ENCLOSURE 4

Core Spray (CS) Pump NPSH Analysis

Exhibit NE-C-420-1, Rev. 2
Effective Date:

PECO Nuclear
Doctype 061

CALCULATION COVER SHEET

1. Calculation No. PM-1011

2. LGS ☐ PBAPS ☑

3. Unit(s) 2 & 3

4. MOD/ECR/Other No. P-00350-2

5. Last Page No. 35

6. Safety Related ☒ Non-Safety Related ☐

7. Description: CORE SPRAY PUMP NPSH

8. System/Topic No.: 14
Structure: N/A
Component:

Record of Revisions

9. Rev. No.	10. Description of Revision	11. Vendor Calc. Number	11. Vendor Calc. Rev.	12. Assumptions YES	12. Assumptions NO	13. Signatures Preparer	13. Signatures Reviewer	13. Signatures Approver(s) / Date
2	INCORPORATE REVISION TO MINIMUM CONTAINMENT PRESSURE FOLLOWING A LARGE BREAK LOCA AS DETERMINED FROM PM-1013 Rev.1					C.J. Bower 6/19/98	[signature]	E-W1K [signature] 6/23/98

14. Related Calculation No(s).
Provides Info. To:
Receives Info. From: PM-1013, R1

15. Manual ☑
Computer ☐
Computer Program & Version No.:

16. Provides Info. To:
UFSAR/Tech.Spec./etc.:

17. Total Pages: 35
(DS Info. Only)

PORC	NO
SQR	NO
NQA	NO
50.59	NO
RESP MGR	YES

CALC. # PM-1011 REV. 2

DCD # ______ DATE: ______

CALCULATION REVIEW CHECKLIST

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

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

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

List the documents used to support this review. PM-1011 & ASSOC. DOC'S LISTED IN 6. REFERENCES

REVIEWED BY: [signature] DATE: 6/19/98

1. PURPOSE / OBJECTIVE

The purpose of this calculation is:

A. to determine the NPSH margin for the Core Spray pumps and required containment overpressure as a function of time following a DBA LOCA, (recirc. suction line break) assuming one case with the strainer design basis debris loading and one case with the maximum expected post LOCA debris load, maximum torus water level drawdown, maximum high pressure service water temperature and containment sprays activated at time = 0 seconds.

B. to determine the effect on NPSHA if a LOCA occurs while purging. Some nitrogen and steam will be lost before the purge valves close, which will affect the containment overpressure and therefore NPSH available to the pumps. This is evaluated with an additional 1 ft. loss of torus water level and the maximum expected post LOCA strainer debris load.

C. to generate curves for various pool levels, pool temperatures and overpressure conditions to determine the limits of these parameters for adequate pump NPSH. Four curves will be generated to demonstrate the temperature impact on allowable pump flow rate from various overpressure conditions for 4 torus water levels; 10.5', 12.3', 14.5' and 20'. All curves assume clean suction strainers.

NOTE: THIS CALCULATION SUPERCEDES THE NPSH AND SUCTION PIPING PRESSURE DROP CALCULATIONS FOR THE UNITS 2 AND 3 CORE SPRAY PUMP SUCTIONS FROM THE TORUS IN CALCULATIONS 18247-M-006, 18247-M-29; AND ME-363; AND PARTIALLY SUPERCEDES CALCULATION 11187-M-024 AND 18247-M-001.

Utilization of this calculation by persons without access to the pertinent factors and without proper regard for its purpose could lead to erroneous conclusions. Should it become desirable to use this calculation to support design or station activities other than those explicitly specified in this section, the responsible engineering branch shall be contacted to ensure that the purposes, assumptions, judgments, and limitations are thoroughly understood.

2. SUMMARY OF RESULTS

Part A

The limiting NPSH margin for the DBA LOCA (700 cu.ft. of NUKON) is 6.65 ft., which occurs at the maximum torus temperature of 205.7°F and a containment pressure of 22.10 psia.

Part B

Should a LOCA occur while the containment is being purged, the NPSH margin would be reduced from 6.65 ft. to 4.59 ft., which is acceptable.

Part C

Curves developed by this calculation for the most limiting condition for the core spray pumps are included in pages 34 through 47.

3. DESIGN INPUT / CRITERIA

Design Inputs for this calculation are as follows:

1. The torus temperatures and pressures evaluated in Parts A and C are taken from Calculation PM-1013, Rev.0 (Ref. 15)
2. The torus temperatures and pressures evaluated in Part B are taken from Reference 1.
3. Piping data was derived from Ref. 5 through 9.
4. Suction strainer data is taken from Ref. 22.
5. Core Spray pump NPSHR data is taken from Ref. 15.
6. Torus level and pump flow rates following LOCA are taken from Reference 1 for all cases.
7. Strainer ΔP data is as follows: (Ref. 22, Appendix III)

1633 ft^3 Nukon debris load (strainer design basis)

Temperature (°F)	Pump flow (gpm)	ΔP (ft.)
205.7	3125	4.34
205.7	4030	5.68

700 ft^3 NUKON debris load (debris load in zone of destruction)

Temperature (°F)	Pump flow (gpm)	ΔP (ft.)
205.7	3125	1.69

Clean Strainer

Temperature (°F)	Pump Flow (gpm)	ΔP (ft.)
205.7	3125	1.35

4. Computer Calculations

No computer calculations were used in the development of this calculation. Excel spreadsheets were utilized. However, these spreadsheets were utilized as an automated calculator only.

5. Assumptions

1. The computation of the torus temperature based on calculated vapor pressure, in part B, is not completely interpolated in that the pressure conversion factor uses the value of 2.31 rather than a temperature corrected value. The effect on NPSH due to this minor underestimation of temperature is not significant.

6. References

1. GE letter Report EAS 10-0289 on Suppression Pool Drawdown, May 18,1989, transmitted by G-HE-9-114, dated May 18, 1989, DC# 027673.

2. Piping Specification M-300, Rev.14

3. NUREG/CR-2772 - "Hydraulic Performance of Pump Suction Inlets for Emergency Core Cooling Systems in Boiling Water Reactors", June 1982.

4. Peach Bottom UFSAR Fig. 6.4.2, Condition IV.

5. Bechtel Drawing 6280-M-93, Rev. 17

6. ISO 2-14-1, Rev. 3

7. ISO 2-14-3, Rev. 11

8. ISO 2-14-8, Rev. 2

9. ISO 2-14-10, Rev. 2

10. Crane Technical Paper N. 410 "Flow of Fluids Through Valves, Fittings, and Pipe", 1980 Edition.

11. ASME Steam Tables, 5th Edition

12. Peach Bottom Improved Tech. Spec. 3.6.2.2

13. NE-265 - Specification for ECCS Suction Strainers, Limerick Generating Station, Units 1 and 2 and Peach Bottom Atomic Power Station Units 2 and 3, Rev. A, dated February 11,1997.

14. Calculation PM-1004, Rev 0

15. Pump Curve - Core Spray Pump - Dwg. 6280-M-1-U-224-14

16. Dwg. 6280-M1-U-99, Rev. 15

17. Calculation PM-1013, Rev. 1

18. P&ID M-362 Sheet 2 Rev. 60 Core Spray Cooling System

19. Calculation 11187-M-024, Rev.2

20. UFSAR Fig. 14.6.10B, Rev.13
21. UFSAR Fig. 14.6.12A, Rev.13
22. SDOC # NE-265-17, Rev.1
23. Calculation ME-
24. Calculation ME-
25. SDOC#NE-265-16, Rev.0

7. Attachments

Attachment #1: Pressure Drops - PBAPS Unit 3 Strainers (Reference 22, pages 19 and 20)

Attachment #2: Core Spray Pump Curves (Reference 15)

8. Analysis

A. NPSH Margins for the Core Spray Pumps Under the Worst Expected Accident Conditions

The methodology used to perform this calculation was to review the suction piping arrangement for the Core Spray pumps at Peach Bottom to determine the K value for each suction loop. The bounding K value was then used along with the strainer head losses from Ref. 22 to calculate the total head losses through the bounding CS suction loop for the temperatures given in Ref. 17. This information was combined with containment pressure data from Ref. 17 to calculate NPSHA. This data was compared to the NPSHR for the Core Spray pumps to determine NPSH margin at various times following a DBA LOCA.

Calculating NPSHA

$NPSHA = Z_{sp} - Z_{pump} + 144P_{sp}/\rho - h_f - h_{st} - 144P_{vap}/\rho$

where: Z_{sp} = Elevation of torus water surface

Z_{pump} = Elevation of pump suction

Note: Center line of the Core Spray pump suction is at elevation 94'-6", (i.e., equal to the elevation of the bottom of the torus). Thus, $Z_{sp} - Z_{pump}$ is equal to the torus water level.

P_{sp} = Torus pressure

P_{vap} = vapor pressure at torus water temperature

h_f = piping friction losses

h_{st} = strainer head loss

ρ = density of water at torus water temperature

Calculating h_f

The method used to calculate h_f for the various flow rates and temperatures is as follows:

1) Calculate h_f at some reference temperature and flow rate.

2) Calculate h_f at other temperatures and flows using the following equation:

$$h_{f2} = h_{f1} x\ (Q_2 / Q_1)^2 \times (\ v_2 / v_1\ )$$

where: h_{f1} = reference piping head loss

h_{f2} = calculated piping head loss

Q_1 = flow rate for reference piping losses

Q_2 = flow rate for calculated piping losses

v_1 = specific volume for water at reference temperature

v_2 = specific volume for water at temperature at which piping losses are being calculated

Reference piping losses:

From Ref. 10, pg. 3-4 $h_f = 0.00259\ KQ^2/d^4$

For 16" Core Spray Suction Piping d = 15.25 in.

D = 1.27 ft.

Piping Takeoffs :

Pump A Suction Piping:

Piping Segment	Dia. (in.)	Length
1	15.25	3'-8"
2	15.25	13'-10"
3	15.25	6'-0"
4	15.25	6'-0"
5	15.25	3'-9"
6	15.25	2'-7¼"
Total		35'-10¾" or 35.90 ft.

K value for "A" Pump Suction Piping: $K = f_t L/D = 35.9f_t / 1.27 = 28.27\ f_t$

Pump B Suction Piping:

Piping Segment	Dia. (in.)	Length
1	15.25	3'-8"
2	15.25	1'-3"
3	15.25	7'-5¾"
4	15.25	3'-6"
5	15.25	11'-4"
Total		27'-2¾" or 27.23 ft

K value for "B" Pump Suction Piping: $K = f_t L/D = 27.23f_t / 1.27 = 21.44\ f_t$

Pump C Suction Piping

Piping Segment	Dia (in.)	Length
1	15.25	3'-6"
2	15.25	1' - 0"
3	15.25	5'-8"
4	15.25	1'-0"
5	15.25	14'-0"
Total		25'-2" or 25.17 ft

K value for "C" Pump Suction Piping: $K = f_t L/D = 25.17f_t / 1.27 = 19.82\ f_t$

Pump D Suction Piping

Piping Segment	Dia (in.)	Length
1	15.25	1'-4"
2	15.25	0'-6"
3	15.25	1'-6"
4	15.25	11'-7¼"
5	15.25	2'-6"
6	15.25	6'-10"
7	15.25	3'-9"
Total		28'-0" or 28.0 ft

K value for "D" Pump Suction Piping: $K = f_t L/D = 28.0 f_t / 1.27 = 22.05 f_t$

Pipe Fitting Takeoff (See Ref. 10 pg. A-27 to A-29, for K values)

Pump "A" Suction Piping

Fitting Type	K	No. of Fittings	Total K
90° L.R. Elbow	14 f_t	4	56 f_t
Tee (flow thru run)	20 f_t	1	20 f_t
60° L.R. Elbow	8.5 f_t	2	17 f_t
Gate Valve	8 f_t	1	8 f_t
Total			101 f_t

Pump "B" Suction Piping

Fitting Type	K	No. of Fittings	Total K
90° L.R. Elbow	14 f_t	5	70 f_t
Tee (flow thru run)	20 f_t	1	20 f_t
60° L.R. Elbow	8.5 f_t	1	8.5 f_t
Gate Valve	8 f_t	1	8 f_t
Total			106.5 f_t

Pump "C" Suction Piping

Fitting Type	K	No. of Fittings	Total K
90° L.R. Elbow	14 f_t	5	70 f_t
Tee (flow thru run)	20 f_t	1	20 f_t
60° L.R. Elbow	8.5 f_t	1	8.5 f_t
Gate Valve	8 f_t	1	8 f_t
Total			106.5 f_t

Pump "D" Suction Piping

Fitting Type	K	No. of Fittings	Total K
90° L.R. Elbow	14 f_t	4	56 f_t
Tee (flow thru run)	20 f_t	1	20 f_t
60° L.R. Elbow	8.5 f_t	1	8.5 f_t
45° L.R. Elbow	9.9 f_t	1	9.9 f_t
Gate Valve	8 f_t	1	8 f_t
Total			102.4 f_t

Total Piping Resistance K Value

Pump Suction	Piping K	Fitting K	Total K
A	28.27 f_t	101.0 f_t	129.27 f_t
B	21.44 f_t	106.5 f_t	127.9 f_t
C	19.82 f_t	106.5 f_t	126.3 f_t
D	22.05 f_t	102.4 f_t	124.45 f_t

For a reference point, calculate the piping loss for a flow rate of 3125 gpm at a temperature of 205.7°F.

