June 28, 1988

Docket Nos. 50-259/260/296

LICENSEE: Tennessee Valley Authority

FACILITY: Browns Ferry Nuclear Plant, Units 1, 2 and 3

SUBJECT: JUNE 2, 1988 MEETING WITH THE TENNESSEE VALLEY AUTHORITY TO DISCUSS IMPLEMENTATION OF THE ANTICIPATED TRANSIENT WITHOUT SCRAM (ATWS) RULE, 10 CFR 50.62

On June 2, 1988 members of the Office of Special Projects met with members of the Tennessee Valley Authority (TVA or the licensee) to discuss TVA's implementation of the ATWS Rule, 10 CFR 50.62. Enclosure 1 is the list of attendees. The meeting was held to discuss the specifics of the Standby Liquid Control System, Alternate Rod Injection (ARI), and Recirculation Pump Trip designs at the Browns Ferry Nuclear Plant. TVA agreed to provide the following information needed to support the staff's review:

- Verification of separation in the recirculation pump trip design between the ATWS trip coil and the reactor protection system trip coil.

- Completion of the checklist for plant specific review of the ARI system (Appendix A to the staff SER on the BWR Owner's Group Topical Report, October 21, 1986).

Enclosure 2 contains calculations provided by TVA at the meeting to support the ARI venting time of the scram air header. The NRC staff is currently scheduled to do a post-implementation review of the ATWS modifications after restart of Browns Ferry Unit 2.

Original Signed by

Janet L. Kelly, Project Engineer
TVA Projects Division
Office of Special Projects

Enclosures:
1. Attendance List
2. TVA Calculation

cc w/enclosures:
See next page

Distribution
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Those On Attached List

DF01 /1

OSP:TVA/LA	OSP:TVA/PE	OSP:TVA/PM	TVA:AD/P
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6/23/88	6/23/88	6/27/88	6/28/88

DISTRIBUTION FOR MEETING SUMMARY DATED: June 28, 1988

Facility: Browns Ferry Nuclear Plant, Units 1, 2 and 3*

Docket File
NRC PDR
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Units 1, 2, and 3

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ENCLOSURE 1

MEETING ON JUNE 2, 1988
ATWS RULE

Name	Organization
Phil Porter	TVA
Lin Turner	TVA
Hulbert Li	NRC/NRR
Hukam Garg	NRC/OSP
Janet Kelly	NRC/OSP
Gerry Gears	NRC/OSP

ENCLOSURE 2

QA RECORD

TVA 10697 (DNE 6-86)

DNE CALCULATIONS

TITLE ARI Venting Time of Scram Air Header				PLANT/UNIT BFNP 2
PREPARING ORGANIZATION BNAPC JOB 19106	KEY NOUNS (Consult RIMS DESCRIPTORS LIST) CRD HYDRAULIC SYSTEM			
BRANCH/PROJECT IDENTIFIERS MD-N2085-88002	Each time these calculations are issued, preparers must ensure that the original (RO) RIMS accession number is filled in.			
	Rev	(for RIMS' use)	RIMS accession number	
	R0	(120)	B22 880302 105	
APPLICABLE DESIGN DOCUMENT(S) N/A	R_			
	R_			
SAR SECTION(S) N/A / UNID SYSTEM(S) 085	R_			

Revision 0	R1	R2	R3
ECN No. (or indicate Not Applicable) E-2-P7045, Rev 0			
Prepared [signature]			
Checked [signature] 2/16/88			
Reviewed [signature] 2/18/88 UVP 2/23/88			
Approved [signature]			
Date 2/24/88			
List all pages added by this revision.			
List all pages deleted by this revision.			
List all pages changed by this revision.			

Use form TVA 10534 if more space required.

Safety-related? Yes ☐ No ☑

Statement of Problem

Calculate the Air Venting time of the scram air header for the ATWS/ARI modifications.

Abstract

These calculations contain an unverified assumption(s) that must be verified later. Yes ☐ No ☒ ~~(Use of an unapproved (by TVA) computer program)~~ UVP 2/23/88

This calculation determines the air venting time of the scram air header for the ATWS/ARI modifications. The result of this analysis shows that the pressure in the scram diaphragm valve will reduce to about 28 psig in ~ 11 seconds. This result is applicable for 3 or 4 vent valves (one or two vent valves at each vent location) opening.

Program application tested 1/..88, 2/10/88

~~This calculation is performed using a Bechtel verified software program not yet approved for use on BFNP by TVA. Therefore the calculation is considered preliminary until TVA approval~~ as required on the calculations ~~is accomplished for the unverified TVA program~~ UVP 2/23/88

Calc has been verified. See sheet 4. UVP 2/23/88 "DIRECT DESIGN INPUT"

☐ Microfilm and store calculations in RIMS Service Center. Microfilm and destroy. ☐

☑ Microfilm and return calculations to: C.E. ANDERSON Address: DS EDB BFN

SH. 1

TVA

Title: ARI Venting Time of Scram Air Header

REVISION LOG

Calc # MD-N2085-88002

Revision No.	DESCRIPTION OF REVISION	Date Approved
0	Original Issue per ECN E-2-P7045, Rev. 0	2-24-88

SHEET	LATEST REV.	SHEET	LATEST REV.	SHEET	LATEST REV.	SHEET	LATEST REV.	SHEET	LATEST REV.	SHEET	LATEST REV.	SHEET	LATEST REV.
i	0	36	0	Attach 1		Attach 2 SH.17	0	13	0				
1	0	37	0	SH.1	0	18	0	14	0				
2	0	38	0	2	0			15	0				
3	0	39	0	3	0	Attach 3 SH.1	0	16	0				
4	0	40	0	4	0			17	0				
5	0	41	0	5	0	Attach 4 SH.1	0	18	0				
6	0	42	0	6	0	2	0	19	0				
7	0	43	0	7	0	3	0	20	0				
8	0			8	0								
9	0			9	0								
10	0			10	0								
11	0			11	0								
12	0			12	0								
13	0			13	0								
14	0			14	0								
15	0			15	0								
16	0			16	0	Attach 5							
17	0	Appendix		17	0	SH.1	0						
18	0	A-1	0	18	0								
19	0	A-2	0			Attach 6							
20	0	A-3	0	Attach 2 SH.1	0	SH.1	0						
21	0	A-4	0	2	0								
22	0	A-5	0	3	0								
23	0	A-6	0	4	0	Attach 7							
24	0	A-7	0	5	0	SH.1	0						
25	0	A-8	0	[illegible]	0	2	0						
26	0	A-9	0	7	0	3	0						
27	0	A-10	0	8	0	4	0						
28	0	A-11	0	9	0	5	0						
29	0	A-12	0	10	0	6	0						
[illegible]	0	A-13	0	11	0	7	0						
[illegible]	0	A-14	0	12	0	8	0						
[illegible]	0			13	0	9	0						
33	0			14	0	10	0						
34	0			15	0	11	0						
35	0			16	0	12	0						

BECHTEL

REVISION STATUS SHEET

ARI Venting Time of Scram Air Header

JOB NO. 19106

CALCULATION NO. MD-N2085-88002

REV. NO. 0

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CALCULATION SHEET

BEPC-2706 Rev. 8/00 (EC

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0.	3

ORIGINATOR	DATE	CHECKED	DATE
[signature]	2/10/88	[signature]	2/12/88

Subject: ARI Venting Time of Scram Air. Header

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BECHTEL

CALCULATION SHEET

BEPC-8706 Rev. 6/80 (ED-4)

JOB NO.	CALC. NO.	REV. NO.	SHEET NO
19106	MD-N2085-88002	0	4

ORIGINATOR	DATE	CHECKED	DATE
John C. Rosswurm	1/11/88	J.M. Gilmore	1/13/88

Subject: ARI Venting Time of Scram Air Header

Purpose: As part of the design efforts to incorporate the ATWS / Alternate Rod Insertion (ARI) modifications it is necessary to verify whether or not the proposed design will allow the HCU scram diaphragm valves to be vented quickly enough to allow the insertion of the control rods within the allowable time limits. As such the purpose of this calculation is to calculate the venting time of the air in the HCU scram diaphragm valves and air header, (Reference 1), per ECN-E-2-P7045, Rev. 0. This analysis considers both 8 Vent Valves and 4 Vent Valves (see sheet 41) operation.

Methodology: To calculate the air venting times, a computer program was developed using Microsoft's QuickBasic for use on a IBM-PC. The program is specific to this analysis and has been verified. Verification is included in Appendix A. Descriptions of the theory used are included in later sections of this calculation.

General Description of Problem Being Analyzed

Figure 1 provides a general schematic of the air volume to be considered for venting in this analysis. Upon an appropriate signal, the ARI vent valves will open causing the depressurization of the air header and the HCU scram diaphragm valves air volumes. The depressurization of the scram diaphragm valve volume permits the opening of the scram discharge inlet and outlet valves, thus permitting control rod insertion.

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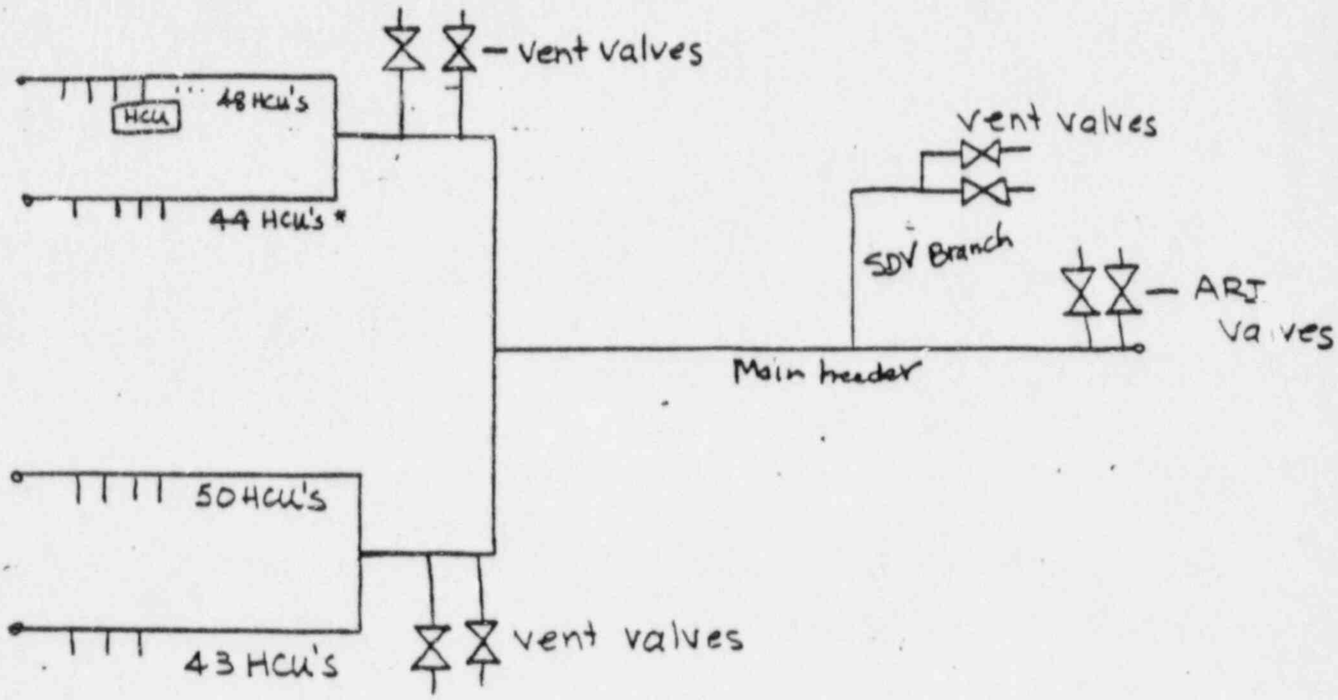
CALCULATION SHEET

8IPC-2706 Rev. 6/06 (ED

JOB NO.	CALC. NO.	REV. NO.	SHEET NO
19106	MD-N2085-88002	0	5

ORIGINATOR	DATE	CHECKED	DATE
John C. R[illegible]	1/11/88	[illegible]	1/13/88

Subject: ARI Venting Time of Scram Air Header



* see below for general drawing of an HCU

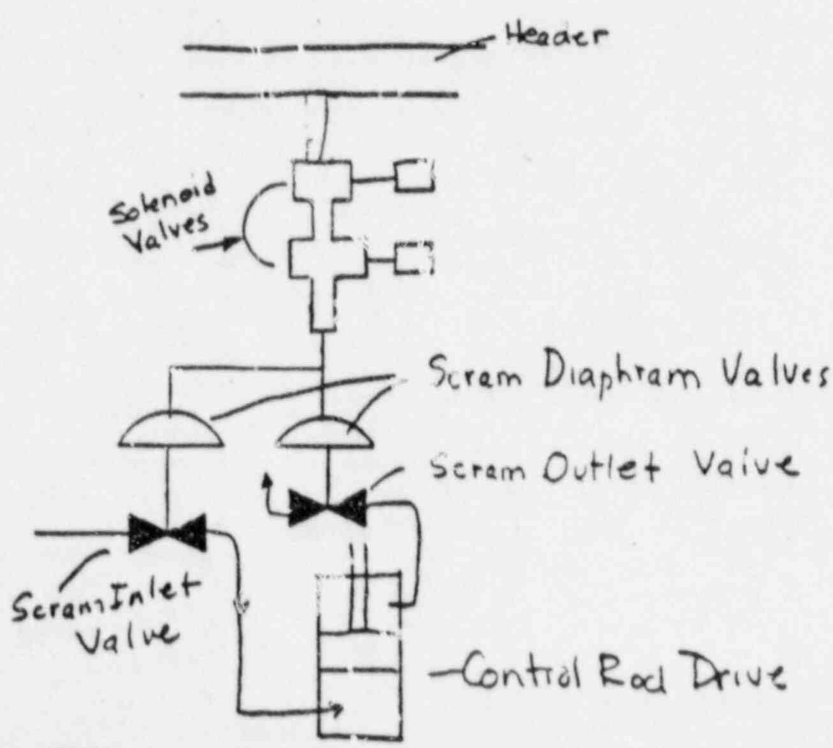


Figure 1

(Reference 2)

CALCULATION SHEET

BECHTEL

BEPC-2706 Rev. 6/00 (ED-4

JOB NO.	CALC. NO.	REV. NO.	SHEET NO
19106	MD-N2085-88002	0	6

ORIGINATOR	DATE	CHECKED	DATE
John C. Rosmund	1/11/88	JM Gilmer	1/13/88

Subject: ARI Venting Time of Scram Air Header

Figure 2 provides the vent path through which depressurization of the HCU's scram diaphragm valves occurs. The minimum flow area occurs at point "G", where a wire is within the grommet. This point provides a large resistance to flow and, as will be shown in the results of this calculation, is responsible for much of the venting time associated with this analysis.

Subject: ARI Venting Time of Scram Air Header

DUAL ASCO SOLENOID SCRAM PILOT VALVE SH.7

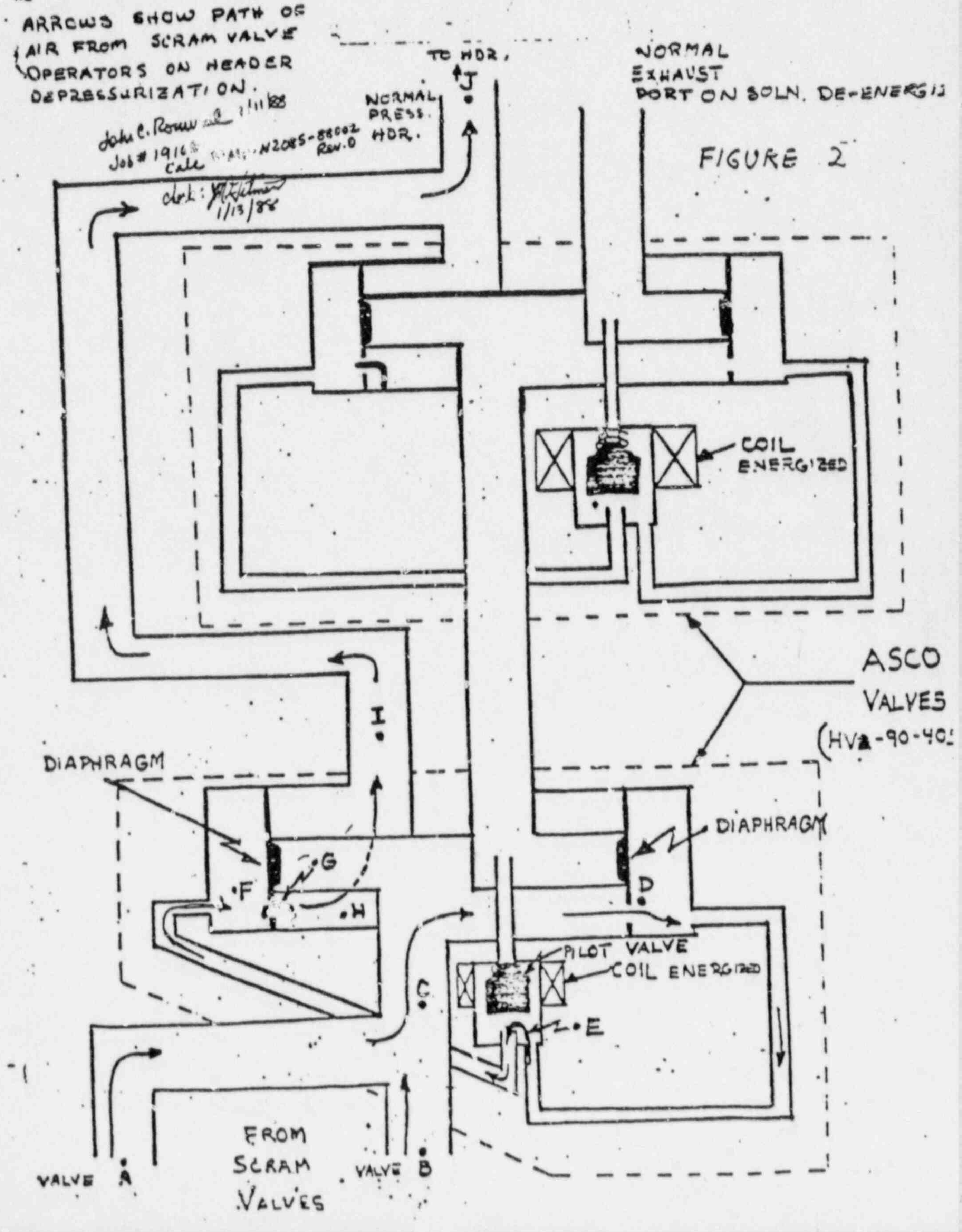


FIGURE 2

CALCULATION SHEET

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BEPC-2766 Rev. 6/06 (ED)

JOB NO.	CALC. NO.	REV. NO.	SHEET NO
19106	MD-N2085-88002	0	8

ORIGINATOR	DATE	CHECKED	DATE
John C. Rosmund	1/11/88	JM Gilmer	1/13/88

Subject: ARI Venting Time of Scram Air Header

Assumptions + DATA

The piping arrangement in Figure 1 was nodalized into 45 nodes with 47 flow paths connecting the various nodes. This nodalization and the flow paths convention is provided in Figures 3, 4+5. The volumes, flow areas, etc are calculated as described in pages 13 - 31.

Other assumptions and data used in the analysis include:

1. The initial pressure in the air volumes of 90 psia (75 psig) (Reference 2)

2. An isothermal process is used. This is conservative (results in larger venting time) versus an isentropic process, as energy would be required to be added to the system to maintain a constant temperature

3. The initial system temperature varies between 50 - 110°F. (Reference TVA Mech. Design Guide DG- 7.3.1 ; Sec 4.1.2

4. The opening times of the ARI and vent valves are small in comparison to the problem analysis time and can thus be neglected. (~0.05 sec vs. ~20 seconds) (Reference 2)

5. There are no flow blockages within the solenoid valve. That is, the minimum flow area (grommet with wire through it - 6.44x10⁻⁴ in²) is not blocked and is available to vent through in all the HCU's. This assumption is critical in that, most of venting time in this analysis is that associated with the depletion of the HCU scram diaphragm valve's volume through this area. (Reference 2)

CALCULATION SHEET

BECHTEL — BEPC-3786 Rev. 6/86 (ED-)

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	9

ORIGINATOR	DATE	CHECKED	DATE
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Subject: ARI Venting Time of Scram Air Header

6. The diaphragms within the solenoid valves remain in place, even when large pressure differentials occur across them. This is conservative, since if diaphragms become dislodged a much larger flow path w/ less resistance will exist within the solenoids.

7. System only contain air, thus isentropic exponent = 1.4 (Reference 3, p. 732) and thus ideal gas equations can be used.

8. All Friction factors are based on turbulent flow. This assumption has minimal effects on results as system depressurization is essentially controlled by flow through grommets in solenoid valve diaphragms.

