PRESSURE VESSEL ENGINERING NOTE

PER CHAPTER 5031

Prepared by: Andrew Szymulanski
Preparation date: September 28, 2004

2004

1. Description and Identification
Fill in the label information below:

This vessel conforms to Fermilab ES&H Manual Chapter 5031 Vessel title **1 Liter Bubble Chamber-outer vessel**	
Vessel Number PPD#10096	←Obtain fromDivision Safety Officer
Vessel Drawing Number U of Chicago/Job No01013 Dwgs.	: 01 ,02 , 03 , 04
Maximum Allowable Working Pressures (MAWP): Internal Pressure 600psi@100F and480psi@230F External Pressure _Ambient atmospheric	
Working Temperature Range 100 °F 230 °F	
Contents DOWFROST HD-DOW (propylene glycol fluid) with volume as differential between vessel inner volume and volume of 1L chamber assembly	
Designer/Manufacturer Meyer Tool Mfg.Inc/CVIP Inc. Oak Lawn, Il.60453 Emaus, Pa.18040	
Test Pressure (if tested at Fermi) Acceptance Date: ______	←Document per Chapter 5034 of the Fermilab ES&H Manual
_______PSI**G**, Hydraulic _____ Pneumatic__________ Accepted as conforming to standard by DAVE PUSHKA	
of Division/Section PPD Date: ~~3-9-05~~ 3/14/05	←Actual signature required

NOTE: Any subsequent changes in contents, pressures, temperatures, valving, etc., which affect the safety of this vessel shall require another review.

Reviewed by: ______________________ Date: 3-14-05

Director's signature (or designee) if the vessel is for manned areas but doesn't conform to the requirements of the chapter.

______________________ Date: ____________

Amendment No.:	Reviewed by:	Date:
____________	____________	____________
____________	____________	____________

Lab Property Number(s)U of Chicago property-contactperson:Andrew Sonnenschein
Lab Location Code:_______________________________(obtain from safety officer)
Purpose of Vessel(s):component of the 1L bubble chamber apparatus__________

Vessel Capacity/Size:2133 [in3] Diameter :11.93 in I.D. Length: 29.5 in
Normal Operating Pressure (OP) = 280 psi
MAWP-OP = 320 PSI

List the numbers of all pertinent drawings and the location of the originals.

Drawing #	Location of Original
MTM - JOB NO 01013 dwg. 01	Meyer Tool @Mfg.,Inc. Oak Lawn,IL.60453
MTM - JOB NO 01013 DWG. 02	
MTM - JOB NO 01013 dwg. 03	
MTM - JOB NO 01013 DWG. 04	

2. Design Verification

Is this vessel designed and built to meet the Code or "In-House Built" requirements?
Yes__*___ No_____.

If "No" state the standard that was used ________________.
Demonstrate that design calculations of that standard have been made and that other requirements of that standard have been satisfied.
Skip to part 3 "system venting verification."

Does the vessel(s) have a U stamp? Yes_*____ No_____. If "Yes", complete section 2A; if "No", complete section 2B.

A. Staple photo of U stamp plate below.
Copy "U" label details to the side

Copy data here:

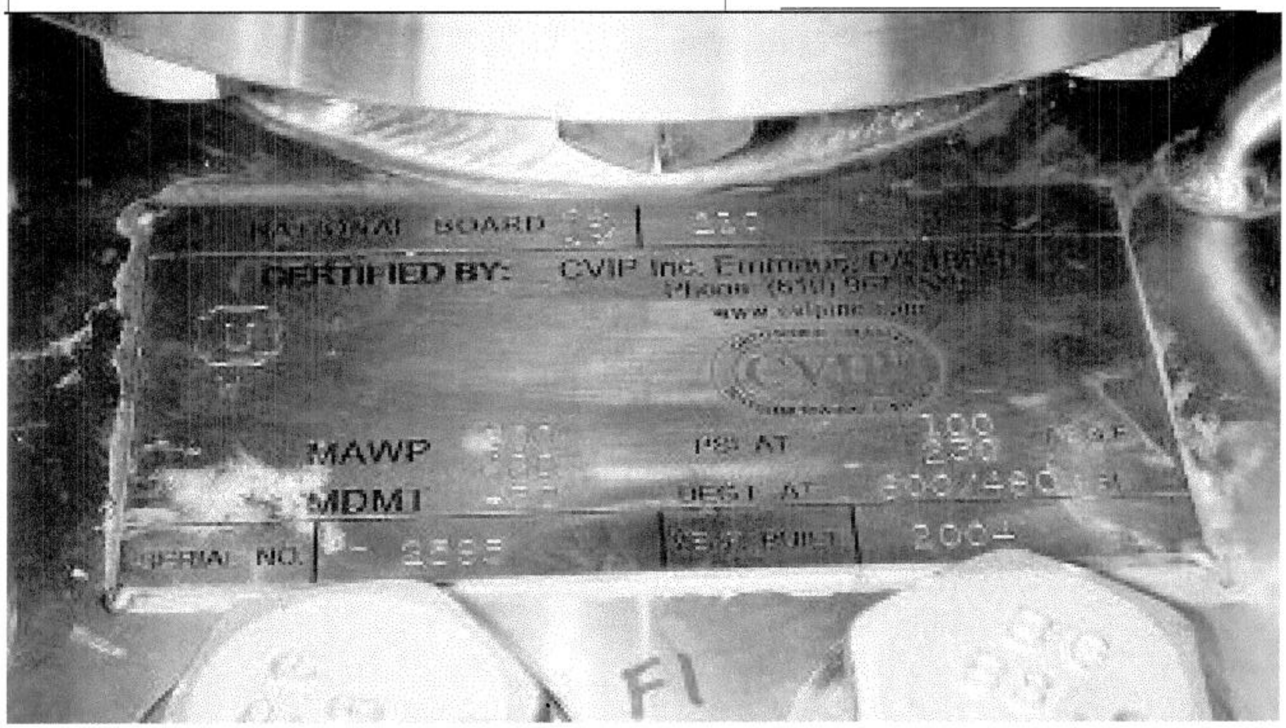
National Board ( ) 210

CERTIFIED BY: CVIP INC.EMMAUS,PA 18049
Phone: (610)967 1525
www.cvipinc.com

MAWP 600 psi at 100 DEG. F
480 230

MDMT _- 30 DEG.F AT 600/480 psi

SERIAL NO. 2595 YEAR BUILT 2004



Provide ASME design calculations in an appendix. On the sketch below, circle all applicable sections of the ASME code per Section VIII, Division I. (Only for non-coded vessels)

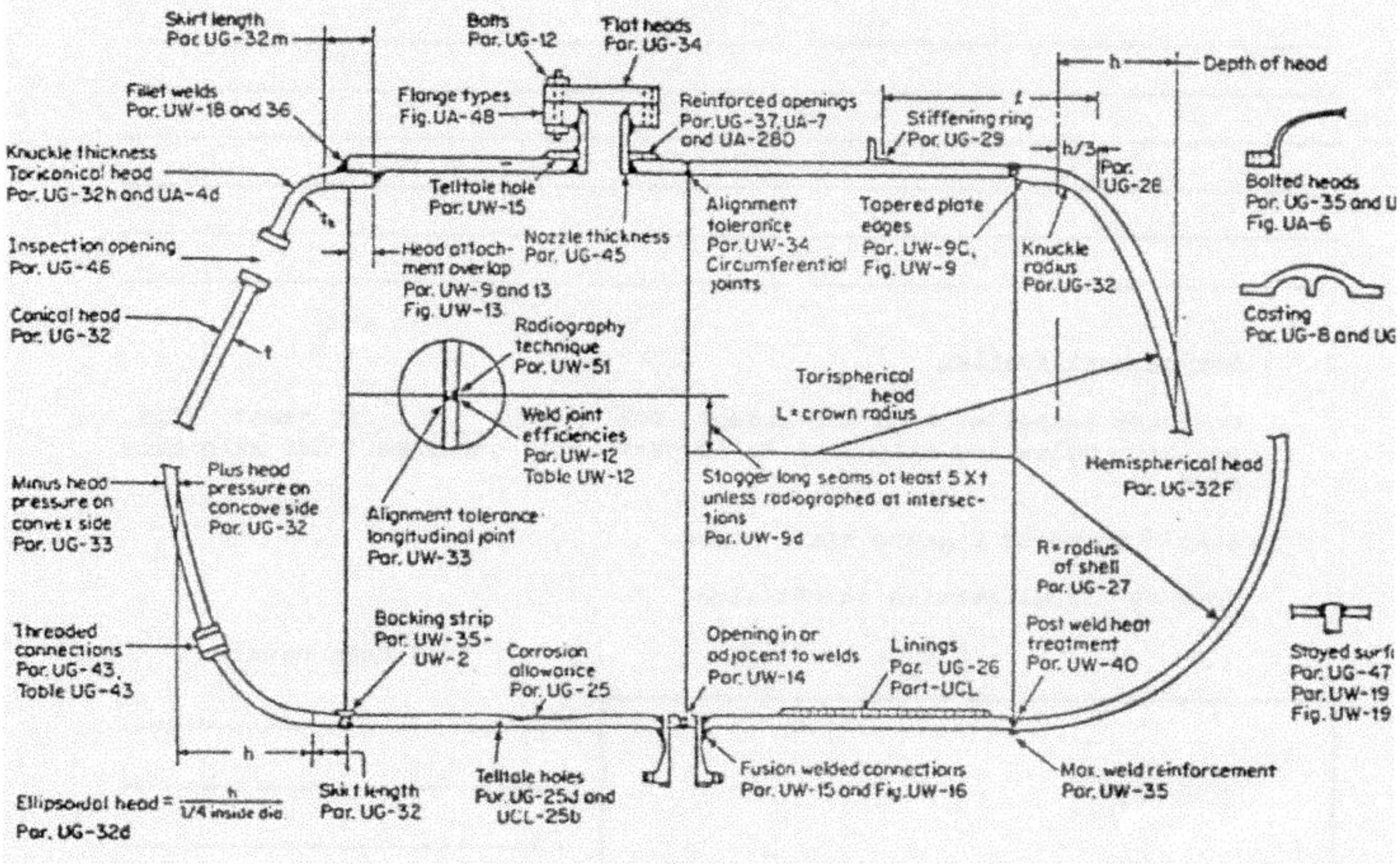


Figure 1. ASME Code: Applicable Sections

2B.

Summary of ASME Code

Item	Reference ASME Code Section	CALCULATION RESULT (Required thickness or stress level vs. actual thickness calculated stress level)
		vs
		vs
		vs
		vs
		vs

3. System Venting Verification Provide the vent system schematic.

Does the venting system follow the Code UG-125 through UG-137?
Yes_*__ No___

Does the venting system also follow the Compressed Gas Association Standards S-1.1 and S-1.3?
Yes __*___ No_____

A "no" response to both of the two proceeding questions requires a justification and statement regarding what standards were applied to verify system venting is adequate.

List of reliefs and settings:

	Manufacturer	Model #	Set Pressure	Flow Rate	Size
a)	Rupture Pin Technology Oklachoma City, OK	CASMF	450 psig	6167 SCFM	1″ (PRV1) **
b)	Swagelok	4CPA	350 psig	0.1 gpm	¼″ (PRV2) **
c)	Circle Seal	5165-4MP-350	350 psig	225 SCFM (air)	½″ (PRV4) **

4. Operating Procedure **

Is an operating procedure necessary for the safe operation of this vessel?
Yes_____ No__*____ (If "Yes", it must be appended)

5. Welding Information

Has the vessel been fabricated in a non-code shop? Yes_____ No_*____
If "Yes", append a copy of the welding shop statement of welder qualification (Procedure Qualification Record, PQR) which references the Welding Procedure Specification (WPS) used to weld this vessel.

6. Existing, Used and Unmanned Area Vessels

Is this vessel or any part thereof in the above categories?
Yes_____ No__*___

If "Yes", follow the requirements for an Extended Engineering Note for Existing, Used and Unmanned Area Vessels.

7. Exceptional Vessels

Is this vessel or any part thereof in the above category?
Yes_____ No__*___

If "Yes", follow the requirements for an Extended Engineering Note for Exceptional Vessels.

THIS VESSEL CONFORMS TO FERMILAB ES&H MANUAL CHAPTER 5031

Vessel Title 1 LITER BUBBLE CHAMBER – OUTER VESSEL

Vessel Number ______________________________

Vessel Drawing Number "MTM" job NO:01013 dwgs. 01,02,03,04 MEYER TOOL&MFG.INC.

OAK LAWN,IL.60453 ___

Maximum Allowable Working Pressures (MAWP):

Internal Pressure _600 psi at 100 deg.F_ and 480 psi_at 230deg. F____________________

External Pressure ___ ATMOSPHERIC ____________________

Working Temperature Range 100 ^{0}F 230 ______ ^{0}F

Contents DOW FROST HD-DOW (PROPYLENE GLYCOL FLUID) ____________

Designer MEYER TOOL & MFG., INC ____________

Test Pressure (if tested at Fermi) DATE __/__/____

____ ________PSIG, Hydraulic ______________________ Pneumatic ____________

Accepted as conforming to standard by

____

Of Division/Section ____

NOTE: Any subsequent changes in content, pressures, temperatures, valving, etc., which affect the safety of this vessel shall require another review and test.

Figure 2. Sample of sticker to be completed and be placed on vessel.

Filling and Operating the 1 Liter Bubble Chamber

Andrew Sonnenschein
Feb. 6, 2004

This document contains notes on the filling and operation of the 1 liter bubble chamber. It includes preliminary procedures for buffer filling, superheated liquid filling, temperature ramping and operation as a detector, along with piping and instrumentation drawings and an equipment list.

1. Operation of Expansion Mechanism- General.

Below (Fig. 1) is a drawing of the expansion mechanism for the 1 liter chamber. The bubble chamber will be connected to a hydraulic cylinder, which is coupled to an air cylinder through the piston shaft. The air cylinder rides on a slide, allowing its position to be precisely adjusted by turning a screw. The purpose of this position adjustment is to allow adjustment of the effective volume of the chamber as the liquids inside warm or cool. The extent of the volume change depends on our final choice of the buffer fluid, which makes up 97% of the total volume (40 liters buffer and 1 liter superheated liquid). The buffer fluid will expand by between 0.02% (pure water) and 0.1% (hydrocarbon based liquids, such as "Paratherm LR") per degree C. Mixtures of water and glycol fall in the middle of this range and silicone oils are at the upper end. The 1.6 liter capacity of the hydraulic cylinder allows the flexibility of a wide choice of buffer liquids. The maximum expansion or contraction will be 40 ml per degree C and the cylinder volume will allow adjustment over at least 40 degrees.

At the operating temperature of the chamber, the screw will be adjusted so that the air cylinder piston is near the end of its stroke. Boiling of the superheated liquid will be limited in volume by the incompressibility of the buffer fluid and the butting up of the air piston against the end of its cylinder. This will prevent rupture of the internal pressure-balancing bellows due to overexpansion. A further advantage of this design is that the air volume on the compressed air side of the cylinder piston is always small, which improves the response time for recompression.

Note that there is a spring-loaded relief valve in the bottom of the pressure vessel, which will relieve excess pressure in case the operator leaves the adjustment nut screwed in too far or there is an unexpected temperature increase (See Figures 2 and 3).

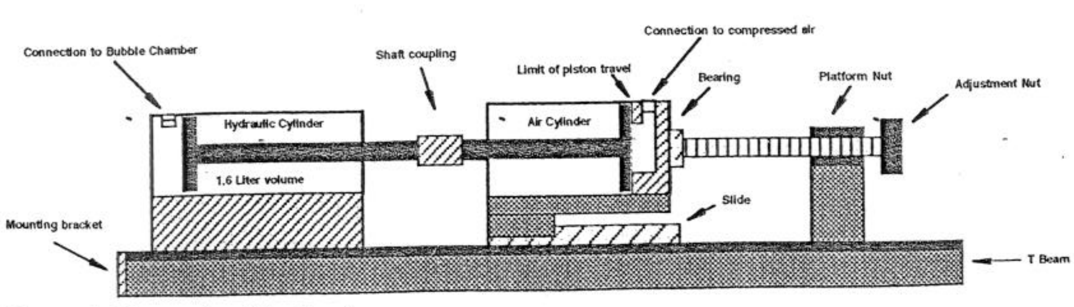


Figure 1. Expansion Mechanism.

2. Filling with buffer fluid.

A drawing of the piping and instrumentation for buffer filling is shown in Figure 2. A second chamber, the "Buffer Degassing Chamber," is used to remove gas bubbles and dissolved gas from the buffer liquid prior to filling. This will prevent gas bubbles from coming out of solution as the buffer fluid warms up.

At the beginning of the procedure, both the bubble chamber outer vessel and buffer degassing chamber are empty and at atmospheric pressure. The bubble chamber inner vessel is filled with distilled water. All valves are closed.

(1) Pump put the degassing chamber to ~10 mbar.
(2) Open valve to liquid storage drum to suck in buffer liquid. Level can be monitored with sight gauge, which consists of a length of 1/2 inch transparent tube running up the side of the tank.
(3) Close valve to storage drum when degassing chamber is 80% full. 365 PSI
(4) Open valves linking bubble chamber gas volume and top of degassing chamber and pump both chambers to ~10 mbar. This will remove bubbles from the buffer liquid.
(5) Close valve to vacuum pump.
(6) Open valve CV1 to bottom of bubble chamber and let in liquid.
(7) Close valves between top of bubble chamber and top of degassing chamber.
(8) Adjust screw on expansion mechanism to be about 2/3 of the way towards the air cylinder. Air cylinder should be vented.
(9) Vent degassing chamber to to bring gas space in degassing chamber up to atmospheric pressure. This will force more liquid into the bubble chamber and push back the air cylinder until it meets the screw.
(10) Seal bottom valve to bubble chamber. Bubble chamber is now full of buffer liquid with no gas volume.

1ATM

3. Filling with CF_3I

(1) Bubble chamber is filled with buffer liquid in the outer volume (OV) and water in the inner volume (IV).
(2) The hydraulic cylinder should be about 1/3 full of liquid and the air cylinder should be vented to the room.
(3) Cool the chamber to 10 degrees C, resulting in a small contraction of the hydraulic piston as it moves to preserve zero gauge pressure in the vessel.
(4) Once the temperature is stable, turn the adjustment screw in to bring the air piston head to the limit of its movement and produce a small positive pressure in the vessel ~ 10 psi.
(5) Connect a cylinder of CF_3I, to the top of the inner quartz vessel (IV) through valve V1. The temporary piping for this should include a provision for pumping out the trapped air space.
(6) Open the valves between the cylinder and the IV. This will cause both the IV and the OV to go to the room temperature vapor pressure of CF_3I, about 50 psi, and liquid CF_3I will begin to condense in the IV.

VAPOR TEST

(3) PAGE 3

4CPA ?

Table 1. Equipment List.

Label	Function	Description
V1	IV isolation valve	Swagelok ELD8 1/2 in. diaphragm valve, electopolished (Borexino type)
V2	IV isolation valve	Swagelok ELD8
V3	Upper connection to OV	Swagelok ball valve, brass, 3/8 inch
PRV1	Pressure relief valve, per ASME code	Model C Valve, Rupture Pin Technology Inc., 1 inch, ~~550~~ 450 psi +/- 5%
PRV2	Pressure relief valve, non code	Swagelok CPA4 check valve with spring return, set at 350 psi.
PRV3	Pressure relief for compressed air	Set at 250 psi, spring return
P1	Pressure gauge with local indicator	Compound gauge, Supco DPG-500, vacuum to 500 psi
P2	Pressure transmitter	Noshok Series 200, vacuum to 300 psi
R1	Pressure regulator for compressed air	Range: 0-300 psi
SV1	Compression control	3-way, McMaster Carr, 12 volts, 1/4 inch
CV1	Lower connection to OV	Swagelok needle valve, 1/4 inch, brass
CV2	Needle valve for pneumatic control	Swagelok needle valve, 1/4 inch, brass
CV3	Upper heating coil flow control	Control valve, 1/2 inch, brass
CV4	Lower heating coil flow control	Control valve, 1/2 inch, brass
TC1	Thermocouple with transmitter	Love Controls, voltage output, 0.25% linearity, T type thermocouple
TC2	Thermocouple with transmitter	Thermocouples are sheathed in 1/16 SS tubes
TC3	Thermocouple with transmitter	
TC4	Thermocouple with transmitter	
	Bubble Chamber Outer Vessel	ASME code stamped pressure vessel, 600 psi, 304 stainless steel
	Bubble Chamber Inner Vessel	Quartz vessel, full vacuum to ~ 1 bar
	Heat exchange coils	Copper heat exchange coil, 1/2 inch soft copper tubing
	Neslab RTE740	Heating or cooling recirculator with temperature controller and pump, 800 W. Temperature controller is claimed accurate to 0.01 degrees C.

(7) In order to fill the IV with CF_3I, water must be removed. Slowly crack open the valve V2 and drain water into a bucket, without loosing pressure in the vessel.
(8) The amount of CF_3I, in the IV should be monitored by eye, looking through the windows into the chamber.
(9) When the desired level has been achieved close the valves. The pressure should now decrease to the vapor pressure at 10 degrees, or 30 psi.

4. Ramp up temperature to operating point.
(1) Apply 200 psi air pressure to the air cylinder. This will compress the piston by about 1/4 inch as the OV is pressurized. The buffer pressure will be 1.3 times the air pressure, – BASIS or 260 psi, due to the difference in piston diameters (4.5 air inch and 4 inch hydraulic). The high pressure in the vessel will prevent boiling of the CF_3I as its temperature and vapor pressure increase.
(2) If necessary, buffer fluid should be drained to bring the hydraulic cylinder piston to about 1 inch from its minimum volume. The buffer will expand by up to 0.1% per degree C when heated. The hydraulic cylinder can accommodate 40 degrees of temperature change (1.6 liters), which is more than enough, since we anticipate an operating temperature of about 40 degrees for CF_3I. Note that there is a needle valve on the bottom of the vessel to drain controlled amounts of buffer fluid. To prevent boiling of CF_3I and damage to steel expansion bellows, do not allow the pressure in the vessel to decrease below 150 psi during draining.
(3) Unscrew the adjustment nut to allow maximum travel of the air cylinder, while maintaining 200 psi air pressure.
(4) Warm the vessel up to the operating temperature (about 40 degrees C) by programming the temperature controller on the Neslab unit. The air piston should retract as the OV volume increases under constant pressure. This may happen in "spurts" due to the popping and resealing of valve PRV3. USE REGULATOR + SAFETY VALVE

5. Pressure Cycling
(1) When a stable operating temperature has been reached, the adjustment nut should be turned to allow a minimum of piston travel beyond the zero pressure point. The allowed travel must be no more than 1 inch and preferably less, to minimize the motion of the stainless steel bellows. There must be at least a small gap between the decompressed position of the piston and the travel limit to allow for small temperature instabilities. For +/- 1 degree temperature stability, we need to allow a 0.18 inch gap in the decompressed state or about 0.4 inches when compressed.
(2) To superheat the CF_3I, vent the air cylinder. This will be exciting the first time! The vent speed can be controlled with a choke valve.
(3) If an event occurs, the chamber pressure will jump from zero to the operating vapor pressure and the hydraulic piston will move out to the limit it can go, with the air cylinder moving back on its slide. The quartz vessel will move down by approximately the same distance that the piston moves, since the bellows diameter is the same as the hydraulic cylinder bore diameter.
(4) If an event is not sensed acoustically, it can be sensed by monitoring pressure or piston position. Acoustic sensing is preferable, since it will reduce the amount of gas that

SPRING CONSTANT OF BELLOWS

boils away and reduce the time to recompress. On the other hand, a sensor measuring the position of the pistons may be quite fast and less prone to noise interference.
(5) Admit compressed air to the air cylinder to recompress the chamber.
(6) Repeat…

Figure 2. Piping and Instrumentation for Buffer Filling.

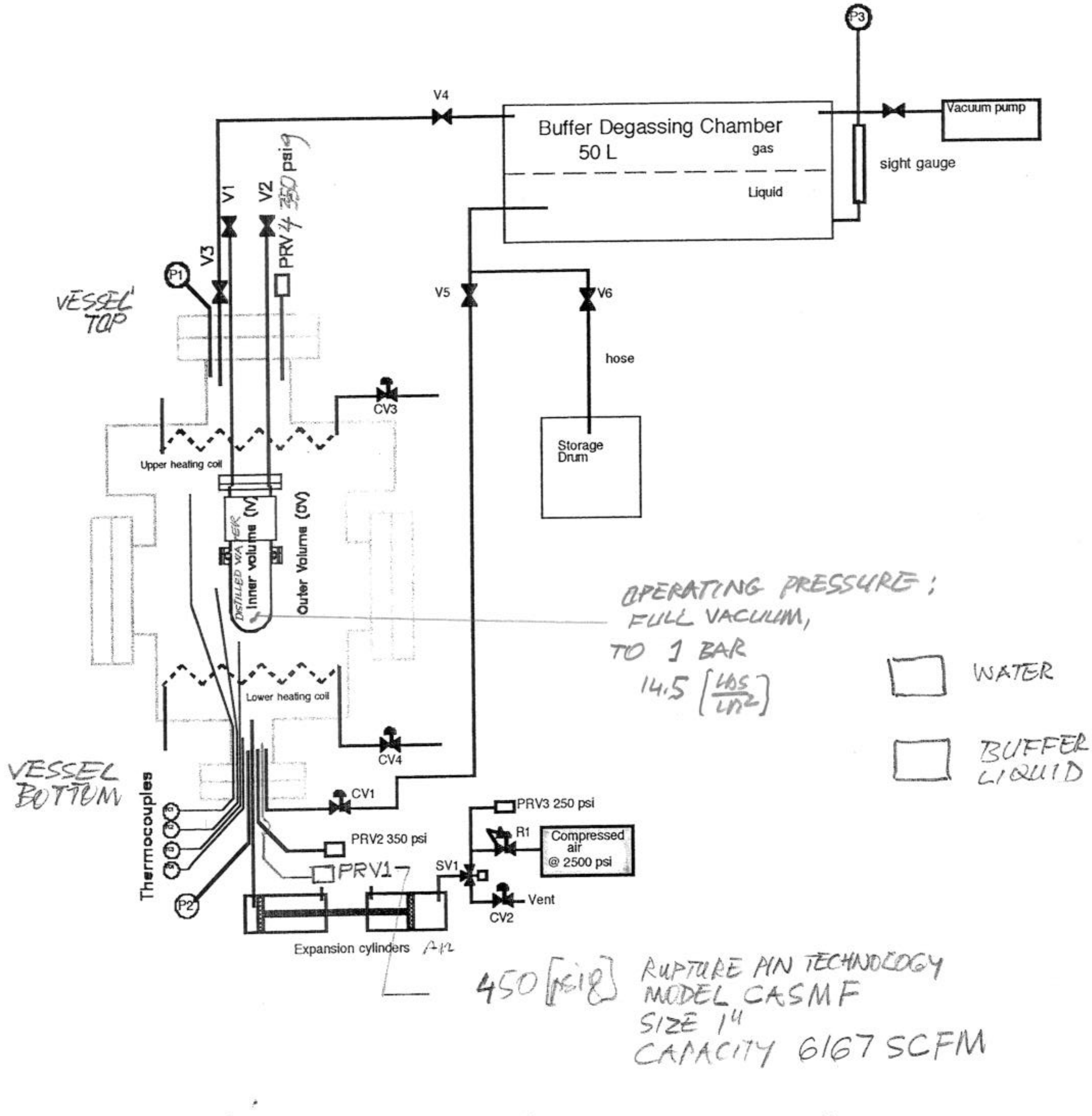
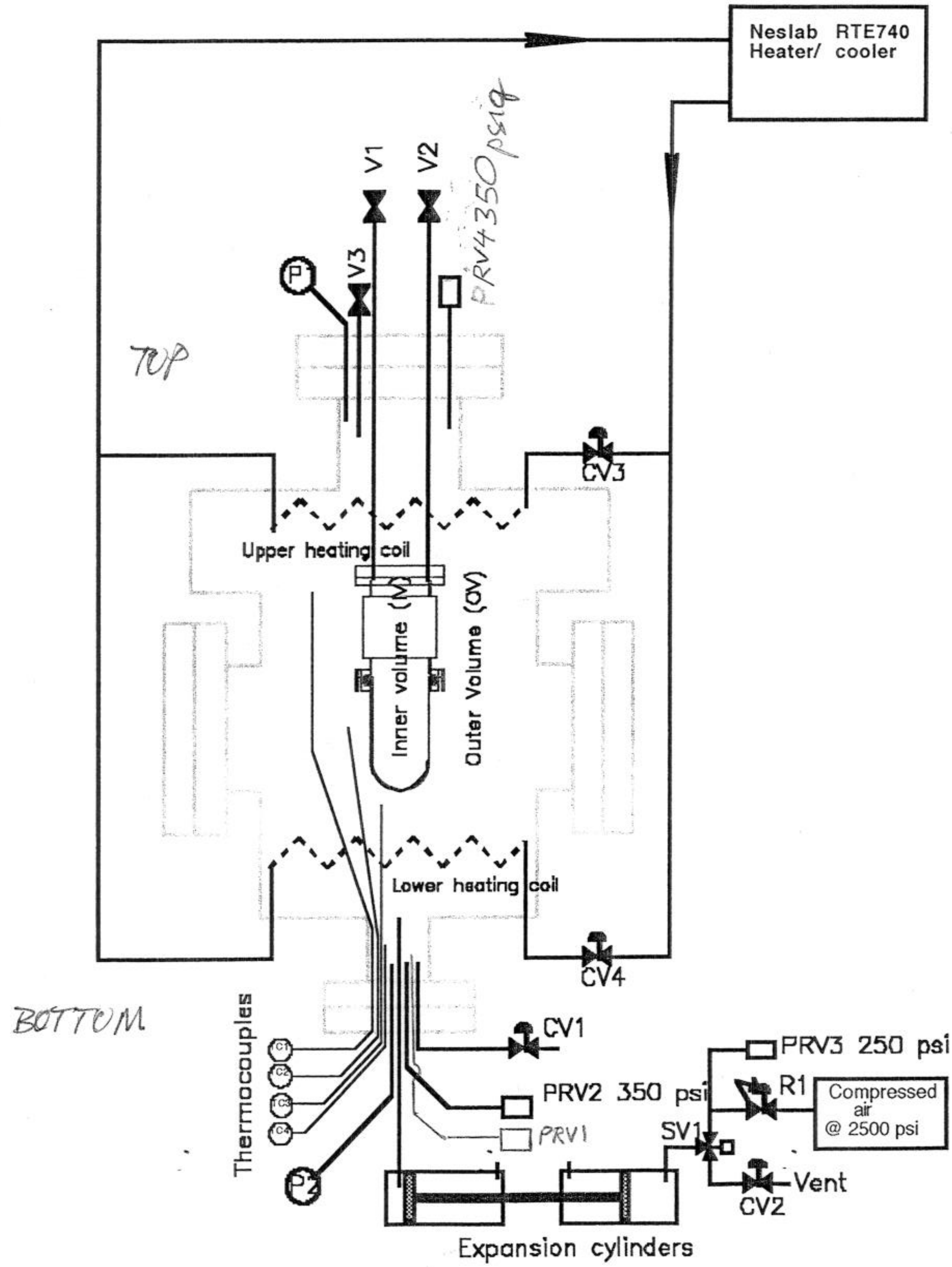


Figure 3. Piping and Instrumentation for Detector Operation.



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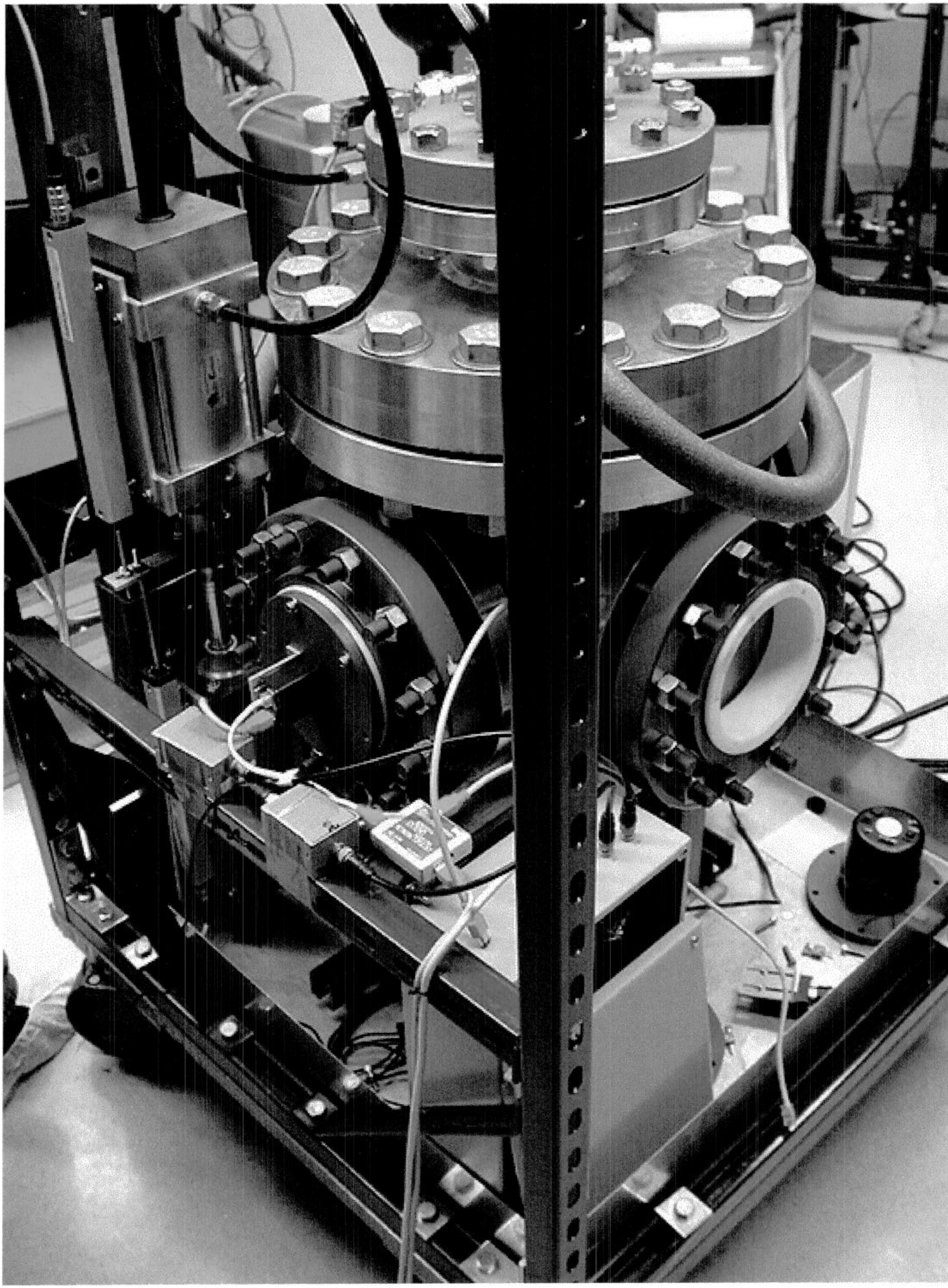