For old Core Spray pipe assume ε = 0.00085 (ref 10, pg. A-23, value for cast iron) (ε/D = 0.00067)

Calculating Reynold's Number $Re = 50.6\, Q\rho / d\mu$ (Ref. 10, pg. 3-2)

$\mu = 0.299$ (Ref. 10, pg. A-2)

Therefore: for 205.7°F $Re = 2.08\ E + 06$

From Ref. 10, pg. A-24

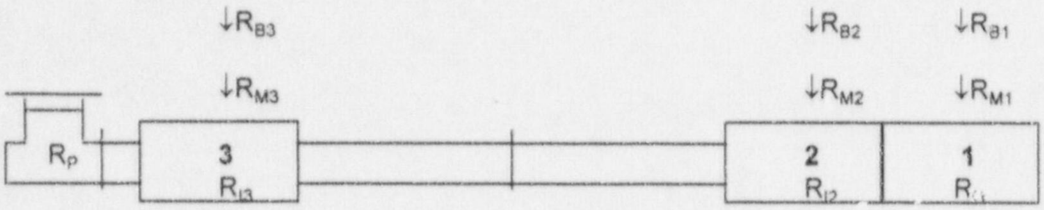
for 205.7°F $f_t = 0.018$

Finally:

Pump	Temp(°F)	K	h_f (ft.)
A	205.7	2.33	1.09
B	205.7	2.3	1.07
C	205.7	2.27	1.06
D	205.7	2.24	1.05

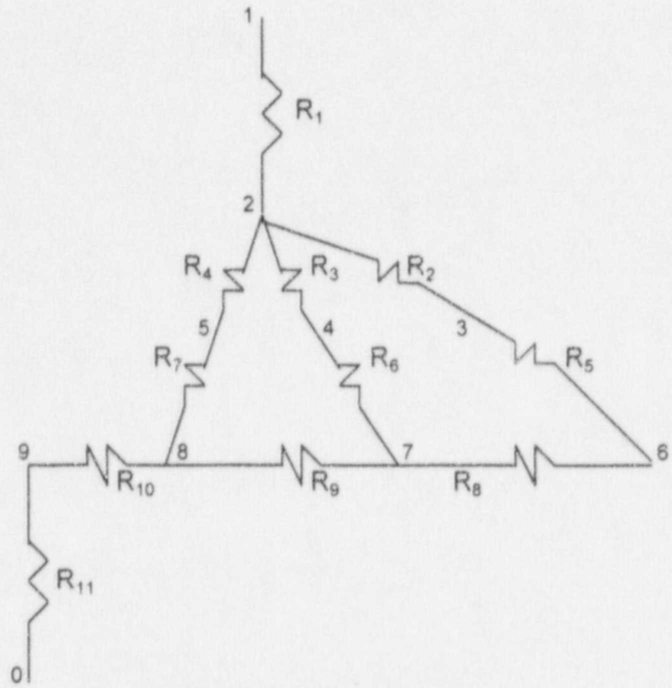
Calculating h_{st}

Given the Core Spray strainer configuration for Peach Bottom as shown below, it can be seen that in order to calculate the strainer head-loss, the percentage of the total strainer flow which passes through each module must be known.



CS Train Configuration

$$R_{B1} + R_{M1} + R_{I1} + R_{I2} + R_{I3} + R_P = R_{TOTAL}$$



CS Resistance Network

Strainer Design Basis Debris Load (1633 ft^3)

From Ref. 22, Appendix :II the percentage of total flow which passes through module 1, the flow rate, temperature and head-loss data is given as follows for a debris load of 1633 ft^3 of NUKON.

Total Strainer Flow (gpm)	Temperature (°F)	Module 1 % of Total Flow	Module 2 % of Total Flow	Module 3 % of Total Flow
4030	205.7	31.75	31.85	36.59
3125	205.7	33.65	33.74	[illegible]7.69

Choosing 4030 gpm at 205.7°F as the reference value, an equation was developed to calculate the percentage of total flow as a function of flow and temperature.

The function for calculating percentage of total flow is as follows:

$$\%_1 = \%_{1ref} \times (Q_1 / Q_{1ref})^{-0.04172} \times (\mu_1 / \mu_{1ref})^{0.01922}$$

$$\%_2 = \%_{2ref} \times (Q_2 / Q_{2ref})^{-0.03913} \times (\mu_2 / \mu_{2ref})^{0.01805}$$

where:

% = Flow percentage at Q and T

$\%_{ref}$ = Flow percentage at reference flow rate and temperature

Q = New flow (gpm)

Q_{ref} = Reference flow (gpm)

μ= Kinematic viscosity at new temperature T

μ_{ref} = Kinematic viscosity at reference temperature T_{ref}

Calculating flow percentages for each module for the data given in Ref. 22 (Appendix II) yields the following results:

Module	Flow	Temperature	Ref. 22 Flow %	Calculated Flow %	Percent Difference
1	4030	213	31.690	31.690	0
	4030	100	32.214	32.214	0
	3125	213	32.028	32.028	0
	3125	100	32.510	32.557	0.15%
2	4030	213	31.789	31.789	0
	4030	100	32.282	32.282	0
	3125	213	32.107	32.107	0
	3125	100	32.569	32.605	0.11%
3	4030	213	36.521	36.521	0
	4030	100	35.504	35.504	0
	3125	213	35.865	35.865	0
	3125	100	34.921	34.867	-0.16%

Maximum Expected Post LOCA Debris Load (700 ft^3)

From Ref. 22, Appendix III the percentage of total flow which passes through module 1, the flow rate, temperature and head-loss data is given as follows for a debris load of 700 ft^3 of NUKON.

Total Strainer Flow (gpm)	Temperature (°F)	Module 1 % of Total Flow	Module 2 % of Total Flow	Module 3 % of Total Flow
3125	205.7	29.40	29.64	40.96

Choosing 3125 gpm at 205.7°F as the reference value, an equation was developed to calculate the percentage of total flow as a function of flow and temperature.

The function for calculating percentage of total flow is as follows:

$$\%_1 = \%_{1ref} \times (Q_1 / Q_{1ref})^{-0.04172} \times (\mu_1 / \mu_{1ref})^{0.02311}$$

$$\%_2 = \%_{2ref} \times (Q_2 / Q_{2ref})^{-0.04172} \times (\mu_2 / \mu_{2ref})^{0.02131}$$

where:

% = Flow percentage at Q and T

$\%_{ref}$ = Flow percentage at reference flow rate and temperature

Q = New flow (gpm)

Q_{ref} = Reference flow (gpm)

μ= Kinematic viscosity at new temperature T

μ_{ref} = Kinematic viscosity at reference temperature T_{ref}

Calculating flow percentages for each module for the data given in Ref. 22 (Appendix II) yields the following results:

Module	Flow	Temperature	Ref. 22 Flow %	Calculated Flow %	Percent Difference
1	3125	213	29.398	29.398	0
	3125	100	29.983	29.983	0
2	3125	213	29.638	29.638	0
	3125	100	30.181	30.181	0
3	3125	213	40.965	40.965	0
	3125	100	39.836	39.836	0

Given the flow percentage, the head loss for the strainer can be extrapolated from some reference value:

Extrapolating Strainer Head Loss:

The head loss across a fouled strainer is equal to the sum of the bed and form losses. The bed losses represent the viscous losses across the debris bed, and the form losses represent the friction losses through the strainer assembly.

Strainer Design Basis Debris Load (1633 ft^3)

Head loss for the replacement strainers is given in Ref. 22 (Appendix III, page III-7) as:

Flow Rate	Temperature	Total Loss (ft.)
4030	205.7	5.680
3125	205.7	4.335

Bed losses:

The bed losses vary as a function of the flow rate and the kinematic viscosity of water at the temperature of the torus water. The bed losses vary as a function of the flow rate and not the flow rate squared because the flow rate across the debris bed is sufficiently low as to be laminar.

The bed losses for the replacement strainers are given in Ref. 22 (App. III, page III-7) as follows:

Flow Rate (gpm)	Temperature (°F)	Bed Loss (ft.)
4030	205.7	4.215
3125	205.7	3.419

Choosing the bed losses at 4030 gpm and 205.7°F as a reference value, the following formula was developed to extrapolate the bed losses to other flows and temperatures:

$h_1 = h_{ref} \times (\%_1 \times Q_1 / \%_{ref} \times Q_{ref})^{0..81878} \times (\mu_{e1} / \mu_{eref})^{0.77147}$

where:

h_1 = calculated bed loss

h_{ref} = reference bed loss

$\%_1$ = calculated % of total flow

$\%_{ref}$ = reference % of total flow

Q_1 = extrapolated total flow

Q_{ref} = reference total flow

μ_{e1} = kinematic viscosity at extrapolated temperature

μ_{eref} = kinematic viscosity at reference temperature

Calculating the bed losses for the Ref. 22, Appendix III data yields the following results:

Total Flow (gpm)	Temperature (°F)	Bed Loss (Ref.22)	Bed Loss (calculated)	% difference
4030	205.7	4.215	4.215	0
3125	205.7	3.419	3.452	1.0%

Form Losses:

The form losses vary as a function of the square of the velocity or flow. The form losses for the replacement strainers are given in Ref. 22, Appendix III. The form losses for the replacement strainers are as follows:

Flow Rate (gpm)	Temperature (°F)	Form Losses (ft)
4030	205.7	1.465
3125	205.7	0.916

The form losses consist of three components, the drag and turning losses through the strainer mesh, the internal drag losses in strainer module 1 and the drag losses in the common tee discharge.

Choosing the form losses at 4030 gpm and 205.7°F as the reference value, the form losses can be extrapolated to other flow and temperature conditions using the following expression:

$$h_1 = h_{mesh}(\%_1 \times Q_1 / \%_{REF} \times Q_{REF})^2$$
$$+ h_{internal} ((Q_1 \times (\%_1 + \%_2)) / (Q_{REF} \times (\%_{REF-1} + \%_{REF-2})))^2$$
$$+ h_{tee} (Q_1 / Q_{REF})^2$$

where:

h_1 = form losses at extrapolated flow and temperature conditions

h_{mesh} = reference drag and turning losses for module 1 mesh

$h_{internal}$ = reference internal strainer drag losses for module 1

h_{tee} = reference drag losses for common tee

$\%_1$ = % of total flow through module 1 at extrapolated flow and temperature conditions

$\%_2$ = % of total flow through module 2 at extrapolated flow and temperature conditions

$\%_{ref-1}$ = % of total flow through module 1 at reference conditions

$\%_{ref-2}$ = % of total flow through module 2 at reference conditions

Q_1 = extrapolated total flow

Q_{ref} = reference total flow

Values for h_{mesh}, $h_{internal}$ and h_{tee} are found in Ref.22 Appendix III, page III-14 as follows:

h_{mesh} = 0.127 ft.

$h_{internal}$ = 0.358 ft.

h_{toe} = 0.979 ft.

Calculating the form losses for the Ref. 22, Appendix III data yields the following results:

Flow (gpm)	Temperature (°F)	Form Losses (Ref.22)	Form Losses (Calculated)	% Difference
4030	205.7	1.465	1.465	0
3125	205.7	0.916	0.887	3.2%

Finally, the form and bed losses as calculated were compared to the Ref. 22, Appendix III values as follows:

Flow (gpm)	Temperature (°F)	Strainer Loss (ft) (Ref.22)	Strainer Loss (ft) (Calculated)	% Difference
4030	205.7	5.680	5.680	0
3125	205.7	4.335	4.339	0.1%

Maximum Expected Post LOCA Debris Load (700 ft^3)

Head loss for the replacement strainers is given in Ref. 22 (Appendix III, page III-7, Licensing Case) as:

Flow Rate	Temperature	Total Head Loss (ft.)
3125	205.7	1.694

Bed losses:

The bed losses vary as a function of the flow rate and the kinematic viscosity of water at the temperature of the torus water. The bed losses vary as a function of the flow rate and not the flow rate squared because the flow rate across the debris bed is sufficiently low as to be laminar.

The bed losses for the replacement strainers are given in Ref. 22 (App. III, page III-7, Licensing Case) as follows:

Flow Rate (gpm)	Temperature (°F)	Bed Loss (ft.)
3125	205.7	0.854

Choosing the bed losses at 3125 gpm and 205.7°F as a reference value, the following formula was developed to extrapolate the bed losses to other flows and temperatures:

$$h_1 = h_{ref} \times (\%_1 \times Q_1 / \%_{ref} \times Q_{ref})^{1.11670} \times (\mu_{e1} / \mu_{eref})^{0.41029}$$

where:

h_1 = calculated bed loss

h_{ref} = reference bed loss

$\%_1$ = calculated % of total flow

$\%_{ref}$ = reference % of total flow

Q_1 = extrapolated total flow

Q_{ref} = reference total flow

μ_{e1} = kinematic viscosity at extrapolated temperature

μ_{eref} = kinematic viscosity at reference temperature

Calculating the bed losses for the Ref. 22, Appendix III data yields the following results:

Total Flow (gpm)	Temperature (°F)	Bed Loss (Ref.22)	Bed Loss (calculated)	% difference
3125	205.7	0.854	0.854	0

Form Losses:

The form losses vary as a function of the square of the velocity or flow. The form losses for the replacement strainers are given in Ref. 22, Appendix III, Page III-7, Licensing Case. The form losses for the replacement strainers are as follows:

Flow Rate (gpm)	Temperature (°F)	Form Losses (ft)
3125	205.7	0.840

The form losses consist of three components, the drag and turning losses through the strainer mesh, the internal drag losses in strainer module 1 and the drag losses in the common tee discharge.

Choosing the form losses at 3125 gpm and 205.7°F as the reference value, the form losses can be extrapolated to other flow and temperature conditions using the following expression:

$$h_1 = h_{mesh}(\%_1 \times Q_1 / \%_{REF} \times Q_{REF})^2$$
$$+ h_{internal} ((Q_1 \times (\%_1 + \%_2)) / (Q_{REF} \times (\%_{REF\text{-}1} + \%_{REF\text{-}2})))^2$$
$$+ h_{tee} (Q_1 / Q_{REF})^2$$

where:

h_1 = form losses at extrapolated flow and temperature conditions

h_{mesh} = reference drag and turning losses for module 1 mesh

$h_{internal}$ = reference internal strainer drag losses for module 1

h_{tee} = reference drag losses for common tee

$\%_1$ = % of total flow through module 1 at extrapolated flow and temperature conditions

$\%_2$ = % of total flow through module 2 at extrapolated flow and temperature conditions

$\%_{ref\text{-}1}$ = % of total flow through module 1 at reference conditions

$\%_{ref\text{-}2}$ = % of total flow through module 2 at reference conditions

$\%_{ref}$ = % of total flow through module 1 at reference conditions

Q_1 = extrapolated total flow

Q_{ref} = reference total flow

Values for h_{mesh}, $h_{internal}$ and h_{tee} are found in Ref.22 Appendix III, page III-14 as follows:

h_{mesh} = 0.066 ft.

