AMMENDED
PRESSURE VESSEL ENGINEERING NOTE
PER CHAPTER 5031

Prepared by: RUSS RUCINSKI
Preparation date: November 7, 1997

LN2 STORAGE DEWAR # 39
PRESSURE VESSEL & VACUUM VESSEL
ENGINEERING NOTE

D-ZERO ENGINEERING NOTE # 3823.115 EN-464

Author: Russ Rucinski, RD/D-Zero Mech.
January 28, 1997

Approved: Kurt Krempetz
PPD/ETT/D-Zero Mechanical Group leader

Lab Property Number(s): NAL 51464

Lab Location Code: RPIS-325 (DAB) (obtain from safety officer)

Purpose of Vessel(s): PROVIDE LN₂ FOR D-ZERO'S HELIUM REFRIGERATOR
SUPER-CONDUCTING SOLENOID, VLPC CRYOSTATS, AND/OR LAr CALORIMETERS

Vessel Capacity/Size: 9000 GAL. Diameter: 120" Length: 387"

Normal Operating Pressure (OP) 35 PSIG

MAWP-OP - 43 PSI

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

Drawing #

Location of Original

3823.115-ME-317223 SHT. 1
(FLOW SCHEMATIC)

D-ZERO ASS'Y BLDG FILES. ALSO IN XDCE ELECTRONIC
DRAWING SYSTEM.

2. Design Verification

Does the vessel(s) have a U stamp? Yes X No _____. If "Yes", fill out data below and skip page 3; if "No", fill out page 3 and skip this page.

Staple photo of U stamp plate below.

Copy "U" label details to the side

Copy data here:

NATIONAL BOARD No. 8602

VLS 9000 INNER VESSEL

ONLY DUPLICATE

MAX. WEIGHT OF CONTENTS

104963 lb.

MAWP 78 PSIG AT -320°F

MIN. ALLOW TEMP.

SERIAL No. 106

YEAR BUILT, 1985

TARE WT. 26000 lb.

3. System Venting Verification Provide the system schematic in the Appendix.

Is it possible to isolate the relief valves by a valve from the vessel?

Yes ☐ No ☒

If "Yes", the system must conform to code rules. Provide an explanation on the appended schematic. (An isolatable vessel, not conforming to code rule is non-compliant under this chapter.)

Is the relief cracking pressure set at or below the M.A.W.P.?

Yes ☒ No ☐ Actual setting 50 PSI

(A "No" response violates this chapter.)

Is the pressure drop of the relief system at maximum anticipated flow such that vessel pressure never rises above the following? (UG 125)

Yes ☒ No ☐
110% of MAWP (one relief)
116% of MAWP (multiple reliefs)
121% of MAWP (unexpected heat source)

Provide test or calculational proof in the Appendix.

(Non-conforming pressure rises is non-compliant under this Chapter.)

List of reliefs and settings:

<u>Manufacturer</u>	<u>Model #</u>	<u>Set Pressure</u>	<u>Flow Rate</u>	<u>Size</u>
FIKE BURST DISC	CPV DISC BU HOLDER	85	893 SCFM AIR	1"
ANDERSON GREENWOOD	81888-8	60	271.6 SCFM AIR	1"x1"

Does the primary relief device follow UG-129? Yes ☒ No ☐

(A "No" response is non-compliant under this chapter)

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. Exceptional, Existing, Used and Unmanned Area Vessels

Is this vessel or any part thereof in the above categories?

Yes ☒ No ☐

If "Yes", follow the Engineering Note requirements for documentation and append to Note.

NOTE: THIS IS AN EXISTING DEWAR THAT WAS MOVED FROM THE E-706 EXPERIMENT (NOW DE-COMMISSIONED) TO D-ZERO. RATHER THAN TRY TO REVISE THE ORIGINAL NOTE, A NEW ENGINEERING NOTE (THIS NOTE) WAS GENERATED.

[A COPY OF THE ORIGINAL NOTE CAN BE OBTAINED FROM THE LABORATORY PRESSURE VESSEL MASTER FILE MAINTAINED BY THE ES&H SECTION.]

1. Manufactured and certified by MINNESOTA VALLEY ENGINEERING, 407 7th St. NW, NEW PRAGUE
(Name and address of manufacturer) (P.N. 5601)

2. Manufactured for Fermi National Accelerator Labs, Batavia, IL 60510
(Name and address of purchaser)

3. Location of installation Fermi National Labs, Batavia, IL 60510
(Name and address)

4. Type VLS 9000 106 NA 145292 15
(Honz. or Vert. Tank) (Mfg's. Serial No.) (CRN) (Drawing No.) (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.
to 5-84 NA LDW TMP. SVC. UWEB. UN401

6. Shell: SA240-304 .288 0 8'-6 18'-9
(Mat'l. (Spec. No., Grade)) (Nom. Thk. (in.)) (Corr. Allow. (in.)) (Diam. I.D. (ft. & in.)) (Length (overall) (ft. & in.))

7. Seams: WLD. DBL. BUTT FULL 100% NA NA WLD. SGL. BUTT PART. 2
(Long. (Welded, Double, Single, Lap, Butt)) (RT. (Spot or Full)) (EFF. %) (H.T. Temp. (F)) (Time (hr.)) (Girth (Welded, Double, Single, Lap, Butt)) (RT. (Spot, Partial, or Full)) (No. of Courses)

8. Heads: (a) Mat'l. SA240-304 (b) Mat'l. SA240-304
(Spec. No., Grade) (Spec. No., Grade)

	Location (Top, Bottom, Ends)	Minimum Thickness	Corrosion Allowance	Crown Radius	Knauss Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure (Concave or Convex)
(a)	TOP	.288	0	NA	NA	2:1	NA	NA	NA	CONCAVE
(b)	BTM	.288	0	NA	NA	2:1	NA	NA	NA	CONCAVE

If removable, bolts used (describe other fastenings) NONE

(Mat'l. Spec. No., Gr., Size, No.)

9. MAWP 78 psi at max. temp. 100
Min. temp. (when less than -20° F) 320 °F. Hydro., pneu., or comb. test pressure 165

10. Nozzles, inspection and safety valve openings:

Purpose (Inlet, Outlet, Drain)	No.	Diameter or Size	Type	Mat'l.	Nom. Thk.	Reinforcement Mat'l.	How Attached	Location
LW. SF	4	1.3000	W.E.	SA269-TP304	.218	NA	WELDED	NA
TF.V								
GPR. LPL	2	1.3000	W.E.	SA249-TP304	.083	NA	WELDED	NA
FT	1	1.0000	W.E.	SA249-TP304	.128	NA	WELDED	NA
GU	1	1.3000	W.E.	SA312-TP304	.158	NA	WELDED	NA
HYDRO	2	1.3000	CPLG.	SA182-F304	.210	NA	WELDED	NA

11. Supports: Skirt NA Lugs NA Legs NA Other STRAPS Attached ENDS WELDED
(Yes or No) (No.) (No.) (Describe) (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 the report: NA

Vacuum jacketed vessel for storage of liquid nitrogen, or argon. Design pressure is 106.0 psi. Inner vessel coded only. Hydro ports are plugged and seal welded.

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. 3377 expires JAN. 15 1986
Date 4/6/85 Co. name MINNESOTA VALLEY ENG. Signed Wm. H. Schmitt Representative

Vessel constructed by MINNESOTA VALLEY ENGINEERING at PRAGUE MINNESOTA 56071

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of MINNESOTA and employed by S. S. I. & I. CO. OF HARTFORD CT.

have inspected the component described in this Manufacturer's Data Report on 4-8 19 85 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 Manufacturer's Data Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date 5-1-85 Signed W. H. Schmitt Commissions NB-3420 4-85-20
(Authorized Inspector)

Rev	By	Date	Description
1	W. J. B. / J. B. B.	10/1/68	Initial Design
2	W. J. B. / J. B. B.	10/1/68	Revised Design
3	W. J. B. / J. B. B.	10/1/68	Final Design
4	W. J. B. / J. B. B.	10/1/68	As-Built

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1. ALL PIPING AND VALVES SHALL BE AS SHOWN IN THIS DRAWING.
2. ALL PIPING SHALL BE 1/2" NPS, UNLESS OTHERWISE SPECIFIED.
3. ALL VALVES SHALL BE 1/2" NPS, UNLESS OTHERWISE SPECIFIED.
4. ALL VALVES SHALL BE 1/2" NPS, UNLESS OTHERWISE SPECIFIED.
5. ALL VALVES SHALL BE 1/2" NPS, UNLESS OTHERWISE SPECIFIED.

LN2 Dewar Relief Summary

Cases (See Appendix A)

Capacity Requirement

1.) Loss of vacuum.	40.8 scfm Air
2.) Fire.	62.2 scfm Air
3.) Pressure building coil failure.	82.3 scfm Air
4.) Pumping overfill.	Alternative method chosen
5.) Filling a warm dewar	Alternative method chosen

Relief Capacities (See Appendix B)

AGCO relief valve, Set Press.= 60 psig	271.6 scfm Air @ 78 psig
1" Fike Rupture disc, Burst Press. = 85 psig	893 scfm Air @ 85 psig

Inlet Pressure Drop Calcs. (See Appendix C)

At maximum flow (Pressure building case), the pressure drop of inlet piping = 0.3 psi

Maximum vessel press. = 60.3 psig << 110% MAWP, ASME UG125, CGA met

Inlet losses = $.3/60 = 0.5\%$ Set pressure < 3 % Relief Set Pressure, API RP520 met

For Reference;

MAWP of LN2 dewar = 78 psig

110% MAWP = $1.10(78+14.7) = 102$ psia = 87.3 psig

Relief set press. chosen to be approx. 70% RD burst pressure.

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3823.115

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A1.

