ATTACHMENT C

Calculation ATD-0377 Rev. 0

"RHR Pump Recirculation Flow"

k:nla:zion:nrc:24

SARGENT & LUNDY ENGINEERS	EXTERNAL DESIGN INFORMATION TRANSMITTAL	DIT-ZI-EXT-1108
		Page 1 of 2

March 11, 1994
Project No. 9140-98
(HVC217A)
File No. 9.12
(DIT-ZI-EXT-1108)

Commonwealth Edison Company
Zion Station - Units 1&2

Transmittal of Calculation ATD-0377
Modification No. N/A
System Code: RH, CS

Mr. W. T. Perchiazzi
Nuclear Engineering Department
Commonwealth Edison Company
1400 Opus Place
Downers Grove, Illinois 60515

Dear Mr. Perchiazzi:

Enclosed please find Sargent & Lundy Design Information Transmittal DIT-ZI-EXT-1108. This DIT transmits Sargent & Lundy Calculation ATD-0377, Revision 0, Approved March 10, 1994.

The location of the calculation purpose, design input, assumptions and approach are referenced in the DIT.

If you have any questions, please feel free to contact me at (312) 269-3942.

Yours very truly,

Robert J Peterson

R. J. Peterson,
Senior Project Engineer
Analysis & Technologies Division

RJP::mfl
Enclosures
Copies:
J. Ashley (1/1)
CHRON System (1/1)
W. C. Cleff/J. S. Steele/P. A. Gazda (1/0)
R. A. Hameetman (1/0)
J. A. Kowalski (1/0)
B. C. Schwartz (1/0)

SARGENT & LUNDY
ENGINEERS

EXTERNAL DESIGN INFORMATION TRANSMITTAL

DIT-ZI-EXT-1108

STATUS OF INFORMATION:

X APPROVED
___ PRELIMINARY
___ REFERENCE/INFORMATION ONLY (not for design purposes)

X SAFETY RELATED
___ NON-SAFETY RELATED
___ REGULATORY RELATED

IDENTIFICATION OF THE SPECIFIC DESIGN INFORMATION TRANSMITTED AND PURPOSE OF ISSUE(List any supporting documents attached to DIT by its title, revision and/or issue date, and total number of pages for each supporting document.)

This DIT transmits to Commonwealth Edison Company the following calculation:

1. Calculation ATD-0377, Revision 0, Approved March 10, 1994, "RHR Pump Recirculation Flow," 17 pages.

The purpose, design input, assumptions and approach are found in the following calculation sections:

Purpose	Section 1.0
Design Input	Section 2.0
Assumptions	Section 3.0
Approach	Section 4.0

SOURCE OF INFORMATION

Calc. No. See above ____________ Report No. N/A ____________

Other N/A

R. J. Peterson	ATD	Robert J Peterson	3/11/94
Preparer	Division	Preparer's Signature	Date
E. Pomraning	ATD	Eric Pomraning	3/11/94
Reviewer	Division	Reviewer's Signature	Date

Form PI-CEC-PG-0006.1, Rev. 3 (06-02-92)

SARGENT & LUNDY ENGINEERS

DESIGN CONTROL SUMMARY
DESIGN VERIFICATION

PAGE 1

PROJECT NAME: ZION
PROJECT NO.: 9140-98
CLIENT: CECo
CALC. NO.: ATD-0377
TITLE: RHR Pump Recirculation Flow.

UNIT NO.: 1+2
FILE NO.: 9140-98
SYSTEM: RH + CS
DIVISION: ATD

[X] SAFETY RELATED [ ] NON SAFETY RELATED

QA SERIAL #

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REVIEWER	TAREK ZAKI Tarek Zaki 3-7-94		
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1.0 Purpose

The purpose of this calculation is to determine the flow delivered from an RHR pump to the containment spray nozzles during the recirculation phase. In addition to supplying flow to the spray nozzles, runout flow is provided to the centrifugal charging pumps and to the safety injection pumps.

2.0 Design Input

2.1 The runout flow rate for the centrifugal charging pumps is 550 gpm per pump There are two centrifugal charging pumps (Ref. 7.4).

2.2 The runout flow rate for the safety injection pumps is 650 gpm per pump. There are two safety injection pumps (Ref. 7.4).

2.3 The loss coefficients are taken from the S&L MAD calculation 91-0083, Rev. 0 (Ref. 7.1).

2.4 The RHR pump head is degraded by 10% (Ref. 7.4).

2.5 The RHR cross-tie header is isolated. The RHR supply to the SI and VC pumps is accomplished via a cross-tie at the SI and VC pumps' suction supplies (Ref. 7.4).

3.0 Assumptions

3.1 The RHR pump curve with the lowest developed head (RHR pump 2A) is used to determine the pump operating point. This conservatively underestimates the average RHR pump performance.

3.2 Since the loss coefficients are taken directly from calculation 91-0083, all of the assumptions in calculation 91-0083 used to determine the loss coefficients are included in this calculation.

4.0 Approach

The operating point of an RHR pump is determined using loss coefficients and data from calculation 91-0083. The only significant change from calculation 91-0083 is that the operating point is recalculated with additional runout flow to the charging pumps and to the safety injection pumps. This additional flow decreases the head developed by an RHR pump.