$h_{internal}$ = 0.1`85 ft.

h_{tee} = 0.588 ft.

Calculating the form losses for the Ref. 22, Appendix III data yields the following results:

Flow (gpm)	Temperature (°F)	Form Losses (Ref.22)	Form Losses (Calculated)	% Difference
3125	205.7	0.840	0.840	0

Finally, the form and bed losses as calculated were compared to the Ref. 22, Appendix III values as follows:

Flow (gpm)	Temperature (°F)	Strainer Loss (ft) (Ref.22)	Strainer Loss (ft) (Calculated)	% Difference
3125	205.7	1.694	1.694	0

NPSH Margin

Combining the piping and strainer losses described above with the pressure and temperature vs. time data from Ref. 17 and the level and flow rate vs. time data from Ref. 1, EXCEL spreadsheets was prepared to calculate the $NPSH_a$ vs $NPSH_R$ and the required overpressure as a function of time after the accident. The spreadsheet is included as Attachment 3. The results of this analysis are shown graphically below. From these graphs, it can be seen that the minimum NPSH margin occurs at the maximum pool temperature. The minimum NPSH margins for the two cases are as follows:

Minimum NPSH Margin (at 205.7°F)

Case	Torus Debris Load (ft^3)	NPSHR (ft)	NPSHA (ft)	Margin (ft)
Strainer Design Basis	1633	26	30.01	4.01
DBA LOCA Design Basis	700	26	32.65	6.65

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CALCULATION SHEET

Core Spray Suction Strainer NPSHa
1633 ft3 of NUKON debris loading

Piping Reference Values

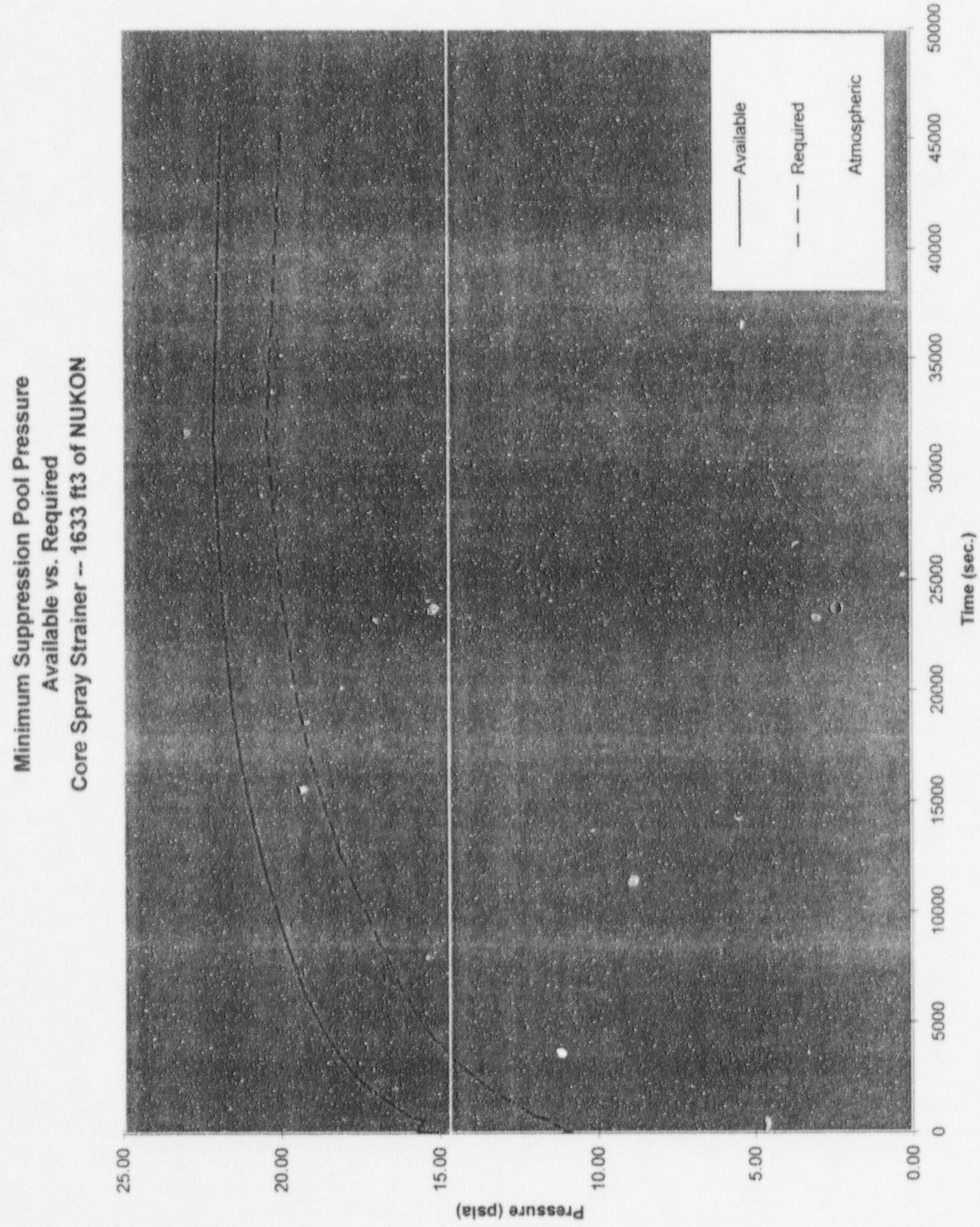
Head Loss	1.09 ft
Flow Rate	3125 gpm
Temperature	205.7 DegF

Strainer Reference Values		Module 1	Module 2	Module 3	Total
Flow Rate	gpm				4030
Temperature	DegF				205.7
Total Head Loss	feet				5.680
Form Loss	feet	0.127438	0.358008	0.079203	1.464849
Flow Fraction	(-)	0.3175	0.3185	0.3659	1.0019
Bed Loss	feet	4.215			

Time seconds	Suppression Pool Pressure psia	Temp DegF	Vap. Press psia	Kin. Visc. ft2/sec	Spec. Volume ft3/lbm	Level feet	CS Pump Flow gpm
0	14.69	95	0.8153	7.791E-06	0.016114	13.65	4030
49	15.41	136	2.6047	5.278E-06	0.016274	13.65	3125
106	15.74	140	2.8892	5.108E-06	0.016293	13.65	3125
600	15.53	148	3.5381	4.794E-06	0.016332	13.65	3125
666	15.74	150.6	3.7184	4.721E-06	0.016343	13.65	3125
805	16.00	154	4.1025	4.581E-06	0.016363	13.65	3125
2074	17.26	168	5.7223	4.143E-06	0.016440	13.65	3125
2622	17.67	172	6.2736	4.032E-06	0.016463	13.65	3125
2995	17.89	174	6.5656	3.978E-06	0.016474	13.65	3125
4290	18.54	180	7.5110	3.825E-06	0.016510	13.65	3125
5571	19.02	184	8.2030	3.728E-06	0.016534	13.65	3125
6475	19.31	186	8.5680	3.682E-06	0.016547	13.65	3125
8592	19.83	190	9.3400	3.592E-06	0.016572	13.65	3125
11143	20.36	194	10.1680	3.506E-06	0.016598	13.65	3125
12505	20.62	196	10.6050	3.465E-06	0.016611	13.65	3125
14383	20.92	198	11.0580	3.424E-06	0.016624	13.65	3125
16448	21.22	200	11.5260	3.385E-06	0.016637	13.65	3125
19302	21.53	202	12.0110	3.346E-06	0.016650	13.65	3125
23787	21.84	204	12.5120	3.308E-06	0.016664	13.65	3125
31667	22.10	206	13.0310	3.271E-06	0.016677	13.65	3125
45533	21.84	204.3	12.5120	3.308E-06	0.016664	13.65	3125
Maxima	22.10	206.00					
Minima	14.69	95.00					

Time seconds	Module 1 Flow Fraction	Module 2 Flow Fraction	Suction Strainer Form Loss ft	Bed Loss ft	Total ft	Piping Form Loss ft	NPSHa ft
0	0.32281	0.32350	1.481	8.310	9.791	1.752	34.30
49	0.32382	0.32444	0.892	5.009	5.902	1.064	36.69
106	0.32361	0.32425	0.892	4.882	5.773	1.065	36.96
600	0.32322	0.32388	0.891	4.644	5.535	1.068	35.25
666	0.32312	0.32379	0.891	4.588	5.479	1.069	35.39
805	0.32294	0.32361	0.891	4.481	5.371	1.070	35.24
2074	0.32231	0.32303	0.889	4.140	5.030	1.075	34.86
2622	0.32214	0.32287	0.889	4.052	4.941	1.076	34.65
2995	0.32206	0.32279	0.889	4.010	1.899	1.077	34.54
4290	0.32182	0.32256	0.888	3.887	4.776	1.080	34.02
5571	0.32166	0.32241	0.888	3.810	4.698	1.081	33.62
6475	0.32158	0.32234	0.888	3.773	4.661	1.082	33.50
8592	0.32143	0.32220	0.888	3.700	4.588	1.084	33.01
11143	0.32128	0.32206	0.888	3.630	4.518	1.085	32.41
12505	0.32121	0.32199	0.887	3.597	4.484	1.086	32.04
14363	0.32113	0.32192	0.887	3.563	4.451	1.087	31.72
16448	0.32106	0.32185	0.887	3.531	4.418	1.088	31.37
19302	0.32099	0.32178	0.887	3.499	4.386	1.089	31.00
23787	0.32092	0.32172	0.887	3.468	4.355	1.090	30.59
31667	0.32085	0.32165	0.887	3.437	4.324	1.090	30.01
45533	0.32092	0.32172	0.887	3.468	4.355	1.090	30.59
Maxima							36.96
Minima							30.01

Time	NPSHr		Suppression Pool	
		Req.Press	Req.Press	Press Margin
seconds	ft	psia	psig	psid
0	26	11.112	-3.578	3.578
49	26	10.847	-3.843	4.563
106	26	11.068	-3.622	4.672
600	26	11.597	-3.093	3.933
666	26	11.748	-2.942	3.992
805	26	12.077	-2.613	3.923
2074	26	13.518	-1.172	3.742
2622	26	14.022	-0.668	3.648
2995	26	14.291	-0.399	3.599
4290	26	15.169	0.479	3.371
5571	26	15.818	1.128	3.202
6475	26	16.161	1.471	3.149
8592	26	16.892	2.202	2.938
11143	26	17.679	2.989	2.681
12505	26	18.097	3.407	2.523
14383	26	18.530	3.840	2.390
16448	26	18.979	4.289	2.241
19302	26	19.445	4.755	2.085
23787	26	19.928	5.238	1.912
31667	26	20.428	5.738	1.672
45533	26	19.928	5.238	1.912
Maxima		20.43	5.74	4.67
Minima		10.85	-3.84	1.67


Minimum Suppression Pool Pressure
Available vs. Required
Core Spray Strainer -- 1633 ft3 of NUKON
Available
Required
Atmospheric
Pressure (psia)
25.00
20.00
15.00
10.00
5.00
0.00
Time (sec.)
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000

Core Spray Suction Strainer NPSHa

700 ft3 of NUKON debris loading

Piping Reference Values

Head Loss	1.09 ft
Flow Rate	3125 gpm
Temperature	205.7 DegF

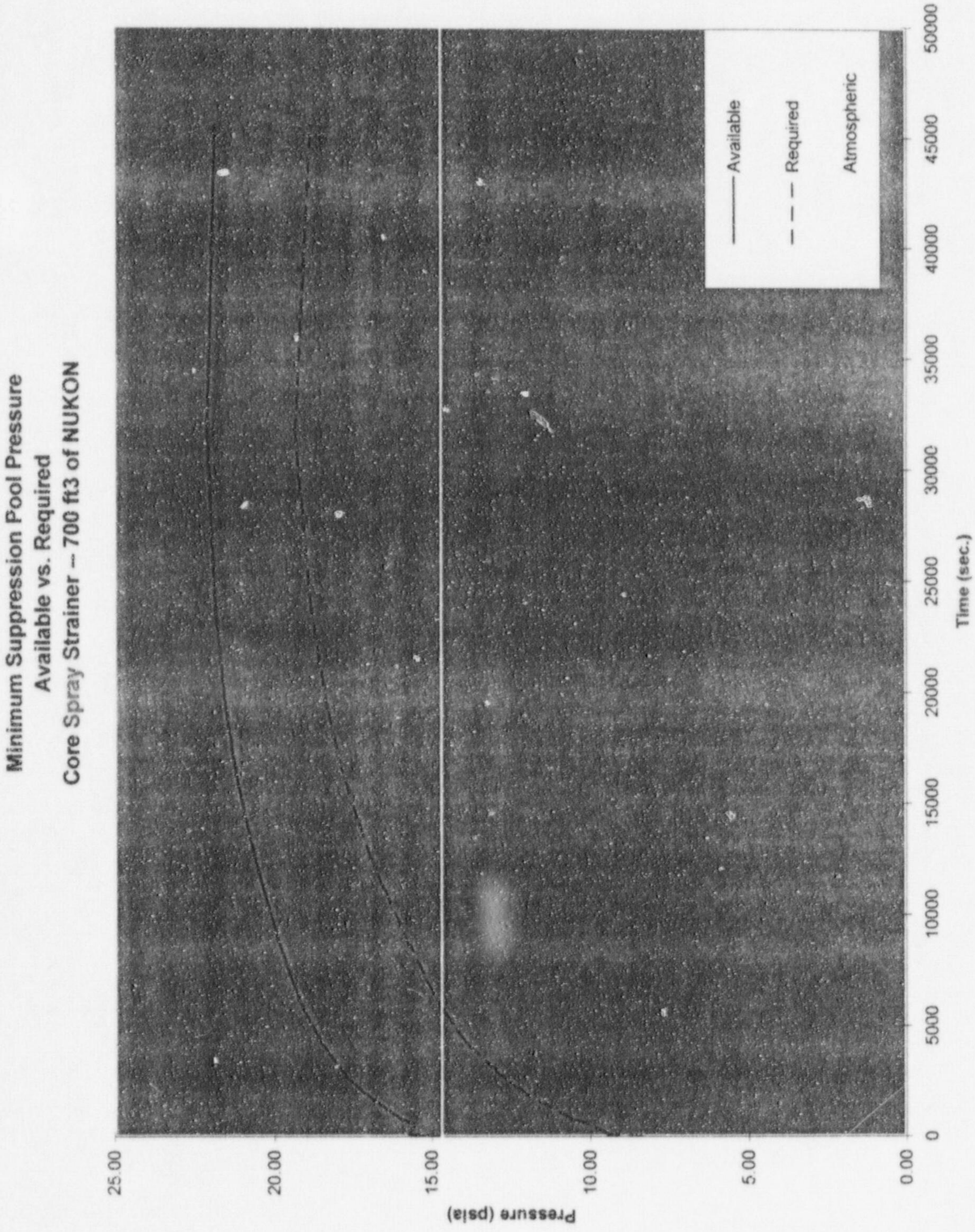
Strainer Reference Values		Module 1	Module 2	Module 3	Total
Flow Rate	gpm				3125
Temperature	DegF				205.7
Total Head Loss	feet				1.594
Form Loss	feet	0.065691	0.185374	0.588793	0.839858
Flow Fraction	(-)	0.2940	0.2964	0.4096	1.0000
Bed Loss	feet	0.854			

