FLORIDA POWER CORPORATION
CRYSTAL RIVER PLANT UNIT # 3

MAIN STEAM SAFETY AND RELIEF VALVE

SYSTEMS STRESS ANALYSIS REPORT

FLORIDA POWER CORPORATION
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MAIN STEAM SAFETY AND RELIEF VALVE

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FLORIDA POWER CORPORATION

CRYSTAL RIVER NUCLEAR POWER PLANT UNIT NO. 3

MAIN STEAM SAFETY AND RELIEF

VALVE SYSTEM STRESS ANALYSIS REPORT

SUMMARY

AUGUST 1974

MOO-ZUNG LEE

PIPING ENGINEERING DEPARTMENT

GILBERT ASSOCIATES, INC.

INTRODUCTION

At least two cases of safety valve installation failures have been reported in recent years. In both cases the failures were attributed to the moments generated by reaction forces of the steam discharged from the valves at the testing stages of the new nuclear power plants.

In view of these incidents, a review of the main steam safety and relief valve installations in Crystal River Unit 3 was undertaken. The discharge stack orientation was modified to correct the unfavorable condition. The following sections represent a condensed presentation of the analysis performed and the results obtained.

GENERAL LAYOUT AND CONSTRUCTION

The main steam piping system of Crystal River Nuclear Power Plant Unit #3 consists of four 24" lines connecting two steam generators to the turbine. Each of these four lines has four spring loaded safety valves located in the Intermediate Building. Fourteen of these valves are of 6" inlet, 10" outlet and two are of 6" inlet, 8" outlet, and all are supplied by Dresser. The safety valves are mounted on 24" schedule 60 (0.986" wall thickness) headers using Bonney Forge sweepolets. The outlets of the valves are inclined so that the bending moments on the branch connections created by the steam discharge flow reaction forces are minimized. The safety valve outlet elbows are connected to the discharge stacks by Flexonic Joints which are esentially closed type flexible bellows connectors.

There are also two power operated atmospheric relief valves installed on two lines, one from each steam generator.

The main steam pipes are made of ASTM A106 Gr. B, the discharge stacks are of ASTM A53 Gr. B. Sweepolets, weldolets, flanges and elbows are made of ASTM A105 Gr. II.

STRESS COMBINATIONS AND ALLOWABLE STRESS CRITERIA

Stresses in the main steam pipes, safety and relief valve inlet branches and outlet pipes are analyzed for sustained loads, occasional loads and thermal expansion loads. Sustained loads include the effects of pressure and dead weight. Occasional loads include seismic responses and the loads created by valve discharge flow reaction forces. Design loads due to seismic responses are taken as twice of those excited by operational basis earthquake (OBE). Dynamic effect of safety valve discharge reaction loads are considered by using dynamic load factor. The load combinations and allowable

stresses are based on Power Piping Code USAS B31.1.0 Par. 104.8 1973 Addenda.

VALVE DISCHARGE REACTION FORCES.

Maximum discharge flow capacities of the safety valves are taken as 111% of the rated capacities given by the valve manufacturer. The order of these figures are checked by independent calculation based on the steam conditions and the orifice sizes of the valves using Napier's formula. Steam flow conditions are established and the maximum reaction forces are calculated for overall isentropic nozzle efficiencies of the safety valves ranging from 25 to 50%. These reaction forces include the pressure and the momentum effects of the flow. The results are in close agreement with the data given by Dresser. (Ref. Consolidated Safety Valves Reactions Forces for steam Services March 1973). It must be noted that Safety Valve Reaction Forces available from manufacturers prior to 1973 were 30% to 50% lower than those stated today.

The flow reaction forces of the power operated relief valves are calculated by assuming that the maximum flow rate may reach 120% of the rated flow rate.

The effects of the back pressure in the Flexonic joints are estimated and added to the discharge flow reaction forces in calculating the stresses due to valve operation. Detailed flow analysis for the stacks performed later showed that the estimated back pressure effects are conservative.

DYNAMIC LOAD FACTOR

The effects of safety valve discharge reaction on the piping is dynamic in nature. The dynamic load factor (DLF) is defined as the ratio of the stress caused by a dynamic load to the stress caused by the same quantity of load applied statically. DLF depends on the nature of the forcing function and

the dynamic characteristics of the piping system.

Most of the safety valves pop open to 70% of their lifts in 40 mili-seconds followed by gradual increase in opening. In this analysis the time characteristics of the safety valve reaction force is assumed to be a ramp function rising from zero to maximum in 40 mili-seconds and remains constant thereafter.

The fundamental natural periods of the main steam pipes are calculated by simplified analysis. The lower bound of this natural period and the forcing function as assumed above establishes the conservative value of DLF.

Although the safety valves on the same line are set to pop at different pressures, it is assumed that all the valves on the same line may open simultaneously and the worst combination of the effect on the header is considered.

STRESS INTENSIFICATION FACTORS

Two methods are employed in calculating stress intensification factors for the branch connections. For safety valve branch connections where sweepolets are used, Bonney Forges' formula for stress intensification is employed. (Ref. Stress Intensification Factors and Stress Indixes for Bonney Forge Sweepolets Jan, 1971.) For the relief valve branches, connected to the header by weldolets, method given by ASME Boiler and Pressure Vessel Code Sec. III Winter 72 Addenda NC-3673.2 (b) and Table NB-3683.2-1 are used.

DISCHARGE STACKS AND FLEXONIC JOINTS

Steam flow conditions in the discharge stacks and the back pressure in the bellows of the Flexonic joints are calculated by employing the conservation equations of mass, momentum and energy assuming adiabatic process. Pressure

in the bellows of the Flexonic joints for the 6" x 10" safety valves was found to be slightly higher than the design pressure. However, considering the conservative assumptions made in the analysis and the bursting pressure and other data provided by the manufacturer, it is our judgement that the joints can be used without compromising the safety.

The effects of flow reaction loads on the stack supports and the stacks themselves were reviewed and necessary modifications in support design were made to meet the stress criteria.

SUMMARY OF DATA AND RESULTS

1. Discharge Flow Rates

Safety Valves 6R10	rated	845,759 lbs./hr.
	max.	940,000 lbs./hr.
Safety Valves 6Q8	rated	579,000 lbs./hr.
	max.	645,000 lbs./hr.
Relief valves 6"	rated	418,500 lbs./hr.

2. Discharge Reaction Forces

Safety Valves 6R10	23.5 Kips
Safety Valves 6Q8	15.3 Kips
Relief Valves	13.5 Kips

3. Dynamic Load Factors

Main Steam Pipe,	calculated	1.22
	used	1.5
Discharge Stack,	calculated	1.21
	used	1.3

4. Stress Intensification Factors

Sweepolet	main pipe	1.5
	branch	1.0
Weldolet	main pipe	1.5
	branch	1.84

5. Maximum stresses and Codes Allowable Stresses.

A. Main Steam Pipe at Safety Valve installation

Max stresses due to sustained loads		Allowable
Line CR-3	7,583 psi	15,000 psi
Line CR-4	7,449 psi	15,000 psi
Line CR-5	7,632 psi	15,000 psi
Line CR-6	7,615 psi	15,000 psi

Max stresses due to sustained + occasional loads		Allowable
Line CR-3	14,871 psi	18,000 psi
Line CR-4	17,701 psi	18,000 psi
Line CR-5	13,739 psi	18,000 psi
Line CR-6	15,382 psi	18,000 psi

Max stresses due to thermal load		Allowable
Line CR-3	3,417 psi	22,500 psi
Line CR-4	13,815 psi	22,500 psi
Line CR-5	13,498 psi	22,500 psi
Line CR-6	13,620 psi	22,500 psi

B. Safety Valve Inlet Connections

Max stresses due to sustained loads		Allowable
Line CR-3	2,773 psi	17,500 psi
Line CR-4	2,773 psi	17,500 psi
Line CR-5	2,908 psi	17,500 psi
Line CR-6	2,660 psi	17,500 psi

Max stresses due to sustained + occasional loads		Allowable
Line CR-3	15,098 psi	21,000 psi
Line CR-4	14,432 psi	21,000 psi
Line CR-5	17,121 psi	21,000 psi
Line CR-6	15,813 psi	21,000 psi

Thermal loads on the safety valve branches are so small that the stress calculations are not meaningful.

C. Stress in safety valve outlet elbow

Max. stress	12,000 psi
Allowable	21,000 psi

D. Relief Valve Branch Connection

Max stresses due to sustained load		Allowable
Run Pipe	7,234 psi	15,000 psi
Branch	7,730 psi	15,000 psi

Max stresses due to sustained + occasional load		Allowable
Run Pipe	9,254 psi	18,000 psi
Branch	14,350 psi	18,000 psi

Thermal stress		Allowable
Run Pipe	9,770 psi	22,500 psi
Branch	5,620 psi	22,500 psi

E. Discharge Stacks

Max. stress		Allowable
14" stack	16,840 psi	18,000 psi
12" stack	14,770 psi	18,000 psi

6. Flexonic Bellows Back Pressure

Calculated Pressure

14" stack	51~54 psig
12" stack	31 psig

Designed Pressure 50 psig
Bursting Process 150~200 psig

CONCLUSION

This analysis of the Main Steam Safety Valve System, with the modification of the discharge angle at the outlet of the safety valves and with the addition of supports MSH 219, 220, 221, 222, 244, 245, concludes that the design is satisfactory based on USAS B31.1.0 stress criteria.

MAIN REPORT

FLORIDA POWER CORPORATION

CRYSTAL RIVER NUCLEAR POWER PLANT UNIT NO. 3

MAIN STEAM SAFETY AND RELIEF VALVE SYSTEM STRESS ANALYSIS REPORT

AUGUST 1974

MOO-ZUNG LEE

PIPING ENGINEERING DEPARTMENT

GILBERT ASSOCIATES, INC.

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CLIENT: Florida Power Corp.

PROJECT: Crystal River #3

FILING CODE

W.O. 4203-017 PAGE 1 of 112

SYSTEM: Main Steam Safety and Relief Valve Systems

ORIGINATOR: M.Z. Lee
DATE 10/22/73

CALCULATION FOR

REVIEWER: J F Ferarella
DATE 12/12/74

RESULTS

Introduction

The main steam piping system of Crystal River Nuclear Power Plant unit #3 consists of four lines connecting two steam generators to the turbine. Each of these lines has four safety valves located outside the containment building. In addition, there are two power relief valves installed on two lines, one from each steam generator. The general layout is shown schematically on Fig. 1. The safety and relief valve installations are shown on Fig 2 and Fig. 23 respectively.

In this report the reaction forces due to safety and relief valves are calculated based on maximum discharge rate and in the case of safety valves an isentropic nozzle efficiency of 25 & 50% is assumed. The stresses induced by these discharge reaction forces, dead load, seismic excitation and thermal effect are analyzed for every critical point and compared with code allowable stresses.

Due to the complexity of the systems and practical difficulties, the loads on critical points due to dead load, seismic excitation, simultaneous blow of all safety valves, thermal effect and the results of anchor movement (static seismic) are taken from piping stress program computer outputs.

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CLIENT: Florida Power Corp
PROJECT: Crystal River #3
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SYSTEM: Main Steam Safety and Relief Valve Systems
ORIGINATOR: M. Z. Lee
DATE 10/22/73
CALCULATION FOR:
REVIEWER: A J. Fernello
DATE 11/16/74

RESULTS

ANSI B31.1.0 - 1967 and Summer 1973 Addenda are used as design criteria. In some places ASME Boiler and Pressure Vessel Code, Sec. III is adopted as supplements.

Two methods are employed in calculating stress intensification factors for the branch connections. For safety valve connections, where sweepolets are used, Bonney Forge's formula are used, [2]. For the relief valve connection, where weldolets are used, method given by BPVC Sec. III is employed.

Dynamic load factor due to safety valve discharge reaction is evaluated from dynamic characteristics of the local piping system and ramp function of reaction force with a rise time of 0.09 sec. Seismic loads and stresses are taken as twice of those resulting from OBE.

Pressure in flexonic connectors and discharge stacks are studied in detail. It was found that some of the designs needed modification.

Stresses in escape stack after rerouting is calculated based on proposed support locations.

Essential results of the analyses after completion of necessary modifications are summarized at the beginning of the report.

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GAI 350 REV. 10-72

FPC CR-3 M.S. SAFETY & RELIEF VALVES	MADE 10/22/73 CHK'D. EQ. CP. CP. DPN. ENG. M. Z. Lee REV. CH. APP. DATE A. F. Fernandez 12/4/74	GILBERT ASSOCIATES, INC. ENGINEERS AND CONSULTANTS READING, PENNA. 4403-027 (WORK ORDER) | SIZE | DRAWING | REV.

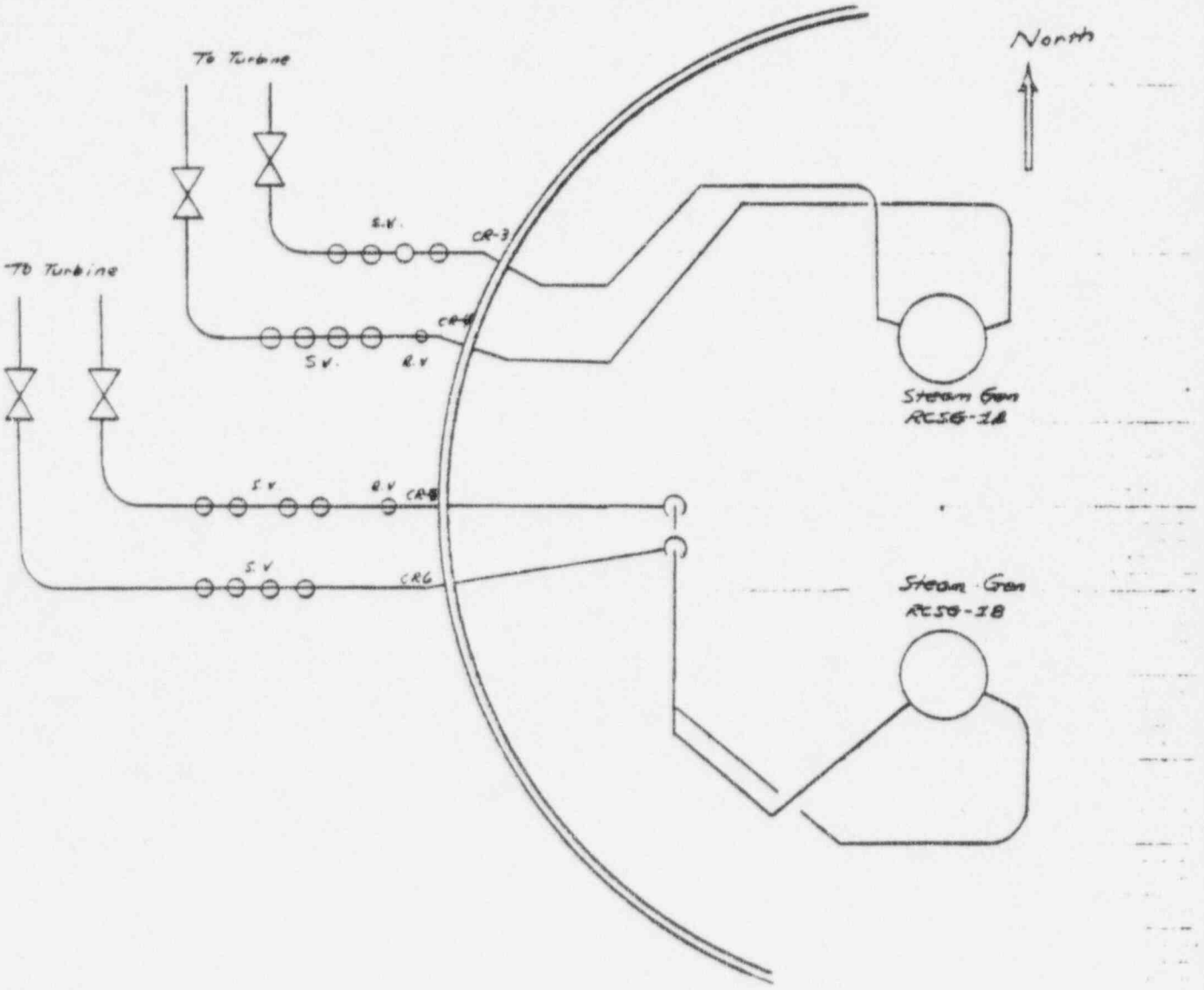
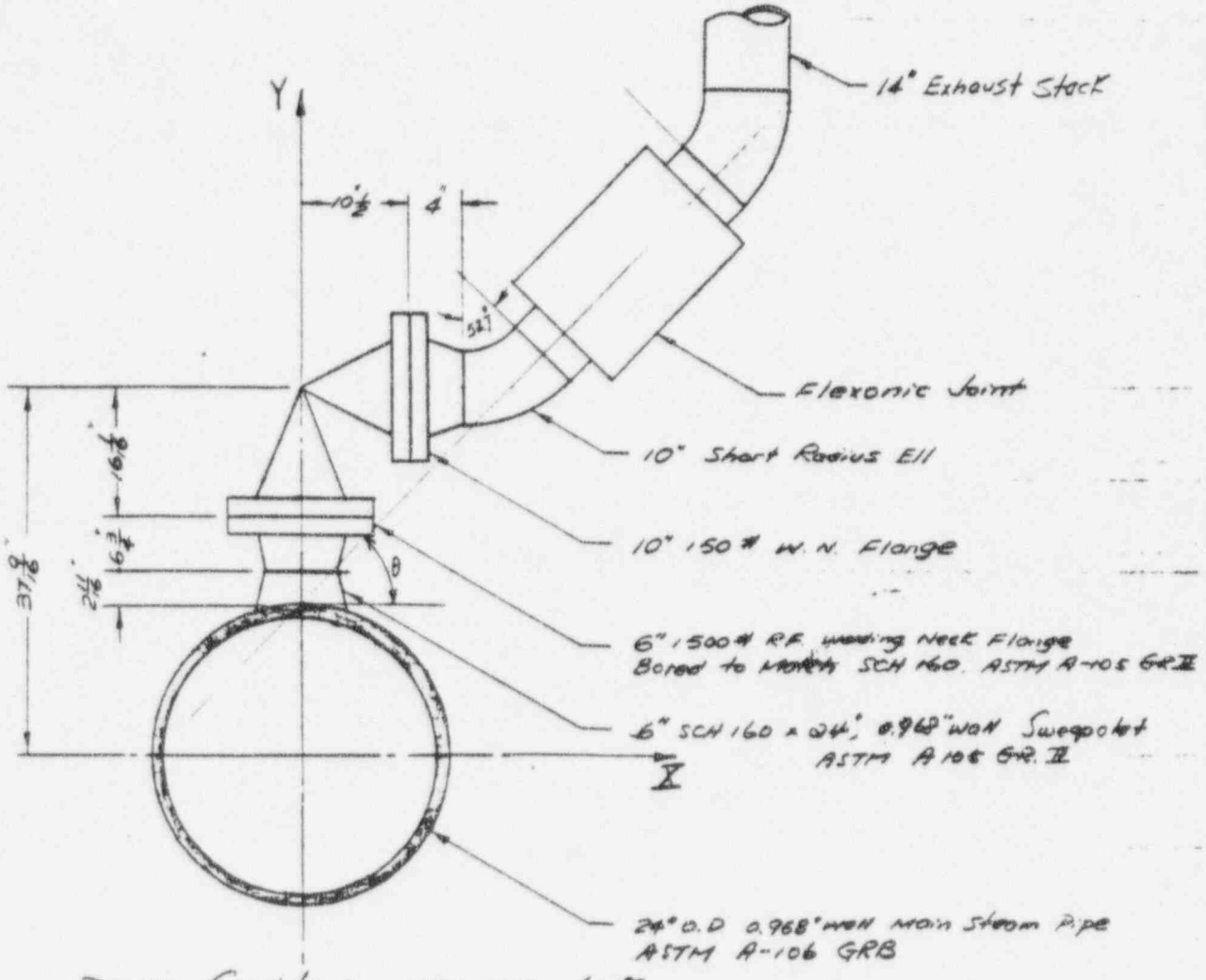


Fig. 1. Schematic Layout of Safety & Relief Valves

FPC	MADE 10/22/73	GILBERT ASSOCIATES, INC.
CR-3	CHK'D.	ENGINEERS AND CONSULTANTS
M.S. SAFETY & RELIEF VALVES	BQ. CF.	READING, PENNA.
	CF. DFN.	4203-027 (WORK ORDER)
	ENG. M.Z. Lee	SIZE / DRAWING / REV.
	REV. CH. APPV. DATE J. Ferranello 12/16/74	



Design Conditions 1050 psig 600°F

Fig. 2. Safety Valve Connections

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CLIENT: Florida Power Corp
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SYSTEM: Main Steam Safety and Relief Valve Systems
ORIGINATOR: M.Z Lee
DATE: 9/22/73
CALCULATION FOR:
REVIEWER: A F Fiorentino
DATE: 12/16/74
RESULTS:

Set Pressure

a. Valve Tag No. Set Pressure and Types (Ref 7, 8, 9)

Valve Tag No	Set Pressure psig	Accumulation %	Type	Electronic Connector No
MSV-33F	1050	9		MSEJ-1
MSV-34F	1050	9		MSEJ-6
MSV-35F	1050	9		MSEJ-15
MSV-36F	1050	9		MSEJ-11
MSV-37F	1070	7	I	MSEJ-2
MSV-38F	1070	7		MSEJ-7
MSV-39F	1070	7		MSEJ-16
MSV-41F	1070	7		MSEJ-12
MSV-42F	1090	5		MSEJ-3
MSV-43F	1090	5		MSEJ-8
MSV-44F	1090	5		MSEJ-17
MSV-45F	1090	5		MSEJ-13
MSV-46F	1100	4		MSEJ-4
MSV-47F	1100	4		MSEJ-18
MSV-40	1100	(4)	II	MSEJ-9
MSV-48	1100	(4)		MSEJ-14

Type I: Dresser 3707RA Orifice 1.6 in²
Inlet 6" 1500# Outlet 10" 150# RF
Weight 1257 #

Type II: Dresser 3777QA Orifice 11.04 in²
Inlet 6" 1500# Outlet 8" 150# RF

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CALCULATION FOR:
REVIEWER: A. J. Furnelle
DATE: 12/16/74
RESULTS

Dead Weight and Center of Gravity (C.G.)

Dead weight and C.G. of components above the safety valve inlet sweepolet connection will be estimated (Ref. Fig. 1)

Component	Spec	Weight W_i (#)	$\bar{X}_i$ (in)	$\bar{Y}_i$ (in)
Safety Valve	Dresser 3707R	1257	1	39.0
Inlet Flange	6" 1500# R.F	164 + Bolts = 190	0	20
Outlet Flange	10" 150# W.N R.F	52 + Bolts = 65	11.5	37.5625
Outlet Elbow	10" S.R 53°	$62.3 \times \frac{53}{90} = 36.7$	16	37.8
Flexonic Joint	MSEJ-4	Half of 181 lb = 91	28.5	42.5
Resultant		1639.7	$\bar{X}$ = 3.16	$\bar{Y}$ = 40.377

Note: $\bar{X} = \frac{\Sigma W_i X_i}{\Sigma W_i}$ $\bar{Y} = \frac{\Sigma W_i Y_i}{\Sigma W_i}$

For the rest of calculation it can be taken that

$W_o = \Sigma W_i = 1640$ lbs

$\bar{X} = 3.2"$

$\bar{Y} = 40.4"$

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ORIGINATOR: M Z Lee
DATE: 10/22/73
CALCULATION FOR:
REVIEWER: J F Furnello
DATE: 11/16/74

RESULTS

Optimal Exit Angles

In order to minimize moment around T-Joint of safety valve inlet created by safety valve discharge reaction force, the discharge angle is chosen in such a way that the discharge thrust force passes the T-Joint (Fig. 2 on p 4)

The optimal jet angle θ can be determined analytically as follows. (See later page for derivation) → Pg 9

For 6"x10" safety valves

$a = 14.5"$ $b = 25.5625"$, $c = 10"$

$A = a^2 + (b+c)^2 = 1474.94$

$B = 2ac = 290$

$C = c^2 - (b+c)^2 = -1164.69$

$$\theta = \sin^{-1}\left[\frac{-B + \sqrt{B^2 - 4AC}}{2A}\right]$$

$= \sin^{-1} 0.7957 = 52.7°$

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SYSTEM: M.S. SAFETY & RELIEF VALVES
ORIGINATOR: M Z. Lee
DATE: 10/22/73
REVIEWER: A J Fiorello
DATE: 12/16/74

CALCULATION FOR:

RESULTS

For 6" x 8" Safety Valves

$a = 14"$, $b = 23.5625"$, $c = 8"$

$A = a^2 + (b+c)^2 = 1192.19$

$B = 2ac = 224$

$C = c^2 - (b+c)^2 = -933.19$

$$\theta = \sin^{-1} \frac{-B + \sqrt{B^2 - 4AC}}{2A}$$

$= \sin^{-1} 0.7952 = 52.68°$

It is chosen to use $\theta = 53°$ for both types of safety valves.

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REVIEWER: A. F. Fiorentello
DATE: 12/16/73
RESULTS

Derivation of Optimal Jet Angle

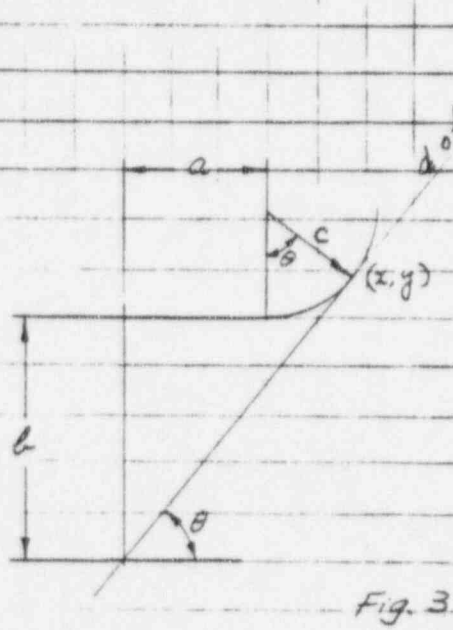

Fig. 3

$$\tan\theta = \frac{b + C(1-\cos\theta)}{a + C\sin\theta}$$

$$a\sin\theta + C = (b+c)\cos\theta$$

$$(b+c)\sqrt{1-\sin^2\theta} = a\sin\theta + C$$

$$\left[a^2 + (b+c)^2\right]\sin^2\theta + 2ac\sin\theta + c^2 - (b+c)^2 = 0$$

$$\sin\theta = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$

where $A = a^2 + (b+c)^2$

$B = 2ac$

$C = c^2 - (b+c)^2$

and

$x = a + c\sin\theta$

$y = x\tan\theta = b + c(1-\cos\theta)$

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ORIGINATOR: M. Z. Lee
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CALCULATION FOR:
REVIEWER: A. F. Fernandez
DATE: 12/16/74

RESULTS

Discharge Capacity W

Maximum discharge capacities at set pressure 1100 psig are as follows.

6" x 10" Orifice "R" valve — 940,000 #/hr

According to Babcock & Wilcox DWG No. 620-1007 Discharge capacity for set pressure 1100 psig at 4% accumulation is 845,795 #/hr.

Since rated capacity is 90% of actual flow

$$W = 845{,}759\ \#/hr \times \frac{1}{0.9} = 940{,}000\ \#/hr$$

$$m = \frac{940{,}000}{3600} \cdot \frac{1}{32.2} = 8.1\ (\#\text{-Sec}^2/\text{ft})$$

Dresser catalog N-100 (Ref 1) gives discharge capacity — see pg 110

W_{10} = 885,529 #/hr for set pr 1100 at 10% Acc
W_3 = 809,855 #/hr for " at 3% Acc

Therefore, W = 845,759 #/hr at 4% acc. is resonable.

By Napier's formula (Ref 2) — see pg 112

$$W_N = 51.5\,Ap$$

where A = orifice area = 16 in²
p = absolute pressure at inlet
= 1.1 x 1050 (design pr) + 14.7
= 1170 psia

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CLIENT: FPC
PROJECT: CR3
FILING CODE:
W.O. 4003-027 PAGE 110F112

SYSTEM: M.S. SAFETY + RELIEF VALVES
CALCULATION FOR:
ORIGINATOR: M Z. Lee
DATE 10/22/73
REVIEWER: A F Ferranello
DATE 12/16/74

RESULTS

$W_N = 51.5 \times 16 \times 1170 = 964{,}000$ #/hr

Which is close to 970,000 #/hr. Therefore, the capacity based on Dresser's data will be used in all calculations.

6" × 8" Orifice "Q" valve (orifice area = 11.04 in²) From Dresser Catalog N = 10.0 (Ref 1) — 645,000 #/hr — see Pg 110.

$W_6 = 611{,}014$ #/hr at set pr 1100 psig, 10% Acc

$W_3 = 572{,}600$ #/hr " 3% Acc

Estimated capacity at 4% accumulation

$W_4 = 579{,}000$ #/hr

$W = W_4 \times \frac{1}{0.9} = 645{,}000$ #/hr.

$m = \frac{645{,}000}{3600} \times \frac{1}{32.2} = 5.56$ (#-Sec/ft)

By Napier's formula (For check only)

$W_N = 51.5 A P = 51.5 \times 11.04 \times 1170$

$= 666{,}000$ #/hr

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ORIGINATOR: M.Z. Lee
DATE: 10/22/73
CALCULATION FOR:
REVIEWED: L. J. Fernandez
DATE: 12/16/74

RESULTS

Discharge Reaction Forces F

Consolidated Technical Manual Con-1 (Ref. 3) and Consolidated Outlet Reaction Chart (Ref. 4) give the following data

10" Outlet Valve Type 3707R — 23.5 Kips
at capacity 940,000 #/hr, 1100 psig set pr. 4% Acc.
Reaction Force F = 23.5 Kips

Outlet Pressure P_o = 125 psig

8" Outlet Valve Type 3777Q

at Set Pressure 1100 psig
4% Accummulation

Reaction Force F = 15.3 Kips — 15.3 Kips

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PROJECT CR-3

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SYSTEM M.S. SAFETY & RELIEF VALVES

ORIGINATOR M. Z. Lee

DATE 10/22/73

CALCULATION FOR

REVIEWER A. J. Fernandez

DATE 12/16/74

RESULTS

Outlet steam condition and reaction force will be calculated independently by the following:

Inlet Steam Conditions

$p_1 = 1100 \times 1.04 + 14.7 = 1157$ psia

$t_1 = 600°F$

From Steam Table

t_1	p_1	Enthalpy h_1'	Spec. Vol v_1	Entropy s_1
600	1150	1230.2	0.4264	1.4152
600	1200	1243.9	0.4222	1.4243
600	1157	1231.7	0.4261	1.4157

At inlet 6" pipe

Flow Velocity $V_1 = \frac{W}{A_1} v_1 = \frac{940,000}{3600} \cdot \frac{0.4261}{\frac{28.9}{144}}$

$= 532.3$ fps

Total Energy at inlet of safety valve

$h_0 = h_1' + \frac{V_1^2}{2gJ}$

$= 1231.7 + 5.655 = 1237.4$

Stagnation Enthalpy $h_0 = 1237.4$ BTU/lb

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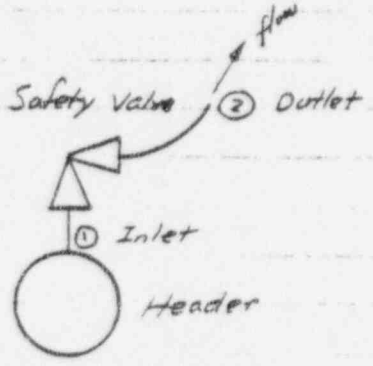
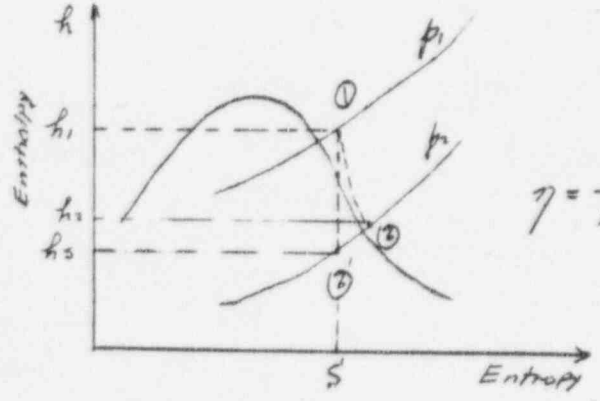


a. Actual Process

b. Modeled Nozzle



$$\eta = \frac{h_1 - h_2}{h_1 - h_2'}$$

c. h-S diagram

Fig. 4 Safety Valve Discharge Process

For Exit Pressure $p_2 = 125$ psig

$p_2 = 125 + 15 = 140$ psia

For isentropic expansion

$S_2 = S_1 = 1.4157$

Quality $x_s = \frac{1.4157 - 0.5069}{1.5751 - 0.5069} = \frac{0.9088}{1.0682} = 0.85$

$h_s = 324.8 + (1193 - 324.8)x_s$

$= 324.8 + 868.2 \cdot 0.85 = 1062.8$

$\Delta h_s = h_1 - h_s = 1237.4 - 1062.8 = 174.6$

Let the safety valve be approximately modeled by a simple nozzle with nozzle efficiency η, then

$\Delta h = h_1 - h_2 = \eta \Delta h_s$

$V_2 = 223.8 \sqrt{\Delta h}$

$W = \frac{3600}{144} A_2 \frac{V_2}{v_2} = 25 \times 78.9 \frac{V_2}{v_2}$

where A_2 = flow area of outlet pipe

$= \begin{cases} 78.9 \text{ in}^2 \text{ for } 10'' \text{ outlet} \\ 50.2 \text{ in}^2 \text{ for } 8'' \text{ outlet} \end{cases}$

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CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4203-027 PAGE 160-112

SYSTEM: M.S. SAFETY & RELIEF VALVES
CALCULATION FOR:
ORIGINATOR: M. Z. Lee
DATE: 10/22/73
REVIEWER: A. F. Fiumello
DATE: 12/16/74

RESULTS

For 10" Outlet

η	Δh	V_o	h_2	V_2	W_2
25%	43.6	1480	1193.8	3227	905,000
30%	52.4	1620	1185.0	3188	1,001,000
26.9%	47.0	1531.1	1190.4	3.213	940,000

Outlet Steam Conditions

Pressure	$p_2 = 125$ psig
Velocity	$V_2 = 1531$ fps
Specific Volume	$v_2 = 3.213$ ft³/#
Enthalpy	$h_2 = 1190.4$ BTU/#
	$t = 353$ °F

Acoustic Velocity $V_s = \sqrt{kg \cdot 144\, pv} = \sqrt{1.22 \times 32.2 \times 144 \times 125 \times 3.213}$
$= 1650$ ft/sec $> V_2 = 1531$ ft/sec o.k.