SUBJECT

LN₂ DEWAR RELIEF SIZING
REQ'MTS. APPENDIX "A"

NAME
RUSS RUCINSK

DATE
10-21-96

REVISION DATE
1-9-97

Math checked
M. ZACZEK
11-7-96

CASES TO BE CONSIDERED:

- 1.) LOSS OF VACUUM
- 2.) FIRE
- 3.) PRESSURE BUILDING COIL FAILURE
- 4.) PUMPING OVERFILL
- 5.) FILLING A WARM DEWAR

CASE 1: LOSS OF VACUUM, REF. CGA 5.1.3-1995 PAR. 5.2.2

$$Q_a = \frac{(590 - T)}{4(1660 - T)} FG; UA$$

WHERE:

$$T = T_{SAT} @ \text{FLOWRATING PRESSURE}$$

$$= T_{SAT} @ (75 + 14.7) 1.10 = 102 \text{ psia}$$

$$= 48.6 K = 177 ^\circ R$$

$$F = 1.576, \text{ ~~INLET PIPING TO RELIEF IS < 24".~~ SEE PAGE A1.2, A1.3 FOR CALCULATIONS} \triangle RAR$$

$$G_i = 10.2 \text{ FROM TABLE 1.}$$

$$U = \frac{K_{PERCENT}}{X} = \frac{.0348 \frac{Btu \cdot h}{hr \cdot ft^2 \cdot ^\circ F}}{\left(\frac{10.5 W}{12 \text{ in/ft}} \right)} = 0.03977 \frac{Btu}{hr \cdot ft^2 \cdot ^\circ F}$$

$$A = (OAL. + .19 OD)(OD)(3.1416) \text{ REF. CGA 5.1.3-1995 5.1.2}$$

$$A = (27.3R + .19(10 \text{ ft}))(10 \text{ ft})(3.1416) = 918 \text{ ft}^2$$

↑ from MVE SPEC. SHT.

$$Q_a = \frac{(590 - 177)}{4(1660 - 177)} \frac{1.576}{(1)} (10.2)(.0398)(918) =$$

$$Q_{a, \text{AV}} = \frac{25.9}{40.3} \text{ scfm AIR}$$

REF: 5032.1TA LN₂ DEWAR INSTALLATION RULES FOR KPERCENT

Vertical Liquid Stations

A 1.1

Two-year warranty

FLOW DIAGRAM

SPECIFICATIONS

MODEL	1,500	3,000	6,000	9,000	11,000	13,000
Diameter (inches)	66	96	96	120	120	120
Height (inches)	180	185	309	328	387	444
Gross Capacity (gallons)	1,629.5	3,062.0	6,095.0	9,200	11,300	13,300
Net Capacity (gallons)	1,458.5	2,980.0	5,962.5	9,000	11,000	13,000
Equivalent Capacity of Gas						
Oxygen (SCF at NTP)	167,862	343,000	686,284	1,035,500	1,266,100	1,496,000
Nitrogen (SCF at NTP)	135,792	277,468	555,168	838,000	1,024,210	1,210,000
Argon (SCF at NTP)	164,070	335,250	670,781	1,012,000	1,237,500	1,462,000
Design Pressure (PSIG)	50	50	50	78	75	72
Weights						
Tare (lbs.)	5,000	10,650	18,900	24,900	30,000	35,400
Loaded Oxygen (lbs.)	18,894	39,040	75,705	110,650	134,800	159,265
Nitrogen (lbs.)	14,837	30,750	59,117	85,600	104,200	122,100
Argon (lbs.)	21,961	45,307	88,244	129,550	157,900	186,570
Normal Evaporation Rate %/Day LOx	.40	.17	.15	.10	.10	.10

VLS 9000
↓

NOMENCLATURE

V-1 VALVE, TOP FILL
V-2 VALVE, BOTTOM FILL
V-3 VALVE, FULL TRYCOCK
V-4 VALVE, VENT
V-5 VALVE, PRESSURE BUILDING
V-6 VALVE, PRESSURE BUILDING AND ECONOMIZER ISOLATION
V-7 VALVE, LIQUID PHASE (HIGH)
V-8 VALVE, GAS PHASE (LOW)
V-9 VALVE, EQUALIZATION
V-10 VALVE, DRAIN
V-11 VALVE, EVACUATION
V-12 VALVE, VACUUM JACKETED (OPTIONAL)

V-14 ISOLATION VALVE, VACUUM TUBE
CV-1 CHECK VALVE, FILL
R-1 REGULATOR, PRESSURE BUILDING
RV-1 RELIEF VALVE, LINE
RV-2 RELIEF VALVE, TANK
BD-1 BURST DISC, TANK
BD-2 BURST DISC, ANNULAS
PB-1 PRESSURE BUILDING COIL
LL-1 GAUGE, LIQUID LEVEL
G-1 GAUGE, PRESSURE
S-1 STRAINER
C-1 CONNECTION, FILL
C-2 CONNECTION, FULL TRYCOCK
C-3 CONNECTION, VENT

C-4 CONNECTION, LIQUID WITHDRAWAL (CAPPED)
C-5 CONNECTION, VENT (CAPPED)
C-6 CONNECTION, DRAIN
C-7 CONNECTION, PUMP
C-8 CONNECTION, FIELD JOINT (OPTIONAL)
C-9 CONNECTION, PUMP VENT
TC-1 VACUUM TUBE

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SUBJECT

LN₂ DEWAR RELIEF SIZING

NAME

RUSS RUCINSKI

DATE

1/9/97

REVISION DATE

- DETERMINATION OF "F" CORRECTION FACTOR
PER CGA 51.3-1995 PAR. 5.1.4

$$F = \sqrt{\frac{Z_i T_i}{Z T}} = \sqrt{\frac{P_i v_i}{P v}}$$

METHOD; I WILL CALCULATE THE FLOW RATE & TEMPERATURE RISE
IN THE RELIEF PIPING. FOLLOW CGA PROCEDURE.

LOSS OF VACUUM CASE:

STEP 1

ASSUME $F = 1.0$ FOR NOW. THEN BY CGA 5.2.2;

$$Q_a = \frac{(590 - T)}{4(1660 - T)} F G_i V_A = 25.9 \text{ scfm air}$$

CONVERTING TO MASS FLOW OF FLOWING MEDIUM;

$$W = \frac{Q_a \rho_c}{18.35} \sqrt{\frac{M}{Z T}} = \frac{(25.9 \text{ scfm air})(356)}{18.35} \sqrt{\frac{28.014}{(0.32)(177^\circ R)}}$$

$$\frac{P}{P_c} = \frac{102 \text{ psia}}{493.134 \text{ psia}} = 0.207$$

$$\frac{T}{T_c} = \frac{177^\circ R}{227.6^\circ R} = 0.778$$

$\Rightarrow Z = 0.32$ FROM GENERALIZED COMPRESSIBILITY CHART;

FIG. A.5
FUNDAMENTALS OF
CLASSICAL THERMO
VAN WYLEN & SONNEN
3rd ED., 1995

$$W = 221 \text{ lbm/hr } N_2$$

STEP 2

$$T_i = 590 - \frac{590 - T_s}{e^{\left[\frac{.55 DL}{WCP} \right]}}$$

$$T_s = 177^\circ R \quad D = 1.90" \quad L \approx 40 \text{ FEET}$$

$$C_p|_{T=177^\circ R} = 1.435 \frac{\text{Btu}}{\text{lbm}^\circ R} \quad C_p|_{T=590^\circ R} = 1.049 \frac{\text{Btu}}{\text{lbm}^\circ R}$$

$$\bar{C}_p = 1.242 \frac{\text{Btu}}{\text{lbm}^\circ R} + \frac{0.29063 \frac{\text{Btu-lbm}}{^\circ R}}{1.2160 \frac{\text{lbm}}{^\circ R}} = 0.29684 \frac{\text{Btu}}{^\circ R}$$

VALUES FROM
TABLE 5 CGA

$$T_i = 590 - \frac{590 - 177}{e^{\left[\frac{.55(1.9)(40)}{221(0.29684)} \right]}}$$

$$T_i = 372^\circ R$$

$$\bar{T} \text{ FOR FLUID PROPERTIES} = \frac{372^\circ R + 177^\circ R}{2} = 275^\circ R$$

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STEP 3

$$P_i = P - 3.36 \times 10^{-6} \frac{F^2 W^2 v}{d^5}$$

$$F = 0.022$$

$$L = 168.3 \text{ ft.}$$

$$W = 221 \frac{\text{lbm}}{\text{hr}} \text{ N}_2$$

$$d = 1.77 \text{ in}$$

SEE APPENDIX C
PAGE C3

$$v = 0.9855 \frac{\text{ft}^3}{\text{lbm}}$$

$T = 275^\circ\text{R}$
 153°K
 $P = 7 \text{ atm}$

$$P_i = 102 \text{ psia} - 3.36 \times 10^{-6} \frac{(0.022)(168.3)(221 \frac{\text{lbm}}{\text{hr}})^2 (0.9855 \frac{\text{ft}^3}{\text{lbm}})}{(1.77 \text{ in})^5}$$

$$P_i = 102 \text{ psia} - 0.034 \text{ psi} \approx 102 \text{ psia} \quad \Delta P \text{ is NEGLIGIBLE.}$$

$$P = P_i$$

STEP 5

$$F = \sqrt{\frac{P_i v_i}{P - 1}}$$

$$v_i = 85.47 \frac{\text{ft}^3}{\text{lbm}}$$

$T_i = 372^\circ\text{R} = 207 \text{ K}$
 $P_i = 102 \text{ psia}$

$$v = 34.409$$

$T = 372^\circ\text{R}$
 $P = 102 \text{ psia}$

$$F = \sqrt{\frac{102 (85.47)}{102 (34.409)}} = 1.576$$

SUBJECT

LN₂ DEWAR RELIEF SIZING
REQ'NTS

NAME

RUSS RUCINSKI

DATE

10-22-96

REVISION DATE

1-13-97

RA2

MINI CHECKED
M. ZACZAK
11-7-96

CASE 2: FIRE, REF. CGA 51.3-1995 PAR. 5.3.3

$$Q_a = F G_i U A^{0.82}$$

ΔT_{RAD}
 $F = 1.14$ SEE CALCS. PAGES A2.1-2.3

$G_i = 10.2$ PER TABLE 1 IN CGA.

$$U = \frac{K_{PERLITE}}{x} = \frac{.058 \frac{BTU \cdot in}{hr \cdot ft^2 \cdot ^\circ F}}{(10.5 \frac{1}{12} ft)} = .06629 \frac{BTU}{hr \cdot ft^2 \cdot ^\circ F} \quad REF$$

{ REFERENCE 5032.1 TA LN₂ DEWAR INSTALL RULES FOR K_{PERLITE} }

$$A = 918 ft^2 \quad \text{FROM PAGE 1}$$

$$Q_a = \frac{1.14 \Delta}{(1.0)} (10.2) (.06629 \frac{BTU}{hr \cdot ft^2 \cdot ^\circ F}) (918 ft^2)^{0.82} = \frac{207.2}{\cancel{181.8}} \text{ SCFM AIR}$$

PER 5.3.6); THE REQ'D CAPACITY OF 5.3.3 CAN BE REDUCED TO 30% OF THAT CALC. BECAUSE THE STORAGE IS NON-FLAMMABLE AND IS ISOLATED FROM POSSIBLE ENGULFMENT IF FIRE.

$$Q_a = (0.30) (\frac{207.2}{\cancel{181.8}} \text{ SCFM AIR})$$

$$Q_a = \frac{62.2 \Delta T_{RAD}}{\cancel{54.5}} \text{ SCFM AIR}$$

FIRE

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LN₂ DEWAR RELIEF REQ'MTS

NAME

RUSS RUCINSKI

DATE

1-10-97

REVISION DATE

- DETERMINATION OF "F" CORRECTION FACTOR PER CGA 51.3 -1995 PAR. 5.1.4

I WILL APPLY THE SAME METHOD AS DONE FOR LOSS OF VACUUM, PAGES A1.2, A1.3. REFERENCE THOSE PAGES FOR LONGHAND ACCOUNT OF STEPS.