The calculation is done iteratively by guessing a flow and calculating the corresponding head loss. When the calculated head loss falls on the pump curve then the operating point has been determined. The flow distribution between the two sets of spray nozzles is calculated by varying the flow through each leg until the head losses across both legs are equal. A nodal diagram is attached in Appendix A.

The head loss through each segment is calculated using the following equation.

$\Delta h = (V^2/2g)K$ (Ref. 7.3)

Δh = Head Loss (ft H_2O)
V = Velocity (ft/s)
g = Gravitational Constant (32.2 ft/s^2)
K = Loss Coefficient

5.0 Calculations

5.1 RHR Heat Exchanger Head Loss

From reference 7.1, the head loss through the heat exchanger at a flow of 3215 gpm is 17.61 ft. Since the head loss is proportional to the flow squared, the head loss at any flow can be calculated from the following equation.

$\Delta h = (Q/3215)^2(17.61)$

Δh = Head Loss (ft)
Q = Flow (gpm)

The actual head losses are summarized in table 1.

5.2 Group 2 Spray Nozzle Loss

The head losses for the spray nozzles are modified by changing the group 2 spray nozzle loss coefficient so that it is consistent with the nozzle loss coefficient for the group 3 spray nozzles. Calculation 91-0083 used a group 2 loss coefficient of 3555.06 as input for the S&L computer program FLO-SERIES. The correct loss coefficient determined in a seperate section of calculation 91-0083 is 13355. This change is judged to have a minimal effect on the results of calculation 91-0083 because the head loss across each set of the spray nozzles is similar (given the spray header flow distribution used in calculation 91-0083) and, thus, the correct head loss across the group 3 nozzles can be used as a basis for accurately predicting the pump operating point. However, to be consistent, the loss coefficient is changed to the correct value. The head loss across the group 2 nozzles is conservatively calculated by maintaining the same flow distribution through the nozzles and replacing the loss coefficient with the corrected loss coefficient. The following equation is used to calculate the head loss.

$\Delta h = (V^2/2g)K$

Where,

Δh = Head Loss (ft)
V = Velocity in 3" Pipe (ft/s) = 0.70 ft/s (Ref. 7.1 case 1)
g = Gravitational Constant = 32.2 ft/s^2
K = Loss Coefficient (Based on 3" Pipe Flow) = 13355 (Ref.7.1)

$\Delta h = (0.70^2/64.4)13355$

Δh = 101.6 ft

This is the head loss of the first nozzle (i.e. the head loss across the entire nozzle header).

The loss coefficient, based on flow in the nozzle header, is calculated using the following equation.

$\Delta h = (V^2/2g)K$

Δh = Head Loss = 101.6 ft
V = Velocity in Header = 11.77 ft/s (Ref. 7.1 case 1)
g = Gravitational Constant = 32.2 ft/s^2
K = Loss Coefficient Based on Header Pipe

$101.6 = (11.77^2/64.4)K$

K = 47.23

5.3 Group 3 Spray Nozzle Loss

The loss coefficient, based on flow in the nozzle header, is calculated using the following equation.

$\Delta h = (V^2/2g)K$

Δh = Head Loss = 92.04 ft (Ref. 7.1 case 1)
V = Velocity in Header = 8.66 ft/s (Ref. 7.1 case 1)
g = Gravitational Constant = 32.2 ft/s^2
K = Loss Coefficient Based on Header Pipe

$92.04 = (8.66^2/64.4)K$

K = 79.04

5.4 Calculated Head Losses

The following table summarizes the head loss through each pipe segment.

Table 1

Nodes	Nominal Pipe Diameter (in)	Flowrate (gpm)	Velocity (ft/s)	Loss Coefficient	Head Loss (ft)
Group 1					
A-B	18	3850	5.52	0.542	0.26
B-C	18	3850	5.52	4.079	1.93
C-D	PUMP	3850	N/A	N/A	N/A
D-E	10	3850	15.65	8.234	31.33
Heat Exchanger	N/A	3850	N/A	N/A	25.25
E-F	8	1450	9.31	6.874	9.25
F-G	10	1450	5.90	7.562	4.08
G-H	10	1450	5.90	1.271	0.69
Elev Change	N/A	N/A	N/A	N/A	192.95
SUBTOTAL 1					265.74
Group 2					
H-HJ	10	1073.5	4.36	10.886	3.22
HJ-J	8	1073.5	6.89	47.23	34.85
Elev Change	N/A	N/A	N/A	N/A	1.8
SUBTOTAL 2					39.87
Group 3					
H-HH	8	376.5	2.42	1.08	0.10
HH-I	6	376.5	4.174	79.04	21.38
Elev Change	N/A	N/A	N/A	N/A	18.3
SUBTOTAL 3					39.78
SUBTOTAL 1 + SUBTOTAL 2					305.61
SUBTOTAL 1 + SUBTOTAL 3					305.52

