5).

2.2 Since the vendor chose to use a postulated minimum available NPSH rather than the minimum tested NPSH for their evaluation of acceptable durations of operation based on potential cavitation damage to the pump impeller, a reassessment of NPSH margins using minimum available NPSH rather than minimum tested NPSH was performed. The following table compares the values used in the vendors evaluations and comparable values at the same flow rates from the witness tests.

PUMP	FLOW (gpm)	Minimum Available NPSH assumed by Vendor for the Impeller Life Study (ft)	Minimum Required NPSH from Original Witness Tests[1] (ft)
CS	3,000	24.0	24.0
	4,600	28.0	No Data
RHR	6,400	23.0	23.2
	7,000	23.5	22.6
	7,600	24.0	23.5

Using the minimum available NPSH values from the impeller life study as required values is conservative since the values are based on the long-term reliability of the pump impellers, and they are equal to or bound the witnessed test data.

NPSH values at other flow rates are based on curve fits developed from the above data points and vendor predicted characteristic curves (NPSH vs. flow rate).

2.2.1 For CS, the curve fit incorporates the witnessed test data points for flow rates between 3,000 gpm and 4,600 gpm.

FLOW (gpm)	NPSH (ft)	SOURCE
3003	24.0	Curve No. 27692
3522	24.9	Curve No. 27692
3810	25.0	Curve No. 27692
3000	24.0	Curve No. 27691
3542	24.5	Curve No. 27691
3810	25.0	Curve No. 27691
4600	28.0	SBPI Document No. E12.5.561 (Attachment 5)

Curve Fit:

A following second order polynomial curve fit to conservatively bound the above data was developed:

[1]NPSH is determined from a curve fit that bounds all data points for each pump.

$$NPSH = 26.4 - 2.965 \times 10^{-3} Q + 7.191 \times 10^{-7} Q^2$$

where Q is Flow Rate in gpm.

Comparison between Data and Curve Fit

FLOW	DATA	FIT
3003	24.0	24.0
3500	none	24.8
3522	24.9	24.9
3810	25.0	25.5
4600	28.0	28.0

2.2.2 RHR

A different approach is taken for RHR. The witness test data were not used to develop a curve fit. The SBPI recommended minimum available NPSH bounded the Minimum Operable NPSH @ Reduced Flow data from the witness tests over the flow range of interest, therefore the recommended minimum available NPSH was used exclusively. A simple linear interpolation scheme is used as the curve fit.

Flow range: 6,400 gpm to 7,600 gpm
Sources: SBPI Document No. E12.5.561, NPSH/Minimum Flow Study-Summary Report, dated May 26, 1998. (Attachment 5)

Data:

FLOW	NPSH
6400	23.0
7000	23.5
7600	24.0

Curve Fit:

$$NPSH = 23.0 + (Q - 6400) / 1200$$

2.3 Available NPSH is calculated using the industry standard equation (Reference 1)

$$NPSH\ Available = (p_{Torus} - p_v)\ (144)v + Z - H_f - H_d - H_s$$

where p_{Torus} = Torus pressure, psia
p_v = vapor pressure of the pumped fluid, psia

v = specific volume of the pumped fluid, cu ft / lb
Z = elevation head, torus to pump suction, ft
H_s = suction strainer loss, ft
H_d = strainer debris loss, ft
H_f = friction loss in suction piping, ft

2.4 The amount of debris on a strainer will vary with time, starting at zero and increasing to the total value as the debris passes through each strainer and is removed from the water. Assuming the debris is uniformly dispersed in the suppression pool, the fraction of debris deposited on the strainers at a time, t, after initiation of flow, assuming a constant flow rate, is (see Attachment 1 for the derivation)

$$D/D_{total} = (1 - e^{-Qt/V})$$

where D/D_{total} = fraction of the total debris deposited on the strainer
Q = total pump flow rate
t = time
V = suppression pool volume = 68,000 cu ft minimum (TS 3.7.A.1.e)

This equation is used to determine the amount of fibrous debris deposited on the strainers during the first 10 minutes following a LOCA.

After ten minutes, it is assumed that one Core Spray pump provides cooling to the core, and one RHR pump cools the suppression pool. The remaining debris in the suppression pool and any debris deposited on an active strainer supplying pump(s) in the short-term that is subsequently secured for the long-term is deposited on the two active strainers in proportion to their flow rates. The total debris thus deposited on the two active strainers is used to determine NPSH margin at the peak suppression pool temperature.

2.5 A survey of ECCS single failures was done to identify what single failure resulted in the maximum debris accumulation on the strainers during the first ten minutes and at the peak suppression pool temperature.

3.0 INPUTS AND ASSUMPTIONS

3.1 The suppression pool temperatures used in the analysis are based on Reference 19

3.2 The head loss term for the RHR and Core Spray strainers is based on the DBA LOCA Base Case documented in Reference 2.

RHR @ 7400 gpm	0.33 ft	RHR @ 14200 gpm	0.48 ft
CS @ 3500 gpm	0.21 ft	CS @ 4600 gpm	0.32 ft

These head loss values are based on debris loads that are different than those calculated in VYC-1677 (Reference 3), and on a peak suppression pool temperature that is less than calculated in Reference 19. Both of these effects cause a slightly higher calculated head loss, and thus represent additional conservatism in the calculation. The degree of conservatism is indicated in the "Revised ECCS Suction Strainer Head Loss Assessment for Vermont Yankee" (Attachment 2). The calculation of NPSH margin is done at the peak LOCA suppression pool temperatures because the negative effect of vapor pressure on NPSH margin significantly outweighs the slight benefit on the debris head loss term.

3.3 The calculation also conservatively assumes that containment pressure is equal to 14.7 psia regardless of the temperature and the initial pressure. This assumption is in accordance with Regulatory Guide 1.1.

3.4 The calculation is done for two conditions called short-term and long-term.

3.4.1 The short-term condition assumes that the suppression pool temperature is at its highest calculated value at 10 minutes, and there has been no operator action to initiate suppression pool cooling or to secure or throttle ECCS pumps. Reactor pressure is assumed to be equal to containment pressure, thus ECCS pumps are operating at their maximum flow rates. The maximum suppression pool temperature at the end of 10 minutes is assumed to be 164°F (page 2, Ref. 19). The debris loading on the ECCS pump suction strainers is based on the maximum fraction of the suppression pool volume that has passed through the strainers during the first 10 minutes of the event. The maximum run out flow for the one RHR pump is 7,400 gpm in one loop, for two RHR pumps in one loop, 14,200 gpm, and for the Core Spray pump, 4,600 gpm (Ref. 7).

3.4.2 The long-term condition is assumed to represent the conditions when the peak suppression pool temperature is reached, several hours after initiation of the LOCA. The peak suppression pool temperature is assumed to be 182.6°F (Table 2, Ref. 19). The peak temperatures were selected to bound both short- and long-term conditions. It is assumed that the ECCS suction strainers have reached their maximum debris loadings by the time the suppression pool reaches its peak temperature. It is also assumed that, in accordance with operating procedures (Ref. 8), operators have initiated torus cooling with the RHR. Previous calculations of NPSH for the RHR assumed that the RHR flow would be throttled to 7,000 gpm, per procedures. In anticipation of a potential change which will eliminate the 7,000 gpm limit on flow, the present calculation will assume an RHR flow rate of 7,400 gpm, which is the maximum short-term flow rate for one RHR pump in the LPCI mode (see Section 3.3). The actual flow rate is expected to be less than 7,400 gpm.

The Core Spray pump is assumed to be throttled based on Emergency Operating Procedures. Operators will monitor NPSH limit curves in the EOPs and will throttle flow if indicated flow and pool temperature are outside the acceptable operating envelope. In order to assure adequate core

cooling, a minimum indicated flow rate of 3,244 gpm will be maintained (Ref. 20). A minimum indicated flow rate of 3,244 gpm could result in a maximum actual flow rate of 3,500 gpm, allowing about 100 gpm for an operator tolerance band and worst case flow instrument uncertainty (Table 10, Ref. 21).

3.5 The elevation head, Z, is based on the calculated torus volume at 10 minutes and at the peak pool temperature from VYC-1628 (Run 3, Ref. 23), and the relationship between volume and level from VYC-1254, Rev. 3 (Ref. 24). The pool volumes from Ref. 23 do not include the volume of water in the downcomers. Therefore, the appropriate relationship between level and volume in Ref. 24 is from Table 4.3-1 using the volumes from the column labeled "downcomers empty". The constants are the elevation of the suction datum for the Core Spray and RHR pumps.

The elevation head, Z, is the difference between the elevation of the suppression pool surface and the pump suction. Key dimensions from Dwg. 6202-1 (Ref. 13):

Torus Centerline Elevation	230 ft 1.5 in
Torus I.D.	27 ft 8 in

Therefore, elevation of torus invert = 230' 1.5" - 1/2 (27' 8") = 216' 3.5", or 216.29 ft.

	Pool Volume	Torus Water Level	Torus Water Elevation
Short-term	76,800 ft^3	11.93 ft	228.22 ft
Long-term	77,640 ft^3	12.03 ft	228.32 ft

Core Spray pump suction center line	215' 9" (215.75 ft)	Ref. 25
RHR pump suction center line	215' 11" (215.92 ft)	Ref. 26

Therefore, Z for Core Spray and RHR,

	Core Spray	RHR
Short-term	12.47 ft	12.30 ft
Long-term	12.57 ft	12.40 ft

3.6 The strainer head loss is based on the vendor calculated values for the clean strainer and fittings (Reference 6).

RHR	Core Spray
0.33 ft @ 7400 gpm	0.38 ft @ 4000 gpm
1.22 ft @ 14200 gpm	0.51 ft @ 4600 gpm

At flow rates less than 4000 gpm for Core Spray, the head loss is adjusted by the square of the ratio of the flow rate to the reference value, thus $H_s = 0.38\ (Q/4000)^2$.

3.7 The head loss in the suction piping from the torus to the pumps is based on the calculations in Attachment 6 for Core Spray and Attachment 7 for RHR. These calculations are adjusted here to remove the terms for the old strainer tees and other fittings associated with the strainers inside the torus since the guaranteed head loss term for the new strainers includes those fittings already, therefore the adjusted values will represent only the piping runs and fittings from the new strainer to the pumps.

Friction and form losses in suction piping, including the old strainer tee entrance, are from Attachment 6 for Core Spray. From p. 3 of Attachment 6, the L/D for the "strainer entrance tee" was given as 30. The total L/D for all fittings was 132. Deducting the strainer entrance tee leaves a revised total L/D of 102. The total equivalent length of 12" (STD) pipe is 102 ft plus 35 ft for the pipe run (from p. 2 of Attachment 6), or 137 ft. This length is then adjusted to 12" Schedule 40 pipe by multiplying by 0.974 (p. 4, Attachment 6), thus 137 ft x 0.974 = 133 ft. of 12" Schedule 40 equivalent. The head loss for 3000 gpm is, from p. 4, Attachment 6,

$$H_{fCS} = 133 \text{ ft } (0.731 \text{ psi}/100 \text{ ft})\ (2.31 \text{ ft/psi}) = 2.25 \text{ ft @ } 3000 \text{ gpm}$$

or, generalizing,

$$H_{fCS} = 2.25\ (Q/3000)^2 = 2.5 \times 10^{-7}\ Q_{CS}^2$$

For RHR, friction and form losses in suction piping, including the old strainer tee entrance, are from Attachment 7. From p. 3 of Attachment 7, the L/D for the "strainer entrance tee" and "Miter Bend" was given as 119 and 6, respectively, in terms of 24" STD pipe. The total L/D for all fittings was 153. Deducting the strainer entrance tee and miter bend leaves a revised total L/D of 28. Converting to the equivalent length of 24" STD pipe,

$$L_{24"} = (28)(23.25"/12"/\text{ft}) = 54.25 \text{ ft}$$

This value is added to the 8.73 ft of piping run from p. 2, Attachment 7, for a total length of 62.98 ft. Attachment 7 next adjusted pipe lengths to an equivalent length of 20" Schedule 40 pipe using an equivalent pressure drop basis. The conversion factor is 0.347 from p. 3 of Attachment 7, thus

$$L_{20"Sch40} = 0.347\ (62.98\ ft) = 21.85\ ft.$$

This value is next added to the equivalent length of 26" pipe in terms of 20"Schedule 40, which is 39.90 ft (p.5, Attachment 7). Thus, the total equivalent length of 20"Schedule 40 pipe from the torus to the tee connection to the RHR pumps is 21.85 + 39.90 = 61.75 ft, excluding the old strainer tee and miter bend. This value can be carried through the remainder of the calculations in Attachment 7, and arrive at the following expressions for single pump and two pump operation.

For single pump operation, refer to p. 11, Attachment 7,

$$H_{f,1RHR} = 4.77 \times 10^{-8}\ Q^2$$

For two pump operation, refer to p. 12, Attachment 7,

$$H_{f,2RHR} = 7.836 \times 10^{-8}\ Q^2$$

here Q in both cases refers to RHR pump flow per pump in gpm.

4.0 CALCULATION

4.1 Debris Accumulation

4.1.1 The following ECCS combinations, based on single failure (including none), were considered in determining short-term debris accumulation (the use of the designations "A" and "B" is arbitrary).

Single Failure	No. of CS Pumps	No. of RHR Pumps, Loop A	No. of RHR Pumps, Loop B	No. of Active Suction Sites, N_s
Diesel Generator	1	1	1	3
CS Pump/Injection Valve	1	2	2	3
LPCI Injection Valve	2	2	0	3
RHR Pump	2	2	1	4
None	2	2	2	4

4.1.2 The run out flow rates, per pump, using the values from Paragraph 3.4,

Single Failure	CS A	CS B	RHR per pump Loop A	Total RHR, Loop A	RHR per pump Loop B	Total RHR, Loop B
Diesel Generator	4,600	0	7,400	7,400	7,400	7,400
CS Pump/Injection Valve	4,600	0	7,100	14,200	7,100	14,200
LPCI Injection Valve	4,600	4,600	7,100	14,200	0	0
RHR Pump	4,600	4,600	7,100	14,200	7,400	7,400
None	4,600	4,600	7,100	14,200	7,100	14200

4.1.3 The total flow rate from the suppression pool to the reactor vessel, and the debris fraction at ten minutes, using the equation from Paragraph 2.4,

Single Failure	Total Flow Rate, Q	$D/D_{total} = (1 - e^{-Qt/V})$ t=10 min V=68,000 ft^3 x 7.48 gal/ft^3
Diesel Generator	4,600+7,400+7,400=19,400	0.317
CS Pump/Injection Valve	4,600+14,200+14,200=33,000	0.477
LPCI Injection Valve	9,200+14,200=23,400	0.369
RHR Pump	9,200+14,200+7,400=30,800	0.454
None	9,200+14,200+14,200=37,600	0.522

4.1.4 After 10 minutes, all but one Core Spray pump and one RHR pump are assumed to be secured. In addition, the Core Spray pump is assumed to be throttled to 3500 gpm. The distribution of debris on the one active CS strainer and the one active RHR strainer will be the amount initially deposited in the short-term, plus the amount redistributed from the now-inactive strainer(s), plus the amount not removed in the short-term. The distribution of the remaining amounts will be in proportion to the CS and RHR flow rates. The results are summarized below.

Single Failure		CS A	CS B	RHR A	RHR B	Total
Diesel Generator	Short Term Flow Rate	4600	0	7400	7400	19400
	Short Term Accumulation	0.075	0.000	0.121	0.121	0.317
	Long Term Flow Rate	3500	0	7400	0	10900
	Redistributed	0.000	0.000	0.000	0.121	0.121
	Long Term Accumulation	0.333	0.000	0.667	0.000	1.000
CS Pump/Inj. Valve	Short Term Flow Rate	4600	0	14200	14200	33000
	Short Term Accumulation	0.066	0.000	0.205	0.205	0.477
	Long Term Flow Rate	3500	0	7400	0	10900
	Redistributed	0.000	0.000	0.000	0.205	0.205
	Long Term Accumulation	0.300	0.000	0.700	0.000	1.000
LPCI Inj. Valve	Short Term Flow Rate	4600	4600	14200	0	23400
	Short Term Accumulation	0.073	0.073	0.224	0.000	0.369
	Long Term Flow Rate	3500	0	7400	0	10900

	Redistributed	0.000	0.073	0.000	0.000	0.073
	Long Term Accumulation	**0.298**	0.000	**0.702**	0.000	1.000
RHR Pump	Short Term Flow Rate	4600	4600	14200	7400	30800
	Short Term Accumulation	0.068	0.068	0.209	0.109	0.454
	Long Term Flow Rate	3500	0	7400	0	10900
	Redistributed	0.000	0.068	0.000	0.109	0.177
	Long Term Accumulation	**0.300**	0.000	**0.700**	0.000	1.000
None	Short Term Flow Rate	4600	4600	14200	14200	37600
	Short Term Accumulation	0.064	0.064	0.197	0.197	0.522
	Long Term Flow Rate	3500	0	7400	0	10900
	Redistributed	0.000	0.064	0.000	0.197	0.261
	Long Term Accumulation	**0.301**	0.000	**0.699**	0.000	1.000

The above information was used to determine the distribution of each of the various debris species postulated to be deposited in the suppression pool following a LOCA (Reference 3). However, the above distributions were not used to determine the head loss due to debris used in this calculation as discussed below. The above distributions were used as input to VYC-1677 (Reference 3), and the resulting debris loads were used to assess the head loss due to debris shown in Attachment 2.

4.2 Head Loss due to Debris

The maximum predicted head loss for the CS and RHR strainers are based on the vendor calculations (Reference 2), using conservative debris loads, fluid temperatures, and flow rates. These were discussed in Section 3.2 as Inputs and Assumptions. The head losses so determined are shown in Attachment 2 to be conservative relative to updated information on debris distribution (Section 4.1), debris loads (Reference 3), flow rates and fluid temperatures. Attachment 2 has not been adopted as the design basis because additional assessments are ongoing regarding the time interval for torus cleaning, which may affect the final specification of the "sludge" term in the head loss calculations.

4.3 NPSH Margin

The Table 1 summarizes the calculated available NPSH at the flow rates and temperatures of interest for a clean strainer. The calculations were done for the design basis flow rates and maximum short-term and long-term temperatures. Other temperature points were calculated to show the sensitivity of the results. The available NPSH is compared to the required NPSH, and if the margin is greater than the maximum head loss due to debris, then it can be concluded that post-accident performance is acceptable at the design basis points.

Table 2 provides similar results for the minimum flow mode. Since Technical Specifications require reactor depressurization when suppression pool temperature reaches 120 F, it is unlikely that a CS or RHR pump would be operating in a minimum flow mode for very long at that temperature. Table 2 shows adequate NPSH margin for pool temperatures $\geq$ 164 F.

Attachment 3 provides an assessment of the time-dependent NPSH margin for the maximum post-accident pool temperature transient. The purpose of this calculation was to show the margin available after the peak temperature is reached in light of the vendor recommended increase in minimum available NPSH after 7 hours. The minimum available NPSH is shown to be above the vendor recommended minimum at all times during the most limiting transient.

TABLE 1

VYC-808, Revision 6

NPSHA = (14.7 - P_g)(144)(v_f) + Z - h_f - h_s - h_d

<u>Suction Line Losses</u>

1 RHR	h_f = 4.77e-8*Q^2	CS	h_f = 2.5e-7*Q^2
2 RHR	h_f = 7.84e-8*(Q/2)^2		

<u>Clean Strainer Losses</u>

1 RHR	h_s = 0.33	CS	h_s = 0.51 for Q=4600 gpm
2 RHR	h_s = 1.22	CS	h_s = 0.38*(Q/4000)^2 for Q≤4000 gpm

<u>Maximum Debris Losses</u>

1 RHR	h_d = 0.33 (maximum)	CS	h_d = 0.21 (maximum @ 4000 gpm)
2 RHR	h_d = 0.48 (maximum)	CS	h_d = 0.32 (maximum @ 4600 gpm)

<u>Required NPSH</u>

RHR	NPSHR = 23 + (Q-6400)/1200	CS	NPSHR = 26.4 - 2.965e-3*Q +7.191e-7*Q^2

	Q (gpm)	T (F)	P_g (psia)	v_f (cu ft/lb)	Z (ft)	h_f (ft)	h_s (ft)	h_d (ft)	"Clean" NPSHA (ft)	NPSHR (ft)	"Clean" Margin (ft)	h_d (ft)	Margin w/ Debris (ft)
1 CS	4600	90	0.69813	0.016099	12.49	5.29	0.51	0	39.1	28.0	11.2		
short-term	4600	120	1.6927	0.016204	12.49	5.29	0.51	0	37.0	28.0	9.1		
	4600	150	3.7184	0.016343	12.49	5.29	0.51	0	32.5	28.0	4.6		
	4600	164	5.212	0.016410	12.49	5.29	0.51	0	29.1	28.0	1.1	0.32	0.8
	4600	182.6	7.954	0.016530	12.49	5.29	0.51	0	22.7	28.0	-5.2		
	4600	190	9.34	0.016572	12.49	5.29	0.51	0	19.5	28.0	-8.5		
1 CS	3500	90	0.69813	0.016099	12.59	3.06	0.29	0	41.7	24.8	16.9		
long-term	3500	120	1.6927	0.016204	12.59	3.06	0.29	0	39.6	24.8	14.8		
	3500	150	3.7184	0.016343	12.59	3.06	0.29	0	35.1	24.8	10.2		
	3500	164	5.212	0.016410	12.59	3.06	0.29	0	31.7	24.8	6.8		
	3500	182.6	7.954	0.016530	12.59	3.06	0.29	0	25.3	24.8	0.5	0.21	0.3
	3500	184	8.203	0.016535	12.59	3.06	0.29	0	24.7	24.8	-0.1		
	3500	185	8.384	0.016541	12.59	3.06	0.29	0	24.3	24.8	-0.6		
2 RHR	14200	90	0.69813	0.016099	12.32	3.95	1.22	0	39.6	23.6	16.0		
short-term	14200	120	1.6927	0.016204	12.32	3.95	1.22	0	37.5	23.6	13.9		
	14200	150	3.7184	0.016343	12.32	3.95	1.22	0	33.0	23.6	9.4		
	14200	164	5.212	0.016410	12.32	3.95	1.22	0	29.6	23.6	6.0	0.48	5.5
	14200	182.6	7.954	0.016530	12.32	3.95	1.22	0	23.2	23.6	-0.4		
	14200	190	9.34	0.016572	12.32	3.95	1.22	0	19.9	23.6	-3.6		
1 RHR	7400	90	0.69813	0.016099	12.32	2.61	0.33	0	41.8	23.8	18.0		
short-term	7400	120	1.6927	0.016204	12.32	2.61	0.33	0	39.7	23.8	15.9		
	7400	150	3.7184	0.016343	12.32	2.61	0.33	0	35.2	23.8	11.4		
	7400	164	5.212	0.016410	12.32	2.61	0.33	0	31.8	23.8	8.0	0.33	7.6
	7400	182.6	7.954	0.016530	12.32	2.61	0.33	0	25.4	23.8	1.6		
	7400	190	9.34	0.016572	12.32	2.61	0.33	0	22.2	23.8	-1.7		
1 RHR	7400	90	0.69813	0.016099	12.42	2.61	0.33	0	41.9	23.8	18.1		
long-term	7400	120	1.6927	0.016204	12.42	2.61	0.33	0	39.8	23.8	16.0		
	7400	150	3.7184	0.016343	12.42	2.61	0.33	0	35.3	23.8	11.5		
	7400	164	5.212	0.016410	12.42	2.61	0.33	0	31.9	23.8	8.1		
	7400	182.6	7.954	0.016530	12.42	2.61	0.33	0	25.5	23.8	1.7	0.33	1.4
	7400	185	8.384	0.016541	12.42	2.61	0.33	0	24.5	23.8	0.7		
	7400	190	9.34	0.016572	12.42	2.61	0.33	0	22.3	23.8	-1.6		

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TABLE 2

VYC-808, Revision 6

NPSHA = (14.7 - P_g)(144)(v_f) + Z - h_f - h_s - h_d

Suction Line Losses

1 RHR	h_f = 4.77e-8*Q^2	CS	h_f = 2.5e-7*Q^2
2 RHR	h_f = 7.84e-8*(Q/2)^2		

Clean Strainer Losses

1 RHR	h_s = 0.33*(Q/7400)^2	CS	h_s = 0.38*(Q/4000)^2
2 RHR	h_s = 1.22*(Q/14200)^2		

Required NPSH

RHR	NPSHR =	30	@ 350 gpm	CS	NPSHR =	32.5	@ 300 gpm
RHR	NPSHR =	26	@ 2700 gpm	CS	NPSHR =	27	@ 1250 gpm

	Q (gpm)	T (F)	P_g (psia)	v_f (cu ft/lb)	Z (ft)	h_f (ft)	h_s (ft)	NPSHA (ft)	NPSHR (ft)	"Clean" Margin (ft)
1 CS	300	90	0.69813	0.016099	12.47	0.0225	0.00	44.9	32.5	12.4
min-flow	300	120	1.6927	0.016204	12.47	0.0225	0.00	42.8	32.5	10.3
≤ 4 hr	300	150	3.7184	0.016343	12.47	0.0225	0.00	38.3	32.5	5.8
	300	164	5.212	0.016410	12.47	0.0225	0.00	34.9	32.5	2.4
	300	181.9	7.836	0.016521	12.47	0.0225	0.00	28.8	32.5	-3.7
	300	190	9.34	0.016572	12.47	0.0225	0.00	25.2	32.5	-7.3
1 CS	1250	90	0.69813	0.016099	12.47	0.39	0.04	44.5	27.0	17.5
min-flow	1250	120	1.6927	0.016204	12.47	0.39	0.04	42.4	27.0	15.4
> 4 hr	1250	150	3.7184	0.016343	12.47	0.39	0.04	37.9	27.0	10.9
	1250	164	5.212	0.016410	12.47	0.39	0.04	34.5	27.0	7.5
	1250	182.6	7.954	0.016530	12.47	0.39	0.04	28.1	27.0	1.1
	1250	184	8.203	0.016535	12.47	0.39	0.04	27.5	27.0	0.5
	1250	185	8.384	0.016541	12.47	0.39	0.04	27.1	27.0	0.1
2 RHR	700	90	0.69813	0.016099	12.30	0.01	0.00	44.7	30.0	14.7
min-flow	700	120	1.6927	0.016204	12.30	0.01	0.00	42.6	30.0	12.6
≤ 4 hr	700	150	3.7184	0.016343	12.30	0.01	0.00	38.1	30.0	8.1
	700	164	5.212	0.016410	12.30	0.01	0.00	34.7	30.0	4.7
	700	181.9	7.836	0.016521	12.30	0.01	0.00	28.6	30.0	-1.4
	700	190	9.34	0.016572	12.30	0.01	0.00	25.1	30.0	-4.9
2 RHR	5400	90	0.69813	0.016099	12.30	0.57	0.18	44.0	26.0	18.0
min-flow	5400	120	1.6927	0.016204	12.30	0.57	0.18	41.9	26.0	15.9
> 4 hr	5400	150	3.7184	0.016343	12.30	0.57	0.18	37.4	26.0	11.4
	5400	164	5.212	0.016410	12.30	0.57	0.18	34.0	26.0	8.0
	5400	182.6	7.954	0.016530	12.30	0.57	0.18	27.6	26.0	1.6
	5400	190	9.34	0.016572	12.30	0.57	0.18	24.3	26.0	-1.7

5.0 SUMMARY & CONCLUSIONS

Available NPSH exceeds required NPSH for the limiting conditions evaluated, short-term and long-term. This includes margin to accommodate the maximum head loss across the Core Spray and RHR suction strainers due to the predicted accumulation of fibrous and other debris following a LOCA.

There is no need to do a Safety Evaluation since the results continue to show adequate NPSH margins for the Core Spray and RHR pumps.

The completion of this calculation also satisfies the commitment made in Reference 16 to revise the NPSH calculation using a corrected curve fit for required NPSH for the RHR pump.

Impact on Other Design Output Documents

Design Basis Documents: Both the Core Spray and RHR DBDs refer to VYC-808. A Pending Change notification for both documents has been issued. A Pending Change notification to delete VYC-1678 from the references in the RHR DBD was also issued.

VYC-0019, Rev. 1: Refers to VYC-808 for the Core Spray suction strainer head loss of 0.42 ft at 4000 gpm. This revision to VYC-808 reduces that value to 0.38 ft, but the impact on VYC-0019, Rev. 1, is minimal and no change is required.

VYC-1628, Rev. 0: Refers to VYC-808 in regards to the fact that Vermont Yankee does not credit any wetwell pressure above atmospheric in the calculation of available NPSH. This revision to VYC-808 does not change that fact.

VYC-1670, Rev. 0: Refers to VYC-808 in support of use of 5 ft as a conservative value for RHR suction strainer head loss. This revision to VYC-808 does not change that conclusion.

VYC-1677, Rev. 0: Refers to VYC-808 for the debris distribution based on the short-term and long-term flow splits documented in Section 4.1.4. This revision of VYC-808 is the first use of this information.

VYC-1803, Rev. 1: Refers to VYC-808 as the basis for the calculation of available NPSH for RHR pumps at elevated suppression pool temperatures. This revision of VYC-808 does not change that statement.

VYPC 96-015, Rev. 2: Refers to VYC-808 as the basis for concluding that there is no need to throttle an RHR pump while operating in the torus cooling mode. This revision to VYC-808 does not change that conclusion.

6.0 REFERENCES

1. American National Standard for Centrifugal Pumps, ANSI/HI 1.1-1.5-1994.

2. VYC-1924, Rev. 0, "DE&S Calc. DC-A34600.006, 'Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment, RHR and CS Debris Head Loss Calculations.'"

3. VYC-1677, "Debris Source Terms For Sizing of Replacement Residual Heat Removal and Core Spray Strainers."

4. Letter, USNRC to VYNPC, Vermont Yankee Design Inspection (NRC Inspection Report 50/271/97-201), NVY 97-130, dated August 27, 1997.

5. VYC-1628F, "Limiting Torus Temperature Response, Million Second Run."

6. VYC-1919, Rev. 0, "DE&S Calc. DC-A34600-01, "RHR and CS Suction Strainer Assembly Clean Head Loss."

7. Memo, R.E.Swenson/P.A.Rainey to M.Mills, "Evaluation of Maximum Expected Flows for ECCS Strainer Replacement," VYS 98/97, dated August 28, 1997.

8. OP-2124, Rev. 43, "Residual Heat Removal System".

9. not used

10. not used

11. not used

12. not used

13. Drawing 6202-1, Rev. 1, "General Plan--Pressure Suppression Containment Vessel."

14. not used

15. not used

16. Letter, VYNPC to USNRC, "Reply to Inspection Report No. 50-271/97-201," (Appendix B, IFI 97-201-04), BVY 97-138, dated 10/27/97.

17. not used

18. not used

19. DE&S Memo, C. D. Fago to J. R. Hoffman, "Torus Temperature Margin Assessment for Confirmatory Analyses," THSAG-VY-98-064, dated April 27, 1998.

20. Memo, B. C. Slifer to K. H. Bronson, "NPSH Limits for Emergency Operating Procedures," VYS 98/58, dated May 13, 1998.

21. VYC-717B, Rev. 0, "Core Spray Pump Discharge Flow, Supplemental Addition to Revision 1."

22. Letter, USNRC to VYNPC, "Summary of Meeting on March 24, 1998, regarding Activities at Vermont Yankee Nuclear Power Station (TAC No. MA0987)," NVY 98-43, dated March 31, 1998.

23. VYC-1628, Rev. 0, "Torus Temperature and Pressure Response to Large Break LOCA and MSLB Accident Scenarios."

24. VYC-1254, Rev. 3, "Containment RPV Volume Calculations."

25. Drawing G-191207, Rev. 10

26. Drawing G-191211, Rev. 16

Derivation of strainer debris accumulation equation.

Debris is added to the suppression pool, which is a constant volume, V. The amount of debris, D, is uniformly mixed in the pool, giving a mixture concentration, D/V. The water containing the debris is pumped through a filter, which is assumed to be 100% efficient in removing the debris from the water. The filtered water is returned to the pool. Assuming a flow rate, Q, through the filter, the rate of accumulation of debris on the strainer can be expressed as follows

$$\frac{dD_{strainer}}{dt} = Q\left(\frac{D}{V}\right)$$

The concentration, $\frac{D}{V}$, changes with time as debris is removed. The rate of change of concentration is determined by taking the derivative of (D/V) with respect to time, thus

$$\frac{d(D/V)}{dt} = \frac{1}{V}\frac{dD}{dt} - \frac{D}{V^2}\frac{dV}{dt}$$

Since V = constant, $dV/dt = 0$. Also, the rate of change of debris in the pool, dD/dt, equals the negative of the rate of accumulation on the strainer. Thus,

$$\frac{d(D/V)}{dt} = -\frac{1}{V}Q\left(\frac{D}{V}\right)$$

$$\frac{d(D/V)}{(D/V)} = -\frac{Q}{V}dt$$

Integrating

$$\int \frac{d(D/V)}{(D/V)} = \int -\frac{Q}{V}\,dt$$

$$\ln\left(\frac{D}{V}\right) = -\frac{Q}{V}t + \text{constant of integration}$$

Initial Conditions,

when $t = 0$, $D = D_0$, $\therefore$ constant $= \ln\left(\frac{D_0}{V}\right)$

Substituting

$$\ln\left(\frac{D}{V}\right) = -\frac{Q}{V}t + \ln\left(\frac{D_0}{V}\right)$$

$$\ln\left(\frac{D}{V}\right) - \ln\left(\frac{D_0}{V}\right) = -\frac{Q}{V}t$$

$$\ln\frac{D/V}{D_0/V} = -\frac{Q}{V}t$$

$$\frac{D}{D_0} = e^{-\frac{Q}{V}t} \quad \text{or} \quad D = D_0 e^{-\frac{Q}{V}t}$$

Now, the amount on the strainer equals the amount removed from the pool, which is $D_0 - D$.

Thus $D_{strainer} = D_0 - D = D_0 - D_0 e^{-\frac{Q}{V}t}$

or $$\boxed{\frac{D_{strainer}}{D_0} = \left(1 - e^{-\frac{Q}{V}t}\right)}$$

ITS/VY-00-001
Rev.0

Revised ECCS Suction Strainer Head Loss Assessment for Vermont Yankee

Prepared for
Vermont Yankee Nuclear Power Corporation

Innovative Technology Solutions Corporation
6000 Uptown Blvd. NE, Suite 300
Albuquerque, NM 87110

October 15, 2000

Prepared By:	Peter K. Mast	Signature	10/15/00 Date
Reviewed By:	Gilbert L. Zigler	Signature	10/16/00 Date

An assessment of ECCS suction strainer head loss for the Vermont Yankee plant was completed in August of 1998 (Calculation DC-A34600.006). Since that time, better information has been obtained on a couple of key parameters in the analysis. These changes are as follows:

- The long-term CS flow rate was determined to be 3500 GPM (previously, a parametric range of 4000-4600 GPM had been considered).
- The long-term pool temperature has been determined to be 185 Deg F.
- The quantity of sludge used for the analysis was reduced by approximately a factor of two.
- Minor changes in fibrous debris distribution.

As a result of the first and fourth of these changes, the distribution of debris on the RHR and CS strainers is changed; a greater fraction of the debris now is deposited on the RHR strainer. Thus, this change would be expected to result in a higher RHR strainer head loss (same flow rate, same temperature, and greater debris quantity) and a lower CS strainer head loss (lower flow rate, same temperature, and lower debris quantity).

The second of these changes, the increased water temperature, and the third of these changes, the reduction in sludge quantity, would tend to reduce head loss for both the CS and RHR strainers, assuming the same assumptions on sludge behavior (filtration) are used in the analysis.

To evaluate the impact of the above changes on strainer head loss, Cases 1 and 3b (the long-term 1-pump RHR and CS analyses, respectively) were reanalyzed. The following table summarizes the debris quantities used in this analysis along with a comparison to those previously used.

Parameter	Units	RHR System		CS System	
		Old Case 1	New Case 1	Old Case 3b	New Case 3b
Flow Rate	GPM	7400	7400	4000	3500
Water Temperature	Deg F	173	185	173	185
Nukon	Lbm	258	256	152	122
Fibermat	Cu-Ft	9.6	10	5.7	5
TempMat	Lbm	20.5	31	12.1	15
Armaflex	Cu-Ft	0 (1)	0 (1)	0 (1)	0 (1)
Sludge (dry)	Lbm	546	271	322	129
Rust	Lbm	35.3	35	20.8	17
Qualified Coat	Lbm	61	60	36	29
Unqual Coat – IOZ	Lbm	70	70	42	42
Unqual Coat – Epox	Sq-Ft	0 (2)	0 (2)	0 (2)	0 (2)

(1) – This material was shown to float and not impact strainer performance.
(2) – ARL testing showed that this coatings debris did not deposit on strainer.

Using the above distributions of fibrous insulation debris, the total mass of fibrous debris changed from 336 lbm to 347 lbm for Case 1 (RHR) and from 198 lbm to 167 lbm in Case 3b (CS). Aside from the change in the particulate debris quantities specified above, and the change in flow rate for Case 3b, all other analysis parameters used in this reassessment are identical to those used in the previous calculations. This includes a reduction of 50% in the quantity of sludge, qualified coatings debris, and IOZ debris being deposited on the strainer due imperfect filtration of this material by the relatively thin fiber mat.

The results of these analyses, along with a comparison to the previously calculated results, are presented in the following table.

Calculated Parameter	Units	RHR System		CS System	
		Old Case 1	New Case 1	Old Case 3b	New Case 3b
Head Loss	Ft water	0.33	0.26	0.21	0.08
Debris Thickness	inches	1.9	2.1	2.6	2.2

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1.0 Introduction

The objective of this CCN is to determine the available NPSH for the Residual Heat Removal (RHR) and Core Spray (CS) pumps at design flow during the most limiting torus heat-up scenario and compare the available NPSH (NPSHa) to the required NPSH (NPSHr).

2.0 Analysis

For each of the RHR and CS pumps, NPSHa as a function of time will be determined based on methods developed in VYC-808, Revision 6. NPSHa varies with time only because the fluid temperature does so during the transient. The limiting torus temperature profile from VYC-1628F (run15) is used for this analysis. The NPSHa for each pump is then plotted against the vendor's allowable NPSHa to demonstrate pump operability.

The vendor's allowable NPSHa are shown in Figures 2.1-1 (RHR Pumps) and 2.2-1 (CS Pumps). For a complete description of these curves, see VYC-808, Revision 6 and its Attachment 5. In summary, the curves show the allowable operating period for a given pump at any NPSHa. Provided the calculated NPSHa for a specific flow rate is, at all times, greater than the corresponding curve for the same flow rate, the pump is considered operable regarding NPSH.

The pump vendor is Sulzer Bingham Pumps, Inc. (SBPI). Their allowable NPSHa are provided for flow rates of 6400, 7000, and 7600 gpm for the RHR pump (VYC-808, Attachment 5). The maximum long-term flow rate of the system is 7400 gpm (VYC-808, Section 3.4). The first step in this calculation is to develop an allowable NPSHa curve at the maximum flow. This is done using the curve fit from VYC-808, Revision 6, Section 2.2.2 for times between 1 and 7 hours, and by linear interpolation between the SBPI curves for 7000 gpm and 7600 gpm beyond 7 hours. The use of a linear interpolation beyond 7 hours is conservative based on the predicted variations among 6400, 7000, and 7600 gpm as shown on the SBPI curves. The curve fit from VYC-808 is:

$$NPSH_{RHR} = 23.0 + \frac{Q - 6400}{1200}\ feet \qquad \text{(Eq. 1.1)}$$

The next step is to plot the available NPSH for the limiting torus temperature scenario. The equation for NPSHa – developed in Section 4.2.2.4 of VYC-808 for the RHR pump at 7400 gpm – is:

$$NPSHa_{RHR} = (p_{torus} - p_v)(144)v + Z - H_t - H_D - H_{strainer} \qquad \text{(Eq. 1.2)}$$

where, p_{torus} = torus pressure (14.7 psia)
p_v = vapor pressure of water at temperature (psia)
144 = conversion factor
v = specific volume of water at temperature (ft^3/lbm)
Z = elevation head (12.42 ft)
H_f = friction head loss (2.61 ft)
H_D = strainer debris head loss (0 ft)
$H_{strainer}$ = clean strainer head loss (0.35 ft)

The method of solution for the Core Spray pump is the same as that for the RHR pump, but with the following exceptions. SBPI's allowable NPSHa are provided for flow rates of 3000, 3500, and 4600 gpm for the CS pump (attached). The maximum long-term flow rate of the system is 3500 gpm (VYC-808, Section 3.4). Therefore, the minimum allowable NPSH is known and needn't be derived.

The equation for NPSHa developed in Section 4.2.3.4 of VYC-808 for the CS pump at 3500 gpm is also Equation 1.2, but with the following values:

p_{torus} = torus pressure (14.7 psia)
p_v = vapor pressure of water at temperature (psia)
144 = conversion factor
v = specific volume of water at temperature (ft^3/lbm)
Z = elevation head (12.59 ft)
H_f = friction head loss (3.06 ft)
H_D = strainer debris head loss (0 ft)
$H_{strainer}$ = clean strainer head loss (0.32 ft)

3.0 Inputs/Outputs

Design inputs used in this calculation are:

- the temperature data from VYC-1628F for the limiting torus heat-up scenario (`run15`), and
- an adder to the above temperatures that accounts for event conditions that were not modeled. From Reference 19, the most limiting adder is 0.9°F.

The assumptions used in this calculation are the same as those in VYC-808, Revision 6.

4.0 Results

4.1 RHR Pump

Figure 2.1-1 shows the SBPI allowable times at NPSH for RHR pump flow rates of 6400, 7000, and 7600 gpm. The same curve for the design flow rate of 7400 gpm is also shown. It is derived by using Equation 1.1 for times between 1 hour and 7 hours, and by linear interpolation between the SBPI curves for times beyond 7 hours. The data points are:

Time (hours)	NPSHa @ 7000 gpm (feet)	NPSHa @ 7600 gpm (feet)	NPSHa @ 7400 gpm (feet)
1	N/A Use Equation 1.1		23.8
7	N/A Use Equation 1.1		23.8
13.5	25.0	28.0	27.0
21	28.5	31.6	30.6
100	29.5	32.75	31.7
8000	29.5	32.75	31.7

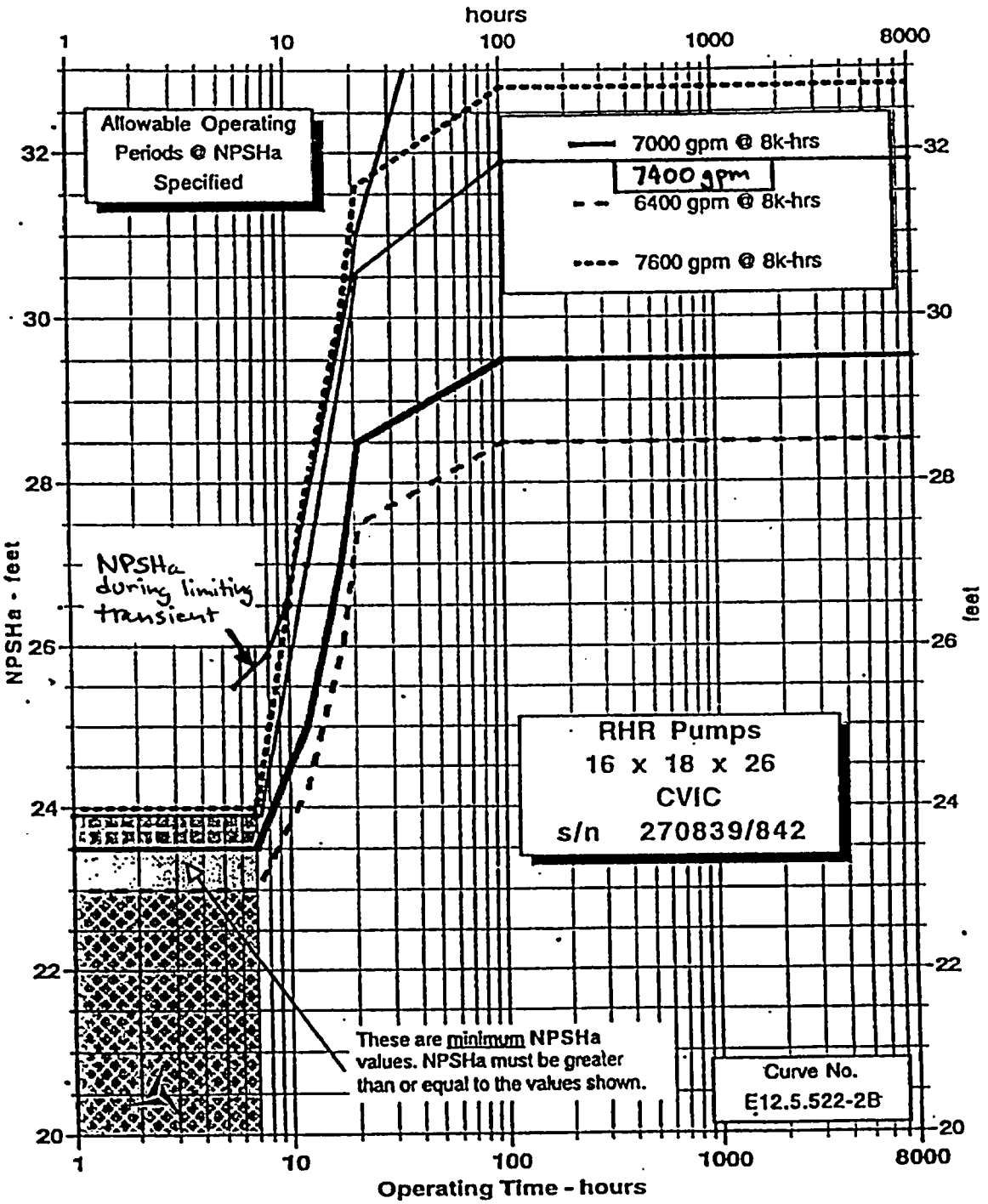
The limiting NPSHa curve for the RHR pump is determined with Equation 1.2 and the limiting torus water temperature profile from VYC-1628F, `run15` (Reference 5). The temperatures from `run15` are increased by 0.9°F to account for event conditions that were not modeled (Reference 19). The data points for the curve are shown in Table 2.1-1. Values for p_v and v are interpolated from the saturated steam tables.

The limiting NPSHa falls above the allowable curve at the design flow rate for all times. Therefore, the pump's operability is not compromised.