FIRE CASE

STEP 1 $Q_a = 54.5 \text{ scfm AIR} \Rightarrow W = 221 \frac{\text{lbm}}{\text{hr}} \times \frac{54.5 \text{ scfm AIR}}{25.9 \text{ scfm air}} = 465 \frac{\text{lbm}}{\text{hr}} \text{ N}_2$

STEP 2 $T_i = 2145 - \frac{2145 - T_s}{e \left[\frac{5.24 D_L}{W C_p} \right]} = 2145 - \frac{2145 - 177}{e \frac{5.24 (1.9) (40)}{465 (.29684)}}$

$$T_i = 2035 \text{ } ^\circ\text{R}$$

$$T_i > 1660 \text{ } ^\circ\text{R} \therefore \text{MORE RESISTOR ANALYSIS SUGGESTED.}$$

WHILE LIQUID REMAINS IN THE TANK THE INNER WALL TEMPERATURE CAN BE ASSUMED TO BE $T_{\text{SAT @ P=121\% MAWP}}$
 $= 112 \text{ PSIA} = 7.6 \text{ ATM}$

FOR NOW NEGLECT THAT

AND BE MORE

CONSERVATIVE. PUT INNER VESSEL INNER WALL @ 21200 °F TOO.

$$T_{s,1} = 180 \text{ } ^\circ\text{R}$$

VESSEL INNER WALL

MODEL AS:

$$Q_{\text{MAX}} = Q_{\text{CONDUCTION}} = \frac{KA \Delta T}{L} = \frac{0.258 \frac{\text{Btu-in}}{\text{hr-ft}^2-\text{F}} \left[\left(\frac{1.9}{2} \right) (40 \text{ ft}) 2 \text{ SIDES} \right]}{4.3 \text{ in.}} \left[1 - \frac{1}{1.9} \right]$$

$$= 252.9 = 253 \frac{\text{Btu}}{\text{hr}} = 74.1 \text{ WATTS}$$

SUBJECT

LN₂ DEWAR RELIEF SIZING REAMTS

NAME

RUSS RUCINSKI

DATE

1-10-97

REVISION DATE

$$Q = \dot{m} \Delta h = W (h_{out} - h_{in}) \quad 1^{st} \text{ LAW OF THERMODYNAMICS}$$

$$h_{out} = \frac{Q}{W} + h_{in} = \frac{74.1 \frac{J}{s}}{465 \frac{lbm}{hr}} \left[\frac{3600s}{1hr} \right] \left[\frac{2.210m}{1000g} \right] + 87.866 \frac{J}{g}$$

$$h_{out} = 89.13 \frac{J}{g} \approx 2^\circ R \text{ INCREASE, NEGLIGIBLE.}$$

$$\begin{aligned} & \uparrow h_{VAPOR} \\ & T = 98.7^\circ R \\ & P = 7 \text{ ATM.} \end{aligned}$$

PERLITE INSULATION INSULATES WELL

ALTERNATIVE CHECK OF THE HEAT FLUX NUMBER;

USE FIG. 5.3 TECHNOLOGY OF LIQUID HELIUM "HEAT FLUX TO MLI INSULATED HELIUM CONTAINER".

$$A_{PIPE} = \pi D L = \pi \left(\frac{1.9}{12} \text{ ft} \right) (40 \text{ ft}) = 20 \text{ ft}^2$$

CHOOSE FIRE, 4.3" SI HEAT FLUX $\approx 20,000 \frac{Btu}{hr}$.

THIS LEADS ME TO BELIEVE $293 \frac{Btu}{hr}$ IS INCORRECT.

CONSIDER:

NOTE: CONVECTION CAN BE NEGLECTED
BECAUSE OF PERLITE INSULATION.

$$U = 0.023236 \frac{Btu}{hr \cdot ft^2 \cdot ^\circ F}$$

TABLE E-1, AS

$$q_r = \frac{2\pi L K (T_g - T_l)}{\ln \left(\frac{r_2}{r_1} \right)}$$

$$L = 40 \text{ ft.}$$

$$K = U$$

$$r_2 = 5.25 \text{ in.}$$

$$r_1 = 0.95 \text{ in.}$$

$$q_r = \frac{2\pi (40 \text{ ft}) (0.023236 \frac{Btu}{hr \cdot ft^2 \cdot ^\circ F}) (1660^\circ R - 180^\circ R)}{\ln \left(\frac{5.25}{0.95} \right)}$$

$$q_r = 5056 \frac{Btu}{hr} = \text{BECAUSE OF PERLITE INSULATION AS REASONABLE.}$$

$$h_{out} = \frac{Q}{W} + h_{in} = \frac{1482 \text{ W}}{465 \frac{lbm}{hr}} \left[\frac{3600s}{1hr} \right] \left[\frac{2.210m}{1000g} \right] + 87.866 \frac{J}{g} = 113.1 \frac{J}{g}$$

FROM THERMO PROPERTY TABLES $P = 7 \text{ ATM.}$ $T_l = 118 \text{ K}$

$$T_g = 212.4^\circ R$$

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$$Q = \dot{m} \Delta h = W (h_{out} - h_{in}) \quad 1^{st} \text{ LAW OF THERMODYNAMICS}$$

$$h_{out} = \frac{Q}{W} + h_{in} = \frac{74.1 \frac{J}{s}}{465 \frac{lbm}{hr}} \left[\frac{3600s}{1hr} \right] \left[\frac{2.210m}{1000g} \right] + 87.866 \frac{J}{g}$$

$$h_{out} = 89.13 \frac{J}{g} \approx 2^\circ R \text{ INCREASE, NEGLIGIBLE. } T = 98.7^\circ R$$

$$P = 7 \text{ ATM.}$$

PERLITE INSULATION INSULATES WELL

ALTERNATIVE CHECK OF THE HEAT FLUX NUMBER;

USE FIG. 6.3 TECHNOLOGY OF LIQUID HELIUM "HEAT FLUX TO MLI INSULATED HELIUM CONTAINER".

$$A_{PIPE} = \pi D L = \pi \left(\frac{1.9}{12} \text{ FE} \right) (40 \text{ FE}) = 20 \text{ FE}^2$$

CHOOSE FIRE, 4.5" SI HEAT FLUX $\approx 20,000 \frac{\text{Btu}}{\text{hr}}$ THIS LEADS ME TO BELIEVE $253 \frac{\text{Btu}}{\text{hr}}$ IS INCORRECT.

CONSIDER;

NOTE: CONVECTION CAN BE NEGLECTED
BECAUSE OF PERLITE INSULATION

$$N_2 \text{ GAS. } U = 0.023236 \frac{\text{Btu}}{\text{hr} \cdot \text{FE} \cdot ^\circ \text{F}}$$

TABLE 3 IN CGA

$$q_r = \frac{2\pi L K (T_{s,1} - T_{s,2})}{\ln(r_2/r_1)}$$

$$L = 40 \text{ FE.}$$

$$K = U$$

$$r_2 = 5.25 \text{ IN.}$$

$$r_1 = 0.95 \text{ IN.}$$

$$q_r = \frac{2\pi (40 \text{ FE}) (0.023236 \frac{\text{Btu}}{\text{hr} \cdot \text{FE} \cdot ^\circ \text{F}}) (1660^\circ \text{R} - 180^\circ \text{R})}{\ln \left(\frac{5.25}{.95} \right)}$$

$$q_r = 5056 \frac{\text{Btu}}{\text{hr}} \quad \text{I BELIEVE THIS NUMBER AS REASONABLE}$$

$$h_{out} = \frac{Q}{W} + h_{in} = \frac{1482 \text{ W}}{465 \frac{\text{lbm}}{\text{hr}}} \left[\frac{3600s}{1hr} \right] \left[\frac{2.210m}{1000g} \right] + 87.866 \frac{J}{g} = 113.1 \frac{J}{g}$$

FROM THERMO PROPERTIES TABLES $P = 7 \text{ ATM, } T_i = 118 \text{ K}$
 $T_o = 212.4^\circ \text{R}$

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STEP 5; $P_i = P - 3.36 \times 10^{-6} \frac{F^2 W^2 v}{d^5}$

$v(T=196.2^\circ R=109K, P=7 \text{ ATM})$
ROUGHLY

$P_i = 112 \text{ psia} - 3.36 \times 10^{-6} \frac{(.022)(168.3 \text{ ft})(465)^2 v}{(1.77 \text{ in})^5} = 0.64394 \frac{\text{ft}^3}{\text{lbm}}$

$P_i = 112 \text{ psia} - 0.10 \text{ psi} = 111.9 \text{ psia}$

ΔP IS NEGLIGIBLE.

$F = \sqrt{\frac{P \cdot v}{P \cdot v}}$

$v_i = \frac{44.905 \text{ cc}}{g}$
 $T_i = 118K$
 $P_i = 7 \text{ ATM}$

$F = \sqrt{\frac{112(44.905)}{112(34.409)}}$

$v = \frac{34.409 \text{ cc}}{g}$
 $T = 78.2K$
 $P = 7 \text{ ATM}$

$F = 1.142$

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MATH CHECKED:
M. ZACZEK
11-7-96CASE 3: PRESSURE BUILDING COIL FAILURE

$$P = (78 + 14.7) 1.1 = 102 \text{ psia}$$

$$\Delta P = \rho g h$$

$$\Delta P_{\text{max}} = (43.7 \frac{\text{lbm}}{\text{ft}^3}) (328 \text{ in}) (\frac{1 \text{ ft}}{12 \text{ in}}) (\frac{1 \text{ ft}^2}{144 \text{ in}^2}) (\frac{1 \text{ lb}}{12 \text{ in}})$$

$$= 8.3 \text{ psi}$$

DETERMINE THE REQUIRED RELIEF VALVE CAPACITY FOR THE CASE OF WIDE OPEN INLET AND OUTLET VALVES TO THE VAPORIZER.