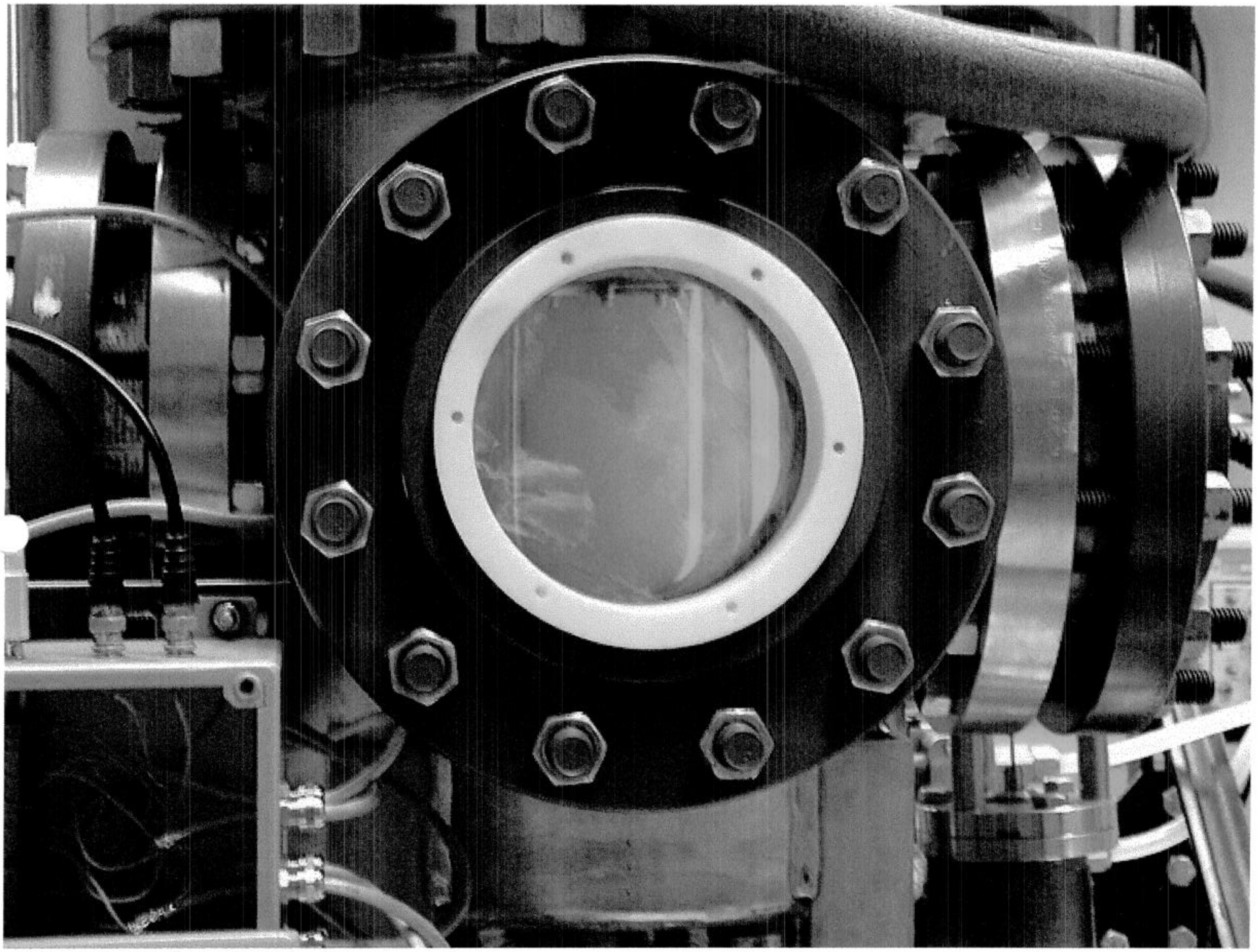

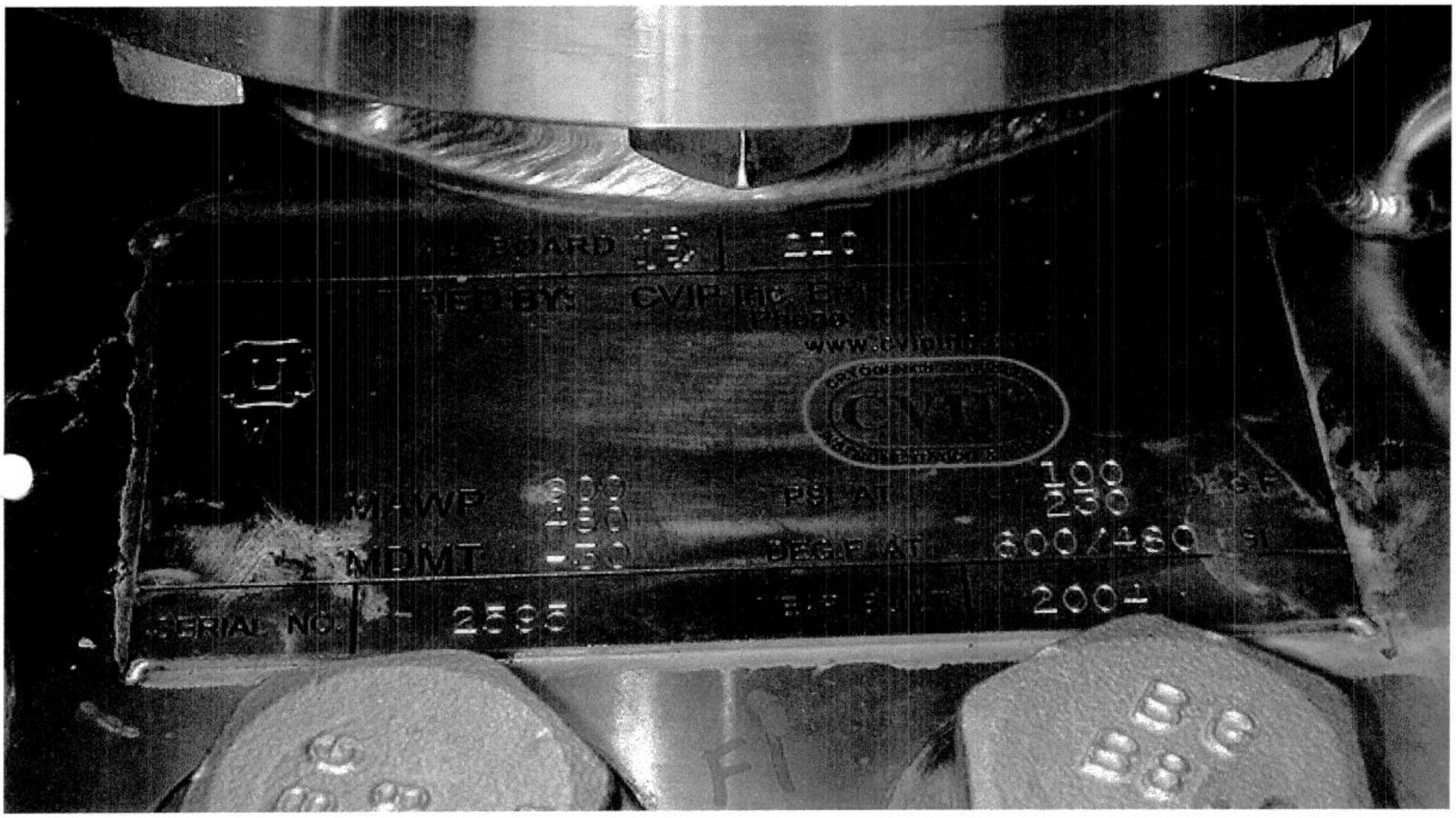
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6167
SCFM

450 psi

CASME

1

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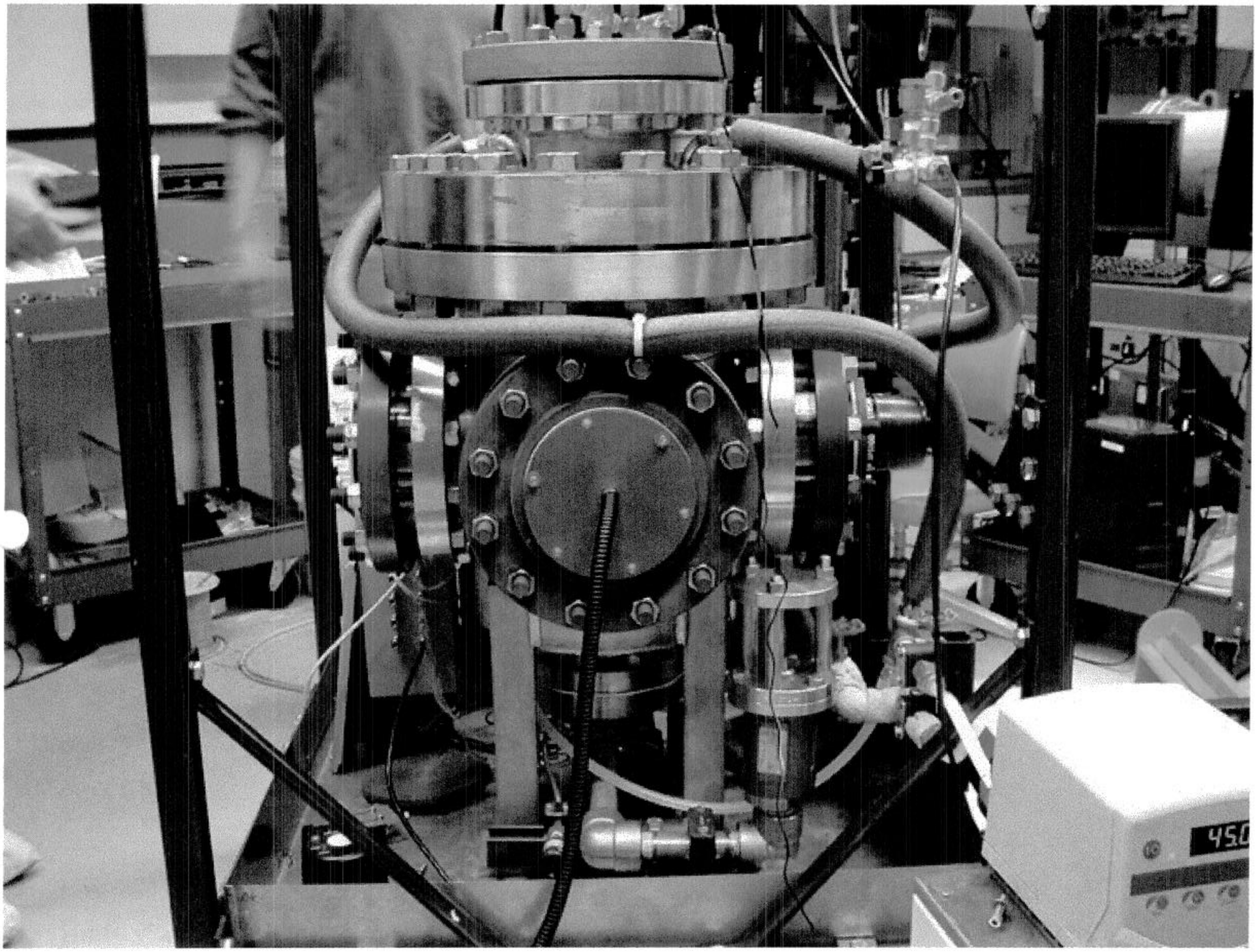
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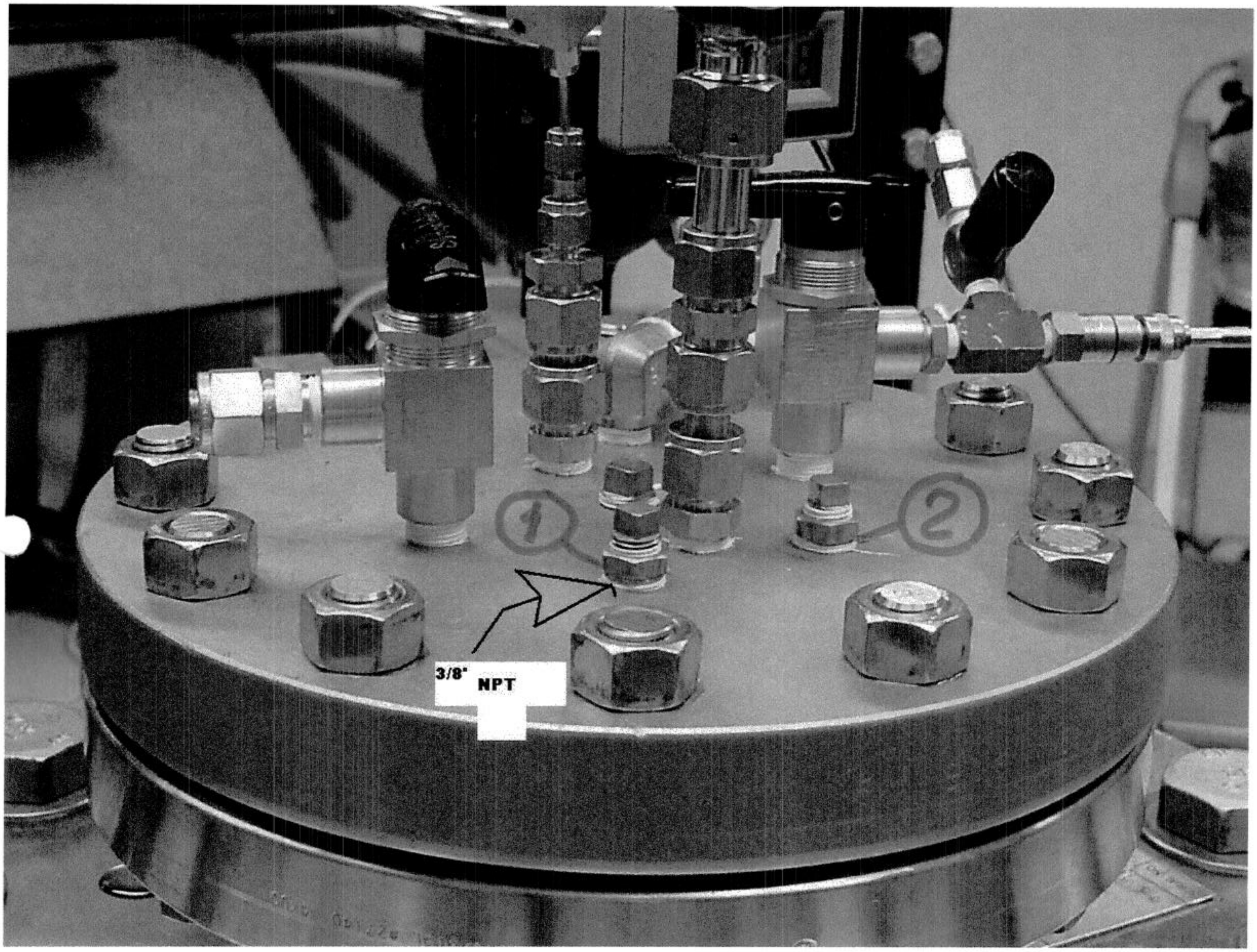
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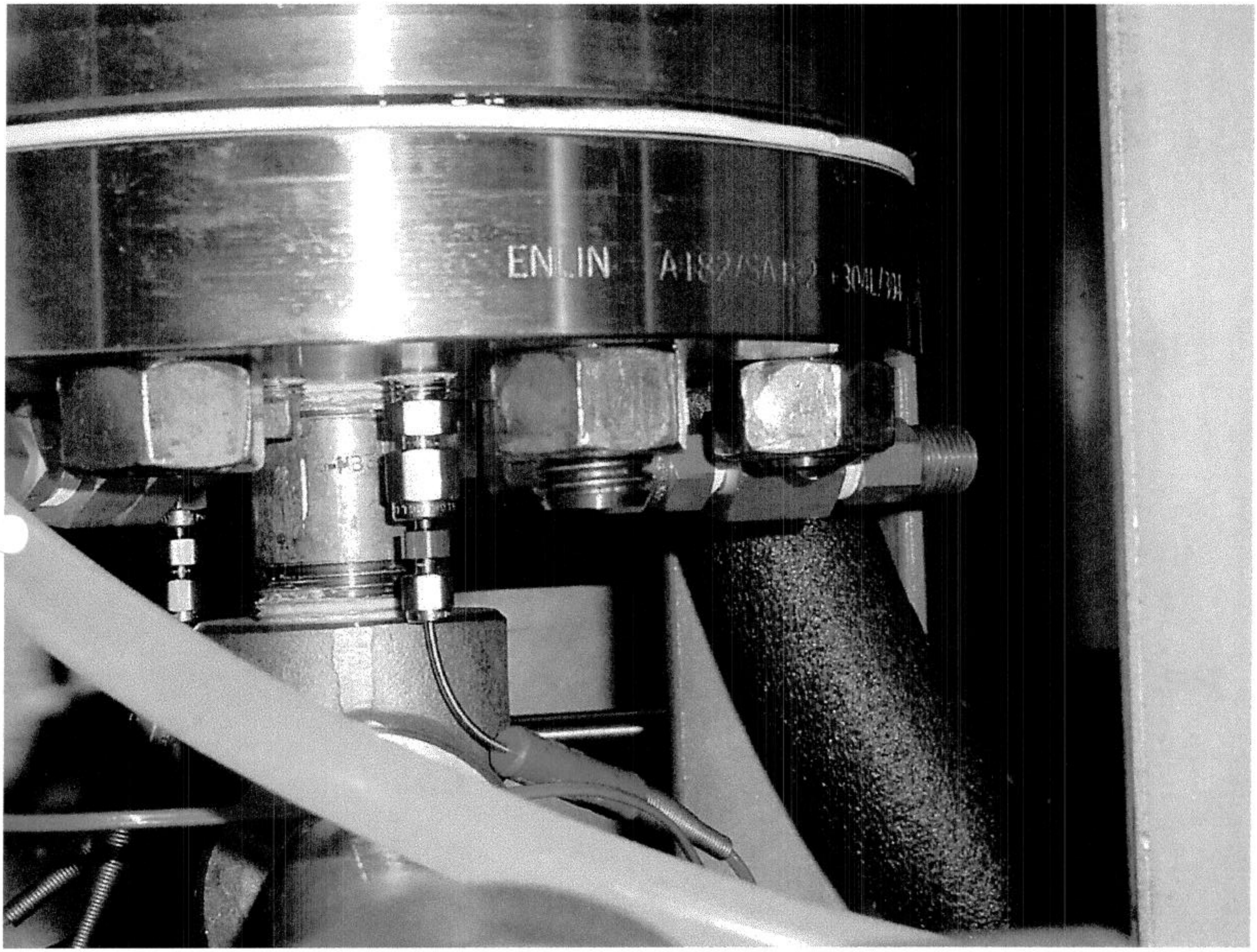
PAGE 14



Meyer Tool & Mfg., Inc.

4601 W. Southwest Hwy., Oak Lawn, Illinois 60453
708 / 425-9080
Fax 708 / 425-2612

CERTIFICATE OF CONFORMANCE

Customer: University of Chicago – UCEC & CFCP

P.O. Number: Z577817

Specification Number: U of C RFQ dated 10/29/03 and MTM quotation 001255-00, Design Pressure of 600 psig

Description: Design and drafting of the Bubble Chamber Outer Vessel for 600 psig design pressure.

Quantity: One

MTM Project Number: 01013

The design of the Bubble Chamber Outer Vessel, as defined by the Purchase Order and Specification(s) listed above and depicted on MTM drawings 01013-01 through 01013-04, meets the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, as documented in the attached design calculations, with the following exceptions:

Exceptions: None

Certified by: Richard D Luther
Richard D. Luther, P.E.

Date: 1/9/04

RDC 1/7/04 ①

JOB 01013 - U. of Chicago

600 psig Bubble Chamber:

600 psig @ 100°F

304 SS

12" Pipe w/4 6" sch 40 pipe nozzles w/CL300 Flanges:

12" Pipe: $R_o = 12.75 \div 2 = 6.375"$

$$t = \frac{PR_o}{SE+.4P} = \frac{600(6.375)}{\begin{matrix}.85(17000)+.4(600) \\ 1.0(20000)+.4(600\end{matrix}} = \left\{\begin{matrix} .2604" \text{ max} \\ .189" \text{ min.}\end{matrix}\right.$$

For this design assume E=1 for all pipes and try Sch 40S pipe ($t = .375(1.0) = .328"$)

$$t_r = \frac{600(6.375-.328)}{(1)(20000)-.6(600)} = 0.185"$$

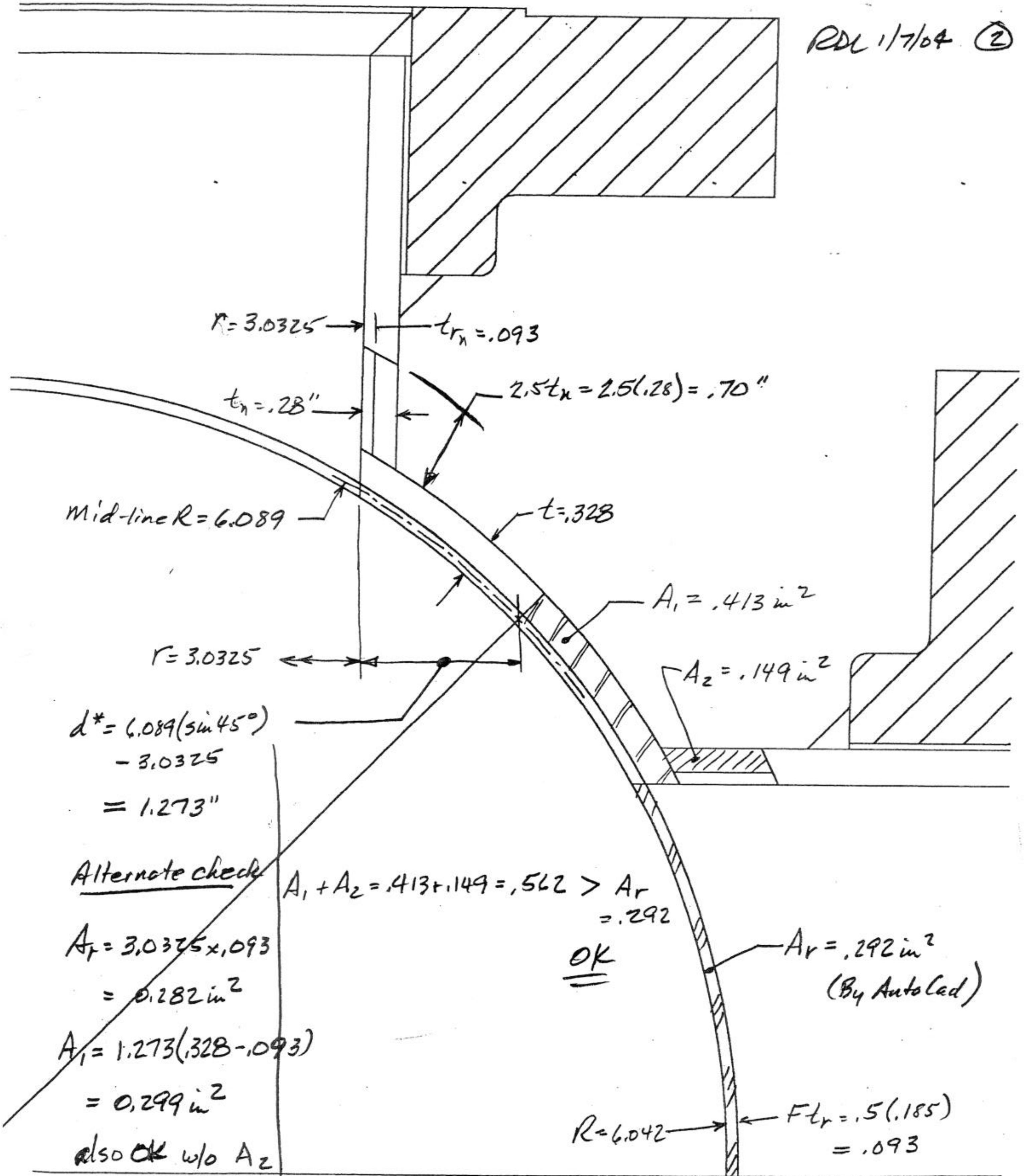
In these calcs we can use the nominal thickness of the 6" pipe ($t_n = .280"$)

$$t_{r_n} = \frac{600\left(\frac{6.625}{2}-.280\right)}{20000-.6(600)} = .093"$$

FIRST LOOK AT A TRANSVERSE CROSS SECTION, F = .5 (Fig. UG-37)

$Ft_r = .5(.185 = .092)$

RDL 1/7/04 ②



$d^* = 6.089(\sin 45°) - 3.0325$

$= 1.273$"

$A_1 + A_2 = .413 + .149 = .562 > A_r = .292$

OK

Alternate check

$A_r = 3.0325 \times .093$

$= 0.282$ in²

$A_1 = 1.273(.328 - .093)$

$= 0.299$ in²

also OK w/o A_2

Also Check Ligament Efficiency.

Check Ligament Efficiency Per Fig UG-53.6:

C/L Rad. = 6.089"

P' = diagonal pitch = $\frac{2\pi(6.089)}{4} = 9.565$"

d = Nozzle Diameter = $2(3.0325) = 6.065$"

$$\frac{P'}{d} = \frac{9.565}{6.065} = 1.58 \qquad \theta = 90^\circ$$

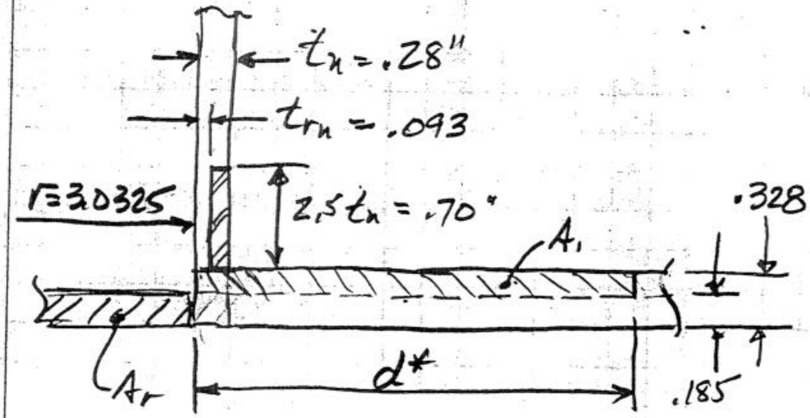
$E = 71\%$ (Fig. UG-53.6)

Substituting for Weld joint efficiency:

$$t_r = \frac{PR}{SE - .6P} = \frac{600(6.042)}{.71(20000) - .6(600)}$$

$t_r = 0.262" < .328$ OK

Check a longitudinal Section:



$F = 1.0$

$F t_r = 0.185''$

$A_r = 3.0325(.185)$

$A_r = .561 \text{ in}^2$

$A_2 = .70 \times (.28 - .093)$

$= 0.131 \text{ in}^2$

$A_1 = d^* \times (.328 - .185)$

$A_1 + A_2 \geq A_r$

$d^*(.328 - .185) + .131 \geq .561$

$$d^* \geq \frac{.561 - .131}{.328 - .185}$$

$d^* \geq 3.007''$

There are more than 3" of shell on either side of the nozzle

$\therefore$ OK.

Look at Flanges:

ANSI B16.5 allows 304SS CL300 flanges up to 750 psig @ 100°F. How much of the hub can be removed from the 6" & 3" flanges to facilitate welding?

Use Code Calc to determine this:

From the Code Calc printouts following, we see that:

1. The 6" CL300 flanges can be used without hubs. (MAWP=622 psig)
2. The 3" CL300 flange can be used without a hub (MAWP=1002 psi)
3. The required thickness of a 12" CL300 blind flange is 1.843". Calculations for area replacement follow the print-outs.

Input Echo, Flange Item 1, Description: 6 in cl 300

Description of Flange Geometry (Type)		Loose Ring	
Description of Flange Analysis		Analysis Only	
Design Pressure	P	600.00	psig
Design Temperature		100.00	F
Corrosion Allowance	FCOR	0.0000	in.
Flange Inside Diameter	B	6.7200	in.
Flange Outside Diameter	A	12.5000	in.
Flange Thickness	T	1.4400	in.
Perform thickness calcs. based on rigidity		No	
Flange Material		SA-182 F304	
Flange Material UNS Number		S30400	
Flange Allowable Stress At Temperature	SFO	20000.00	psi
Flange Allowable Stress At Ambient	SFA	20000.00	psi
Bolt Material		SA-193 B8	
Bolt Material UNS Number		S30400	
Bolt Allowable Stress At Temperature	SBO	18800.00	psi
Bolt Allowable Stress At Ambient	SBA	18800.00	psi
Length of Weld Leg at Back of Ring	WLEG	0.2500	in.
Number of Splits in Ring Flange	NSPLT	0	
Diameter of Bolt Circle	C	10.6200	in.
Nominal Bolt Diameter	DB	0.7500	in.
Type of Threads		UNC Thread Series	
Number of Bolts		12	
Flange Face Outside Diameter	FOD	8.5000	in.
Flange Face Inside Diameter	FID	6.7200	in.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	GOD	9.8750	in.
Gasket Inside Diameter	GID	6.7500	in.
Gasket Factor, m,	M	2.0000	
Gasket Design Seating Stress	Y	1200.00	psi
Column for Gasket Seating		2, Code Column II	
Gasket Thickness		0.1200	in.

FLANGE ANALYSIS, FLANGE NUMBER 1, Description: 6 in cl 300
ASME Code, Section VIII, Division 1, App. 2, Ed-2001

Code R Dimension,	R = (C-B)/2.0 - G1	1.950	in.
Gasket Contact Width,	N = (GOD-GID) / 2	0.875	in.
Basic Gasket Width,	B0 = N / 2.0	0.438	in.
Effective Gasket Width,	BE = SQRT(B0) / 2.0	0.331	in.
Gasket Reaction Diameter,	G = GOD-2.0*BE	7.839	in.

Basic Flange and Bolt loads:
Hydrostatic End Load due to Pressure:
H = 0.785 * G * G * PEQ
H = 0.7854 * 7.8386 * 7.8386 * 600.0000
H = 28954. lb.
Contact Load on Gasket Surfaces:
HP = 2 * BE * PI * G * M * P
HP = 2 * 0.3307 * 3.1416 * 7.8386 * 2.0000 * 600.00
HP = 19546. lb.
Hydrostatic End Load at Flange ID:
HD = 0.785 * Bcor * Bcor * P

```
    HD = 0.785 * 6.7200 * 6.7200 * 600.0000
    HD = 21280. lb.
Pressure Force on Flange Face:
    HT = H - HD
    HT = 28954 - 21280
    HT = 7674. lb.
Operating Bolt Load:
   WM1 = H + HP +  HPP
   WM1 = ( 28954 + 19545 + 0 )
   WM1 = 48500. lb.
Gasket Seating Bolt Load:
   WM2 = Y * BE * PI * G  + Ypart * BEpart * GLPG + HPGY
   WM2 = 1200.00*0.3307*3.141*7.839+0.00*0.0000*0.00
   WM2 = 9773. lb.
Required Bolt Area:
    AM = Maximum of WM1/SBO, WM2/SBA
    AM = Maximum of 48500 / 18800 , 9772 / 18800
    AM = 2.57980 in²

Bolting Information for UNC Thread Series:
Total Area of Bolts, AB                                     3.624  in²
Minimum radial distance between hub and bolts               1.125  in.
Minimum radial distance between bolts and edge              0.813  in.
Minimum circumferential spacing between bolts               1.750  in.
Actual  circumferential spacing between bolts               2.749  in.
Maximum circumferential spacing between bolts               4.956  in.
Distance Across Corners for Nuts                            1.383  in.
Circular Wrench End Diameter                          a     2.062  in.

Min. Gasket Contact Width (Brownell Young):
  Nmin = AB * SBA/(Y * PI * (GOD+GID) )
       = 3.624 * 18800.00/( 1200.00 * 3.14 * ( 8.50 + 6.75) )
  Nmin = 1.185 in.


Flange Design Bolt Load, Gasket Seating:
     W = SBA * ( AM + AB ) / 2.0
     W = 18800.00 * ( 2.5798 + 3.6240 ) / 2.0
     W = 58315.75 lb.
Gasket Seating Force:
    HG = WM1 - H
    HG = 48500 - 28954
    HG = 19545.94 lb.
    HG = 19545.94 lb.
MOMENT ARM CALCULATIONS:
Distance to Gasket Load Reaction:
   DHG = (C - G ) / 2.0
   DHG = ( 10.6200 - 7.8386 ) / 2.0
   DHG = 1.3907 in.
Distance to Face Pressure Reaction:
   DHT = ( DHD + DHG ) / 2.0
   DHT = ( 1.9500 + 1.3907 ) / 2.0
   DHT = 1.6704 in.
Distance to End Pressure Reaction:
   DHD = ( C - BCOR )/ 2.0
   DHD = ( 10.6200 - 6.7200 ) / 2.0
   DHD = 1.9500 in.
```

SUMMARY OF MOMENTS FOR INTERNAL PRESSURE:

LOADING		Force	Distance	Bolt Corr	Moment
End Pressure,	MD	21280.	1.9500	1.0000	3458. ft.lb.
Face Pressure,	MT	7674.	1.6704	1.0000	1068. ft.lb.
Gasket Load,	MG	19546.	1.3907	1.0000	2265. ft.lb.
Gasket Seating,	MA	58316.	1.3907	1.0000	6758. ft.lb.

```
TOTAL MOMENT FOR OPERATION,      RMO                              6791. ft.lb.
TOTAL MOMENT FOR GASKET SEATING, RMA                              6758. ft.lb.

Effective Hub Length, H0 =                                       0.000  in..
Hub Ratio,          HRAT = Defined as 0.0                        0.000
Thickness Ratio,    GRAT = Defined as 0.0                        0.000
Factors from Figure 2-7.1                          K =           1.860
                    T =        1.560               U =           3.623
                    Y =        3.297               Z =           1.813
Tangential Flange Stress, Operating:
   STO = ( Y*RMO )/( TH*TH*BCOR )
   STO = ( 3.2970 * 81497 )/( 1.4400 * 1.4400 * 6.7200 )
   STO = 19283. psi
Tangential Flange Stress, Seating:
   STA = ( Y*RMA )/( TH*TH*BCOR )
   STA = ( 3.2970 * 81100)/( 1.4400 * 1.4400 * 6.7200 )
   STA = 19189. psi
Bolt Stress, Operating:
   BSO = ( WM1 / AB )
   BSO = ( 48500 / 3.6240 )
   BSO = 13383. psi
Bolt Stress, Seating:
   BSA = ( WM2 / AB )
   BSA = ( 9772 / 3.6240 )
   BSA = 2697. psi
```

Stress Computation Results:	OPERATING		GASKET SEATING	
	Actual	Allowed	Actual	Allowed
Tangential Flange	19283.	20000.	19189.	20000. psi
Bolting	13383.	18800.	2697.	18800. psi

OK

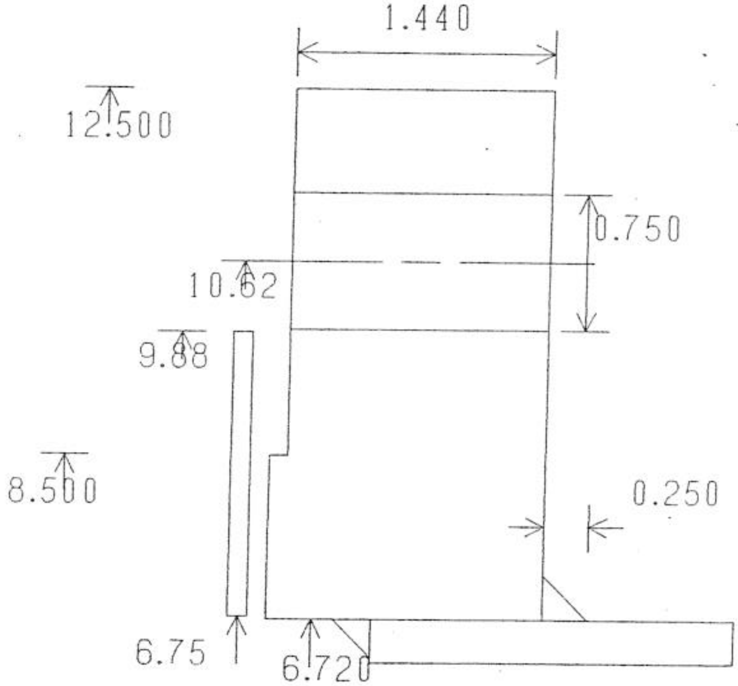
```
Estimated M.A.W.P. ( Operating )                         622.3  psig
Estimated M.A.W.P. ( Gasket Seating )                    661.0  psig
Estimated Finished Weight of Flange                       35.2  lb.
Estimated Unfinished Weight of Forging                    35.2  lb.
APP. S Flange Rigidity Index for Seating Case            0.855
APP. S Flange Rigidity Index for Operating Case          0.859

Minimum Design Metal Temperature Results:
```

9

Loose Ring	:	6 in cl 300
Flange Material	:	SA-182 F304
Bolt Material	:	SA-193 B8
Temperature (F)	:	100.000
Pressure (psi)	:	600.000

Diameter Dimensic



Dimension Units : in.

CodeCalc 6.

Input Echo, Flange Item 2, Description: 3 in cl 300

Description of Flange Geometry (Type)		Loose Ring	
Description of Flange Analysis		Analysis Only	
Design Pressure	P	600.00	psig
Design Temperature		100.00	F
Corrosion Allowance	FCOR	0.0000	in.
Flange Inside Diameter	B	3.5700	in.
Flange Outside Diameter	A	8.2500	in.
Flange Thickness	T	1.1200	in.
Perform thickness calcs. based on rigidity		No	
Flange Material		SA-182 F304	
Flange Material UNS Number		S30400	
Flange Allowable Stress At Temperature	SFO	20000.00	psi
Flange Allowable Stress At Ambient	SFA	20000.00	psi
Bolt Material		SA-193 B8	
Bolt Material UNS Number		S30400	
Bolt Allowable Stress At Temperature	SBO	18800.00	psi
Bolt Allowable Stress At Ambient	SBA	18800.00	psi
Length of Weld Leg at Back of Ring	WLEG	0.2200	in.
Number of Splits in Ring Flange	NSPLT	0	
Diameter of Bolt Circle	C	6.6200	in.
Nominal Bolt Diameter	DB	0.7500	in.
Type of Threads		UNC Thread Series	
Number of Bolts		8	
Flange Face Outside Diameter	FOD	5.0000	in.
Flange Face Inside Diameter	FID	3.5700	in.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	GOD	5.8800	in.
Gasket Inside Diameter	GID	4.1200	in.
Gasket Factor, m,	M	2.0000	
Gasket Design Seating Stress	Y	1200.00	psi
Column for Gasket Seating		2, Code Column II	
Gasket Thickness		0.1200	in.

FLANGE ANALYSIS, FLANGE NUMBER 2, Description: 3 in cl 300
ASME Code, Section VIII, Division 1, App. 2, Ed-2001

Code R Dimension,	R = (C-B)/2.0 - G1	1.525	in.
Gasket Contact Width,	N = (GOD-GID) / 2	0.440	in.
Basic Gasket Width,	B0 = N / 2.0	0.220	in.
Effective Gasket Width,	BE = B0	0.220	in.
Gasket Reaction Diameter,	G = (GOD+GID) / 2.0	4.560	in.