Table 2.1-1
RHR Pump NPSHa During the Limiting Torus Temperature Transient

Time	Temperature (°F)		p_v (psia)	v (ft^3/lbm)	NPSHa (ft)
	From run15	+0.9°F			
5.6 hrs (20,240 sec)	181.7	182.6	7.956	0.016525	25.5
8 hrs (28,797 sec)	180.9	181.8	7.819	0.016521	25.8
10 hrs (36,050 sec)	179.2	180.1	7.529	0.016511	26.5
20 hrs (72,054 sec)	167.7	168.6	5.807	0.016443	30.5
21 hrs (75,554 sec)	166.7	167.6	5.555	0.016432	31.1
100 hrs (360,079 sec)	138.1	139.0	2.816	0.016288	37.3

Figure 2.1-1
RHR Pump Allowable Operating Periods @ NPSHa Specified



4.2 CS Pump

Figure 2.2-1 shows the SBPI allowable times at NPSH for CS pump flow rates of 3000, 3500, and 4600 gpm.

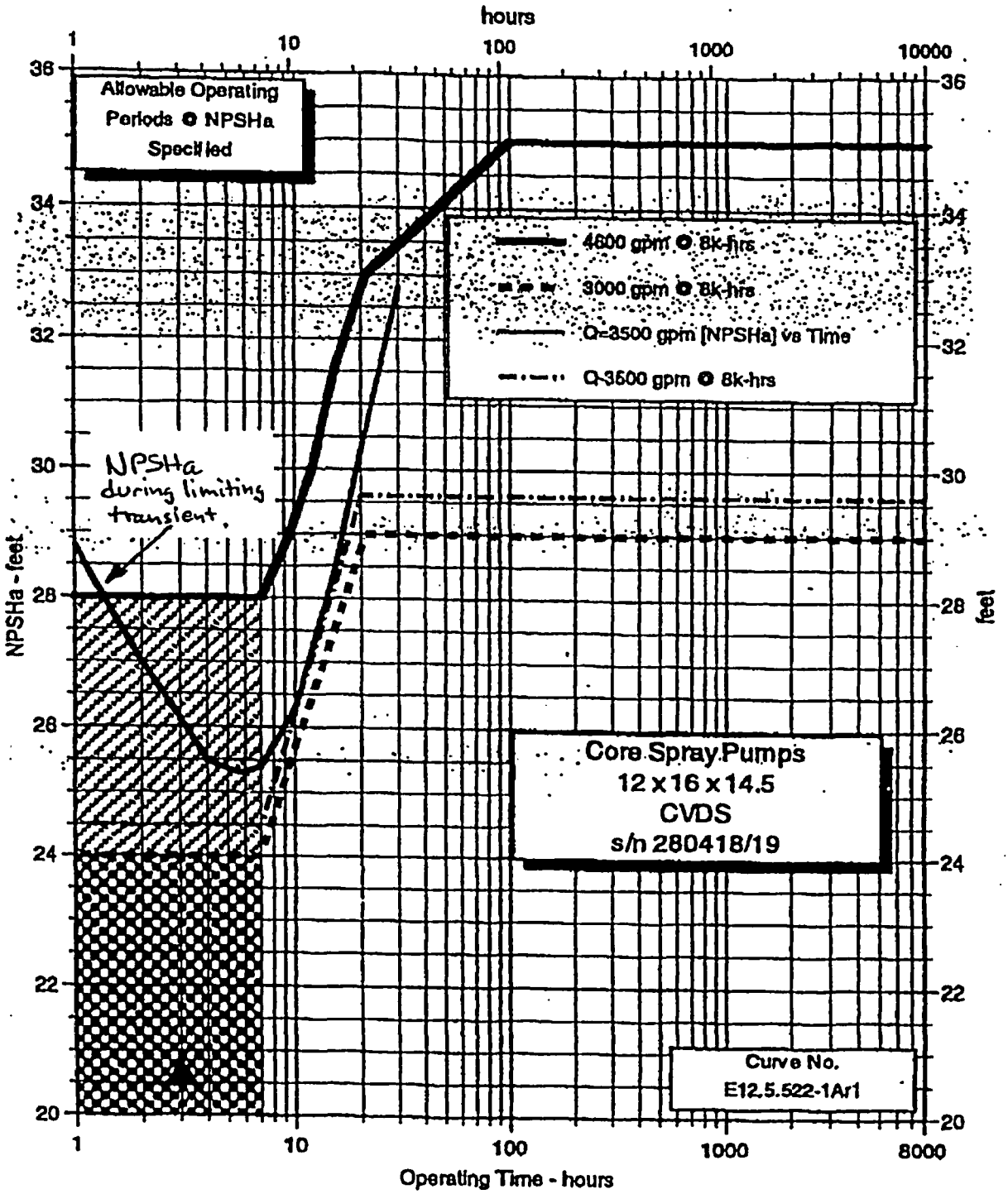
The limiting NPSHa curve for the CS pump is determined with Equation 1.2 and the limiting torus water temperature profile from VYC-1628F, run15 (Reference 5). The temperatures from run15 are increased by 0.9°F to account for event conditions that were not modeled (Reference 19). The data points for the curve are shown in Table 2.2-1. Values for p_v and v are interpolated from the saturated steam tables.

The limiting NPSHa falls above the allowable curve at the design flow rate for all times. Therefore, the pump's operability is not compromised.

Table 2.2-1
CS Pump NPSHa During the Limiting Torus Temperature Transient

Time	Temperature (°F)		p_v (psia)	v (ft^3/lbm)	NPSHa (ft)
	From run15	+0.9°F			
1 hrs (3,595 sec)	172.3	173.2	6.449	0.01647	28.8
2 hrs (7,203 sec)	177.2	178.1	7.204	0.016499	27.0
4 hrs (14,410 sec)	181.0	181.9	7.836	0.016521	25.5
5.6 hrs (20,240 sec)	181.7	182.6	7.956	0.016525	25.3
7 hrs (25,194 sec)	181.4	182.3	7.904	0.016524	25.4
10 hrs (36,050 sec)	179.2	180.1	7.529	0.016511	26.3
15 hrs (54, 052 sec)	173.4	174.3	6.613	0.016476	28.4
20 hrs (72,054 sec)	167.7	168.6	5.807	0.016443	30.3
30 hrs (108,056 sec)	158.7	159.6	4.697	0.016393	32.8

Figure 2.2-1
CS Pump Allowable Operating Periods @ NPSHa Specified



5.0 Conclusion

The limiting NPSH available for the RHR and CS pumps have been determined for the respective design flow rates during the limiting torus temperature transient. In both cases, the limiting NPSHa falls above the respective allowable NPSH for all times. Therefore, the pumps' operability are not compromised.

Attachment – Letter, Sulzer-Bingham to D. E. Yasi, VYNPC, March 26, 1999

Telefax

SULZER PUMPS
Division of Sulzer Rotec

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Date: 26 March, 1999

To: Mr. Dan Yasi
VERMONT YANKEE DESIGN ENGINEERING OFFICE
Massachusetts

Fax: 8-1-978-568-3732

Pages: 1 (including this one)

Subject: Serial #270839/842 – 280418/419
F-97-10782 30P59
Yankee PO QA42125

With reference to your letter of 12 March 99, based on original NPSHr curve, test data the period of operation will nearly equal the 3000 gpm curve.

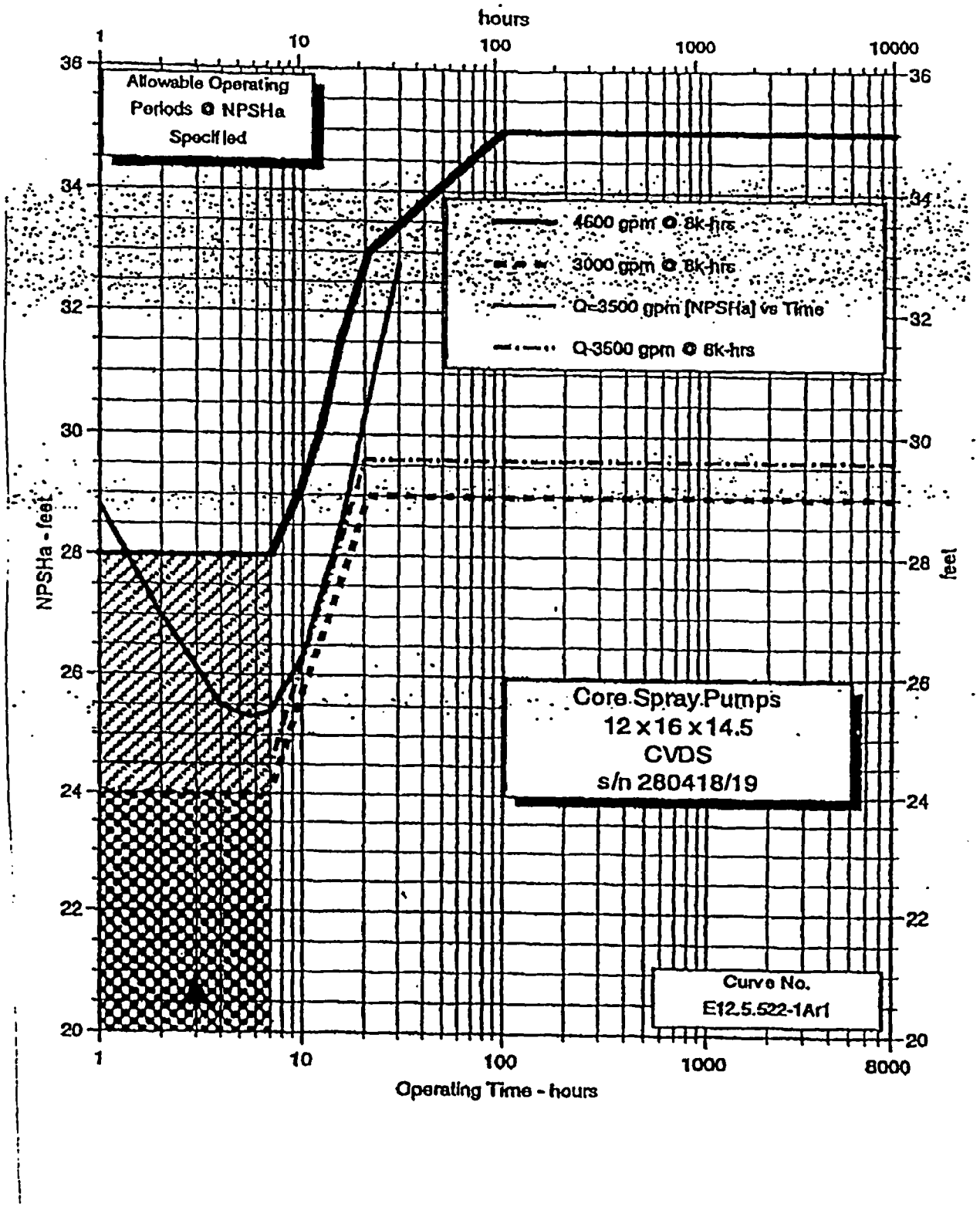
Please see curve (E12.5.522-1Ar1) attached.

Kind Regards,

Kenny Thomson

Kenny Thomson

/kla


hours
1
10
100
1000
10000
Allowable Operating Periods @ NPSHa Specified
4600 gpm @ 8k-hrs
3000 gpm @ 8k-hrs
Q=3500 gpm [NPSHa] vs Time
Q-3500 gpm @ 8k-hrs
Core Spray Pumps
12 x 16 x 14.5
CVDS
s/n 280418/19
Curve No.
E12.5.522-1Ar1
NPSHa - feet
feet
36
34
32
30
28
26
24
22
20
1
10
100
1000
8000
Operating Time - hours

Vermont Yankee – Strainer/Torus Design Change Overview
Refuel Outage 20, Spring 1998

Hydraulic Design of the RHR and CS Strainer Assemblies

- Increase in Filtering Area

		Existing	Replacement
RHR	Suction (A or B)	47 ft^2	808 ft^2
CS	Suction (A or B)	24 ft^2	432 ft^2

Note: Areas shown are for each suction line.

- Improved fitting geometry. Replace fabricated Tees with Rams Head, (24" SR Elbows) and Reducing Elbow (24x16 LR Elbow)

- Cylindrical perforated plate strainers replaced with PCI stacked disk strainers with ported core tube for uniform flow distribution to screen area. Strainers have 47" OD disks and 24" OD core tubes.

Predicted Performance Under URG Debris Loads

Conditions Shown are for Strainer Design not Plant Design Basis.		1 RHR-Pump, full flow, LT	2 RHR-Pumps, full flow, ST	2 RHR-Pumps, full flow, LT	1 CS-Pump, full flow, ST	1-CS-Pump, red. flow, LT
Flow Rate per Penetration	gpm	7400	14200	14200	4600	4000
Max Guaranteed Head Loss: Clean Strainer+Fittings	ft H2O	0.35	1.22	1.22	0.55	0.42
Max Guaranteed Head Loss: Strainer+Fittings+Debris	ft H2O	0.56	1.53	1.59	0.69	0.65
Debris Head Loss Alone**	ft H2O	0.21	0.31	0.37	0.14	0.23
** Note: Debris head loss being confirmed by test **Debris quantities based on URG methodology						

SULZER BINGHAM PUMPS INC.

QUALITY LEVEL
- ☐ Direct
- ☐ Indirect

SULZER BINGHAM PUMPS INC. DOCUMENT
E12.5.561
NPSH / MINIMUM FLOW STUDY - SUMMARY REPORT
F-97-10782 (30P59)

SALES ORDER 270839/72 and 280418/9

ASME CODE
SECTION
CLASS NO.
CODE EDITION (YEAR)
ADDENDA:
SEASON
YEAR

CUSTOMER Yankee Atomic Electric Co. / Vermont Yankee

PROJECT NPSH Study of RHR CS Pumps

CUSTOMER P.O. NO. QA42125

CHANGE ORDER NO.

SPECIFICATION NO. N/A

REVISION NO.

CUSTOMER APPROVAL NUMBER

SPACE FOR CUSTOMER APPROVAL STAMP
(when applicable/available)

CALCULATION VYC- 808-R6
ATTACHMENT 5
PAGE 1 OF 19

CUSTOMER APPROVAL REQUIREMENT

☒ YES ☐ NO ☐ INFORMATION ONLY

CERTIFIED AS A VALID SULZER BINGHAM PUMPS INC. DOCUMENT

☒ For Outside Vendor

☐ For Manufacture at Sulzer Bingham Pumps Inc.

☐ Risk Release Inspection Report # _____

☐ Other (specify) _____

INITIAL APPROVALS (SIGNATURE)		Date
Engrg. Assurance		5/26/98
Quality Assurance		

CERTIFICATION (when applicable)

This Document is certified to be in compliance with THE APPLICABLE PURCHASE ORDER, SPECIFICATIONS, PROCEDURES, AND ADDITIONAL REQUIREMENTS LISTED IN THE APPENDICES.

Professional Engineer

State Registration No.

Date _____ (Seal)

Originating Dept.: HQ Engineering

By: Rolf Lueneberg

Title: Hydraulic Design Consultant

Initial Date: 1 May, 1998

APPLICABLE S.O. NUMBERS

270839/842 and 280418/9

Control	Order Number	Rev.
		1

DOCUMENT IDENTIFICATION

Kenny/misc/f97-10782c

CALCULATION VYC- 808.26
ATTACHMENT 5
PAGE 2 OF 19

SULZER PUMPS
Division of Sulzer Roteq

Status Sheet For: DOCUMENT REVISOIN RECORD

Revision No.	Issue Date	ECN No.	Location	Description	By/Approved
1	05-20-98	---	Page 3 Graphs	Item 3, Added Paragraph Revised graphs to E12.5.522 1B and 2B	KT/DLE 5/26/98

Initial Issue Date _____ Status Sheet Pg. _____ Cont. on Pg. _____ Doc. I.D. _____

SUBJECT: NPSH/Minimum Flow - Study (Summary Report)
Yankee Atomic Electric Company
Vermont Yankee
F97-10782
FS Reference - 30P59
Detailed Report - See E12.5.522

CALCULATION VYC- 808R6
ATTACHMENT 5
PAGE 3 OF 19

ORIGINAL PERFORMANCE CURVE No's.:

I) 16 x 18 x 26 CVIC: No. 28567 (S.O. No. 270839)
27922 (S.O. No. 270840)
28469 (S.O. No. 270841)
28470 (S.O. No. 270842)

SERVICE: Residual Heat Removal (RHR)

II) 12 x 16 x 14½ CVDS: No. 27691 (S.O. No. 280418)
27692 (S.O. No. 280419)

SERVICE: Core Spray (CS)

I) Introduction

Purpose: To determine the pump operability requirements for (a) minimum pump flow and (b) minimum NPSH for the hypothetical design basis accident mode of operation. The minimum NPSH requirements are based on original pump test data and the application of SBPI knowledge and technology to supplement that data and to extend the range of the original data to higher and/or lower flow rates.

Note: This is a summary report of detailed NPSH report E12.5.522

II) Minimum Flow

A. Expected modes of operation under minimum flow conditions (defined by Vermont Yankee).

RHR - Pumps

CALCULATION VYC- 808 R6
ATTACHMENT 5
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0 to ≤ 4 hours at 350 GPM
≥ 4 hours at 2700 GPM

CS - Pumps

0 to ≤ 4 hours at 300 GPM
≥ 4 hours at 1250 GPM

B. Vibration Data at Minimum Flow (supplied by Vermont Yankee).

Following vibration data were supplied to SBPI:

Data for pump and motor in table - form on 14 January 1998, for:
RHR - Pumps at 425 and 6500 GPM for
CS - Pumps at 300 and 3000 GPM

Additional vibration signatures for pump and motor on 18 March 1998, for CS - pumps at 300 GPM, to complete data from 14 January, 1998.

C. Evaluation of Vibration Data

RHR - Pumps

Data from 14 January 1998 are acceptable for the expected modes of operation under minimum flow conditions, although the overall vibration velocities (in/sec) peak readings were taken at a minimum flow of 425 GPM in lieu of 350 GPM.

CS - Pumps

Data from 14 January 1998 were not complete and indicated signs of unacceptability. Additional vibration signatures from 18 March 1998 are acceptable for the expected modes of operation under minimum flow conditions.

D. Basis for Minimum Flow Requirements

Continuous minimum flow is a function of pump specific speed "N_S", head per stage and suction specific speed N_{SS}-3% (at B.E.P.).

Lower minimum flows than continuous minimum flow are possible and acceptable for shorter durations of operation, depending on acceptable vibration levels (on pump and motor) and NPSH-Margin (NPSHA vs. NPSHR-3%).

For the expected modes of operation under minimum flow conditions:

RHR - Pumps

NPSHA from Vermont Yankee NPSHA-Curve. NPSHR-3% from SBPI Curve No. Id.

At 350 GPM
NPSHA = 35.8 Feet @ 155 °F, old strainer
NPSHR-3% = 30 Feet

At 2700 GPM
NPSHA = 34.5 Feet @ 155 °F, old strainer
NPSHR-3% = 26 Feet

CALCULATION VYC- 808 R6
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CS - Pumps

NPSHA from Vermont Yankee NPSHA-Curve. NPSHR-3% from SBPI Curve No. IId.

At 300 GPM
NPSHA = 36 Feet
NPSHR-3% = 32.5 Feet

At 1250 GPM
NPSHA = 35.5 Feet
NPSHR-3% = 27 Feet

E. Recommended Minimum Flow Requirements

The recommended minimum flow modes are the same as the expected modes of operations.

RHR - Pumps

0 to ≤ 4 hours at 350 GPM
≥ 4 hours at 2700 GPM

CS - Pumps

0 to ≤ 4 hours at 300 GPM
≥ 4 hours at 1250 GPM

III) NPSH

A. Expected modes of operation under minimum NPSH conditions (defined by Vermont Yankee).

Based on the operating conditions and the NPSHA per May-Witt Decay heat diagrams the expected modes are as follows:

CALCULATION VYC- 808 R6
ATTACHMENT 5
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RHR - Pumps at 7000 GPM

7 hours with NPSHA of 23 to 24 ft.

Plus 5 additional hours with NPSHA of 24 to 26 ft.
Plus 5.5 additional hours with NPSHA of 26 to 28 ft.
Plus 3.5 additional hours with NPSHA of 28 to 29 ft.

CS - Pumps at 3000 GPM

7 hours with NPSHA of 24 to 25 ft.

Plus 2.5 additional hours with NPSHA of 25 to 26 ft.
Plus 2.5 additional hours with NPSHA of 26 to 27 ft.
Plus 3 additional hours with NPSHA of 27 to 28 ft.
Plus 6 additional hours with NPSHA of 28 to 30 ft.

B. Discuss pump performance based on original test data (included original data and curves)

The RHR - and CS - pumps have been NPSH-tested over a limited flow-range. No head-drop was specified on the original curves.

RHR-Pumps: B.E.P. - Flow at 6200 GPM

The most complete NPSH-Test was performed on Pump No. 270840 at maximum impeller diameter of 26.5 in.. NPSH-tests were performed at 6300, 8065 and 9502 GPM (See T-270840-A). 5 to 8 tests points were taken at each of the above capacities to establish the slope and shape of NPSH vs. Head. Purpose of the 'witness' tests were to demonstrate that the pump met the contractual requirements.

Witness - tests for each pump with a trimmed impeller diameter of 25.563 inch, only 2 to 3 NPSH - tests points were taken at capacities of approximately 6300, 7200, 8500 and 8900 GPM.

These tests are not complete enough to determine the exact NPSH-characteristics of the pumps. The duration of the witness - test of each pump, including flow from 0 to runout, pressures, head, RPM, efficiency, power and NPSH took between 1 and 2 hours.

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This implies that the pumps were running only a few minutes with reduced NPSH. This is sufficient time to observe pump behavior at reduced NPSHA. In addition, no vibration readings were taken during these short duration NPSHA tests. A more thorough representation of the complete NPSHR characteristic is test T-270840-A. See SBPI Curve Ic. The difference in NPSHR due to impeller trim does not have a significant influence with these pumps.

<u>CS-Pumps:</u> B.E.P. - Flow at 3750 GPM

The most representative NPSH-Test was performed during Test No. 176101 at 13.81 inches and 13.00 inches impeller diameters. It was a pump for a different order, but an identical pump. NPSH - tests were performed at approximately 1780 RPM.

Converted to 3582 RPM, by using the affinity laws, the flow rates were 3005, 4037, 5038, 5120, 6000, 6020 and 6524 GPM (see T-176101-D/G). 4 to 10 tests points were taken at each of the above capabilities to establish the slope and shape of NPSH vs. Head. These tests are sufficient to develop NPSHR characteristics for the pump and are representative of the units delivered on the above serial numbers. Trim diameters have been factored in the developed NPSHR curves.

The most complete and representative test T-176101-D/G. (see also SBPI Curve No. IIc).

1. **Relationship to "Knee" of Pump Curve**

   When plotting the results of an NPSH-test (NPSH vs. Head), starting with ample NPSH, the head will either stay constant, vary or drop slightly with reducing NPSH. At some reduced NPSH value, the head will fall off more quickly before falling off totally. This defines the "Knee" of an NPSH-test.

   The knee may be very sharp, that means 1%, 3%, 6%, etc. head-drop will occur at about the same NPSHA value. Operation near or close to this type of knee is not recommended. The knee may also be well-rounded, that means 1%, 3%, 6% etc. head-drop will happen at different NPSHA values. To develop the shape of the NPSHR knee several test points are required.

2. **Similarity to Other Pumps Used in Nuclear Application**

   Pump designs provided for the above services are found in other nuclear installations in the same or similar applications. They are basically of similar style and design, but may differ in nozzle and maximum impeller sizes. There are pumps of same specific speed, suction specific speed and impeller inlet design features (NPSH).

3. **Relevant Operating Experience of Similar Pumps at Minimum NPSH**

   Operating conditions at various nuclear stations vary, however similar units to those furnished have been supplied to other installations with similar reduced NPSH levels during a nuclear incident. Similar reviews have been conducted for them.

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Specified "normal" operating conditions (NPSHA) are not that close to NPSHR-3% or NPSHR-6%.

Operating for short durations at NPSHR-3% to NPSHR-6% should not be detrimental to the pump life in this service.

4. **Cavitation-Tests performed on same or similar pumps and conclusion from those tests.**

Cavitation (NPSH) - Tests have been performed on same pumps or similar pumps that have been used on the NPSH-study for Vermont Yankee.

NPSH-Test on same pumps is T-270840-A (RHR-Pump) and T-176101-D/G (CS-Pump) for discussion and conclusion see IIIB.

NPSH - Tests on similar pumps are used to establish tendencies and extrapolation of NPSH-Curves. (See SBPI Curve No. Id & IId). Similar pumps are of same suction specific speed, number of vanes and suction vane inlet angles.

5. **Acceptability of the units in their specified services.**

RHR - Pumps:

When operating for seven (7) hours at 7000 GPM with NPSHA of 23 to 24 feet, the pumps will be in the cavitation mode. The head-drop will be above 6% but the NPSHA is still greater than the original minimum operational NPSH (See SBPI Curve No. Ic and Id). The pumps, if operated with the minimum NPSH, are within acceptable limits of the NPSH "knee".

The pumps will remain acceptable following the "Postulated Accident Scenario" and operation under reduce NPSH conditions, providing NPSHA > NPSHR-3%.

CS - Pumps:

When operating for seven (7) hours at 3000 GPM with NPSHA of 24 to 25 feet, the pumps will be in the cavitation mode. The head-drop however will be less than 3% (see SBPI Curve No. IIc and IId). The pumps, if operated with the minimum NPSH limits, have adequate margin prior to the NPSH "knee".

The pumps will remain acceptable following the "Postulated Accident Scenario" and operation under minimum NPSH conditions, providing NPSHA > NPSHR-3%.

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C. **Extrapolation to higher/lower flows using test date from other sources.**

1. **Technical Basis for Extrapolation**

When pumps have been NPSH-tested for a small flow-range only (Vermont Yankee) and NPSH-data are required outside this flow-range, the NPSH-curves have to be extrapolated. Only NPSH-tests of pumps of similar style, design, specific speed, suction specific speed, impeller number of vanes and suction vane angles can be used for this purpose.

2. **Pump data selected and similarity to Vermont Yankee pumps**

RHR - Pumps:

Following pump sizes have been used to extend NPSHR to lower flows (see SBPI curve No. Ia):

18 x 24 x 28 CVIC
8 x 10 x 21 CVIC

CS - Pumps:

Following pump sizes have been used to extend NPSHR to lower flows (see SBPI curve No. IIa):

12 x 14 x 14$^1/_2$ CVDS
14 x 16 x 23 CVDS

3. **Predicted NPSH at lower/higher flow rates as extrapolations of original test data**

In this case, the minimum flow rates are extremely low:

RHR-Pumps: $350 \text{ GPM} \hat{=} \frac{350}{6200} x100 = 5.6\%$ of B.E.P. Flow

CS-Pumps: $300 \text{ GPM} \hat{=} \frac{300}{3750} x100 = 8.0\%$ of B.E.P. Flow

No NPSH-tests of same or similar pumps are available at these low percentages of B.E.P. flow.

Extrapolation to these low flow rates based only on estimation and experience of NPSH-tests on other style of pumps. Experience comes from NPSH-tests which have been performed in recent years, when more detailed NPSH-tests were required.

Extrapolation for higher flow rate NPSHR is not necessary since sufficient test data exists for these flow rates. If extrapolation for higher flow rates is necessary a similar method will be used.

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D. Basis for Minimum NPSH Recommendations

1. No Permanent Pump Damage Due to Cavitation

Depending on water temperature and water chemistry there can be some 'frosting' (e.g. light pitting) on the impeller suction vanes, but there will be no detrimental pump damage due to cavitation when operating at minimum NPSH for the specified hours of operation.

This applies mainly to the RHR-pumps when operating for seven (7) hours at 7000 GPM with NPSHA of 23 to 24 feet. It will apply to a lesser degree to the CS-pumps when operating for seven (7) hours at 3000 GPM with NPSHA of 24 to 25 feet.

2. Operation above the "Knee" of the Pump Curve

Maintaining the minimum NPSH values is a "must" when operating near or at the NPSHR knee. For continuous operation this is essential, since small variances in product temperature can suddenly reduce the NPSHA. Provided the NPSH values are supplied for the RHR and CS services and durations, at these values limited, operation at the NPSHR "knees" are acceptable.

Short-Term Operation at the "Knee" is acceptable providing temperature is controlled.

3. Conformance to Original Pump Requirements and Extrapolated Requirements, as defined herein

These pumps meet the original NPSHR requirements as specified. The original pump NPSH requirements were not well defined. The result was only two (2) NPSH-Test points for each capacity were measured. From two (2) NPSH-test points it is not possible to establish the "knee". At each NPSH-test point (during witness tests) the pumps were operating only a few minutes and the capacity-range was limited. This was not considered critical since similar pumps of the same hydraulics had been comprehensively tested.

The extrapolated NPSH requirements apply mainly to a flow regime of 350 and 2700 GPM for the RHR-pumps and 300 and 1250 GPM for the CS-pumps as described under III.c.3. Due to unknown suction vane profile and clean-up on NPSH-margin as described under II.d is required.

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E. **Recommended Minimum NPSH Requirements**

1. **Acceptable durations of operation:**

RHR-Pumps:

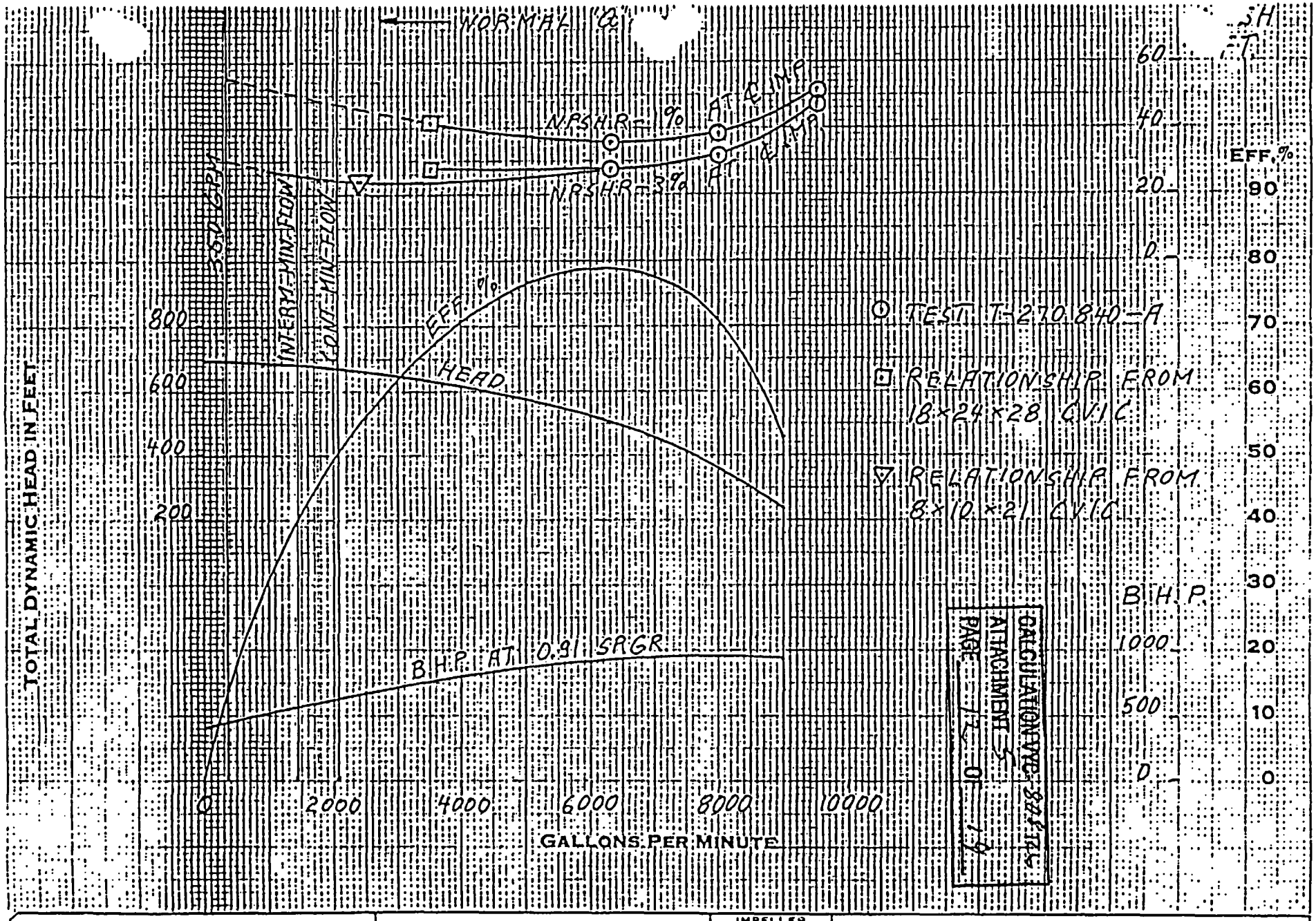
At minimum flow of 350 and 2700 GPM: as described under II.d and II.e.
At 7000 GPM: as shown on SBPI Curve No. E12.5.522-2B

CS-Pumps:

At minimum flow of 300 and 1250 GPM: as described under II.d and II.e.
At 3000 and 4600GPM: as shown on SBPI Curve No. E12.5.522-1B

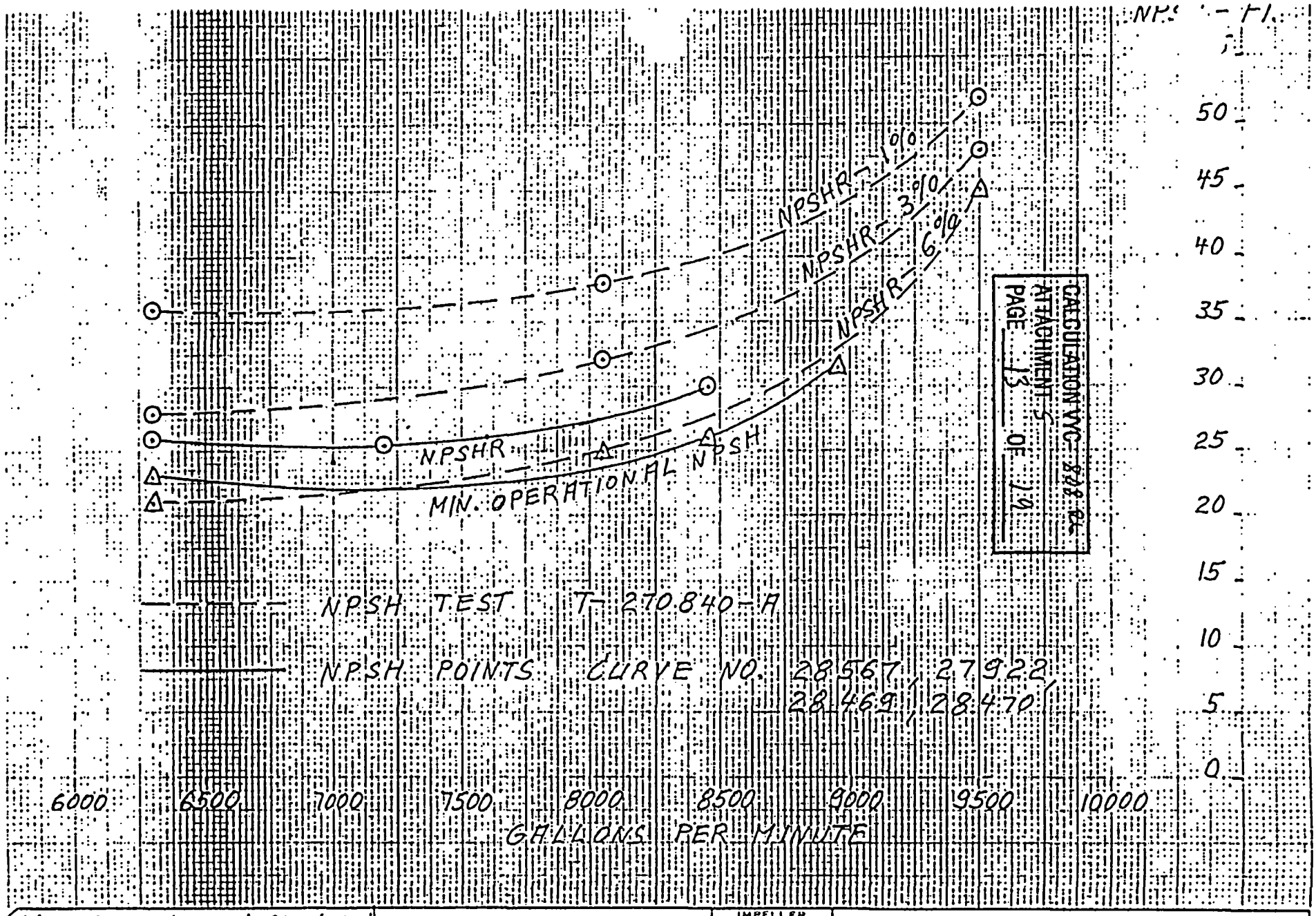
2. **Purpose of this report:**

This report and review was conducted to clarify test results taken approximately thirty (30) years earlier. It is also intended to provide additional understanding regarding the limits of these machines both hydraulically and mechanically. These machines are suitable for the services they were originally supplied to, however they must operated within the agreed limits.



YANKEE ATOMIC ELECTRIC VERMONT YANKEE RHR PUMPS S.O. NO. 270839/842	PUMP ENGINEERING DEPT. **SULZER BINGHAM PUMPS INC.** 2. Dec. 97; R.L.	IMPELLER MAX. DIA. 26.500"	16 × 18 × 26 CVIC		PUMP
		MIN. DIA.	DIA. IMPELLER 25.563"	IMPELLER PATT. 1613 CVIC-1	1785 R.P.M.
		EYE AREA 121.3 SQ. IN.	N.P.S.H. REQUIRED	REFERENCE	CURVE No. Ia

Form No. 930-1



CALCULATION VVC-808-86
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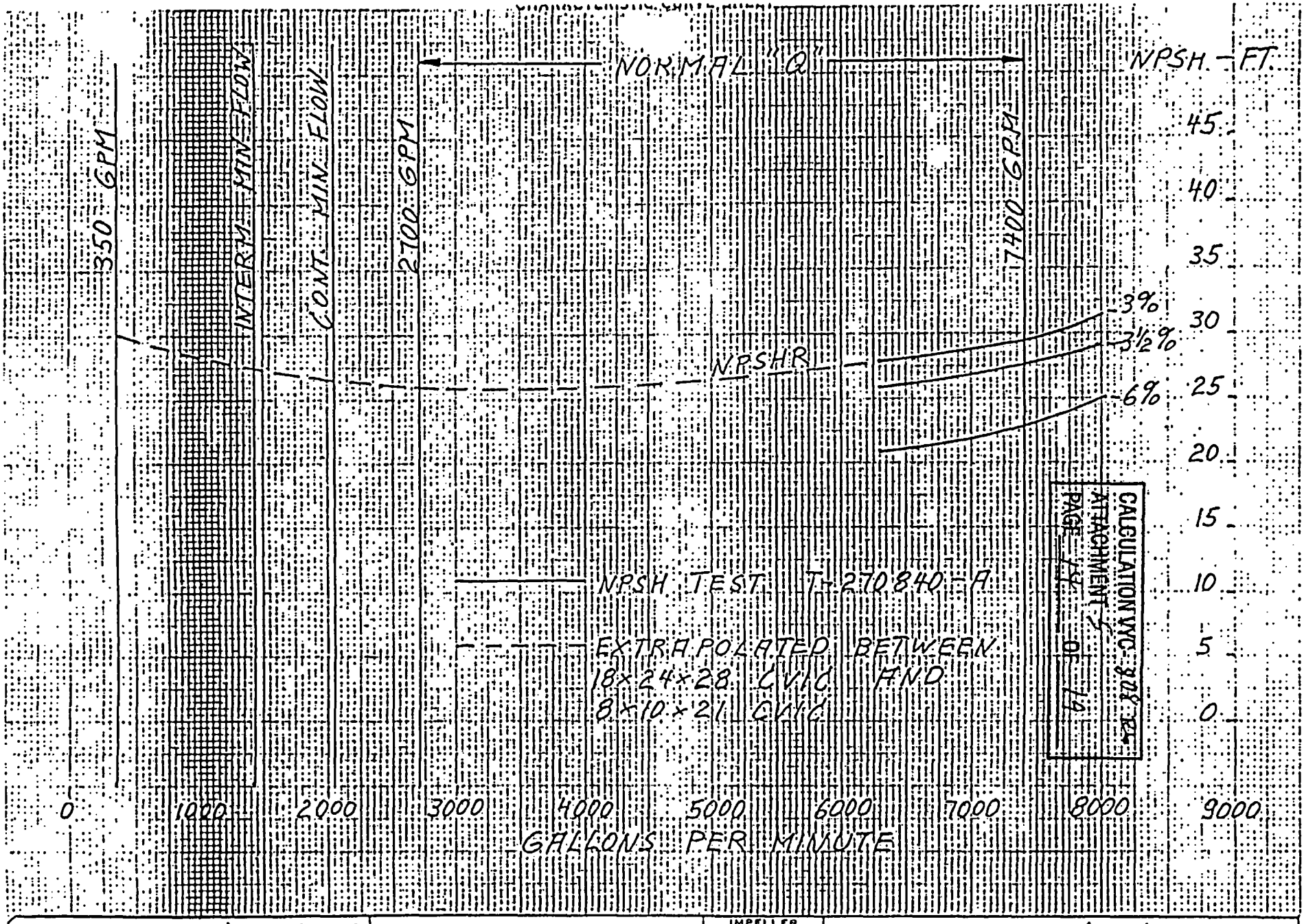
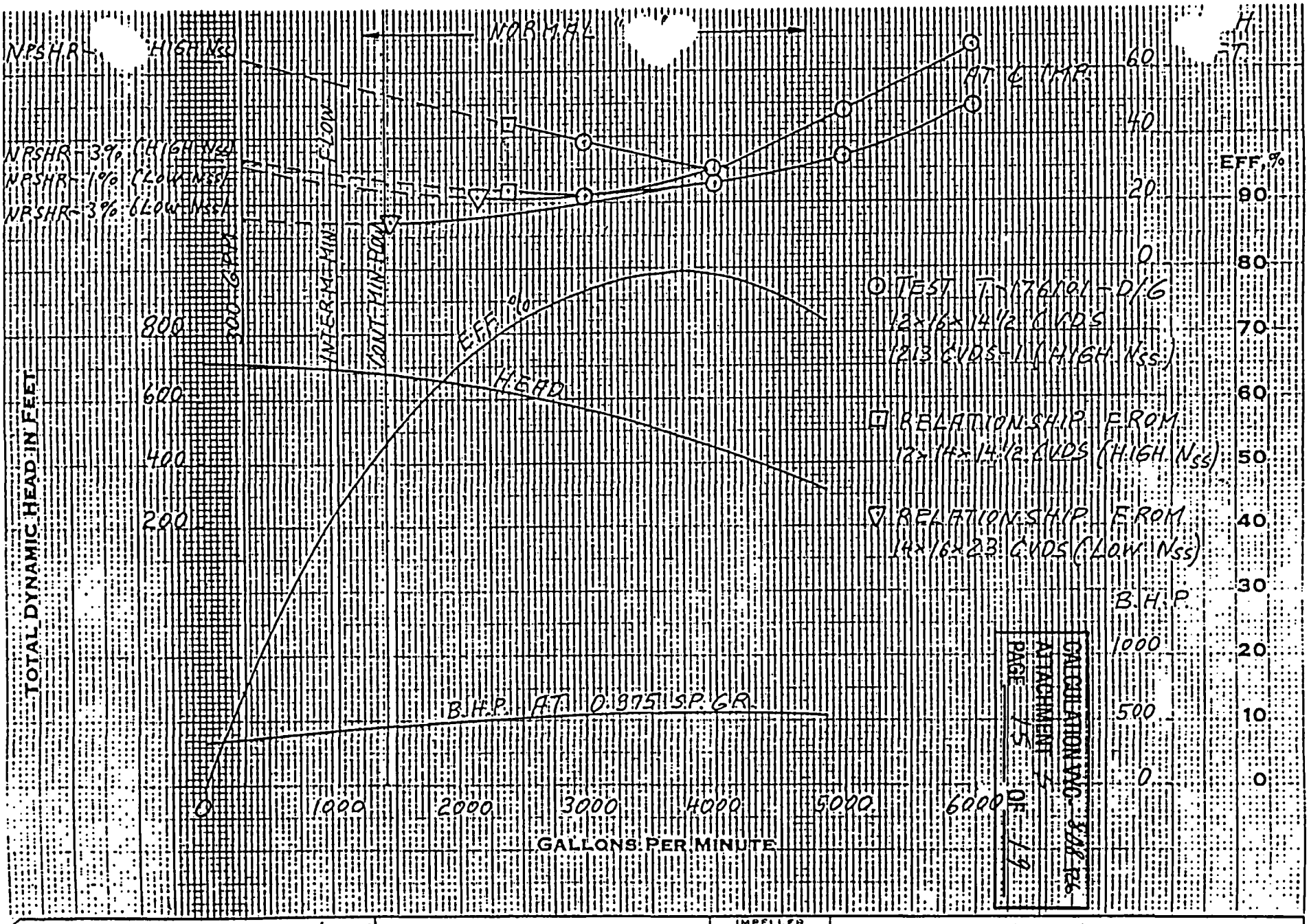
YANKEE ATOMIC ELECTRIC VERMONT YANKEE RHR PUMPS S.O. NO. 270.839/842	PUMP ENGINEERING DEPT. **SULZER BINGHAM PUMPS INC.** 18 MAR 98; R.L.	IMPELLER MAX. DIA. 26.500"	16×18×26 CVIC		PUMP
		MIN. DIA.	DIA. IMPELLER 25.563"	IMPELLER PATT. 1613 CVIC-1	1785 R.P.M.
		EYE AREA 121.3 SQ. IN.	N.P.S.H. REQUIRED	REFERENCE	CURVE No. I C