THE SOLUTION TO THIS PROBLEM CAN BE BOUNDED BY THE LESSER OF 2 MODELS;

1st MODEL: CONSIDER THE VAPORIZER AS AN INFINITE SOURCE OF HEAT. THE MASS FLOW RATE IS THEN LIMITED BY THE INLET & OUTLET PIPING SIZE AND THE MAXIMUM HEAD OF 8.3 PSI. ASSUMING SATURATED LIQUID THRU THE VAPORIZER INLET PIPING AND SATURATED VAPOR THRU THE OUTLET, THE RESULT IS;

$$\dot{m}_{\text{MODEL 1}} = 1564 \text{ lb/hr N}_2$$

2nd MODEL: CONSIDER THE PIPING TO BE SUFFICIENTLY LARGE SUCH THAT THE MASS FLOW RATE IS LIMITED BY THE HEAT INPUT CAPACITY OF THE VAPORIZER. THE RESULT IS;

$$\dot{m}_{\text{MODEL 2}} = 683 \frac{\text{lbm}}{\text{hr}}$$

SAT. N₂ VAPOR

$$Q_a = 82.3 \text{ SCFM AIR}$$

THE RAW CALCS: FOR BOTH MODELS FOLLOW.

PB COIL FAILURE

SCENARIO: PRV-2770-N FAILED FULL OPEN,
SAY SPRING SNAPPED OR OPERATOR ERROR*

*NOTES: RANGE 20 TO 70 PSI $\therefore$ THEORETICALLY CAN'T
BE SET TO $>$ MAWP = 78 PSIG.

DRIVING FORCE FOR MASS FLOW IS LIQUID HEAD.

$$h = 328 \text{ IN.}$$

$$\rho_{\text{LIQ.}} (102 \text{ psia}, T_{\text{SAT}}) = .70 \text{ g/cc} = 43.70 \text{ lb/ft}^3$$

$$\Delta P = \left(43.7 \frac{\text{lb}}{\text{ft}^3} \right) (328 \text{ IN.}) \left(\frac{1 \text{ ft}^2}{144 \text{ IN}^2} \right) \left(\frac{1 \text{ ft}}{12 \text{ IN.}} \right) = \underline{8.3 \text{ psi}}$$

- MAX. FLOW RATE CAN BE CONSERVATIVELY CALCULATED BY ASSUMING SAT. LIQUID - THROUGH VAPORIZER INLET & OUTLET PIPING WITH 3.3 PSI ΔP . SAT. VAPOR 2

PHYSICAL PIPING SKETCH

- CALCULATE EQUIVALENT PIPING LENGTH FOR 1/2" IPS SIZE.

INLET PIPE $L = 12 + 14\frac{1}{2} + 12 + 9 = 47.5" = 4 \text{ ft.}$

INLET VALVES $K = 340 \text{ ft}$ EACH VALVE

$$L_{\text{E}} = \dots$$

$$L = \frac{KD}{f} = \frac{2(340)(.027)(\frac{.622}{12})}{.027} = 35.2 \text{ FE}$$

1/2" PIPE

MATH CHECKED
M. ZAKS
11-7-

INLET TEE + 2 ELBOWS $\Rightarrow K = 60 f_e + 2(12 f_e) = 84 f_e = (17.6 f_e) \times \frac{84}{340} = 4.35 \text{ FE}$

OUTLET PIPING $L = 56 + 6 + 12 = 74" = 6.17 \text{ FE}$ 1" PIPE *

$$K_{\text{PIPE}} = \frac{fL}{D} = \frac{.023(6.17)}{(\frac{1.049}{12})} = 1.6225 \text{ FOR 1" SIZE}$$

OUTLET VALVE $K = 340 f_e = 340(.023) = 7.82 \text{ FOR 1" SIZE}$

OUTLET: 2 TEES + 1 ELBOW $= 20 f_e + 20 f_e + 60 f_e = 100 f_e$

$$K = 100(.023) = 2.3 \text{ FOR 1" SIZE}$$

$$\sum K_{\text{OUTLET}} = 10.12$$

$$L_{\text{OUTLET FITTINGS VALVES}} = \frac{KD}{f} = \frac{10.12(\frac{1.049}{12})}{.023} = 38.46 \text{ FE}$$

L TOTAL

* COULD ADD LENGTH INSIDE VT
TO TOP OF VESSEL. ADD 2'

$$L_{\text{TOTAL INLET}} = 4 + 35.2 + 4.35 = 43.6 \text{ FE} ; 1/2" \text{ SCH. 40 PIPE}$$

$$L_{\text{TOTAL OUTLET}} = 6.17 + 38.46 = 44.63 \text{ FE} ; 1" \text{ SCH. 40 PIPE}$$

71.6

• ΔP CALCULATIONS

ASSUME TURBULENT FLOW $f_e = .027 \text{ FOR } 1/2"$

$f_e = .023 \text{ FOR } 1"$

AND CHECK Re & f AFTER FLOW RATE IS KNOWN

IN GEN'L

$$\Delta P = 3.36 \times 10^{-6} \frac{f L W^2}{\rho d^5}$$

CONSIDER 1 - FIRST PART 1/2" PIPE
2 - 2" PART 1" PIPE

FOR THE 2 PARTS

$$\Delta P_{\text{TOTAL}} = 3.36 \times 10^{-6} \left[\frac{f_1 L_1 W^2}{\rho_1 d_1^5} + \frac{f_2 L_2 W^2}{\rho_2 d_2^5} \right]$$

SOLVING FOR W ;

$$W^2 = \frac{\Delta P_{\text{TOTAL}}}{3.36 \times 10^{-6} \left[\frac{f_1 L_1}{\rho_1 d_1^5} + \frac{f_2 L_2}{\rho_2 d_2^5} \right]}$$

MATH CHECKS
M.2 AC 25K
11-2-96VALUES ; $\Delta P_{TOTAL} = 8.3$ PSI

$$F_1 = .027 \quad F_2 = .023 \quad \rightarrow 71.6 \text{ Ft.}$$

$$L_1 = 43.6 \quad L_2 = 44.6$$

$$\rho_L = 43.7 \frac{\text{lb}}{\text{ft}^3} \quad \rho_g = .02884 \frac{\text{g}}{\text{cc}} = 1.8 \frac{\text{lb}}{\text{ft}^3}$$

$$d_1 = .622 \text{ in.} \quad d_2 = 1.049 \text{ in.}$$

$$W^2 = \frac{8.30 \text{ psi}}{3.36 \times 10^{-6}} \left[\frac{.027(43.6)}{43.7(.622)^5} + \frac{.023(44.6)}{1.8(1.049)^5} \right]^{-1}$$

$$W = \frac{1564.2}{\cancel{1429.5}} \text{ lb/hr} \quad \text{N}_2$$

$$\Delta P_1 = 3.36 \times 10^{-6} \frac{(.027)(43.6)(1564.2)^2}{43.7(.622)^5} = 2.38 \text{ psi}$$

$$\Delta P_2 = 8.3 - 2.4 = 5.9 \text{ psi}$$

$$Re_1 = 6.31 \frac{W}{d\mu} = 6.31 \frac{(1829.5)(1564.2)}{(.622)(755.9 \times 10^{-6} \frac{\text{g}}{\text{cm-s}})} \left(\frac{100 \text{ cp}}{\frac{\text{g}}{\text{cm-s}}} \right) = \frac{2.14 \times 10^5}{2.5 \times 10^5}$$

$$\frac{\varepsilon}{D} = \frac{.00015}{\frac{.622}{12}} = .0029$$

$$\Rightarrow F_1 = .026$$

$$Re_2 = 6.31 \frac{W}{d\mu} = 6.31 \frac{1829.5(1564.2)}{(1.049)(70.79 \times 10^{-6} \frac{\text{g}}{\text{cm-s}})} \left(\frac{100 \text{ cp}}{\frac{\text{g}}{\text{cm-s}}} \right) = \frac{1.33 \times 10^6}{1.55 \times 10^6}$$

$$\frac{\varepsilon}{D} = \frac{.00015}{\frac{1.049}{12}} = .0017$$

$$\Rightarrow F_2 = .023$$

FRICTION FACTORS ARE O.K. MAXIMUM FLOW RATE
CALC. IS O.K.

$$W = 1564 \text{ lb/hr} \quad \text{N}_2$$

o CHECK AMT. OF HEAT REQ'D TO CHANGE THE PHASE
FROM LIQUID TO GAS.

$$Q_{\text{REQ'D}} = \dot{m} h_{fg} = 1564 \frac{\text{lb}}{\text{hr}} \times \frac{1 \text{ hr}}{3600 \text{ s}} \left[87.866 - (-75.578) \right] \text{ Btu/lb}$$

P = 7 ATM, NBS-TN-1025 TAG

$$Q_{\text{REQ'D VAP.}} = 32,276 \text{ WATTS.}$$

THIS PROBABLY EXCEEDS AMOUNT POSSIBLE BY VAPORIZER.
∴ AT THIS FLOW RATE; OUTLET OF VAPORIZER WOULD
BE 2 PHASES; ΔP BY LIQUID HEAD GOES AWAY.

CONSERVATIVELY ESTIMATE VAPORIZER CAPACITY:

SURFACE AREA OF FINS;

$$A = \pi_{\text{FINS}} \cdot (\text{WIDTH FIN}) (\text{HEIGHT FIN}) = \frac{10 \text{ FINS}}{5 \frac{3}{4} \text{ in}} \times \left(46 \frac{1}{2} \text{ in.} \right) \left(2 \frac{1}{2} \text{ in.} \right) (2 \text{ in.}) (2 \text{ in.})$$

$$A_{\text{FINS}} = 8491.3 \text{ in}^2 = 5.48 \text{ m}^2$$

SAY $h = 10 \frac{\text{W}}{\text{m}^2 \text{K}}$ RANGE: FREE CONV 2-25 $\frac{\text{W}}{\text{m}^2 \text{K}}$

$$\Delta T = 293 \text{ K} - 99 \text{ K} = 194 \text{ K}$$

$$q'' = h \Delta T = 10 \frac{\text{W}}{\text{m}^2 \text{K}} (194 \text{ K}) = 1940 \frac{\text{W}}{\text{m}^2}$$

SAY FIN EFFICIENCY = 1.0

$$Q_{\text{TOTAL VAP}} = q'' A = 1940 \frac{\text{W}}{\text{m}^2} (5.48 \text{ m}^2) = \underline{10,631 \text{ W}}$$

FLOW WILL BE LIMITED BY AMOUNT OF HEAT VAPORIZER
CAN PROVIDE RATHER THAN FRICTION PRESSURE
DROP. THEREFORE A BETTER CALCULATION OF
THE VAPORIZER CAPACITY IS PRUDENT.

