TELEDYNE
ENGINEERING SERVICES

TECHNICAL REPORT

TR-6121-4

REVISION 2

PILGRIM NUCLEAR POWER STATION

FLUID ANALYSIS TO DETERMINE IF THE STANDBY
GAS TREATMENT SYSTEM PURGE AND VENT LINE DUCT WORK
IS OVERPRESSURIZED DURING DBA LOCA

OCTOBER 1985

BOSTON EDISON COMPANY
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BRAINTREE, MASSACHUSETTS 02184

TECHNICAL REPORT TR-6121-4
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OCTOBER 1985

TELEDYNE ENGINEERING SERVICES

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TELEDYNE ENGINEERING SERVICES

BY LBS DATE 7-24-84
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TR-6121-4 PURGE & VENT DUCTWORK

SHEET NO. 1 OF 22
PROJ. NO. 6121

FLUID ANALYSIS TO DETERMINE IF THE STANDBY GAS TREATMENT PURGE AND VENT DUCTWORK IS OVERPRESSURIZED DURING DESIGN BASIS ACCIDENT LOSS OF COOLANT ACCIDENT

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BY LBS DATE 7-17-84
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TR-6121-4 MARK I LOCA DRYWELL

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APPENDICES

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1.0 INTRODUCTION

Prior to start up and following shutdown the reactor containment building must be purged and vented of its atmosphere. During normal plant operation the atmosphere within the containment is nitrogen (N_2). This reduces chances of combustion in the containment.

The purge and vent system consists of 20" pipe leading from the containment to the isolation valves and then continues on to duct work which brings the gases to the standby gas Treatment system (SGTS).

The purge and vent process goes on as the plant is starting up and while it is shutting down. If a loss of coolant accident (LOCA) should occur during this process there is concern that the pressure in the duct work would exceed the rated pressure of 2 psig.[1]

(1) Letter Stephen Rosen (BECO) to L. Sempruch (TES) 2-4-80

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PILGRIM NUCLEAR POWER STATION
SGTS PURGE AND VENT

1.0 INTRODUCTION (CONT.)

This analysis determines what that pressure is.

2.0 SUMMARY

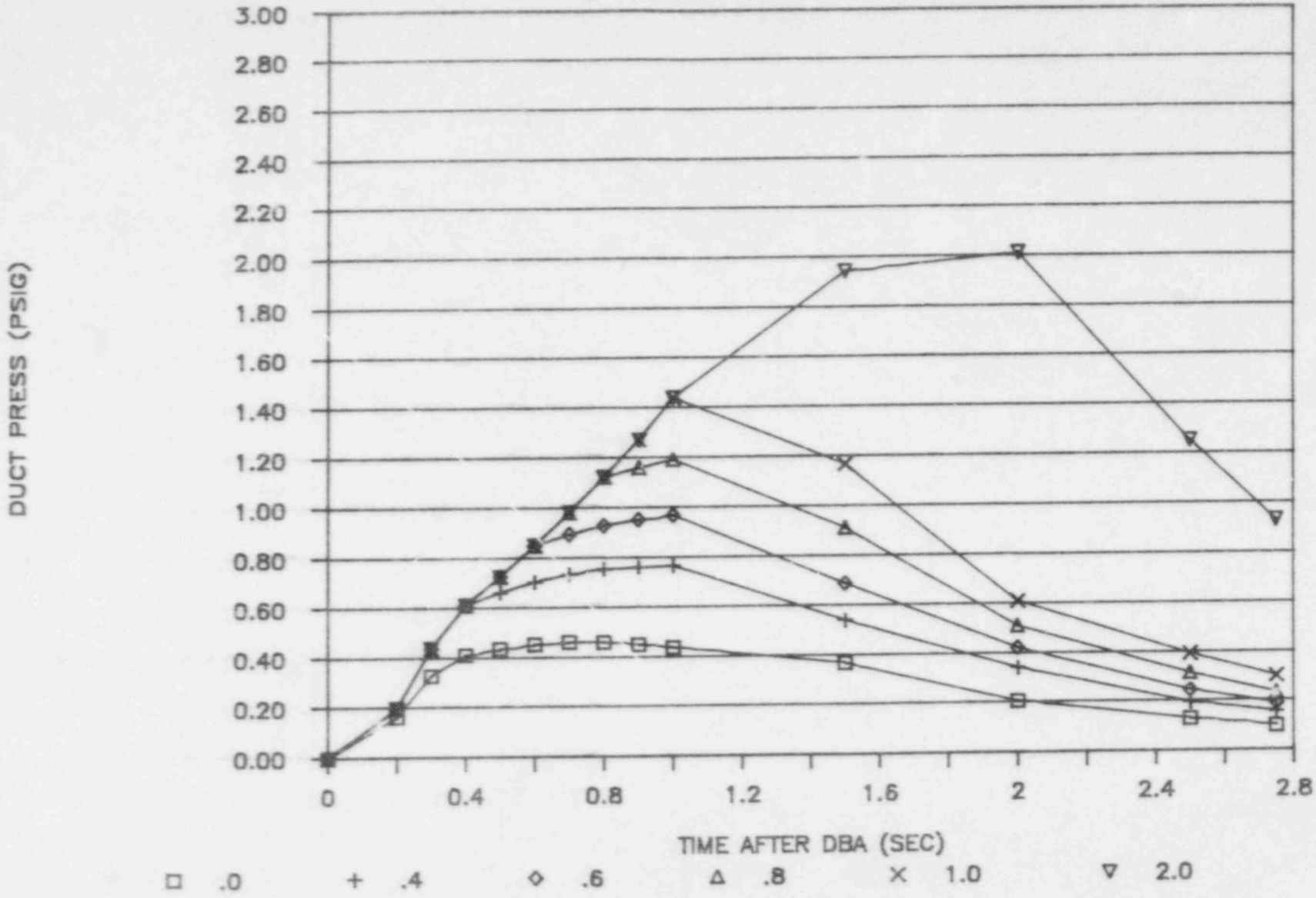
Boston Edison plans on installing Two 8" Butterfly isolation valves on each of the purge and vent lines. If a Design Basis Loss of Coolant Accident (DBA LOCA) occurs during a plant start up or shutdown the resistance of these valves (in the partially closed position) is enough to maintain the pressure in the ductwork below the 2 psig allowable.

∴ the 8" Valves are satisfactory

This conclusion is valid if the isolation valves begin to close no later than 2.0 seconds after drywell pressurization begins. If the valve closing is initiated more than 2.0 seconds after drywell pressurization has begun the 2 psig allowable will be exceeded. BECO has informed TES (REF 9.) that the valve will commence closing 0.7 seconds after drywell pressurization begins. The following figures present a family of curves which give the duct pressure as a function of time for various delays in the initiation of the valve closure

PILGRIM NPP STANDBY GAS TREATMNT SYS

DUCT PRESS VS DEL 5 SEC VAL CLOSING

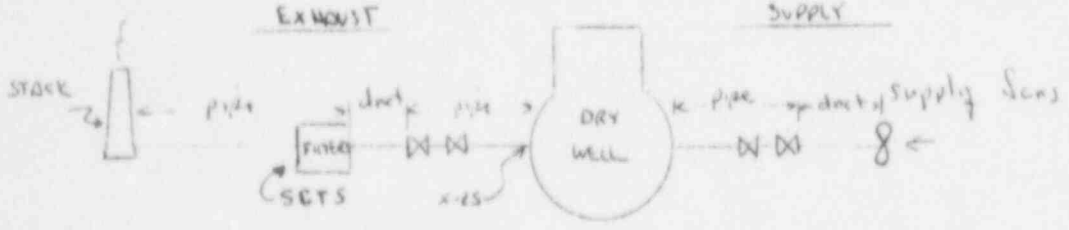


DONE BY SDW 10-8-85

CHKD BY [illegible] 10-8-85

3.0 METHOD OF ANALYSIS

The duct work on the exhaust side from penetration X-25 (dry well) and penetration X-227 (wet well) to the plant stack is the most susceptible to being ruptured by high presure. This is because there is much more piping behind the ductwork to the stacks on the exhaust side than there is between the ductwork and the supply fans on the purge (or supply) side



The pressure drops from the drywell to the ductwork will be determined for the peak drywell pressure and temperature during a DBA LOCA. This pressure will be compared to 2 psig.

The Butterfly valves close in 5 seconds.(1) Valve characteristics and DBA LOCA properties will be determined at time intervals in the LOCA to account for the additional resistance of the closing valves if this is necessary. 2

(1) REF 9 2

3.0

This analysis begins by using the compressible flow orifice equation to determine the pressure drop from the drywell to the ductwork

$$W = 0.525\, Y d^2 \sqrt{\frac{\Delta P}{K \bar{V}_1}}$$

It is then found that choking occurs at the Butterfly valves with an expansion to incompressible flow downstream of the valves. The restriction of the Butterfly valves is enough that the DBA LOCA gases expand to less than two (2) psig in the 12 ductwork.

This analysis is organized such that the main analysis is presented in section 5.0 with the supporting calculations in the appendices.

4.0 ASSUMPTIONS

The following assumptions are used in determining the pressure drop from the drywell to the ductwork

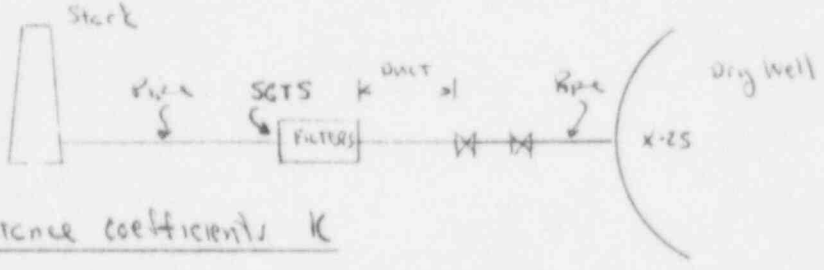
1 The problem is treated as a steady flow condition.

2. The pressure in the exhaust side is the most critical. 12

3. The torus pressurization will be neglected because it is significantly less than the drywell. Therefore gas will actually flow from the drywell penetration to the purge and vent plenums and down into the torus.

5.0 ANALYSIS

Determine the pressure in the ductwork on the exhaust side from containment penetration X-25



Sum the resistance coefficients K

No.	Component	K	Description	
1	entrance	0.5	Sudden entrance	Ref 3 pg A-26
2	Pipe inside containment	0.0375	5 ft 20" pipe	Appendix G sheet 3
3	elbow	0.375	one 90° elbow	Appendix G sheet 3
4	2-8" Butterfly valves	115.0	Two 8" Butterfly valves	Ref App E
5	filters	3.84	SGTS filters	App. N
6	ductwork	0.0	negligible	see App C sheet 5
7	Pipe to stack	5.21	Appendix B	sheet 1 of 2
	Total K_D	125.0		

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TR-6121-4 PARCEL VENT

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5.0 ANALYSIS

Determine the flowrate through the exhaust line

$$W_o = 0.525\, Y_o d^2 \sqrt{\frac{\Delta P_o}{K_o \bar{V}_1}}$$ Ref 3 pg 3-4

where the net expansion factor Y is determined from pg A-22 of CRONE (Ref 3)

$$\frac{\Delta P_o}{P} = \frac{41.1}{41.1 + 14.7} = 0.738$$ (REF 2)

56.2

$K_o = 125.0$ (note this K exceeds the limits of pg A-22 Ref 3)

$Y_o = 0.78$ } Ref 3 pg A-22

$\bar{V}_1 = 4.932 \frac{ft^3}{lbm}$ @ 42 psig Ref App A

$d = 19$ in

W_o = flow rate lbm/sec with drywell at peak pressure and iso valves fully opened.

Substituting into the expression for W_o

$$W_o = 0.525 \times 0.78 \times 19^2 \sqrt{\frac{41.5}{125 \times 4.932}}$$

$$= 38.35 \frac{lbm}{sec}$$

5.0 ANALYSIS

Having found the flowrate it is now possible to find the pressure drop from the drywell to the ductwork $\Delta P_o'$

$$\Delta P_o' = \frac{W_o^2 K_o' \bar{V}_1}{(0.525 Y_o d^2)^2}$$

The K_o' in this expression is the total K minus the resistance of the pipe to the stack and filters ($K_o' = 125.0 - 5.21 - 3.84 = 115.95$)

$$\Delta P_o' = \frac{(38.5)^2 \times 115.95 \times 4.932}{(0.525 \times 078 \times 19^2)^2}$$

$$\boxed{\Delta P_o' = 38.48 \text{ psi}}$$

This pressure drop to the ductwork from the drywell was established with the isolation valves wide open and the drywell at peak pressure. For this condition the pressure in the ductwork would be 3.02 psig which is more than the allowable of 2 psig

$(41.5 - 38.48) = 3.02$

5.0 ANALYSIS

The total resistance of the exhaust system (K= 125) exceeds the limits of the Net Expansion Factor Table (Ref 3 pg A-22). This indicates that this analysis is at the limits of the physical problem as described by the compressible flow equation

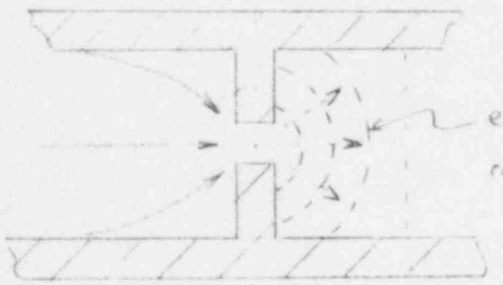
$$w = 0.525\, Y d^2 \sqrt{\frac{\Delta P}{K \bar{v}_1}}$$

Before attempting to extrapolate this curve it must be noted that the majority of the resistance occurs at the Butterfly valves. This suggests the possibility of another phenomena occuring within the purge and vent system. A physical phenomena that is not adequately described by the simple compressible flow equation.