Basic Flange and Bolt loads:
Hydrostatic End Load due to Pressure:
H = 0.785 * G * G * PEQ
H = 0.7854 * 4.5600 * 4.5600 * 600.0000
H = 9799. lb.
Contact Load on Gasket Surfaces:
HP = 2 * BE * PI * G * M * P
HP = 2 * 0.2200 * 3.1416 * 4.5600 * 2.0000 * 600.00
HP = 7564. lb.
Hydrostatic End Load at Flange ID:
HD = 0.785 * Bcor * Bcor * P

```
    HD = 0.785 * 3.5700 * 3.5700 * 600.0000
    HD = 6006. lb.
 Pressure Force on Flange Face:
    HT = H - HD
    HT = 9798 - 6005
    HT = 3793. lb.
 Operating Bolt Load:
    WM1 = H + HP +  HPP
    WM1 = ( 9798 + 7563 + 0 )
    WM1 = 17363. lb.
 Gasket Seating Bolt Load:
    WM2 = Y * BE * PI * G  + Ypart * BEpart * GLPG + HPGY
    WM2 = 1200.00*0.2200*3.141*4.560+0.00*0.0000*0.00
    WM2 = 3782. lb.
 Required Bolt Area:
    AM = Maximum of WM1/SBO, WM2/SBA
    AM = Maximum of 17362 / 18800 , 3781 / 18800
    AM = 0.923548 in²

 Bolting Information for UNC Thread Series:
 Total Area of Bolts, AB                                   2.416  in²
 Minimum radial distance between hub and bolts             1.125  in.
 Minimum radial distance between bolts and edge            0.813  in.
 Minimum circumferential spacing between bolts             1.750  in.
 Actual  circumferential spacing between bolts             2.533  in.
 Maximum circumferential spacing between bolts             4.188  in.
 Distance Across Corners for Nuts                          1.383  in.
 Circular Wrench End Diameter                      a       2.062  in.

 Min. Gasket Contact Width (Brownell Young):
   Nmin = AB * SBA/(Y * PI * (GOD+GID) )
        = 2.416 * 18800.00/( 1200.00 * 3.14 * ( 5.00 + 4.12) )
   Nmin = 1.321 in.


 Flange Design Bolt Load, Gasket Seating:
    W = SBA * ( AM + AB ) / 2.0
    W = 18800.00 * ( 0.9235 + 2.4160 ) / 2.0
    W = 31391.75 lb.
 Gasket Seating Force:
    HG = WM1 - H
    HG = 17362 - 9798
    HG = 7563.95 lb.
    HG = 7563.95 lb.
 MOMENT ARM CALCULATIONS:
 Distance to Gasket Load Reaction:
    DHG = (C - G ) / 2.0
    DHG = ( 6.6200 - 4.5600 ) / 2.0
    DHG = 1.0300 in.
 Distance to Face Pressure Reaction:
    DHT = ( DHD + DHG ) / 2.0
    DHT = ( 1.5250 + 1.0300 ) / 2.0
    DHT = 1.2775 in.
 Distance to End Pressure Reaction:
    DHD = ( C - BCOR )/ 2.0
    DHD = ( 6.6200 - 3.5700 ) / 2.0
    DHD = 1.5250 in.
```

SUMMARY OF MOMENTS FOR INTERNAL PRESSURE:

LOADING		Force	Distance	Bolt Corr	Moment
End Pressure,	MD	6006.	1.5250	1.0000	763. ft.lb.
Face Pressure,	MT	3793.	1.2775	1.0000	404. ft.lb.
Gasket Load,	MG	7564.	1.0300	1.0000	649. ft.lb.
Gasket Seating,	MA	31392.	1.0300	1.0000	2694. ft.lb.

```
TOTAL MOMENT FOR OPERATION,       RMO                        1816. ft.lb.
TOTAL MOMENT FOR GASKET SEATING,  RMA                        2694. ft.lb.

Effective Hub Length, H0 =                                   0.000  in.
Hub Ratio,            HRAT = Defined as 0.0                  0.000
Thickness Ratio,      GRAT = Defined as 0.0                  0.000
Factors from Figure 2-7.1                         K =        2.311
                      T =       1.398             U =        2.705
                      Y =       2.462             Z =        1.461
Tangential Flange Stress, Operating:
   STO = ( Y*RMO )/( TH*TH*BCOR )
   STO = ( 2.4619 * 21795 )/( 1.1200 * 1.1200 * 3.5700 )
   STO = 11982. psi
Tangential Flange Stress, Seating:
   STA = ( Y*RMA )/( TH*TH*BCOR )
   STA = ( 2.4619 * 32333)/( 1.1200 * 1.1200 * 3.5700 )
   STA = 17775. psi
Bolt Stress, Operating:
   BSO = ( WM1 / AB )
   BSO = ( 17362 / 2.4160 )
   BSO = 7187. psi
Bolt Stress, Seating:
   BSA = ( WM2 / AB )
   BSA = ( 3781 / 2.4160 )
   BSA = 1565. psi
```

Stress Computation Results:

	OPERATING Actual	OPERATING Allowed	GASKET SEATING Actual	GASKET SEATING Allowed	
Tangential Flange	11982.	20000.	17775.	20000.	psi
Bolting	7187.	18800.	1565.	18800.	psi

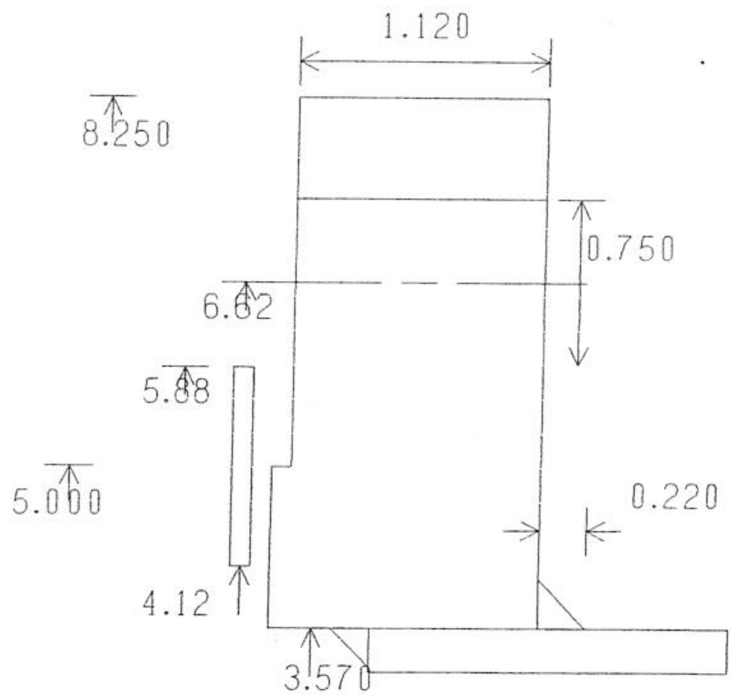
OK

```
Estimated M.A.W.P. ( Operating )                          1001.5  psig
Estimated M.A.W.P. ( Gasket Seating )                      871.6  psig
Estimated Finished Weight of Flange                         13.6  lb.
Estimated Unfinished Weight of Forging                      13.6  lb.
APP. S Flange Rigidity Index for Seating Case              0.537
APP. S Flange Rigidity Index for Operating Case            0.362
```

Minimum Design Metal Temperature Results:

(13)

Loose Ring :	3 in cl 300	Diameter Dimensic
Flange Material :	SA-182 F304	
Bolt Material :	SA-193 B8	
Temperature (F) :	100.000	
Pressure (psi) :	600.000	



Dimension Units : in.

CodeCalc 6.

Input Echo, Flange Item 1, Description: 12 in cl 300 blind

Description of Flange Geometry (Type)		Blind	
Description of Flange Analysis		Partial, Thickness	
Design Pressure	P	600.00	psig
Design Temperature		100.00	F
Corrosion Allowance	FCOR	0.0000	in.
Flange Inside Diameter	B	0.0000	in.
Flange Outside Diameter	A	20.5000	in.
Perform thickness calcs. based on rigidity		No	
Flange Material		SA-182 F304	
Flange Material UNS Number		S30400	
Flange Allowable Stress At Temperature	SFO	20000.00	psi
Flange Allowable Stress At Ambient	SFA	20000.00	psi
Bolt Material		SA-193 B8	
Bolt Material UNS Number		S30400	
Bolt Allowable Stress At Temperature	SBO	18800.00	psi
Bolt Allowable Stress At Ambient	SBA	18800.00	psi
Diameter of the Load Reaction, Long Span	DL	17.7500	in.
Diameter of the Load Reaction, Short Span	DS	17.7500	in.
Perimeter along the Center of the Bolts	L	55.7633	in.
Diameter of Bolt Circle	C	17.7500	in.
Nominal Bolt Diameter	DB	1.1250	in.
Type of Threads		UNC Thread Series	
Number of Bolts		16	
Flange Face Outside Diameter	FOD	15.0000	in.
Flange Face Inside Diameter	FID	0.0000	in.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	GOD	16.6300	in.
Gasket Inside Diameter	GID	12.8800	in.
Gasket Factor, m,	M	2.0000	
Gasket Design Seating Stress	Y	1200.00	psi
Column for Gasket Seating		2, Code Column II	
Gasket Thickness		0.1200	in.

FLANGE ANALYSIS, FLANGE NUMBER 1, Description: 12 in cl 300 bl
ASME Code, Section VIII, Division 1, App. 2, Ed-2001

Gasket Contact Width,	N = (GOD-GID) / 2	1.060	in.
Basic Gasket Width,	B0 = N / 2.0	0.530	in.
Effective Gasket Width,	BE = SQRT(B0) / 2.0	0.364	in.
Gasket Reaction Diameter,	G = GOD-2.0*BE	14.272	in.

```
Basic Flange and Bolt loads:
Hydrostatic End Load due to Pressure:
     H = 0.785 * G * G * PEQ
     H = 0.7854 * 14.2720 * 14.2720 * 600.0000
     H = 95986. lb.
Contact Load on Gasket Surfaces:
    HP = 2 * BE * PI * G * M * P
    HP = 2 * 0.3640 * 3.1416 * 14.2720 * 2.0000 * 600.00
    HP = 39170. lb.
Hydrostatic End Load at Flange ID:
    HD = 0.3 * G * G * P
    HD = 0.3 * 14.2720 * 14.2720 * 600.0000
```

```
     HD = 36664. lb.
  Pressure Force on Flange Face:
     HT = 0.0 For Blind Flanges
     HT = 0.0 For Blind Flanges
     HT = 0. lb.
  Operating Bolt Load:
    WM1 = H + HP +  HPP
    WM1 = ( 95986 + 39169 + 0 )
    WM1 = 135156. lb.
  Gasket Seating Bolt Load:
    WM2 = Y * BE * PI * G  + Ypart * BEpart * GLPG + HPGY
    WM2 = 1200.00*0.3640*3.141*14.272+0.00*0.0000*0.00
    WM2 = 19585. lb.
  Required Bolt Area:
     AM = Maximum of WM1/SBO, WM2/SBA
     AM = Maximum of 135156 / 18800 , 19584 / 18800
     AM = 7.18918 in²

  Bolting Information for UNC Thread Series:
  Total Area of Bolts, AB                               11.088  in²
  Minimum radial distance between hub and bolts          1.500  in.
  Minimum radial distance between bolts and edge         1.125  in.
  Minimum circumferential spacing between bolts          2.500  in.
  Actual  circumferential spacing between bolts          3.463  in.
  Maximum circumferential spacing between bolts          6.674  in.

  Min. Gasket Contact Width (Brownell Young):
   Nmin = AB * SBA/(Y * PI * (GOD+GID) )
        = 11.088 * 18800.00/( 1200.00 * 3.14 * ( 15.00 + 12.88) )
   Nmin = 1.983 in.


  Flange Design Bolt Load, Gasket Seating:
     W = SBA * ( AM + AB ) / 2.0
     W = 18800.00 * ( 7.1892 + 11.0880 ) / 2.0
     W = 171805.45 lb.
  Gasket Seating Force:
     HG = WM1
     HG = 135156
     HG = 135156.50 lb.
     HG = 135156.50 lb.
  MOMENT ARM CALCULATIONS:
  Distance to Gasket Load Reaction:
    DHG = (C - G ) / 2.0
    DHG = ( 17.7500 - 14.2720 ) / 2.0
    DHG = 1.7390 in.
  Distance to Face Pressure Reaction:
    DHT = 0.0 for blind flange
    DHT = 0.0 for blind flange
    DHT = 0.0000 in.
  Distance to End Pressure Reaction:
    DHD = G / 4.0
    DHD = 14.2720 / 4.0
    DHD = 3.5680 in.
```

SUMMARY OF MOMENTS FOR INTERNAL PRESSURE:

LOADING		Force	Distance	Bolt Corr	Moment
End Pressure,	MD	36664.	3.5680	1.0000	10901. ft.lb.
Face Pressure,	MT	0.	0.0000	1.0000	0. ft.lb.
Gasket Load,	MG	135156.	1.7390	1.0000	19586. ft.lb.
Gasket Seating,	MA	171805.	1.7390	1.0000	24898. ft.lb.

```
TOTAL MOMENT FOR OPERATION,        RMO              30488. ft.lb.
TOTAL MOMENT FOR GASKET SEATING,   RMA              24898. ft.lb.
```

```
Tangential Flange Stress, Flat Head, Operating:
   STO = 1.9*WM1*DHG*BCORR/(TH^2*G) + C*ZRAT*PEQ*G^2/(TH^2)
   STO = 1.9 * 135156 * 1.7390 * 1.0000/( 1.8433^2 * 14.2720 ) +
         0.30 * 1.0000 * 600.00 * 14.2720^2 )/( 1.8433^2 )
   STO = 20000. psi
Tangential Flange Stress, Flat Head,  Seating:
   STA = 1.9*W*DHG*BCORR/(TH^2*G)) + 0
   STA = 1.9 * 171805 * 1.7390 * 1.0000 /( 1.8433^2 * 14.2720 ) + 0
   STA = 11706. psi
Bolt Stress, Operating:
   BSO = ( WM1 / AB )
   BSO = ( 135156 / 11.0880 )
   BSO = 12189. psi
Bolt Stress, Seating:
   BSA = ( WM2 / AB )
   BSA = ( 19584 / 11.0880 )
   BSA = 1766. psi
```

Stress Computation Results:	OPERATING		GASKET SEATING		
	Actual	Allowed	Actual	Allowed	
Tangential Flange	20000.	20000.	11706.	20000.	psi
Bolting	12189.	18800.	1766.	18800.	psi

Minimum Required Flange Thickness + CA	1.843	in.
Estimated M.A.W.P. (Operating)	600.0	psig
Estimated M.A.W.P. (Gasket Seating)	1680.7	psig
Estimated Finished Weight of Flange	170.4	lb.
Estimated Unfinished Weight of Forging	170.4	lb.

OK

Minimum Design Metal Temperature Results:

Blind Flange : 12 in cl 300 bl

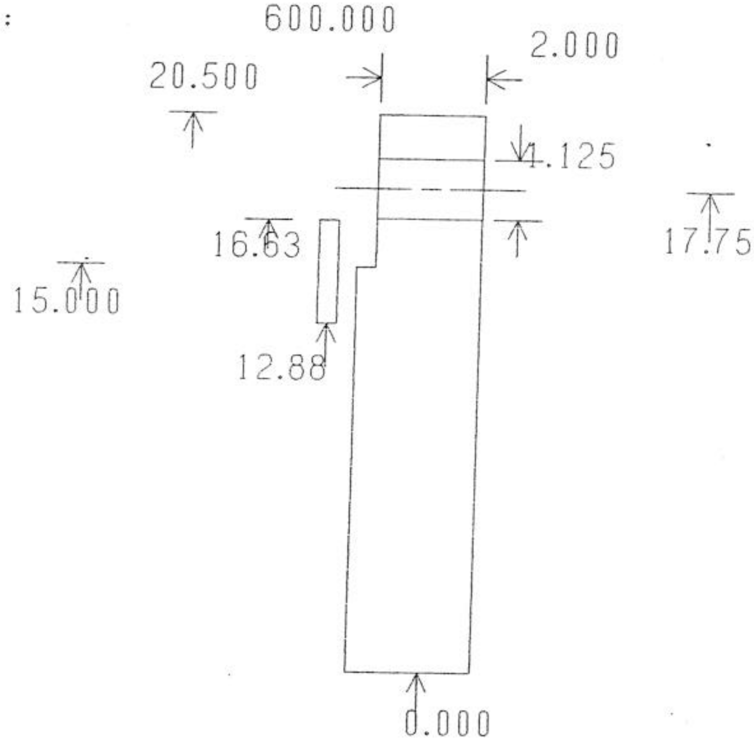
Flange Material : SA-182 F304

Bolt Material : SA-193 B8

Temperature (F) : 100.000

Pressure (psi) : 600.000

Diameter Dimensic

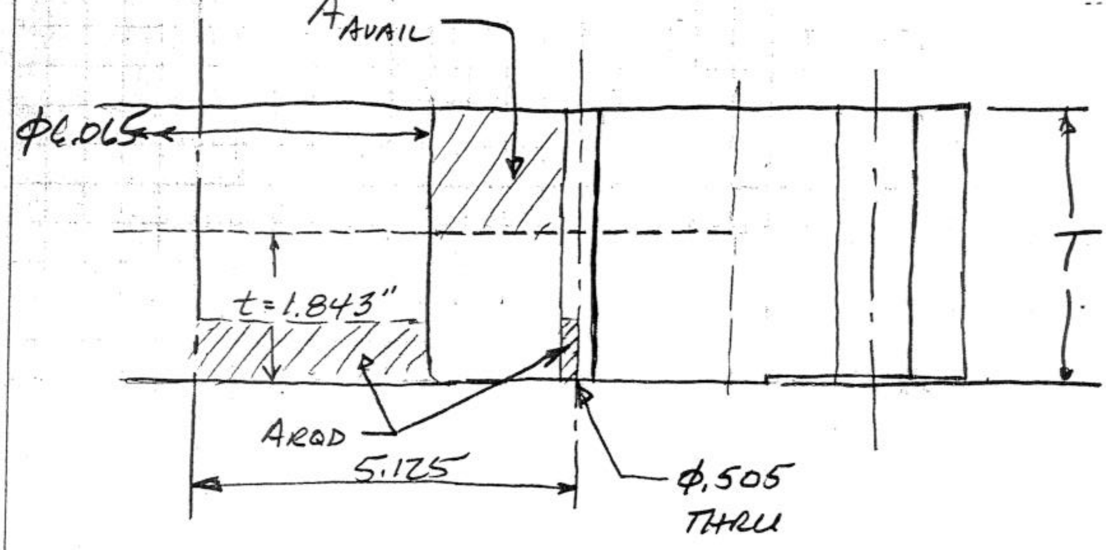


Dimension Units : in.

CodeCalc 6.

Look at the 12" blind for area-replacement:

The head diameter D, per UG-34, is equal to the bolt circle diameter less 2 hg. From Code Calc this is G = 14.272"



The large central opening has an ID of 6.065."

$$\frac{d}{D} = \frac{6.065}{14.272} = 0.425 < .5 \text{ so UG-39 applies}$$

The required thickness of a blind with no penetrations is 1.843" (from Code Calc)

Use .51" for the diameter of the small opening.

$$\bar{d} = \frac{d_1 + d_2}{2} = \frac{6.065 + .51}{2} = 3.288 = .23D < .25D$$

UG-39(b)(2)

p = spacing = 5.125 = 1.56 $\bar{d}$ → 50% of the reinforcement must be between the openings. (UG-39(b)(2))

$$A_r = \sum_{i=1}^{2}\left[.5 d_i t + t t_n \cancelto{0}{(1 - f_{r1})}\right]$$

$$= .5(6.065)(1.843) + .5(.510)(1.843)$$

$$= 5.590 + .470$$

$$A_r = 6.060 \text{ in}^2$$

50% MUST BE BETWEEN THE OPENINGS

$$A_{AVAIL} \geq .5 A_r$$

$$\left[\left(5.125 - \frac{.51}{2}\right) - \frac{6.065}{2}\right](T - 1.843) \geq .5(6.060)$$

$$T \geq \frac{3.03}{1.838} + 1.843$$

$$T \geq 1.649 + 1.843$$

$$T \geq 3.492 \longrightarrow 3\tfrac{1}{2}\text{" PLATE}$$

UG-39(e)(2) offers an alternative approach:

rqd t from EQN(2) of UG-34(c) (CodeCalc result)

UG-39(d)(2)

$$T = t \times \sqrt{2} \times h, \text{ where } h = \sqrt{\frac{.5}{e}}$$

$$\text{and } e = \frac{p - \bar{d}}{p}$$

for a spacing, p, of 5.125":

$$e = \frac{P - \bar{d}}{P} = \frac{5.125 - 3.288}{5.125} = .3584$$

$$h = \sqrt{\frac{.5}{e}} = \sqrt{\frac{.5}{.3584}} = 1.1811$$

$$T = th\sqrt{2}$$

$$= 1.843(1.1811)\sqrt{2}$$

$$= 3.078"$$

Find the min spacing that will allow the use of 3" plate:

$$T = 3.00 = 1.843\, h\sqrt{2}$$

$$h = 1.1510 = \sqrt{\frac{.5}{e}}$$

$$1.3248 = \frac{.5}{e}$$

$$e = \frac{.5}{1.3248} = 0.3774$$

$$\frac{P - \bar{d}}{P} = e = .3774$$

$$P - 3.288 = .3774\, P$$

$$P(1-.3774) = 3.288$$

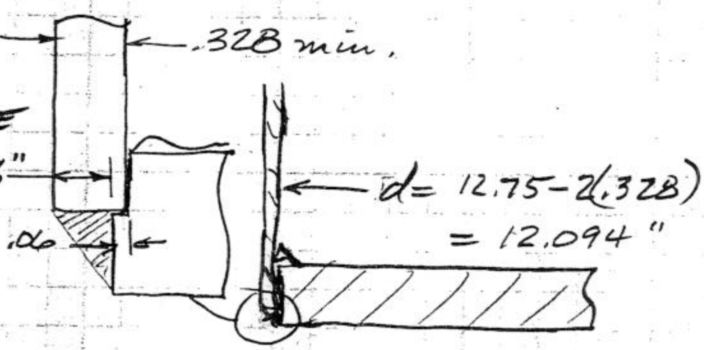
$$P = \frac{3.288}{.6226}$$

$$P = 5.281$$

Use 3" PLATE w/ 5.3" spacing.

SIZE BOTTOM PLATE

UG-34, Sketch e



$C = .33m$

$m = \frac{t_r}{t_s} = \frac{.222}{.268}$ max $= .828$

For the pipe:

$t_r = \frac{600(6.375)}{1.0(17000)+.4(600)}$

$= 0.222"$

Per UG-39(d)(1) for reinforcement

$2C = 2(.33)(.828) = 0.547 > .50 \rightarrow$ use .5 in calcs

UG-34, Formula 1, modified per UG-39(d)(1)

$$t = d\sqrt{\frac{0.5P}{SE}} = 12.094\left[\frac{(.5)(600)}{1.0(20000)}\right]^{\frac{1}{2}} = 1.481"$$

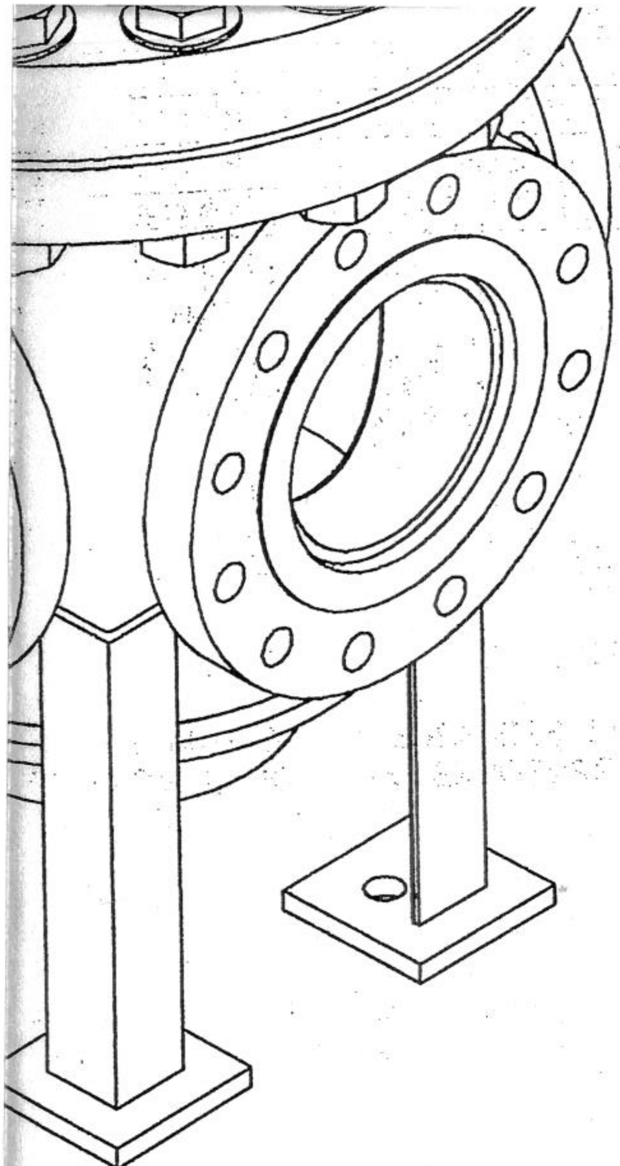
Check spacing: $d_1 = 3.5-2(.875)(.216) = 3.122$ (3" Sch 40 pipe)

$d_2 = .510"$ $\quad \bar{d} = \frac{3.122+.510}{2} = 1.816$

Spacing $= 5.25" = 2.75\bar{d}$ $\therefore$ $t = 1.481"$ → use $1\frac{1}{2}"$ plate.

4. APPENDIX 3 — DRAWINGS DOCUMENTATION

01013-01
01013-02
01013-03
01013-04



REV.	DESCRIPTION	BY	CHK' D

UNLESS NOTED OTHERWISE DIMENSIONS IN INCHES

TOLERANCES

FRACT. ± 1/16
.X± .03
.XX± .01
.XXX± .005
ANGLES± 1Deg

MTM

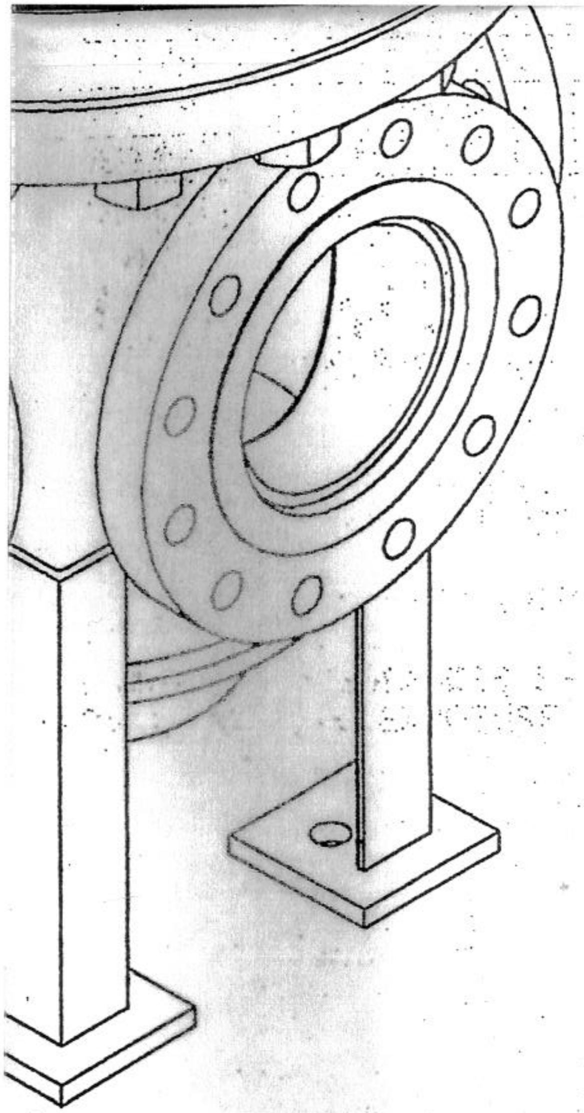
Meyer Tool & Mfg., Inc.

BY: CME 1/9/04

CHK' D: RDL 1/12/04

600 PSI BUBBLE CHAMBER OUTER VESSEL
GENERAL ARRANGEMENT

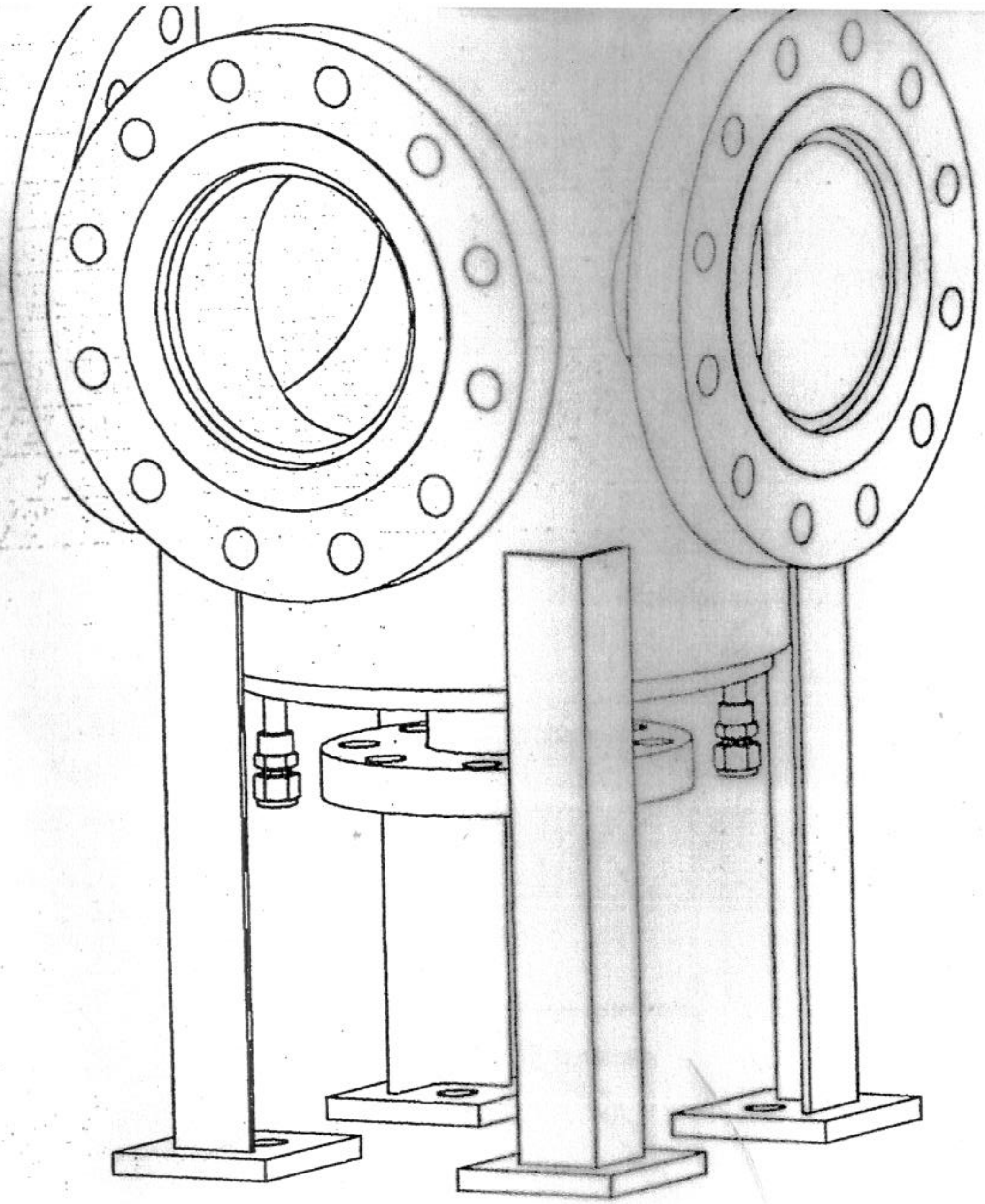
SCALE	CUSTOMER	JOB NO.	DWG.	SIZE: D
1: 4	U OF CHICAGO	01013	01	REV. 0



APPROXIMATE WEIGHT OF THE INSTALLATION ASSEMBLY : 1499 Lbs

REV.	DESCRIPTION	BY	CHK'D

UNLESS NOTED OTHERWISE DIMENSIONS IN INCHES	MTM Meyer Tool & Mfg., Inc.
TOLERANCES FRACT. ± 1/16 .X± .03 .XX± .01 .XXX± .005 ANGLES± 1Deg	BY: CME 1/9/04 — CHK'D: RDL 1/12/04 600 PSI BUBBLE CHAMBER OUTER VESSEL GENERAL ARRANGEMENT
SCALE 1:4	CUSTOMER: U OF CHICAGO — JOB NO. 01013 — DWG. 01 — SIZE: D — REV. 0



REV.	DESCRIPTION	BY	CHK' D

UNLESS NOTED OTHERWISE DIMENSIONS IN INCHES

TOLERANCES

FRACT. ± 1/16
.X± .03
.XX± .01
.XXX± .005
ANGLES± 1Deg

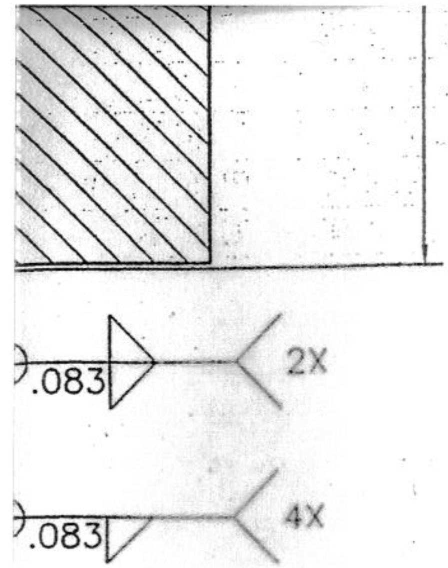
MTM

Meyer Tool & Mfg., Inc.

BY: CME 1/9/04 | CHK' D: RDE 1/12/04

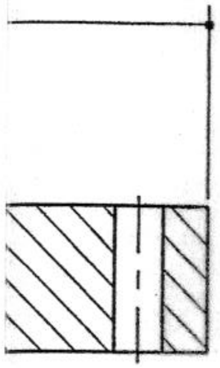
600 PSI BUBBLE CHAMBER OUTER VESSEL
VESSEL WELDMENT

SCALE	CUSTOMER	JOB NO.	DWG.	SIZE: D
1: 4	U OF CHICAGO	01013	02	REV. 0



REV.	DESCRIPTION		BY	CHK' D
UNLESS NOTED OTHERWISE DIMENSIONS IN INCHES	MTM Meyer Tool & Mfg., Inc.			
TOLERANCES				
FRACT. ± 1/16 .X± .03 .XX± .01 .XXX± .005 ANGLES± 1Deg	BY: CME 1/9/04	CHK' D: RDL 1/12/04		
	600 PSI BUBBLE CHAMBER OUTER VESSEL TOP COVER WELDMENT			
SCALE HALF	CUSTOMER U OF CHICAGO	JOB NO. 01013	DWG. 03	SIZE: D REV. 0

DESIGN IS THE PROPERTY OF
G. CO. UNAUTHORIZED USE OR
TRICTLY PROHIBITED.



REV.	DESCRIPTION	BY	CHK'D

UNLESS NOTED OTHERWISE DIMENSIONS IN INCHES	MTM *Meyer Tool & Mfg., Inc.*			
TOLERANCES				
FRACT. ± 1/16 .X± .03 .XX± .01 .XXX± .005 ANGLES± 1Deg	BY: CME 1/9/04	CHK'D:		
	600 PSI BUBBLE CHAMBER OUTER VESSEL TOP AND BOTTOM PLATES			
SCALE HALF	CUSTOMER U OF CHICAGO	JOB NO. 01013	DWG. 04	SIZE: D REV. 0

FORM U-1A MANUFACTURER'S DATA REPORT FOR PRESSURE VESSELS
(Alternate Form for Single Chamber, Completely Shop-Fabricated Vessels Only)
As Required by the Provisions of the ASME Code Rules, Section VIII, Division

1. Manufactured and certified by CVIP, Inc, 801 Broad Street, Emmaus, PA 18049
(Name and address of Manufacturer)

2. Manufactured for University of Chicago, Chicago, IL
(Name and address of Purchaser)

3. Location of installation Unknown
(Name and address)

4. Type Vertical (Horiz, Vert, Sphere) Vessel (Tank, Separator Vessel) 2595 (Mfg's Serial No.) None (CRN) 01013 (Drawing No.) 210 (Nat'l. Bd. No.) 2004 (Year Built)

5. The chemical and physical properties of all parts meet the requirements of material specifications of the ASME BOILER AND PRESSURE VESSEL CODE. The design, construction, and workmanship conform to ASME Rules, Section VIII, Division 1 2001 (Year) 2003 (Addenda) (Date) (Code Case) (Special Service per UG-120 (d)

6. Shell: SA312-304 (Matl. (Spec No., Grade)) 0.375" (Nom. Thk. (in.)) 0" (Corr. Allow. (in.)) 1'- 0" (Dia. I D. (ft. & in.)) 2'- 0" (Length (overall) (ft. & in.))