Reaction Force

$$F = p_2 A_2 + \frac{W}{g} V_2$$

$$= 125 \times 78.9 + \frac{940{,}000}{3600} \times \frac{1531}{32.2}$$

$$= 9{,}850 + 12{,}400$$

$$= 22{,}250 \text{ lbs.}$$

Dresser's data $F = 23.5$ Kips shall be used

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SYSTEM: M.S. SAFETY + RELIEF VALVES
ORIGINATOR: M Z Lee
DATE: 10/22/73
CALCULATION FOR:
REVIEWER: J F. Ferranello
DATE: 12/16/74
RESULTS

Reaction Forces for other Outlet Pressures

$p_2 = 100$ Psia

$S_2 = S_1 = 1.4157$

$X_s = \frac{1.4157 - 0.4740}{1.6026 - 0.4740} = 0.834$

$h_s = 298.4 + (1187.2 - 298.4) \times X_s = 1042.4$

$\Delta h_s = h_1 - h_s = 1237.4 - 1042.4 = 195$

η	Δh	V_2	h_2	v_2	W
20%	39	1396	1198.4	4.55	605,000
25%	48.8	1560	1188.6	4.45	692,000
30%	58.5	1710	1178.9	4.3	785,000

Since 1710 fps is approximately the choking velocity of steam with $h_1 = 1237.4$ at $p = 1100$ psia, it is impossible to increase flow rate beyound 785,000 #/hr

$F = (100 - 15) \times 78.9 + \frac{785,000}{3600} \times \frac{1710}{32.2}$

$= 6,700 + 11,600 = 18,300^{\#} < 23.5$ Kips

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CLIENT: E.P.C.
PROJECT: CR-3
FILING CODE:
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SYSTEM: M. S. SAFETY & RELIEF VALVES
ORIGINATOR: M. Z. Lee
DATE: 10/22/73
CALCULATION FOR:
REVIEWER: A. F. Fiorello
DATE: 12/16/74
RESULTS

$p_2 = 150$ psia $\quad s_2 = s_1 = 1.4157$

$$x_s = \frac{1.4157 - 0.5138}{1.5694 - 0.5138} = 0.855$$

$$h_s = 330.5 + (1194.1 - 330.5) \times 0.855 = 1067.5$$

$$\Delta h_s = h_1 - h_s = 1237.4 - 1067.5 = 169.9$$

η	Δh	v	h_2	v_2	W
30%	51	1600	1186.4	2.9	1085.000
25%	42.4	1458	1195	3.023	950.000
20%	34	1305	1203.4	3.1	820.000
24.8%	42.2	1445	1194.8	3.02	940.000

Acoustic Velocity

$$V_s = \sqrt{kg \times 144 pv} = \sqrt{1.3 \times 32.2 \times 144 \times 150 \times 3.02} = 1650 \text{ fps} > 1445 \text{ fps}$$

$$F = (150 - 15)\,78.9 + \frac{940.000}{3600} \cdot \frac{1445}{32.2}$$

$$= 10,640 + 11,720$$

$$= 22,360 \text{ lbs} \quad \leftrightharpoons 23.5 \text{ Kips}$$

by Dresser

$\therefore$ p_a may reach 135 psig

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SYSTEM M. S. SAFETY & RELIEF VALVES

ORIGINATOR N. Z. Lee

DATE 10/22/73

CALCULATION FOR

REVIEWER A. J. Fernello

DATE 12/16/74

RESULTS

6"x8" Type 3777 QA

$p_2 = 120$ psia $\quad S_2 = S_1 = 1.4157$

$$x_s = \frac{1.4157 - 0.4916}{1.0967} = 0.845$$

$$h_2 = 312.4 + 877.9x = 1124.4$$

$$\Delta h_t = 1237.4 - 1124.4 = 113 \text{ BTU/\#°R}$$

η	Δh	V_2	h_2	U_2	W
25	28.2	1190	1209.2	3.93	378,000
30	33.9	1350	1203.5	3.86	437,000
35	39.6	1410	1197.8	3.8	464,000
40	45.2	1500	1192.2	3.75	500,000
50	56.5	1680	1180.9	3.65	575,000

Acoustic Velocity

$$V_2 = \sqrt{kg \times 144 p v} = \sqrt{1.3 \times 32.2 \times 144 \times 120 \times 3.65} = 1630 \text{ ft/sec}$$

∴ max flow capacity of 645,000 #/hr can not be obtained for $.25 < \eta < 0.5$ at $p_2 = 120$ psia

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SYSTEM M. S. SAFETY & RELIEF VALVES

ORIGINATOR M. Z. Lee

DATE 10/22/73

CALCULATION FOR

REVIEWER J. F. Farnsell

DATE 11/16/74

RESULTS

$p = 150$ psia $\quad S = 1.4157$

$$x = \frac{1.4157 - 0.5138}{1.5694 - 0.5138} = 0.852$$

$$h_{s_2} = 331.6 + 863.6x = 1066.6 \ \text{BTU/\#/°R}$$

$$\Delta h_{12} = 1237.4 - 1066.6 = 170.8$$

η	Δh	V_2	h_2	$\sqrt{}$	W
25	42.6	1460	1194.8	3.01	606,000
30	51.2	1610	1186.2	2.9	695,000
27.2	46.3	1520	1191.1	2.95	645,000

Acoustic Velocity

$$V_s = \sqrt{kg\,p'v} = \sqrt{1.3 \times 32.2 \times 150 \times 2.95 \times 144}$$

$$= 1630 > 1520$$

$p_2 = 135$ psig

$v_2 = 2.95$ ft³/#

$V_2 = 1520$ ft/sec

$h_{t_2} = 1191.1$

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SYSTEM M.S. SAFETY & RELIEF VALVES

CALCULATION FOR

ORIGINATOR M.Z. Lee

DATE 10/22/73

REVIEWER J. F. Ferranello

DATE 12/16/74

RESULTS

Reaction Force

$$F = P_o A_1 + \dot{m} V_2 = 135 \times 50 + \frac{645{,}000}{3600} \frac{1520}{32.2}$$

$$= 6{,}750 + 8{,}450 = 15{,}200 \text{ lbs}$$

Dresser's Reaction Force Table shows

$F = 15.3$ Kips

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SYSTEM M.S. SAFETY + RELIEF VALUES

CALCULATION FOR

ORIGINATOR M. Z. Lee

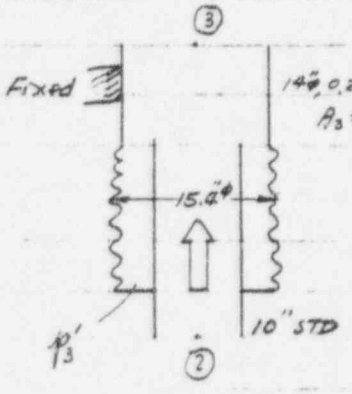
DATE 10/22/73

REVIEWER J. F. Furnello

DATE 12/16/74

RESULTS

Force on Flexonic Shroud



p_2 = 1400 psia
V_2 = 1531 ft/sec
v_2 = 3.213 ft³/#
h_2 = 1190.4 BTU/#
S_2 = 1.574 BTU/#/°F
A_2 = 78.9 in²

Fig. 5 Flexonic Connector.

When the steam flows from state ② to state ③ the following conditions must be satisfied

Continuity: $\frac{V_3 A_3}{v_3} = \frac{V_2 A_2}{v_2}$

Energy Eq. $h_2 + \frac{V_2^2}{2gJ} = h_3 + \frac{V_3^2}{2gJ}$

Adiabatic Process. $\left(\frac{p_2}{p_3}\right) = \left(\frac{v_3}{v_2}\right)^k \quad k = \frac{c_p}{c_v}$

(CRANE: Flow of Fluid through Pipes p1-9)

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ORIGINATOR: M. Z. Lee
DATE: 10/22/73

CALCULATION FOR:

REVIEWER: A. J. Fernello
DATE: 12/16/74

RESULTS

Assume $p_2 = 210$ psia

$k = 1.295$

$$v_3 = v_2 \left(\frac{p_2}{p_3}\right)^{\frac{1}{k}} = 2.213 \left(\frac{140}{210}\right)^{\frac{1}{1.295}} = 2.34$$

$$V_3 = V_2 \cdot \frac{A_2}{A_3} \cdot \frac{v_3}{v_2} = 1531 \times \frac{28.9}{143.1} \times \frac{2.34}{3.213} = 65 \text{ ft/sec}$$

$$\frac{V_3^2}{2gJ} + h_3 \quad (\text{at } p=210,\ v=2.34)$$

$$= \frac{(65)^2}{64.4 \times 778} + 1228 = 7.6 + 1228 = 1236$$

$$h_2 + \frac{V_2^2}{2gJ} = h_0 = 1237.4$$

$\therefore p_3 \doteq 195$ psig

For long stack

This pressure may be reached at some distance from the flexonic joint. The pressure inside the flexonic joint may be much lower. According to Prandtl (Ref 20, p 80), the pressure in the flexonic joint is the same as the pressure in exit elbow, i.e ← see pg. 111

$$p_3' = p_2 = 135 \text{ psi}$$

Pressure area in flexonic shroud

$$A_3 = \frac{\pi}{4}(15.4^2 - 10.75^2) = 96 \text{ in}^2$$

$$p_3' A_3' = 135 \times 96 = 13 \text{ Kips} \quad (\text{used in p. 38})$$

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SYSTEM M. S. SAFETY & RELIEF VALVES

ORIGINATOR M. Z. Lee

DATE July 30, 74

CALCULATION FOR

REVIEWER A. F. Fiorentino

DATE 12/16/74

RESULTS

Dynamic Load Factors

Rise time of valve discharge reaction force
Most of the safety valves open to 70% lift in 0.04 Sec. Assume max discharge reaction force is reached in 0.04 Sec at constant rate

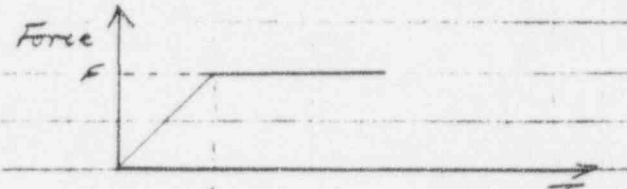

Fig 6

For this type of forcing function the DLF depends on the parameter

$$\frac{t_r}{T} = f \cdot t_r \qquad f = \text{natural freq.}$$

Lowest Natural Frequency

The following arguments are utilized in estimating the lowest natural frequency of the pipe.

1. For the same length of span, the simply supported beam gives lowest f among all type of supports.

2. A single span simply supported beam gives the lower f than the same

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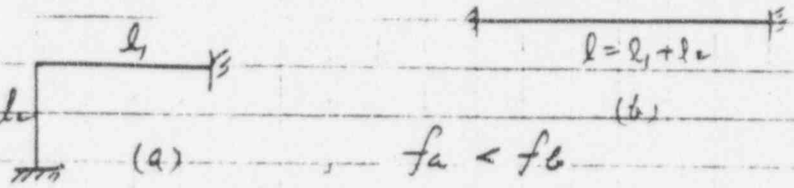
SYSTEM M.S. SAFETY + RELIEF VALVES		ORIGINATOR M. Z. Lee DATE 7/30/74
CALCULATION FOR		REVIEWER S. F. Ferrarelli DATE 12/16/74

section of the beam as a part of a continuous beam.

3. The longest span gives the lowest fundamental freq.

4. For the same length, a bend pipe has lower f than a straight pipe. The ratio is approximately the same as those given in Fig 9.13 of Kellog [Ref 52]

RESULTS: ← see pg 112



, $f_a < f_b$

Fig. 7

5. For a concentrated mass mounted on a pipe, min f is obtained when the mass is located at the center of the span.

Take the longest span between MSH218, MSH222 of line CR-3

$l = 7.31 + 15.75 = 22.56'$

$E = 27.9 \times 10^6$ psi

$I = 4653$ in^4

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CALCULATION FOR

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DATE 7/30/74

REVIEWER L. F. Fennello

DATE 12/16/74

RESULTS

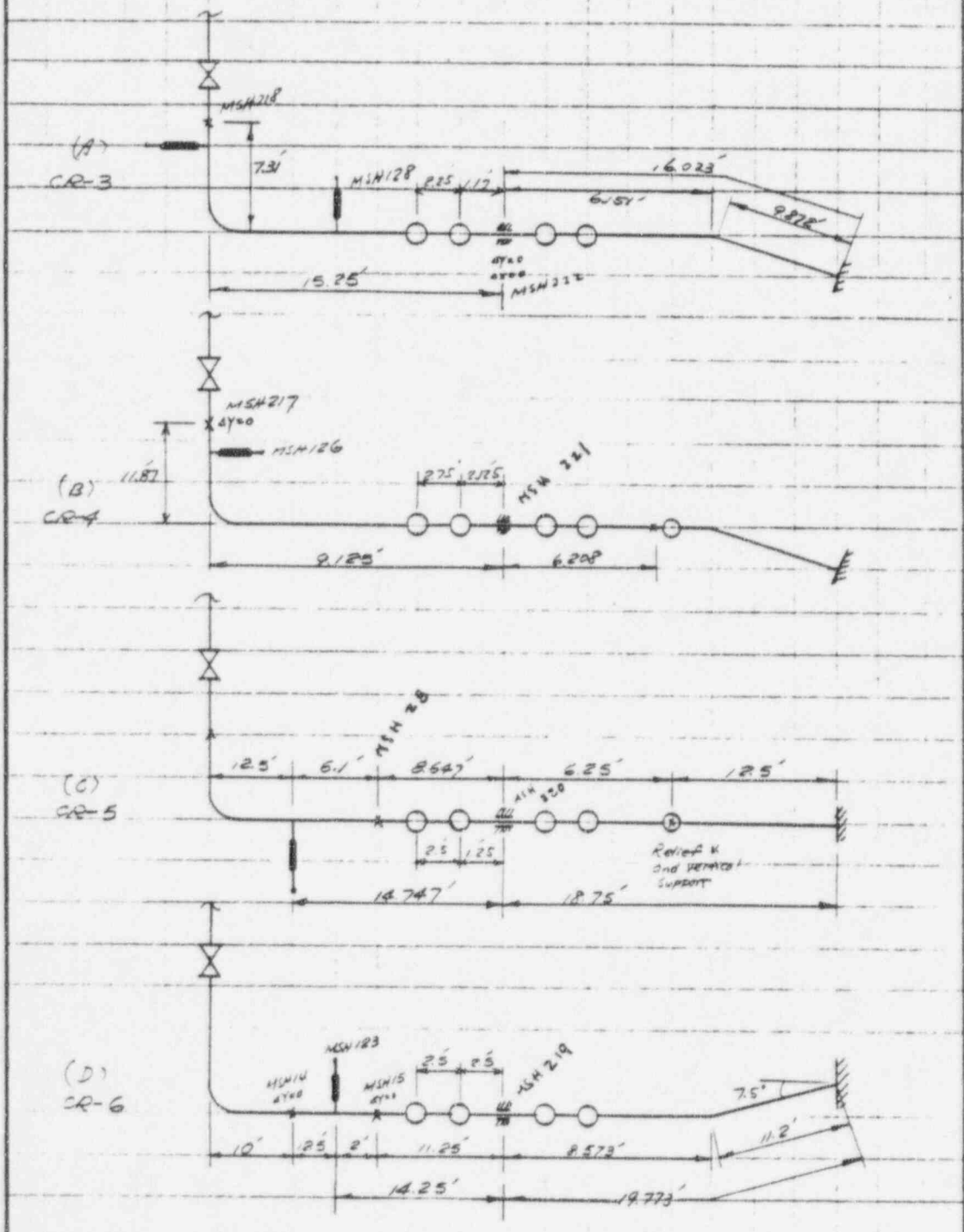

Fig 8

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ORIGINATOR M. Z. Lee

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CALCULATION FOR

REVIEWER A. F. Ferranello

DATE 12/16/74

RESULTS

$W = 238.1 + 19.4 + 0 = 257.5$ lb/ft
(pipe) (Insulation) (Steam)

It can be shown that the fundamental frequency can be calculated by

$$f = 0.565 \sqrt{\frac{EI}{(\frac{1}{2}W + \Sigma P_i \sin^2 \frac{\pi}{\ell} x_i)\ell^3}}$$

For the worst case (Line eR-4)

$$\frac{1}{2}W + \sum_{i=1}^{2} P_i \sin \frac{\pi}{\ell} x_i$$

$$= \frac{1}{2} \times 257.5 \times 21 + 1608 \left(\sin^2 \frac{4.25}{21}\pi + \sin^2 \frac{3.125}{21}\pi \right)$$
(Value WT)

$$= 2704 + 1608 (0.4444 + 0.0977) = 3575$$

$$f = 0.565 \sqrt{\frac{27.9 \times 10^6 \times 46.53}{(21)^3 \times 3575}} = 32.9 \text{ Hz.}$$

This is for straight pipe of length 21'.

For bend $\ell/R_2 = \frac{9.125}{11.53} = 0.768$, $\alpha = \pi/2$

From Fig 9.13 of Kellog the correction ratio is

$$\frac{1.3}{1.69} = 0.77$$

$f' = 0.77 \times 32.9 = 25.3$ Hz

$f' \cdot T = 25.3 \times 0.04 = 1.01$

From Fig 2.9 (a) of Biggs

DLF ≤ 1.22 for $fT \geq 1.01$

$\therefore$ DLF = 1.22

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GILBERT ASSOCIATES, INC. ENGINEERS AND CONSULTANTS READING, PA.	CLIENT: F.P.C. PROJECT: CR-3	FILING CODE	W.O. 4203-027	PAGE 28 OF 112

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CALCULATION FOR:

ORIGINATOR: M.Z. Lee DATE 10/22/73

REVIEWER: [illegible] DATE 12/16/74

RESULTS

Stress Intensification Factors for Sweepolets

Overall stress intensification factors for the sweepolets used will be calculated by using the formula given by Bonney Forge (Ref. 12).

r = mean radius of branch pipe (Ref. Detail of Fig.)

$$= \frac{ID+OD}{4} = \frac{5.326+(5.187+0.719\times 2)}{4} = 2.988''$$

R = mean radius of run pipe

$$= (24-0.968)/2 = 11.516''$$

t = wall thickness of branch pipe (take minimum wall at weld)

$$= -(5.326-5.187)/2 + 0.719 = 0.6495''$$

Say $0.65''$

T = nominal wall thickness of run pipe = 0.968"

Fs = side correction factor

$$\max\begin{Bmatrix} 1. + 0.05(r-3) = 1 + 0.05(2.988-3) \\ 1 \end{Bmatrix} = 1.0$$

$F_1 = F_2 = 1.0$ for dressed welds

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SYSTEM M.S. SAFETY + RELIEF VALVES		ORIGINATOR M.Z. Lee	DATE 10/22/73
CALCULATION FOR		REVIEWER A.F. Ferrarelli	DATE 12/16/74

Stress intensification factors (Table 1 of Ref. 12)

$$i_{bt_3} = 0.45\left(\frac{R}{T}\right)^{2/3}\left(\frac{r}{R}\right)^{1/2}\left(\frac{t}{T}\right)F_1F_5$$

$$= 0.45\left(\frac{11.516}{0.968}\right)^{2/3}\left(\frac{2.988}{11.516}\right)^{1/2}\left(\frac{0.65}{0.968}\right)\times 1 \times 1 =$$

$$= 0.7986 < 0.85$$

$\therefore$ $\boxed{i_{bt_3} = 0.85}$ — RESULTS: $i_{bt_3} = 0.85$

$$i_{bp_3} = \min\begin{cases}\left[0.17\left(\frac{R}{T}\right)^{2/3} + 0.25\right]\left(\frac{t}{T}\right)F_1F_5 \\ 0.45\left(\frac{R}{T}\right)^{2/3}\left(\frac{r}{R}\right)^{1/2}\left(\frac{t}{T}\right)F_1F_5\end{cases}$$

$$= \min\begin{cases}\left[0.17\left(\frac{11.516}{0.968}\right)^{2/3} + 0.25\right]\left(\frac{0.65}{0.968}\right)F_1F_2 = 0.7627 \\ 0.7986\end{cases}$$

$$= 0.7627 < 0.85$$

$\therefore$ $\boxed{i_{bp_3} = 0.85}$ — RESULTS: $i_{bp_3} = 0.85$

$i_{t_3} = 1.0$ (Table 1, Ref 12 Line #4 for M_{t3}) — RESULTS: $i_{t_3} = 1.0$

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RESULTS

$$i_{t_1} = max \begin{cases} 1.5 \\ 0.8 \left(\frac{R}{T}\right)^{2/3} \left(\frac{r}{R}\right) F_s \end{cases}$$

$$= max \begin{cases} 1.5 \\ 0.8 \left(\frac{11.576}{0.968}\right)^{2/3} \left(\frac{2.988}{11.576}\right) \times 1.0 = 1.085 \end{cases}$$

$$= 1.5$$

$$i_{t_2} = i_{bt_1} = i_{bt_2} = i_{bp_1} = i_{bp_2} = i_{t_1} = 1.5$$

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ORIGINATOR M.Z. Lee

DATE 10/22/73

CALCULATION FOR

REVIEWER A.F. Fiorentino

DATE 12/16/74

RESULTS

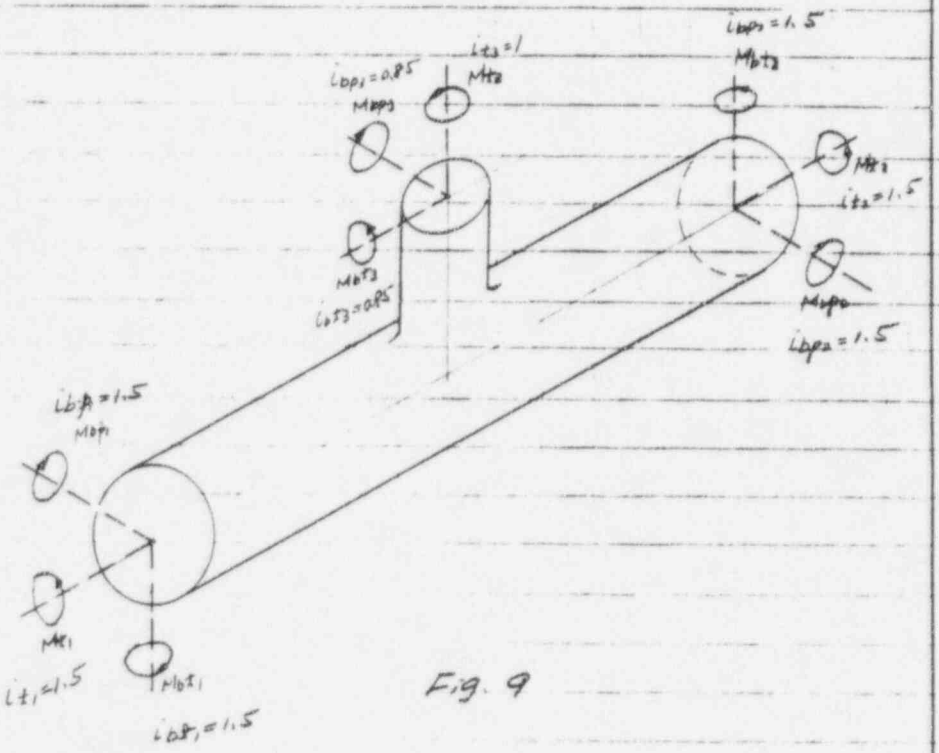

Fig. 9

For application of ASME Boiler and P.V. Code Sec. III or B31.1.0 we can take

$i_b = 1$ for branch

$i_r = 1.5$ for main run

for moments in any direction.

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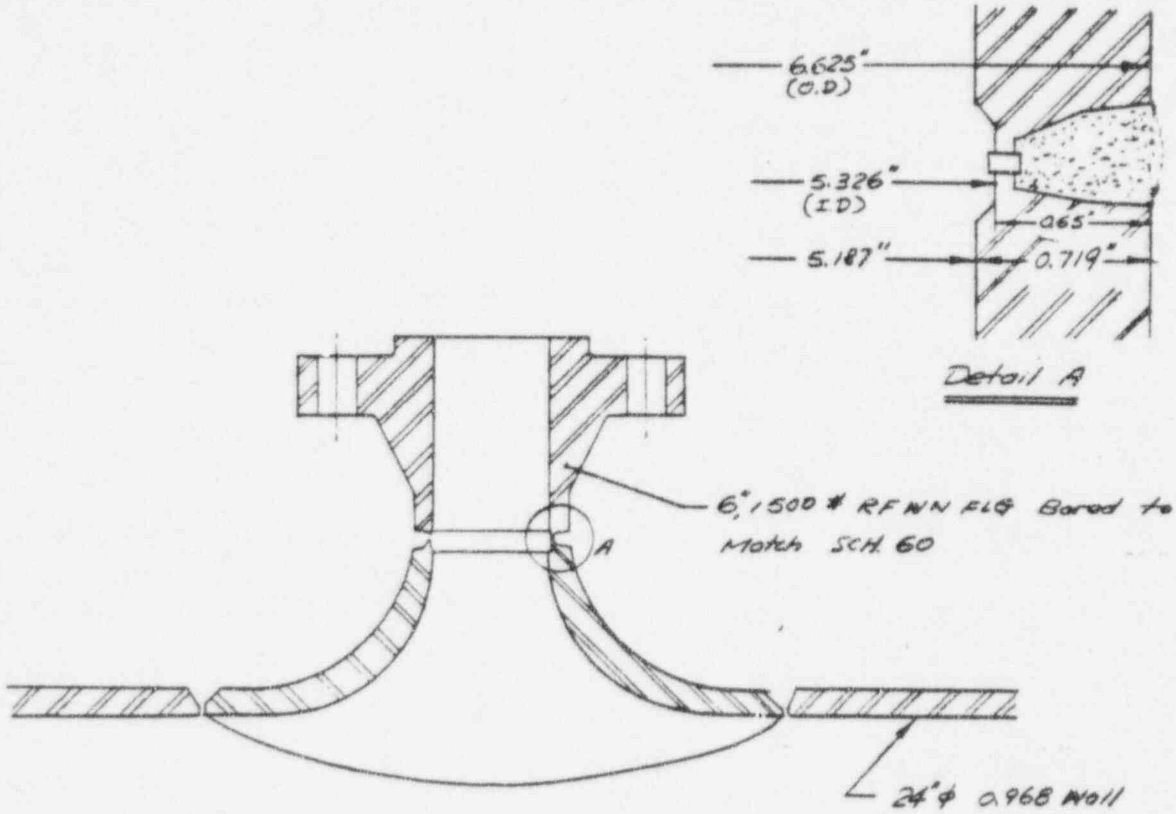
FPC	MADE 10/22/73	GILBERT ASSOCIATES, INC. ENGINEERS AND CONSULTANTS READING, PENNA.
CR-3	CHK'D.	
M.S. SAFETY & RELIEF VALVES	SQ. CF.	
	CF. DFN.	4203-027 WORK ORDER
	ENG. M.Z. Lee	SIZE DRAWING
	REV. CH. APP. DATE J.F. Fumarello	2/16/74



Notes 1. Flush or Dressed Weld Reqd on Both Branch and Run Welding.

2. Bonney Forge Sweepolet ASTM A-105 Gr. II

3. Detail A is taken from Fig. 4 PD 301-001 or GAI DWG 4203 C-301-001 Ref. 43

Fig. 10 Weldolet Connections

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DATE: 10/22/73
CALCULATION FOR:
REVIEWER: A. F. Fiumelli
DATE: 12/16/74
RESULTS

Sectional Modulus

Header

$Z_h = \pi (R)^2 T$

R = mean radius of pipe = 11.516"
T = nominal wall thickness of header = 0.968

$Z_h = \pi \times (11.516)^2 \times 0.968 = 405 \text{ in}^3$

GAI DWG STANDARD gives

$Z_h = 388 \text{ in}^3$ for 24" SCH 60 (wall = 968)

Branch (see Ref. 13 Section 104.8.4)

$Z_b = \pi (r_m)^2 t_{bs}$

r_m = mean radius of branch = 2.988"
t_{bs} = less of T_h or $i T_b$ = 0.968
$T_h = 0.968$
$i T_b = 1.0 \times 0.65 = 0.65$

$Z_b = \pi (2.988)^2 \times .65 = 18.4 \text{ in}^3$

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GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4203-027 PAGE 34 OF 112
SYSTEM: M.S. SAFETY + RELIEF VALVES
ORIGINATOR: M. Z. Lee
DATE 10/22/73
CALCULATION FOR:
REVIEWER: A F Ferranti
DATE 12/16/74

RESULTS

Allowable stresses

Sweepolet, Weldolet, Flanges, Elbow
Material ASTM A105 GR. II

S_h = 17,500 lbs/in² for temp ≤ 650°F
(p58 of Ref 13)
S_c = 17,500
$S_a = f(1.25 S_c + 0.25 S_h)$ = 26,200 lbs/in²
take f=1

24" Main Run
Material ASTM A106 GR B

S_h = 15,000 lbs/in² for temp ≤ 650°F
(Ref. 13. p57)
$S_c = S_h$
$S_a = f(1.25 S_c + 0.5 S_h)$ = 22,500 lbs/in²

6". 1500# R.F. W.N Flange, Valve Body
Material ASTM A105-GR II

S_h = 17,500 lbs/in² for temp ≤ 650°F

S_a = 26,200 lbs/in²

Discharge stack (Line Spec 150-4)
Material ASTM A53 Gr B Seamless
S_h = 15,000 lbs/in²

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CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4203-027 PAGE 350 of 112

SYSTEM: M.S. SAFETY & RELIEF VALVES
CALCULATION FOR:

ORIGINATOR: M.Z. Lee
DATE: 10/22/73
REVIEWER: A.F. Ferranello
DATE: 12/10/74

RESULTS

Stresses due to Internal Pressure

Pressure

Design Pressure $P_D = 1050$ psig

Safety Valve Set Pr. and Accumulation

Set Pr.	Acc	Peak Pr.
1050	9%	$1050 \times 1.09 = 1144$
1070	7%	$1070 \times 1.07 = 1144$
1100	4%	$1100 \times 1.04 = 1142$

Max Peak Pressure $P_{max} = 1144$ psig

Branch

Axial $S_x = \frac{PD_o}{4t_b} = \frac{1144 \times 6.625}{4 \times 0.719} = 2,640$ lbs/in²

Hoop $S_\phi = 2S_x = 5,280$ lbs/in²

Main Run

Axial $S_x = \frac{PD_o}{4T} = \frac{1144 \times 24}{4 \times 0.968} = 7,100$ lbs/in²

Hoop $S_\phi = 2S_x = 14,200$ lbs/in²

* 6,243 lb/in²
USING $S = \frac{P(d^2)}{D^2 - d^2}$
Ron Amos 9-24-79

FILING

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CLIENT: F PC
PROJECT: CR-3
FILING CODE:
W.O. 4203-027 PAGE 360F112
SYSTEM: M. S. SAFETY & RELIEF VALVES
ORIGINATOR: M. Z. Lee
DATE 10/22/73
CALCULATION FOR:
REVIEWER: A. J. Fernandez
DATE 12/10/74
RESULTS

Torsion due to Safety Valve Reaction

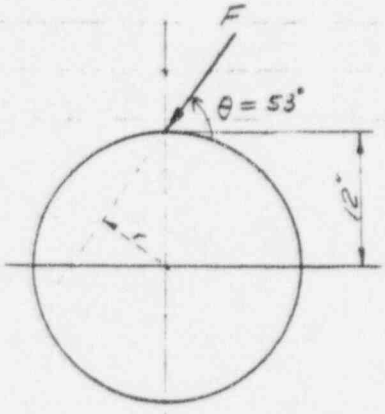

Fig. 11

$r = 12 \cos 53^\circ = 7.28''$

6"x10" valve

Safety Valve Discharge Reaction = 23.5 Kips
Flexonic Backpressure 13.0
Total 36.5

Torsion $M_t = 36.5 \times 7.28 = 267$ Kip-in

6"x8" valve

S. V. Discharge Reaction = 15.3 Kips
Flexonic Backpressure * 12.2 Kips
Total 27.5 Kips

Torsion $M_t = 27.5 \times 7.28 = 200$ Kip-in

* $F = \frac{\pi}{4}(17.75^2 - 2.625^2) \times 135^{psig} = 12,200$ #

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GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
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CLIENT: F. P. C.

PROJECT: CR-3

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SYSTEM: M. S. SAFETY + RELIEF VALVES

CALCULATION FOR:

ORIGINATOR: M. Z. Lee
DATE 10/20/73

REVIEWER: J. F. Ferranello
DATE 12/16/74

RESULTS

Moments at outlet of sweepolet

Ref. to Fig. 2.

Moment arm $r = 2\frac{11}{16} \cos 53^\circ = 2.688 \times 0.6$
$= 1.62$

Allow erection error say
$r = 3.''$

$M = 36.5 \times 3 = 110$ Kip-in

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CLIENT: FPC
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W.O.: 4203-02 PAGE: 38 of 112
SYSTEM: M.S. SAFETY + RELIEF VALVES
ORIGINATOR: M. Z. Lee
DATE: 11/8/74
CALCULATION FOR:
REVIEWER: J. F. Fennello
DATE: 12/16/74
RESULTS

Loads on Safety Valve Connection for Computer Input

6"x10" Safety Valves

Safety Valve Discharge Reaction Force = 23.5 Kips (p. 12)

Flexonic Backpressure (p23) = 13.0 Kips

Total 36.5 Kips

D.L.F = 1.5

Dynamic Load = $36.5 \times 1.5 = 54.75$ Kips = F_D

The components of discharge force are:

Horizontal Component $F_H = F_D \cos 53^\circ = 54.75 \times 0.6018 = 32,949$

Vertical Component $F_V = F_D \sin 53^\circ = 54.75 \times 0.7986 = 43,732$

Torsion

$M_t = F_D \cdot r = 54.75 \times 7.28 = 399$ Kip-in (p.36)

$M_t' = M_t \times \frac{1}{12} \times 1000 = 33,200$ lb-ft

Note: Proper signs must be chosen for Fx, Mt depending on actual valve installations

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CLIENT: FPC
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SYSTEM: M.S. SAFETY + RELIEF VALVE
ORIGINATOR: M Z. Lee
DATE: 11/8/73
CALCULATION FOR:
REVIEWER: A F. Ferranello
DATE: 12/16/74

RESULTS

6"×8" Safety Valves (MSV-40, MSV-48)

Safety Valve Discharge Reaction (p.12) 15.3 Kips
Flexonic Back pressure 12.2
Total 27.5 Kips

D.L.F. = 1.5

Dynamic Load $F_D = 1.5 \times 27.5 = 41.2$ Kips

Torsion $M_t = 41.2 \times 7.28'' = 800$ Kip-in

$M_t' = 300 \times \frac{1000}{12} = 25{,}000$ lb-ft

$F_V = 41.2 \times \sin 53° = 41.2 \times 0.7986 = 32.9$ Kips

$F_H = 41.2 \times \cos 53° = 41.2 \times 0.6018 = 24.8$ Kips

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CLIENT: FPC
PROJECT: CR-3
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SYSTEM: M.S. SAFETY + RELIEF VALVE
ORIGINATOR: M. Z. Lee
DATE: 10/8/74
CALCULATION FOR:
REVIEWER: A. F. Ferarello
DATE: 12/16/74
RESULTS

For Line CR-3 (Fig 12 on p 36)

Loads \ Branch Pt / Valve	45 / MSV-46	52 / MSV-42	60 / MSV-37	67 / MSV-33
Fx	-32,949 lbs	+32,949 lbs	-32,949 lbs	+32,949 lbs
Fy	-43,732	-43,732	-43,732	-43,732
Mz	+33,200 lb-ft	-33,200 lb-ft	+33,200 lb-ft	-33,200 lb-ft

For Line CR-6

$F_x = -32,949$ lb

$F_y = -43,732$ lb

$M_z = +33,200$ lb-ft

For Line CR-5

Load \ Point / Valve	62 / MSV-48	66 / MSV-45	71 / MSV-41	75 / MSV-36	79 / MSV-26
Fx	-24,800	-32,949	-32,949	-32,949	0
Fy	-32,900	-43,732	-43,732	-43,732	-81,100 lbs *
Mz	+25,000 lb-ft	+33,200	+33,200	+33,200	0

* See pg 94

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GAI 350 REV. 10-72

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CLIENT: F.P.C.
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SYSTEM: M.S. SAFETY & RELIEF VALVES
ORIGINATOR: M. Z. Lee
DATE 11/8/73
CALCULATION FOR:
REVIEWER: J. J. Fernandez
DATE 12/16/74
RESULTS

Line CR-4 (Ref Fig. 14. p 48)

MSV-34

$F_y = -43,732$

$F_x = -32949 \cos 10° = -32,448.$

$F_z = -32949 \sin 10° = -5,726.$

$M_z = +33,200 \cos 10° = +32,696.$ 16-ft

$M_x = -33,200 \sin 10° = -5,765.$ 16-ft

$M_y = 0.$

MSV-38

$F_y = -43,732.$ 165

$F_x = +32949. \cos 35° = +26,990.$ 165

$F_z = +32,949 \sin 35° = +18,899.$ 165

$M_z = -33,200 \cos 35° = -27,196.$ 16-ft

$M_x = +33,200 \sin 35° = 19,043.$ 16-ft

Loads \ Pt / Valve	54 MSV-40	58 MSV-43	62 MSV-38	69 MSV-34	73 MSV-25
F_x	+24800 (165)	+32949 (165)	+26,990	-32,448.	0
F_y	-32900 (165)	-42,732 (165)	-43,732	-43,732.	-31,100 (165)
F_z	0	0	+18,899	-5,726.	0
M_x	0	0	+19,043.	-5765	0
M_y	0	0	0	0	0
M_z	-25,000 (4-165)	-33,200 (4-165)	-27196	+32,696	0

* See pg 94

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CLIENT: FPC
PROJECT: CR #3
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SYSTEM: M.S. SAFETY & RELIEF VALVES
ORIGINATOR: A.L.E
DATE: 7/8/74
CALCULATION FOR: CR-3 DEADLOAD
REVIEWER: M.Z. Lee
DATE: 7/8/74
RESULTS

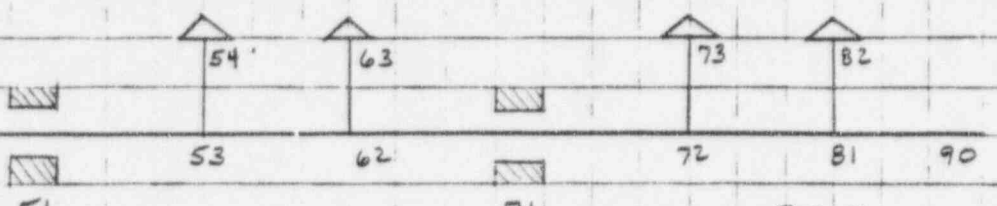

Fig. 11

POINT	MX FT.LB.	MY FT.LB	MZ FT LB	M IN. LB.		
51	4928	-368	997	60,492	✓	
53	776	-492	997	16,260		
53	776	-492	1268	18,780		
62	-7185	-555	1268	87,804		
62	-7185	-555	997	87,300		
SUPPORT 71	-13,826	-587	997	166,488	✓	66,492
71	-13,826	-587	356	166,116		
72	-8050	-500	356	96,876	✓	96,880
72	-8050	-500	628	97,068	✓	97,079
81	-871	-317	628	13,428		
81	-871	-317	356	11,904		
90	499	-208	356	7764		
53	0	0	-272	3264		
54	0	0	-272	3264		
62	0	0	272	3264		
63	0	0	272	3264		
72	0	0	-272	3264		
73	0	0	-272	3264		
81	0	0	272	3264		
82	0	0	272	3264		

FILING CODE

GAI 260 REV 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC
PROJECT: CR-3
FILING CODE:
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SYSTEM: M.S. SAFETY & RELIEF VALVES
ORIGINATOR: A.L.E.
DATE: 7/8/74
CALCULATION FOR: CR-3 SEISMIC X-Y QUAKE
REVIEWER: M.Z. Lee
DATE: 7/8/74
RESULTS

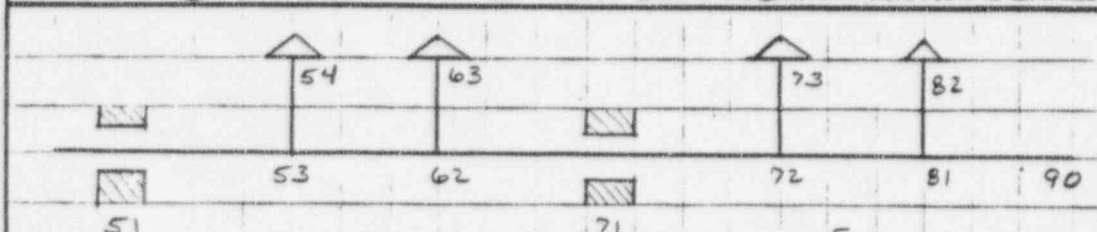

Fig. 11

POINT	MX FT. LB.	MY FT. LB	MZ FT. LB.	M IN. LB.	
51	3446	4979	2432	78,300	✓
53	1531	1387	2432	38,280	
53	1109	1363	2909	40,776	
62	1676	2688	2909	51,600	
62	1623	2691	3363	55,224	
71	2405	4040	3363	85,500	69,367
71	2405	4040	2713	65,136	
72	2036	3675	2713	60,012	✓
72	2085	3671	1772	54,936	54,943
81	1418	3386	1772	48,912	
81	1592	3383	803	45,888	
90	1143	3244	803	42,372	
53	979	69	1776	24,348	✓
54	671	69	1230	16,824	
62	903	62	1285	18,852	
63	619	62	890	13,020	
72	815	40	1439	19,848	
73	559	40	996	13,704	
81	814	33	2217	28,332	✓
82	558	33	1535	19,596	

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GAI 350 REV 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC

PROJECT: CR-3

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SYSTEM: M.S. SAFETY + RELIEF VALVES

ORIGINATOR: A.L.E

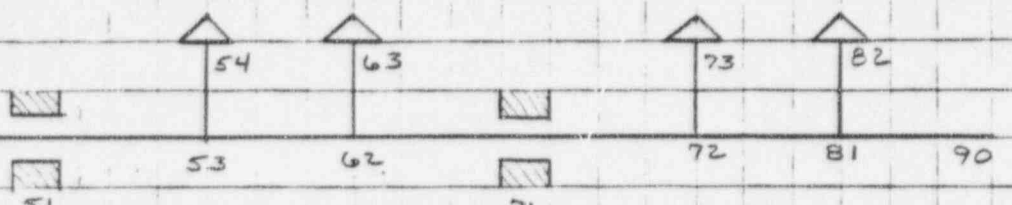
DATE: 7/8/74

CALCULATION FOR: CR-3 SEISMIC Y-Z QUAKE

REVIEWER: M Z Lee

DATE: 7/8/74

RESULTS



E.g. 11

POINT	MX FT. LB.	MY FT. LB	MZ FT. LB.	M IN. LB.		RESULTS
51	10,724	14,649	7804	237,132	✓	
53	6101	5342	7804	135,048		
53	3162	5241	7835	119,304		
62	4411	12,800	7835	187,704		
62	2902	12,848	7880	184,176		
71	5113	17,282	7880	236,028	✓	236,028
71	5113	17,282	3344	219,960		
72	4553	14,684	3344	188,760		
72	5143	14,649	2713	189,120		189,130
81	3213	10,262	2713	133,080		
81	5210	10,247	1268	138,780		
90	3802	8456	1268	112,284		
53	3339	135	829	41,316	✓	
54	2288	135	569	28,332		
62	3494	136	470	42,336		
63	2395	136	326	29,040		
72	3513	145	748	43,128	✓	43,136
73	2407	145	516	29,580		
81	3265	122	1971	45,780		45,789
82	2238	122	1366	31,488		

FILING CODE

GAI 360 REV 10-72

GILBERT ASSOCIATES, INC.
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READING, PA.