Whenever there is a severe flow restriction in a piping system with a pressure differential greater than one atmosphere the possibility of choked flow must be considered.

5.0 ANALYSIS

When the Butterfly valve begins to close the resistance increases so dramatically that the flow chokes at the butterfly valve. When the flow chokes at an orifice the expansion of the flow down stream of the orifice is a complicated pattern of 2 dimensional expansion waves as the flow adjusts to the downstream conditions



The downstream conditions can be determined however without the need of two dimensional expansion theory because knowing the flow has choked will determine the flowrate. When the flowrate is known assumptions about the exit conditions

5.0 ANALYSIS

at the discharge end of the downstream pipe can be made which will allow all the conditions in the pipe to be determined

The procedure is as follows

1. Assume the flow has choked at the valve
2. Determine the choked flowrate based on the stagnation conditions in the drywell and the flow area of the 8" Butterfly valves using Fliegner's Formula (1)
3. Assume the exit pressure of the pipe at the stack is atmospheric
4. Determine the Mach number of the flow at the pipe exit at the stack. This is found knowing the mass flowrate pipe area and exit pressure
5. If the Mach number is less than 1.0 the assumption of p exit equal to 14.7 is valid. If furthermore the Mach number is less than 0.3 then

(1) Ref 7 Pg 85

BY L.S.S DATE 7-26-84
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TR-6121-4 PURGE & VENT

5.0 ANALYSIS

5 (cont.) the flow can be treated as incompressible and the pressure back at the Butterfly valve exit can be determined from the incompressible flow eqs i.e. the Darcy Weisbach formula $\Delta P_f = f \frac{\rho V^2}{2g}$

6. The fact that the flow behaves incompressibly can be confirmed from the Gas Tables[1]. When the Mach number at the pipe exit is known and the resistance between two points is also known the change in Mach No. can be found. If the higher Mach Number is less than 0.3 the flow remains incompressible

(1) Ref 8 pg 157

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TR-6121-4 DRYWELL VENT

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S.O ANALYSIS

The flowrate through the cracked valve is found using Fliegners Formula (1)

$$\frac{W}{A^*} = \frac{0.532\ P_o}{\sqrt{T_o}}$$

where

W = flowrate lbm/sec

A^* = effective flow area of the valve ft^2

P_o = stagnation pressure in the drywell (lbf/ft^2) | 1

T_o = stagnation temperature in the drywell (°R) |

Assume the worst condition, that the valves are fully open and the drywell is at peak pressure

$A^* = 31.04\ in^2 = 0.2156\ ft^2$ (See App D sheet D4) | 2

$P_o = 41.5\ psig = 5,976\ lbf/ft^2$ Ref 2 | 1

$T_o = 283 + 460 = 743\ °R$ Ref 2

(1) Ref 7 pg 85

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S.O ANALYSIS

Substitute into Fliegner's Formula

$$w = A^* \times 0.532 \frac{P_o}{\sqrt{T_o}}$$

$$= 0.2156 \times 0.532 \times \frac{5,976}{\sqrt{743}}$$

$$w = 25.14 \ \frac{lbm}{sec}$$

Note that this flow is less than the 38.35 lbm/sec flow on pg 10. This supports the assumption that choking occurs at the valve because choked flow is more restrictive than unchoked flow.

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SO ANALYSIS

Find the Mach No. from the continuity eq.

$$w = \rho A V$$

$$V = \frac{w}{\rho A} \quad \text{or} \quad \frac{\mu w}{A}$$

where A is the pipe area of the stack

$$A = \frac{\pi \times 19^2}{4 \times 144} = 1.965 \text{ ft}^2$$

$$= \frac{15.02 \frac{\text{ft}^3}{\text{lbm}} \times 25.14 \frac{\text{lbm}}{\text{sec}}}{1.965 \text{ ft}^2}$$

$$= 191.8 \frac{\text{ft}}{\text{sec}}$$

1,2

Determine the sonic velocity C

$$C = \sqrt{K_g R T}$$

$$= \sqrt{1.4 \times 32.2 \frac{\text{ft}}{\text{sec}^2} \times 53.34 \frac{\text{ft-lbf}}{\text{lbm-°R}} \times 747 °R}$$

$$= 1336 \text{ ft/sec}$$

The Mach No at the exit is

$$M_{exit} = \frac{191.8}{1336}$$

MACH NUMBER AT EXIT OF EXHAUST STACK

$$M = 0.1435$$

1,2

REV - 0 SDC 10-9-85

REV 1 8-27-85 SDW 8-28-85

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5.0 ANALYSIS

When the Mach No is less than 0.3 the flow is basicly incompressible and the pressure drop can be found using the Darcy Weisbach eq

$$\Delta P_f = K \frac{\rho V^2}{2g}$$

unit check

$$\frac{\frac{lbm}{ft^3} \times \frac{ft^2}{sec^2}}{\frac{ft}{sec^2} \times \frac{lbm}{lbf}} \qquad \frac{lbf}{ft^2}$$

The flow resistance between the stack and the butterfly valves is $K = 9.05$ (see section 5.0 sheet 9)

$$\Delta P_f = 9.05 \frac{(191.8)^2 \frac{ft^2}{sec^2}}{\frac{15.02\ ft^3}{lbm} \times 2 \times 32.2 \frac{ft}{sec^2} \times \frac{lbm}{lb_f} \times 144 \frac{in^2}{ft^2}}$$

$$= 2.390 \frac{lbf}{in^2}$$

This pressure exceeds the allowable of 2.0 psig (Ref 2). However this calculation is overly conservative because it assumes the peak drywell pressure occurs when the 8" Butterfly valves are fully open. The following calculations take credit for the fact that the drywell pressure varies with time and that the Butterfly valves may begin to close before the peak drywell pressure occurs

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5.0 ANALYSIS

The butterfly valves are assumed to begin to close when the LOCA occurs. Therefore the peak pressure in the drywell will occur when the valves are partially closed. The calculations on the previous pages will be repeated for various times during valve operation in order to determine the duct pressure as a function of time. Also, because the initiation of valve closure is critical. These calculations are repeated for various delays in the initiation of valve closure. The parameters used in these calculations are determined as explained below.

Drywell Pressure : fig P4.1.1-1 ref 2

Temperatures : fig P4.1.1-2 ref 2

Valve flow area : See Appendix D

Flow : Fliegners formula

TABLE OF DBA AND VALVE CLOSURE STARTING AT .0 SEC DIFFERENT

TIME SEC	DRYWELL PRESSURE PSIG	DRYWELL TEMP DEG R	VALVE FLOW AREA %FULL	CHOKED FLOW LBM/SEC	VELOCITY FT/SEC	DUCT PRESSUR PSIG	MACH NUMBER	VALVE TIME
0.0	0.006	580.093	100%	0.004	0.031	0.000	0.0000	0
0.2	12.000	680.500	91%	6.914	52.744	0.164	0.0412	0.1999
0.3	18.000	688.000	86%	9.805	74.794	0.329	0.0581	0.2999
0.4	21.364	695.500	82%	10.972	83.699	0.412	0.0647	0.3999
0.5	23.414	703.000	77%	11.304	86.233	0.437	0.0663	0.4999
0.6	25.464	710.500	73%	11.519	87.870	0.454	0.0672	0.5999
0.7	27.514	718.000	68%	11.618	88.625	0.462	0.0674	0.6999
0.8	29.564	725.500	64%	11.603	88.512	0.461	0.0670	0.7999
0.9	31.614	733.004	59%	11.476	87.543	0.451	0.0659	0.8999
1	33.664	733.560	55%	11.292	86.138	0.436	0.0649	0.9999
1.5	39.185	736.340	43%	10.376	79.148	0.368	0.0595	1.4999
2	39.950	739.120	32%	7.767	59.250	0.206	0.0444	1.9999
2.5	40.715	741.900	25%	6.173	47.086	0.130	0.0353	2.4999
2.75	41.097	743.290	21%	5.353	40.837	0.098	0.0305	2.7499

FLOW TABLE OF DBA AND VALVE CLOSURE STARTING AT .2 SEC DIFFERENT

TIME SEC	DRYWELL PRESSURE PSIG	DRYWELL TEMP DEG R	VALVE FLOW AREA %FULL	CHOKED FLOW LBM/SEC	VELOCITY FT/SEC	DUCT PRESSUR PSIG	MACH NUMBER	VALVE TIME
0.0	0.006	580.093	100%	0.004	0.031	0.000	0.0000	0
0.2	12.000	680.500	100%	7.598	57.958	0.197	0.0453	0
0.3	18.000	688.000	95%	10.824	82.571	0.401	0.0642	0.1
0.4	21.364	695.500	91%	12.176	92.880	0.507	0.0718	0.2
0.5	23.414	703.000	86%	12.616	96.241	0.544	0.0740	0.3
0.6	25.464	710.500	82%	12.938	98.697	0.573	0.0755	0.4
0.7	27.514	718.000	77%	13.144	100.263	0.591	0.0763	0.5
0.8	29.564	725.500	73%	13.234	100.952	0.599	0.0764	0.6
0.9	31.614	733.004	68%	13.211	100.778	0.597	0.0759	0.7
1	33.664	733.560	64%	13.139	100.225	0.591	0.0755	0.8
1.5	39.185	736.340	48%	11.472	87.513	0.450	0.0658	1.3
2	39.950	739.120	37%	8.883	67.762	0.270	0.0508	1.8
2.5	40.715	741.900	28%	6.864	52.357	0.161	0.0392	2.3
2.75	41.097	743.290	24%	6.050	46.152	0.125	0.0345	2.55

TABLE OF DBA AND VALVE CLOSURE STARTING AT .4 SEC DIFFERENT

TIME SEC	DRYWELL PRESSURE PSIG	DRYWELL TEMP DEG R	VALVE FLOW AREA %FULL	CHOKED FLOW LBM/SEC	VELOCITY FT/SEC	DUCT PRESSUR PSIG	MACH NUMBER	VALVE TIME
0.0	0.006	580.093	100%	0.004	0.031	0.000	0.0000	0
0.2	12.000	680.500	100%	7.598	57.958	0.197	0.0453	0
0.3	18.000	688.000	100%	11.334	86.462	0.439	0.0672	0
0.4	21.364	695.500	100%	13.380	102.066	0.612	0.0789	0
0.5	23.414	703.000	95%	13.929	106.255	0.664	0.0817	0.1
0.6	25.464	710.500	91%	14.358	109.530	0.705	0.0838	0.2
0.7	27.514	718.000	86%	14.670	111.906	0.736	0.0852	0.3
0.8	29.564	725.500	82%	14.866	113.398	0.756	0.0859	0.4
0.9	31.614	733.004	77%	14.947	114.018	0.764	0.0859	0.5
1	33.664	733.560	73%	14.986	114.319	0.768	0.0861	0.6
1.5	39.185	736.340	53%	12.569	95.882	0.540	0.0721	1.1
2	39.950	739.120	41%	9.999	76.279	0.342	0.0572	1.6
2.5	40.715	741.900	31%	7.555	57.630	0.195	0.0431	2.1
2.75	41.097	743.290	27%	6.747	51.470	0.156	0.0385	2.35

TABLE OF DB* AND VALVE CLOSURE STARTING AT .6 SEC DIFFERENT

TIME SEC	DRYWELL PRESSURE PSIG	DRYWELL TEMP DEG R	VALVE FLOW AREA %FULL	CHOKED FLOW LBM/SEC	VELOCITY FT/SEC	DUCT PRESSUR PSIG	MACH NUMBER	VALVE TIME
0.0	0.006	580.093	100%	0.004	0.031	0.000	0.0000	0
0.2	12.000	680.500	100%	7.598	57.958	0.197	0.0453	0
0.3	18.000	688.000	100%	11.334	86.462	0.439	0.0672	0
0.4	21.364	695.500	100%	13.380	102.066	0.612	0.0789	0
0.5	23.414	703.000	100%	14.585	111.262	0.728	0.0856	0
0.6	25.464	710.500	100%	15.779	120.363	0.852	0.0921	0
0.7	27.514	718.000	95%	16.196	123.550	0.897	0.0940	0.1
0.8	29.564	725.500	91%	16.497	125.844	0.931	0.0953	0.2
0.9	31.614	733.004	86%	16.683	127.259	0.952	0.0959	0.3
1	33.664	733.560	82%	16.834	128.413	0.969	0.0967	0.4
1.5	39.185	736.340	59%	14.191	108.254	0.689	0.0814	0.9
2	39.950	739.120	46%	11.116	84.795	0.423	0.0636	1.4
2.5	40.715	741.900	34%	8.468	64.599	0.245	0.0484	1.9
2.75	41.097	743.290	30%	7.444	56.788	0.190	0.0425	2.15