Form No. 308-2



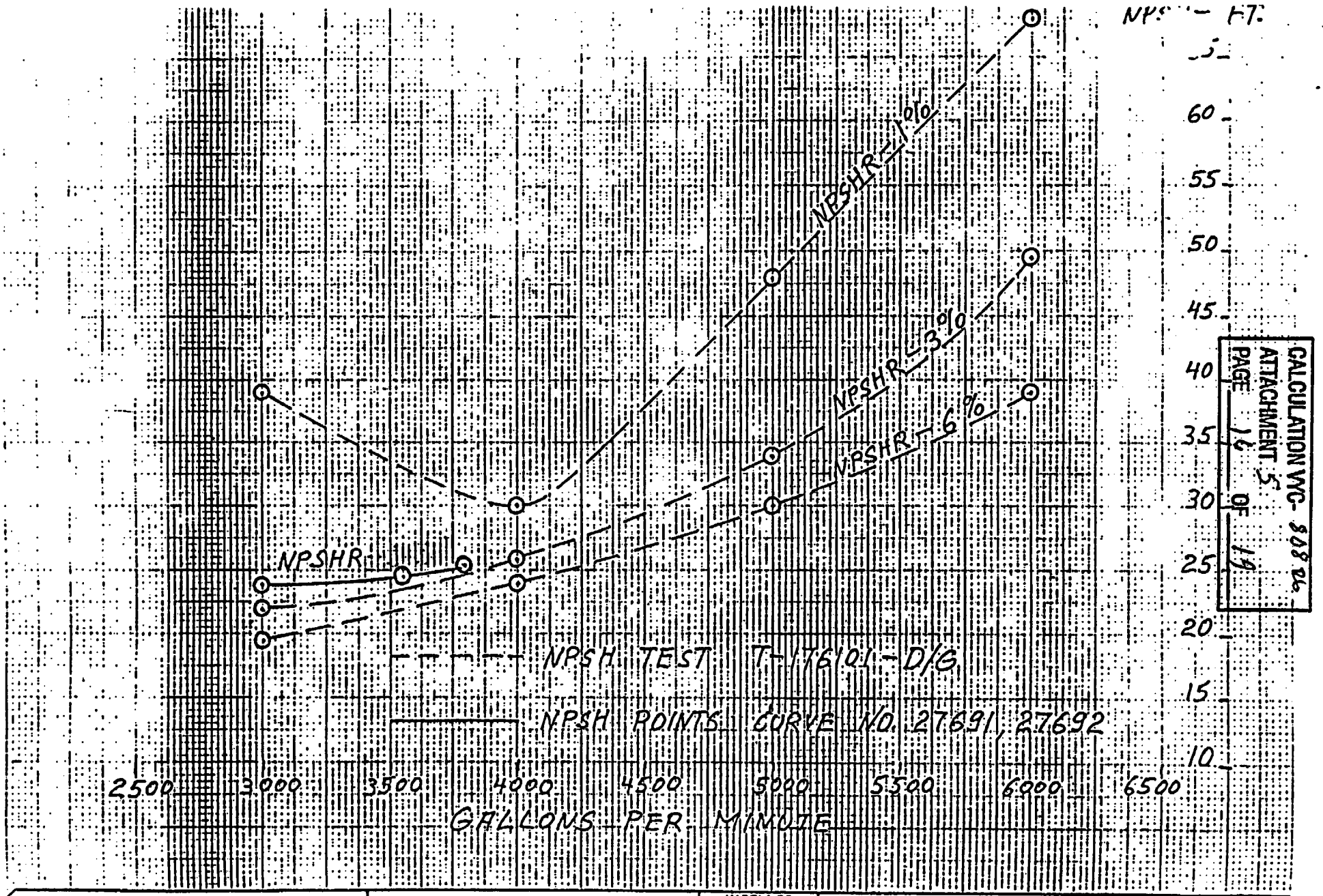
YANKEE ATOMIC ELECTRIC VERMONT YANKEE R.H.R. PUMPS S.O. NO. 270839/842	PUMP ENGINEERING DEPT. **SULZER BINGHAM PUMPS INC.** 16. JAN. 98, R.L.	IMPELLER MAX. DIA. 26.500"	16×18×26 CVIC PUMP		
		MIN. DIA.	DIA. IMPELLER 25.563"	IMPELLER PATT. 1613 CVIC-1	1785 R.P.M.
		EYE AREA 121.3 SQ. IN.	N.P.S.H. REQUIRED	REFERENCE I a, b, c	CURVE NO. I d

Form No. 308-2



YANKEE ATOMIC ELECTRIC VERMONT YANKEE CS PUMPS S.O. NO. 280.418/419	PUMP ENGINEERING DEPT. **SULZER BINGHAM PUMPS INC.** 4 DEC 97 ; R.L.	IMPELLER MAX. DIA. 14.500" MIN. DIA. EYE AREA 72.2 SQ. IN.	12×16×14 1/2 CVDS PUMP		
			DIA. IMPELLER 12.500"	IMPELLER PATT. 1213 CVDS-1	3582 R.P.M.
			N.P.S.H. REQUIRED	REFERENCE	CURVE NO. II a

Form No. 930-1



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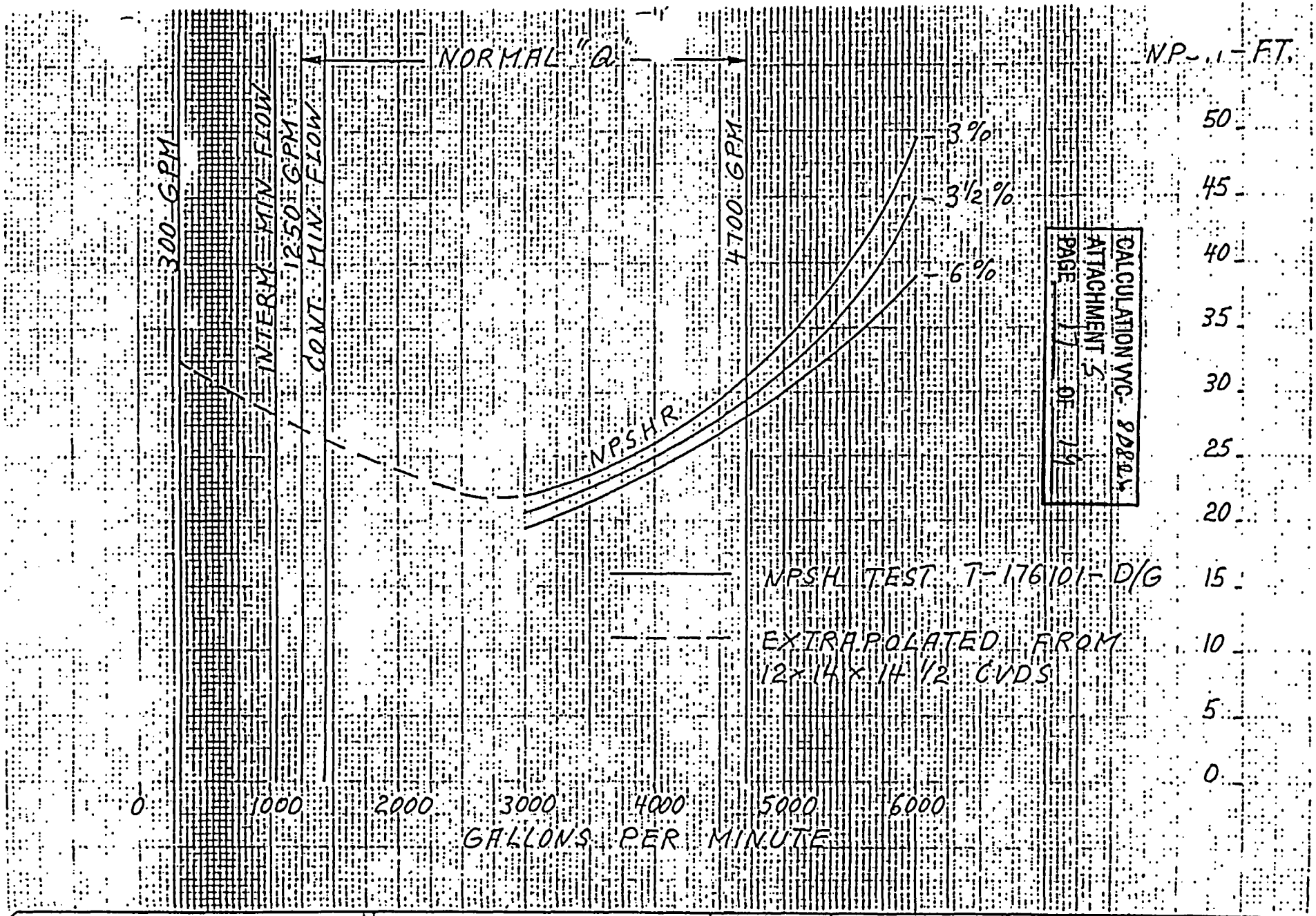
YANKEE ATOMIC ELECTRIC VERMONT YANKEE CS PUMPS S.O. NO. 280.418/419	PUMP ENGINEERING DEPT. **SULZER BINGHAM PUMPS INC.** 18 MAR 98; R.L.	IMPELLER MAX. DIA. 14.500"	12 × 16 × 14 1/2 CVDS PUMP		
		MIN. DIA.	DIA. IMPELLER 12.500"	IMPELLER PATT. 1213 CVDS-1	3582 R.P.M.
		EYE SQ. AREA 72.2 IN.	N.P.S.H. REQUIRED	REFERENCE	CURVE No. II C

Form No. 208-2



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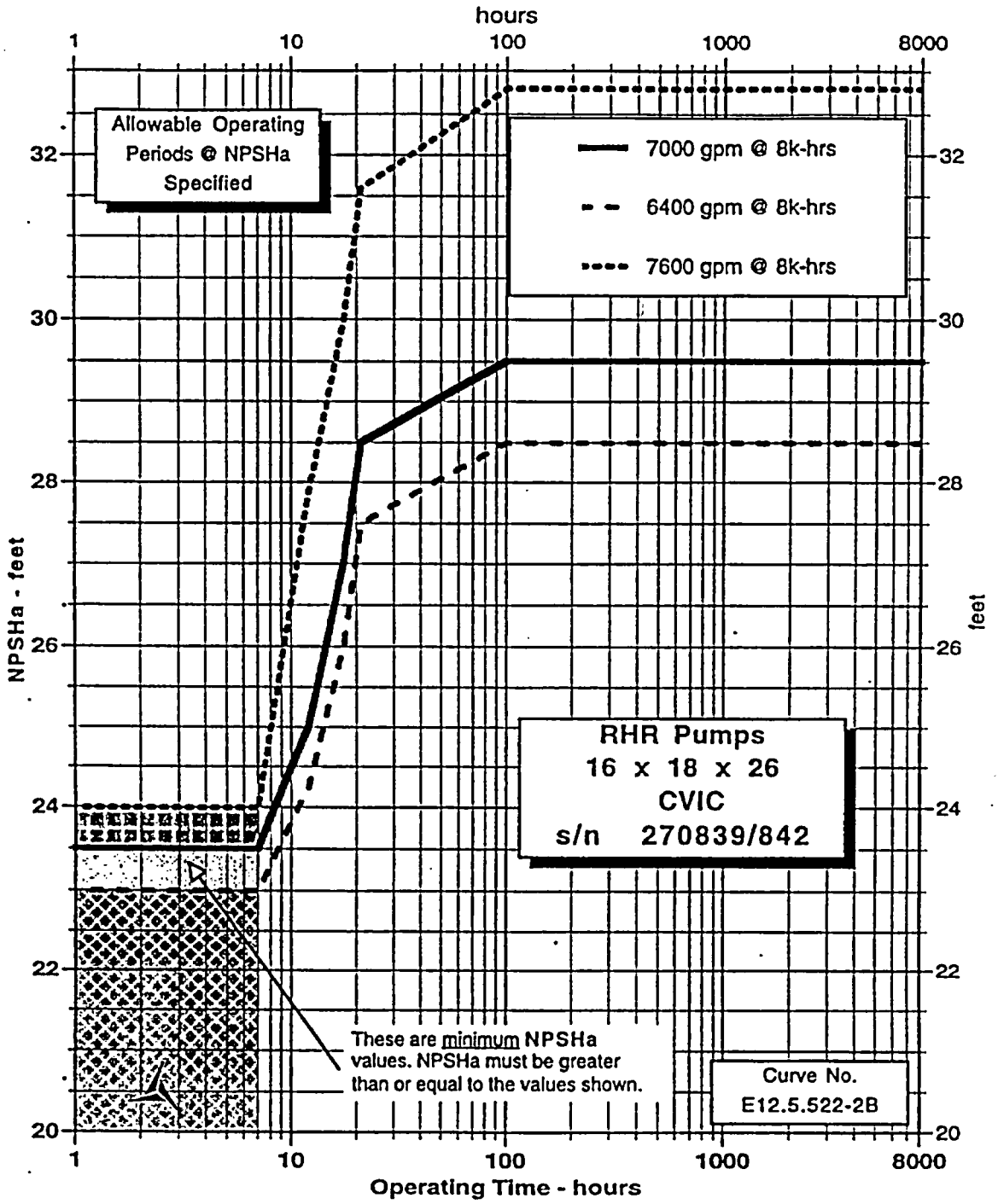
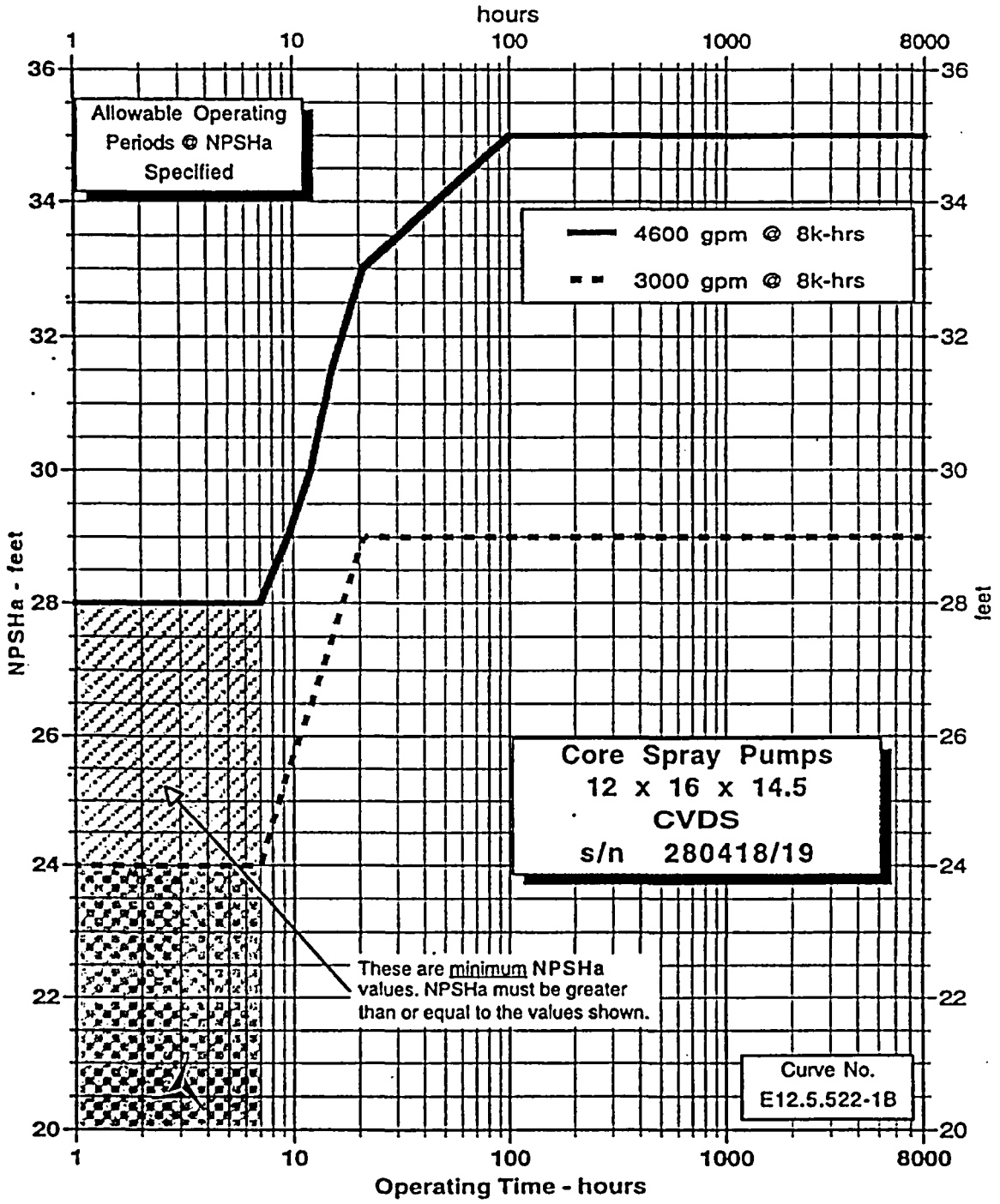
YANKEE ATOMIC ELECTRIC VERMONT YANKEE C.S. PUMPS S.O. NO. 280418/419	PUMP ENGINEERING DEPT. **SULZER BINGHAM PUMPS INC.** 16. JAN. 98; R.L.	IMPELLER MAX. DIA. 14.500"	12 × 16 × 14½ CVDS PUMP		
		MIN. DIA.	DIA. IMPELLER 12.500"	IMPELLER PATT. 1213 CVDS-1	3582 R.P.M.
		EYE AREA 72.2 SQ. IN.	N.P.S.H. REQUIRED	REFERENCE II a, b, c	CURVE NO. II d

Form No. 308-2


hours
1
10
100
1000
8000
Allowable Operating Periods @ NPSHa Specified
7000 gpm @ 8k-hrs
6400 gpm @ 8k-hrs
7600 gpm @ 8k-hrs
32
30
28
26
24
22
20
NPSHa - feet
feet
RHR Pumps
16 x 18 x 26
CVIC
s/n 270839/842
These are minimum NPSHa values. NPSHa must be greater than or equal to the values shown.
Curve No.
E12.5.522-2B
Operating Time - hours


hours
1
10
100
1000
8000
36
34
32
30
28
26
24
22
20
NPSHa - feet
feet
Allowable Operating Periods @ NPSHa Specified
4600 gpm @ 8k-hrs
3000 gpm @ 8k-hrs
Core Spray Pumps
12 x 16 x 14.5
CVDS
s/n 280418/19
These are minimum NPSHa values. NPSHa must be greater than or equal to the values shown.
Curve No.
E12.5.522-1B
Operating Time - hours

YANKEE ATOMIC ELECTRIC COMPANY

(VYC 808, Rev. 5, Attachment 6)

CALCULATION NO. ~~VYC-1358~~ PAGE ~~1~~ OF ~~_____~~

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SUBJECT Core Spray NPSH Evaluation

PREPARED BY _____ DATE _____ REVIEWED BY _____ DATE _____ WORK ORDER NO. 4922

5.0 References:

~~(a) Drawing, G-191168, Flow Diagram - Core Spray System~~ Stit. BEB 4/25/00

(b) Drawing, 5920-9209, Core Spray (CS) Part 3

(c) Technical Paper No. 410, Flow of Fluids Through Valves Fittings and Pipe, Crane Co., 24th Printing, 1988

(d) Goulds Pump Manual, Gould Pumps Inc., Seneca Falls N.Y., 1973

(e) Pump Curve for Core Spray Pumps #280418,#280419, Bingham Pump Co., Curve Nos. 27691, 27692

(f) Drawing (CB & I), 6202-233, Torus Penetrations

(g) VYNPS FSAR, Fig. 5.2-1

(h) Drawing, G-191206, Core Spray System Piping Plan

(i) Drawing, G-191207, Core Spray System Piping Sections

(j) "Thermodynamic Properties of Steam", Keenan and Keyes, John Wiley and Sons, New York, 1959

(k) Drawing, 5920-6683, C.S. Suction Strainer for Torus Penetrations X-226A and X-226B

~~(l) Handbook of Hydraulic Resistance, I.E.Idelchik, 2nd Ed., Hemisphere Publishing Co., New York, 1986~~

(m) Hydraulic Institute Engineering Data Book, 1st Ed.

YANKEE ATOMIC ELECTRIC COMPANY

(VYC808, Rev.5, Attachment 6)
CALCULATION NO. ~~VYC-1300 PAGE 5~~ OF
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SUBJECT Core Spray NPSH Evaluation

PREPARED BY _____ DATE _____ REVIEWED BY _____ DATE _____ WORK ORDER NO. 4922

6.0 Calculation:

6.1 Suction Piping Lengths

Each Core Spray pump takes suction from its own Torus penetration. The two suction piping paths are essentially "mirror images".

6.1.1 Torus to CS Pump piping:

Pipe size = 12" STD [Ref. (a)]

Piping Lengths [Ref. (b)]

	Feet	Inches	
	3	0.0	
	3	2.5	
	3	1.5	
	1	9.0	
	7	6.0	
	4	3.0	
	0	3.5	
	1	0.5	
	1	6.0	
	2	4.0	
	3	6.0	
	2	5.0	
	0	11.5	
Total	30	58.5	or 34.875', say 35'

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CALCULATION NO. ~~VYC-1394, PAGE 6 OF~~

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SUBJECT Core Spray NPSH Evaluation

PREPARED BY _____ DATE _____ REVIEWED BY _____ DATE _____ WORK ORDER NO. 4922

6.1.2 Fittings [Ref. (b)]

	L/D		[Ref. (c)]
90° LR 16"x12" Red. Elbow	14	(Note 1)	
45° LR Elbow	11		[Ref. (m)]
67 1/2° LR Elbow	14	(Note 1)	
90° LR Elbow	14		
90° LR Elbow	14		
TEE (Str. Run)	20		
16"x12" Reducer (Exp.)	7		
Valve, Gate (CS-7A)	8		
~~Strainer Entrance Tee (16")~~	~~30~~		~~[Ref. (l)]~~
Total	~~132~~ 102'		

Total equivalent length (12") pipe = 35 + ~~132~~ 102 = ~~167'~~ 137' BCS 4/25/00

Note 1: Conservatively assumed same as 90° LR Elbow.

YANKEE ATOMIC ELECTRIC COMPANY

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SUBJECT Core Spray NPSH Evaluation

PREPARED BY _____ DATE _____ REVIEWED BY _____ DATE _____ WORK ORDER NO. 4922

6.1.3 Correction to Sched. 40 [Ref. (c)]

12" STD : I.D. = 12.00"

12" SCH 40 : I.D. = 11.938"

$dP_a = dP_{40} \; (D_{40}^5 \; / \; D_a^5)$ [Ref. (c), @ B-15]

Therefore,

$dP_{STD} = dP_{40} \; (11.938^5 \; / \; 12.00^5) = dP_{40} \; (0.974)$

Equivalent length Sched. 40:

$L_{40} = L_{STD} \; (0.974)$

$= (\cancel{167}\ 137)(0.974) = \cancel{162.63,\ say\ 163'}\ 133$

6.2 Friction loss:

$H_f = (L)(h_f)$ [Ref. (c)]

@ 3000 gpm, h_f = 0.731 psi/100', (60 °F water)

$H_{f@3000} = (\cancel{163}\ 133 \text{ ft.})(0.731 \text{ psi/100 ft.})(2.31 \text{ ft./psi}) = \cancel{2.752}\ 2.25 \text{ ft.}$

For other flow rates:

$H_{f1} = H_{f0} \; (Q_1^2 \; / \; Q_0^2)$

Note: This is slightly conservative for $Q_1 > Q_0$, but difference is insignificant in the range of interest.

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SUBJECT Residual Heat Removal (LPCI) NPSH Evaluation

PREPARED BY _____ DATE _____ REVIEWED BY _____ DATE _____ WORK ORDER NO. 4922

5.0 References:

✓ (a) Drawing, G-191172, Flow Diagram - Residual Heat Removal System

✓ (b) Drawing, 5920-9284, Residual Heat Removal (RHR) Part 5

✓ (c) Technical Paper No. 410, Flow of Fluids Through Valves Fittings and Pipe, Crane Co., 24th Printing, 1988

(d) Goulds Pump Manual, Gould Pumps Inc., Seneca Falls N.Y., 1973

(e) Pump Curve for RHR Pump #270841, Bingham Pump Co., Curve No. 28469

(f) Drawing (CB & I0, 6202-233, Torus Penetrations

(g) VYNPS FSAR Fig. 5.2-1

(h) Drawing, G-191211, RHR System Piping Sections

(i) Drawing G-191210, RHR System Piping Plan

(j) "Thermodynamic Properties of Steam", Keenan and Keyes, John Wiley and Sons, New York, 1959

✓ (k) Handbook of Hydraulic Resistance, I.E.Idelchik, 2nd Ed., Hemisphere Publishing Co., New York, 1986

✓ (l) Hydraulic Institute Engineering Data Book, 1st Ed.

~~(m) Drawing 5920-6764, RHR Suction Strainer for Torus Penetrations X-224A & X-224B~~

VERMONT YANKEE DESIGN ENGINEERING
CALCULATION NO. VYC- 808
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SUBJECT Residual Heat Removal (LPCI) NPSH Evaluation

PREPARED BY _____ DATE _____ REVIEWED BY _____ DATE _____ WORK ORDER NO. 4922

6.0 Calculation:

6.1 Suction Piping Lengths

Two RHR pumps take suction from one Torus penetration therefore a portion of suction piping is common to both pumps from the Torus to a Tee at which point there is a single branch to each pump. Both the A and B RHR loops are mirror image so the calculation need be done for only one loop. (A and C pump loop.) By inspection of the piping isometric drawings it is noted that there are some small differences in the single suction lines the most significant of which is that one has a straight run at the Tee while the other is a branch run. The run with the greater loss will be used for conservative results.

6.1.1 Common piping Torus to Tee 24" pipe.

Pipe size = 24", 0.375 wall. I.D. = 23.25" (STD.) [Ref.(a)]

Piping Lengths [Ref.(b)]

	Feet	Inches		
	1	2.625		
	3	6.125		
	4	0.0		
Total	8	8.75	or	8.73 ft.

VERMONT YANKEE DESIGN ENGINEERING
CALCULATION NO. VYC- 808
REVISION NO. 5
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SUBJECT Residual Heat Removal (LPCI) NPSH Evaluation

PREPARED BY _____ DATE _____ REVIEWED BY _____ DATE _____ WORK ORDER NO. 4922

6.1.2 Fittings

	L/D		[Ref. (c)]
33° LR Elbow	7	(estimated)	
90° SR Elbow	20		
26"x24" Reducer (Exp.)	1		
~~Strainer Entrance Tee~~	~~119~~		~~[Ref. (k)]~~
~~24" 24° Mitre Bend~~	~~6~~		

Total ~~153~~ 2.8 or ~~296.44~~ 54.25 ft. equivalent

6.1.3 Correction to Sched. 40 (20")

24" STD : I.D. = 23.25"

20" SCH 40 : I.D. = 18.814"

$dP_a = dP_{40} (D_{40}^{5} / D_a^{5})$ [Ref. (c) @ B-15]

Therefore,

$dP_{STD} = dP_{40} (18.814^{5} / 23.25^{5}) = dP_{40} (0.347)$

Equivalent length Sched. 40:

$L_{40} = L_{STD} (0.347)$

$= (8.73 + \cancel{296.44}\ 54.25) (0.347) = \cancel{105.89}\ 21.85$

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6.1.4 Common piping Torus to Tee 26" pipe.

Pipe size = 26", 0.375 wall. I.D. = 25.25" [Ref.(a)]

Piping Lengths [Ref.(b)]

	Feet	Inches		
	1	4.125		
	2	8.25		
	17	10.125		
	5	5.5		
	2	2.0		
	6	0.0		
	4	3.0		
	2	0.0		
	1	3.0		
Total	40	36	or	43.00 ft.

6.1.5 Fittings

	L/D		
			[Ref.(c)]
45° LR Elbow	11		[Ref.(1)]
45° LR Elbow	11		[Ref.(1)]
90° SR Elbow	20		
90° SR Elbow	20		
Total	62	or	130.46 ft. equivalent

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6.1.6 Correction to Sched. 40 (20")

26" STD : I.D. = 25.25"

20" SCH 40 : I.D. = 18.814"

$dP_a = dP_{40} (D_{40}^{5} / D_a^{5})$ [Ref. (c) @ B-15]

Therefore,

$dP_{STD} = dP_{40} (18.814^{5} / 25.25^{5}) = dP_{40} (0.230)$

Equivalent length Sched. 40:

$L_{40} = L_{STD} (0.230)$

$= (43.00 + 130.46) (0.230) = 39.90'$

6.1.7 Total common piping 20" Sched. 40 equivalent

$L_{COM} = \overset{21.85}{\cancel{105.89}} + 39.90 = \overset{61.75}{\cancel{145.79}}'$ (20",Sch.40)

6.1.8 Single piping Tee to Pump A 26"

Pipe size = 26", 0.375 wall. I.D. = 25.25" [Ref. (a)]

Piping Lengths [Ref. (b)]

	Feet	Inches		
	3	10.0		
	2	5.5		
	2	3.5		
Total	7	19	or	8.58 ft.

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6.1.9 Fittings

	L/D	
Tee (Str. Run)	20	
90° SR Elbow	20	
10° LR Elbow	1	(estimated)
26"x20" Reducer	17	
Total	58	or 122.04 ft. equivalent

6.1.10 Correction to Sched. 40 (20")

26" STD : I.D. = 25.25"

20" SCH 40 :I.D. = 18.814"

$dP_a = dP_{40} (D_{40}^{5} / D_a^{5})$ [Ref. (c) @ B-15]

Therefore,

$dP_{STD} = dP_{40} (18.814^{5} / 25.25^{5}) = dP_{40} (0.230)$

Equivalent length Sched. 40:

$L_{40} = L_{STD} (0.230)$

$= (8.58 + 122.04) (0.230) = 30.04'$

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6.1.11 Single piping Tee to Pump A 20"

Pipe size = 20", 0.375 wall. I.D. = 19.25" [Ref. (a)]

Piping Lengths [Ref. (b)]

	Feet	Inches		
	1	8.0		
	3	7.0		
	3	5.0		
	2	11.0		
	2	7.0		
	3	5.0		
Total	14	43	or	17.58 ft.

6.1.12 Fittings

	L/D		
90° SR Elbow	20		[Ref. (c)]
Valve (10-13A), Gate	8		
90° SR Elbow	20		
Tee (20x20x20, Str. Run)	20		
Tee (20x4x20, Str. Run)	1		[Ref. (k)]
20"x18" Reducer	2	(estimated)	
Total	71	or 113.90 ft. equivalent	

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6.1.13 Correction to Sched. 40 (20")

20" STD : I.D. = 19.25"

20" SCH 40 : I.D. = 18.814"

$dP_a = dP_{40} (D_{40}^{5} / D_a^{5})$ [Ref. (c) @ B-15].

Therefore,

$dP_{STD} = dP_{40} (18.814^{5} / 19.25^{5}) = dP_{40} (0.892)$

Equivalent length Sched. 40:

$L_{40} = L_{STD} (0.892)$

$= (17.58 + 113.90) (0.892) = 117.28'$

6.1.14 Total single piping Tee to Pump A 20" Sched. 40 equivalent

$L_{T-A} = 30.04 + 117.28 = 147.32'$

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6.1.15 Single piping Tee to Pump C 20"

Pipe size = 20", 0.375 wall. I.D. = 19.25" [Ref.(a)]

Piping Lengths [Ref.(b)]

	Feet	Inches		
	2	3.5		
	0	9.5		
	2	10.0		
	3	4.0		
	3	4.0		
	3	0.0		
	1	10.5		
	2	9.0		
Total	16	50.5	or	20.21 ft.

6.1.16 Fittings

	L/D		
Tee (Br. Run)	60		[Ref.(c)]
90° SR Elbow	20		
Valve (10-13C), Gate	8		
90° SR Elbow	20		
Tee (20x20x20, Str. Run)	20		
Tee (20x4x20, Str. Run)	1		[Ref.(k)]
20"x18" Reducer	2	(estimated)	
10° LR Elbow	1		
Total	132	or 211.75 ft. equivalent	

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6.1.17 Correction to Sched. 40 (20")

20" STD : I.D. = 19.25"

20" SCH 40 :I.D. = 18.814"

$dP_a = dP_{40} (D_{40}^{5} / D_a^{5})$ [Ref. (c) @ B-15]

Therefore,

$dP_{STD} = dP_{40} (18.814^{5} / 19.25^{5}) = dP_{40} (0.892)$

Equivalent length Sched. 40:

$L_{40} = L_{STD} (0.892)$

$= (20.21 + 211.75) (0.892) = 206.91'$

6.1.18 Total single piping Tee to Pump C 20" Sched. 40 equivalent

$L_{T-C} = 206.91'$

6.1.19 Piping Summary - Equivalent Feet 20" Sched. 40

Torus to Tee (Common), (L_{COM}) = ~~145.79'~~ 61.75

Tee to Pump A, (L_{T-A}) = 147.32'

Tee to Pump C, (L_{T-C}) = 206.91'

Pump C has the longer run ; use for conservative result.

6.2 Friction Loss

$H_f = H_{fcommon} + H_{f\ single}$

Head loss in common line will depend on number of pumps operating. Assume that if both pumps are operating they are operating at the same flow rate. Consider two configurations : One pump operation (Case I), and two pump operation (Case II).

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Case I Friction Loss :

$H_f = H_f$ common $+ H_f$ single

and $H_{fa} = H_{fb} \; (Q_a^2 / Q_b^2)$ [Ref. (c)]

as a function of flow where $Q_{common} = Q_{single}$ for Case I.

(Note: This is slightly conservative for $Q_a < Q_b$, but difference is not significant in range of interest.)

$H_{fI} = H_{fc0} \; (Q^2 / Q_0^2) + H_{fs0} \; (Q^2 / Q_0^2)$

where H_{fc0} = friction loss at Q_0 for the common piping

and H_{fs0} = friction loss at Q_0 for the single piping

For Q_0 = 7000 gpm, friction loss for 20" Sched. 40 pipe is 0.376 psi per 100', [Ref. (c)]

$H_{fc0} = L_{COM} \cdot (H_{f0})$

$= (\cancel{445.39} \; 61.75) \; (0.376 / 100) \; (2.31 \text{ ft/psi}) = \cancel{1.266'} \; 0.536$

$H_{fs0} = L_{T-C} \; (H_{f0})$

$= (206.91) \; (0.376 / 100) \; (2.31 \text{ ft/psi}) = 1.80'$

$H_{foI} = H_{fc0} + H_{fs0} = \cancel{1.266} \; 0.536 + 1.80 = \cancel{3.066'} \; 2.336$ @ 7000gpm

therefore,

$H_{fI} = \cancel{3.066} \; 2.336 \; (Q^2 / 7000^2) = \cancel{6.26} \; 4.77 \times 10^{-8} \; Q^2$

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Case II Friction Loss :

$H_f = H_f$ common $+ H_f$ single

and $H_{fa} = H_{fb} (Q_a^2 / Q_b^2)$ [Ref. (c)]

as a function of flow where $Q_{common} = 2\ Q_{single}$ for Case II.

$H_{fII} = H_{fc0} (Q^2 / Q_0^2) + H_{fs0} (Q^2 / Q_0^2)$

where H_{fc0} = friction loss at Q_0 for the common piping

and H_{fs0} = friction loss at Q_0 for the single piping

For Q_0 = 7000 gpm (one pump flow), friction loss for 20" Sched. 40 pipe is 0.376 psi per 100' [Ref. (c)]

For Q_0 = 14000 gpm (two pump flow), friction loss for 20" Sched. 40 pipe is 1.43 psi per 100' [Ref. (c)]

$H_{fc0} = L_{COM} (H_{f0})$

$= (\cancel{145.79} \ 61.75) (1.43 / 100) (2.31 \text{ ft/psi}) = \cancel{4.816} \ 2.040 \ \cancel{2.039}$

$H_{fs0} = L_{T-C} (H_{f0})$

$= (206.91) (0.376 / 100) (2.31 \text{ ft/psi}) = 1.80'$

$H_{foII} = H_{fc0} + H_{fs0} = \cancel{4.816} \ 2.04 + 1.80 = \cancel{6.616'} \ 3.84'$ @ 7000gpm per pump

therefore,

$H_{fII} = \cancel{4.816} \ 2.04 (Q_C^2 / 14000^2) + 1.80 (Q_S^2 / 7000^2)$

and for $Q_C = 2Q_S$

$H_{fII} = \cancel{4.816} \ 2.04 ((2Q_S)^2 / 14000^2) + 1.80 (Q_S^2 / 7000^2)$

$= \cancel{9.820x10^{-8}} \ 4.163x10^{-8} Q^2 + 3.673x10^{-8} Q^2 = \cancel{1.350x10^{-7}} \ 7.836x10^{-8} Q^2$

Attachment 8

VY CALCULATION REVIEW FORM

Calculation Number: VYC-808 Revision Number: 6 CCN Number: NA

Title: Core Spray and Residual Heat Removal Pump Net Positive Suction Head Margin Following a Loss of Coolant Accident

Reviewer Assigned: W. Timofeev Required Date: NA

☐ Interdiscipline Review ☒ Independent Review

Comments*	Resolution
1. Page 7 – Need page numbers for all sections	✓1. OK
2. Attachment 6 page 3 – add "ft" to 137	✓2. OK
3. Page 17 – Add "F"to "riction"	✓3. OK
4. Page 18 bottom of page – add "w" to "here"	✓4. OK
5. Page 3 & 25 Ref. 3 – Calculation 1677 pending approval	✓5. Calculation approved.
6. Page 13 & 14 Sect. 2.2, 2.3 & 2.4 should be renumbered	✓6. OK
7. Page 10 & 11 for Vendor recommendation add Ref. Attach 5	✓7. OK
8. Conclusion should address RHR & Core Spray fibrous margin for debris plugging on the Intake Strainers	8. Revised

Reviewer Signature / 12-12-00 Date

BC Slifer / 12/13/00 Calculation Preparer (Comments Resolved) Date

Method of Review: ☒ Calculation/Analysis Review
☐ Alternative Calculation
☐ Qualification Testing

Reviewer Signature (Comments Resolved) / 12-13-00 Date

*Comments shall be specific, not general. Do not list questions or suggestions unless suggesting wording to ensure the correct interpretation of issues. Questions should be asked of the preparer directly.

VY CALCULATON CHANGE NOTICE (CCN)

CCN Number: 1 Calculation Number: VYC-0808 Rev. Number: 6

Calculation Title: **Core Spray and Residual Heat Removal Pump Net Positive Suction Head Margin Following a Loss of Coolant Accident**

Initiating Document: STP 2000-021
VYDC/MM/TM/Spec. No./ other

Safety Evaluation Number: N/A

Superseded Document: N/A

Implementation Required: ☐ Yes ☒ No

Reason for Change:

STP 2000-021 [1] being performed in support of the reactor water chemistry project and noble metals injection proposes to operate the RHR system in an atypical mode. Specifically, it is proposed to operate both trains of RHR, either with one pump operating in each train or two, taking a suction from the common shutdown cooling line off of recirculation loop "A" and injecting back into the vessel via the respective recirculation loop injection lines.

These modes of operation are considered a departure from normal shutdown cooling in that shutdown cooling normally utilizes only one train of RHR with a single pump operating as opposed to two trains of RHR [2]. This CCN documents the NPSH margin for shutdown cooling operation using either one or two trains.

Description of Change: See attached.

Technical Justification for Change: See attached.

Conclusion:
Minimum NPSH margins for various modes of SDC are calculated:

- single train of RHR with one pump operating at 7600 gpm is 50.8 ft
- two trains of RHR with one pump operating at 7600 gpm in each loop is 48.2 ft
- two trains of RHR with two pumps (each) operating at 7300 gpm (each) in each loop is –15.5 ft
- two trains of RHR with two pumps (each) operating at 7300 gpm (each) in each loop with RWCU operating is –16.0 ft
- two trains of RHR with two pumps (each) operating at 6625 gpm (each) in each loop with RWCU operating is 0.5 ft

No specific 50.59(a)(1) or (a)(2) is required as this CCN only validates existing NPSH margins. This CCN does not justify any additional modes of operation (though may be used as a basis for other documents doing so).

Prepared By/Date	Interdiscipline Review By/Date	Independent Review By/Date	Approved By/Date
2/13/01 Carl Fago	N/A	2/13/01 Bruce Slifer	2/26/01 Jim Callaghan

* STP 2000-021 controls flows to acceptable limits based on NPSH results identified above.

Installation Verification / Final Turnover to DCC:

Open Items Associated with CCN ☐ Yes ☒ No ☐ Closed (Section 2.3.2)

Installation Verification (Section 2.3.4)
☒ Calculation accurately reflects plant as-built configuration, OR
☐ N/A, calculation does not affect plant configuration

Resolution of documents identified in the Design Output Documents Section of VYAPF 0017.07 (Section 2.3.6)

Print Name	Signature	Date
Carl D. Fago		2/26/01

Total number of pages in package including all attachments 16

Note: VYAPF 0017.07 should be included immediately following this form.

VY CALCULATION DATABASE INPUT FORM

VYC-0808 / 1	6	N/A	N/A
VY Calculation/CCN #	Revision #	Vendor Calculation #	Revision #

Vendor Name: N/A PO Number: N/A

Originating Department: Fluid Systems

Critical References Impacted: ☐ FSAR ☐ DBD ☐ Reload "Check" the appropriate box if any critical document is identified in the tables below.

EMPAC Asset/Equipment ID Number(s): P-10-1A/B/C/D

EMPAC Asset/System ID Number(s): 10, 14

Keywords: Residual Heat Removal (RHR), Net Positive Suction Head (NPSH), Pump, Shutdown Cooling (SDC)

For Revision/CCN only: Are deletions to General References, Design Input Documents or Design Output Documents required? ☐ Yes† ☒ No

General References

*Reference #	** DOC #	REV #	*** Reference Title (including Date, if applicable) (See App. A, Section 3.2.7 for Guidance)	**** Affected Program	Critical Reference (√)
1.	STP 2000-021	Draft	Noble Metals Injection Process		
2.	OP-2124	49	Residual Heat Removal System		
19	OP-2112	30	Reactor Water Clean-Up System		

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Design Input Documents – The following documents provide design input to this calculation. (Refer to Appendix A, section 4)

*Reference #	** DOC #	REV #	*** Reference Title (including Date, if applicable) (See App. A, Section 3.2.7 for Guidance)	**** Affected Program	Critical Reference (√)
3.	VYC-808	6	Core Spray and Residual Heat Removal Pump Net Positive Suction Head Margin Following a Loss of Coolant Accident		
4.		202	VY Technical Specifications, Section 4.5.A		
5.	G191172	59	VY DWG, Flow Diagram – Residual Heat Removal System		
6.	5920-3773 Sht 2	12	VY DWG, Assembly – Reactor for Nuclear Boiler		
7.	5920-13	2	VY DWG, Arrangement – Primary and Secondary Containment		
8.	G-191211	16	VY DWG, RHR System Piping		
9.	N/A	N/A	Crane Flow of Fluids, Technical Paper No. 410		
10.	5920-6637	0	VY DWG, Residual Heat Removal Piping – Doc of As-Built Dims		
11.	5920-9283	4	VY DWG, Residual Heat Removal (RHR) Part 5, Sheet 1		
12.	5920-9284	3	VY DWG, Residual Heat Removal (RHR) Part 5, Sheet 2		
13.	5920-9286	4	VY DWG, Residual Heat Removal (RHR) Part 6, Sheet 2		
14.	5920-9285	4	VY DWG, Residual Heat Removal (RHR) Part 6, Sheet 1		
15.	VYC-1628	0	Torus Temperature and Pressure Response to Large Break LOCA and MSLB Accident Scenarios		
16.	5920-6620	0	VY DWG, Recirculation Loop Piping – Doc of As-Built Dims		
17.	VYS 98/97	N/A	Memorandum, Swenson & Rainey to Mills, "Evaluation of Maximum Expected Flows for ECCS Strainer Replacement", dated August 28, 1997		
18	G191210	18	VY DWG, RHR System Piping Section		

Design Output Documents – This calculation provides output to the following documents. (Refer to Appendix A, section 5)

*Reference #	** DOC #	REV #	Document Title (including Date, if applicable)	**** Affected Program	Critical Reference (√)

* Reference # - Assigned by preparer to identify the reference in the body of the calculation.

** Doc # - Identifying number on the document, if any (e.g. 5920-0264, G191172, VY6-1286)

*** Reference Title - List the specific documentation in this column. "See attached list" is not acceptable. Design Input/Output Documents should identify the specific design input document used in the calculation or the specific document affected by the calculation and not simply reference the document (e.g., VYDC, MM) that the calculation was written to support.

**** Affected Program - List the affected program or the program that reference is related to or part of. If the reference is FSAR, DBD or Reload (IASD or OPL), check Critical Reference column and check FSAR, DBD or Reload, as appropriate, on this form (above).

† If "yes", attach a copy of "VY Calculation Data" marked-up to reflect deletion (See Section 3.1.8 for Revision and 5.2.3.18 for CCNs).

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CCN 1

VY CALCULATION REVIEW FORM

Calculation Number: VYC-0808 Revision Number: 6 CCN Number: 1

Title: Core Spray and Residual Heat Removal Pump Net Positive Suction Head Margin Following a Loss of Coolant Accident

Reviewer Assigned: _____ Required Date: N/A

☐ Interdiscipline Review ☒ Independent Review

Comments*	Resolution
Reviewed in accordance with AP 0017 and have no comments.	N/A

Brian C. Slyfer / _____
Reviewer Signature Date

_____ / _____
Calculation Preparer (Comments Resolved) Date

Method of Review:
☒ Calculation/Analysis Review
☐ Alternative Calculation
☐ Qualification Testing

N/A / _____
Reviewer Signature (Comments Resolved) Date

*Comments shall be specific, not general. Do not list questions or suggestions unless suggesting wording to ensure the correct interpretation of issues. Questions should be asked of the preparer directly.

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1.0 Introduction

This purpose of this CCN is to add an evaluation of RHR pump NPSH margin while in the shutdown cooling (SDC) mode of operation. Several modes are evaluated:

- one RHR train in service with one pump operating
- two RHR trains in service with one pump operating per train
- two RHR trains in service with two pumps operating per train

2.0 Methodology

Available NPSH is calculated using the equation:

$$NPSH_a = (p_{Vessel} - p_v)(144)v + Z - H_f \qquad \text{[Ref. 3, pg. 13]}$$

where: p_{Vessel} = Reactor vessel pressure, psia
p_v = vapor pressure of pumped fluid, psia
v = specific volume of pumped fluid, ft^3/lbm
Z = height of fluid above pump suction, ft
H_f = friction head loss in suction line, ft

For this particular case, the conservative assumption is $p_{Vessel} = p_v$ based on the highest possible fluid temperature conditions in the vessel, saturated liquid. Therefore, the $NPSH_a$ is simply the difference between the elevation head and the friction loss to the pump suction.

From the shutdown cooling connection on recirculation loop "A" to the RHR pump suction, the friction losses will be calculated by summing the components and pipe lengths from piping isometrics. Simplifying (and conservative) assumptions regarding certain component form losses will be made to simplify the calculation. The total L/D for this section will be determined for each pump. The friction loss for the pump with the highest L/D will be used for the NPSH calculation.

From the water source (reactor vessel) down through the downcomer outside the core shroud, past the jet pumps and into the recirculation suction nozzle at the reactor vessel and through recirculation loop "A" to the shutdown cooling connection, the friction losses will be calculated based on the results from an existing detailed, steady-state RELAP model of the reactor vessel.

The total head loss is calculated as follows:

$$h_L = 0.00259 \cdot f \frac{L}{D} \frac{Q^2}{d^4}$$ [9, pg. 3-4]

where: h_L = head loss, ft

f = friction factor, nominally 0.012 for the pipe sizes relevant to this calculation [9, pg. A-26]

$\frac{L}{D}$ = equivalent length-to-diameter ratio

Q = flow rate, gpm

d = pipe inside diameter, inches

Available and required NPSH for the RHR pumps has previously been calculated in VYC-808 Rev. 6 [3] when taking suction on the torus.

3.0 Assumptions

The following assumptions are made to facilitate a simple calculation of NPSH during SDC. The assumed conditions are chosen to bound potential SDC operations when in hot shutdown (>212°F).