CLIENT: FPC
PROJECT: CR-3
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SYSTEM: M.S. SAFETY & RELIEF VALVE
ORIGINATOR: A.L.E.
DATE: 7/8/74
CALCULATION FOR: CR-3 THERMAL
REVIEWER: M.Z. Lee
DATE: 7/8/74
RESULTS

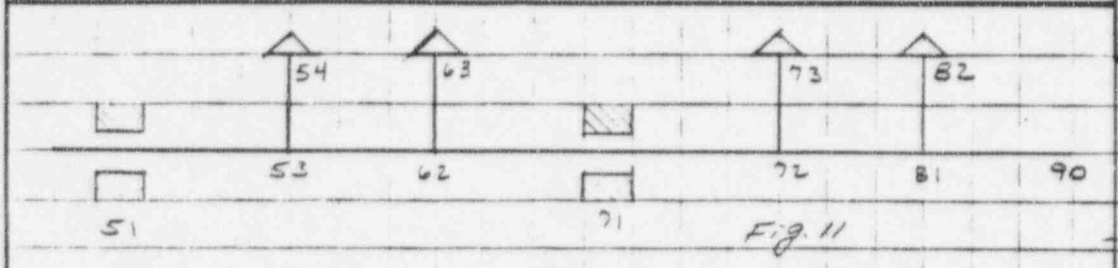

Fig. 11

POINT	MX FT. LB.	MY FT. LB.	MZ FT. LB.	M IN. LB		
51	22,122	-7905	-31,527	471,792		
53	31,152	-34,346	-31,527	672,852	✓	672.869
53	31,152	-34,346	-31,527	672,852		
62	35,710	-47,690	-31,527	808,860		
62	35,710	-47,690	-31,527	808,860	✓	
71	38,073	-54,609	-31,527	883,896	✓	883.917
71	38,073	-54,609	6415	802,548		
72	32,994	-67,937	6415	909,564	✓	
72	32,994	-67,937	6415	909,564		
81	22,445	-95,617	6415	1,181,100	✓	
81	22,445	-95,617	6415	1,181,100		
90	16,094	-112,282	6415	1,363,320	✓	
53	0	0	0	0		
54	0	0	0	0		
62	0	0	0	0		
63	0	0	0	0		
72	0	0	0	0		
73	0	0	0	0		
81	0	0	0	0		
82	0	0	0	0		

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CLIENT: FPC

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W.O. 4283-027 | PAGE 46 OF 112

SYSTEM: M. S. SAFETY & RELIEF VALVES

ORIGINATOR: A. L. E

DATE: 7/8/74

CALCULATION FOR: CR-3 SAFETY VALVE LOADS

REVIEWER: M. Z. Lee

DATE: 7/8/74

RESULTS

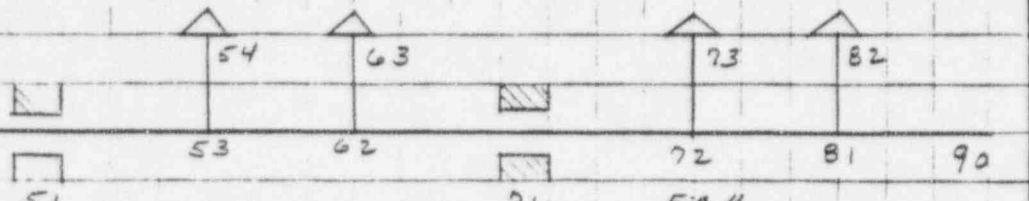

Fig 11

POINT	MX FT. LB.	MY FT. LB	MZ FT. LB	M IN. LB.	
51	21,066	-9900	12,979	319,800	
53	33,168	-11,292	12,979	448,368	
53	33,168	-11,292	-20,221	485,436	
62	-59,122	62,140	-20,221	1,057,476	✓
62	-59,122	62,140	12,979	1,040,976	
71	-157,999	61,776	12,979	2,041,704	✓
71	-157,999	61,776	11,513	2,040,432	
72	-68,308	42,008	11,513	972,156	✓
72	-68,308	42,008	-21,687	996,864	✓
81	19,581	75,085	-21,687	966,828	
81	19,581	75,085	11,513	941,340	
90	13,256	50,367	11,513	640,068	
53	0	0	0	0	
54	0	0	0	0	
62	0	0	0	0	
63	0	0	0	0	
72	0	0	0	0	
73	0	0	0	0	
81	0	0	0	0	
82	0	0	0	0	

FILING CODE

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC
PROJECT: CR-3
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SYSTEM: M.S. SAFETY & RELIEF VALVES
ORIGINATOR: M. Z. Lee
DATE: 7/8/74
CALCULATION FOR: CR-3
REVIEWER: J. F. Ferraello
DATE: 12/16/74

RESULTS

Header

$$\frac{PD}{4t} + 0.75i\frac{M_A}{B} = 7,100 + \frac{0.75 \times 1.5}{388} \times 166,492$$

$$= 7,100 + 483$$

$$= 7,583 \text{ psi}$$

Seismic

$$\sigma_{B1} = 0.75i\frac{M_{O1}}{B} = \frac{0.75 \times 1.5}{388} \cdot 236,039 = 684 \text{ psi}$$

Safety Valve

$$\sigma_{B2} = 0.75i\frac{M_{O2}}{B} = \frac{0.75 \times 1.5}{388} \cdot 2,041,704 = 5,920 \text{ psi}$$

Thermal

$$\sigma_c = i\frac{M_C}{B} = 1.5 \times \frac{1}{388} \times 883,907 = 3,417 \text{ psi}$$

Sustained load

$$\frac{PD}{4t} + 0.75\frac{M_A}{B} = 7,583 \text{ psi} < 15,000 \text{ psi}$$

Occasional load

$$\frac{PD}{4t} + 0.75\frac{M_A + M_B}{B} = 7,583 + 684 \times 2 + 5920 = 14,871 \text{ psi}$$

$$< 18,000 \text{ psi}$$

Thermal load

$$i\frac{M_C}{B} = 3,417 < 22,500 \text{ psi} = S_A$$

FILING CODE

GAI 250 REV. 10-72

GILBERT ASSOCIATES, INC. ENGINEERS AND CONSULTANTS READING, PA.	CLIENT F.P.C.	FILING CODE
	PROJECT CR-3	W.O. 4203-027 PAGE 48 OF 112
SYSTEM M.S. SAFETY + RELIEF VALVES		ORIGINATOR M. Z. Lee DATE 7/8/74
CALCULATION FOR Line CR-3		REVIEWER A. F. [illegible] DATE 12/10/74

RESULTS

Branches

$$\frac{pD_o}{4t} = 2,640 \text{ psi}$$

$$0.75i \frac{M_A}{Z} = 0.75 \times 1.5 \times \frac{3264}{18.4} = 133 \text{ psi}$$

Seismic

$$\frac{0.75i}{Z} M_{B_1} = \frac{0.75 \times 1.5}{18.4} \times 45,789 = 2,800$$

Safety valve

$$\frac{0.75i}{Z} M_{B_2} = 0.75 \times 1.5 \times \frac{\overset{p.15}{110,000} \times \overset{DLF}{1.5}}{18.4} = 6,725 \text{ psi}$$

$$\frac{pD_o}{4t} + 0.75i \frac{M_A}{Z} = 2640 + 133 = 2,773 \text{ psi}$$

$$\frac{PD_o}{4t} + 0.75i \frac{M_A + M_B}{Z} = 2,773 + 2 \times 2,800 + 6725$$

$$= 15,098 \text{ psi}$$

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT F. P. C.

PROJECT CR-3

FILING CODE

W.O. 4203 - 027 PAGE 49 OF 112

SYSTEM M.S. SAFETY + RELIEF VALVES

ORIGINATOR M Z. Lee

DATE 7/8/74

CALCULATION FOR CR-3

REVIEWER A F Fernandez

DATE 12/16/74

RESULTS

		Header			Branch	
		Max		Allowable	Max.	Allowable
(1)	Pressure	7100 (6,243)			2,640	
(2)	Dead Load	483			123	
(3)	(1) + (2)	7,583 (6,726)		15,000	2,773	12,500
(4)	Seismic	1,268			5,600	
(5)	Safety Valve Discharge	5,920			6,725	
(6)	(3) + (4) + (5)	14,871 (14,014)		18,000	15,098	21,000
(7)	Thermal	3,417		22,500	Small	

NUMBERS IN PARENTHESES SEE page 35 R. Brown 9-24-79

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GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: F. P. C

PROJECT: CR-3

FILING CODE

W.O. 4203-027 | PAGE 50 OF 112

SYSTEM: M. S. SAFETY + RELIEF VALVES

ORIGINATOR: M. Z. Lee

DATE: 7/8/74

CALCULATION FOR: CR-4 DEADLOAD

REVIEWER: L. J. Fiorelli

DATE: 12/16/74

RESULTS

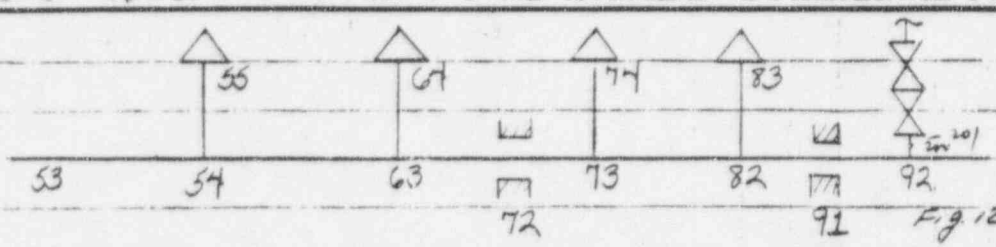

Fig. 12

Point	Mx ft. lb.	My ft lb.	Mz ft. lb.	M in. lb.	
53	6014	-228	432	72,406	✓
54	5875	-150	432	70,713	✓
54	5875	-150	161	70,549	✓
63	-338	21	161	4,500	
63	-338	21	-111	4,277	
72	-9959	153	-111	119,530	✓
72	-9959	153	1293	120,525	✓
73	-3580	130	1293	49.102	
73	-3724	130	1070	46,522	
82	-2236	105	1070	29,773	
82	-2283	105	1331	31,737	
91	-5030	86	1331	62,446	
91	-5030	86	1331	62,446	
92	-3598	81	1331	46,046	
54	0	0	272	3,264	
55	0	0	272	3,264	
63	0	0	272	3,264	
64	0	0	272	3.264	✓
73	-156	0	222	3,256	
74	-156	0	222	3,256	
82	47	0	-261	3,182	
83	47	0	-261	3,182	
201	0	0	1,650	19,800	

CR-4FDL 05/21/74

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GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: F. P. C.
PROJECT: C R - 3
FILING CODE:
W.O. 4203 - 027
PAGE 5 OF 112

SYSTEM: M. S. SAFETY & RELIEF VALVES
ORIGINATOR: M. Z. Lee
DATE: 7/8/74
CALCULATION FOR: CR-4 Seismic y - z
REVIEWER: J. F. Ferranello
DATE: 12/16/74
RESULTS

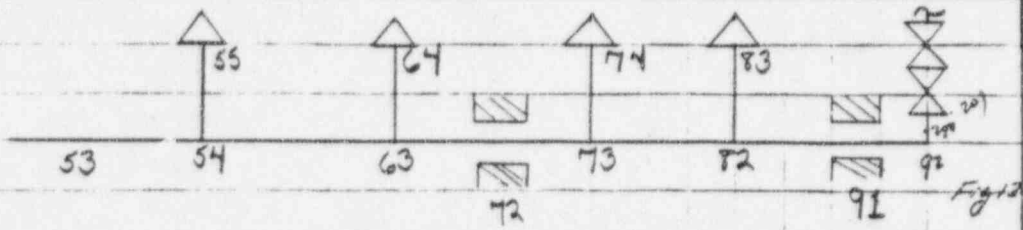


Fig 13

Point	Mx ft. lb.	My ft. lb.	Mz ft. lb.	M in. lb.	
53	22058	19115	14385	390,483	✓
54	18826	11910	14385	318214	
54	18937	11941	14416	319529	✓
63	12020	6767	14416	239427	
63	13528	6854	14494	251731	✓
72	9761	18739	14494	307468	✓
72	9761	18739	4012	258076	
73	5205	14262	4012	188439	
73	6799	14278	2572	192263	
82	1982	10225	2572	128738	
82	3681	10235	1137	131233	
91	1655	7501	1137	93181	
91	1655	7501	1137	93181	
92	1602	6986	1137	87083	
54	4831	194	1439	60534	✓
55	3310	194	1000	41558	
63	4188	167	982	51658	
64	2870	167	681	35453	
73	3414	100	1689	45723	✓
74	2349	100	1172	31525	
82	3381	128	3006	54311	✓
83	2318	128	2081	37412	
92 200 201	1511	623	1341	25370	

Ref. CR-4F 05/21/74

FILING CODE

GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC. ENGINEERS AND CONSULTANTS READING, PA.	CLIENT F. P. C.	FILING CODE
	PROJECT CR-3	W.O. 4203-027 / PAGE 52 of 112

SYSTEM: M. S. SAFETY + RELIEF VALVES

ORIGINATOR: M. Z. Lee DATE 7/8/74

CALCULATION FOR: CR-4 Seismic X-Y

REVIEWER: S. F. Ferrucello DATE 12/16/74

RESULTS

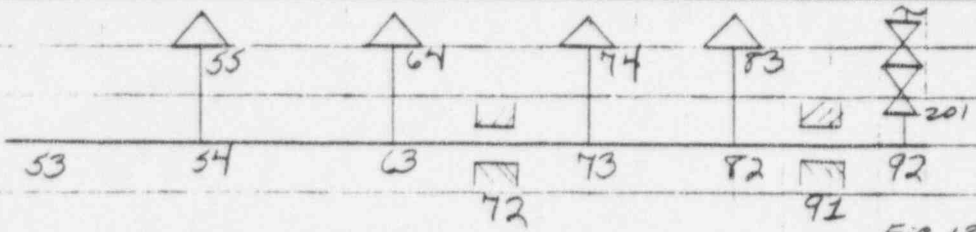


Fig. 18

Point	Mx ft. lb.	My ft. lb.	Mz ft. lb.	M in. lb.	
(53	11,056	8,880	7,266	191,205	✓
(54	9,554	6,100	7,266	161,570	✓
(54	9,615	6,122	7,496	163,710	
(63	6,399	2,247	7,496	121,305	
(63	6,995	2,267	8,098	131,260	
(72	5,430	7,275	8,098	145,980	✓
(72	5,430	7,275	4,688	122,604	✓
(73	3,140	5,343	4,688	93,249	
(73	3,830	5,358	2,945	86,575	
(82	1,458	4,551	2,945	67,361	
(82	2,010	4,551	1,243	61,536	
(91	1,333	3,920	1,243	51,876	
(91	1,333	3,920	1,243	51,876	
(92	1,288	3,805	1,243	50,460	
(54	2,399	96	3,194	47,949	✓
(55	1,644	96	2,215	33,121	
(63	2,128	85	2,197	36,718	
(64	1,458	75	1,523	25,321	
(73	1,712	85	2,437	35,753	
(74	1,175	85	1,675	24,672	
(82	1,663	77	3,708	48,775	✓
(83	1,138	77	2,567	33,708	
92 200 201	1795	740	1,513	29,538	

Ref: CR-4F 05/21/74

FILING CODE

GAI 350 REV 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT FPC

PROJECT CR3

FILING CODE

W.O. 4203-027 PAGE 53 OF 112

SYSTEM M.S. SAFETY & RELIEF VALVES

ORIGINATOR M.Z. Lee
DATE 7/18/74

CALCULATION FOR CR-4 SAFETY VALVE LOADS

REVIEWER S.F. Fiorentino
DATE 12/10/74

RESULTS

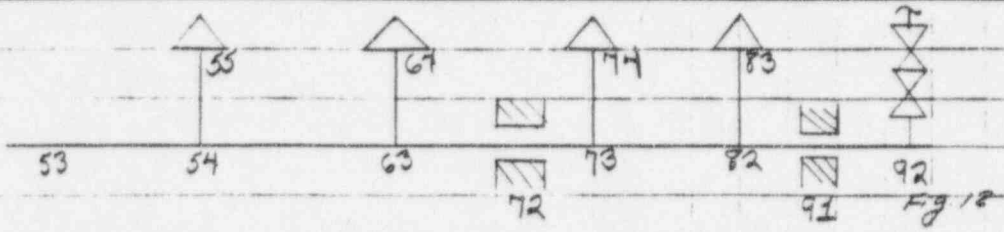


Fig 1

Point	Mx ft lb	My ft lb	Mz ft lb	M in lb	
53	10369	46483	14356	597589	
54	13005	69659	14356	867626	
54	13005	69659	39356	972696	
63	-71671	52444	39356	1,165,669	
63	-71664	52448	72556	1376128	✓
72	-230026	-32995	72556	2,921,329	✓
72	-230026	-32995	1005	2,798,590	✓
73	-62468	-20827	1005	790273	
73	-81511	-20827	28201	1,064,766	✓
82	-2494	-68671	28201	891336	
82	3271	-68671	-4495	826748	
91	-12519	-48168	-4495	599650	
91	-12519	-48168	-4495	599650	
92	472	-43507	-4495	524894	
54	0	0	0	0	
55	0	0	0	0	
63	0	0	0	0	
67	0	0	0	0	
73	0	0	0	0	
74	0	0	0	0	
82	0	0	0	0	
83	0	0	0	0	

) support

Ref CR-4FSVL 06/10/74
Safety valve discharge reaction load check with pg 2 of Stress report (Torsions are included)

FILING

GAI 360 REV 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT FPC

PROJECT CR-3

FILING CODE

W.O. 4203-027 PAGE 54 OF 112

SYSTEM M.S. SAFETY & RELIEF VALVES

ORIGINATOR M. Z Lee

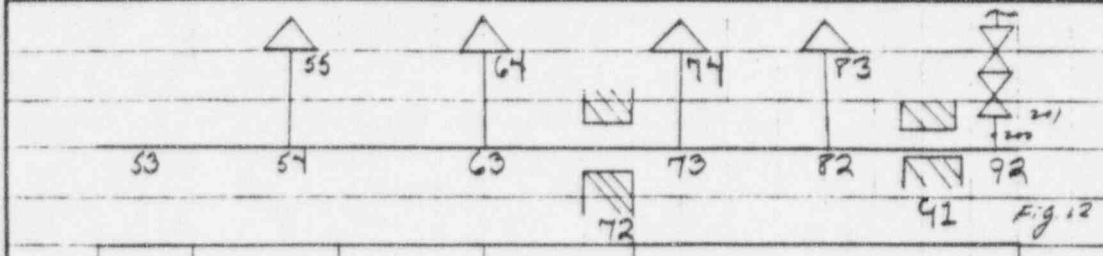
DATE 7/8/74

CALCULATION FOR CR-4 Thermal

REVIEWER A. J Bennett

DATE 12/16/74

RESULTS



Point	Mx ft lb	My ft lb	Mz ft lb	M in lb		
53	17975	-96875	-4375	1183507		
54	23248	-157637	-4375	1912825		
54	23248	-157637	-4375	1912825		
63	34850	-291314	-4375	3521085	✓	
63	34850	-291309	-4375	3521026		
72	43815	-394605	-4375	4764650	✓	Support
72	43815	-394605	-322	4764362		
73	27640	-335545	-322	4040180	✓	
73	27640	-335545	-322	4040180		
82	10515	-273011	-322	3278563		
82	10515	-273011	-322	3278563		
91	-3440	-222058	-322	2665019		
91	-3440	-222058	-322	2665019		
92	-3245	-210477	-322	2526027		
54	0	0	0	0		
55	0	0	0	0		
63	0	0	0	0		
64	0	0	0	0		
73	0	0	0	0		
74	0	0	0	0		
82	0	0	0	0		
83	0	0	0	0		
92 (20, 21)	0	0	0	0		

Ref. CR-4FT 06/07/74

FILING CODE

GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC. ENGINEERS AND CONSULTANTS READING, PA.	CLIENT: FPC	FILING CODE	
	PROJECT: CR-3	W.O. 4203-027	PAGE 55 OF 112
SYSTEM: M.S. SAFETY & RELIEF VALVES		ORIGINATOR: M. Z. Lee DATE 7/5/74	
CALCULATION FOR: CR-4 Combined Stresses		REVIEWER: S. F. Farrell DATE 12/16/74	

Header

Axial Stress due to Internal Pressure

$\sigma_p = \frac{p D_o}{4t} = 7,100$ psi (p35)
(6,243 psi) *

SEE PAGE 35
Ron Snow
9-24-79

Stress due to dead load

stress intensification factr $i = 1.5$

Sectional Modulus $Z = 388\ in^3$

$MA = 120,525$ lb-in

$\sigma_A = 0.75 i \frac{MA}{Z} = 0.75 \times 1.5 \times \frac{120,525}{388} = 349$ psi

Seismic Stress.

max Seismic Moment = 390,483 lb-in at pt. 53

$\sigma_{B1} = 0.75 i \frac{M}{Z} = 0.75 \times 1.5 \times \frac{390,483}{388} \times 2$

$= 2,264$ psi pt 53-54

$\sigma_{B1} = 0.75 i \frac{M}{Z} = 0.75 \times 1.5 \times \frac{307,468}{388} \times 2 = 1782$ psi
at pt 72

GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT F. P. C.

PROJECT C R-3

FILING CODE

W.O. 4203 - 027

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SYSTEM M. S. SAFETY + RELIEF VALVES

ORIGINATOR M. Z Lee

DATE 7/5/74

CALCULATION FOR CR-4 Combined Stress

REVIEWER A. J. Fasoulla

DATE 12/16/74

RESULTS

Safety Valve Reaction (DLF=1.5)

$$\sigma_{B2} = 0.75i\frac{M}{Z} = 0.75\times1.5\times\frac{3921.329}{388} = 8{,}470 \text{ psi}$$

at pt 72

$$\sigma_{B2} = 0.75i\frac{M}{Z} = 0.75\times1.5\times\frac{867{,}626}{388} = 2{,}516 \text{ psi}$$

at pt 54

Thermal

$$\sigma_C = i\frac{M_C}{Z} = 1.5\times\frac{4{,}764{,}650}{388} = 13{,}815 \text{ psi}$$

FILING CODE

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4203-027 | PAGE 57 OF 112

SYSTEM: M.S. SAFETY + RELIEF VALVES
ORIGINATOR: M Z Lee
DATE: 7/8/74

CALCULATION FOR: CR-4 Combined Stress
REVIEWER: J F Fernello
DATE: 12/16/74

RESULTS

Branch Connections

Internal Pr. $\frac{PD_o}{4t} = 2,640$ psi

Dead Load

$0.75i \frac{M_A}{Z} = 0.75 \times 1.5 \times \frac{3264}{18.4} = 133$ psi

Seismic $0.75 \times 1.5 \times \frac{60534 \times 2}{18.4} = 4,934$ psi

Safety Valve (p.25) DLF

$0.75 \times 1.5 \times \frac{110,000 \times 1.5}{18.4} = 6,725$ psi

Sustained Load

$2,640 + 133 = 2,773 < 17,500$ psi
p.32

Occasional Load

$2,640 + 133 + 4,934 + 6,725 = 14,432$ psi
$< 1.2 \times 17,500$ psi

FILING CODE

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4203-027 PAGE 58 OF 112

SYSTEM: M.S. SAFETY & RELIEF VALVES
ORIGINATOR: M. Z. Lee
DATE: 7/8/74
CALCULATION FOR: CR-4
REVIEWER: J. F. Fanello
DATE: 12/16/74

RESULTS

Summary

	Load	Header			Branch		
		Pts 53, 54	Pt 72	Allowable	Max	Allowable	
(1)	Pressure	7,100	7,100 (6,243)*		2,640		
(2)	Dead Load	(349)	(342)		183		
(3)	(1) + (2)	7,449	7,442 (6,592)*	15,000	2,773	17,500	* SEE PAGE 35 Ro Brown 9-24-79
(4)	Seismic	2,264	1,782		4,934		
(5)	Safety Valve Discharge	2,516	2,470		6725		
(6)	(3) + (4) + (5)	12,229	17,701 (16,844)*	18,000	14,432	21,000	
(7)	Thermal	(13,815)	13,815	22,500	Small		

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GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC
PROJECT: CR #3
FILING CODE:
W.O. 4203-027 PAGE 59 OF 112

SYSTEM: M.S. SAFETY & RELIEF VALVES
ORIGINATOR: A.L.E.
DATE: 7/8/74
CALCULATION FOR: CR-5 DEADLOAD
REVIEWER: M.Z. Lee
DATE: 7/8/74
RESULTS

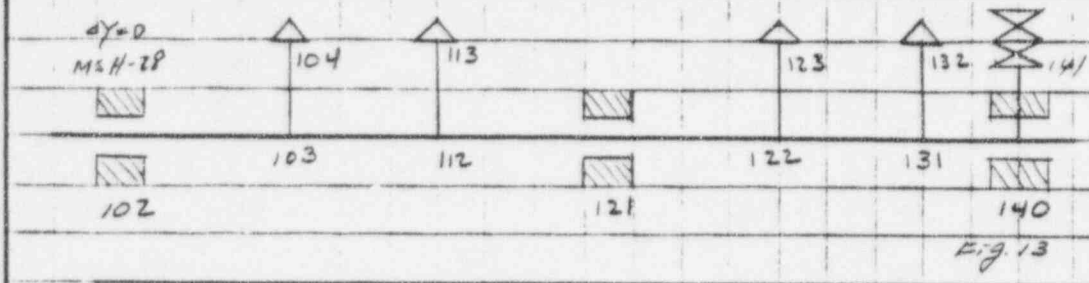

Fig. 13

POINT	MX FT. LB	MY FT. LB	MZ FT. LB	M IN. LB.	
102	-15,158	126	2069	183,588	✓
103	-300	156	2069	25,152	
103	-300	156	2434	29,484	
112	550	171	2434	30,012	
112	550	171	2800	34,296	
121	-1768	178	2800	39,792	✓
121	-1768	178	-1734	29,784	
122	1269	161	-1734	25,848	
122	1269	161	-1369	22,476	
131	1871	126	-1369	27,852	
131	1871	126	-1003	25,512	
140	-3439	91	-1003	42,996	✓
103	0	0	-365	4380	✓
104	0	0	-365	4380	
112	0	0	-365	4380	
113	0	0	-365	4380	
122	0	0	-365	4380	
123	0	0	-365	4380	
131	0	0	-365	4380	
132	0	0	-365	4380	
140 141	0	0	1650	19800	

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GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC

PROJECT: CR-3

FILING CODE

W.O. 4203-027 PAGE 60 OF 112

SYSTEM: M.S. SAFETY + RELIEF VALUES

ORIGINATOR: A.L.E

DATE: 7/8/74

CALCULATION FOR: CR-5 SEISMIC XY QUAKE

REVIEWER: M.Z. Lee

DATE: 7/8/74

RESULTS

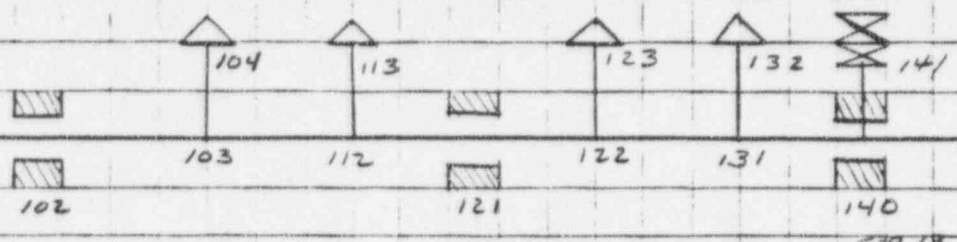

Fig 13

POINT	MX FT. LB	MY FT. LB	MZ FT. LB	M IN. LB.		RESULTS
102	2094	1735	1787	39,036		39,048
103	707	1373	1787	28,332		
103	690	1366	3054	40,980		
112	177	2594	3054	48,120		
112	132	2590	6715	86,376		
121	466	4400	6715	96,492		
121	466	4400	7128	100,668	✓	100,675
122	352	2551	7128	90,936		
122	415	2559	2866	46,368		
131	249	2452	2866	45,348		
131	238	2474	1356	33,972		
140	127	2202	1356	31,068		
103	110	66	2883	34,620	✓	
104	77	66	1999	24,012		
112	209	122	4554	54,720		
113	145	122	3153	37,896		
122	181	161	5098	61,236	✓	61,245
123	126	161	3530	42,420		
131	96	69	3211	38,556		
132	67	69	2227	26,748		
140 141	152	63	1500	22,885		

FILING CODE

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4203-027 | PAGE 61 OF 112
SYSTEM: M.S. SAFETY & RELIEF VALVES
ORIGINATOR: A.L.E.
DATE: 7/8/74
CALCULATION FOR: CR-5 Y-Z QUAKE
REVIEWER: M.Z. Lee
DATE: 7/8/74
RESULTS

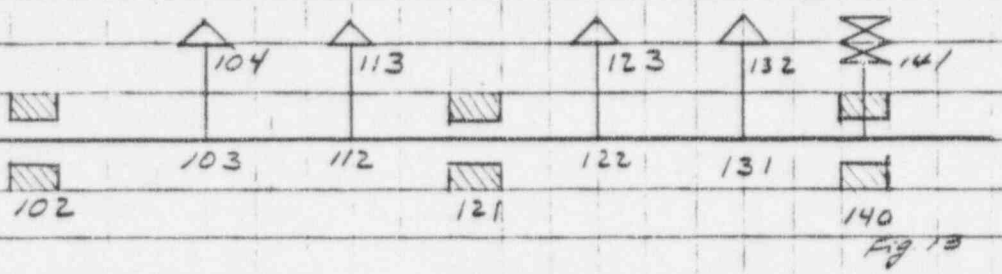

Fig 13

POINT	MX FT. LB.	MY FT. LB	MZ FT. LB	M IN. LB.	
102	3599	749	2734	54,972	
103	3757	2494	2734	63,276	✓
103	3493	2494	2708	60,888	
112	4012	3890	2708	74,508	
112	2026	3876	2741	61,932	
121	1352	4615	2741	66,420	✓
121	1352	4615	602	58,152	
122	1122	4227	602	52,968	
122	4274	4231	393	72,312	
131	3232	3487	393	57,240	
131	3140	3494	246	56,448	
140	1641	2600	246	37,008	
103	2547	130	366	30,912	
104	1744	130	253	21,204	
112	5030	182	362	60,552	✓
113	3450	182	250	41,556	
122	4406	177	334	53,064	
123	3022	177	231	36,420	
131	2037	104	354	24,840	
132	1395	104	245	17,040	
140, 141	2015	831	374	26,538	

62,282

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GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC
PROJECT: CR-3
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W.O. 4203-027 | PAGE 62 OF 112

SYSTEM: M.S. SAFETY + RELIEF VALVES
ORIGINATOR: A.L.E
DATE: 7/8/74

CALCULATION FOR: CR-5 THERMAL
REVIEWER: H.Z. Lee
DATE: 7/8/74

RESULTS

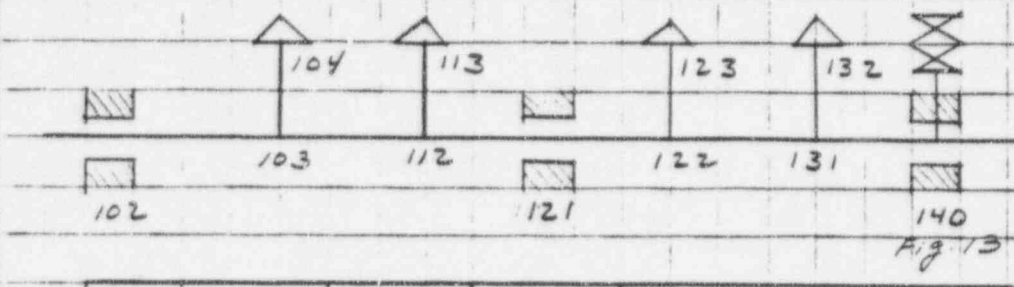

Fig 13

POINT	MX FT. LB	MY FT. LB	MZ FT. LB	M IN. LB
102	-202	-208,139	-80	2,497,668
103	-64	-255,033	-80	3,060,396
103	-64	-255,033	-80	3,060,396
112	7	-278,980	-80	3,347,760
112	7	-278,980	-80	3,347,760
121	42	-290,966	-80	3,491,592 ✓
121	42	-290,966	0	3,491,592
122	33	-262,504	0	3,150,048
122	33	-262,504	0	3,150,048
131	14	-205,514	0	2,466,168
131	14	-205,514	0	2,466,168
140	-5	-148,523	0	1,782,276
103	0	0	0	0
104	0	0	0	0
112	0	0	0	0
113	0	0	0	0
122	0	0	0	0
123	0	0	0	0
131	0	0	0	0
132	0	0	0	0

FILING CODE

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC

PROJECT: CR-3

FILING CODE

W.O. 4203-027 | PAGE 63 OF 112

SYSTEM: M.S. SAFETY & RELIEF VALVES

ORIGINATOR: A.L.G.

DATE: 7/8/74

CALCULATION FOR: CR-5 SAFETY VALVE LOADS

REVIEWER: M.Z. Lee

DATE: 7/8/74

RESULTS

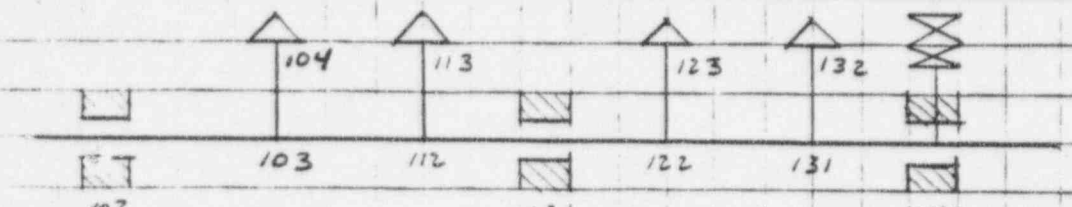

Fig 13

POINT	MX FT. LB.	MY FT. LB	MZ FT. LB	M IN. LB.	
102	-10,482	-6764	2459	152,568	
103	52,446	-7591	2459	636,588	
103	52,446	-7591	-22,541	691,044	
112	2330	53,987	-22,541	702,600	
112	2330	53,987	-55,241	931,608	
121	-77,476	126,037	-55,741	1,897,164	
121	-77,476	126,037	57,558	1,904,964	✓
122	-216	47,593	57,558	896,232	
122	-216	47,593	24,358	641,568	
131	45,161	-27,113	24,358	696,396	
131	45,161	-27,113	-8842	640,932	
140	-18,793	-19,446	-8842	341,412	
103	0	0	0	0	
104	0	0	0	0	
112	0	0	0	0	
113	0	0	0	0	
122	0	0	0	0	
123	0	0	0	0	
131	0	0	0	0	
132	0	0	0	0	

FILING CODE

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: F.P.C.