~~9. The computer program developed for this calculation will be accepted by TVA.~~ WYP 2/23/88

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CALCULATION SHEET

BEPC-2706 Rev. 6/83

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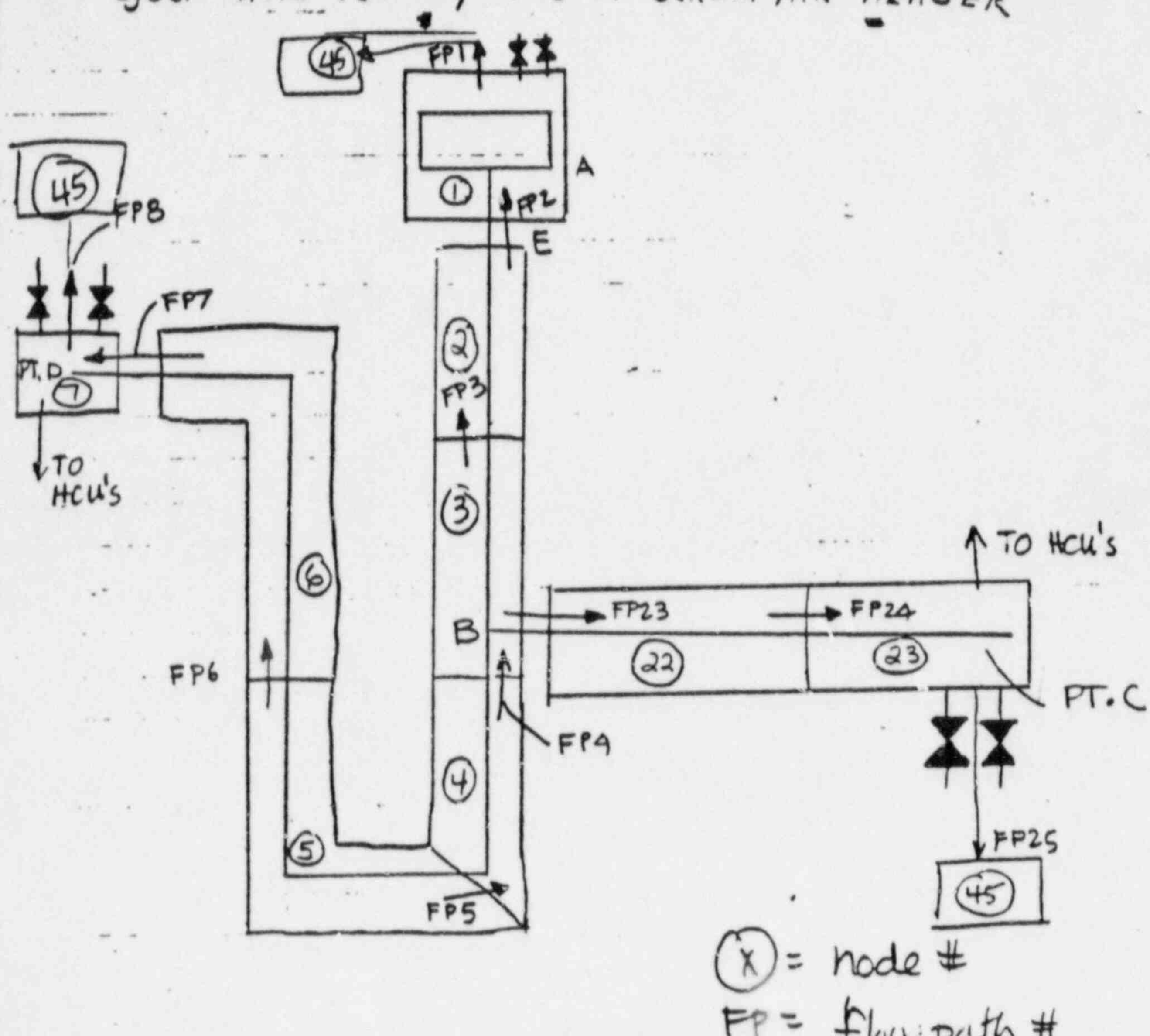
19106	MD-N2085-88002	0	10

ORIGINATOR	DATE	CHECKED	DATE
John C. Rosumek	1/11/88	JM Gilmore	1/13/88

Models

Subject: ARI Venting Time of Scram Air Header



Scram Valve Air Header Modelling

Figure 3

(Reference 2)

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CALCULATION SHEET

BEPC-3706 Rev. 8/80 (ED

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	11

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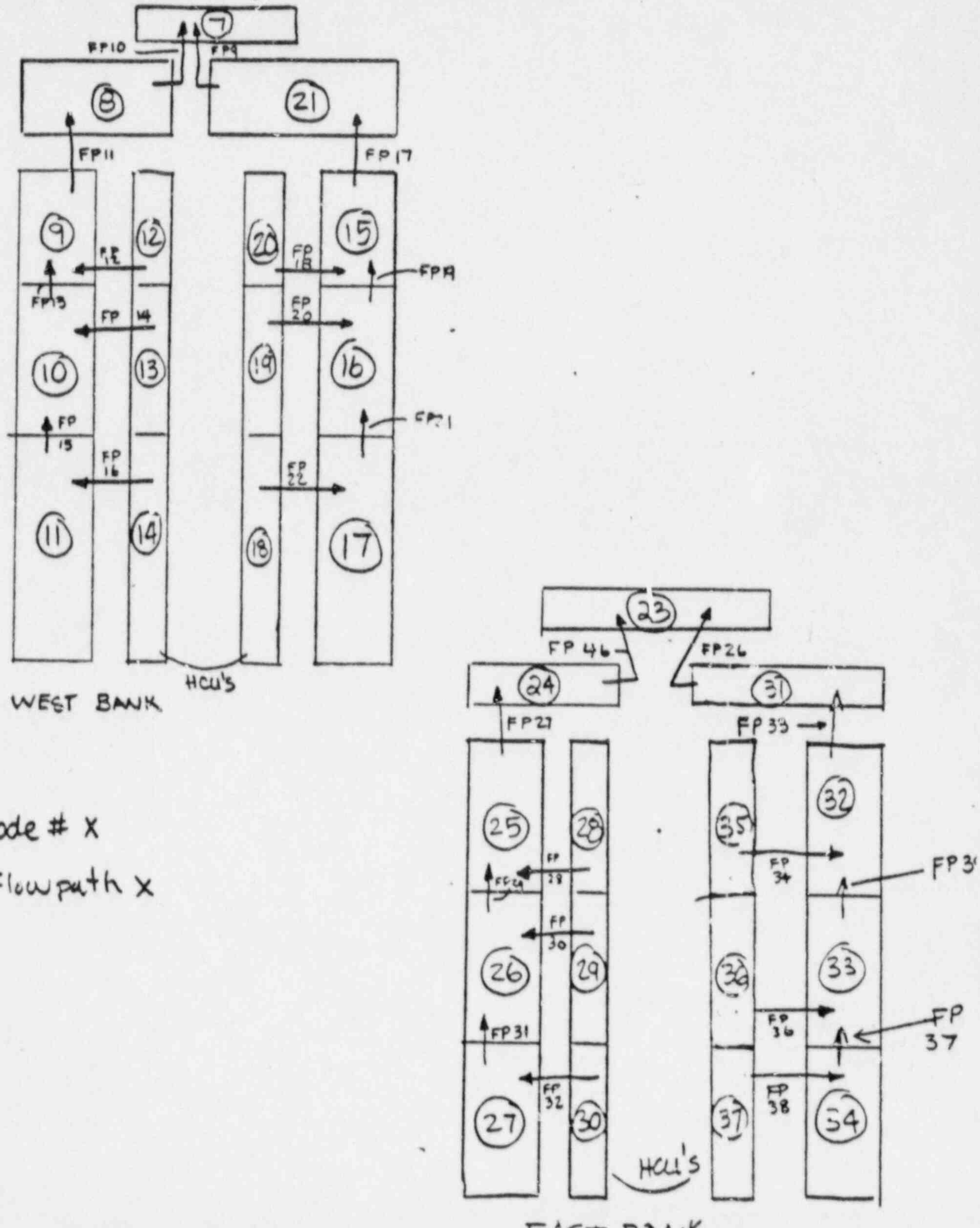
John C. Rosuwel	1/11/88	JMGilmore	1/13/88

Subject: ARI Venting Time of Scram Air Header



(x) = node # X

FPX = Flowpath X

FIGURE 4

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CALCULATION SHEET

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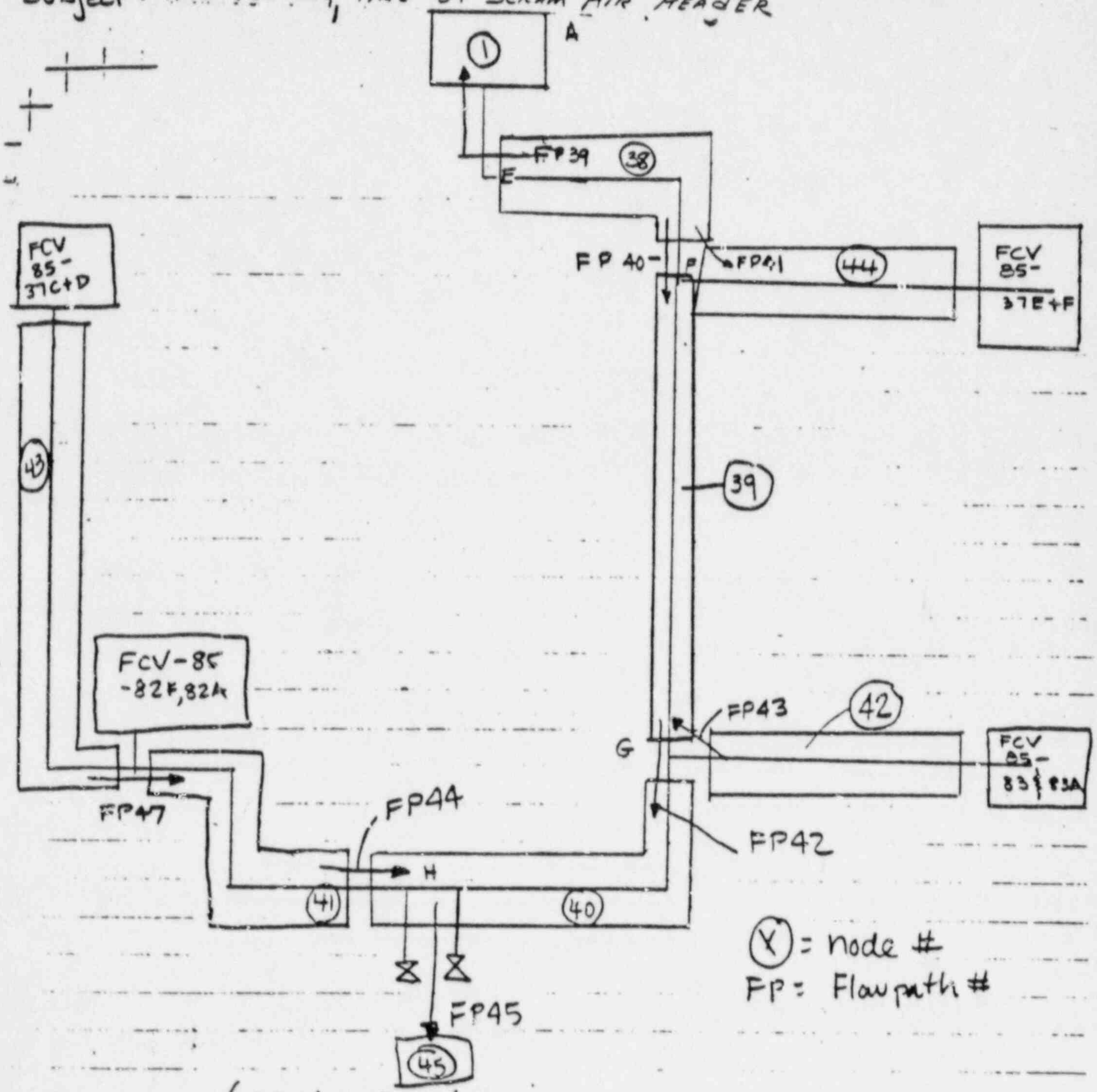
JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	12

ORIGINATOR	DATE	CHECKED	DATE
John C. Rozumil	1/11/88	JMGilmor	1/13/88

Subject: ARI Venting Time of Scram Air Header



(SDV VENT/DRAIN VALVE AIR HEADER MODELLING)

Figure 5 (Reference 3)

CALCULATION SHEET

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19106	MD-N2085-88002	0	13

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John. Rosecrueul	1/11/88	J.M. Gilmer	1/13/88

Subject: ARI Venting Time of Scram Air Header

CALCULATIONS

• Calculation of Volumes, Flow Areas and Loss Coefficients

The model used in this analysis is shown in Figures 3,4 + 5. The actual volumes, flowarea etc used were provided in Reference 2 Memo and Calc.

Volumes

Node 1 - From Point "A" to ($1\frac{5}{8}$" to $1\frac{1}{8}$" Reducer) : $V = 34.33\ in^3$

Node 2, Node 3 } From ($1\frac{5}{8}$" to $1\frac{1}{8}$" Reducer) to Point B assuming equally divided among 2 node

$$V = \frac{2477.54}{2} = 1238.77 in^3$$

Node 4, Node 5, Node 6 } From Point B to ($1\frac{5}{8}$" x $1\frac{1}{8}$" Reducer - Point D) assuming equally divided among 3 nodes

$$V = \frac{3373.77}{3} = 1124.59\ in^3$$

NODE 7 ($1\frac{5}{8}$" to $1\frac{1}{8}$" Reducer) to Point X

Volume = $121.95\ in^3$

NODE 8 Pt x to ($1\frac{1}{8}$" to $\frac{7}{8}$" RED on West Bank ①)

Volume = $137.5\ in^3$

NODE 9, NODE 10 } West Bank Header ① + (48 + ①-②-③)

Volume = 282.9 + 48 + 5.6 = $551.7\ in^3$

Subject: ARI Venting Time of Scram Air Header

Node 9,10,11 (cont) assuming split equally among 3 volumes

See Reference 5 $V = \frac{551.7 in^3}{3} = 183.9 in^3$

48*{①④⑤ + scram diaphragm valve} — See Reference 9

Node 12, Node 13, Node 14: $(6.4 + 24.5*2) * 48 = 2659.2 in^3$

splitting into three nodes $= \frac{2659.2}{3} = 886.4 in^3$

Volume = $886.4 in^3$

Node 15, Node 16, Node 17: West Bank Header ② + (44 + ① - ② - ③)

Volume = $426.5 + 44(5.6) = 672.9 in^3$

splitting into three nodes

$V = \frac{672.9}{3} = 224.3 in^3$

Node 18, Node 19, Node 20: 44*{③-④-⑤ + scram diaphragm valves}

$44 * \{6.4 + 24.5*2\} = 2437.6 in^3$

splitting into three nodes

$V = \frac{2437.6}{3} = 812.53 in^3$

Node 21: Point A to 1⅛ x ⅞" - West Bank ②

Volume = $136.3 in^3$

Node 22, Node 23: Point B to Point C

Volume = $255.45 in^3$

splitting into two nodes $= \frac{255.45}{2} = 127.73 in^3$

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CALCULATION SHEET

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JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	15

ORIGINATOR	DATE	CHECKED	DATE
John C Rosmumel	1/11/88	JM Sitoner	1/13/88

Subject: ARI Venting Time of Scram Air Header

Node 24 — Point C to $1\frac{1}{8}" \times \frac{7}{8}"$ Reducer on E. Bank 1

Volume = 80.2 in^3

Node 25, Node 26, Node 27 — East Bank 1 + 50x (①-②-③)

Volume = 303 + 50(5.6) = 583 in^3

splitting into 3 nodes

Volume = $\frac{583}{3}$ = 194.3 in^3

Node 28, Node 29, Node 30 — 50x((③-④-⑤) + scram diaphragm valves)

V = 50 (6.4 + 24.5*2) = 2770 in^3

splitting into 3 nodes

Volume = $\frac{2770 in^3}{3}$ = 923.33 in^3

Node 31 — Point C to $1\frac{1}{8}" \times \frac{7}{8}"$ reducer on E. Bank 2

Volume = 250.0 in^3

Node 32, Node 33, Node 34 — 43 + (①-②-③) + East Bank 2

43*(5.6) + 368.4 = 609.2 in^3

Splitting equally into 3 nodes

Volume = $\frac{609.2 in^3}{3}$ = 203.07 in^3

Node 35, Node 36, Node 37 — 43x((③-④-⑤) + scram diaphragm valves)

43(6.4 + 24.5*2) = 2382.2 — splitting into 3 gives $\frac{2382.2}{3}$ = 794.1

Node 38 — Point E to Point F

Volume = 15.36 + 119 = 134.36 in^3

Node 39 — Point F to Point G

Volume = 80.2 in^3

CALCULATION SHEET

BEPC-2706 Rev. 6/84 (ED)

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	16

ORIGINATOR	DATE	CHECKED	DATE
John C. Rommel	1/11/88	J.M. Gilmer	1/13/88

Subject: ARI Venting Time of Scram Air Header

Node 40 — Point G to Point H
Volume = 94.58 in³ ✓

Node 41 — Point H to Point Y
Volume = 150.6 in³ ✓

Node 42 — Point G to FCV-85-83+83A.
Volume = 50 + 12.2 = 62.2 in³ ✓

Node 43 — Point Y to FCV-85-37C+D
Volume = 125 + 23.3 = 148.3 in³ ✓

Node 44 — Point F to FCV 85-37E+F.
Volume = 31 in³ ✓

Node 45 (Models Atmosphere)

Volume → ∞ (set at 1.E10) ✓

BECHTEL — **CALCULATION SHEET** BEPC-2700 Rev. 8/86 (SD-

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	17

ORIGINATOR	DATE	CHECKED	DATE
John C. Rosmund	1/11/88	[signature]	1/13/88

Subject: ARI Venting Time of Scram Air Header

- Flow Path Data

Path 1 - ARI valves (Node 1 to ATM)

- two valves - 1" valves
- area = $\frac{2 * \pi}{4}$ = 1.57 in²
- Cv for each valve (13, see Attachment 4.)

K (loss coefficient) =

$$K = \frac{891 * 1^4}{13^2} \quad \text{(Reference 4, p A-31)}$$

$$K = 5.27$$

note: K factor and loss are used interchangeably in calculation.

Additional loss to include friction losses in node 1

- friction loss (K-factor for piping) = $\frac{0.011 * 42}{1.025}$ = 0.45 *(($\frac{fL}{D}$) (both f_T and K factor for fittings lengths and friction loss term for this section of calculation are taken from Reference 2
- Valve/fittings loss (K factor for valve/fittings) = $\frac{3.06}{3.51}$ *((based on 1.025"-diameter)

Converting this K-factor to the area of the flow path (1.57 in²):

$$3.51 * \left(\frac{1.57}{\frac{\pi (1.025)^2}{4}}\right)^2 = 12.7$$

thus the total loss (K factor) for this flowpath (based on input flow area of 1.57 in²) is 12.7 + 5.27 = 17.97

* all losses in calculation as based on turbulent flow

CALCULATION SHEET

BEPC-2706 Rev. 8/06 (ED-4)

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	F8

ORIGINATOR	DATE	CHECKED	DATE
John C. Rozumnal	1/11/88	JM Gilmer	1/13/88

Subject: ARI Venting Time of Scram Air Header

Flow path 2 - Between nodes 2 and 1
Flow path 3 - Between nodes 3 and 2

Friction length loss = $\frac{.010 \times 1363.5}{1.505}$ = 9.06

valve fitting losses + 3.57

total 12.63 ✓

splitting between both flow paths ⇒ K = 6.32 $\left(\frac{12.63}{2}\right)$

Flow area = $\frac{(1.505)^2 \times \pi}{4}$ = 1.78 in^2 ✓

Flow path 4 Between Nodes 4 and 3
Flow path 5 Between Nodes 5 and 4
Flow path 6 Between Nodes 6 and 5

Friction length loss = $\frac{0.01 \times 1895.5}{1.505}$ = 12.59

valve fitting losses = 5.03

17.62 - TOTAL

splitting equally over each flow path = $\frac{17.62}{3}$ = 5.87 ✓
area = 1.78 in^2

Flow path 7 Between nodes 6 and 7

Friction length loss = $\frac{0.01 \times 1480}{1.025}$ = 1.44 ✓

valve/fitting losses = 0.33

1.77 ✓ - TOTAL

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CALCULATION SHEET

BEPC-2700 Rev. 8/86 (ED-4)

JOB NO.	CALC. NO.	REV. NO.	SHEET NO
19106	MD-N2085-88002	0	19

ORIGINATOR	DATE	CHECKED	DATE
John Rosswell	1/11/88	J.M. Elmer	1/13/88

Subject: ARI Venting Time of Scram Air Header

Flowpath 8 - Vent Valves (Node 7 to Atmosphere)

area = 1.57 in^2 (from page 17)
K = 5.27

Flow path 9 - Nodes 21 to 7

area = 0.83 in^2 (see page 18)

friction losses = $\frac{0.011 * 165.38}{1.025} = 1.77$

valve fitting losses = 1.1
total 2.87

Flow Path 10 - Nodes 8 to 7

area = 0.83 in^2 (see page 18)

friction losses = $\frac{0.011 * 166.75}{1.025} = 1.79$

valve fittings losses = 2.2
3.99

Flow Path 11 Nodes 9-8
Flow Path 13 Nodes 10-9
Flow Path 15 Nodes 11-10

area = $\frac{\pi (0.785)^2}{4} = 0.484\ in^2$

friction losses = West Book! = $\frac{0.011 * 584.5}{0.785} = 8.19$

CALCULATION SHEET

BECHTEL — BEPC-2706 Rev. 8/86 (ED-4)

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	20

ORIGINATOR	DATE	CHECKED	DATE
John C Rosewell	1/11/88	J M Palmer	1/13/88

Subject: ARI Venting Time of Scram Air Header

Flowpaths 11, 13, 15 (cont)

Valve / Fitting losses : West Bank 1 - 14.71

① - ② - ③ - 1.74

Convert all losses to an equivalent area (using area of header).

$$A = \frac{\pi (0.785)^2}{4} = 0.484 \text{ in}^2 ✓$$

area of (①-②-③) = $\left(\frac{\pi * (0.43)^2}{4}\right) = 0.145$

converting friction losses : $0.97 * \left(\frac{0.484}{0.145}\right)^2 = 10.81$ ✓

valve fittings = $1.74 * \left(\frac{0.484}{0.145}\right)^2 = 19.39$

30.20 ✓

total loss = 30.20
+ 8.19
+ 14.71
53.10

Splitting equally among 3 flow paths gives : $\frac{53.10}{3} = 17.70$ ✓

Area for each flowpath = 0.484 in² ✓

Flow path 12 Nodes 12-9
Flow path 14 Nodes 13-10
Flow path 16 Nodes 14-11

Assume all of loss within this node occurs at the

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CALCULATION SHEET

BEPC-2706 Rev. 8/86 (ED-)

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	21

ORIGINATOR	DATE	CHECKED	DATE
John C. Rosauwel	1/11/88	JM Gilmer	1/13/88

Subject: ARI Venting Time of Scram Air Header

solenoid valves is partially blocked by the 0.036" OR guide wire (See Figure 2). Per attachment 4, the flow area through this partially blocked area is approximately 6.44×10^{-4} in². Additionally, per Reference 5 the thickness of the diaphragm is about 5/32" near the location of the hole. The diameter of the grommet is ~0.046" (Reference 5).

An equivalent diameter of the partially blocked hole is determined by

$$D = \sqrt{6.44 \times 10^{-4} \times \frac{4}{\pi}} = .0286 \text{ in}$$

$$\frac{l}{D} = \frac{\text{length (thickness)}}{\text{diameter}} = \frac{5/32''}{0.0286''} = 5.5$$

From IdelChek, Reference 6, p. 171

$$K_0 = 0.5\left(1 - \frac{A_0}{A_1}\right) + \left(1 - \frac{A_0}{A_1}\right)^2 + \tau\sqrt{1 - \frac{A_0}{A_1}}\left(1 - \frac{A_0}{A_1}\right)$$

where A_0 = area of hole
A_1 = upstream/downstream area (assumed equal in this case)

Using the area of ③-④-⑤ $\left(\pi \frac{(0.43)^2}{4}\right) = 0.145$ in²

gives

$$\frac{A_0}{A_1} = \frac{6.44 \times 10^{-4}}{0.145} = 4.44 \times 10^{-3} \approx 0$$

CALCULATION SHEET

BECHTEL — BEPC-2706 Rev. 6/86 (ED)

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	22

ORIGINATOR	DATE	CHECKED	DATE
Karl Rosmund	1/11/88	JM Gilman	1/13/88

Subject: ARI Venting Time of Scram Air Header

then

$$K_0 = 0.5(1) + 1 + 0 = 1.5$$

Converting this value to 0.145 in² gives

$$K_1 = 1.5\left(\frac{1}{4.44\times10^{-3}}\right)^2 = 76090$$

Additionally for the grommet w/o the wire $K_0 = 1.5$ and converting this to 0.145 in² gives

$$K_1 = 1.5\left(\frac{0.145}{\frac{\pi}{4}(0.046)^2}\right)^2 = 11419$$

Thus $K_{1_{TOTAL}} = 76090 + 11419 = 87509$

Area = 0.145 in² × 16 = 2.32 in² (models 48/3 HCU's)

note: K_1 is applied to the area as calculated since these paths are in parallel.