1. The pumped liquid is at saturated conditions (i.e. $T_f = T_{sat}$). This minimizes the $NPSH_a$ which is conservative.
2. Maximum single pump flow of 7600 gpm based on the Technical Specification vessel-to-vessel requirement for RHR pump flow (7450 gpm +/- 150 gpm) (4.5.A.1.c) [4].
3. Maximum two pump flow (in one loop) of 14,600 gpm based on:
   - single pump, vessel-to-vessel is 7600 gpm (above) and torus-to-torus is 7400 gpm [17] for a difference of 200 gpm
   - two pump, torus-to-torus is 14,200 gpm [17]
   - therefore, maximum flow for two pump, vessel-to-vessel is 14,200 + 200 gpm *2 = 14,600 gpm
4. Reactor vessel water level is assumed to be at least 155 inches above TAF. This represents a "minimum" water level needed to preserve the NPSH margins calculated herein.
5. In calculating the system L/D, all 90° elbows are assumed to be short-radius (r/d = 1) elbows vice long-radius elbows. This is a simplifying assumption that maximizes the head loss and minimizes the $NPSH_a$.
6. Component L/D values (used in Tables 1 through 4) are obtained from previously determined values in VYC-0808 Rev. 6, Attachment 7. Also, all valves in the analyzed flow paths are gate valves. [5]
7. Branch lines of a diameter less than half of the main run diameter will be ignored (i.e. treated as straight pipe). The losses from such a branch line are not significant when compared to the total system losses.
8. Fluid viscosity is taken at standard temperature and pressure. Actual viscosity at the higher temperature will be lower than at standard temperature. Therefore, the form losses are overestimated (conservative).
9. RWCU flow is assumed to be 130 gpm (65 gpm for each filter demineralizer unit) [19].
10. The head loss through the portion of the vessel downcomer above the jet pump nozzles is negligible. This head loss component is very small when compared with the overall head loss and other conservative treatments in the calculation.

4.0 Analysis

- **Elevation Head**

The elevation head is simply the difference between the water level in the vessel, assumed to be at 155" above TAF and the elevation of the RHR pump suction.

TAF is defined as 351.5" above the vessel invert [6]. The vessel invert is at elevation 266'-11" [7]. Therefore, the water elevation at 266'-11" + 351.5" + 155" = 309.125 ft.

The elevation of the RHR pump suction is 215'-11" [8] (213'-9" + 2'-2").

Therefore, the total fluid elevation head is at least 93.2 ft (309.125 ft – 215.917 ft).

- **Limiting Pump L/D**

The total L/D for each pump is calculated using a summary of piping lengths and components. The summary for each pump is provided on Tables 1 through 4. Included in these tables are component L/D values per Assumption #6.

By inspection, the limiting line-up is SDC using the "D" RHR pump with a total suction-side L/D of 712.1.

- **Reactor Vessel and Recirculation Line Losses**

The previously calculated L/D does not include any losses in the reactor vessel or recirculation lines. Due to the complex nature of the geometry, the losses are not readily calculated using the standard methods presented in Crane [9]. However, a detailed RELAP model of the reactor vessel and recirculation loops has been previously developed and used for detailed VY LOCA analyses. The model is of sufficient detail that the pressure drop from some arbitrary point in the vessel to some point in the "A" recirculation loop can be approximated based on a steady-state RELAP solution. The static head difference can then be determined and subtracted leaving the unrecoverable form losses for a given flow. The losses can then be scaled to the flow rates of interest and added to the total losses for determining the NPSH.

The steady state run from VYC-1628 Rev. 0 [15] will be used as the baseline case for determining pressure drop. Figure 2.2 from VYC-1628 provides the RELAP nodalization for the baseline case. For convenience, node 274, corresponding to the top of the jet pump will be taken as the upstream location. The SDC suction is nine feet below the recirculation suction nozzle [16]. Therefore, node 314, extending 11.4198 ft below the recirculation suction nozzle (see Table 5), will be the endpoint for the vessel pressure drop calculation. It is noted that the pressures reported in RELAP5YA output correspond to the center of the given node. Therefore, the total pressure drop and head loss do not correspond exactly to the SDC connection. However, the difference, 2.4198 ft of 28-inch pipe represents a negligible head loss when compared with the total head loss (and the total head loss in the vessel is small to begin with) and can be safely ignored.

The nodalization summary and results are shown in Table 5. The node data (pressure, temperature, flow, elevation) are taken from the last major edit of the RELAP output file labeled "*r5bavss1.o*" contained on microfiche "*028YQ*". Nodes with a zero elevation difference are not

included in the summary (but their effect on form loss is included in the calculated pressures from RELAP).

The pressure due to static head is calculated from the equation:

$$P_2 = P_1 + \left(Z_1/2 + Z_2/2 \right) \cdot \frac{\rho}{144} \cdot \frac{g}{g_c}$$

where P = pressure at the node center, psi
Z = node elevation difference, ft
ρ = fluid density, lbm/ft3
g = gravitational acceleration constant, 32.2 ft/s^2
g_c = conversion constant, 32.2 ft-lbm/lbf-s^2

The flow loss is calculated from the equation:

$$h_L = \left(P_{static} - P_{RELAP} \right) \cdot \frac{144}{\rho}$$

The resultant flow loss from the top of the jet pumps to the SDC connection is taken as 9.5 ft for a flow of 7201.6 lbm/sec or 68310.5 gpm at a density of 47.318 lbm/ft^3.

Table 5 – RELAP Summary of Vessel Downcomer and Recirculation Line Losses

Density = 47.318 lb/ft^3 Flow = 7201.6 lbm/sec

RELAP Node	Height ft	Head psi	Head ft	Pressure, static only	Flow Loss ft
274	3.796	1051.9	3201.2	1051.9	0.00
276	3.6417			1053.1	
278	3.8542			1054.4	
280	2.58	1053.2	3205.1	1055.4	6.73
314	11.4198	1054.6	3209.4	1057.7	9.47

- **Single-Train Head Loss**

The resulting maximum suction head loss during SDC using one RHR pump (without RWCU) is:

$$h_L = 0.00259 \cdot 0.012 \cdot 712.1 \cdot \frac{7600^2}{19.25^4} + 9.5 \cdot \left(\frac{7600}{68310.5} \right)^2$$
$$= 9.4\ ft$$

The resultant NPSH$_a$ would be 83.8 ft (93.2 ft – 9.4 ft).

- **Dual-Train Head Loss – One Pump per Train**

For the shutdown cooling with two trains of RHR in operation and one pump operating in each train (without RWCU flow), the NPSH margin is calculated based on double the RHR flow rate for the combined suction portion of the piping. Table 6 provides the take-off summary differentiating between the common suction and the separate loops. For conservatism, the branch

connection where the flow separates is assumed to see full flow. The L/D for the combined suction is 311.4 and the L/D to the pump from the combined suction is 400.7.

The head loss is calculated as follows:

$$h_L = 0.00259 \cdot 0.012 \cdot 311.4 \cdot \frac{(7600 \cdot 2)^2}{19.25^4} + 0.00259 \cdot 0.012 \cdot 400.7 \cdot \frac{7600^2}{19.25^4} + 9.5 \cdot \left(\frac{(7600 \cdot 2)}{68310.5} \right)^2$$
$$= 22.0\, ft$$

The resultant $NPSH_a$ would be 71.2 ft (93.2 ft – 22.0 ft).

- **Dual-Train Head Loss – Two Pumps Per Train**

For the shutdown cooling with two trains of RHR in operation and two pumps operating in each train (without RWCU flow), the NPSH margin is calculated based on a maximum of 14,600 gpm per train or 7300 gpm per pump (see Assumption 3).

Table 7 provides the take-off summary differentiating between the common suction and the separate loops. For conservatism, the branch connection where the flow separates is assumed to see the maximum flow. The L/D for the combined train suction is 311.4 and the L/D for the combined pump suction is 277.3 and the L/D to the pump from the combined pump suction is 123.4.

The head loss is calculated as follows:

$$h_L = 0.00259 \cdot \frac{0.012}{19.25^4} \cdot \left(311.4 \cdot (14600 \cdot 2)^2 + 277.3 \cdot (14600)^2 + 123.4 \cdot (7300)^2\right) + 9.5 \cdot \left(\frac{(14600 \cdot 2)}{68310.5} \right)^2$$
$$= 76.7\, ft$$

The resultant $NPSH_a$ would be 16.5 ft (93.2 ft – 76.7 ft).

It is noted that RWCU takes suction off the SDC header inside the drywell [5]. Adding this 130 gpm flow (see Assumption 9) into the combined train suction and vessel and recirculation loop flow yields a head loss of:

$$h_L = 0.00259 \cdot \frac{0.012}{19.25^4} \cdot \left(311.4 \cdot (14600 \cdot 2 + 130)^2 + 277.3 \cdot (14600)^2 + 123.4 \cdot (7300)^2\right) + 9.5 \cdot \left(\frac{(14600 \cdot 2 + 130)}{68310.5} \right)^2$$
$$= 77.2\, ft$$

The resultant $NPSH_a$ would be 16.0 ft (93.2 ft – 77.2 ft).

- **Dual-Train Head Loss – Two Pumps Per Train – Throttled Condition**

Based on the results to be presented, it will be noted that the above NPSHa is inadequate to maintain a positive NPSH margin to the RHR pumps. Therefore, a throttled condition will be examined that does provide adequate NPSH margin. It will be assumed that the throttled condition results in RHR pump flows of 6625 gpm per pump or 13,250 gpm per train and including RWCU flow.

The head loss is calculated as follows:

$$h_L = 0.00259 \cdot \frac{0.012}{19.25^4} \cdot \left(311.4 \cdot (13250 \cdot 2 + 130)^2 + 277.3 \cdot (13250)^2 + 123.4 \cdot (6625)^2\right) + 9.5 \cdot \left(\frac{(13250 \cdot 2 + 130)}{68310.5}\right)^2$$
$$= 63.7\ ft$$

The resultant $NPSH_a$ would be 29.5 ft (93.2 ft – 63.7 ft).

- **NPSH Margin**

The RHR pump required NPSH for unlimited operation at 7600 gpm is 33 ft, at 7400 gpm is 32 ft, at 7000 gpm is 29.5 ft and at 6400 gpm is 28.5 ft [VYC-0808 Rev. 6, Att. 3 pg. 5].

The minimum NPSH margin for each of the combinations analyzed above is summarized as follows:

Description	$NPSH_a$, ft	$NPSH_r$, ft	NPSH Margin, ft
SDC, One Train, One Pump	83.8	33	50.8
SDC, Two Trains, One Pump per Train	71.2	33	38.2
SDC, Two Trains, Two Pumps per Train, max. flow	16.5	32	-15.5
SDC, Two Trains, Two Pumps per Train, max. flow w/ RWCU	16.0	32	-16.0
SDC, Two Trains, Two Pumps per Train, throttled w/ RWCU	29.5	29	0.5

Table 1 – From Recirc Loop "A" to RHR Pump "A" Suction

Reference	Length		Valves	Elbows		Tee		Misc	
	ft	in	Gate	90° SR	45° LR	Run	Branch	20-18 Red.	
Component L/D →			8	20	11	20	60		
5920-6637 Rev. 0 [10]		10.5	2	2			1		
		63							
		3.57							
G191210 Rev. 18 [18]	2	6		2					
& G191211 Rev. 16 [8]	10	3							
	8	7							
	5	5							
5920-9283 Rev. 4 [11]	5	6	1	1	2		1		
	2	8.5		3					
	3	6.5							
	2	1							
	2								
	2	11							
	8								
	3	8							
	9	2							
	1	6							
	9	4.5							
	6	7							
	5	1							
	2	9.5							
	14	7							
	4	3							
5920-9284 Rev. 3 [12]	8	6	1	2		1	1	2	
	1	6							
	7	2							
	2	6							
	3	4							
	9	6							
	2	7							
	3	5							
Total L/D →	85.4	11.5	32	200	22	20	180	2	552.9

Table 2 - From Recirc Loop "A" to RHR Pump "B" Suction

Reference	Length		Valves	Elbows		Tee		Misc	
	ft	in	Gate	90° SR	45° LR	Run	Branch	20-18 Red.	
Component L/D →			8	20	11	20	60		
5920-6637 Rev. 0 [10]		10.5	2	2			1		
		63							
		3.57							
G191210 Rev. 18 [18]	2	6		2					
& G191211 Rev. 16 [8]	10	3							
	8	7							
	5	5							
5920-9283 Rev. 4 [11]	5	6	1	1	2		1		
	2	8.5		3					
	3	6.5							
	2	1							
	2								
	2	11							
	8								
	3	8							
	9	2							
	4	2							
	2	9							
	4	7							
	2	7							
5920-9286 Rev. 4 [13]	19	3		4	1				
	5								
	1	3							
	7	1.5							
	1	4.5							
	3								
	3								
	7	6							
		1.5							
5920-9285 Rev. 4 [14]	4	3	1	2		2	1	2	
	3	10.5							
	4	6							
	11								
	3	4							
	9	6							
	3	8							
	2	10							
Total L/D →	98.5	12.1	32	280	33	40	180	2	677.6

Table 3 - From Recirc Loop "A" to RHR Pump "C" Suction

Reference	Length		Valves	Elbows		Tee		Misc	
	ft	in	Gate	90° SR	45° LR	Run	Branch	20-18 Red.	
Component L/D →			8	20	11	20	60		
5920-6637 Rev. 0 [10]		10.5	2	2			1		
		63							
		3.57							
G191210 Rev. 18 [18]	2	6		2					
& G191211 Rev. 16 [8]	10	3							
	8	7							
	5	5							
5920-9283 Rev. 4 [11]	5	6	1	1	2		1		
	2	8.5		3					
	3	6.5							
	2	1							
	2								
	2	11							
	8								
	3	8							
	9	2							
	1	6							
	9	4.5							
	6	7							
	5	1							
	2	9.5							
	14	7							
	4	3							
5920-9284 Rev. 3 [12]	8	6	1	2			2	2	
	5	10							
	3	5							
	9	6							
	1	10.5							
	2	9							
Total L/D →	81.0	11.7	32	200	22	0	240	2	588.8

Table 4 - From Recirc Loop "A" to RHR Pump "D" Suction

Reference	Length		Valves	Elbows		Tee		Misc	
	ft	in	Gate	90° SR	45° LR	Run	Branch	20-18 Red.	
Component L/D →			8	20	11	20	60		
5920-6637 Rev. 0 [10]		10.5	2	2			1		
		63							
		3.57							
G191210 Rev. 18 [18]	2	6		2					
& G191211 Rev. 16 [8]	10	3							
	8	7							
	5	5							
5920-9283 Rev. 4 [11]	5	6	1	1	2		1		
	2	8.5		3					
	3	6.5							
	2	1							
	2								
	2	11							
	8								
	3	8							
	9	2							
	4	2							
	2	9							
	4	7							
	2	7							
5920-9286 Rev. 4 [13]	19	3		4	1				
	5								
	1	3							
	7	1.5							
	1	4.5							
	3								
	3								
	7	6							
		1.5							
5920-9285 Rev. 4 [14]	4	3	1	2		1	2	2	
	3	10.5							
	4	6							
	6								
	3	4							
	9	1							
	1	8							
	1	4.5							
Total L/D →	93.5	11.6	32	280	33	20	240	2	712.1

Table 6 - From Recirc Loop "A" to RHR Pump "D" Suction

Reference	Length		Valves	Elbows		Tee		Misc	
	ft	in	Gate	90° SR	45° LR	Run	Branch	20-18 Red.	
Component L/D →			8	20	11	20	60		
5920-6637 Rev. 0 [10]		10.5	2	2			1		
		63							
		3.57							
G191210 Rev. 18 [18]	2	6		2					
& G191211 Rev. 16 [8]	10	3							
	8	7							
	5	5							
5920-9283 Rev. 4 [11]	5	6	1	1	2		1		
	2	8.5							
	3	6.5							
	2	1							
	2								
	2	11							
	8								
	3	8							
	9	2							
Full Flow L/D →	38.0	7.3	24	100	22	0	120	0	311.4
	4	2		3					
	2	9							
	4	7							
	2	7							
5920-9286 Rev. 4 [13]	19	3		4	1				
	5								
	1	3							
	7	1.5							
	1	4.5							
	3								
	3								
	7	6							
		1.5							
5920-9285 Rev. 4 [14]	4	3		1			1		
	3	10.5							
	4	6							
	6		1	1		1	1	2	
	3	4							
	9	1							
	1	8							
	1	4.5							
Half Flow L/D →	55.5	4.2	8	180	11	20	120	2	400.7

Table 7 - From Recirc Loop "A" to RHR Pump "D" Suction

Reference	Length		Valves	Elbows		Tee		Misc	
	ft	in	Gate	90° SR	45° LR	Run	Branch	20-18 Red.	
Component L/D →			8	20	11	20	60		
5920-6637 Rev. 0 [10]		10.5	2	2			1		
		63							
		3.57							
G191210 Rev. 18 [18]	2	6		2					
& G191211 Rev. 16 [8]	10	3							
	8	7							
	5	5							
5920-9283 Rev. 4 [11]	5	6	1	1	2		1		
	2	8.5							
	3	6.5							
	2	1							
	2								
	2	11							
	8								
	3	8							
	9	2							
Full Flow L/D →	38.0	7.3	24	100	22	0	120	0	311.4
	4	2		3					
	2	9							
	4	7							
	2	7							
5920-9286 Rev. 4 [13]	19	3		4	1				
	5								
	1	3							
	7	1.5							
	1	4.5							
	3								
	3								
	7	6							
		1.5							
5920-9285 Rev. 4 [14]	4	3		1			1		
	3	10.5							
	4	6							
Half Flow L/D →	43.0	3.3	0	160	11	0	60	0	277.3
	6		1	1		1	1	2	
	3	4							
	9	1							
	1	8							
	1	4.5							
Quarter Flow L/D →	12.5	0.9	8	20	0	20	60	2	123.4

VY CALCULATION CHANGE NOTICE (CCN)

CCN Number: 03 Calculation Number VYC-0808 Rev. No. 6

Calculation Title: Core Spray and Residual Heat removal Pump Net Positive Suction Head Margin Following a Loss of Coolant Accident"

Initiating Document: VYC-1924 Rev 0 CCN#2 and VYC-1677 Rev 0 CCN # 3
VYDC/MM/TM/Spec. No./ other

Safety Evaluation Number: NA

Superseded Calculation: VYC-0808 R6 CCN2 Superceded by: NA

Implementation Required: ☐ Yes ☒ No

Computer Codes:

Reason for Change:

VYC-1677 Rev. 0 CCN#3 (Ref 2) identifies up-to-date debris source term information for both the RHR and CS suction strainers. This CCN is written to update the limiting head loss for these suction strainers previously calculated in VYC-1924 Rev 0 CCN2 (Ref 1).

Description of Change:

The limiting head loss for the RHR and CS ECCS suction strainers is calculated in VYC-1924 Rev 0 CCN#2 (Ref 1) using HLOSS 1.0. The sludge debris loading has been increased in VYC-1677 Rev 0 CCN #3 (Ref 2) by increasing the yearly sludge generation from 53 lbm/yr for 3 cycles (4.5 yrs) to 88 lbm/yr for 4 cycles (6 yrs). The sensitivity study has been modified to determine the head loss with a fiber loading that will result in a uncompressed debris bed thickness equal to the strainer hole diameter of 0.125" as identified in Ref #6 of VYC-1924 R0 CCN #1. This is the limiting head loss.

Rerun the Table 1 of VYC-808 Rev 6 to determine the revised margin with debris as a function of suppression pool temperature and the revised strainer debris loading.

Technical Justification for Change:

NPSH available has been evaluated based on the impact of a rise in torus sludge generation from 53 lbm/yr to 88 lbm/yr (~67%) concurrently with an expansion in the period of torus desludge from 4.5 years (3 cycles) to 6 years (4 cycles). These increases, as a result of more accurate calculation of strainer head loss in VYC-1924, result in essentially no impact on calculated NPSH margin. In addition, calculation of NPSH margin remains conservative in that the maximum torus temperature of record for this analysis is 182.6°F. This temperature is 0.9°F higher than maximum long-term LOCA temperature analyzed in VYC-1628F (181.7°F). This temperature differential provides additional conservatism to NPSH available.

Conclusions:

The sensitivity study in Ref 1 shows that the revised limiting debris head loss for a RHR strainer is 0.24 ft, and for a CS strainer is 0.19 ft. These limiting head loss values, based on additional debris loading and an additional operating cycle, are greater than the previously calculation limiting debris loading head losses of 0.13 ft for RHR or 0.09 ft for CS identified in VYC-1924 CCN01. The revised limiting head loss, will encroach on, yet not exceed, the head loss margin (h_d) as identified in VYC-0808 Table 1. These limiting head loss values are less the head loss values currently used in the ECCS pump NPSH analyses in VYC-0808 Rev 6.

Note: VYAPF 0017.07 should be included immediately following this form.

VYC-0808 Rev 6 Table 1 calculates Margin with Debris as a function of temperature. In VYC-0808 Rev 6 CCN #2, the RHR and CS debris head loss are bounded by the values in VYC-0808 Rev 6 Table 1. The Margin with Debris value is actually higher than the limiting debris head loss that was determined by the sensitivity study in Ref 1. The revise Table 1 shows the limiting debris head loss for RHR (0.24 ft) and CS (0.19) and the Margin with Debris calculated at both 182.6° F and 181.7° F (Ref 3) . The margin debris is determined by subtracting the actual calculated debris head loss from the "Clean" Margin. The NSPHA was also calculated at 182.6° F and 181.7° to demonstrate the affect temperature has on NPSHA.

Additional conservatism in NPSH margin is a result of a conservative estimates in yearly sludge load generation from 53 lbm/yr to 88 lbm/yr and maintaining the sludge generated for an operating cycle of 24 months opposed to the 18 month cycle. Torus desludging was performed during RFO20. Based on the revised debris loading, the Torus desludging is not required until RFO 24 with the limiting head loss margin being on the Core Spray Pump. A 0028 commitment has been generated to track desludging the Torus.

No change to DBDs or FSAR is required. The 50.59 Screen indicates that no safety evaluation is required. The net impact of the revised sludge loading is that sufficient NPSH is available to the RHR and CS ECCS pumps and there is no negative impact on the pumps or post accident RHR or CS operation / capabilities.

Are there any open items in this CCN? ☒ Yes ☐ No

Prepared By/Date	Interdiscipline Review By/Date	Independent Review By/Date	Approved By/Date
Greg Brede 10/20/02	NA	Allan L Rohtsler 10/21/02	James G Rogers 10/21/02

Final Turnover to DCC (Section 2):

1) All open items, if any, have been closed.

2) Implementation Confirmation (Section 2.3.4)

☒ Calculation accurately reflects existing plant configuration, (confirmation method indicated below)

☐ Walkdown ☒ As-Build input review ☐ Discussion with _____ (print name)

OR

☐ N/A, calculation does not reflect existing plant configuration

3) Resolution of documents identified in the Design Output Documents Section of VYAPF 0017.07 has been initiated as required (Section 2.3.6, 2.3.7)

Greg Brede / Greg Brede / 10/20/02

Print Name / Signature / Date

Total number of pages in package including all attachments 8

VYC-808 R6
CCN #3

Note: VYAPF 0017.07 should be included immediately following this form.

VY CALCULATION DATABASE INPUT FORM

Place this form in the calculation package immediately following the Title page or CCN form.

VYC-0808 / 03 — VY Calculation/CCN Number
6 — Revision Number
NA — Vendor Calculation Number
NA — Revision Number
Vendor Name: NA
PO Number: NA
Originating Department: FLUIDS SYSTEMS
Critical References Impacted: ☐ UFSAR ☐ DBD ☐ Reload. "Check" the appropriate box if any critical document is identified in the tables below.
EMPAC Asset/Equipment ID Number(s): P-101A/B/C/D
EMPAC Asset/System ID Number(s): 10 (RHR), 14 (CS)
Keywords: Shut Down Cooling, Net Positive Suction Head (NPSH), Residual Heat Removal (RHR), Core Spray (CS)
For Revision/CCN only: Are deletions to General References, Design Input Documents or Design Output Documents required? ☐ Yes† ☒ No

Design Input Documents and General References - The following documents provide design input or supporting information to this calculation. (Refer to Appendix A, sections 3.2.7 and section 4)

* Reference #	** DOC #	REV #	***Document Title (including Date, if applicable)	Significant Difference Review ††	**** Affected Program	Critical Reference (✓)
1	VYC-1924	0/CCN 2	DE&S Calc. DC-A34600-006, "Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations"			
2	VYC-1677	0/CCN 03	Debris Source Terms for Sizing of Replacement Residual Heat Removal and Core Spray Strainers			
3	VYC-1628F	Rev 0	Limiting Torus temperature Response, Million Second Run			
4		5th ED	ASTM Steam Tables			

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VY CALCULATION DATABASE INPUT FORM (Continued)

Design Output Documents - This calculation provides output to the following documents. (Refer to Appendix A, section 5)

* Reference #	** DOC #	REV #	Document Title (including Date, if applicable)	**** Affected Program	†††Critical Reference (✓)

* Reference # -	Assigned by preparer to identify the reference in the body of the calculation.
** Doc # -	Identifying number on the document, if any (e.g., 5920-0264, G191172, VYC-1286)
*** Document Title -	List the specific documentation in this column. "See attached list" is not acceptable. Design Input/Output Documents should identify the specific design input document used in the calculation or the specific document affected by the calculation and not simply reference the document (e.g., VYDC, MM) that the calculation was written to support. If a DBD is used as a general reference, include the most current interim change number after the title.
**** Affected Program -	List the affected program or the program that reference is related to or part of.
†	If "yes," attach a copy of "VY Calculation Data" marked-up to reflect deletion (See Section 3.1.8 for Revision and 5.2.3.18 for CCNs).
††	If the listed input is a calculation listed in the calculation database that is not a calculation of record (see definition), place a check mark in this space to indicate completion of the required significant difference review. (see Appendix A, section 4.1.4.4.3). Otherwise, enter "N/A."
†††	If the reference is UFSAR, DBD or Reload (IASD or OPL), check Critical Reference column and check UFSAR, DBD or Reload, as appropriate, on this form (above).

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CCN # 3
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TABLE 1

VYC-808, Revision 6

NPSHA = (14.7 - P_g)(144)(v_f) + Z - h_f - h_s - h_d

Suction Line Losses

1 RHR	h_f = 4.77e-8*Q^2	CS	h_f = 2.5e-7*Q^2
2 RHR	h_f = 7.84e-8*(Q/2)^2		

Clean Strainer Losses

1 RHR	h_s = 0.33	CS	h_s = 0.51 for Q=4600 gpm
2 RHR	h_s = 1.22	CS	h_s = 0.36*(Q/4000)^2 for Q≤4000 gpm

Maximum Debris Losses

1 RHR	h_d = 0.33 (maximum)	CS	h_d = 0.21 (maximum @ 4000 gpm)
2 RHR	h_d = 0.48 (maximum)	CS	h_d = 0.32 (maximum @ 4600 gpm)

Required NPSH

RHR	NPSHR = 23 + (Q-6400)/1200	CS	NPSHR = 26.4 - 2.965e-3*Q +7.191e-7*Q^2

	Q (gpm)	T (F)	P_g (psia)	v_f (cu ft/lb)	Z (ft)	h_f (ft)	h_s (ft)	h_d (ft)	"Clean" NPSHA (ft)	NPSHR (ft)	"Clean" Margin (ft)	h_d (ft)	Margin w/ Debris (ft)
1 CS	4600	90	0.69613	0.016009	12.49	5.29	0.51	0	39.1	28.0	11.2		
short-term	4600	120	1.6927	0.016204	12.49	5.29	0.51	0	37.0	28.0	9.1		
	4600	150	3.7184	0.016343	12.49	5.29	0.51	0	32.5	28.0	4.5		
	4600	184	5.212	0.016410	12.49	5.29	0.51	0	29.1	28.0	1.1	0.32	0.8
	4600	182.6	7.954	0.016530	12.49	5.29	0.51	0	22.7	28.0	-5.2		
	4600	190	9.34	0.016572	12.49	5.29	0.51	0	19.5	28.0	-8.5		
1 CS	3500	90	0.69613	0.016009	12.59	3.06	0.29	0	41.7	24.8	16.9		
long-term	3500	120	1.6927	0.016204	12.59	3.06	0.29	0	39.6	24.8	14.8		
	3500	150	3.7184	0.016343	12.59	3.06	0.29	0	35.1	24.8	10.2		
	3500	184	5.212	0.016410	12.59	3.06	0.29	0	31.7	24.8	6.8		
	3500	182.6	7.954	0.016530	12.59	3.06	0.29	0	25.3	24.8	0.5	0.21	0.3
	3500	184	8.203	0.016535	12.59	3.06	0.29	0	24.7	24.8	-0.1		
	3500	185	8.364	0.016541	12.59	3.06	0.29	0	24.3	24.8	-0.6		
2 RHR	14200	90	0.69613	0.016009	12.32	3.95	1.22	0	39.6	23.6	16.0		
short-term	14200	120	1.6927	0.016204	12.32	3.95	1.22	0	37.5	23.6	13.9		
	14200	150	3.7184	0.016343	12.32	3.95	1.22	0	33.0	23.6	9.4		
	14200	184	5.212	0.016410	12.32	3.95	1.22	0	29.6	23.6	6.0	0.48	5.5
	14200	182.6	7.954	0.016530	12.32	3.95	1.22	0	23.2	23.6	-0.4		
	14200	190	9.34	0.016572	12.32	3.95	1.22	0	19.9	23.6	-3.6		
1 RHR	7400	90	0.69613	0.016009	12.32	2.61	0.33	0	41.8	23.8	18.0		
short-term	7400	120	1.6927	0.016204	12.32	2.61	0.33	0	39.7	23.8	15.9		
	7400	150	3.7184	0.016343	12.32	2.61	0.33	0	35.2	23.8	11.4		
	7400	184	5.212	0.016410	12.32	2.61	0.33	0	31.8	23.8	8.0	0.33	7.6
	7400	182.6	7.954	0.016530	12.32	2.61	0.33	0	25.4	23.8	1.6		
	7400	190	9.34	0.016572	12.32	2.61	0.33	0	22.2	23.8	-1.7		
1 RHR	7400	90	0.69613	0.016009	12.42	2.61	0.33	0	41.9	23.8	18.1		
long-term	7400	120	1.6927	0.016204	12.42	2.61	0.33	0	39.8	23.8	16.0		
	7400	150	3.7184	0.016343	12.42	2.61	0.33	0	35.3	23.8	11.5		
	7400	184	5.212	0.016410	12.42	2.61	0.33	0	31.9	23.8	8.1		
	7400	182.6	7.954	0.016530	12.42	2.61	0.33	0	25.5	23.8	1.7	0.33	1.4
	7400	185	8.364	0.016541	12.42	2.61	0.33	0	24.5	23.8	0.7		
	7400	190	9.34	0.016572	12.42	2.61	0.33	0	22.3	23.8	-1.6		

CCN 03

	Q	Temp	P_g	v_f	Z	h_f	h_s	h_d	clean NPSHA	HPSHR	clean margin	calc h_d	margin Debris
		F							(ft)	(ft)	(ft)	(ft)	(ft)
		Ref 3	Ref 4	Ref 4								Ref 1	
1 CS long term	3500	182.6	7.9540	0.016530	12.59	3.06	0.29	0	25.30	24.80	0.50	0.19	0.31
	3500	181.7	7.7987	0.016520	12.59	3.06	0.29	0	25.66	24.80	0.86	0.19	0.67
	Q	Temp	P_g	v_f	Z	h_f	h_s	h_d	clean NPSHA	HPSHR	clean margin	calc h_d	margin Debris
		F							(ft)	(ft)	(ft)	(ft)	(ft)
		Ref 3	Ref 4	Ref 4								Ref 1	
1 RHR long term	7400	182.6	7.9540	0.016530	12.42	2.61	0.33	0	25.50	23.80	1.70	0.24	1.46
	7400	181.7	7.7987	0.016520	12.42	2.61	0.33	0	25.90	23.80	2.10	0.24	1.86

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50.59 SCREEN

I. **Activity/Document Number:** VYC-1677R0 CCN3, VYC-1924R0 CCN2, VYC-0808 R6 CCN~~6~~3 MJB 10/18/02 **Revision Number:** 0

Title: Torus Debris loading generation, head loss determination and effects on CS & RHR Suction Strainers after a LOCA

Provide or attach a brief description of activities (section 6.3 of RM)

VYC-1677 CCN 3 changes the current debris source term calculation is based on a three-cycle (4.5 year) interval and a 53 lbm/year sludge generation for Torus desludging. It is desired to determine the acceptability of Torus desludging on a four-cycle (6 year) interval with a debris generation of 88 lbm/year typical of the industry average.

VYC-1924 Rev 0 CCN2 updates the limiting head loss for the ECCS RHR and CS suction strainers and used the new debris loading determined in VYC-1677 CCN 3.

VYC-0808 Rev 6 CCN~~6~~3 MJB 10/16/02 updates the NPSHA based on the limiting head loss for the ECCS RHR and CS suction strainers determined in VYC-1924 Rev 0 CCN2.

The revised limiting head loss, will encroach on, yet not exceed, the head loss margin (h_d) as identified in VYC-0808 Rev 6 Table 1. These limiting head loss values are less the head loss values currently used in the ECCS pump Net Positive Suction Head Available (NPSHA) analyses in VYC-0808

II. **Applicability Determination**

Other applicable processes identified during the applicability determination:

NONE

III **50.59 Screening Questions** (Section 5.2.2 of the 50.59 Resource Manual (RM) provides additional guidance) (Check correct response and provide a brief response to each question answered "No". If "YES" is checked for any question, the 50.59 Screen does not need to be completed since a 50.59 Evaluation is required):

1. Does the proposed activity involve a change to an SSC that adversely affects an UFSAR described *design function*? (Section 5.2.2.1 of the RM) ☐ YES ☒ NO

   Increasing the debris loading on the ECCS suction strainers, determining the limiting head loss and NPSHA does not adversely affect an UFSAR described design function.

2. Does the proposed activity involve a change to a procedure that adversely affects how UFSAR described SSC design functions are performed or controlled? (Section 5.2.2.2 of the RM) ☐ YES ☒ NO

   Increasing the debris loading on the ECCS suction strainers, determining the limiting head loss and NPSHA does not change a procedure that adversely affects how UFSAR described design function is performed. The new limiting debris head loss and NPSHA do not affect how the ECCS RHR and CS pumps perform their function.

3. Does the proposed activity involve revising or replacing an UFSAR described evaluation methodology that is used in establishing the *design bases* or used in the *safety analyses*? (Section 5.2.2.3 of the RM) ☐ YES ☒ NO

   Increasing the debris loading on the ECCS suction strainers, determining the limiting head loss and NPSHA does not revising an UFSAR described evaluation methodology that is used in establishing the design bases.

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50.59 SCREEN (Continued)

4. Does the proposed activity involve a *test or experiment not described in the UFSAR*, where an SSC is utilized or controlled in a manner that is outside the reference bounds of the design for that SSC or is inconsistent with analyses or descriptions in the UFSAR? (Section 5.2.2.4 of the RM) ☐ YES ☒ NO

   Increasing the debris loading on the ECCS suction strainers, determining the limiting head loss and NPSHA does not involve a special test.

5. Does the proposed activity require a change to the Technical Specifications? (Section 5.2.2.5 of the RM) ☐ YES ☒ NO

   Increasing the debris loading on the ECCS suction strainers, determining the limiting head loss and NPSHA does not require a change to Tech Specs

IV. If all questions are answered NO, then implement the activity per the applicable plant procedure for the type of activity without obtaining a License Amendment.
If screen question 5 is answered YES, then request and receive a License Amendment to support the activity.
If screen question 5 is answered NO and question 1, 2, 3 or 4 is answered YES, then a 50.59 Evaluation shall be performed.
If only question 3 is answered YES, then only question 8 of the 10CFR50.59 Evaluation needs to be answered.

V. List the documents reviewed including section numbers and key words (UFSAR, Technical Specifications and associated bases, TRM and associated bases, DBDs and other controlled documents) where related information was found. If changes to controlled documents, including plant procedures, are identified, ensure that changes are initiated in accordance with the controlling plant procedures (e.g. FSAR changes are initiated per AP 6036, DBD changes per AP 6007). (ER960591_02)

Searched on the words HEAD LOSS, SUCTION STRAINERS, DEBRIS LOADING AND NPSH

UFSAR-. Sections 6.6.2 (CS) and 6.4.4 (LPCI) discussed the debris loading and NPSH. The CCN do not affect these sections in the UFSAR.

Tech Spec-No discussion on requirements

Residual Heat Removal DBD

Sections 2.3.4 Suction Strainer Blockage and 3.21.1 RHR Suppression Pool Suction Strainers discussed head loss and the NPSHA requirement. The reference section included VYC-808. The CCNs do not affect any of these sections in the DBD.

Core Spray DBD

Sections 2.2.4.7,8,9 referenced Suction Strainers. Section 2.3.4 discussed head loss and the NPSHA requirement. The reference section included VYC-808. The CCNs do not affect any of these sections in the DBD.

50.59 Screen Signoffs: Preparer: Greg Brede (Print name) Greg Brede (Sign) Date: 10/16/02

Reviewer: Alan L. Robertshaw (Print name) Alan L. Robertshaw (Signature) Date: 10/18/02

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VY CALCULATION REVIEW FORM

Calculation Number: VYC-0808 Revision Number: 6 CCN Number: 03

Title: Core Spray and Residual Heat Removal Pump Net Positive Suction Head Margin Following a Loss of Coolant Accident

Reviewer Assigned: Alan L. Robertshaw Required Date: 10/19/2002

☐ Interdiscipline Review ☒ Independent Review

Comments*	Resolution
1) Need Calculation Number, Revision, CCN, and Page Number on each page of CCN	Calc, Rev & CCN # & Pg # on each Page or in header
2) Page 5, Table 1. Temperature of 181.7F was used. Should a temp. of 182.6F be used to be consistent with other two supporting calcs?	See Conclusion, using the revised worst case Temp gives additional NPSHA
3) Page 5, Table 1. Density associated with T=181.7F appears to be a little low (try value of 0.016520).	ADDRESSED, changed head loss by .01 psi.
4) Page 5, Table 1. Did value of Head Loss = 0.19 for CS case change from VYC-1924?	No. this value was carried in to VYC-0808 R6 by prior revs, Actual H_d was used
5) Page 6. Independent Safety Screening needed for VYC-0808, R6, CCN 03	INCLUDED
Alan L Robertshaw, 10/15/2002	Greg Brede, 10/16/02
Reviewer Signature Date	Calculation Preparer (Comments Resolved) Date

Method of Review:
☒ Calculation/Analysis Review
☐ Alternative Calculation
☐ Qualification Testing

Alan L Robertshaw, 10/18/02
Reviewer Signature (Comments Resolved) Date

*Comments shall be specific, not general. Do not list questions or suggestions unless suggesting wording to ensure the correct interpretation of issues. Questions should be asked of the preparer directly.

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VY CALCULATION CHANGE NOTICE (CCN)

CCN Number: 4 Calculation Number: VYC-0808 Rev. No. 6

Calculation Title: Core Spray and Residual Heat Removal Pump Net Positive Suction Head Margin Following a Loss of Coolant Accident or Anticipated Transients Without Scram

Initiating Document: VYDC 2003-008
VYDC/MM/TM/Spec. No./ other

Safety Evaluation Number: N/A

Superseded Calculation: N/A Superceded by: N/A

Implementation Required: ☒ Yes ☐ No

Computer Codes: N/A

Reason for Change:
Residual Heat Removal (RHR) and Core Spray (CS) Pump NPSH must be evaluated for the affect of increased suppression pool temperatures, resulting from the Extended Power Uprate (EPU).

Description of Change:

NPSH evaluation of the RHR and CS pumps is performed for the following events for which EPU suppression pool temperature/pressure data is presently available.

- DBA-Loss of Coolant Accident (LOCA), short term and long term
- Anticipated Transients Without Scram (ATWS)

Technical Justification for Change:
The reactor core decay heat increases as core power in increased. This heat is transferred to the suppression pool during accidents, transients and other events, which result in peak suppression pool temperatures that are higher than at the existing (pre-EPU) power level. Since increased pool temperature reduces available NPSH, the adequacy of available NPSH must be demonstrated for each event that credits pumping suppression pool water at elevated temperatures. If available NPSH is inadequate, then torus overpressure must be credited.

Conclusions:
There is adequate NPSH available for operating the RHR and CS pumps at EPU conditions for the DBA-Loss of Coolant Accident (LOCA), short term, without crediting torus overpressure.

Torus overpressure must be credited for operating the RHR and CS pumps at EPU conditions for the following events in order to achieve adequate NPSH available:

- DBA-Loss of Coolant Accident (LOCA), long term
- Anticipated Transients Without Scram (ATWS)

The overpressure credit required for LOCA bounds that required for ATWS.

The results of this CCN will provide input to the PUSAR (Ref: 12) for the RHR and CS NPSH evaluation and will alter input to calculation VYC-1628 (Ref: 13) to address the need for crediting torus overpressure in the calculation of NPSH available. Note that calculation VYC-1628 may be superseded by GE EPU Analysis. The need for crediting torus overpressure in the RHR and CS NPSH evaluation, shall also be addressed in the SADBD (Ref: 14), UFSAR (Ref: 15), and system DBDs RHR (Ref: 16) and CS (Ref: 17).

Note that use of overpressure credit must be approved by the NRC as part of EPU.

No specific 50.59 Screening/Evaluation is required for this CCN since all EPU design changes and associated 50.59 documentation will be part of VYDC-2003-008.

See Section 5.0 for Summary of Results

Note: VYAPF 0017.07 should be included immediately following this form.

Are there any open items in this CCN? ☐ Yes ☒ No

Prepared By/Date	Interdiscipline Review By/Date	Independent Review By/Date	Approved By/Date
Frank Capuano /SW/ 08-08-03 F. Capuano	N/A	Edward Lind / SW / 08-12-03 Edward Lind	for O E Gori 8/14/03

Final Turnover to DCC (Section 2): Accepted by B C Shifer 8/14/03

1) All open items, if any, have been closed.

2) Implementation Confirmation (Section 2.3.4)

☐ Calculation accurately reflects existing plant configuration, (confirmation method indicated below)
☐ Walkdown ☐ As-Build input review ☐ Discussion with _____ (print name)
OR
☐ N/A, calculation does not reflect existing plant configuration

3) Resolution of documents identified in the Design Output Documents Section of VYAPF 0017.07 has been initiated as required (Section 2.3.6, 2.3.7)

_____ / _____ / _____
Print Name Signature Date

Total number of pages in package including all attachments 53

VYC-0808 Revision 6
CCN #4

Note: VYAPF 0017.07 should be included immediately following this form.

VY CALCULATION DATABASE INPUT FORM

Place this form in the calculation package immediately following the Title page or CCN form.

VYC-0808 / 04	6	N/A	N/A
VY Calculation/CCN Number	Revision Number	Vendor Calculation Number	Revision Number

Vendor Name: N/A PO Number: N/A

Originating Department: Fluid Systems

Critical References Impacted: ☒ UFSAR ☒ DBD ☐ Reload. "Check" the appropriate box if any critical document is identified in the tables below.

EMPAC Asset/Equipment ID Number(s): P-10-1A/B/C/D, P-46-1A/B

EMPAC Asset/System ID Number(s): 10, 14

Keywords: Residual Heat Removal (RHR), Core Spray (CS), Net Positive Suction Head (NPSH), Loss of Coolant Accident (LOCA), Extended Power Uprate (EPU) Anticipated Transients Without Scram (ATWS)

For Revision/CCN only: Are deletions to General References, Design Input Documents or Design Output Documents required? ☐ Yes† ☒ No

Design Input Documents and General References - The following documents provide design input or supporting information to this calculation. (Refer to Appendix A, sections 3.2.7 and section 4)

* Reference #	** DOC #	REV #	***Document Title (including Date, if applicable)	Significant Difference Review ††	**** Affected Program	Critical Reference (✓)
1	GE-VYNPS-AEP-177	N/A	VYNPS EPU T0400: Suppression Pool Temperature/Pressure Response to DBA-LOCA (4/5/030)			
2	VYC-1924	0	DE&S Calc. DC-A34600-006. Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment, RHR and CS Debris Head Loss Calculations			
3	VYC-0808 / CCN 03	6	Core Spray and Residual Heat Removal Pump Net Positive Suction Head Margin Following a Loss of Coolant Accident			
4	VYC-0808	6	Core Spray and Residual Heat Removal Pump Net Positive Suction Head Margin Following a Loss of Coolant Accident			
5	GE-NE-0000-0016-3831-01	0	YYNPS EPU Task T0902: Anticipated Transients Without Scram			
6			NOT USED			
7			ASME Steam Tables, 1967 IFC Formulation for Industrial Use			
8	ERC No. 2003-027	N/A	Debris Source Terms Appropriate for Power Uprate Evaluations of ECCS NPSH (5/13/03)			
9	RHR	1/IC16	Design Basis Document for Residual Heat Removal System			✓
10	VYC-1924 / CCN 02	0	DE&S Calc. DC-A34600-006. Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment, RHR and CS Debris Head Loss Calculations			
11	VYC-1524	3	Containment and RPV Volume Calculations			

Design Output Documents - This calculation provides output to the following documents. (Refer to Appendix A, section 5)

* Reference #	** DOC #	REV #	Document Title (including Date, if applicable)	**** Affected Program	†††Critical Reference (✓)
12	NEDC-33090P	0	Safety Analysis Report For VYNPS Constant Pressure Power Uprate (PUSAR)		
13	VYC-1628	0	Torus Temperature and Pressure Response to Large Break LOCA and MSLB Accident Scenarios (may be superseded be GE EPU analysis)		
14	SADBD	2/IC2	Topical Design Basis Document for Safety Analysis		✓
15	UFSAR	17	Updated Final Safety Analysis Report		✓
16	RHR	1/IC16	Design Basis Document for Residual Heat Removal System		✓
17	CS	0/IC10	Design Basis Document for Core Spray System		✓

* Reference # - Assigned by preparer to identify the reference in the body of the calculation.

** Doc # - Identifying number on the document, if any (e.g., 5920-0264, G191172, VYC-1286)

*** Document Title - List the specific documentation in this column. "See attached list" is not acceptable. Design Input/Output Documents should identify the specific design input document used in the calculation or the specific document affected by the calculation and not simply reference the document (e.g., VYDC, MM) that the calculation was written to support. If a DBD is used as a general reference, include the most current interim change number after the title.

**** Affected Program - List the affected program or the program that reference is related to or part of.

† If "yes," attach a copy of "VY Calculation Data" marked-up to reflect deletion (See Section 3.1.8 for Revision and 5.2.3.18 for CCNs).

†† If the listed input is a calculation listed in the calculation database that is not a calculation of record (see definition), place a check mark in this space to indicate completion of the required significant difference review. (see Appendix A, section 4.1.4.4.3). Otherwise, enter "N/A."