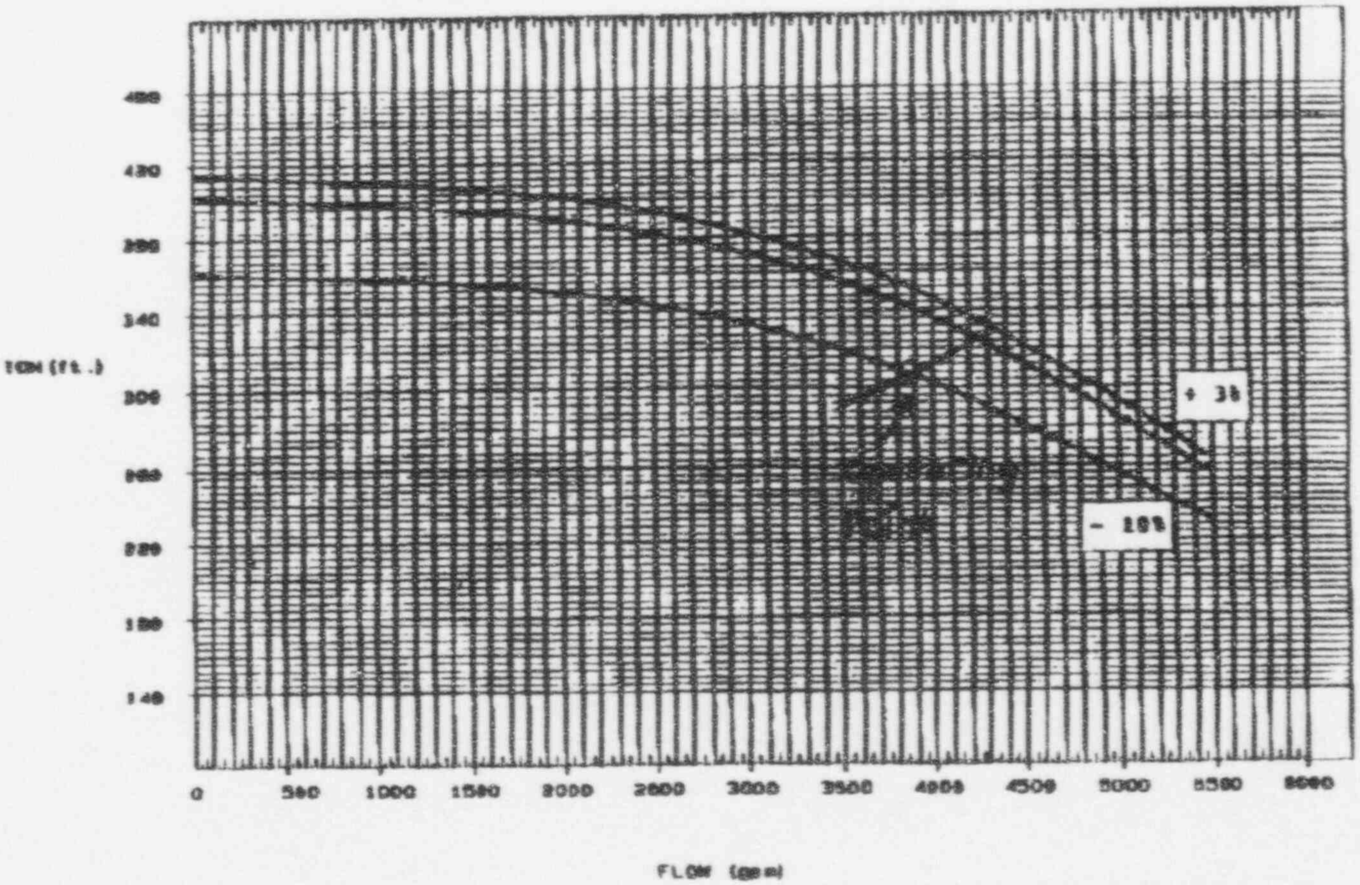
6.0 Results

The RHR pump, in the recirculation mode, delivers a flow of approximately 3850 gpm (1450 gpm to the containment spray nozzles or an average of 8.48 gpm per nozzle and 2400 gpm to the SI and VC pumps). The pump curve on the following page graphically illustrates the pump operating point.

This computer generated pump head curve has been evaluated as a suitable substutute for the currently approved pump curve incorporated in the applicable pump test procedure. This curve has been verified to be similar in general shape and has been checked for accuracy at a minimum of 5 points across the range of the curve. This curve is within the readable limits of the accepted curve and may be used as a substutute or in lieu of the current accepted curve.