Flow Path 17 - Between Nodes 15-21
Flow Path 19 - Between Nodes 16-15
Flow Path 21 - Between Nodes 17-16

area = 0.484 in² (see page 19)

friction losses = West Bank 2 = $\frac{0.011 * 881}{0.785}$ = 12.34

①-②-③ = 10.81 (see page 2_)
(based on area of 0.484 in²)

valve fitting losses West Bank 2 16.47

①-②-③ 19.39

57.01

CALCULATION SHEET

Subject: ARI Venting Time of Scram Air Header

Flow Path 18 Between Nodes 20 - 15
Flow Path 20 Between Nodes 19 - 16
Flow Path 22 Between Nodes 18 - 17

Using similar assumptions as discussed previously for flow paths 12, 14 & 16 —

- $area = 0.145 * \frac{44}{3} = 2.13\ in^2$ ✓

- $K = 87509$ ✓ (see page 22)

Flow Path 23 Between Nodes 22 - 3
Flow Path 24 Between Nodes 23 - 22

$area = \frac{\pi (1.025)^2}{4} = 0.825\ in^2$ ✓

Friction loss $= \frac{0.011 * 310}{1.025} = 3.33$ ✓

valve/fitting loss 2.0 ✓

total loss 5.33 ✓

splitting this loss equally among two flow paths:

- $K = \frac{5.33}{2} = 2.67$ ✓

Flow Path 25 Between Node 23 - Atmosphere

$area = 1.57\ in^2$ ✓ (see page 17)
$K = 5.27$ ✓

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CALCULATION SHEET

BEPC-3700 Rev. 6/86 (ED-

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	24

ORIGINATOR	DATE	CHECKED	DATE
John C. Rosenwel	1/11/88	JM Gilmer	1/13/88

Subject: ARI Venting Time of Scram Air Header

Flow Path 26 Between Nodes 31-23

area = $0.825 in^2$ ✓ (see page 23)

friction losses: $\frac{0.011 * 303.4}{1.025} = 3.26$

valve fittings losses 1.87

K = 5.13 ✓

Flow Path 27 Between Nodes 25-24
Flow Path 29 Between Nodes 26-25
Flow Path 31 Between Nodes 27-26

area = $0.484 in^2$ ✓ (see page 19)

friction losses East Bank 1 $\frac{0.011 * 626.0}{0.785} = 8.77$

valve/fittings losses East Bank 1 15.48

friction losses ① - ② - ③ } 10.81 (see page 20)
valve/fittings losses ① - ② - ③ } 19.39

54.45

Splitting - Between 3 flow paths = $\frac{54.45}{3} = 18.15$ ✓

Flow path 28 Between Nodes 28-25
Flow path 30 Between Nodes 29-26
Flow Path 32 Between Nodes 30-27

area = π 1.45 * 5.0 = 7.25 in^2 = 2.42 in^2 ✓

CALCULATION SHEET

BEPC-3706 Rev. 6/86 (ED-

JOB NO.	CALC. NO.	REV. NO.	SHEET NO
19106	MD-N2085-88002	0	25

ORIGINATOR	DATE	CHECKED	DATE
[signature]	1/11/88	[signature]	1/13/88

Subject: ARI Venting Time of Scram Air Header

Flowpath 33 Between Nodes 32-31
Flow path 35 Between Nodes 33-32
Flow path 37 Between Nodes 34-33

friction losses East 2 $\frac{0.011 \times 761}{0.785} = 10.67$

valve/fittings East 2 15.84

friction losses ①-②-③ 10.81 (see page 20)
valve/fittings ①-②-③ 19.39
—————
56.71

Splitting between 3 flow paths

$K = \frac{56.71}{3} = 18.90$ ✓

area = 0.484 in² ✓ (see page 20)

Flow Paths 34 Between Nodes 35-32
Flow Path 36 Between Nodes 36-33
Flow Path 38 Between Nodes 37-34

area = $\frac{0.145 \times 43}{3} = \frac{6.24}{3}$ in² = 2.08 in² ✓

K = 87509 ✓ (see page 22)

Flow Path 39 Between nodes 38 and 1

friction losses – Pt "E" to reducer – $\frac{0.011 \times 65.63}{.545} = 1.32$ ✓

reducer to F $\frac{0.011 \times 810}{0.43} = 20.72$ ✓

CALCULATION SHEET

BEPC-2706 rev. 6/80 (ED-61)

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	26

ORIGINATOR	DATE	CHECKED	DATE
John L. Rozumel	1/11/88	J.M. Gilmer	1/13/88

Subject: ARI Venting Time of Scram Air Header

valve fitting losses

- Pt "E" to reducer - 1.07
- reducer to "F" - 3.19

Converting all losses to the area of $\frac{\pi(.43)^2}{4} = 0.145\ in^2$ ✓

friction losses = $1.32 * \left(\frac{0.43}{0.545}\right)^4 = 0.51$ ✓

valve/fitting losses $1.07 * \left(\frac{0.43}{0.545}\right)^4 = 0.42$ ✓

Total loss = $20.72 + 3.19 + 0.51 + 0.42 = 24.84$ ✓

Flow Path 40 Between Nodes 39-38

friction losses = $\frac{0.011 * 549}{0.43} = 14.04$

valve/fittings loss = 1.32

total 15.36 ✓

area = $0.145\ in^2$ (see above)

Flow Path 41 Between Nodes 44-38

area = $(0.277)^2 * \pi/4 = 0.060\ in^2$ ✓

friction losses = $\frac{0.011 * 440}{.277} = 17.47$

valve/fittings = 3.23

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CALCULATION SHEET

BEPC-2700 Rev. 8/80 (ED-4)

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	27

ORIGINATOR	DATE	CHECKED	DATE
John Beaumel	1/11/88	J M Gilmore	1/13/88

Subject: ARI Venting Time of Scram Air Header

Flow Path 42 Between Nodes 40-39

area = 0.145 in² (see page 26)

friction losses = $\frac{0.011 * 647.75}{0.43} = 16.57$

valve/fitting losses = —

16.57 ✓

Flow Path 43 Between Node 42 - 39

area = 0.145 in² (see page 26)

area = 0.145 "G → reducer" { friction losses : $\frac{0.011 * 340}{.43} = 8.70$
valve/fittings loss 1.32

10.02 ✓

area = 0.06 reducer - FCV 85-83 & 84 { friction losses = $\frac{0.011 * 153.75}{0.277} = 6.11$
valve/fitting loss : 0.69

6.80 ✓

convert this loss to area of 0.145 in² $6.8 * \left(\frac{0.145}{0.06}\right)^2 = 39.71$

$K_T = 39.71 + 10.02 = 49.73$ ✓

Flow Path 44 . Between nodes 41 and 40

friction losses = $\frac{0.011 * 1031.0}{0.43} = 26.37$

valve/fittings loss = 1.76

28.13 ✓

area = 0.145 in² ✓ (...)

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CALCULATION SHEET

BEPC-2706 Rev. 6/86 (ED-61)

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	28

ORIGINATOR	DATE	CHECKED	DATE
John L. Rosswell	1/11/88	[signature]	1/13/88

Subject: ARI Venting Time of Scram Air Header

Flow Path 45 Between Nodes 40 - ~~Atmosphere~~

$K = 5.27$ ✓ (see page 17)
Area $= 1.57 \text{ in}^2$ ✓

Flow Path 46 ~~Between~~ Nodes 24 and 23

$\text{area} = \pi \frac{(1.025)^2}{4} = 0.825$ ✓

$\text{friction losses} = \frac{0.011 * 97.25}{1.025} = 1.04$ ✓

K for valve/fittings = 0.88 ✓

1.92 ✓

Flow Path 47 Between Nodes 43 and 41

$\text{area} = 0.145 \text{ in}^2$ (see page 26)

$\text{Friction losses} \quad \frac{0.011 * 856}{.43} = 21.90$

valve/fittings 1.54

23.44 ✓

} "Y" for reducer area $= 0.145 \text{ in}^2$

$\text{Friction losses} \quad \frac{0.011 * 312}{0.277} = 12.39$ ✓

valve/fittings loss 1.24

13.63 → converting to area of 0.145 in^2

$13.63 * \left(\frac{0.43}{0.277}\right)^4 = 79.15$ ✓

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CALCULATION SHEET

BEPC-2706 Rev. 8/86 (ED-4)

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	29

ORIGINATOR	DATE	CHECKED	DATE
[signature]	1/11/88	[signature]	1/13/88

Subject: ARI Venting Time of Scram Air Header

From the previous calculations of volumes, flow area and loss the following Tables can be developed and used for input purposes

Node	Volume (in^3)	Node	Volume (in^3)
1	34.33	24	80.2
2	1238.77	25	194.3
3	1238.77	26	194.3
4	1124.59	27	194.3
5	1124.59	28	923.33
6	1124.59	29	923.33
7	121.95	30	923.33
8	137.5	31	250.0
9	183.9	32	203.07
10	183.9	33	203.07
11	183.9	34	203.07
12	886.4	35	794.1
13	886.4	36	794.1
14	886.4	37	794.1
15	224.3	38	134.36
16	224.3	39	80.2
17	224.3	40	94.58
18	81253	41	150.6
19	812.53	42	62.2
20	812.53	43	148.3
21	136.3	44	31.0
22	127.73	45	$1.\times10^{10}$
23	127.73		

CALCULATION SHEET

BEPC-2706 Rev. 6/84 (ED

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	30

ORIGINATOR	DATE	CHECKED	DATE
[signature]	1/11/88	[signature]	1/13/88

Subject : ARI Venting Time of Scram Air Header

Flow Path	From	To	Area (in²)	Loss Factor (K)
1	1	45	1.57	17.97
2	1	2	1.78	6.32
3	2	3	1.78	6.32
4	3	4	1.78	5.87
5	4	5	1.78	5.87
6	5	6	1.78	5.87
7	6	7	0.83	1.77
8	7	45	1.57	5.27
9	7	21	0.83	2.87
10	7	8	0.83	3.99
11	8	9	0.484	17.70
12	9	12	2.32	87509
13	9	10	0.484	17.70
14	10	13	2.32	87509
15	10	11	0.484	17.70
16	11	14	2.32	87509
17	21	15	0.484	19.67
18	15	20	2.13	87509
19	15	16	0.484	19.67
20	16	19	2.13	87509
21	16	17	0.484	19.67
22	17	18	2.13	87509
23	3	22	0.83	2.67
24	22	23	0.83	2.67
25	23	45	1.57	5.27
26	23	31	0.83	5.13
27	24	25	0.484	18.15
28	25	28	2.42	87509
29	25	26	0.484	18.15
30	28	29	2.42	87509
31	26	27	0.484	18.15

CALCULATION SHEET

BEFC-2706 Rev. 8/86 (ED-4)

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	31

ORIGINATOR	DATE	CHECKED	DATE
	1/11/88		1/13/88

Subject: ARI Venting Time of Scram Air Header

Flow Path	From	To	Area (in^2)	Loss (K)
33	31	32	0.484	18.90
34	32	35	2.08	87509
35	32	33	0.484	18.90
36	33	36	2.08	87509
37	33	34	0.484	18.90
38	34	37	2.08	87509
39	1	38	0.145	24.84
40	38	39	0.145	15.36
41	38	44	0.060	20.70
42	39	40	0.145	16.57
43	39	42	0.145	49.73
44	40	41	0.145	28.13
45	40	45	1.57	5.27
46	23	24	0.83	1.92
47	41	43	0.145	702.59

CALCULATION SHEET

BEPC-2706 Rev. 8/00 (ED-)

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	32

ORIGINATOR	DATE	CHECKER	DATE
[signature]	1/11/88	[signature]	1/13/88

Subject: ARI Venting Time of Scram Air Header

Results

The results of this analysis (air pressure vs. time) are given by the computer output included as Attachment 9. Additionally, a plot of pressure vs. time of a few of the nodes is provided in Figure 6. As can be seen from the plot, the header and most of the piping system depressurize rapidly. However the air volume within the diagraphm valves' take a much longer time to depressurize, thus controlling the transient.

Only one of the nodes modelling the air volume within the diaphragm is provided in Figure 6. This was done since review of the output shows that all of the nodes modelling the diaphragm air volumes depressurized at essentially the same rate

Additionally review of the output shows that some nodes (in particular, node 1) have a pressure that is subatmospheric. The reason for this is the small volume of the node and that minor flow oscillations develop. However because of these flow oscillations occur only after the header has depressurized and that the venting time is essentially controlled by the small flow paths within the solenoid valves, these oscillations should not influence the results of the calculation.

Subject: Air Venting Time of Scram Air Header

John [signature] 2/18/88   Checked: J McL[signature] 2/12/88

S4.33

Calc #, MD-N2085-88002 Rev 0

Job. 14106

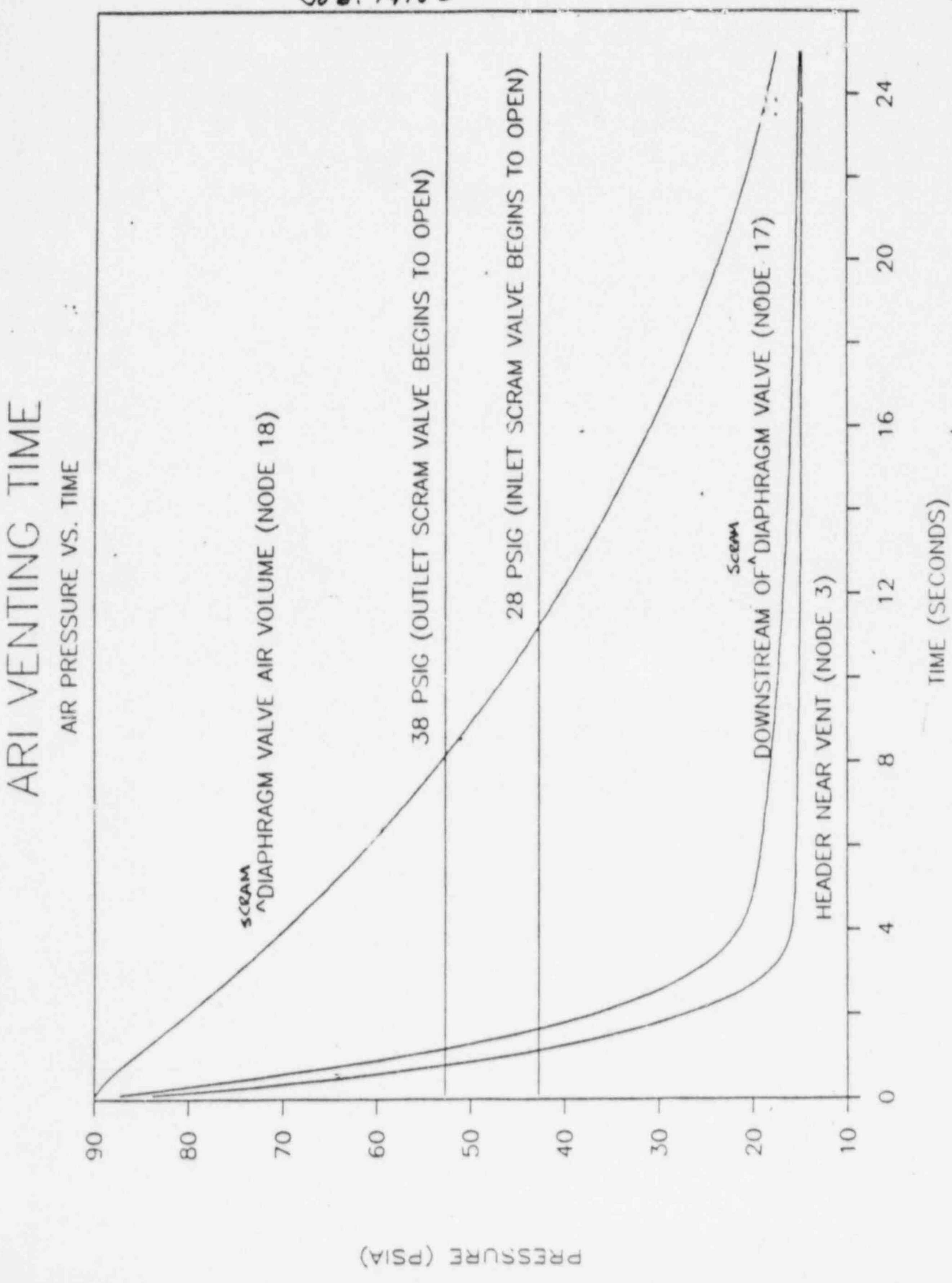

FIGURE 6

CALCULATION SHEET

Subject: ARI Venting Time of Scram Air Header

Results (cont)

As a rough check of reasonableness of the results of the air venting times, the following evaluation is performed.

Assuming that the header depletes much more quickly than the HCU scram diaphragm valve air volume, the flow through the flowpaths modelling the internals of the solenoid valves will be choked very quickly. From the results shown in Figure 6, choking should begin @ about 1 second. Anyhow, if the flow is choked, the flow rate through the flow path is evaluated by

$$- \quad \frac{dm}{dt} = C_D A \sqrt{g_c \gamma P_1 \rho_1 \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma+1}{\gamma-1}}} \qquad (1)$$

(a description of each variable is given in the code description section)

– Assuming an ideal gas and a isothermal process, then

$$PV = mRT \qquad (2)$$

and $$\frac{dP}{dt} = -\frac{RT}{V}\frac{dM}{dt} \qquad (3)$$

where negative sign indicates pressure decreases with loss of mass

and $$\rho = \frac{P}{RT} \qquad (4)$$

Additionally as defined in the code description section of this calculation (Appendix A)

(5)

CALCULATION SHEET

BEPC-2706 Rev. 8/06 (ED-4)

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2885-88002	0	35

ORIGINATOR	DATE	CHECKED	DATE
[signature]	1/11/88	[signature]	1/13/88

Subject: ARI Venting Time of Scram Air Header

Combining (1), (4) + (5) and realizing that γ, g_c, RT, K, A are constants, equation (1) becomes

$$\frac{dm}{dt} = C_1 * C_2 * P \qquad (6)$$

where $C_1 = \frac{A}{\sqrt{K}}$ (7)

$$C_2 = \sqrt{\frac{g_c \gamma \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma+1}{\gamma-1}}}{RT}} \qquad (8)$$

Combining (6) and (3) gives

$$\frac{dP}{dt} = -\frac{RT}{V}\left(C_1 * C_2\right) P \qquad (9)$$

with $\frac{RT}{V}$ being a constant in an isothermal process (9) becomes

$$\frac{dP}{dt} = -C_1 * C_2 * C_3 * P \qquad (10)$$

with $C_3 = \frac{RT}{V}$ (11)

Rearranging (10) gives

$$\frac{dP}{P} = -(C_1 * C_2 * C_3)\, dt \qquad (12)$$

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CALCULATION SHEET

BEPC-2706 Rev. 8/00 (EC

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	36

ORIGINATOR	DATE	CHECKED	DATE
[signature]	1/11/88	[signature]	1/13/88

Subject: ARI Venting Time of Scram Air Header

Integration of (12) gives

$$P(t) = P_0 e^{-C_1 C_2 C_3 t} \qquad (13)$$

where P(t) = pressure within HCU scram Diaphragm Valve air Volume

Evaluation of Constants

$$C_1 = \frac{A}{\sqrt{K}}$$

using the area of 1 HCU ③-④-⑤ as input into code = 0.145 in² = 1.007×10^{-3} ft²

K = .87509

$$C_1 = \frac{1.007 \times 10^{-3}}{\sqrt{.87509}} = 3.404 \times 10^{-6} \text{ ft}^2$$

$$C_2 = \sqrt{\frac{g_c \gamma \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma+1}{\gamma-1}}}{RT}}$$

γ = 1.4 for air (Reference 3, p7..

R = 53.34 $\frac{lbf \cdot ft}{lbm \cdot °R}$ (Ref 3, p 732

Use T = 50°F → 510°R

$$C_2 = \sqrt{\frac{32.2 \frac{lbm \cdot ft}{lbf \cdot sec^2} * 1.4 \left(\frac{2}{2.4}\right)^6}{53.34 \frac{lbf \cdot ft}{lbm \cdot °R} (510\ °R)}} = 0.02356 \frac{lbm}{lbf \cdot sec}$$

$$C_3 = \frac{RT}{V}$$

V = (6.4 + 24.5*2) in³ = 55.4 in³ } one HCU air volume

$$V = \frac{55.4 \text{ in}^3}{1728 \text{ in}^3/\text{ft}^3} = 0.03206 \text{ ft}^3$$

$$C_3 = \frac{53.34 \frac{lbf \cdot ft}{lbm \cdot °R} * 510\ °R}{0.03206 \text{ ft}^3} = 8.485 \times 10^5 \frac{lbf}{lbm \cdot ft^2}$$

CALCULATION SHEET

BEPC-2706 Rev. 6/06 (ED-4

JOB NO.	CALC. NO.	REV. NO.	SHEET NO
19106	MD-N2085-88002	0	37

ORIGINATOR	DATE	CHECKED	DATE
John C. [signature]	1/11/88	[signature]	1/13/88

Subject: ARI Venting Time of Scram Air Header

Combining C_1, C_2, + C_3 gives

$$C_T = 3.404 \times 10^{-6}\ ft^2 * 0.02356\ \frac{lbm}{lb_f \cdot sec} * 8.485 \times 10^5\ \frac{lb_f}{lbm\ ft^2} = 0.068/sec$$

thus P(t) can be calculated by

$$P(t) = P_0 e^{-0.068(t-1)} \qquad (14)$$

where (t-1) accounts for ≈1.0 second delay to reduce downstream pressure to point where choking can occur.

Plugging in a few times gives (assuming 85 psia at 1 second - approximated from Figure 6)

Time (sec)	Pressure (psia)
1	85
4	69.3
8	52.8
12	40.2
15	32.8
20	23.4
25	16.6

These pressures are compared against the code calculated values in Figure 7. The good agreement provides a reasonableness check of the results provided in Figure 6. The above approach does predict a faster depressurization beyond about 20 seconds because flow

CALCULATION SHEET

BEPC-2706 Rev. 5/86

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	38

ORIGINATOR	DATE	CHECKED	DATE
[signature]	1/11/88	[signature]	1/13/88

Subject: ARI Venting Time of Scram Air Header

Sensitivity Studies

To assess the sensitivity of the results to some of the assumptions used in the analysis, the following additional evaluations were completed. These additional studies were performed using the methodology described in pages 34 – 37 of this calculation

Case 1 - Temperature Effects - Use 100°F initial temperature rather than 50°F.

$C_1 = 3.404 \times 10^{-6}\ ft^2$ - no change

$$C_2 = 0.02248\ \frac{lbm}{lbf \cdot sec}\left(\sqrt{\frac{32.2 * 1.4 * \left(\frac{2}{2.4}\right)^{6}}{53.34\ (560)}}\right)$$

$$C_3 = \frac{53.34 * 560}{0.03206} = 9.317 \times 10^5\ \frac{lbf}{lbm \cdot ft^2}$$

$$C_T = 3.404 \times 10^{-6} * 0.02248 * 9.317 \times 10^5 = 0.0713/sec$$

Assuming that at one second the Pressure is still at 85 psia the following table can be developed using the formula

$$P(t) = 85\ e^{-0.0713(t-1)}$$

t (sec)	P (psia)
1	85
4	68.6
8	51.6
12	38.8
15	31.3

CALCULATION SHEET

BEPC-2706 Rev. 5/86 (ED

JOB NO.	CALC. NO.	REV. NO.	SHEET NO
19106	MD-N2085-88002	0	39

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John C. Rosenmund	1/11/88	J.M. Litmer	1/13/88

Subject: ARI Venting Time of Scram Air Header

Case #2 - Increase Loss across the Solenoid Valves by 20%

thus $K_n = 87509 * 1.20 = 105011$

Then

$$C_1 = \frac{1.007\times10^{-3}}{\sqrt{105011}} = 3.108\times10^{-6}\ ft^2$$

$$C_2 = 0.07356\ \frac{lbm}{lbf\cdot sec} \quad \text{(no change)}$$

$$C_3 = 8.485\times10^5\ \frac{lbf}{lbm\cdot ft^2} \quad \text{(no change)}$$

$C_T = 0.0621$

Thus $P(t) = 85e^{-0.0621(t-1)}$

t (sec)	P (psia)
1	85
4	70.6
8	55.0
12	42.9
15	35.6
20	26.1
25	19.1

These sensitivity study results are compared in graphical form on Figure 7.

No time step sensitivity is presented as the good agreement between

SH. 40

Subject: ARI Venting Time of Scram Air Header

[signature] 1/11/88

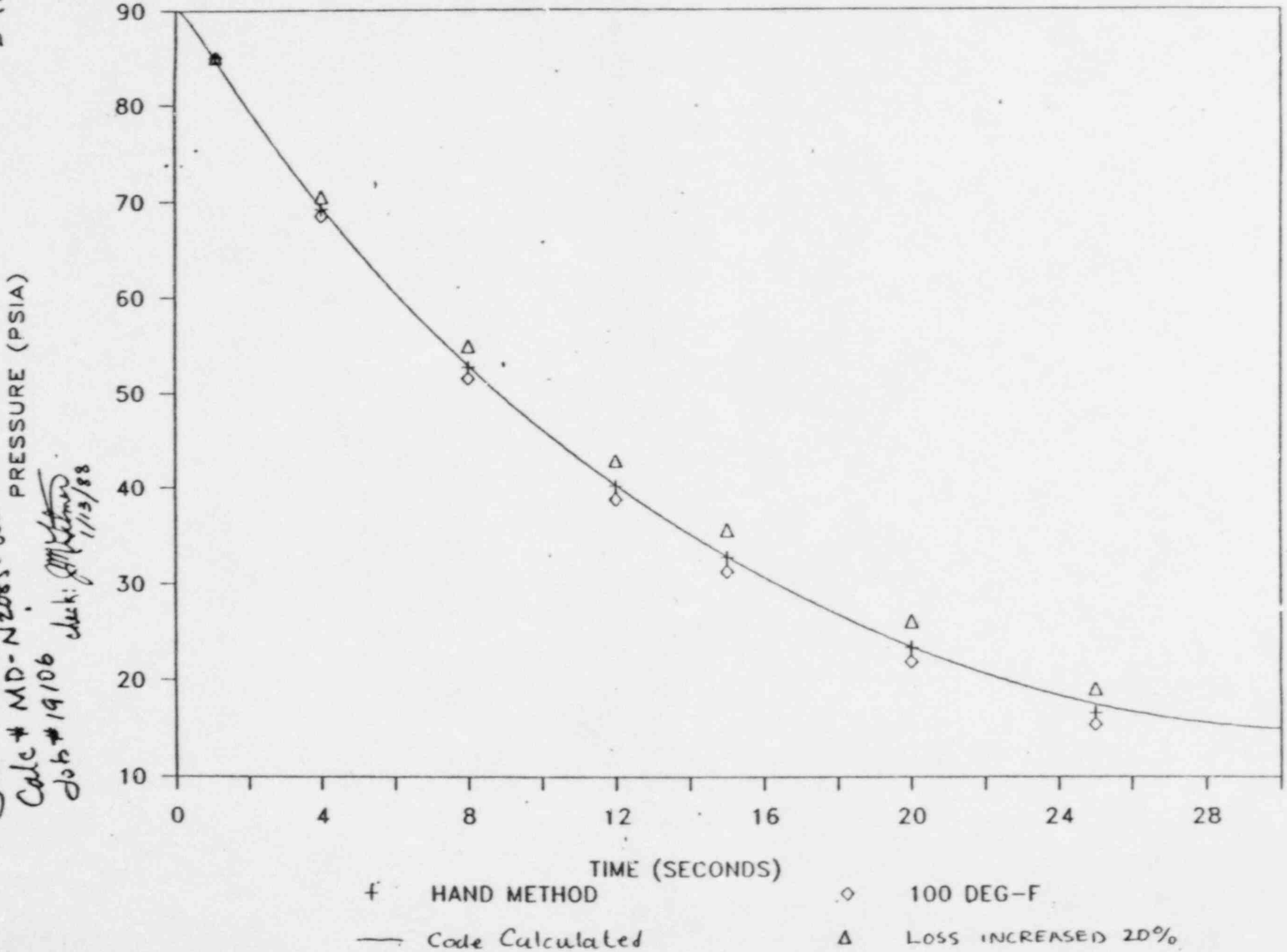
Calc # MD-N2085-88002 Rev 0

Job # 19106

chk: [signature] 1/13/88

HCU VALVE DIAPHRAGM VALVE VENTING TIME

SENSITIVITY STUDIES



CALCULATION SHEET

BEPC-1706 Rev. 5/86 (EJ)

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	41

ORIGINATOR	DATE	CHECKED	DATE
Joel Rosenwinkel	2/10/88	JM Gilmer	2/12/88

Subject: ARI Venting Time of Scram Air Header

An additional sensitivity study was performed to assess the system response if only one of the two vent valves at each of the three locations and only one ARI valve (see Figure 1, page 5) were to open. This study was performed by reducing the flow area at the vent paths (FP's 1, 8, 25, 45) by a factor of two. The coding used for this run along with the output is given in Attachment 7. The results of this run were essentially identical to the 8 valve opening case. This is to be expected since the controlling parameter in the analysis was the vent path through the grommet.