7. Seams: Seamless pipe (Long. (Welded, Dbl, Sngl Lap, Butt)) N/A (R.T. (Spot or Full)) 70% (Eff (%)) N/A (H.T. Temp (F)) N/A (Time (hr)) N/A (Girth (Welded, Dbl Sngl, Lap, Butt)) None (RT (Spot or Full)) 1 (No. of Courses)

8. Heads: (a) Matl SA240-304 (Spec. No. Grade) (b) Matl. SA240-304 (Spec. No. Grade)

	Location (Top, Bottom. Ends	Minimum Thickness	Corr. Allow.	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure Convex or Concave
(a)	Top	3.0"	0"	N/A	N/A	N/A	N/A	N/A	20.5"	Flat
(b)	Bottom	1.5"	0"	N/A	N/A	N/A	N/A	N/A	11.94"	Flat

If removable, bolts used (Describe other fastenings) 1 1/8" -7 UNC x 6.5" long bolts(SA193-B8) Qty 16 with Nuts(SA194-8) Qty 16
(Matl., Spec. No., Grade Size)

9. MAWP * Remark 1 (Internal) N/A (External) psi at max. temp. * Remark 1 F. Min. design metal temp -30 at 600 / 480 psi

Hydro.test pressure 780 psi.

10. Nozzles, inspection and safety valve openings:

Purpose	No.	Diameter Size	Flange Type	Material Nozzle	Material Flange	Nozzle Thickness Nom.	Nozzle Thickness Corr.	Reinforcement Material	How Attached Nozzle	How Attached Flange	Location (Insp. Open.)
Sight glass	4	6"	RFSO	SA312-304	SA182-304	0.28"	0	N/A	UW16.1(d)	SO	Side of Shell
Bottom flange	1	3"	RFSO	SA312-304	SA182-304	0.216"	0	N/A	UW16.1(k)	SO	Bottom Head assy
Top flange	1	6"	RFSO	SA312-304	SA182-304	0.28"	0	N/A	UW16.1(k)	SO	Top of Head
Bottom connections	2	1/2"	N/A	SA213-304	N/A	0.083"	0	N/A	UW16.1(i)	N/A	Bottom Head assy
Top connections	2	1/2"	N/A	SA213-304	N/A	0.083"	0	N/A	UW16.1(i)	N/A	Top Head assy

11. Supports: Skirt N/A (Yes or no) Lugs N/A (Number) Legs 4 (Number) Other N/A (Describe) Attached Legs welded to shell. (Where and how)

12. Remarks: Manufacturer's Partial Data Reports properly identified and signed by Commissioned Inspectors have been furnished for the following items of this report:
None
(Name of part, item number, Manufacturers name and identifying stamp)
* Remark 1- MAWP for the vessel is 600 psi at 100F or 480 psi at 230F

CERTIFICATE OF SHOP COMPLIANCE

We certify that the statements made in this report are correct and that all details of design, material, construction, and workmanship of this vessel conform to the ASME Code for Pressure Vessels, Section VIII, Division 1. "U" Certificate of Authorization No. 28713 expires 9-Nov 2004

Date: 4/16/04 Co. name CVIP, Inc. Signed [signature] (Representative)

CERTIFICATE OF SHOP INSPECTION

Vessel constructed by CVIP, Inc at Emmaus, PA

I, the undersigned, holding a valid commission issued by The National Board of Boiler and Pressure Vessel Inspectors and the State or Province of PA and employed by ABS Group of Houston, TX have inspected the component described in this Manufacterers Data Report on 16 APRIL 2004 and state that, to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with ASME Code, Section VIII, Division 1. By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturers Data Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for the personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date: 16 APR 04 Signed Salem M Salem (Authorized Inspector) Commissions NB12215A, PA2876
(Nat'l Board (incl endorsements) State, Province) & No

APPENDIX 5

DETERMINE THE RELIEF VALVE REQUIREMENTS FOR VESSEL EXPOSURE TO OPEN FIRES.

FIND THE HEAT INPUT TO THE WETTED SURFACE OF A VESSEL

$$q = 21{,}000\, F A^{-0.18} \quad (8)$$

$$Q = 21{,}000\, F A^{0.82} \quad (9)$$

[FEF. 1]

Where:

- q = average unit heat absorption, in British thermal units per hour per square foot of wetted surface.
- Q = total heat absorption (input) to the wetted surface, in British thermal units per hour.
- A = total wetted surface, in square feet.[a] (The expression $A^{-0.18}$, or $\frac{1}{A^{0.18}}$, is the area-exposure factor or ratio. This ratio recognizes the fact that large vessels are less likely to be completely exposed to the flame of an open fire than are small vessels.)
- F = environment factor, values of which are shown in Table 3 for various types of installation.

[a] It is recommended that the total wetted surface (A in the foregoing formulas) is at least that wetted surface included within a height of 25 feet above grade or—in the case of spheres and spheroids—at least the elevation of the maximum horizontal diameter or a height of 25 feet, whichever is greater. The term "grade" usually refers to ground grade, but may be at any level at which a sizable fire could be sustained.

TABLE 3—Environment Factor

Type of Installation	Factor F[a]
1. Bare vessel	1.0
2. Insulated vessels[b] (These arbitrary insulation conductance values are shown as examples and are in British thermal units per hour per square foot per degree Fahrenheit):	
a. 4.0	0.3
b. 2.0	0.15
c. 1.0	0.075
3. Water-application facilities, on bare vessel[c]	1.0
4. Depressurizing and emptying facilities[d]	1.00
5. Underground storage	0.0
6. Earth-covered storage above grade	0.03

[a] These are suggested values for the conditions assumed in Paragraph 5.2. When these conditions do not exist, engineering judgment should be exercised either in selecting a higher factor or in providing means of protecting vessels from fire exposure as suggested in Paragraph 6.1.

[b] Insulation shall resist dislodgement by fire hose streams. For the examples a temperature difference of 1,600 degrees Fahrenheit was used. In practice it is recommended that insulation be selected to provide a temperature difference of at least 1,000 degrees Fahrenheit and that the thermal conductivity be based on a temperature that is at least the mean temperature.

[c] See Paragraph 6.3.3 for recommendations regarding water application.

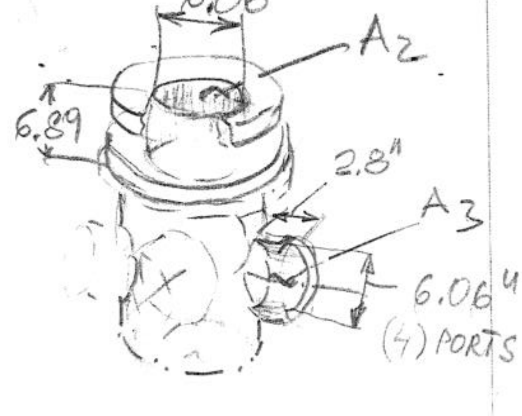
[d] Depressurizing will provide a lower factor if done promptly but no credit is to be taken when safety valves are being size for fire exposure.

$$Q = 21{,}000(1.0)(A)^{0.82}$$

$$A_1 = \pi(11.938)\times 17 - 4\left(\frac{\pi(6.06)^2}{4}\right)$$

$$A_1 = 637.57 - 115$$

$$A_1 = 622.57\ [in^2]$$

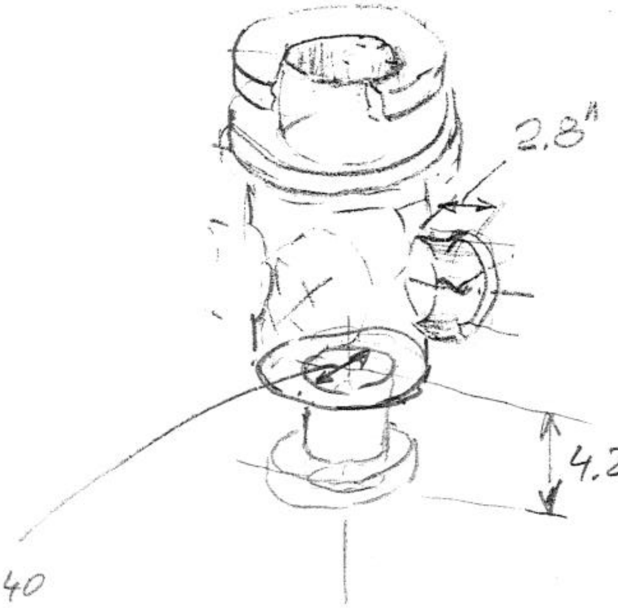


$$A_2 = \pi(6.06)\times 6.89 + \frac{\pi(6.06)^2}{4}$$

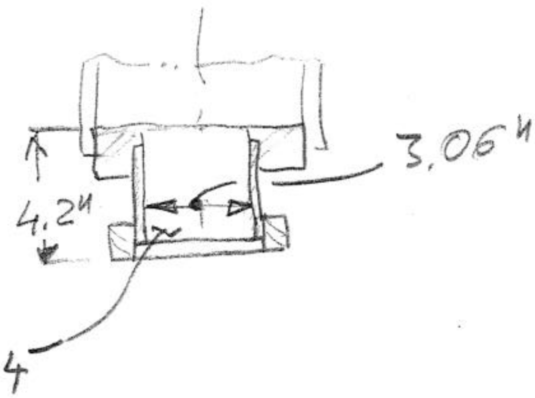
$$A_2 = 131.17 + 28.84$$

$$A_2 = 160\ [in^2]$$

$$\pi(6.06)\times 2.8 = 53.3\ [in^2]$$



3" SCH. 40
PIPE
3.06" INSIDE
DIA.



$$A_4 = \pi(3.06) \times 4.2 + \frac{\pi(3.06)^2}{4}$$

$$A_4 = 40.37 + 7.35$$

$$A_4 = \underline{47.72} \; [in^2]$$

$$A = A_1 + A_2 + 4(A_3) + A_4$$

$$A = 622.57 + 160 + 4(53.3) + 47.72$$

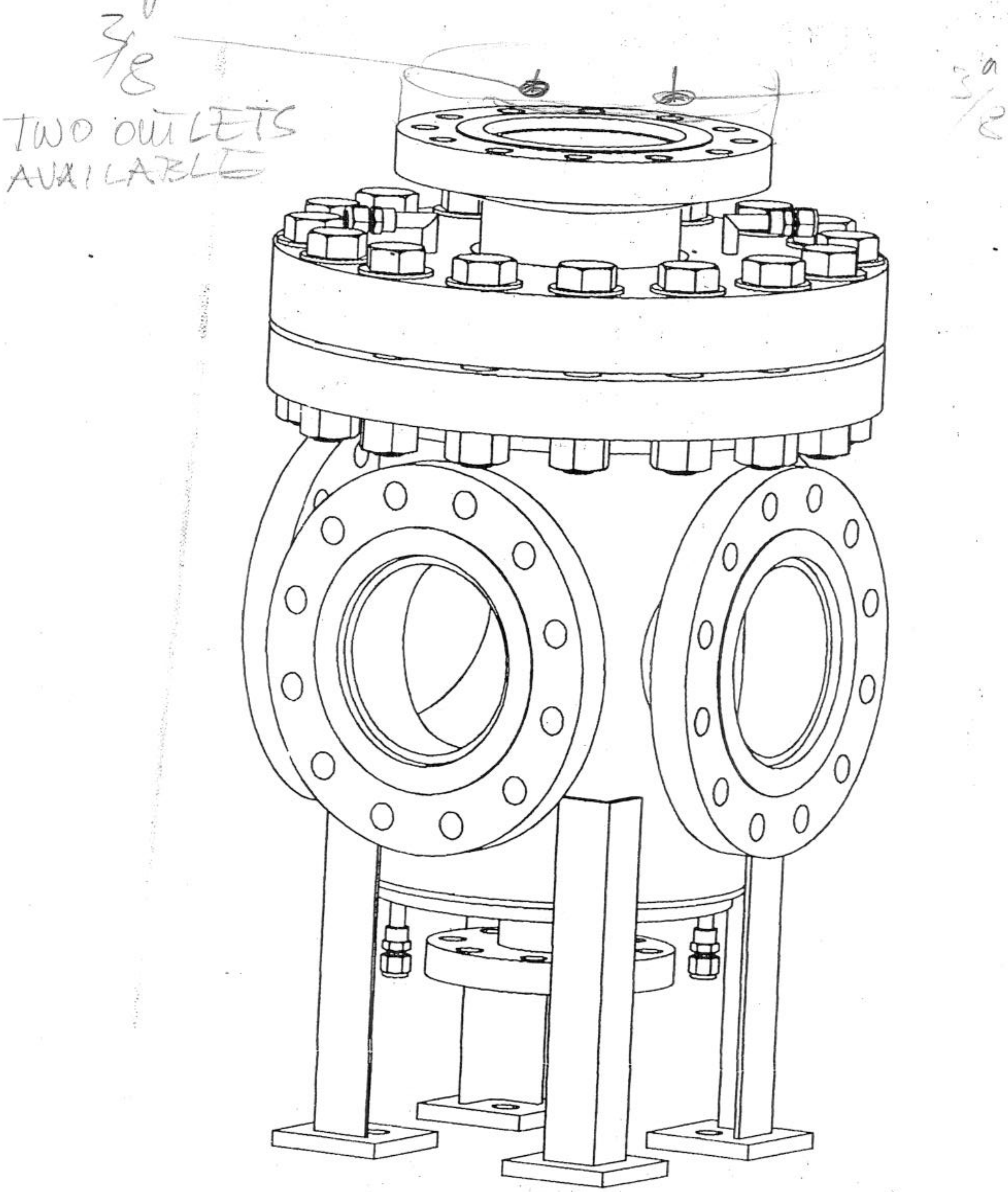
$$A = 1043.49 \; [in^2]$$

$$A = \frac{1043.49}{12 \times 12} = 7.24$$

$$A = \underline{7.24} \; [Ft^2]$$

$$Q = 21{,}000.00(1.0)(7.24)^{0.82}$$

$$Q = 106{,}542.74 \; [Btu/hr]$$


3/8"
TWO OUTLETS AVAILABLE
3/8"

DETERMINING A VAPOR AMOUNT GENERATED BY THE "Q" HEAT VALUE.

GIVEN DATA:

SET PRESSURE $p = 350$ [psig]

$p = 350 + 14.7$

$p = \underline{364.7}$ [psia]

ENTHALPIES:

EVAPORATION $h_1 = 790.95 \ \frac{Btu}{lb}$

VAPOR $h_2 = 1205,07$

AFTER INITIAL TEMPERATURE BUILD UP, AND REACHING THE LEVEL OF EVAPORATION, THE ADDITIONAL AMOUNT OF HEAT, CAUSES TRANSITION FROM WATER TO VAPOR @ Δh

THE AMOUNT OF GENERATED VAPOR:

$$G = \frac{Q}{\Delta h}$$

$$\Delta h = h_2 - h_1$$

$$\Delta h = 1205.07 - 790.95$$

$$\Delta h = 414.12 \ \left[\frac{Btu}{lb}\right]$$

$$G = \frac{Q}{\Delta h} = \frac{106,542.74}{414.12} \ \frac{\frac{Btu}{hr}}{\frac{Btu}{lb}} = \frac{Btu}{hr}\,\frac{lb}{Btu}$$

$$G = 257.275 \ \left[\frac{lb}{hr}\right] = \underline{4.28} \ \left[\frac{lbs}{min}\right]$$

$$G = 4.28 \frac{lbs}{min}$$

STEAM PROPERTY – SPECIFIC VOLUME

$$v = 1.278 \left[\frac{Ft^3}{lb}\right]$$ SEE TABLE ON PAGE 26

(26.8) @ * 14.7 psia

$$G = 4.28 (26.8)$$

$$G = \underline{115.} \left[\frac{Ft^3}{min}\right]$$

SAFETY RELIEF DEVICES ARE MOUNTED AT THE BOTTOM OF THE TANK. THESE UNITS SHOULD BE ABLE TO PASS THE REQUIRED VOLUME OF LIQUID WHEN THE LEVEL OF CRACKING PRESSURE IS MET,

IN ADDITION TO THAT, ON TOP OF THE TANK, THE SAFETY RELIEF (CHECK) VALVE IS MOUNTED. THIS VALVE CAPACITY HAS TO BE GREATER THAN THE VAPOR'S GENERATED AMOUNT.

(WATER)
ENTHALPIES!
Btu/lb

PRESSURE abs. press. lb/in²	TEMP. °F	ENTHALPY Btu/lb. LIQUID	EVAP.	VAPOR
350	431.82	409.9	795.0	1204.9
364.7			790.95	1205.07
400	444.70	424.2	781.2	1205.5
			$\frac{795.-781.2}{50} =$	$\frac{1205.5-1204.9}{50} =$
			$= 0.276$	$= 0.012$
			$0.276 \times 14.7 =$	$0.012 \times 14.7 =$
			$= 4.05$	$= 0.176$

	VAPOR
SPEC. VOLUME @ 350°F	1.3267
@ 400	1.1620
@ 364.7	1.278

PAGE 26

HEAT TRANSFER

MARK'S
STANDARD HANDBOOK FOR
MECHANICAL ENGINEERS
EIGHT Edition

Table 28. Properties of Saturated Steam

Abs press, lb/in²	Temp., °F	Specific volume Ft³/lb Liquid	Specific volume Vapor	Enthalpy BTU/lb Liquid	Enthalpy Evap.	Enthalpy Vapor	Entropy Liquid	Entropy Evap.	Entropy Vapor	Internal energy, Evap.
0.08866	32.02	0.016022	3302	0.01	1075.4	1075.4	0.00000	2.1869	2.1869	1021.2
1.0	101.70	0.016136	333.6	69.74	1036.0	1105.8	0.13266	1.8453	1.9779	974.3
1.5	115.65	0.016187	227.7	83.65	1028.0	1111.7	0.15714	1.7867	1.9438	964.8
2	126.04	0.016230	173.75	94.02	1022.1	1116.1	0.17499	1.7448	1.9198	957.8
3	141.43	0.016300	118.72	109.39	1013.1	1122.5	0.20089	1.6852	1.8861	947.2
4	152.93	0.016358	90.64	120.89	1006.4	1127.3	0.21983	1.6426	1.8624	939.3
5	162.21	0.016407	73.53	130.17	1000.9	1131.0	0.23486	1.6093	1.8441	932.9
10	193.19	0.016590	38.42	161.23	982.1	1143.3	0.28358	1.5041	1.7877	911.0
14.696	211.99	0.016715	26.80	180.15	970.4	1150.5	0.31212	1.4446	1.7567	897.5
15	213.03	0.016723	26.29	181.19	969.7	1150.9	0.31367	1.4414	1.7551	896.8
20	227.96	0.016830	20.09	196.26	960.1	1156.4	0.33580	1.3962	1.7320	885.8
25	240.08	0.016922	16.306	208.52	952.2	1160.7	0.35345	1.3607	1.7142	876.9
30	250.34	0.017004	13.748	218.93	945.4	1164.3	0.36821	1.3314	1.6996	869.2
35	259.30	0.017078	11.900	228.04	939.3	1167.4	0.38093	1.3064	1.6873	862.4
40	267.26	0.017146	10.501	236.16	933.8	1170.0	0.39214	1.2845	1.6767	856.2
45	274.46	0.017209	9.403	243.51	928.8	1172.3	0.40218	1.2651	1.6673	850.7
50	281.03	0.017269	8.518	250.24	924.2	1174.4	0.41129	1.2476	1.6589	845.5
55	287.10	0.017325	7.789	256.46	919.9	1176.3	0.41963	1.2317	1.6513	840.8
60	292.73	0.017378	7.177	262.25	915.8	1178.0	0.42733	1.2170	1.6444	836.3
65	298.00	0.017429	6.657	267.67	911.9	1179.6	0.43450	1.2035	1.6380	832.1
70	302.96	0.017478	6.209	272.79	908.3	1181.0	0.44120	1.1909	1.6321	828.1
75	307.63	0.017524	5.818	277.61	904.8	1182.4	0.44749	1.1790	1.6265	824.3
80	312.07	0.017570	5.474	282.21	901.4	1183.6	0.45344	1.1679	1.6214	820.6
85	316.29	0.017613	5.170	286.58	898.2	1184.8	0.45907	1.1574	1.6165	817.1
90	320.31	0.017655	4.898	290.76	895.1	1185.9	0.46442	1.1475	1.6119	813.8
95	324.16	0.017696	4.654	294.76	892.1	1186.9	0.46952	1.1380	1.6076	810.6
100	327.86	0.017736	4.434	298.61	889.2	1187.8	0.47439	1.1290	1.6034	807.5
150	358.48	0.018089	3.016	330.75	864.2	1194.9	0.51422	1.0562	1.5704	781.0
200	381.86	0.018387	2.289	355.6	843.7	1199.3	0.5440	1.0025	1.5464	759.6
250	401.04	0.018653	1.8448	376.2	825.8	1202.1	0.5680	0.9594	1.5274	741.4
300	417.43	0.018896	1.5442	394.1	809.8	1203.9	0.5883	0.9232	1.5115	725.1
350	431.82	0.019124	1.3267	409.9	795.0	1204.9	0.6060	0.8917	1.4978	710.3
400	444.70	0.019340	1.1620	424.2	781.2	1205.5	0.6218	0.8638	1.4856	696.7
450	456.39	0.019547	1.0326	437.4	768.2	1205.6	0.6360	0.8385	1.4746	683.9
500	467.13	0.019748	0.9283	449.5	755.8	1205.3	0.6490	0.8154	1.4645	671.7
550	477.07	0.019943	0.8423	460.9	743.9	1204.8	0.6611	0.7941	1.4551	660.2
600	486.33	0.02013	0.7702	471.7	732.4	1204.1	0.6723	0.7742	1.4464	649.1
700	503.23	0.02051	0.6558	491.5	710.5	1202.0	0.6927	0.7378	1.4305	628.2
800	518.36	0.02087	0.5691	509.7	689.6	1199.3	0.7110	0.7050	1.4160	608.4
900	532.12	0.02123	0.5009	526.6	669.5	1196.0	0.7277	0.6750	1.4027	589.6
1000	544.75	0.02159	0.4459	542.4	650.0	1192.4	0.7432	0.6471	1.3903	571.5
1500	596.39	0.02346	0.2769	611.5	557.2	1168.7	0.8082	0.5276	1.3359	486.9
2000	636.00	0.02565	0.18813	671.9	464.4	1136.3	0.8623	0.4238	1.2861	404.2
2500	668.31	0.02860	0.13059	730.9	360.5	1091.4	0.9131	0.3196	1.2327	313.4
3000	695.52	0.03431	0.08404	802.5	213.0	1015.5	0.9732	0.1843	1.1575	185.4
3203.6	705.44	0.05053	0.05053	902.5	0	902.5	1.0580	0	1.0580	0

364.7° 1.278276

SOURCE: Abstracted from Keenan, Keyes, Hill, and Moore, "Steam Tables," 1969.

VALVE SELECTION

THE ANDERSON GREENWOOD DIRECT SPRING OPERATED PRESSURE RELIEF VALVE WILL BE USED. a)

REQUIRED CAPACITY "V" = G [PAGE 24]

G = 115 SCFM

DETERMINE ORIFICE AREA.

$$A = \frac{V\sqrt{MTZ}}{6.32\,C K P_1}$$

a) SECOND CHOICE —
"CIRCLE SEAL VALVE"
SEE PAGES: FOR TECHNICAL INFORMATION

28

Preliminary Selection Guide

Valve Type	Applications: Gas/ Vapor	Liquid	Gas/Liquid Thermal Relief	Steam	Seat Type	Body Material: Brass	CS	SS	Set Pressure psig	[barg]	Relieving Temperature °F	[°C]	Balanced for Back Pressure
81	X		X		Plastic	X	X	X	50 to 10,000	[3.45 to 689.5]	-423°F to 500°F	[-253°C to 260°C]	N
81P		X	X		Plastic	X	X	X	50 to 6,000	[3.45 to 413.7]	-40°F to 400°F	[-40°C to 205°C]	Y
83	X		X		O-ring	X	X	X	20 to 2,000	[1.40 to 137.9]	-40°F to 550°F	[-40°C to 288°C]	N
86				X	Plastic	X	X	X	50 to 720	[3.45 to 49.6]	-423°F to 515°F	[-253°C to 268°C]	N
61	X		X		Plastic	X			30 to 500	[2.07 to 34.5]	-320°F to 400°F	[-196°C to 205°C]	N
63B	X		X		O-ring	X			37 to 531	[2.55 to 36.6]	-40°F to 400°F	[-40°C to 205°C]	N

Note

1. Minimum and maximum set pressures may not be available in all orifice sizes (see pages 19 - 22).

Sizing – How to Size a Valve

Pressure relief valves are selected on the basis of their ability to meet an expected relieving condition and flowing a sufficient amount of fluid to prevent excessive pressure increase. This means that the size of the valve orifices must be calculated taking the required flow, lading fluid properties, and other factors into consideration.

To select the minimum required orifice area that will flow the required capacity of the system you wish to protect, please refer to the following information, which appears in this section:

1. Sizing formulas
2. Physical properties of the fluid to be relieved
3. Capacities of different orifice areas at different pressures
4. Conversion tables to aid calculations

Once you have determined the required orifice area for your service conditions, refer to Ordering, pages 18 through 44, to select a specific valve model number.

Orifice Areas and Nozzle Coefficient

The orifice areas and nozzle coefficients for all Series 80 valves are tabulated in the table below.

These values are derived from the values certified by the National Board of Boiler and Pressure Vessel Inspectors, in accordance with Section VIII, Division 1 of the ASME Pressure Vessel Code.

Verification of Sizing

Orifice area calculations are made and/or verified whenever sufficient data is provided. If no data is furnished, the size selection responsibility will remain totally with the purchaser.

Nozzle Coefficient and Available Orifice Sizes, in² [cm²]

Valve Type	K	0.049 [0.316] (-4)	0.077 [0.497] (-5)	0.110 [0.710] (-6)	0.150 [0.968] (-7)	0.196 [1.265] (-8 or E)	0.307 [1.981] (F)	0.503 [3.245] (G)	0.785 [5.065] (H)	1.287 [8.303] (J)
81	0.816	X		X		X	X	X	X	X
81P	0.720	X				X		X		X
83	0.816	X		X		X	X	X	X	X
86	0.816	X				X		X		X
61	0.877			X						
63B	0.847		X		X					

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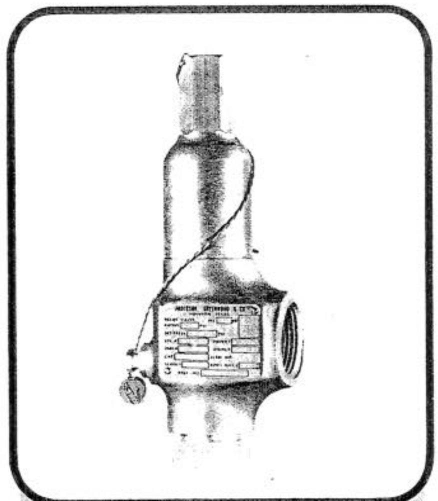
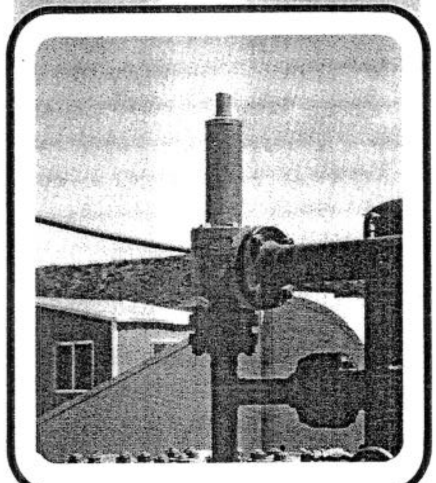
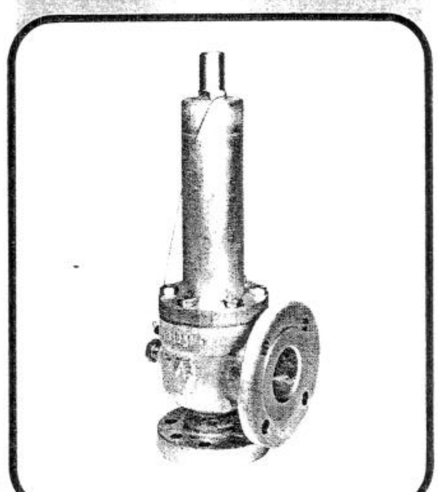
AGCO
SERIES 80
SAFETY-RELIEF VALVES







- **PREMIUM TIGHTNESS**
- **SOFT SEATS**
- **20 PSIG TO 10,000 PSIG**
- **−423°F TO +400°F**
- **EXTERNAL BLOWDOWN SETTING**
- **FULL LIFT AT SET PRESSURE**

ANDERSON, GREENWOOD & CO.

5425 S. RICE AVE. HOUSTON, TX 77081 P.O. BOX 1097 BELLAIRE, TX 77401
713/668-0631 • TWX: 910-881-2652 • TELEX: 0775219

CATALOG 1800
REVISED AUGUST 1981

SIZING

FORMULAS

Safety relief valves are usually sized either by calculating a required orifice area or by selecting an orifice area from a capacity chart prepared for the particular service. This brochure is an effort to present both methods in as simple and usable a form as possible. Converted ASME formulas are used to calculate the orifice area required to pass given capacities of vapors, or gases:

VAPORS OR GASES (capacity in scfm)

$$A = \frac{V\sqrt{MTZ}}{6.32\ CKP_1}$$

VAPOR OR GASES (capacity in #/hr)

$$A = \frac{W\sqrt{TZ}}{CKP_1\sqrt{M}}$$

where:

A = Valve orifice area (in.^{2})
V = Flow capacity (SCFM)
W = Flow capacity (lbs./hr.)
M = Molecular weight of flowing media
T = Inlet temperature, absolute (°F + 460)
Z = Compressibility factor (Consideration not mandatory by ASME)
C = Gas constant based on ratio of specific heats at std. conditions
K = Valve coefficient of discharge (0.816)
P_1 = Pressure at valve inlet during flow, psia (set pressure + overpressure + 14.7).
See note below.

To convert flow capacity from SCFM to lbs./hr. use:

$$W = \frac{MV}{6.32}$$

NOTE: P_1 is the pressure at the valve inlet during relief. It may be different than process pressure due to pressure losses in the inlet piping. These losses should be determined for accurate sizing and to ensure proper valve action.

A pressure drop in the inlet piping which exceeds the reseat pressure of the safety valve will cause the valve to rapid cycle. Such cycling can adversely affect the endurance life of the valve.

USE OF TABLES & CHARTS

On the following pages are published capacity charts for some of the common gases, such as air, oxygen, nitrogen, helium, hydrogen, and typical natural gas. These charts can be used for direct selection of the Safety Relief Valve orifice required without calculations. These charts are based on gas at temperature of 60°F.

MOLECULAR WEIGHTS AND "C" FACTORS

Listed below are the molecular weights, specific heat ratios, and "C" factors for many common gases. This "C" factor is used in both formulae for sizing valves for gas or vapor service.

LIQUID CAPACITIES

Formula for liquid capacities can be found in SECTION 3-81P (Page 24).

Gas	Mol. WT.	Cp/Cv	C	C/356
Acetylene	26	1.28	345	.969
Air	29	1.40	356	1.000
Ammonia	17	1.33	351	.986
Argon	40	1.66	377	1.059
Benzene	78	1.10	327	.919
Carbon Disulphide	76	1.21	338	.949
Carbon Dioxide	44	1.28	345	.969
Carbon Monoxide	28	1.40	356	1.000
Chlorine	71	1.36	352	.989
Cyclohexane	84	1.08	324	.910
Ethane	30	1.22	339	.952
Ethylene	28	1.20	337	.947
Helium	4	1.66	377	1.059
Hexane	86	1.08	324	.910
Hydrochloric Acid	36.5	1.40	356	1.000
Hydrogen	2	1.40	356	1.000
Hydrogen Sulphide	34	1.32	348	.978
Iso-Butane	58	1.11	328	.921
Methane	16	1.30	346	.972
Methyl Alcohol	32	1.20	337	.947
Methyl Chloride	50.5	1.20	337	.947
N-Butane	58	1.11	328	.921
Natural Gas	19	1.27	345	.969
Nitrogen	28	1.40	356	1.000
Oxygen	32	1.40	356	1.000
Petane	72	1.09	325	.913
Propane	44	1.14	331	.930
Sulphur Dioxide	64	1.26	342	.961
* Water Vapor/Steam	18	1.30	347	.975

K	C	K	C
1.00	315	1.52	366
1.02	318	1.54	368
1.04	320	1.56	369
1.06	322	1.58	371
1.08	324	1.60	372
1.10	327	1.62	374
1.12	329	1.64	376
1.14	331	1.66	377
1.16	333	1.68	379
1.18	335	1.70	380
1.20	337	1.72	382
1.22	339	1.74	383
1.24	341	1.76	384
1.26	343	1.78	386
1.28	345	1.80	387
1.30	347	1.82	388
1.32	349	1.84	390
1.34	351	1.86	391
1.36	352	1.88	392
1.38	354	1.90	394
1.40	356	1.92	395
1.42	358	1.94	397
1.44	359	1.96	398
1.46	361	1.98	399
1.48	363	2.00	400
1.50	364	2.02	401
		2.20	412

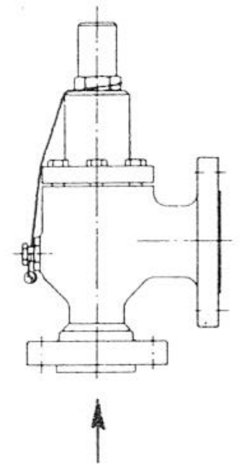


FIGURE 1

The formulas used for calculating orifice areas for sonic flow are:

$$A = \frac{V\sqrt{MTZ}}{6.32\ CK\ P_1} \qquad \text{(Eq. 1)}$$

$$A = \frac{W\sqrt{TZ}}{C\ K\ P_1\ \sqrt{M}} \qquad \text{(Eq. 2)}$$

where: A = Valve orifice area (in^2)

V = Flow capacity (SCFM)

W = Flow capacity (lbs./hr.)

M = Molecular weight of flowing media

T = Inlet temperature, absolute ($^{o}F + 460$)

Z = Compressibility factor

C = Gas constant based on ratio of specific heats at std. conditions

K = Valve coefficient of discharge

P_1 = Inlet pressure (psia) during flow, stagnation
{Set pressure (psig) + allowable overpressure (psig) + 14.7}

To convert flow capacity from SCFM to lbs./hr. use

$$W = \frac{MV}{6.32}$$

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Sizing – English Sizing Formulas

Vapors or Gases (capacity in SCFM)[1]

$$A = \frac{V \sqrt{MTZ}}{6.32\ CKP_1}$$

Vapors or Gases (capacity in lb/hr)[1]

$$A = \frac{W \sqrt{TZ}}{CKP_1 \sqrt{M}}$$

Steam (capacity in lb/hr)[1]

$$A = \frac{W}{51.5\ K\ P_1\ K_s}$$

Liquids (capacity in gpm)

$$A = \frac{V_L \sqrt{G}}{38\ K\ K_P\ K_W\ K_V \sqrt{P_A - P_B}}$$

A - VALVE ORIFICE AREA [in^2]

English Sizing Formulas

Orifice area calculations are made and/or verified whenever sufficient data is provided. If no data is furnished, the size selection responsibility will remain totally with the purchaser.

V = Required capacity, SCFM

W = Required capacity, lb/hr

V_L = Required capacity, gpm

G = Specific gravity of liquid at flowing temperature referred to water = 1.00 at 70°F (see Physical Properties on pages 12 - 14)

M = Molecular weight of vapor or gas ($M = 29 \times G$, see Physical Properties on pages 10 - 11)

T = Relief temperature, °R (°R = °F + 460)

Z = Compressibility factor (if unknown, assume $Z = 1.0$)

k = Specific heat ratio $k = \frac{C_p}{C_V}$

C = Gas constant based on k (if unknown, assume $C = 315$; see Physical Properties on pages 10 - 11; also see page 8)

K = Nozzle coefficient for 90 percent of actual capacity, derived from National Board Certified Testing (see page 4)

P_1 = Inlet flowing pressure, psia = Set pressure - inlet pressure loss + allowable overpressure + 14.7

P_A = Inlet flowing pressure, psig = Set pressure - inlet pressure loss + allowable overpressure

P_B = Back pressure - psig

K_p = Overpressure correction factor, 1.0

K_w = Back pressure correction factor (see page 7)

K_v = Viscosity correction factor (see page 7)

K_s = Superheat correction factor (for saturated steam, $K_s = 1.0$, refer to Table on page 9)

Note

1. As is accepted industry practice, built-up back pressure for conventional (unbalanced) gas or steam valves should not exceed 10 percent.