[signature] 2/18/94
System Engineer Date

2A RH Pump Curve



2A RESIDUAL HEAT REMOVAL PUMP

RCV BY: SARGENT & LUNDY 28P29 : 2-22-94 : 2:26PM : ENC-NO→ 3122693598:# 7

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7.0 References

7.1 Sargent and Lundy calculation MAD 91-0083, Rev 0, 6-24-91.

7.2 Cameron Hydraulic Data, 17th edition.

7.3 Crane Technical Paper 410, 1988 edition

7.4 Letter from J. C. Ashley (CECo) to R. Hameetman, Dated February 22, 1994 (Appendix B).

7.5 Zion P&ID M-44, Rev JN

7.6 Zion P&ID M-55, Rev AT

7.7 Zion P&ID M-62, Rev AL

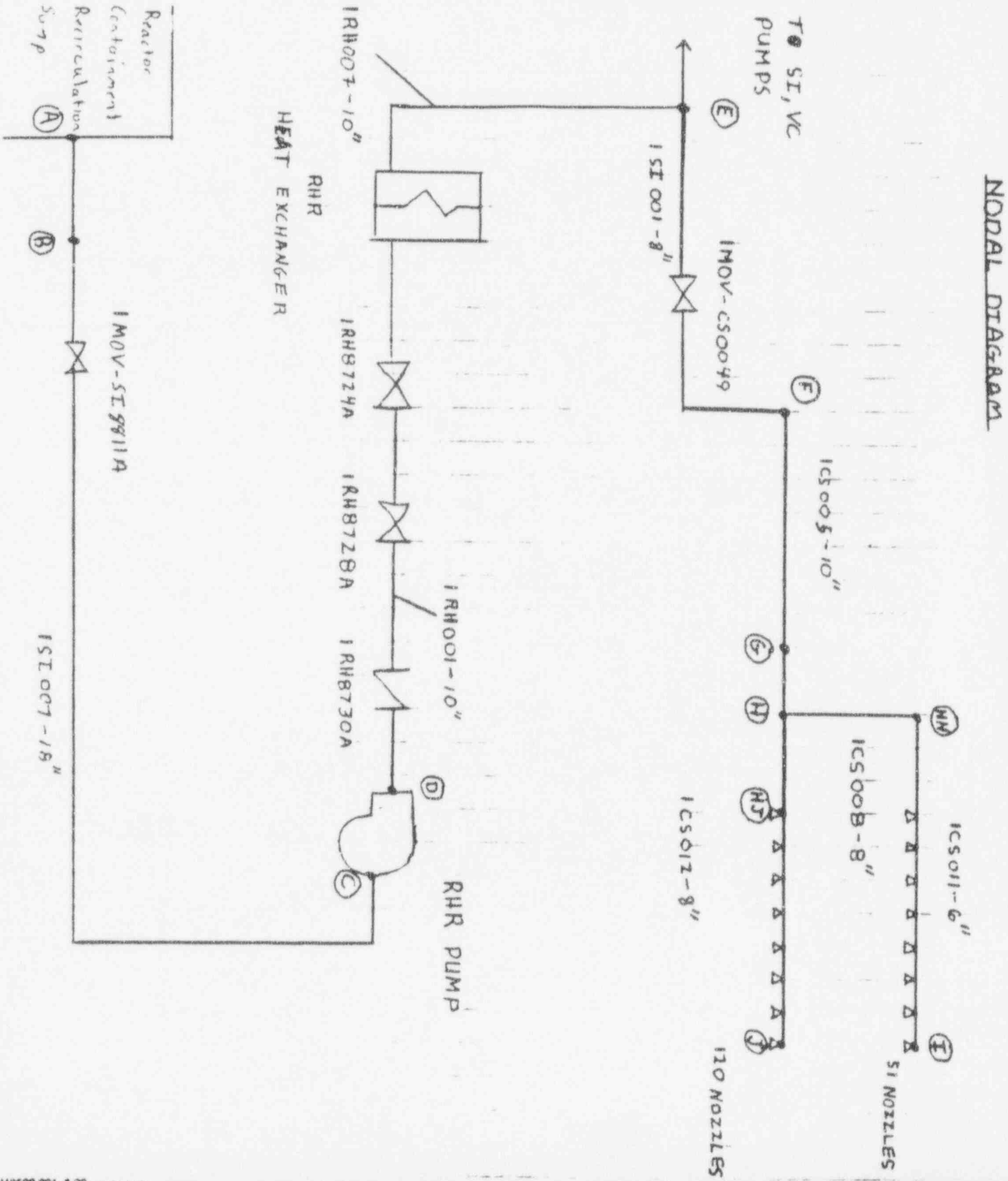
7.8 Zion P&ID M-64, Rev AG

7.9 Zion P&ID M-65, Rev AM

7.10 Zion Station Mechanical Drawing List, Dated 2-4-94

SARGENT & LUNDY ENGINEERS	Calcs. For		Calc. No. ATD-0377	
			Rev. Ø	Date
	X Safety-Related	Non-Safety-Related	Page A1	of Last Pa..

Client		Prepared by	Date
Project		Reviewed by	Date
Proj. No. 9140-98	Equip. No.	Approved by	Date



Form GQ-3.08.1 Rev. 2

M3599.001 6-90

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February 22,1994

To: R. Hameetman

Subject: Control Room Habitability Radiological Dose Analysis

Following is a list of inputs to be used when reanalyzing the containment spray flow delivered to containment during the recirculation phase of an accident:

- Runout flow for the safety injection pumps should be assumed to be 650 gpm per pump. (FSAR Question 6.16; attached)
- Runout flow for the centrifugal charging pumps should be assumed to be 550 gpm per pump. (FSAR Question 6.16)
- 10 % RHR pump degradation should be assumed. The RHR pump curves are attached.
- The RHR crosstie header is isolated. The RHR supply to both the SI and VC pumps is accomplished via a crosstie at the SI and VC pumps' suction supplies.