PROJECT: CR-3

FILING CODE:

W.O. 403-027 | PAGE 64 of 112

SYSTEM: M.S. SAFETY + RELIEF VALVES

ORIGINATOR: M.Z. Lee

DATE: 2/8/74

CALCULATION FOR: CR-5

REVIEWER: A.F. Fernandez

DATE: 12/16/74

RESULTS

+ SEE PAGE 35

R.A. Arnau 9-24-79

Header

$\frac{PD}{4t}$ = 7,100 Psi (6.243 psi) *

$0.75i\ \frac{M_A}{Z} = 0.75 \times 1.5 \times \frac{183,588}{388} = 532$

$0.75i\ \frac{M_{B1}}{Z} = 0.75 \times 1.5 \times \frac{100,668}{388} = 292$

$0.75i\ \frac{M_{B2}}{Z} = 0.75 \times 1.5 \times \frac{1,904,964}{388} = 5,523$

$i\ \frac{M_C}{Z} = 1.5 \times \frac{3,491,592}{388} = 13,498$

Branch

$\frac{PD}{4t}$ = 2,640

$0.75i\ \frac{M_A}{Z} = 0.75 \times 1.5 \frac{4380}{18.4} = 268$

$0.75i\ \frac{M_{B1}}{Z} = 0.75 \times 1.5 \times \frac{61,236}{18.4} = 3,744$

$0.75i\ \frac{M_{B2}}{Z}$ = 6,725 psi

FILING CODE

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: F.P.C.

PROJECT: CR-3

FILING CODE:

W.O. 4209-027 PAGE 65 OF 112

SYSTEM: M.S. SAFETY + RELIEF VALVE

ORIGINATOR: M. Z. Lee
DATE: 7/8/74

CALCULATION FOR: CR-5

REVIEWER: L. J. Ferranello
DATE: 12/16/74

RESULTS

		Header			Branch		
		Max		Allowable	Max	Allowable	
(1)	Pressure	7,100 (6,243)*			2,640		* SEE PAGE 35 Ron Amore 9-24-79
(2)	Dead Load	532			268		
(3)	(1) + (2)	7632 (6,775)		15,000	2,908	17,500	
(4)	Seismic	584			7,488		
(5)	Safety Valve Discharge	5,523			6,725		
(6)	(3) + (4) + (5)	13739 (12,882)		18,000	17,121	21,000	
(7)	Thermal	13,498		22,500	Small		

FILING

GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT FPC

PROJECT CR #3

FILING CODE

W.O. 4203-027 PAGE 66 OF 112

SYSTEM M.S. SAFETY & RELIEF VALUES

ORIGINATOR A.L.E

DATE 7/8/74

CALCULATION FOR CR-6 DEADLOAD

REVIEWER M.Z. Lee

DATE 7/8/74

RESULTS

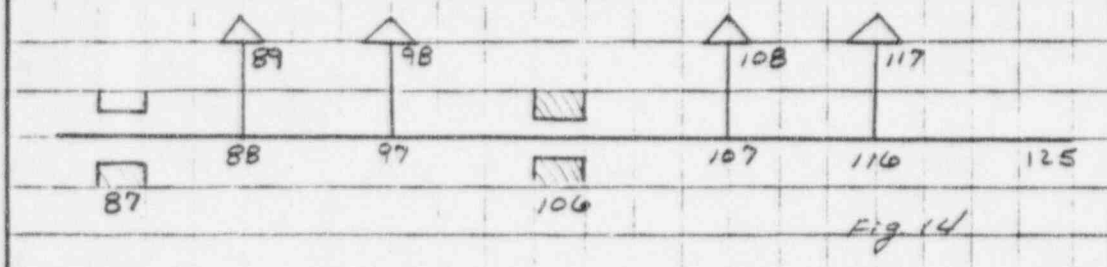

Fig 14

POINT	Mx FT.LB.	My FT.LB.	Mz FT.LB	M IN LB.		
87	-3913	53	117	46,980		
88	1385	82	117	16,704		
88	1385	82	389	17,280		
97	-4289	92	389	51,684		
97	-4289	92	661	52,080		
106	-9768	97	661	117,480	✓	117,490
106	-9768	97	-765	117,576	✓	117,580
107	-3637	86	-765	45,024		
107	-3637	86	-494	44,052		
116	3341	65	-494	40,524		
116	3341	65	-222	40,176		
125	4488	29	-222	53,916		
88	0	0	-272	3264	✓	
89	0	0	-272	3264		
97	0	0	-272	3264		
98	0	0	-272	3264		
107	0	0	-272	3264		
108	0	0	-272	3264		
116	0	0	-272	3264		
117	0	0	-272	3264		

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GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC

PROJECT: CR3

FILING CODE

W.O. 4203-827 | PAGE 67 OF 112

SYSTEM: M.S. SAFETY + RELIEF VALVES

ORIGINATOR: ALE

DATE: 7/8/74

CALCULATION FOR: CR-6 SEISMIC X-Y QUAKE

REVIEWER: M.Z. Lee

DATE: 7/8/74

RESULTS

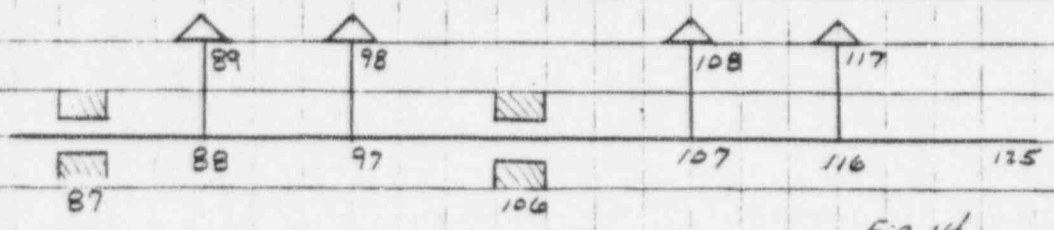

Fig. 14

POINT	MX FT. LB	MY FT. LB.	MZ FT. LB	M IN. LB		
87	846	1451	1156	24,456		
88	1418	1809	1156	30,864		
88	1000	1797	3650	50,268		
97	1262	2574	3650	55,692		
97	723	2577	5073	68,820		
106	752	3734	5073	76,116		
106	752	3734	5096	76,344	✓	
107	517	2950	5096	70,920		
107	577	2974	3279	53,568		
116	1134	3130	3279	56,064		
116	1578	3127	1019	43,764		
125	732	1517	1019	23,616		
88	661	37	3740	45,576		
89	453	37	2590	31,548		
97	898	47	2160	28,068		
98	615	47	1496	19,416		
107	1016	47	2429	31,596		
108	697	47	1683	21,864		
116	856	36	4297	52,572	✓	52,579
117	587	36	2977	36,408		

FILING CODE

GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT F.P.C.

PROJECT CR-3

FILING CODE

W.O. 4203-027 PAGE 68 OF 112

SYSTEM M.S. SAFETY & RELIEF VALVES

ORIGINATOR A.L.E

DATE 7/8/74

CALCULATION FOR CR-6 SEISMIC Y-Z QUAKE

REVIEWER M.Z. Lee

DATE 7/8/74

RESULTS

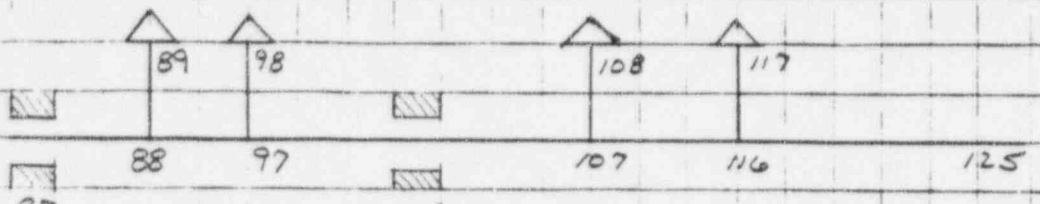

Fig. 14

POINT	M_X FT. LB	M_Y FT. LB	M_Z FT. LB	M IN. LB		
87	876	1254	2080	30,972		
88	2745	2766	2080	53,004		
88	1506	2759	2364	47,196		
97	2426	3536	2364	58,752	✓	58,760
97	389	3527	2642	53,076		
106	732	4056	2642	58,740	✓	58,747
106	732	4056	2318	56,736		
107	983	3531	2318	52,032		
107	1624	3562	1412	49,932		
116	1155	2703	1412	39,120		
116	2668	2732	568	46,320		
125	1259	1000	568	20,460		
88	1793	75	1318	26,712		
89	1229	75	914	18,396		
97	2351	97	540	28,968		
98	1611	97	374	19,872		
107	2519	101	961	32,364		
108	1726	101	666	22,224		
116	2109	84	1978	34,704	✓	34,712
117	1445	84	1369	23,904		

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GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4203-027 PAGE 69 OF 112

SYSTEM: M.S. SAFETY + RELIEF VALVES
ORIGINATOR: A.L.E.
DATE: 7/8/74

CALCULATION FOR: CR-6 THERMAL
REVIEWER: M.Z. Lee
DATE: 7/8/74

RESULTS

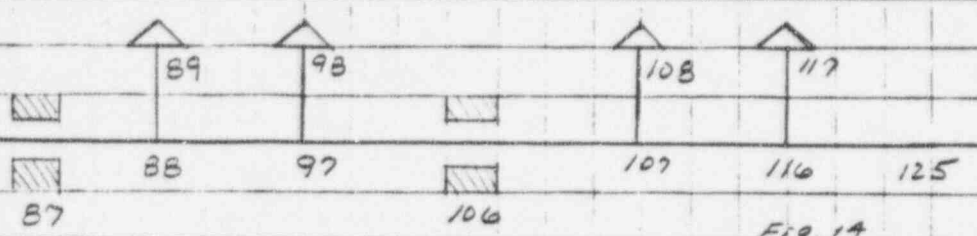

Fig 14

POINT	MX FT. LB	MY FT. LB	MZ FT. LB	M IN. LB.	
87	133	-206,064	-32	2,472,768	
88	27	-264,418	-32	3,173,016	
88	27	-264,418	-32	3,173,016	
97	-8	-283,869	-32	3,406,428	
97	-8	-283,869	-32	3,406,428	
106	-26	-293,594	-32	3,523,128	✓
106	-26	-293,594	1	3,523,128	
107	-23	-258,557	1	3,102,684	
107	-23	-258,557	1	3,102,684	
116	-17	-188,481	1	2,261,772	
116	-17	-188,481	1	2,261,772	
125	-8	-71,664	1	859,968	
88	0	0	0	0	
89	0	0	0	0	
97	0	0	0	0	
98	0	0	0	0	
107	0	0	0	0	
108	0	0	0	0	
116	0	0	0	0	
117	0	0	0	0	

FILING CODE

GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT F.P.C.

PROJECT ER-3

FILING CODE

W.O. 4203-027 PAGE 70 OF 112

SYSTEM M.S. SAFETY & RELIEF VALVES

ORIGINATOR A.L.E.

DATE 7/8/74

CALCULATION FOR CR-6 SAFETY VALVE LOADS

REVIEWER M.Z. Lee

DATE 7/8/74

RESULTS

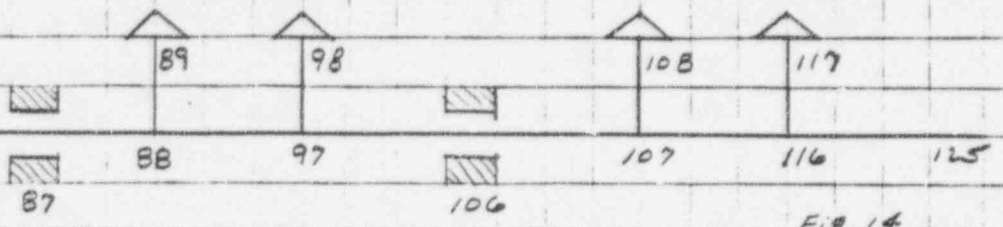

Fig 14

POINT	Mx FT. LB	My FT. LB	Mz FT. LB	M IN. LB.	
87	-18,493	-10,623	4056	260,508	
88	51,448	-12,387	4056	636,876	
88	51,448	-12,387	-29,144	724,944	
97	-34,568	69,397	-29,144	993,912	
97	-34,568	69,397	-62,344	1,193,844	
106	-132,242	151,476	-62,344	2,526,269	✓
106	-132,242	151,476	54,721	2,704	
107	-32,561	70,635	54,721	1,141,188	
107	-32,561	70,635	21,521	968,412	
116	57,470	-8675	21,521	743,724	
116	57,470	-8675	-11,675	711,384	
125	25,298	-3570	-11,675	337,068	
88	0	0	0	0	
89	0	0	0	0	
97	0	0	0	0	
98	0	0	0	0	
107	0	0	0	0	
108	0	0	0	0	
116	0	0	0	0	
117	0	0	0	0	

FILING CODE

GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4203-027 PAGE 71 OF 172

SYSTEM: M.S. SAFETY + RELIEF VALVES
ORIGINATOR: M. Z. Lee
DATE: 7/8/74
CALCULATION FOR: CR-6
REVIEWED: A. F. Fencello
DATE: 12/16/74

RESULTS

Header

$\frac{PD}{4t}$ = 7,100 psi
(6,243 psi) *

* SEE PAGE 35
Ron Lamb
9-24-79

$0.75i\ \frac{M_A}{Z} = 0.75 \times 1.5 \times \frac{177,580}{388} = 515$

$0.75i\ \frac{M_{B1}}{Z} = 0.75 \times 1.5 \times \frac{76,344}{388} = 221$

$0.75i\ \frac{M_{B2}}{Z} = 0.75 \times 1.5 \times \frac{2,526,269}{388} = 7,325$

$i\ \frac{M_C}{Z} = 1.5 \times \frac{3,523,128}{388} = 13,620$

Branch

$\frac{PD}{4t}$ = 2,640

$0.75i\ \frac{M_A}{Z} = 0.75 \times 1.5 \times \frac{3264}{18.4} = 200$

$0.75i\ \frac{M_{B1}}{Z} = 0.75 \times 1.5 \times \frac{52,572}{18.4} = 3,214$

$0.75i\ \frac{M_{B2}}{Z} = 6,725$

FILING CODE

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4208-027
PAGE 72 OF 112

SYSTEM: M.S. SAFETY + RELIEF VALVES
ORIGINATOR: M Z. Lee
DATE: 7/8/74
CALCULATION FOR: CR-6
REVIEWED: A. F. Fernandez
DATE: 12/16/74
RESULTS

		Header			Branch		
		Max		Allowable	Max.	Allowable	
(1)	Pressure	7100 (6,243) *			2,460		* SEE PAGE 35 for Branch
(2)	Dead Load	515			200		
(3)	(1) + (2)	7615 (6,758) *		15,000	2660	17,500	
(4)	Seismic	442			6,428		
(5)	Safety Valve Discharge	7,325			6,725		
(6)	(3) + (4) + (5)	15382 (14,525) *		18,000	15,813	21,000	
(7)	Thermal	13,620		22,500	Small		

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GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT FPC

PROJECT CR 3

FILING CODE

W.O. 4203-027 PAGE 73 OF 112

SYSTEM M. S. SAFETY + RELIEF VALUES

ORIGINATOR M. Z. Lee

DATE 10/23/73

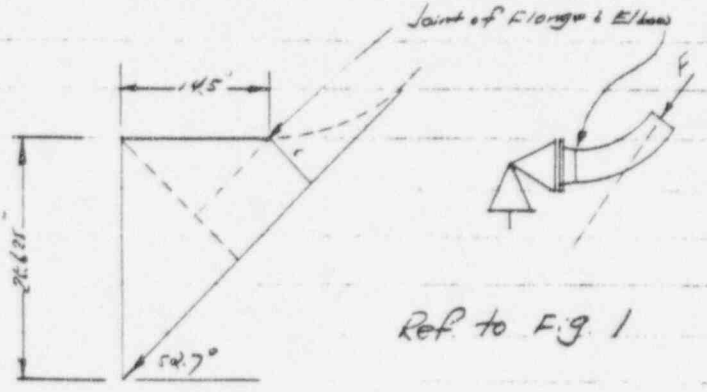
CALCULATION FOR

REVIEWED F. Ferranello

DATE 12/16/74

RESULTS

Stresses of Outlet Elbow



Ref to Fig 1

Fig. 15

Safety valve discharge reaction force and the force due to flexonic joint backpressure create a bending moment around the connection of outlet elbow

r = moment arm

$= 24.625 \cos 52.7° - 14.5 \sin 52.7°$

$= 15.55 - 11.5 = 4.05"$ Say $4.1"$

$$M = \left(\underset{p\,36}{36.5} \right) \times 4.1 = 150 \text{ Kip-in}$$

Piping Spec for safety valve relief line
Line No. 150-4 gives wall = 0.25" for 10" pipe

10" 0.25" wall $Z = 21.16$ in^3

$$S_b = \frac{M}{Z} = \frac{150}{21.16} = 7.1 \text{ Ksi}$$

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ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC

PROJECT: CR-3

FILING CODE:

W.O. 4203-027 PAGE 74 OF 112

SYSTEM: M.S. SAFETY & RELIEF VALVES

ORIGINATOR: M. Z. Lee

DATE: 10/23/73

CALCULATION FOR:

REVIEWER: A. F. Ferarello

DATE: 12/16/74

RESULTS

$$S_t = \frac{PD_o}{4t} = \frac{125 \times 10.75}{4 \times 0.25} = 1,340 \ \text{lbs/in}^2$$

Take DLF = 1.5

$$S_{max} = S_t + 1.5 \times S_b = 1,340 + 1.5 \times 7,100 = 12,000 \ \text{lbs/in}^2$$

$$< 1.2 S_h = 1.2 \times 17,500 = 21,000 \ \text{lbs/in}^2$$

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GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC

PROJECT: CRYSTAL RIVER #3

FILING CODE:

W.O. 4203-027 PAGE 75 of 112

SYSTEM: Main Steam SAFETY + RELIEF VALVES

ORIGINATOR: M. Z. Lee

DATE: 7/24/74

CALCULATION FOR: 24" S.V. Header Support

REVIEWER: J. F. Ferranello

DATE: 12/16/74

RESULTS

Sustained Loads

		M_R in-lb	F_x lb	F_y lb
Dead load	Line CR-3	641	-109	16,335
	CR-4	-1,403	73	7,975
	" 5	4,534	20	4,620
	" 6	1,426	12	9,633
	max abs	4534	109	11,335

Occasional Loads

		M_R in-ft	F_x lb	F_y lb
Seismic	Line CR-3	15,982	12,248	5144
	CR-4	30,122	16,324	5852
	CR-5	26,282	7,276	822
	CR-6	15,828	4,600	946
Safety valve	CR-3	1,466	17,936	167,544
	CR-4	71,551	-45,935	153,374
	CR-5	-113,299	120,411	125,661
	CR-6	-117,065	130,336	157,883
Dead load + Safety valve + Seismic	CR-3	18,089	30,575	184,023
	CR-4	100,270	-62,196	167,201
	CR-5	-135,047	127,707	131,113
	CR-6	-131,467	135,045	168,462
max abs		-135,047	135,045	184,023

Note: 1. Seismic Load = (max of X-Y and Y-Z quakes) × 2

2. Forces and moments listed are imposed by the supports on the pipes

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GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT F.P.C.

PROJECT CR-3

FILING CODE

W.O. 1203-827 PAGE 76 OF 112

SYSTEM M.S. SAFETY + RELIEF VALVES

ORIGINATOR M.Z. Lee

DATE 7/24/74

CALCULATION FOR

REVIEWER A.F. Ferarello

DATE 12/16/74

RESULTS

Thermal Expansion Loads

		Mz	Fx	Fy
Thermal Load	Line CR-3	-37,943	6,372	-6,714
	CR-4	-4043	-76,403	-11,831
	CR-5	-80	-32,375	-36
	CR-6	-33	-35,811	16
	max (abs)	-37,943	-76,403	-11,831

Design Loads $F_y = 200$ Kips

$F_x = 140$ Kips

$M_z = 140$ Kip-ft

FILING CODE

Crystal River 3	MADE MZK / CHK'D. 7/24/7? / DG. CF. / CF. DFN. / ENG.	GILBERT ASSOCIATES, INC. ENGINEERS AND CONSULTANTS READING, PENNA.
Main Steam Pipe Support Outline Sketch	REV. CH. APP. DATE: S.F. Ferranelli 12/16/?	WORK ORDER: 1183-077 / SIZE / DRAWING / REV.

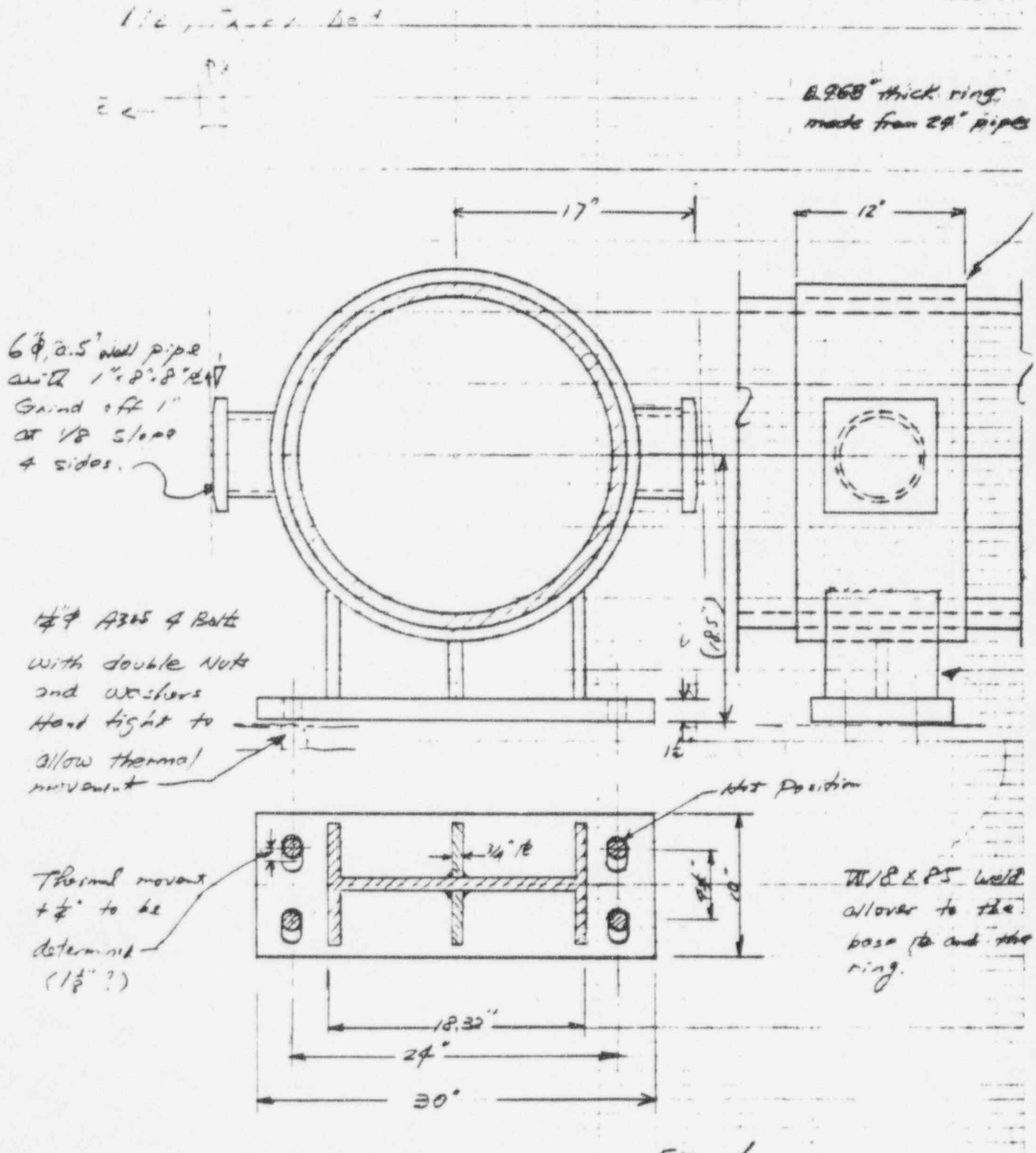

Fig. 16

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC
PROJECT: CR 3
FILING CODE:
W.O. 4203-027 | PAGE 78 OF 112
SYSTEM: M.S. SAFETY & RELIEF VALVES
ORIGINATOR: M. Z. Lee
DATE: 7/24/74
CALCULATION FOR:
REVIEWER: A. F. Ferranello
DATE: 12/16/74

RESULTS

Stress in Main Parts of Header Support

Trunnions 6"ϕ 0.5" wall pipe

$$S_c = \frac{F_x}{A} = \frac{140{,}000}{9.62_{in^2}} = 14{,}600 \text{ psi} < 18{,}000$$

Bolts

$$\frac{M_z}{l} = \frac{140{,}000 \times 12}{24} = 70{,}000 \text{ lbs}$$

$$\frac{(F_y)_{min}}{2} = \frac{120{,}000}{2} = 60{,}000 \text{ lbs}$$

F_y = DOWNWARD VERTICAL THRUST DUE TO S.V. DISCHARGE

$$R_1 = 70 - 60 = 10 \text{ Kips}$$

Seismic + D.L. + Thermal $M_z = 40$ Kip-ft

$$\frac{M_z}{l} = \frac{40 \times 12}{24} = 20 \text{ Kips} \quad (\pm)$$

$$\frac{F_y}{2} = \frac{1}{2}(7.975 - 5.252 - 11.831) = -4.9 \text{ Kip (up)}$$

$$R_1 = 20 + 4.9 = 25 \text{ Kips}$$

Use 1¼" A325 2 Bolts in one side

Allowable load = 18.89 x 2 = 37.78 Kips

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GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

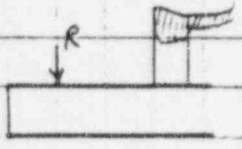
CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4203-027
PAGE 79 of 112

SYSTEM: M.S. SAFETY + RELIEF VALUES
CALCULATION FOR:
ORIGINATOR: M.Z. Lee
DATE: 7/24/74
REVIEWER: J.F. Ferranello
DATE: 12/16/74

RESULTS

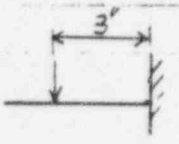
Base Plate

$M = R_1 \times 3 = 2.5 \times 3 = 7.5$ Kip-in



$Z = \frac{1}{6} b h^2 = \frac{1}{6} \times 10 \times (1.5)^2 = 3.75\ in^3$

$S_b = \frac{M}{Z} = \frac{75}{3.75} = 20$ Ksi



S.F. to $S_y = \frac{36}{20} = 1.8$

S.F. = Safety Factor

Base Pl $1\frac{1}{2}$" thick

Stand W18×85 Depth 18.32" W 8.38"
$Z = 157\ in^3$ $A = 25\ in^2$ Web 0.526"

$S_b = \frac{M_2}{Z} = \frac{140^{K-in} \times 12^{in/ft}}{157} = 10.7$ Ksi

Stiffener $\frac{3}{4}" \times (8.38 - 0.526) = 5.88\ in^2$

Stress area for compression $= 2.5 + 5.88 = 30.88\ in^2$

$S_c = \frac{F_y}{A} = \frac{200}{30.88} = 6.48$ Ksi

$S_{max} = 10.7 + 6.48 = 17.2$ Ksi

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SYSTEM M.S. SAFETY & RELIEF VALVES

ORIGINATOR M Z Lee

DATE 7/24/74

CALCULATION FOR

REVIEWER A J Fernandez

DATE 12/16/74

RESULTS

Stand and Ring Interface

$$S_s = \frac{M}{r}\frac{1}{A} = \frac{140\times 12}{13}\times\frac{1}{25} = 5.18 \text{ Ksi}$$

$$S_{s\,max} = \sqrt{\left(\tfrac{1}{2}S_a\right)^2 + S_s^2}$$

$$= \sqrt{\left(\frac{17.2}{2}\right)^2 + (5.18)^2} = 10.5 \text{ Ksi}$$

$$S_{max} = \tfrac{1}{2}\times 17.2 + 10.5 = 19.1 \text{ Ksi}$$

Ring and Header Interface

$$F_s = \frac{M_a}{r} = \frac{140\times 12}{12} = 140 \text{ Kips}$$

For 3/4" leg fillet weld,

throat $= \frac{3}{4}\times 0.707 = 0.53"$

Take $S_s = 14$ Ksi

Required length of weld

$$l = \frac{140}{14\times 0.53} = 18"$$

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SYSTEM: Main Steam Safety Valve Header Support

ORIGINATOR: M. Z. Lee

DATE: 7/30/74

CALCULATION FOR: Thermal Stress in Reinforcement Ring

REVIEWER: A. J. Fernandez

DATE: 12/16/74

RESULTS

THERMAL STRESSES WHICH MAY RESULT FROM INCOMPLETE ATTACHMENT OF REINFOR. RING TO HEADER

Temperature Difference Across the Air Gap.

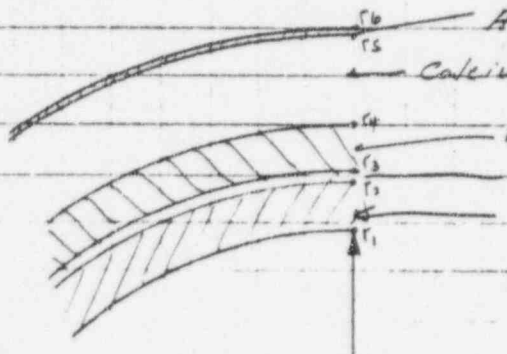

Fig. 17

Assumptions. 1. air gap is 0.1"
2. Aluminum Jacket is 0.016" thick

Then $r_1 = 11.032"$
$r_2 = 12.00"$
$r_3 = 12.1"$
$r_4 = 13.068"$
$r_5 = 15.568"$
$r_6 = 15.584"$

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SYSTEM M.S. SAFETY & RELIEF VALVES
ORIGINATOR M. Z. Lee
DATE 7/24/74

CALCULATION FOR
REVIEWED L. F. Fumarello
DATE 12/16/74

RESULTS

Consider 1 ft pipe length

$$q = \frac{t_1 - t_6}{\sum_{i=1}^{5} \frac{1}{2\pi k_i} \ln \frac{r_{i+1}}{r_i}}$$

Ref. Eckert & Drake Heat & Mass Transf

Carbon steel $C < 0.5\%$ $k_1 = k_3 = 26$ BTU/hr-ft-°F

Air at 600°F $k_2 = 0.02654$ "

Calcium Silicate $k_4 = 0.0327$ "

Aluminum $k_5 = 132$

Heat Resistance

$$R_1 = \frac{1}{2\pi k_1} \ln \frac{r_2}{r_1} = \frac{1}{2\pi \times 26} \ln \frac{12}{11.032} = 0.000514$$

$$R_2 = \frac{1}{2\pi k_2} \ln \frac{r_3}{r_2} = \frac{1}{2\pi \times 0.02654} \ln \frac{12.1}{12} = 1.049766$$

$$R_3 = \frac{1}{2\pi k_3} \ln \frac{r_4}{r_3} = \frac{1}{2\pi \times 26} \ln \frac{13.068}{12.1} = 0.000471$$

$$R_4 = \frac{1}{2\pi k_4} \ln \frac{r_5}{r_4} = \frac{1}{2\pi \times 0.0327} \ln \frac{15.568}{13.068} = 0.851995$$

$$R_5 = \frac{1}{2\pi k_5} \ln \frac{r_6}{r_5} = \frac{1}{2\pi \times 132} \ln \frac{15.584}{15.568} = 0.000001$$

$$\sum_{i=1}^{5} R_i = 0.902747$$

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SYSTEM: M.S. SAFETY & RELIEF VALVES

ORIGINATOR: M Z Lee

DATE: 7/24/74

CALCULATION FOR:

REVIEWER: A. F. Fiumello

DATE: 12/16/74

RESULTS

$$q = \frac{t_1 - t_6}{\Sigma R_i} = \frac{600 - 80}{0.902747} = 576.019268 \ \text{BTU/hr ft}^2$$

$\Delta t_1 = q R_1 = 0.296$

$\Delta t_2 = q R_2 = 28.666$

$\Delta t_3 = q R_3 = 0.271$

$\Delta t_4 = q R_4 = 490.766$

$\Delta t_5 = q R_5 = 0.000576$

$t_1 = 600°$

$t_2 = 600 - 0.296 = 599.704 \ °F$

$t_3 = 599.704 - 28.666 = 571.038$

$t_4 = t_3 - \Delta t_3 = 570.767$

$t_5 = t_4 - \Delta t_4 = 80.001$

$t_6 = t_5 - \Delta t_5 = 80.0$

$\boxed{\Delta t_2 = 28.666}$ temp difference across the air gap

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SYSTEM: M.S. SAFETY + RELIEF VALVES
ORIGINATOR: M. Z. Lee
DATE: 7/24/74
CALCULATION FOR:
REVIEWER: S. F. Fernello
DATE: 12/16/74
RESULTS:

Expansion Stress in the Ring

Consider the ring and the header as a compound cylinder with shrinkage allowance equal to the difference in thermal expansions of O.D of header and I.D of ring.

Ref § 20-16 Doughtie et al
Design of Machine Members

DEFINITION OF "B" on pg. 457

$$B = \delta d = \alpha \cdot d_c \cdot \Delta T$$

$$\alpha = 7.23 \times 10^{-6} \text{ in/in/°F}$$

$$d_c \doteq 24"$$

$$\Delta T = 28.666°F \quad \text{Say } 30°F$$

$$B = 7.23 \times 10^{-6} \times 24 \times 30 = 5.2 \times 10^{-3}"$$

$$p_c = \frac{BE\,(d_c^2 - d_i^2)(d_i^2 - \delta_i^2)}{2 d_i^3 (d_c^2 - d_i^2)}$$ eqt. 20-43

$$= \frac{5.2 \times 10^{-3} \times 27.7 \times 10^6 (24^2 - 22.064^2)(25.936^2 - 24^2)}{2 \times 24^3 (25.936^2 - 22.064^2)}$$

$$= 242 \text{ psi}$$

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SYSTEM M.S. SAFETY + RELIEF VALVES

ORIGINATOR M. Z Lee

DATE 7/24/74

CALCULATION FOR

REVIEWER J. F. Fernello

DATE 12/16/74

RESULTS

Tangential Stress at the inner surface of the outer cylinder due to differential expansion

$$S_{ro} = p_i \left(\frac{d_o^2 + d_i^2}{d_o^2 - d_i^2} + \mu \right)$$ eq. 20-40

$$= 242 \left(\frac{\overline{25.936}^2 + \overline{24}^2}{\overline{25.936}^2 - \overline{24}^2} + .3 \right)$$

$$= 3,210 \text{ psi} \quad < S_A = 22,500 \text{ psi}$$

Tangential Stress at the inner surface of the outer cylinder due to internal pr.

$$S_t = (1-\mu) \frac{p_i d_i^2}{d_o^2 - d_i^2} + (1+\mu) \frac{p_i d_i^2 d_o^2}{4r^2 (d_o^2 - d_i^2)}$$

$p_i = 1100$ psi $\quad \mu = .3 \quad r = 12"$

$$S_t = \left[(1-0.3) \frac{\overline{22.064}^2}{(\overline{25.936}^2 - \overline{22.064}^2)} + (1+0.3) \frac{\overline{22.064}^2 \overline{25.936}^2}{4 \times \overline{12}^2 (\overline{25.936}^2 - \overline{22.064}^2)} \right] \times 1100$$

$$= [1.8335 + 3.9766] \times 1100$$

$$= 6,391 \text{ psi} \quad < 15,000 \text{ psi}$$

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SYSTEM M.S. SAFETY + RELIEF VALVES

ORIGINATOR M.Z. Lee

DATE 7/24/74

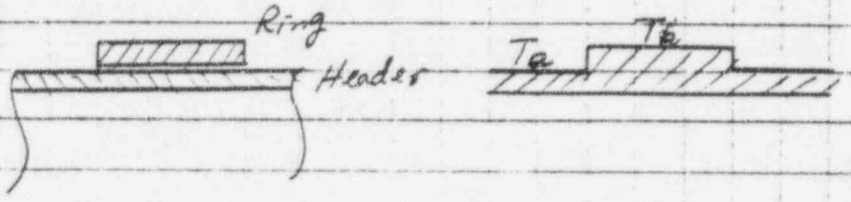
CALCULATION FOR

REVIEWED J.F. Fanello

DATE 12/16/74

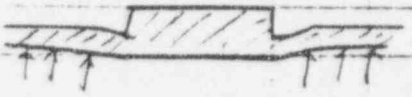
RESULTS

Thermal Stress due to Geometrical Discontinuity



a. Actual (b) Conservative model of (a)

Fig 18



c. Deflected shape

Expansion stress

$$S_3 = C_3 E \alpha_b |\alpha_a T_a - \alpha_b T_b|$$

$$= C_3 E \alpha |T_a - T_b|$$

$C_3 = 0.46$ for $t_a/t_b = 0.5$

pK-26 Teledyne Material Research 1973 Seminar

$E = 27.9 \times 10^6$ psi

$\alpha = 7.23 \times 10^{-6}$ in/in/°F

$T_b = 579.767$

$T_a \leq 600$

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SYSTEM: M.S. SAFETY & RELIEF VALVES
ORIGINATOR: M.Z. Lee
DATE: 7/24/74
CALCULATION FOR:
REVIEWER: A.F. Zenarella
DATE: 12/16/74

RESULTS

$\therefore S_3 = 0.46 \times 27.6 \times 10^6 * 2.83 \times 10^{-6} / |60 - 57.20|$

$= 2,720$ psi

Expansion Stress calculated from the Expansion loads given by stress program

$S = 13,815$ psi line CR-4

Max Combined Expansion Stress

$S_C = 13,815 + 2,720$

$= 16,540$ psi $< S_A = 22,500$ psi

O.K.