Time seconds	Suppression Pool Pressure psia	Temp DegF	Vap. Press psia	Kin. Visc. ft2/sec	Spec. Volume ft3/lbm	Level feet	CS Pump Flow gpm
0	14.69	95	0.8153	7.791E-06	0.016114	13.65	4030
49	15.41	136	2.6047	5.278E-06	0.016274	13.65	3125
106	15.74	140	2.8892	5.108E-06	0.016293	13.65	3125
600	15.53	148	3.5381	4.794E-06	0.016332	13.65	3125
666	15.74	150.6	3.7184	4.721E-06	0.016343	13.65	3125
805	16.00	154	4.1025	4.581E-06	0.016363	13.65	3125
2074	17.26	168	5.7223	4.143E-06	0.016440	13.65	3125
2622	17.67	172	6.2736	4.032E-06	0.016463	13.65	3125
2995	17.89	174	6.5656	3.978E-06	0.016474	13.65	3125
4290	18.54	180	7.5110	3.825E-06	0.016510	13.65	3125
5571	19.02	184	8.2030	3.728E-06	0.016534	13.65	3125
6475	19.31	186	8.5680	3.682E-06	0.016547	13.65	3125
8592	19.83	190	9.3400	3.592E-06	0.016572	13.65	3125
11143	20.36	194	10.1680	3.506E-06	0.016598	13.65	3125
12505	20.62	196	10.6050	3.465E-06	0.016611	13.65	3125
14383	20.92	198	11.0580	3.424E-06	0.016624	13.65	3125
16448	21.22	200	11.5260	3.385E-06	0.016637	13.65	3125
19302	21.53	202	12.0110	3.346E-06	0.016650	13.65	3125
23787	21.84	204	12.5120	3.308E-06	0.016664	13.65	3125
31667	22.10	206	13.0310	3.271E-06	0.016677	13.65	3125
45533	21.84	204.3	12.5120	3.308E-06	0.016664	13.65	3125
Maxima	22.10	206.00					
Minima	14.69	95.00					

Time seconds	Module 1 Flow Fraction	Module 2 Flow Fraction	Suction Strainer Form Loss ft	Suction Strainer Bed Loss ft	Suction Strainer Total ft	Piping Form Loss ft	NPSHa ft
0	0.29675	0.29891	1.404	1.996	3.400	1.752	40.69
49	0.29723	0.29940	0.845	1.219	2.064	1.064	40.53
106	0.29700	0.29919	0.845	1.189	2.034	1.065	40.70
600	0.29657	0.29879	0.844	1.134	1.978	1.068	38.81
666	0.29647	0.29869	0.844	1.121	1.965	1.069	38.91
805	0.29626	0.29850	0.844	1.096	1.939	1.070	38.67
2074	0.29557	0.29786	0.842	1.016	1.858	1.075	38.03
2622	0.29539	0.29769	0.842	0.995	1.838	1.076	37.75
2995	0.29529	0.29760	0.842	0.985	1.827	1.077	37.61
4290	0.29503	0.29735	0.842	0.957	1.798	1.080	36.99
5571	0.29485	0.29719	0.841	0.938	1.780	1.081	36.54
6475	0.29477	0.29711	0.841	0.930	1.771	1.082	36.39
8592	0.29460	0.29696	0.841	0.912	1.753	1.084	35.85
11143	0.29443	0.29680	0.841	0.896	1.737	1.085	35.19
12505	0.29435	0.29673	0.840	0.888	1.729	1.086	34.79
14383	0.29427	0.29665	0.840	0.880	1.721	1.087	34.45
16448	0.29419	0.29658	0.840	0.873	1.713	1.088	34.07
19302	0.29412	0.29651	0.840	0.865	1.705	1.089	33.68
23787	0.29404	0.29644	0.840	0.858	1.698	1.090	33.25
31667	0.29396	0.29636	0.840	0.850	1.690	1.090	32.65
45533	0.29404	0.29644	0.840	0.858	1.698	1.090	33.25
Maxima							40.70
Minima							32.65

Time seconds	NPSHr ft	Suppression Pool Req.Press psia	Suppression Pool Req.Press psig	Suppression Pool Press Margin psid
0	26	8.358	-6.332	6.332
49	26	9.210	-5.480	6.200
106	26	9.474	-5.216	6.266
600	26	10.085	-4.605	5.445
666	26	10.255	-4.435	5.485
805	26	10.621	-4.069	5.379
2074	26	12.178	-2.512	5.082
2622	26	12.712	-1.978	4.958
2995	26	12.996	-1.694	4.894
4290	26	13.916	-0.774	4.624
5571	26	14.592	-0.098	4.428
6475	26	14.948	0.258	4.362
8592	26	15.704	1.014	4.126
11143	26	16.516	1.826	3.[illegible]44
12505	26	16.945	2.255	3.6[illegible]5
14383	26	17.390	2.700	3.530
16448	26	17.850	3.160	3.370
19302	26	18.327	3.637	3.203
23787	26	18.820	4.130	3.020
31667	26	19.332	4.642	2.768
45533	26	18.820	4.130	3.020
Maxima		19.33	4.64	6.33
Minima		8.36	-6.33	2.77

PECO ENERGY NUCLEAR GROUP	CALCULATION SHEET	CALC. NO. : PM-1011 PAGE : 29 REVISION : 2



B. **LOCA While Purging with a concurrent drop in torus water level**

As previously stated in Part A of this calculation, the available NPSH for the NPSH pumps is expressed by the following equation:

$$NPSHA = P_{cont.} + Z - h_f - P_{sat}$$

where P_{cont} = Torus pressure

Z = Static Head (Torus water level)

h_f = suction line friction losses (including suction strainer losses)

P_{sat} = vapor pressure of the pumped fluid

From the results in Part A, it can be seen that the NPSH margin at the limiting torus temperature and pressure conditions is 6.65 ft.

From Ref. 17, it can be seen that a LOCA occurring while purging reduces the available containment pressure at the limiting torus temperature to 21.21 psia. This reduction in torus pressure (0.890 psi or 2.057 ft) will still provide an NPSH margin of 4.59 ft. Therefore, even with maximum expected accident fouling, the suction strainers can accommodate a DBA LOCA while purging.

C. NPSH LIMIT CURVES AND ECCS SUCTION REQUIREMENTS CURVES FOR THE MOST LIMITING CONDITIONS FOR CORE SPRAY PUMPS

The purpose of this section is to determine: 1) the torus temperature limit at which the NPSH requirements will be satisfied for a variety of flow, torus level and pressure conditions. 2) the torus water level at which the NPSH requirements will be satisfied for a variety of flow, torus temperature and pressure conditions.

These limits are determined by setting NPSHA equal to NPSHR and solving for the required variable. This equation takes the form:

$NPSHA = NPSHR = P_a + h_s - h_f - h_{vap}$

To solve for torus temperature, the values of NPSHR and h_f which correspond to various Core Spray system flows are input into the equation along with varying torus levels and pressures. The equation is then solved for vapor pressure, which is converted to saturation temperature by reference to the steam tables.

Similarly, when solving for torus level, torus temperature conditions are converted into vapor pressure and combined with the torus pressure and flow dependent variables, and the equation solved directly for static head, which corresponds to torus level, since the Core Spray pump suction elevation corresp[illegible] with torus level zero.

Torus Temperature Limits

The torus temperature limits were calculated for the following conditions:

- Core Spray system flows of 2250, 2500, 2750, 3000, 3250, 3500, 3750, 4000 gpm
- Torus water Levels of 10.5', 12.3', 14.5' and 20'
- Torus overpressures of 0, 3, 6, 10, 20, 30 and 60 psig

A clean suction strainer was assumed in formulating these curves, since these curves will be used to respond to many transients, such as ATWS and Appendix R fires which will not transport insulation debris to the torus.

Suction line friction losses, including strainer losses were calculated using the EXCEL spreadsheet in section A above. These losses were computed as a function of flow only. All losses were calculated at 3125 gpm at 205.7°F. These losses were then corrected for other flows by applying the following formula:

$hf_1 = hf_{ref} (Q_1 / Q_{ref})^2$

hf_1 = friction losses at new flow

hf_{ref} = friction losses at reference flow (3125 gpm)

Q_1 = new flow

Q_{ref} = reference flow (3125 gpm)

These friction losses are combined in an EXCEL spreadsheet with the flow level and torus pressure conditions given above to calculate the torus temperature limits, using the following equation:

$h_{vap} = 144 P_a / \rho + h_s - h_f - NPSHR$

Once h_{vap} is found, the results are converted into temperature by referring to at ASME Steam Tables (Ref. 11)

The results are shown in the following spreadsheet.

Torus Level Limits

The torus temperature limits were calculated for the following conditions:

- Core Spray system flows of 2250, 2500, 2750, 3000, 3250, 3500, 3750, 4000 gpm
- Torus water temperature of 95° to 300°
- Torus overpressures of 0, 3, 6, 10, 20, 30 and 60 psig

A clean suction strainer was assumed in formulating these curves, since these curves will be used to respond to many transients, such as ATWS and Appendix R fires which will not transport insulation debris to the torus.

Suction line friction losses, including strainer losses were calculated using the EXCEL spreadsheet in section A above. These losses were computed as a function of flow only. All losses were calculated at 3125 gpm at 205.7°F. These losses were then corrected for other flows by applying the following formula:

$hf_1 = hf_{ref} (Q_1 / Q_{ref})^2$

hf_1 = friction losses at new flow

hf_{ref} = friction losses at reference flow (3125 gpm)

Q_1 = new flow

Q_{ref} = reference flow (3125 gpm)

These friction losses are combined in an EXCEL spreadsheet with the flow level and torus pressure conditions given above to calculate the torus temperature limits, using the following equation:

$h_s = NPSHR + h_f + h_{vap} - 144\ P_a / \rho$

The results are shown in the following spreadsheet .

Torus Level Limits

The torus temperature limits were calculated for the following conditions:

- Core Spray system flows of 2350, 2800, 3125, 3500, 4030, 4200 gpm
- Torus water temperature of 95° to 300°
- Torus overpressures of 0, 3, 6, 10, 20, 30 and 60 psig

A clean suction strainer was assumed in formulating these curves, since these curves will be used to respond to many transients, such as ATWS and Appendix R fires which will not transport insulation debris to the torus.

Suction line friction losses, including strainer losses were calculated using the EXCEL spreadsheet in section A above. These losses were computed as a function of flow only. All losses were calculated at 3125 gpm at 205.7°F. These losses were then corrected for other flows by applying the following formula:

$hf_1 = hf_{ref} (Q_1 / Q_{ref})^2$

hf_1 = friction losses at new flow

hf_{ref} = friction losses at reference flow (3125 gpm)

Q_1 = new flow

Q_{ref} = reference flow (3125 gpm)

These friction losses are combined in an EXCEL spreadsheet with the flow level and torus pressure conditions given above to calculate the torus temperature limits, using the following equation:

$h_s = NPSHR + h_f + h_{vap} - 144 P_a / \rho$

The results are shown in the following spreadsheet .

Table C-1 Core Spray Pumps with Clean Strainer
Determination of Torus Temp vs flow
Conversion of friction loss (Hf) for for new strainers
Clean strainers have .81 ft @100 F & piping is 1.09 ft loss. (For 3125 gpm)
Using the equation hvap = hs - NPSHR - hf + PA
Friction loss is converted based on the ratio of the flows squared.
thus the Hf at 3125= 1.9 feet H2O is coverted for various flows
Note: this value is not temperature corrected. This is conservative because
strainer head loss values are at 100 F.