If there are any questions regarding this matter, contact me at Zion ext. 2978.

J.C. Ashley
Modification Design Engineering

cc: K.A. Ainger
P.J. Beinecke

QUESTION 6.16

Provide the details of how the available NPSH for the ECCS and containment spray pumps during the injection and recirculation modes were evaluated. How will your assure that adequate NPSH will always be available for the high pressure pumps and what are the consequences of inadvertent loss of NPSH to these pumps? Your response should include conformance with S.C. No. 1.

ANSWER

During the injection mode of operation following a LOCA, all ECC pumps (2 centrifugal charging, 2 safety injection and 2 RHR) are supplied from the RWST. The available NPSH for the injection mode was calculated as follows:

$$NPSH_{avail} = h_{el} + h_{sub.\ cool} - h_{H.L.}$$

h_{el} - elevation head for this case is defined as the difference in elevation between the bottom of the RWST and the pump center line.

$h_{sub.\ cooling}$ - defined as the difference between atmospheric pressure and the vapor pressure of water in the RWST at 100°F.

$h_{H.L.}$ - head losses in the piping from the RWST to the pumps at maximum pump runout flows.

During the recirculation mode of operation, the RHR pumps will be supplied from the recirculation sump inside containment and provide recirculation flow to the RCS hot legs and to the SI and charging pump suction headers. The available NPSH for the RHR pump during the recirculation mode was calculated as follows:

$$NPSH_{avail} = h_{el} + h_{sub.\ cool} - h_{H.L.}$$

h_{el} - elevation head for this case is defined as the difference in elevation between water level in containment and the pump centerline.

$h_{H.L.}$ - head losses in the piping from the containment sump to the RHR pump at maximum pump runout flows.

$h_{sub.\ cooling}$ - to conservatively conform to S.G. No. 1, the coolant inside containment is assumed to be saturated and no credit is taken for subcooling.

Calculated available NPSH and required NPSH for the ECCS pumps are tabulated below.

Net Positive Suction Heads For
Post-DBA Operational Pumps

Pump	Flow and Condition	Suction Source	Available NPSH	Required NPSH	Water Temp.
1. Safety Injection	650 gpm runout flow	Refueling Water Storage Tank	44 ft.	22 ft.	100°F max.
2. Centrifugal Charging	550 gpm runout flow	Refueling Water Storage Tank	23 ft.	23 ft.	100°F max.
3. Residual Heat Removal	4750 gpm runout flow	Refueling Water Storage Tank	25.7 ft.	22 ft.	100°F max.
4. Residual Heat Removal	4750 gpm runout flow	Containment Sump	23.5 ft.	22 ft.	Saturation

22

The available NPSH as calculated for each pump is considered to be conservative for the following reasons:

1. The elevation head used is the differential between the bottom of the RWST and the pumps. Under actual conditions the injection phase is terminated at the RWST low level alarm point with 105,000 gal remaining in the tank which would give an additional 10 ft. of NPSH.

2. Credit is taken for subcooling only to 100°F. Actual temperatures of coolant in the RWST will be closer to 75°F.

3. No credit is taken for subcooling of fluid in the containment sump or for increased containment pressures following the LOCA.