FILING CODE

Atmospheric Relief Valve MSV-25, 26

Reaction Force

Designed Flow Rate $Q_d = 418{,}500$ #/hr.
Ref 17. Fisher Data Sheet, I&C File

Assuming that the valve may discharge 120% of the rated capacity

$$W_{max} = 1.2\,Q_d \doteq 500{,}000 \text{ #/hr}$$

$$m = \frac{W}{3600} \times \frac{1}{32.2} = 4.31 \text{ slug/sec}$$

Inlet Steam Condition

$t_1 = 600°F$

p_1 = peak pr $= 1100 \times 1.04 + 15 = 1159$ psig

$v_1 = 0.4261$ ft³/#

$S_1 = 1.4157$ BTU/#/°F

$h_1 = 1231.7$ BTU/#

$A_1 = 28.9$ in²

$$V_1 = \frac{W \times v}{A} = \frac{500{,}000 \times 0.4261}{3600 \times 28.9/144} = 295 \text{ ft/sec}$$

Stagnant Enthalpy

$h_o = 1237.4$ BTU/# from Safety valve data

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PROJECT: CR-3
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SYSTEM: M.S. SAFETY + RELIEF VALVES
ORIGINATOR: M.Z. Lee
DATE: 10/23/73
CALCULATION FOR:
REVIEWER: S.F. Fernando
DATE: 12/16/74
RESULTS:

Reaction Forces

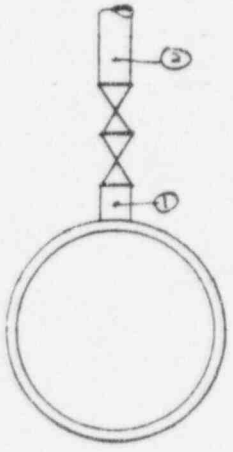

Fig. 19

If $\underline{p_2 = p_a} = 14.7$ psia

$v_2 = 26.8$ (assume saturated steam)

Acoustic Velocity

$$V_s = \sqrt{kg \times 144\, p\, v}$$

$$= \sqrt{1.32 \times 32.2 \times 144 \times 14.7 \times 26.8} = 1{,}550 \text{ ft/sec}$$

$k = \frac{\alpha_e}{C_v}$ from A-9 Crane [21]

Reaction Force

$$F = mV = \frac{500{,}000}{3600} \times \frac{1}{32.2} \times 1550 = 6{,}700 \text{ lbs}$$

$$W = \frac{AV}{v} = \frac{28.9}{144} \times \frac{1550}{26.8} \times 3600 = 41{,}700 \text{ \#/hr}$$

$\ll 500{,}000$

Max. flow rate can not be obtained.

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$p_2 = 170$ psia $\quad S_2 = S_1$

$$x_1 = \frac{1.4157 - 0.5266}{1.032} = 0.86$$

$$h_2 = 341.1 + 854.9\,x = 1091.5$$

$$\Delta h_s = 1237.4 - 1091.5 = 142.3$$

η	Δh	V_2	h_2	v_2	W	k
.47	66.5	1790	1170.9	2.6	500,000	

$$V_2 = \sqrt{144\,kg\,pv} = \sqrt{144 \times 32.2 \times 1.3 \times 170 \times 2.6}$$

$$= \sqrt{26700} = 1,640 \text{ fe/sec}$$

V_2 obtained is slightly too high

Max flow rate W can not be obtained at this exit pressure.

$$W = \frac{AV}{v} = \frac{28.9}{144} \times \frac{1640}{2.6} \times 3600 = 456,000 \text{ \#/hr} < 500,000 \text{ \#/hr}$$

For Reference only

$$F = pA + mV$$

$$= 155 \times 28.9 + 4.31 \times 1790$$

$$= 4.480 + 7,900^{\#} = 12.4 \text{ Kips}$$

$p_2 = 200$ psia

$$x = \frac{1.4157 - 0.5435}{1.0018} = \frac{0.8722}{1.0018} = 0.87$$

$$h_s = 355.4 + 843x = 355.4 + 733 = 1088.4$$

$$\Delta h = 1237.4 - 1088.4 = 149$$

η	Δh	V_2	h_2	v_2	W
0.32	48.	1550	1189.4	2.23	500,000

$$V_s = \sqrt{kg \times 144 pv} = \sqrt{1.297 \times 32.2 \times 144 \times 200 \times 2.27}$$

$$= \sqrt{2.74 \times 10^6} = 1,660 \text{ fe/sec}$$

$$> V_2$$

$$F = pA + mV$$

$$= (200 - 15)\,28.9 + \frac{500\,000}{3600 \times 32.2} \times 1550$$

$$= 5,350^{\#} + 6,700^{\#} = 12.1 \text{ Kips.}$$

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SYSTEM M. S. SAFETY + RELIEF VALVES

ORIGINATOR M. Z. Lee

DATE 10/23/73

CALCULATION FOR

REVIEWER A F Fiorello

DATE 12/16/74

RESULTS

$p_2 = 250$ psia $\quad s_2 = s_1 = 1.4157$

$$x = \frac{1.4157 - 0.5175}{0.9588} = 0.885$$

$$h_{fs} = 376 + 825.1x = 376 + 731 = 1107$$

$$\Delta h_s = 1237.4 - 1107 = 130.4$$

η	Δh	V_2	h_2	v_2	W
0.25	32.6	1280	1204.8	1.845	500,000

$$V_s = \sqrt{kg \times 144\, pv}$$

$$= \sqrt{1.296 \times 32.2 \times 144 \times 250 \times 1.845}$$

$$= \sqrt{2.765 \times 10^6} = 1{,}660 \text{ ft/sec}$$

$V_t > V_2$

$$F = pA + m\bar{V}$$

$$= (250 - 15) \times 28.9 + 431 \times 1280$$

$$= 6{,}800 + 5{,}520 \text{ lb} = 12.3 \text{ Kips}$$

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SYSTEM M.S. SAFETY + RELIEF VALVES

CALCULATION FOR

ORIGINATOR M. Z. Lee
DATE 10/23/73

REVIEWER J F Fiumello
DATE 12/16/74

RESULTS

$p_2 = 300$ psia, $S_2 = S_1 = 1.4157$

$$x = \frac{1.4157 - 0.5579}{0.9225} = 0.897$$

$$h_s = 393.8 + 809.4x = 393.8 + 725 = 1118.8$$

$$\Delta h_s = h_w - h_s = 1237.4 - 1118.8 = 118.6$$

η	Δh	V_2	h_2	U_2	W
0.22	26.4	1150	1211	1.65	502,000 #/hr
0.19	22.9	1070	1214.5	1.59	486,000

$$V_s = \sqrt{kg\,144\,pv}$$

$$= \sqrt{1.29 \times 32.2 \times 144 \times 1150 \times 1.65}$$

$$= \sqrt{1,140,000} = 1,070 \text{ fe/sec}$$

max flow can not be obtained from this backpressure p_2.

For reference

$$F = pA + mV$$

$$= (300 - 15) \times 28.9 + 4.31 \times 1150$$

$$= 8,250 + 4,950^{\#} = 13.2 \text{ Kips}.$$

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PROJECT CR-3

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W.O. 4203-027 PAGE 946 of 1112

SYSTEM M. S. SAFETY + RELIEF VALUES

CALCULATION FOR

ORIGINATOR M. Z. Lee

DATE 10/23/73

REVIEWED A. F. Fernandez

DATE 12/16/74

RESULTS

Summary

η	p_2 psig	$p_2 A_2$ Kips	$\dot{m} V_2$ Kips	F Kips	
	0	0	(6.7)	(6.7)	max flow can not be obtained.
0.47	155	4.4	(7.9)	(12.4)	
0.32	185	5.35	6.7	12.1	
0.25	235	6.8	5.52	12.3	←
0.2	285	8.25	(4.95)	(13.2)	η may be too small

Estimated Discharge Reaction Force 13.5 Kips

Flexonic Back pressure force

$A = \frac{\pi}{4}(11.8^2 - 6.625^2) = 75\ in^2$

Assume $p = 235$ psig

$F = pA = 235 \times 75 = 17600$ lbs

Total force on run pipe $= 13.5 + 17.6 = 31.1$ Kips

F = 31.1 Kips on Run Pipe

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CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4207-027 PAGE 950 OF 1172
SYSTEM: M.S. SAFETY + RELIEF VALVES
ORIGINATOR: M.Z. Lee
DATE: 10/23/73
CALCULATION FOR:
REVIEWER: A F Fernandez
DATE: 12/10/74
RESULTS

Stress Intensification Factor of Weldolet

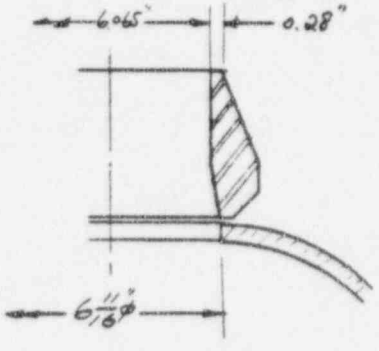

Fig. 20

ANSI B31.1.0 Summer 1973 Addenda Ref. 13 (Table D-2) gives the stress intensification factor

$$i = 1.5 \left(\frac{Rm}{Tr}\right)^{3/3} \left(\frac{r'm}{Rm}\right)^{1/2} \left(\frac{To'}{Tr}\right) \left(\frac{r'm}{rp}\right)$$

Rm = mean radius of run pipe = 11.516"
Tr = nominal thickness of run pipe = 0.968"
r'm = mean radius of branch pipe = 3.1725"
To' = nominal thickness of branch pipe = 0.28"
rp = outer radius of branch at the outer surface of run pipe
= $\frac{6.625}{2}$ + 0.28 (at least) = 3.65"

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SYSTEM M.S. SAFETY + RELIEF VALUES

CALCULATION FOR

ORIGINATOR M. Z. Lee

DATE 10/23/73

REVIEWER A. F. Fiorello

DATE 12/16/74

RESULTS

$$i = 1.5 \left(\frac{11.516}{0.968}\right)^{2/3} \left(\frac{3.1725}{11.516}\right)^{1/2} \left(\frac{0.28}{0.968}\right) \left(\frac{3.1725}{3.65}\right)$$

$$= 1.0316$$

Boiler & Press. Vessel Code Sec. III winter 72 Addenda NC-3673.2(b) and Tabe NB-3683.2-1 Note 7 give

$$i = \frac{1}{2} C_2 K_2$$

For branch $K_{2b} = 1$

$$C_{2b} = 3 \left(\frac{R_m}{T_r}\right)^{2/3} \left(\frac{r_a'}{R_m}\right)^{1/2} \left(\frac{T_a}{T_r}\right) \left(\frac{r_m'}{r_p}\right) = 2.0632$$

$$i = \frac{1}{2} \times 2.06 \times 1 = 1.0316 \quad \text{for branch}$$

For run $K_{2r} = 2.0$

$$C_{2r} = 0.8 \left(\frac{R_m}{T_r}\right)^{2/3} \left(\frac{r_m'}{R_m}\right)$$

$$= 0.8 \left(\frac{11.516}{2.968}\right)^{2/3} \left(\frac{3.1725}{11.516}\right) = 1.1486$$

$$K_{2r} C_{2r} = 2.29 < 3 \quad \therefore K_{2r} C_{2r} = 3$$

$$i = \frac{1}{2} K_{2r} C_{2r} = 1.5 \quad \text{for run pipe}$$

Therefore, we can take

$i = 1.5$ for run pipe
$i = 1.1$ for branch

FILING CODE

Section Modulus

Run $Z_m = \pi (r_m)^2 T_h = \pi \times (11.516)^2 \times 0.968 = 405 \ in^3$

$Z_m = 388 \ in^3$ by $\frac{\pi}{64}(D_o^4 - D_i^4) \times \frac{2}{D_o}$

Branch

$$Z_b = \pi (r_b)^2 t_s$$

$$t_s = \min \begin{cases} i \, T_h & (i \times 0.968) \\ i \, t_b & (1.1 \times 0.28) \end{cases} = 1.1 \times 0.28$$

$$Z_b = i \cdot \pi (r_b)^2 t_b = i \times \pi \times (3.725)^2 \times 0.28$$

$$= 8.87 i$$

Stress due to Internal Pressure

6" $\frac{PD_i}{4t_b} = \frac{1144 \times 6.625}{4 \times 0.28} = 6,770 \ psi$

24" $\frac{PD_i}{4t_h} = \frac{1144 \times 24}{4 \times 0.968} = 7,100 \ psi$

GILBERT ASSOCIATES, INC. ENGINEERS AND CONSULTANTS READING, PA.	CLIENT FPC	FILING CODE	
	PROJECT CR-3	W.O. 4203-027	PAGE 98o+112
SYSTEM M.S. SAFETY & RELIEF VALVES		ORIGINATOR M. Z. Lee	
CALCULATION FOR		DATE 10/23/73	
		REVIEWER S. F. Fernandez	
		DATE 12/16/74	

RESULTS

Studies of vendor drawings reveal that both the relief valves and the isolation valvs are prepared to be welded according to sch. 40 (0.78") (Fig. 21) It is easily seen that the welds can be increased to 0.5" min. as shown in Fig. 22 to lower the stress level to satisfy the code requirements.

Th. 0.5" min. weld is required at

1. Joint of Relief Valve & Isolation valve
2. Isolation valve and Weldolet
3. Weldolet and Run pipe.

FPC	MADE 10/23/73	GILBERT ASSOCIATES, INC. ENGINEERS AND CONSULTANTS READING, PENNA.
CR-3	CHK'D.	
MS. SAFETY & RELIEF VALVES	DES. CP.	
	CP. DPN.	
	ENG. M. Z. Lee	WORK ORDER / SIZE / DRAWING / REV.
	REV. EN. APP. DATE J. F. Ferranello 10/16/74	

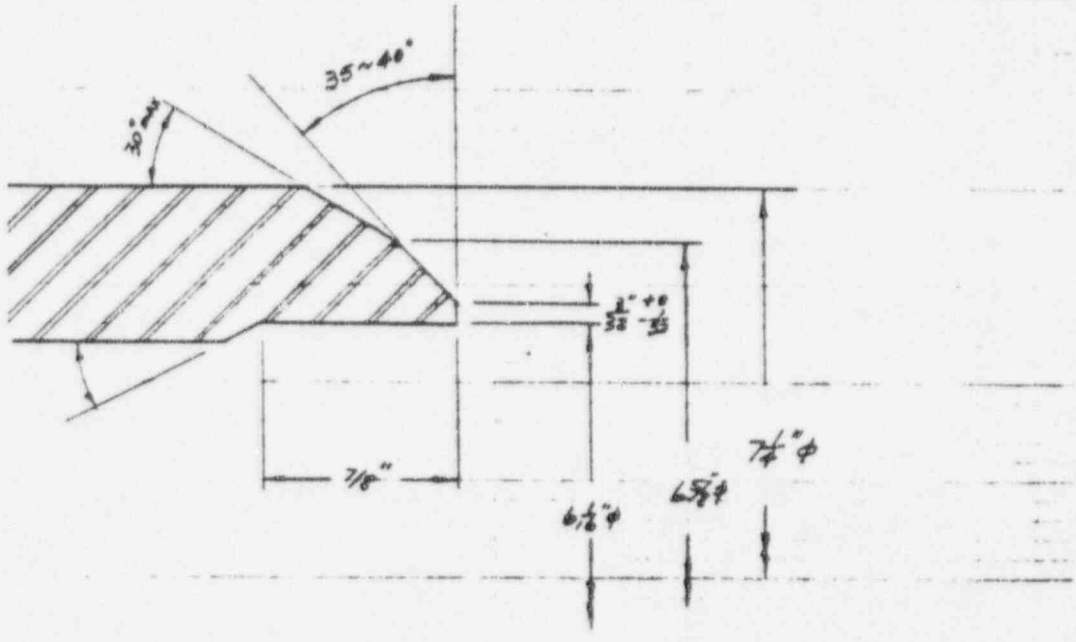


Fig 24 MSV-25&26 End Preparation

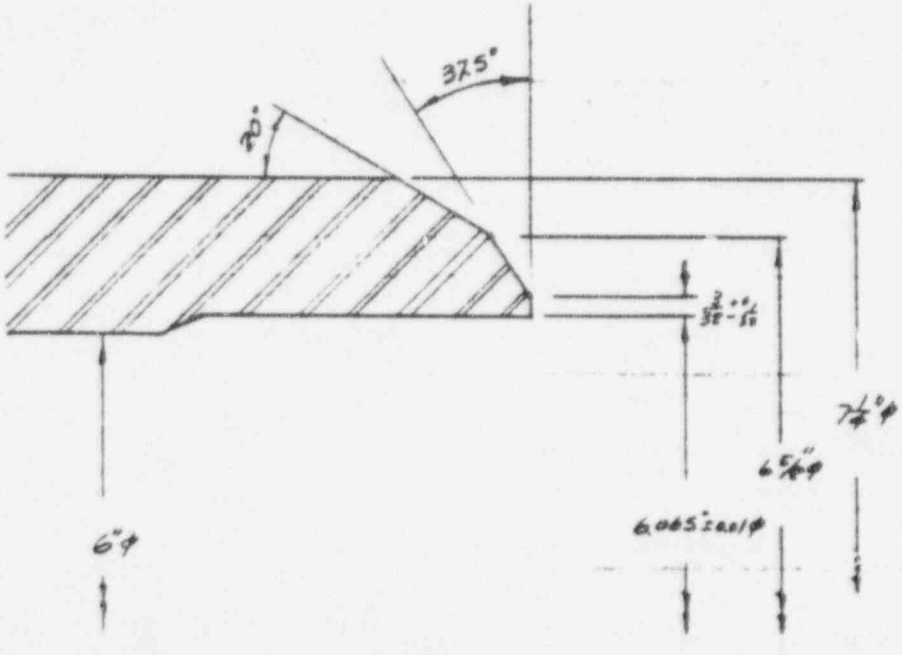
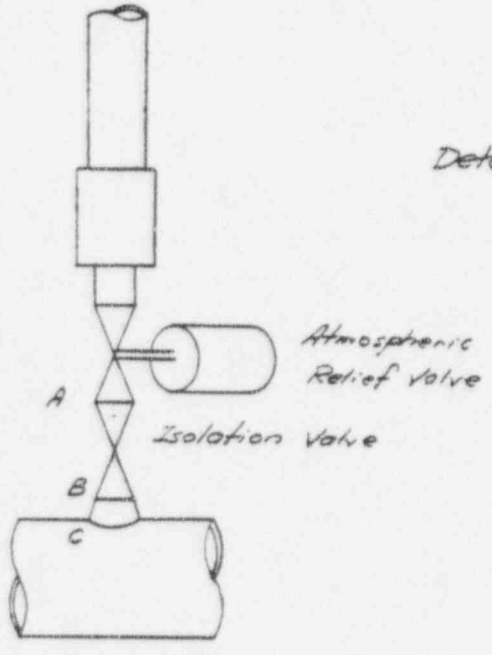
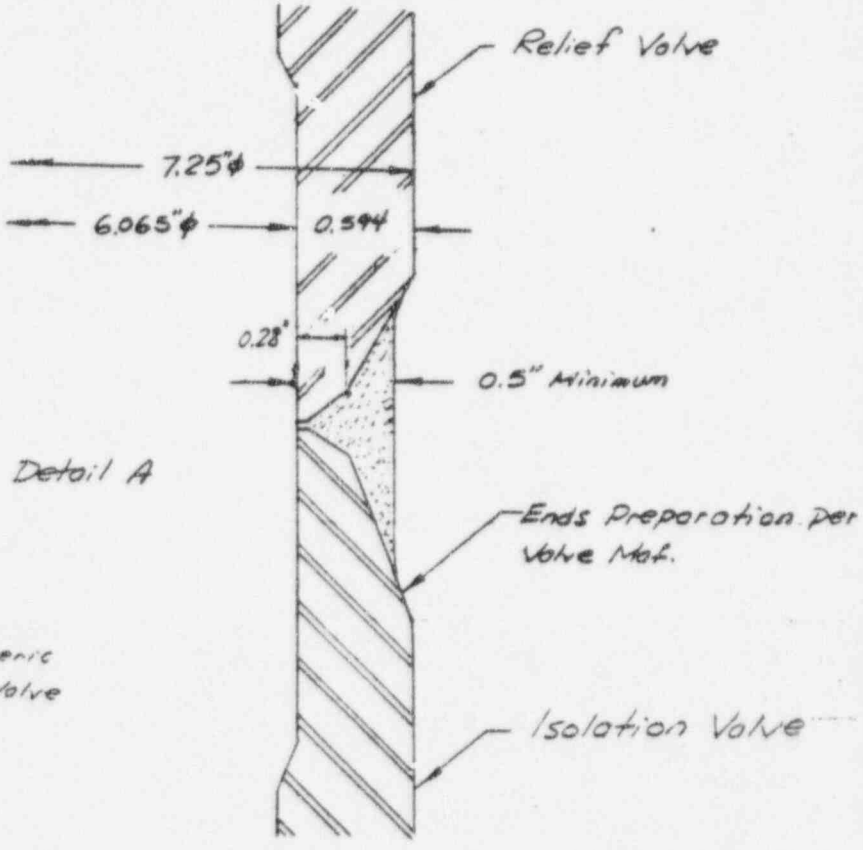


Fig 25 MSV-27 & 28 End Preparation

FPC CR-3	MADE 10/23/73 CHK'D. SQ. CF. CF. DFTG. ENG. M.Z. Lee REV. CH. APP. DATE A.F. Ferraiuolo 12/16/74	GILBERT ASSOCIATES, INC. ENGINEERS AND CONSULTANTS READING, PENNA. 4203-077 WORK ORDER | SIZE | DRAWING | REV
M.S. SAFETY + RELIEF VALVES		





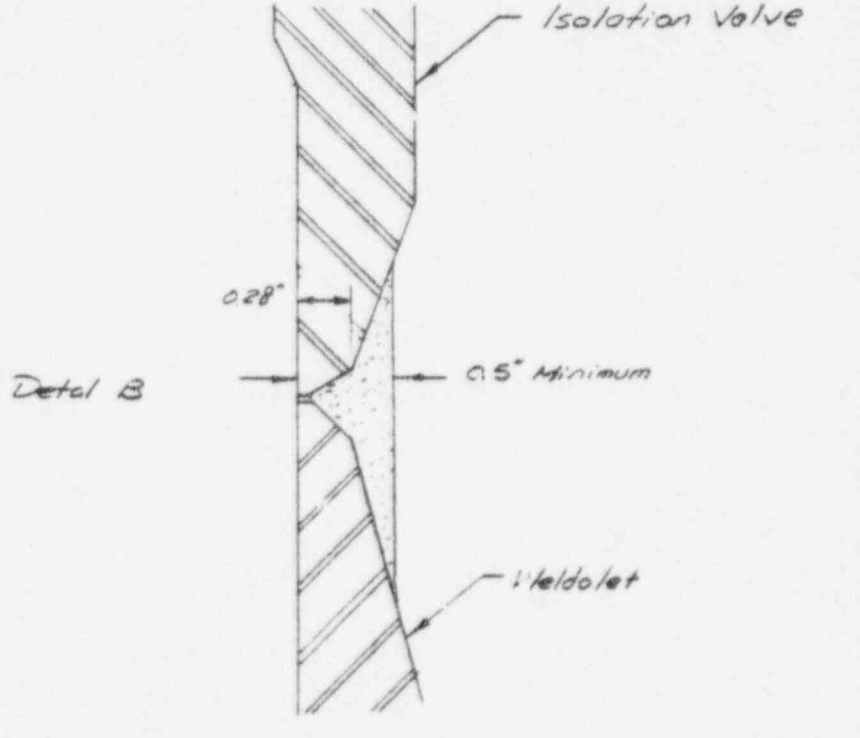


Fig. 22

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CLIENT FPC

PROJECT CR-3

FILING CODE

W.O. 4203-027 PAGE 101 OF 112

SYSTEM M.S. SAFETY & RELIEF VALVES

ORIGINATOR M.Z. Lee

DATE 10/23/73

CALCULATION FOR

REVIEWER S.F. Ferraello

DATE 12/16/74

RESULTS

Modification.

Suppose the wall of branch is 0.5" with I.D. 6.065" (of SCH. 40) already fabricated, then

$$r_m' = \frac{6.065 + 7.065}{4} = 3.28"$$

$$r_p = \frac{1}{2} \times 6.688 + 0.5 = 3.844"$$

$$i = 1.5 \left(\frac{R_m}{T_r}\right)^{2/3} \left(\frac{r_m'}{R_m}\right)^{1/2} \left(\frac{T_b'}{T_r}\right) \left(\frac{r_m'}{r_p}\right)$$

$$= 1.5 \left(\frac{11.516}{0.968}\right)^{2/3} \left(\frac{3.28}{11.516}\right)^{1/2} \left(\frac{0.5}{0.968}\right) \left(\frac{3.28}{3.844}\right)$$

$$= 1.84 \quad \text{for branch}$$

For run pipe

$$C_{2r} = 0.8 \left(\frac{R_m}{T_r}\right)^{2/3} \left(\frac{r_m}{R_m}\right)$$

$$= 0.8 \left(\frac{11.516}{0.968}\right)^{2/3} \left(\frac{3.28}{11.516}\right) = 1.19$$

$$C_{2r} K_{2r} = 1.19 \times 2 = 2.38 < 3 \quad \therefore C_{2r} K_{2r} = 3$$

$$i = \frac{1}{2} C_{2r} K_{2r} = 1.5$$

FILING

GAI 310 REV. 10-72

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ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT F. P. C

PROJECT CR-3

FILING CODE

W.O. 4203-027 PAGE 102 OF 112

SYSTEM M. S. SAFETY & RELIEF VALVES

CALCULATION FOR

ORIGINATOR M. Z. Lee

DATE 10/23/73

REVIEWER A. F. Fiumarelli

DATE 12/14/73

RESULTS

Section Modules

$$t_s = \min \begin{cases} 0.968 \\ 1 \times 0.5 = 1.08 \times 0.5 = 9.2 \end{cases} = 0.50$$

$$Z_s = \pi (r_o')\, t_s = \pi (3.28)^2 \cdot 0.5 = 16.9 \text{ in}^3$$

Stress due to Internal Pressure

$$\frac{pD_o}{4t_n} = \frac{1144 \times 7.065}{4 \times 0.5} = 4{,}050 \text{ psi}$$

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GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC

PROJECT: CR-3

FILING CODE:

W.O. 4203-027 PAGE 103 OF 112

SYSTEM: M.S. SAFETY & RELIEF VALVES

ORIGINATOR: M 2 Lee

DATE: 8/20/74

CALCULATION FOR:

REVIEWER: A.F. Fiorello

DATE: 12/16/74

RESULTS

Loads from Computer Output

CR-4 pt. 92

		Run Pipe in-lb	Branch in-lb
MA	Dead Weight	46,446	19,800
	Seismic	174,166	59,076
MB	Safety V. Disch.	524,894	—
	Total	699,060	
	Thermal	2,526,027	0
MC	Anchor Movement	—	—
	Total	2,526,027	

Notes

1 Relief valve on CR-5 line has smaller loads.

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PROJECT CR-3

FILING CODE

W.O. 4203-027 PAGE 104 OF 112

SYSTEM M.S. SAFETY & RELIEF VALVES

ORIGINATOR M.Z. Lee

DATE 8/20/74

CALCULATION FOR

REVIEWER S.F. Fernando

DATE 12/16/74

RESULTS

Header

$\frac{PD}{4t} = 7,100$ psi

$0.75i\frac{M_A}{Z} = 0.75 \times 1.5 \times \frac{46046}{388} = 134$ psi

$0.75\,i\,\frac{M_B}{Z} = 0.75 \times 1.5 \times \frac{649,060}{388} = 2020$ psi

$1.5\,\frac{M_C}{Z} = 1.5\,\frac{2,526027}{388} = 9,770$ psi

Sustained Load Stress

$\frac{PD}{4t} + 0.75i\,\frac{M_B}{Z} = 7,100 + 134 = 7,234$ psi

$< 15,000$ psi O.K

Occasional Load stress

$\frac{PD}{4t} + 0.75i\,\frac{M_A + M_B}{Z} = 7,234 + 2020 = 9,254$ psi

$< 18,000$ psi

O.K

Thermal Load Stress

$1.5\,\frac{M_C}{Z} = 9,770 < 22,500$ psi O.K

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GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: F. P. C

PROJECT: CR-3

FILING CODE:

W.O. 4203-027 PAGE 105 OF 112

SYSTEM: M. S. SAFETY & RELIEF VALVES

CALCULATION FOR:

ORIGINATOR: M. Z. Lee
DATE 10/23/73

REVIEWER: A. F. Fernello
DATE 12/16/74

RESULTS

Bending moments due to weight of valves

Isolation valves

$M_x = 580^{lbs} \times 15" = 8,700^{lb-in}$ (Ref 15)

Relief valve

Fisher's Data (Ref 17) gives valve weight = 700 lbs which does not include actuator.

Since the actuator is about 60" long (Ref 16) the dead weight moment can not be ignored.

The similar valves used in Three Mile Island #1 have the following data

MSV-4A&B (RC-1)	6"	2195 lb	C.G 29.2" from ℄ of Flow
MSV-30	6"	1640 lb	

Since no information can be found, it is estimated that the relief valve and actuator assembly

Weighs 2000 lb with CG 30" from ℄ of flow

Then

$M_x = 2000 \times 30 = 60,000^{in-lb}$

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CLIENT FPC

PROJECT CR-3

FILING CODE

W.O. 4203-007 PAGE 106 of 112

SYSTEM M. S. SAFETY & RELIEF VALVES

CALCULATION FOR

ORIGINATOR M. Z. Lee

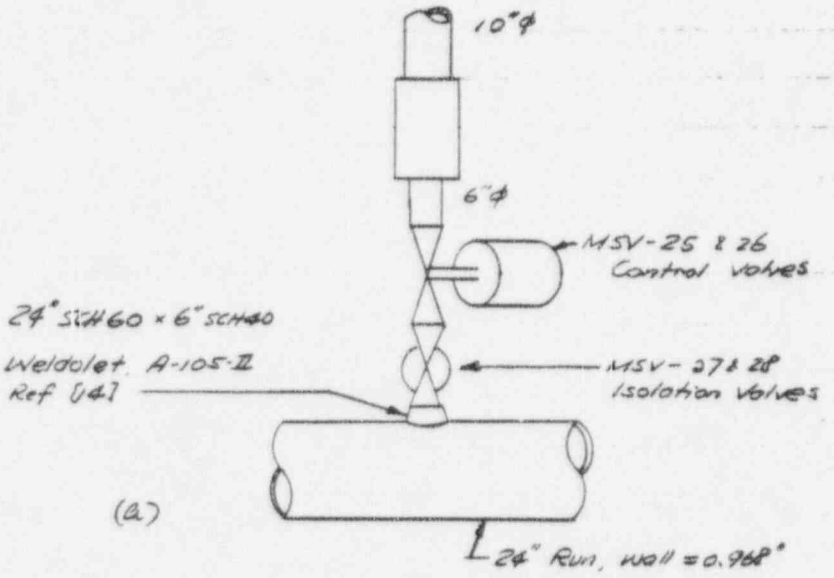
DATE 10/23/73

REVIEWER A. F. Fiorentino

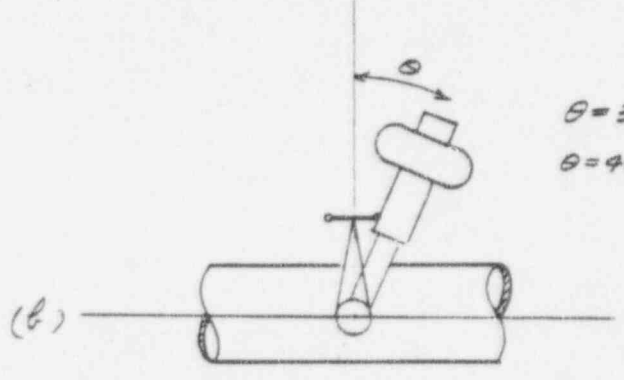
DATE 12/16/74

RESULTS

Moments on T-Joint of Atmospheric Relief valve



SECTION



PLAN

Fig. 23

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READING, PA.

CLIENT: F.P.C.

PROJECT: CR-3

FILING CODE:

W.O. 4203-027 PAGE 107 OF 112

SYSTEM: M.S. SAFETY & RELIEF VALVES

ORIGINATOR: M. Z. Lee
DATE 12/3/73

CALCULATION FOR:

REVIEWER: A. F. Fernandez
DATE 12/16/74

RESULTS

From Ref. 7. the relief and isolation valve have min angle difference of 30° in plan view. Therefore, the combine moment is

$$M = \sqrt{M_I^2 + M_R^2 + 2 M_I M_R \cos 30^\circ}$$

$$= \sqrt{(8.7)^2 + (60)^2 + 2 \times 8.7 \times 60 \times 0.866}$$

$$= \sqrt{4579.8} = 67.7 \quad \text{Kip-in}$$

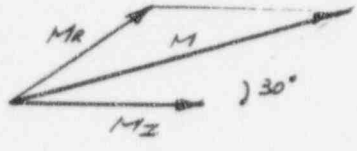

Fig. 24

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GAI 350 REV. 10-72

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ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT F. P. C.

PROJECT CR-3

FILING CODE

W.O. 4203-027 PAGE 108 OF 112

SYSTEM M. S. SAFETY & RELIEF VALVES

ORIGINATOR M. Z. Lee

DATE 8/20/74

CALCULATION FOR

REVIEWER A. J. Fernello

DATE 12/16/74

RESULTS

Branch

$\frac{pD}{4t} = 4,670$ psi

$MA = 19,800 + 67,700 = 87,500$ lb-in

Computer output due to valve weight

Actuator dead weight (estimated)

$0.75i \frac{MA}{Z} = 0.75 \cdot \frac{87500}{16.9} = 3,680$ psi

Max acceleration at the relief valves is in the order of 10^{-3} ft/sec^2 (CR-4 5/31/74 p 14.). Assume conservatively that the earthquake moment is the same as dead weight moment, then

$MB = 59,076 + 67,700 = 126,776$ in-lb

Computer output due to value weight OBE x 2

estimated seismic load created by actuator

$0.75i \frac{MB}{Z} = 0.75 \times \frac{126,776}{16.9} = 5,620$ psi

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ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: F.P.C.

PROJECT: CR-3

FILING CODE

W.O. 4203-027 PAGE 109 OF 112

SYSTEM: M.S. SAFETY + RELIEF VALVES

ORIGINATOR: M Z Lee

DATE: 8/20/74

CALCULATION FOR

REVIEWER: L. P. Fennell

DATE: 12/16/74

RESULTS

$$\frac{PD}{4t} + 0.75i\frac{M_A}{Z} = 4{,}050 + 3{,}680 = 7{,}730 \text{ psi}$$

$< 15{,}000$ psi

$$\frac{PD}{4t} + 0.75i\frac{M_A + M_B}{Z} = 7{,}730 + 6{,}620 = 14{,}350 \text{ psi}$$

$< 18{,}000$ psi

Thermal stress is negligible.

GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
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CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4203-02 PAGE 10 OF 12

SYSTEM: M.S. SAFETY & RELIEF VALVES
CALCULATION FOR:

ORIGINATOR: M.Z. Lee
DATE: 10/23/73
REVIEWER: A.F. Fasullo
DATE: 12/16/74

RESULTS

References

[1] Consolidated and Hancock Valves for Nuclear Service. Dresser Catalog N-100

[2] Criteria and Guidelines for the design of Safety and Relief valve Installation on Westinghouse PWR plants Westinghouse Elect. Corp. 1972

[3] Dresser Technical Manuals Con-1
Consolidated Outlet Reaction Charts. March, 73.

[4] Consolidated Outlet Reaction Charts. Aug-1972

[5] GAI DWG 4203 E 304-011

[6] -012

[7] 025

[8] B & W DWG 620,007. 38-41-600 03

[9] Dresser Ind. Valve DWG CP-1072

[10] " SK-6472

[11] Biggs. Introd to Structure Dynamics. McGraw 1964.

[12] Stress Intensification Factors and Stress Indices for Boney Forge Sweepolets. Boney forge Allenton, Pa.

[13] Power Piping Code ANSI B31.1. 1967
" Summer 73 Add.

[14] Kellog. Pipe Fabrication DWG Sheet No F139 Rev. 3 Mark No MS-30.

[15] GAI DWG 4203 C-305-803

FILING CODE

GILBERT ASSOCIATES, INC. ENGINEERS AND CONSULTANTS READING, PA.	CLIENT F. P. C.	FILING CODE
	PROJECT CR-3	W.O. 4003-177 PAGE 111 OF 112
SYSTEM M. S. SAFETY & RELIEF VALVES		ORIGINATOR M. Z. Lee DATE 10/23/73
CALCULATION FOR		REVIEWER S. F. Fernandes DATE 12/16/74

RESULTS

[16] Crystal River #3 Valve Master, File No. 6178 Fisher DWG AV33244

[17] Fisher Gov. Corp. Globe Valve Quotation P21A 6/12/70 (I&C File)

[18] Fisher DWG 30A0649 in Valve Master File, 6178.

[19] Chapman DWG PE-149244 File. 6178

[20] Prandtl, Ludwig: Essentials of Fluid Dynamics. Hafner Pub. Co. New York 1952.

[21] CRANE Flow of Fluids through Valves Fittings and Pipe.

[22] Crystal River #3 Piping Spec.

[23] Piping Stress Analysis CR-3BDL 03/26/74
[24] " CR-3.C (Seismic) 04/17/74
[25] " CR-3BT 03/26/74
[26] " CR-3S.T. 04/26/74.
[27] " CR-3BT Safety Valve Load 04/22/74

[28] " CR-4FTI 06/07/74
[29] " CR-4FSVL 06/10/74
[30] " CR-4F Seismic 05/24/74
[31] " CR-4 SS 07/11/73
[32] " CR-4FDL 05/21/74

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GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: F.P.C.