4 valves total open

BECHTEL

CALCULATION SHEET

BEPC-2706 Rev. 5/86 (E)

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	42

ORIGINATOR	DATE	CHECKED	DATE
John. Rosmud	1/11/88	JM Gilmore	1/13/88

Subject: ARI Venting Time of Scram Air Header

Conclusion

Based on the analysis performed, it can be concluded that the proposed ARI modifications will result in a depressurization of the diaphragm valve air volume as shown in Figure 6. The depressurization rate is bounded by the flow paths through the solenoid valves. In particular, the flow is limited by the grommets in the diaphragms of the solenoid valves. Any further reduction of these flow areas (6.44×10^{-4} in^2 - minimum area used in analysis) due to blockage or plugging, will result in increased depressurization time. This time increase could be significant depending on the degree of blockage. This result is applicable for 8 or 4 (one at each of the four vent locations) opening vent valves.

CALCULATION SHEET

BEPC-2706 Rev. 5/86 (ED)

JOB NO.	CALC. NO.	REV. NO.	SHEET NO
19106	MD-N2085-88002	0	43

ORIGINATOR	DATE	CHECKED	DATE
John C. Rommel	1/12/88	[signature]	1/13/88

Subject: ARI Venting Time of Scram Air Header

References

1. Letter, Rich Gallagher to Neil Howard, "Staff Calc of ATWS/ARI Modification", December 18, 1987, (Included as Attachment 3)

2. Memo, U. Young Park to John Rommel., "ATWS/ARI CalcInfo" December 23, 1987. (Included as Attachment 4), and C[illegible] No. MD-N2085-88039, Rev. 0.

3. Van Wylen, G. J and Sonntag, R. E, "Fundamentals of Classical Thermodynamics", SI Version 2e, John Wiley and Sons, 1976.

4. Crane Co., "Flow of Fluids Through Valves, Fittings and Pipe", Technical Paper No. 410, 1982.

5. Telecon, John Rommel to U. Young Park, 1/8/87. (Included as Attachment 5)

6. Idelchik, I. E. "Handbook of Hydraulic Resistance", 2nd Edition, Hemisphere Publishing Corporation, 1986.

7. Fox, R.W and McDonald, A.T, "Introduction to Fluid Mechanics", 2nd ed., John Wiley + Sons, 1978.

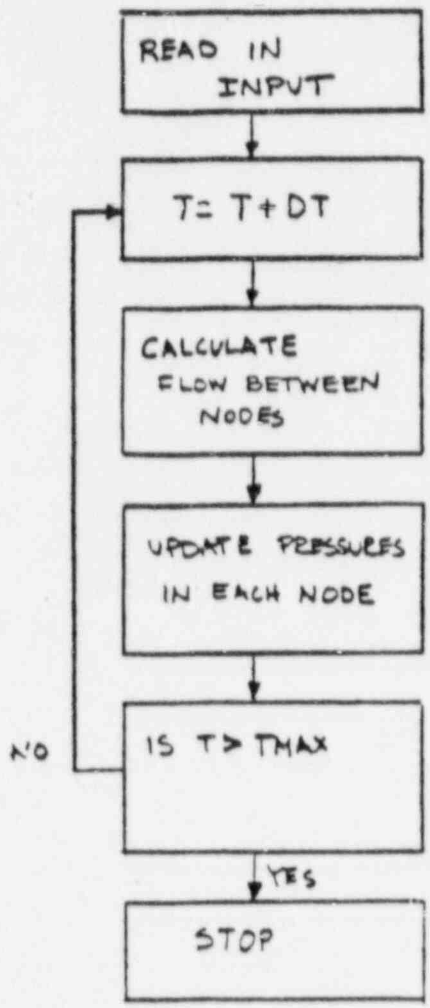
8. BN-TOP-4, Rev 0, "Subcompartment Pressure and Temperature Transient Analysis", Bechtel Power Corp., 1976.

Subject: ARI Venting Time of Scram Air Header

~~Appendix A~~: Code Validation + Description

Code Description

The following flow diagram provide the basic steps used in the computer code developed for this analysis



THE following pages describe the details used in each of the above steps

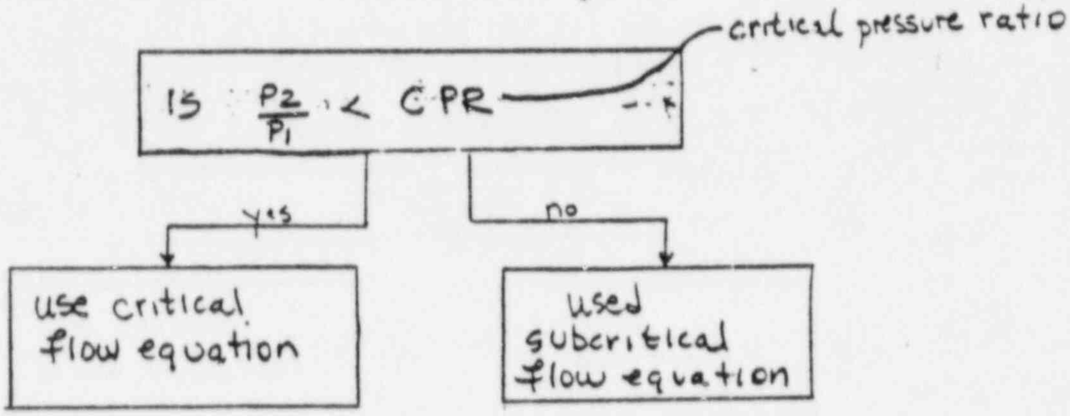
1. Input – The nodalization structure of the problem (shown in Figures 3,4 + 5)

Subject: ARI Venting Time of Scram Air Header

Input (cont) is entered into the code at this point. Required information includes the volume of each node in $(\text{inches})^3$, the nodes connected by each flow path, the area (in^2) and loss (K-factor) associated with each flowpath and time step information. A echo of the node and flowpath data is given in the output to ensure all data is provided correctly.

2. Calculate flow between nodes

For each flowpath the following logic is used



for air CPR = 0.528 (Reference 7, p 530)

thus if $\frac{P_2}{P_1} < 0.528$ where P_2 = downstream node, P_1 = upstream node

then use critical flow equation

CALCULATION SHEET

BEPC-5706 Rev. 6/86 (ED-4)

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	A-3

ORIGINATOR	DATE	CHECKED	DATE
[signature]	1/11/88	[signature]	1/13/88

Subject: ARI Venting Time of Scram Air Header

The critical flow equation used for this program is taken from Reference 8, and is

$$\dot{m} = C_D A \sqrt{g_c \gamma P_1 \rho_1 \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma+1}{\gamma-1}}} \qquad \langle A\text{-}1 \rangle$$

where:

$\dot{m}$ = mass flow rate $\left(\frac{lbm}{sec}\right)$
C_D = discharge coefficient
A = flow path area (ft^2)
g_c = gravitational constant $\left(32.2 \frac{lbm \cdot ft}{lbf \cdot sec^2}\right)$

γ = isentropic exponent (1.4 for air)

P_1 = upstream pressure $\left(\frac{lbf}{ft^2}\right)$

ρ_1 = upstream density $\left(\frac{lbm}{ft^3}\right)$
P_2 = downstream pressure (lbf/ft^2)

If $\frac{P_2}{P_1} > 0.528$, then use subcritical flow equation. Again this equation is taken from Reference 8 and is

$$\dot{m} = C_D A \sqrt{\frac{2 g_c \gamma}{\gamma - 1} \rho_1 P_1 \left(\left(\frac{P_2}{P_1}\right)^{2/\gamma} - \left(\frac{P_2}{P_1}\right)^{\frac{\gamma+1}{\gamma}}\right)} \qquad \langle A\text{-}2 \rangle$$

definition are the same as above.

Subject: ARI Venting Time of Scram Air Header

Additionally from Reference 8, the discharge coefficient can be related to the loss term (K) via the following:

$$C_D = \frac{1}{\sqrt{K}} \qquad (A\text{-}3)$$

where

C_D = discharge coefficient

K = loss term

At points where choking could occur, K should include the expansion term beyond the choke point when this relationship is used. Thus all K calculated for this analysis include this expansion loss term.

3. Update Pressures

The flow into and out of each node during each time step is tracked and using ideal gas laws and an isothermal process the pressures in each node are updated by

$$\dot{m}_{i_T} = \Sigma \dot{m}_{in} - \Sigma \dot{m}_{out} \qquad (A\text{-}4)$$

where

$\dot{m}_{i_T}$ = total rate of mass change (lbm/sec) in node i during dt

$\Sigma \dot{m}_{in}$ = summation of all mass into node i during dt

$\Sigma \dot{M}_{out}$ = summation of all mass out of node i during dt

then

$$m_i^{(t)} = m_i(t\text{-}dt) + \dot{m}_{i_T} * dt \qquad (A\text{-}5)$$

CALCULATION SHEET

BEPC-2700 Rev. 8/84 (ED-6)

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	A-5

ORIGINATOR	DATE	CHECKED	DATE
John Braunel	1/11/88	JM Gilman	1/13/88

Subject: ARI Venting Time of Scram Air Header

where $m_i^{(t)}$ = mass in node i (lbm)
dt = time step (sec)

$$P_i(t) = \frac{m_i(t) R T_i}{V_i} \qquad (A-6)$$

where:

$P_i(t)$ = pressure in node i (lbf/ft^2)
R = gas constant for air (53.34 lbf·ft/lbm·R)
T_i = temperature in node i (assumed a constant) (°R)
V_i = Volume of node i (ft^3)

A listing of the program used is provided in pages A6 – A11.

To verify that the coding is correctly implemented in the code, a verification run was made where flow rate and pressure data were printed at each time step. A check of the mathematics included in the code was performed using this verification run and is included in the following pages. The actual verification run output is given in Attachment 2. Please note the time step used in this run was set to a large number, so that the mass flow values would be easier to see. However because of this unrealistic pressures occur, and thus this run should not be used for anything other than testing and verifying the computations of the computer code.

Subject: ARI Venting Time of Scram Air Header
Code Listing

Jdd. Bennl 1/11/88
Calc# MD-N2085-88002 Rev. C
Job #19106
SH A6

check: JM Gilmore 1/13/88

```
REM  THIS PROGRAM HAS BEEN DEVELOPED TO EVALUATE THE
REM  AIR VENTING TIME FOR THE ATWS/ARI MODIFICATIONS
REM  AT THE TVA'S BROWNS FERRY NUCLEAR PLANT
REM
REM  THIS PROGRAM IS DEVELOPED FOR USE ON IBM PC'S
REM  USING MICROSOFT'S QUICK BASIC COMPILER
REM
REM DIMENSION ARRAYS TO BE USED
DIM  P(50),T(50),V(50),M(50),NIN(50),NOUT(50),A(50),K(50),MDOT(50)
DIM  MIN(50),MOUT(50),DP(50),PS(50),RHO(50),CA(50),IFI(50)
REM
REM OPEN AN OUPUT FILE FOR COLLECTION OF OUPTUT DATA
OPEN "D:\TVA\OUTPUT.PRN" FOR OUTPUT AS #1
REM READ THE TITLE CARD AND THEN PRINT IT OUT
READ TITLE$
LPRINT;TITLE$:LPRINT
REM READ IN NUMBER OF NODES
READ NV
REM RC=IDEAL GAS CONSTANT FOR AIR (53.34 FT*LBF/LBM/DEG-R)
RC=53.34
REM KA=ISENTROPIC EXPONENT FOR AIR
KA=1.4
REM GC=GRAVITIONAL CONSTANT (LBM*FT/LBF/SEC^2)
GC=32.17
REM READ IN THE INPUT DATA FOR NODES
REM P(I)=INITIAL PRESSURE IN NODE I (PSIA)
REM T(I)=INITIAL TEMPERATURE IN NODE I (DEG-F)
REM V(I)=VOLUME IN NODE I (IN^3)
REM M(I)=MASS (LBM) OF AIR WITHIN NODE I
REM RHO(I)=DENSITY (LBM/FT^3) OF AIR IN NODE I
LPRINT"**************    INITIAL NODE DATA ****************"
LPRINT:LPRINT
LPRINT" NODE        PRESSURE     TEMPERATURE       VOLUME"
LPRINT"              (PSIA)        (DEG-F)         (IN^3)"
LPRINT"**************************************************"
LPRINT
FOR I=1 TO NV
READ P(I),T(I),V(I)
LPRINT I,P(I),T(I),V(I)
REM CONVERT T(I) TO DEG-R AND P(I) TO LBF/FT^2
T(I)=T(I)+460
P(I)=P(I)*144
REM CONVERT VOLUME TO FT^3
V(I)=V(I)/12/12/12
REM CALCULATE MASS IN VOLUME USING IDEAL GAS LAW
M(I)=P(I)*V(I)/T(I)/RC
RHO(I)=M(I)/V(I)
NEXT I
REM READ IN THE NUMBER OF FLOW PATHS
READ NFP
REM READ IN THE INPUT DATA FOR EACH FLOW PATH
REM NFP=NUMBER OF FLOW PATHS
REM NIN=INDEX FOR NODE INTO FOR FLOW PATH I
REM NOUT=INDEX FOR NODE OUT OF FOR FLOW PATH I
REM A(I)= AREA FOR FLOW PATH I (IN^2)
REM K(I)=LOSS FACTOR FOR FLOW PATH I
LPRINT:LPRINT:LPRINT:LPRINT:LPRINT:LPRINT
LPRINT" *************    INITIAL FLOW PATH DATA    *************"
LPRINT
LPRINT"FLOW        FROM         TO             AREA       LOSS"
```

Subject: ARI Venting Time of Scram Air Header

J.A. Rosumal 1/11/88
Calc # MD-N2085-88002 Rev
Job # 19106
SH. A7
check: J.M. Gilmer 1/13/88

```
LPRINT"PATH                                               (IN^2)"
LPRINT"**********************************************************************"
LPRINT
FOR I=1 TO NFP
READ NIN(I),NOUT(I),A(I),K(I)
LPRINT I,NOUT(I),NIN(I),A(I),K(I)
REM CONVERT AREA TO FT^2
A(I)=A(I)/144
REM CONVERT LOSS TERM TO DISCHARGE COEFFICIENT
K(I)=(1/(K(I)))^0.5
REM CONVERT AREA TO EFFECTIVE AREA
A(I)=A(I)*K(I)
NEXT I
LPRINT
FOR J=1 TO 7 :LPRINT
NEXT J
REM DEFINE THE CRITICAL PRESSURE RATIO FOR AIR
CPR=0.528
REM READ IN THE TIME STEP, PRINTOUT INTERVAL AND MAXIMUM TIME OF TRANSIENT
REM ALSO READ IN THE STORAGE OUTPUT INTERVAL (SOCMAX)
READ DT,PTMAX,TMAX,SOCMAX
REM INITIALIZE TIME TO ZERO
T=0
REM ESTABLISH TIME STEP LOOP
TIMSTP:
T=T+DT
PRINT T,"  SECONDS"
REM ZERO OUT THE VALUE OF NIN(I) AND NOUT(I) FOR ALL FLOW PATHS
FOR I=1 TO NFP
NIN(I)=0
NOUT(I)=0
NEXT I
REM DETERMINE THE PRESSURE DIFFERENCE IN THE CONNECTING NODES FOR USE IN
REM FLOW EQUATIONS USING STAGNATION PRESSURES AT PREVIOUS TIME STEP
FOR I=1 TO NFP
J=NIN(I)
K=NOUT(I)
DP(I)=P(K)-P(J)
REM DETERMINE FLOW DIRECTION AND ESTABLISH UPSTREAM DENSITY
REM IFI(I) IS AN INDEX SHOWING DIRECTION OF FLOW (+1 : NORMAL
REM -1 : REVERSE)
IF (DP(I)>0) THEN
    IFI(I)=1
    PHIGH=P(K)
    PLOW=P(J)
    RHOH=RHO(K)
ELSE
    IFI(I)=-1
    PHIGH=P(J)
    PLOW=P(K)
    RHOH=RHO(J)
END IF
REM DETERMINE IF CRITICAL PRESSURE RATIO (CPR) HAS BEEN
REM EXCEEDED ACROSS THIS FLOW PATH AND GO TO APPROPRIATE
REM SUBROUTINE TO CALCULATE THE FLOW
PR=PLOW/PHIGH
IF (PR>CPR) THEN
    GOSUB SUBCRITICAL
ELSE
    GOSUB CRITICAL
```

Subject: ARI Venting Time of Scram Air Header

Job. Brunnel 1/11/88
Calc # MD-N2085-88002 Rev. 0
Job # 19106
SH. A8

check: JMWittmer 1/13/88

```
END IF
REM DETERMINE TOTAL FLOW RATE INTO AND OUT OF EACH NODE
IF (DP(I)>0) THEN
     MIN(J)=MDOT(I)+MIN(J)
     MOUT(K)=MDOT(I)+MOUT(K)
ELSE
     MIN(K)=MDOT(I)+MIN(K)
     MOUT(J)=MDOT(I)+MOUT(J)
END IF
NEXT I
REM DETERMINE CHANGE IN MASS IN EACH NODE DURING TIME STEP
FOR I=1 TO NV
M(I)=M(I)+(MIN(I)-MOUT(I))*DT
REM UPDATE PRESSURE TERM USING IDEAL GAS LAW
REM ASSUME AN ISOTHERMAL PROCESS
P(I)=M(I)*RC*T(I)/V(I)
REM UPDATE DENSITY TERM
RHO(I)=P(I)/RC/T(I)
NEXT I
REM UPDATE PRINT INTERVAL COUNTER
CT=CT+1
REM UPDATE STORAGE OUTPUT COUNTER
SOC=SOC+1
REM IF AT STORAGE OUTPUT INTERVAL THEN WRITE
REM PRESSURES OF VOLUME WITHIN THE SCRAM DIAPHARGM VALVES
REM TO THE STORAGE DEVICE FOR FUTURE PLOTTING
IF SOC=SOCMAX THEN
PRINT#1, T,P(14)/144,P(18)/144,P(30)/144,P(37)/144,P(3)/144,P(17)/144
SOC=0
END IF
REM IF AT PRINTOUT INTERVAL PRINTOUT DATA
IF CT=PTMAX THEN
    LPRINT
    LPRINT " THE CURRENT TIME IS "; T,"SECONDS"
    LPRINT
    LPRINT " NODE          PRFSSURE"
    LPRINT "               (PSIA)"
    LPRINT "****************************"
    LPRINT
    FOR I=1 TO NV
    LPRINT I,P(I)/144
    NEXT I
    FOR J= 1 TO 9: LPRINT
    NEXT J
    LPRINT"FLOW PATH        MDOT      FROM           TO"
    LPRINT"               (LBM/SEC)"
    LPRINT"**********************************************"
    LPRINT
    FOR I=1 TO NFP
    LPRINT I,MDOT(I)*IFI(I),NOUT(I),NIN(I)
    NEXT I
    FOR J=1 TO 8 :LPRINT
    NEXT J
    CT=0
END IF
REM IF T<MAXIMUM TRANSIENT TIME THEN LOOP BACK THROUGH CALCULATIONS
IF T<TMAX GO TO  TIMSTP
REM PRINTOUT DATA AT END OF PROBLEM
LPRINT
LPRINT " THE CURRENT TIME IS "; T,"SECONDS"
```

Subject: ARI Venting Time of Scram Air Header

John Rosewell 1/11/88
Calc # MD-N2085-88002 Rev. 0
Job # 19106
SH. A-9
check: JM Gutmer 1/13/88

```
LPRINT
LPRINT " NODE          PRESSURE"
LPRINT "               (PSIA)"
LPRINT "******************************"
LPRINT
FOR I=1 TO NV
LPRINT I,P(I)/144
NEXT I
FOR J= 1 TO 9: LPRINT
NEXT J
LPRINT"FLOW PATH        MDOT       FROM          TO"
LPRINT"                (LBM/SEC)"
LPRINT"**********************************************"
LPRINT
FOR I=1 TO NFP
LPRINT I,MDOT(I)*IFI(I),NOUT(I),NIN(I)
NEXT I
FOR J=1 TO 8 :LPRINT
NEXT J
REM END OF PROGRAM
END
REM SUBROUTINES FOR THE CALCULATION OF SUBCRITCAL AND CRITICAL FLOW
REM
REM SUBCRITICAL FLOW
REM
SUBCRITICAL:
MDOT(I)=A(I)*(2*GC*KA*RHOH*PHIGH/(KA-1)*(PR^(2/KA)-PR^((KA+1)/KA)))^0.5
RETURN
REM
REM CRITICAL FLOW
REM
CRITICAL:
MDOT(I)=A(I)*(GC*KA*RHOH*PHIGH*(2/(KA+1))^((KA+1)/(KA-1)))^0.5
RETURN
REM INPUT DATA
DATA  TVA HCU SCRAM DIAPHRAGM VENTING ANALYSIS 1/10/88
DATA  45
DATA 90,50,34.33
DATA 90,50,1238.77
DATA 90,50,1238.77
DATA 90,50,1124.59
DATA 90,50,1124.59
DATA 90,50,1124.59
DATA 90,50,121.95
DATA 90,50,137.5
DATA 90,50,183.9
DATA 90,50,183.9
DATA 90,50,183.9
DATA 90,50,886.4
DATA 90,50,886.4
DATA 90,50,886.4
DATA 90,50,224.3
DATA 90,50,224.3
DATA 90,50,224.3
DATA 90,50,812.33
DATA 90,50,812.53
DATA 90,50,812.53
DATA 90,50,136.30
DATA 90,50,127.73
DATA 90,50,127.73
```

Subject: Air Venting in HCU Scram Diaphragm Valves

John Rosenwasser 1/11/87
Calc # MD-N2085-88002 Rev. 0
Job # 19106
check: [illegible] 1/13/88