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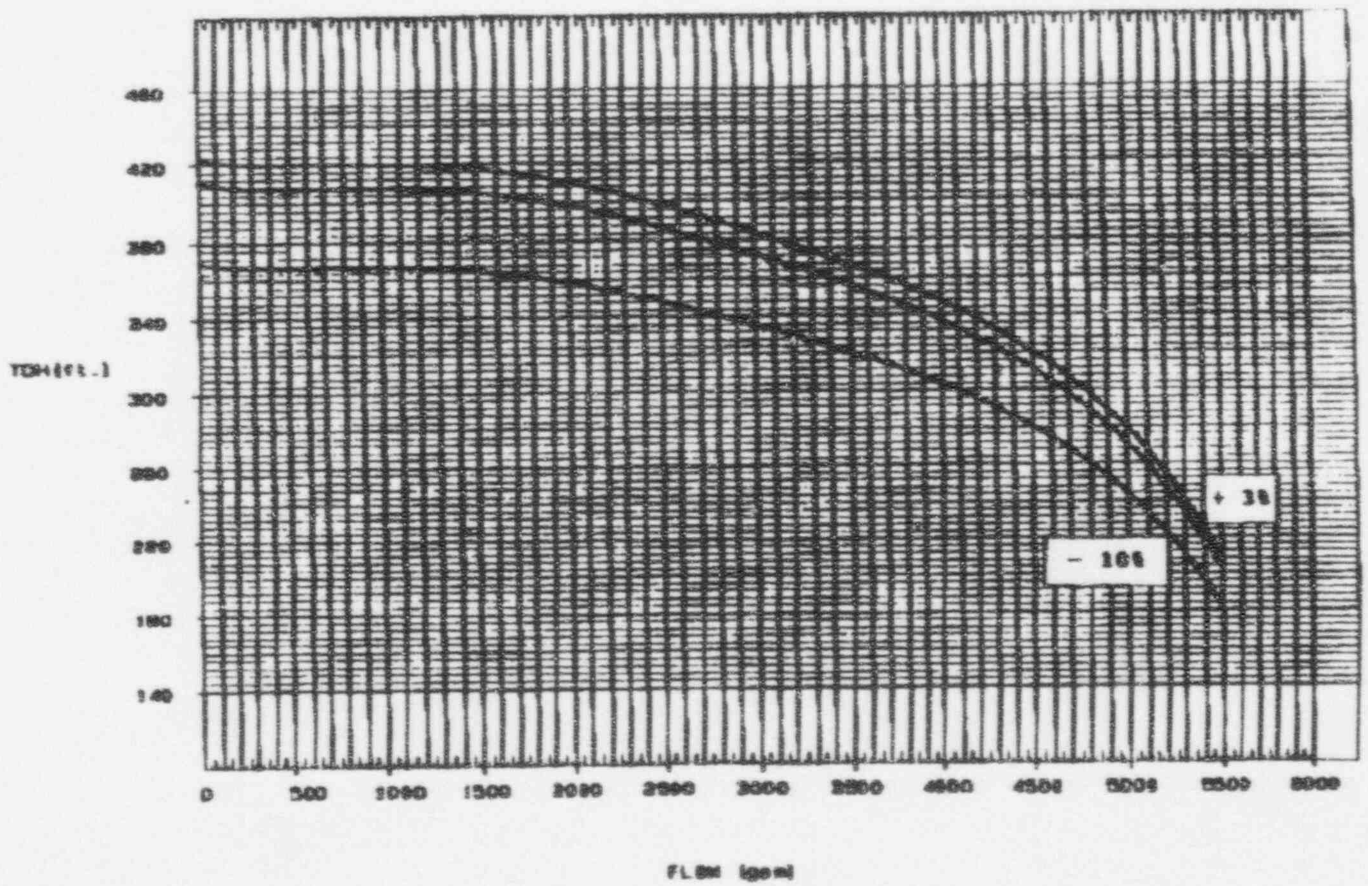
This computer generated pump head curve has been evaluated as a suitable substutute for the currently approved pump curve incorporated in the applicable pump test procedure. This curve has been verified to be similar in general shape and has been checked for accuracy at a minimum of 5 points across the range of the curve. This curve is within the readable limits of the accepted curve and may be used as a substutute or in lieu of the current accepted curve.

System Engineer 2/15/92 Date

1A RH Pump Curve



1A RESIDUAL HEAT REMOVAL PUMP

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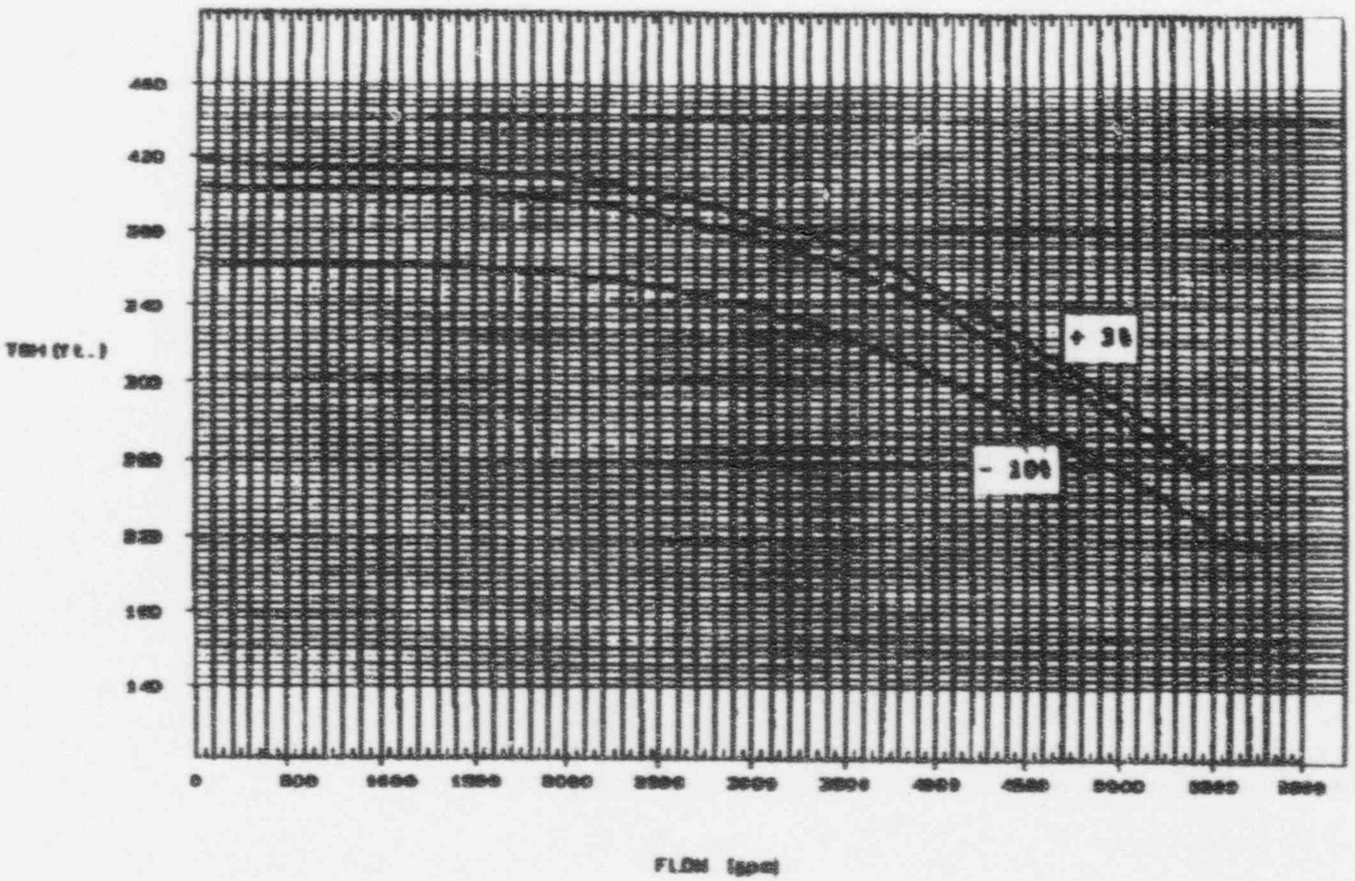
System Engineer   Date