Rev 2

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21A

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PROJ. NO. 6741C

TABLE OF DBA AND VALVE CLOSURE STARTING AT .7 SEC DIFFERENT

TIME SEC	DRYWELL PRESSURE PSIG	DRYWELL TEMP DEG R	VALVE FLOW AREA %FULL	CHOKED FLOW LBM/SEC	VELOCITY FT/SEC	DUCT PRESSUR PSIG	MACH NUMBER	VALVE TIME
0.0	0.006	580.093	100%	0.004	0.031	0.000	0.0000	0
0.2	12.000	680.500	100%	7.598	57.958	0.197	0.0453	0
0.3	18.000	688.000	100%	11.334	86.462	0.439	0.0672	0
0.4	21.364	695.500	100%	13.380	102.066	0.612	0.0789	0
0.5	23.414	703.000	100%	14.585	111.262	0.728	0.0856	0
0.6	25.464	710.500	100%	15.779	120.363	0.852	0.0921	0
0.7	27.514	718.000	100%	16.960	129.371	0.984	0.0985	0
0.8	29.564	725.500	95%	17.313	132.067	1.025	0.1000	0.1
0.9	31.614	733.004	91%	17.551	133.880	1.054	0.1008	0.2
1	33.664	733.560	86%	17.758	135.460	1.079	0.1020	0.3
1.5	39.185	736.340	64%	15.265	116.441	0.797	0.0875	0.8
2	39.950	739.120	48%	11.674	89.054	0.466	0.0668	1.3
2.5	40.715	741.900	37%	9.036	68.930	0.279	0.0516	1.8
2.75	41.097	743.290	31%	7.793	59.447	0.208	0.0445	2.05

TABLE OF DBA AND VALVE CLOSURE STARTING AT .8 SEC DIFFERENT

TIME SEC	DRYWELL PRESSURE PSIG	DRYWELL TEMP DEG R	VALVE FLOW AREA %FULL	CHOKED FLOW LBM/SEC	VELOCITY FT/SEC	DUCT PRESSUR PSIG	MACH NUMBER	VALVE TIME
0.0	0.006	580.093	100%	0.004	0.031	0.000	0.0000	0
0.2	12.000	680.500	100%	7.598	57.958	0.197	0.0453	0
0.3	18.000	688.000	100%	11.334	86.462	0.439	0.0672	0
0.4	21.364	695.500	100%	13.380	102.066	0.612	0.0789	0
0.5	23.414	703.000	100%	14.585	111.262	0.728	0.0856	0
0.6	25.464	710.500	100%	15.779	120.363	0.852	0.0921	0
0.7	27.514	718.000	100%	16.960	129.371	0.984	0.0985	0
0.8	29.564	725.500	100%	18.129	138.290	1.124	0.1047	0
0.9	31.614	733.004	95%	18.418	140.500	1.160	0.1058	0.1
1	33.664	733.560	91%	18.681	142.507	1.194	0.1073	0.2
1.5	39.185	736.340	68%	16.338	124.629	0.913	0.0937	0.7
2	39.950	739.120	50%	12.232	93.312	0.512	0.0700	1.2
2.5	40.715	741.900	39%	9.604	73.262	0.315	0.0548	1.7
2.75	41.097	743.290	33%	8.254	62.960	0.233	0.0471	1.95

REV 2

TELEDYNE ENGINEERING SERVICES

BY LBS DATE 10-9-85

CHKD. BY SDM DATE 10-9-85

21B

PILGRIM NUCLEAR STATION

SHEET NO. 21B OF 22

PROJ. NO. 6341 C

TELEDYNE ENGINEERING SERVICES

REV 2 — 21C

BY LGS DATE 10-5-85

CHKD. BY SDW DATE 10-4-85

PILGRIM NUCLEAR POWER STATION

SHEET NO. 21C OF 22

PROJ. NO.

TABLE OF DBA AND VALVE CLOSURE STARTING AT 1.0 SEC DIFFERENT

TIME SEC	DRYWELL PRESSURE PSIG	DRYWELL TEMP DEG R	VALVE FLOW AREA %FULL	CHOKED FLOW LBM/SEC	VELOCITY FT/SEC	DUCT PRESSUR PSIG	MACH NUMBER	VALVE TIME
0.0	0.006	580.093	100%	0.004	0.031	0.000	0.0000	0
0.2	12.000	680.500	100%	7.598	57.958	0.197	0.0453	0
0.3	18.000	688.000	100%	11.334	86.462	0.439	0.0672	0
0.4	21.364	695.500	100%	13.380	102.066	0.612	0.0789	0
0.5	23.414	703.000	100%	14.585	111.262	0.728	0.0856	0
0.6	25.464	710.500	100%	15.779	120.363	0.852	0.0921	0
0.7	27.514	718.000	100%	16.960	129.371	0.984	0.0985	0
0.8	29.564	725.500	100%	18.129	138.290	1.124	0.1047	0
0.9	31.614	733.004	100%	19.286	147.121	1.272	0.1108	0
1	33.664	733.560	100%	20.529	156.601	1.442	0.1179	0
1.5	39.185	736.340	77%	18.484	141.003	1.169	0.1060	0.5
2	39.950	739.120	55%	13.349	101.828	0.610	0.0764	1
2.5	40.715	741.900	43%	10.740	81.925	0.395	0.0613	1.5
2.75	41.097	743.290	38%	9.399	71.697	0.302	0.0536	1.75

TABLE OF DBA AND VALVE CLOSURE STARTING AT 1.5 SEC DIFFERENT

TIME SEC	DRYWELL PRESSURE PSIG	DRYWELL TEMP DEG R	VALVE FLOW AREA %FULL	CHOKED FLOW LBM/SEC	VELOCITY FT/SEC	DUCT PRESSUR PSIG	MACH NUMBER	VALVE TIME
0.0	0.006	580.093	100%	0.004	0.031	0.000	0.0000	0
0.2	12.000	680.500	100%	7.598	57.958	0.197	0.0453	0
0.3	18.000	688.000	100%	11.334	86.462	0.439	0.0672	0
0.4	21.364	695.500	100%	13.380	102.066	0.612	0.0789	0
0.5	23.414	703.000	100%	14.585	111.262	0.728	0.0856	0
0.6	25.464	710.500	100%	15.779	120.363	0.852	0.0921	0
0.7	27.514	718.000	100%	16.960	129.371	0.984	0.0985	0
0.8	29.564	725.500	100%	18.129	138.290	1.124	0.1047	0
0.9	31.614	733.004	100%	19.286	147.121	1.272	0.1108	0
1	33.664	733.560	100%	20.529	156.601	1.442	0.1179	0
1.5	39.185	736.340	100%	23.851	181.940	1.946	0.1367	0
2	39.950	739.120	77%	18.810	143.486	1.210	0.1076	0.5
2.5	40.715	741.900	55%	13.579	103.584	0.631	0.0776	1
2.75	41.097	743.290	49%	12.262	93.538	0.514	0.0700	1.25

REV 2

TELEDYNE ENGINEERING SERVICES

BY LGS DATE 10-5-85

CHKD. BY SDW DATE 10-9-85

210

PILGRIM NUCLEAR POWER STATION

SHEET NO. 210 OF 22

PROJ. NO. 6341 C

TABLE OF DBA AND VALVE CLOSURE STARTING AT 2.0 SEC DIFFERENT

TIME SEC	DRYWELL PRESSURE PSIG	DRYWELL TEMP DEG R	VALVE FLOW AREA %FULL	CHOKED FLOW LBM/SEC	VELOCITY FT/SEC	DUCT PRESSUR PSIG	MACH NUMBER	VALVE TIME
0.0	0.006	580.093	100%	0.004	0.031	0.000	0.0000	0
0.2	12.000	680.500	100%	7.598	57.958	0.197	0.0453	0
0.3	18.000	688.000	100%	11.334	86.462	0.439	0.0672	0
0.4	21.364	695.500	100%	13.380	102.066	0.612	0.0789	0
0.5	23.414	703.000	100%	14.585	111.262	0.728	0.0856	0
0.6	25.464	710.500	100%	15.779	120.363	0.852	0.0921	0
0.7	27.514	718.000	100%	16.960	129.371	0.984	0.0985	0
0.8	29.564	725.500	100%	18.129	138.290	1.124	0.1047	0
0.9	31.614	733.004	100%	19.286	147.121	1.272	0.1108	0
1	33.664	733.560	100%	20.529	156.601	1.442	0.1179	0
1.5	39.185	736.340	100%	23.851	181.940	1.946	0.1367	0
2	39.950	739.120	100%	24.271	185.143	2.015	0.1389	0
2.5	40.715	741.900	77%	19.134	145.959	1.252	0.1093	0.5
2.75	41.097	743.290	66%	16.495	125.826	0.931	0.0941	0.75

6.0 REFERENCES

1. Letter from Stephen L. Rosen (Boston Edison) to L Sempruch (Teledyne Engineering Services) 2-4-80 NED 80-22

2. Mark I Containment Program Plant Unique Load Definition Pilgrim Nuclear Power Station: Unit 1. G.E. Report NEDO-24565 81 NEDO 93 May 1982 Rev 2

3. Flow of Fluids Through Valves fittings, and Pipe CRANE Technical Paper No 410 1969

4. ISA Handbook of Control Valves J.W. Hutchison 2nd ed. Instrument Society of America, Pittsburgh, Pennsylvania, 1976

5. BECO office memorandum To A.A Snow from G.M. McHugh 5-15-84

6. Mark 1 Containment ... G.E. Report NEDO-24565 REV 0

7. A.H. Shapiro "The Dynamics and Thermodynamics of Compressible fluid flow" The Ronald Press Co. N.Y. N.Y. 1953

8. J.H. Keenan & J. Kaye; GAS TABLES, John Wiley & Sons New York 1948 10th printing

9. Letter from R.N. Swanson, Manager Nuclear Engineering Dept (BECO) To L.B. Sempruch (TES) 10-3-85 NEDL 85-118

2

Appendix A

SPECIFIC VOLUME OF AIR IN DRYWELL

When the DBA LOCA occurs the peak pressure and temperature is

$$P_{peak} = 41.1 + 14.7 = 55.8 \text{ psig}$$

$$T_{peak} = 283°F$$

} (gage pressure)

From the ideal gas law

$$PV = RT$$

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

$$= \frac{53.34 \frac{ft \cdot lbf}{lbm \cdot °R} (283 + 460)°R}{55.8 \frac{lbf}{in^2} \times \frac{144 in^2}{ft^2}}$$

$$V = 4.932 \frac{ft^3}{lbm}$$

APPENDIX A

The specific volume at 1sec in the drywell based on air (K=1.4) and a temp and pressure determined from fig P. 4.1.1-2 pg 7 Att 2

$$T = 261°F + 460°F = 721°R$$

$$P = 35.2 + 14.7 = 49.9 \text{ psia}$$

$$v = \frac{RT}{P}$$

$$= \frac{53.34\,(721)}{49.9 \times 144}$$

$$v_{ratio} = 5.35 \ \frac{ft^3}{lbm}$$

APPENDIX A

Determine the average specific volume of the air from the outboard isolation valve to the stack following a LOCA. The specific volume is given by the ideal gas law as

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

The peak temperature in the drywell during a LOCA is 283°F. The temperature of the stack is 70°F. Therefore the average temperature in the line going from the drywell to the stack can be conservatively assumed to be a

$$T = \frac{283 + 70}{2} + 460$$

$$= 636.5°R$$

The average pressure in the duct is $\frac{2.0 + 0}{2} + 14.7 = 15.7$ psia. This assumes the duct pressure does not exceed 2 psig.

$$V = \frac{53.34\ (636.5)}{15.7 \times 144} = 15.02\ ft^3/lbm$$

BY NJ DATE 4/4/80
CHKD. BY JDC DATE 4/7/80

TR-612-4 PURGE & VENT
ASSUME K (FILTER) .384

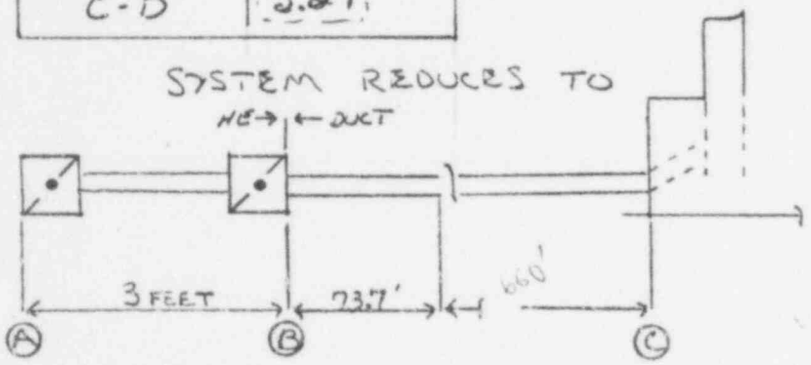
SHEET NO. B1 OF B1
PROJ. NO. 612/

APPENDIX B

	← SECTION →	K	
1)	(A'-A)	?	DEPENDS ON VALVE SETTING
2)	(A-B)	(.000)	
3)	B-C	3.84	
4)	C-D	5.21	

EXHAUST

SYSTEM REDUCES TO



DUCT TO STACK: CONSISTS OF: a) 73.7' DUCT
B-C ΔP=2 PSIG
b) FILTER SYSTEM
c) PIPE (660 FT)

INITIALLY NEGLECT EFFECT OF DUCT (FLOW DEPENDANT)
AND LET K = K FILTER + K PIPE

K FILTER = 3.84 - PREVIOUS WORK (JDC 3/11/80)

K PIPE = f L/D
= .0125 660(12)/19 ✓

K = 5.21

K (B-C) = 384 + 521
K = 9.05 ✓

ΔP/P' = 2/16.7 = .1197 ✓

Y = .96 ✓

w = .525(.96)(19)² (2/9.05(11.255))^½ ✓

w = 24.946 lb/sec ✓

BY JDC DATE 3/24/80
CHKD. BY LBS DATE 4-1-80

TR-6121-4
PURGE AND VENT CALCS.