FERMILAB
ENGINEERING NOTE

SECTION	PROJECT	SERIAL-CATEGORY	PAGE
			34

SUBJECT

NAME

DATE

REVISION DATE

"AGCO" SAFETY-RELIEF VALVES (ANDERSON, GREENWOOD & CO)

$$A = \frac{V\sqrt{MTZ}}{6.32\,CKP_1}$$

$V = 115$ SCFM

M - molecular weight

steam $= 18$

$C = 347$

$T = (°F + 460) =$

$T = (211.99 + 460) = 671.99$

Z = not mandatory

$K = 1.30$

$P_1 = 364.7$

$$A = \frac{115\sqrt{18\,(671.99)}}{6.32\,(347)(0.86)(364.7)}$$

$$A = \frac{12,647.81}{687829.45}$$

$A = 0.0183$ [in^2] min

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Ordering – Pressure and Temperature Ratings

Pressure and Temperature Ratings for Orifice Sizes -4 through -8

Valve Model Type	Seat Material	Temperature Range	Set Pressure Range, psig [barg] -4 Brass	-4 CS & SS	-6 (D) Brass	-6 (D) CS & SS	-8 (E) Brass	-8 (E) CS & SS
83	BUNA-N [1]	-65°F to 275°F [-54°C to 135°C]	20 to 2,000 [1.4 to 137.9]	20 to 2,000 [1.4 to 137.9]	20 to 2,000 [1.4 to 137.9]	20 to 2,000 [1.4 to 137.9]	20 to 2,000 [1.4 to 137.9]	20 to 2,000 [1.4 to 137.9]
83	Viton® [3]	-40°F to 400°F [-40°C to 204°C]	20 to 2,000 [1.4 to 137.9]	20 to 2,000 [1.4 to 137.9]	20 to 2,000 [1.4 to 137.9]	20 to 2,000 [1.4 to 137.9]	20 to 2,000 [1.4 to 137.9]	20 to 2,000 [1.4 to 137.9]
83	EPR	-65°F to 325°F [-54°C to 163°C]	20 to 2,000 [1.4 to 137.9]	20 to 2,000 [1.4 to 137.9]	20 to 2,000 [1.4 to 137.9]	20 to 2,000 [1.4 to 137.9]	20 to 2,000 [1.4 to 137.9]	20 to 2,000 [1.4 to 137.9]
83	Kalrez®	-0°F to 550°F [-18°C to 288°C]	20 to 2,000 [1.4 to 137.9]	20 to 2,000 [1.4 to 137.9]	20 to 2,000 [1.4 to 137.9]	20 to 2,000 [1.4 to 137.9]	20 to 2,000 [1.4 to 137.9]	20 to 2,000 [1.4 to 137.9]
81	Teflon® [1]	-320°F to 400°F [-196°C to 204°C]	100 to 1,000 [6.9 to 69.0]	100 to 1,000 [6.9 to 69.0]	100 to 900 [6.9 to 62.1]	100 to 900 [6.9 to 62.1]	50 to 900 [3.4 to 62.1]	50 to 900 [3.4 to 62.1]
81	PCTFE [1]	-320°F to 300°F [-196°C to 149°C]	1,001 to 4,000 [69.1 to 275.8]	1,001 to 4,000 [69.1 to 275.8]	901 to 1,500 [62.2 to 103.4]	901 to 1,500 [62.2 to 103.4]	901 to 1,500 [62.2 to 103.4]	901 to 1,500 [62.2 to 103.4]
81	Vespel [1]	-423°F to 500°F [-256°C to 260°C]	— —	4,001 to 10,000 [276.1 to 689.5]	1,501 to 4,740 [103.5 to 326.8]	1,501 to 9,600 [103.5 to 661.9]	1,501 to 4,000 [103.5 to 275.8]	1,501 to 6,000 [103.5 to 413.7]
81P	Teflon® [1, 2]	-65°F to 400°F [-54°C to 204°C]	50 to 2,000 [3.4 to 137.9]	50 to 2,000 [3.4 to 137.9]	— —	— —	50 to 2,000 [3.4 to 137.9]	50 to 2,000 [3.4 to 137.9]
81P	PCTFE [1, 2]	-65°F to 300°F [-54°C to 149°C]	2,001 to 4,000 [138.1 to 275.8]	2,001 to 6,000 [138.1 to 413.7]	— —	— —	2,001 to 4,000 [138.1 to 275.8]	2,001 to 6,000 [138.1 to 413.7]
86	Teflon® [1, 2]	-320°F to 400°F [-196°C to 204°C]	50 to 720 [3.4 to 49.7]	50 to 720 [3.4 to 49.7]	— —	— —	50 to 720 [3.4 to 49.7]	50 to 720 [3.4 to 49.7]
* 86	PEEK [1]	-423°F to 515°F [-256°C to 269°C]	236 to 720 [16.3 to 49.7]	236 to 720 [16.3 to 49.7]	— —	— —	178 to 720 [12.3 to 49.7]	178 to 720 [12.3 to 49.7]

Notes

1. Standard seat material.
2. Minimum temperature is based on elastomer spindle and guide seals. Minimum temperature: NACE option: -40°F [-40°C].
3. Viton® maximum temperature ratings (tested with air):
   3000 hours at 450°F [232°C]
   1000 hours at 500°F [260°C]
   240 hours at 550°F [288°C]
   48 hours at 600°F [316°C].
4. Normal set pressure range (Type 81), NACE option:
   -4 Orifice: 100 to 10,000 psig [6.9 to 689.5 barg]
   -6 Orifice: 100 to 7,100 psig [6.9 to 489.6 barg]
   -8 Orifice: 50 to 3,120 psig [3.5 to 215.1 barg].
5. Set pressure range (Type 83), NACE option:
   -4, -6, -8 Orifice: 20 to 2,000 psig [1.4 to 137.9 barg].
6. Temperature range:
   Brass: -325F to 400°F [-198°C to 205°C]
   CS: -20°F to 550°F [-29°C to 288°C]
   SS: -423°F to 550°F [-253°C to 288°C].
7. Viton®, Kalrez® and Teflon® are registered trademarks of the E.I. duPont de Nemours Company.

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Ordering – Dimensions and Weights

Dimensions and Weights for -4 Orifice

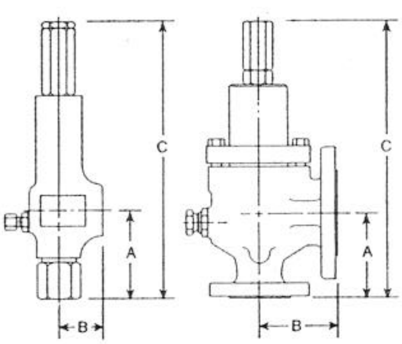
Valve Model Type	Body Material	Set Pressure Range	Valve Connections Inlet in	[mm]	Valve Connections Outlet in	[mm]	Threaded Connections Inlet	Threaded Connections Outlet	Dimensions A in	[mm]	Dimensions B in	[mm]	C max[2] in	[mm]	Approx. Weight lb	[kg]
81, 83	Brass, CS, SS	20 to 4,000 psig [1.4 to 276 barg][1,3]	1/2	[15]	3/4 & 1	[18 & 25]	FNPT	FNPT	2.90	[74]	1.50	[38]	9.55	[243]	4.3	[2.0]
			1/2	[15]	3/4 & 1	[18 & 25]	MNPT	FNPT	2.90	[74]	1.50	[38]	9.55	[243]	4.3	[2.0]
			3/4	[18]	3/4 & 1	[18 & 25]	FNPT	FNPT	3.07	[78]	1.50	[38]	9.72	[247]	4.3	[2.0]
			3/4	[18]	3/4 & 1	[18 & 25]	MNPT	FNPT	2.90	[74]	1.50	[38]	9.55	[243]	4.3	[2.0]
			1	[25]	1	[25]	MNPT	FNPT	3.07	[78]	1.50	[38]	9.72	[247]	4.3	[2.0]
81, 83	CS, SS	4,001 to 10,000 psig [276.1 to 690 barg]	3/4 & 1	[18 & 25]	1	[25]	FNPT	FNPT	3.70	[94]	1.81	[46]	14.10	[358]	13.3	[6.1]
			3/4 & 1	[18 & 25]	1	[25]	MNPT	FNPT	3.80	[97]	1.81	[46]	14.20	[361]	13.3	[6.1]
* 86	Brass, CS, SS used	50 to 720 psig [3.4 to 49.7 barg]	1/2	[15]	3/4 & 1	[18 & 25]	FNPT	FNPT	2.90	[74]	1.50	[38]	10.46	[266]	4.5	[2.1]
			1/2	[15]	3/4 & 1	[18 & 25]	MNPT	FNPT	2.90	[74]	1.50	[38]	10.46	[266]	4.5	[2.1]
			3/4	[18]	3/4 & 1	[18 & 25]	FNPT	FNPT	3.07	[78]	1.50	[38]	10.63	[270]	4.5	[2.1]
			3/4	[18]	3/4 & 1	[18 & 25]	MNPT	FNPT	2.90	[74]	1.50	[38]	10.46	[266]	4.5	[2.1]
			1	[25]	1	[25]	MNPT	FNPT	3.07	[78]	1.50	[38]	10.63	[270]	4.5	[2.1]
81P	Brass CS, SS	50 to 1,160 psig [3.4 to 80 barg]	3/4 & 1	[18 & 25]	1	[25]	FNPT	FNPT	3.70	[94]	1.81	[46]	10.87	[276]	8.3	[3.8]
			3/4 & 1	[18 & 25]	1	[25]	MNPT	FNPT	3.80	[97]	1.81	[46]	10.95	[278]	8.3	[3.8]
81P	Brass, CS, SS	1,161 to 6,000 psig [80.1 to 414 barg][4]	3/4 & 1	[18 & 25]	1	[25]	FNPT	FNPT	3.70	[94]	1.81	[46]	14.10	[358.1]	13.8	[6.3]
			3/4 & 1	[18 & 25]	1	[25]	MNPT	FNPT	3.80	[97]	1.81	[46]	14.20	[360.7]	13.8	[6.3]

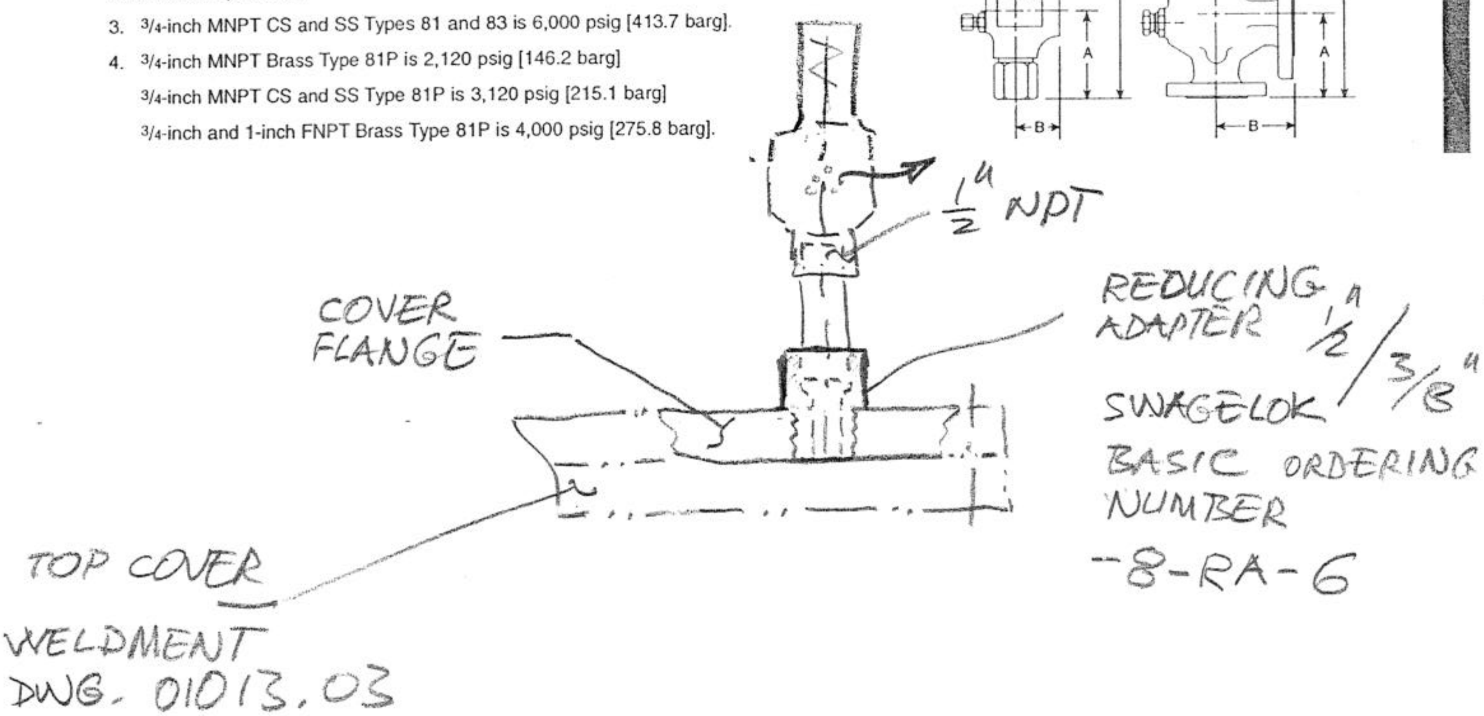
Notes

1. Normal set pressure range for Type 81: 100 to 4,000 psig [6.9 to 275.8 barg]; Type 83: 20 to 2,000 psig [1.4 to 137.9 barg].
2. Add 0.90-inch [23 mm] to 'C max' dimension for numbered orifice Type 81, 83, 86 and 81P with packed lift lever option.

Maximum set pressure:

3. 3/4-inch MNPT CS and SS Types 81 and 83 is 6,000 psig [413.7 barg].
4. 3/4-inch MNPT Brass Type 81P is 2,120 psig [146.2 barg]
   3/4-inch MNPT CS and SS Type 81P is 3,120 psig [215.1 barg]
   3/4-inch and 1-inch FNPT Brass Type 81P is 4,000 psig [275.8 barg].





"PEEK"

37.

Jim Tweed 3734

Appendix
Type 86 Capacities

DISCHARGE AREA

Type 86 Capacities[1] - lb/hr [kg/hr] Saturated Steam - National Board Certified

Set Pressure psig	[barg]	-4 0.049 in² [0.32 cm²]		-8 0.196 in² [1.27 cm²]		G 0.503 in² [3.25 cm²]		J 1.287 in² [8.30 cm²]	
50	[3.45]	144	[65.3]	574	[260]	1473	[668]	3770	[1710]
60	[4.14]	166	[75.3]	665	[302]	1706	[774]	4365	[1980]
80	[5.52]	211	[95.7]	846	[384]	2171	[985]	5555	[2520]
100	[6.9]	257	[116.6]	1027	[466]	2636	[1196]	6744	[3059]
120	[8.3]	302	[137.0]	1208	[548]	3101	[1407]	7934	[3599]
140	[9.7]	347	[157.4]	1390	[631]	3566	[1618]	9124	[4139]
160	[11.0]	393	[178.3]	1571	[713]	4031	[1829]	10,314	[4678]
180	[12.4]	438	[198.7]	1752	[795]	4496	[2040]	1,504	[5218]
200	[13.8]	483	[219.1]	1933	[877]	4961	[2250]	12,694	[5758]
220	[15.2]	529	[240.0]	2114	[959]	5426	[2461]	13,884	[6298]
240	[16.6]	574	[260.4]	2296	[1042]	5891	[2672]	15,073	[6837]
260	[17.9]	619	[280.8]	2477	[1124]	6356	[2883]	16,263	[7377]
280	[19.3]	664	[301.2]	2658	[1206]	6821	[3094]	17,453	[7917]
300	[20.7]	710	[322.1]	2839	[1288]	7286	[3305]	18,643	[8457]
320	[22.1]	755	[342.5]	3020	[1370]	7751	[3516]	19,833	[8996]
340	[23.4]	800	[362.9]	3202	[1452]	8216	[3727]	21,023	[9536]
350		823		3293		8449			
360	[24.8]	846	[383.7]	3383	[1535]	8681	[3938]	22,213	[10,076]
380	[26.2]	891	[404.2]	3564	[1617]	9146	[4149]	23,403	[10,617]
400	[27.6]	936	[424.6]	3745	[1699]	9611	[4360]	24,592	[11,155]
420	[29.0]	982	[445.4]	3926	[1781]	10,077	[4571]	25,782	[11,695]
440	[30.3]	1027	[456.9]	4108	[1863]	10,542	[4782]	26,972	[12,235]
460	[31.7]	1072	[486.3]	4289	[1946]	11,007	[4993]	28,162	[12,774]
480	[33.1]	1118	[507.1]	4470	[2028]	11,472	[5204]	29,352	[13,314]
500	[34.5]	1163	[527.5]	4651	[2110]	11,937	[5415]	30,542	[13,854]
520	[35.9]	1208	[547.9]	4832	[2192]	12,402	[5626]	31,732	[14,394]
540	[37.2]	1253	[568.4]	5014	[2274]	12,867	[5837]	32,921	[14,933]
560	[38.6]	1299	[589.2]	5195	[2357]	13,332	[6047]	34,111	[15,473]
580	[40.0]	1344	[609.6]	5376	[2439]	13,797	[6258]	35,301	[16,013]
600	[41.4]	1389	[630.1]	5557	[2521]	14,262	[6469]	36,491	[12,016]
620	[42.7]	1435	[650.9]	5739	[2603]	14,727	[6680]	37,681	[17,092]
640	[44.2]	1480	[671.3]	5920	[2685]	15,192	[6891]	38,871	[17,632]
660	[45.5]	1525	[691.7]	6101	[2767]	15,657	[7102]	40,061	[18,172]
680	[46.9]	1571	[712.6]	6282	[2850]	16,122	[7313]	41,251	[18,712]
700	[48.3]	1616	[733.0]	6463	[2932]	16,587	[7524]	42,440	[19,251]
720	[49.6]	1661	[753.4]	6645	[3014]	7,052	[7735]	43,630	[19,791]

Notes

1. Saturation temperature - 10% overpressure.
2. Metric conversions:
   barg = psig x 0.06895
   cm² = in² x 6.4516
   kg/hr = lb/hr x 0.4536
   °C = [°F - 32] x 0.5556

120 SCFM Steam

saturated vapor at 14.7 psia
specific volume
$26.80 \frac{ft^3}{lb}$

$823 \frac{lb}{hr} \times 26.80 \frac{ft^3}{lb} \times \frac{1\ hr}{60\ min}$

= 367 SCFM steam

1/2" connection

THE FOLLOWING SAFETY-RELIEF VALVE IS SELECTED:

MFG.: "ANDERSON GREENWOOD" a)

VALVE MODEL TYPE: 86

SEAT MATERIAL: PEEK

SET PRESSURE: 350 psig

DISCHARGE AREA: 0.049 in²

THREADED CONNECTIONS;

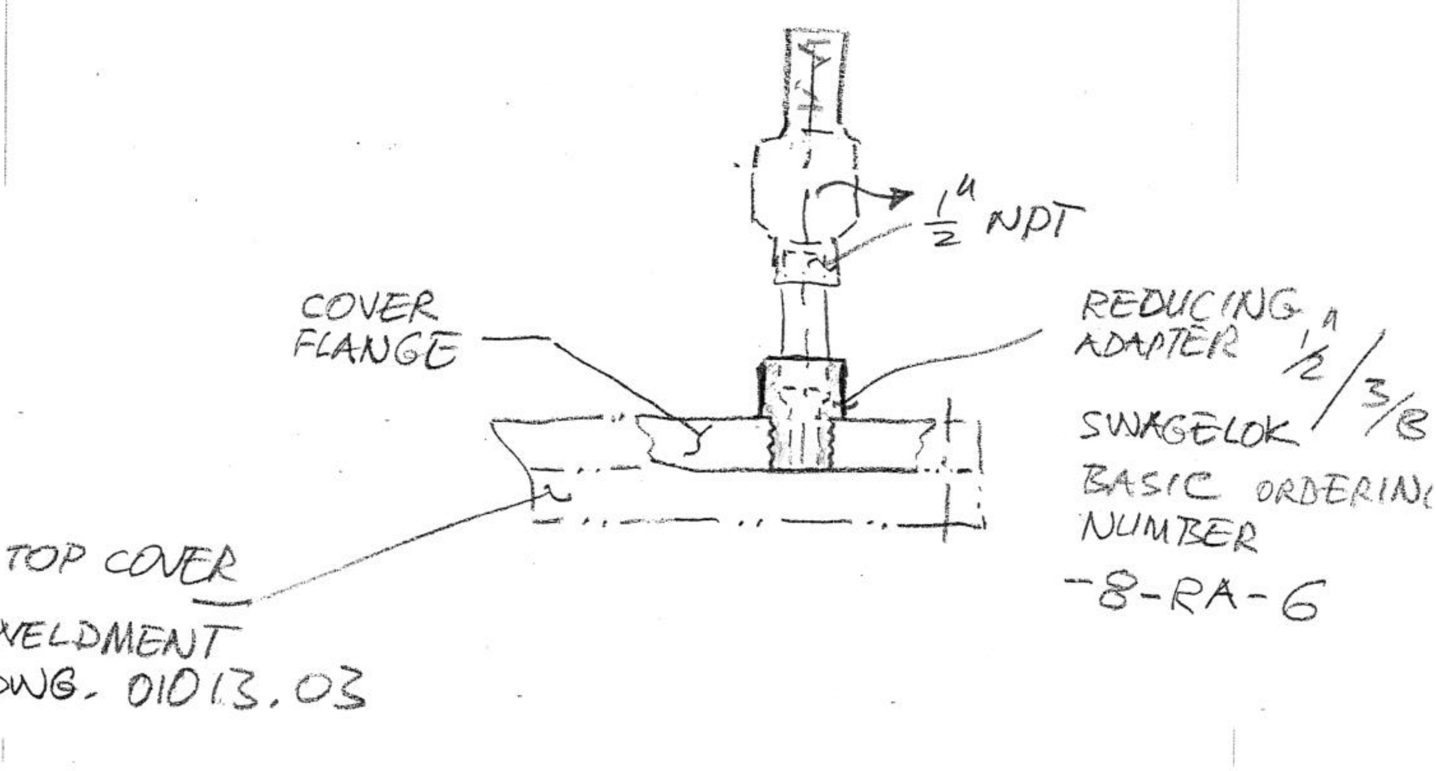
INLET $\frac{1}{2}$" FNTP

OUTLET $\frac{3}{4}$" FNTP

BODY MATERIAL: SS

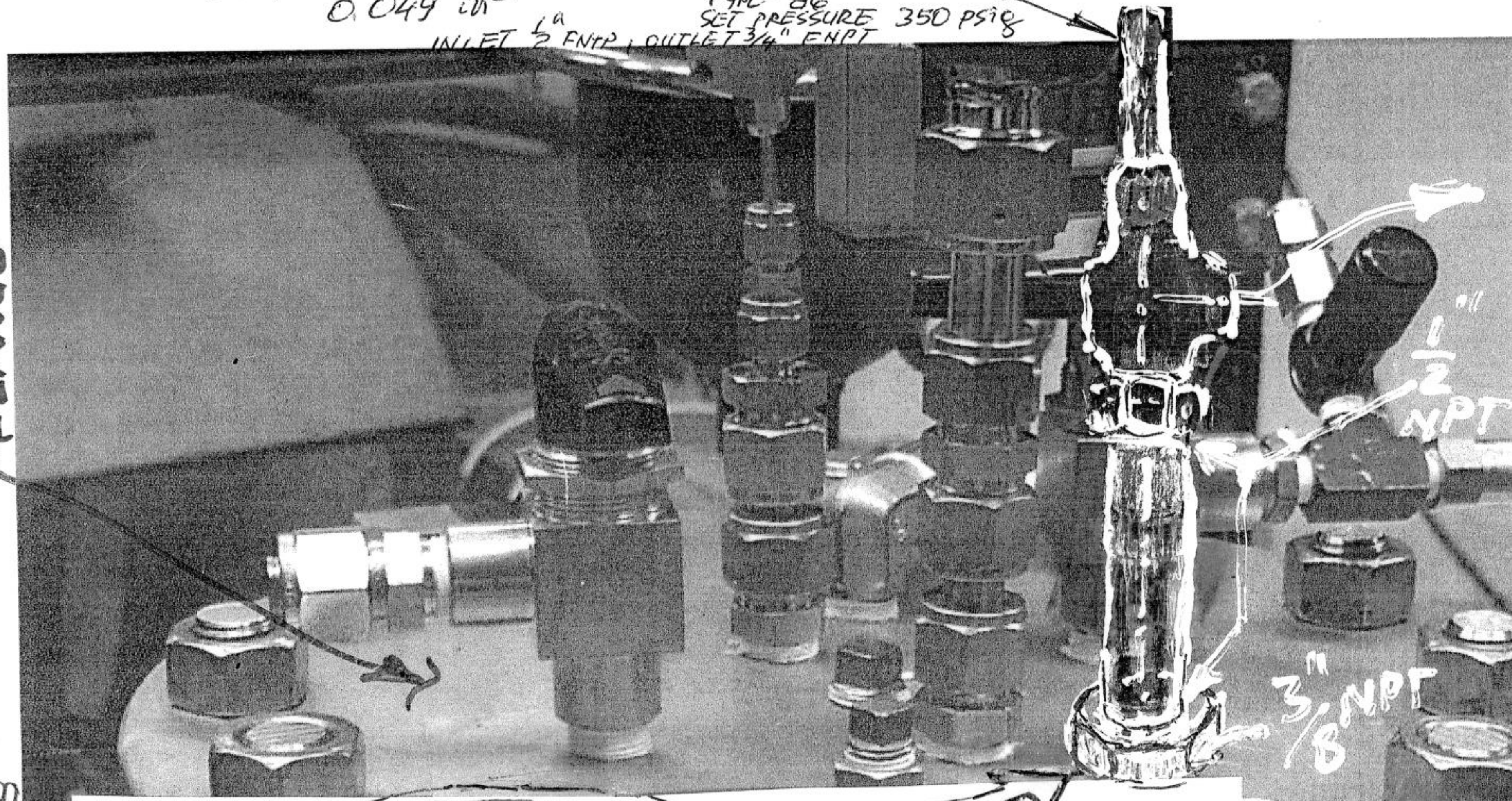
a) SEE PAGE 27 FOR ALTERNATIVE SELECTION

INSTALLATION SCHEMATIC.



DISCHARGE AREA: 0.049 in²

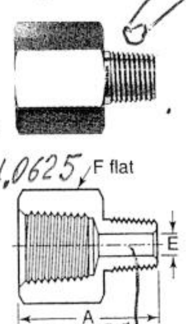
AN[illegible] ON GREENWOOD SA[illegible] RELIEF VALVE TYPE 86 SET PRESSURE 350 psig
INLET ½" FNPT, OUTLET ¾" FNPT



COVER FLANGE

PIPE FITTINGS PAGE 8

Reducing Adapters



Female to Male NPT Threads

Female Pipe Size in.	Male Pipe Size in.	Basic Ordering Number	Dimensions in. (mm) A	Dimensions in. (mm) E	F in.	Pressure Ratings psig (bar) 316 SS, Steel	Pressure Ratings psig (bar) Brass
1/8	1/16	-2-RA-1	1.09 (27.7)	0.12 (3.0)	9/16	6 500 (447)	3200 (220)
1/4	1/8	-4-RA-2	1.26 (32.0)	0.19 (4.8)	3/4	6 600 (454)	3300 (227)
3/8		-6-RA-2	1.33 (33.8)		7/8	5 300 (365)	2600 (179)
	1/4	-6-RA-4	1.50 (38.1)	0.28 (7.1)			
1/2	1/8	-8-RA-2	1.58 (40.1)	0.19 (4.8)	1 1/16	4 900 (337)	2400 (165)
	1/4	-8-RA-4	1.76 (44.7)	0.28 (7.1)			
	3/8	-8-RA-6	1.75 (44.4)	0.38 (9.6)			

CROSS SECTION AREA $A = \frac{\pi (E)^2}{4} = \frac{\pi (0.38)^2}{4} = 0.113 \, [in^2]$

SELECTION FOR "CIRCLE SEAL" VALVE

INPUT DATA FROM PAGE (24).

AMOUNT OF GENERATED VAPOR : $G = \underline{4.28 \ \text{lbs}/\text{min}}$
@ 350 [psig]

"CIRCLE SEAL" IS OFFERING $\frac{1}{2}$" (ASME) STAMPED
VALVE 5,1.65T-4-MP-350
SET PRESSURE: (350 psig + 10% = 385 psig)
DISCHARGE CAPACITY
225 [SCFM]

SPECIFIC VOLUME
OF STEAM @ 350 psig (364.7 psia) $\frac{Ft^3}{lb}$ = 1.278282
[TABLE 28 ON PAGE 26]

$$@\ 385\ \text{psig}\ (\underset{\sim 400}{399.7}\ \text{psia})\ \frac{Ft^3}{lb} = 1.1620$$

$$= \frac{1}{1.1620}\ \frac{lb}{Ft^3} =$$

$$= \underline{0.86058} \left[\frac{lb}{Ft^3}\right]$$

DETERMINING A VAPOR AMOUNT GENERATED BY THE "Q" HEAT VALUE.

GIVEN DATA:

SET PRESSURE $p = \cancel{350}\ 385\ [psig]$

$p = \cancel{350}\ 385 + 14.7$

$p = \cancel{364.7}\ 400\ [psia]$

ENTHALPIES:

EVAPORATION $h_1 = \cancel{790.95}\ 781.2\ \frac{Btu}{lb}$

VAPOR $h_2 = \cancel{1205.07}\ 1205.5$

AFTER INITIAL TEMPERATURE BUILD UP, AND REACHING THE LEVEL OF EVAPORATION, THE ADDITIONAL AMOUNT OF HEAT, CAUSES TRANSITION FROM WATER TO VAPOR @ Δh
THE AMOUNT OF GENERATED VAPOR:

$$G = \frac{Q}{\Delta h}$$

$$\Delta h = h_2 - h_1$$

$$\Delta h = \cancel{1205.07}\ 1205.05 - \cancel{790.95}\ 781.2$$

$$\Delta h = \cancel{414.12}\ 423.85\ \left[\frac{Btu}{lb}\right]$$

$$G = \frac{Q}{\Delta h} = \frac{106,542.74}{\cancel{414.12}\ 423.85} \quad \frac{\frac{Btu}{hr}}{\frac{Btu}{lb}} = \frac{Btu}{hr}\ \frac{lb}{Btu}$$

$$G = \cancel{257.275}\ 251.36\ \left[\frac{lbs}{hr}\right] = \cancel{4.28}\ 4.18\ \left[\frac{lbs}{min}\right]$$

$$G = \cancel{4.28}\ 4.18\ \frac{lbs}{min}$$

STEAM PROPERTY – SPECIFIC VOLUME

$$V = \cancel{1.278}\ 1.1620 \left[\frac{Ft^3}{lb}\right]$$

SEE TABLE ON PAGE 26

(26.8) @ * 14.7 psia

PROPERTIES TABLE 281 PAGE 26

$$\frac{P_2}{P_1} = \frac{V_1}{V_2}$$

$$\frac{14.7}{400} = \frac{1.1620}{V_2}$$

$$V_2 = 31.6$$

$$G = \cancel{4.28}\ 4.18\ (\cancel{26.8}\ 31.6)$$

$$G = \cancel{115.}\ 132. \left[\frac{Ft^3}{min}\right] = \boxed{SCFM!}$$

"CIRCLE SEAL" = $\boxed{225}$ SCFM
5.1.6ST – 4 – MP – 350

SAFETY RELIEF DEVICES ARE MOUNTED AT THE BOTTOM OF THE TANK. THESE UNITS SHOULD BE ABLE TO PASS THE REQUIRED VOLUME OF LIQUID WHEN THE LEVEL OF CRACKING PRESSURE IS MET.

IN ADDITION TO THAT, ON TOP OF THE TANK, THE SAFETY RELIEF (CHECK) VALVE IS MOUNTED. THIS VALVE CAPACITY HAS TO BE GREATER THAN THE VAPOR'S GENERATED AMOUNT.

THIS VALVE'S CRACKING PRESSURE IS $<$ THAN 400 psig – RATING PRESSURE FOR HYDRAULIC CYLINDER IN BUBBLE CHAMBER INSTALLATION.

O.K.

(WATER)
ENTHALPIES!
Btu/lb

PRESSURE abs. press. lb/in²	TEMP. °F	ENTHALPY Btu/lb.		
		LIQUID	EVAP.	VAPOR
350	431.82	409.9	795.0	1204.9
364.7			790.95	1205.07
400	444.70	424.2	781.2	1205.5

EVAP.	VAPOR
$\frac{795.-781.2}{50} =$	$\frac{1205.5-1204.9}{50} =$
$= 0.276$	$= 0.012$
$0.276 \times 14.7 =$	$0.012 \times 14.7 =$
$= 4.05$	$= 0.176$

	VAPOR
SPEC. VOLUME @ 350°F	1.3267
@ 400	1.1620
@ 364.7	1.278

FAX

Fluid Process Control Corporation
15W700 79th Street
Burr Ridge, IL 60527

To:	Andrew Szymulanski
Fax number:	840-3694
From:	Alan Nelson
Fax number:	630-986-1669
Business phone:	630-986-1600
Home phone:	
Date & Time:	9/20/2004 3:55:04 PM
Pages:	7
Re:	Relief Valve information

As we discussed, the flow in your application would require a 1/2" version of the 5100-series relief valve.

180°F) An example part number would be 5165T-4MP-350. This valve is constructed in 303SS with Kalrez o-ring seals, 1/2" NPT connections and a 350 psig cracking pressure. The 5165T-4MP-350 has a unit price of $339.00 each and currently has a 6-8 week lead time.

At 10% overpressure this valve will flow approximately 225 SCFM Air.

For reference, the ID of the inlet side of the valve is approximately 0.531" diameter.

If you have any questions or need additional information please feel free to contact me.

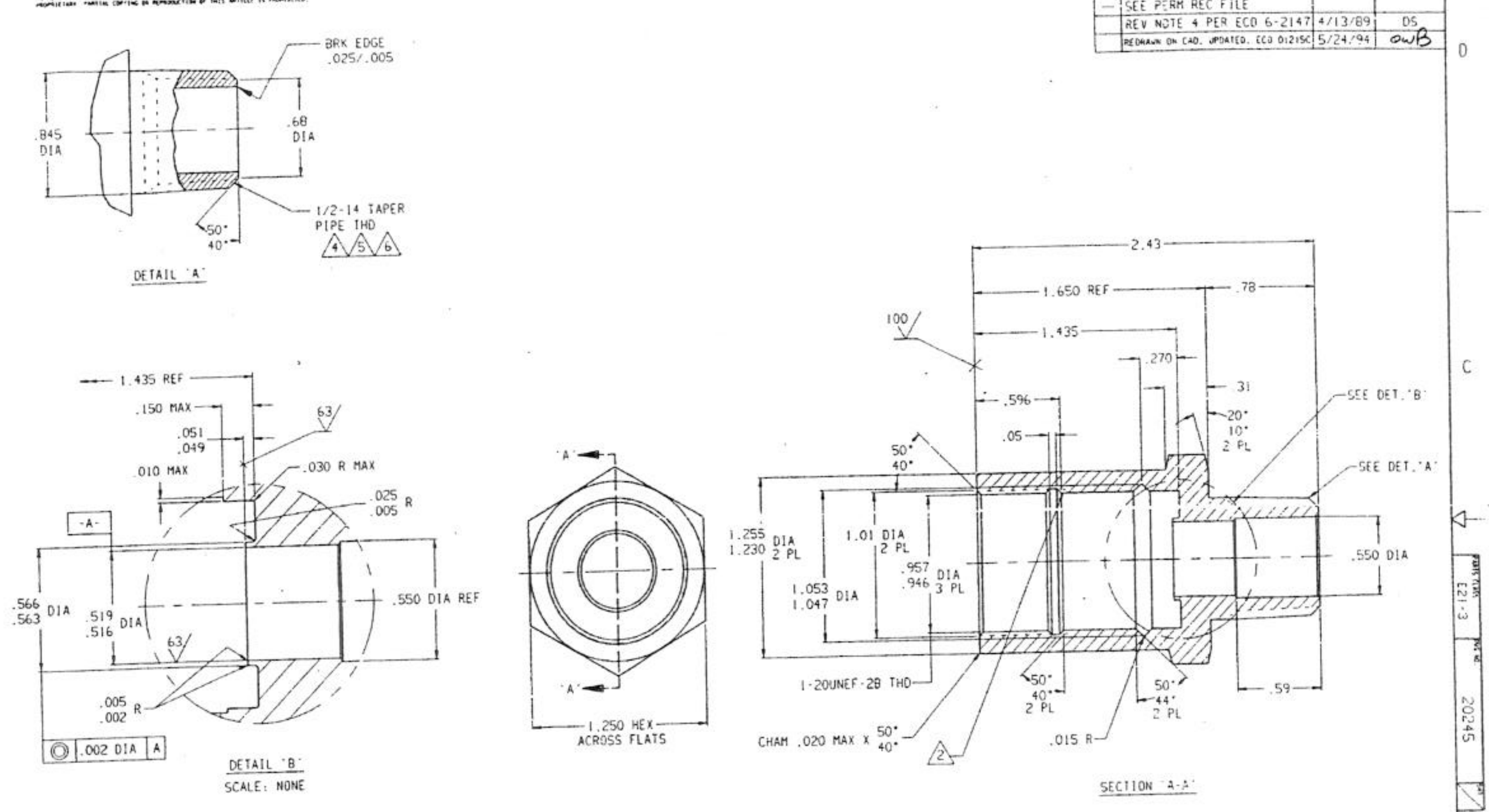
AVAILABLE AT FNAL: JIM TWEED: => SEPT. 21, 2004

250° BUNA 5159 5132 [5180] TEF 450°

VITON 400°

- NO MANUAL REVISIONS ALLOWED

REV	DESCRIPTION	DATE	APPROVED
—	SEE PERM REC FILE		
	REV NOTE 4 PER ECO 6-2147	4/13/89	DS
	REDRAWN ON CAD, UPDATED, ECO 01215C	5/24/94	OWB



NOTES:

6. MINIMUM OF (5) THREADS REQUIRED (CREST AND ROOT).

5. GAGING: ONLY NPT GAGES AND THREADING TOOLS TO BE USED PER FED-STD-H28/7.

4. GAGING: THREADS ARE TO BE GAGED FROM FACE OF PRODUCT ±ONE (1) TURN TO FACE OF L1 RING GAGE.

3. MAY BE USED FOR P/N'S 20260, 35830, 36070 & 32859.

2. ONLY PARTIAL THREADS MAY EXTEND INTO THIS SURFACE.

1. CAUTION: SEE SPECIAL NOTE ON A.B. DRAWING FOR CRES MATERIAL.

UNLESS OTHERWISE SPECIFIED: DIMENSIONS IN INCHES. REMOVE BURRS. FILLET RADII .005 TO .035. MACHINE FINISH 125. DRILL POINTS STD. TOLERANCES ARE: DECIMALS: .XX = ±.015, .XXX = ±.005. ANGLES: ±1°. CONCENTRICITY .010 DIA. DO NOT SCALE DRAWING.