Calculate the Hf at various flows

Q (GPM)	Q^2 ratio	Hf new
2250	0.518	0.985
2500	0.640	1.216
2750	0.774	1.471
3000	0.922	1.751
3250	1.082	2.055
3500	1.254	2.383
3750	1.440	2.736
4000	1.638	3.113

					Vortex Limit			Drawdown Level			Min Tech Spec Level					
Torus					10.5 Ft Torus Level			12.3 Ft Torus Level			14.5 Ft Torus Level			20 Ft Torus Level		
Wetwell Pressure PA		FLOW	NPSHR	hf	Vapor Pressure		TEMP	Vapor Pressure		TEMP	Vapor Pressure		TEMP	Vapor Pressure		TEMP
PSIG	FT (ABS)	GPM	FT	FT	FT	PSIA	deg F	FT	PSIA	deg F	FT	PSIA	deg F	FT	PSIA	deg F
0	33.9717	2250	26	0.98	17.4867	7.5667	180.00	19.2867	8.3456	184.00	21.4867	9.2976	189.00	26.9867	11.6775	200.00
	33.9717	2500	26	1.22	17.2557	7.4668	179.00	19.0557	8.2457	184.00	21.2557	9.1976	189.00	26.7557	11.5775	200.00
	33.9717	2750	26	1.47	17.0003	7.3563	179.00	18.8003	8.1352	183.00	21.0003	9.0871	188.00	26.5003	11.4670	199.00
	33.9717	3000	26.5	1.75	16.2207	7.0189	176.00	18.0207	7.7978	181.00	20.2207	8.7497	186.00	25.7207	11.1297	198.00
	33.9717	3250	27	2.06	15.4167	6.6710	174.00	17.2167	7.4499	179.00	19.4167	8.4018	185.00	24.9167	10.7818	196.00
	33.9717	3500	28	2.38	14.0883	6.0962	170.00	15.8883	6.8751	176.00	18.0883	7.8271	181.00	23.5883	10.2070	194.00
	33.9717	3750	29	2.74	12.7357	5.5109	166.00	14.5357	6.2898	172.00	16.7357	7.2418	178.00	22.2357	9.6217	191.00
	33.9717	4000	30	3.11	11.3587	4.9151	161.00	13.1587	5.6940	167.00	15.3587	6.6459	174.00	20.8587	9.0259	188.00
3	40.9047	2250	26	0.98	24.4197	10.5667	195.00	26.2197	11.3456	199.00	28.4197	12.2976	203.00	33.9197	14.6775	211.00
	40.9047	2500	26	1.22	24.1887	10.4668	195.00	25.9887	11.2457	198.00	28.1887	12.1976	202.00	33.6887	14.5775	211.00
	40.9047	2750	26	1.47	23.9333	10.3563	194.00	25.7333	11.1352	198.00	27.9333	12.0871	202.00	33.4333	14.4670	211.00
	40.9047	3000	26.5	1.75	23.1537	10.0189	193.00	24.9537	10.7978	196.00	27.1537	11.7497	200.00	32.6537	14.1297	210.00
	40.9047	3250	27	2.06	22.3497	9.6710	191.00	24.1497	10.4499	195.00	26.3497	11.4018	199.00	31.8497	13.7818	208.00
	40.9047	3500	28	2.38	21.0213	9.0962	188.00	22.8213	9.8751	192.00	25.0213	10.8271	196.00	30.5213	13.2070	206.00
	40.9047	3750	29	2.74	19.6687	8.5109	185.00	21.4687	9.2898	189.00	23.6687	10.2418	194.00	29.1687	12.6217	204.00
	40.9047	4000	30	3.11	18.2917	7.9151	182.00	20.0917	8.6940	186.00	22.2917	9.6459	191.00	27.7917	12.0259	202.00
6	47.8377	2250	26	0.98	31.3527	13.5667	207.00	33.1527	14.3456	210.00	35.3527	15.2976	214.00	40.8527	17.6775	221.00
	47.8377	2500	26	1.22	31.1217	13.4668	207.00	32.9217	14.2457	210.00	35.1217	15.1976	213.00	40.6217	17.5775	221.00
	47.8377	2750	26	1.47	30.8663	13.3563	207.00	32.6663	14.1352	210.00	34.8663	15.0871	213.00	40.3663	17.4670	220.00
	47.8377	3000	26.5	1.75	30.0867	13.0189	205.00	31.8867	13.7978	208.00	34.0867	14.7497	212.00	39.5867	17.1297	219.00
	47.8377	3250	27	2.06	29.2827	12.6710	204.00	31.0827	13.4499	207.00	33.2827	14.4018	210.00	38.7827	16.7818	218.00
	47.8377	3500	28	2.38	27.9543	12.0962	202.00	29.7543	12.8751	205.00	31.9543	13.8271	208.00	37.4543	16.2070	216.00
	47.8377	3750	29	2.74	26.6017	11.5109	199.00	28.4017	12.2898	203.00	30.6017	13.2418	206.00	36.1017	15.6217	215.00
	47.8377	4000	30	3.11	25.2247	10.9151	197.00	27.0247	11.6940	200.00	29.2247	12.6459	204.00	34.7247	15.0259	213.00
10	57.07	2250	26	0.98	40.5850	17.5617	221.00	42.3850	18.3406	223.00	44.5850	19.2925	226.00	50.0850	21.6725	232.00
	57.07	2500	26	1.22	40.3540	17.4617	220.00	42.1540	18.2406	223.00	44.3540	19.1926	225.00	49.8540	21.5725	232.00
	57.07	2750	26	1.47	40.0986	17.3512	220.00	41.8986	18.1301	222.00	44.0986	19.0821	225.00	49.5986	21.4620	231.00
	57.07	3000	26.5	1.75	39.3190	17.0138	219.00	41.1190	17.7927	221.00	43.3190	18.7447	224.00	48.8190	21.1246	230.00
	57.07	3250	27	2.06	38.5150	16.6659	218.00	40.3150	17.4448	220.00	42.5150	18.3968	223.00	48.0150	20.7767	229.00
	57.07	3500	28	2.38	37.1866	16.0911	216.00	38.9866	16.8700	219.00	41.1866	17.8220	221.00	46.6866	20.2019	228.00
	57.07	3750	29	2.74	35.8340	15.5058	214.00	37.6340	16.2847	217.00	39.8340	17.2367	220.00	45.3340	19.6166	226.00
	57.07	4000	30	3.11	34.4570	14.9100	212.00	36.2570	15.6889	215.00	38.4570	16.6409	218.00	43.9570	19.0208	225.00

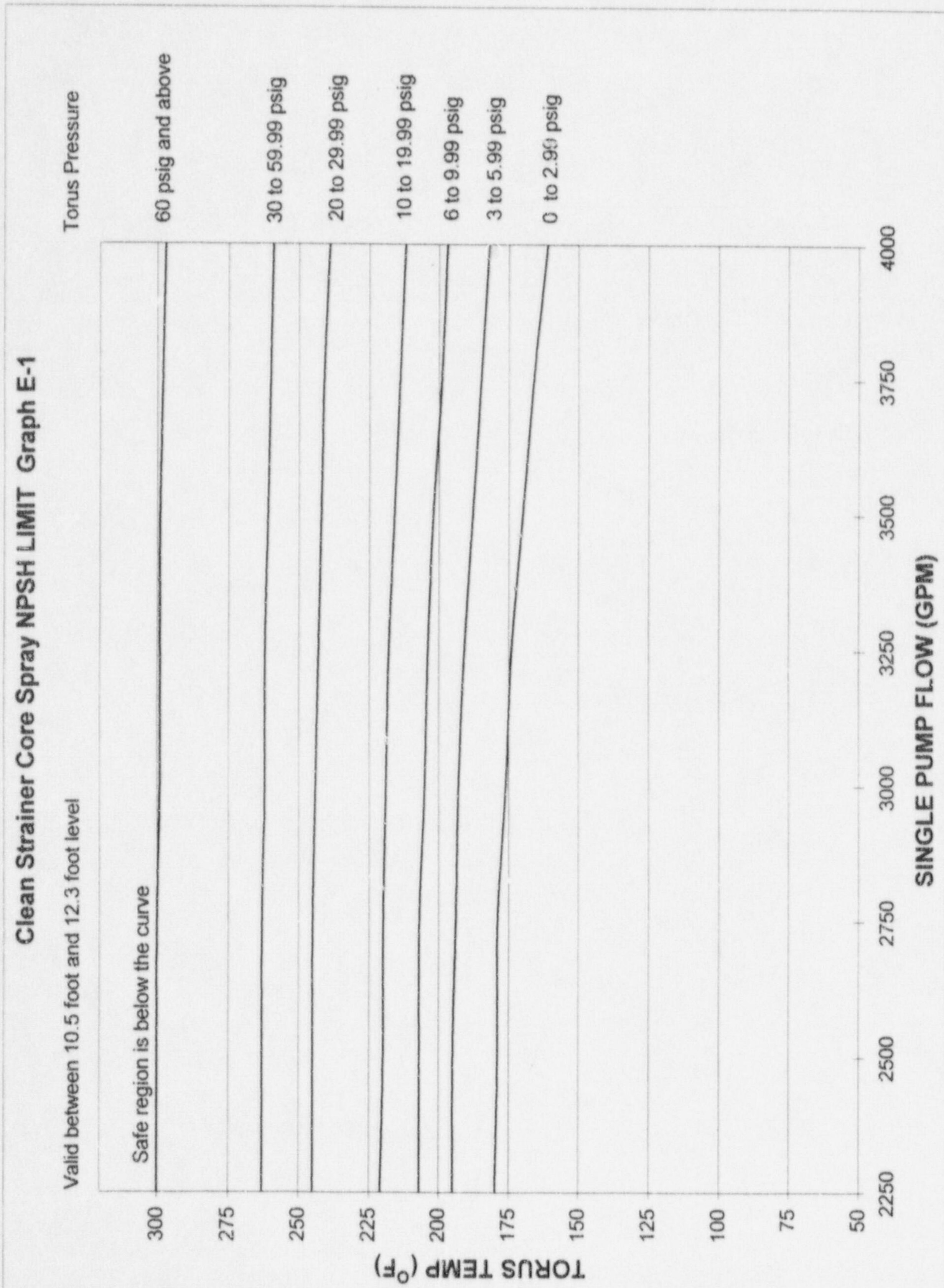
Table C-1 Core Spray Pumps with Clean Strainer
Determination of Torus Temp vs flow
Conversion of friction loss (Hf) for for new strainers
Clean strainers have .31 ft @100 F & piping is 1.09 ft loss. (For 3125 gpm)
Using the equation hvap = hs - NPSHR - hf + PA
Friction loss is converted based on the ratio of the flows squared.
thus the Hf at 3125= 1.9 feet H2O is coverted for various flows
Note: this value is not temperature corrected. This is conservative because
strainer head loss values are at 100 F.

Calculate the Hf at various flows

Q (GPM)	Q ratio	Hf new
2250	0.518	0.985
2500	0.640	1.216
2750	0.774	1.471
3000	0.922	1.751
3250	1.082	2.055
3500	1.254	2.383
3750	1.440	2.736
4000	1.638	3.113

					Vortex Limit			Drawdown Level			Min Tech Spec Level					
Torus					10.5 Ft Torus Level			12.3 Ft Torus Level			14.5 Ft Torus Level			20 Ft Torus Level		
Wetwell Pressure PA		FLOW	NPSHR	hf	Vapor Pressure		TEMP	Vapor Pressure		TEMP	Vapor Pressure		TEMP	Vapor Pressure		TEMP
PSIG	FT (ABS)	GPM	FT	FT	FT	PSIA	deg F	FT	PSIA	deg F	FT	PSIA	deg F	FT	PSIA	deg F
20	80.18	2250	26	0.98	63.6950	27.5617	245.00	65.4950	28.3406	247.00	67.6950	29.2925	248.00	73.1950	31.6725	253.00
	80.18	2500	26	1.22	63.4640	27.4617	245.00	65.2640	28.2406	246.00	67.4640	29.1926	248.00	72.9640	31.5725	253.00
	80.18	2750	26	1.47	63.2086	27.3512	245.00	65.0086	28.1301	246.00	67.2086	29.0821	248.00	72.7086	31.4620	253.00
	80.18	3000	26.5	1.75	62.4290	27.0138	244.00	64.2290	27.7927	245.00	66.4290	28.7447	247.00	71.9290	31.1246	252.00
	80.18	3250	27	2.06	61.6250	26.6659	243.00	63.4250	27.4448	245.00	65.6250	28.3968	247.00	71.1250	30.7767	251.00
	80.18	3500	28	2.38	60.2966	26.0911	242.00	62.0966	26.8700	244.00	64.2966	27.8220	246.00	69.7966	30.2019	250.00
	80.18	3750	29	2.74	58.9440	25.5058	241.00	60.7440	26.2847	242.00	62.9440	27.2367	244.00	68.4440	29.6166	249.00
	80.18	4000	30	3.11	57.5670	24.9100	239.00	59.3670	25.6889	241.00	61.5670	26.6409	243.00	67.0670	29.0208	248.00
30	103.29	2250	26	0.98	86.8050	37.5617	263.00	88.6050	38.3406	264.00	90.8050	39.2925	266.00	96.3050	41.6725	269.00
	103.29	2500	26	1.22	86.5740	37.4617	263.00	88.3740	38.2406	264.00	90.5740	39.1926	265.00	96.0740	41.5725	269.00
	103.29	2750	26	1.47	86.3186	37.3512	263.00	88.1186	38.1301	264.00	90.3186	39.0821	265.00	95.8186	41.4620	269.00
	103.29	3000	26.5	1.75	85.5390	37.0138	262.00	87.3390	37.7927	263.00	89.5390	38.7447	265.00	95.0390	41.1246	268.00
	103.29	3250	27	2.06	84.7350	36.6659	262.00	86.5350	37.4448	263.00	88.7350	38.3968	264.00	94.2350	40.7767	268.00
	103.29	3500	28	2.38	83.4066	36.0911	261.00	85.2066	36.8700	262.00	87.4066	37.8220	263.00	92.9066	40.2019	267.00
	103.29	3750	29	2.74	82.0540	35.5058	260.00	83.8540	36.2847	261.00	86.0540	37.2367	262.00	91.5540	39.6166	266.00
	103.93	4000	30	3.11	81.3170	35.1869	259.00	83.1170	35.9658	260.00	85.3170	36.9178	262.00	90.8170	39.2977	266.00
60	172.59	2250	26	0.98	156.1050	67.5487	300.00	157.9050	68.3276	301.00	160.1050	69.2795	302.00	165.6050	71.6595	304.00
	172.59	2500	26	1.22	155.8740	67.4487	300.00	157.6740	68.2276	301.00	159.8740	69.1796	302.00	165.3740	71.5595	304.00
	172.59	2750	26	1.47	155.6186	67.3382	300.00	157.4186	68.1171	301.00	159.6186	69.0691	302.00	155.1186	71.4490	304.00
	172.59	3000	26.5	1.75	154.8390	67.0008	299.00	156.6390	67.7797	300.00	158.8390	68.7317	301.00	164.3390	71.1116	303.00
	172.59	3250	27	2.06	154.0350	66.6529	299.00	155.8350	67.4318	300.00	158.0350	68.3838	301.00	163.5350	70.7637	303.00
	172.59	3500	28	2.38	152.7066	66.0782	299.00	154.5066	66.8570	299.00	156.7066	67.8090	300.00	162.2066	70.1889	303.00
	172.59	3750	29	2.74	151.3540	65.4929	298.00	153.1540	66.2717	299.00	155.3540	67.2237	300.00	160.6540	69.6036	302.00
	172.59	4000	30	3.11	149.9770	64.8970	297.00	151.7770	65.6759	298.00	153.9770	66.6279	299.00	159.4770	69.0078	301.00