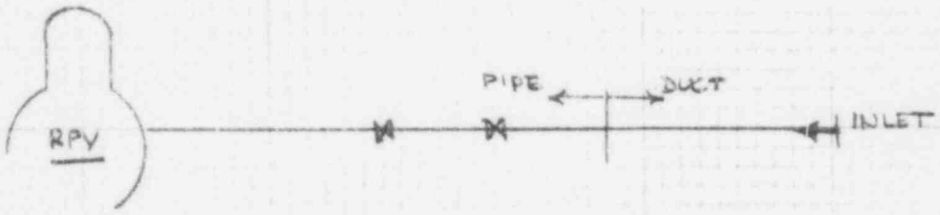
SHEET NO. C1 OF C7
PROJ. NO. 6121

APPENDIX C

THE PROCEDURE FOLLOWED TO CALCULATE VALVE OPENING WAS DONE IN TWO STEPS:

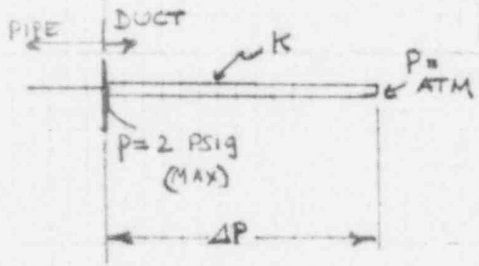
(1.) SINCE THE DUCTWORK FROM THE INLET TO THE BEGINNING OF PIPE HAS A FIXED RESISTANCE AND IT CAN ONLY TAKE A KNOWN PRESSURE (2 PSIG), THE FLOW RATE ACHIEVED WITH THAT RESISTANCE AND PRESSURE DROP CAN BE CALCULATED.

(2.) SINCE THIS WILL BE THE LIMITING FLOWRATE, THE VALVES WILL HAVE TO BE ADJUSTED TO GIVE THAT RATE. FROM THE DUCTWORK TO THE REACTOR, THE PRESSURE DROP IS KNOWN (BASED ON THE 42 PSIG DURING A LOCA) BUT THE RESISTANCE OF THE LINE IS VARIABLE, DEPENDING ON VALVE SETTING. GIVEN THE FLOW RATE CALCULATED IN (1.) AND THE PRESSURE DROP IN THE PIPE, CALCULATE THE RESISTANCE NEEDED. THE VALVE SETTING THEN HAS TO BE SUCH THAT THIS RESISTANCE IS DEVELOPED IN THE LINE.



STEP 1

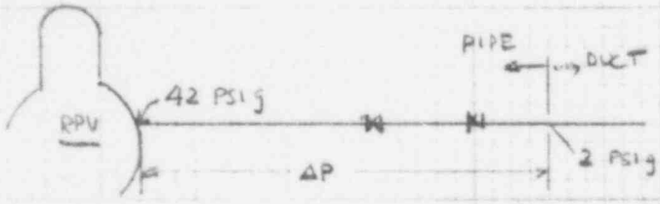
DUCTWORK TO INLET



ΔP, K KNOWN → CALCULATE FLOW RATE

STEP 2

DUCTWORK TO RPV



ΔP, FLOWRATE KNOWN → CALCULATE "K" (RESISTANCE OF LINE). ADJUST VALVES TO GIVE THAT "K".

TELEDYNE ENGINEERING SERVICES

BY JDC DATE 3/24/80
CHKD. BY LBS DATE 4-1-80

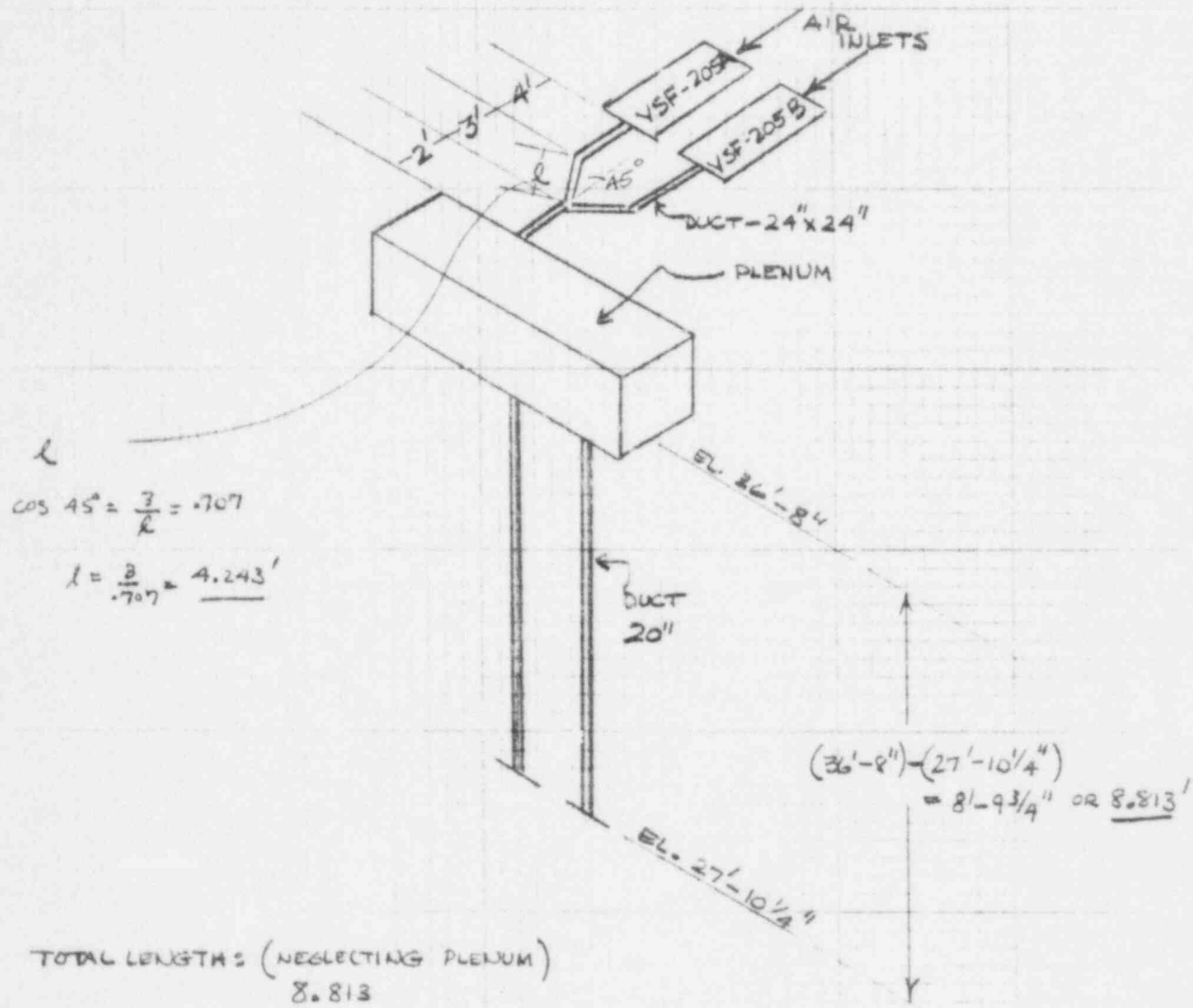
TE-6121-4
PURGE AND VENT CALCS

SHEET NO. C2 OF C7
PROJ. NO. 6121

APPENDIX C

LENGTH OF DUCT

TOTAL LENGTH OF DUCT WORK FROM INLET SUPPLY FANS (VSF 205 A AND B) TO BEGINNING OF PIPE AT ELEVATION 27'-10¼" IS 19.056'.



ℓ

$\cos 45° = \frac{3}{\ell} = .707$

$\ell = \frac{3}{.707} = 4.243'$

$(36'-8") - (27'-10\frac{1}{4}") = 8'-9\frac{3}{4}"$ OR $8.813'$

TOTAL LENGTH: (NEGLECTING PLENUM)

8.813
2.0
4.243
+ 4.0
19.056'

BY JDC DATE 3/25/80
CHKD. BY LBJ DATE 4-1-80

TR-6121-4
PURGE AND VENT CALCS.

SHEET NO. C3 OF C7
PROJ. NO. 6121

APPENDIX C

ACTUALLY THE DUCT IS OF CIRCULAR CROSS SECTION UP TO THE PLENUM AND THEN SQUARE FROM THE PLENUM TO THE INLET FANS. THE CROSS SECTIONAL AREA IS NOT THE SAME FOR THE ROUND AND SQUARE DUCTS SO THE VELOCITY THROUGH THEM WILL BE DIFFERENT. THE CROSS SECTION OF THE SQUARE DUCT IS LARGER AND THUS THE FLUID VELOCITY WILL BE SMALLER HERE THAN IN THE CIRCULAR DUCT. THIS WOULD ONLY AFFECT THE FRICTION FACTOR, HOWEVER, AND SINCE THE FLOW IS HIGHLY TURBULENT, THE FRICTION FACTOR IS ESSENTIALLY CONSTANT AND INDEPENDENT OF REYNOLDS NUMBER. TO SEE JUST HOW MUCH THE VELOCITY WOULD BE CHANGED, THE VELOCITY IN THE SQUARE CROSS SECTION WAS COMPARED TO THAT IN THE ROUND DUCT. (ROUND DUCT AREA = A_1)

$$A_1V_1 = A_2V_2$$

$$V_2 = V_1\frac{A_1}{A_2} = V_1\frac{\frac{\pi d^2}{4}}{A_2} = V_1\frac{\frac{\pi}{4}\left(\frac{19}{12}\right)^2}{\frac{24\times24}{144}} = V_1\left(\frac{1.968}{4}\right)$$

THE RATIO OF A_1/A_2 IS ABOUT $1/2$ AND THEREFORE THE VELOCITY THROUGH THE SQUARE DUCT IS ABOUT HALF THE VELOCITY IN THE CIRCULAR DUCT. THE REYNOLDS NUMBER FOR THE SQUARE SECTION SHOULD BE BASED ON THE HYDRAULIC DIAMETER AND IS:

$$\left(\begin{matrix}d_2\\ \text{HYDRAULIC}\\ \text{DIA}\end{matrix}\right) = 4\frac{\text{AREA}}{\text{PERIMETER}} = 4\frac{24\times24}{4(24)} = 24 \text{ IN}$$

THE HYDRAULIC DIAMETER OF THE SQUARE DUCT IS 24" OR 1.26 TIMES THE CIRCULAR DUCT DIA. THE REYNOLDS NUMBER IN THE NEW SECTION WOULD BE:

$$Re = \frac{\rho_2 V_2 d_2}{\mu_2} = \frac{\rho_1(V_1/2)1.26d_1}{\mu_1} \qquad \left\{\begin{matrix}\text{WITH } \rho_1=\rho_2\\ \text{AND } \mu_1=\mu_2\end{matrix}\right\}$$

$$\boxed{(Re)_2 = 0.63(Re)_1}$$

THIS CHANGE IN REYNOLDS NUMBER WOULD NOT AFFECT THE VALUE OF THE FRICTION FACTOR IN THE HIGHLY TURBULENT REGION.

STEP 1: DUCTWORK TO INLET FANS

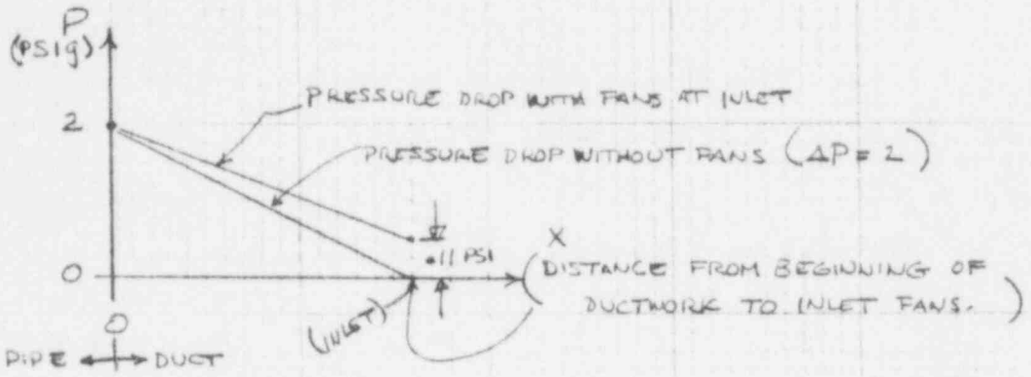
THE MAXIMUM PRESSURE THE DUCT CAN STAND IS 2 PSIG. THIS WOULD OCCUR RIGHT AT THE PIPE-DUCT CONNECTION. IF THERE WERE NO FANS AT THE INLET, THE PRESSURE DROP WOULD BE 2 PSIG TO ATMOSPHERIC, OR $\Delta P = 2$ PSI. SINCE THERE IS A FAN, THE PRESSURE JUST DOWNSTREAM OF THE FAN UNDER NORMAL CONDITIONS WOULD BE ABOUT 0.11 PSIG. (BEGO FAN SPECS — STATIC PRESSURE OF MODEL 121 IS 3" WATER). THE PRESSURE DROP WILL BE SLIGHTLY LESS THAN IF THERE WERE NO FAN PRESENT. THIS IS SHOWN IN THE FIGURE BELOW. WITHOUT THE FANS THE PRESSURE DROP WOULD BE THE FULL 2 PSI SINCE THE INLET WOULD BE AT ATMOSPHERIC PRESSURE. WITH THE FAN THE PRESSURE ON THE DOWNSTREAM SIDE IS BOOSTED BY THE STATIC PRESSURE.