APPROVALS		DATE
DRAWN	MATTHES	10/5/64
CHECKED	HB	10/20/64
APPROVED	LGC	2/11/65

INITIAL USAGE (REF ONLY): 5100-4MP

CSC CAD FILE NAME: 20245

MATERIAL: PER 2011 (1) — FINISH: —

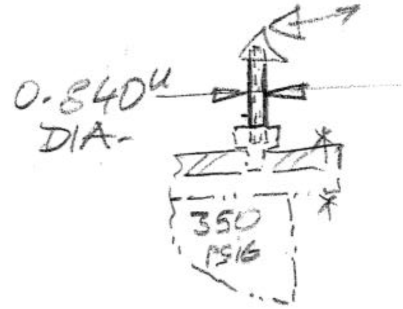
CIRCLE SEAL CONTROLS, INC. CORONA, CALIFORNIA

TITLE: END

SIZE: C — CAGE CODE: 91816 — DWG NO.: 20245 — REV: —

SCALE: 2/1 — SHEET

- DETERMINE THE REQUIRED WALL THICKNESS OF THE SAFETY RELIEF CONNECTING PIPE



$$t = \frac{P \cdot D}{2(SE + PY)}$$

$P = 350$ [psig]

$D = 0.840$ [in]

$S = 15{,}000$ [psi]

SEAMLESS PIPE

$E = 1$

PIPE MATERIAL:

A 312 SEAMLESS STEEL

AUSTENITIC:

$y = 0.4$

$$t = \frac{350(0.840)}{2\left[15{,}000(1) + 350 \cdot (0.4)\right]}$$

$$t = \frac{294}{30{,}280}$$

$$t = 0.009''$$

$$t_m = t + c$$

ANSI B31.3-1984
CHEMICAL PLANT AND PETROLEUM REFINERY PIPING

(a) This Code prescribes requirements for the materials, design, fabrication, assembly, erection, examination, inspection, and testing of piping systems subject to pressure or vacuum.

(b) This Code applies to piping systems handling all fluids, including fluidized solids, and to all types of service, including raw, intermediate, and finished chemicals, oil and other petroleum products, gas, steam, air, water, and refrigerants, except as provided in 300.1.2 or 300.1.3. Only Category D and M fluid services as defined in 300.2 are segregated for special consideration.

Internal Pressure

$$t_m = t + c \qquad t = \frac{Pd}{2[SE - P(1 - Y)]}$$

(See notes 1, 7, 8)

$$t = \frac{PD}{2(SE + PY)}$$

VALUES OF, S, 1000 psi
For Materials ASTM A 53b and A 106b
For Metal Temperatures not Exceeding Deg. F

	−20 to 100	200	300	400	500
A 53B A106B	20.00	20.00	20.00	20.00	18.90

A312 $\boxed{15000}$

External Pressure
For determining wall thickness and stiffening requirements the procedures outlined in Paras. UG-28, 29 and 30 of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code shall be followed.

Summary of Major Requirements of
PIPING CODES
(continuation from facing page)

NOTATION

A = an additional thickness, in inches to compensate for material removed in threading, grooving etc., and to provide for mechanical strength, corrosion and erosion.

For cast iron pipe the following values of A shall apply:

Centrifugally cast . . . . 0.14 in.
Statically cast . . . . 0.18 in.

c = the sum in inches of the mechanical allowances (thread or groove depth) plus corrosion and erosion allowance.

d = inside diameter of the pipe in corroded condition, inches

D & D_o = outside diameter of pipe, inches

E = efficiency factor of welded joint in pipe (see applicable code) For seamless pipe E = 1.0

F = for cast iron pipe casting quality factor F shall be used in place of E

P = internal design pressure, or maximum allowable working pressure, psig

S = maximum allowable stress in material due to internal pressure at the design temperature, psig.

t = thickness of pipe required for pressure, inches

t_m = minimum thickness of pipe in inches required for pressure and to compensate for material removed for threading, grooving, etc., and to provide for mechanical strength, corrosion and erosion.

y & Y = coefficients as tabulated below

Values of y & Y

Temperature F	900[1] and below	950	1000	1050	1100	1150 and above
Ferritic Steels	0.4	0.5	0.7	0.7	0.7	0.7
Austenitic Steels	0.4	0.4	0.4	0.4	0.5	0.7

Note: For intermediate temperatures the values may be interpolated. For nonferrous materials and cast iron, y equals 0.4.

[1] For pipe with a D_o/t_m ratio less than 6, the value of y for ferritic and austenitic steels designed for temperatures of 900 F and below shall be taken as:

$$y = \frac{d}{d + D_o}$$

NOTES

1. The minimum thickness for the pipe selected, considering manufacturer's minus tolerance, shall not be less than t_m. The minus tolerance for seamless steel pipe is 12.5% of the nominal pipe wall thickness.
2. Where steel pipe is threaded and used for steam service at pressure above 250 psi, or for water service above 100 psi with water temperature above 220 F the pipe shall be seamless having the minimum ultimate tensile strength of 48,000 psi and weight at least equal to Sch 80 of ANSI B36.10. (Code ANSI B31.1, Para. 104.1.2 C.1)
3. Piping systems installed in open easements, which are accesible to the general public or to individuals other than the owner of the piping system or his employee or agent, shall be designed in accordance with USAS B31.8. (Code USAS B31.02, Para. 201.1)
4. When not specifically required by a gas using process or equipment, the maximum working pressure for piping systems installed in buildings intended for human use and occupancy shall not exceed 10 psig. (Code USAS B31.2, Para 201.2.1)
5. Every piping system, regardless of anticipated service conditions shall have a design pressure of at least 10 psig between the temperatures of minus 20 F and 250 F. (Code USAS B31.2, Para. 201.2.2.b.)
6. Where the minimum wall thickness is in excess of 0.10 of the nominal diameter, the piping system shall meet the requirements of USAS B31.3. (Code USAS B31.2, Para. 203)
7. Pipe with t equal to or greater than D/6, or P/SE greater than 0.385, requires special consideration, taking into account design and material factors such as theory of failure, fatigue, and thermal stresses. (Code B31.3, Para. 304.1.2,b.)
8. Pipe bends shall meet the flattening limitations of the applicable Code.

C = 0.057

MACHINERY'S HANDBOOK
DATA FOR PIPE THREADS

Engagement Between External and Internal Taper Threads. — The normal length of engagement between external and internal taper threads when screwed together handtight is shown as L_1 in Table 3. This length is controlled by the construction and use of the pipe thread gages. It is recognized that in special applications, such as flanges for high-pressure work, longer thread engagement is used, in which case the pitch diameter E_1 (Table 3) is maintained and the pitch diameter E_0 at the end of the pipe is proportionately smaller.

Railing Joint Taper Pipe Threads, NPTR. — Railing joints require a rigid mechanical thread joint with external and internal taper threads. The external thread is basically the same as the ANSI Standard Taper Pipe Thread, except that sizes ½ through 2 inches are shortened by 3 threads and sizes 2½ through 4 inches are shortened by 4 threads to permit the use of the larger end of the pipe thread. A recess in the fitting covers the last scratch or imperfect threads on the pipe.

Table 3 (*Continued*). **Basic Dimensions, American National Standard Taper Pipe Threads, NPT** (ANSI B2.1-1968)

Nominal Pipe Size	Wrench Makeup Length for Internal Thread		Vanish Thread, (3.47 thds.), V	Overall Length External Thread, L_4	Nominal Perfect External Threads[5]		Height of Thread, h	Basic Minor Diam. at Small End of Pipe,[6] K_0
	Length,[7] L_3	Diam., E_3			Length, L_5	Diam., E_5		
1/16	0.1111	0.26424	0.1285	0.3896	0.1870	0.28287	0.02963	0.2416
1/8	0.1111	0.35656	0.1285	0.3924	0.1898	0.37537	0.02963	0.3339
1/4	0.1667	0.46697	0.1928	0.5946	0.2907	0.49556	0.04444	0.4329
3/8	0.1667	0.60160	0.1928	0.6006	0.2967	0.63056	0.04444	0.5676
* 1/2	0.2143	0.74504	0.2478	0.7815	0.3909	0.78286	0.05714	0.7013 *
3/4	0.2143	0.95429	0.2478	0.7935	0.4029	0.99286	0.05714	0.9105
1	0.2609	1.19733	0.3017	0.9845	0.5089	1.24543	0.06957	1.1441
1 1/4	0.2609	1.54083	0.3017	1.0085	0.5329	1.59043	0.06957	1.4876
1 1/2	0.2609	1.77978	0.3017	1.0252	0.5496	1.83043	0.06957	1.7265
2	0.2609	2.25272	0.3017	1.0582	0.5826	2.30543	0.06957	2.1995
2 1/2	0.2500[8]	2.70391	0.4337	1.5712	0.8875	2.77500	0.100000	2.6195
3	0.2500[8]	3.32500	0.4337	1.6337	0.9500	3.40000	0.100000	3.2406
3 1/2	0.2500	3.82188	0.4337	1.6837	1.0000	3.90000	0.100000	3.7375
4	0.2500	4.31875	0.4337	1.7337	1.0500	4.40000	0.100000	4.2344
5	0.2500	5.37511	0.4337	1.8400	1.1563	5.46300	0.100000	5.2907
6	0.2500	6.43047	0.4337	1.9462	1.2625	6.52500	0.100000	6.3461
8	0.2500	8.41797	0.4337	2.1462	1.4625	8.52500	0.100000	8.3336
10	0.2500	10.52969	0.4337	2.3587	1.6750	10.65000	0.100000	10.4453
12	0.2500	12.51719	0.4337	2.5587	1.8750	12.65000	0.100000	12.4328
14 OD	0.2500	13.75938	0.4337	2.6837	2.0000	13.90000	0.100000	13.6750
16 OD	0.2500	15.74688	0.4337	2.8837	2.2000	15.90000	0.100000	15.6625
18 OD	0.2500	17.73438	0.4337	3.0837	2.4000	17.90000	0.100000	17.6500
20 OD	0.2500	19.72188	0.4337	3.2837	2.6000	19.90000	0.100000	19.6375
24 OD	0.2500	23.69688	0.4337	3.6837	3.0000	23.90000	0.100000	23.6125

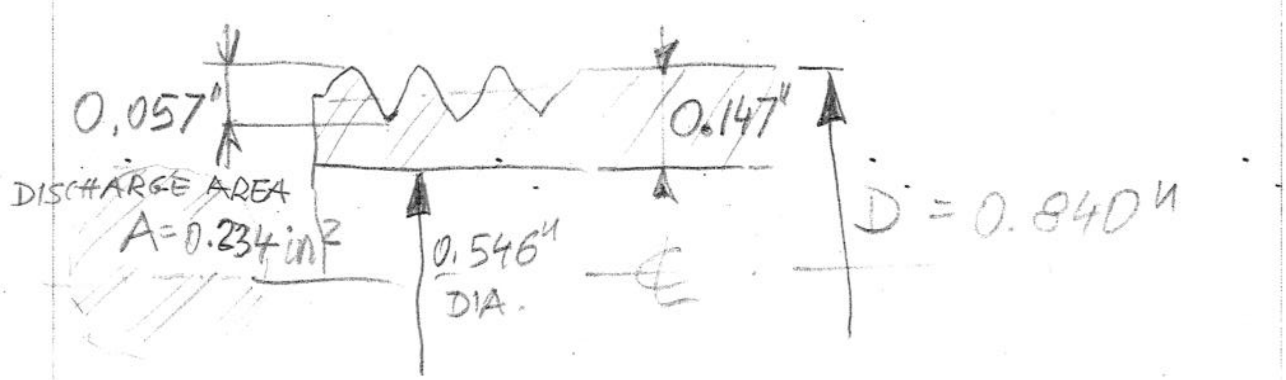
[5] The length L_5 from the end of the pipe determines the plane beyond which the thread form is imperfect at the crest. The next two threads are perfect at the root. At this plane the cone formed by the crests of the thread intersects the cylinder forming the external surface of the pipe. $L_5 = L_2 - 2p$.

[6] Given as information for use in selecting tap drills.

[7] Three threads for 2-inch size and smaller; two threads for larger sizes.

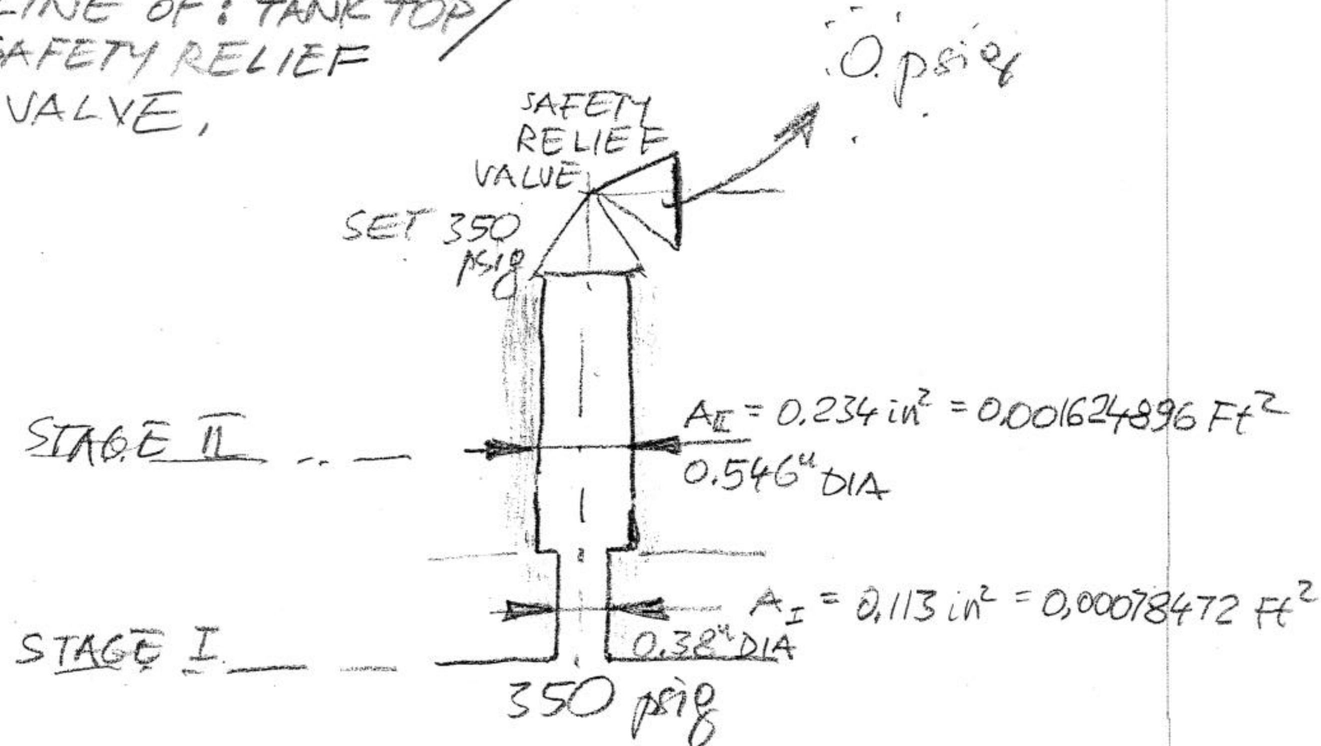
[8] Military Specification MIL—P—7105 gives the wrench makeup as three threads for 3 in. and smaller. The E_3 dimensions are then as follows: Size 2½ in., 2.69609 and size 3 in., 3.31719.

Increase in diameter per thread is equal to $0.0625/n$.



1/2" NOMINAL PIPE, SS SCHEDULE 80 IS SELECTED
MATERIAL

CHECK THE PRESSURE DROP IN THE CONNECTING LINE OF: TANK TOP / SAFETY RELIEF VALVE,



AMOUNT OF THE STEAM GENERATED DURING THE FIRE CONDITION:

$$G = 115\ \frac{Ft^3}{min}$$ [APPENDIX 5 PAGE 24]

$$G = 115\ \frac{Ft^3}{60\ sec}$$

$$G = \underline{1.9166}\ \frac{Ft^3}{sec} \Rightarrow$$ MUST BE CONVERTED TO W

Compressible flow:

$$q'_h = 40\,700\ Yd^2 \sqrt{\frac{\Delta P\, P'_1}{K T_1 S_g}} \qquad \textit{Equation 3-20}$$

$$q'_h = 24\,700\ \frac{Yd^2}{S_g} \sqrt{\frac{\Delta P\, \rho_1}{K}}$$

$$q'_m = 678\ Yd^2 \sqrt{\frac{\Delta P\, P'_1}{K T_1 S_g}} = 412\ \frac{Yd^2}{S_g} \sqrt{\frac{\Delta P\, \rho_1}{K}}$$

$$q' = 11.30\ Yd^2 \sqrt{\frac{\Delta P P'_1}{K T_1 S_g}} = 6.87\ \frac{Yd^2}{S_g} \sqrt{\frac{\Delta P \rho_1}{K}}$$

$$w = 0.525\ Yd^2 \sqrt{\frac{\Delta P}{K \bar{V}_1}} \qquad \boxed{W = 1891\ Yd^2 \sqrt{\frac{\Delta P}{K \bar{V}_1}}}$$

Values of Y are shown on page A-22. For K, Y, and ΔP determination, see examples on pages 4-13 and 4-14.

"CRANE" TECHNICAL PAPER No 410 ... FLOW OF FLUIDS THROUGH VALVES, FITTINGS, AND PIPE

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

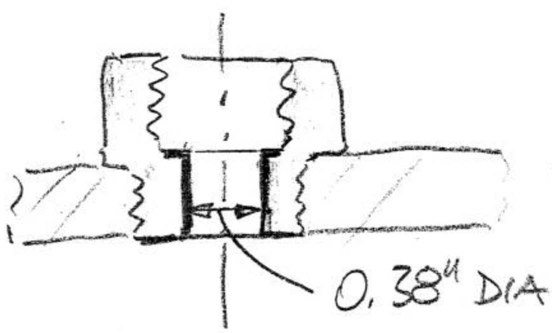
$W = \underline{4.28}$ $\left[\frac{lbs}{min}\right]$ [APPENDIX 5 PAGE 24]

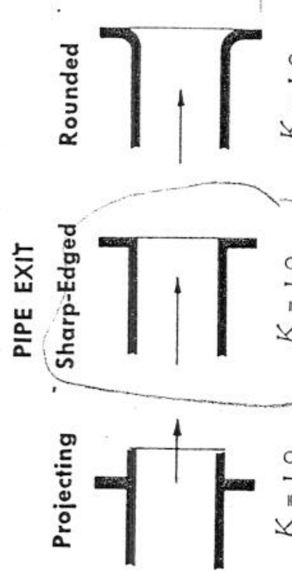
Y – NET EXPANSION FACTOR

Y ASSUMED FOR STEAM 1.3 [CRANE A21]

d – INTERNAL DIA 0.38 INCH

$K = 1.0$





$\bar{V}_1$ SPECIFIC VALUE OF FLUID IN $\frac{Ft^3}{lb}$

[CRANE PAGE A29]

$$\bar{V}_1 = 1.3267 \ \frac{Ft^3}{lb}$$

Nomenclature

Unless otherwise stated, all symbols used in this book are defined as follows:

A = cross sectional area of pipe or orifice, in square feet

a = cross sectional area of pipe or orifice, or flow area in valve, in square inches

B = rate of flow in barrels (42 gallons) per hour

C = flow coefficient for orifices and nozzles = discharge coefficient corrected for velocity of approach = $C_d / \sqrt{1-\beta^4}$

C_d = discharge coefficient for orifices and nozzles

C_V = flow coefficient for valves; expresses flow rate in gallons per minute of 60 F water with 1.0 psi pressure drop across valve

D = internal diameter of pipe, in feet

d = internal diameter of pipe, in inches

e = base of natural logarithm = 2.718

f = friction factor in formula $h_L = fLv^2/D\,2g$

f_T = friction factor in zone of complete turbulence

g = acceleration of gravity = 32.2 feet per second per second

H = total head, in feet of fluid

h = static pressure head existing at a point, in feet of fluid

h_g = total heat of steam, in Btu per pound

h_L = loss of static pressure head due to fluid flow, in feet of fluid

h_w = static pressure head, in inches of water

K = resistance coefficient or velocity head loss in the formula, $h_L = Kv^2/2g$

k = ratio of specific heat at constant pressure to specific heat at constant volume = c_p/c_v

L = length of pipe, in feet

L/D = equivalent length of a resistance to flow, in pipe diameters

L_m = length of pipe, in miles

M = molecular weight

MR = universal gas constant = 1545

n = exponent in equation for polytropic change ($p'V_a^n$ = constant)

P = pressure, in pounds per square inch gauge

P' = pressure, pounds per square inch absolute

(see page 1-5 for diagram showing relationship between gauge and absolute pressure)

p' = pressure, in pounds per square foot absolute

Q = rate of flow, in gallons per minute

q = rate of flow, in cubic feet per second at flowing conditions

q' = rate of flow, in cubic feet per second at standard conditions (14.7 psia and 60F)

q'_d = rate of flow, in millions of standard cubic feet per day, MMscfd

q'_h = rate of flow, in cubic feet per hour at standard conditions (14.7 psia and 60F), scfh

q_m = rate of flow, in cubic feet per minute at flowing conditions

q'_m = rate of flow, in cubic feet per minute at std. conditions (14.7 psia and 60F), scfm

R = individual gas constant = MR/M = $1545/M$

R_H = hydraulic radius, in feet

r_c = critical pressure ratio for compressible flow

S = specific gravity of liquids at specified temperature relative to water at standard temperature (60 F)

S_g = specific gravity of a gas relative to air = the ratio of the molecular weight of the gas to that of air

T = absolute temperature, in degrees Rankine ($460 + t$)

t = temperature, in degrees Fahrenheit

$\overline{V}$ = specific volume of fluid, in cubic feet per pound

V = mean velocity of flow, in feet per minute

V_a = volume, in cubic feet

v = mean velocity of flow, in feet per second

v_s = sonic (or critical) velocity of flow of a gas, in feet per second

W = rate of flow, in pounds per hour

w = rate of flow, in pounds per second

w_a = weight, in pounds

x = percent quality of steam = 100 minus per cent of moisture

Y = net expansion factor for compressible flow through orifices, nozzles, or pipe

Z = potential head or elevation above reference level, in feet

Greek Letters

Beta

β = ratio of small to large diameter in orifices and nozzles, and contractions or enlargements in pipes

Delta

$\triangle$ = differential between two points

Epsilon

ϵ = absolute roughness or effective height of pipe wall irregularities, in feet

Mu

μ = absolute (dynamic) viscosity, in centipoise

μ_e = absolute viscosity, in pound mass per foot second or poundal seconds per sq foot

μ'_e = absolute viscosity, in slugs per foot second or pound force seconds per square foot

Nu

ν = kinematic viscosity, in centistokes

ν' = kinematic viscosity, square feet per second

Rho

ρ = weight density of fluid, pounds per cubic ft

ρ' = density of fluid, grams per cubic centimeter

Theta

θ = angle of convergence or divergence in enlargements or contractions in pipes

Subscripts for Diameter

(1)... defines smaller diameter
(2)... defines larger diameter

Subscripts for Fluid Property

(1)... defines inlet (upstream) condition

STAGE I

$$W \frac{lbs}{min} = 1891(1.3)(d)^2 \sqrt{\frac{\Delta P}{K \bar{V}}}$$

$$4.28 = 2458.3 \left(d^2\right) \sqrt{\frac{\Delta P}{(1)(\bar{V})}}$$

$$0.38 \text{ in} = \frac{0.38}{12} = \underline{0.031} \text{ Ft}$$

$$4.28 = 2.465 \sqrt{\frac{\Delta P}{\bar{V}}}$$

$$\sqrt{\frac{\Delta P}{\bar{V}}} = 1.73$$

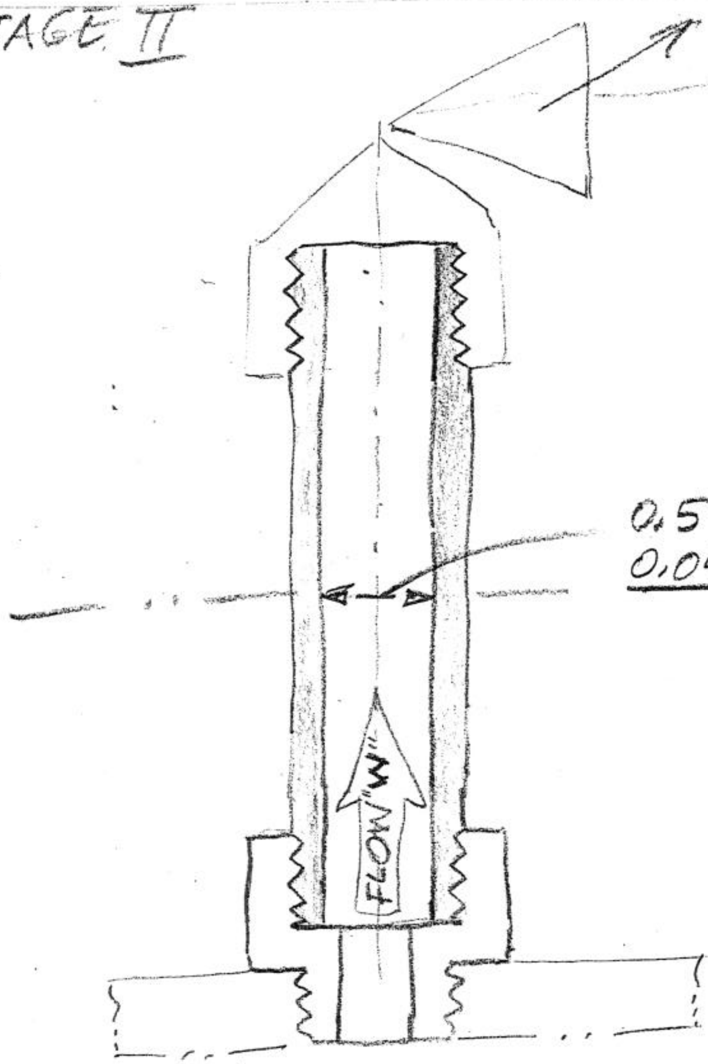
$$\frac{\Delta P}{\bar{V}} = (1.73)^2$$

$$\Delta P = (1.73)^2 (\bar{V})$$

$$\Delta P = 3.0144 (\bar{V})$$

$$\Delta P = \underline{3.99}$$

STAGE II



$$W = 4.28 \ \frac{lbs}{min}$$

$$4.28 = 1891(1.3)(0.0455)^2\sqrt{\frac{\Delta P}{(1)(\bar{V})}}$$

$$4.28 = 5.08\sqrt{\frac{\Delta P}{\bar{V}}}$$

$$\sqrt{\frac{\Delta P}{\bar{V}}} = 0.8409$$

$$\frac{\Delta P}{\bar{V}} = 0.7072$$

$$\Delta P = 0.533$$

LOSS AT STAGE I AND II

TOTAL :

$$\Delta P_T = 3.99 + 0.533$$
$$\Delta P_T = \underline{4.52}$$

COMPARING WITH THE SET PRESSURE

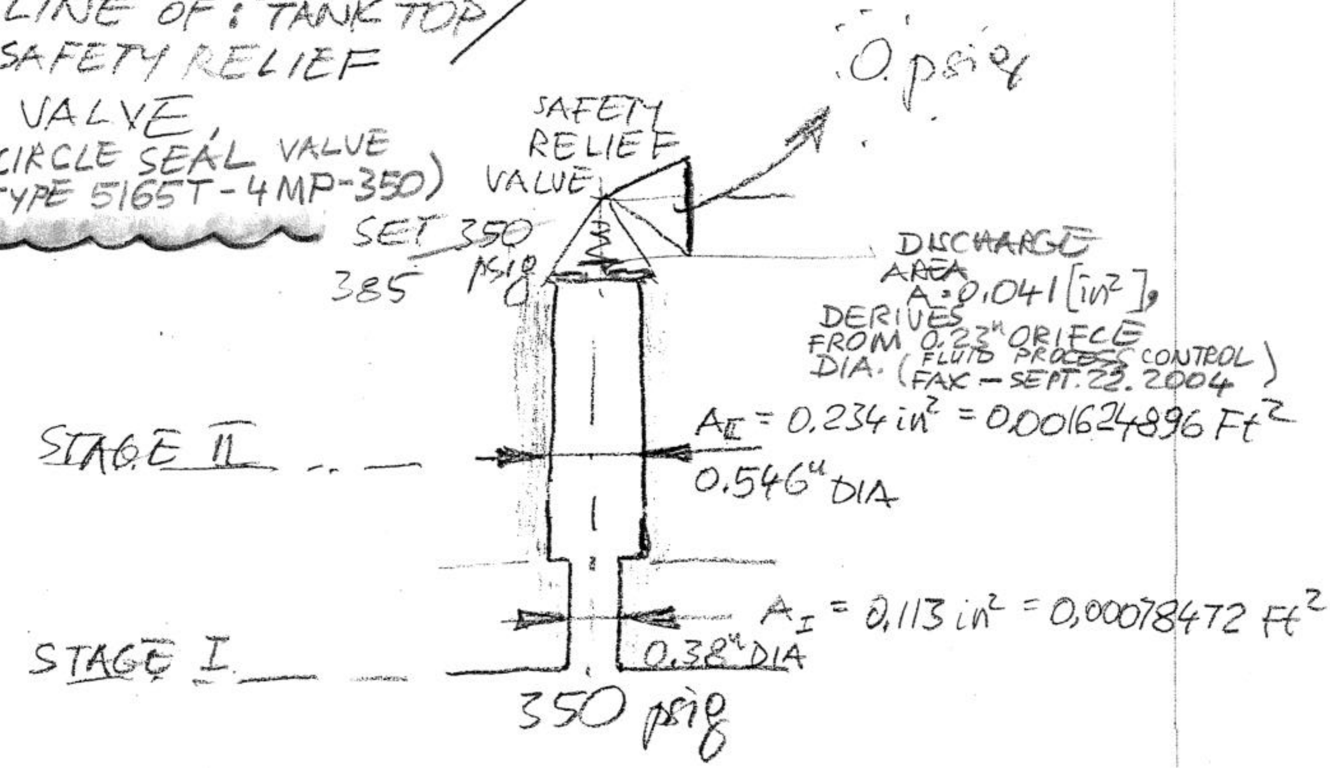
$$\begin{array}{l} 350 - 100\,\% \\ 4{,}52 - x \end{array}$$

$$x = \frac{4.52(100)}{350}$$

$$x = \underline{1{,}29}\ \%$$

O.K.

• CHECK THE PRESSURE DROP IN THE CONNECTING LINE OF : TANK TOP/ SAFETY RELIEF VALVE.
(CIRCLE SEAL VALUE TYPE 5165T-4MP-350)



AMOUNT OF THE STEAM GENERATED DURING THE FIRE CONDITION :

$$G = 115\ \frac{Ft^3}{min}$$ [APPENDIX 5 PAGE 24]

$$G = 115\ \frac{Ft^3}{60\ sec}$$

$$G = \underline{1.9166}\ \frac{Ft^3}{sec}$$ ⇒ MUST BE CONVERTED TO W

Compressible flow:

$$q'_h = 40\,700\ Yd^2 \sqrt{\frac{\Delta P\, P'_1}{K T_1 S_g}} \qquad \textit{Equation 3-20}$$

$$q'_h = 24\,700\ \frac{Yd^2}{S_g} \sqrt{\frac{\Delta P\, \rho_1}{K}}$$

$$q'_m = 678\ Yd^2 \sqrt{\frac{\Delta P\, P'_1}{K T_1 S_g}} = 412\ \frac{Yd^2}{S_g} \sqrt{\frac{\Delta P\, \rho_1}{K}}$$

$$q' = 11.30\ Yd^2 \sqrt{\frac{\Delta P P'_1}{K T_1 S_g}} = 6.87\ \frac{Yd^2}{S_g} \sqrt{\frac{\Delta P \rho_1}{K}}$$

$$w = 0.525\ Yd^2 \sqrt{\frac{\Delta P}{K \overline{V}_1}} \qquad \boxed{W = 1891\ Yd^2 \sqrt{\frac{\Delta P}{K \overline{V}_1}}}$$

Values of Y are shown on page A-22. For K, Y, and ΔP determination, see examples on pages 4-13 and 4-14.