VAPORIZER HEAT TRANSFER CAPACITY.

ASSUME HEAT TRANSFER RATE INSIDE OF TUBES IS $\gg$ OUTSIDE SINCE NUCLEATE BOILING INSIDE & FREE CONVECTION OUTSIDE.

$$T_{\text{TUBES}} = T_{\text{SAT LN2}} = 99 \text{ K}$$

102 psia

$$T_{\text{AMBIENT}} = 300 \text{ K} \quad (80^\circ\text{F} - \text{A SUMMER DAY})$$

THE HEAT TRANSFER MODEL THAT DESCRIBES THIS SITUATION IS FREE CONVECTION WITHIN ISOTHERMAL PARALLEL PLATE CHANNELS - ; ASSUME $T_{\text{INS}} = T_{\text{TUBES}}$
 $T_{\infty} = \text{AMBIENT}$

$$S = .575 \text{ IN.} \quad S/L = .230$$

$$L = 2.5 \text{ IN.}$$

$$T_{\infty} = 300 \text{ K}$$

$$T_{s,1} = T_{s,2} = 100 \text{ K}$$

$$\bar{T} = 200 \text{ K} \quad \text{FOR FLUID PROPERTIES.}$$

SEE SECTION 9.7.1 FUNDAMENTALS OF HEAT & MASS X-FER
3rd Ed. INCROPERA & DE WITT

$$\overline{Nu}_s = \frac{1}{24} Ra_s \left(\frac{S}{L} \right) \left\{ 1 - \exp \left[- \frac{35}{Ra_s (S/L)} \right] \right\}^{3/4} \quad \text{EQN.}$$

$$Ra_s = \frac{g \beta (T_s - T_{\infty}) S^3}{\alpha \nu}$$

$$g = 9.8 \text{ m/s}^2 \quad S = .575 \text{ IN} = 1.46 \text{ IN}$$

$$\beta = \frac{1}{T_f} = \frac{1}{200 \text{ K}}$$

$$\alpha = 10.3 \times 10^{-6} \text{ m}^2/\text{s} \quad \text{THERMAL DIF. OF AIR}$$

$$\nu = 7.590 \times 10^{-6} \text{ m}^2/\text{s} \quad \text{KINEMATIC VISCOSITY OF T=200K}$$

TABLE A.4

$$Ra_s = \frac{(9.8 \text{ m/s}^2) \left(\frac{1}{200 \text{ K}} \right) (100 \text{ K} - 300 \text{ K}) (1.46 \times 10^{-2} \text{ m})^3}{(10.3 \times 10^{-6} \text{ m}^2/\text{s}) (7.59 \times 10^{-6} \text{ m}^2/\text{s})}$$

$$Ra_s = -3.9053 \times 10^5$$

LAMINAR FREE CONVECTION

$$\overline{Nu}_s = \frac{1}{24} Ra_s \left(\frac{s}{L} \right) \left\{ 1 - \exp \left[\frac{-35}{Ra_s (s/L)} \right] \right\}^{3/4}$$

$$\overline{Nu}_s = \frac{1}{24} (+3.9053 \times 10^5)(.23) \left\{ 1 - \exp \left[\frac{-35}{(+3.9053 \times 10^5)(.23)} \right] \right\}^{3/4}$$

$$\overline{Nu}_s = \left\{ 3.89584 \times 10^{-4} \right\}^{3/4}$$

$$\overline{Nu}_s = 10.378$$

$$\# \overline{Nu}_s = \left(\frac{q/A}{T_s - T_\infty} \right) \frac{s}{K} \quad \text{EQN 9.37}$$

$$K_{\text{AIR } 200K} = 18.1 \times 10^{-3} \frac{W}{mK} \quad \text{TABLE A.4}$$

RE-ARRANGING 9.37

$$\frac{q}{A} = \frac{\overline{Nu}_s \cdot K}{s} (T_s - T_\infty) = \frac{(10.378)(18.1 \times 10^{-3} \frac{W}{mK})}{(1.46 \times 10^{-2} m)} (100 - T_\infty)$$

$$\underline{\underline{\frac{q}{A} = -2573 \frac{W}{m^2}}}$$

STILL LET FIN EFFICIENCY = 1.0 TO BE CONSERVATIVE
THIS WILL MORE THAN COMPENSATE FOR NOT INCLUDING
THE SURFACE AREA OF THE BARE TUBES.

$$Q_{\text{TOTAL}} = \frac{q}{A} \cdot A_{\text{FINS}} = (2573 \frac{W}{m^2}) (5.48 m^2)$$

$$\boxed{Q_{\text{TOTAL}} = 14,100 \text{ Watts}}$$

THIS IS
REASONABLE.

$$\dot{m}_{\text{VAP}} = \frac{Q_{\text{TOTAL}}}{h_{\text{fg}}} = 1564 \frac{lb}{hr} \times \frac{14,100 W}{32,276 W} = 683 \frac{lb}{hr}$$

AIR EQUIVALENT:

$$Q_a = \frac{13.1}{60} W \frac{356}{C} \sqrt{\frac{ZT}{M} \frac{28.97}{520}}$$

EQN. 6A-1
TECH. OF LHE

PRESS. BLDG. COIL FAIL.

CASE 3
RAW CALCS.

RUSS RUCINSKI 10/24/96 A3.7

$$Q_a = \frac{13.1}{60} (683 \frac{\text{lbm}}{\text{hr}}) \frac{356}{356} \sqrt{\frac{(.85)(180^\circ\text{R})}{28.014} \frac{28.97}{520}} \quad \text{MATH CO
M.2AC
11-7-}$$

$$\frac{T}{T_r} = \frac{100\text{K}}{126.26\text{K}} = .792 \quad \frac{P}{P_r} = \frac{102\text{ psia}}{493.134} = .2068$$

$Z = 0.85$ FROM FIG. A.5 GENERAL COMPRESS. CHART.

FUNDAMENTALS OF CLASSICAL THERMODYNAMICS
3rd ED. VAN WYLEN & SONN

$$Q_a = 82.3 \text{ scfm AIR}$$

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REQ'NTS.

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11-5-96

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CASE 4 ; PUMPING OVERFILL

* { REF. CGA 51.3-1995 4.1.6.1 }
REF. FESH 5032.1TA 70(C)

MATH CHECKED:
A. ZACZAK

LIQ. NITROGEN DELIVERY TRUCKS HAVE RECENTLY BEGUN
UPGRADED TO DELIVER AT RATES UP TO 200 GPM
AT 435 PSIG. WITH HIGH CAPACITY PUMPS.
{ REFERENCE FERMILAB ESH MESSAGE # 960322-01 }

THE RELIEVING REQUIREMENT FOR SUCH A LARGE
FLOW RATE CANNOT BE MET BY CONVENTIONAL
MEANS. THEREFORE, A SUITABLE ALTERNATIVE
METHOD HAS BEEN CHOSEN.*

VESSEL OVERPRESSURE DUE TO FILLING IS
PREVENTED BY AN AUTOMATIC SHUT OFF
VALVE INSTALLED ON THE FILL LINE. A
SIMPLIFIED SYSTEM SCHEMATIC IS SHOWN
BELOW:

SKETCH 4.1 SIMPLIFIED SCHEMATIC
OF AUTOMATIC FILL SHUT-OFF

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PUMPING OVERFILL (CONT.)

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MATH CHECKED
M. ZACZEL
11-8-96

SPECIFIC DETAILS, MODEL NUMBERS, ETC.

FOR THE COMPONENTS OF THE SYSTEM ARE ATTACHED.

THE NORMAL OPERATING PRESSURE OF THIS DEWAR IS 35 PSIG. DURING A NORMAL FILL THIS PRESSURE SHOULD NOT VARY MORE THAN 5 PSIG. FOR A FILLING ACCIDENT CASE (DRIVER DISREGARDS LEVEL GAGE.) THE PRESSURE SWITCH, PS 2737-N WILL TRIP AT A FIXED SET POINT OF 55 PSIG. WHEN TRIPPED, IT BREAKS THE CIRCUIT SUPPLYING POWER TO THE 4 WAY SOLENOID. THE 4 WAY SOLENOID BLOCKS AND VENTS THE AIR SUPPLY THAT HOLDS OPEN THE FILL VALVE PV-2736-N. THE FILL VALVE CLOSSES WHICH PROTECTS THE VESSEL FROM THE SOURCE OF OVERPRESSURE.

THE PRESSURE SWITCH IS PROVIDED WITH A LATCHING RESET BUTTON SO THAT MANUAL INTERVENTION IS NECESSARY TO RESUME FILLING OPERATIONS. ALL COMPONENTS ARE COMMERCIALY AVAILABLE, COMMON ITEMS WITH GOOD RELIABILITY. THE SYSTEM IS FAIL SAFE IN AS MUCH AS A LOSS OF EITHER ELECTRICAL POWER OR INSTRUMENT AIR WILL CLOSE THE FILL VALVE PV-2736-N.

A RELIABILITY ANALYSIS FOLLOWS AND SHOWS THAT THE SYSTEM IS AS SAFE AS A CLASS Ø ODH AREA.

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RELIABILITY / PROBABILITY ANALYSIS

FOR AUTO FILL
SHUT-OFF
ON OVERPRESSURE

I WILL USE A PROBABILITY TREE DIAGRAM & THERP MODEL

{ REF. "HUMAN FACTORS" BY KANTOWITZ & SORKIN, ISBN 0-471-09544-X }
PAGE 51

MATH CHECK
M. ZACZEK
11-8-96

FILLING EVENT

PROBABILITIES

$$K = .01$$

$$\bar{K} = .99$$

.01 PROBABILITY OF FAILURE TO RECOGNIZE AN INCORRECT STATUS WHEN CHECKING ITEM IN FRONT OF YOUR NOSE. TABLE 2-2 p.53 "HUMAN FACTORS"

$$S = .00001$$

$$\bar{S} = .99999$$

REF. FESHM 5064 TABLE 2

$$T = .001$$

$$\bar{T} = .999$$

$$R = .0003$$

$$\bar{R} = .9997$$

PROBABILITY OF = Pr

$$Pr(\text{SAFE outcome}) = K + \bar{K}(S|\bar{K})(\bar{t}|(S|\bar{K}))(\bar{r}|\bar{t}|(S|\bar{K}))$$

$$Pr(\text{SAFE outcome}) = .99 + .01(.99999)(.999)(.9997)$$

99% PROB. OPERATOR SHUTS OFF FLOW

1% PROBABILITY OPERATOR SCREWS UP

PROB. P.S. OPERATES CORRECTLY

PROB. SOLENOID WORKS CORR.