BY JDC DATE 3/26/80
CHKD. BY LBS DATE 4-1-80

TR-6121-4
PURGE AND VENT CALCS.

SHEET NO. C4 OF C7
PROJ. NO. 6121

APPENDIX C



THE PRESSURE DROP THE DUCT SEES IS $2.0 - 0.11 = 1.89$ PSI

$$\Delta P = 1.89 \text{ PSI}$$

IF THE FRICTION FACTOR FORMERLY USED FOR THE PIPE SECTION IS APPLIED, THE RESISTANCE "K" OF THE DUCT WOULD BE:

$$K = f\frac{L}{D} = .0125\,\frac{19}{\frac{19}{12}} = 0.15$$

THIS K IS NOT EVEN ON THE COMPRESSIBLE FLOW - EXPANSION CURVE. THE SMALLEST K IS 1.2. IF 1.2 IS USED INSTEAD, $\Delta P/p$ CAN BE USED TO READ A VALUE OF Y, THE EXPANSION FACTOR.

$$\frac{\Delta P}{P} = \frac{2}{16.7} = 0.1198 \approx 0.12 \Rightarrow Y = 0.92$$

THE FLOW RATE IS:

$$w = .525\,(Y)\,d^2\sqrt{\frac{\Delta P}{K\,\bar{v}}}$$

$$w = .525(.92)(19)^2\sqrt{\frac{2}{1.2/.075}} = 62$$

$$w = 62 \quad \frac{lb}{SEC}$$

BY JDC DATE 4/1/80
CHKD. BY LGS DATE 4-1-80
APPENDIX C

TR-6121-4
PURGE AND VENT CALCS.

SHEET NO. C5 OF C7
PROJ. NO. 6121

THE PREVIOUS CALCULATION ASSUMED THE DUCTWORK TO HAVE THE SAME FRICTION FACTOR AS PIPE. HOWEVER, THIS IS NOT THE CASE AND IN FACT THE RESISTANCE OF THE DUCT IS FAR LESS THAN THAT OF PIPE. THE CHART ON PAGE 6 SHOWS THE FRICTION LOSS IN AIR DUCTS. IT IS SEEN TO BE MUCH SMALLER THAN TYPICAL LOSSES IN PIPE NETWORKS. FOR EXAMPLE, AT THE NORMAL FLOW RATE THROUGH THE SYSTEM (4000 CFM) THE FRICTION LOSS THROUGH 100 FT. OF 20" DUCT WOULD BE .22 IN. OF WATER. THUS FOR 19 FT. OF DUCTWORK THE LOSS WOULD BE

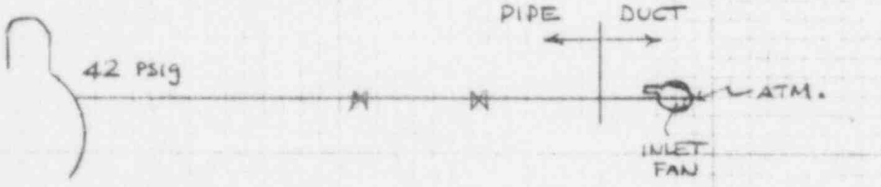
$$\text{LOSS} = .22 \frac{\text{IN}}{100 \text{ FT}} \; 19 \text{ FT} = 0.0418 \text{ IN WATER.}$$

OR IN PSI: $\text{LOSS} = 0.0418\,(0.036)$ PSI

$$\boxed{\text{LOSS} = 0.0015 \text{ PSI}}$$

EVEN UNDER THE MOST EXTREME CONDITIONS ON THE CHART, THE FRICTION LOSS WOULD BE ABOUT 5 IN/100 FT., GIVING IN OUR CASE (19 FT) A PRESSURE DROP OF ABOUT 0.03 PSI.

THEREFORE THE DUCT CAN REALLY BE NEGLECTED AND THE SYSTEM JUST BE CONSIDERED FROM THE REACTOR TO THE END OF PIPE, AS SHOWN BELOW.



THE CONDITION RIGHT AT THE PIPE-DUCT CONNECTION WILL BE SLIGHTLY ABOVE ATMOSPHERIC BECAUSE OF THE LINE AND THE FAN, BUT CAN BE ASSUMED TO BE AT ATMOSPHERIC PRESSURE.

KNOWING THE PRESSURE DROP, THE VALVES CAN BE ADJUSTED TO GIVE THE RESISTANCE THAT WILL GIVE THE MAXIMUM FLOW RATE, THAT IS THE CHOKING CONDITION.

$$\frac{\Delta P}{P} = \frac{42}{56.7} = 0.741$$

INTERPOLATE FOR K AND Y →

K	ΔP/P	Y
6	.737	.671
6.32	.741	.67324
8	.762	.685

APPENDIX C

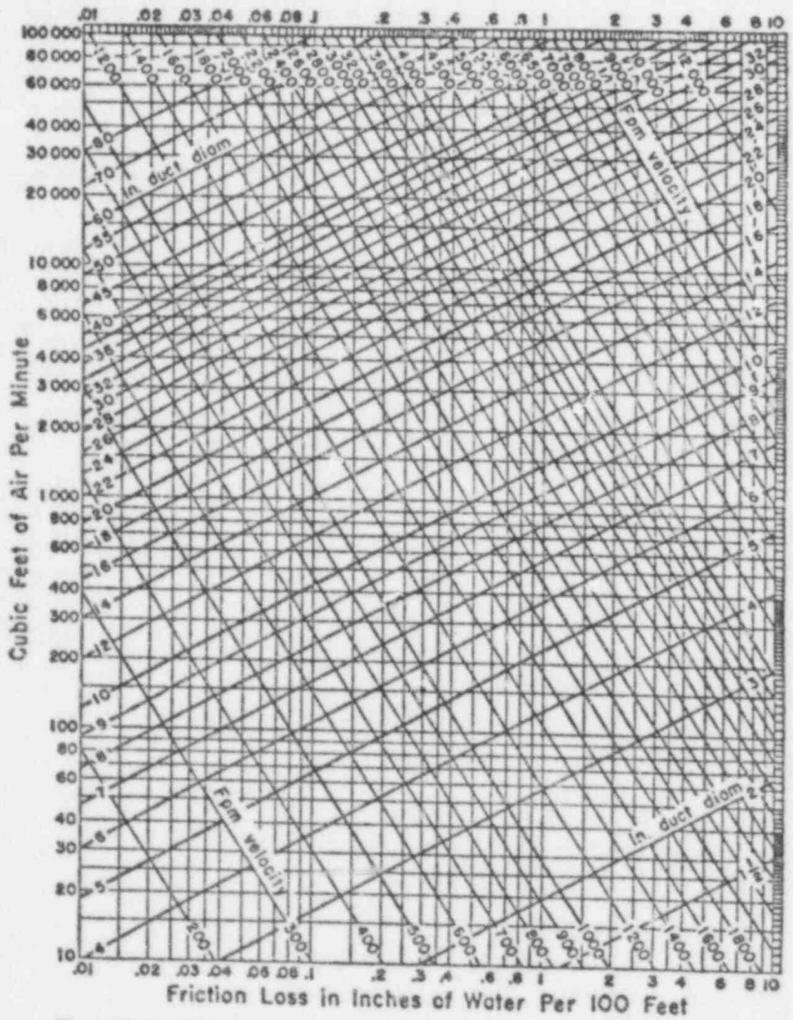


FIG. 12–4. Friction loss in air ducts. (Reproduced, by permission, from *Heating Ventilating Air Conditioning Guide 1949.*)

BY JDC DATE 4/1/80
CHKD. BY LBS DATE 4-1-80

TR-6121-4
PURGE AND VENT CALCS.

SHEET NO. C7 OF C7
PROJ. NO. 6121

APPENDIX C

THE K NEEDED IS 6.32

FROM PREVIOUS CALCULATIONS (JDC-3/6/80) THE RESISTANCES OF ELBOWS AND PIPE LINE ALE KNOWN.

$$K = 6.32 = K_{VALVES} + K_{ELBOWS} + K_{PIPE}$$

$$6.32 = K_{VALVE} + 0.75 + 0.195$$

$$\boxed{K_{VALVES} = 5.375}$$

THE FLOW RATE IS:

$$w = .525(.67324)(19)^2\sqrt{\frac{42}{6.32/.075}}$$

$w = 90$ lb/sec WITH $\rho = .075$. AT THE DRYWELL THE DENSITY CAN BE AS HIGH AS .28 AND THE FLOW RATE BASED ON THAT DENSITY IS ABOUT DOUBLED OR 174.

	ρ .075	.28
w	90	174

THE VALVES HAVE TO BE CLOSED ENOUGH SO THAT THEIR RESISTANCE EQUALS 5.375. THIS CAN BE DONE BY EITHER KEEPING ONE VALVE OPEN AND THE OTHER ADJUSTED TO YIELD 5.375 OR BY SPLITTING THIS K BETWEEN THE TWO VALVES.

	BECO K
90°	0.5
60	3.0
45	15.0

FROM THE GRAPH OF THIS DATA, IT CAN BE SEEN THAT WITH ONE VALVE COMPLETELY CONTRIBUTING THE FULL RESISTANCE, IT WOULD HAVE TO BE OPEN ABOUT 55°. WITH TWO VALVES EACH TAKING HALF OF THE RESISTANCE (2.688), THEY EACH WOULD HAVE TO BE OPEN ABOUT 65°. INTERPOLATIONS YIELD THE FOLLOWING VALUES:

	DEGREES OPEN
WITH ONE VALVE	57°
WITH TWO PARTIALLY CLOSED	64°

APPENDIX D

DETERMINE THE EFFECTIVE FLOW AREA OF THE BUTTERFLY VALVES

The effective flow area of a valve is related to its flow coefficient C_v by the relation

$$A_{eff} = 0.0263\, C_v$$

This can be shown as follows. The valve flowrate is given by the following eq.

$$Q = A\sqrt{\frac{2g\,\Delta P}{K\rho}} \qquad \text{(REF 7 page 3-4)}$$

or

$$Q = \frac{A}{\sqrt{K}}\sqrt{\frac{2g\,\Delta P}{\rho}}$$

Notice that K has the effect of reducing the flow area and therefore the effective flow area is

$$A_{eff} = \frac{A}{\sqrt{K}}$$

C_V can be related to K from the eq

$$K = \frac{891\, d^2}{C_V^2}$$

Substituting C_V for K gives

$$A_{eff} = A \times \frac{1}{\sqrt{K}}$$

$$= \frac{\pi d^2}{4} \times \sqrt{\frac{1}{\frac{891\, d^4}{C_V^2}}}$$

$$= \frac{\pi\, C_V}{4\sqrt{891}}$$

$$A_{eff} = 0.0263\ C_V$$

The C_V of the 8" Butterfly valves is 1460 (ref 5)

Therefore the effective flow area is

$$A_{EFF} = 0.0263 \times 1460$$

$$= 38.398\ in^2$$

The preceding calculations of effective flow area took no credit for the resistance of the inlet line before the isolation valves. This is very conservative and some of this conservatism will be removed by considering some of that resistance here.