"CRANE" TECHNICAL PAPER No 410 ... FLOW OF FLUIDS THROUGH VALVES, FITTINGS, AND PIPE

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

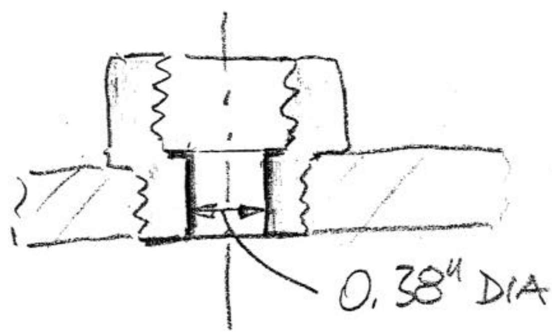
$$W = \frac{8.39}{\cancel{4.28}} \left[\frac{lbs}{min}\right]$$ [APPENDIX 5 PAGE 24]

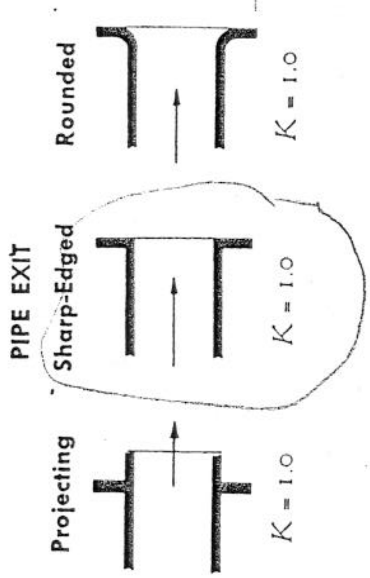
Y – NET EXPANSION FACTOR

Y ASSUMED FOR STEAM 1.3 [CRANE A21]

d – INTERNAL DIA 0.38 INCH

K = 1.0





$\bar{V}_1$ SPECIFIC VALUE OF FLUID IN $\frac{Ft^3}{lb}$

[CRANE PAGE A29]

$$\bar{V}_1 = 1.3267 \frac{Ft^3}{lb}$$

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M = molecular weight

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n = exponent in equation for polytropic change ($p'V_a^n$ = constant)

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P' = pressure, pounds per square inch absolute *(see page 1-5 for diagram showing relationship between gauge and absolute pressure)*

p' = pressure, in pounds per square foot absolute

Q = rate of flow, in gallons per minute

q = rate of flow, in cubic feet per second at flowing conditions

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q'_d = rate of flow, in millions of standard cubic feet per day, MMscfd

q'_h = rate of flow, in cubic feet per hour at standard conditions (14.7 psia and 60F), scfh

q_m = rate of flow, in cubic feet per minute at flowing conditions

q'_m = rate of flow, in cubic feet per minute at std. conditions (14.7 psia and 60F), scfm

R_H = hydraulic radius, in feet

r_c = critical pressure ratio for compressible flow

S = specific gravity of liquids at specified temperature relative to water at standard temperature (60 F)

S_g = specific gravity of a gas relative to air = the ratio of the molecular weight of the gas to that of air

T = absolute temperature, in degrees Rankine ($460 + t$)

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$\overline{V}$ = specific volume of fluid, in cubic feet per pound

V = mean velocity of flow, in feet per minute

V_a = volume, in cubic feet

v = mean velocity of flow, in feet per second

v_s = sonic (or critical) velocity of flow of a gas, in feet per second

W = rate of flow, in pounds per hour

w = rate of flow, in pounds per second

w_a = weight, in pounds

x = percent quality of steam = 100 minus per cent of moisture

Y = net expansion factor for compressible flow through orifices, nozzles, or pipe

Z = potential head or elevation above reference level, in feet

Greek Letters

Beta

β = ratio of small to large diameter in orifices and nozzles, and contractions or enlargements in pipes

Delta

Δ = differential between two points

Epsilon

ϵ = absolute roughness or effective height of pipe wall irregularities, in feet

Mu

μ = absolute (dynamic) viscosity, in centipoise

μ_e = absolute viscosity, in pound mass per foot second or poundal seconds per sq foot

μ'_e = absolute viscosity, in slugs per foot second or pound force seconds per square foot

Nu

ν = kinematic viscosity, in centistokes

ν' = kinematic viscosity, square feet per second

Rho

ρ = weight density of fluid, pounds per cubic ft

ρ' = density of fluid, grams per cubic centimeter

Theta

θ = angle of convergence or divergence in enlargements or contractions in pipes

Subscripts for Diameter

(1)...defines smaller diameter
(2)...defines larger diameter

STAGE. I

$$W \frac{lbs}{min} = 1891(1.3)(d)^2 \sqrt{\frac{\Delta P}{K \bar{V}}}$$

$$\cancel{4.28}\ 8.39 = 2458.3\,(d^2)\sqrt{\frac{\Delta P}{(1)(\bar{V})}}$$

$$0.38\ in = \frac{0.38}{12} = 0.031\ Ft$$

$$\cancel{4.28}\ 8.39 = \cancel{2.465}\ 51.52\sqrt{\frac{\Delta P}{\bar{V}}}$$

$$\sqrt{\frac{\Delta P}{\bar{V}}} = \cancel{1.73}\ 0.163$$

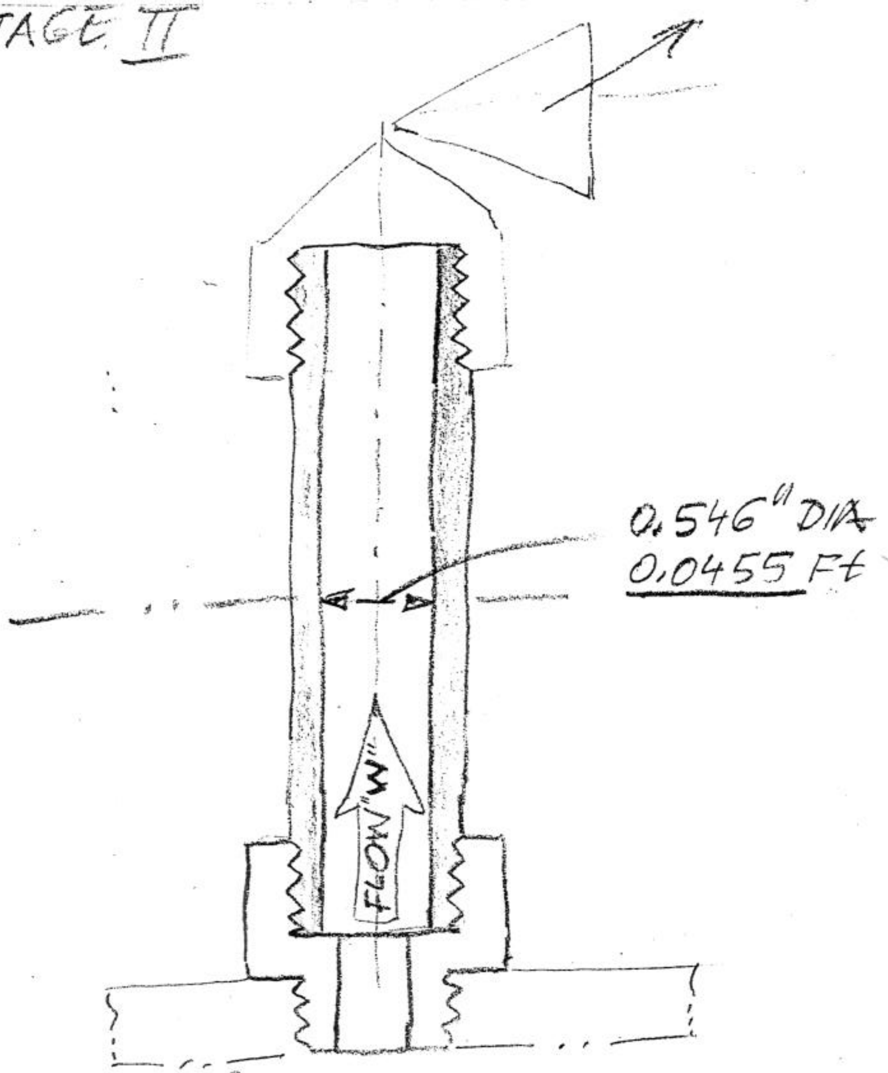
$$\frac{\Delta P}{\bar{V}} = (\cancel{1.73}\ 0.163)^2$$

$$\Delta P = (\cancel{1.73}\ 0.163)^2(\bar{V})$$

$$\Delta P = \cancel{3.0144}\ 0.026\,(\bar{V}\ 1.3267)$$

$$\Delta P = \cancel{3.99}\ 0.035\ [psig]$$

STAGE II



$$W = \cancel{4.28}\ 8.39\ \frac{lbs}{min}$$

$$\cancel{4.28}\ 8.39 = 1891(1.3)\left(\cancel{0.0455}\ 0.546\right)^2\sqrt{\frac{\Delta P}{(1)(\bar{V})}}$$

$$\cancel{4.28}\ 8.39 = \cancel{5.08}\ 732.85\sqrt{\frac{\Delta P}{\bar{V}}}$$

$$\sqrt{\frac{\Delta P}{\bar{V}}} = \cancel{0.8409}\ 0.011448$$

$$\frac{\Delta P}{\bar{V}} = \cancel{0.7072}\ 0.00013105$$

$$\Delta P = 0.00013105(1.3267)$$

LOSS AT STAGE I AND II

TOTAL :

$$\Delta P_T = \cancel{3.99}\ 0.035 + \cancel{0.533}\ 0.0001738$$

$$\Delta P_T = \cancel{4.52}\ 0.03534\ [psig]$$

COMPARING WITH THE SET PRESSURE

$$350 - 100\ \%$$

$$0.03534\ \cancel{4.52} - x$$

$$x = \frac{0.03534\ \cancel{4.52}\ (100)}{350}$$

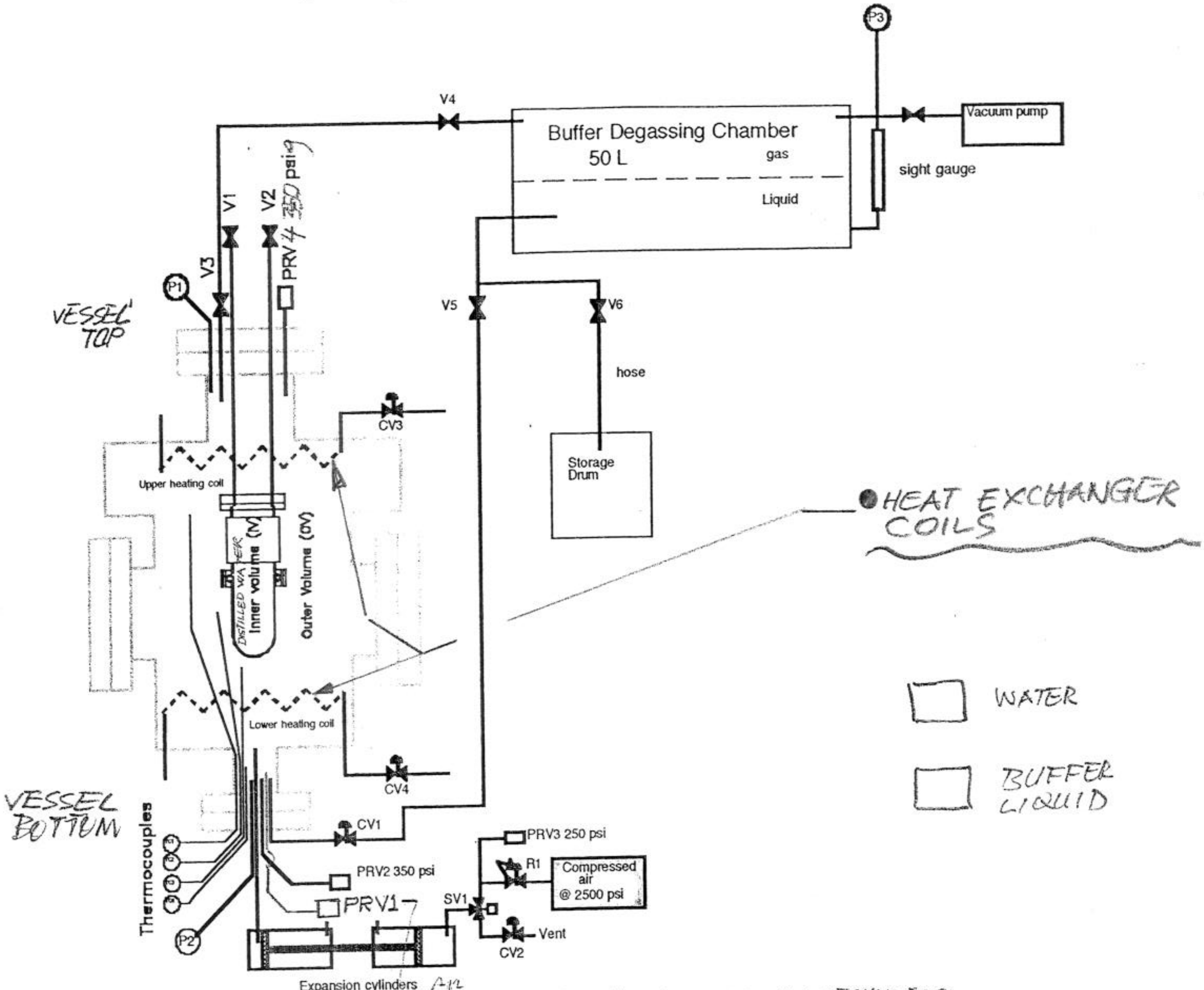
$$x = \cancel{1.29}\ 0.010099\ \%$$

O.K.

7. APPENDIX 6

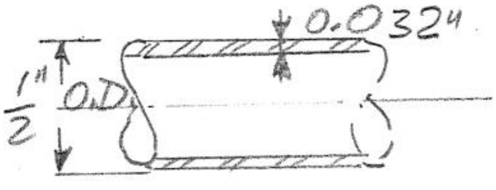
HEAT EXCHANGER COILS

Figure 2. Piping and Instrumentation for Buffer Filling.



450 [psig] RUPTURE PIN TECHNOLOGY
MODEL CASMF
SIZE 1"
CAPACITY 6167 SCFM

- TECHNICAL INFORMATION DATA
  - SOFT COPPER TUBING $\frac{1}{2}$" O.D. × 0.032" WALL
  - FERMILAB STOCK NO : 1065-007500



PAGE 2

 [MARK'S STANDARD HANDBOOK FOR MECHANICAL ENGINEERS]

Table 20. Sizes and Weights of Copper Tubes
(American Brass Co.)

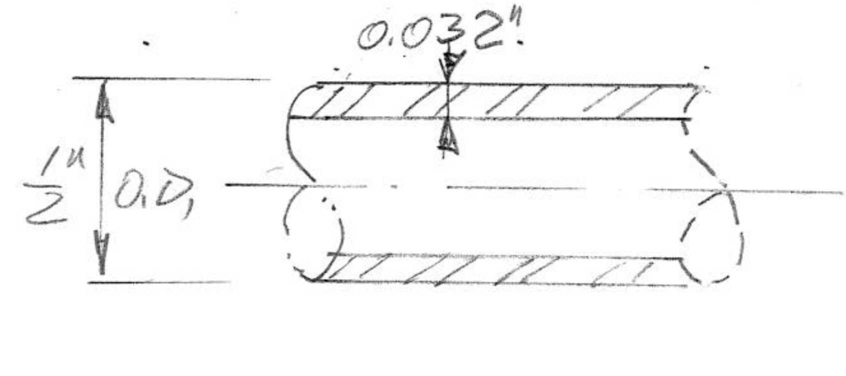
Nominal size, in	OD, in, types* K, L	ID, in Type K	ID, in Type L	Wall thickness, in Type K	Wall thickness, in Type L	Permissible variation of mean OD, in Types K, L Annealed	Permissible variation of mean OD, in Types K, L Hard-drawn	Weight,† lb/ft Type K	Weight,† lb/ft Type L
⅜	0.500	0.402	0.430	0.049	0.035	0.0025	0.001	0.269	0.198
½	0.625	0.527	0.545	0.049	0.040	0.0025	0.001	0.344	0.285
⅝	0.750	0.652	0.666	0.049	0.042	0.0025	0.001	0.418	0.362
¾	0.875	0.745	0.785	0.065	0.045	0.003	0.001	0.641	0.455
1	1.125	0.995	1.025	0.065	0.050	0.0035	0.0015	0.839	0.655
1¼	1.375	1.245	1.265	0.065	0.055	0.004	0.0015	1.04	0.884
1½	1.625	1.481	1.505	0.072	0.060	0.0045	0.002	1.36	1.14
2	2.125	1.959	1.985	0.083	0.070	0.005	0.002	2.06	1.75
2½	2.625	2.435	2.465	0.095	0.080	0.005	0.002	2.93	2.48
3	3.125	2.907	2.945	0.109	0.090	0.005	0.002	4.00	3.33
3½	3.625	3.385	3.425	0.120	0.100	0.005	0.002	5.12	4.29
4	4.125	3.857	3.905	0.134	0.110	0.005	0.002	6.51	5.38
5	5.125	4.805	4.875	0.160	0.125	0.005	0.002	9.67	7.61
6	6.125	5.741	5.845	0.192	0.140	0.005	0.002	13.9	10.2
8	8.125	7.583	7.725	0.271	0.200	0.006	0.003	25.9	19.3
10	10.125	9.449	9.625	0.338	0.250	0.008	0.004	40.3	30.1
12	12.125	11.315	11.565	0.405	0.280	0.008	0.004	57.8	40.4

*Type K recommended for underground service and general plumbing. Type L suitable for interior plumbing and other services.
†Multiply these values by 1.48 to obtain weight in kg/m.

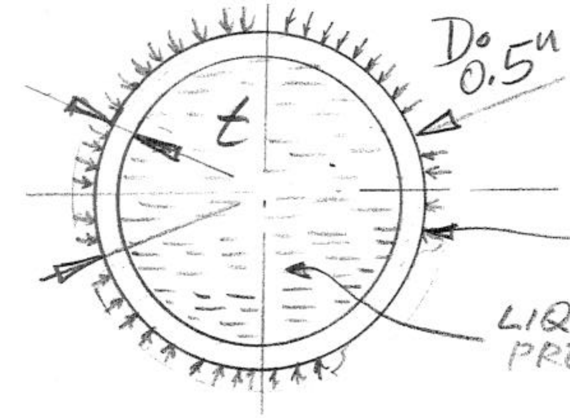
FERMILAB STOCK No 1065-007500

TUBING, COPPER. SOFT

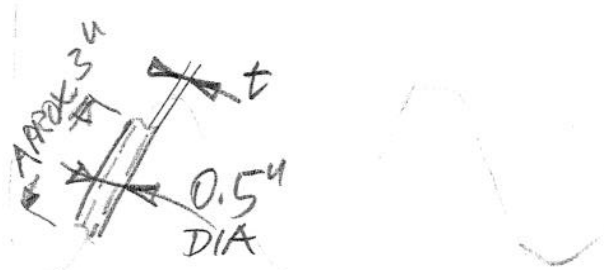
½" O.D. × 0.032" WALL



- DETERMINE THE REQUIRED MINIMUM THICKNESS OF THE COPPER TUBE



- THE INSTALLATION ASSEMBLY COMPRISES 3/8" NOMINAL, TYPE "L", SOFT COPPER TUBING.



- ASSUMED STRAIGHT SEGMENT OF THE TUBING $\sim 3"$

- $$\frac{D_o}{t} = \frac{0,5}{0,032} = 15$$

- DIFFERENTIAL PRESSURE p (EXTERNAL PRESSURE MINUS LIQUID INTERNAL PRESSURE)

$$p = 350 - 14.7$$

$$p = \underline{353.3}\ [psi]$$

$$p < p_c$$

PAGE4

REF : [1]

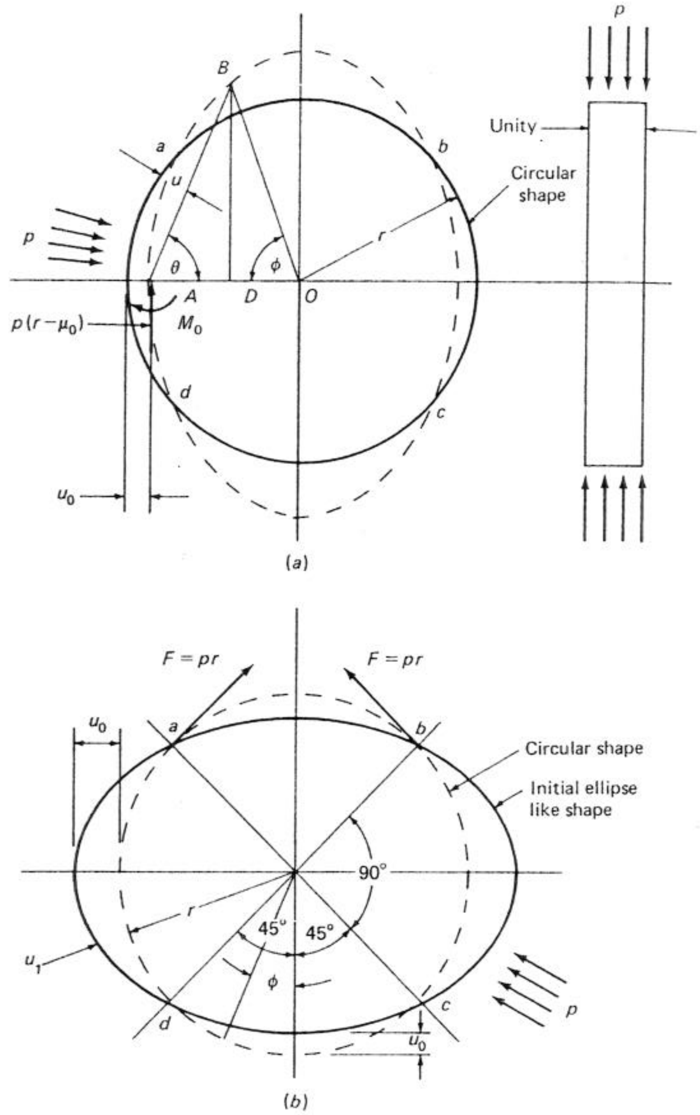


Fig. 8.4. (*a*) Cylindrical Ring under External Pressure During Buckling to Ellipselike Shape. (*b*) Cylinder with Initial Ellipticity under External Pressu

Substituting Eq. 8.2.23 in Eq. 8.2.18 gives

$$M = M_0 - pr(u_0 - u) \qquad (8.2.$$

Further, substituting Eq. 8.2.24 in Eq. 8.2.17 noting $d^2s = r^2$ gives

PAGE 5

REF.: [1]

Substituting Eq. 8.2.34 in Eq. 8.2.27 and noting $I = h^3/12$ gives

$$p_c = \frac{3EI}{r^3} = \frac{E}{4}\left(\frac{h}{r}\right)^3 = 2E\left(\frac{h}{d}\right)^3 \tag{8.2.35}$$

The value of p_c, Eq. 8.2.35, is the critical uniform buckling or collapsing pressure (force per unit area) for the ring shown in Fig. 8.4, where h is the thickness, r is the outside radius, and d is the outside diameter. The basic premise in thin vessel analysis is that the difference between the inside radius and the outside radius is nil. However; when the pressure is external, the pressure boundary is established by the outside surface dimensions and these are used in satisfying static equilibrium. Correspondingly, when vessels are subject to internal pressure, Chapter 2, the pressure boundary is established by the inside surface dimensions and these are used to satisfy static equilibrium. The factor 2 in Eq. 8.2.35 is compared to the approximate value of 2.67, Eq. 8.2.2, when the arc *ad* is assumed to act as a straight column.

In Eq. 8.2.32 k is the number of full sine waves around the periphery, and other roots, such as, $k\pi/2 = 2\pi$, 3π, etc., correspond to a larger number of waves in the buckled ring and a greater value of the critical pressure, Eq. 8.2.27. Thus,

$$p_c = \frac{EI}{r^3}(k^2 - 1) = \frac{EI}{r^3}(0, 3, 8, 15, \cdots)$$
$$\text{for} \quad k = 1, 2, 3, 4, \cdots \tag{8.2.36}$$

Mathematically, $k = 1$ means a small displacement of the undistorted ring which is in equilibrum without pressure.[3] At a value of $k = 2$ the ring goes into a two-lobe or ellipselike shape for the minimum critical pressure. Higher modes[4] of buckling gives higher critical pressures, Fig. 8.2, and the design method for obtaining this increased stability is through fastened ends, structured stiffeners, diaphragms, closure heads, or bends, Fig. 8.1*b*.

3. *Buckling of Long Cylinders or Tubes*

The theory of buckling for a circular ring can also be used for long cylinders or tubes subjected to external pressure because the ring may be considered cut from a long cylinder by two cross sections a unit distance apart,[5] Fig. 8.4*a*. Since the cross section of the long cylinder will not be distorted during ring bending, it is only necessary to substitute for the ring rigidity, EI, the comparable plate flexural

$$pc = 2E\left(\frac{0.032}{0.5}\right)^3$$

$$pc = 2(E)(0.000262144)$$

REF. [2]

Table 3. Elastic Constants of Metals
(Mostly from tests of R. W. Vose)

Metal	E Modulus of elasticity (Young's modulus). 1,000,000 lb/in²	G Modulus of rigidity (shearing modulus). 1,000,000 lb/in²	K Bulk modulus. 1,000,000 lb/in²	μ Poisson's ratio
Cast steel	28.5	11.3	20.2	0.265
Cold-rolled steel	29.5	11.5	23.1	0.287
Stainless steel 18–8	27.6	10.6	23.6	0.305
All other steels, including high-carbon, heat-treated	28.6–30.0	11.0–11.9	22.6–24.0	0.283–0.292
Cast iron	13.5–21.0	5.2–8.2	8.4–15.5	0.211–0.299
Malleable iron	23.6	9.3	17.2	0.271
Copper	15.6	5.8	17.9	0.355
Brass, 70–30	15.9	6.0	15.7	0.331
Cast brass	14.5	5.3	16.8	0.357
Tobin bronze	13.8	5.1	16.3	0.359
Phosphor bronze	15.9	5.9	17.8	0.350
Aluminum alloys, various	9.9–10.3	3.7–3.9	9.9–10.2	0.330–0.334
Monel metal	25.0	9.5	22.5	0.315
Inconel	31	11		
Z-nickel	30	11		
Beryllium copper	17	7		
Elektron (magnesium alloy)	6.3	2.5	4.8	0.281
Titanium (99.0 Ti), annealed bar	15–16			
Zirconium, crystal bar	11–14			
Molybdenum, arc-cast	48–52			

$$P_e = 2(15600000)(0.000262144)$$

$$P_c = 8{,}178.8 \; [psi]$$

REFERENCES:

1. THEORY AND DESIGN OF PRESSURE VESSELS
JOHN F. HARVEY, P.E.
VAN NOSTRAND REINHOLD COMPANY
NEW YORK

2. MARKS' STANDARD HANDBOOK FOR MECHANICAL ENGINEERS
EIGHTH EDITION

8. APPENDIX 7

- OBSERVATION PORT WINDOW / TECHNICAL INFORMATION

THE WINDOW IS RATED FOR 600 psi
AT TEMP 450 °F

MAWP OF THE VESSEL IS 600 psi
AT 100 °F
AND 480 psi AT 230 °F

AT NORMAL OPERATING CONDITIONS THE
VESSEL WILL OPERATE BELOW
450 psig AND TEMPERATURE
OF ______ °F .

SZYMULAN

From: "Andrew Sonnenschein" <Sonnenschein@cfcp.uchicago.edu>
To: "SZYMULAN" <SZYMULAN@FNAL.GOV>
Sent: Tuesday, October 19, 2004 2:20 PM
Attach: Canty Siteglass.pdf; Canty SG rivised dimensions.pdf
Subject: Re: observation port window

Hi Andrew,

The window assembly was purchased. I am attaching a data sheet. We have the 6 inch site glass rated to 600 psi.

Please let me know if you need more than this. We are relying on the manufacturer's claims about the design and have not done any engineering analysis.

Andrew

On Oct 19, 2004, at 2:08 PM, SZYMULAN wrote:

> Hi Andrew,
> Dave Pushka,who is reviewing the engineering note,pointed out on lack
> of
> engineering calculations for the window assembly.
> As I understand ,this part was done by the U of Chicago.
> Do you have any calculations for this?
> If no,please give us the essential technical data for checking the
> stresses,or give the
> technical parameters if the item was purchased.
>
>
> Regards,
>
> Andrew
>

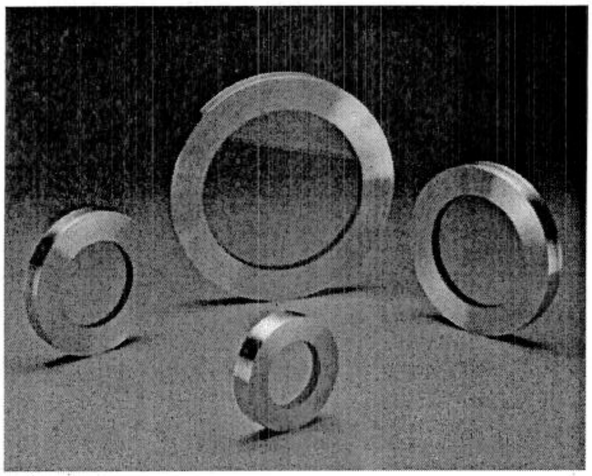
----
home page: http://cfcp.uchicago.edu/~sonnenschein

PAGE 3

CANTY

PROCESS TECHNOLOGY

FUSEVIEW™ ANSI/DIN SIGHT GLASS



THE CANTY ADVANTAGE

J.M. Canty Fuseview™ sight glasses have been engineered to meet all your process and safety needs. All standard Fuseviews™ feature Factory Mutual approval and were designed and tested to ensure the safest product available. Canty can provide certification of material and testing if required, typical of ASME code requirements for process vessels.

UNMATCHED SAFETY, RELIABILITY

All Canty sight glasses feature the Fuseview™ window. Our unique fused glass windows far exceed all conventional tempered glass windows in safety and performance. By fusing glass to metal, a high pressure, high safety, hermetic seal is formed. The fused glass technology ensures safety with every Fuseview™. What's more, our windows can easily be removed for cleaning. Canty windows do not have to be discarded, as do traditional tempered glass windows. Canty fused glass windows can be re-used again and again.

FM

APPROVED

FEATURES

- Standard models are *FM approved !*
- Stainless steel, carbon steel, alloy C, C276, and C22 fusing ring
- 150# through 1500#, 10 bar through 40 bar models
- Special pressures through 10,000 PSI are available
- Standard temperatures to 650°F, specials to 2000°F
- Specials available to retrofit any existing sight glass
- Quartz and Sapphire faced Fuseviews™ for caustic service
- Glass wetted models for glass lined vessels
- Straight thread or NPT Fuseviews™ for threaded connections

UNIQUE OPTIONS

- Dual fused glass option - for high temperature applications
- Lighting - Flex bundle light available to eliminate the need for a second nozzle
- Canty Jet spray ring - used for cleaning or cooling
- Tri-clamp® one piece Fuseview™ for sanitary processes

ADVANTAGES OF THE FUSEVIEW™

- *Standard models feature FM approval !*
- Extremely high strength due to radial compression on the hermetically sealed glass
- Eliminates chance of catastrophic failure due to bolt-up
- Very high impact strength and thermal shock resistance due to prestressing
- Operates under positive or negative pressure
- Certification on material and pressure rating is available, typical of ASME code requirements

CANTY FUSEVIEW™ VS. OTHERS

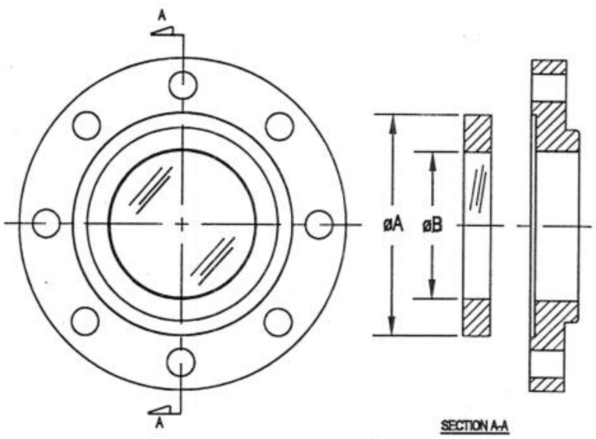
- No bolt loading on glass. All the load is carried by the fusing ring so you can use whatever torque you need as specified by the gasket manufacturer and your process.
- The Fuseview™ sight glass allows the use of standard process gasketing. No special gaskets are required.
- Canty Fuseviews™ may be removed for cleaning and inspection. This is not allowed with ordinary glass, due to residual stresses incurred at bolt-up.
- No loss of glass temper over time!
- Scratches do not affect safety or life.
- Unlike tempered glass, a Fuseview™ will not blow out if the surface is damaged.
- No shims, packing, or adjusting screws to worry about
- Canty mounts to standard ANSI or DIN dimensions

PAGE 4

Dimensional Information

ANSI Dimensions

SIZE	A	VIEW B	PRESSURE RATING PSI	TEMP RATING °F
1"	2.000	1.125	150/300/600	450
1.5"	3.000	1.500	150/300/600	450
2"	3.625	2.125	150/300/600	450
2.5"	4.000	2.500	150/300/600	450
3"	5.000	3.000	150/300/600	450
4"	6.000	4.000	150/300/600	450
5"	7.500	5.000	150/300/600	450
6"	8.375	6.000	150/300/600	450
8"	10.500	8.000	150/300	400
10"	12.000	9.500	50	300



DIN Dimensions

SIZE mm	A	VIEW B	PRESSURE RATING BAR	TEMP RATING °C
25	68	38	10/16/25/40	232
32	78	38	10/16/25/40	232
40	88	51	10/16/25/40	232
50	92	51	10/16/25/40	232
65	122	76	10/16/25/40	232
80	127	76	10/16/25/40	232
100	152	102	10/16/25/40	232
125	190	127	10/16/25/40	232
150	213	152	10/16/25/40	232
200	267	203	10/16	204
250	305	241	10	150

FM
APPROVED

Retrofit Cartridge Dimensions

SIZE	A	VIEW B	PRESSURE RATING PSI	TEMP RATING °F
2"	3.000	2.000	150/300/600	450
2.5"	4.500	2.500	150/300/600	450
3"	4.800	3.000	150/300/600	450
4"	5.900	4.000	150/300/600	450
4.5"	6.500	4.500	150/300/600	450
4.5"	6.750	4.500	150/300/600	450
4.5"	6.890	4.500	150/300/600	450
4.5"	7.000	4.500	150/300/600	450
5.6"	7.875	5.600	150/300	450
7.0"	9.500	7.000	150	400
7.3"	9.813	7.300	150	400

Ordering Information

HOW TO ORDER: Select the appropriate symbols and build a model number as shown:

EXAMPLE: HC - 4 - FV150 - NF - 5.9OD

WINDOW MATERIAL
CS = CARBON STEEL
SS = 316L STAINLESS STEEL
HC = ALLOY C
C276 = ALLOY C276
C22 = ALLOY C22

SIZE
ANSI - 1", 1.5", 2", 2.5", 3", 4", 5", 6", 8", 10"
DIN - 25, 40, 50, 65, 80, 100, 125, 150, 200, 250 mm
ANSI - 2", 2.5", 3", 4", 4.5", 5.6", 7", 7.3"

OUTSIDE DIAMETER - "A" (CARTRIDGE ONLY)

RETAINING FLANGE
CS = CARBON STEEL
SS = STAINLESS STEEL
NF = NO FLANGE

PRESSURE

ANSI	DIN
150 = 150 PSI	10 = 10 BAR
300 = 300 PSI	16 = 16 BAR
600 = 600 PSI	25 = 25 BAR
	40 = 40 BAR

JM CANTY INC.
Buffalo, NY USA
Ph:(716) 625 - 4227
Fax:(716) 625 - 4228

JM CANTY LTD.
Dublin, Ireland
Ph:+353 (01) 459 8808
Fax:+353 (01) 462 5133

sales@jmcanty.com

Represented by:

Document #98A7652 Rev. 1121099

FUSEVIEW FLAT GASKET CARTRIDGES

ORDERING INFORMATION - PART NUMBER

	MODEL	PRESSURE	SIZE	FUSEVIEW MATL. WETTED	FUSING GLASS WETTED	LAMINATING MATERIAL	RETAINER MATERIAL	TEMP.	OUTER FUSEVIEW MATL.
S	1				1	0	0	A	0
	1) FV	A=150 PSI B=300 PSI * D=600 PSI	VIEW / O.D. B) 1.00" / 2.00" C) 1.50" / 3.00 D) 2.00" / 3.00" E) 2.00" / 3.63" F) 2.50: / 4.00" G) 2.50" / 4.50" H) 3.00" / 5.00" I) 3.50" / 5.50" J) 4.00" / 6.00" K) 4.00" / 5.90" L) 4.50" / 6.50" VIEW / O.D. M) 4.50" / 6.75" N) 4.50" / 6.89" O) 4.50" / 7.00" P) 5.00" / 7.50" Q) 5.62" / 7.87" R) 6.00" / 8.38" S) 7.00" / 9.50" T) 7.30" / 9.8" U) 7.50" / 10.00" V) 8.00" / 10.50" W) 9.50" / 12.00"	A = CS B = SS C = HC D = C276 E = C22	1 = BORO PLUS	0 = NONE	0 = NONE	A = < 450°F	0 = NONE

MODEL NUMBER

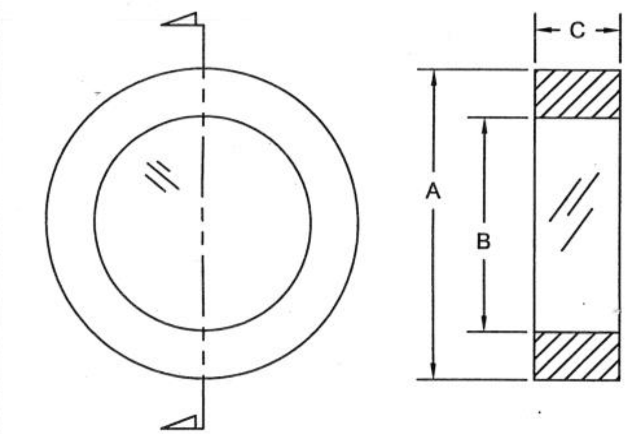
__ - __ - FV __ - NF

WINDOW MATERIAL — SIZE — PRESSURE — NO RETAINING FLANGE

LEGEND
C276=ALLOY C276
HC=ALLOY C
C22=ALLOY C22
SS=316L STAINLESS STEEL
CS=CARBON STEEL

EXAMPLE:
P/N S1AJE100A0 = MODEL C22-4-FV150-NF

FM
APPROVED



VARIABLE DIMENSION SPECIFICATIONS

SIZE	A	VIEW B	C	PRESSURE RATING PSI
1"	2.000	1.125	.750	150/300/600
1. 5"	3.000	1.500	.750	150/300/600
2"	3.000	2.125	.750	150/300/600
2"	3.625	2.125	.750	150/300/600
2.5"	4.000	2.500	.750	150/300
2.5"	4.500	2.500	.750	150/300/600
3"	5.000	3.000	.750	150/300
3"	5.000	3.000	.90	600
3.5"	5.500	3.500	.750	150/300
4"	5.900	4.000	.750	150
4"	6.000	4.000	.750	150
4"	6.000	4.000	.90	300/600
4.5"	6.500	4.500	.750	150/300
4.5"	6.750	4.500	.750	150/300
4.5"	6.889	4.500	.750	150/300

SIZE	A	VIEW B	C	PRESSURE RATING PSI
4.5"	7.000	4.500	.750	150/300
5"	7.500	5.000	.750	150
5"	7.500	5.000	.90	300/600
5. 6"	7.875	5.625	.750	150
5. 6"	7.875	5.625	.90	300/600
6"	8.375	6.000	.750	150
* 6"	8.375	6.000	.90	300/600 *
7"	9.500	7.000	.750	150
7"	9.500	7.000	1.000	300
7.25"	9.813	7.313	.750	150
7.25"	9.813	7.313	1.000	300
7.5"	10.000	7.500	1.000	150/300
8"	10.500	8.000	1.000	150/300
10"	12.000	9.500	1.000	150/300

NOTE:
1. VARIOUS MODELS ARE FM APPROVED SEE DRAWING 94A5064.
2. CARBON STEEL SIGHTGLASSES ARE NICKEL PLATED.
3. ALL SIZES 3" AND LARGER AVAILABLE IN ALLOY C.
4. INFORMATION SUBJECT TO CHANGE WITHOUT NOTICE.

DRAWN BY	KAZ	DATE	02-21-94
APPROVAL	RFM	DATE	02-21-94
ENGINEERING ANALYSIS	CURRENT	DATE	
MFG. APPROVAL	PENDING	DATE	
QUALITY CONTROL	I.O.A.	DATE	

J.M. CANTY INC.
6100 DONNER RD.
BUFFALO, N.Y. 14094
U.S.A.