SHA-10

```
DATA 90,50,80.2
DATA 90,50,194.3
DATA 90,50,194.3
DATA 90,50,194.3
DATA 90,50,923.33
DATA 90,50,923.33
DATA 90,50,923.33
DATA 90,50,250
DATA 90,50,203.07
DATA 90,50,203.07
DATA 90,50,203.07
DATA 90,50,794.1
DATA 90,50,794.1
DATA 90,50,794.1
DATA 90,50,134.36
DATA 90,50,80.2
DATA 90,50,94.58
DATA 90,50,150.6
DATA 90,50,62.2
DATA 90,50,148.3
DATA 90,50,31
DATA 14.7,50,1.0E10
DATA 47
DATA 45,  1, 1.57,  17.97
DATA  2,  1, 1.78, 6.32
DATA  3,  2. 1.78, 6.32
DATA  4,  3, 1.78, 5.87
DATA  5,  4, 1.78, 5.87
DATA  6,  5, 1.78, 5.87
DATA  7,  6, 0.825, 1.77
DATA 45,  7, 1.57 , 5.27
DATA 21,  7, 0.825, 2.37
DATA  8,  7, 0.825, 3.99
DATA  9,  8, 0.484, 17.70
DATA 12,  9, 2.32, 87509
DATA 10,  9, 0.484, 17.70
DATA 13, 10, 2.32, 87509
DATA 11, 10, 0.484, 17.70
DATA 14, 11, 2.32, 87509
DATA 15, 21, 0.484, 19.67
DATA 20, 15, 2.13 ,87509
DATA 16, 15, 0.484, 19.67
DATA 19, 16, 2.13 , 87509
DATA 17, 16, 0.484, 19.67
DATA 18, 17, 2.13 , 87509
DATA 22,  3, 0.825, 2.67
DATA 23, 22, 0.825, 2.67
DATA 45, 23, 1.57 , 5.27
DATA 31, 23, 0.825, 5.13
DATA 25, 24, 0.484, 18.15
DATA 28, 25, 2.42 , 87509
DATA 26, 25, 0.484, 18.15
DATA 29, 26, 2.42 , 87509
DATA 27, 26, 0.484, 18.15
DATA 30, 27, 2.42 , 87509
DATA 32, 31, 0.484, 18.90
DATA 35, 32, 2.08 ,87509
DATA 33, 32, 0.484, 18.90
DATA 36, 33, 2.08 , 87509
DATA 34, 33, 0.484, 18.90
```

Subject: Air Venting in HCU Scram Diaphragm Valves

J.W. Rosswell 1/11/88

Calc # MD-N2085-88002 Rev. 0

Job # 19106 SH A-11

check: J.M. Gilmore 1/13/88

```
DATA 37, 34, 2.08 , 87509
DATA 38,  1, 0.145, 24.84
DATA 39, 38, 0.145, 15.36
DATA 44, 38, 0.06 , 20.70
DATA 40, 39, 0.145, 16.57
DATA 42, 39, 0.145, 49.73
DATA 41, 40, 0.145, 28.13
DATA 45, 4[illegible], 1.57 , 5.27
DATA 24, [illegible], 0.825, 1.92
DATA 43, 41, 0.145, 102.59
DATA 0.001,5000,35.00,100
```

CALCULATION SHEET

BEPC-2706 Rev. 6/86 (ED-4)

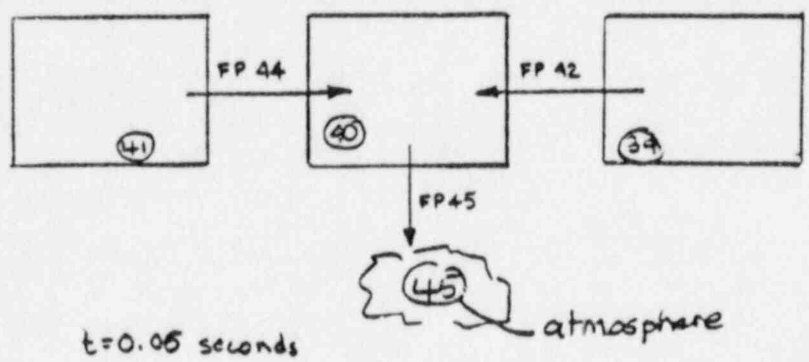
JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	A-12

ORIGINATOR	DATE	CHECKED	DATE
John Bramuel	1/11/88	JM Gilmer	1/13/88

Subject: Air Venting in HCU Scram Diaphragm Valves

Verification Calculations.

Using the Verification Run @ t = 0.05 seconds and the flow paths going into and out of node 40, the following calculations can be performed.



t = 0.05 seconds

Node	P (psia)	T (°R)	ρ ($\frac{lbm}{ft^3}$)	V (in³)	Mass (lbm)
40	20.36321	510	0.10779 ✓	94.58 ✓	5.90x10⁻³ ✓
41	84.86157	↓	0.4492 ✓		
39	82.34415		0.43588 ✓		
45	14.70001		0.0778 ✓		

— See Attachment 2 for values

$\rho = \frac{P \cdot 144}{RT}$ $R = 53.34 \frac{lbf \cdot ft}{lbm \cdot °R}$

$M = \rho V = 0.10779 \frac{lbm}{ft^3} \cdot 94.58\ in^3 \div \frac{ft^3}{1728\ in^3} = 5.8997 \times 10^{-3}\ lbm$

CALCULATION SHEET

BECHTEL — BEPC-2706 Rev. 8/86 (ED-4)

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	A-13

ORIGINATOR	DATE	CHECKED	DATE
[signature]	1/11/88	[signature]	1/13/88

Subject: Air Venting in HCU Scram Diaphragm Valves

flow path	area (in²)	Loss	From	To	$C_D = \frac{1}{\sqrt{Loss}}$
42	0.145	16.57	39	40	0.2457
44	0.145	28.13	41	40	0.1885
45	1.57	5.27	40	45	0.4356

Test for critical flow

Flowpath	P_2/P_1		CPR	
42	20.36321/82344	<	0.528	⇒ critical flow
44	20.36321/84.86157	<	0.528	⇒ critical flow
45	14.7/20.36321	>	0.528	⇒ subcritical flow

Flowpath 42

$$\dot{m} = 0.2457 * \frac{0.145}{144} * \sqrt{32.2 * 1.4 * 82.344 * 0.4359 * 144 \left(\frac{2}{2.4}\right)^{\frac{2.4}{.4}}}$$

$\dot{m} = 0.0691 \frac{lbm}{sec}$ (agrees with output at 0.07 seconds)

Flowpath 44

$$\dot{m} = 0.1885 * \frac{0.145}{144} * \sqrt{32.2 * 1.4 * 84.86157 * 144 \left(\frac{2}{2.4}\right)^{2.4/.4} * .4492}$$

$\dot{m} = 0.0546 \frac{lbm}{sec}$ (agrees with output @ 0.07 seconds)

Flowpath 45

$$\dot{m} = 0.4356 * \frac{1.57}{144} * \sqrt{\frac{2(32.2)(1.4)}{.4} (0.10779)\, 20.363 * 144 \left[\left(\frac{14.7}{20.363}\right)^{2/1.4} - \left(\frac{14.7}{20.363}\right)^{\frac{2.4}{1.4}}\right]}$$

$\dot{m} = 0.2994 \frac{lbm}{sec}$ (agrees with output @ 0.07 seconds)

CALCULATION SHEET

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
19106	MD-N2085-88002	0	A-14

ORIGINATOR	DATE	CHECKED	DATE
John C. Rosswurm [signature]	1/11/88	[signature]	1/13/88

Subject: Air Venting in HCU Scram Diaphragm Valves

$$\Delta m_T = ((0.0691 + 0.0546) - (0.2994)) * 0.01 \text{ sec} = -0.001757 \text{ lbm}$$

$$m_n = 5.9\times10^{-3} - 1.757\times10^{-3} = 4.143\times10^{-3} \text{ lbm}$$

thus

$$P_n = \frac{(4.143\times10^{-3}\text{ lbm})(53.34 \frac{\text{lbf-ft}}{\text{lbm}^\circ\text{R}})(510\,^\circ\text{R})}{(94.58/1728)\text{ ft}^3 (144 \frac{\text{in}^2}{\text{ft}^2})} = 14.30 \text{ psi}$$

agrees with output of code @ 0.07 seconds.

Based on this calculation, it can be seen that the code is working as intended.

Subject: Air Venting in HCU Scram Diaphragm Valves

TVA HCU SCRAM DIAPHRAGM VENTING ANALYSIS 1/10/88

[signature] 1/11/88
Calc # MD-N2085-88002 Rev. 0
Job # 19106

Attachment 1 to Calc # MD-N2085-88002
Attachment Rev. 0 (used in Results)
Number of Sheets 18
Sheet 1 of 18

Chk: [signature] 1/13/88

************** INITIAL NODE DATA **************

NODE	PRESSURE (PSIA)	TEMPERATURE (DEG-F)	VOLUME (IN^3)
1	90	50	34.33
2	90	50	1238.77
3	90	50	1238.77
4	90	50	1124.59
5	90	50	1124.59
6	90	50	1124.59
7	90	50	121.95
8	90	50	137.5
9	90	50	183.9
10	90	50	183.9
11	90	50	183.9
12	90	50	886.4
13	90	50	886.4
14	90	50	886.4
15	90	50	224.3
16	90	50	224.3
17	90	50	224.3
18	90	50	812.53
19	90	50	812.5.
20	90	50	812.53
21	90	50	136.3
22	90	50	127.73
23	90	50	127.73
24	90	50	80.2
25	90	50	194.3
26	90	50	194.3
27	90	50	194.3
28	90	50	923.33
29	90	50	923.33
30	90	50	923.33
31	90	50	250
32	90	50	203.07
33	90	50	203.07
34	90	50	203.07
35	90	50	794.1
36	90	50	794.1
37	90	50	794.1
38	90	50	134.36
39	90	50	80.2
40	90	50	94.58
41	90	50	150.6
42	90	50	62.2
43	90	50	148.3
44	90	50	31
45	14.7	50	1E+10

Attachment 1
Sheet 2 of 18

ATTACHMENT: 1 Rev. 0
CALC: MD-N2055-580-02
SHEET ___ OF ___

************* INITIAL FLOW PATH DATA *************

FLOW PATH	FROM	TO	AREA (IN^2)	LOSS
1	1	45	1.57	17.97
2	1	2	1.78	6.32
3	2	3	1.78	6.32
4	3	4	1.78	5.87
5	4	5	1.78	5.87
6	5	6	1.78	5.87
7	6	7	.825	1.77
8	7	45	1.57	5.27
9	7	21	.825	2.87
10	7	8	.825	3.99
11	8	9	.484	17.7
12	9	12	2.32	87509
13	9	10	.484	17.7
14	10	13	2.32	87509
15	10	11	.484	17.7
16	11	14	2.32	87509
17	21	15	.484	19.67
18	15	20	2.13	87509
19	15	16	.484	19.67
20	16	19	2.13	87509
21	16	17	.484	19.67
22	17	18	2.13	87509
23	3	22	.825	2.67
24	22	23	.825	2.67
25	23	45	1.57	5.27
26	23	31	.825	5.13
27	24	25	.484	18.15
28	25	28	2.42	87509
29	25	26	.484	18.15
30	26	29	2.42	87509
31	26	27	.484	18.15
32	27	30	2.42	87509
33	31	32	.484	18.9
34	32	35	2.08	87509
35	32	33	.484	18.9
36	33	36	2.08	87509
37	33	34	.484	18.9
38	34	37	2.08	87509
39	1	38	.145	24.84
40	38	39	.145	15.36
41	38	44	.06	20.7
42	39	40	.145	16.57
43	39	42	.145	49.73
44	40	41	.145	28.13
45	40	45	1.57	5.27
46	23	24	.825	1.92
47	41	43	.145	102.59

Attachment 1
Sheet 3 of

ATTACHMENT: 1 Rev. 1
CALC: MD-N2085-85002
SHEET ___ OF ___

THE CURRENT TIME IS 4.99982 SECONDS

NODE	PRESSURE (PSIA)
1	13.88473
2	14.97264
3	14.958
4	14.97586
5	14.97178
6	14.98729
7	14.90141
8	15.24086
9	18.10976
10	19.1827
11	19.4356
12	64.59122
13	64.77164
14	64.82206
15	17.91592
16	18.95367
17	19.19878
18	64.93505
19	64.86791
20	64.63021
21	15.17073
22	15.08004
23	14.87954
24	15.26869
25	18.43029
26	19.60914
27	19.88573
28	64.48969
29	64.69516
30	64.7537
31	15.26722
32	17.73369
33	18.67887
34	18.90307
35	64.56211
36	64.77083
37	64.82993
38	14.74366
39	14.72089
40	14.75897
41	14.69982
42	14.72708
43	14.70139
44	14.73502
45	14.7

Attachment 1
Sheet 4 of 18

ATTACHMENT: 1
CALC: MD-N2095-88C0A Rev.0
SHEET____OF____

FLOW PATH	MDOT (LBM/SEC)	FROM	TO
1	7.141975E-02	1	45
2	.1218489	1	2
3	-2.747129E-02	2	3
4	1.229298E-02	3	4
5	-1.476335E-02	4	5
6	.0115262	5	6
7	-3.954908E-02	6	7
8	7.929545E-02	7	45
9	-2.084924E-02	7	21
10	-2.851583E-02	7	8
11	-3.685154E-02	8	9
12	-1.192886E-02	9	12
13	-2.461078E-02	9	10
14	-1.196218E-02	10	13
15	-.0123182	10	11
16	-1.197149E-02	11	14
17	-3.419113E-02	21	15
18	-1.095854E-02	15	20
19	-2.283748E-02	15	16
20	-1.099884E-02	16	19
21	-1.143486E-02	16	17
22	-1.101023E-02	17	18
23	2.824148E-02	3	22
24	-4.728403E-02	22	23
25	8.415309E-02	23	45
26	-2.372396E-02	23	31
27	-3.869752E-02	24	25
28	-1.242348E-02	25	28
29	-2.569103E-02	25	26
30	-1.246306E-02	26	29
31	-1.286183E-02	26	27
32	-1.247433E-02	27	30
33	-3.310391E-02	31	32
34	-1.069002E-02	32	35
35	-2.212539E-02	32	33
36	-1.072458E-02	33	36
37	-1.107583E-02	33	34
38	-1.073436E-02	34	37
39	5.540619E-03	1	38
40	-3.720473E-04	33	39
41	-2.2961E-04	38	44
42	1.969352E-03	39	40
43	3.006649E-04	39	42
44	-1.239685E-03	40	41
45	-3.028912E-02	40	45
46	-7.203554E-03	23	24
47	1.059331E-04	41	43

THE CURRENT TIME IS 10.00041 SECONDS

Attachment 1

Sheet 5 of 18

ATTACHMENT: 1
CALC: MD-N2055-88002 Rev. 0
SHEET ___ OF ___

NODE	PRESSURE (PSIA)
1	13.85048
2	14.91839
3	14.90116
4	14.91944
5	14.91507
6	14.93119
7	14.71869
8	15.12537
9	16.60209
10	17.18401
11	17.32396
12	45.97135
13	46.09976
14	46.13568
15	16.4956
16	17.05107
17	17.18496
18	46.19139
19	46.14362
20	45.97453
21	15.13956
22	15.02775
23	14.73073
24	15.29507
25	16.80029
26	17.44243
27	17.59672
28	45.87754
29	46.0237
30	46.06533
31	15.16431
32	16.40569
33	16.91006
34	17.03238
35	45.93877
36	46.0873
37	46.12935
38	14.73615
39	14.71505
40	14.75873
41	14.69951
42	14.72134
43	14.70109
44	14.72744
45	14.7

Attachment 6

Sheet 6 of 18

ATTACHMENT: 1
CALC: MD-N2085-890002 REV. 0
SHEET ____ OF ____

FLOW PATH	MDOT (LBM/SEC)	FROM	TO
1	7.022914E-02	1	45
2	.122959	1	2
3	-2.678467E-02	2	3
4	1.244273E-02	3	4
5	-1.500864E-02	4	5
6	1.334106E-02	5	6
7	-4.604381E-02	6	7
8	7.753672E-02	7	45
9	1.430636E-02	7	21
10	-6.508193E-03	7	8
11	-2.674267E-02	8	9
12	-8.490096E-03	9	12
13	-1.734952E-02	9	10
14	-8.513812E-03	10	13
15	-8.67337E-03	10	11
16	-8.520446E-03	11	14
17	-2.471075E-02	21	15
18	-7.795327E-03	15	20
19	-1.603191E-02	15	16
20	-7.823998E-03	16	19
21	-8.016782E-03	16	17
22	-7.832098E-03	17	18
23	3.073865E-02	3	22
24	-5.299462E-02	22	23
25	8.340544E-02	23	45
26	-8.800791E-03	23	31
27	-2.814143E-02	24	25
28	-8.837978E-03	25	28
29	-.0180991	25	26
30	-8.8[illegible]E-03	26	29
31	-9[illegible]177[illegible]E-03	26	27
32	[illegible].874[illegible]6E-03	27	30
33	2.35[illegible]46E-02	31	32
34	-7.6[illegible]6417E-03	32	35
35	-1.555019E-02	32	33
36	-7.631009E-03	33	36
37	-7.785783E-03	33	34
38	-7.637972E-03	34	37
3[illegible]	5.464585E-03	1	38
[illegible]	-4.821365E-04	38	39
41	-2.297811E-04	38	44
42	1.909593E-03	39	40
43	3.039892E-04	39	42
44	-1.240023E-03	40	41
45	-3.037972E-02	40	45
46	2.810856E-02	23	24
47	1.059898E-04	41	43

Attachment 1
Sheet 7 of 18

ATTACHMENT: 1
CALC: MD-N2085-88002 Rev. 0
SHEET ___ OF ___

THE CURRENT TIME IS 15.00243 SECONDS

NODE	PRESSURE (PSIA)
1	13.84978
2	14.91727
3	14.89941
4	14.91736
5	14.91231
6	14.93294
7	14.65508
8	15.24699
9	15.91317
10	16.21796
11	16.29262
12	32.71908
13	32.81047
14	32.83606
15	15.83307
16	16.12263
17	16.19366
18	32.85813
19	32.82414
20	32.70385
21	15.21749
22	15.04272
23	14.6611
24	15.31621
25	15.9742
26	16.31368
27	16.39647
28	32.63697
29	32.74092
30	32.77057
31	15.21298
32	15.80468
33	16.06813
34	16.13292
35	32.68746
36	32.79313
37	32.82305
38	14.73604
39	14.71497
40	14.75873
41	14.69954
42	14.72126
43	14.70111
44	14.72734
45	14.7

Attachment 1
Sheet 8 of 18

ATTACHMENT 1
CALC: MC-N2085-8 3002
SHEET ___ OF ___
REV. 0

FLOW PATH	MDOT (LBM/SEC)	FROM	TO
1	7.020645E-02	1	45
2	.122986	1	2
3	-2.676474E-02	2	3
4	1.327569E-02	3	4
5	-.0149594	4	5
6	1.471375E-02	5	6
7	-6.586735E-02	6	7
8	9.271602E-02	7	45
9	3.395026E-02	7	21
10	2.223799E-02	7	8
11	-1.901606E-02	8	9
12	-6.042636E-03	9	12
13	-1.229194E-02	9	10
14	-6.059513E-03	10	13
15	-6.156821E-03	10	11
16	-6.06424E-03	11	14
17	-1.771253E-02	21	15
18	-5.545183E-03	15	20
19	-1.133559E-02	15	16
20	-5.565579E-03	16	19
21	-5.679491E-03	16	17
22	-5.571343E-03	17	18
23	3.211806E-02	3	22
24	-6.176932E-02	22	23
25	9.281904E-02	23	45
26	1.727034E-02	23	31
27	-2.087253E-02	24	25
28	-6.287277E-03	25	28
29	-1.280344E-02	25	26
30	-6.307302E-03	26	29
31	-6.422163E-03	26	27
32	-6.313014E-03	27	30
33	-1.680161E-02	31	32
34	-.0054123	32	35
35	-1.103246E-02	32	33
36	-5.429798E-03	33	36
37	-5.524016E-03	33	34
38	-5.434751E-03	34	37
39	5.463047E-03	1	38
40	-4.837359E-04	38	39
41	-2.298142E-04	38	44
42	1.90877E-03	39	40
43	3.040302E-04	39	42
44	-1.240335E-03	40	41
45	-3.038065E-02	40	45
46	5.119761E-02	23	24
47	1.059311E-04	41	43

Attachment 1
Sheet 9 of 8

ATTACHMENT: 1 REV. 0
CALC: MD-N2085-88002
SHEET ___ OF ___

THE CURRENT TIME IS 20.00064 SECONDS

NODE	PRESSURE (PSIA)
1	13.82163
2	1[illegible]87207
3	14.85156
4	14.86864
5	14.86269
6	14.88265
7	14.57501
8	15.13523
9	[illegible].42026
10	15.56834
11	15.60477
12	23.35867
13	23.43309
14	23.45366
15	15.36736
16	15.50802
17	15.54267
18	23.45172
19	23.42569
20	23.[illegible]325
21	15.11118
22	14.99396
23	14.58278
24	15.20875
25	15.44264
26	15.60787
27	15.64813
28	23.29408
29	23.37893
30	23.40272
31	15.10163
32	15.36814
33	15.49583
34	15.52741
35	23.32723
36	23.40942
37	23.43239
38	14.72978
39	14.7103
40	14.75854
41	14.6993
42	14.71667
43	14.70088
44	14.72106
45	14.7

Attachment 1
Sheet 10 of 18

ATTACHMENT: 1
CALC: MD-A2085-88002
SHEET ___ OF ___
REV. 0

FLOW PATH	MDOT (LBM/SEC)	FROM	TO
1	6.919234E-02	1	45
2	.1238783	1	2
3	-.0258953	2	3
4	1.403556E-02	3	4
5	-1.450542E-02	4	5
6	.0156674	5	6
7	-6.751753E-02	6	7
8	8.973671E-02	7	45
9	4.282348E-02	7	21
10	3.205427E-02	7	8
11	-1.362489E-02	8	9
12	-4.144274E-03	9	12
13	-8.39873E-03	9	10
14	-4.146337E-03	10	13
15	-4.216615E-03	10	11
16	-.0041473	11	14
17	-1.283727E-02	21	15
18	-3.804285E-03	15	20
19	-7.750907E-03	15	16
20	-3.811443E-03	16	19
21	-3.892507E-03	16	17
22	-3.813839E-03	17	18
23	3.285933E-02	3	22
24	-6.289339E-02	22	23
25	8.961387E-02	23	45
26	2.595413E-02	23	31
27	-1.581807E-02	24	25
28	-4.302873E-03	25	28
29	-8.696516E-03	25	26
30	-4.305751E-03	26	29
31	-4.385607E-03	26	27
32	-4.30706E-03	27	30
33	-1.181232E-02	31	32
34	-3.713816E-03	32	35
35	-7.559194E-03	32	33
36	-3.719532E-03	33	36
37	-3.788845E-03	33	34
38	-3.721494E-03	34	37
39	5.398431E-03	1	38
40	-5.64035E-04	38	39
41	-2.300856E-04	38	44
42	1.858879E-03	39	40
43	3.055668E-04	39	42
44	-1.240606E-03	40	41
45	-.0304494	40	45
46	6.110276E-02	23	24
47	1.059883E-04	41	43

Attachment 1
Sheet 11 of 18

ATTACHMENT: 1 Rev. 0
CALC: MD-N2085-88 002
SHEET____OF____

THE CURRENT TIME IS 24.99789 SECONDS

NODE	PRESSURE (PSIA)
1	13.78338
2	14.80991
3	14.78576
4	14.80157
5	14.79449
6	14.81316
7	14.48533
8	14.9818
9	15.03566
10	15.08422
11	15.09575
12	17.44607
13	17.51135
14	17.5287
15	15.01173
16	15.05766
17	15.06861
18	17.5082
19	17.48828
20	17.41432
21	14.97137
22	14.92432
23	14.49189
24	15.07007
25	15.07733
26	15.13255
27	15.14486
28	17.41556
29	17.48905
30	17.50874
31	14.94773
32	15.01324
33	15.05431
34	15.06433
35	17.41583
36	17.48178
37	17.49954
38	14.72088
39	14.70385
40	14.75826
41	14.699
42	14.71028
43	14.70058
44	14.71215
45	14.7

Attachment 1
Sheet 12 of 18

ATTACHMENT: 1 Rev. C
CALC: MD-N2085-85002
SHEET____OF____

FLOW PATH	MDOT (LBM/SEC)	FROM	TO
1	.0677611	1	45
2	.1250569	1	2
3	-2.459648E-02	2	3
4	1.492543E-02	3	4
5	-1.381012E-02	4	5
6	.0166305	5	6
7	-6.770698E-02	6	7
8	.0835411	7	45
9	.0498439	7	21
10	.039767	7	8
11	-8.977302E-03	8	9
12	-2.281936E-03	9	12
13	-4.586609E-03	9	10
14	-2.294998E-03	10	13
15	-2.355099E-03	10	11
16	-2.298522E-03	11	14
17	-8.770659E-03	21	15
18	-2.090065E-03	15	20
19	-4.229235E-03	15	16
20	-2.106646E-03	16	19
21	-2.170005E-03	16	17
22	-2.111207E-03	17	18
23	3.356516E-02	3	22
24	-6.295791E-02	22	23
25	8.319618E-02	23	45
26	3.284921E-02	23	31
27	-1.253479E-02	24	25
28	-2.345635E-03	25	28
29	-4.572936E-03	25	26
30	-2.36316E-03	26	29
31	-2.429506E-03	26	27
32	-2.367597E-03	27	30
33	-7.220252E-03	31	32
34	-2.04179E-03	32	35
35	-4.160132E-03	32	33
36	-2.055625E-03	33	36
37	-2.111797E-03	33	34
38	-2.059526E-03	34	37
39	5.308008E-03	1	38
40	-6.642211E-04	38	39
41	-2.302114E-04	38	44
42	1.786611E-03	39	40
43	3.069722E-04	39	42
44	-1.240926E-03	40	41
45	-3.053813E-02	40	45
46	6.931789E-02	23	24
47	1.059862E-04	41	43

Attachment 1
Sheet 13 of 18

ATTACHMENT: 1
CALC: MD-N2085-88002
SHEET ___ OF ___
Rev 0

THE CURRENT TIME IS 29.99514 SECONDS

NODE	PRESSURE (PSIA)
1	13.74313
2	14.74349
3	14.71549
4	14.7298
5	14.72155
6	14.73865
7	14.39732
8	14.81899
9	14.78911
10	14.80605
11	14.80536
12	14.91711
13	14.93859
14	14.94441
15	14.78638
16	14.79886
17	14.7979
18	14.93294
19	14.92716
20	14.90556
21	14.82501
22	14.84922
23	14.40314
24	14.92697
25	14.81433
26	14.83657
27	14.83604
28	14.94658
29	14.97094
30	14.97733
31	14.783
32	14.77427
33	14.78421
34	14.78438
35	14.89186
36	14.91124
37	14.91652
38	14.71115
39	14.69693
40	14.75795
41	14.69867
42	14.70339
43	14.70024
44	14.70242
45	14.7

Attachment 1
Sheet 14 of 18.