Inlet line resistance has the effect of reducing the C_v of the valve. C_v is related to the resistance coefficient by the relation

$$C_v = \frac{29.9\, d^2}{\sqrt{K}} \qquad \text{Ref 3 pg 3-4}$$

The additional resistance of the inlet line K_{add} is accounted for as follows

$$C_v = \frac{29.9\, d^2}{\sqrt{K + K_{add}}}$$

The additional resistance K_{add} is found in section 5.0 where the first three items can be totaled to give

a sum of

$$K_{add} = 0.5 + 0.0375 + 0.375$$

$$= 0.913 \qquad \text{(REF SECTION 5.0)}$$

The effective area of the valve may now be calculated accounting for this resistance

$$A'_{eff} = \frac{\sqrt{K}}{\sqrt{K+K_{add}}} A_{eff} \qquad \text{where } K = 1.718 \text{ Ref E1}$$

$$= \sqrt{\frac{1.718}{1.718 + 0.913}} A_{eff}$$

$$= 0.8083\ A_{eff}$$

Using the area on sheet D2

$$A'_{eff} = 0.8083 \times 38.398\ m^2$$

$$= 31.04\ in^2$$

TELEDYNE ENGINEERING SERVICES

BY LBS DATE 10-7-85
CHKD. BY SDW DATE 10-9-85

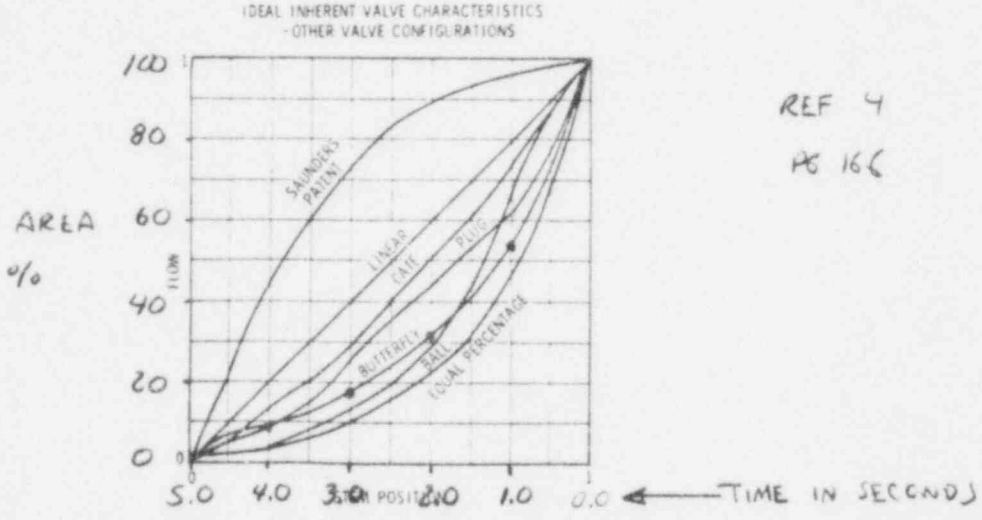
PILGRIM NUCLEAR STATION

SHEET NO. 05 OF 06
PROJ. NO. 6341 C

The following figure from ref 4 pg 11C presents the inherent valve characteristic for several types of control valves including the Butterfly valve. This curve presents flow or effective flow area as a function of stem position. The flow is 100% when the valve stem is at full travel (i.e 1.0) and the flow is 0% when the valve stem is at 0.0 Travel. Ref 9 states that the valve closes in 5 seconds. It can be assumed that time is directly proportional to stem position and therefore this figure can be taken as flow area vs time

2

APPENDIX D



REF 4
PG 16

Figure 2. PERCENT OF MAXIMUM FLOW VERSUS STEM TRAVEL FOR TYPICAL VALVE TYPES.

TIME (SECS)	FLOW AREA
0	A_0
1	$0.55 A_0$
2	$0.32 A_0$
3	$0.18 A_0$
4	$0.09 A_0$
5	$0.0 A_0$

APPENDIX E

DETERMINE THE RESISTANCE COEFFICIENT OF THE 8" BUTTERFLY VALVES

The flow coefficient of the new valves are known to be

$$C_v = 1460 \quad \text{(Ref 5)}$$

This flow coefficient can be converted to a resistance coefficient K by the following eq

$$C_v = \frac{29.9\, d^2}{\sqrt{K}}$$

$$K = \left[\frac{29.9\, d^2}{C_v}\right]^2$$

$$\therefore \left[\frac{29.9\,(8)^2}{1460}\right]^2$$

$K = 1.718$ Two valves will give 3.4358

This is the resistance of one valve. Two valves will be twice this much or 3.4358

APPENDIX E

These 8" valves are to be installed in 20" pipe threature

The valves will have a higher resistance coefficient

$$K_{20} = K_8 \frac{f_{20}}{f_8} \left(\frac{d_{20}}{d_8}\right)^4$$

$$= 1.718 \times \frac{.012}{.014} \left(\frac{20}{8}\right)^4$$

$$= 1.718 \times .8571 \times 39.05$$

$$= 1.718 \times 33.48$$

$$K_{20} = 57.5$$

When the 8" valve is installed in a 20" pipe it will have an equivalent resistance coefficient which is 33.48 times greater than if it were installed in an eight inch line

$$K_{eq} = 57.5$$

Since there are two valves in series $K = 2 \times 57.52 = 115$

APPENDIX F.

DRYWELL PRESSURE & TEMPURATURE CURVES

THE FOLLOWING TWO CURVES WERE USED IN THE DETERMINATION OF THE DWLT PRESSURES. THE PRESSURES AND TEMPURATURES SHOWN ARE EQUAL TO OR GREATER THAN THE REFERENCED CURVES. TES DUPLICATED THE REFERENCED CURVES ONLY TO THE DEGREE NECESSARY TO PRODUCE ACCURATE RESULTS

TELEDYNE ENGINEERING SERVICES

43

BY SDW DATE 9-5-85

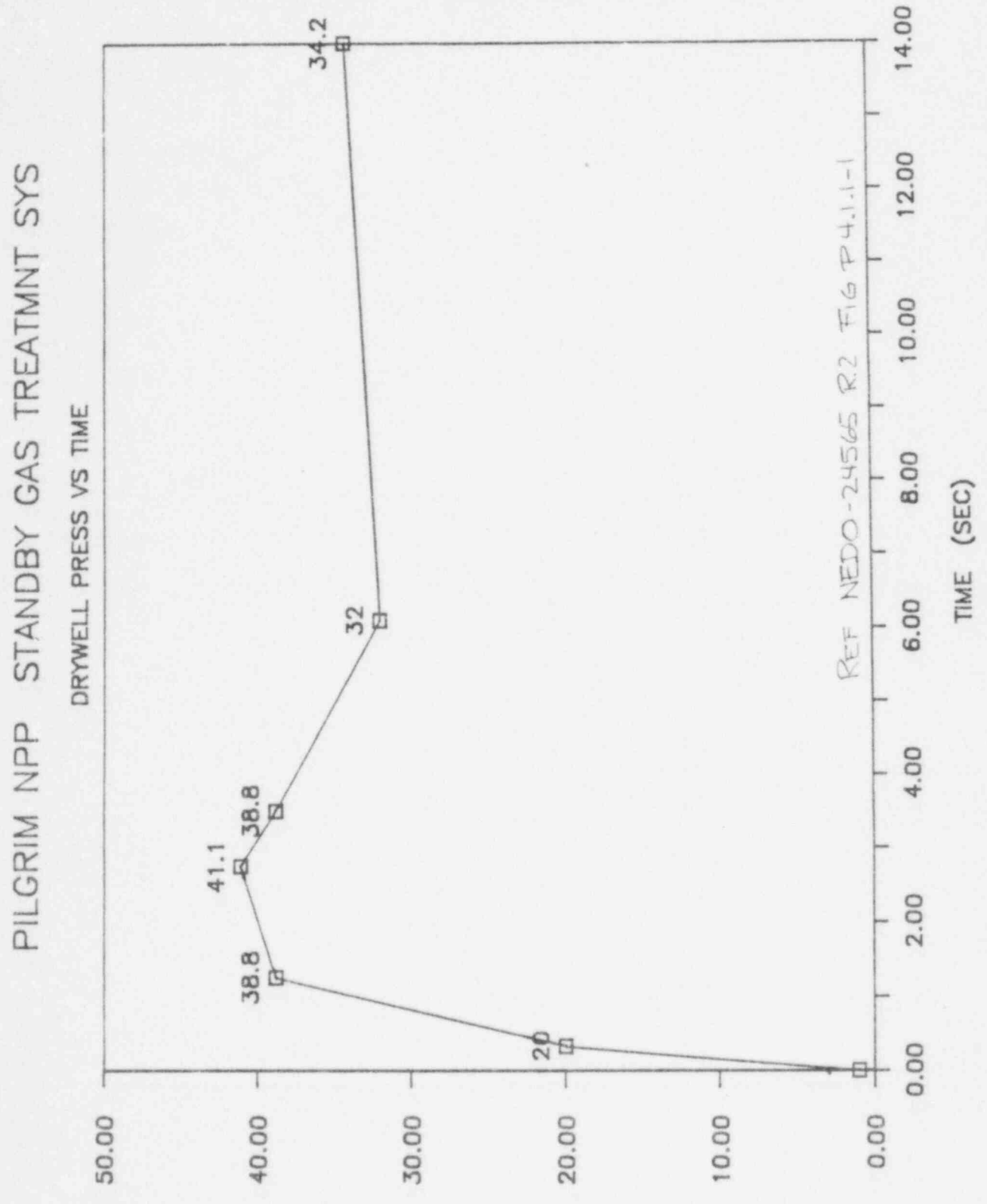
CHKD. BY LBS DATE 9-6-85

PILGRIM NUCLEAR POWER PLANT
SGTS PURGE AND VENT

SHEET NO. F2 OF F3

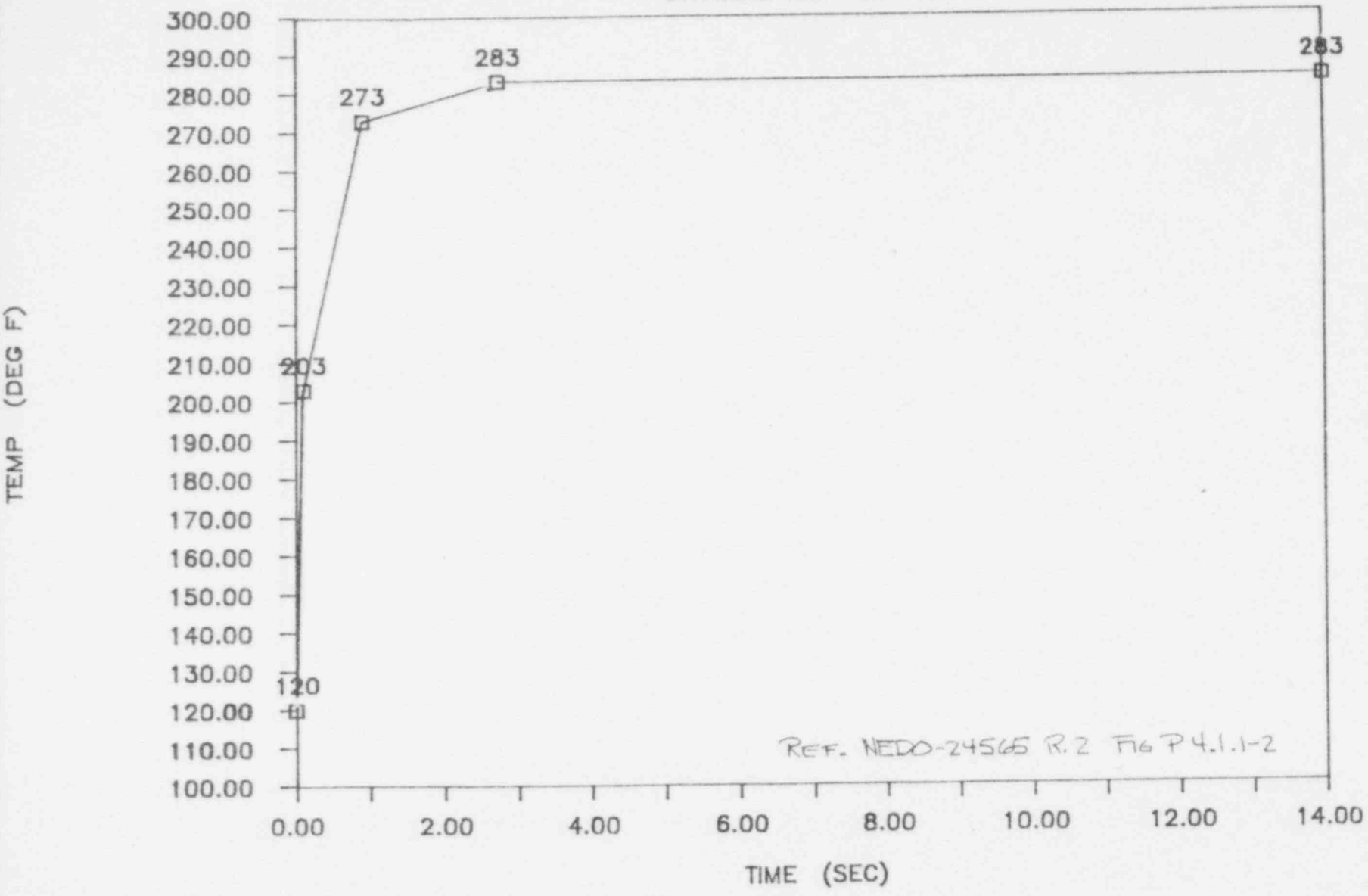
PROJ. NO. 6121

REV-1



PILGRIM NPP STANDBY GAS TREATMNT SYS

DRYWELL TEMP VS TIME



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BY SDW DATE 9-5-85

CHKD. BY LBS DATE 9-6-85

PILGRIM NUCLEAR POWER PLANT
SGTS PURGE AND VENT

SHEET NO. F3 OF F3

PROJ. NO. 6121

REV. 1

TELEDYNE ENGINEERING SERVICES

APPENDIX G

BY JDC DATE 3/8/80
CHKD. BY LQJ DATE 4-1-80
STEP! APPENDIX G

TR-6121-4
PURGE & VENT LINE CALCS.

SHEET NO. 61 OF 63
PROJ. NO. 6121

THIS SET OF CALCULATIONS FOR
TWO BUTTERFLY VALVES OPEN HALF WAY: (PURGE SIDE ONLY)

"K" LOSS FACTOR FOR VALVES

	BECO		ALLIS-CHALMERS[1]
90°	0.5	90°	0.4
60°	3.0	70°	1.5
45°	15.0	40°	20.0
		20°	105.0
		10°	480.0

$K = {}^{45°}_{(BECO)} = 15$ ($\frac{1}{2}$ OPEN)

2 VALVES = $2K = 2(15) = 30$ (2)

$\Sigma K = K_{PIPE} + K_{ELBOWS} + K_{VALVES}$

$\Sigma K = K_{TOTAL} = 0.195 + 0.75 + 30$

$\boxed{K_{TOTAL} = 30.95}$

NOW INTERPOLATE FOR $\Delta P/P_1'$
TABLE P.1A-22 (CRANE)

K	$\Delta P/P_1'$	Y	
20	.839	.710	INTERPOLATED VALUES.
31	.863	.710	
40	.883	.710	

MAXIMUM PRESSURE RATIO IS $\frac{\Delta P}{P_1'} = 0.863$. WE HAVE $\frac{\Delta P}{P_1'} = 0.74$

THEREFORE WE ARE BELOW MAXIMUM RATIO, NO CHOKING OCCURS.