††† If the reference is UFSAR, DBD or Reload (IASD or OPL), check Critical Reference column and check UFSAR, DBD or Reload, as appropriate, on this form (above).

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(CS pump – Max NPSHr)

Attachment A VY Calculation Review Form (VY APF0017.04) ..... 2 pages

Attachment B VY Documentation of Computer Resource Use (VY APF0017.08) ..... 1 page

* Attachment C VY Dispositioned Comments ..... 8 pages

** NOTE: All VY comments on this CCN have been resolved and incorporated as applicable. The resolutions have been accepted by VY.*

1.0 Objective

The objective of this CCN is to evaluate the adequacy of the available NPSH for the Residual Heat Removal (RHR) and Core Spray (CS) pumps to operate at Extended Power Uprate (EPU) conditions. This includes identification of the amount of suppression pool (torus) overpressure required, if any, to maintain adequate NPSH.

The reactor core decay heat increases as core power in increased. This heat is transferred to the suppression pool during accidents, transients and other events, which result in peak suppression pool temperatures that are higher than at the existing (pre-EPU) power level. Since increased pool temperature reduces available NPSH, the adequacy of available NPSH must be demonstrated for each event that credits pumping suppression pool water at elevated temperatures.

EPU data is presently available for the following events, and as such the EPU impact of these events on NPSH is included in this CCN.

- DBA-Loss of Coolant Accident (LOCA), short term and long term
- Anticipated Transients Without Scram (ATWS) which include:
  - Main Steam Isolation Valve Closure (MSIVC)
  - Pressure Regulator Fail Open – Maximum Steam Demand (PRFO)

Additionally, a basis for readily determining overpressure requirements, when performing RHR and CS pump NPSH evaluation for any other events which cause elevated suppression pool temperatures, will be provided. This will be in the form of a family of curves profiling overpressure required vs. pool temperature.

2.0 Methodology

General

The methodology for determining the NPSH available (NPSHa) for a given event and temperature is the same as that developed in VYC-0808 Rev 6 and presented in Table 1 of that calculation (Ref: 4). The NPSH required (NPSHr) is also per VYC-0808 Rev 6 and is discussed in detail in Section 4.0 of this CCN.

Note that prior revisions and CCNs of this calculation have considered torus pressure to remain at atmospheric pressure in the evaluation of NPSHa. However, because of the increased pool temperature and resulting increased vapor pressure, there will not be adequate NPSHa for some events without taking credit for some torus air space pressure. If NPSHa is inadequate, then the necessary torus air space pressure, above atmospheric pressure, (overpressure) will be calculated to yield adequate NPSHa.

For a high temperature, time dependent event, such as a LOCA, the NPSH will be evaluated over the time-temperature profile of the event in lieu of just at the maximum temperature. This will allow development of a time dependent profile for required overpressure.

Pump Suction Strainer Head Loss during a LOCA

As documented in ERC No. 2003-027 (Ref: 8), EPU does not affect the debris source terms developed in VYC-1677. Therefore the limiting head loss due to debris loading on the RHR and CS suction strainers remains the same as addressed in VYC-0808 Rev 6 including CCN #3 (Ref: 3).

CCN #3 dispositions the up-to-date suction strainer head loss calculated in CCN #2 of VYC-1924 Rev 0 (Ref: 10) which in turn is based on the up-to-date debris source term information per VYC-1677 Rev 0 CCN #3. Note that the debris loading from calc VYC-0808 Rev 6, as extracted from calc VYC-1924 Rev 0 (Ref: 2), is slightly larger than that documented in CCN #3. For conservatism, the larger debris loading is used.

It should be noted that the limiting head loss due to debris loading on the RHR and CS suction strainers is calculated at a specific temperature. Strainer head loss is essentially inversely proportional to fluid temperature as documented in the sensitivity evaluation in VYC-1924 Rev 0 (Ref: 2). Therefore the calculated limiting head loss, described above, will be conservatively used for all fluid temperatures greater than or equal to that used in the calculation of the limiting head loss. For lower temperatures, the head loss will be increased in proportion to the decrease in temperature.

General Profile – Overpressure Required vs. Pool Temperature

In addition to specifically addressing the LOCA and ATWS events, a general profile of Overpressure Required vs. Pool Temperature, for both the RHR and CS pumps, is provided. This profile is intended to serve as the basis for determining overpressure requirements when performing RHR and CS pump NPSH evaluation for any other events, which cause elevated suppression pool temperatures, without strainer debris loading.

This profile is provided for a range of pump flows consistent with the maximum flows evaluated for LOCA and the flows for which NPSH data is provided by the pump vendor.

Only the clean strainer loss is accounted for in the profile, as debris loading on the pump suction strainer is not postulated.

The suppression pool volume is conservatively taken to be at its minimum volume (68,000 ft^3), as addressed in Section 2.4 of Calc VYC-0808 (Ref: 4). This conservatively minimizes the suction elevation head.

There is no additional NPSH margin included in this evaluation.

3.0 Assumptions

1. The RHR flow rate evaluated for ATWS is not specified in GE Task Report T0902 (Ref: 5). Therefore, based on the system design basis provided in Section 2.3.2 of the RHR DBD (Ref: 9) the analyzed flow rates are conservatively taken as 7400 gpm for one RHR pump and 14,200 gpm for two RHR pumps (DBD Section 2.3.2.1.2). These are the same flows rates used for the LOCA evaluation and are greater than the 6400 gpm (minimum) specified in DBD Section 2.3.2 for suppression pool cooling. Suctions losses and strainer losses are conservatively larger with larger flow rates.

2. The torus is considered to be at atmospheric pressure for the purpose of calculating the specific volume of the pool water in the evaluation performed in Section 4.4, General Profile – Overpressure Required vs Pool Temperature. The impact of small variations in pressure is insignificant. An example follows:
   v @ 180°F/14.7 psia = .016510 ft^3/lb
   v @ 180°F/20.7 psia = .016509 ft^3/lb

4.0 Analysis

As stated in Section 2.0, the methodology for determining the NPSHa is the same as that developed in VYC-0808 Rev 6 and presented in Table 1 of that calculation (Ref: 4). The following terms are used in the evaluation.

NPSHa (ft) = net positive suction head available without overpressure credit
(14.7-Pg)(144vf)+Z-hf-hs-hd

where:

Z (ft) = suction elevation head

hf (ft) = suction line losses

hs (ft) = clean strainer losses

hd (ft) = strainer debris losses

Pg (psia) = vapor pressure @ torus temperature

vf (ft^3/lb) = specific volume @ torus temperature and pressure

Pg and vf are obtained from ASME Steam Tables 1967 Formulation (Ref: 7)

NPSHr (ft) = net positive suction head required.
It should be noted that the NPSH required data provided by the pump vendor, as documented in Figures 2.1-1 and 2.2-1 of Attachment 3 to calculation VYC-0808, is actually *Allowable Operating Periods @ NPSHa Specified.* Allowable hours of operation at specified NPSHa values are identified for a range of flows. For this CCN, the NPSHa specified in these Figures is taken as the NPSHr at a given operating time.

Q (gpm) = pump flow rate

OPR (psig) = Overpressure Required
(NPSHr – NPSHa)/(144*Vf)

For those profile points where there is inadequate NPSH, when considering the suppression pool pressure to be atmospheric (14.7 psia), OPR is the amount of suppression pool pressure required to make NPSHa (ft) equal to NPSHr (ft).

OPA (psig)– Overpressure Available
The suppression pool pressure available, above atmospheric, for a given event and time.

OPC (psig)– Overpressure Credit Taken
The overpressure credited in the evaluation of NPSH. Engineering judgement is used to select the credit to be greater than the OPR, by a reasonable amount, and less than the OPA.

Detailed discussion of the above terms, as applicable for each event, is provided in the subsections that follow.

4.1 LOCA – Short Term

The temperature and pressure (T/P) profile for the suppression pool during a LOCA is developed in GE-VYNPS-AEP-177 (Ref: 1). The short term data is provided from 0-600 seconds.

The evaluation of NPSH is documented in Table 4.1 using the peak pool temperature of 165.1°F which occurs at 600 seconds with a corresponding pool pressure of 17.75 psia. The peak temperature results in the largest vapor pressure and lowest NPSHa. Note that the temperature at lowest pool pressure is 162.5°F / 17.56psia. At this temperature the gain in vapor pressure more than offsets the reduction in pool pressure, therefore the 165.1°F case governs. The details of the evaluation are presented at the top of the Table followed by a matrix of the NPSH results for CS and RHR. Further discussion of selected terms is presented below.

Suction Elevation Head, Z

The values of Z for RHR and CS (12.30' and 12.47'respectively) as calculated in Section 3.5 of VYC-0808 are conservatively used in this evaluation. The suction elevation head is based on the water elevation in the torus. The EPU suppression pool water volume is slightly larger than the existing value used in VYC-0808, which would result in a slight increase in water elevation, and therefore Z.

A water volume comparison at maximum pool temperature is provided below:

	Pre-EPU	EPU
Ref:	(VYC-0808 Rev 6 Section 3.5)	(GE-VYNPS-AEP-177)
Short Term	76,800 cuft	79,370 cuft

Maximum Debris Losses (hd)

1 RHR: CCN #3 (Ref: 3) calculated the limiting head loss as 0.24 ft at 181.7°F and 7400 gpm. Note that this is a slight reduction from the head loss (0.33 ft) addressed in Section 3.2 of VYC-0808 Rev 6 (Ref: 4). For conservatism, 0.33 ft at 173°F is used. (Case 1 of Tables 2 and 8 of Ref: 2).

2 RHR: The head loss is taken as .48 ft (Ref: 4) at 170°F (Case 2b of Tables 2 and 8 of Ref: 2) and 14200 gpm.

CS The head loss is conservatively taken as .32 ft (Ref: 4) at 173°F (Case 3d of Tables 2 and 8 of Ref: 2) and 4600 gpm.

Refer to Section 2.0 for application of head loss at temperatures other than those used in its calculation.

NPRHr - CS
Figure 2.2-1 of Attachment 3 to calculation VYC-0808 provides a plot of *Allowable Operating Periods @ NPSHa Specified* values for various flow rates. This plot shows that at 4600 gpm an allowable NPSH of 28.0 ft is acceptable between 0 and 7 hrs of operation.

NPRHr - 1 RHR
Figure 2.1-1 of Attachment 3 to calculation VYC-0808 provides a plot of *Allowable Operating Periods @ NPSHa Specified* values for various flow rates. This plot shows that at 7400 gpm an allowable NPSH of 23.8 ft is acceptable between 0 and 7 hrs of operation.

NPRHr - 2 RHR
With two RHR pumps operating at a total flow of 14,200 gpm this yields a flow of 7100 gpm per pump.
Also per Figure 2.1-1, the plot shows that at between 0 and 7 hrs of operation, an allowable NPSH of 23.5 ft is acceptable at 7000 gpm and 24.0 ft is acceptable at 7600 gpm.

Interpolating between plotted NPSH values of 23.5 ft @ 7000 gpm and 24.0 ft @ 7600 gpm yields 23.6 ft @ 7100 gpm.

The interpolation equation is developed as documented Section 2.2.2 of VYC-0808 Rev 6 and is 23.0+(Q-6400)/1200

4.1.1 Evaluation
As can been seen from Table 4.1, there is adequate NPSHa and overpressure is not required.

4.2 LOCA – Long Term

The temperature and pressure (T/P) profile for the suppression pool during a LOCA is developed in GE-VYNPS-AEP-177 (Ref: 1). The long term data is provided from 0-172,800 seconds.

The evaluation of NPSH is documented in Table 4.2 using a selected T/P points representing the long term profile of the suppression pool. The details of the evaluation are presented at the top of the Table followed by a matrix of the NPSH results for the T/P profile of CS and RHR. The evaluated long term flow rates of 7400 gpm (RHR) and 3500 gpm (CS) are consistent with calculation VYC-0808 Rev 6 (Ref: 4). Further discussion of selected terms is presented below.

Suction Elevation Head, Z
The values of Z for RHR and CS (12.40' and 12.57' respectively) as calculated in Section 3.5 of VYC-0808 are conservatively used in the evaluation. The suction elevation head is based on the water elevation in the torus. The EPU suppression pool water volume is slightly larger than the existing value used in VYC-0808, which would result in a slight increase in water elevation, and therefore Z.

A water volume comparison at maximum pool temperature is provided below:

	Pre-EPU	EPU
Ref:	(VYC-0808 Rev 6 Section 3.5)	(GE-VYNPS-AEP-177)
Long term	77,640 cuft	79,470 cuft

Maximum Debris Losses (hd)
1 RHR: Refer to Section 4.1

CS Note that CCN #3 (Ref: 3) documents the up-to-date limiting head loss as 0.19 ft at 181.7°F and 3500 gpm. This is a slight reduction from the head loss (0.21 ft) addressed in Section 3.2 of VYC-0808 Rev 6 (Ref: 4). For conservatism, 0.21 ft at 173°F is used. This is based on a conservative CS flow rate of 4000 gpm. (Case 3b of Tables 2 and 8 of Ref: 2).

NPRHr - CS
Figure 2.2-1 of Attachment 3 to calculation VYC-0808 provides a plot of *Allowable Operating Periods @ NPSHa Specified* values for various flow rates. This plot shows that at 3500 gpm the allowable NPSH increases between 7 and 20 hrs of operation and a value of 29.6 ft is acceptable beyond 20 hrs of operation. This maximum value is conservatively used for the entire long term period (>600 sec).

NPRHr - RHR
Figure 2.1-1 of Attachment 3 to calculation VYC-0808 provides a plot of *Allowable Operating Periods @ NPSHa Specified* values for various flow rates. This plot shows that at 7400 gpm the allowable NPSH increases between 7 and 100 hrs of operation and a value of 31.7 ft is acceptable beyond 100 hrs of operation. This maximum value is conservatively used for the entire long term period (>600 sec).

4.2.1 Evaluation

As can been seen from Figure 4.2 the overpressure required for RHR envelopes that required for CS and the overpressure varies continuously over time. In order to facilitate reporting and presentation of the overpressure required, an enveloping, stepped, overpressure credit is overlaid on Figure 4.2. Refer to Section 4.0 for discussion on selection of overpressure credit.

Though the long term flow rates are postulated at time 600 seconds (e.g. CS throttled down from 4600gpm to 3500gpm), it is not the intent of this calculation to imply at what time throttling should commence or how much throttling is required. This is a function of the time dependent NPSHr and pool temperature. This calculation conservatively evaluates the maximum NPSHr as occurring over the entire operating period (>600 sec). The actual NPSHr is lower between 0-7 hrs and increases after 7 hrs.

Note that Section 4.4 develops required overpressure for both the CS and RHR pumps as a function of flow, temperature and NPSHr without any debris loading. Refer to Table 4.4 and Figures 4.4-1 to 4.4-4.

4.3 ATWS

Note that NPSH evaluation of the ATWS event was not previously addressed by calculation VYC-0808. The temperature and pressure (T/P) profile for the suppression pool during the ATWS events is developed in GE-Task Report T0902 (Ref: 5).

The evaluated events are MSIVC and PRFO with the peak temperatures and corresponding pressures tabulated by GE in Section 3.3.1.2 of the Task Report. Selected data points are extracted from the included T/P profile plots, Figures 3-10 and 3-12 of the Task Report, and are shown below. The two events have essentially the same temperature pressure profile. For convenience, these are combined into one enveloping event with maximum temperatures and minimum pressure at each time step.

MSIVC			PRFO			Combined		
Time, sec	Temp, °F	Press, psig	Time, sec	Temp, °F	Press, psig	Time, sec	Temp, °F	Press, psig
0	90	0	0	90	0	0	90	0
300	160	6.3	300	157	6.3	300	160	6.3
600	175	8.8	600	168	8.2	600	175	8.2
1000	182	11.2	1000	180	10.7	1000	182	10.7
1300	187	11.5	1300	187	11.8	1300	187	11.5
1724	189	12.3	1838	190	12.5	1838	190	12.3
3000	186	11.9	3000	187	12.1	3000	187	11.9
5000	182	11.2	5000	182	11.3	5000	182	11.2
6000	180	10.8	6000	180	11.0	6000	180	10.8
8000	175	10.0	8000	175	10.2	8000	175	10.0

As documented in T0902, Section 3.2.11 and 3.2.2.2, the suppression pool cooling is based on two loops of RHR operating and an initial pool volume of 68,000 cuft. Note that CS does not operate for ATWS events.

The evaluation of RHR pump NPSH is documented in Table 4.3 for the reduced NPSHr (0-7 hrs) The details of the evaluation are presented at the top of the Table followed by a matrix of the NPSH results for RHR. Further discussion of selected terms is presented below.

Since there are no data points available beyond 8000 seconds. Evaluation of intermediate NPSHr (7hrs – 20hrs) and maximum NPSHr (20hrs – 100hrs) are addressed individually below.

Flow rate – Q (gpm)
The RHR flow rate that was evaluated is not specified in T0902. The flow rates are assumed to be 7400 gpm for one RHR pump and 14,200 gpm for two RHR pumps. Refer to Assumption No. 1 of this CCN.

Evaluation will be performed for both 1 and 2 RHR pump operation.

Suction Elevation Head, Z
The suppression pool volume addressed in the GE report is 68,000 ft^3. As noted in Section 3.5 of Calc VYC-808 the relationship between suppression pool volume and level is documented in Table 4.3-1 of Calc VYC-1254 Rev 3 (Ref: 11). The suppression pool level corresponding to 68,000 ft^3 is 10.88'from VYC-1254.

This water level is 1.05' less than (11.93'-10.88') that used for calculating the RHR short term Z (12.30') in calc VYC-0808. Therefore the adjusted Z for the ATWS evaluation is 12.3'-1.05' = 11.25'.

Maximum Debris Losses (hd)
This term is not applicable for ATWS since there is no high-energy line break (HELB) to dislodge insulation and create debris in the suppression pool.

Minimum NPRHr - 1 RHR (<7hrs)
Refer to Section 4.1

Minimum NPRHr - 2 RHR (<7hrs)
Refer to Section 4.1

Intermediate NPRHr - 1 RHR (20 hrs)
Figure 2.1-1 of Attachment 3 to calculation VYC-0808 provides a plot of *Allowable Operating Periods @ NPSHa Specified* values for various flow rates. There is an intermediate peak at 20 hrs. This plot shows that at 7400 gpm the allowable NPSH increases between 7 and 20 hrs of operation and a value of 30.5 ft is acceptable at 20 hrs of operation.

Intermediate NPRHr - 2 RHR (20 hrs)
With two RHR pumps operating at a total flow of 14,200 gpm this yields a flow of 7100 gpm per pump.
Also per Figure 2.1-1, the plot shows that the allowable NPSH increases between 7 and 20 hours of operation. At 20 hrs of operation an allowable NPSH of 28.5 ft is acceptable at 7000 gpm and 31.6 ft is acceptable at 7600 gpm.

Interpolating between these NPSH values, at a flow of 7100 gpm, yields 29.0ft @ 7100 gpm

Maximum NPRHr - 1 RHR
Refer to Section 4.2

Maximum NPRHr - 2 RHR
With two RHR pumps operating at a total flow of 14,200 gpm this yields a flow of 7100 gpm per pump.
Also per Figure 2.1-1, the plot shows that an allowable NPSH of 29.5 ft @ 7000 gpm and 32.75 ft @ 7600 gpm is acceptable between 100 and 8000 hrs of operation.

Interpolating between these NPSH values, at a flow of 7100 gpm, yields 30.0 ft @ 7100 gpm.

4.3.1 Evaluation Minimum NPSHr (<7 hrs)

As can been seen from Table 4.3, the results for 2 RHR pump operation provide lower NPSHa than for 1 pump operation and overpressure is required from about 600 to 6000 seconds. An overpressure of 2.4 psig is required to accommodate the peak pool temperature of 190°F at 1828 seconds. A plot of the overpressure required is shown in Figure 4.3. Refer to Section 4.0 for discussion on selection of overpressure credit.

Note that for the same time period, this overpressure credit (2.4 psig) is bounded by that required for LOCA (2.4 to 4.4 psig).

4.3.2 Evaluation of Intermediate and Maximum NPSHr (>7 hrs)

As seen from Figures 3-10 and 3-12 of the Task Report and the data tabulated above, the temperature and pressure profiles decay linearly between 3000 – 8000 seconds at the rate of about 2.4°F and 0.4 psig per 1000 seconds. The available data ends at 8000 seconds (175°F/10.0psig). However the temperature will continue to decay though the rate of decay will decrease as the pool cools.

Included, as part of Table 4.3, is a tabulation of "NPSHa vs. decreasing pool temperature" for 1 and 2 RHR pump operation. Two pump operation is selected for detailed evaluation as it yields an NPSHa about 2.2' less than one pump operation. Since pool pressure has a negligible affect upon the specific volume of the water, pool pressure is taken as atmospheric.

<u>Intermediate NPSHr</u>
Between 7-20 hrs, the NPSHr for 2 RHR pump operation increases from 23.6' to 29.0'. Conservatively ignoring this ramp up, the NPSHr at 7 hrs (25,200 seconds) is taken as 29.0'. As can be inferred from Table 4.3 "NPSHa vs. decreasing pool temperature" the pool only needs to cool about 13°F to 162°F over 17,200 seconds, to achieve an adequate NPSHa of about 29.0' without crediting any overpressure. This equates to a cooldown rate of about 0.8°F/1000 seconds, which is much less than the exhibited cooldown rate between 3000-8000 seconds. (Note that if the 20 hour (72,000 sec) time is used, then the required cooldown rate becomes 13°F over 64,000 sec or about 0.2°F/1000 sec.)

In consideration of the conservative selection of NPSHr (@ 7 hrs) and the minimal cooldown rate required, there is adequate NPSHa without crediting overpressure.

Maximum NPSHr
Between 20-100 hrs, the NPSHr for 2 RHR pump operation increases from 29.0' to 30.0'. Conservatively ignoring this ramp up, the NPSHr at 20 hrs (72,000 seconds) is taken as 30.0'. As can be inferred from Table 4.3 "NPSHa vs. decreasing pool temperature" the pool only needs to cool about 4°F to 158°F between 7hrs and 20 hrs (46,800 seconds), to achieve an adequate NPSHa of about 30.0' without crediting any overpressure. This equates to a cooldown rate of about 0.1°F/1000 seconds.

In consideration of the conservative selection of NPSHr (@ 20 hrs) and the minimal cooldown rate required, there is adequate NPSHa without crediting overpressure.

Suppression Pool Cooldown Comparison to LOCA
The temperature profile for the suppression pool during a LOCA is developed in GE-VYNPS-AEP-177 (Ref: 1). The pool temperature rises until about 24,000 seconds (~7 hrs).

Shortly after peaking, there is essentially a uniform decrease in temperature between ~9hrs (194.1°F) and 30hrs (174.4°F) of about 0.2°F/1000 sec. Between ~30hrs (174.4°F) and the end of the tabulated data at ~48hrs (166.2°F), the uniform decrease in temperature is about 0.1°F/1000sec.

The required suppression pool cooldown rates, projected above for ATWS, are similar to the suppression pool cooldown rates developed for LOCA.

4.4 General Profile – Overpressure Required vs Pool Temperature

A wide temperature range is evaluated, up to 205°F, which is about 10°F more than the peak LOCA temperature addressed by GE-VYNPS-AEP-177 (Ref: 1).

The NPSH evaluation of general overpressure requirements for the RHR and CS pumps is documented in Table 4.4 for the minimum NPSHr (0-7 hours of operation) and maximum NPSHr (>7 hours of operation). The details of the evaluation are presented at the top of the Table followed by a matrix of the NPSH results. Further discussion of selected terms is presented below.

Flow rates – Q (gpm) - RHR
1 RHR: 7400 and 7000*gpm
2 RHR: 14,200 gpm (7100 gpm each) and 12,800 gpm (6400* gpm each)
* these values are conveniently selected, based upon the pump vendor's data, for the purpose of establishing a profile range.

Flow rates – Q (gpm) - CS
CS: 4600 gpm and 3500 gpm

Suction Elevation Head, Z

Based on a minimum suppression pool volume of 68,000 ft^3.

RHR: 11.25' as calculated in Section 4.3

CS: 11.42' based on the evaluation documented in Section 4.3 of this CCN and adjusting for the CS short term Z (12.47'). Therefore the adjusted Z is 12.47'-1.05' = 11.42'.

Clean Strainer Losses (hs)

Refer to Section 3.6 of VYC-0808 (Ref: 4)

1 RHR @ 7400 gpm = 0.33'

1 RHR @ 7000 gpm = 0.30' = 0.33*(Q/7400)^2**

2 RHR @ 14,200 gpm (7100 each) = 1.22'

2 RHR @ 12,800 gpm (6400 each) = 0.99' = 1.22*(Q/14200)^2**

** head loss at other than the reference flow rate is proportional to the square of the flow ratio

CS @ 4600 gpm = 0.51'

CS @ 3500 gpm = 0.29 = 0.38*(Q/4000)^2

Maximum Debris Losses (hd)

This term is not applicable since no high-energy line break (HELB) is postulated to dislodge insulation and create debris in the suppression pool.

Minimum NPRHr

1 RHR @ 7400 gpm = 23.8' Refer to Section 4.1

1 RHR @ 7000 gpm = 23.5' Refer to Section 4.1

2 RHR @ 7100 gpm (each) = 23.6' Refer to Section 4.1

2 RHR @ 6400 gpm (each) = 23.0' (see below)

Figure 2.1-1 of Attachment 3 to calculation VYC-0808 provides a plot of *Allowable Operating Periods @ NPSHa Specified* values for various flow rates. This plot shows that at 6400 gpm an allowable NPSH of 23.0 ft is acceptable for less than 7 hrs of operation.

CS @ 4600 gpm = 28.0' Refer to Section 4.1

CS @ 3500 gpm = 24.8' (see below)

Figure 2.2-1 of Attachment 3 to calculation VYC-0808 provides a plot of *Allowable Operating Periods @ NPSHa Specified* values for various flow rates. This plot shows that at 3500 gpm an allowable NPSH of 24.8 ft is acceptable for less than 7 hrs of operation.

Maximum NPRHr
1 RHR @ 7400 gpm = 31.7' Refer to Section 4.2
1 RHR @ 7000 gpm = 29.5' Refer to Section 4.3

2 RHR @ 7100 gpm (each) = 30.0' Refer to Section 4.3
2 RHR @ 6400 gpm (each) = 28.5' (see below)

Figure 2.1-1 of Attachment 3 to calculation VYC-0808 provides a plot of *Allowable Operating Periods @ NPSHa Specified* values for various flow rates. This plot shows that at 6400 gpm an allowable NPSH of 28.5 ft is acceptable at greater than 100 hrs of operation.

CS @ 4600 gpm = 35.0' (see below)
CS @ 3500 gpm = 29.6' Refer to Section 4.2

Figure 2.2-1 of Attachment 3 to calculation VYC-0808 provides a plot of *Allowable Operating Periods @ NPSHa Specified* values for various flow rates. This plot shows that at 4600 gpm an allowable NPSH of 35.0 ft is acceptable at greater than 100 hrs of operation.

5.0 Summary of Results

NPSHa is rounded to the nearest 0.1ft and OPR, OPC, and OPA are rounded to the nearest 0.1psig.

5.1 LOCA - Short Term (0-600 sec):

NPSHa is adequate for both CS and RHR pumps without crediting overpressure. NPSHa shown below is at the peak temperature.

Pump	Total flow, gpm	NPSHr, ft	NPSHa, ft
CS	4,600	28.0	28.4
1RHR	7,400	23.8	31.1
2 RHR	14,200	23.6	28.8

5.2 LOCA - Long Term (>600 sec):

NPSHa is adequate for both CS and RHR pumps with an overpressure credit that varies over time, as shown in Fig. 4.2. NPSHa, OPR, OPC, OPA are shown below, at the peak temperature

Pump	Total flow, gpm	NPSHr, ft	NPSHa, ft	OPR, psig	OPC, psig	OPA, psig
CS	3,500	29.6	19.5	4.2	6.1	8.1
1RHR	7,400	31.7	19.6	5.1	6.1	8.1

5.3 ATWS – (<7hrs):

NPSHa is adequate for RHR pumps with an overpressure credit of 2.4 psig required between 600-6000 seconds, as shown in Fig. 4.3. NPSHa, OPR, OPC, OPA are shown below, at the peak temperature.

Pump	Total flow, gpm	NPSHr, ft	NPSHa, ft	OPR, psig	OPC, psig	OPA, psig
1RHR	7,400	23.8	21.1	1.1	2.4	12.3
2RHR	14,200	23.6	18.9	2.0	2.4	12.3

Note that for the same time period, this overpressure credit (2.4 psig) is bounded by that required for LOCA Long Term (2.4 to 4.4 psig).

5.4 ATWS – (>7hrs):

NPSHa is adequate for the RHR pumps without crediting overpressure. This is due to the significant rate of reduction of the suppression pool temperature over time. The reduction in temperature, and associated vapor pressure, will more than offset increases in NPHr at extended operating times. Note that between 3000 –8000 seconds (the end of tabulated data provided by GE) the pool temperature decreases to 175°F, at the substantial uniform rate of about 2.4°F/1000sec. The increased NPSHr, at significant time intervals, is shown below along with the approximate pool temp, in parentheses, at or below which, over pressure credit is not required.

Pump	Total flow, gpm	0-7 hr NPSHr, ft	20 hr NPSHr, ft	>100 hr NPSHr, ft
1RHR	7,400	23.8	30.5 (164°F)	31.7 (160°F)
2RHR	14,200	23.6	29.0 (162 °F)	30.0 (158°F)

5.5 General Profile – Overpressure Required vs. Pool Temperature

General profiles of "Overpressure Required vs. Pool Temperature", for the scenarios listed below are provided in Figures 4.4-1 through 4.4-4. The profiles are intended to serve as the basis for determining overpressure requirements when performing RHR and CS pump NPSH evaluation for any other events, which cause elevated suppression pool temperatures, without strainer debris loading. A representative flow range is presented based on available vendor data for NPSH.

Profiles

Figure	Pumps operating	Flow range, gpm	NPSHr
4.4-1	1 RHR	7000-7400	Minimum (0-7 hrs of operation)
4.4-1	1 RHR	7000-7400	Maximum (>7 hrs of operation)
4.4-2	2 RHR	12,800-14,200	Minimum (0-7 hrs of operation)
4.4-2	2 RHR	12,800-14,200	Maximum (>7 hrs of operation)
4.4-3	1 CS	3500-4600	Minimum (0-7 hrs of operation)
4.4-4	1 CS	3500-4600	Maximum (>7 hrs of operation)

6.0 Conclusions

There is adequate NPSH available for operating the RHR and CS pumps at EPU conditions for the DBA-Loss of Coolant Accident (LOCA), short term, without crediting torus overpressure.

Torus overpressure must be credited for operating the RHR and CS pumps at EPU conditions for the following events in order to achieve adequate NPSH available:

- DBA-Loss of Coolant Accident (LOCA), long term
- Anticipated Transients Without Scram (ATWS)

The overpressure credit required for LOCA bounds that required for ATWS.

A basis for readily determining overpressure requirements, when performing RHR and CS pump NPSH evaluation for any other events which cause elevated suppression pool temperatures has provided in the form of a family of curves profiling overpressure required vs. pool temperature.

The results of this CCN will provide input to the PUSAR (Ref: 12) for the RHR and CS NPSH evaluation and will alter input to calculation VYC-1628 (Ref: 13) to address the need for crediting torus overpressure in the calculation of NPSH available. Note that calculation VYC-1628 may be superseded by GE EPU Analysis. The need for crediting torus overpressure in the RHR and CS NPSH evaluation, shall also be addressed in the SADBD (Ref: 14), UFSAR (Ref: 15), and system DBDs RHR (Ref: 16) and CS (Ref: 17).

Note that use of overpressure credit must be approved by the NRC as part of EPU.

No specific 50.59 Screening/Evaluation is required for this CCN since all EPU design changes and associated 50.59 documentation will be part of VYDC-2003-008.

Table 4.1
LOCA - Short term

LOCA - Short Term

NPSHa = (14.7-Pg)(144Vf)+Z-hf-hs-hd
OPR = (NPSHr – NPSHa)/(144*Vf)
OPA = Over pressure available
OPC = Over pressure credited

Cross references:
Section 2.3 of VYC-0808 Rev 6 (Ref: 4)
See Discussion in Section 4.0 of this CCN

Short Term Flow Rate (gpm)
1 RHR Q = 7400 CS Q = 4600 — Table of 1 calc VYC-0808 Rev 6 (Ref: 4)
2 RHR Q = 14200

Suction Line Losses (ft)
1 RHR hf = 4.77E-8*Q^2 CS hf = 2.5E-7*Q^2 — Section 3.7 of VYC-0808 Rev 6 (Ref: 4)
2 RHR hf = 7.84E-8*(Q/2)^2

Clean Strainer Losses (ft)
1 RHR hs = 0.33 CS hs = 0.51 — Section 3.6 of VYC-0808 Rev 6 (Ref: 4)
2 RHR hs = 1.22

Maximum Debris Losses (ft) @ >=base temperature — See discussion in Section 4.1 of this CCN
1 RHR hd = 0.33@173F CS hd = 0.32@173F — Ref: 2, 3, 4
2 RHR hd = 0.48@170F — Ref: 2, 4

Maximum Debris Losses (ft) @ < base temperature
1 RHR hd = .33*(173/T) CS hd = .32*(173/T) — See discussion in Section 2.0 of this CCN
2 RHR hd = .48*(170/T)
where T = suppression pool temperature, F

Elevation Head (ft)
RHR Z = 12.3 CS Z = 12.47 — See discussion in Section 4.1 of this CCN for conservatism.

NPSHr (ft)
1 RHR NPSHr = 23.8 CS NPSHr = 28.0 — See discussion in Section 4.1 of this CCN
2 RHR NPSHr = 23.6

Short Term (After EPU) - Peak Torus Temperature

Pump(s)	Time (sec)	GE Pool Temp (F)	GE Pool Pressure psia	Pg (psia)	Vf (ft^3/lb)	Z (ft)	hf (ft)	hs (ft)	hd (ft)	NPSHa (ft)	NPSHr (ft)	OPR (psig)	OPA (psig)	OPC (psig)
CS	600	165.1	17.75	5.349	0.016423	12.47	5.29	0.51	0.34	28.44	28.00	0.00	3.05	0.00
1 RHR	600	165.1	17.75	5.349	0.016423	12.30	2.61	0.33	0.35	31.12	23.80	0.00	3.05	0.00
2 RHR	600	165.1	17.75	5.349	0.016423	12.30	3.95	1.22	0.49	28.75	23.60	0.00	3.05	0.00

Table 4.2
LOCA - Long term

LOCA - Long Term

NPSHa = (14.7-Pg)(144Vf)+Z-hf-hs-hd
OPR = Over pressure required (NPSHr – NPSHa)/(144*Vf)
OPA = Over pressure available
OPC = Over pressure credited

Cross references:
Section 2.3 of VYC-0808 Rev 6 (Ref: 4)
See Discussion in Section 4.1 of this CCN

Long Term Flow Rate (gpm)				
1 RHR	Q = 7400	CS	Q = 3500	Table of 1 calc VYC-0808 Rev 6 (Ref: 4)
Suction Line Losses (ft)				
1 RHR	hf = 4.77E-8*Q^2	CS	hf = 2.5E-7*Q^2	Section 3.7 of VYC-0808 Rev 6 (Ref: 4)
Clean Strainer Losses (ft)				
1 RHR	hs = 0.33	CS	hs = .38*(Q/4000)^2 for Q<= 4000	Section 3.6 of VYC-0808 Rev 6 (Ref: 4)
Maximum Debris Losses (ft) @ >= 173F				
1 RHR	hd = 0.33	CS	hd = 0.21	See discussion in Section 4.2 of this CCN
Maximum Debris Losses (ft) @ < 181.7F				
1 RHR	hd = .33*(173/T)	CS	hd = .21*(173/T)	See discussion in Section 2.0 of this CCN
where T = suppression pool temperature, F				
Elevation Head (ft)				
RHR	Z = 12.4	CS	Z = 12.57	See discussion in Section 4.2 of this CCN for conservatism.
NPSHr (ft)				
1 RHR	NPSHr = 31.7	CS	NPSHr = 29.6	See discussion in Section 4.2 of this CCN

Table 4.2
LOCA - Long term

CS - Long Term (After EPU)

Time (sec)	GE Pool Temp (F)	GE Pool Pressure psia	Pg (psia)	Vf (ft^3/lb)	Z (ft)	hf (ft)	hs (ft)	hd (ft)	CS NPSHa (ft)	CS NPSHr (ft)	CS OPR (psig)	OPA (psig)	OPC (psig)
779	169.6	17.88	5.938	0.016448	12.57	3.06	0.29	0.21	29.76	29.60	0.00	3.18	2.40
1,400	173.6	18.34	6.506	0.016471	12.57	3.06	0.29	0.21	28.44	29.60	0.49	3.64	2.40
1,711	175.2	18.51	6.746	0.016481	12.57	3.06	0.29	0.21	27.88	29.60	0.72	3.81	2.40
2,022	176.6	18.72	6.962	0.016489	12.57	3.06	0.29	0.21	27.38	29.60	0.94	4.02	3.40
2,951	180.0	19.30	7.511	0.016509	12.57	3.06	0.29	0.21	26.10	29.60	1.47	4.60	3.40
3,876	182.6	19.90	7.955	0.016525	12.57	3.06	0.29	0.21	25.06	29.60	1.91	5.20	3.40
4,185	183.3	20.07	8.078	0.016529	12.57	3.06	0.29	0.21	24.77	29.60	2.03	5.37	4.40
5,109	185.1	20.51	8.402	0.016541	12.57	3.06	0.29	0.21	24.01	29.60	2.35	5.81	4.40
5,997	186.6	20.93	8.680	0.016550	12.57	3.06	0.29	0.21	23.35	29.60	2.62	6.23	4.40
7,121	188.1	21.42	8.966	0.016559	12.57	3.06	0.29	0.21	22.68	29.60	2.90	6.72	5.10
8,035	189.1	21.73	9.161	0.016566	12.57	3.06	0.29	0.21	22.22	29.60	3.09	7.03	5.10
8,970	190.0	21.92	9.340	0.016571	12.57	3.06	0.29	0.21	21.80	29.60	3.27	7.22	5.10
10,191	191.0	22.10	9.541	0.016578	12.57	3.06	0.29	0.21	21.32	29.60	3.47	7.40	6.10
12,040	192.1	22.31	9.767	0.016585	12.57	3.06	0.29	0.21	20.79	29.60	3.69	7.61	6.10
13,915	193.1	22.47	9.977	0.016591	12.57	3.06	0.29	0.21	20.29	29.60	3.90	7.77	6.10
16,375	194.0	22.63	10.168	0.016597	12.57	3.06	0.29	0.21	19.84	29.60	4.08	7.93	6.10
20,064	194.6	22.74	10.298	0.016601	12.57	3.06	0.29	0.21	19.53	29.60	4.21	8.04	6.10
24,094	194.7	22.77	10.320	0.016601	12.57	3.06	0.29	0.21	19.48	29.60	4.23	8.07	6.10
30,391	194.4	22.73	10.255	0.016599	12.57	3.06	0.29	0.21	19.63	29.60	4.17	8.03	6.10
40,033	192.5	22.36	9.851	0.016587	12.57	3.06	0.29	0.21	20.59	29.60	3.77	7.66	5.60
51,025	189.5	21.77	9.240	0.016568	12.57	3.06	0.29	0.21	22.03	29.60	3.17	7.07	5.10
61,023	186.7	21.29	8.699	0.016550	12.57	3.06	0.29	0.21	23.31	29.60	2.64	6.59	4.60
70,699	183.9	20.82	8.185	0.016533	12.57	3.06	0.29	0.21	24.52	29.60	2.13	6.12	4.10
80,699	181.3	20.40	7.730	0.016517	12.57	3.06	0.29	0.21	25.58	29.60	1.69	5.70	3.60
90,697	178.8	20.03	7.313	0.016502	12.57	3.06	0.29	0.21	26.56	29.60	1.28	5.33	3.10
100,697	176.4	19.68	6.931	0.016488	12.57	3.06	0.29	0.21	27.45	29.60	0.90	4.98	3.10
110,697	174.4	19.39	6.625	0.016476	12.57	3.06	0.29	0.21	28.16	29.60	0.60	4.69	2.60
120,697	172.9	19.14	6.404	0.016467	12.57	3.06	0.29	0.21	28.68	29.60	0.39	4.44	2.60
130,685	171.5	18.92	6.202	0.016459	12.57	3.06	0.29	0.21	29.15	29.60	0.19	4.22	2.10
140,685	170.2	18.72	6.020	0.016452	12.57	3.06	0.29	0.21	29.57	29.60	0.01	4.02	2.10
150,685	169.0	18.53	5.856	0.016445	12.57	3.06	0.29	0.21	29.95	29.60	0.00	3.83	1.70
160,685	167.7	18.35	5.683	0.016437	12.57	3.06	0.29	0.22	30.34	29.60	0.00	3.65	1.70
170,685	166.5	18.20	5.526	0.016431	12.57	3.06	0.29	0.22	30.70	29.60	0.00	3.50	1.30
172,800	166.2	18.16	5.488	0.016429	12.57	3.06	0.29	0.22	30.79	29.60	0.00	3.46	1.30

Table 4.2
LOCA - Long term

RHR - Long Term (After EPU)

Time (sec)	GE Pool Temp (F)	GE Pool Pressure psia	Pg (psia)	Vf (ft^3/lb)	Z (ft)	hf (ft)	hs (ft)	hd (ft)	RHR NPSHa (ft)	RHR NPSHr (ft)	RHR OPR (psig)	OPA (psig)	OPC (psig)
779	169.6	17.88	5.938	0.016448	12.40	2.61	0.33	0.34	29.87	31.70	0.77	3.18	2.40
1,400	173.6	18.34	6.506	0.016471	12.40	2.61	0.33	0.33	28.56	31.70	1.32	3.64	2.40
1,711	175.2	18.51	6.746	0.016481	12.40	2.61	0.33	0.33	28.00	31.70	1.56	3.81	2.40
2,022	176.6	18.72	6.962	0.016489	12.40	2.61	0.33	0.33	27.50	31.70	1.77	4.02	3.40
2,951	180.0	19.30	7.511	0.016509	12.40	2.61	0.33	0.33	26.22	31.70	2.31	4.60	3.40
3,876	182.6	19.90	7.955	0.016525	12.40	2.61	0.33	0.33	25.18	31.70	2.74	5.20	3.40
4,185	183.3	20.07	8.078	0.016529	12.40	2.61	0.33	0.33	24.89	31.70	2.86	5.37	4.40
5,109	185.1	20.51	8.402	0.016541	12.40	2.61	0.33	0.33	24.13	31.70	3.18	5.81	4.40
5,997	186.6	20.93	8.680	0.016550	12.40	2.61	0.33	0.33	23.47	31.70	3.45	6.23	4.40
7,121	188.1	21.42	8.966	0.016559	12.40	2.61	0.33	0.33	22.80	31.70	3.73	6.72	5.10
8,035	189.1	21.73	9.161	0.016566	12.40	2.61	0.33	0.33	22.34	31.70	3.92	7.03	5.10
8,970	190.0	21.92	9.340	0.016571	12.40	2.61	0.33	0.33	21.92	31.70	4.10	7.22	5.10
10,191	191.0	22.10	9.541	0.016578	12.40	2.61	0.33	0.33	21.44	31.70	4.30	7.40	6.10
12,040	192.1	22.31	9.767	0.016585	12.40	2.61	0.33	0.33	20.91	31.70	4.52	7.61	6.10
13,915	193.1	22.47	9.977	0.016591	12.40	2.61	0.33	0.33	20.41	31.70	4.72	7.77	6.10
16,375	194.0	22.63	10.168	0.016597	12.40	2.61	0.33	0.33	19.96	31.70	4.91	7.93	6.10
20,064	194.6	22.74	10.298	0.016601	12.40	2.61	0.33	0.33	19.65	31.70	5.04	8.04	6.10
24,094	194.7	22.77	10.320	0.016601	12.40	2.61	0.33	0.33	19.60	31.70	5.06	8.07	6.10
30,391	194.4	22.73	10.255	0.016599	12.40	2.61	0.33	0.33	19.75	31.70	5.00	8.03	6.10
40,033	192.5	22.36	9.851	0.016587	12.40	2.61	0.33	0.33	20.71	31.70	4.60	7.66	5.60
51,025	189.5	21.77	9.240	0.016568	12.40	2.61	0.33	0.33	22.15	31.70	4.00	7.07	5.10
61,023	186.7	21.29	8.699	0.016550	12.40	2.61	0.33	0.33	23.43	31.70	3.47	6.59	4.60
70,699	183.9	20.82	8.185	0.016533	12.40	2.61	0.33	0.33	24.64	31.70	2.97	6.12	4.10
80,699	181.3	20.40	7.730	0.016517	12.40	2.61	0.33	0.33	25.71	31.70	2.52	5.70	3.60
90,697	178.8	20.03	7.313	0.016502	12.40	2.61	0.33	0.33	26.68	31.70	2.11	5.33	3.10
100,697	176.4	19.68	6.931	0.016488	12.40	2.61	0.33	0.33	27.57	31.70	1.74	4.98	3.10
110,697	174.4	19.39	6.625	0.016476	12.40	2.61	0.33	0.33	28.29	31.70	1.44	4.69	2.60
120,697	172.9	19.14	6.404	0.016467	12.40	2.61	0.33	0.33	28.80	31.70	1.22	4.44	2.60
130,685	171.5	18.92	6.202	0.016459	12.40	2.61	0.33	0.33	29.27	31.70	1.03	4.22	2.10
140,685	170.2	18.72	6.020	0.016452	12.40	2.61	0.33	0.34	29.68	31.70	0.85	4.02	2.10
150,685	169.0	18.53	5.856	0.016445	12.40	2.61	0.33	0.34	30.06	31.70	0.69	3.83	1.70
160,685	167.7	18.35	5.683	0.016437	12.40	2.61	0.33	0.34	30.46	31.70	0.52	3.65	1.70
170,685	166.5	18.20	5.526	0.016431	12.40	2.61	0.33	0.34	30.82	31.70	0.37	3.50	1.30
172,800	166.2	18.16	5.488	0.016429	12.40	2.61	0.33	0.34	30.91	31.70	0.33	3.46	1.30

Table 4.3
ATWS

ATWS

NPSHa = (14.7-Pg)(144Vf)+Z-hf-hs-hd
OPR = (NPSHr – NPSHa)/(144*Vf)
OPA = Over pressure available
OPC = Over pressure credited
NPSHcm = NPSH credited margin (NPSHa+OPC(144*vf) -NPSHr)

Cross references:
Section 2.3 of VYC-0808 Rev 6 (Ref: 4)
See Discussion in Section 4.0 of this CCN

Flow Rate (gpm)

1 RHR	Q = 7400	2 RHR	Q = 14200	Table of 1 calc VYC-0808 Rev 6 (Ref: 4)

Suction Line Losses (ft)