ATTACHMENT: 1
CALC: MD-N2085-85002 Rev. 0
SHEET____OF____

FLOW PATH	MDOT (LBM/SEC)	FROM	TO
1	6.618086E-02	1	45
2	.1262582	1	2
3	-2.309686E-02	2	3
4	1.579766E-02	3	4
5	-1.296417E-02	4	5
6	1.750543E-02	5	6
7	-6.712532E-02	6	7
8	7.552175E-02	7	45
9	5.561891E-02	7	21
10	4.605856E-02	7	8
11	-.007074	8	9
12	-4.987471E-04	9	12
13	5.205795E-04	9	10
14	-5.442682E-04	10	13
15	-1.709384E-03	10	11
16	-5.434157E-04	11	14
17	-7.089563E-03	21	15
18	-4.450986E-04	15	20
19	3.00701E-04	15	16
20	-4.875228E-04	16	19
21	-9.918354E-04	16	17
22	-4.938347E-04	17	18
23	3.412741E-02	3	22
24	-6.246487E-02	22	23
25	.0750028	23	45
26	3.842706E-02	23	31
27	-1.070758E-02	24	25
28	-5.173466E-04	25	28
29	7.424104E-04	25	26
30	-5.724022E-04	26	29
31	-1.711182E-03	26	27
32	-5.723601E-04	27	30
33	-4.863208E-03	31	32
34	-4.374254E-04	32	35
35	-6.768402E-05	32	33
36	-4.741428E-04	33	36
37	-1.412813E-03	33	34
38	-4.75437E-04	34	37
39	5.209011E-03	1	38
40	-7.593775E-04	38	39
41	-2.300016E-04	38	44
42	1.704553E-03	39	40
43	3.076257E-04	39	42
44	-1.241026E-03	40	41
45	-3.062845E-02	40	45
46	7.584494E-02	23	24
47	1.059838E-04	41	43

Attachment 1
Sheet 15 of 18

ATTACHMENT: 1
CALC: MD-N2085-88 Rev. 002
SHEET____OF____

THE CURRENT TIME IS 34.9924 SECONDS

NODE	PRESSURE (PSIA)
1	13.72895
2	14.71984
3	14.69059
4	14.70437
5	14.69579
6	14.71246
7	14.36966
8	14.76361
9	14.69344
10	14.70392
11	14.69928
12	14.70082
13	14.70081
14	14.70079
15	14.6949
16	14.70269
17	14.6997
18	14.70066
19	14.70065
20	14.7007
21	14.77541
22	14.82293
23	14.3752
24	14.87577
25	14.69137
26	14.70462
27	14.70009
28	14.70199
29	14.70169
30	14.70154
31	14.7288
32	14.69594
33	14.70286
34	14.69945
35	14.70066
36	14.70057
37	14.70052
38	14.70758
39	14.6944
40	14.75783
41	14.69855
42	14.70085
43	14.70013
44	14.69884
45	14.7

Attachment 1
Sheet 16 of 18

ATTACHMENT: 1 Rev. 0
CALC: MD-N2085-58002
SHEET____OF____

FLOW PATH	MDOT (LBM/SEC)	FROM	TO
1	6.560454E-02	1	45
2	.1266714	1	2
3	-2.257497E-02	2	3
4	1.607382E-02	3	4
5	-1.268758E-02	4	5
6	1.768949E-02	5	6
7	-6.687203E-02	6	7
8	7.244192E-02	7	45
9	5.711535E-02	7	21
10	4.772593E-02	7	8
11	-5.697357E-03	8	9
12	1.212336E-04	9	12
13	2.183034E-03	9	10
14	-8.718043E-05	10	13
15	-1.468746E-03	10	11
16	5.08726E-05	11	14
17	-5.785868E-03	21	15
18	9.873604E-05	15	20
19	1.785084E-03	15	16
20	-6.453244E-05	16	19
21	-1.117125E-03	16	17
22	3.651236E-05	17	18
23	3.422306E-02	3	22
24	-6.222695E-02	22	23
25	7.185528E-02	23	45
26	3.989067E-02	23	31
27	-.009125	24	25
28	1.452433E-04	25	28
29	2.415692E-03	25	26
30	-9.311397E-05	26	29
31	-1.435777E-03	26	27
32	4.98173E-05	27	30
33	-3.774016E-03	31	32
34	8.578045E-05	32	35
35	1.720879E-03	32	33
36	-6.635734E-05	33	36
37	-1.215937E-03	33	34
38	4.076046E-05	34	37
39	5.173263E-03	1	38
40	-7.909532E-04	38	39
41	-2.29796E-04	38	44
42	1.673198E-03	39	40
43	3.077611E-04	39	42
44	-1.241052E-03	40	41
45	-3.066003E-02	40	45
46	7.754065E-02	23	24
47	1.059829E-04	41	43

THE CURRENT TIME IS 35.00039 SECONDS

ATTACHMENT: 1 Rev 0
CALC: MD-N2085 - 85002
SHEET____OF____

NODE	PRESSURE (PSIA)
1	13.72895
2	14.71984
3	14.69059
4	14.70437
5	14.69579
6	14.71246
7	14.36965
8	14.76361
9	14.69344
10	14.70392
11	14.69927
12	14.70081
13	14.7008
14	14.70078
15	14.6949
16	14.70268
17	14.6997
18	14.70065
19	14.70065
20	14.70069
21	14.77541
22	14.82293
23	14.3752
24	14.87576
25	14.69136
26	14.70461
27	14.70008
28	14.70197
29	14.70167
30	14.70152
31	14.7288
32	14.69594
33	14.70286
34	14.69945
35	14.70065
36	14.70056
37	14.70051
38	14.70758
39	14.6944
40	14.75783
41	14.69855
42	14.70085
43	14.70013
44	14.69884
45	14.7

Attachment 1
Sheet 18 of 18

ATTACHMENT: 1 Rev. 0
CALC: MD-N2085- 85002
SHEET____OF____

FLOW PATH	MDOT (LBM/SEC)	FROM	TO
1	6.560454E-02	1	45
2	.1266714	1	2
3	-2.257497E-02	2	3
4	1.607382E-02	3	4
5	-1.268758E-02	4	5
6	1.768949E-02	5	6
7	-6.687203E-02	6	7
8	7.244192E-02	7	45
9	5.711548E-02	7	21
10	4.772604E-02	7	8
11	-5.697285E-03	8	9
12	1.212645E-04	9	12
13	2.183034E-03	9	10
14	-8.716966E-05	10	13
15	-1.468608E-03	10	11
16	5.087259E-05	11	14
17	-5.785805E-03	21	15
18	9.872001E-05	15	20
19	1.784678E-03	15	16
20	-6.445897E-05	16	19
21	-.0011168	16	17
22	3.657718E-05	17	18
23	3.422351E-02	3	22
24	-6.222707E-02	22	23
25	7.185508E-02	23	45
26	3.989066E-02	23	31
27	-9.124869E-03	24	25
28	1.452783E-04	25	28
29	2.415853E-03	25	26
30	-9.307008E-05	26	29
31	-1.435502E-03	26	27
32	4.985817E-05	27	30
33	-3.774116E-03	31	32
34	8.585065E-05	32	35
35	1.720879E-03	32	33
36	-6.62665E-05	33	36
37	-1.215937E-03	33	34
38	4.083429E-05	34	37
39	5.173263E-03	1	38
40	-7.909532E-04	38	39
41	-2.29796E-04	38	44
42	1.673198E-03	39	40
43	3.077611E-04	39	42
44	-1.241052E-03	40	41
45	-3.066003E-02	40	45
46	7.754091E-02	23	24
47	1.059829E-04	41	43

Subject: ARI Venting Time of Scram Air Header

TVA HCU SCRAM DIAPHRAGM VENTING VERIFICATION RUN 1/10/88

************* INITIAL NODE DATA ***************

NODE	PRESSURE (PSIA)	TEMPERATURE (DEG-F)	VOLUME (IN^3)
1	90	50	34.33
2	90	50	1238.77
3	90	50	1238.77
4	90	50	1124.59
5	90	50	1124.59
6	90	50	1124.59
7	90	50	121.95
8	90	50	137.5
9	90	50	183.9
10	90	50	183.9
11	90	50	183.9
12	90	50	886.4
13	90	50	886.4
14	90	50	886.4
15	90	50	224.3
16	90	50	224.3
17	90	50	224.3
18	90	50	812.53
19	90	50	812.53
20	90	50	812.53
21	90	50	136.3
22	90	50	127.73
23	90	50	127.73
24	90	50	80.2
25	90	50	194.3
26	90	50	194.3
27	90	50	194.3
28	90	50	923.33
29	90	50	923.33
30	90	50	923.33
31	90	50	250
32	90	50	203.07
33	90	50	203.07
34	90	50	203.07
35	90	50	794.1
36	90	50	794.1
37	90	50	794.1
38	90	50	134.36
39	90	50	80.2
40	90	50	94.58
41	90	50	150.6
42	90	50	62.2
43	90	50	148.3
44	90	50	31
45	14.7	50	1E+10

[signature] 1/11/88

Calc # MD-N2085-8[illegible] Re

Job # 19106

Check: [signature] 1/13/88

Attachment 2 to Calc # MD-N2085-[illegible] Rev. 0 (18 pages) (Verification Run from program)

Sheet 1 of 18

Attachment 2 REV. 0

Sheet 2 of 18

Calc # MD-N2065-88002

************* INITIAL FLOW PATH DATA *************

FLOW PATH	FROM	TO	AREA (IN^2)	LOSS
1	1	45	1.57	17.97
2	1	2	1.78	6.32
3	2	3	1.78	6.32
4	3	4	1.78	5.87
5	4	5	1.78	5.87
6	5	6	1.78	5.87
7	6	7	.825	1.77
8	7	45	1.57	5.27
9	7	21	.825	2.87
10	7	8	.825	3.99
11	8	9	.484	17.7
12	9	12	2.32	87509
13	9	10	.484	17.7
14	10	13	2.32	87509
15	10	11	.484	17.7
16	11	14	2.32	87509
17	21	15	.484	19.67
18	15	20	2.13	87509
19	15	16	.484	19.67
20	16	19	2.13	87509
21	16	17	.484	19.67
22	17	18	2.13	87509
23	3	22	.825	2.67
24	22	23	.825	2.67
25	23	45	1.57	5.27
26	23	31	.825	5.13
27	24	25	.484	18.15
28	25	28	2.42	87509
29	25	26	.484	18.15
30	26	29	2.42	87509
31	26	27	.484	18.15
32	27	30	2.42	87509
33	31	32	.484	18.9
34	32	35	2.08	87509
35	32	33	.484	18.9
36	33	36	2.08	87509
37	33	34	.484	18.9
38	34	37	2.08	87509
39	1	38	.145	24.84
40	38	39	.145	15.36
41	38	44	.06	20.7
42	39	40	.145	16.57
43	39	42	.145	85.51
44	40	41	.145	28.13
45	40	45	1.57	5.27
46	23	24	.825	1.92
47	41	43	.145	79.15

note: these value are not the same as used in actual runs - this does not affect the results of the actual run as this run is used solely for verification purposes - verification can be made

Attachment 2 REV.0
Sheet 3 of 18
Calc # MD-N2085-88002

THE CURRENT TIME IS .01 SECONDS

NODE	PRESSURE (PSIA)
1	15.36665
2	90.00001
3	90.00001
4	90
5	90
6	90
7	51.2034
8	89.99999
9	90
10	90
11	90
12	90
13	90
14	90
15	90
16	90
17	90
18	90
19	90
20	90
21	90
22	90
23	52.95902
24	90
25	90
26	90
27	90
28	90.00001
29	90.00001
30	90.00001
31	90
32	90
33	90
34	90
35	90
36	90
37	90
38	90
39	90
40	39.97627
41	90.00001
42	90
43	90
44	90
45	14.7

FLOW PATH	MDOT (LBM/SEC)	FROM	TO
1	.7848784	1	45
2	0	1	2
3	0	2	3
4	0	3	4
5	0	4	5
6	0	5	6
7	0	6	7
8	1.449343	7	45
9	0	7	21
10	0	7	8
11	0	8	9
12	0	9	12
13	0	9	10
14	0	10	13
15	0	10	11
16	0	11	14
17	0	21	15
18	0	15	20
19	0	15	16
20	0	16	19
21	0	16	17
22	0	17	18
23	0	3	22
24	0	22	23
25	1.449343	23	45
26	0	23	31
27	0	24	25
28	0	25	28
29	0	25	26
30	0	26	29
31	0	26	27
32	0	27	30
33	0	31	32
34	0	32	35
35	0	32	33
36	0	33	36
37	0	33	34
38	0	34	37
39	0	1[illegible]	38
40	0	38	39
41	0	38	44
42	0	39	40
43	0	39	42
44	0	40	41
45	1.449343	40	45
46	0	23	24
47	0	41	43

THE CURRENT TIME IS .02 SECONDS

NODE	PRESSURE (PSIA)
1	158.5583
2	86.04587
3	89.99651
4	90.00228
5	90
6	86.19926
7	115.0498
8	69.29861
9	89.99782
10	90
11	90
12	90
13	90
14	90
15	90
16	90
17	90
18	90
19	90
20	90
21	65.37291
22	62.88727
23	109.8483
24	39.05311
25	90.00014
26	90.00014
27	90.00014
28	89.99998
29	89.99998
30	89.99998
31	80.0013
32	90
33	90
34	90
35	90
36	90
37	90
38	88.50204
39	86.92735
40	22.36187
41	88.74377
42	90
43	90.00039
44	90
45	14.7

Attachment 2 REV. 0
Sheet 6 of 18
Calc # MD-N2085-88002

FLOW PATH	MDOT (LBM/SEC)	FROM	TO
1	5.629336E-02	1	45
2	-1.500508	1	2
3	0	2	3
4	7.850773E-04	3	4
5	0	4	5
6	0	5	6
7	1.309359	6	7
8	.8245696	7	45
9	-1.028264	7	21
10	-.8720853	7	8
11	-1.229335E-04	8	9
12	0	9	12
13	0	9	10
14	0	10	13
15	0	10	11
16	0	11	14
17	0	21	15
18	0	15	20
19	0	15	16
20	0	16	19
21	0	16	17
22	0	17	18
23	5.395228E-04	3	22
24	1.061409	22	23
25	.8528418	23	45
26	-.7657369	23	31
27	0	24	25
28	-8.741793E-06	25	28
29	0	25	26
30	-8.741793E-06	26	29
31	0	26	27
32	-8.741793E-06	27	30
33	0	31	32
34	0	32	35
35	0	32	33
36	0	33	36
37	0	33	34
38	0	34	37
39	-6.165509E-02	1	38
40	0	38	39
41	0	38	44
42	7.548896E-02	39	40
43	0	39	42
44	-5.793751E-02	40	41
45	.6437701	40	45
46	-1.251664	23	24
47	1.741623E-05	41	43

THE CURRENT TIME IS .03 , SECONDS

NODE	PRESSURE (PSIA)
1	-234.4927
2	94.67922
3	85.76286
4	89.88058
5	88.17267
6	92.38742
7	-39.103
8	100.5163
9	86.32325
10	89.95597
11	90
12	89.99938
13	90
14	90
15	86.94195
16	90
17	90
18	90
19	90
20	90
21	101.8909
22	121.6379
23	-29.78412
24	111.5374
25	85.95433
26	89.99931
27	89.99931
28	90.00015
29	90.00015
30	90.00015
31	93.14602
32	87.54935
33	90
34	90
35	90
36	90
37	90
38	90.80409
39	85.32255
40	14.88864
41	87.68679
42	89.34673
43	89.81623
44	89.22285
45	14.70001

Attachment 2 REV. 0

Sheet 8 of 18

Calc # MD-112085-83002

FLOW PATH	MC (LBM/SEC)	FROM	TO
1	1.382767	1	45
2	2.64233	1	2
3	-.6338356	2	3
4	-2.574025E-02	3	4
5	1.618497E-02	4	5
6	.6457011	5	6
7	-1.486123	6	7
8	1.852739	7	45
9	1.314629	7	21
10	1.105265	7	8
11	-.2096552	8	9
12	-1.690693E-04	9	12
13	-2.480058E-03	9	10
14	0	10	13
15	0	10	11
16	0	11	14
17	-.2101214	21	15
18	0	15	20
19	0	15	16
20	0	16	19
21	0	16	17
22	0	17	18
23	.9984853	3	22
24	-1.300315	22	23
25	1.768975	23	45
26	.8542218	23	31
27	-.2407601	24	25
28	4.945108E-05	25	28
29	0	25	26
30	4.945108E-05	26	29
31	0	26	27
32	4.945108E-05	27	30
33	-.1524481	31	32
34	0	32	35
35	0	32	33
36	0	33	36
37	0	33	34
38	0	34	37
39	.1084078	1	38
40	2.103755E-02	38	39
41	-7.380059E-03	38	44
42	7.291172E-02	39	40
43	-1.244728E-02	39	42
44	-5.712881E-02	40	41
45	.3465632	40	45
46	[illegible].[illegible]40036	23	24
47	-8.366093E-03	41	43

Attachment 2 REV. 0
Sheet 9 of 18
Calc # MD-N2085-83002

THE CURRENT TIME IS .04 SECONDS

NODE	PRESSURE (PSIA)
1	66.28741
2	86.01955
3	93.56549
4	86.66304
5	91.44048
6	86.47563
7	60.78756
8	72.68612
9	91.65561
10	88.41104
11	89.80236
12	89.9744
13	89.99721
14	90
15	91.05038
16	88.74213
17	90
18	90
19	90
20	89.97709
21	69.35373
22	50.38297
23	73.60597
24	37.45443
25	92.11369
26	88.27322
27	90.00114
28	89.97398
29	89.99976
30	89.99976
31	81.15287
32	90.8256
33	88.7264
34	90
35	89.97943
36	90
37	90
38	88.16453
39	84.564
40	17.39629
41	86.69779
42	88.60638
43	89.57803
44	90.02453
45	14.70001

Attachment 2 Rev. 0
Sheet 10 of 18
Calc # MD-N2085-88002

FLOW PATH	MDOT (LBM/SEC)	FROM	TO
1	-.1281969	1	45
2	-1.578521	1	2
3	.9486775	2	3
4	-.6702894	3	4
5	.4381556	4	5
6	-.6876071	5	6
7	1.349007	6	7
8	-.236726	7	45
9	-1.168376	7	21
10	-.9775484	7	8
11	.1946867	8	9
12	-6.784047E-03	9	12
13	-9.892685E-02	9	10
14	-7.59017E-04	10	13
15	-1.113393E-02	10	11
16	0	11	14
17	.1901615	21	15
18	-5.702603E-03	15	20
19	-8.642971E-02	15	16
20	0	16	19
21	0	16	17
22	0	17	18
23	-1.341959	3	22
24	1.44611	22	23
25	-.236726	23	45
26	-.7989025	23	31
27	.2563549	24	25
28	-[illegible].406687E-03	25	28
29	-.1028483	25	26
30	-1.09534E-04	26	29
31	0	26	27
32	-1.09534E-04	27	30
33	.1195753	31	32
34	-5.003776E-03	32	35
35	-.0792274	32	33
36	0	33	36
37	0	33	34
38	0	34	37
39	-6.220594E-02	1	38
40	.0388228	38	39
41	7.613014E-03	38	44
42	7.156567E-02	39	40
43	-1.410675E-02	39	42
44	-5.644838E-02	40	41
45	5.535964E-02	40	45
46	-1.563717	23	24
47	-1.082168E-02	41	43

THE CURRENT TIME IS .05 SECONDS

NODE	PRESSURE (PSIA)
1	91.188
2	86.15275
3	86.33823
4	91.29865
5	87.18967
6	85.21239
7	94.76317
8	64.83719
9	86.23895
10	91.27189
11	88.73002
12	89.99166
13	89.98058
14	89.99409
15	86.93279
16	90.71606
17	89.18434
18	90
19	89.98515
20	89.99091
21	61.35146
22	99.92408
23	6.451567
24	89.48734
25	86.1746
26	91.20776
27	88.85316
28	89.99347
29	89.98241
30	90.00026
31	77.69352
32	87.16267
33	90.89639
34	89.07526
35	89.99169
36	89.98507
37	90
38	86.13486
39	83.52583
40	14.59077
41	85.75919
42	87.86767
43	89.30264
44	89.16033
45	14.70001

Attachment 2 REV.0

Sheet 12 of 18

Calc # MD-N2085-88002

FLOW PATH	MDOT (LBM/SEC)	FROM	TO
1	-.1281969	1	45
2	-1.467489	1	2
3	-.7590826	2	3
4	8713871	3	4
5	-.7255849	4	5
6	.7388184	5	6
7	1.174008	6	7
8	.9789112	7	45
9	-.5377164	7	21
10	-.5364295	7	8
11	-.2058249	8	9
12	4.687827E-03	9	12
13	.0946345	9	10
14	-4.513773E-03	10	13
15	-6.201696E-02	10	11
16	-1.606716E-03	11	14
17	-.2035946	21	15
18	3.43972E-03	15	20
19	7.588836E-02	15	16
20	-3.697822E-03	16	19
21	-5.604488E-02	16	17
22	0	17	1[illegible]
23	1.112113	3	22
24	-.8263351	22	23
25	1.185336	23	45
26	-.4159795	23	31
27	-.246414	24	25
28	5.515518E-03	25	28
29	.1015705	25	26
30	-4.908156E-03	26	29
31	-6.818834E-02	26	27
32	1.404146E-04	27	30
33	-.151049	31	32
34	2.982778E-03	32	35
35	.0738295	32	33
36	-3.633171E-03	33	36
37	-5.752589E-02	33	34
38	0	34	37
39	-6.039769E-02	1	38
40	3.134849E-02	38	39
41	-8.206738E-03	38	44
42	7.092942E-02	39	40
43	-.0140753	39	42
44	-5.581171E-02	40	41
45	.2080258	40	45
46	1.031931	23	24
47	1.251047E-02	41	43