PROJECT: CR-3

FILING CODE

W.O. 4203-007 PAGE 112 OF 112

SYSTEM: M.S. SAFETY + RELIEF VALVES

CALCULATION FOR

ORIGINATOR M.Z. Lee
DATE 10/23/73

REVIEWER A.F. Fiumello
DATE 12/16/74

RESULTS

[33] Piping Stress Analysis CR-5BDL 04/08/74
[34] " CR-5C (Seismic) 04/18/74
[35] " CR-5AT, 04/04/74
[37] " CR-5ASV 04/24/74
[38] " CR-6BT3 04/04/74
[39] " CR-6CDL 04/08/74
[40] " CR-6-SS E4203MS6130 07/05/73
[41] " CR-6B-T3 Safety Valve 04/25/73
[42] " CR-6E Seismic 04/23/74

[43] GAI DWG 4203 C 301-001 Welding Ends Details

[44] Supports to Resist Force and Moments Imposed by Safety Valve. Preliminary Design. May 3, 1973 Sketch.

[45] Letter from Dexter Cobb of Thermecon, Inc. to A.P. Rockino 4/27/72

[46] Piping Stress Analysis CR-3-AT 10/31/73 S.V. Load Run #1
[47] " 10/31/73 Run #2
[48] " T4203MS06D1 10/1/73 " Run #1
[49] " T4203MS06D1 11/05/73 " Run #3
[50] " T4203MS07D2 11/06/73
[51] " T4203MS01D2 11/02/73

[52] Kellog Company Design of Piping Systems.

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GAI 350 REV. 10-72

APPENDIX "A"

FLORIDA POWER CORPORATION

CRYSTAL RIVER NUCLEAR POWER PLANT UNIT NO. 3

MAIN STEAM SAFETY AND RELIEF

VALVE SYSTEM STRESS ANALYSIS REPORT

APPENDIX "A"

FLEXONIC JOINT BACKPRESSURE

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: Florida Power Co.
PROJECT: Crystal River #3
FILING CODE:
W.O. 4703-027
PAGE A-20 OF A-240
SYSTEM: Main steam Safety Valve Vent
ORIGINATOR: M Z. Lee
DATE: 7/2/74
CALCULATION FOR: Flexonic Joint Back Pressure
REVIEWER: J F Fumello
DATE: 12/16/74
RESULTS

Basic Assumptions

1. No heat is added or lost across the stack wall.
2. Steady state flow is established.
3. Complete turbulent flow
4. Equivalent length of 37° elbow is approximated by 45° elbow

Methods Pressure Drop Calculation

A. Adiabatic Process Governed by Ideal Gas Law

B. Adiabatic Process using steam table One Step solution

C Ditto Four Step Solution.

D Modified Dancys Formula

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GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT

PROJECT Crystal River #3

FILING CODE

W.O. 4203-027 PAGE A-A-212 OF 240

SYSTEM Main Steam Safety Valve Vent

ORIGINATOR M. Z. Lee

DATE 3/12/74

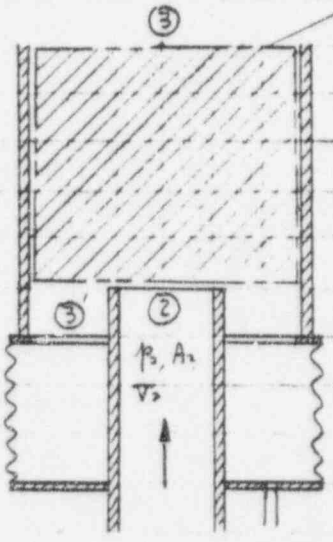
CALCULATION FOR Flexonic Joint Pressure

REVIEWER A. F. Ferranello

DATE 12/16/74

RESULTS

Determination of Flexonic Pressure



Momentum Balance across the control surface

$$P_2A_2 + m V_2 + P_{3'}(A_3 - A_2) = P_3A_3 + m V_3$$

NOTE - "m" is a MASS FLOW RATE

$$P_{3'} = \frac{P_3A_3 - P_2A_2 - m(V_2 - V_3)}{A_2 - A_3}$$

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GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: F.P.C

PROJECT: C R - 3

FILING CODE:

W.O. 4203 - 027

PAGE A- 230 OF A- 240

SYSTEM: Main Steam Vent

ORIGINATOR: M Z Lee

DATE: 3/12/74

CALCULATION FOR: Flexonic Back Pressure

REVIEWER: L F Fiumello

DATE: 12/16/74

RESULTS

It can be shown that the following relation holds for flow in constant flow area with friction

$$\frac{1}{2g}\left(\frac{W}{A}\right)^2 = \frac{144\int_{p_1}^{p_2} p\,dp}{-4f\frac{L}{D} + 2\ln\frac{p_2}{p_1}} \qquad \text{see ref 1} \qquad (1)$$

where

W = flow rate lbs/sec
A = flow area ft^2
p_1 = inlet pressure, lbs/in^2
p_2 = outlet pressure, lbs/in^2
$4f$ = friction factor
L/D = Pipe length / Diameter
$\rho_1 = 1/v_1$ = density (inlet) lbs/ft^3
$\rho_2 = 1/v_2$ = " (outlet) lbs/ft^3

Assume the steam follows the ideal gas law

$$pv^k = \text{const}$$

Then

$$\int_{p_1}^{p_2} p\,dp = \int_{p_1}^{p_2} \frac{1}{v}\,dp = \frac{k}{1+k}\frac{p_2}{v_2}\left[1 - \left(\frac{p_1}{p_2}\right)^{\frac{k+1}{k}}\right] \qquad (2)$$

Substituting (2) into (1), we have

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GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: F.P.C.

PROJECT: C R-3

FILING CODE:

W.O. 4203-027 PAGE A 204 OF 240

SYSTEM: M. S. SAFETY & RELIEF VALVES

ORIGINATOR: M Z Lee

DATE: 2/12/74

CALCULATION FOR:

REVIEWER: A F Fernello

DATE: 12/16/74

RESULTS

$$\left(\frac{W}{A}\right)^2 = 2g\frac{k}{k+1}\frac{p_2}{v_2}\left[\frac{\left(\frac{p_1}{p_2}\right)^{\frac{k+1}{k}}-1}{4f\frac{L}{D}+\frac{2}{k}\ln\left(\frac{p_1}{p_2}\right)}\right] \quad (3)$$

For $\frac{W}{A}$, p_2, v_2 known p_1 is a function of $4f\frac{L}{D}$ or

$$p_1 = p_1\left(4f\frac{L}{D}\right)$$

After p_1 is determined from (3) the rest of the variable can be obtained as follows.

$$v_1 = \left(\frac{p_2}{p_1}\right)^{\frac{1}{k}} v_2 \quad (4)$$

$$V_1 = \left(\frac{p_2}{p_1}\right)^{\frac{1}{k}} V_2 \quad (5)$$

$$M_1 = \frac{V_1}{V_s} = \frac{V_1}{\sqrt{kgpv}} \quad (6)$$

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PROJECT CR3

FILING CODE

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SYSTEM M.S. SAFETY & RELIEF VALVES

ORIGINATOR M Z Lee

DATE 2/13/74

CALCULATION FOR

REVIEWER A F Fernandez

DATE 12/16/74

RESULTS

A. Adiabatic Process using Steam Table

Start from basic equation

$$\frac{1}{2g}\left(\frac{W}{A}\right)^2 = \frac{144\int_{p_3}^{p_4} \rho\, dp}{-4f\frac{L}{D} + 2\ln\frac{\rho_4}{\rho_3}} \qquad (1)$$

Use trapezoidal rule for integration

$$\int_{p_3}^{p_4} \rho\, dp = \frac{1}{2}(p_4 - p_3)(\rho_4 + \rho_3)$$

$$= \frac{1}{2}(p_4 - p_3)\left(\frac{1}{v_4} + \frac{1}{v_3}\right)$$

Then

$$\left(\frac{W}{A}\right)^2 \frac{1}{2g} \cdot \frac{1}{144} = \frac{\frac{1}{2}(p_3 - p_4)\left(\frac{1}{v_4} + \frac{1}{v_3}\right)}{4f\frac{L}{D} + 2\ln\left(\frac{v_4}{v_3}\right)}$$

For W in #/hr. A in in^2

$$W = 3600 \times \frac{A}{144}\sqrt{g} \times 12 \sqrt{\frac{(p_3 - p_4)\left(\frac{1}{v_3} + \frac{1}{v_4}\right)}{4f\frac{L}{D} + 2\ln\left(\frac{v_4}{v_3}\right)}}$$

$$= 300\sqrt{g}\, A \sqrt{\frac{(p_3 - p_4)\left(\frac{1}{v_3} + \frac{1}{v_4}\right)}{4f\frac{L}{D} + 2\ln\left(\frac{v_4}{v_3}\right)}}$$

$$= 243{,}606 \sqrt{\frac{(p_3 - 70.575)\left(\frac{1}{v_3} + \frac{1}{6.2108}\right)}{0.981 + 2\ln\left(\frac{6.2108}{v_3}\right)}}$$

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CLIENT: FPC
PROJECT: CR-3
FILING CODE:
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SYSTEM: M.S. SAFETY & RELIEF VALVES
ORIGINATOR: M Z Lee
DATE: 2/12/74
CALCULATION FOR:
REVIEWER: J. F. Ferrello
DATE: 12/16/74

RESULTS

14" stack 0.25" wall

Exit steam Condition

$p_4 = 70$ psia

V_4	Δh	h_4	v_4	V_4
1632	53.16	1184.2	6.2722	1624.3
1634.3	53.31	1184.09	6.2695	1633.96
1634	53.29	1184.1	6.2699	1634.0147
1634.0147	53.29	1184.1	6.2699	1634.0147

converge

$$W = \frac{AV}{v} \times 3600 = \frac{143.1}{144} \times \frac{1634}{6.2699} \times 3600 = 932,341 \text{ lb/hr}$$

$p_4 = 72$ psia

V_4	Δh	h_4	v_4	V_4
1634	53.29	1184.1	6.0959	1834

converge

$$W = \frac{143.1}{144} \times \frac{1634}{6.0959} \times 3600 = 958,967 \text{ lb/hr}$$

By interpolation

$$p_4 = 70 + 2 \frac{940,000 - 932,341}{958,967 - 932,341} = 70 + 2 \times 0.2876 = 70.575 \text{ psia}$$

$V_4 = 1634$

$$v_4 = 6.2699 - (6.2699 - 6.0959) \times 0.2876 = 6.2199 \text{ ft}^3/\text{lb}$$

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CLIENT: F.P.C.

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SYSTEM: M.S. SAFETY & RELIEF VALVES

ORIGINATOR: M Z Lee

DATE: 3/12/74

CALCULATION FOR:

REVIEWER: A J Fiorello

DATE: 12/16/74

RESULTS

Try $p_3 = 142$ psia

v_3	T_3	Δh	h_3	$v = v(p,h)$
?	893.36	15.93	1221.5	3.4228
?	859	16.13	1221.4	3.4213

$$W = 243,606.5 \sqrt{\frac{(142 - 70.575) \div \left(\frac{1}{3.421} + 6.2195\right)}{0.981 + 2 \ln\left(\frac{6.2169}{3.421}\right)}}$$

$$= 243,606.5 \sqrt{14.8648} = 939,224 \text{ lbs/hr}$$

Try $p_3 = 144$ psia

v	T	Δh	h	v
3.4	893.36	15.93	1221.5	3.4228
3.38	888.1	15.74	1221.66	3.3769
3.377	887.3	15.71	1221.7	3.3771

$$W' = 243,606.5 \sqrt{\frac{(144 - 70.575)\left(\frac{1}{3.377} + 6.2199\right)}{0.981 + 2 \ln\left(\frac{6.2194}{3.421}\right)}}$$

$$= 243,606.5 \sqrt{15.2313} = 950,731 \text{ lbs/hr}$$

$\therefore$ $p_3 = 142$ psia is close to solution.

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SYSTEM: M.S. SAFETY + RELIEF VALUES

CALCULATION FOR:

ORIGINATOR: M Z Lee

DATE: 2/12/74

REVIEWER: A. J. Fiorentello

DATE: 12/16/74

RESULTS

Flexonic Pressure

$$P_3' = \frac{(142-14.7)\times 143.1 - 8.1(1531-899) - 125\times 78.9}{143.1-78.9}$$

$$= \frac{18216.6 - 5119.2 - 9862.5}{64.2} = \frac{3234.9}{64.2}$$

$$= 50 \text{ psig.}$$

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CLIENT: F.P.C.
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SYSTEM: M.S. SAFETY & RELIEF VALVES
ORIGINATOR: M. Z. Lee
DATE: 2/12/74
CALCULATION FOR:
REVIEWER: L. F. Fumarello
DATE: 12/16/74

B. Adiabatic Process Governed By IDEAL GAS LAW

RESULTS

For 14", 0.25" wall stack

d = I.D = 13.5" $\quad A_f = 143.1$ in²

$D = \frac{d}{12} = 1.125$ ft

L = Pipe length = 31'

$\frac{L}{D} = \frac{31}{1.125} = 27.6$

$\frac{L}{D} = 3 \times 16 = 48$ for 3 @ 45° elbows — See Pg A-30 Ref #2

$f^* = 4f = 0.013$ 13.5" I.D. turbulent flow

$\therefore 4f\frac{L}{D} = 0.013\ (27.6 + 48) = 0.981$

$k = \frac{C_p}{C_v} = 1.308$

Let outlet condition be approximated by calculated outlet steam conditions. See page 206.

$p_2 = 70.575$ psia

$T_2 = 1634$ °F abs

$V_2 = 6.2199$ ft³/lbm

Then

$$\left(\frac{W}{A}\right)^2 \frac{1}{2g} \frac{k+1}{k} \frac{V_2}{p_2 \times 144}$$

$$= \left(\frac{940{,}000}{3600} \times \frac{144}{143.1}\right)^2 \times \frac{1}{64.4} \times \frac{2.308}{1.308} \times \frac{6.2}{70.575 \times 144}$$

$$= 1.154$$

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SYSTEM M.S. SAFETY + RELIEF VALVES

ORIGINATOR A.Z. Lee

DATE 2/12/74

CALCULATION FOR

REVIEWED Santo Ferranello

DATE 12/16/74

RESULTS

It remains to solve p_3 from

$$\frac{\left(\frac{p_3}{p^*}\right)^{\frac{k+1}{k}} - 1}{0.981 + \frac{2}{k} \ln \frac{p_3}{p^*}} = 1.154$$

p_3	p_3/p_4	Denomin.	Numer.	LHS
140	1.9837	2.0293	2.34	1.1575
130	1.842	1.916	1.9384	1.0117
135	1.9128	1.9737	2.1407	1.0846
139	1.9695	2.0183	2.3068	1.1429
139.76	1.9803	2.0267	2.3388	1.1529

$p_3 = 139.76$ psia

$v_3 = \left(\frac{p_3}{p_4}\right)^{\frac{1}{k}} v_4 = 0.5931\ v_2 = 3.68$

$V_3 = \left(\frac{p_3}{p_4}\right)^{\frac{1}{k}} V_4 = 0.5931\ V_2 = 966.2$

$$M = \frac{V_3}{\sqrt{kgpv}} = \frac{966.2}{\sqrt{1.308 \times 32.2 \times 139.76 \times 144 \times 3.68}}$$

$$= \frac{966.2}{1765.5} = 0.547$$

$p_3 - p_a = 139.76 - 70.575 = 69$

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PROJECT: CR-3

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SYSTEM: M. S. SAFETY & RELIEF VALVES

ORIGINATOR: M Z. Lee

DATE: 7/12/74

CALCULATION FOR

REVIEWER: A. F. Fiorello

DATE: 12/16/74

RESULTS

Flexonic Pressure

$$P_3' = \frac{(139.8-147)143.1 - 8.1(153-966.2) - 125\times78.9}{143.1-78.9}$$

$$= \frac{17{,}920 - 4570 - 9860}{64.2} = \frac{3490}{64.2} = 54.3 \text{ psig}$$

Note. Use $k=1.3$ $P_3 = 139.6$ the effect of k is appreciably small

$P_3' =$ 54.3 psig

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PROJECT: CR-3

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SYSTEM: M.S. SAFETY & RELIEF VALVES

ORIGINATOR: M Z Lee

DATE: 2/12/74

CALCULATION FOR

REVIEWED: A. F. Fumello

DATE: 11/16/74

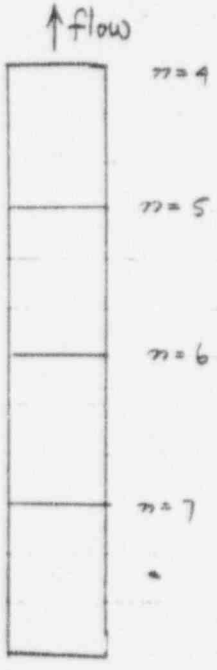
RESULTS

C. Multi-Stage Solution using Steam Table

Divide the stack into four equal (equivalent) length, and solve pressure drop section by section starting from exit end downward to the inlet.

$$4f\frac{4L}{D} = \frac{1}{4}\,a981 = 0.24525$$

$$W' = 243,606.5\sqrt{\frac{(P_{n+1} - P_n)\left(\frac{1}{v_{n+1}} + \frac{1}{v_n}\right)}{0.24525 + 2\ln\left(\frac{v_{n+1}}{v_n}\right)}}$$



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SYSTEM M.S. SAFETY & RELIEF VALVES

ORIGINATOR M Z Lee

DATE 2/12/74

CALCULATION FOR

REVIEWED J F Buonello

DATE 12/16/74

RESULTS

First section (Exit End)

$p_5 = 106$ psia

v_5	T_5	Δh_5	h_5	$v = v(p_5, h_5)$
4.4	1156.1	26.7	1210.7	4.45
4.45	1169.3	27.3	1210.1	4.45

converge

$$W' = 243,606.5 \sqrt{\frac{(106 - 70.575)\left(\frac{1}{4.45} + \frac{1}{6.2199}\right)}{0.24525 + 2\ln\left(\frac{6.2199}{4.45}\right)}}$$

$$= 243,606.5 \times 3.8628 = 941,025 \text{ lbs/hr}$$

$$\frac{941,025 - 940,000}{940,000} = 0.001 = .1\%$$

$\therefore$

$p_5 = 106$ psia

$v_5 = 4.45$ ft³/#

$V_5 = 1169.3$ ft/sec

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SYSTEM M.S. SAFETY & RELIEF VALVES

CALCULATION FOR

ORIGINATOR M. Z. Lee

DATE 12/12/74

REVIEWER L. F. Fernandez

DATE 12/16/74

RESULTS

Second Section

$p_6 = 120$ psia

v_6	V_6	Δh	h_6	$v_6 = v(p_6, h_6)$
3.93	1032.6	21.28	1216.1	3.9945
3.99	1048.4	21.94	1215.5	3.9878

converge

$$W = 243,606.5 \sqrt{\frac{(120-106)\left(\frac{1}{3.99}+\frac{1}{4.45}\right)}{0.24525 + 2\ln\left(\frac{4.45}{3.99}\right)}}$$

$$= 243,606.5 \times 3.789 = 923,046 \text{ lbs/hr.}$$

$p_6 = 122$ psia

v_6	V_6	Δh	h_6	$v_6 = v(p_6, h_6)$
3.8	998.5	19.9	1217.5	3.943
3.94	1035.25	21.39	1216.	3.9276
3.93	1032.6	21.28	1216.1	3.9287

$$W = 243,606.5 \sqrt{\frac{(122-106)\left(\frac{1}{3.93}+\frac{1}{4.45}\right)}{0.24525 + 2\ln\left(\frac{4.45}{3.93}\right)}}$$

$$= 243,606.5 \times 3.94 = 959,833 \text{ lbs/hr.}$$

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CALCULATION FOR:

ORIGINATOR: M Z Lee
DATE: 3/12/74
REVIEWER: A. F. Fernello
DATE: 12/16/74

RESULTS

By interpolation

$$\frac{940,000 - 923,046}{959,833 - 923,046} = \frac{16,954}{33,787} = 0.5$$

$p_6 = 120 + 2 \times 0.5 = 121$ psia

$v_6 = (3.99 + 3.93)\frac{1}{2} = 3.96$ $ft^3/\#$

$V_6 = (1032.6 + 1048.4) = 1040.5$ ft/sec

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SYSTEM: M.S. SAFETY + RELIEF VALVES

CALCULATION FOR:

ORIGINATOR: M Z. Lee

DATE: 3/12/74

REVIEWER: J. F. Ferranello

DATE: 12/16/74

RESULTS

Third Section

$p_7 = 132$ psia

v_7	T_7	Δh_7	h_7	$v_7 = v(p_7, h_7)$
3.65	959	18.36	1219	3.6591
3.658	961.2	18.44	1218.96	3.6584

$$W' = 243,606.5 \sqrt{\frac{(132-121)\left(\frac{1}{3.658}+\frac{1}{3.96}\right)}{0.24525 + 2\ln\left(\frac{3.96}{3.658}\right)}}$$

$$= 243,606.5 \times 3.7841 = 921,841 \text{ lbs/hr}$$

$p_7 = 134$ psia

v_7	T_7	Δh_7	h_7	$v_7 = v(p_7, h_7)$
3.658	961.2	18.44	1218.96	3.603
3.61	948.5	17.96	1219.4	3.6078

$$W' = 243,606.5 \sqrt{\frac{(134-121)\left(\frac{1}{3.61}+\frac{1}{3.96}\right)}{0.24525 + 2\ln\left(\frac{3.96}{3.61}\right)}}$$

$$= 243,606.5 \cdot 4 = 974,400 \text{ lbs/hr}$$

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SYSTEM: M.S. SAFETY & RELIEF VALVES

ORIGINATOR: M.Z. Lee

DATE: 2/12/74

CALCULATION FOR:

REVIEWER: A. F. Fernandez

DATE: 12/16/74

RESULTS

Interpolation

$$\frac{940,000 - 921\,841}{974,400 - 921.841} = \frac{18159}{52.560} = 0.3452$$

$$p_7 = 132 + 2 \times 0.3452 = 132.7 \text{ psia}$$

$$v_7 = 3.658 - (3.658 - 3.61) \times 0.3452 = 3.6414 \ ft^3/\#$$

$$\nabla_7 = 961.2 - (961.2 - 948.5) \times 0.3452 = 956.8 \ ft/sec$$

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SYSTEM: M.S. SAFETY & RELIEF VALVES
ORIGINATOR: M Z Lee
DATE: 2/12/74
CALCULATION FOR:
REVIEWER: A F Fiorello
DATE: 12/16/74

RESULTS

Fourth Section

$P_s = 142$ psia

V_s	V_f	Δh	h_f	$V_f = V(P_s, h_s)$
3.42	p98.6	16.1	1221.3	3.4213
3.4213	898.96	16.13	1221.3	3.4213

$$W = 243,606.5 \sqrt{\frac{(142 - 132.7)\left(\frac{1}{3.4213} + \frac{1}{3.6414}\right)}{0.24525 + 2\ln\left(\frac{3.6414}{3.4213}\right)}}$$

$$= 243,606.5 \times 3.775 = 919,639 \text{ lbs/hr.}$$

$P_s = 144$ psia

V_s	V_f	Δh	h_f	$V_f = V(P_s, h_s)$
3.4	p93.4	15.93	1221.47	3.375
3.38	888.1	15.74	1221.66	3.3769
3.377	887.3	15.71	1221.7	3.377

$$W = 243,606.5 \sqrt{\frac{(144 - 1327)\left(\frac{1}{3.377} + \frac{1}{3.6414}\right)}{0.24525 + 2\ln\left(\frac{3.6414}{3.4213}\right)}}$$

$$= 243,606.5 \times 4.0355 = 983,091 \text{ lbs/hr.}$$

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SYSTEM M.S. SAFETY & RELIEF VALVES

ORIGINATOR M Z Lee

DATE 2/12/74

CALCULATION FOR

REVIEWER J. Fernando

DATE 12/16/74

RESULTS

Interpolation

$$\frac{940,000 - 919,639}{983,091 - 919,639} = \frac{20,361}{63,452} = 0.321$$

$P_8 = 142 + 2 \times 0.321 = 142.6$ psia

$v_8 = 3.4213 - (3.4213 - 3.377) \times 0.321 = 3.41$ ft³/#

$V_8 = 898.96 - (898.96 - 887.3) \times 0.321 = 895.2$ ft/sec

Inlet Condition

P_8 =	142.6	psia	$= P_3$
v_8 =	3.41	ft³/#	$= v_3$
V_8 =	895.2	ft/sec	$= V_3$

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CALCULATION FOR		REVIEWER S.F. Ferrarello DATE 12/16/74
		RESULTS

Flexonic Back Pressure

$$p_{3'} = \frac{(142.6 - 14.7)\,143.1 - 8.1(1531 - 895.7) - 125 \times 78.9}{143.1 - 78.9}$$

$$= \frac{18{,}300 - 5{,}150 - 9862.5}{64.2} = \frac{3287}{64.2} = 51.2 \text{ psig}$$

GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
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ORIGINATOR: M Z Lee
DATE 2/12/74
CALCULATION FOR:
REVIEWED: J. F. Ferranello
DATE 12/16/74
RESULTS

D. Modified Darcys Formula
(Take enterance velocity into consideration)

$$W' = 1891\, Y d^2 \sqrt{\frac{\Delta p}{K v_3}}$$

$$\Delta p = p_3 - p_4 + \frac{V_3^2}{2g v_3} \times \frac{1}{144}$$

Try $p_3 = 152$ psia

v_1	v_2	Δh	h_3	$v = v(p,h)$
3.2	840.8	14.1	1223.3	3.2125
3.2115	843.9	14.21	1223.19	3.2115

$$\Delta p = p_1 - p_2 + \frac{V_3^2}{2g v_3}$$

$$= 152 - 70.575 + \frac{(883.9)^2}{64.4 \times 3.2115}$$

$$= 152 - 70.575 + 23.9 = 103.9$$

$$\frac{p_3 - p_4}{p_3} = \frac{152 - 70.575}{152} = 0.5263 \quad \text{which gives}$$

$Y = 0.672$ $\quad K = 1.981$ CRANE pA-22

$$W = 1891 \times 0.672 \times (13.5)^2 \sqrt{\frac{103.9}{1.981 \times 3.2115}} = 935,979 \text{ lbs/hr}$$

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SYSTEM M.S. SAFETY + RELIEF VALVES

ORIGINATOR M Z. Lee

DATE 2/13/74

CALCULATION FOR

REVIEWER A F Ferranello

DATE 2/16/74

RESULTS

Try $p_3 = 154$ psia

v_1	v_2	Δh	h_2	$v = v(p, h)$
3.2	840.8	14.1	1223.3	3.17
3.17	832.9	13.85	1223.55	3.1726
3.1723	833.58	13.87	1223.53	3.1724

$$\Delta p = 154 - 70.575 + \frac{1}{144}\frac{(833.58)^2}{64.4 \times 3.1725}$$

$$= 154 - 70.575 + 23.62 = 105.62 \text{ psi}$$

$$\frac{p_3 - p_4}{p_3} = \frac{154 - 70.575}{154} = 0.5324$$

$$Y = 0.67$$

$$W' = 1891 \times 0.67 \times (13.5)^2 \sqrt{\frac{105.62}{1.981 \times 3.1725}}$$

$$= 946.596 \ \#/\text{hr}$$

FILING CODE

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4203-027 PAGE A-30 OF 240

SYSTEM: M.S. SAFETY & RELIEF VALVES
ORIGINATOR: M Z Lee
DATE: 3/12/74
CALCULATION FOR:
REVIEWER: J Fernandez
DATE: 12/16/74

RESULTS

$$\frac{940,000 - 935,979}{946,596 - 935,979} = \frac{4,021}{10,617} = 0.3787$$

$$p_2 = 152 + 2 \times 0.3787 = 152.8 \text{ psia}$$

$$v_3 = 3.2115 - (3.2115 - 3.1725) \times 0.3787 = 3.2 \text{ ft}^3/\#$$

$$V_3 = 262,753\, v_2 = 839.95 \doteq 840 \text{ ft/sec}$$

$$h_{3} = h_{3} - \frac{V^2}{2gJ} = 1223.3 \text{ BTU/\#}$$

Flexonic Pressure

$$p_3' = \frac{(1152.8 - 147) \times 143.1 - 8.1(153 - 840) - 125 \times 78.9}{143.1 - 78.9}$$

$$= \frac{19,762.1 - 5,597.1 - 9862.5}{64.2}$$

$$= 67 \text{ psig}$$

FILING

GAI 350 REV. 10-72

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ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4203-027
PAGE A 239 thru A 240

SYSTEM: M.S. SAFETY + RELIEF VALVE
CALCULATION FOR:
ORIGINATOR: M Z Lee
DATE: 3/2/74
REVIEWER: J Farinella
DATE: 12/16/74

RESULTS

E. Increased Stock Wall Thickness

Pressure drop in Stack and Flexonic Backpressure if 14" STD (wall = 0.375") pipe were used

$d = 14 - 0.375 \times 2 = 13.25$ $\quad A_f = 137.9\ in^2$

$D = \frac{d}{12} = 1.104$

$\frac{L}{D} = \frac{31}{1.104} = 28$ pipe

$\frac{L}{D} = 3 \times 16 = 48$ 3 of 45° Elbows

$f = 0.013$

$K = f\frac{L}{D} = 0.013\,(28+48) = 0.988$

$K = 1$ Exit loss

$K = 1 + 0.988 = 1.988$

$k = \frac{C_p}{C_v} = 1.3$

$\max \frac{\Delta p}{p_1} = 0.592$ } CRANE A-22

$Y = 0.635$

FILING CODE

GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT FPC
PROJECT CR-3
FILING CODE
W.O. 4203-027
PAGE A 1250F240

SYSTEM M.S. SAFETY + RELIEF VALVES
CALCULATION FOR
ORIGINATOR M. Z. Lee
DATE 12/12/74
REVIEWER A. F. Fennello
DATE 12/16/74

RESULTS

Flow area of 14" STD pipe (ID=13.25")

$A_4 = A_3 = 137.9 \text{ in}^2$

Steam Conditions at Exit of stack

p_4 psia	V_4	$\Delta h = \frac{V^2}{gJ}$	$h_4 = h_0 - \Delta h$	$v_4 = v(p_4, h_4)$	V_4	W
72	1650	54.34	1183.06	6.09	1633	934.051
	1635	53.35	1184.05	6.094	1624	924.953
73	1634	53.29	1184.01	6.012	1624	936.995
74	1634	53.29	1184.01	5.9311	1624	949.780

$\therefore p_4 = 73 \sim 74$ psia

By interpolation.

$$\frac{940.000 - 936.995}{949.780 - 936.995} = \frac{3}{12.8} = 0.234$$

$p = 73.234 \doteq 73.2$ psia

$V = 1634$ ft/sec

$v = 5.99$ ft³/#

FILING CODE

GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT F.P.C.

PROJECT CR-3

FILING CODE

W.O. 4203-027 PAGE A 226 OF 240

SYSTEM M. S. SAFETY + RELIEF VALVE

ORIGINATOR M Z Lee

DATE 2/12/74

CALCULATION FOR

REVIEWER A J Fernelle

DATE 2/10/74

RESULTS

use steam table / Step Method

Try $P_3 = 148$ psia

v	V	Δh	h_v	$V = v(p,h)$
3.28	894.32	15.96	1221.44	3.2836
3.2836	895.3	15.999	1221.4	3.2833
3.2833	895.24	15.999	"	"

$$W = 300\sqrt{g}\, A \sqrt{\frac{(P_1 - P_2)\left(\frac{1}{v_1} + \frac{1}{v_2}\right)}{4f\frac{L}{D} + 2\ln\left(\frac{v_2}{v_1}\right)}}$$

$$= 300\sqrt{32.2} \times 137.9 \sqrt{\frac{(148 - 732)\left(\frac{1}{3.2833} + \frac{1}{5.99}\right)}{0.988 + 2\ln\left(\frac{5.99}{3.2833}\right)}}$$

$$= 941,672 \text{ lbs/hr.} \approx 940,000 \text{ lbs/hr.}$$

Flexonic Pressure

$$P_3' = \frac{(148 - 147) \times 137.9 - 8.1(1531 - 895) - 125 \times 78.9}{137.9 - 78.9}$$

$$= \frac{18,382 - 5151.6 - 9862.5}{59} = 57 \text{ psig}$$

FILING CODE

GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: F.P.C.

PROJECT: CR-3

FILING CODE:

W.O. 4203-027

PAGE # 227 of 240

SYSTEM: M.S. SAFETY & RELIEF VALVES

ORIGINATOR: M.Z. Lee

DATE: 3/12/74

CALCULATION FOR:

REVIEWER: A.F. Fiorelli

DATE: 12/16/74

RESULTS

F 14" stock. 0.375 wall

use Modified Darcy Formula

Try $p_s = 158$ psia

v	T	Δh	h	$v = v(p,h)$
3	817.98	13.35	1224.15	3.0959
3.09	842.5	14.17	1223.23	3.089
3.0895	842.39	14.16	1223.24	3.0895

$$\frac{1}{144}\frac{V_s^2}{gv} = \frac{1}{144}\frac{(842.4)^2}{64.4 \times 3.09} = 24.8$$

$$\Delta p = 158 - 73.2 + 24.8 = 109.6$$

$$\frac{p_s - p_{sat}}{p_s} = \frac{158 - 73.2}{158} = 0.5367$$

$$Y = 0.665$$

$$W = 1891\, Y\, d^2 \sqrt{\frac{\Delta p}{K v_s}}$$

$$= 1891 \times 0.665 \times (13.25)^2 \sqrt{\frac{109.6}{1.988 \times 3.0895}}$$

$$= 932,477 \text{ lbs/hr.}$$

FILING CODE

GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: F. P. C.

PROJECT: CR-3

FILING CODE:

W.O. 4203-827 PAGE A 180 OF A 240

SYSTEM: M. S. SAFETY & RELIEF VALVE

ORIGINATOR: M. Z. Lee

DATE: 12/12/74

CALCULATION FOR:

REVIEWER: J. F. Fanarello

DATE: 12/16/74

RESULTS

Try $p_1 = 160$ psia

v	V	Δh	h	$v = v(p,h)$
3	817.98	13.35	1224.05	3.0575
3.057	833.5	13.87	1223.53	3.0536
3.054	832.7	13.84	1223.56	3.0538

$$\frac{1}{144}\frac{V^2}{2gv} = \frac{1}{144}\frac{(832.7)^2}{3.054 \times 64.4} = 24.5$$

$$\Delta p = 160 - 73.2 + 24.5 = 111.3$$

$$\frac{p_1 - p_2}{p_1} = \frac{160 - 73.2}{160} = 0.5425$$

$$Y = 0.664$$

$$W = 1891 \times 0.664 \times (13.25)^2 \sqrt{\frac{111.3}{1.98 p_1 \times 3.054}}$$

$$= 943,750 \text{ lbs/hr.}$$

FILING CODE

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: F. P.C.