PROB. BALL VALVE ACTUATES

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LN₂ DEWAR RELIEF SIZING REQ'D MT
PUMPING OVERFILL (cont.)

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MATH CHECKED
M. ZACZEK
11-8-96

$$Pr(\text{SAFE outcome}) = .9999869031$$

$$Pr(\text{FAILURE outcome}) = K(S|K) + K(S|K)(T|S|K) + \dots + K(S|K)(T|S|K)(R(T|S|K))$$

$$Pr(\text{FAILURE outcome}) = .01(.00001) + .01(.99999)(.001) + .01(.99999)(.999)(.001)$$

$$Pr(\text{FAILURE outcome}) = .00001309687003$$

$$\text{CHECK: } Pr(\text{SAFE outcome}) + Pr(\text{FAILURE outcome}) \stackrel{?}{=} 1.0$$

$$\begin{array}{r} .9999869031 \\ + .0000130969 \\ \hline 1.0000000000 \end{array} \quad \checkmark \text{ CHECKS O.K.}$$

WHAT THIS MEANS IN MORE TANGIBLE TERMS IS,

$$[Pr(\text{FAILURE outcome})]^{-1} = 76,354$$

THERE IS A PROBABILITY OF 1 FAILURE OUTCOME IN 76,354 FILLING OPERATIONS. ASSUMING 3 FILLS/WEEK; THIS MEANS 1 FAILURE IN 489 YEARS. PUTTING THIS IN ODH PROBABILITY UNITS OF hr^{-1} ;

$$\begin{aligned} Pr(\text{FAILURE outcome}) &= .00001309687 \frac{\text{FAILURES}}{\text{EVENT}} \times \frac{3 \text{ EVENTS}}{\text{WEEK}} \times \frac{1 \text{ WEEK}}{7 \text{ DAYS}} \times \frac{1 \text{ DAY}}{24 \text{ hrs.}} \\ &= 2.34 \times 10^{-7} \frac{\text{FAILURES}}{\text{HR}} \end{aligned}$$

A FAILURE OUTCOME JUST MEANS THE RELIEF CAPACITY WOULD BE EXCEEDED IF THE PUMPING RATE WAS GREATER THAN 110 gpm (FROM CAPACITY CALCS. NOT PRESENTED.) DURING THAT FILL EVENT. JUST FOR DISCUSSION, ASSUME A ONE IN TEN FATALITY FACTOR FOR A FAILURE EVENT. THEN THE FATALITY RATE WOULD BE:

$$\Phi = Pr \cdot F = (2.34 \times 10^{-7} \frac{\text{FAILURES}}{\text{HR}}) \left(\frac{1 \text{ FATALITY}}{10 \text{ FAILURES}} \right) = 2 \times 10^{-8} \text{ hr}^{-1}$$

FERMILAB

ENGINEERING NOTE

SECTION

RD100

PROJECT

LN₂
DEWAR

SERIAL-CATEGORY

3823.115

PAGE

A4.4

SUBJECT

LN₂ DEWAR RELIEF SIZING REOMT
PUMPING OVERFILL (cont.)

NAME

RUSS RUCINSKY

DATE

11-7-96

REVISION DATE

MATH CHECKED
M.2452BK

FOR COMPARISON, THE ODH CLASS CRITERIA IS THAT

$$\phi < 10^{-7} \text{ hr}^{-1} \text{ FOR AN ODH CLASS } \phi \text{ AREA.}$$

I CONCLUDE THAT IN GOOD ENGINEERING JUDGEMENT, THE
AUTO FILL SHUT-OFF SYSTEM ON OVERPRESSURE
IS RELIABLE ENOUGH TO REDUCE THE HAZARD
TO AN ACCEPTABLE LEVEL.

ID # 8351

PURCHASE REQUISITION

(SEE INSTRUCTIONS ON REVERSE SIDE - DO NOT WRITE IN SHADED AREAS)

DESIRED DELIVERY

12/9/96

REQUESTED BY Russ Rucinski		EMPLOYEE NO 8351	EXT.	ORGANIZATION UNIT RD/DO	MAIL STATION 357	REQUESTOR'S IDENTIFIER		REQ. DATE 11/5/96	
SUGGESTED VENDOR B&B Instruments, Inc. 6444 Columbia Ave., PO box 4039 Hammond, IN 46324		PHONE NO 219-932-4474		PROJECT DESCRIPTION DØ Upgrade Solenoid DELIVER TO (INCLUDE NAME & BUILDING NO) Russ Rucinski, D-Zero Ass'y Bldg.		APPROVALS EMPLOYEE NO			
SHORT DESCRIPTION (30 CHARACTERS OR LESS) Pressure switches - LN2 dewar					PREVIOUS P.O.		DIR. OFFICE		
REC. AREA CODE	QUANTITY	ITEM DESCRIPTION				ESTIMATED UNIT PRICE	DO NOT USE UNIT PRICE DISCOUNT DEL DATE		
	3	UE Electromechanical Products, Pressure switch. Model Number H100-270-1530.				\$138.00			
CHECK BOX IF CONFERENCE REQ.		CHECK BOX TO RECEIVE P.O. COPY VIA E-MAIL		TOTAL AMOUNT THIS REQUISITION				\$414.00	
BUDGET CODE	PERCENTAGE	NEPA APPROVAL		DIVISION OFFICE APPROVAL		WBS NUMBER	PERCENTAGE	PURCHASING/CONTRACTS DEPT. STAMP	
EEH	100					3.1.1.4.5	100%		
P.O. NUMBER		VENDOR CODE		BUYER		AT RIGHT INDICATE SPECIAL ORDER TYPE (SPARES/ISS/GSA/CAFE/AB/T&M)		GSA/FSS CONTRACT NO.	
SEND P.O. TO ATTENTION OF		SHIP VIA	F.O.B. & POINT OF SHIPMENT FOR FB/FC/FD			TERMS	REPORTING CODE	COST ELEMENT	CONFIRMED TO & DATE
CHECK IF P.O. FOR INTERNAL USE ONLY		CHECK IF REQUESTER TO APPROVE PAYMENT		BEGINNING STD. TEXT CODES		ENDING STD. TEXT CODES		REQUISITION NUMBER	

DØ-9/29/96

A4.5

UE

PAGE A4.6

UE Electromechanical Products

Pressure and Temperature Switches
Indicating Temperature Controls
Temperature Recorders

bbi

B&B Instruments, Inc.

6444 COLUMBIA AVE.

P.O. BOX 4039

HAMMOND, IN 46324

312-891-8840/219-832-4474/FAX: 219-832-6399

INDUSTRIAL GAUGES AND PROCESS CONTROLS

SWITCHES FOR NEMA 4, General Purpose Service

A4.7

- Introducing a family of low-cost pressure and temperature switches for the process plant or OEM
- Wide selection of adjustable ranges within 3-5000 psi and -180 to 1000°F
- Internal reference scales and adjustment lock
- Enclosure design permits safe and easy access for wiring
- Many models available from stock
- Factory setting

Specifications

Approvals:

UL listed

CSA certified.

Storage Temperature:

-65 to $\pm 160^{\circ}\text{F}$

Ambient Temperature limits:

-40 to $\pm 160^{\circ}\text{F}$, except models 701-706, 0 to 160°F .
Set point typically shifts less than 1% of range for a 50°F (28°C) ambient temperature change.

Shock:

Set point repeats after 15 G, 10 millisecond duration.

Vibration:

Set point repeats after 2.5 G, 5-500 CPS.

Enclosure Classification:

NEMA 4; (4X see 117 series).

Set point Repeatability:

Temperature Models $\pm 1\%$ of adjustable range.

Pressure Models 701-706, 270-376 $\pm 1\%$ of adjustable range.

190-194, 612-680 $\pm 1.5\%$ of adjustable range.

1 SPDT. Switch may be wired "normally open" or "normally closed".

15 amp 125/250/480 VAC resistive.

Die cast aluminum, (max 0.6% copper)

Light grey aluminum lacquer finish, gasketed

Approx. 2 lbs.

$\frac{1}{2}$ " NPT, (2) $\frac{3}{8}$ " diameter knockouts.

$\frac{1}{4}$ " NPTF except models 190-194 ($\frac{1}{2}$ " NPTF).

6 feet copper or 304 stainless steel models M9B.

M9BB 347 stainless steel.

Switch Output:

Electrical Rating:

Enclosure:

Weight:

Electrical connection:

Pressure connection:

Temperature Assembly

Bulb and Capillary:

Immersion Stem

Fill:

Temperature

Deadband:

HTFP Heat Tracing/ Freeze Protection:

Brass

Models 1BC, 1BS are solvent filled, models

2-8 are oil-filled and models M9B, M9BB are mercury filled.

Typically 1% of range under laboratory conditions (70°F ambient circulating bath at rate of $\frac{1}{2}^{\circ}\text{F}$ per minute change).

Switches designed specifically for heat tracing and freeze protection applications. Available with types B100 and E100. Specifications are the same as above except:

B100-13546 includes: 22 amp switch with a stainless steel immersion stem.

E100-13545 includes: 22 amp switch and 10 feet of stainless steel capillary.

Dimensions

How To Order

Follow Steps 1-4 to specify the 100 Series pressure and temperature switch for your application.

1 Specify Type

Pressure:

Type H100 - One SPDT output

Temperature:

Type C100 - Immersion stem, internal adjustment

Type B100 - Immersion stem,

Type F100 - Bulb and capillary, internal adjustment
Type E100 - Bulb and capillary, internal adjustment via calibrated dial

2 Select standard models in stock for fast delivery. Order by type and stock number (eg. H100-

95122). Be sure to check for stocked models with options. If your selection is not stock, go to step 3.