CANTY
WWW.JMCANTY.COM

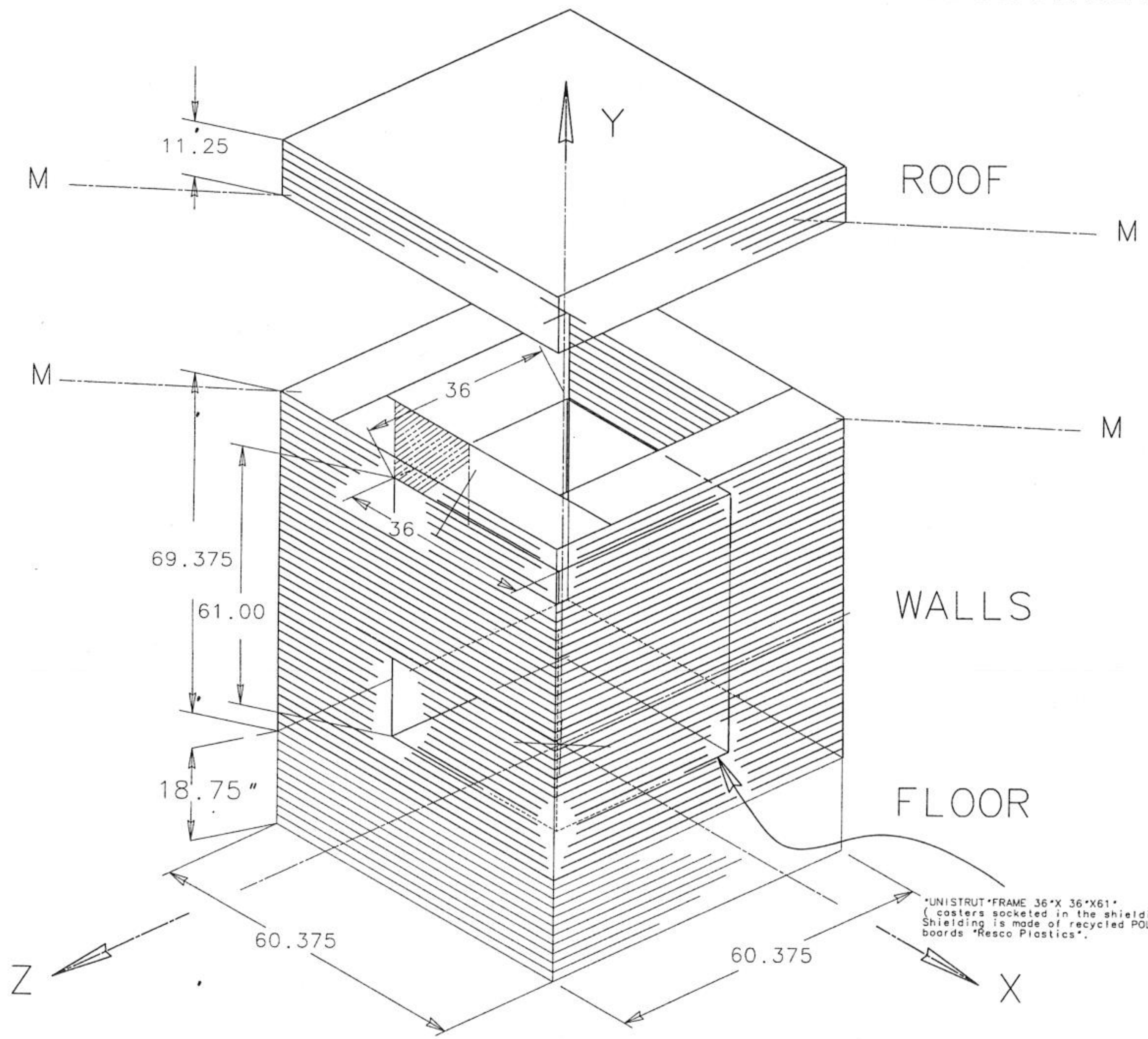
J.M. CANTY INTL. LTD.
BALLYCOOLIN BUS. PK.
BLANCHARDSTOWN
DUBLIN 15, IRELAND

TITLE: FUSEVIEW CARTRIDGE ORDERING INFO. & SPECIFICATIONS

SIZE: C | REVISION: 9 | FILE NAME: 94C5070

SCALE: N.T.S. | SHEET 1 OF 1

PAGE 5



"UNISTRUT"FRAME 36"X 36"X61"
(casters socketed in the shielding).
Shielding is made of recycled POLYETHYLENE
boards "Resco Plastics".

NOV. 19, 2004

ORIGINATOR: A.SZ.

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

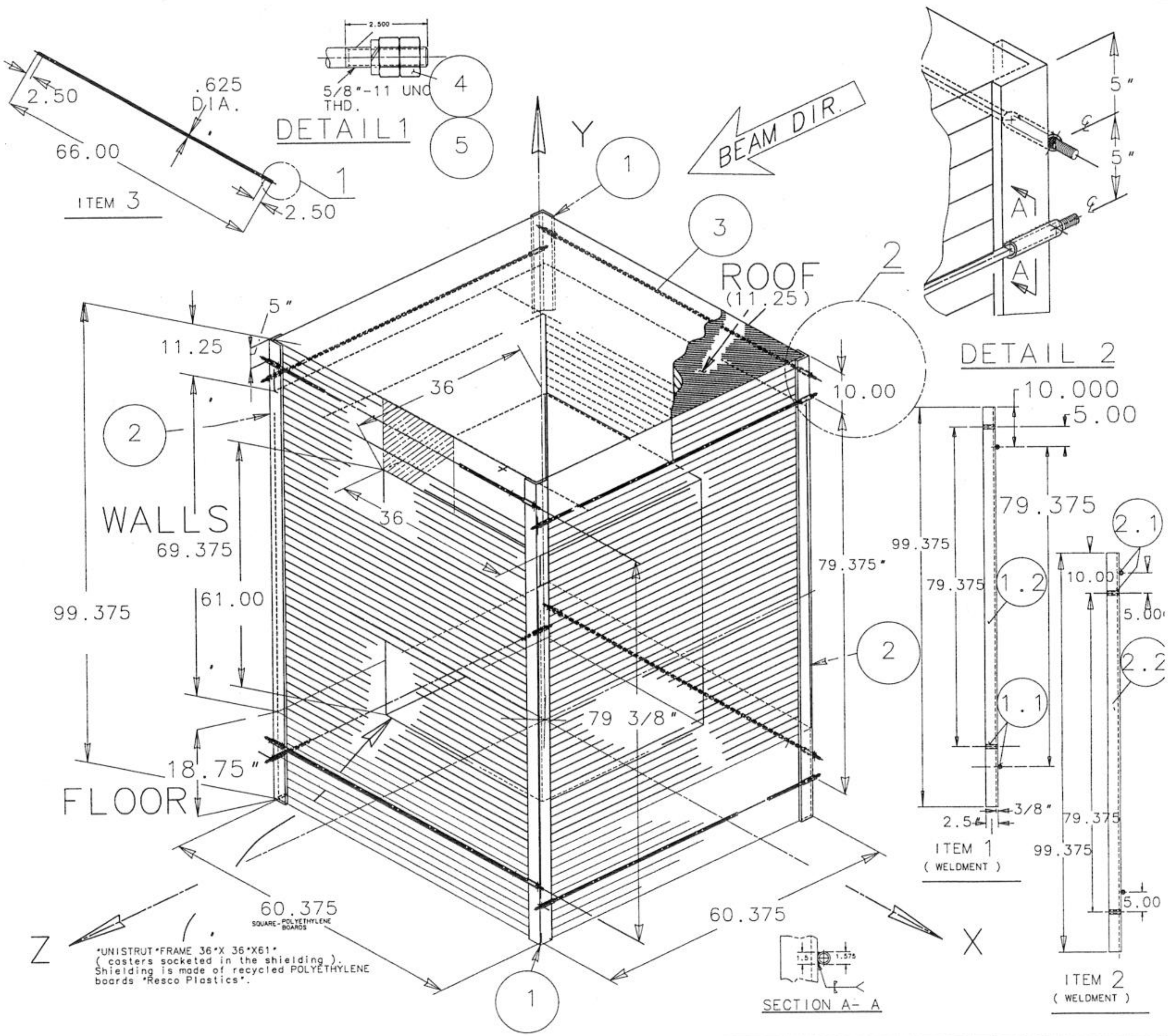
UNIVERSITY OF CHICAGO
1 LITER BUBBLE CHAMBER
SHIELDING

DRAWING NUMBER: SKETCH ASZ 11.19.04

SHEET 1 OF 1

12-FRONT

Plotted by aszymulan on 19-Nov-04 . File: 1Lbubblechshielding.plt



NOTES:
1. ITEM 4
McMASTER CARR CAT. PART NO : 91694A320
2. ITEM 5
McMASTER CARR CAT. PART NO : 90073A240

ITEM	MATERIAL	DESCRIPTION	Q'TY
5		5/8" SPRING LOCK WASHER 0.24 " THICK	16
4	ASTM A563 GRADE DH	5/8" -11 UNC HEX NUT	32
3		STEEL ROD 5/8" DIA X 66" LG.	8
2.2	ASTM-A36	ANGLE 2 1/2" X 2 1/2" X 3/8"wall X 99.375 "LG.	2
2.1	ASTM-A53	PIPE 1.050" O.D. X 0.154"WALL X 2.625" LG.	8
2		WELDMENT	2
1.2	ASTM-A36	ANGLE 2 1/2" X 2 1/2" X 3/8"wall X 99.375 "LG.	2
1.1	ASTM-A53	PIPE 1.050" O.D. X 0.154"WALL X 2.625" LG.	8
1		WELDMENT	2

ORIGINATOR A.SZ.
DRAWN A.SZ. DEC.03.04

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

UNIVERSITY OF CHICAGO
1 LITER BUBBLE CHAMBER
SHIELDING /RESTRAIN COMP.

DRAWING NUMBER SKETCH:asz12.03.04 SHEET 1 OF 1

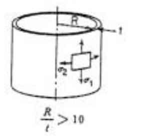
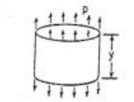
Plotted by szymulan on 08-Dec-04 , File: 1LBBLCHCOMPONENTS.pff

REF [1]
FORMULAS FOR STRESS AND STRAIN
FIFTH Edition
R.J. ROARK AND W.C. YOUNG

BELLOW INSIDE QUARTZ VESSEL

TABLE 29 *Formulas for membrane stresses and deformations in thin-walled pressure vessels*

NOTATION: P = axial load (pounds); p = unit load (pounds per linear inch); q and w = unit pressures (pounds per square inch); δ = density (pounds per cubic inch); σ_1 = meridional stress (pounds per square inch); σ_2 = circumferential, or hoop, stress (pounds per square inch); R_1 = radius of curvature of a meridian, a principal radius of curvature of the shell surface (inches); R_2 = length of the normal between the point on the shell and the axis of rotation, the second principal radius of curvature (inches); R = radius of curvature of a circumference (inches); ΔR = radial displacement of a circumference (inches); Δy = change in the height dimension y (inches); ψ = rotation of a meridian, positive when ΔR increases with y (radians); E = modulus of elasticity (pounds per square inch); and ν = Poisson's ratio. *Note:* y is considered positive upward where applicable.

Case no., form of vessel	Manner of loading	Formulas
1. Cylindrical  $\frac{R}{t} > 10$	1a. Uniform axial load, p lb/linear in 	$\sigma_1 = \frac{p}{t}$ $\sigma_2 = 0$ $\Delta R = \frac{-p\nu R}{Et}$ $\Delta y = \frac{py}{Et}$ $\psi = 0$
	1b. Uniform radial pressure, q lb/in² 	$\sigma_1 = 0$ $\sigma_2 = \frac{qR}{t}$ $\Delta R = \frac{qR^2}{Et}$ $\Delta y = \frac{-qR\nu y}{Et}$ $\psi = 0$
	1c. Uniform internal or external pressure, q lb/in² (ends capped)	At points away from the ends $\sigma_1 = \frac{qR}{2t}$ $\sigma_2 = \frac{qR}{t}$ $\Delta R = \frac{qR^2}{Et}\left(1 - \frac{\nu}{2}\right)$ $\Delta y = \frac{qRy}{Et}(0.5 - \nu)$ $\psi = 0$

1c) VERSION I — SIMPLIFIED APPROACH
* ASSUMED AS A SMALL PIECE OF A CYLINDER

$\sigma_1 = 0$

$$\sigma_2 = \frac{q \cdot R}{2t}$$

$t = 2 \times 0.005$
$t = 0.010''$
$R = \frac{4.77}{2} - 0.010$
$R = 2.375''$
$q = 14.5$ psi

$$\sigma_2 = \frac{(14.5)(2.375)}{0.010}$$

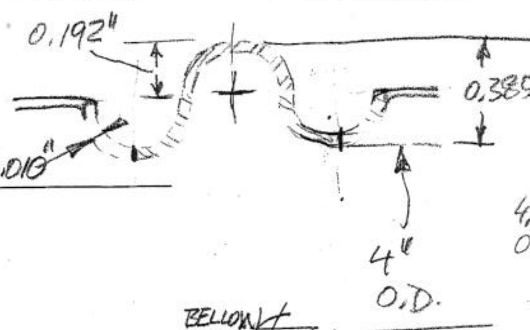
$$\sigma_2 = 3,443.75 \ [psi]$$

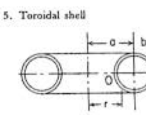
ASME
MICL'S [1.3]

$$S = \frac{P \cdot D}{2t} = \frac{14.5(4.77)}{2(0.010)}$$

3,458.2 [psi]

VERSION II —



Case no., form of vessel	Manner of loading	Formulas
5. Toroidal shell  $\frac{b}{t} > 10$	5a. Uniform internal or external pressure, q lb/in²	$\sigma_1 = \frac{qb}{2t}\frac{r+a}{r}$ $\text{Max } \sigma_1 = \frac{qb}{2t}\frac{2a-b}{a-b}$ at point O $\sigma_2 = \frac{qb}{2t}$ (throughout) $\Delta r = \frac{qb}{2Et}[r - \nu(r+a)]$ [*Note:* There are some bending stresses at the top and bottom where R_2 (see case 4) is infinite (see Ref. 52)]

4.77"

a = 2 + 0.385

a = 2.385"   b = 0.192"

q = 14.5 [psi]

$$\sigma_2 = \frac{14.5\,(0.192)}{2\,(0.010)}$$

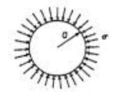
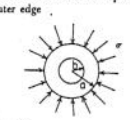
$$\sigma_2 = 139.2 \ [psi]$$

TABLE 35 *Formulas for elastic stability of plates and shells*

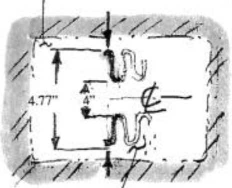
NOTATION: E = modulus of elasticity; ν = Poisson's ratio; and t = thickness for all plates and shells. All dimensions are in inches, all forces are in pounds, and all angles are in radians. Compression is positive; tension is negative

VERSION III

TABLE 35 *Formulas for elastic stability of plates and shells* (*Cont.*)

Form of plate or shell and manner of loading	Manner of support	Formulas for critical unit compressive stress σ', unit shear stress τ', load P', bending moment M', or unit external pressure q' at which elastic buckling occurs
11. Isotropic circular plate under uniform radial edge compression 	11a. Edges simply supported	$\sigma' = 0.35\frac{E}{1-\nu^2}\left(\frac{t}{a}\right)^2$ (Ref. 1)
	11b. Edges clamped	$\sigma' = 1.22\frac{E}{1-\nu^2}\left(\frac{t}{a}\right)^2$ (Ref. 1) For elliptical plate with major semiaxis a, minor semiaxis b, $\sigma' = K\frac{E}{1-\nu^2}\left(\frac{t}{b}\right)^2$, where K has values as follows: $\frac{a}{b}$ = 1.0 1.1 1.2 1.3 2.0 5.0 K = 1.22 1.13 1.06 1.01 0.92 0.94 (Ref. 21)
12. Circular plate with concentric hole under uniform radial compression on outer edge  $\frac{a}{t} > 10$	12a. Outer edge simply supported, inner edge free	$\sigma' = K\frac{E}{1-\nu^2}\left(\frac{t}{a}\right)^2$ Here K depends on $\frac{b}{a}$ and is given approximately by following table: $\frac{b}{a}$ = 0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 K = 0.35 0.33 0.30 0.27 0.23 0.21 0.19 0.18 0.17 0.16 (Ref. 1)
	12b. Outer edge clamped, inner edge free	$\sigma' = K\frac{E}{1-\nu^2}\left(\frac{t}{a}\right)^2$ Here K depends on $\frac{b}{a}$ and is given approximately by following table: $\frac{b}{a}$ = 0 0.1 0.2 0.3 0.4 0.5 K = 1.22 1.17 1.11 1.21 1.48 2.07 (Ref. 1)

QUARTZ VESSEL



VACUUM OR 14.5 psi

$$b = 2''$$

$$a = 2.385''$$

$$t = 0.010''$$

$$\frac{a}{t} = \frac{2.385}{0.010} = 238.5$$

$$\frac{b}{a} = \frac{2}{2.385} = 0.8385$$

$$K = 0.17$$

$$\sigma_1 = (0.17)\,\frac{30{,}000{,}000}{1-(0.3)^2}\left(\frac{0.010}{2.385}\right)^2$$

$$\sigma_1 = \frac{0.17\,(30{,}000{,}000)}{0.91}\,(0.00001758)$$

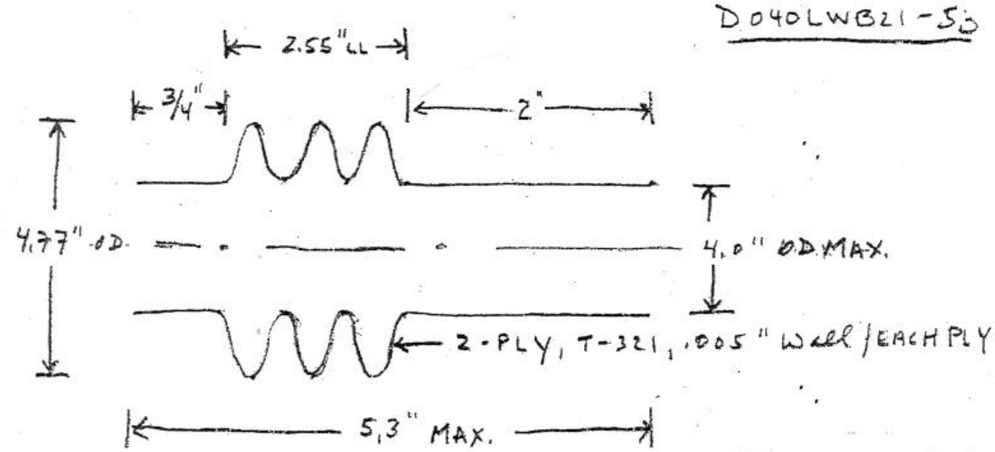
$$\sigma_1 = \underline{98.52}\ [\text{psi}]$$

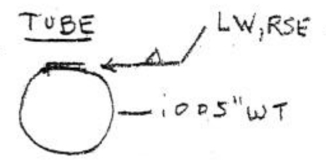
ACTUAL PRESSURE, SORROUNDING BELLOW IS 14.5 psi

$\sigma_1 > 14.5$

O.K.

D040LWB21-5





SINGLE LAP-WELDED

OD, cuff, 4.00" max.
Length of cuffs - one end 3/4", other end = 2.00"
Overall length of assembly - 5.3"
Live length of bellows - 2.55"
OD of Bellows - 4.77"
Motion - .10" axial
Material - T-321 stainless steel
Bellows - Resistance lap welded - no filler metals / no consumable electrode
Construction - Two Ply (telescoped together with opposing welds), both lap welded
Cuffs - extended necks from original tube (not added or welded on)
Ply thickness - .005" wall
Pressure - at least to requirements (Internal pressure 15 psig/ External pressure 10 psig)
Leak testing - 1 x 10 -6 He std

DEAN DELLACECCA
DURAFLEX, INC.
9-12-2004

1 Liter Bubble Chamber-Outer Vessel
COUPP
Revision to Engineering Note: K. Krempetz
7/2/07

PPD-10096

Introduction

The 1 Liter Bubble Chamber-Outer Vessel has been in operation at the University of Chicago and the MINOS Hall for approximately the past 2 years. The original Engineering Note for this vessel was done by Andrew Szymulanski; Preparation Date: September 28, 2004. This vessel is intended to run again in July of 2007. Since the Engineering note for this vessel was written some primary relief valves changes were made. This paper is intended to document those changes.

History

The original Engineering Note shows three relieving devices on the vessel.

1) A Rupture Pin Technology relief; Model CASMF: set pressure 450 psig ;1" valve (PRV1)
2) Swagelock relief; Model CPA 4; set pressure 350 psig;1/4" valve (PRV2)
3) Circle Seal; Model 5165-4MP-350; set pressure 350 psig; ½" valve (PRV4)
4) There is also a relief valve to protect expansion cylinders system (PRV 3) which is set at 250 psig.

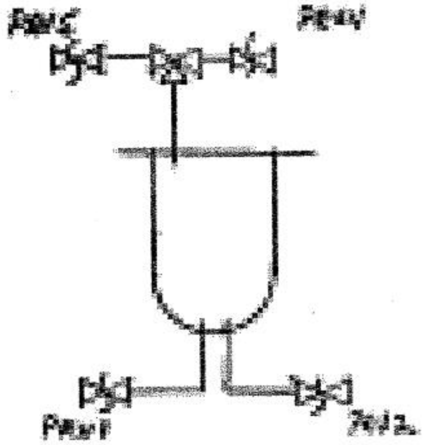
It is believed that because the Circle Seal relief was not UV stamped it was removed and an AGCO Safety Relief Valve Type 86; set pressure 350 psig, Discharge area .049 in^2 was installed for operation at Fermilab. The original Engineering Note has some conflicting information but does show either relief is capable of adequately reliefing the vessel. It should also be noted that PRV1 and PRV2 relief at the bottom of the vessel and it was believed that the ASME code requires the vessel be relieved from the top. Therefore the original note only considers the Circle Seal or AGCO valves to do the vessel's pressure relief.

July 2007 Revision

Some new piping and instrumentation has been added to the vessel for the July 2007 operation (the vessel has not changed just some of the piping). The operating pressure for some of the new additions is 300 psig requiring a lower relief valve setting. Since the 300 psig relief valve setting is closer to the nominal operating pressure (pulses to approx. 275psig) of the vessel, changes were felt necessary.

Since rupture pin reliefs are less likely to open prematurely it was desired that one be installed. The disadvantage of a rupture pin relief is that it doesn't automatically reset and if it relieved the entire contents of the vessel would be lost. To address this issue a three way ball valve, which in any position always gave full flow, was installed along with a rupture pin relief and an AGCO relief valve. The current arrangement is shown below.

COUPP Relieving System



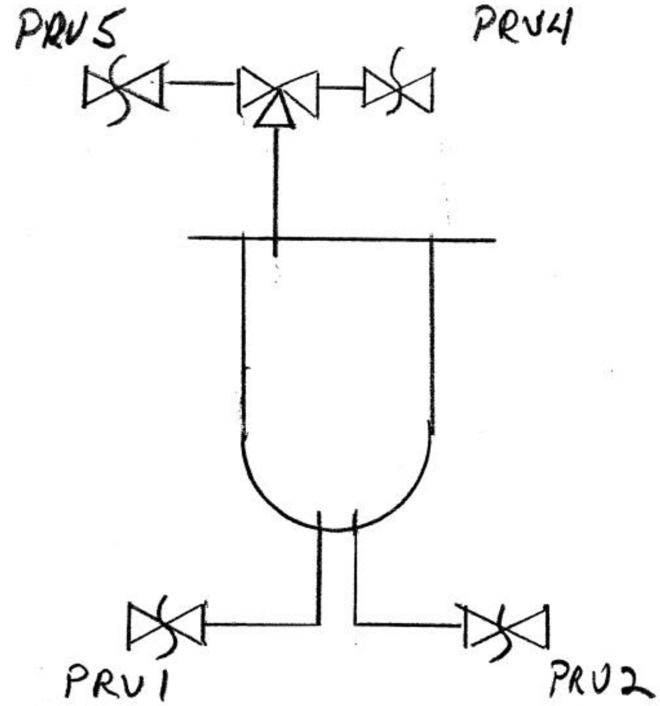
PRV1 - Rupture Disc Technology Model [illegible]
PRV2 Swagelok Model [illegible]
PRV3 - [illegible]
PRV4 - AGCO Series 50
PRV5 Rupture Disc Technology Model "A"
3-way Ball Valve [illegible]

<u>Conclusions</u>

The 1 Liter Bubble Chamber-Outer Vessel relieving capability has not changed and now relieves at a lower pressure.

COUPP Relieving System

7/2/07
KK



PRV1 - Rupture Pin Technology Model # CASMF
PRV2 Swagelok Model CPA-4
PRV3 - not shown for expansion cylinder protection
PRV4 - AGCO Series 80
PRV5 Rupture Pin Technology Model "A"
3-way Ball Valve McMaster Carr 4467K45

Metal & Composite Ball Valves

For information about ball valves, see page 384. For information about pipe size, see pages 2-3.

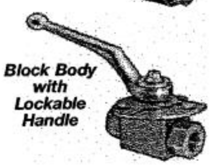
Pipe OD to Pipe Size Conversions

Pipe OD	⅜″	½″	⅝″	¾″	1″	1⅜″	1⅝″	1⅞″	2⅜″	2⅞″	3½″	4½″
Pipe Size	⅛″	¼″	⅜″	½″	¾″	1″	1¼″	1½″	2″	2½″	3″	4″

Hydraulic Carbon Steel Ball Valves

Round Body with Nonlockable Handle

Block Body with Lockable Handle



- Maximum Pressure:
  Hydraulic oils and water glycols:
  ⅛″ to ½″: 7250 psi @ 212° F
  ¾″ to 2″: 5000 psi @ 212° F
  W.S.P. (working steam pressure): Not rated
- Vacuum Rating: Not rated
- Temp. Range: −20° to +212° F
- Ports: Full

Use in high-pressure applications. Body and stem are zinc-plated carbon steel; ball is chrome-plated carbon steel. Seats are Delrin filled with molybdenum disulfide; seals are Viton. Handle is zinc on sizes ⅛″ to ½″ and zinc-plated steel on sizes ¾″ to 2″. Stem is blowout proof.

Valves ***with lockable handle*** can be locked in the open or closed position using a padlock (not included) with shackle dia. up to 5/16″.

Connections: NPT female or SAE female.

NPT				SAE			
Pipe Size	End-to-End Lg.		Each	Thread Size	End-to-End Lg.		Each
Block Body with Nonlockable Handle							
⅛″	2 23/32″	**4715K11**	$32.76	—	—	—	—
¼″	2 23/32″	**4715K12**	32.63	7/16″-20	2 23/32″	**4715K15**	$33.94
⅜″	2 27/32″	**4715K43**	36.36	9/16″-18	2 53/64″	**4715K63**	38.28
½″	3 9/32″	**4715K44**	38.69	¾″-16	3 17/64″	**4715K64**	43.94
¾″	3¾″	**4715K45**	65.40	1 1/16″-12	3¾″	**4715K65**	69.80
1″	4 7/16″	**4715K46**	84.95	1 5/16″-12	4 29/64″	**4715K66**	85.45
Round Body with Nonlockable Handle							
1¼″	4 23/32″	**4715K47**	168.18	1⅝″-12	4⅜″	**4715K67**	168.18
1½″	5⅛″	**4715K48**	211.21	1⅞″-12	5⅛″	**4715K68**	211.21
2″	5½″	**4715K49**	270.91	2½″-12	5½″	**4715K69**	270.91
Block Body with Lockable Handle							
⅛″	2 23/32″	**4776K11**	62.57	—	—	—	—
¼″	2 23/32″	**4776K12**	64.04	7/16″-20	2 23/32″	**4776K22**	65.45
⅜″	2 27/32″	**4776K43**	67.88	9/16″-18	2 53/64″	**4776K63**	69.70
½″	3 9/32″	**4776K44**	70.40	¾″-16	3 17/64″	**4776K64**	75.76
¾″	3¾″	**4776K45**	99.09	1 1/16″-12	3¾″	**4776K65**	102.93
1″	4 7/16″	**4776K46**	118.99	1 5/16″-12	4 29/64″	**4776K66**	119.39
Round Body with Lockable Handle							
1¼″	4 23/32″	**4776K47**	199.90	1⅝″-12	4⅜″	**4776K67**	199.90
1½″	5⅛″	**4776K48**	248.89	1⅞″-12	5⅛″	**4776K68**	248.89
2″	5½″	**4776K49**	302.42	2½″-12	5½″	**4776K69**	302.42

Flanged Metal Ball Valves

Lever Handle

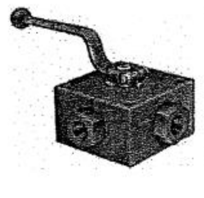
- Maximum Pressure:
  W.O.G. (water, oil, inert gas):
  Stainless Steel: 275 psi @100° F
  Carbon Steel: 284 psi @ 100° F
  W.S.P. (working steam pressure): 150 psi @ 366° F
- Vacuum Rating: 28″ Hg
- Temperature Range: −50° to +450° F
- Ports: Full

Valves are unthreaded and mount directly to flanges. Face-to-face dimensions meet ASME B16.10, Class 150; flange dimensions meet ASME B16.5, Class 150. A mounting pad with four holes permits mounting to an actuator (½″ and ¾″ valves have M5 holes; 1″ has M6 holes; 1½″ and 2″ have M8; 2½″ to 4″ have M10). Choose from Type 316 stainless steel and carbon steel bodies. Stem and ball are Type 316 stainless steel, seals are TFE, and seats and packing are glass-filled TFE. Stem is blowout proof. Handles can be locked in the open or closed position using a padlock (not included). The ½″ to 2″ valves accept shackle diameters up to 0.30″; 2½″ to 4″ accept 0.34″.

Connections: Class 150 flange.

		Flange			Type 316 Stainless Steel		Carbon Steel	
Pipe Size	End-to-End-Lg.	Dia.	No. of Holes	Hole Size		Each		Each
Type 304 Stainless Steel Lever Handle								
½″	4¼″	3½″	4	⅝″	**45995K91**	$148.53	—	—
¾″	4⅝″	3 27/32″	4	⅝″	**45995K92**	191.02	—	—
1″	5″	4¼″	4	⅝″	**45995K93**	209.24	**46155K13**	$184.13
1½″	6½″	5″	4	⅝″	**45995K94**	282.02	**46155K14**	223.07
2″	7″	6″	4	¾″	**45995K95**	324.09	**46155K15**	243.20
Galvanized Steel Pipe Handle								
2½″	7½″	7″	4	¾″	**45995K96**	418.72	**46155K16**	332.21
3″	8″	7 31/64″	4	¾″	**45995K97**	633.22	**46155K17**	382.12
4″	9″	9″	8	¾″	**45995K98**	970.24	**46155K18**	660.02

Multi-Port Hydraulic Carbon Steel Ball Valves



- Maximum Pressure:
  Hydraulic oils and water glycols:
  ¼″ and ⅜″: 7250 psi @ 212° F
  ½″: 5800 psi @ 212° F
  ¾″: 4500 psi @ 212° F
  W.S.P. (working steam pressure): Not rated
- Vacuum Rating: Not rated
- Temperature Range: −4° to +212° F
- Ports: Reduced

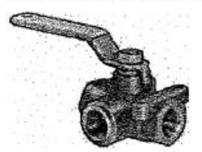
All ports are seated for positive shut-off under high pressure. Body and stem are carbon steel; ball is chrome-plated carbon steel. Body seals are Viton, ball seal is polyacetal, and handle is aluminum.

Valves with Three Ports—Use to divert flow from one port to two different ports. ***Valves with Four Ports***—Use as a two-position, four-way directional valve for extending/retracting a hydraulic cylinder.

Connections: NPT female.

Pipe Size	End-to-End Lg.	With Three Ports	Each	With Four Ports	Each
¼″	3 15/16″	**46185K311**	$220.00	**46185K421**	$220.00
⅜″	4 17/32″	**46185K312**	277.16	**46185K422**	277.16
½″	5 5/16″	**46185K313**	360.86	**46185K423**	360.86
¾″	5 43/64″	**46185K314**	637.92	**46185K424**	424.89

Three-Way Type 316 Stainless Steel Ball Valves



- Maximum Pressure:
  W.O.G. (water, oil, inert gas): 800 psi @ 100° F
  W.S.P (working steam pressure): Not rated
- Vacuum Rating: Not rated
- Temperature Range: −50° to +450° F
- Ports: See table

Flow from center inlet can be sent to either port at full flow, or to both simultaneously at a reduced flow. Valves have no full shutoff position.

Body, ball, and stem are Type 316 stainless steel. Seats, seals, and packing are glass-filled PTFE. Stem is blowout proof. Valves have two mounting holes and a Type 304 stainless steel lever handle with vinyl grip. **Connections:** NPT female.

Pipe Size	Ports	End-to-End Lg.	Mounting Holes		Each
¼″	Full	2 5/16″	10-24	**4467K41**	$90.77
⅜″	Full	2 5/16″	10-24	**4467K42**	90.77
½″	Full	2 5/16″	10-24	**4467K43**	89.86
¾″	Standard	3″	10-24	**4467K44**	121.58
1″	Standard	3 7/32″	10-24	**4467K45**	151.20
1½″	Standard	4 13/32″	¼″-20	**4467K46**	287.16
2″	Standard	5 29/64″	¼″-20	**4467K47**	375.11

Flanged Composite Ball Valves

- Maximum Pressure: Water, oil, chemicals:
  1″ and 1½″: 275 psi @ 100° F
  2″ and 3″: 250 psi @ 100° F
  4″: 150 psi @ 100° F
  W.S.P. (working steam pressure): Not rated
- Vacuum Rating: 29.92″ Hg
- Temperature Range: −50° to +275° F
- Ports: Standard

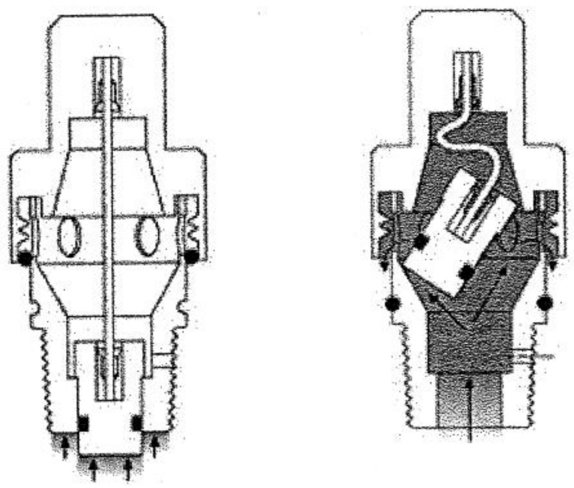
Valves have a composite body, ball, and stem of made of glass-filled vinyl ester that's half the weight of metal flanged ball valves. Composite material is highly resistant to corrosion and harsh chemicals such as hydrochloric acid.

Seats, seals, and packing are PTFE. Handle is lockable and made of glass-filled vinyl ester. Stem is blowout proof. Face-to-face dimensions meet ANSI B16.10. Flange dimensions meet ASME B16.5, Class 150. **Connections:** Class 150 flange.

		Flange				
Pipe Size	End-to-End Lg.	Dia.	No. of Holes	Hole Size		Each
1″	5″	4¼″	4	⅝″	**5927T11**	$274.79
1½″	6½″	5″	4	⅝″	**5927T12**	360.65
2″	7″	6″	4	¾″	**5927T13**	407.96
3″	8″	7½″	4	¾″	**5927T14**	609.06
4″	9″	9″	8	¾″	**5927T15**	925.31

RELIEF VALVE

Model "A" Rupture Pin Fuse (Pressure Relief To Atmosphere)



ADVANTAGES: Simple, accurate and reliable pressure relief of non-toxic fluids. Small, up to 1" npt, show externally it has opened because the protective "O" ring blows down. The cap threads engage body threads on the hex corners.

NOTE: Rupture discs are designed to fail early because the burst pressure is greater than the elast disc. This causes disc fatigue and early failure. The pin obeys Euler's Law and cannot fatigue.

Fermilab
Requistion

PURCHASE REQUISITION

PROCARD

Requisition Number (Filled in by System	Oracle Preparer (Filled in by System)	Date 6/7/2007	Request Originator: Mark Ruschman	MS: 351
Division/Section Approval		Date	NEPA Approval	Ext: 4472
Business Office Approval		Date		
Directorate Approval		Date		

Requistion Header

Description (of entire requistion) COUPP 2 kg
Note to Approver
Justification (To Approver)

Requistion Entry Defaults

Requester: Mark Ruschman		Deliver-To-Location: (not Mail Station) PAB	Buyer Note (use attachments, i.e. Previous P.O.)	
Suggested Vendor: Rupture Pin Technology		Suggested Vendor Site: 8230 SW 8th St. Oklahoma City, Ok 73128	Suggested Vendor Contact:	Vendor Telephone # : 405-789-1884
Reference # 22	Need-By-Date	Project / Task / Expenditure Type / Expenditure Organization Proj: 40 / Task: 40.42.01 / Exp Type: Purchased / Exp Org: PPD/MD		Building Maintenance: Yes or No FIMS#
Note to Receiver				Total of Requisition $250

Requistion Lines

Line#	LineType	PO Line Category	Description (Start with a Noun) (240 Characters Maximum, Enter Additional Description in Cell Below Line Item)	Qty, Unit /Measure and Price		Project Information		Split Coding
1	SR		Reclaibrate Type "A" rupture discs to 300psi	Quantity	2	Project	40	100 %
				Unit of Measure	EA	Task	40.42.01	
				Price Per Unit	$125	Exp Type	Purchased Services	
			UN Number: (Chemical #) Hazard Class:	Extended Price	$250	Exp Org	PPD/MD	
2	SR			Quantity		Project	40	100 %
				Unit of Measure		Task	40.42,01	
				Price Per Unit		Exp Type	Purchased Services	
			UN Number: (Chemical #) Hazard Class:	Extended Price		Exp Org	PPD/MD	
3	GR			Quantity		Project	40	100 %
				Unit of Measure		Task	40.42.01	
				Price Per Unit		Exp Type	Purchased Services	
			UN Number: (Chemical #) Hazard Class:	Extended Price		Exp Org	PPD/MD	

F.N.A.L STK. NO. 1335-0200 FL-29 REV 3