PROJECT: CR-3

FILING CODE

W.O. 4203-027 PAGE A 229 OF 240

SYSTEM: M.S. SAFETY + RELIEF VALVE

CALCULATION FOR

ORIGINATOR: M Z Lee
DATE: 2/12/74

REVIEWER: J. Fiorello
DATE: 12/16/74

RESULTS

$$\frac{940.000 - 932,477}{943,750 - 932,477} = \frac{7522}{11272} = 0.6673$$

$P_3 = 158 + 2 \times 0.667 = 159.3$ psia

$V_3 = 3.054 - 0.0355 \times 0.6673 = 3.03$ ft³/#

$V_3 = 826$ #/ft²

Flexonic Pressure

$$P_{3'} = \frac{(159.3-147)137.9 - 8.1(1531-834) - 125 \times 78.9}{137.9 - 78.9}$$

$$= \frac{19,981.7 - 5710 - 9862.5}{59}$$

$$= \frac{4,367}{59} = 74 \text{ psig.}$$

FILING CODE

GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4203-027 PAGE A2 OF A240

SYSTEM: M.S. SAFETY + RELIEF VALVES
ORIGINATOR: M. Z. Lee
DATE: 2/3/74
CALCULATION FOR:
REVIEWER: L.J.B.
DATE: 2-4-74

RESULTS

G

6"x8" Safety Valve Stack 12"

Discharge Capacity $W = 645{,}000$ #/hr

$p_2 = 135$ psig

$V_2 = 2.95$ ft³/#

$v_2 = 1520$ ft/sec

$h_2 = 1191.1$ BTU/#

Stack 12", wall = 1/4" wall

ID = 12.25"

Flow Area $A_3 = A_4 = 117.9$ in²

FILING CODE

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4203-027 PAGE A/A 231 OF 240
SYSTEM: M.S. SAFETY + RELIEF VALVES
ORIGINATOR: M. Z. Lee
DATE: 2/2/74
CALCULATION FOR:
REVIEWER: L.J.B.
DATE: 2-4-74
RESULTS:

6"x8" valve

Steam Condition at Stack Exit

Known $W = 645{,}000$ #/hr

$A_4 = 117.9$ in^2

$h_4 + \frac{V_4^2}{2gJ} = h_0 = 1207.4$ BTU/#

To find p_4, v_4, h_4, V_4

By ① $W = \frac{A_4}{144} \frac{V_4}{v_4} \times 3600$

② $V_4 = \sqrt{kg \times 144\, p_4 v_4}$

③ $v_4 = v(p_4, h_4)$

④ $h_4 = h_0 - \frac{V_4^2}{2gJ}$

p_4	V_4	$V_4^2/2gJ$	h_4	v_4	V_5	W	
70	1600	51.09	1186.3	6.3245	1641	745,670	
	1635	53.35	1184.05	6.27	1634	768,610	
60	1630	53.03	1184.37	7.3167	1634	656,636	
	1634	53.29	1184.1	7.3214	1634.7	657,820	> 645,000
58	1634	53.29	1184.1	7.5617	1634.4	636,915	< 645,000

$\therefore p_4 = 58 \sim 60$ psia

FILING CODE

GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT FPC

PROJECT CR-3

FILING CODE

W.O. 4203 027

PAGE A 232 OF A 240

SYSTEM MS SAFETY & RELIEF VALVES

ORIGINATOR M. Z. Lee

DATE 7/2/74

CALCULATION FOR

REVIEWER L. J. B

DATE 2-4-74

RESULTS

6"x8" Safety Valve

$p_4 = 60$ psia

$v_4 = 7.3214$

$V_4 = 1634$ ft/sec

$h_4 = 1154.1$

$t \simeq 308°F$

FILING CODE

GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: EPC
PROJECT: CR-3
FILING CODE:
J.O. 803 027
PAGE A A 230F340

SYSTEM: M.S. SAFETY + RELIEF VALVES
CALCULATION FOR:

ORIGINATOR: M Z Lee
DATE: 7/2/74
REVIEWER: L.J.B.
DATE: 2-4-74

RESULTS

12" Stack Pressure Drop
(¼" wall)

d = I.D = 12.25" $\quad A_f = 117.9\ in^2$

$D = d/12 = 1.02$

$L/D = 31/1.02 = 30.4$ pipe

$L/D = 3 \times 16 = 48$ 3 of 45° Elbow

$f = 0.013$

$K = f\frac{L}{D} = 0.013\ (30.4+48) = 1.019$ // pipe only

$K = 1$ Exit

$K = 1 + 1.019 = 2.019$ // Total System

FILING CODE

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT FPC

PROJECT CR-3

FILING CODE

W.O. 4203-027 PAGE A, A 234 OF 240

SYSTEM M.S. SAFETY & RELIEF VALVES

ORIGINATOR M. Z. Lee

DATE 7/12/74

CALCULATION FOR

REVIEWER J. F. Fenarillo

DATE 12/16/74

RESULTS

use steam table, one step method

Try $p_2 = 120$

v_3	v_2	Δh	h_2	$v = v(p,h)$
4	870.2	15.29	1222.1	4.057
4.06	888.45	15.75	1221.6	4.052
4.053	886.9	15.7	1221.7	4.053

$$W = 300\sqrt{g}\,A\sqrt{\frac{(p_3 - p_4)\left(\frac{1}{v_4} + \frac{1}{v_4}\right)}{4f\frac{L}{D} + 2\ln\left(\frac{v_4}{v_4}\right)}}$$

$$= 300\sqrt{32.2} \times 117.9\sqrt{\frac{(120-60)\left(\frac{1}{4.053} + \frac{1}{7.32}\right)}{1.019 + 4.053}}$$

$$= 648{,}735 \ \text{lbs/hr}$$

Try $p_2 = 118$

v_3	v_2	Δh	h	$v = v(p,h)$
4.1	897.2	16.07	1224.3	4.168
4.116	900.7	16.19	1221.2	4.116

$$W = 300\sqrt{32.2} \times 117.9\sqrt{\frac{(118-60)\left(\frac{1}{4.116} + \frac{1}{7.32}\right)}{1.019 + 2\ln\left(\frac{7.32}{4.116}\right)}}$$

$$= 639{,}124 \ \text{lbs/hr}$$

FILING CODE

GILBERT ASSOCIATES, INC. ENGINEERS AND CONSULTANTS READING, PA.	CLIENT FPC	FILING CODE	
	PROJECT CR-3	W.O. 4208 027	PAGE A- A- 235 OF 240
SYSTEM M. S. SAFETY & RELIEF VALVES		ORIGINATOR M. Z. Lee	DATE 9/12/74
CALCULATION FOR		REVIEWER S. F. Ferrarello	DATE 12/16/74

RESULTS

$$\frac{645000-639124}{648,735-639124} = 0.6113$$

$$\begin{cases} p_1 = 119.2 \\ v_1 = 4.077 \\ V_1 = 892 \end{cases}$$

Flexonic Pr.

$$p_{3'} = \frac{(119.2-14.7)\times 117.9 - 5.56\,(1520-892) - 135\times 50}{117.9-50}$$

$$= \frac{12320.6 - 3491.7 - 6750}{67.9} = 31 \text{ psig}$$

FILING CODE

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4203-027 PAGE A-236 OF A-240
SYSTEM: M.S. SAFETY & RELIEF VALVES
ORIGINATOR: M Z Lee
DATE: 2/12/74
CALCULATION FOR:
REVIEWER: A J Fernullo
DATE: 12/16/74

RESULTS

#4

12" stack 0.375 wall

$ID = d = 12"$

$D = d/12 = 1'$

$A_f = 113.1 \text{ in}^2$

$\frac{L}{D} = \frac{31}{1} = 31$ pipe $\frac{L}{D} = 48$ elbow

$K = 1 + f\frac{L}{D} = 1 + 0.013(31+48) = 2.03$

$\frac{\Delta p}{p_3} = 0.5959$

$Y = 0.6363$

At Stack Exit

p_4	V_4	V_4^2/gJ	L_4	$V_4 = V_4(p_3, h_3)$	V_3	W
60	1634	53.29	1184.1	7.3214	1634.7	631.045 lb/ft²
62	1634	53.29	1184.1	7.0758	1626	
	1627	52.83	1184.56	7.0852	1627.25	648.289 lb/ft²

$60 < p_4 < 62$ psia

say $p_4 = 62$ psia

FILING CODE

GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4203-027
PAGE A A 237 OF 240
SYSTEM: M.S. SAFETY & RELIEF VALVES
ORIGINATOR: M. Z. Lee
DATE: 2/12/74
CALCULATION FOR:
REVIEWER: J. F. Fenarello
DATE: 12/16/74
RESULTS

12" Stock 0.375" wall

Try $p_2 = 124$ psia

v_2	V_2	Δh	h_2	$v = v(p, h)$
3.9	889.6	15.8	1221.6	3.921
3.92	894.2	15.96	1221.4	3.919

$$W = 300\sqrt{g}\,A\sqrt{\frac{(p-p_2)\left(\frac{1}{v_1}+\frac{1}{v_2}\right)}{4\frac{f\bar{L}}{D}+2\ln\left(\frac{v_2}{v_1}\right)}}$$

$$= 300\sqrt{32.2}\times 113.1\sqrt{\frac{(124-61)\left(\frac{1}{3.92}+\frac{1}{7.1}\right)}{1.03+2\ln\left(\frac{7.1}{3.92}\right)}}$$

$$= 640,027 \text{ lbs/hr}$$

Try $p_2 = 126$ psia

v	V	Δh	h	$v = v(p, h)$
3.9	889.6	15.8	1221.6	3.921
3.92	894.2	15.96	1221.4	3.919

$$W = 300\sqrt{32.2}\times 113.1\sqrt{\frac{(126-6)\left(\frac{1}{3.92}+\frac{1}{7.2}\right)}{1.03+2\ln\left(\frac{7.2}{3.92}\right)}}$$

$$= 648,949 \text{ lbs/hr}$$

FILING

GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4203-027
PAGE A8 OF A240

SYSTEM: M.S. SAFETY & RELIEF VALVES
ORIGINATOR: M.Z. Lee
DATE: 3/12/74
CALCULATION FOR:
REVIEWER: A.J. Ferranello
DATE: 12/16/74

RESULTS

$$\frac{645{,}000 - 640{,}027}{648{,}949 - 640{,}027} = 0.557$$

$P_3 = 125$ psia

$V_3 = 3.89$ psia

$W_3 = 647$ #/sec

Flexonic $P_{3'}$

$$P_{3'} = \frac{(125 - 14.7) \times 113.1 - 5.56\,(1520 - 867) - 135 \times 50}{113.1 - 50}$$

$$= \frac{12474.9 - 3524 - 6750}{63.1} = 35 \text{ psig}$$

FILING CODE

GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT FPC

PROJECT CR-3

FILING CODE

W.O. 4203-227 PAGE A-239 OF 240

SYSTEM M.S. SAFETY + RELIEF VALVES

CALCULATION FOR

ORIGINATOR M. Z. Lee

DATE 7/12/74

REVIEWER A. J. Ferranello

DATE 12/10/74

RESULTS

Summary

Items								
valve size	6" × 10"						6" × 8"	
Stack size	14"						12"	
Stack wall t	0.26"				0.375"		0.25"	0.225"
Method	$pv^k=C$	Steam 1 step	Steam 4 step	Modified Darcy Formula	Steam 1 step	Modified Darcy Formula	steam 1 step	steam 1 step
Vent Inlet Pr P_2, psia	140	142	143	153	148	159	119	125
Vent Inlet Spec. Volume v_2, ft^3/lb	3.68	3.42	3.41	3.2	3.28	3.03	4.08	3.89
Vent Inlet Velocity V_2 ft/sec	966	899	895	840	895	826	892	887
Pressure Drop in vent $P_3 - P_4$ psi	69	71	72	82	77	88	59	65
Effective Pr. P_3, psig	54	50	51	67	57	74	31	35

FILING CODE

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: F P C.

PROJECT: CR-3

FILING CODE:

W.O. 4203-027 | PAGE A-24 OF A-240

SYSTEM: M.S. SAFETY + RELIEF VALVES

ORIGINATOR: M Z Lee
DATE: 3/12/74

CALCULATION FOR:

REVIEWER: J F Furnello
DATE: 12/16/74

RESULTS

References

1. LEE, M.Z. AND ROLHING, A.P. "STEADY STATE ANALYSIS OF SAFETY VALVE DISCHARGE SYSTEMS", PAPER TO BE SUBMITTED TO THE SECOND NATIONAL CONGRESS ON PRESSURE VESSELS AND PIPING, JUNE 1975, SAN FRANCISCO

2. CRANE Technical Paper No. 410 Flow of Fluids Through Valves, Fittings, and Pipe

3. Safety / Relief Valve Connectors
Flexonics Co. DWG No. D 96142-012049
-012052

FILING CODE

GAI 350 REV. 10-72

APPENDIX "B"

FLORIDA POWER CORPORATION

CRYSTAL RIVER NUCLEAR POWER PLANT UNIT NO. 3

MAIN STEAM SAFETY AND RELIEF

VALVE SYSTEM STRESS ANALYSIS REPORT

APPENDIX "B"

DISCHARGE STACK

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: Florida Power Corp.
PROJECT: Crystal River #3
FILING CODE:
W.O. 4203-027
PAGE B-300 OF 345
SYSTEM: Main Steam Discharge Stack
ORIGINATOR: M. Z. Lee
DATE: 5/8/74
CALCULATION FOR:
REVIEWER: S. F. Ferruello
DATE: 12/16/74
RESULTS

Contents

FILING CODE

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC

PROJECT: CR-3

FILING CODE:

W.O. 4203-027 | PAGE B-30 OF B-345

SYSTEM: Main Steam Safety Valve Stack

ORIGINATOR: M. Z. Lee

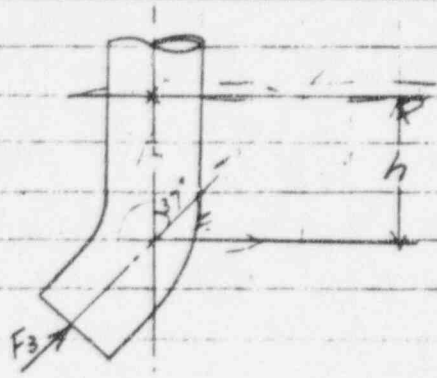
DATE: 4/24/74

CALCULATION FOR: Bending Stresses due to Flow Thrust

REVIEWER: A. Fiumello

DATE: 12/16/74

RESULTS



MSV	MK-RVH	Support EL.	H	inch	Stack Size		
33	33	129'-11"	1'-4 3/16	16.187		○	
34	37	129'-0 3/4"	5 1/16	5.062			
35	24	131'-1 5/16"	2'-6 11/16	30.687		X	
36	28	131'-2"	2'-7 1/16	31.062	14"	X	✓
37	32	129'-11"	1'-4 5/16	16.312		○	
38	36	129'-0 3/4"	6 1/16	6.062			
39	23	131'-1 5/16"	2'-6 1/16	30.687		X	
41	27	131'-2"	2'-3 3/16	27.187		X	✓
42	31	129'-11"	1'-4 3/16	16.187		△	
43	35	129'-0 3/4"	6 1/16	6.062			
44	22	131'-1 5/16"	2'-3"	27.0		X	
45	26	131'-2"	2'-3 3/16	27.187"		X	✓
46	30	129'-11"	1'-4 5/16	16.312"		△	
47	21	131'-1 5/16"	2'-3"	27.0		X	
40	34	129'-0 3/4"	0 3/4"	0.75"	12"		
48	25	131'-2"	2'-9 7/16"	33.875"		X	✓

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GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT FPC

PROJECT CR-3

FILING CODE

W.O. 4203-027 PAGE B-302 OF B-345

SYSTEM M.S. SAFETY & RELIEF VALVES

CALCULATION FOR

ORIGINATOR M. Z. Lee

DATE 4/25/74

REVIEWER A. J. Ferrarello

DATE 12/16/74

RESULTS

Thrust Force at Stack Inlet

p_3, v_3 taken from Main Steam Safety and Relief Valve System Stress Report "Flexonic Joint Back Pressure" 3/12/74

14" stack

see p. 10

$F_3 = p_3 A_3 + \dot{m} v_3 = (143 - 14.7) \times 143 / 4 \times 8.1 \times 895$

$= 25{,}609$ lb $\doteq 25{,}610$ lbs

14" 0.25" wall $Z = 36.5$ in^3

$S_b = \frac{M}{Z} = \frac{F_3 \cdot H \cdot \sin 37^\circ}{Z}$ DLF

$= \frac{25610 \times \sin 37^\circ \times 2}{36.5} H = 845\,H$ psi

H in inches.

$H_{max} = 31.062 \doteq 31.1$"

$S_b = 845 \times 31.1 = 26{,}300$ psi [too high]

$H = 16.312$"

$S_b = 845 \times 16312 = 13{,}800$ psi

$\frac{PD}{4t} = \frac{128.3 \times 14}{4 \times 0.25} = 1{,}800$ psi

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PROJECT CR 3

FILING CODE

W.O. 4203-027

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SYSTEM M.S. SAFETY & RELIEF VALVES

CALCULATION FOR

ORIGINATOR M. Z. Lee

DATE 4/25/74

REVIEWER S. F. Iannello

DATE 12/16/74

RESULTS

Other stresses from piping stress program

Analysis No	Pressure stress	Deadload stress	Seismic stress
7C (12")	1801	392	354
8C (14")	1988	669	840
9E (14")	1988	106	160
max	1988	669	840

Combined Stress (H=16.312")

$S = 13,850 + 1988 + 669 + 840 = 17297$ psi

$< 18,000$ psi $= 1.2\ S_h$

∴ H shall not exceed 16.312" ✓

For those stack having H > 16.312 the support must be modified to decrease bending stresses in the stack.

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	PROJECT: CR-3	W.O. 4203-027	PAGE A1 A 304 of 345
SYSTEM: M. S. SAFETY + RELIEF VALVES		ORIGINATOR: M. Z. Lee	DATE 4/25/74
CALCULATION FOR		REVIEWER: S. F. Fenuello	DATE 12/16/74

12" Stack

P_3, V_3 from summary of Main steam S.V. stress report

(mass flow rate)

$F_3 = (119 - 14.7) \times 117.9 + 892 \times 5.56 = 17,256$ lbs

$\doteq 17,300$ lbs.

10" 0.25" wall $Z = 30.1$ in^3

$S_b = \frac{M}{Z} = \frac{F_3 \cdot H \cdot \sin 37^\circ}{Z}$ DLF

$= \frac{17300 \times 0.6018}{30.1} \times 2 \times H = 692 H$ psi

MSV 40 $H = 8.75$

$S_b = 8.75 \times 692 = 6,060$ psi

Other stresses (Ref. Analysis No. 7C Previous Page)

Combined stress $= 6,060 + 1,801 + 392 + 354$
$= 8,607$ psi $< 18,000 = 1.2 S_h$

MSV 4F $H = 33.875$"

$S_b = 33.875 \times 692 = 23,600$ psi [too high]

RESULTS

GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC. ENGINEERS AND CONSULTANTS READING, PA.	CLIENT: FPC	FILING CODE	
	PROJECT: CR-3	W.O. 4203-027	PAGE B-305 OF 345
SYSTEM: M.S. SAFETY & RELIEF VALVES		ORIGINATOR: M. Z. Lee	
CALCULATION FOR		DATE: 4/25/74	
		REVIEWER: A. F. Fumarello	
		DATE: 12/16/74	

12" Stock

Max H allowed

$$S_b = 18{,}000 - 1801 - 393 - 354 = 15{,}453 \text{ psi}$$

(allowable stress − pr stress − Deadweight stress − Seismic stress)

Say $S_b = 15{,}000$ psi

$M_a = S_b Z = 15{,}000 \times 30.1$ (12" ϕ, 0.375" wall)

$P = F_3 \cdot \sin 37° \times 2 = 17{,}300 \times 0.602 \times 2 = 20{,}800$ lbs

$$H_{max} = \frac{M_a}{P} = \frac{15000 \times 30.1}{20800} = 21.7"$$

RESULTS

10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT F.P.C

PROJECT CR-3

FILING CODE

W.O. 4203-027 PAGE B-30 OF B-345

SYSTEM M.S. SAFETY + RELIEF VALVES

ORIGINATOR M.Z. Lee

DATE 4/25/74

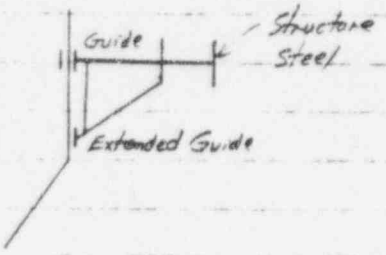
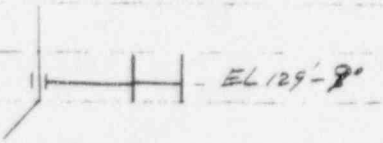
CALCULATION FOR

REVIEWER A.F. Ferarello

DATE 12/16/74

RESULTS

Options

1.	Increase pipe wall thickness to about 0.5" wall to at least 9' above the lower guide.	Decrease flow area and increase steam back pressure which is already high.
2.	Provide external pad on the outer surface of 0.25" wall pipe so that additional mechanical strength is obtained without affecting the flow area.	10' is too long to weld a pad.
3	Modify the guide to decrease bending of the pipe 	Structure will be subject to force and moment. The structure was not designed to take moment. Structural Dept. must check moment load.
4	Bring the guide and the support structure down 17" 	Structural design needs slight modification.

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CLIENT: F. P. C

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W.O. 4203-027

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SYSTEM: M. S. SAFETY & RELIEF VALVES

ORIGINATOR: M. Z. Lee

DATE: 4/25/74

CALCULATION FOR:

REVIEWER: J. F. Ferranello

DATE: 12/16/74

RESULTS

Recommendation

1. Bring down the support for MSV 36, 41, 45, 46 to EL 129'-9"

2. Bring down the support for MSV 35, 38, 44, 47 to EL 129'-9"

3. More accurate analysis to be done for new support position taking into consideration the torsional loads in offset stacks

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	PROJECT CR-3	W.O. 4203-027 PAGE B-309 OF 345
SYSTEM M.S. SAFETY & RELIEF VALVES		ORIGINATOR H. Z. Lee DATE 4/25/74
CALCULATION FOR		REVIEWER A F Ferrarello DATE 12/16/74

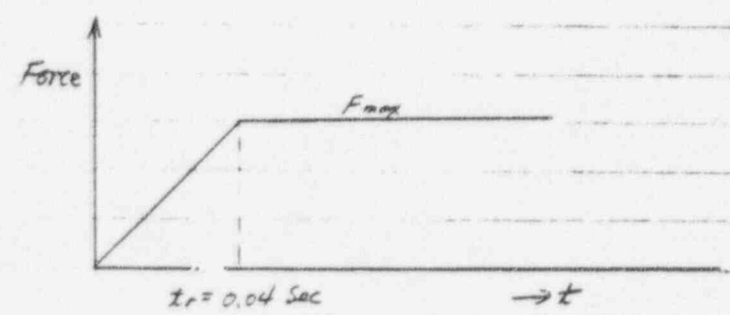
Dynamic Load Factor

Natural Frequencies of the first modes taken from Seismic Analysis Work order 4203-071.

Analysis No	size of stack		frequencies
CR-7C	12"		26.7 cps
CR-8C	14"		21.77
CR-9E	14"		27.5
CR-10	10"	Relief v.	24.1
CR-11	10"	Relief v.	23.68

Forcing Function

Most of the safety valves open to 70% of full lift in 40 mili sec. Assume conservatively that the max reaction force is reached in 40 milisec as follows



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CLIENT: FPC
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W.O. 4203-027
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SYSTEM: M.S. SAFETY & RELIEF VALVES
ORIGINATOR: M. Z. Lee
DATE: 4/25/74
CALCULATION FOR:
REVIEWER: A. F. Fernandez
DATE: 12/16/74
RESULTS

Stack for MSV-44F, MSV-47F (Sec. JJ of DWG E304-025 Rev. 4 is very close to CR-8C which gives $f = 21.77$ cps

$$t_r/T = t_r \cdot f = 0.04 \times 21.77 = 0.87$$

From Fig 2.9 (a) on p. 48 of Biggs Introd to Structure Dynamics. The Dynamic load factor is

$$DLF = 1.21 \text{ for } \frac{t_r}{T} \geq 0.87$$

$$\boxed{DLF = 1.3}$$

Note: The seismic analysis was done for lower guide at EL - 129'-11" (MSV-33). This gives span

$$S_1 = (152'-0") - (129'-11") = 22'-1" = 265"$$

For valves 44 & 47 (new guide position)

$$S_2 = (152'-0") - (129'-9") = 267"$$

The projected natural frequency for MSV 44 stack will be

$$f = 21.77 \times \left(\frac{265}{267}\right)^2 = 21.77 \frac{1}{1.015} = 21.44$$

$$f t_r = 21.44 \times 0.04 = 0.8578$$

The difference is negligible.

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SYSTEM: M.S. SAFETY + RELIEF VALVES

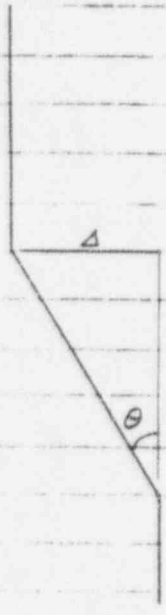
ORIGINATOR: M. Z. Lee
DATE: 4/25/74

CALCULATION FOR

REVIEWER: J. F. Furnell
DATE: 12/10/74

RESULTS

Offset Angles Ref GAI DWG E304-025 Rev 4



Sec. in DWG	Piping stress Analysis IDEN.	Stack size	θ	e	calculated Δ	Valve No
A.A.	CR-P	14"	15°	65.5625"	17.57°	MSV 46F 37F 34F
DD		14"	30°	30.4375"	17.573"	MSV 38F 43F
JJ		14"	15°	76.625"	20.53°	MSV-47F, 44F
CC	CR-7	12"	20°	49.8125"	18.13°	MSV 40F

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SYSTEM: M.S. SAFETY & RELIEF VALVES

CALCULATION FOR:

ORIGINATOR: M. Z. Lee
DATE: 4/25/74

REVIEWED: A. F. Fiorello
DATE: 12/6/74

RESULTS

Sec. JJ of Valves 44F, 47F

$l = (152'-0") - (129'-9") = 267"$

$h = (129'-9") - (128'-10\frac{5}{8}") = 10.375"$

$l_1 = 185\frac{1}{16}" \approx 185"$

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PROJECT CR-3

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SYSTEM M.S. SAFETY & RELIEF VALVES

CALCULATION FOR

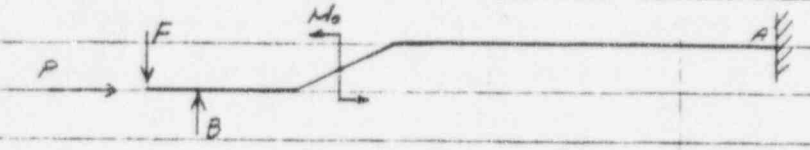
ORIGINATOR M.Z. Lee

DATE 4/25/74

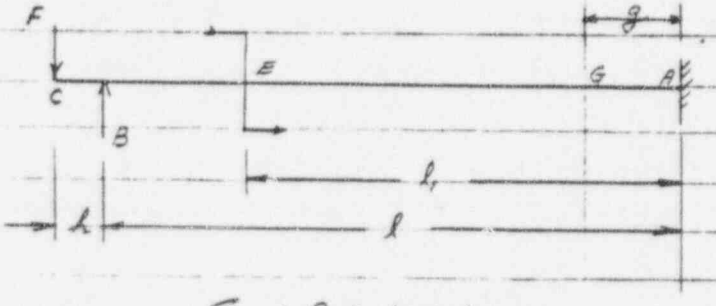
REVIEWER L.F. Fiumarello

DATE 12/10/74

RESULTS



Actual Model



Simplified Model

A = anchor plate at EL 152'-0" above roof

G = guides with $\frac{1}{8}$" clearance, 60" from A.

B = guides above flexonic joint

E = center of offset section, assume torsional moment is acting at this point.

Moments at critical points will be calculated using the simplified model.

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CLIENT: FPC

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SYSTEM: M.S. SAFETY & RELIEF VALVES

ORIGINATOR: M. Z. Lee

DATE: 4/25/74

CALCULATION FOR:

REVIEWER: J. Fernello

DATE: 12/16/74

RESULTS

	Deflection of B	Deflection at G	Moment at "x" to the right of B	Moment at A
(1)	$y_B = \frac{F}{6EI}\left[x^3 - 3(l+R)x^2 + 2(l+R)^3\right]$ $\phi_B = \frac{F}{2EI}\left[x^2 - 2(l+R)x + (l+R)^2\right]$	$x = l+R-g$ $y_G = -\frac{F}{6EI}\left[x^3 - 3(l+R)x^2 + 2(l+R)^3\right]$ $\phi_G = -\frac{F}{2EI}\left[x^2 - 2(l+R)x + (l+R)^2\right]$	$M_B = F_x(l+R)$	
(2)	$y_B = \frac{Rl^3}{3EI}$ $\phi_B = \frac{Rl^2}{2EI}$	$x = l-g$ $y_G = \frac{R}{12EI}\left[x^3 - 3lx^2 + 2l^3\right]$ $\phi_G = \frac{R}{4EI}\left[x^2 - 2lx + l^2\right]$	$M_x = R \cdot l$	
(3)	$y_B = \frac{M_0 l^2}{2EI}\left(1 - \frac{l_1}{3}\right)$ $\phi_B = \frac{M_0 l_1}{EI}$	$x = l-g$ $y_G = \frac{M_0}{12EI}\left[(x-l+l_1)^2 - 2l_1(x-l+l_1) + l_1^2\right]$ $\phi_G = \frac{M_0}{2EI}\left[(x-l+l_1) - l_1\right]$	$M_{xx} = M_0$	

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Reaction force at B

Put $y_{B1} + y_{B2} + y_{B3} = 0$

$$\frac{Bl^3}{3EI} = \frac{F}{6EI}\left[l^3 - 3(l+h)^2 h + 2(l+h)^3\right]$$

$$+ \frac{M_0 l}{EI}\left(l - \tfrac{1}{2}l\right)$$

$$B = \frac{F}{2l^3}\left[h^3 - 3(l+h)^2 h + 2(l+h)^3\right]$$

$$+ \frac{3M_0 l}{l^3}\left[l - \tfrac{1}{2}l\right]$$

Reaction Moment at A

$$M_A = -F_x(l+h) + B \cdot l - M_0$$

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SYSTEM: M.S. SAFETY + RELIEF VALVES
ORIGINATOR: M. T. Lee
DATE: 4/15/74
CALCULATION FOR:
REVIEWER: A. J. Fernandez
DATE: 12/16/74
RESULTS

Take Sec JJ of GAI DWG E804-025 Rev. 4

$F = F_2 \cos 53^\circ = 25{,}610 \cos 53^\circ = 15{,}412$ lbs

$P = F_2 \sin 53^\circ = 25{,}610 \sin 53^\circ = 20{,}453$ lbs

$M_o = P \cdot \Delta = 20{,}453 \times 20.53 = 419{,}901$ lbs.-in

$L = 267''$, $l_1 = 185''$, $h = 10.375''$

$$B = \frac{F}{2l^3}\left[h^3 - 3(l+h)^2 h + 2(l+h)^3\right] + \frac{3M_o l_1}{l^3}\left[l - \frac{1}{2}l_1\right]$$

$$= \frac{15{,}412}{2 \cdot (267)^3}\left[10.375^3 - 3(277.375)^2 \cdot 10.375 + 2(277.375)^3\right]$$

$$+ \frac{3 \times 419{,}901 \times 185}{(267)^3}\left[267 - 0.5 \times 185\right]$$

$$= 16{,}310 + 2{,}136 = 18{,}446$$

$B = 18{,}446$ lbs

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SYSTEM	M.S. SAFETY + RELIEF VALVES	ORIGINATOR M. Z. Lee DATE 4/25/74
CALCULATION FOR		REVIEWER S. F. Pananello DATE 12/16/74

RESULTS

Moments at B

$$M_B = -F \cdot h = -15{,}412 \times 10.375 = -159{,}899.5 \text{ lb-in}$$

Moment at the left of E ($x = l - l_1 = 267 - 185 = 82"$)

$$M_{E^-} = -F(h+x) + B \cdot x$$

$$= -15{,}412 (10.375 + 82) + 18{,}446 \times 82$$

$$= +88{,}888.5 \text{ lb-in}$$

Moment at the right of E

$$M_{E^+} = M_{E^-} - M_o = 88{,}888.5 - 419{,}901$$

$$= -331{,}012.5 \text{ lb-in}$$

Moment at A

$$M_A = -F(l+h) + B \cdot l - M_o$$

$$= -15{,}412 \times 277.375 + 18{,}446 \times 267 - 419{,}901$$

$$= 230{,}277.5 \text{ lb-in}$$

Maximum Moment

$$M_{max} = 331{,}012.5 \text{ lb-in at } E^+$$

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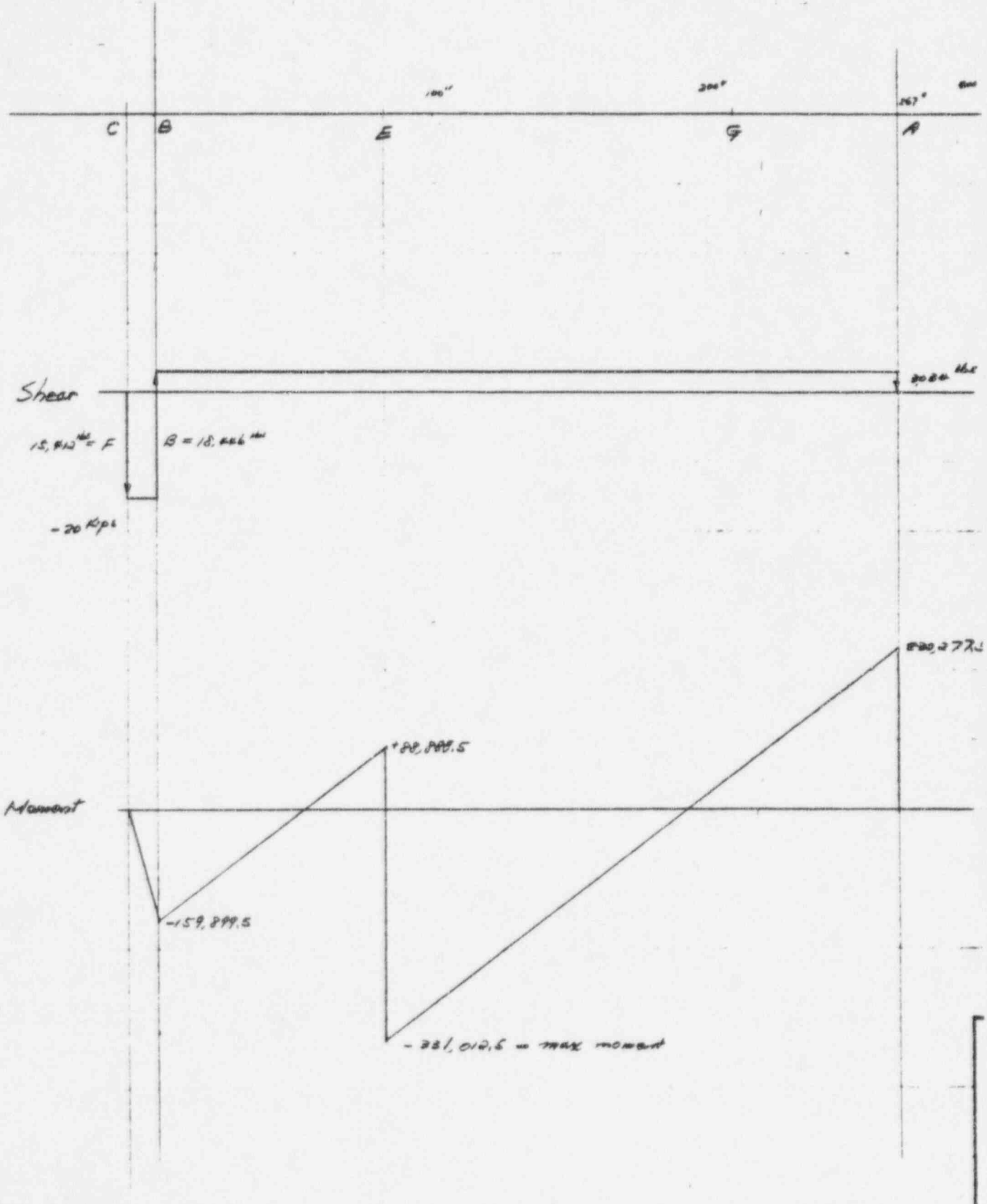
STRUCTURE M.S. SAFETY & RELIEF VALVES		ORIGINATOR M. Z. Lee	DATE 4/25/84
CALCULATION FOR		REVIEWER F. Fernandez	DATE 11/16/84



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SYSTEM: M. S. SAFETY & RELIEF VALVES
CALCULATION FOR:

ORIGINATOR: M. Z. Lee
DATE: 4/25/74
REVIEWER: J F Fennello
DATE: 12/16/74

RESULTS

Stresses in Stack

1. Bending stress due to flow reaction

$$S_b = \frac{M_{max}}{Z} = \frac{331,012.5}{36.5} = 9,069 \text{ psi}$$

$Z = 36.5 \text{ in}^3$ for 14"ϕ 0.25" wall pipe

2. Other stresses from piping stress program

Pressure	1988
Dead weight	106
Seismic	840
Total	2,934 psi

3. Combined Stress

$S_b \times DLF + 2934 = 9069 \times 1.3 + 2934$

$$S = 14,724.$$

4. Allowable Stress

$15,000 \times 1.2 = 18,000 > 14,724$ psi

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CLIENT: FPC
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PAGE B-320 thru B-345

SYSTEM: M.S. SAFETY + RELIEF VALVES
ORIGINATOR: M. Z. Lee
DATE: 4/25/74
REVIEWER: A. J. Fernello
DATE: 12/16/74

CALCULATION FOR:

RESULTS

Deflection at G

To see whether $\frac{1}{16}$" clearace is exceeded.

$$y_{G1} = -\frac{F}{6EI}\left[x^3 - 3(l+k)^2 x + 2(l+k)^3\right]$$

Put $x = l+h-g = 267+10.375-60 = 217.375"$

$I = 255\ in^3$ for 14"ø 0.25" wall pipe

$$y_{G1} = -\frac{15,412}{6\times30\times10^6\times255}\left[(217.375)^3 - 3(277.375^2)(217.375)+2(277.375)^3\right]$$

$$= -0.9333"$$

Put $x = l-g = 207$

$$y_{G2} = +\frac{18,446}{6\times30\times10^6\times255}\left[207^3 - 3\times267^2\times207+2(267)^3\right]$$

$$= 1.0720"$$

$$y_{G3} = -\frac{41901}{2\times30\times10^6\times255}\left[(-60+185)^3 - 2\times185(-60+185)+185^2\right]$$

$$= -0.0988$$

$$y_G = y_{G1} + y_{G2} + y_{G3} = -0.9333 + 1.0720 - 0.0988 = 0.0398"$$

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SYSTEM: M.S. SAFETY & RELIEF VALVES

ORIGINATOR: M. Z. Lee
DATE: 4/20/74

CALCULATION FOR:

REVIEWER: J. F. Farinello
DATE: 12/16/74

RESULTS

Since $Y_G = 0.0398" < \frac{1}{16}" = 0.0625"$, the angle guides at the lower edge of the mat will not restrain the stack deflection consequently, the assume model is correct.

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CLIENT: F.P.C.