1B RH Pump Curve



1B RESIDUAL HEAT REMOVAL PUMP

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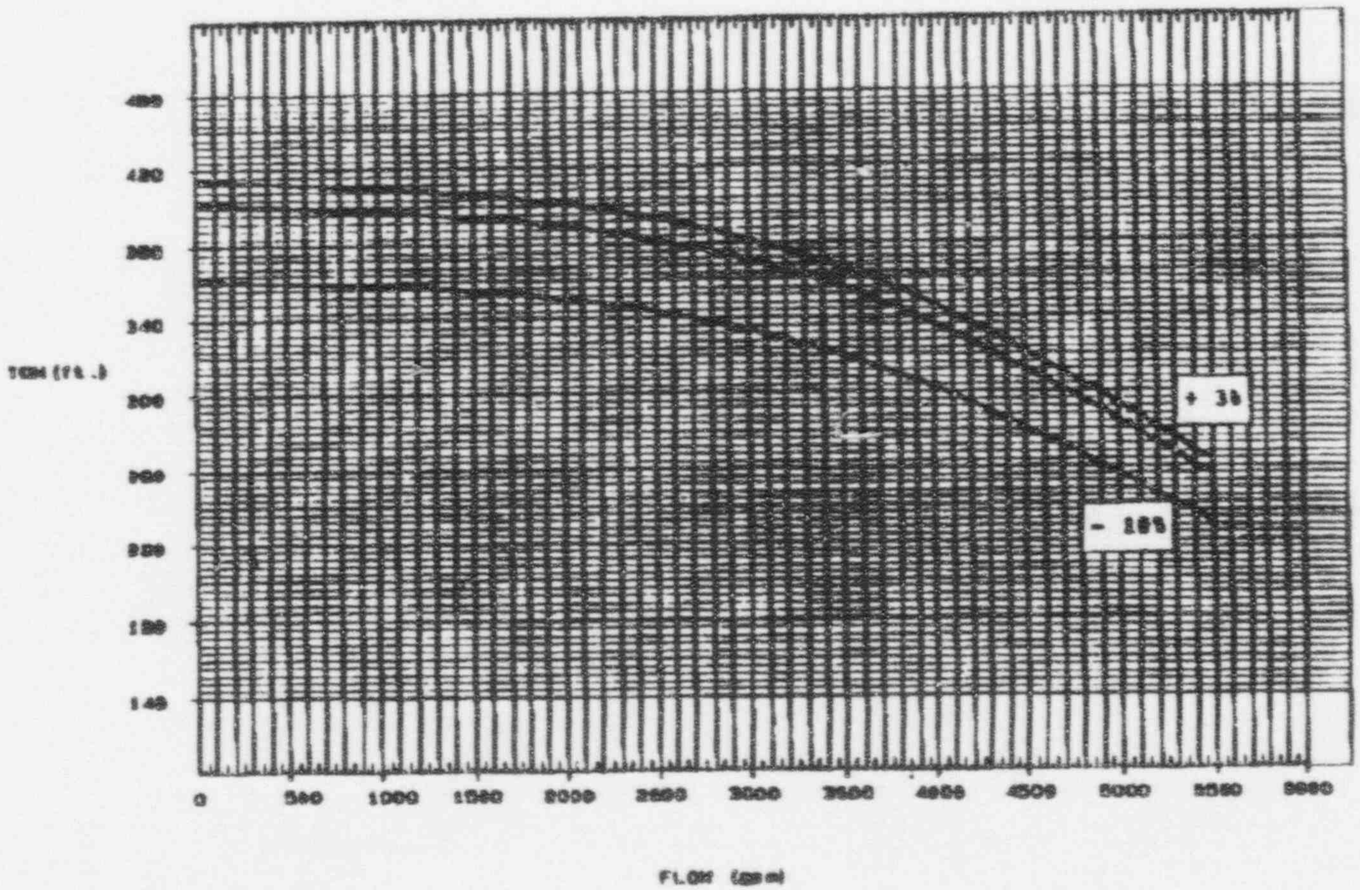
System Engineer Date