1 RHR	hf = 4.77E-8*Q^2	2 RHR	hf = 7.84E-8*(Q/2)^2	Section 3.7 of VYC-0808 Rev 6 (Ref: 4)

Clean Strainer Losses (ft)

1 RHR	hs = 0.33	2 RHR	hs = 1.22	Section 3.6 of VYC-0808 Rev 6 (Ref: 4)

Maximum Debris Losses (ft)

1 RHR	hd = 0	2 RHR	hd = 0	See discussion in Section 4.3 of this CCN

Elevation Head (ft)

RHR	Z = 11.25	See discussion in Section 4.3 of this CCN

NPSHr (ft)

		0-7 hrs	>7 hrs	>20 hrs	
1 RHR	NPSHr =	23.8	30.5	31.7	See discussion in Section 4.3 of this CCN
2 RHR	NPSHr =	23.6	29.0	30.0	

Table 4.3
ATWS

Minimum NPSHr (0-7 hrs of operation)

Pump(s)	Time (sec)	GE Pool Temp (F)	GE Pool Pressure psia	Pg (psia)	Vf (ft^3/lb)	Z (ft)	hf (ft)	hs (ft)	hd (ft)	NPSHa (ft)	NPSHr (ft)	OPR (psig)	OPA (psig)	OPC (psig)
1 RHR	300	160.0	21.00	4.741	0.016394	11.25	2.61	0.33	0.00	31.82	23.80	-3.40	6.30	0.00
1 RHR	600	175.0	22.90	6.716	0.016479	11.25	2.61	0.33	0.00	27.25	23.80	-1.46	8.20	0.00
1 RHR	1,000	182.0	25.40	7.850	0.016521	11.25	2.61	0.33	0.00	24.60	23.80	-0.34	10.70	2.40
1 RHR	1,300	187.0	26.20	8.756	0.016552	11.25	2.61	0.33	0.00	22.48	23.80	0.56	11.50	2.40
1 RHR	1,838	190.0	27.00	9.340	0.016571	11.25	2.61	0.33	0.00	21.10	23.80	1.13	12.30	2.40
1 RHR	3,000	187.0	26.60	8.756	0.016552	11.25	2.61	0.33	0.00	22.48	23.80	0.56	11.90	2.40
1 RHR	5,000	182.0	25.90	7.850	0.016521	11.25	2.61	0.33	0.00	24.60	23.80	-0.34	11.20	2.40
1 RHR	6,000	180.0	25.50	7.511	0.016509	11.25	2.61	0.33	0.00	25.40	23.80	-0.67	10.80	0.00
1 RHR	8,000	175.0	24.70	6.716	0.016479	11.25	2.61	0.33	0.00	27.25	23.80	-1.46	10.00	0.00
2 RHR	300	160.0	21.00	4.741	0.016394	11.25	3.95	1.22	0.00	29.59	23.60	-2.54	6.30	0.00
2 RHR	600	175.0	22.90	6.716	0.016479	11.25	3.95	1.22	0.00	25.02	23.60	-0.60	8.20	2.40
2 RHR	1,000	182.0	25.40	7.850	0.016521	11.25	3.95	1.22	0.00	22.37	23.60	0.52	10.70	2.40
2 RHR	1,300	187.0	26.20	8.756	0.016552	11.25	3.95	1.22	0.00	20.25	23.60	1.41	11.50	2.40
2 RHR	1,838	190.0	27.00	9.340	0.016571	11.25	3.95	1.22	0.00	18.87	23.60	1.98	12.30	2.40
2 RHR	3,000	187.0	26.60	8.756	0.016552	11.25	3.95	1.22	0.00	20.25	23.60	1.41	11.90	2.40
2 RHR	5,000	182.0	25.90	7.850	0.016521	11.25	3.95	1.22	0.00	22.37	23.60	0.52	11.20	2.40
2 RHR	6,000	180.0	25.50	7.511	0.016509	11.25	3.95	1.22	0.00	23.17	23.60	0.18	10.80	2.40
2 RHR	8,000	175.0	24.70	6.716	0.016479	11.25	3.95	1.22	0.00	25.02	23.60	-0.60	10.00	0.00

NPSHa vs decreasing pool temperature

1 RHR		166.0	14.70	5.462	0.016428	11.25	2.61	0.33	0.00	30.16				
1 RHR		164.0	14.70	5.212	0.016417	11.25	2.61	0.33	0.00	30.74				
1 RHR		162.0	14.70	4.972	0.016406	11.25	2.61	0.33	0.00	31.29				
1 RHR		160.0	14.70	4.741	0.016395	11.25	2.61	0.33	0.00	31.82				
1 RHR		158.0	14.70	4.520	0.016384	11.25	2.61	0.33	0.00	32.33				
1 RHR		156.0	14.70	4.307	0.016373	11.25	2.61	0.33	0.00	32.81				
2 RHR		166.0	14.70	5.462	0.016428	11.25	3.95	1.22	0.00	27.93				
2 RHR		164.0	14.70	5.212	0.016417	11.25	3.95	1.22	0.00	28.51				
2 RHR		162.0	14.70	4.972	0.016406	11.25	3.95	1.22	0.00	29.06				
2 RHR		160.0	14.70	4.741	0.016395	11.25	3.95	1.22	0.00	29.59				
2 RHR		158.0	14.70	4.520	0.016384	11.25	3.95	1.22	0.00	30.10				
2 RHR		156.0	14.70	4.307	0.016373	11.25	3.95	1.22	0.00	30.58				

Table 4.4
General Profile - Overpressure vs Pool Temperature

General Profile – Overpressure Required vs Pool Temperature

NPSHa = (14.7-Pg)(144Vf)+Z-hf-hs-hd
OPR = (NPSHr – NPSHa)/(144*Vf)

Cross references:
Section 2.3 of VYC-0808 Rev 6 (Ref: 4)
See Discussion in Section 4.0 and 3.0 of this CCN

Flow Rate (gpm)

	1 RHR	2 RHR	CS
high Q	7400	14200	4600
low Q	7000	12800	3500

See discussion in Section 4.4 of this CCN

Suction Line Losses (ft)

	1 RHR	2 RHR	CS
hf =	4.77E-8*Q^2	7.84E-8*(Q/2)^2	2.5E-7*Q^2

Section 3.7 of VYC-0808 Rev 6 (Ref: 4)

Clean Strainer Losses (ft) @ flow rates tabulated above

	1 RHR	2 RHR	CS
(high Q) hs	0.33	1.22	0.51
(low Q) hs	.33*(Q/7400)^2	1.22*(Q/14200)^2	.38*(Q/4000)^2

See discussion in Section 4.4 of this CCN

Maximum Debris Losses (ft)

	1 RHR	2 RHR	CS
hd	0	0	0

See discussion in Section 4.4 of this CCN

Elevation Head (ft)

	RHR	CS
Z	11.25	11.42

See discussion in Section 4.4 of this CCN

Minimum NPSHr (ft) @ flow rates tabulated above

	1 RHR	2 RHR	CS
(High Q) NPSHr	23.8	23.6	28.0
(Low Q) NPSHr	23.5	23.0	24.8

See discussion in Section 4.4 of this CCN

Maximum NPSHr (ft) @ flow rates tabulated above

	1 RHR	2 RHR	CS
(High Q) NPSHr	31.7	30.0	35.0
(Low Q) NPSHr	29.5	28.5	29.6

See discussion in Section 4.4 of this CCN

Table 4.4
General Profile - Overpressure vs Pool Temperature

General Profile – Overpressure Required vs Pool Temperature **1 RHR @ Min NPSHr** **(0-7 hrs of operation)**

Pump(s)	Flow, Q (gpm)	Pool Temp (F)	Pool Pressure psia	Pg (psia)	Vf (ft^3/lb)	Z (ft)	hf (ft)	hs (ft)	hd (ft)	NPSHa (ft)	NPSHr (ft)	OPR (psig)
1RHR	7,400	175.0	14.70	6.716	0.016480	11.25	2.61	0.33	0.00	27.25	23.80	-1.46
1RHR	7,400	180.0	14.70	7.511	0.016510	11.25	2.61	0.33	0.00	25.40	23.80	-0.67
1RHR	7,400	185.0	14.70	8.384	0.016540	11.25	2.61	0.33	0.00	23.35	23.80	0.19
1RHR	7,400	190.0	14.70	9.340	0.016572	11.25	2.61	0.33	0.00	21.10	23.80	1.13
1RHR	7,400	195.0	14.70	10.385	0.016604	11.25	2.61	0.33	0.00	18.63	23.80	2.16
1RHR	7,400	200.0	14.70	11.526	0.016637	11.25	2.61	0.33	0.00	15.91	23.80	3.29
1RHR	7,400	205.0	14.70	12.770	0.016670	11.25	2.61	0.33	0.00	12.94	23.80	4.52
1RHR	7,000	175.0	14.70	6.716	0.016480	11.25	2.34	0.30	0.00	27.56	23.50	-1.71
1RHR	7,000	180.0	14.70	7.511	0.016510	11.25	2.34	0.30	0.00	25.70	23.50	-0.93
1RHR	7,000	185.0	14.70	8.384	0.016540	11.25	2.34	0.30	0.00	23.66	23.50	-0.07
1RHR	7,000	190.0	14.70	9.340	0.016572	11.25	2.34	0.30	0.00	21.40	23.50	0.88
1RHR	7,000	195.0	14.70	10.385	0.016604	11.25	2.34	0.30	0.00	18.93	23.50	1.91
1RHR	7,000	200.0	14.70	11.526	0.016637	11.25	2.34	0.30	0.00	16.22	23.50	3.04
1RHR	7,000	205.0	14.70	12.770	0.016670	11.25	2.34	0.30	0.00	13.25	23.50	4.27

Table 4.4
General Profile - Overpressure vs Pool Temperature

General Profile – Overpressure Required vs Pool Temperature 2 RHR @ Min NPSHr (0-7 hrs of operation)

Pump(s)	Flow, Q (gpm)	Pool Temp (F)	Pool Pressure psia	Pg (psia)	Vf (ft^3/lb)	Z (ft)	hf (ft)	hs (ft)	hd (ft)	NPSHa (ft)	NPSHr (ft)	OPR (psig)
2RHR	14,200	170.0	14.70	5.993	0.016451	11.25	3.95	1.22	0.00	26.70	23.60	-1.31
2RHR	14,200	175.0	14.70	6.716	0.016480	11.25	3.95	1.22	0.00	25.02	23.60	-0.60
2RHR	14,200	180.0	14.70	7.511	0.016510	11.25	3.95	1.22	0.00	23.17	23.60	0.18
2RHR	14,200	185.0	14.70	8.384	0.016540	11.25	3.95	1.22	0.00	21.12	23.60	1.04
2RHR	14,200	190.0	14.70	9.340	0.016572	11.25	3.95	1.22	0.00	18.87	23.60	1.98
2RHR	14,200	195.0	14.70	10.385	0.016604	11.25	3.95	1.22	0.00	16.39	23.60	3.01
2RHR	14,200	200.0	14.70	11.526	0.016637	11.25	3.95	1.22	0.00	13.68	23.60	4.14
2RHR	14,200	205.0	14.70	12.770	0.016670	11.25	3.95	1.22	0.00	10.71	23.60	5.37
2RHR	12,800	170.0	14.70	5.993	0.016451	11.25	3.21	0.99	0.00	27.68	23.00	-1.97
2RHR	12,800	175.0	14.70	6.716	0.016480	11.25	3.21	0.99	0.00	26.00	23.00	-1.26
2RHR	12,800	180.0	14.70	7.511	0.016510	11.25	3.21	0.99	0.00	24.14	23.00	-0.48
2RHR	12,800	185.0	14.70	8.384	0.016540	11.25	3.21	0.99	0.00	22.09	23.00	0.38
2RHR	12,800	190.0	14.70	9.340	0.016572	11.25	3.21	0.99	0.00	19.84	23.00	1.32
2RHR	12,800	195.0	14.70	10.385	0.016604	11.25	3.21	0.99	0.00	17.37	23.00	2.36
2RHR	12,800	200.0	14.70	11.526	0.016637	11.25	3.21	0.99	0.00	14.65	23.00	3.48
2RHR	12,800	205.0	14.70	12.770	0.016670	11.25	3.21	0.99	0.00	11.68	23.00	4.72

Table 4.4
General Profile - Overpressure vs Pool Temperature

General Profile – Overpressure Required vs Pool Temperature **CS Min NPSHr** **(0-7 hrs of operation)**

Pump(s)	Flow, Q (gpm)	Pool Temp (F)	Pool Pressure psia	Pg (psia)	Vf (ft^3/lb)	Z (ft)	hf (ft)	hs (ft)	hd (ft)	NPSHa (ft)	NPSHr (ft)	OPR (psig)
CS	4,600	155.0	14.70	4.204	0.016368	11.42	5.29	0.51	0.00	30.36	28.00	-1.00
CS	4,600	160.0	14.70	4.741	0.016395	11.42	5.29	0.51	0.00	29.13	28.00	-0.48
CS	4,600	165.0	14.70	5.336	0.016422	11.42	5.29	0.51	0.00	27.76	28.00	0.10
CS	4,600	170.0	14.70	5.993	0.016451	11.42	5.29	0.51	0.00	26.25	28.00	0.74
CS	4,600	175.0	14.70	6.716	0.016480	11.42	5.29	0.51	0.00	24.57	28.00	1.45
CS	4,600	180.0	14.70	7.511	0.016510	11.42	5.29	0.51	0.00	22.71	28.00	2.22
CS	4,600	185.0	14.70	8.384	0.016540	11.42	5.29	0.51	0.00	20.66	28.00	3.08
CS	4,600	190.0	14.70	9.340	0.016572	11.42	5.29	0.51	0.00	18.41	28.00	4.02
CS	4,600	195.0	14.70	10.385	0.016604	11.42	5.29	0.51	0.00	15.94	28.00	5.05
CS	4,600	200.0	14.70	11.526	0.016637	11.42	5.29	0.51	0.00	13.22	28.00	6.17
CS	4,600	205.0	14.70	12.770	0.016670	11.42	5.29	0.51	0.00	10.25	28.00	7.39
CS	3,500	155.0	14.70	4.204	0.016368	11.42	3.06	0.29	0.00	32.81	24.80	-3.40
CS	3,500	160.0	14.70	4.741	0.016395	11.42	3.06	0.29	0.00	31.58	24.80	-2.87
CS	3,500	165.0	14.70	5.336	0.016422	11.42	3.06	0.29	0.00	30.21	24.80	-2.29
CS	3,500	170.0	14.70	5.993	0.016451	11.42	3.06	0.29	0.00	28.69	24.80	-1.64
CS	3,500	175.0	14.70	6.716	0.016480	11.42	3.06	0.29	0.00	27.01	24.80	-0.93
CS	3,500	180.0	14.70	7.511	0.016510	11.42	3.06	0.29	0.00	25.16	24.80	-0.15
CS	3,500	185.0	14.70	8.384	0.016540	11.42	3.06	0.29	0.00	23.11	24.80	0.71
CS	3,500	190.0	14.70	9.340	0.016572	11.42	3.06	0.29	0.00	20.86	24.80	1.65
CS	3,500	195.0	14.70	10.385	0.016604	11.42	3.06	0.29	0.00	18.38	24.80	2.68
CS	3,500	200.0	14.70	11.526	0.016637	11.42	3.06	0.29	0.00	15.67	24.80	3.81
CS	3,500	205.0	14.70	12.770	0.016670	11.42	3.06	0.29	0.00	12.70	24.80	5.04

Table 4.4
General Profile - Overpressure vs Pool Temperature

General Profile – Overpressure Required vs Pool Temperature **1 RHR @ Max NPSHr** **(>7 hrs of operation)**

Pump(s)	Flow, Q (gpm)	Pool Temp (F)	Pool Pressure psia	Pg (psia)	Vf (ft^3/lb)	Z (ft)	hf (ft)	hs (ft)	hd (ft)	NPSHa (ft)	NPSHr (ft)	OPR (psig)
1RHR	7,400	155.0	14.70	4.204	0.016368	11.25	2.61	0.33	0.00	33.05	31.70	-0.57
1RHR	7,400	160.0	14.70	4.741	0.016395	11.25	2.61	0.33	0.00	31.82	31.70	-0.05
1RHR	7,400	165.0	14.70	5.336	0.016422	11.25	2.61	0.33	0.00	30.45	31.70	0.53
1RHR	7,400	170.0	14.70	5.993	0.016451	11.25	2.61	0.33	0.00	28.93	31.70	1.17
1RHR	7,400	175.0	14.70	6.716	0.016480	11.25	2.61	0.33	0.00	27.25	31.70	1.87
1RHR	7,400	180.0	14.70	7.511	0.016510	11.25	2.61	0.33	0.00	25.40	31.70	2.65
1RHR	7,400	185.0	14.70	8.384	0.016540	11.25	2.61	0.33	0.00	23.35	31.70	3.51
1RHR	7,400	190.0	14.70	9.340	0.016572	11.25	2.61	0.33	0.00	21.10	31.70	4.44
1RHR	7,400	195.0	14.70	10.385	0.016604	11.25	2.61	0.33	0.00	18.63	31.70	5.47
1RHR	7,400	200.0	14.70	11.526	0.016637	11.25	2.61	0.33	0.00	15.91	31.70	6.59
1RHR	7,400	205.0	14.70	12.770	0.016670	11.25	2.61	0.33	0.00	12.94	31.70	7.81
1RHR	7,000	155.0	14.70	4.204	0.016368	11.25	2.34	0.30	0.00	33.35	29.50	-1.63
1RHR	7,000	160.0	14.70	4.741	0.016395	11.25	2.34	0.30	0.00	32.12	29.50	-1.11
1RHR	7,000	165.0	14.70	5.336	0.016422	11.25	2.34	0.30	0.00	30.76	29.50	-0.53
1RHR	7,000	170.0	14.70	5.993	0.016451	11.25	2.34	0.30	0.00	29.24	29.50	0.11
1RHR	7,000	175.0	14.70	6.716	0.016480	11.25	2.34	0.30	0.00	27.56	29.50	0.82
1RHR	7,000	180.0	14.70	7.511	0.016510	11.25	2.34	0.30	0.00	25.70	29.50	1.60
1RHR	7,000	185.0	14.70	8.384	0.016540	11.25	2.34	0.30	0.00	23.66	29.50	2.45
1RHR	7,000	190.0	14.70	9.340	0.016572	11.25	2.34	0.30	0.00	21.40	29.50	3.39
1RHR	7,000	195.0	14.70	10.385	0.016604	11.25	2.34	0.30	0.00	18.93	29.50	4.42
1RHR	7,000	200.0	14.70	11.526	0.016637	11.25	2.34	0.30	0.00	16.22	29.50	5.54
1RHR	7,000	205.0	14.70	12.770	0.016670	11.25	2.34	0.30	0.00	13.25	29.50	6.77

Table 4.4
General Profile - Overpressure vs Pool Temperature

General Profile – Overpressure Required vs Pool Temperature **2 RHR @ Max NPSHr** **(>7 hrs of operation)**

Pump(s)	Flow, Q (gpm)	Pool Temp (F)	Pool Pressure psia	Pg (psia)	Vf (ft^3/lb)	Z (ft)	hf (ft)	hs (ft)	hd (ft)	NPSHa (ft)	NPSHr (ft)	OPR (psig)
2RHR	14,200	155.0	14.70	4.204	0.016368	11.25	3.95	1.22	0.00	30.82	30.00	-0.35
2RHR	14,200	160.0	14.70	4.741	0.016395	11.25	3.95	1.22	0.00	29.59	30.00	0.17
2RHR	14,200	165.0	14.70	5.336	0.016422	11.25	3.95	1.22	0.00	28.22	30.00	0.75
2RHR	14,200	170.0	14.70	5.993	0.016451	11.25	3.95	1.22	0.00	26.70	30.00	1.39
2RHR	14,200	175.0	14.70	6.716	0.016480	11.25	3.95	1.22	0.00	25.02	30.00	2.10
2RHR	14,200	180.0	14.70	7.511	0.016510	11.25	3.95	1.22	0.00	23.17	30.00	2.87
2RHR	14,200	185.0	14.70	8.384	0.016540	11.25	3.95	1.22	0.00	21.12	30.00	3.73
2RHR	14,200	190.0	14.70	9.340	0.016572	11.25	3.95	1.22	0.00	18.87	30.00	4.66
2RHR	14,200	195.0	14.70	10.385	0.016604	11.25	3.95	1.22	0.00	16.39	30.00	5.69
2RHR	14,200	200.0	14.70	11.526	0.016637	11.25	3.95	1.22	0.00	13.68	30.00	6.81
2RHR	14,200	205.0	14.70	12.770	0.016670	11.25	3.95	1.22	0.00	10.71	30.00	8.04
2RHR	12,800	155.0	14.70	4.204	0.016368	11.25	3.21	0.99	0.00	31.79	28.50	-1.39
2RHR	12,800	160.0	14.70	4.741	0.016395	11.25	3.21	0.99	0.00	30.56	28.50	-0.87
2RHR	12,800	165.0	14.70	5.336	0.016422	11.25	3.21	0.99	0.00	29.19	28.50	-0.29
2RHR	12,800	170.0	14.70	5.993	0.016451	11.25	3.21	0.99	0.00	27.68	28.50	0.35
2RHR	12,800	175.0	14.70	6.716	0.016480	11.25	3.21	0.99	0.00	26.00	28.50	1.06
2RHR	12,800	180.0	14.70	7.511	0.016510	11.25	3.21	0.99	0.00	24.14	28.50	1.83
2RHR	12,800	185.0	14.70	8.384	0.016540	11.25	3.21	0.99	0.00	22.09	28.50	2.69
2RHR	12,800	190.0	14.70	9.340	0.016572	11.25	3.21	0.99	0.00	19.84	28.50	3.63
2RHR	12,800	195.0	14.70	10.385	0.016604	11.25	3.21	0.99	0.00	17.37	28.50	4.66
2RHR	12,800	200.0	14.70	11.526	0.016637	11.25	3.21	0.99	0.00	14.65	28.50	5.78
2RHR	12,800	205.0	14.70	12.770	0.016670	11.25	3.21	0.99	0.00	11.68	28.50	7.01

Table 4.4
General Profile - Overpressure vs Pool Temperature

General Profile – Overpressure Required vs Pool Temperature **CS Max NPSHr** **(>7 hrs of operation)**

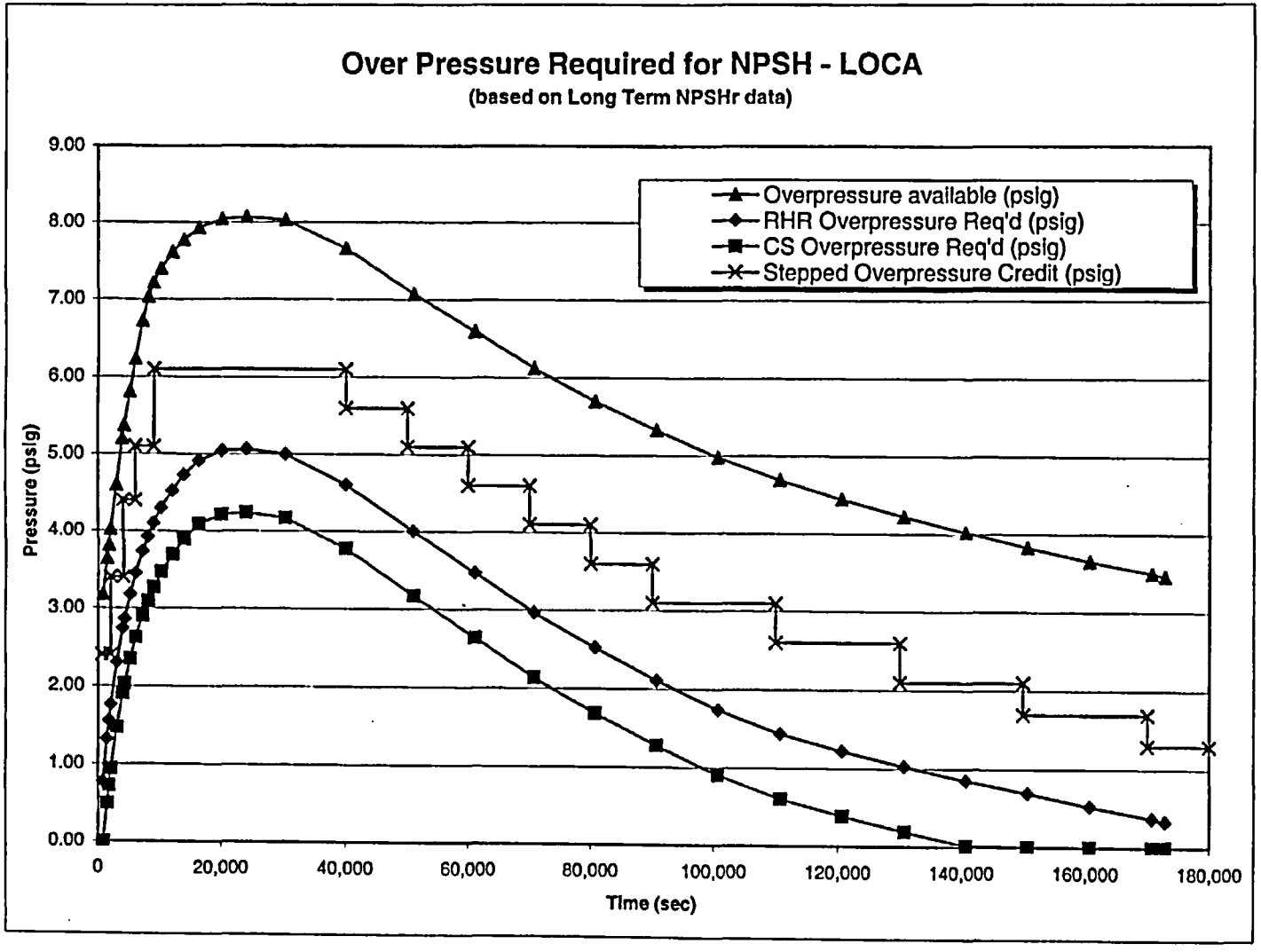
Pump(s)	Flow, Q (gpm)	Pool Temp (F)	Pool Pressure psia	Pg (psia)	Vf (ft^3/lb)	Z (ft)	hf (ft)	hs (ft)	hd (ft)	NPSHa (ft)	NPSHr (ft)	OPR (psig)
CS	4,600	125.0	14.70	1.942	0.016225	11.42	5.29	0.51	0.00	35.43	35.00	-0.18
CS	4,600	130.0	14.70	2.223	0.016246	11.42	5.29	0.51	0.00	34.81	35.00	0.08
CS	4,600	135.0	14.70	2.537	0.016269	11.42	5.29	0.51	0.00	34.11	35.00	0.38
CS	4,600	140.0	14.70	2.889	0.016293	11.42	5.29	0.51	0.00	33.33	35.00	0.71
CS	4,600	145.0	14.70	3.282	0.016317	11.42	5.29	0.51	0.00	32.45	35.00	1.09
CS	4,600	150.0	14.70	3.718	0.016342	11.42	5.29	0.51	0.00	31.46	35.00	1.50
CS	4,600	155.0	14.70	4.204	0.016368	11.42	5.29	0.51	0.00	30.36	35.00	1.97
CS	4,600	160.0	14.70	4.741	0.016395	11.42	5.29	0.51	0.00	29.13	35.00	2.49
CS	4,600	165.0	14.70	5.336	0.016422	11.42	5.29	0.51	0.00	27.76	35.00	3.06
CS	4,600	170.0	14.70	5.993	0.016451	11.42	5.29	0.51	0.00	26.25	35.00	3.70
CS	4,600	175.0	14.70	6.716	0.016480	11.42	5.29	0.51	0.00	24.57	35.00	4.40
CS	4,600	180.0	14.70	7.511	0.016510	11.42	5.29	0.51	0.00	22.71	35.00	5.17
CS	4,600	185.0	14.70	8.384	0.016540	11.42	5.29	0.51	0.00	20.66	35.00	6.02
CS	4,600	190.0	14.70	9.340	0.016572	11.42	5.29	0.51	0.00	18.41	35.00	6.95
CS	4,600	195.0	14.70	10.385	0.016604	11.42	5.29	0.51	0.00	15.94	35.00	7.97
CS	4,600	200.0	14.70	11.526	0.016637	11.42	5.29	0.51	0.00	13.22	35.00	9.09
CS	4,600	205.0	14.70	12.770	0.016670	11.42	5.29	0.51	0.00	10.25	35.00	10.31

Table 4.4
General Profile - Overpressure vs Pool Temperature

General Profile – Overpressure Required vs Pool Temperature **CS Max NPSHr** **(>7 hrs of operation)**

Pump(s)	Flow, Q (gpm)	Pool Temp (F)	Pool Pressure psia	Pg (psia)	Vf (ft^3/lb)	Z (ft)	hf (ft)	hs (ft)	hd (ft)	NPSHa (ft)	NPSHr (ft)	OPR (psig)
CS	3,500	125.0	14.70	1.942	0.016225	11.42	3.06	0.29	0.00	37.88	29.60	-3.54
CS	3,500	130.0	14.70	2.223	0.016246	11.42	3.06	0.29	0.00	37.26	29.60	-3.27
CS	3,500	135.0	14.70	2.537	0.016269	11.42	3.06	0.29	0.00	36.56	29.60	-2.97
CS	3,500	140.0	14.70	2.889	0.016293	11.42	3.06	0.29	0.00	35.78	29.60	-2.63
CS	3,500	145.0	14.70	3.282	0.016317	11.42	3.06	0.29	0.00	34.90	29.60	-2.25
CS	3,500	150.0	14.70	3.718	0.016342	11.42	3.06	0.29	0.00	33.91	29.60	-1.83
CS	3,500	155.0	14.70	4.204	0.016368	11.42	3.06	0.29	0.00	32.81	29.60	-1.36
CS	3,500	160.0	14.70	4.741	0.016395	11.42	3.06	0.29	0.00	31.58	29.60	-0.84
CS	3,500	165.0	14.70	5.336	0.016422	11.42	3.06	0.29	0.00	30.21	29.60	-0.26
CS	3,500	170.0	14.70	5.993	0.016451	11.42	3.06	0.29	0.00	28.69	29.60	0.38
CS	3,500	175.0	14.70	6.716	0.016480	11.42	3.06	0.29	0.00	27.01	29.60	1.09
CS	3,500	180.0	14.70	7.511	0.016510	11.42	3.06	0.29	0.00	25.16	29.60	1.87
CS	3,500	185.0	14.70	8.384	0.016540	11.42	3.06	0.29	0.00	23.11	29.60	2.72
CS	3,500	190.0	14.70	9.340	0.016572	11.42	3.06	0.29	0.00	20.86	29.60	3.66
CS	3,500	195.0	14.70	10.385	0.016604	11.42	3.06	0.29	0.00	18.38	29.60	4.69
CS	3,500	200.0	14.70	11.526	0.016637	11.42	3.06	0.29	0.00	15.67	29.60	5.81
CS	3,500	205.0	14.70	12.770	0.016670	11.42	3.06	0.29	0.00	12.70	29.60	7.04

Figure 4.2



OPC overpressure credit	
(sec)	(psig)
601	2.4
2000	2.4
2001	3.4
4000	3.4
4001	4.4
6000	4.4
6001	5.1
9000	5.1
9001	6.1
40000	6.1
40001	5.6
50000	5.6
50001	5.1
60000	5.1
60001	4.6
70000	4.6
70001	4.1
80000	4.1
80001	3.6
90000	3.6
90001	3.1
110000	3.1
110001	2.6
130000	2.6
130001	2.1
150000	2.1
150001	1.7
170000	1.7
170001	1.3
180000	1.3

Figure 4.3

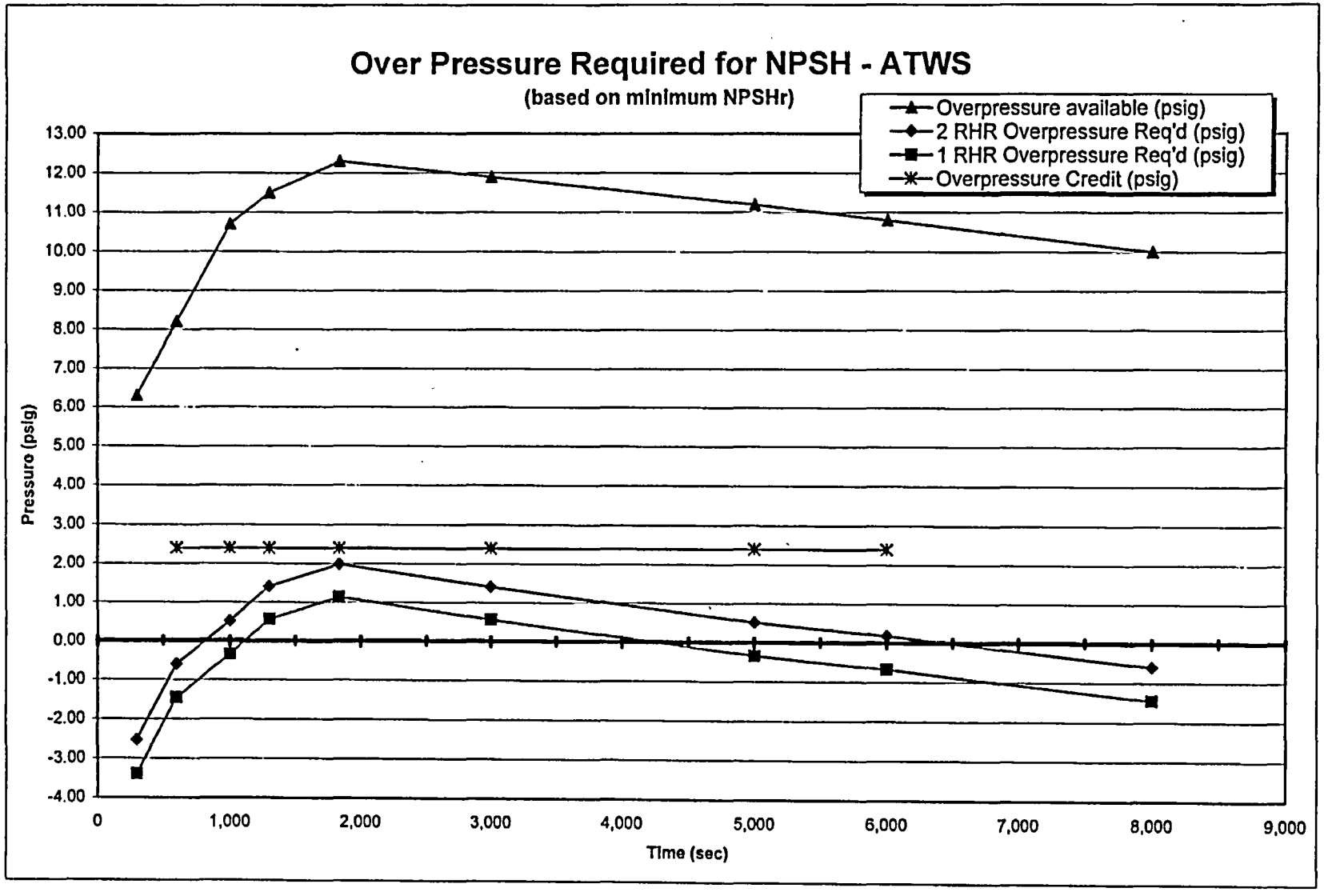

Over Pressure Required for NPSH - ATWS
(based on minimum NPSHr)
Overpressure available (psig)
2 RHR Overpressure Req'd (psig)
1 RHR Overpressure Req'd (psig)
Overpressure Credit (psig)
Pressure (psig)
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
Time (sec)

Figure 4.4-1

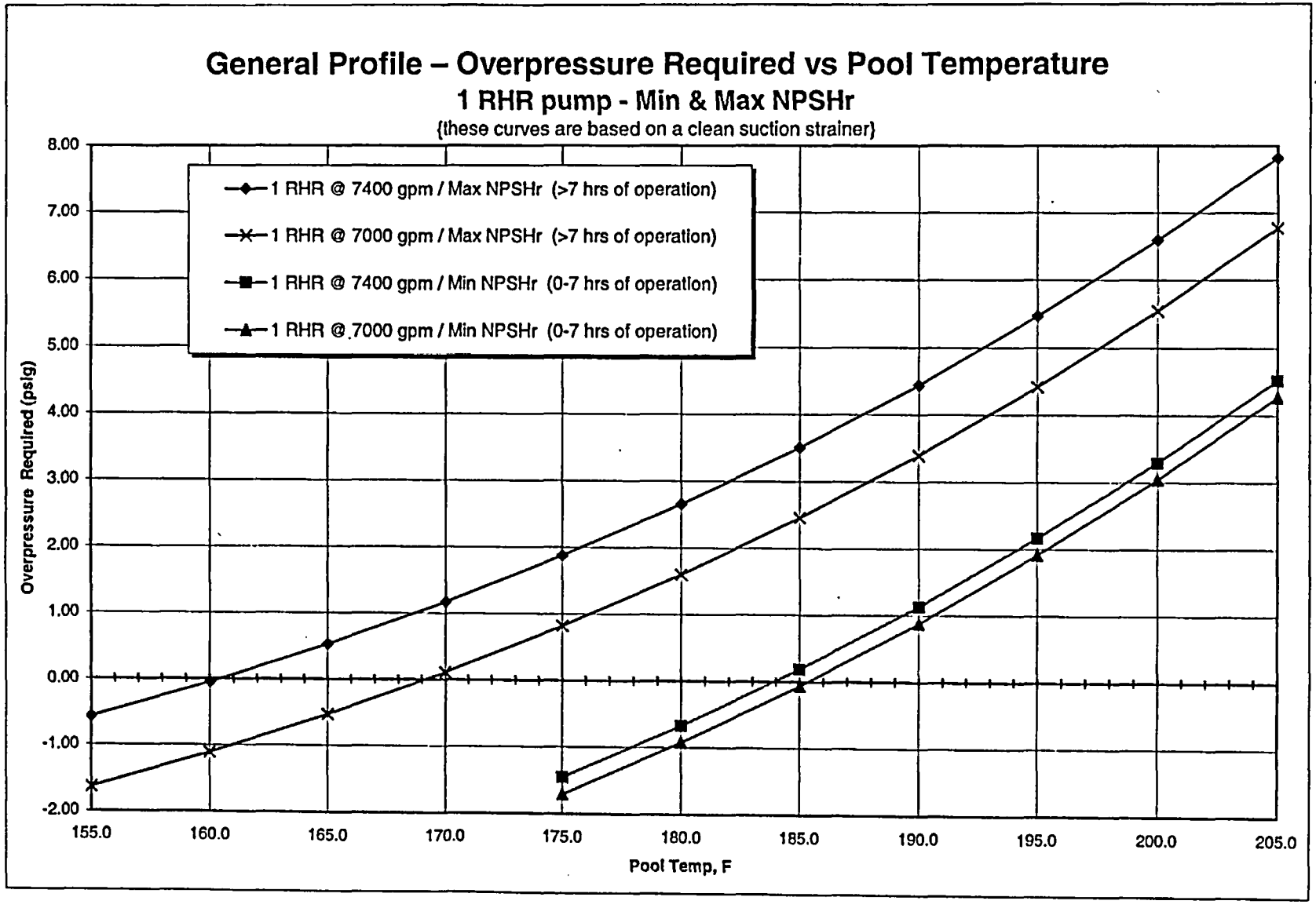

General Profile – Overpressure Required vs Pool Temperature
1 RHR pump - Min & Max NPSHr
(these curves are based on a clean suction strainer)
1 RHR @ 7400 gpm / Max NPSHr (>7 hrs of operation)
1 RHR @ 7000 gpm / Max NPSHr (>7 hrs of operation)
1 RHR @ 7400 gpm / Min NPSHr (0-7 hrs of operation)
1 RHR @ 7000 gpm / Min NPSHr (0-7 hrs of operation)
Overpressure Required (psig)
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
155.0
160.0
165.0
170.0
175.0
180.0
185.0
190.0
195.0
200.0
205.0
Pool Temp, F

Figure 4.4-2

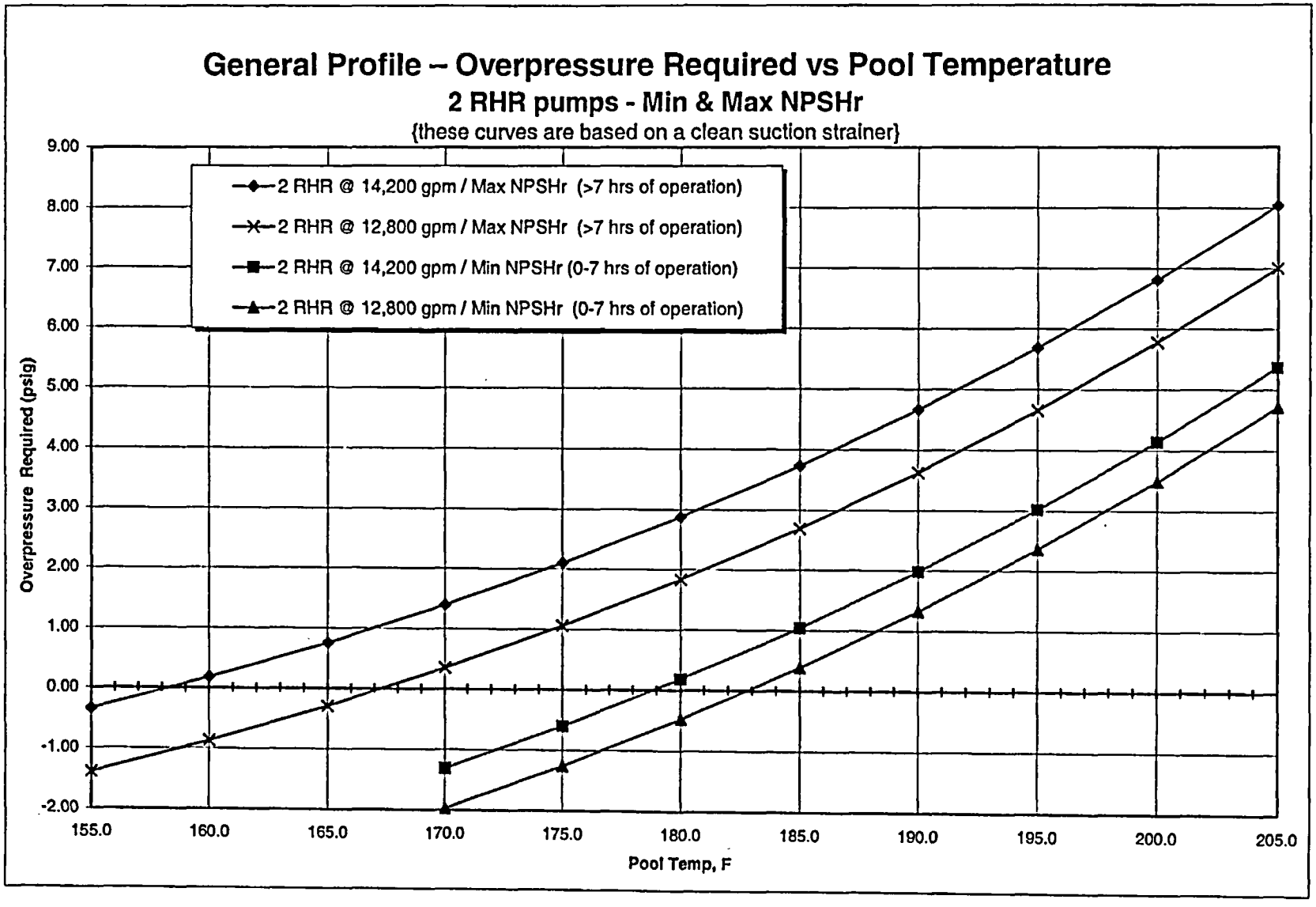

General Profile – Overpressure Required vs Pool Temperature
2 RHR pumps - Min & Max NPSHr
{these curves are based on a clean suction strainer}
2 RHR @ 14,200 gpm / Max NPSHr (>7 hrs of operation)
2 RHR @ 12,800 gpm / Max NPSHr (>7 hrs of operation)
2 RHR @ 14,200 gpm / Min NPSHr (0-7 hrs of operation)
2 RHR @ 12,800 gpm / Min NPSHr (0-7 hrs of operation)
Overpressure Required (psig)
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
155.0
160.0
165.0
170.0
175.0
180.0
185.0
190.0
195.0
200.0
205.0
Pool Temp, F

Figure 4.4-3

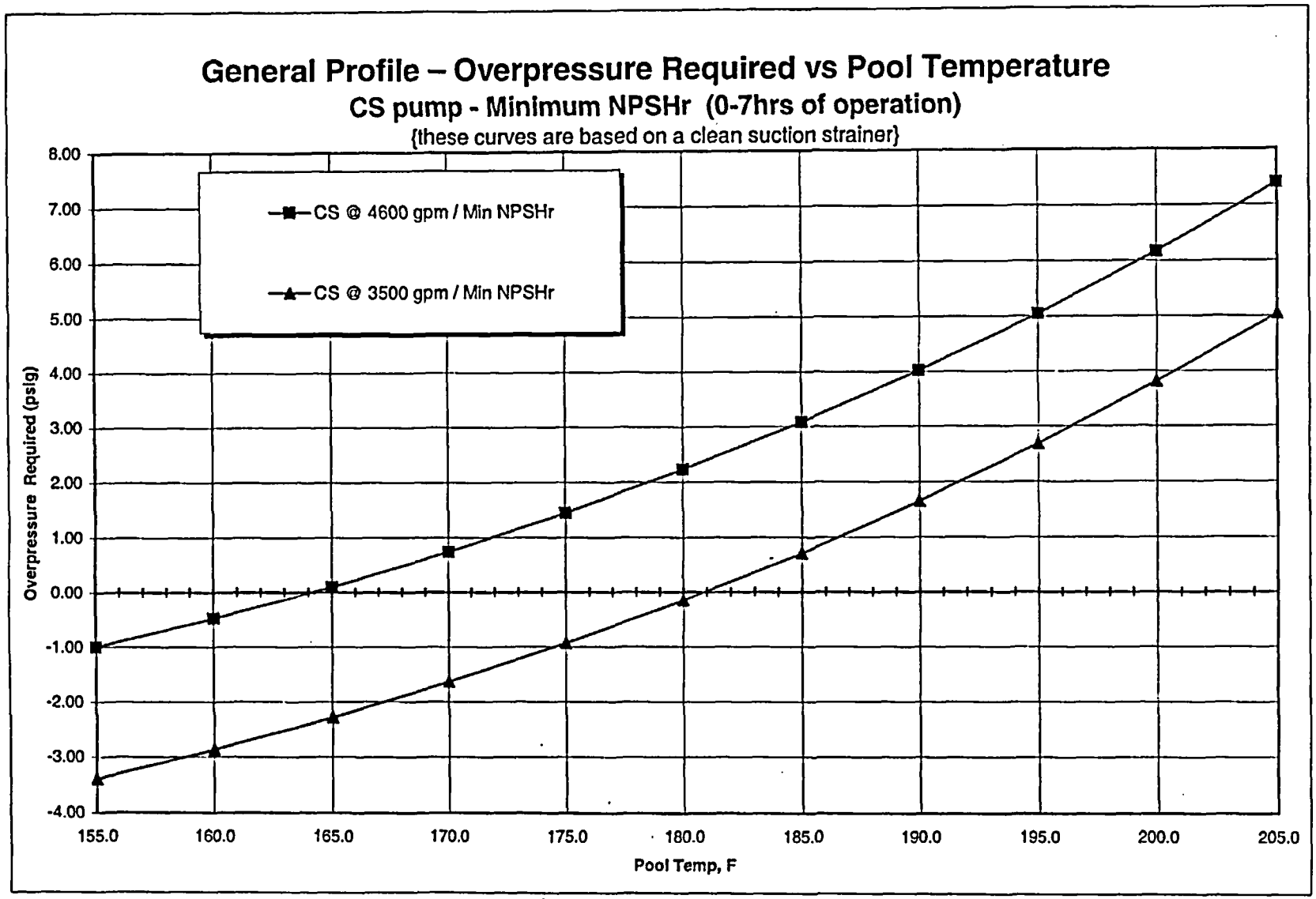
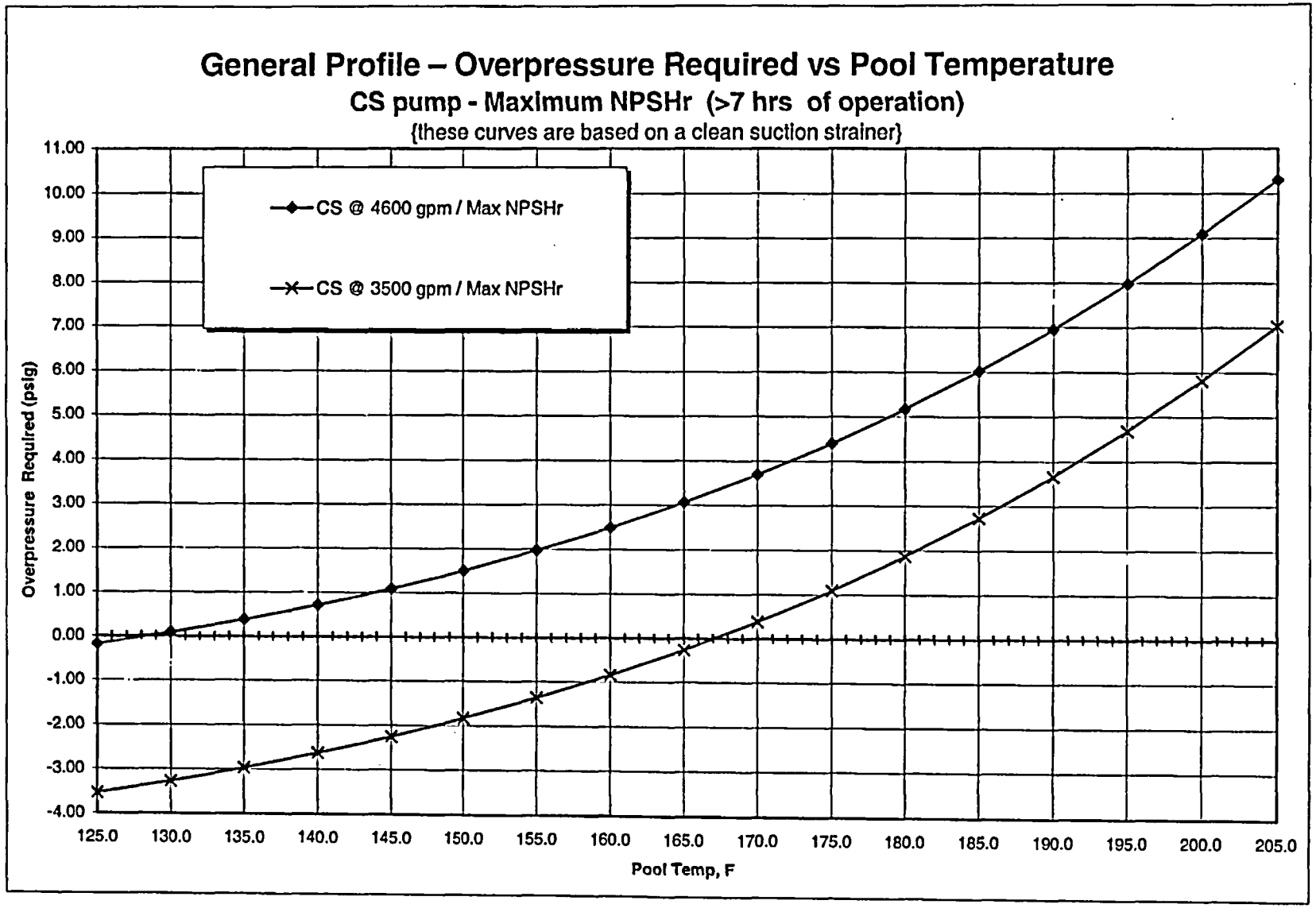

General Profile – Overpressure Required vs Pool Temperature
CS pump - Minimum NPSHr (0-7hrs of operation)
{these curves are based on a clean suction strainer}
CS @ 4600 gpm / Min NPSHr
CS @ 3500 gpm / Min NPSHr
Overpressure Required (psig)
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
155.0
160.0
165.0
170.0
175.0
180.0
185.0
190.0
195.0
200.0
205.0
Pool Temp, F

Figure 4.4-4


General Profile – Overpressure Required vs Pool Temperature
CS pump - Maximum NPSHr (>7 hrs of operation)
{these curves are based on a clean suction strainer}
CS @ 4600 gpm / Max NPSHr
CS @ 3500 gpm / Max NPSHr
Overpressure Required (psig)
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
125.0
130.0
135.0
140.0
145.0
150.0
155.0
160.0
165.0
170.0
175.0
180.0
185.0
190.0
195.0
200.0
205.0
Pool Temp, F

VY CALCULATION REVIEW FORM

Calculation Number: VYC-0808 Revision Number: 6 CCN Number: 4

Title: Core Spray and Residual Heat Removal Pump Net Positive Suction Head Margin Following a Loss of Coolant Accident or Anticipated Transients Without Scram

Reviewer Assigned: Edward Lind Required Date 8-12-03.