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SYSTEM: M.S. SAFETY + RELIEF VALUES

ORIGINATOR: M Z. Lee

DATE: 4/25/74

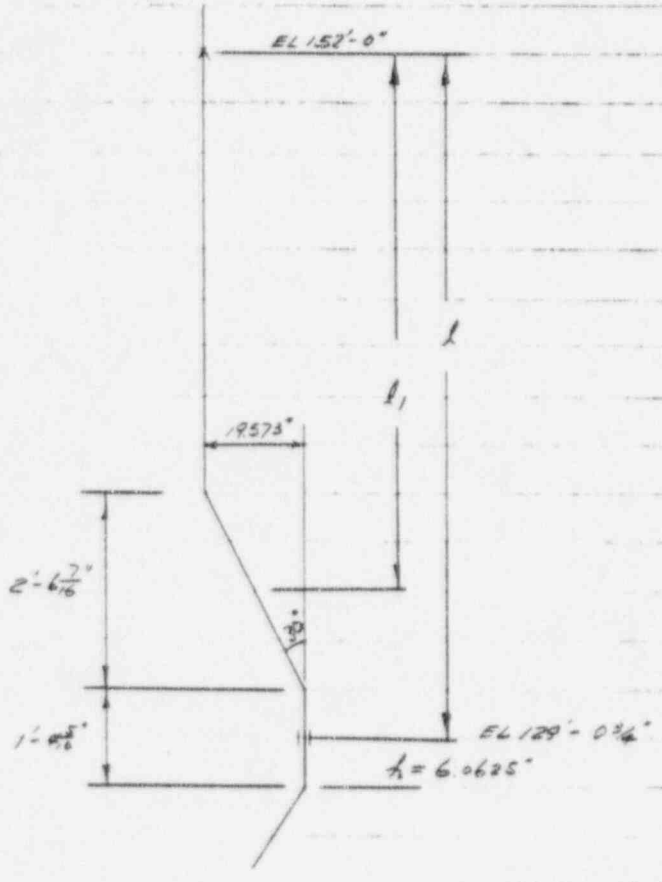
CALCULATION FOR:

REVIEWER: J Fernello

DATE: 12/16/74

RESULTS

MSV-38F & MSV-43F



$l = 275.25"$

$l_1 = 249.78"$

$h = 6.0625"$

$l + h = 281.3125"$

$\Delta = 17.573"$

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SYSTEM M.S. SAFETY + RELIEF VALVE		ORIGINATOR M Z Lee DATE 4/25/74
CALCULATION FOR		REVIEWER S F Ferarello DATE 12/16/74
		RESULTS

$F = 15{,}412$ lbs

$M_0 = 20453$ lbs $\times 17.573'' = 359\,421$ lb-in

$$B = \frac{F}{2l^3}\left[h^3 - 3(l+h)^2h + 2(l+h)^3\right]$$

$$+ \frac{3M_0 l_1}{l^3}\left[l - \tfrac{1}{2}l_1\right]$$

$$= \frac{15{,}412}{2(275.25)^3}\left[6.0625^3 - 3(281.3125)^2 \times 6.0625 + 2(281.3125)^3\right]$$

$$+ \frac{3 \times 359{,}421 \cdot 249.78}{(275.25)^3}\left[275.25 - 0.5 \times 249.78\right]$$

$= 15{,}921 + 1{,}942 = 17{,}863$ lbs (< 18,446 lb for valve MSV 44, 47)

$R_A = B - F = 17863 - 15412 = 2{,}451$ lbs

$M_B = -Fh = -15{,}412 \times 6.062 = -93{,}435$ lb-in

$M_E^- = -F(h+x) + Bx \quad (x = l - l_1 = 25.4687)$

$= -15{,}412(6.0625 + 25.4687) + 17863 \times 25.4687$

$= -31{,}011$ lb-in

$M_E^+ = M_E^- - M_0 = -31{,}011 - 359{,}421 = -390{,}432$

$M_A = -F(l+h) + Bl - M_0$

$= -15412 \times 281.3125 + 17863 \times 275.25 - 359{,}421$

$= 221{,}782$ lb-in

GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: F.P.C.

PROJECT: CR-3

FILING CODE:

W.O. 4203-027 PAGE E-4 B-324-345

SYSTEM: M.S. SAFETY + RELIEF VALVES

ORIGINATOR: M.Z. Lee
DATE: 4/25/74

CALCULATION FOR:

REVIEWER: A. F. Fiorarello
DATE: 12/16/74

RESULTS

$$S_b = \frac{M_{max}}{Z} = \frac{390,432}{36.5} = 10,697 \text{ psi}$$

Combined Stress

$S_b \times DLF + 2934$ (pr + D.L + Seismic)

$= 10,697 \times 1.3 + 2934 = 16,840$ psi

$< 18,000$ psi $= 1.2\, S_h$

FILING

GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC. ENGINEERS AND CONSULTANTS READING, PA.	CLIENT FPC	FILING CODE
	PROJECT CR-3	W.O. 4203-027 PAGE B-5 B-325 OF 345
SYSTEM M. S. SAFETY & RELIEF VALVES		ORIGINATOR N. Z. Lee DATE 4/25/74
CALCULATION FOR		REVIEWER J. Ferrell DATE 12/16/74

RESULTS

14" straigh stack MSV-36

$l = 267"$
$h = 14.062"$
$l+h = 281.062"$

$$B = \frac{F}{2l^3}\left[h^3 - 3(l+h)^2 h + 2(l+h)^3\right]$$

$$= \frac{15412}{2 \times 267^3}\left[14.062^3 - 3(281.062)^2 \times 14.062 + 2(281.062)^3\right]$$

$$= 16,630 \text{ lbs}$$

$$M_B = -Fh = -15,412 \times 14.062 = -216,724$$

$$M_A = -F(l+h) + B \cdot l = -15,412 \times 281.062 + 16,630 \times 267$$

$$= 31,422$$

$$S_b = \frac{M_{max}}{Z} = \frac{216.724}{36.5} = 5,938 \text{ psi}$$

Lower than S_b in offset stack, further analysis is not required

$5938 \times 1.3 + 2934 = 10,640$ psi

GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4203-027
PAGE B-326 thru B-345

SYSTEM: M.S. SAFETY + RELIEF VALVES
CALCULATION FOR:

ORIGINATOR: M. Z. Lee
DATE: 4/25/74
REVIEWER: J. F. Ferruello
DATE: 12/16/74

RESULTS

12" offset Stack MSV-40F

$l = 277.7"$

$L = 246"$

$h = 8.7"$

Reaction force $F_3 = 17,300$ lbs

$F = F_3 \cos 53° = 10,411$ lbs

$P = F_3 \sin 53° = 13,816$ lbs

$M_o = P\Delta = 13816 \times 18.13 = 250,484$ lb-in

$$B = \frac{F}{2l^3}\left[h^3 - 3(l+h)^2 h + 2(l+h)^3\right] + \frac{3M_o l_1}{l^3}\left[l - \frac{1}{2}l_1\right]$$

$$= \frac{10411}{2\times(277.7)^3}\left[8.7^3 - 3\times 286.4^2 \times 8.7 + 2\times(286.4)^3\right]$$

$$+ \frac{3\times 250,484\times 246}{(277.7)^3}\left[277.7 - 123\right]$$

$= 10,900 + 1335 = 12,235$ lbs

$B = 12,235$ lbs

FILING CODE

GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC. ENGINEERS AND CONSULTANTS READING, PA.	CLIENT F.P.C.	FILING CODE
	PROJECT CR-3	W.O. 4203-027 PAGE B-326-24C
SYSTEM M.S. SAFETY & RELIEF VALVES		ORIGINATOR M. Z. Lee DATE 4/15/74
CALCULATION FOR		REVIEWER J. F. Fernandez DATE 12/16/74

RESULTS

$M_B = -FR = -10,411 \times 8.7 = -90,576$ lb-in

$M_E^- = -F(R+31.7) + B \times 31.7)$

$= -10,411(8.7 \times 31.7) + 12,235 \times 31.7$

$= -32,755$ lb-in

$M_E' = M_E^- - M_o = -32,755 - 250,484 = -283,239$ lb-in

$M_A = -F(l+R) + Bl - M_o$

$= -10,411(286.4) + 12,235 \times 277.7 - 250,484$

$= 165,465$ lb-in

$S_b = \frac{M_{max}}{Z} = \frac{283,239}{30.1} = 9410$ psi

Other stresses from piping stress analysis CR-3C

Pressure	1801
Deadload	892
Seismic	354
Total	2,547

Combined Stress

$S_b \times DLF + 2547 = 9410 \times 1.3 + 2547$

$= 14,770$ psi $< 1.2 S_h$

$S = 14,770$ psi

FILING CODE

GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4203-027
PAGE B-8-328 OF B-345
SYSTEM: M.S. SAFETY + RELIEF VALVES
ORIGINATOR: M. Z. Lee
DATE: 4/26/74
CALCULATION FOR:
REVIEWER: J. F. Ferranello
DATE: 12/16/74
RESULTS

12" Straight stack MSV-48F

$l = 267''$

$h = 16.875$ $\quad l+h = 283.875$

$\Delta = 0 \quad l_1 = 0$

$$B = \frac{F}{2l^3}\left[h^3 - 3(l+h)^2 h + 2(l+h)^3\right]$$

$$= \frac{10411}{2\times 267^3}\left[16.875^3 - 3\times 283.875^2 \times 16.875 + 2(283.875)^3\right]$$

$= 11,398$ lbs

$M_B = -Fl = -10411 \times 16,875 = -175,686$ lb-in

$M_A = -F(l+h) + B\cdot l$

$= -10411 \times 283.875 + 11,398 \times 267 = 87,843$ lb-in

$$S_b = \frac{M_{max}}{B} = \frac{175,686}{30.1} = 5837 \text{ psi}$$

Combined Stress

$S_{max} = 5837 \times 1.3 + 2537 = 10,240$ psi //

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GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC

PROJECT: CR-3

FILING CODE:

W.O. 4203-027 | PAGE B 329 OF 345

SYSTEM: M.S. SAFETY & RELIEF VALVES

ORIGINATOR: M. Z. Lee

DATE: 4/25/74

CALCULATION FOR:

REVIEWER: J. F. Ferranello

DATE: 12/16/74

RESULTS

Pipe Stresses and Support Loads

Stack	14" Offset	14" Straight	12" Offset	12" Straight
Valves involved MSV-	38, 43	36	40	48
Guide Loads B	18,446 lb	16,630 lb	12,235 lbs	11,398 lbs
1.3 × B	24 K	22 K	16 K	15 K
Combined Stress in Pipe	16,440	10,640 psi	14,770 psi	10,240 psi

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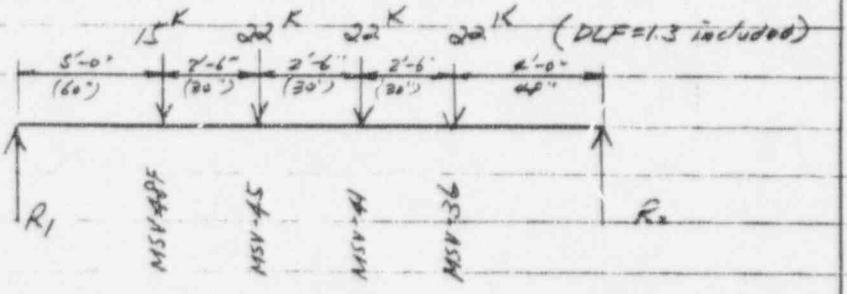
CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4203-227 PAGE 330 OF 345

SYSTEM: M.S. SAFETY & RELIEF VALVES
CALCULATION FOR:
ORIGINATOR: M. Z. Lee
DATE: 4/25/74
REVIEWER: J. F. Ferranello
DATE: 12/16/74

RESULTS

Structure Loads for the Line through Pen #107



$$R_1 = \frac{22(48+78+108)+15\times 198}{198} = 36.455$$

$$R_2 = (15+22\times 3) - R_1 = 44.545$$

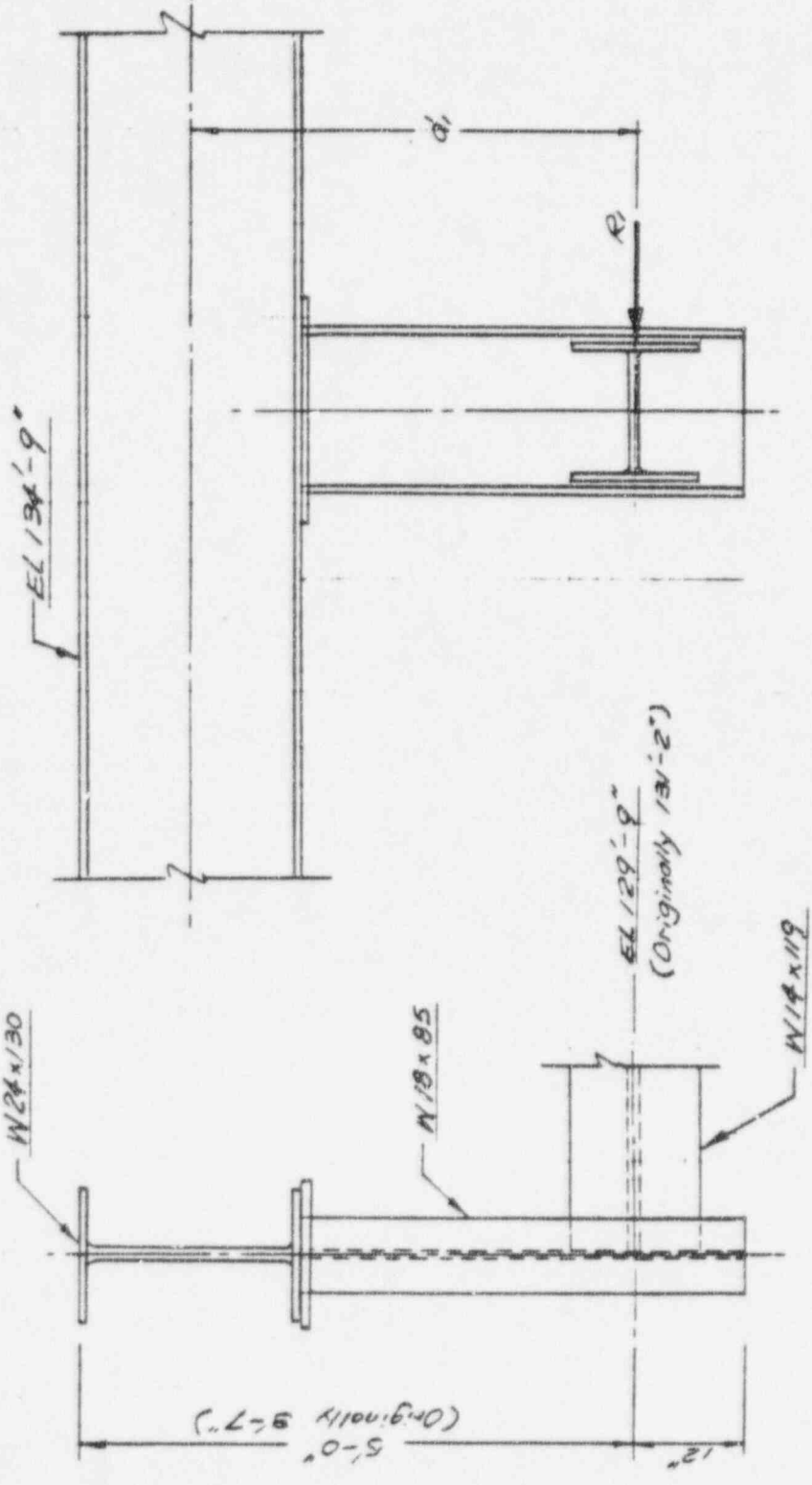
$$R_2 = \frac{15\times 60 + 22(90+120+150)}{198} = 44.545 \text{ (check)}$$

Structure Load $R_1 = 37$ Kips

$R_2 = 45$ Kips

FILING CODE

GILBERT ASSOCIATES, INC. ENGINEERS AND CONSULTANTS READING, PENNA.	FPC CR-3	FILING CODE	
		W 04203-027	PAGE B-331 OF B-345
STRUCTURE M.S. SAFETY & RELIEF VALVES		ORIGINATOR M.Z.Lee	DATE 5/5/74
CALCULATION FOR		REVIEWER A.F. Fencelli	DATE 12/16/74



R_1 = 337 Kips (including DLF of 1.3)
(Originally 5450 Kips)

d_1 = 45°
(Originally 31°)

VIEW LOOKING WEST

VIEW LOOKING SOUTH

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CLIENT: FPC

PROJECT: CR-3

FILING CODE

W.O. 4203-027 PAGE B-3 332 of 345

SYSTEM: M. S. SAFETY + RELIEF VALVES

ORIGINATOR: M. Z. Lee

DATE: 4/25/74

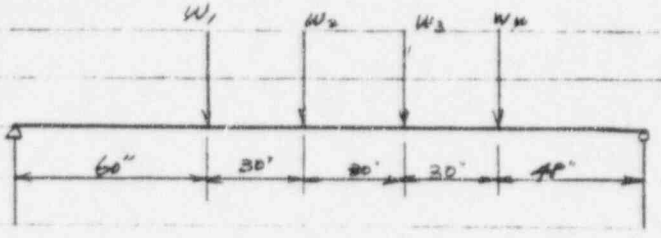
CALCULATION FOR

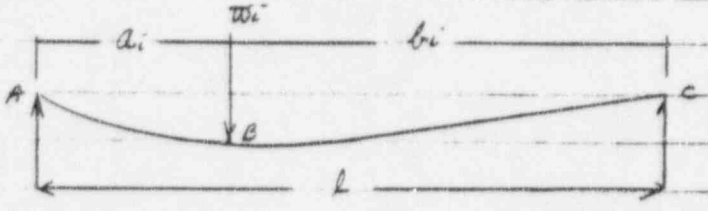
REVIEWER: J. F. Fennello

DATE: 12/16/74

RESULTS

Beam Deflection due to steady state Loads





Deflection formula

A-B $$y = \frac{W b x}{6EIl}\left[2l(l-x) - b^2 - (l-x)^2\right]$$

B-C $$y = \frac{W a (l-x)}{6EIl}\left[2lb - b^2 - (l-x)^2\right]$$

i	Wi	ai	bi
1	11.4 Kips	60"	138"
2	16.63	90	108
3	16.63	120	78
4	16.63	150	48

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GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
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CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4203-027
PAGE B 333 of B 345

SYSTEM: M.S. SAFETY + RELIEF VALVES
CALCULATION FOR:

ORIGINATOR: M Z Lee
DATE: 4/25/74
REVIEWER: J F Fernello
DATE: 12/16/74

RESULTS

Influence Coefficient

W_1 Put $x = a_i$, $i = 1, 2, 3, 4$

$$-6EI\, y_{11} = W_1 \cdot \frac{1}{\ell} a_1 (\ell - a_1)\left[2\ell b_1 - b_1^2 - (\ell - a_1)^2\right]$$

$$= W_1 \cdot \frac{1}{198} \times 60 \times 138\left[2 \times 198 \times 138 - 138^2 - 138^2\right]$$

$$= 692{,}509.09\, W_1$$

$$-6EI\, y_{21} = W_1 \times \frac{1}{198} \times 60 \times 108\left[2 \times 198 \times 138 - 138^2 - 108^2\right]$$

$$= 783{,}490.91\, W_1$$

$$-6EI\, y_{31} = W_1 \cdot \frac{1}{198} \times 60 \times 78\left[2 \times 198 \times 138 - 138^2 - 78^2\right]$$

$$= 697{,}745.45\, W_1$$

$$-6EI\, y_{41} = W_1 \cdot \frac{1}{198} \times 60 \times 48\left[2 \times 198 \times 138 - 138^2 - 48^2\right]$$

$$= 484{,}363.63\, W_1$$

y_{ij} = deflection at a_i due to load at a_j

FILING CODE

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CLIENT F.P.C.

PROJECT C R-3

FILING CODE

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SYSTEM M. S. SAFETY + RELIEF VALVES

CALCULATION FOR

ORIGINATOR M. Z. Lee

DATE 4/25/74

REVIEWER A. F. Fernandez

DATE 12/16/74

RESULTS

W_2

$$-6EI\, y_{12} = \frac{W_2}{198} \times 108 \times 60 [2 \times 198 \times 138 - 108^2 - 138^2]$$

$$= 783,490.91\, W_2$$

$$-6EI\, y_{22} = \frac{W_2}{198} \times 108 \times 90 [2 \times 198 \times 108 - 108^2 - 108^2]$$

$$= 954,327.27\, W_2$$

$$-6EI\, y_{32} = \frac{W_2}{198} \times 90 \times 78 [2 \times 198 \times 108 - 108^2 - 78^2]$$

$$= 887,072.73\, W_2$$

$$-6EI\, y_{42} = \frac{W_2}{198} \times 90 \times 48 [2 \times 198 \times 108 - 108^2 - 48^2]$$

$$= 628,363.64\, W_2$$

W_3

$$-6EI\, y_{13} = \frac{W_3}{198} 78 \times 60 [2 \times 198 \times 138 - 78^2 - 138^2]$$

$$= 697,745.45\, W_3$$

$$-6EI\, y_{23} = \frac{W_3}{198} \times 78 \times 90 [2 \times 198 \times 108 - 78^2 - 108^2]$$

$$= 887,072.73\, W_3$$

$$-6EI\, y_{33} = \frac{W_3}{198} 78 \times 100 [2 \times 198 \times 78 - 78^2 - 78^2]$$

$$= 884,945.45$$

$$-6EI\, y_{43} = \frac{W_3}{198} \times 120 \times 48 [2 \times 198 \times 78 - 78^2 - 48^2]$$

$$= 654,545.45\, W_3$$

FILING CODE

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CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4209-027
PAGE B 335 OF B 345
SYSTEM: M.S. SAFETY + RELIEF VALVES
ORIGINATOR: M. Z. Lee
DATE: 4/25/74
CALCULATION FOR:
REVIEWER: J F Fennello
DATE: 12/16/74
RESULTS

W_4

$$-6EI\,y_{,4} = \frac{W_4}{198}\times 48\times 60\,[2\times 198\times 138 - 48^2 - 138^2]$$

$$= 484{,}363.63\ W_4$$

$$-6EI\,y_{24} = \frac{W_4}{198}\times 48\times 90\,[2\times 198\times 108 - 48^2 - 108^2]$$

$$= 628{,}363.64\ W_4$$

$$-6EI\,y_{34} = \frac{W_4}{198}\times 48\times 120\,[2\times 198\times 78 - 48^2 - 78^2]$$

$$= 652{,}545.45\ W_4$$

$$-6EI\,y_{44} = \frac{W_4}{198}\times 48\times 150\,[2\times 198\times 48 - 48^2 - 48^2]$$

$W14\times 119 \qquad I = 1370\ in^4$

$$y_1 = \frac{-1}{6EI}\sum_{j=1}^{4} y_{1j}W_j$$

$$= \frac{-1}{6\times 30\times 10^6\times 1370}\,[692{,}509.09\times 11.4$$

$$+ (783{,}490.91 + 697{,}745.45 + 484{,}363.63)\times 16.3]$$

$$= -0.1645''$$

GILBERT ASSOCIATES, INC.
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READING, PA.

CLIENT FPC

PROJECT CR-3

FILING CODE

W.O. 4203-027 PAGE B B 336 OF 345

SYSTEM M.S. SAFETY + RELIEF VALUES

CALCULATION FOR

ORIGINATOR M. Z. Lee
DATE 4/25/74

REVIEWER S. F. Zurawello
DATE 12/16/74

RESULTS

$$y_2 = \frac{-1}{6EI} \sum_{j=1}^{4} y_{2j} W_j$$

$$= \frac{-1000}{6 \times 30 \times 10^6 \times 1370} \left[78,490.91 \times 11.4 + (954,327.27 + 887,072.73 + 628,363.64) \times 16\tfrac{2}{3} \right]$$

$$= -0.2027"$$

$$y_3 = \frac{-1}{6EI} \left[697,745.45 \times 11.4 + (887,072.73 + 884,945.45 + 654,545.45) \times 16\tfrac{2}{3} \right]$$

$$= -0.1958"$$

$$y_4 = \frac{-1}{6EI} \left[484,363.64 \times 11.4 + (628,363.64 + 654,545.45 + 523,636.36) \times 16\tfrac{2}{3} \right]$$

$$= -0.1442"$$

Max deflection $\doteq -0.203"$ at $a_2 \leq x < a_3$

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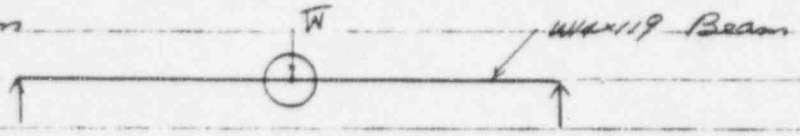
READING, PA.

CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4203-827 PAGE B 337 OF B 345
SYSTEM: M. S. SAFETY + RELIEF VALVES
ORIGINATOR: M. Z. Lee
DATE: 4/25/74
CALCULATION FOR:
REVIEWER: G. F. Fernandez
DATE: 12/16/74
RESULTS

Effect of Beam Flexibility on DLF

Beam



$$k = \frac{48EI}{l^3} = \frac{48 \times 30 \times 10^6 \times 1370}{(198)^3} = 254{,}000 \ \text{lbf/in}$$

$$m = \frac{119}{12} \cdot \frac{1}{386} = 0.0256 \ \frac{\text{lb-sec}^2}{\text{in}}$$

$$\omega_1 = \frac{\pi^2}{l^2}\sqrt{\frac{EI}{m}} = \frac{\pi^2}{(198)^2}\sqrt{\frac{30 \times 10^6 \times 1370}{0.0256}}$$

$$= 319 \ \text{rad/sec}$$

$$f = \omega/2\pi = 50.8 \ \text{cps}$$

Equivalent mass

$$M_1 = \frac{k}{\omega_1^2} = \frac{254{,}000}{(319)^2} = 2.496$$

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CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4203-027 PAGE 337 of 345

SYSTEM: M. S. SAFETY & RELIEF VALVES
CALCULATION FOR:
ORIGINATOR: M. Z. Lee DATE 4/5/74
REVIEWER: A. F. Fernandez DATE 12/16/74

RESULTS

Stack

Weight 1130 lbs (CRBC = Dead load Analysis)

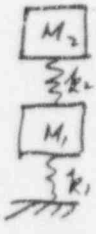
Assume half of the inertial force is acting on W14×119 beam through lower guide. Then

$$M_2 = \frac{W_2}{2g} = \frac{1130}{2\times 386} = 1.462 \ \frac{lb\text{-}sec^2}{in}$$

$f_1 = 21.77$ cps

$\omega = 2\pi f_1 = 319$ cps

$k_2 = M_2\omega^2 = 27,354 \ lb/in$



$$\omega^4 - \left(\frac{k_1+k_2}{M_1} + \frac{k_2}{M_2}\right)\omega^2 + \left(\frac{k_1 k_2}{M_1 M_2}\right) = 0$$

Ref. Churchil, Mechanical Vibration p224

Substitute k_1, k_2, M_1, M_2 from above

$$\omega^4 - 131,432\,\omega^2 + 1,903,995 = 0$$

$\omega^2 = 16,577$ $\omega = 128.75$ $f = 20.49$ cps

or

$\omega^2 = 114,854$ $\omega = 338.9$ $f = 53.93$

$$\frac{21.77 - 20.49}{21.77} \times 100 = 5.9\%$$

$\frac{t_r}{T} = t_r f = 0.04 \times 20.49 = 0.8196$

DLF = 1.3 for $t_r f = 0.8196 \times \frac{1}{1.1} = 0.745$

FILING CODE

GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC

PROJECT: CR-3

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W.O. 4203-027 PAGE B 338 OF B 345

SYSTEM: M.S. SAFETY + RELIEF VALVES

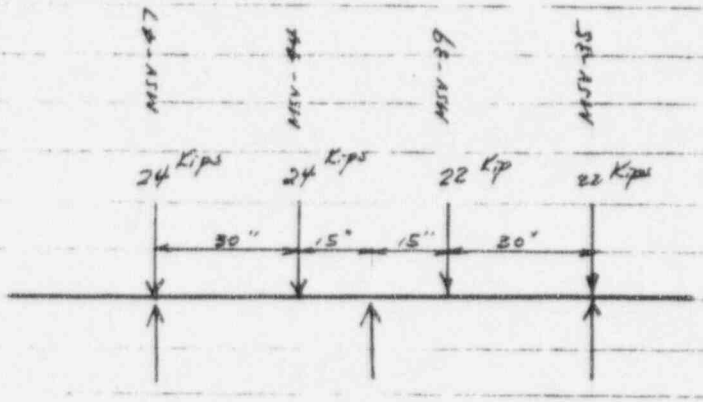
ORIGINATOR: M. Z. Lee
DATE: 4/25/74

CALCULATION FOR:

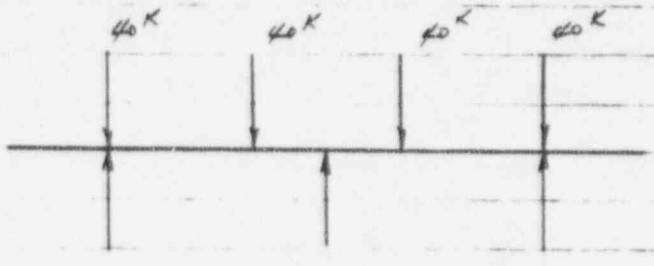
REVIEWER: S. F. Fiumello
DATE: 12/16/74

RESULTS

Structure Load for the Line through Pen. 20 #



Structure Loads with DLF 1.3



Preliminary Design Loads 5/15/73
By S.L. Fox.

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GAI 350 REV. 10-72

GILBERT ASSOCIATES, INC.
ENGINEERS & CONSULTANTS
READING, PA.

CLIENT: FPC

PROJECT: CR-3

FILING CODE:

W.O. 4203-027 PAGE B 339 OF 345

SYSTEM: M. S. SAFETY + RELIEF VALVES

ORIGINATOR: M. Z. Lee

DATE: 4/25/74

CALCULATION FOR:

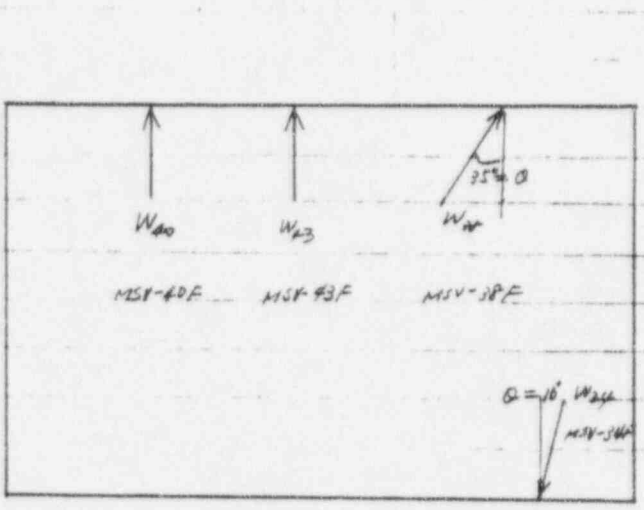
REVIEWER: ~~A. F.~~ Ferranello

DATE: 12/16/74

RESULTS

Structure Loads on the Line through Pen # 106

MSV-38F MSV-43F MSV-40F



	W_{40}	W_{43}	W_{38}	W_{24}
New Value	16	24	24	24
Preliminary Design	50	50	50 (θ=0)	50 (θ=0)
Increased Load			13.8 K to East	44.2 K to West

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GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS
READING, PA.

CLIENT: FPC

PROJECT: CR-3

FILING CODE:

W.O. 4203-027 | PAGE B 344 of 345

SYSTEM: M.S. SAFETY + RELIEF VALVES

ORIGINATOR: M. Z. Lee

DATE: 4/25/74

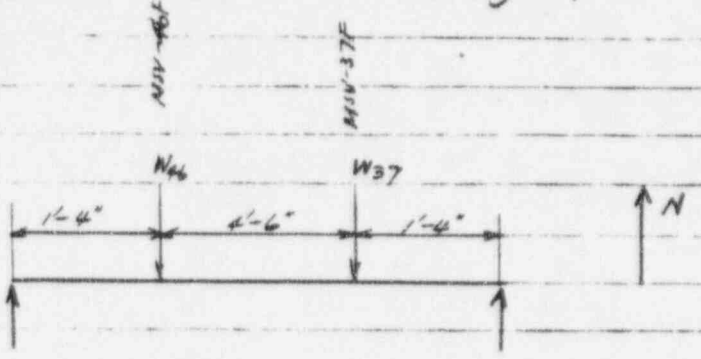
CALCULATION FOR:

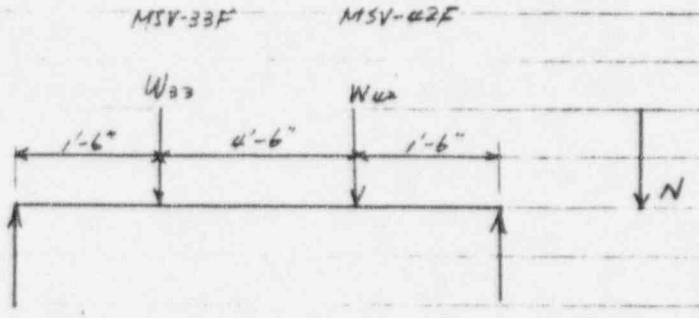
REVIEWER: A. F. Fernandez

DATE: 12/16/74

RESULTS

Structure Loads on Line through Pen. # 105





	W46	W37	W33	W42
New Valve	24 Kips	24 Kips	22 Kip	22 Kip
Preliminary Design Value	40	40	29	29

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CLIENT: FPC
PROJECT: CR-3
FILING CODE:
W.O. 4208-027 PAGE B-34 OF 345
SYSTEM: M.S. SAFETY + RELIEF VALVES
ORIGINATOR: M. Z. Lee
DATE: 4/25/74
CALCULATION FOR:
REVIEWER: J F Bernard
DATE: 10/16/74
RESULTS

Transient Loads on Lower Guide Supports

Consider 14" stack

Acoustic Vecokity at Stack Inlet

$$Va = \sqrt{kgpv} = \sqrt{1.3 \times 32.2 \times (142.6 \times (144) \times 341}$$

$= 1712$ fe/sec say 1700 fe/sec

(p, v from p219 of Flexonic Bath Pe Analysis)

Impulse force $F = pA \times nV = 25,610$ lbs

Assume F rise from zero to 25,610 in $t_r = 0.04$ Sec then the unbalanced transient force on a pipe section of length l in between elbows will be

$$\Delta F = 25.60 \times \frac{l}{Va \cdot t_r}$$

Stacks for Valves MSV-44F, MSE-47F

$$l = 76.625 \cdot \frac{1}{\cos 15^\circ} \times \frac{1}{12} = 6.61 \text{ ft}$$

$Va \cdot t_r = 1700 \times 0.04 = 68$ fe (wave length)

$$\Delta F = 25610 \times \frac{6.61}{68} = 2.490 \text{ lb}$$

Force on guide $= \Delta F \sin 15^\circ = 645$ lbs

Negligibly small

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CLIENT: FPC

PROJECT: CR-3

FILING CODE:

W.O. 4203-007 PAGE B 342 OF 345

SYSTEM: M.S. SAFETY + RELIEF VALVES

ORIGINATOR: M. Z. Lee
DATE: 4/25/74

CALCULATION FOR:

REVIEWER: J. F. Fernandez
DATE: 12/10/74

RESULTS

MSV-38F

$$l = \frac{30.44}{\cos 30^\circ} \cdot \frac{1}{12} = 2.93$$

$$\Delta F = 2,610 \times \frac{2.93}{6.8} = 1,110 \text{ lb}$$

Load on Guide = $\Delta F \sin 30^\circ = 1110 \sin 30^\circ = 555$ lb

Scroll

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CLIENT: FPC
PROJECT: CR-3
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W.O. 4203-027 PAGE B 343 OF 345

SYSTEM: M.S. SAFETY + RELIEF VALVES
ORIGINATOR: M. Z. Lee
DATE: 4/25/74
CALCULATION FOR:
REVIEWED: S. F. Francella
DATE: 12/16/74

RESULTS

Stresses in Stack at Roof Anchor

Transient Load:

Consider MSV-36F stack which has longest vertical straight section

l = EL 157'-0" − EL 128'-7" = 28'-11" ≈ 29'

Acoustic Velocity at Stack inlet 1702 ft/sec
Outlet 1634 "
(Ref P209 Flexonic Back Pr. Analysis)

$\lambda = V_a \cdot t_r = 1634 \times 0.04 = 65.4$ feet

$\Delta P = 25{,}610 \times \frac{29}{65.4} = 11{,}400$ (downward)

Steady state load

$F_y = 25{,}610 (\sin 53° - 1)$

$= 25{,}610 (0.202) = -5{,}180$ lbs

Note: This is more conservative than

$F_y = F_3 \sin 53° - F_4$

where

$F_4 = P_4 A_4 + m V_4$
$= (0.575 - 147) \times 143.1 + 84 \times 1634$
$= 21{,}230$

$F_y = 25{,}610 \sin 53° - 21{,}230 = -777$ lb

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	PROJECT CR-3	W.O. 4203-027 PAGE B-344 OF B-345
SYSTEM M.S. SAFETY & RELIEF VALVES		ORIGINATOR M. Z. Lee DATE 4/25/74
CALCULATION FOR		REVIEWER S. P. Ferarelle DATE 4/16/74

RESULTS

Vertical Load on Anchor

$F_v = \Delta F + \text{Dead Weight} = 11,400 + 1130 = 12,530$ lbs.

Tensile strength

$$S_t = \frac{F_v}{\pi D t} = \frac{12530}{\pi \cdot 14 \cdot 1/4} = 1,140 \text{ psi}$$

Shear in the Anchoring plate

$$S_s = \frac{12530}{\pi \times 14 \cdot 3/4} = 380 \text{ psi}$$

Bending stress in pipe at anchor point

$M_A = 230,278$ lb-in

$$S_b = \frac{M_A}{Z} = \frac{230,278}{36.5} = 6,400 \text{ psi}$$

(steady state)

at transient S_b is less than 6,400 psi

Combined stress

Pr. + Dead load + Seismic =	2934
transient	1,140
transient bending	< 6,400
Total	10,474
	< 18,000

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CLIENT: FPC

PROJECT: CR-3

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W.O. 4203-027 | PAGE B-345 OF B-345

SYSTEM: M.S. SAFETY + RELIEF VALVES

ORIGINATOR: M. Z. Lee
DATE: 5/7/74

CALCULATION FOR:

REVIEWER: S. F. Fenerello
DATE: 12/16/74

RESULTS

References

1. GAI Piping Stress Analysis Computer Output 4203-071 CR-7C, -8C, 9C, -10, -11.

2. GAI DWG E304-025 Rev. 4
   E304-035 Rev. 4

3. Biggs: Introduction to Structure Dynamics McGraw-Hill, 1964.

4. Roark, Formulas for Stress & Strain.

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