PECO ENERGY NUCLEAR GROUP	CALCULATION SHEET	CALC. NO. : PM-1011 PAGE : 36 REVISION : 2



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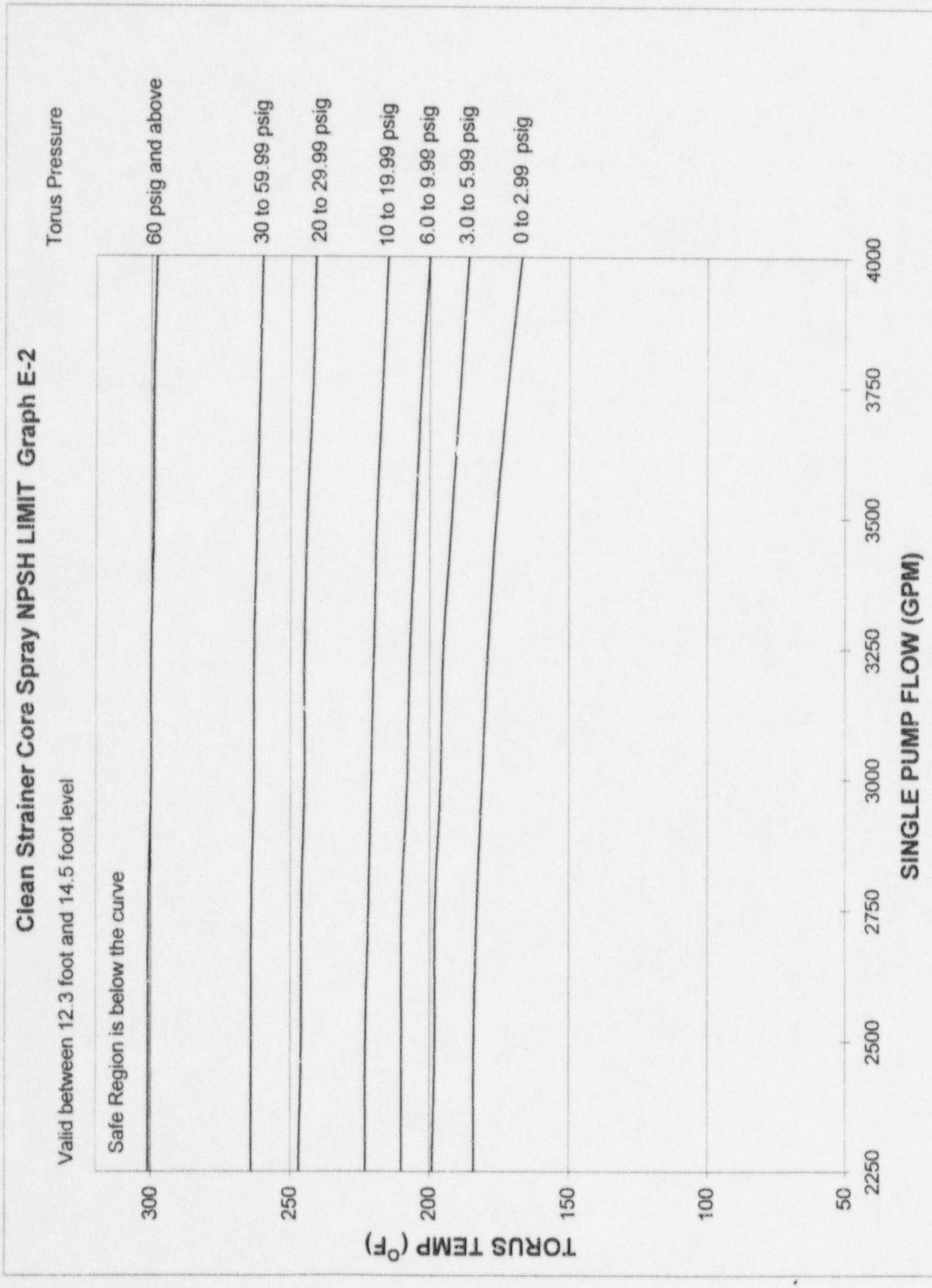

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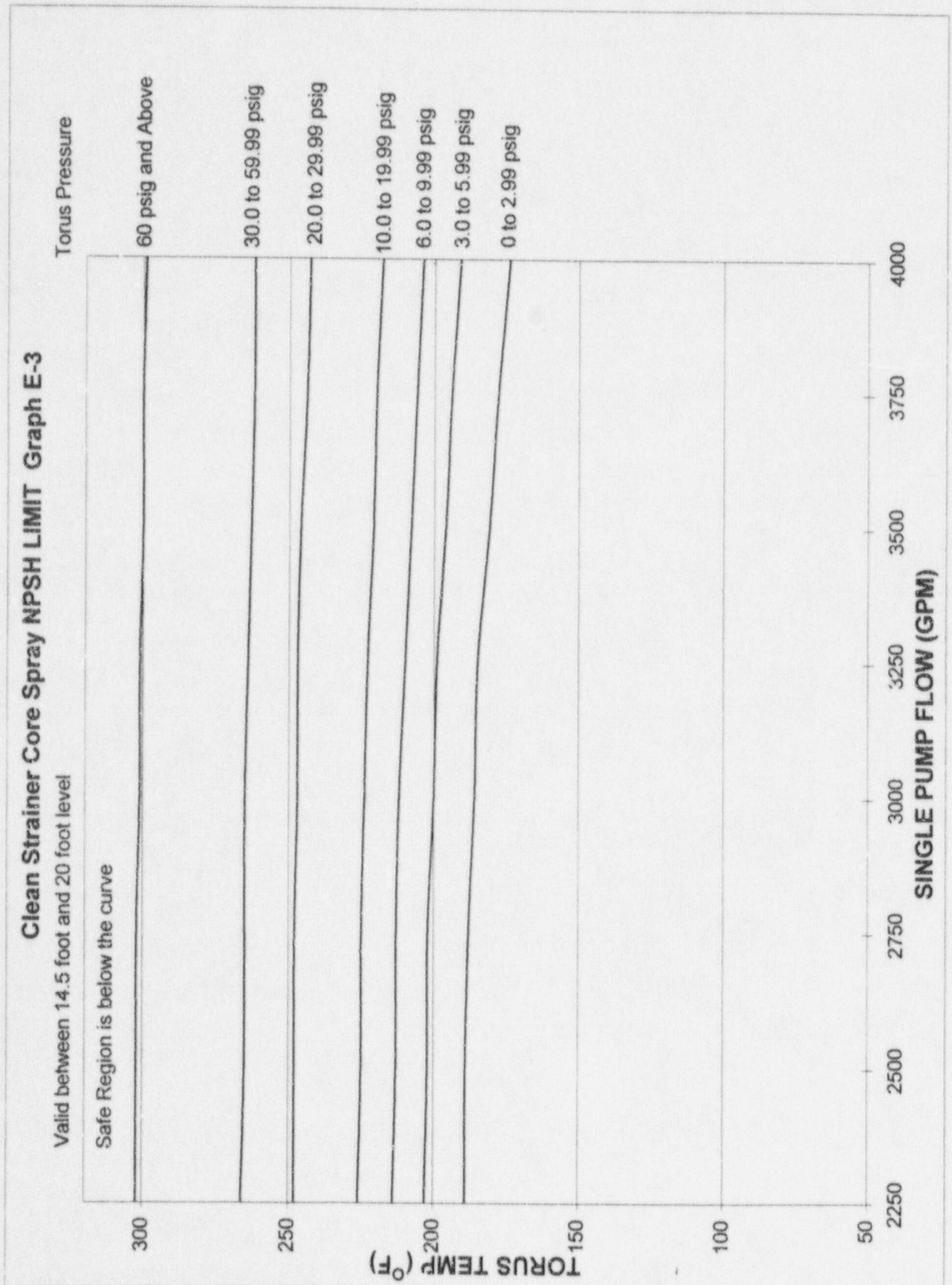

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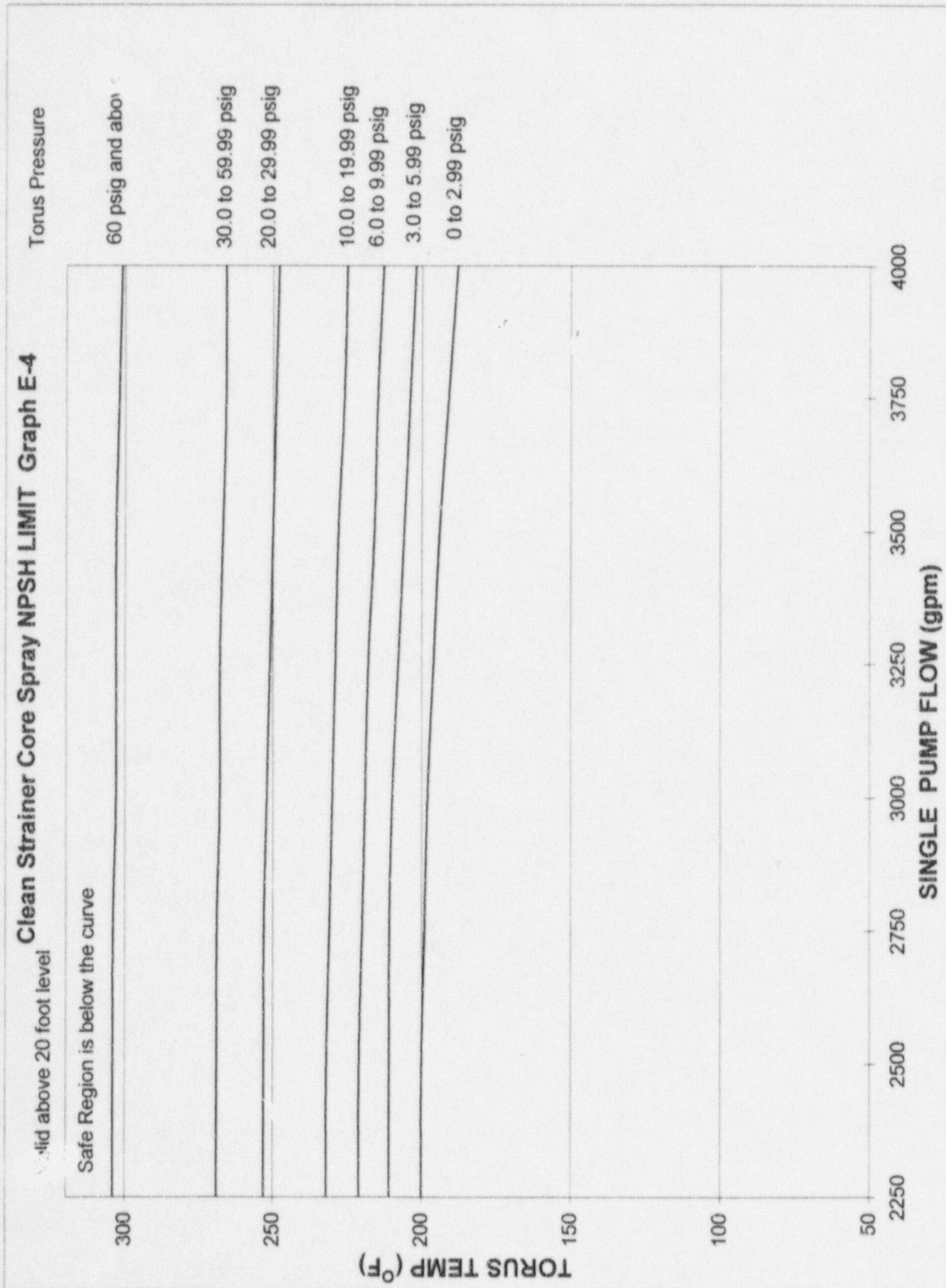

Table C-2 Core Spray Pumps with Clean Strainers
Determine torus level as a function of flow
using the equation hs = NPSHR + hf - PA + hvap
where hst is static head (which is torus level)
hf at 3125 gpm & 100F 1.9 ft H2O
Note: this value is not temperature corrected.
This is considered to be conservative because the strainer values are based on 100 F.