3 For models not in stock, specify type and model (eg. H100 model 706)

4 If an option is required, add code number from pages 46 and 47 to type and model (eg. H100-701*M201).

PRESSURE Model Chart Type H100

316 Stainless Steel diaphragm and 1/2" NPTF pressure connection.						
Model	Stock numbers for Type H100	Adjustable Range (English)	Adjustable Range (Metric)	Deadband Lower 75% range span	Top 25% range span	Proof Pressure
190†	95303	5 to 30 PSI	35 to 200 kPa	1.0 to 3.0	6 max.	2500 PSI
191†	95310	10 to 100 PSI	70 to 700 kPa	1.0 to 8.0	15 max.	2500 PSI
192†	95317	30 to 300 PSI	200 to 2000 kPa	3.0 to 18	25 max.	2500 PSI
193†	95324	50 to 500 PSI	0.35 to 3.5 MPa	4.0 to 30	45 max.	2500 PSI
194†	95331	200 to 1700 PSI	1.4 to 11.7 MPa	5.0 to 120	150 max.	2500 PSI

†Deadband Note: Models 190-194 are expressed as the lower 75% and top 25% of the range span because of the operating characteristics of the diaphragm sensor and switch.

Phosphor bronze bellows and 1/4" NPTF brass pressure connection						
Model	Stock numbers for Type H100	Adjustable Range (English)	Adjustable Range (Metric)	Deadband		Proof Pressure
218	95704	30"Hg VAC to 0 PSI	-100 to 0 kPa	1 to 2"Hg		30 PSI
270	95166	20 to 200 PSI	140 to 1400 kPa	1 to 4.0 PSI		250 PSI
274		30 to 300 PSI	200 to 2000 kPa	1 to 5.0 PSI		350 PSI
316 Stainless steel bellows and 1/4" NPTF pressure connection						
358		20 to 200 PSI	140 to 1400 kPa	1 to 3.0 PSI		250 PSI
361		30 to 300 PSI	200 to 2000 kPa	1 to 1.4 PSI		350 PSI
376		50 to 500 PSI	0.35 to 3.5 MPa	1.5 to 5.0 PSI		575 PSI
316 Stainless steel bellows and 1/4" NPTF pressure connection						
680	95415	100 to 1700 PSI	7 to 11.7 MPa	9 to 23 PSI		2500 PSI
303 Stainless steel piston and Buna-N "O" ring 1/4" NPTF pressure connection, (not recommended for gas service since drying of the "O" ring can allow bleeding of medium into the atmosphere).						
610		100 to 1000 PSI	0.7 to 7MPa	30 to 150 PSI		10000PSI
612	95712	200 to 3000 PSI	1.4 to 20.0 MPa	40 to 250 PSI		10000 PSI
616		700 to 5000 PSI	4.8 to 35.0 MPa	40 to 375 PSI		10000 PSI
Buna-N diaphragm, "O" ring and 1/4" NPTF brass pressure connection. Buna-N diaphragm limited to process temperatures below 165°F.						
701	95122	3 to 30 PSI	20 to 200 kPa	1.0 to 2.0 PSI		600 PSI
702	95129	10 to 100 PSI	70 to 700 kPa	1.0 to 4.0 PSI		600 PSI
703	95136	30 to 300 PSI	200 to 2000 kPa	1.0 to 5.0 PSI		600 PSI
704	95142	50 to 500 PSI	0.35 to 3.5 MPa	2.0 to 8.0 PSI		2500 PSI
705	96149	100 to 1000 PSI	0.7 to 7.0 MPa	3.0 to 20.0 PSI		2500 PSI
706		200 to 1700 PSI	1.4 to 11.7 MPa	10.0 to 30.0 PSI		2500 PSI

*Stocked items with options.

Options

Many UE products with options are available from stock. These are indicated in model charts throughout the catalog by a stock number beginning with the number "9" (H100-95606, for example, refers to an H100 pressure switch with option M315). Order these by type and stock number (H100-9536, eg.). Switches listed below are UL listed, CSA approved. All switches are SPDT unless stated otherwise.

For products with options that are not in stock, follow 1-3.

1. Specify product type H100
2. Select model from chart H100-701
3. Select option from these pages after checking availability listed H100-701*0140*M201.

Optional Switches

Code	Description/availability
0140	1 amp 125 VAC res. gold flashed contact (dry circuit). Available: Types J400, J&H402, J403 (C400, 02, 03) (F400, 02, 03) Types J, C, F, 120; E, B, H122 series J6 and 100
0500	5 amp 125/250 VAC res. switch, close deadband. Available: Series 400, 120, 100, 6, 21K, 54, 55
1010	DPDT switch, 10 amp 125/250 VAC resistive 120 deadbands wider than standard. Available for certain models J120, J120K; all models F120, E121, H100, F100, C100
1070	10 amp 125 VDC switch. Available for the following: Types J, C, F 400, all type 402 Types C, F, J 120 Series J6, 100 and 54 Deadbands wider than standard.
1180	Hermetic Seal, SPDT, 11 amp 125/250 VAC, resistive UL, CSA listed. Available C, F, J120.
1190	DPDT, 11 amp Hermetic Seal. Available: 117, 120 Series.
1519	15 amp adjustable deadband 480 VAC res. max. Available: J120, J120K, C120, F120, C, F, H100.
1520	15 amp 277 VAC res. max., adjustable deadband. Available: Series J6 (126-S160, 218-230) Types J, C, F 400 and J, C, F 402 Types H 105, J54 and J54S Series J21K
1521	15 amp 277 VAC res. max., 2.40% of span adjustable deadband construction. Available: J6 (126-S160B) J400, (126-S164B, 451-454) J400K
1530	15 amp 125/250 VAC res. external manual reset on increasing pressure and temperature. Types J, C, F 400; J, C, F 402 Series: J21K, J6 Types C, F, H 100; B, C, E, F, J54 Types C, F, J120*, E55, E55A
2000	20 amp 125/250 VAC res. switch. Available: Types J, C, F 400, 402, 403 Series 120 single switch only. Series 55, 100, J6, J21K, J27KB, 800, 820 Type E105, B105

Recorder options

Code	Description/availability
M002	60Hz, 115VAC, 7 day chart drive Available: 650 Series
M003	50 Hz, 115VAC, 7 day chart drive
M008	50Hz, 230VAC, 7 day chart drive
M009	60Hz, 230VAC, 24 hour rotation

Note: For celsius models, std. 24 hour rotation order option M270
For celsius models, 7 day rotation suffix "C" after option code
(eg: M002C).

*Use of 1530 or M450 options provide CSA, Class I, Div. 1 group C & D only.

General Options

Code	Description/availability
M007	Drilled electrical opening 800 Series, right side.
M201	Set one switch; specify increasing or decreasing pressure or temperature and set point.
M202	Set two switches; specify increasing or decreasing pressure or temperature and set point.
M203	Set three switches; specify increasing or decreasing pressure or temperature and set point.
M210	Differential pressure indication Available: H122K, H121K, J400K, J402K (models 147-S157B)
M270	Metric calibrated diala (Celsius) Dual reference scales standard for many Series. Available: E54, E55, 650's only.
M300	NEMA 4 construction Available for the 800 Series Standard for many Series. J21K, 400 Series only requires option M900 for compliance.
M315	Epoxy Polyamide coating of enclosure, external aluminum parts. Available: Types J, C, F 402 Series: 100 Series: Types C, F, J 120, B, E, H122 only.
M321	Gasketed Lexan® window Available on Types, B, E, H 400 Series.
Cenelec	Flameproof enclosure, BS5501, part 5, 1977, IP-66.
BASEEFA	CENELEC EN 50014/50018; EExd IIB T6. Approval available for the 120 Series only. Prefix model number with 'Q' eg. QF120-6BS (EExd IIC T6-Consult factory).
M410	CSA option Available for the following: J6, J40, 54.
M411	Compliance to NACE std. MR-01-80, 120, 100; 117 Series pressure models 190-193. Consult factory.
M444	Paper ID tag
M446	Stainless steel ID tag & wire attachment (attachment will vary depending on product)
M449	Mounting hardware 800 Series
M450	Breather drain Available for certain 120 Series models only. Consult factory
M540	Viton construction (deadbands may increase slightly) H100, H100D, H117, H117D and 120 Series models 700-713, wetted parts include Viton diaphragm and "O" ring plus 303 St/St, 1/4" NPTF pressure connection. 120 Series models 450-454, 400 Series models 448-454, 54 Series models 22-28 plus 120K, 400K, and 105K models 455-457; wetted parts include Viton diaphragm and "O" ring plus standard connection material. All products within models 610-618 and 50-55: "O" ring (only) is changed to Viton.
M550	Oxygen service cleaning. Internal construction may change, consult UE. Available for: Pressure controls (H60, 100, 105, 120, 400 Series). Not available: J400-614, J402-610. Differential pressure controls (120K, 105K, 400K)
M900	Watertight conduit fitting. Converts 7/8" hole to 1/2" NPT Available for the following: 400 Series 800 Series 117 Series 650 Series 100 Series
M901	Watertight conduit fitting. Converts 1/2" NPT to 3/4" NPT. (117 Series).

(SEE INSTRUCTIONS ON REVERSE SIDE - ~~DO NOT~~ DO NOT WRITE IN SHADED AREAS)

REQUESTED BY J MARKLEY		EMPLOYEE NO. 4741	EXT. 2817	ORGANIZATION UNIT RD/DP	MAIL STATION 357	REQUESTER'S IDENTIFIER	REQ. DATE 10/18/96
REQUESTED VENDOR TRUMENT ASSOCIATES		PHONE NO. 708-597-9880	PROJECT DESCRIPTION DP HELIUM SYSTEM			APPROVALS	
DESCRIPTION (30 CHARACTERS OR LESS) 12 DEWAR CONTROL			DELIVER TO (INCLUDE NAME & BLDG. NO.) DAN MARKLEY DP ASSEMBLY HALL			BUS. OFFICE	
			PREVIOUS P.O.			DIR. OFFICE	
QUANTITY	ITEM DESCRIPTION				ESTIMATED UNIT PRICE	DO NOT USE UNIT PRICE DISCOUNT DEL. DATE	
3	PARKER GOLD RING SOLENOID VALVE 2 position, 4way, 100 PSI MAX PRESSURE. 24VDC COIL, OUTDOOR TYPE 4 ENCLOSURE PART # 04F48S2106A3F 4 C 80				\$112.71		
	WBS# 3.1.1.4.10						
CHECK BOX IF FINANCE REQ.		CHECK BOX TO RECEIVE P. O. COPY VIA E-MAIL		TOTAL AMOUNT OF THIS REQUISITION \$		\$338.13	
CODE	PERCENTAGE	NEPA APPROVAL	DIVISION OFFICE APPROVAL		BUDGET OFFICE APPROVAL	PURCHASING/CONTRACTS DEPT. STAMP	
H							
FIBER		VENDOR CODE	BUYER	AT RIGHT, INDICATE SPECIAL ORDER TYPE (SPARES/ISS/GSA/CAFE/FAB/T&M)		GSA/FSS CONTRACT NO.	
TO ATTENTION OF		SHIP VIA	F.O.B. & POINT OF SHIPMENT FOR FB/FC/FD		TERMS	REPORTING CODE	COST ELEMENT
P.O. FOR USE ONLY		CHECK IF REQUESTER TO APPROVE PAYMENT	BEGINNING STD. TEXT CODES		ENDING STD. TEXT CODES	REQUISITION NUMBER	

A 4.10

Gold Ring™ Solenoid Valves

2 Position 4-Way Solenoid Valves

Brass & Buna-N

Series 48

1/4"

A 4.11

General Description

Parker Gold Ring™ 2 position 4-way solenoid valves are available in brass with 1/4 inch N.P.T. They can be used for media flow control in systems used to control small double acting cylinders not larger than 4" in diameter.