THE CURRENT TIME IS 5.999999E-02 SECONDS

NODE	PRESSURE (PSIA)
1	-55.28619
2	88.40147
3	90.12368
4	87.19693
5	87.80432
6	89.04487
7	-20.48413
8	90.39323
9	84.76896
10	87.64423
11	90.29166
12	89.96643
13	89.99572
14	89.97923
15	85.39926
16	88.37391
17	90.13002
18	67.988
19	89.99654
20	89.96799
21	91.5075
22	48.1915
23	91.95635
24	34.62717
25	89.79105
26	87.86707
27	90.26199
28	89.96799
29	89.99717
30	89.98606
31	70.90157
32	86.46614
33	88.17116
34	90.23286
35	89.96964
36	89.99779
37	89.98724
38	86.45715
39	82.34415
40	20.36321
41	84.86157
42	87.10692
43	88.99894
44	88.07145
45	14.70001

Attachment 2 REV.0
Sheet 14 of 18
Calc # MD-N2085-88002

FLOW PATH	MDOT (LBM/SEC)	FROM	TO
1	.7952387	1	45
2	.7156944	1	2
3	-.1376416	2	3
4	-.7379008	3	4
5	.6751453	4	5
6	.4634001	5	6
7	-.856891	6	7
8	1.526048	7	45
9	1.051944	7	21
10	.8704649	7	8
11	-.2059798	8	9
12	-6.850766E-03	9	12
13	-.1163171	9	10
14	4.109183E-03	10	13
15	8.393728E-02	10	11
16	-.0040773	11	14
17	-.2071726	21	15
18	-5.702359E-03	15	20
19	-9.609966E-02	15	16
20	2.839074E-03	16	19
21	6.199262E-02	16	17
22	-2.985652E-03	17	18
23	-.8362343	3	22
24	1.187962	22	23
25	-.2367261	23	45
26	-.6663681	23	31
27	.0932229	24	25
28	-7.205883E-03	25	28
29	-.1148257	25	26
30	4.175576E-03	26	29
31	7.983983E-02	26	27
32	-4.014702E-03	27	30
33	-.1462169	31	32
34	-5.363471E-03	32	35
35	-9.752462E-02	32	33
36	3.095481E-03	33	36
37	6.890882E-02	33	34
38	-3.102376E-03	34	37
39	2.945643E-02	1	38
40	2.653178E-02	38	39
41	-1.034036E-02	38	44
42	7.0(864E-02	39	40
43	-1.449534E-02	39	42
44	-5.520749E-02	40	41
45	-4.107942E-02	40	45
46	-1.254582	23	24
47	-1.379695E-02	41	43

THE CURRENT TIME IS 6.999999E-02 SECONDS

NODE	PRESSURE (PSIA)
1	102.6835
2	85.63641
3	84.67927
4	89.60639
5	88.13161
6	84.18881
7	72.27739
8	66.62901
9	88.62273
10	87.7039
11	88.74458
12	89.93701
13	89.97557
14	89.98667
15	88.48893
16	88.16689
17	89.15025
18	89.99303
19	89.97971
20	89.94025
21	63.48064
22	103.5121
23	-24.08578
24	96.87876
25	84.57613
26	90.50967
27	88.88344
28	89.96239
29	89.97794
30	89.99307
31	82.07475
32	84.74897
33	88.35733
34	89.03452
35	89.94522
36	89.97996
37	89.99386
38	84.39903
39	81.49171
40	14.30065
41	83.99879
42	86.31596
43	88.67258
44	87.27412
45	14.70001

Attachment 2 REV. 0
Sheet 16 of 18
Calc # MD-NZ085-68002

FLOW PATH	MDOT (LBM/SEC)	FROM	TO
1	-.1281969	1	45
2	-1.473856	1	2
3	-.4245821	2	3
4	.3701014	3	4
5	-.2599608	4	5
6	-.3727133	5	6
7	1.300201	6	7
8	-.2367261	7	45
9	-1.04931	7	21
10	-.8790985	7	8
11	.1218733	8	9
12	-7.98827E-03	9	12
13	-8.724063E-02	9	10
14	-5.470255E-03	10	13
15	-8.513191E-02	10	11
16	2.022013E-03	11	14
17	.1209055	21	15
18	-6.903607E-03	15	20
19	-8.448435E-02	15	16
20	-4.190532E-03	16	19
21	-6.606954E-02	16	17
22	1.251788E-03	17	18
23	1.071351	3	22
24	-1.093237	22	23
25	1.480847	23	45
26	.677225	23	31
27	-.2402007	24	25
28	-1.585715E-03	25	28
29	7.178104E-02	25	26
30	-5.438202E-03	26	29
31	-8.007033E-02	26	27
32	1.98223E-03	27	30
33	-.1784574	31	32
34	-5.943074E-03	32	35
35	-6.569387E-02	32	33
36	-4.336437E-03	33	36
37	-7.293854E-02	33	34
38	1.607486E-03	34	37
39	-5.922604E-02	1	38
40	.0330538	38	39
41	-7.571777E-03	38	44
42	6.906749E-02	39	40
43	-.0150708	39	42
44	-5.462965E-02	40	41
45	.2993484	40	45
46	1.289197	23	24
47	-1.482627E-02	41	43

Attachment 2 REV.0
Sheet 17 of 18
Calc # MD-N2085-88002

THE CURRENT TIME IS 7.999999E-02 SECONDS

NODE	PRESSURE (PSIA)
1	-111.9304
2	88.26228
3	89.97861
4	86.31061
5	87.42687
6	83.52178
7	39.3617
8	80.87746
9	84.04713
10	89.63898
11	87.86723
12	89.92186
13	89.95576
14	89.97192
15	85.10023
16	89.36172
17	88.47548
18	89.98084
19	89.96194
20	89.92432
21	81.81261
22	47.1991
23	66.11791
24	34.37864
25	89.77144
26	87.27393
27	90.06507
28	89.93243
29	89.98766
30	89.97911
31	73.92907
32	85.07585
33	87.57645
34	88.41222
35	89.91579
36	89.96314
37	89.98087
38	85.30944
39	80.44952
40	21.26684
41	83.16643
42	85.52409
43	88.32756
44	86.22337
45	14.70001

Attachment 2 REV. 0
Sheet 18 of 18
Calc # MD-N2085-88002

FLOW PATH	MDOT (LBM/SEC)	FROM	TO
1	.8954892	1	45
2	1.306335	1	2
3	.3098797	2	3
4	-.7283018	3	4
5	.4070982	4	5
6	.6498789	5	6
7	.8796699	6	7
8	1.163941	7	45
9	.556892	7	21
10	.3684839	7	8
11	-.2116746	8	9
12	-4.114127E-03	9	12
13	5.020557E-02	9	10
14	-5.378623E-03	10	13
15	-5.342844E-02	10	11
16	-4.002397E-03	11	14
17	-.2085294	21	15
18	-3.966021E-03	15	20
19	2.827616E-02	15	16
20	-4.423774E-03	16	19
21	-4.939761E-02	16	17
22	-3.03428E-03	17	18
23	-.9727999	3	22
24	1.230619	22	23
25	-.2367261	23	45
26	-.7039455	23	31
27	.1772961	24	25
28	-8.472199E-03	25	28
29	-.1234601	25	26
30	2.751305E-03	26	29
31	6.638245E-02	26	27
32	-3.949333E-03	27	30
33	-8.011989E-02	31	32
34	-7.160209E-03	32	35
35	-9.453753E-02	32	33
36	-4.09178E-03	33	36
37	-.0418696	33	34
38	-3.159113E-03	34	37
39	5.515306E-02	1	38
40	2.765994E-02	38	39
41	-9.978388E-03	38	44
42	6.835249E-02	39	40
43	-1.508832E-02	39	42
44	-5.407424E-02	40	41
45	-7.940552E-02	40	45
46	-1.358207	23	24
47	-1.567394E-02	41	43

Subject: Air Venting in HCU Scram Diaphragm Valves.

John Rommel 1/11/88
Calc # MD-N2085-88002 Rev. 0
Job # 19106
Check: [signature] 1/12/88

Bechtel North American Power Corporation

Attachment 3 to MD-N2085-88002 Rev. 0, 1 SHEET

Interoffice Memorandum

Attachment Number of Sheets 1

To	Neil Howard Chief Nuclear Engineer	**Date**	December 18, 1937
Subject	Staff Calc of ATWS ARI Modification	**From**	Rich Gallagher
		Of	Project Engineer
		At	Athens, Alabama **Ext.** 574
Copies	See Distribution	**File**	Project File, w/a

TVA has awarded Bechtel the contract to incorporate the ATWS/ARI modifications into the Browns Ferry design. As a part of this design it is necessary to verify whether or not the proposed Alternate Rod Insertion (ARI) design meets the ARI performance time requirement. We would like to request Nuclear Staff to calculate the air venting time for the subject modification. By using a computer code, the calc will verify the venting time of the air in the HCU scram diaphragm valves and the air header. The air will vent through the holes in the scram pilot solenoid valves to the scram valve air header and thru various vent valves which will be installed at several locations on the air header piping. Detailed discussions on this matter have been made between Young Park (Athens) and John Rommel (Nuclear Staff). All necessary drawings and references have been/will be sent directly to John.

The attached memo is concerning the use of computer programs to perform calculations for Browns Ferry. This is for your information and we will inform you later if we have any more information on the use of Bechtel computer code.

The calc is needed ASAP or by January 15, 1988. Manhour for the work is approximately 200 hours. The charge number is 19106 (Project)-062 (Sub)-234 (Sub Sub)-D062DD (Activity).

We appreciate your assistance on this matter.

Rich Gallagher

Rich Gallagher

Written Response Required: Yes
Date Due: January 15, 1988

REG:GLL:UYP:vlt
Attachment

<u>Distribution:</u>

L. Lushbaugh, w/a
R. Mays, w/a (Gaithersburg)
U. Y. Park, w/a
J. Rommel, w/a (Gaithersburg)
A. W. Wilk, w/a (Gaithersburg)

Attachment A to Calc # MD-N2085-88002
Attachment Rev. 0 Number of Sheets 3
Sheet 1 of 3

John Rommel 1/11/88
Calc# MD-N2085-88002 Rev. 0
Job 19106
check: [signature] 1/13/88

BECHTEL

MEMORANDUM

"DON'T SAY IT — WRITE IT"

BEPC-9906 Rev. 8/86 (Form G-3)

TO	LOCATION	
John Rommel, Nuclear Staff	Gaithersburg, Rm. 2A-11	
FROM	DATE	FILE
U. Young PARK	12/23/87	

SUBJECT Your Telecopy of 12/23/87 : ATWS/ARI Calc Info

In response to your subject telecopy, the following info are provided:

1) Volume of piping/components — Volume calc for each piping sections is attached. Several sections of the piping can be grouped for calc purpose. Also note that the venting air is pressurized from initial press. of (app) 75 psig to average of 30 psig when the scram valves start to open. (see the references sent previously).

2) Volume between scram valve and pilot valves — see sheet 3 of the attached calc, bottom line. Use 41 in³ for preliminary value. The final value, if different from 41 in³, will be provided as soon as it is obtained from TVA. The air is also pressurized here.

3) Piping friction data — This can be varied depending on the nature of flow which may change depending on the location of the flow in pipe. Refer to the attached memo from Goswami about the piping friction factor. Also a constant number of friction factor can be assumed if Staff desires.

4) Effective flow areas / flow coefficients for vent valves — A value of Cv can be sufficient for these. Use Cv of 13 for 1 inch vent valves – for two ARI scram air block valves and six other vent valves. All valves will be 3-way solenoid, 1 inch size. (see attached ASCO valve catalog).

5) Minimum flow area w/i solenoid valve — We consider this area as the grommet with wire in the solenoid valve diaphragm. (refer to my memo of 12/16/87). The solenoid valve model number and actual picture were sent previously. Use area of 6.44×10^{-4} in^2 for preliminary value. We will confirm this number as soon as it can be verified from TVA.

Also copies of PECo calcs for this grommet K-factor are attached. Excerpts of the reference (Idel'Chick, AEC-TR-6630, NTIS) are also attached for your reference & use. <Reference 2>

6) Opening times for vent valves — use 40~50 msec (0.04 - 0.05 sec) for the above quoted values (ref: Telecon w/ ASCo, copy attached)

7) Initial air temperature – Use 50°F min to 110°F max. Assuming fixed pressures of initial 75 psig to 35 psig of scram valve movement, the lower temp, hence higher air mass, will give a more conservative result.

Due to the time constraint of this task and also to the difficulties for obtaining engineering data from TVA within a short period, I regret that we can not supply final data at this time. However, I expect that the above data will not be changed much, if at all, after the official values are obtained.

Please call me if you have any questions.

Encl.:

1. Memo from Goswami to U.V. Park
2. Air volume calc
3. Excerpts of PECo Calc for piping friction factor
4. ASCo 3-Way valve catalogo (copy)
5. Excepts of PECo Calc for Solenoid valve diaphragm grommet flow calc
6. Excerpts of TVA Browns Ferry FSAR – CRD & HCU Sections.
7. Telecon with ASCo dated 12/23/87

Attachment 5 to
Calc # MD-N2085-88002 Attachment 1
Rev. 0 Number of sheets 1
Sheet 1 of 1

Bechtel Power Corporation

John C. Rommel 1/11/88
Calc # MD-N2085-88002 Rev 0

Check J. McLilman 1/13/88

BECHTEL

Telephone call

Route ______

By John C. Rommel Of Nuclear Staff

To U. Young Park Of Athens

Date 1/8/88 19__ Time ______

Subject ATWS/ARI Calculation Information Job No. 19106

I called Young about three things:

1. The approximation thickness of the diaphragm near the location of the gromment.
2. The diameter of the gromment w/o the wire.
3. Number of HCU's associated with West and East Bank Headers

Young replied as follows.

1. He measured the thickness to be about 5/32" of an inch near the gromment.
2. Young indicated that the number to use for the diameter of the grommet w/o the wire should be 0.046 inches.
3. West Bank 1 - 48
   West Bank 2 - 44
   East Bank 1 - 50
   East Bank 2 - 43

John C. Rommel

JAN 04 '88 15:19 J.W. Rommel 1/11/88 MD-N2085-88002 Rev. 0
Calc# MD-N2085-88002
DP 19106

Attachment 6 to Calc# MD-N2085-88002
Attachment Rev. 0 Number of Sheets 1
Sheet 1 of 1

check: J.M. Gilmore
4/13/88

MEMORANDUM

"DON'T SAY IT — WRITE IT"

R. Mays (Gaith)
R. Gallagher
J. Rommel (Gaith)
U. V. PARK

BEPC-9906 Rev. 8/86 (Form G-3)

TO: Neil Howard, Nuclear Chief	LOCATION: Gaithersburg Rm 2A-12
FROM: Lee Lushbaugh, Athens AL	DATE: 1-4-88

SUBJECT: ATWS-ARI Vent Time Calc

Reference: Memo from U.V. Park to J. Rommel (12/23/87)

In regard to the subject calc by your staff, the data for the space between the two HCU scram valve diaphragm heads and the scram pilot solenoid valve (see reference memo, item 2) is provided as following;

a) Air volume in scram valve diaphragm w/ valve closed (pressurized @ 75 psig): 24.5 in^3 (per valve vender info.)

b) Air volume in tubing between scram diaphragm valve and scram solenoid valve: 6.4 in^3 (see reference memo, calc sheet 3, bottom line)

c) Total space volume (air pressurized @ 75 psig) = 24.5 x 2 (for two scram valves) + 6.4 in^3 = 55.4 in^3

Please have your staff use the volume of 55.4 in^3 for the subject calc. All other data were provided by the reference memo.

L. Lushbaugh

Subject: ARI Venting time of Scram Air Header

Attachment 7 Rev. 0

Sheet 1 of 20

Calc # MD-N2085-88002

[signature] 2/10/88

[signature] 2/12/88

```
REM  THIS PROGRAM HAS BEEN DEVELOPED TO EVALUATE THE
REM  AIR VENTING TIME FOR THE ATWS/ARI MODIFICATIONS
REM  AT THE TVA'S BROWNS FERRY NUCLEAR PLANT
REM
REM  THIS PROGRAM IS DEVELOPED FOR USE ON IBM PC'S
REM  USING MICROSOFT'S QUICK BASIC COMPILER
REM
REM DIMENSION ARRAYS TO BE USED
DIM  P(50),T(50),V(50),M(50),NIN(50),NOUT(50),A(50),K(50),MDOT(50)
DIM  MIN(50),MOUT(50),DP(50),PS(50),RHO(50),CA(50),IFI(50)
REM
REM OPEN AN OUPUT FILE FOR COLLECTION OF OUPTUT DATA
OPEN "D:\TVA\OUTPUT.PRN" FOR OUTPUT AS #1
REM READ THE TITLE CARD AND THEN PRINT IT OUT
READ TITLE$
LPRINT;TITLE$:LPRINT
REM READ IN NUMBER OF NODES
READ NV
REM RC=IDEAL GAS CONSTANT FOR AIR (53.34 FT*LBF/LBM/DEG-R)
RC=53.34
REM KA=ISENTROPIC EXPONENT FOR AIR
KA=1.4
REM GC=GRAVITIONAL CONSTANT (LBM*FT/LBF/SEC^2)
GC=32.17
REM READ IN THE INPUT DATA FOR NODES
REM P(I)=INITIAL PRESSURE IN NODE I (PSIA)
REM T(I)=INITIAL TEMPERATURE IN NODE I (DEG-F)
REM V(I)=VOLUME IN NODE I (IN^3)
REM M(I)=MASS (LBM) OF AIR WITHIN NODE I
REM RHO(I)=DENSITY (LBM/FT^3) OF AIR IN NODE I
LPRINT"**************    INITIAL NODE DATA ****************"
LPRINT:LPRINT
LPRINT" NODE        PRESSURE     TEMPERATURE       VOLUME"
LPRINT"              (PSIA)        (DEG-F)          (IN^3)"
LPRINT"****************************************************"
LPRINT
FOR I=1 TO NV
READ P(I),T(I),V(I)
LPRINT I,P(I),T(I),V(I)
REM CONVERT T(I) TO DEG-R AND P(I) TO LBF/FT^2
T(I)=T(I)+460
P(I)=P(I)*144
REM CONVERT VOLUME TO FT^3
V(I)=V(I)/12/12/12
REM CALCULATE MASS IN VOLUME USING IDEAL GAS LAW
M(I)=P(I)*V(I)/T(I)/RC
RHO(I)=M(I)/V(I)
NEXT I
REM READ IN THE NUMBER OF FLOW PATHS
READ NFP
REM READ IN THE INPUT DATA FOR EACH FLOW PATH
REM NFP=NUMBER OF FLOW PATHS
REM NIN=INDEX FOR NODE INTO FOR FLOW PATH I
REM NOUT=INDEX FOR NODE OUT OF FOR FLOW PATH I
REM A(I)= AREA FOR FLOW PATH I (IN^2)
REM K(I)=LOSS FACTOR FOR FLOW PATH I
LPRINT:LPRINT:LPRINT:LPRINT:LPRINT:LPRINT
LPRINT" *************    INITIAL FLOW PATH DATA    *************"
LPRINT
LPRINT"FLOW          FROM          TO          AREA       LOSS"
```

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Calc # MD-N2095-88002

```
LPRINT"PATH                                             (IN^2)"
LPRINT"****************************************************************"
LPRINT
FOR I=1 TO NFP
READ NIN(I),NOUT(I),A(I),K(I)
LPRINT I,NOUT(I),NIN(I),A(I),K(I)
REM CONVERT AREA TO FT^2
A(I)=A(I)/144
REM CONVERT LOSS TERM TO DISCHARGE COEFFICIENT
K(I)=(1/(K(I)))^0.5
REM CONVERT AREA TO EFFECTIVE AREA
A(I)=A(I)*K(I)
NEXT I
LPRINT
FOR J=1 TO 7 :LPRINT
NEXT J
REM DEFINE THE CRITICAL PRESSURE RATIO FOR AIR
CPR=0.528
REM READ IN THE TIME STEP, PRINTOUT INTERVAL AND MAXIMUM TIME OF TRANSIENT
REM ALSO READ IN THE STORAGE OUTPUT INTERVAL (SOCMAX)
READ DT,PTMAX,TMAX,SOCMAX
REM INITIALIZE TIME TO ZERO
T=0
REM ESTABLISH TIME STEP LOOP
TIMSTP:
T=T+DT
PRINT T," SECONDS"
REM ZERO OUT THE VALUE OF MIN(I) AND MOUT(I) FOR ALL FLOW PATHS
FOR I=1 TO NFP
MIN(I)=0
MOUT(I)=0
NEXT I
REM DETERMINE THE PRESSURE DIFFERENCE IN THE CONNECTING NODES FOR USE IN
REM FLOW EQUATIONS USING STAGNATION PRESSURES AT PREVIOUS TIME STEP
FOR I=1 TO NFP
J=NIN(I)
K=NOUT(I)
DP(I)=P(K)-P(J)
REM DETERMINE FLOW DIRECTION AND ESTABLISH UPSTREAM DENSITY
REM IFI(I) IS AN INDEX SHOWING DIRECTION OF FLOW (+1 : NORMAL
REM -1 : REVERSE)
IF (DP(I)>0) THEN
     IFI(I)=1
     PHIGH=P(K)
     PLOW=P(J)
     RHOH=RHO(K)
ELSE
     IFI(I)=-1
     PHIGH=P(J)
     PLOW=P(K)
     RHOH=RHO(J)
END IF
REM DETERMINE IF CRITICAL PRESSURE RATIO (CPR) HAS BEEN
REM EXCEEDED ACROSS THIS FLOW PATH AND GO TO APPROPRIATE
REM SUBROUTINE TO CALCULATE THE FLOW
PR=PLOW/PHIGH
IF (PR>CPR) THEN
     GOSUB SUBCRITICAL
ELSE
```

```
END IF
REM DETERMINE TOTAL FLOW RATE INTO AND OUT OF EACH NODE
IF (DP(I)>0) THEN
     MIN(J)=MDOT(I)+MIN(J)
     MOUT(K)=MDOT(I)+MOUT(K)
ELSE
     MIN(K)=MDOT(I)+MIN(K)
     MOUT(J)=MDOT(I)+MOUT(J)
END IF
NEXT I
REM DETERMINE CHANGE IN MASS IN EACH NODE DURING TIME STEP
FOR I=1 TO NV
M(I)=M(I)+(MIN(I)-MOUT(I))*DT
REM UPDATE PRESSURE TERM USING IDEAL GAS LAW
REM ASSUME AN ISOTHERMAL PROCESS
P(I)=M(I)*RC*T(I)/V(I)
REM UPDATE DENSITY TERM
RHO(I)=P(I)/RC/T(I)
NEXT I
REM UPDATE PRINT INTERVAL COUNTER
CT=CT+1
REM UPDATE STORAGE OUTPUT COUNTER
SOC=SOC+1
REM IF AT STORAGE OUTPUT INTERVAL THEN WRITE
REM PRESSURES OF VOLUME WITHIN THE SCRAM DIAPHARGM VALVES
REM TO THE STORAGE DEVICE FOR FUTURE PLOTTING
IF SOC=SOCMAX THEN
PRINT#1, T,P(14)/144,P(18)/144,P(30)/144,P(37)/144,P(3)/144,P(17)/144
SOC=0
END IF
REM IF AT PRINTOUT INTERVAL PRINTOUT DATA
IF CT=PTMAX THEN
    LPRINT
    LPRINT " THE CURRENT TIME IS "; T,"SECONDS"
    LPRINT
    LPRINT " NODE          PRESSURE"
    LPRINT "                (PSIA)"
    LPRINT "*****************************"
    LPRINT
    FOR I=1 TO NV
    LPRINT I,P(I)/144
    NEXT I
    FOR J= 1 TO 9: LPRINT
    NEXT J
    LPRINT"FLOW PATH        MDOT        FROM          TO"
    LPRINT"                (LBM/SEC)"
    LPRINT"**************************************************"
    LPRINT
    FOR I=1 TO NFP
    LPRINT I,MDOT(I)*IFI(I),NOUT(I),NIN(I)
    NEXT I
    FOR J=1 TO 8 :LPRINT
    NEXT J
    CT=0
END IF
REM IF T<MAXIMUM TRANSIENT TIME THEN LOOP BACK THROUGH CALCULATIONS
IF T<TMAX GO TO  TIMSTP
REM PRINTOUT DATA AT END OF PROBLEM
LPRINT
LPRINT " THE CURRENT TIME IS "; T,"SECONDS"
```