Determination of hf for flows

flow	ratio^2	hf
2250	0.5184	0.985
2500	0.64	1.216
2750	0.7744	1.471
3000	0.9216	1.751
3250	1.0816	2.055
3500	1.2544	2.383
3750	1.44	2.736
4000	1.6384	3.113

					Torus Temperature (deg F)												
					35	110	125	150	165	180	190	200	220	240	260	280	300
Wetwell Pressure PA				hvap	1.891906	2.968	4.538	8.751	12.619	17.857	22.288	27.613	41.516	60.855	87.178	122.313	168.400
(psig)	(psia)	Flow (gpm)	NPSHR (ft)	hf (ft)		hs (ft) (equates to torus level)											
0	14.7	2250	26	0.985	-5.233	-4.266	-2.822	1.142	4.840	9.894	14.193	19.381	32.991	52.011	77.989	112.753	158.440
0	14.7	2500	26	1.216	-5.002	-4.035	-2.591	1.373	5.072	10.125	14.424	19.612	33.222	52.242	78.220	112.984	158.671
0	14.7	2750	26	1.471	-4.746	-3.779	-2.336	1.628	5.327	10.380	14.680	19.867	33.477	52.498	78.475	113.239	158.926
0	14.7	3000	26.5	1.751	-3.967	-3.000	-1.556	2.408	6.107	11.160	15.459	20.647	34.257	53.277	79.255	114.019	159.706
0	14.7	3250	27	2.055	-3.163	-2.196	-0.752	3.212	6.911	11.964	16.263	21.451	35.061	54.081	80.059	114.823	160.510
0	14.7	3500	28	2.383	-1.834	-0.867	0.576	4.540	8.239	13.292	17.592	22.779	36.389	55.410	81.387	116.151	161.838
0	14.7	3750	29	2.736	-0.482	0.485	1.929	5.893	9.592	14.645	18.944	24.132	37.742	56.762	82.740	117.504	163.191
0	14.7	4000	30	3.113	0.895	1.862	3.306	7.270	10.968	16.022	20.321	25.509	39.119	58.139	84.117	118.881	164.568
3	17.7	2250	26	0.985	-12.194	-11.249	-9.831	-5.918	-2.254	2.761	7.034	12.194	25.744	44.699	70.606	105.295	150.900
3	17.7	2500	26	1.216	-11.963	-11.018	-9.600	-5.687	-2.023	2.992	7.265	12.425	25.975	44.930	70.837	105.526	151.131
3	17.7	2750	26	1.471	-11.708	-10.763	-9.345	-5.432	-1.768	3.248	7.521	12.680	26.230	45.186	71.093	105.781	151.387
3	17.7	3000	26.5	1.751	-10.928	-9.983	-8.565	-4.652	-0.988	4.027	8.300	13.460	27.010	45.965	71.873	106.561	152.166
3	17.7	3250	27	2.055	-10.124	-9.179	-7.761	-3.848	-0.184	4.831	9.104	14.264	27.814	46.769	72.677	107.365	152.970
3	17.7	3500	28	2.383	-8.796	-7.851	-6.433	-2.520	1.144	6.160	10.433	15.592	29.142	48.098	74.005	108.693	154.299
3	17.7	3750	29	2.736	-7.443	-6.498	-5.080	-1.157	2.497	7.512	11.785	16.945	30.495	49.450	75.357	110.046	155.651
3	17.7	4000	30	3.113	-6.066	-5.121	-3.703	0.210	3.874	8.889	13.162	18.322	31.872	50.827	76.734	111.423	157.028
10	24.7	2250	26	0.985		-27.544		-22.392		-13.881		-4.576	8.834	27.638	53.381	87.892	133.308
10	24.7	2500	26	1.216		-27.313		-22.161		-13.650		-4.345	9.065	27.869	53.612	88.123	133.539
10	24.7	2750	26	1.471		-27.057		-21.905		-13.394		-4.090	9.320	28.124	53.867	88.379	133.794
10	24.7	3000	26.5	1.751		-26.278		-21.126		-12.615		-3.310	10.100	28.904	54.647	89.158	134.574
10	24.7	3250	27	2.055		-25.474		-20.322		-11.811		-2.506	10.904	29.708	55.451	89.962	135.378
10	24.7	3500	28	2.383		-24.145		-18.993		-10.482		-1.178	12.232	31.036	56.779	91.291	136.706
10	24.7	3750	29	2.736		-22.793		-17.641		-9.130		0.175	13.585	32.389	58.132	92.643	138.059
10	24.7	4000	30	3.113		-21.416		-16.264		-7.753		1.552	14.962	33.766	59.509	94.020	139.436
20	34.7	2250	26	0.985		-50.822		-45.925		-37.655		-28.533	-15.323	3.264	28.773	63.032	108.175
20	34.7	2500	26	1.216		-50.590		-45.694		-37.424		-28.302	-15.092	3.495	29.004	63.263	108.406
20	34.7	2750	26	1.471		-50.335		-45.439		-37.169		-28.047	-14.836	3.751	29.259	63.518	108.662
20	34.7	3000	26.5	1.751		-49.555		-44.659		-36.389		-27.267	-14.057	4.530	30.039	64.298	109.441
20	34.7	3250	27	2.055		-48.751		-43.855		-35.585		-26.463	-13.253	5.334	30.843	65.102	110.245
20	34.7	3500	28	2.383		-47.423		-42.527		-34.257		-25.135	-11.924	6.663	32.171	66.430	111.574
20	34.7	3750	29	2.736		-46.070		-41.174		-32.904		-23.782	-10.572	8.015	33.524	67.783	112.926
20	34.7	4000	30	3.113		-44.694		-39.797		-31.527		-22.405	-9.195	9.392	34.901	69.160	114.303

Table C-2 Core Spray Pumps with Clean Strainers
Determine torus level as a function of flow
using the equation hs = NPSHR + hf - PA + hvap
where hst is static head (which is torus level)
hf at 3125 gpm & 100F= 1.9 ft H2O
Note: this value is not temperature corrected.
This is considered to be conservative because the strainer values are based on 100 F.

Determination of hf for flows

flow	ratio^2	hf
2250	0.5184	0.985
2500	0.64	1.216
2750	0.7744	1.471
3000	0.9216	1.751
3250	1.0816	2.055
3500	1.2544	2.383
3750	1.44	2.736
4000	1.6384	3.113

Wetwell Pressure PA					Torus Temperature (deg F)												
					95	110	125	150	165	180	190	200	220	240	260	280	300
				hvap	1.891906	2.968	4.538	8.751	12.619	17.857	22.288	27.613	41.516	60.855	87.178	122.313	168.400
(psig)	(psia)	Flow (gpm)	NPSHR (ft)	hf (ft)		hs (ft) (equates to torus level)											
30	44.7	2250	26	0.985		-74.099		-69.458		-61.430		-52.490	-39.479	-21.109	4.165	38.171	83.043
30	44.7	2500	26	1.216		-73.868		-69.227		-61.199		-52.259	-39.248	-20.878	4.396	38.402	83.274
30	44.7	2750	26	1.471		-73.613		-68.972		-60.943		-52.004	-38.993	-20.623	4.651	38.657	83.529
30	44.7	3000	26.5	1.751		-72.833		-68.192		-60.164		-51.224	-38.213	-19.843	5.431	39.437	84.309
30	44.7	3250	27	2.055		-72.029		-67.388		-59.360		-50.420	-37.409	-19.039	6.235	40.241	85.113
30	44.7	3500	28	2.383		-70.701		-66.060		-58.031		-49.092	-36.081	-17.711	7.563	41.569	86.441
30	44.7	3750	29	2.736		-69.348		-64.707		-56.679		-47.739	-34.728	-16.358	8.916	42.922	87.794
30	44.7	4000	30	3.113		-67.971		-63.330		-55.302		-46.382	-33.351	-14.961	10.293	44.299	89.171
60	74.7	2250	26	0.985		-143.933		-140.058		-132.753		-124.361	-111.949	-94.230	-69.659	-36.411	7.646
60	74.7	2500	26	1.216		-143.702		-139.827		-132.522		-124.130	-111.718	-93.999	-69.428	-36.180	7.877
60	74.7	2750	26	1.471		-143.447		-139.572		-132.260		-123.875	-111.463	-93.744	-69.172	-35.924	8.132
60	74.7	3000	26.5	1.751		-142.667		-138.792		-131.487		-123.095	-110.883	-92.064	-68.393	-35.144	8.912
60	74.7	3250	27	2.055		-141.863		-137.988		-130.683		-122.291	-109.879	-92.160	-67.589	-34.340	9.716
60	74.7	3500	28	2.383		-140.535		-136.660		-129.354		-120.963	-108.551	-90.832	-66.260	-33.012	11.044
60	74.7	3750	29	2.736		-139.182		-135.307		-128.002		-119.610	-107.198	-89.479	-64.908	-31.660	12.397
60	74.7	4000	30	3.113		-137.805		-133.930		-126.625		-118.233	-105.821	-88.102	-63.531	-30.283	13.774

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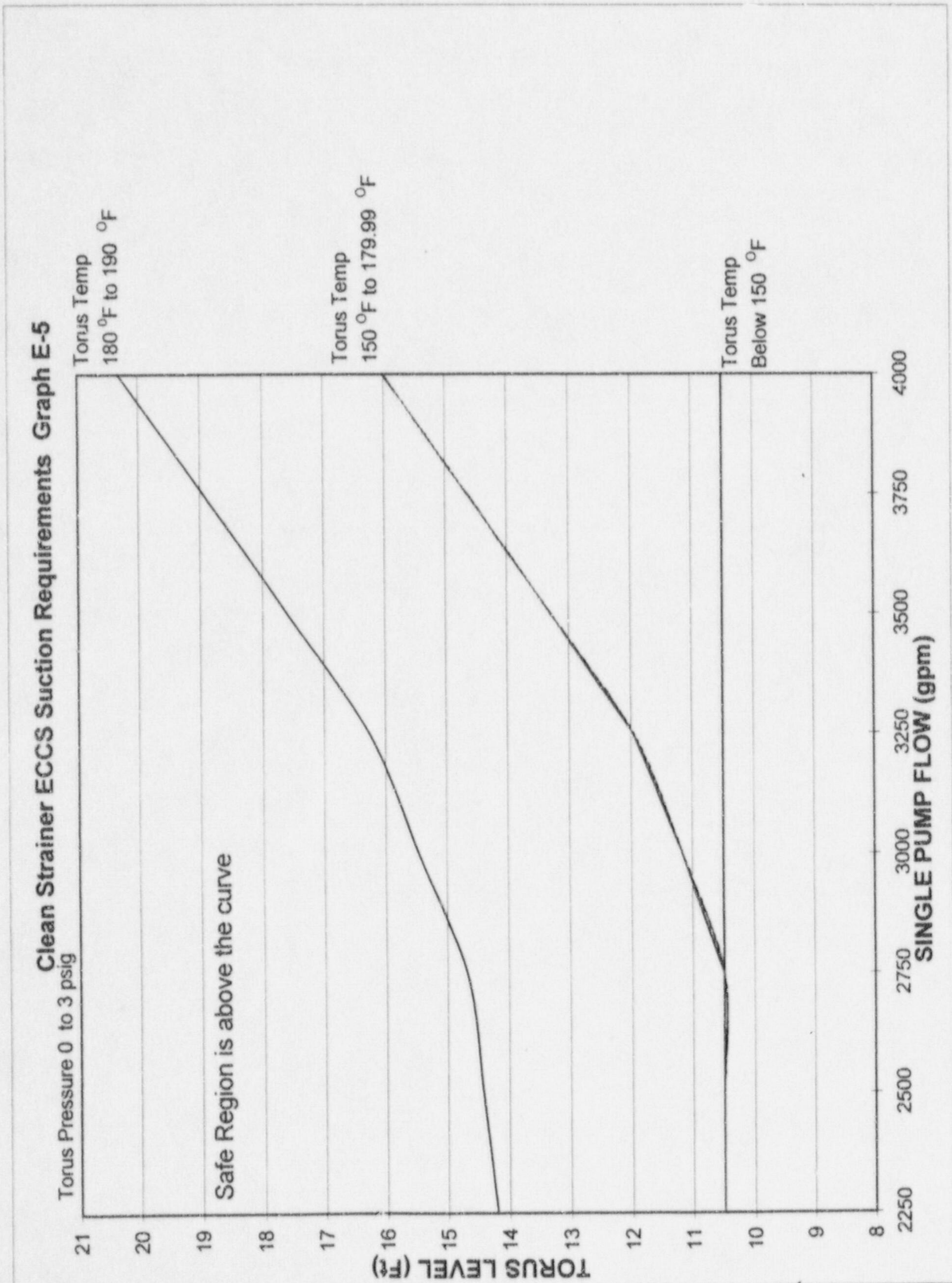