☐ Interdiscipline Review ☒ Independent Review

Comments*	Resolution
Section 2 –Identify that previous revisions and CCNs of Calculation VYC-0808 had not not taken credit for torus air space pressure.	Section 2: 2nd paragraph revised as requested.
Section 4- Revise text referencing Figure 2.1-1 and 2.1.2 of Attachment 3 to calculation VYC-0808 to state that figures provide a plot of *Allowable Operating Periods @ NPSHa Specified* values for various flow rates not *NPSHr*	Section 4.0, 4.1, 4.2, and 4.3 revised as requested.
Calculation Title – Since this calc now addresses ATWS, in addition to LOCA, revise title to reflect ATWS.	Title on cover page and Attachment A revised to add ATWS.

Edward Lind / 8-12-03		Frank Capuano / 8-12-03	
Reviewer Signature	Date	Calculation Preparer (Comments Resolved)	Date

Method of Review:
- ☒ Calculation/Analysis Review
- ☐ Alternative Calculation
- ☐ Qualification Testing

Edward Lind / 8-12-03	
Reviewer Signature (Comments Resolved)	Date

*Comments shall be specific, not general. Do not list questions or suggestions unless suggesting wording to ensure the correct interpretation of issues. Questions should be asked of the preparer directly.

DOCUMENTATION OF COMPUTER RESOURCE USE

CALCULATION NO.: VYC-0808 REVISION NO.: 6 CCN No.: 4

Computer Used (include manufacturer, CPU Type, and operating system version and level):

Not Applicable - See Below

Computer Input Attached*? ☐ Yes ☐ No

Location/Identifier:

Computer Output Attached*? ☐ Yes ☐ No

Location/Identifier:

* Large volume input/output should be provided on CD. See Appendix E for format requirements.

List the computer codes used, and complete the following:

	Approved per PP 7800		Appropriateness Verified		Outstanding SPRs or Code Errors[1]	
Code Name/Version and/or Script File	Yes[3]	No	Yes	No	Yes[2]	No
NONE Only Microsoft Office software used, Word 97 SR-2 and Excel 97 SR-2						

[1] Software Problem Report (SPR), does not exist as a reporting method in PP 7800 and AP 6030. Contact the Code sponsor and review any outstanding SPRs or Code errors. [ER2000805]
[2] If yes, fill out information below.
[3] If yes, include the Code name on the Computer Code line of the title page, VYAPF 0017.01.

If a computer code was not verified in accordance with PP 7800 and AP 6030, or if there are outstanding SPRs, state below why it is appropriate.

Code Name/Script File	Appropriateness

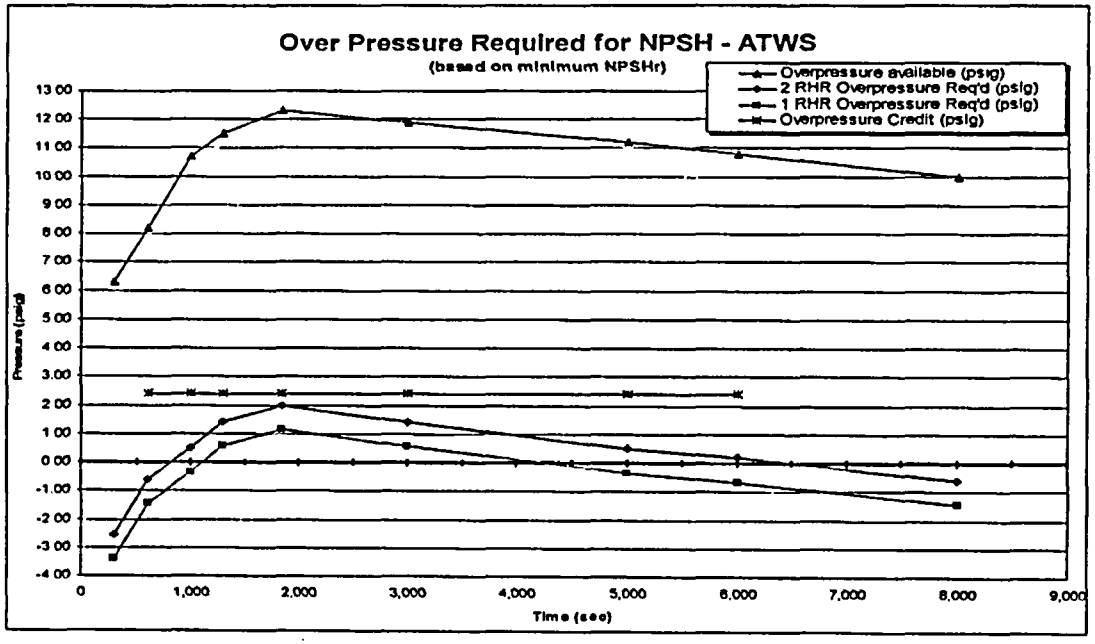
Comment No.	Task Number	Reviewer	Comment	Resolution	Disposition
1843	VYC-0808	Paul Rainey	CCN cover sheet, Conclusion, Add word "required" after words "The overpressure credit" after 2nd bullet.	"required" Incorporated on Cover sheet and in Section 6.0	Resolution accepted. B. Slifer 8/12/03
1844	VYC-0808	Paul Rainey	Section 2, p 8, typo next to last paragraph after Section.	Typo corrected: text revised to read *Section 2.4 of Calc ...* vs *Section .4 of Calc ....*	Resolution accepted. B. Slifer 8/12/03
1845	VYC-0808	Paul Rainey	Section 4, What is bases for determining OPC? Why isn't margin OPA-OPR?	Section 4.0: Added discussion about selection of OPC, excerpt follows: *OPC (psig)– Overpressure Credit Taken* *The overpressure credited in the evaluation of NPSH. Engineering judgement is used to select the credit to be greater than the OPR, by a reasonable amount, and less than the OPA.* While OPC-OPR is a simpler form of defining margin (NPSHcm), all discussion of NPSHcm is deleted throughout calc, as agreed on 8/7/03 tel-con discussion.	Resolution accepted. B. Slifer 8/12/03
1846	VYC-0808	Paul Rainey	Section 4.1, 2nd paragraph, discussion would lead you to believe that overpressure is required in short term. Add statement that overpressure is not required in short term.	Short Term Evaluation Section 4.1.1 concludes that overpressure is not required. The conclusion on the Cover sheet and Section 6.0 for Short Term LOCA is revised to state that overpressure is not required for the short term.	Resolution accepted. B. Slifer 8/12/03
1847	VYC-0808	Paul Rainey	Section 4.3, governing analysis should be based on 1 RHR pump in each loop. Plant doesn't run 2 RHR pumps in 1 loop while in torus cooling. NPSH required should be 23.8 ft since analysis is only run for 8000 seconds. With 1 pump per loop OPR is less than 2.4 psig.	As agreed to by tel-con on 8/7/03, analysis of two RHR pumps is maintained in the calculation for conservatism. However, Figure 4.3 is revised to add the 1 RHR pump OPR. This then clearly shows that there is additional NPSH margin for one pump operation. See excerpt of Fig 4.3 below. Since selection of OPC is somewhat arbitrary, see response to comment 1845, use of an OPC of 2.4 is appropriate. It is consistent with the limit used for LOCA (up to 2000 seconds) while enveloping for both 1 RHR and 2RHR pump operation.	Resolution accepted. B. Slifer 8/12/03

1848	VYC-0808	Paul Rainey	Section 5.3 and 5.4, revise per comment 1847.	Section 5.3 (<7hrs) revised to address NPSHa, OPR, OPC, and OPA for both 1 RHR and 2 RHR pumps. See excerpt of Section 5.3 below. Section 5.4 (>7hrs) revised to address both 1RHR and 2RHR pump operation, citing NPSHr at pertinent time increments and discussing the impact of the substantial rate of decrease of the pool temperature. See excerpt of Section 5.4 below.	Resolution accepted. B. Slifer 8/12/03
1849	VYC-0808	Paul Rainey	Section 5.5, add words "without strainer debris loading" to end of next to last sentence.	Incorporated words into Section 5.5 and Section 2.0. Excerpt follows: *The profiles are intended to serve as the basis for determining overpressure requirements when performing RHR and CS pump NPSH evaluation for any other events, which cause elevated suppression pool temperatures,* ***without strainer debris loading.***	Resolution accepted. B. Slifer 8/12/03
1850	VYC-0808	Paul Rainey	General comment, unless you're familiar with calc details the impression is left that you need to cut back flow at 10 minutes which is not the case. It would be helpful to state when we actually need to cut back flow for the various cases.	Section 4.2 revised to address flow rates evaluated. Section 4.2.1 revised to discuss throttling and reference generic profiles from Section 4.4. See excerpts of Section 4.2 and 4.2.1 below.	Resolution accepted. B. Slifer 8/12/03
1851	VYC-0808	Paul Rainey	Table 4.3 , see comment 1847.	1 RHR pump is added to Table 4.3 "NPSHa vs decreasing pool temperature". Refer to response to comments 1847 and 1848	Resolution accepted. B. Slifer 8/12/03
1852	VYC-0808	Paul Rainey	Fig. 4.2, per Bruce Slifer comment remove OPC graph and table.	As agreed to by tel-con on 8/7/03, OPC is maintained in Fig 4.2, however it is revised to be approximately midway between OPA and OPR, where practical. See excerpt of Fig 4.2 below.	Resolution accepted. B. Slifer 8/12/03
1853	VYC-0808	Paul Rainey	Fig. 4.3, base on 1 RHR pump per loop.	Refer to response to comment 1847.	Resolution accepted. B. Slifer 8/12/03

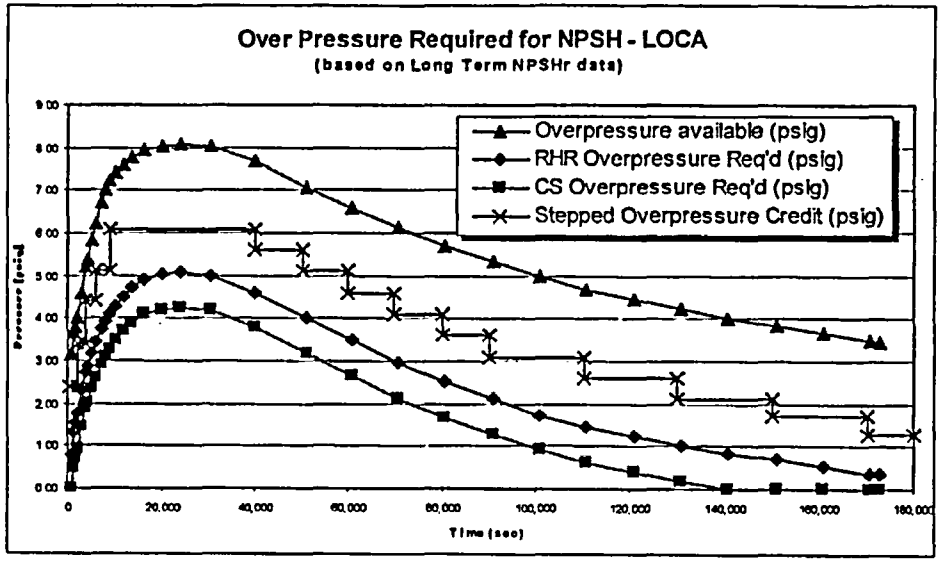
1857	VYC-0808	Bruce Slifer	Page 8, the debris head loss from CCN03 is used in lieu of the values from Rev. 6. CCN03 was an assessment of increased sludge. The calculated head loss was less than the head loss due to debris assumed in Rev. 6. The intent of CCN03 was not to replace the debris head loss in Rev. 6. This is considered margin that VY may want to reserve for input to maintenance decisions regarding torus cleaning intervals.	Revised to use conservative debris loading from Rev 6, in lieu of loading from CCN#3 CS long term (hd) @ 3500gpm changed to 0.21' RHR one pump (hd) changed to 0.33' Sections 2.0, 4.1, 4.2, Tables 4.1 and 4.2, and Fig 4.2 revised accordingly. See excerpt from Section 2.0 below.	Resolution accepted. B. Slifer 8/12/03
1858	VYC-0808	Bruce Slifer	Page 9, the draft ATWS report is listed as an open item. This task report is now final.	Final Task Report T0902 is referenced in lieu of Draft Task Report. All related Open items and Assumptions removed. Reference 5 updated, Assumption # 2 of Section 3.0 removed, Open Item List removed and TOC revised, Section 4.3 revised accordingly.	Resolution accepted. B. Slifer 8/12/03
1859	VYC-0808	Bruce Slifer	Page 10, the basis for determining Overpressure Credit Taken needs more discussion.	See response to comment 1845.	Resolution accepted. B. Slifer 8/12/03
1860	VYC-0808	Bruce Slifer	Page 11, as noted in comment 1857, the design values for debris losses should not be changed, i.e. use 0.33 ft for 1 RHR and 0.21 ft for CS at 3500 gpm.	See response to comment 1857.	Resolution accepted. B. Slifer 8/12/03
1861	VYC-0808	Bruce Slifer	Page 13, Section 4.2.1, as noted in item 3, need more discussion on basis for determining overpressure credit.	Section 4.2.1 is revised to refer to discussion in Section 4.0 for discussion of OPC. See response to comment 1845 above.	Resolution accepted. B. Slifer 8/12/03
1862	VYC-0808	Bruce Slifer	Page 13, Section 4.3, final task report for ATWS is available, revise section accordingly.	See response to comment 1858.	Resolution accepted. B. Slifer 8/12/03
1863	VYC-0808	Bruce Slifer	Page 15, Section 4.3.1, explain basis for choosing 2.4 psig for ovepressure credit.	Section 4.3.1 is revised to refer to discussion in Section 4.0 for discussion of OPC. See response to comment 1845 above. Basis for 2.4 psig credit is discussed in response to comment 1847 above.	Resolution accepted. B. Slifer 8/12/03

1864	VYC-0808	Bruce Slifer	Page 16, Section 4.3.2, compare the assumptions made about cooldown rates between 7 and 20 hours, and 20 and 100 hours, to the LOCA analysis results. The cooldown rates should be similar.	Section 4.3.2 revised to add LOCA comparison. See excerpt below.	Resolution accepted. B. Slifer 8/12/03
1865	VYC-0808	Bruce Slifer	Page 19, Section 5.0, show COP available, required, and credited in addition to NPSHr and NPSHcm. (NPSHcm is difficult to understand. Is this standard for plants crediting COP?)	As agreed to by tel-con on 8/07/03, NPSHcm is deleted throughout calc. NPSHa, OPA, OPR, OPC added to Sections 5.2 and 5.3. See excerpt of Section 5.2 below. Excerpt of Section 5.3 is provided below, in response to Comment 1848. Excerpt of Section 5.4 is provided below in response to Comment 1848. (OPA, OPR, OPC not applicable to this Section)	Resolution accepted. B. Slifer 8/12/03
1866	VYC-0808	Bruce Slifer	Page 20, Section 5.5, should not have 4 different Figure 4s. Either list sequentially, or use 4.4.1, 4.4.2, etc.	Figures are renumbered 4.4-1 thru 4.4-4	Resolution accepted. B. Slifer 8/12/03
1867	VYC-0808	Bruce Slifer	Page 20, Section 6.0, VYC-1628 is superceded by the GE analysis, therefore revise section accordingly.	As agreed to by tel-con on 8/7/03, existing notation that VYC-1628 may be superseded by GE EPU Analysis is adequate. No change required.	Resolution accepted. B. Slifer 8/12/03
1868	VYC-0808	Bruce Slifer	Page 20, provide source of reference to VYDC-2003-008.	As confirmed by email dated 811/03, YYDC-2003-008 is correct. No change required.	Resolution accepted. B. Slifer 8/12/03

EXCERPTS FROM CCN #4 of VYC-0808 REFLECTING COMMENT INCORPORATION

Comment #	CCN Section	Excerpt
1847	Fig 4.3	
1848	5.3	**ATWS (<7hrs)** NPSHa is adequate for RHR pumps with an overpressure credit of 2.4 psig required between 600-6000 seconds, as shown in Fig. 4.3. NPSHa, OPR, OPC, OPA are shown below, at the peak temperature. Pump / Total flow, gpm / NPSHr, ft / NPSHa, ft / OPR, psig / OPC, psig / OPA, psig 1RHR / 7,400 / 23.8 / 21.1 / 1.1 / 2.4 / 12.3 2RHR / 14,200 / 23.6 / 18.9 / 2.0 / 2.4 / 12.3 Note that for the same time period, this overpressure credit (2.4 psig) is bounded by that required for LOCA Long Term (2.4 to 4.4 psig).

1848	5.4	**ATWS (>7hrs)** NPSHa is adequate for the RHR pumps without crediting overpressure. This is due to the significant rate of reduction of the suppression pool temperature over time. The reduction in temperature, and associated vapor pressure, will more than offset increases in NPHr at extended operating times. Note that between 3000-8000 seconds (the end of tabulated data provided by GE) the pool temperature decreases to 175F, at the substantial uniform rate of about 2.4F/1000sec. The increased NPSHr, at significant time intervals, is shown below along with the approximate pool temp, in parentheses, at or below which, over pressure credit is not required. Pump / Total flow, gpm / 0-7 hr NPSHr, ft / 20 hr NPSHr, ft / >100 hr NPSHr, ft 1RHR / 7,400 / 23.8 / 30.5 (164F) / 31.7 (160F) 2RHR / 14,200 / 23.6 / 29.0 (162F) / 30.0 (158F)
1850	4.2	**LOCA - Long Term** The evaluation of NPSH is documented in Table 4.2 using a selected T/P points representing the long term profile of the suppression pool. The details of the evaluation are presented at the top of the Table followed by a matrix of the NPSH results for the T/P profile of CS and RHR. **The evaluated long term flow rates of 7400 gpm (RHR) and 3500 gpm (CS) are consistent with calculation VYC-0808 Rev 6 (Ref: 4).**
1850	4.2.1	**Evaluation** As can been seen from Figure 4.2 the overpressure required for RHR envelopes that required for CS and the overpressure varies continuously over time. In order to facilitate reporting and presentation of the overpressure required, an enveloping, stepped, overpressure credit is overlaid on Figure 4.2. **Refer to Section 4.0 for discussion on selection of overpressure credit.** **Though the long term flow rates are postulated at time 600 seconds (e.g. CS throttled down from 4600gpm to 3500gpm), it is not the intent of this calculation to imply at what time throttling should commence or how much throttling is required. This is a function of the time dependent NPSHr and pool temperature. This calculation conservatively evaluates the maximum NPSHr as occurring over the entire operating period (>600 sec). The actual NPSHr is lower between 0-7 hrs and increases after 7 hrs.** **Note that Section 4.4 develops required overpressure for both the CS and RHR pumps as a function of flow, temperature and NPSHr without any debris loading. Refer to Table 4.4 and Figures 4.4-1 to 4.4-4.**

1852	Fig 4.2	
1857	2.0	**<u>Pump Suction Strainer Head Loss during a LOCA</u>** As documented in ERC No. 2003-027 (Ref: 8), EPU does not affect the debris source terms developed in VYC-1677. Therefore the limiting head loss due to debris loading on the RHR and CS suction strainers remains the same as addressed in VYC-0808 Rev 6 including CCN #3 (Ref: 3). CCN #3 dispositions the up-to-date suction strainer head loss calculated in CCN #2 of VYC-1924 Rev 0 (Ref: 10) which in turn is based on the up-to-date debris source term information per VYC-1677 Rev 0 CCN #3. **Note that the debris loading from calc VYC-0808 Rev 6, as extracted from calc VYC-1924 Rev 0 (Ref: 2), is slightly larger than that documented in CCN #3. For conservatism, the larger debris loading is used.**

1864	4.3.2	Intermediate NPSHr Between 7-20 hrs, the NPSHr for 2 RHR pump operation increases from 23.6' to 29.0'. Conservatively ignoring this ramp up, the NPSHr at 7 hrs (25,200 seconds) is taken as 29.0'. As can be inferred from Table 4.3 "NPSHa vs. decreasing pool temperature" the pool only needs to cool about 13F to 162F over 17,200 seconds, to achieve an adequate NPSHa of about 29.0' without crediting any overpressure. This equates to a cooldown rate of about 0.8F/1000 seconds, **which is much less than the exhibited cooldown rate between 3000-8000 seconds.** **(Note that if the 20 hour (72,000 sec) time is used, then the required cooldown rate becomes 13F over 64,000 sec or about 0.2F/1000 sec.)** In consideration of the conservative selection of NPSHr (@ 7 hrs) and the minimal cooldown rate required, there is adequate NPSHa without crediting overpressure. Maximum NPSHr Between 20-100 hrs, the NPSHr for 2 RHR pump operation increases from 29.0' to 30.0'. Conservatively ignoring this ramp up, the NPSHr at 20 hrs (72,000 seconds) is taken as 30.0'. As can be inferred from Table 4.3 "NPSHa vs. decreasing pool temperature" the pool only needs to cool about 4F to 158F between 7hrs and 20 hrs (46,800 seconds), to achieve an adequate NPSHa of about 30.0' without crediting any overpressure. This equates to a cooldown rate of about 0.1F/1000 seconds. **Suppression Pool Cooldown Comparison to LOCA** **The temperature profile for the suppression pool during a LOCA is developed in GE-VYNPS-AEP-177 (Ref: 1). The pool temperature rises until about 24,000 seconds (~7 hrs). Shortly after peaking, there is essentially a uniform decrease in temperature between ~9hrs (194.1F) and 30hrs (174.4F) of about 0.2F/1000 sec. Between ~30hrs (174.4F) and the end of the tabulated data at ~48hrs (166.2F), the uniform decrease in temperature is about 0.1F/1000sec. The required suppression pool cooldown rates, projected above for ATWS, are similar to the suppression pool cooldown rates developed for LOCA.**
1865	5.2	**LOCA - Long Term (>600 sec):** NPSHa is adequate for both CS and RHR pumps with an overpressure credit that varies over time, as shown in Fig. 4.2. NPSHa, OPR, OPC, OPA are shown below, at the peak temperature Pump / Total flow, gpm / NPSHr, ft / NPSHa, ft / OPR, psig / OPC, psig / OPA, psig CS / 3,500 / 29.6 / 19.5 / 4.2 / 6.1 / 8.1 1RHR / 7,400 / 31.7 / 19.6 / 5.1 / 6.1 / 8.1

MINOR CALCULATION CHANGE FORM (Tracked via DRN in MERLIN)

Calculation No.: VYC-0808	**Revision:** 6
Calculation Title: Core Spray and Residual Heat Removal Pump Net Positive Suction Head Margin Following a Loss of Coolant Accident or Anticipated Transient Without Scram	**Indicate Status of Minor Calculation Change:** - Prel; - Pend; - As-Built
MERLIN DRN No. or Minor Calculation Change No.: 05	
Modification No./Task No./ER No. VYDC-2003-008	
Computer Code Used ☐ Yes ☒ No. **If "Yes", Code:**	

1 Purpose of Change:	Incorporate GE-VYNPS-AEP-346
2 SSC affected:	See attached VYAPF0017.07
3 Design Input Documents not used in parent Calculation:	See attached VYAPF0017.07
4 Drawings/Procedures/ Calculations / other Documents affected	See attached VYAPF0017.07
5 Description of Change:	See attached description
6 Impact on existing calculation conclusion:	Revised containment overpressure envelope for long term LOCA
7 Impact on DBD's, UFSAR, Technical Specifications:	See attached VYAPF0017.07

8. The existing calculation does/does not (circle one) have a calculation verification checklist. (See Remarks)

Remarks: This ENN-DC-126 MCC is to a VY design verified calculation prepared under AP-0017. AP-0017 did not have a "checklist", instead design verification was documented on form VYAPF0017.04

NOTE:
A. If UFSAR or Technical Specifications need to be revised, Minor Calculation Change Form should not be used unless it is an editorial change to the UFSAR or Technical Specifications.
B. Minor Calculation Change Forms do not change the status of the Parent Calculation Revision.

	Print/Sign		Date:
Prepared by:	E. P. O'Brien EPOBrien		7/1/04
Reviewed by: *	E.G. Lind E.G. Lind		7/1/04
Approved by	D.E. Yasi D E Yasi		7/1/04

* Where the original calculation was design verified, the reviewer signature confirms the latest design verification is still valid.

This IS a Quality Record -

5. Description of Change

The NPSH evaluation of the RHR and CS pumps is performed, using the same methodology as CCN04, for long term DBA-Loss of Coolant Accident (LOCA) case only. This CCN uses the EPU suppression pool temperature/pressure data supplied in Reference 1. Note – all References contained in AP0017.07 (Attachment B)

Reason for Change:
This CCN provides additional results regarding the Residual Heat Removal (RHR) and Core Spray (CS) Pump NPSH resulting from the Extended Power Uprate (EPU), which was initially evaluated in CCN04.
Specifically, this CCN05 updates the post LOCA results based on revised containment temperature and pressure profiles provided in Reference 1. The revised containment profiles reflect two changes from the CCN04 EPU evaluation: (1) The post LOCA time was extended to 200,000 seconds, beyond which overpressure is no longer being required, and (2) the containment leakage was increased from 0.8 to 1.5 weight percent per day, to reflect the recently submitted Alternate Source Term (AST) License Amendment Request (Ref: 5, ERC-2004-024)

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Note: No Table 4.1 or Figure 4.1 are contained in this CCN.

Attachment A Excel Verification Sample Calculation....4 pages
Attachment B VY Calculation Database Input Form (VY APF0017.07) ....2 pages

TOTAL PAGES: 17

1.0 Objective

The objective of this CCN is to update the CCN04 post LOCA Extended Power Uprate (EPU) evaluation of the adequacy of the available NPSH for the Residual Heat Removal (RHR) and Core Spray (CS) pumps. This includes identification of any change in the amount and duration of suppression pool (torus) overpressure required to maintain adequate NPSH.

Specifically, this CCN05 updates the post LOCA results based on revised containment temperature and pressure profiles provided in Reference 1. The revised containment profiles reflect two changes from the CCN04 EPU evaluation: (1) The post LOCA time was extended to 200,000 seconds, beyond which overpressure is no longer being required, and (2) the containment leakage was increased from 0.8 to 1.5 weight percent per day, to reflect the recently submitted Alternate Source Term (AST) License Amendment Request (Ref: 5, ERC-2004-024)

2.0 Methodology

General

The methodology for determining the NPSH available (NPSHa) for a given event and temperature is the same as that developed in VYC-0808 Rev 6 and presented in Table 1 of that calculation (Ref: 4). The NPSH required (NPSHr) is also per VYC-0808 Rev 6 and is discussed in detail in Section 4.0 of this CCN. The methodology for determining the pump suction strainer head loss during a LOCA, and the time dependent profile for required overpressure is the same as that developed in CCN04.

3.0 Assumptions

1. None made

4.0 Analysis

As stated in Section 2.0, the methodology for determining the NPSHa is the same as that developed in VYC-0808 Rev 6 and presented in Table 1 of that calculation (Ref: 4). The following terms are used in the evaluation.

NPSHa (ft) = net positive suction head available without overpressure credit
(14.7-Pg)(144vf)+Z-hf-hs-hd

where:

Z (ft) = suction elevation head

hf (ft) = suction line losses

hs (ft) = clean strainer losses

hd (ft) = strainer debris losses

Pg (psia) = vapor pressure @ torus temperature

vf (ft^3/lb) = specific volume @ torus temperature and pressure

Pg and vf are obtained from ASME Steam Tables 1967 Formulation (Ref: 7)

NPSHr (ft) = net positive suction head required.
It should be noted that the NPSH required data provided by the pump vendor, as documented in Figures 2.1-1 and 2.2-1 of Attachment 3 to calculation VYC-0808, is actually *Allowable Operating Periods @ NPSHa Specified.* Allowable hours of operation at specified NPSHa values are identified for a range of flows. For this CCN, the NPSHa specified in these Figures is taken as the NPSHr at a given operating time.

Q (gpm) = pump flow rate

OPR (psig) = Overpressure Required
(NPSHr – NPSHa)/(144*Vf)
For those profile points where there is inadequate NPSH, when considering the suppression pool pressure to be atmospheric (14.7 psia), OPR is the amount of suppression pool pressure required to make NPSHa (ft) equal to NPSHr (ft).

OPA (psig)– Overpressure Available
The suppression pool pressure available, above atmospheric, for a given event and time.

OPC (psig)– Overpressure Credit Taken
The overpressure credited in the evaluation of NPSH. Engineering judgement is used to select the credit to be greater than the OPR, by a reasonable amount, and less than the OPA.

Detailed discussion of the above terms is provided in the subsections that follow.

4.1 LOCA – Long Term

The temperature and pressure (T/P) profile for the suppression pool during a LOCA is developed in GE-VYNPS-AEP-346 (Ref: 1). The long term data is provided from 0-864,000 seconds.

The evaluation of NPSH is documented in Table 4.2 using selected T/P points representing the long term profile of the suppression pool. The details of the evaluation are presented at the top of the Table followed by a matrix of the NPSH results for the T/P profile of CS and RHR. The evaluated long term flow rates of 7400 gpm (RHR) and 3500 gpm (CS) are consistent with calculation VYC-0808 Rev 6 (Ref: 4). Further discussion of selected terms is presented below.

Suction Elevation Head, Z
The values of Z for RHR and CS (12.40' and 12.57' respectively) as calculated in Section 3.5 of VYC-0808 are conservatively used in the evaluation. The suction elevation head is based on the water elevation in the torus. The EPU suppression pool water volume is slightly larger than the existing value used in VYC-0808, which would result in a slight increase in water elevation, and therefore Z.

A water volume comparison at maximum pool temperature is provided below:

	Pre-EPU	EPU
Ref:	(VYC-0808 Rev 6 Section 3.5)	(GE-VYNPS-AEP-346)
Long term	77,640 cuft	79,470 cuft

Maximum Debris Losses (hd)

1 RHR: CCN #3 (Ref: 3) calculated the limiting head loss as 0.24 ft at 181.7°F and 7400 gpm. Note that this is a slight reduction from the head loss (0.33 ft) addressed in Section 3.2 of VYC-0808 Rev 6 (Ref: 4). For conservatism, 0.33 ft at 173°F is used. (Case 1 of Tables 2 and 8 of Ref: 2).

CS: Note that CCN #3 (Ref: 3) documents the up-to-date limiting head loss as 0.19 ft at 181.7°F and 3500 gpm. This is a slight reduction from the head loss (0.21 ft) addressed in Section 3.2 of VYC-0808 Rev 6 (Ref: 4). For conservatism, 0.21 ft at 173°F is used. This is based on a conservative CS flow rate of 4000 gpm. (Case 3b of Tables 2 and 8 of Ref: 2).

NPRHr - CS

Figure 2.2-1 of Attachment 3 to calculation VYC-0808 provides a plot of *Allowable Operating Periods @ NPSHa Specified* values for various flow rates. This plot shows that at 3500 gpm the allowable NPSH increases between 7 and 20 hrs of operation and a value of 29.6 ft is acceptable beyond 20 hrs of operation. This maximum value is conservatively used for the entire long term period (>600 sec).

NPRHr - RHR

Figure 2.1-1 of Attachment 3 to calculation VYC-0808 provides a plot of *Allowable Operating Periods @ NPSHa Specified* values for various flow rates. This plot shows that at 7400 gpm the allowable NPSH increases between 7 and 100 hrs of operation and a value of 31.7 ft is acceptable beyond 100 hrs of operation. This maximum value is conservatively used for the entire long term period (>600 sec).

4.1.1 Evaluation

As can been seen from Figure 4.2 the overpressure required for RHR envelopes that required for CS and the overpressure varies continuously over time. In order to facilitate reporting and presentation of the overpressure required, an enveloping, stepped, overpressure credit is overlaid on Figure 4.2. Refer to Section 4.0 for discussion on selection of overpressure credit.

Though the long term flow rates are postulated at time 600 seconds (e.g. CS throttled down from 4600gpm to 3500gpm), it is not the intent of this calculation to imply at what time throttling should commence or how much throttling is required. This is a function of the time dependent NPSHr and pool temperature. This calculation conservatively evaluates the maximum NPSHr as occurring over the entire operating period (>600 sec). The actual NPSHr is lower between 0-7 hrs and increases after 7 hrs.

5.0 Summary of Results

NPSHa is rounded to the nearest 0.1ft and OPR, OPC, and OPA are rounded to the nearest 0.1psig.

5.1 LOCA - Long Term (>600 sec):

NPSHa is adequate for both CS and RHR pumps with an overpressure credit that varies over time, as shown in Fig. 4.2. NPSHa, OPR, OPC, OPA are shown below, at the peak temperature

Pump	Total flow, gpm	NPSHr, ft	NPSHa, ft	OPR, psig	OPC, psig	OPA, psig
CS	3,500	29.6	19.5	4.2	6.1	8.0
1RHR	7,400	31.7	19.6	5.1	6.1	8.0

6.0 Conclusions

Torus overpressure must be credited for 200,000 seconds for operating the RHR and CS pumps at EPU conditions for a long term DBA-Loss of Coolant Accident (LOCA) to achieve adequate NPSH available.

The results of this CCN will provide input to the PUSAR (Ref: 12) for the RHR and CS NPSH evaluation and will alter input to calculation VYC-1628 (Ref: 13) to address the need for crediting torus overpressure in the calculation of NPSH available. Note that calculation VYC-1628 may be superseded by GE EPU Analysis. The need for crediting torus overpressure in the RHR and CS NPSH evaluation, shall also be addressed in the SADBD (Ref: 14), UFSAR (Ref: 15), and system DBDs RHR (Ref: 16) and CS (Ref: 17).

Note that the changes to the UFSAR were originally proposed in CCN04 and are pending incorporation via the design change and licensing processes. This MCC simply updates the previous CCN04 performed under AP-0017. The UFSAR does not currently contain information on containment overpressure.

Note that use of overpressure credit must be approved by the NRC as part of EPU.

No specific 50.59 Screening/Evaluation is required for this CCN since all EPU design changes and associated 50.59 documentation will be part of VYDC-2003-008.