FLOW RATE:

$$w = 0.525\, Y d^2 \sqrt{\frac{\Delta P}{K \bar{V}_1}}$$

@ $\frac{\Delta P}{P_1} = 0.74 \rightarrow Y = 0.75$

$\bar{V}_1 = \frac{1}{.274} = \frac{1}{.28} = 3.57$

$$w = 0.525(.75)(19)^2 \sqrt{\frac{40}{(31)3.57}}$$

$w = 85.5$ lb/sec

[1] DATA SUPPLIED BY ALLIS-CHALMERS - TELECON - JDC - 3/7/80

TELEDYNE ENGINEERING SERVICES

APPENDIX G

BY JDC DATE 3/8/80
CHKD. BY LRS DATE 4-1-80

TR-6121-4
PURGE & VENT LINE CALCS.

SHEET NO. 62 OF 63
PROJ. NO. 6121

PERFORMING THE SAME CALCULATION WITH ALLIS-CHALMER'S DATA FOR 40° (K = 20):

$K_{TOTAL} = 41$

$Y = 0.76$

$W = 75.3$

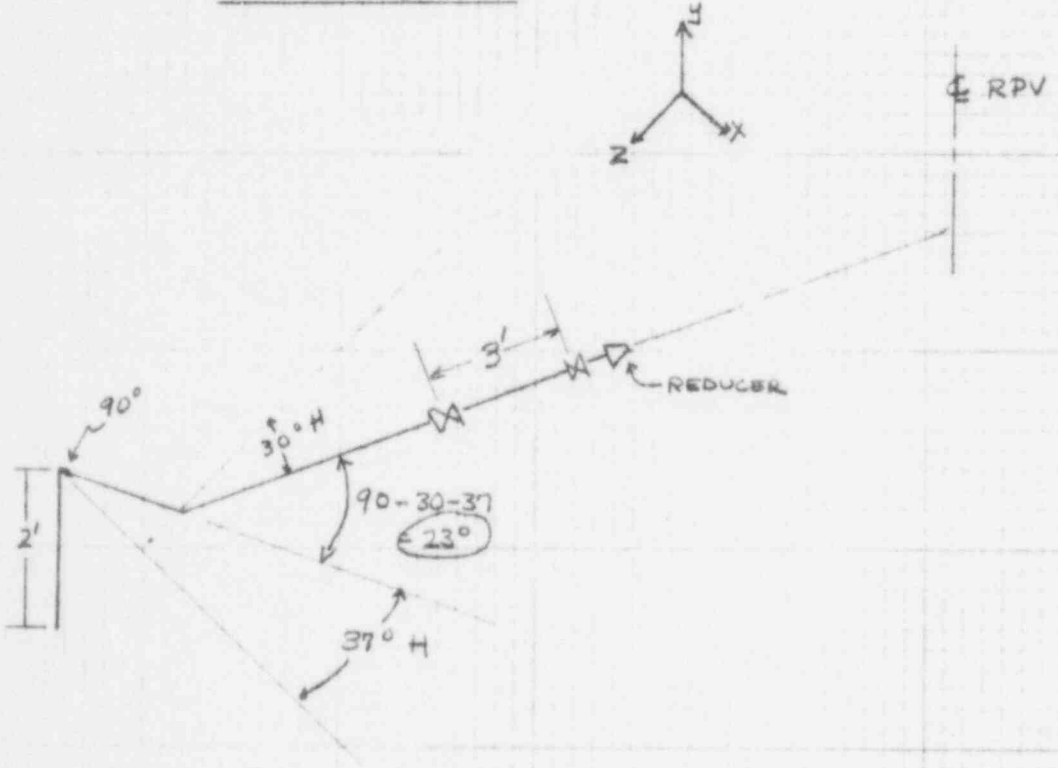
	BECO	ALLIS-CHALMERS
K_{TOTAL}	31	41
W	85.5	75.3

STEP 2.

FIND PRESSURE DROP NEEDED TO SUSTAIN 4000 CFM WITH VALVES WIDE OPEN, BOTH PURGE & EXHAUST SIDE.

FROM DRAWING 6498-647 (BECHTEL)

EXHAUST SIDE LINE



TELEDYNE ENGINEERING SERVICES

APPENDIX G

BY JDC DATE 3/8/80
CHKD. BY LBS DATE 4-1-80

TR-6121-4
PURGE & VENT LINE CALCS.

SHEET NO. G3 OF G3
PROJ. NO. 6121

Exhaust

LEFT SIDE

		K
STRAIGHT LENGTH OF PIPE	5'	$f L/D = \frac{0.0125(5)12}{20} = 0.0375$ (pipe)
VALVES	2 (K=0.5)	1.0 (valves)
ELBOWS	1 (90°)	30(.0125) = 0.375 (elbows)

$\Sigma K = K_{TOTAL\ LEFT\ SIDE} = 1.41$

Exhaust

Purge

RIGHT SIDE

(PIPE) (ELBOWS) (VALVES)

$\Sigma k = \Sigma K_{TOTAL\ RT.\ SIDE} = 0.195 + 0.75 + 1.0$

2 two valve fully open

$K_{TOTAL\ RT.\ SIDE} = 1.95$

Left Side Right Side

$K_{TOTAL} = 1.41 + 1.95 = 3.36$
(RT. & LEFT SIDE)

the purge and exhaust sides are in series

$4000\ CFM \rightarrow 4000\ \frac{FT^3}{MIN}\ \frac{0.078\ lb}{FT^3}\ \frac{60\ MIN}{HR} = 18{,}720\ \frac{lb}{HR}$

$$W = 1891\ Y d^2 \sqrt{\frac{\Delta P}{K \bar{v}_1}}$$

OR $$\Delta P = \left[\frac{W}{1891\ Y}\right]^2 \frac{K \bar{v}_1}{d^4}$$

GUESS $\Delta P/P_1 = 0.3 \rightarrow Y = 0.84$

$$\Delta P = \left[\frac{18{,}720}{1891(0.84)}\right]^2 \frac{3.36/0.078}{(19)^4}$$

$\Delta P = 0.046$ PSI

CHECK: SEE WHAT Y THIS GIVES

$\frac{\Delta P}{P} = \frac{.046}{14.7} = 0.003$

STEP 3 GIVEN PREVIOUS DROP ABOVE, HOW MUCH IS FLOW RATE OF 4000 CFM REDUCED?

$W_2 = W_1 \sqrt{\frac{K_1}{K_2}}$

$K_1 = 3.36$

K_2 = WITH VALVES HALF OPEN
$= 61.36$

$W_2 = 4000 \sqrt{\frac{3.36}{61.36}} = 736$ CFM

TELEDYNE ENGINEERING SERVICES

BY JDC DATE 3/11/80
CHKD. BY LBS DATE 7-15-84

TR-6121-4 OVERALL PURGE & VENT RESISTANCE OF FILTER UNIT - "K"

SHEET NO. H1 OF H2
PROJ. NO. 6121

APPENDIX H

GAS TREATMENT SYSTEM (FIG. 1)

SYSTEM CONSISTS OF:

(1) WATER SEPARATOR (DEMISTER)
(2) ELECTRICAL RESISTANCE AIR HEATER
(3) HEPA FILTER
(4) CHARCOAL FILTERS (2)
(5) HEPA FILTER

THE AIR OR NITROGEN PASSES THROUGH EACH OF THE ABOVE UNITS (IN THAT ORDER) BEFORE PASSING OUT THE EXHAUST STACK.

THE RESISTANCE OF EACH UNIT IS AS FOLLOWS:

WATER SEPARATOR	1.0 INCH WATER
AIR HEATER	0.1 "
(2) HEPA FILTER	1.0 "
(2) CHARCOAL FILTER	1.0 "
TOTAL =	5.1 IN WATER

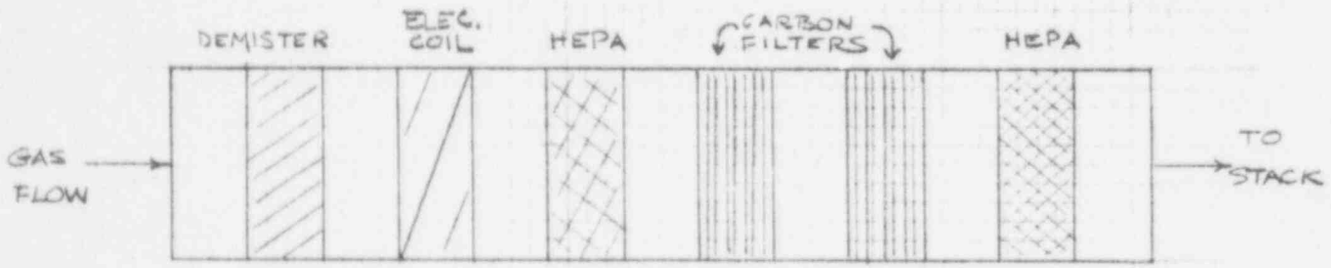


FIG. 1

TOTAL ΔP ACROSS GAS FILTER SYSTEM IS 5.1 IN WATER OR ABOUT 0.2 PSI.

$$\Delta P = \gamma h_L$$

$$\Delta P\,(PSI) = 62.4\ \frac{lbf}{FT^3}\ (h_L)\ FT\ \frac{FT^2}{144\ IN^2}$$

$$\Delta P = \frac{62.4}{144}\left(\frac{5.1}{12}\right) = 0.184$$

$$\boxed{\Delta P = 0.184\ PSI}$$

BY JDC DATE 3/11/80
CHKD. BY LBS DATE 7/15/84

TR-6121-4 PURGE & VENT
RESISTANCE OF FILTER UNIT

APPENDIX H

OVERALL RESISTANCE "K" OF FILTER BOX CAN BE FOUND:

$$h_L = \frac{KV^2}{2g}$$

h_L - LOSS IN FT
V - VELOCITY IN FT/SEC
g - 32.2 FT/SEC²

OR $$K = \frac{2g\,h_L}{V^2}$$

FLOW RATE IS 4000 CFM:
5'X5' DUCT CROSS SECTION = 25 FT²

$$Q = AV \quad \text{OR} \quad V = \frac{Q}{A} = \frac{4000 \frac{FT^3}{\cancel{MIN}} \frac{\cancel{MIN}}{60\ SEC}}{25\ FT^2} = 2.67 \frac{FT}{SEC}$$

$$\therefore \quad K = \frac{2(32.2)^{50}/_{12}}{(2.67)^2} = 3.84$$

$$K_{\substack{FILTER \\ UNIT}} = 3.84$$

ATTACHMENT B

RS

CALCULATION COVER SHEET

CAPITAL AUTHORIZATION NO _____

PILGRIM UNIT 1

Sheet 1 of 14

CALC NO. N3 REV. 0 File No. _____

Subject Flow through Venting / Purge Piping following a postulated LOCA

Discipline Group Leader PETROS KATSAROULAS

Approval (S) [signature] Date 9/13/83

SR ☒

NSR ☐

Preliminary Calc. ☐
Finalization due date _____

Final Calc. ☒

Independent Verifier Ben Tucker Statement Attached ☒

Author	Date	Chk'd	Date	Agree
S. M. Miraglia	9/6/83	J. W. Gosnell	9/9/83	✓
G. Sylvia Miraglia		/s/ [signature]		

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CALCULATION COVER SHEET

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PILGRIM UNIT 1

Sheet 1 of 14

CALC NO. N 3 REV. 0 File No. _____

Subject Flow through Venting / Purge Piping following a postulated LOCA.

Discipline Group Leader PETROS ANTONOPOULOS

Approval /s/ L. C. Hu for Date 9/13/83

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NSR ☐

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Final Calc. ☒

Independent Verifier Ben Tucker Statement Attached ☒

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All	/s/ Silvia M. Mihaiu	09/6/83	/s/ J W Gosnell	9/9/83	✓

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CALCULATION SHEET

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SHEET 2 OF 14

SUBJECT:

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STATEMENT OF THE PROBLEM:

This calculation determines the flow discharged to the atmosphere from the Purge / Venting Piping, following a postulated LOCA and prior to valves complete isolation.
Refer to P&ID # 6498-M-227, penetrations X25 & X26
This calculation was initiated by Memo NMS# 83-587

SUMMARY OF RESULTS

Following the pipe break the drywell pressure increases as RPV blowdown continues into the drywell. Flow will be discharged thru the Purge / Vent Piping. This flow is initially a mixture of air and saturated steam and becomes subsequently saturated steam only as all air

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is plugged to the atmosphere. The flow calculations refer to the pipe with less restrictions since this pipe allows higher flow to escape to the atmosphere. This flow is $\dot{M} = 674.00$ LB .. the total outflow is assumed to be twice as much:

$$M_{TOT} = 2\dot{M} = 1348.00 \text{ LB}$$

METHOD OF SOLUTION

Refer to "Flow of Fluids" Crane pg. 1-9 - Principles of Compressible Flow in Pipe.