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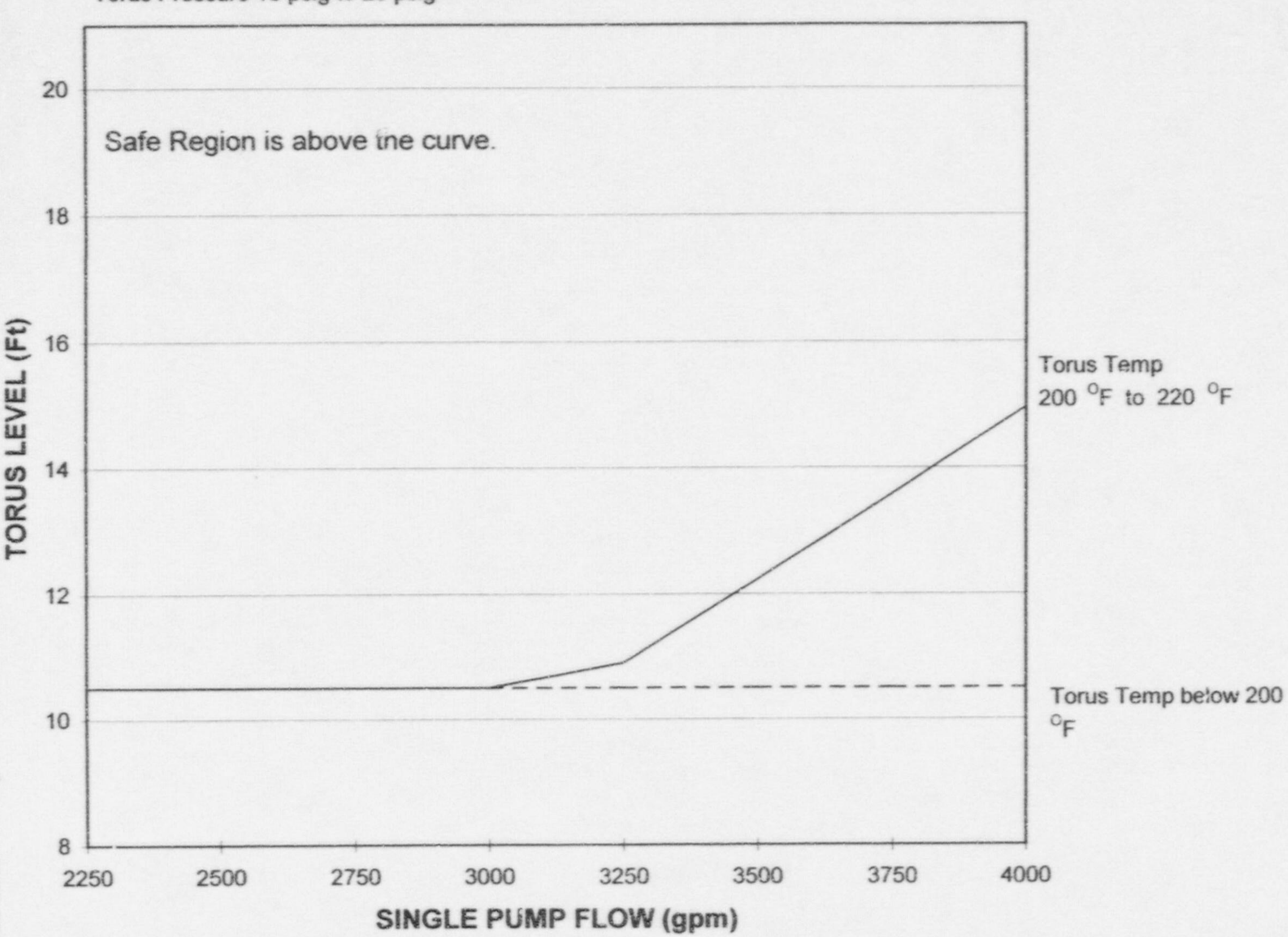
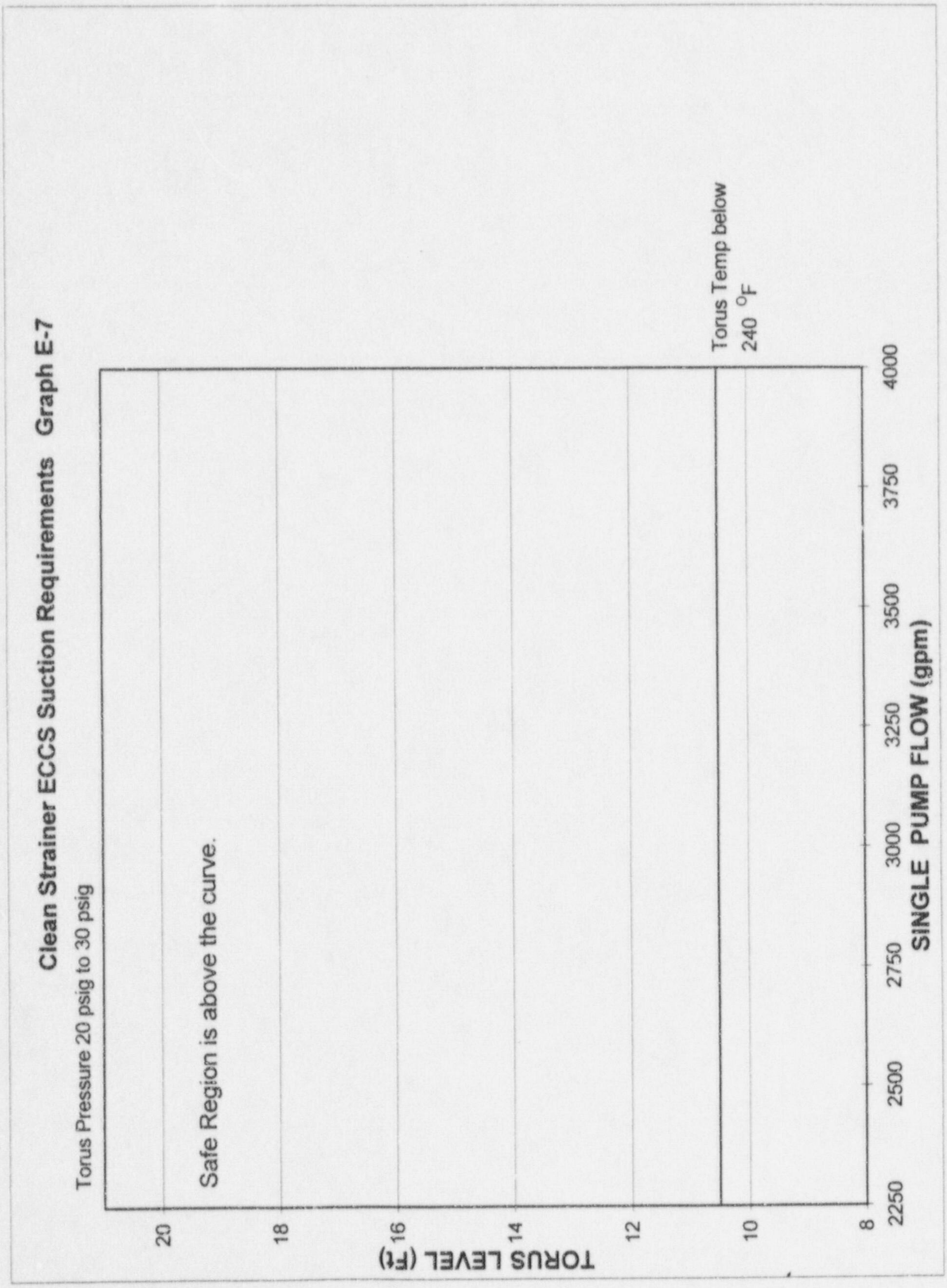
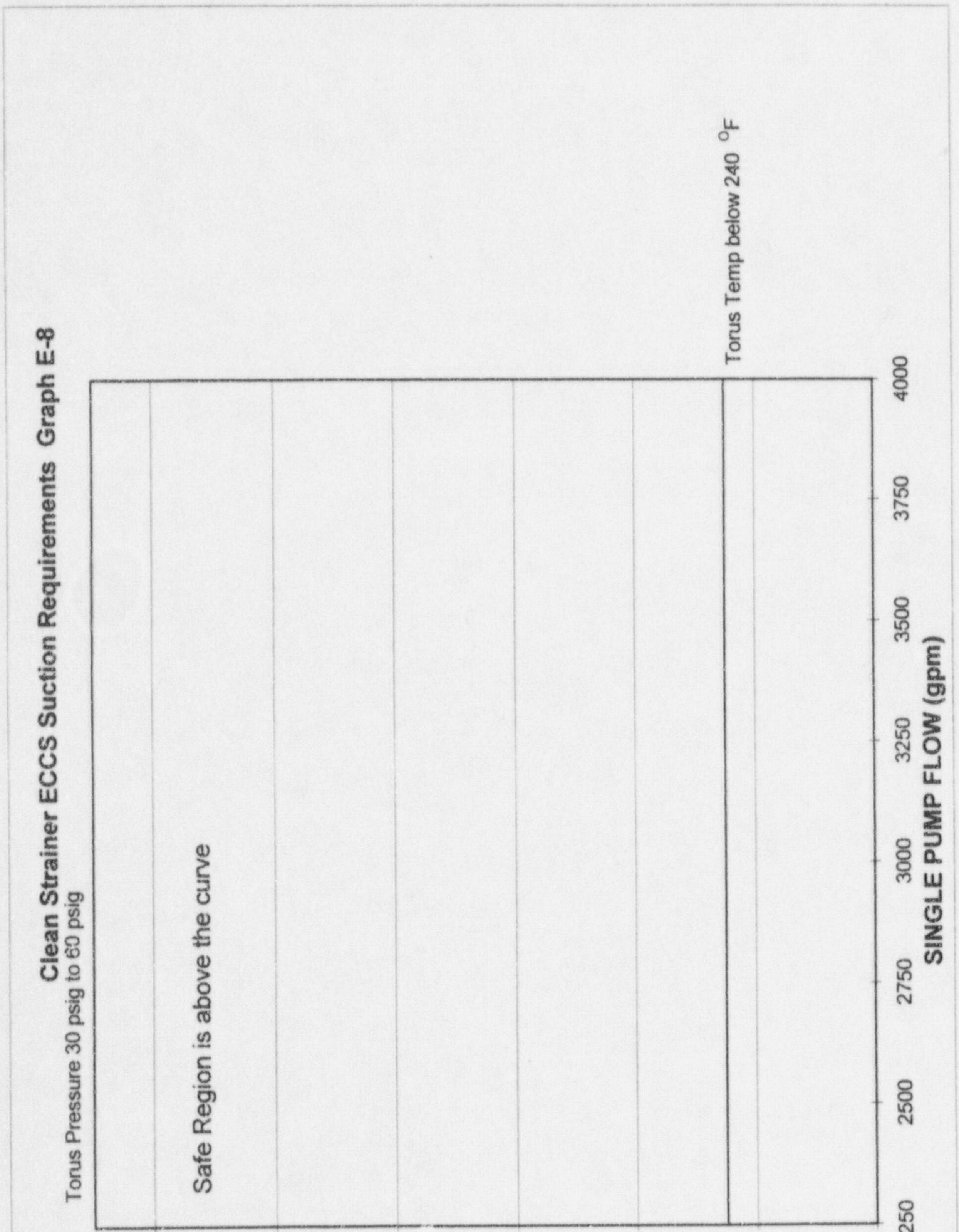
Clean Strainer ECCS Suction Requirements Graph E-6

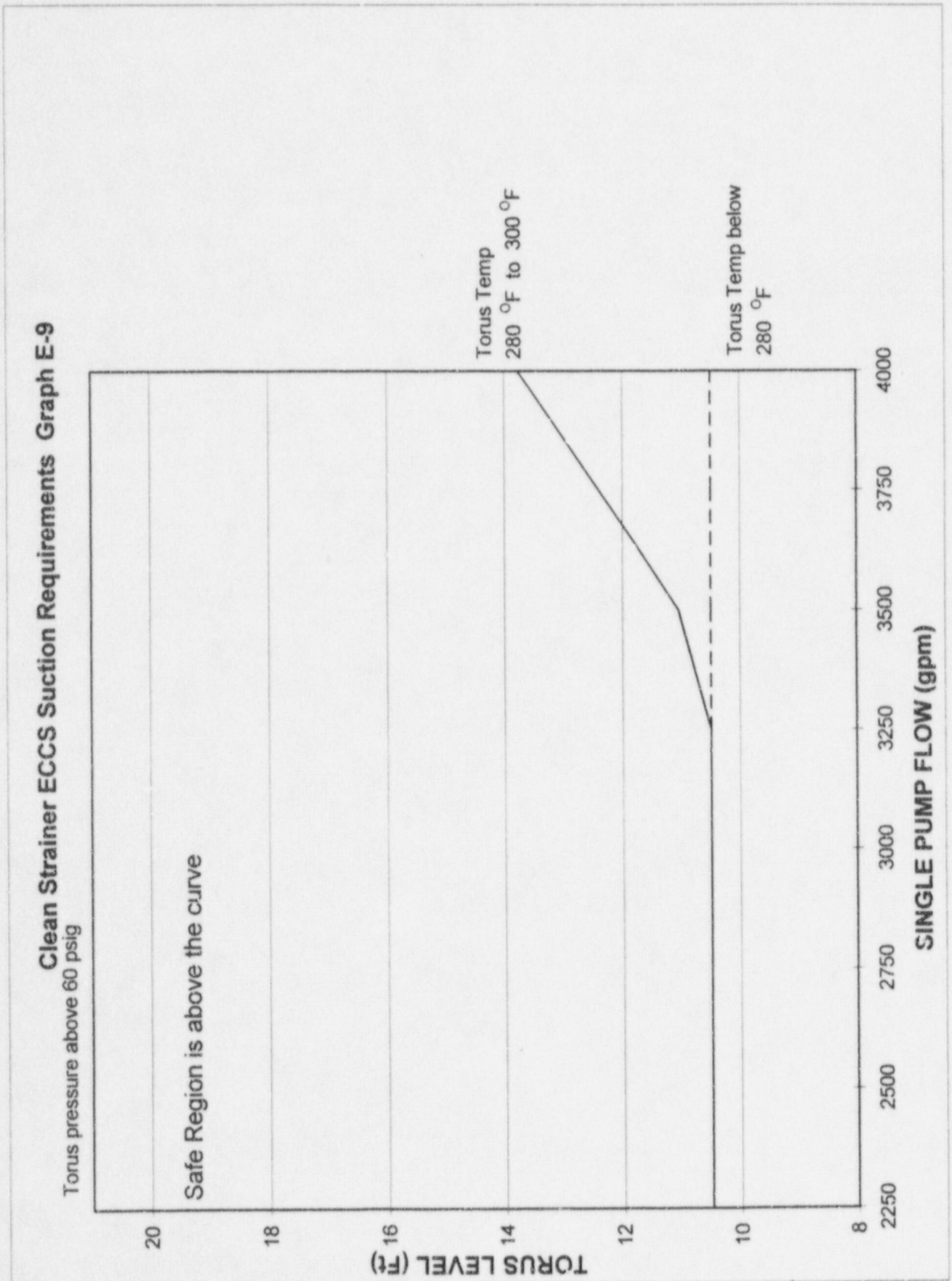
Torus Pressure 10 psig to 20 psig




Clean Strainer ECCS Suction Requirements Graph E-7
Torus Pressure 20 psig to 30 psig
Safe Region is above the curve.
Torus Temp below
240 °F
TORUS LEVEL (Ft)
20
18
16
14
12
10
8
SINGLE PUMP FLOW (gpm)
2250
2500
2750
3000
3250
3500
3750
4000

PECO ENERGY NUCLEAR GROUP	CALCULATION SHEET	CALC. NO. : PM-1011 PAGE : 45 REVISION : 2




Clean Strainer ECCS Suction Requirements Graph E-9
Torus pressure above 60 psig
Safe Region is above the curve
Torus Temp
280 °F to 300 °F
Torus Temp below
280 °F
TORUS LEVEL (Ft)
20
18
16
14
12
10
8
SINGLE PUMP FLOW (gpm)
2250
2500
2750
3000
3250
3500
3750
4000

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