2A RH Pump Curve



2A RESIDUAL HEAT REMOVAL PUMP

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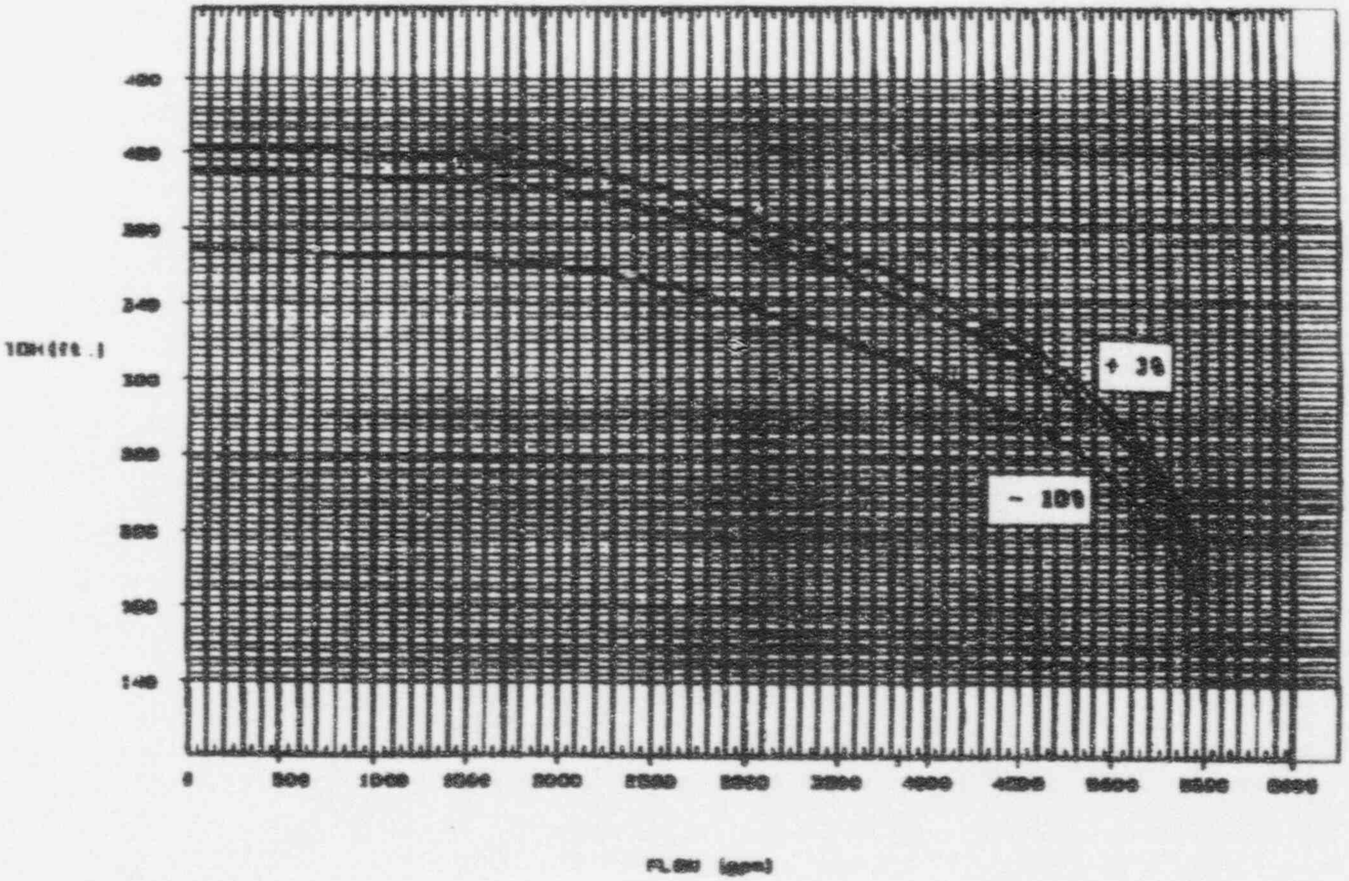
This computer generated pump head curve has been evaluated as a suitable substutute for the currently approved pump curve incorporated in the applicable pump test procedure. This curve has been verified to be similar in general shape and has been checked for accuracy at a minimum of 5 points across the range of the curve. This curve is within the readable limits of the accepted curve and may be used as a substutute or in lieu of the current accepted curve.

[signature] 2/25/92
System Engineer Date

2B RH Pump Curve



2B RESIDUAL HEAT REMOVAL PUMP

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ATTACHMENT D

Calculation ZI-3-86 Rev. 1

"Calculation of Post-LOCA Iodine Spray Removal Rate"

and

Calculation ZI-5-91 Rev. 0

"Control Room Infilteration Study"