A modified Darcy formula is used to determine the flow thru the piping system. The correction factors compensate for the changes in fluid properties due to expansion of the fluid. The correction factors are identified as Y - net expansion factors. Y factors were determined from the charts on pg. A-22 (Crane - Flow of Fluids) as a function of the pressure drop across the line - ΔP. When the ratio $\Delta P / P_1$ (P_1 - inlet pressure) falls beyond the limits of the "K" curves in the chart (pg. A-22), sonic velocity occurs at the pipe discharge and limiting values for

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Y and ΔP were used (pg. A-22 Crane)
The drywell pressure (P'_1) and temperature (T'_1) at various instants following the occurence of a Design Basis Accident, were determined from ~~FSAR~~ curves "Loss of Coolant Accident Primary Containment Pressure /Temperature Response" - Figures 14.7-10, 14.7-11.
The mixture flow was calculated at various times prior to valves complete isolation. Valves are 45° opened (BECo Ltr. #81-46). A curve of flow (LB/HR) variation as a function of time (SEC before complete isolation) has been generated (Fig. 1; pg. 13). The area under the curve represents the total mass released to the atmosphere, from the purge line and prior to Isolation.

INPUT DATA AND ASSUMPTIONS

The calculation is based on the following assumptions:

1. Based on Ref. NMS # 83-587 and considering the escalating drywell pressure

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following a Design Basis Accident, the duct work associated with the vent/purge piping is assumed to be destroyed and therefore no pressure drop in such lines is accounted for.

2. The flow thru the vent/purge lines is assumed adiabatic. This assumption can be made for compressible fluids discharging from a short pipe of uniform cross section into an area of larger cross section. (Flow of Fluids - Crane pg. 1-9)
3. The flow equation is based on the general gas laws for perfect gases. Steam and vapor deviate from the perfect gas laws and the flow equation including Y factors determined from the charts will allow flow rates slightly higher - approximately 5% compared with the results obtained on the basis of sonic velocity at the outlet. This assumption maximizes the flow escaped to the atmosphere.

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4. Since the Purge / Venting lines are relatively short and the flow is discharged to atmosphere the flow regime is assumed fully turbulent and therefore the friction factor (f_T) is independent of Reynolds number.

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CALCULATION SHEET

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SHEET 1 OF 14

SUBJECT:

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CALCULATIONS / ANALYSIS

Pipes Characteristics - Refer to DWG's HM45-1, HE 45-1

Purge Line	Venting Line
Length = 5.1 FT	Length = 27.25 FT
2 Butterfly valves 45°	2 Butterfly valves 45°
1 90° elbow	3 90° elbows.

Valves Isolation Signal is set at 2 PSIG. (PNPS - FSAR Table 7.3-2) The dry well pressure reaches this limit almost instantaneously after the break occurence. There is a 15 sec delay time on the isolation signal. The flow discharged thru the purge line is determined at various times prior to valve isolation.

*Resistence factor "K" for Purge Line (Pen. X 25)

See next page

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Resistance to flow due to sudden contraction:

$K_1 = 0.5\left(1 - \frac{d_1^2}{d_2^2}\right)$ d_1 - small diameter
d_2 - large diameter

Assume $d_2 = \infty$ (drywell volume) $\Rightarrow$

$K_1 = 0.5$

Resistance to flow due to sudden enlargement:

$K_2 = \left(1 - \frac{d_1^2}{d_2^2}\right)^2$ d_1 - small diameter
d_2 - large diameter

Assume $d_2 = \infty$ (outside volume) $\Rightarrow$

$K_2 = 1.0$

Resistance coefficient due to pipe length:

$K_3 = f_T \frac{L}{D}$

$f_T = 0.012$ (for complete turbulent flows) Crane pg. A-26.

$L = 5.1$ FT

$D = 17.25'' = 1.4375$ FT (STANDARD 18" PIPE)

$K_3 = 0.012 \frac{5.1}{1.4375} = 0.04257$

$K_3 = 0.04257$

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CALCULATION SHEET

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SHEET 7 OF 14

SUBJECT:

SR ☒
NSR ☐

Resistence to flow due to 90° bend :

Assume $\frac{r}{d} = 1 \Rightarrow K_4 = 20\, f_T = 20 * 0.012$

$K_4 = 0.24$

Resistence to flow due to flow thru butterfly valve 45° opened :

Ref. " Handbook of Hydraulic Resistence " pg 361

$\theta = 45° \Rightarrow K = 21.7$

$K_5 = K_{S1} + K_{S2} = 43.7$.

$K_5 = 43.7$

$$K_{TOT} = \sum_{1}^{5} K_i = 0.5 + 1.0 + 0.04257 + 0.24 + 43.7 =$$

$$= 45.48$$

$K_{TOT} = 45.48$

Modified Darcy equation for steam discharging from piping system:

$$W = 1891\, Y\, d^2 \sqrt{\frac{\Delta P}{K \bar{V}_1}} \quad \frac{LB}{HR} \qquad (Eq.\ 1.)$$

Ref. " Flow of Fluids " Crane - pg. 4-13

where:

K - resistance coefficient

ΔP - pressure drop across the line (PSIA)

d - pipe inside diameter (inches)

$\bar{V}$ - mixture specific volume FT^3/LB

Y - n-t expansion factors.

Mixture Specific Volume $\bar{V}$

The flow escaping thru the Vent/Purge System is a mixture of air and saturated steam. As the blowdown continues into the drywell, all air is purged to the atmosphere and the outflow thru the piping becomes saturated steam only. The following set of equation is used to determine the specific volume of the air, steam mixture:

$P'_1 \equiv P_{TOT}$ - total drywell pressure PSIA

P_{DW} - steam saturation pressure at drywell temp. (PSIA)

P_{AIR} - air pressure at drywell temperature (PSIA)

γ_w - steam specific gravity (LB/FT^3) at drywell temperature

$T'_1 \equiv T_{TOT}$ - drywell temperature °

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CALCULATION SHEET

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SHEET 11 OF 17

SUBJECT:

SR ☒
NSR ☐

$$P_{TOT} = P_{DW} + P_{AIR}$$

$$P_{AIR} = \frac{R_{AIR} T_{AIR}}{V_{AIR}} \Rightarrow P_{TOT} = P_{DW} + \frac{R_{AIR} T_{TOT}}{V_{AIR}} \Rightarrow$$

$$\frac{1}{V_{AIR}} = \frac{P_{TOT} - P_{DW}}{R_{AIR} T_{TOT}} \quad \frac{LB}{FT^3} \Rightarrow$$

$$\bar{V} = \frac{1}{\rho_W + \frac{P_{TOT} - P_{DW}}{R_{AIR} T_{TOT}}} \quad \frac{FT^3}{LB} \qquad (Eq. 2)$$

TIME SEC	P_{TOT} (P'_1) PSIA	T_{TOT} (T'_1) °R	$\rho_W(T_{TOT})$ LB/FT³	$P_{DW}(T_{TOT})$ PSIA	R_{AIR} FT LB / LB°R	$\bar{V}$ FT³/LB USE EQ.2
0.17	29.7	660	0.02972	11.526	53.34	9.61372
0.315	34.7	680	0.0432	17.186	- " -	8.87
0.565	41.7	696	0.05724	23.27	- " -	7.755
1.0	49.7	725	0.0905	37.894	- " -	7.437
1.755	54.7	730	0.10251	43.249	- " -	6.9033
3.15	58.7	750	0.13797	59.35	- " -	6.8724
ALL HP PURGED TO THE ATMOSPHERE $P_{TOT} = P_{DW}(T_{TOT})$.						$\bar{V}$ FT³/LB FROM SAT TABLE
5.65	59.7	750	0.13797	59.7		7.4275
10.0	52.7	745	0.12277	52.7		8.1453
17.33	42.7	732	0.10285	≅ 42.7		9.722

☐ PRELIMINARY
REV ___ DATE _____

☐ FINAL
REV ___ DATE _____

SUBJECT:

CALCULATION SHEET

Edison

CAPITAL AUTHORIZATION NO. _____

PREPARED BY Sullivan DATE 09/6/83

CHECKED BY [illegible] DATE 9/9/83

APPVD BY [illegible] DATE 9/14/83

SHEET 12 OF 14

SR ☒
NSR ☐

k - isentropic coefficient : $k = 1.3$ (for STEAM, AIR)

$K = 45.18$

TIME SEC	$\bar{V}$ FT³/LB	$\Delta P/P'$	Y (CHARTS)	Y SONIC (CONST)	TYPE OF FLOW	(EQ 1) $W \times 10^5$ LB/HR
0.17	9.6137	0.505	0.84	0.718	SUBSONIC	0.8783591
0.315	8.87	0.576	0.82	- " -	SUBSONIC	1.02736
0.565	7.755	0.6474	0.79	- " -	SUBSONIC	1.22985
1.0	7.437	0.704	0.77	- " -	SUBSONIC	1.30755
1.755	6.9033	0.731	0.77	- " -	SUBSONIC	1.551638
3.15	6.8724	0.749	0.76	- " -	SUBSONIC	1.609871
5.65	7.4275	0.753	0.75	- " -	SUBSONIC	1.564466
10.0	8.1453	0.721	0.77	0.718	SUBSONIC	1.392265
17.33	9.722	0.655	0.78	0.718	SUBSONIC	1.106249

The flow variation as a function of time is represented on Figure 1 attached. The total mass released to the atmosphere in LB is determined by graphically approximating the area under the curve on Figure 1. The outflow to the atmosphere, from the purge line and prior to vent complete isolation is $W = .646$ LBS.

NED-1001

B.E.Co. FORM 3930

CALCULATION SHEET CAPITAL AUTHORIZATION NO.

☐ PRELIMINARY REV___ DATE___ PREPARED BY Sun DATE 9/6/83 CHECKED BY [illegible] DATE 9/16/83 SR ☒ NSR ☐

☐ FINAL REV___ DATE___ APPVD BY [illegible] DATE 9/16/83 SHEET 13 OF 17

☐ PRELIMINARY REV___ DATE___ PREPARED BY___ DATE___ CHECKED BY___ DATE___ APPVD BY___ DATE___ SR ☐ NSR ☐

☐ FINAL REV___ DATE___ CAPITAL AUTHORIZATION NO.___ CALCULATION SHEET SHEET___ OF___

0.1 ×10⁵ LB/HR²
1SEC

W(LB/HR)

2.5×10⁵
2×10⁵
1×10⁵

30
30
20
20
20
10
1.1

119

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 t (SEC)

SR ☐
NSR ☐

An alternate method was used to determine the total mass released to the atmosphere. ($\dot{M}$)

$$\dot{M} = \int_{t_1}^{t_2} w(t)\,dt \qquad \text{if } y = \ln t =$$

$$dy = \frac{dt}{t} \Rightarrow t\,dy = dt$$

Then: $$\int_{t_1}^{t_2} w(t)\,dt = \int_{y_1=\ln t_1}^{y_2=\ln t_2} t\,w(t)\,dy$$

$t_1 = 0.17 \Rightarrow y_1 = -1.726$

$t_2 = 17.33 \Rightarrow y_2 = 2.8525$

Since y_n (where $n = 8$) are approximately equally spaced, Simpson's rule can be applied:

$$\int_{t_1=0.17}^{t_2=17.33} w(t)\,dt = 674 \text{ LB}$$

$$\dot{M} = 674 \text{ LB}$$

The area from $t = 0$ to $t = 0.17$ can be neglected.

Since this method determines higher flows it has been concluded that the total mass release to the atmosphere is:

$$M_{TOT} = 2\dot{M} = 1348.00 \text{ LB}$$

Attachment I - Independent Verification Statement

Calculation # U3, Revision # _____ has been independently verified by the following method(s), as noted below:

Design Review ☒ including verification that:

* Design inputs were correctly selected and included in the calculation.

* Assumptions are adequately described and are reasonable.

* Input or assumptions requiring confirmation are identified, and if any exist, the culation has been identified as "Preliminary" and a "Finalization Due Date" has be specified.

* Design requirements from applicable codes, standards and regulatory documents are identified and reflected in the design.

* Applicable construction and operating experience was considered in the design.

* The calculation number has been properly obtained and entered.

* An appropriate design method or computer code was used.

° A mathematical check has been performed.

° The output is reasonable compared to the input.

Alternate Calculation ☐ including verification of asterisked items noted above. The alternate calculation (_____ pages) is attached.

Qualification Testing ☐ for design feature _____ including verification of asterisked items noted above and the following:

° The test was performed in accordance with written test procedures.

° Most adverse design conditions were used in the test.

° Scaling laws were established and verified and error analyses were performed, if applicable.

° Test acceptance criteria were clearly related to the design calculation.

° Test results (documented in _____) were reviewed by the calculation Preparer or other cognizant engineer.

Independent Verifier Comments: The results of this analysis were compared to a design basis calculation using the computer code CONTEPT. The estimated total mass agreed approximately 560 lbs. (See NAG 83-10)

See NED Procedure 3.05, Sec. 7.1.1 /s/ Don Lucas 9/13/83
Independent Verifier Date

R5

Preparer concurrence with findings and comment resolution /s/ Silvia M. Mihan 09/13/83
Preparer or other cognizant engineer Date