Table 4.2 LOCA – Long Term (1.5 wt. % Containment Leakage)

LOCA - Long

NPSHa = (14.7-Pg)(144Vf)+Z-hf-hs-hd
OPR = Over pressure required (NPSHr – NPSHa)/(144*Vf)
OPA = Over pressure available
OPC = Over pressure credited

Cross references:
Section 2.3 of VYC-0808 Rev 6 (Ref: 4)
See Discussion in Section 4.0 of this CCN

Long Term Flow Rate (gpm)				
1 RHR	Q = 7400	CS	Q = 3500	Table of 1 calc VYC-0808 Rev 6 (Ref: 4)
Suction Line Losses (ft)				
1 RHR	hf = 4.77E-8*Q^2	CS	hf = 2.5E-7*Q^2	Section 3.7 of VYC-0808 Rev 6 (Ref: 4)
Clean Strainer Losses (ft)				
1 RHR	hs = 0.33	CS	hs = .38*(Q/4000)^2 for Q<= 4000	Section 3.6 of VYC-0808 Rev 6 (Ref: 4)
Maximum Debris Losses (ft) @ >= 173F				
1 RHR	hd = 0.33	CS	hd = 0.21	See discussion in Section 4.1 of this CCN
Maximum Debris Losses (ft) @ < 173F				
1 RHR	hd = .33*(173/T)	CS	hd = .21*(173/T)	See discussion in Section 2.0 of VYC-0808 Rev 6 CCN 4 (Ref: 11)
where T = suppression pool temperature, F				
Elevation Head (ft)				
RHR	Z = 12.4	CS	Z = 12.57	See discussion in Section 4.1 of this CCN for conservatism.
NPSHr (ft)				
1 RHR	NPSHr = 31.7	CS	NPSHr = 29.6	See discussion in Section 4.1 of this CCN

Table 4.2 LOCA – Long Term (1.5 wt. % Containment Leakage)

CS - Long Term (After EPU) 1.5 wt. % Containment Leakage

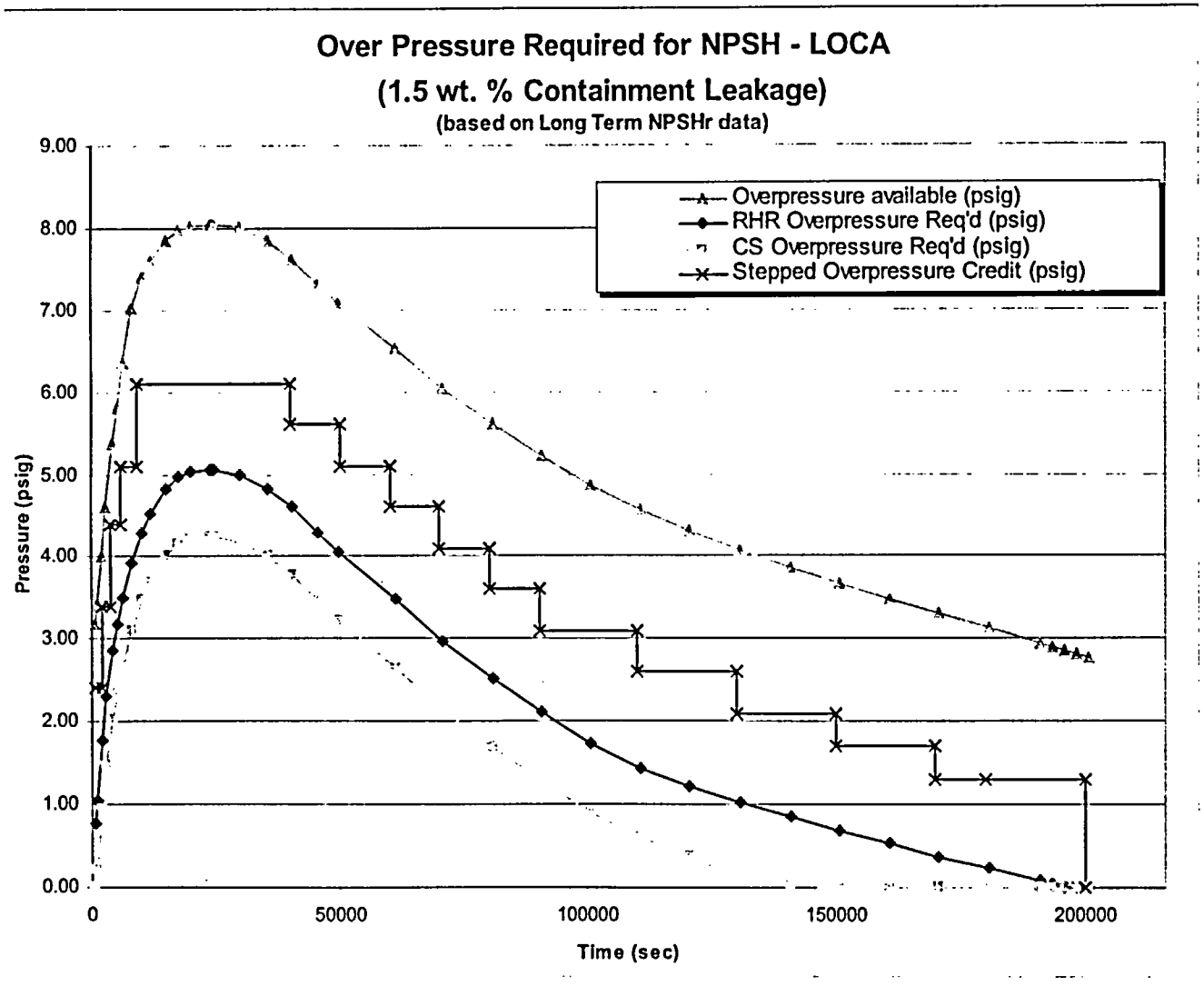
Time (sec)	GE Pool Temp (F)	GE Pool Pressure psia	Pg (psia)	Vf (ft^3/lb)	Z (ft)	hf (ft)	hs (ft)	hd (ft)	CS NPSHa (ft)	CS NPSHr (ft)	CS OPR (psig)	OPA (psig)	OPC (psig)
778.85	169.6	17.88	5.938	0.016448	12.57	3.06	0.29	0.21	29.76	29.60	0.00	3.18	2.40
1088.64	171.7	18.12	6.231	0.016460	12.57	3.06	0.29	0.21	29.08	29.60	0.22	3.42	2.40
2022.07	176.6	18.72	6.962	0.016489	12.57	3.06	0.29	0.21	27.38	29.60	0.94	4.02	3.40
2950.64	180	19.3	7.511	0.016509	12.57	3.06	0.29	0.21	26.10	29.60	1.47	4.60	3.40
4185.2	183.3	20.07	8.078	0.016529	12.57	3.06	0.29	0.21	24.77	29.60	2.03	5.37	4.40
5108.82	185.1	20.5	8.402	0.016541	12.57	3.06	0.29	0.21	24.01	29.60	2.35	5.80	4.40
6241.48	186.9	21.05	8.737	0.016552	12.57	3.06	0.29	0.21	23.22	29.60	2.68	6.35	5.10
8035.1	189.1	21.72	9.161	0.016566	12.57	3.06	0.29	0.21	22.22	29.60	3.09	7.02	5.10
10190.79	191	22.09	9.541	0.016578	12.57	3.06	0.29	0.21	21.32	29.60	3.47	7.39	6.10
12039.95	192.1	22.29	9.767	0.016585	12.57	3.06	0.29	0.21	20.79	29.60	3.69	7.59	6.10
15125.17	193.6	22.55	10.083	0.016594	12.57	3.06	0.29	0.21	20.04	29.60	4.00	7.85	6.10
17625.17	194.3	22.67	10.233	0.016599	12.57	3.06	0.29	0.21	19.68	29.60	4.15	7.97	6.10
20063.67	194.6	22.71	10.298	0.016601	12.57	3.06	0.29	0.21	19.53	29.60	4.21	8.01	6.10
23735.2	194.7	22.74	10.320	0.016601	12.57	3.06	0.29	0.21	19.48	29.60	4.23	8.04	6.10
24093.8	194.7	22.74	10.320	0.016601	12.57	3.06	0.29	0.21	19.48	29.60	4.23	8.04	6.10
24359.79	194.7	22.74	10.320	0.016601	12.57	3.06	0.29	0.21	19.48	29.60	4.23	8.04	6.10
29855.07	194.4	22.71	10.255	0.016599	12.57	3.06	0.29	0.21	19.63	29.60	4.17	8.01	6.10
35212.2	193.6	22.54	10.083	0.016594	12.57	3.06	0.29	0.21	20.04	29.60	4.00	7.84	6.10
40032.64	192.5	22.31	9.851	0.016587	12.57	3.06	0.29	0.21	20.59	29.60	3.77	7.61	5.60
45400.32	190.9	22.01	9.521	0.016577	12.57	3.06	0.29	0.21	21.37	29.60	3.45	7.31	5.60
49775.32	189.8	21.77	9.300	0.016570	12.57	3.06	0.29	0.21	21.89	29.60	3.23	7.07	5.60
61022.64	186.7	21.22	8.699	0.016550	12.57	3.06	0.29	0.21	23.31	29.60	2.64	6.52	4.60
70699.13	183.9	20.74	8.185	0.016533	12.57	3.06	0.29	0.21	24.52	29.60	2.13	6.04	4.10
80699.13	181.3	20.3	7.730	0.016517	12.57	3.06	0.29	0.21	25.58	29.60	1.69	5.60	3.60
90697.01	178.8	19.93	7.313	0.016502	12.57	3.06	0.29	0.21	26.56	29.60	1.28	5.23	3.10
100697.01	176.4	19.56	6.931	0.016488	12.57	3.06	0.29	0.21	27.45	29.60	0.90	4.86	3.10
110697.01	174.4	19.26	6.625	0.016476	12.57	3.06	0.29	0.21	28.16	29.60	0.60	4.56	2.60
120697.01	172.9	19	6.404	0.016467	12.57	3.06	0.29	0.21	28.68	29.60	0.39	4.30	2.60
130684.82	171.5	18.77	6.202	0.016459	12.57	3.06	0.29	0.21	29.15	29.60	0.19	4.07	2.10
140684.83	170.2	18.56	6.020	0.016452	12.57	3.06	0.29	0.21	29.57	29.60	0.01	3.86	2.10
150684.83	169	18.36	5.856	0.016445	12.57	3.06	0.29	0.21	29.95	29.60	0.00	3.66	1.70
160684.83	167.7	18.17	5.683	0.016437	12.57	3.06	0.29	0.22	30.34	29.60	0.00	3.47	1.70
170684.83	166.5	18.01	5.526	0.016431	12.57	3.06	0.29	0.22	30.70	29.60	0.00	3.31	1.30
180684.83	165.3	17.83	5.374	0.016424	12.57	3.06	0.29	0.22	31.05	29.60	0.00	3.13	1.30
190684.83	164.1	17.65	5.225	0.016417	12.57	3.06	0.29	0.22	31.40	29.60	0.00	2.95	1.30
193184.83	163.8	17.6	5.188	0.016415	12.57	3.06	0.29	0.22	31.48	29.60	0.00	2.90	1.30
195684.83	163.5	17.56	5.151	0.016414	12.57	3.06	0.29	0.22	31.57	29.60	0.00	2.86	1.30
198184.83	163.2	17.52	5.115	0.016412	12.57	3.06	0.29	0.22	31.65	29.60	0.00	2.82	1.30
200684.83	162.9	17.47	5.079	0.016410	12.57	3.06	0.29	0.22	31.73	29.60	0.00	2.77	0.00

Table 4.2 - LOCA – Long Term (1.5 wt. % Containment Leakage)

RHR - Long Term (After EPU) 1.5 wt. % Containment Leakage

Time (sec)	GE Pool Temp (F)	GE Pool Pressure psia	Pg (psia)	Vf (ft^3/lb)	Z (ft)	hf (ft)	hs (ft)	hd (ft)	RHR NPSHa (ft)	RHR NPSHr (ft)	RHR OPR (psig)	OPA (psig)	OPC (psig)
778.85	169 6	17.88	5.938	0.016448	12.40	2.61	0.33	0.34	29.87	31.70	0.77	3.18	2.40
1088.64	171.7	18.12	6.231	0.016460	12.40	2.61	0.33	0.33	29.20	31.70	1.05	3.42	2.40
2022.07	176.6	18.72	6.962	0.016489	12.40	2.61	0.33	0.33	27.50	31.70	1.77	4.02	3.40
2950.64	180	19.3	7.511	0.016509	12.40	2.61	0.33	0.33	26.22	31.70	2.31	4.60	3.40
4185.2	183.3	20.07	8.078	0.016529	12.40	2.61	0.33	0.33	24.89	31.70	2.86	5.37	4.40
5108.82	185.1	20.5	8.402	0.016541	12.40	2.61	0.33	0.33	24.13	31.70	3.18	5.80	4.40
6241.48	186.9	21.05	8.737	0.016552	12.40	2.61	0.33	0.33	23.34	31.70	3.51	6.35	5.10
8035.1	189.1	21.72	9.161	0.016566	12.40	2.61	0.33	0.33	22.34	31.70	3.92	7.02	5.10
10190.79	191	22.09	9.541	0.016578	12.40	2.61	0.33	0.33	21.44	31.70	4.30	7.39	6.10
12039.95	192.1	22.29	9.767	0.016585	12.40	2.61	0.33	0.33	20.91	31.70	4.52	7.59	6.10
15125.17	193.6	22.55	10.083	0.016594	12.40	2.61	0.33	0.33	20.16	31.70	4.83	7.85	6.10
17625.17	194.3	22.67	10.233	0 016599	12.40	2.61	0.33	0.33	19.81	31.70	4.98	7.97	6.10
20063.67	194.6	22.71	10.298	0.016601	12.40	2.61	0.33	0.33	19.65	31.70	5.04	8.01	6.10
23735.2	194.7	22.74	10.320	0.016601	12.40	2.61	0.33	0.33	19.60	31.70	5.06	8.04	6.10
24093.8	194.7	22.74	10.320	0.016601	12.40	2.61	0.33	0.33	19.60	31.70	5.06	8.04	6.10
24359.79	194.7	22.74	10.320	0 016601	12.40	2.61	0.33	0.33	19.60	31.70	5.06	8.04	6.10
29855.07	194.4	22.71	10.255	0.016599	12.40	2 61	0.33	0.33	19.75	31.70	5.00	8.01	6.10
35212.2	193.6	22.54	10.083	0.016594	12.40	2.61	0.33	0.33	20.16	31.70	4.83	7.84	6.10
40032.64	192.5	22.31	9 851	0.016587	12.40	2.61	0.33	0.33	20.71	31.70	4.60	7.61	5.60
45400.32	190.9	22.01	9.521	0.016577	12.40	2.61	0.33	0.33	21.49	31.70	4.28	7.31	5.60
49775.32	189.8	21.77	9.300	0.016570	12.40	2.61	0.33	0.33	22.01	31.70	4.06	7.07	5.60
61022.64	186.7	21.22	8.699	0.016550	12.40	2.61	0.33	0.33	23.43	31.70	3.47	6.52	4.60
70699.13	183.9	20.74	8.185	0.016533	12.40	2.61	0.33	0.33	24.64	31.70	2.97	6.04	4.10
80699.13	181.3	20.3	7.730	0.016517	12.40	2 61	0.33	0.33	25.71	31.70	2.52	5.60	3.60
90697.01	178 8	19.93	7.313	0.016502	12.40	2 61	0.33	0.33	26.68	31.70	2.11	5.23	3.10
100697.01	176.4	19.56	6.931	0.016488	12.40	2.61	0.33	0.33	27.57	31.70	1.74	4.86	3.10
110697.01	174.4	19.26	6 625	0 016476	12.40	2.61	0.33	0.33	28.29	31.70	1.44	4.56	2.60
120697.01	172.9	19	6.404	0.016467	12.40	2.61	0.33	0.33	28.80	31.70	1.22	4.30	2.60
130684.82	171.5	18.77	6.202	0.016459	12.40	2.61	0.33	0.33	29.27	31.70	1.03	4.07	2.10
140684 83	170.2	18.56	6.020	0.016452	12.40	2.61	0.33	0.34	29.68	31.70	0.85	3.86	2.10
150684 83	169	18.36	5.856	0.016445	12.40	2.61	0.33	0.34	30.06	31.70	0.69	3 66	1.70
160684.83	167.7	18.17	5.683	0.016437	12.40	2.61	0.33	0.34	30.46	31.70	0.52	3.47	1.70
170684.83	166.5	18.01	5 526	0.016431	12.40	2.61	0.33	0.34	30.82	31.70	0.37	3.31	1.30
180684.83	165.3	17.83	5.374	0.016424	12.40	2.61	0.33	0.35	31.16	31.70	0.23	3.13	1.30
190684.83	164.1	17.65	5.225	0.016417	12.40	2.61	0.33	0.35	31.51	31.70	0.08	2.95	1.30
193184.83	163 8	17.6	5.188	0.016415	12.40	2.61	0.33	0.35	31.59	31.70	0.05	2.90	1.30
195684.83	163.5	17.56	5.151	0.016414	12.40	2.61	0.33	0.35	31.68	31.70	0.01	2.86	1.30
198184.83	163.2	17.52	5.115	0.016412	12.40	2.61	0.33	0.35	31.76	31.70	0.00	2.82	1.30
200684.83	162.9	17.47	5 079	0.016410	12.40	2.61	0.33	0.35	31.84	31.70	0.00	2.77	0.00

Figure 4.2 LOCA – Long Term (1.5 wt. % Containment Leakage)



OPC overpress credit	
(sec)	(psig)
600	2.4
2000	2.4
2001	3.4
4000	3.4
4001	4.4
6000	4.4
6001	5.1
9000	5.1
9001	6.1
40000	6.1
40001	5.6
50000	5.6
50001	5.1
60000	5.1
60001	4.6
70000	4.6
70001	4.1
80000	4.1
80001	3.6
90000	3.6
90001	3.1
110000	3.1
110001	2.6
130000	2.6
130001	2.1
150000	2.1
150001	1.7
170000	1.7
170001	1.3
180000	1.3
200000	1.3
200001	0

Excel Verification Sample Calculation

CS Table Verification (Line 50):

Cell F50 = $F$25
= 12.57

Cell G50 = 0.00000025*$F$9^2
= 0.00000025*3500^2
= 3.06

Cell H50 = 0.38*(($F$9/4000)^2)
= 0.38*((3500/4000)^2)
= 0.29

Cell I50 = ROUND(IF(B50<173,$F$18*(173/B50),$F$18),2)
194.4<173 = False (For True outcome see below, Cell I72)
= $F$18
= 0.21

Cell I72 = ROUND(IF(B72<173,$F$18*(173/B72),$F$18),2)
= 162.9<173 = True
= $F$18*(173/B72)
= 0.21*(173/162.9)
= 0.22

Cell J50 = +((14.7-D50)*144*E50)+F50-G50-H50-I50
= ((14.7-10.255)*144*0.016599)+12.57-3.06-0.29-0.21
= 19.63

Cell K50 = $F$28
= 29.6

Cell L50 = IF((+K50-J50)/(144*E50)>0,(+K50-J50)/(144*E50),0)
(29.6-19.63)/(144*0.016599) = 4.17>0 True (For False outcome see below, Cell L34)
= 4.17

Cell L34 = IF((+K34-J34)/(144*E34)>0,(+K34-J34)/(144*E34),0)
= (29.6-29.76)/(144*0.016448) = -0.068>0 False
= 0

Cell M50 = +C50-14.7
= 22.71-14.7
= 8.01

RHR Table Verification (Line 78):

Cell F78 = $C$25
= 12.40

Cell G78 = 0.0000000477*$C$9^2
= 0.0000000477*7400^2
= 2.61

Cell H78 = $C$15
= 0.33

Cell I78 = ROUND(IF(B78<173,$C$18*(173/B78),$C$18),2)
169.6<173 = True (For False outcome see below, Cell I81)
= $C$18*(173/B78)
= 0.33*(173/169.6)
= 0.34

Cell I81 = ROUND(IF(B81<173,$C$18*(173/B81),$C$18),2)
180<173 = False
= $C$18
= 0.33

Cell J78 = +((14.7-D78)*144*E78)+F78-G78-H78-I78
= ((14.7-5.938)*144*0.016448)+12.40-2.61-0.33-0.34
= 29.87

Cell K78 = $C$28
= 31.7

Cell L78 = IF((+K78-J78)/(144*E78)>0,(+K78-J78)/(144*E78),0)
(31.7-29.87)/(144*0.016448)=0.77>0 True (For False outcome see below, Cell L116)
= 0.77

Cell L116 = IF((+K116-J116)/(144*E116)>0,(+K116-J116)/(144*E116),0)
= (31.7-31.84)/(144*0.016410) = -0.059>0 False
= 0

Cell M78 = +C78-14.7
= 17.88-14.7
= 3.18

Excel Verification

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	**LOCA - Long Term**							Cross references:						
2	NPSHa =	(14 7-Pg)(144/Vf)+Z-hf-hs-hd						Section 2.3 of VYC-0808 Rev 6 (Ref 4)						
3	OPR =	Over pressure required (NPSHr – NPSHa)(144*Vf)						See Discussion in Section 4 0 of this CCN						
4	OPA =	Over pressure available												
5	OPC =	Over pressure credited												
6														
7														
8	Long Term Flow Rate (gpm)													
9		1 RHR	Q = 7400		CS	Q = 3500		Table of 1 calc VYC-0808 Rev 6 (Ref 4)						
10														
11	Suction Line Losses (ft)													
12		1 RHR	hf = 4 77E-8*Q^2		CS	hf = 2 5E-7*Q^2		Section 3 7 of VYC-0808 Rev 6 (Ref 4)						
13														
14	Clean Strainer Losses (ft)													
15		1 RHR	hs = 0 33		CS	hs = 38*(Q/4000)^2 for Q<= 4000		Section 3 8 of VYC-0808 Rev 6 (Ref 4)						
16														
17	Maximum Debris Losses (ft) @ >= 173F													
18		1 RHR	hd = 0 33		CS	hd = [illegible]		See discussion in Section 4 1 of this CCN						
19														
20	Maximum Debris Losses (ft) @ < 173F													
21		1 RHR	hd = 33*(173/T)		CS	hd = [illegible]		See discussion in Section 2 0 of VYC-0808 Rev 6 CCN 4 (Ref 11)						
22	where T = suppression pool temperature, F													
23														
24	Elevation Head (ft)													
25		RHR	Z = 12 4		CS	Z = 12 57		See discussion in Section 4 1 of this CCN for correction term						
26														
27	NPSHr (ft)													
28		1 RHR	NPSHr = 31 7		CS	NPSHr = 29 6		See discussion in Section 4 1 of this CCN						
29														
30	**CS - Long Term (After EPU) 1.5 wt. % Containment Leakage**													
31		OE Pool	OE Pool								CS	CS		
32	Time	Temp	Pressure	Pg	Vf	Z	hf	hs	hd	CS NPSHa	NPSHr	OPR	OPA	OPC
33	(sec)	(F)	psia	(psia)	(ft^3/lb)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(psig)	(psig)	(psig)
34	778 85	189 6	17 68	5 938	0 016448	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B34<173,$F$18*(173/B34),$F$18),2)	=+((14 7-D34)*144*E34)+F34-G34-H34-I34	=$F$28	=IF(((=K34-J34)*(144*E34)>0,(=K34-J34)*(144*E34),0))	=+C34-14 7	2 4
35	1088 64	171 7	18 12	6 231	0 016446	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B35<173,$F$18*(173/B35),$F$18),2)	=+((14 7-D35)*144*E35)+F35-G35-H35-I35	=$F$28	=IF(((=K35-J35)*(144*E35)>0,(=K35-J35)*(144*E35),0))	=+C35-14 7	2 4
36	2022 07	176 6	18 72	6 962	0 016489	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B36<173,$F$18*(173/B36),$F$18),2)	=+((14 7-D36)*144*E36)+F36-G36-H36-I36	=$F$28	=IF(((=K36-J36)*(144*E36)>0,(=K36-J36)*(144*E36),0))	=+C36-14 7	3 4
37	2950 64	180	19 3	7 511	0 016509	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B37<173,$F$18*(173/B37),$F$18),2)	=+((14 7-D37)*144*E37)+F37-G37-H37-I37	=$F$28	=IF(((=K37-J37)*(144*E37)>0,(=K37-J37)*(144*E37),0))	=+C37-14 7	3 4
38	4185 2	183 3	20 07	8 078	0 016529	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B38<173,$F$18*(173/B38),$F$18),2)	=+((14 7-D38)*144*E38)+F38-G38-H38-I38	=$F$28	=IF(((=K38-J38)*(144*E38)>0,(=K38-J38)*(144*E38),0))	=+C38-14 7	4 4
39	5108 82	185 1	20 5	8 402	0 016541	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B39<173,$F$18*(173/B39),$F$18),2)	=+((14 7-D39)*144*E39)+F39-G39-H39-I39	=$F$28	=IF(((=K39-J39)*(144*E39)>0,(=K39-J39)*(144*E39),0))	=+C39-14 7	4 4
40	6241 48	186 9	21 05	8 737	0 016552	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B40<173,$F$18*(173/B40),$F$18),2)	=+((14 7-D40)*144*E40)+F40-G40-H40-I40	=$F$28	=IF(((=K40-J40)*(144*E40)>0,(=K40-J40)*(144*E40),0))	=+C40-14 7	5 1
41	8035 1	189 1	21 72	9 161	0 016566	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B41<173,$F$18*(173/B41),$F$18),2)	=+((14 7-D41)*144*E41)+F41-G41-H41-I41	=$F$28	=IF(((=K41-J41)*(144*E41)>0,(=K41-J41)*(144*E41),0))	=+C41-14 7	5 1
42	10190 79	191	22 09	9 541	0 016578	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B42<173,$F$18*(173/B42),$F$18),2)	=+((14 7-D42)*144*E42)+F42-G42-H42-I42	=$F$28	=IF(((=K42-J42)*(144*E42)>0,(=K42-J42)*(144*E42),0))	=+C42-14 7	6 1
43	12039 95	192 1	22 29	9 787	0 016585	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B43<173,$F$18*(173/B43),$F$18),2)	=+((14 7-D43)*144*E43)+F43-G43-H43-I43	=$F$28	=IF(((=K43-J43)*(144*E43)>0,(=K43-J43)*(144*E43),0))	=+C43-14 7	6 1
44	15125 17	193 8	22 66	10 083	0 016594	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B44<173,$F$18*(173/B44),$F$18),2)	=+((14 7-D44)*144*E44)+F44-G44-H44-I44	=$F$28	=IF(((=K44-J44)*(144*E44)>0,(=K44-J44)*(144*E44),0))	=+C44-14 7	6 1
45	17825 17	194 3	22 87	10 233	0 016599	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B45<173,$F$18*(173/B45),$F$18),2)	=+((14 7-D45)*144*E45)+F45-G45-H45-I45	=$F$28	=IF(((=K45-J45)*(144*E45)>0,(=K45-J45)*(144*E45),0))	=+C45-14 7	6 1
46	20063 67	194 8	22 71	10 298	0 016601	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B46<173,$F$18*(173/B46),$F$18),2)	=+((14 7-D46)*144*E46)+F46-G46-H46-I46	=$F$28	=IF(((=K46-J46)*(144*E46)>0,(=K46-J46)*(144*E46),0))	=+C46-14 7	6 1
47	23735 2	194 7	22 74	10 32	0 016601	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B47<173,$F$18*(173/B47),$F$18),2)	=+((14 7-D47)*144*E47)+F47-G47-H47-I47	=$F$28	=IF(((=K47-J47)*(144*E47)>0,(=K47-J47)*(144*E47),0))	=+C47-14 7	6 1
48	24093 8	194 7	22 74	10 32	0 016601	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B48<173,$F$18*(173/B48),$F$18),2)	=+((14 7-D48)*144*E48)+F48-G48-H48-I48	=$F$28	=IF(((=K48-J48)*(144*E48)>0,(=K48-J48)*(144*E48),0))	=+C48-14 7	6 1
49	24359 79	194 7	22 74	10 32	0 016601	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B49<173,$F$18*(173/B49),$F$18),2)	=+((14 7-D49)*144*E49)+F49-G49-H49-I49	=$F$28	=IF(((=K49-J49)*(144*E49)>0,(=K49-J49)*(144*E49),0))	=+C49-14 7	6 1
50	29855 07	194 4	22 71	10 255	0 016599	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B50<173,$F$18*(173/B50),$F$18),2)	=+((14 7-D50)*144*E50)+F50-G50-H50-I50	=$F$28	=IF(((=K50-J50)*(144*E50)>0,(=K50-J50)*(144*E50),0))	=+C50-14 7	6 1
51	35212 2	193 6	22 54	10 083	0 016594	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B51<173,$F$18*(173/B51),$F$18),2)	=+((14 7-D51)*144*E51)+F51-G51-H51-I51	=$F$28	=IF(((=K51-J51)*(144*E51)>0,(=K51-J51)*(144*E51),0))	=+C51-14 7	6 1
52	40032 64	192 5	22 31	9 851	0 016587	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B52<173,$F$18*(173/B52),$F$18),2)	=+((14 7-D52)*144*E52)+F52-G52-H52-I52	=$F$28	=IF(((=K52-J52)*(144*E52)>0,(=K52-J52)*(144*E52),0))	=+C52-14 7	5 6
53	45400 32	190 9	22 01	9 521	0 016577	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B53<173,$F$18*(173/B53),$F$18),2)	=+((14 7-D53)*144*E53)+F53-G53-H53-I53	=$F$28	=IF(((=K53-J53)*(144*E53)>0,(=K53-J53)*(144*E53),0))	=+C53-14 7	5 6
54	49775 32	189 8	21 77	9 3	0 01657	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B54<173,$F$18*(173/B54),$F$18),2)	=+((14 7-D54)*144*E54)+F54-G54-H54-I54	=$F$28	=IF(((=K54-J54)*(144*E54)>0,(=K54-J54)*(144*E54),0))	=+C54-14 7	5 6
55	61022 64	186 7	21 22	8 690	0 01655	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B55<173,$F$18*(173/B55),$F$18),2)	=+((14 7-D55)*144*E55)+F55-G55-H55-I55	=$F$28	=IF(((=K55-J55)*(144*E55)>0,(=K55-J55)*(144*E55),0))	=+C55-14 7	4 6
56	70699 13	183 8	20 74	8 165	0 016533	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B56<173,$F$18*(173/B56),$F$18),2)	=+((14 7-D56)*144*E56)+F56-G56-H56-I56	=$F$28	=IF(((=K56-J56)*(144*E56)>0,(=K56-J56)*(144*E56),0))	=+C56-14 7	4 1
57	80699 13	181 3	20 3	7 73	0 016517	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B57<173,$F$18*(173/B57),$F$18),2)	=+((14 7-D57)*144*E57)+F57-G57-H57-I57	=$F$28	=IF(((=K57-J57)*(144*E57)>0,(=K57-J57)*(144*E57),0))	=+C57-14 7	3 6
58	90697 01	178 8	19 93	7 313	0 016502	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B58<173,$F$18*(173/B58),$F$18),2)	=+((14 7-D58)*144*E58)+F58-G58-H58-I58	=$F$28	=IF(((=K58-J58)*(144*E58)>0,(=K58-J58)*(144*E58),0))	=+C58-14 7	3 1
59	100697 01	176 4	19 58	6 931	0 016488	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B59<173,$F$18*(173/B59),$F$18),2)	=+((14 7-D59)*144*E59)+F59-G59-H59-I59	=$F$28	=IF(((=K59-J59)*(144*E59)>0,(=K59-J59)*(144*E59),0))	=+C59-14 7	3 1
60	110697 01	174 4	19 28	6 625	0 016478	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B60<173,$F$18*(173/B60),$F$18),2)	=+((14 7-D60)*144*E60)+F60-G60-H60-I60	=$F$28	=IF(((=K60-J60)*(144*E60)>0,(=K60-J60)*(144*E60),0))	=+C60-14 7	2 6
61	120697 01	172 9	19	6 404	0 016467	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B61<173,$F$18*(173/B61),$F$18),2)	=+((14 7-D61)*144*E61)+F61-G61-H61-I61	=$F$28	=IF(((=K61-J61)*(144*E61)>0,(=K61-J61)*(144*E61),0))	=+C61-14 7	2 6
62	130684 82	171 5	18 77	6 202	0 016459	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B62<173,$F$18*(173/B62),$F$18),2)	=+((14 7-D62)*144*E62)+F62-G62-H62-I62	=$F$28	=IF(((=K62-J62)*(144*E62)>0,(=K62-J62)*(144*E62),0))	=+C62-14 7	2 1
63	140684 83	170 2	18 56	6 02	0 016452	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B63<173,$F$18*(173/B63),$F$18),2)	=+((14 7-D63)*144*E63)+F63-G63-H63-I63	=$F$28	=IF(((=K63-J63)*(144*E63)>0,(=K63-J63)*(144*E63),0))	=+C63-14 7	2 1
64	150684 83	169	18 38	5 858	0 016445	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B64<173,$F$18*(173/B64),$F$18),2)	=+((14 7-D64)*144*E64)+F64-G64-H64-I64	=$F$28	=IF(((=K64-J64)*(144*E64)>0,(=K64-J64)*(144*E64),0))	=+C64-14 7	1 7
65	160684 83	167 7	18 17	5 683	0 016437	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B65<173,$F$18*(173/B65),$F$18),2)	=+((14 7-D65)*144*E65)+F65-G65-H65-I65	=$F$28	=IF(((=K65-J65)*(144*E65)>0,(=K65-J65)*(144*E65),0))	=+C65-14 7	1 7
66	170684 83	166 5	18 01	5 526	0 016431	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B66<173,$F$18*(173/B66),$F$18),2)	=+((14 7-D66)*144*E66)+F66-G66-H66-I66	=$F$28	=IF(((=K66-J66)*(144*E66)>0,(=K66-J66)*(144*E66),0))	=+C66-14 7	1 3
67	180684 83	165 3	17 83	5 374	0 016424	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B67<173,$F$18*(173/B67),$F$18),2)	=+((14 7-D67)*144*E67)+F67-G67-H67-I67	=$F$28	=IF(((=K67-J67)*(144*E67)>0,(=K67-J67)*(144*E67),0))	=+C67-14 7	1 3
68	190684 83	164 1	17 65	5 225	0 016417	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B68<173,$F$18*(173/B68),$F$18),2)	=+((14 7-D68)*144*E68)+F68-G68-H68-I68	=$F$28	=IF(((=K68-J68)*(144*E68)>0,(=K68-J68)*(144*E68),0))	=+C68-14 7	1 3
69	193184 83	163 8	17 6	5 188	0 016415	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B69<173,$F$18*(173/B69),$F$18),2)	=+((14 7-D69)*144*E69)+F69-G69-H69-I69	=$F$28	=IF(((=K69-J69)*(144*E69)>0,(=K69-J69)*(144*E69),0))	=+C69-14 7	1 3
70	195684 83	163 5	17 58	5 151	0 016414	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B70<173,$F$18*(173/B70),$F$18),2)	=+((14 7-D70)*144*E70)+F70-G70-H70-I70	=$F$28	=IF(((=K70-J70)*(144*E70)>0,(=K70-J70)*(144*E70),0))	=+C70-14 7	1 3
71	198184 83	163 2	17 52	5 115	0 016412	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B71<173,$F$18*(173/B71),$F$18),2)	=+((14 7-D71)*144*E71)+F71-G71-H71-I71	=$F$28	=IF(((=K71-J71)*(144*E71)>0,(=K71-J71)*(144*E71),0))	=+C71-14 7	1 3
72	200684 83	162 9	17 47	5 079	0 01641	=$F$25	=0 00000025*$F$9^2	=0 38*(($F$9/4000)^2)	=ROUND(IF(B72<173,$F$18*(173/B72),$F$18),2)	=+((14 7-D72)*144*E72)+F72-G72-H72-I72	=$F$28	=IF(((=K72-J72)*(144*E72)>0,(=K72-J72)*(144*E72),0))	=+C72-14 7	0
73														

Excel Verification

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
74	RHR - Long Term (After EPU) 1.5 wt. % Containment Leakage													
75-77	Time (sec)	GE Pool Temp (F)	GE Pool Pressure psia	Pg (psia)	Vf (ft^3/lb)	Z (ft)	hf (ft)	hs (ft)	hd (ft)	RHR NPSHa (ft)	RHR NPSHr (ft)	RHR OPR (psig)	OPA (psig)	OPC (psig)
78	778.85	169.6	17.88	5.938	0.016448	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B78<173,$C$18*(173-B78),$C$18),2)	=+((14.7-D78)*144*E78)+F78-G78+H78-I78	=$C$28	=IF((+K78-J78)/(144*E78)>0,(+K78-J78)/(144*E78),0)	=+C78-14.7	2.4
79	1088.64	171.7	18.12	6.231	0.01646	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B79<173,$C$18*(173-B79),$C$18),2)	=+((14.7-D79)*144*E79)+F79-G79+H79-I79	=$C$28	=IF((+K79-J79)/(144*E79)>0,(+K79-J79)/(144*E79),0)	=+C79-14.7	2.4
80	2022.07	176.6	18.72	6.962	0.016489	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B80<173,$C$18*(173-B80),$C$18),2)	=+((14.7-D80)*144*E80)+F80-G80+H80-I80	=$C$28	=IF((+K80-J80)/(144*E80)>0,(+K80-J80)/(144*E80),0)	=+C80-14.7	3.4
81	2950.64	180	19.3	7.511	0.016509	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B81<173,$C$18*(173-B81),$C$18),2)	=+((14.7-D81)*144*E81)+F81-G81+H81-I81	=$C$28	=IF((+K81-J81)/(144*E81)>0,(+K81-J81)/(144*E81),0)	=+C81-14.7	3.4
82	4185.2	183.3	20.07	8.078	0.016529	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B82<173,$C$18*(173-B82),$C$18),2)	=+((14.7-D82)*144*E82)+F82-G82+H82-I82	=$C$28	=IF((+K82-J82)/(144*E82)>0,(+K82-J82)/(144*E82),0)	=+C82-14.7	4.4
83	5108.82	185.1	20.5	8.402	0.016541	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B83<173,$C$18*(173-B83),$C$18),2)	=+((14.7-D83)*144*E83)+F83-G83+H83-I83	=$C$28	=IF((+K83-J83)/(144*E83)>0,(+K83-J83)/(144*E83),0)	=+C83-14.7	4.4
84	6241.48	186.9	21.05	8.737	0.016552	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B84<173,$C$18*(173-B84),$C$18),2)	=+((14.7-D84)*144*E84)+F84-G84+H84-I84	=$C$28	=IF((+K84-J84)/(144*E84)>0,(+K84-J84)/(144*E84),0)	=+C84-14.7	5.1
85	8035.1	189.1	21.72	9.161	0.016568	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B85<173,$C$18*(173-B85),$C$18),2)	=+((14.7-D85)*144*E85)+F85-G85+H85-I85	=$C$28	=IF((+K85-J85)/(144*E85)>0,(+K85-J85)/(144*E85),0)	=+C85-14.7	5.1
86	10190.79	191	22.09	9.541	0.016578	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B86<173,$C$18*(173-B86),$C$18),2)	=+((14.7-D86)*144*E86)+F86-G86+H86-I86	=$C$28	=IF((+K86-J86)/(144*E86)>0,(+K86-J86)/(144*E86),0)	=+C86-14.7	6.1
87	12039.95	192.1	22.29	9.767	0.016585	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B87<173,$C$18*(173-B87),$C$18),2)	=+((14.7-D87)*144*E87)+F87-G87+H87-I87	=$C$28	=IF((+K87-J87)/(144*E87)>0,(+K87-J87)/(144*E87),0)	=+C87-14.7	6.1
88	15125.17	193.6	22.55	10.083	0.016594	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B88<173,$C$18*(173-B88),$C$18),2)	=+((14.7-D88)*144*E88)+F88-G88+H88-I88	=$C$28	=IF((+K88-J88)/(144*E88)>0,(+K88-J88)/(144*E88),0)	=+C88-14.7	6.1
89	17625.17	194.3	22.67	10.233	0.016599	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B89<173,$C$18*(173-B89),$C$18),2)	=+((14.7-D89)*144*E89)+F89-G89+H89-I89	=$C$28	=IF((+K89-J89)/(144*E89)>0,(+K89-J89)/(144*E89),0)	=+C89-14.7	6.1
90	20063.67	194.6	22.71	10.298	0.016601	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B90<173,$C$18*(173-B90),$C$18),2)	=+((14.7-D90)*144*E90)+F90-G90+H90-I90	=$C$28	=IF((+K90-J90)/(144*E90)>0,(+K90-J90)/(144*E90),0)	=+C90-14.7	6.1
91	23735.2	194.7	22.74	10.32	0.016601	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B91<173,$C$18*(173-B91),$C$18),2)	=+((14.7-D91)*144*E91)+F91-G91+H91-I91	=$C$28	=IF((+K91-J91)/(144*E91)>0,(+K91-J91)/(144*E91),0)	=+C91-14.7	6.1
92	24093.8	194.7	22.74	10.32	0.016601	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B92<173,$C$18*(173-B92),$C$18),2)	=+((14.7-D92)*144*E92)+F92-G92+H92-I92	=$C$28	=IF((+K92-J92)/(144*E92)>0,(+K92-J92)/(144*E92),0)	=+C92-14.7	6.1
93	24359.79	194.7	22.74	10.32	0.016601	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B93<173,$C$18*(173-B93),$C$18),2)	=+((14.7-D93)*144*E93)+F93-G93+H93-I93	=$C$28	=IF((+K93-J93)/(144*E93)>0,(+K93-J93)/(144*E93),0)	=+C93-14.7	6.1
94	29855.07	194.4	22.71	10.255	0.016599	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B94<173,$C$18*(173-B94),$C$18),2)	=+((14.7-D94)*144*E94)+F94-G94+H94-I94	=$C$28	=IF((+K94-J94)/(144*E94)>0,(+K94-J94)/(144*E94),0)	=+C94-14.7	6.1
95	15212.2	193.6	22.54	10.083	0.016594	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B95<173,$C$18*(173-B95),$C$18),2)	=+((14.7-D95)*144*E95)+F95-G95+H95-I95	=$C$28	=IF((+K95-J95)/(144*E95)>0,(+K95-J95)/(144*E95),0)	=+C95-14.7	6.1
96	40032.64	192.5	22.31	9.851	0.016587	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B96<173,$C$18*(173-B96),$C$18),2)	=+((14.7-D96)*144*E96)+F96-G96+H96-I96	=$C$28	=IF((+K96-J96)/(144*E96)>0,(+K96-J96)/(144*E96),0)	=+C96-14.7	5.6
97	45400.32	190.9	22.01	9.521	0.016577	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B97<173,$C$18*(173-B97),$C$18),2)	=+((14.7-D97)*144*E97)+F97-G97+H97-I97	=$C$28	=IF((+K97-J97)/(144*E97)>0,(+K97-J97)/(144*E97),0)	=+C97-14.7	5.6
98	49775.32	189.8	21.77	9.3	0.01657	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B98<173,$C$18*(173-B98),$C$18),2)	=+((14.7-D98)*144*E98)+F98-G98+H98-I98	=$C$28	=IF((+K98-J98)/(144*E98)>0,(+K98-J98)/(144*E98),0)	=+C98-14.7	5.6
99	61022.64	186.7	21.22	8.699	0.01655	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B99<173,$C$18*(173-B99),$C$18),2)	=+((14.7-D99)*144*E99)+F99-G99+H99-I99	=$C$28	=IF((+K99-J99)/(144*E99)>0,(+K99-J99)/(144*E99),0)	=+C99-14.7	4.6
100	70699.13	183.9	20.74	8.185	0.016533	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B100<173,$C$18*(173-B100),$C$18),2)	=+((14.7-D100)*144*E100)+F100-G100+H100-I100	=$C$28	=IF((+K100-J100)/(144*E100)>0,(+K100-J100)/(144*E100),0)	=+C100-14.7	4.1
101	80699.13	181.3	20.3	7.73	0.016517	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B101<173,$C$18*(173-B101),$C$18),2)	=+((14.7-D101)*144*E101)+F101-G101+H101-I101	=$C$28	=IF((+K101-J101)/(144*E101)>0,(+K101-J101)/(144*E101),0)	=+C101-14.7	3.6
102	90697.01	178.8	19.93	7.313	0.016502	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B102<173,$C$18*(173-B102),$C$18),2)	=+((14.7-D102)*144*E102)+F102-G102+H102-I102	=$C$28	=IF((+K102-J102)/(144*E102)>0,(+K102-J102)/(144*E102),0)	=+C102-14.7	3.1
103	100697.01	176.4	19.56	6.931	0.016488	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B103<173,$C$18*(173-B103),$C$18),2)	=+((14.7-D103)*144*E103)+F103-G103+H103-I103	=$C$28	=IF((+K103-J103)/(144*E103)>0,(+K103-J103)/(144*E103),0)	=+C103-14.7	3.1
104	110697.01	174.4	19.26	6.625	0.016476	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B104<173,$C$18*(173-B104),$C$18),2)	=+((14.7-D104)*144*E104)+F104-G104+H104-I104	=$C$28	=IF((+K104-J104)/(144*E104)>0,(+K104-J104)/(144*E104),0)	=+C104-14.7	2.6
105	120697.01	172.9	19	6.404	0.016467	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B105<173,$C$18*(173-B105),$C$18),2)	=+((14.7-D105)*144*E105)+F105-G105+H105-I105	=$C$28	=IF((+K105-J105)/(144*E105)>0,(+K105-J105)/(144*E105),0)	=+C105-14.7	2.6
106	130684.82	171.5	18.77	6.202	0.016459	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B106<173,$C$18*(173-B106),$C$18),2)	=+((14.7-D106)*144*E106)+F106-G106+H106-I106	=$C$28	=IF((+K106-J106)/(144*E106)>0,(+K106-J106)/(144*E106),0)	=+C106-14.7	2.1
107	140684.83	170.2	18.56	6.02	0.016452	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B107<173,$C$18*(173-B107),$C$18),2)	=+((14.7-D107)*144*E107)+F107-G107+H107-I107	=$C$28	=IF((+K107-J107)/(144*E107)>0,(+K107-J107)/(144*E107),0)	=+C107-14.7	2.1
108	150684.83	169	18.36	5.858	0.016445	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B108<173,$C$18*(173-B108),$C$18),2)	=+((14.7-D108)*144*E108)+F108-G108+H108-I108	=$C$28	=IF((+K108-J108)/(144*E108)>0,(+K108-J108)/(144*E108),0)	=+C108-14.7	1.7
109	160684.83	167.7	18.17	5.683	0.016437	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B109<173,$C$18*(173-B109),$C$18),2)	=+((14.7-D109)*144*E109)+F109-G109+H109-I109	=$C$28	=IF((+K109-J109)/(144*E109)>0,(+K109-J109)/(144*E109),0)	=+C109-14.7	1.7
110	170684.83	168.5	18.01	5.526	0.016431	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B110<173,$C$18*(173-B110),$C$18),2)	=+((14.7-D110)*144*E110)+F110-G110+H110-I110	=$C$28	=IF((+K110-J110)/(144*E110)>0,(+K110-J110)/(144*E110),0)	=+C110-14.7	1.3
111	180684.83	165.3	17.83	5.374	0.016424	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B111<173,$C$18*(173-B111),$C$18),2)	=+((14.7-D111)*144*E111)+F111-G111+H111-I111	=$C$28	=IF((+K111-J111)/(144*E111)>0,(+K111-J111)/(144*E111),0)	=+C111-14.7	1.3
112	190684.83	164.1	17.65	5.225	0.016417	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B112<173,$C$18*(173-B112),$C$18),2)	=+((14.7-D112)*144*E112)+F112-G112+H112-I112	=$C$28	=IF((+K112-J112)/(144*E112)>0,(+K112-J112)/(144*E112),0)	=+C112-14.7	1.3
113	193184.83	163.8	17.6	5.188	0.016415	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B113<173,$C$18*(173-B113),$C$18),2)	=+((14.7-D113)*144*E113)+F113-G113+H113-I113	=$C$28	=IF((+K113-J113)/(144*E113)>0,(+K113-J113)/(144*E113),0)	=+C113-14.7	1.3
114	195684.83	163.5	17.56	5.151	0.016414	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B114<173,$C$18*(173-B114),$C$18),2)	=+((14.7-D114)*144*E114)+F114-G114+H114-I114	=$C$28	=IF((+K114-J114)/(144*E114)>0,(+K114-J114)/(144*E114),0)	=+C114-14.7	1.3
115	198184.83	163.2	17.52	5.115	0.016412	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B115<173,$C$18*(173-B115),$C$18),2)	=+((14.7-D115)*144*E115)+F115-G115+H115-I115	=$C$28	=IF((+K115-J115)/(144*E115)>0,(+K115-J115)/(144*E115),0)	=+C115-14.7	1.3
116	200684.83	162.9	17.47	5.079	0.01641	=$C$25	=0.0000000477*$C$9^2	=$C$15	=ROUND(IF(B116<173,$C$18*(173-B116),$C$18),2)	=+((14.7-D116)*144*E116)+F116-G116+H116-I116	=$C$28	=IF((+K116-J116)/(144*E116)>0,(+K116-J116)/(144*E116),0)	=+C116-14.7	0
117														

VY CALCULATION DATABASE INPUT FORM

Place this form in the calculation package immediately following the Title page or CCN form.

VYC-0808 / 05	6	N/A	N/A
VY Calculation/CCN Number	Revision Number	Vendor Calculation Number	Revision Number

Vendor Name: N/A PO Number: N/A

Originating Department: Fluid Systems

Critical References Impacted: ☒ UFSAR ☒ DBD ☐ Reload. "Check" the appropriate box if any critical document is identified in the tables below.

EMPAC Asset/Equipment ID Number(s): P-10-1A/B/C/D, P-46-1A/B

EMPAC Asset/System ID Number(s): 10, 14

Keywords: Residual Heat Removal (RHR), Core Spray (CS), Net Positive Suction Head (NPSH), Loss of Coolant Accident (LOCA), Extended Power Uprate (EPU)

For Revision/CCN only: Are deletions to General References, Design Input Documents or Design Output Documents required? ☐ Yes† ☒ No

Design Input Documents and General References - The following documents provide design input or supporting information to this calculation. (Refer to Appendix A, sections 3.2.7 and section 4)

* Reference #	** DOC #	REV #	***Document Title (including Date, if applicable)	Significant Difference Review ††	**** Affected Program	Critical Reference (✓)
1	GE-VYNPS-AEP-346	N/A	VYNPS EPU T0400: DBA-LOCA for Long Term NPSH evaluation (6/10/04)			
2	VYC-1924	0	DE&S Calc. DC-A34600-006. Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment, RHR and CS Debris Head Loss Calculations			
3	VYC-0808 / CCN 03	6	Core Spray and Residual Heat Removal Pump Net Positive Suction Head Margin Following a Loss of Coolant Accident			
4	VYC-0808	6	Core Spray and Residual Heat Removal Pump Net Positive Suction Head Margin Following a Loss of Coolant Accident			
5	ERC-2004-024	N/A	Revised OPL-4 Input for Minimum DW Pressure Case dated 6/8/04			
6			NOT USED			
7			ASME Steam Tables, 1967 IFC Formulation for Industrial Use			
8	ERC No. 2003-027	N/A	Debris Source Terms Appropriate for Power Uprate Evaluations of ECCS NPSH (5/13/03)			
9	RHR	1/IC16	Design Basis Document for Residual Heat Removal System			✓
10	VYC-1924 / CCN 02	0	DE&S Calc. DC-A34600-006. Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment, RHR and CS Debris Head Loss Calculations			
11	VYC-0808 / CCN 04	6	Core Spray and Residual Heat Removal Pump Net Positive Suction Head Margin Following a Loss of Coolant Accident or Anticipated Transients Without Scram			

Design Output Documents - This calculation provides output to the following documents. (Refer to Appendix A, section 5)

* Reference #	** DOC #	REV #	Document Title (including Date, if applicable)	**** Affected Program	†††Critical Reference (✓)
12	NEDC-33090P	0	Safety Analysis Report For VYNPS Constant Pressure Power Uprate (PUSAR)		
13	VYC-1628	0	Torus Temperature and Pressure Response to Large Break LOCA and MSLB Accident Scenarios (may be superseded be GE EPU analysis)		
14	SADBD	2/IC2	Topical Design Basis Document for Safety Analysis		✓
15	UFSAR	17	Updated Final Safety Analysis Report		✓
16	RHR	1/IC16	Design Basis Document for Residual Heat Removal System		✓
17	CS	0/IC10	Design Basis Document for Core Spray System		✓

* Reference # - Assigned by preparer to identify the reference in the body of the calculation.

** Doc # - Identifying number on the document, if any (e.g., 5920-0264, G191172, VYC-1286)

*** Document Title - List the specific documentation in this column. "See attached list" is not acceptable. Design Input/Output Documents should identify the specific design input document used in the calculation or the specific document affected by the calculation and not simply reference the document (e.g., VYDC, MM) that the calculation was written to support. If a DBD is used as a general reference, include the most current interim change number after the title.

**** Affected Program - List the affected program or the program that reference is related to or part of.

† If "yes," attach a copy of "VY Calculation Data" marked-up to reflect deletion (See Section 3.1.8 for Revision and 5.2.3.18 for CCNs).

†† If the listed input is a calculation listed in the calculation database that is not a calculation of record (see definition), place a check mark in this space to indicate completion of the required significant difference review. (see Appendix A, section 4.1.4.4.3). Otherwise, enter "N/A."

††† If the reference is UFSAR, DBD or Reload (IASD or OPL), check Critical Reference column and check UFSAR, DBD or Reload, as appropriate, on this form (above).