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Calc # MD-N2085-88002

```
LPRINT
LPRINT " NODE          PRESSURE"
LPRINT "                (PSIA)"
LPRINT "****************************"
LPRINT
FOR I=1 TO NV
LPRINT I,P(I)/144
NEXT I
FOR J= 1 TO 9: LPRINT
NEXT J
LPRINT"FLOW PATH         MDOT       FROM           TO"
LPRINT"                (LBM/SEC)"
LPRINT"**************************************************"
LPRINT
FOR I=1 TO NFP
LPRINT I,MDOT(I)*IFI(I),NOUT(I),NIN(I)
NEXT I
FOR J=1 TO 8 :LPRINT
NEXT J
REM END OF PROGRAM
END
REM SUBROUTINES FOR THE CALCULATION OF SUBCRITCAL AND CRITICAL FLOW
REM
REM SUBCRITICAL FLOW
REM
SUBCRITICAL:
MDOT(I)=A(I)*(2*GC*KA*RHOH*PHIGH/(KA-1)*(PR^(2/KA)-PR^((KA+1)/KA)))^0.5
 RETURN
REM
REM CRITICAL FLOW
REM
CRITICAL:
MDOT(I)=A(I)*(GC*KA*RHOH*PHIGH*(2/(KA+1))^((KA+1)/(KA-1)))^0.5
RETURN
REM INPUT DATA
DATA  TVA HCU VENTING ANALYSIS WITH SMALLER VENT SIZE (ONLY 4 VALVES) 1/28/88
DATA  45
DATA 90,50,34.33
DATA 90,50,1238.77
DATA 90,50,1238.77
DATA 90,50,1124.59
DATA 90,50,1124.59
DATA 90,50,1124.59
DATA 90,50,121.95
DATA 90,50,137.5
DATA 90,50,183.9
DATA 90,50,183.9
DATA 90,50,183.9
DATA 90,50,886.4
DATA 90,50,886.4
DATA 90,50,886.4
DATA 90,50,224.3
DATA 90,50,224.3
DATA 90,50,224.3
DATA 90,50,812.53
DATA 90,50,812.53
DATA 90,50,812.53
DATA 90,50,136.30
DATA 90,50,127.73
```

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Sheet 5 of 20
Calc # MD-N2035-88002

```
DATA 90,50,80.2
DATA 90,50,194.3
DATA 90,50,194.3
DATA 90,50,194.3
DATA 90,50,923.33
DATA 90,50,923.33
DATA 90,50,923.33
DATA 90,50,250
DATA 90,50,203.07
DATA 90,50,203.07
DATA 90,50,203.07
DATA 90,50,794.1
DATA 90,50,794.1
DATA 90,50,794.1
DATA 90,50,134.36
DATA 90,50,80.2
DATA 90,50,94.58
DATA 90,50,150.6
DATA 90,50,62.2
DATA 90,50,148.3
DATA 90,50,31
DATA 14.7,50,1.0E10
DATA 47
DATA 45,  1, 0.785,  17.97
DATA  2,  1, 1.78, 6.32
DATA  3,  2, 1.78, 6.32
DATA  4,  3, 1.78, 5.87
DATA  5,  4, 1.78, 5.87
DATA  6,  5, 1.78, 5.87
DATA  7,  6, 0.825, 1.77
DATA 45,  7, 0.785 , 5.27
DATA 21,  7, 0.825, 2.87
DATA  8,  7, 0.825, 3.99
DATA  9,  8, 0.484, 17.70
DATA 12,  9, 2.32, 87509
DATA 10,  9, 0.484, 17.70
DATA 13, 10, 2.32, 87509
DATA 11, 10, 0.484, 17.70
DATA 14, 11, 2.32, 87509
DATA 15, 21, 0.484, 19.67
DATA 20, 15, 2.13 ,87509
DATA 16, 15, 0.484, 19.67
DATA 19, 16, 2.13 , 87509
DATA 17, 16, 0.484, 19.67
DATA 18, 17, 2.13 , 87509
DATA 22,  3, 0.825, 2.67
DATA 23, 22, 0.825, 2.67
DATA 45, 23, 0.785 , 5.27
DATA 31, 23, 0.825, 5.13
DATA 25, 24, 0.484, 18.15
DATA 28, 25, 2.42 , 87509
DATA 26, 25, 0.484, 18.15
DATA 29, 26, 2.42 , 87509
DATA 27, 26, 0.484, 18.15
DATA 30, 27, 2.42 , 87509
DATA 32, 31, 0.484, 18.90
DATA 35, 32, 2.08 ,87509
DATA 33, 32, 0.484, 18.90
DATA 36, 33, 2.08 , 87509
DATA 34, 33, 0.484, 18.90
```

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Sheet 6 of 20
Calc # MD-N2085-88002

```
DATA 37, 34, 2.08 , 87509
DATA 38,  1, 0.145, 24.84
DATA 39, 38, 0.145, 15.36
DATA 44, 38, 0.06 , 20.70
DATA 40, 39, 0.145, 16.57
DATA 42, 39, 0.145, 49.73
DATA 41, 40, 0.145, 28.13
DATA 45, 40, 0.785 , 5.27
DATA 24, 23, 0.825, 1.92
DATA 43, 41, 0.145, 102.59
DATA 0.001,5000,25.00,100
```

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Sheet 7 of 20
Calc # MD-N2085-88002

TVA HCU VENTING ANALYSIS WITH SMALLER VENT SIZE (ONLY 4 VALVES) 1/28/88

************* INITIAL NODE DATA ***************

NODE	PRESSURE (PSIA)	TEMPERATURE (DEG-F)	VOLUME (IN^3)
1	90	50	34.33
2	90	50	1238.77
3	90	50	1238.77
4	90	50	1124.59
5	90	50	1124.59
6	90	50	1124.59
7	90	50	121.95
8	90	50	137.5
9	90	50	183.9
10	90	50	183.9
11	90	50	183.9
12	90	50	886.4
13	90	50	886.4
14	90	50	886.4
15	90	50	224.3
16	90	50	224.3
17	90	50	224.3
18	90	50	812.53
19	90	50	812.53
20	90	50	812.53
21	90	50	136.3
22	90	50	127.73
23	90	50	127.73
24	90	50	80.2
25	90	50	194.3
26	90	50	194.3
27	90	50	194.3
28	90	50	923.33
29	90	50	923.33
30	90	50	923.33
31	90	50	250
32	90	50	203.07
33	90	50	203.07
34	90	50	203.07
35	90	50	794.1
36	90	50	794.1
37	90	50	794.1
38	90	50	134.36
39	90	50	80.2
40	90	50	94.58
41	90	50	150.6
42	90	50	62.2
43	90	50	148.3
44	90	50	31
45	14.7	50	1E+10

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Calc # MD-N2085-6900

************* INITIAL FLOW PATH DATA *************

FLOW PATH	FROM	TO	AREA (IN^2)	LOSS
1	1	45	.785	17.97
2	1	2	1.78	6.32
3	2	3	1.78	6.32
4	3	4	1.78	5.87
5	4	5	1.78	5.87
6	5	6	1.78	5.87
7	6	7	.825	1.77
8	7	45	.785	5.27
9	7	21	.825	2.87
10	7	8	.825	3.99
11	8	9	.484	17.7
12	9	12	2.32	87509
13	9	10	.484	17.7
14	10	13	2.32	87509
15	10	11	.484	17.7
16	11	14	2.32	87509
17	21	15	.484	19.67
18	15	20	2.13	87509
19	15	16	.484	19.67
20	16	19	2.13	87509
21	16	17	.484	19.67
22	17	18	2.13	87509
23	3	22	.825	2.67
24	22	23	.825	2.67
25	23	45	.785	5.27
26	23	31	.825	5.13
27	24	25	.484	18.15
28	25	28	2.42	87509
29	25	26	.484	18.15
30	26	29	2.42	87509
31	26	27	.484	18.15
32	27	30	2.42	87509
33	31	32	.484	18.9
34	32	35	2.08	87509
35	32	33	.484	18.9
36	33	36	2.08	87509
37	33	34	.484	18.9
38	34	37	2.08	87509
39	1	38	.145	24.84
40	38	39	.145	15.36
41	38	44	.06	20.7
42	39	40	.145	16.57
43	39	42	.145	49.73
44	40	41	.145	28.13
45	40	45	.785	5.27
46	23	24	.825	1.92
47	41	43	.145	102.59

THE CURRENT TIME IS 4.99982 SECONDS

NODE	PRESSURE (PSIA)
1	14.72905
2	15.5639
3	15.57549
4	15.59109
5	15.59664
6	15.61019
7	15.58992
8	15.88323
9	18.74044
10	19.81687
11	20.07111
12	65.0578
13	65.22173
14	65.26551
15	18.60074
16	19.66101
17	19.91183
18	65.37943
19	65.32131
20	65.[illegible]0547
21	15.80793
22	15.72354
23	15.6202
24	15.92776
25	19.0847
26	20.26817
27	20.54645
28	64.94263
29	65.12979
30	65.18013
31	15.96579
32	18.43139
33	19.3831
34	19.6093
35	64.99174
36	65.1783
37	65.22851
38	14.8529
39	14.78034
40	14.72056
41	14.70584
42	14.78157
43	14.70669
44	14.84754
45	14.7

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Calc #MD-N2085-0800

FLOW PATH	MDOT (LBM/SEC)	FROM	TO
1	3.671794E-02	1	45
2	7.438755E-02	1	2
3	-3.038386E-02	2	3
4	-7.654475E-03	3	4
5	-1.362968E-02	4	5
6	-6.548703E-03	5	6
7	-3.874017E-02	6	7
8	6.381646E-02	7	45
9	-2.671893E-02	7	21
10	-3.222337E-02	7	8
11	-3.751966E-02	8	9
12	-1.201503E-02	9	12
13	-2.507876E-02	9	10
14	-.0120453	10	13
15	-1.255359E-02	10	11
16	-1.205339E-02	11	14
17	-3.514919E-02	21	15
18	-1.103912E-02	15	20
19	-2.352304E-02	15	16
20	-1.107572E-02	16	19
21	-1.178156E-02	16	17
22	-1.109557E-02	17	18
23	1.874918E-02	3	22
24	-4.958082E-02	22	23
25	6.703823E-02	23	45
26	-2.683055E-02	23	31
27	-3.938244E-02	24	25
28	-1.251073E-02	25	28
29	-2.619774E-02	25	26
30	-1.254679E-02	26	29
31	-1.311649E-02	26	27
32	-1.255648E-02	27	30
33	-3.384016E-02	31	32
34	-1.076115E-02	32	35
35	-2.263642E-02	32	33
36	-1.079204E-02	33	36
37	-1.133343E-02	33	34
38	-1.080036E-02	34	37
39	5.420845E-03	1	38
40	1.715273E-03	38	39
41	-1.937683E-04	38	44
42	1.985511E-03	39	40
43	1.210912E-04	39	42
44	-6.213532E-04	40	41
45	-5.52682E-03	40	45
46	-1.495308E-02	23	24
47	7.672401E-05	41	43

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Calc # MD-N2085-88002

THE CURRENT TIME IS 10.00041 SECONDS

NODE	PRESSURE (PSIA)
1	14.38785
2	15.19611
3	15.18935
4	15.20897
5	15.20654
6	15.22485
7	15.1203
8	15.41582
9	16.83321
10	17.41813
11	17.5594
12	46.30342
13	46.4201
14	46.45128
15	16.75122
16	17.30812
17	17.44289
18	46.5075
19	46.46617
20	46.31258
21	15.42414
22	15.32593
23	15.10692
24	15.58676
25	17.08112
26	17.72603
27	17.88121
28	46.19976
29	46.33288
30	46.36871
31	15.45109
32	16.67262
33	17.1812
34	17.30459
35	46.24448
36	46.37723
37	46.41294
38	14.75982
39	14.72977
40	14.71909
41	14.70321
42	14.7316
43	14.70408
44	14.75316
45	14.7

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Calc # MD-N2085-88002

FLOW PATH	MDOT (LBM/SEC)	FROM	TO
1	3.469647E-02	1	45
2	9.951527E-02	1	2
3	-2.824899E-02	2	3
4	1.023709E-02	3	4
5	-1.569369E-02	4	5
6	1.045711E-02	5	6
7	-4.586685E-02	6	7
8	5.174377E-02	7	45
9	2.276495E-03	7	21
10	-1.007735E-02	7	8
11	-2.638958E-02	8	9
12	-8.551424E-03	9	12
13	-1.753097E-02	9	10
14	-8.572973E-03	10	13
15	-8.774319E-03	10	11
16	-8.578732E-03	11	14
17	-.024459	21	15
18	-7.852647E-03	15	20
19	-1.618655E-02	15	16
20	-7.878688E-03	16	19
21	-8.104062E-03	16	17
22	-7.88569[illegible] 03	17	18
23	2.786833E-02	3	22
24	-5.207171E-02	22	23
25	5.398724E-02	23	45
26	-6.857028E-03	23	31
27	-.0281762	24	25
28	-8.90005E-03	25	28
29	-1.829549E-02	25	26
30	-8.925697E-03	26	29
31	-9.161599E-03	26	27
32	-8.932597E-03	27	30
33	-2.365081E-02	31	32
34	-7.657036E-03	32	35
35	-1.574762E-02	32	33
36	-7.679016E-03	33	36
37	-7.881963E-03	33	34
38	-7.684928E-03	34	37
39	5.328657E-03	1	38
40	8.727034E-04	38	39
41	-2.031054E-04	38	44
42	1.387567E-03	39	40
43	1.618413E-04	39	42
44	-6.432311E-04	40	41
45	-6.733248E-03	40	45
46	2.308199E-02	23	24
47	7.852135E-05	41	43

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Sheet 13 of 20
Calc # MD-N2095-88002

THE CURRENT TIME IS 15.00243 SECONDS

NODE	PRESSURE (PSIA)
1	14.22202
2	14.98445
3	14.96943
4	14.98664
5	14.98155
6	14.99903
7	14.83078
8	15.22917
9	15.9203
10	16.23001
11	16.30589
12	32.95542
13	33.03846
14	33.06066
15	15.85728
16	16.1517
17	16.22393
18	33.08301
19	33.0536
20	32.94435
21	15.21579
22	15.10004
23	14.82699
24	15.32652
25	16.01804
26	16.36231
27	16.4463
28	32.86617
29	32.9609
30	32.98639
31	15.22139
32	15.82827
33	16.09579
34	16.16156
35	32.90498
36	32.9974
37	33.02484
38	14.73636
39	14.71817
40	14.71378
41	14.70147
42	14.72142
43	14.70238
44	14.72925
45	14.7

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Sheet 14 of 20
Calc #MD-N2085-8300

FLOW PATH	MDOT (LBM/SEC)	FROM	TO
1	3.190851E-02	1	45
2	.1035956	1	2
3	-2.568935E-02	2	3
4	1.314972E-02	3	4
5	-1.464184E-02	4	5
6	1.370599E-02	5	6
7	-5.198585E-02	6	7
8	4.405477E-02	7	45
9	2.225286E-02	7	21
10	.0116118	7	8
11	-1.901386E-02	8	9
12	-6.086284E-03	9	12
13	-1.239945E-02	9	10
14	-6.10162E-03	10	13
15	-6.20889E-03	10	11
16	-6.105721E-03	11	14
17	-1.769955E-02	21	15
18	-5.585962E-03	15	20
19	-1.144451E-02	15	16
20	-5.604486E-03	16	19
21	-5.732426E-03	16	17
22	-5.609473E-03	17	18
23	3.016237E-02	3	22
24	-5.350876E-02	22	23
25	4.528619E-02	23	45
26	9.43049E-03	23	31
27	-2.076877E-02	24	25
28	-6.331432E-03	25	28
29	-1.292051E-02	25	26
30	-6.349679E-03	26	29
31	-6.477936E-03	26	27
32	-6.35459E-03	27	30
33	-.0168769	31	32
34	-5.448316E-03	32	35
35	-.0111279	32	33
36	-5.46395E-03	33	36
37	-5.570704E-03	33	34
38	-5.468163E-03	34	37
39	4.945894E-03	1	38
40	1.946829E-04	38	39
41	-2.077616E-04	38	44
42	1.290122E-03	39	40
43	2.185013E-04	39	42
44	-6.712504E-04	40	41
45	-7.609545E-03	40	45
46	3.995901E-02	23	24
47	8.008743E-05	41	43

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Calc # MD-N2085-88002

THE CURRENT TIME IS 20.00064 SECONDS

NODE	PRESSURE (PSIA)
1	14.1575
2	14.89984
3	14.88141
4	14.89749
5	14.89137
6	14.90862
7	14.70514
8	15.11146
9	15.41156
10	15.56179
11	15.5988
12	23.51935
13	23.58756
14	23.60571
15	15.36594
16	15.50847
17	15.54361
18	23.60478
19	23.58195
20	23.4967
21	15.09428
22	15.0118
23	14.70445
24	15.19539
25	15.45114
26	15.61837
27	15.6592
28	23.4508
29	23.52886
30	23.54977
31	15.09391
32	15.3683
33	15.49749
34	15.52946
35	23.47577
36	23.54993
37	23.5698
38	14.73135
39	14.71274
40	14.71853
41	14.7007
42	14.71683
43	14.70161
44	14.72395
45	14.7

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Sheet 16 of 20
Calc #MD-N2085-85002

FLOW PATH	MDOT (LBM/SEC)	FROM	TO
1	3.067553E-02	1	45
2	.1049333	1	2
3	-2.449587E-02	2	3
4	1.411983E-02	3	4
5	-1.410846E-02	4	5
6	1.480267E-02	5	6
7	-5.541485E-02	6	7
8	4.104681E-02	7	45
9	3.314627E-02	7	21
10	2.360515E-02	7	8
11	-1.352673E-02	8	9
12	-4.185514E-03	9	12
13	-8.468435E-03	9	10
14	-4.186174E-03	10	13
15	-4.248089E-03	10	11
16	-4.186564E-03	11	14
17	-.0127027	21	15
18	-3.84208E-03	15	20
19	-7.811484E-03	15	16
20	-3.847502E-03	16	19
21	-3.919868E-03	16	17
22	-3.849176E-03	17	18
23	3.112209E-02	3	22
24	-5.522825E-02	22	23
25	4.194641E-02	23	45
26	1.952012E-02	23	31
27	-1.554476E-02	24	25
28	-4.343214E-03	25	28
29	-8.770498E-03	25	26
30	-4.344391E-03	26	29
31	-4.417225E-03	26	27
32	-4.344958E-03	27	30
33	-1.179967E-02	31	32
34	-3.747081E-03	32	35
35	-7.608132E-03	32	33
36	-3.751083E-03	33	36
37	-3.811805E-03	33	34
38	-3.752362E-03	34	37
39	4.765203E-03	1	38
40	-2.026191E-04	38	39
41	-2.118399E-04	38	44
42	1.244449E-03	39	40
43	2.451432E-04	39	42
44	-6.810272E-04	40	41
45	-7.938729E-03	40	45
46	5.126718E-02	23	24
47	8.054981E-05	41	43

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Calc # MD-N2085-88002

THE CURRENT TIME IS 24.99789 SECONDS

NODE	PRESSURE (PSIA)
1	14.13306
2	14.86751
3	14.84751
4	14.86331
5	14.85674
6	14.87407
7	14.63835
8	15.0214
9	15.08321
10	15.13237
11	15.14416
12	17.54473
13	17.60686
14	17.62297
15	15.06154
16	15.10809
17	15.11926
18	17.60428
19	17.58602
20	17.51612
21	15.01306
22	14.97819
23	14.63729
24	15.11046
25	15.12405
26	15.17985
27	15.19246
28	17.51364
29	17.58374
30	17.602
31	14.99672
32	15.06657
33	15.10814
34	15.11831
35	17.51008
36	17.57185
37	17.58802
38	14.7279
39	14.71008
40	14.71837
41	14.70042
42	14.71436
43	14.70134
44	14.72044
45	14.7

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Calc # MD-N2085-85002

FLOW PATH	MDOT (LBM/SEC)	FROM	TO
1	3.018463E-02	1	45
2	.1054008	1	2
3	-2.395868E-02	2	3
4	1.442819E-02	3	4
5	-1.390841E-02	4	5
6	1.550852E-02	5	6
7	-5.847985E-02	6	7
8	4.059077E-02	7	45
9	4.233842E-02	7	21
10	3.332397E-02	7	8
11	-8.774756E-03	8	9
12	-2.309641E-03	9	12
13	-4.654102E-03	9	10
14	-2.320738E-03	10	13
15	-2.379498E-03	10	11
16	-2.323588E-03	11	14
17	-8.523979E-03	21	15
18	-2.116043E-03	15	20
19	-4.292489E-03	15	16
20	-2.130401E-03	16	19
21	-2.193606E-03	16	17
22	-2.134163E-03	17	18
23	3.200971E-02	3	22
24	-5.697095E-02	22	23
25	4.110156E-02	23	45
26	.0278427	23	31
27	1.204814E-02	24	25
28	-2.375196E-03	25	28
29	-4.662357E-03	25	26
30	-2.390277E-03	26	29
31	-2.457015E-03	26	27
32	-2.393882E-03	27	30
33	-7.158257E-03	31	32
34	-2.062679E-03	32	35
35	-4.211039E-03	32	33
36	-2.074473E-03	33	36
37	-2.130157E-03	33	34
38	-2.077647E-03	34	37
39	4.697632E-03	1	38
40	-3.17618E-04	38	39
41	-2.128522E-04	38	44
42	1.209707E-03	39	40
43	2.504677E-04	39	42
44	-6.831462E-04	40	41
45	-8.035506E-03	40	45
46	6.154415E-02	23	24
47	8.085783E-05	41	43

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Calc # MD-N2085-88002

THE CURRENT TIME IS 25.00089 SECONDS

NODE	PRESSURE (PSIA)
1	15.467
2	14.83334
3	14.86598
4	14.85501
5	14.86521
6	14.85252
7	15.10601
8	14.92131
9	15.08617
10	15.13199
11	15.14393
12	17.54217
13	17.6043
14	17.6204
15	15.06437
16	15.10775
17	15.11904
18	17.60171
19	17.58345
20	17.51357
21	14.89111
22	14.7507
23	15.11631
24	14.81076
25	15.13227
26	15.17926
27	15.19228
28	17.51112
29	17.58121
30	17.59946
31	14.95088
32	15.06774
33	15.10784
34	15.11808
35	17.50754
36	17.56929
37	17.58546
38	14.71519
39	14.71731
40	14.6841
41	14.70208
42	14.71304
43	14.70116
44	14.72267
45	14.7

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FLOW PATH	MDOT (LBM/SEC)	FROM	TO
1	-2.545652E-02	1	45
2	-.1107333	1	2
3	1.876294E-02	2	3
4	-1.730361E-02	3	4
5	1.115811E-02	4	5
6	-.0181292	5	6
7	5.598933E-02	6	7
8	-1.580251E-02	7	45
9	-5.541569E-02	7	21
10	-4.751762E-02	7	8
11	-5.387703E-03	8	9
12	-2.30975E-03	9	12
13	-4.816418E-03	9	10
14	-2.31958E-03	10	13
15	-2.360711E-03	10	11
16	-2.322501E-03	11	14
17	-4.524306E-03	21	15
18	-2.116092E-03	15	20
19	-4.442328E-03	15	16
20	-2.129346E-03	16	19
21	-2.179903E-03	16	17
22	-2.133157E-03	17	18
23	-3.419219E-02	3	22
24	5.480454E-02	22	23
25	-1.593663E-02	23	45
26	-.0405945	23	31
27	-2.500089E-03	24	25
28	-2.[illegible]77477E-03	25	28
29	-5.073374E-03	25	26
30	-2.38896E-03	26	29
31	-2.416461E-03	26	27
32	-2.392739E-03	27	30
33	-5.538382E-03	31	32
34	-2.062155E-03	32	35
35	-4.282791E-03	32	33
36	-2.073464E-03	33	36
37	-2.121963E-03	33	34
38	-2.076664E-03	34	37
39	-4.096316E-03	1	38
40	9.211882E-04	38	39
41	2.12528E-04	38	44
42	-6.050789E-04	39	40
43	-2.511374E-04	39	42
44	6.82837E-04	40	41
45	8.640707E-03	40	45
46	-7.611347E-02	23	24
47	-8.085376E-05	41	43