Series 48 solenoid valves require a minimum 10 psi operating pressure for acceptable system operation. Avoid exhaust flow restriction.

Applications

Series 48 Gold Ring™ solenoid valves are ideal for the control of a variety of media including gases, fluid light oils and other clean flowing media compatible with brass. This valve can be used in the following applications:

- Pilots
- Air motors
- Air vises
- Dampers

Operating Specifications

De-energized: Pressure to "A"; "B" to exhaust.

Energized: Pressure to "B"; "A" to exhaust.

Installation

- For proper operation, solenoid valves should be mounted vertical and upright
- See mounting dimensions (nominal) shown here
- For certified dimensions consult factory

Approvals

Standard valves with general purpose or explosion proof solenoid enclosures are U.L. Listed and CSA Certified. For details, consult factory.

Wetted Materials

Valve body:	Brass
Seals:	Buna-N
Plunger and Pole Piece:	430FR S.S.
Plunger Tube:	305 S.S.
Springs:	302 S.S.
Shading Coil:	Copper (Brass Bodies)
Disc Holder:	Celcon

Solenoid Types

Open Frame:	Open Frame (O)
Type 1:	General Purpose (G), Splice Box (S) or Conduit Hub (T)
Type 2, 3, 3R:	Rainproof (R), Explosion Proof (E), S.S. Explosion Proof (M), S.S. or Standard Submersible (U or W)
Type 4, 4X:	Gold Ring II™ totally encapsulated (4)
Type 6:	Submersible Splice Box (W)
Type 7, 9:	Explosion Proof (E), S.S. Explosion Proof (M)
D.I.N.:	ISO 4400 & DIN 43650 (P)

Electrical

24/60, 110/120-50/60, 220/240-50/60, 440/480-50/60 volts A.C.
6, 12, 24, 120, 125 volts D.C. Other voltages as requested.

Coil

Class F, Standard. Class H Available.

Temperature Ratings

Media as listed

- A.C. voltages: 180°F max.
- D.C. voltages: 104°F max.

Ambient: 32-77°F (standard)

For temperature variations, consult factory.

Series 48
AC & DC

Gold Ring™ Solenoid Valves

Material & Trim: Brass & Buna N

A 4.12

AC Valve Specifications										
NPT	ORIFICE INLET EXH	Cv INLET EXH	Oper. Press. Differential				° F MAX TEMP	AC WATT	DWG NO	VALVE PART NUMBER
			MIN PSI	Max (MOPD) PSI						
				AIR INERT GAS	WATER	LIGHT OIL 300SSU				
Operation: Universal (Pressure at P)										
1/4	1/16 3/32	.09 .09	10	150	150	150	180	11.0	83	04F48S2106ACF

DC Valve Specifications										
NPT	ORIFICE INLET EXH	Cv INLET EXH	Oper. Press. Differential				° F MAX TEMP	DC WATT	DWG NO	VALVE PART NUMBER
			MIN PSI	Max (MOPD) PSI						
				AIR INERT GAS	WATER	LIGHT OIL 300SSU				
Operation: Universal (Pressure at P)										
1/4	1/16 3/32	.09 .09	10	100	100	100	104	11.2	83	04F48S2106A3F

Drawing 83

Explosion-Proof/Watertight
Shown in Outline

PURCHASE REQUISITION

(SEE INSTRUCTIONS ON REVERSE SIDE - DO NOT WRITE IN SHADED AREAS)

DESIRED DELIVERY

12/10/96

REQUESTED BY Russ Rucinski		EMPLOYEE NO 8351	EXT.	ORGANIZATION UNIT RD/DO	MAIL STATION 357	REQUESTOR'S IDENTIFIER	REQ. DATE 11/1/96
SUGGESTED VENDOR Columbia Pipe & Supply 1803 Moen Avenue Rockdale, IL 60435		PHONE NO 815-729-3200		PROJECT DESCRIPTION DØ Upgrade Solenoid DELIVER TO (INCLUDE NAME & BUILDING NO) Russ Rucinski, D-Zero Ass'y Bldg.		APPROVALS EMPLOYEE NO BUS. OFFICE DIR. OFFICE	
SHORT DESCRIPTION (30 CHARACTERS OR LESS) LN2 dewar valves					PREVIOUS P.O.		
REC AREA CODE	QUANTITY	ITEM DESCRIPTION				ESTIMATED UNIT PRICE	DO NOT USE UNIT PRICE DISCOUNT DEL. DATE
	1	Worcester 1-1/2" C4466-PM-SW-V1 Cryogenic diverter ball valve				\$1,000.00	
		with extended stem handle. 300 series stainless steel body, ball & stem.					
→	1	Worcester 1-1/2" C4466-PM-SW Cryogenic C4 Ball valve with mounted				\$1,100.00	←
		actuator #2039SN, Spring return, air to open, fail closed, no solenoid.					
		300 series stainless steel body, ball & stem. Will be operated					
		with 80 psi air supply.					
CHECK BOX IF CONFERENCE REQ.		CHECK BOX TO RECEIVE P.O. COPY VIA E-MAIL		TOTAL AMOUNT THIS REQUISITION		\$2,100.00	
BUDGET CODE	PERCENTAGE	NEPA APPROVAL		DIVISION OFFICE APPROVAL		WBS NUMBER	PERCENTAGE
EEH	100					3.1.1.4.5	100%
P.O. NUMBER V 98400		VENDOR CODE		BUYER		AT RIGHT INDICATE SPECIAL ORDER TYPE (SPARES/ISS/GSA/CAFE/AB/T&M)	
SEND P.O. TO ATTENTION OF		SHIP VIA		F.O.B. & POINT OF SHIPMENT FOR FB/FC/FD		TERMS	REPORTING CODE
CHECK IF P.O. FOR INTERNAL USE ONLY		CHECK IF REQUESTER TO APPROVE PAYMENT		BEGINNING STD. TEXT CODES		ENDING STD. TEXT CODES	
						REQUISITION NUMBER	

DØ-8/29/96

A 4.13

C4 and C4 Diverter Valves with Stem Extensions

Valve Sizes:	1/4", 3/8", 1/2", 3/4", 1" 1/2" and 2" (Diverter Not Available in 1/4" and 3/8")
Styles:	Unidirectional Flow, Three-Piece Design Extended, One-Piece, Blowout-Proof Stem Diverter-V1, V2 Porting
Body:	ASTM A743 CF3M, 316L Stainless Steel ASTM B283 C37700, Brass
Pipe Ends:	ASTM A743 CF3M, (316L) Stainless Steel ASTM A743 CF8M, (316) Stainless Steel ASTM B283 C37700, Brass
Ball:	ASTM A276 316 Stainless Steel, Condition A ASTM B16 HO2 Upstream relief hole (V3) in ball to relieve cavity pressure. Slot in top of ball for insertion of stem alignment pin to insure proper orientation in valve. Gives external positive indication of ball position.
Stem:	ASTM A479 316L or ASTM A276, 316L Condition A solution annealed. One-piece stem with alignment pin in bottom and arrow on top for proper orientation of ball in valve. Gives positive external indication of ball position.
Seats:	Polyfill
Body Seals:	"S" Gaskets (Teflon Coated 316 Stainless Steel)
Stem Packing:	Chevron Packing (Teflon Style C-VH Rings)
Packing Followers:	ASTM A479 316L
Split Ring:	ASTM A479 316L
Split Thrustbearing:	Polyfill
Externals:	300 Series Stainless Steel
End Connections:	SE - Screwed Pipe Ends (NPT) (Dimensions to ANSI B1.20.1) SW - Socket Weld Ends (Diameter and Depth of Bore to ANSI B16.11) SW0 - Socket Weld Ends for O.D. Tubing to ASTM A269 (Stainless Steel Only) BW1 - Butt Weld Ends for Schedule 10 Pipe (Dimensions to ANSI B16.25) (Stainless Steel Only) TE - Tube Ends (Sweat Ends for Type K, L and M Copper Tubing to ASTM B88) (Brass Only)
Temperature Range:	-425°F to +500°F
Maximum Pressure:	1500 psi 1000 psi (1 1/2" & 2" Brass)

Wafer Valves and Flanged Valves with and without Extensions

Valve Sizes:	3", 4" and 6"
Style:	Unidirectional Flow, Wafer/Flangeless and flanged Design Blowout-Proof Stem
Valve Ratings:	Wafer - Fits between ANSI Class 150 and 300 Flanges Flanged - ANSI Class 150
Body and End Plug:	ASTM A351 CF8M Stainless Steel ASTM B584 C83600 Brass (Wafer Only)
Ball:	ASTM A240-316 or ASTM A312 GR TP-316 Stainless Steel ASTM B584 C83600 Brass (Wafer Only)
Stem:	ASTM A276 316 Stainless Steel Condition A
Seats:	Polyfill
Body Seal:	TFE-Virgin
Stem Seals:	TFE - 15% Glass Filled
Centering Washers:	AISI 316 Stainless Steel ASTM B121 C34200 Brass (Wafer Only)
Thrustbearing:	TFE - 15% Glass Filled
Follower:	AISI - 304 Stainless Steel
Externals:	300 Series Stainless Steel

C4 and C4 Diverter Valves without Extensions

Valve Sizes:	1/4", 3/8", 1/2", 3/4", 1" 1/2" and 2" (Diverter Not Available in 1/4" and 3/8")
Styles:	Unidirectional Flow, Three-Piece Design Top Entry Extended, One-Piece, Blowout-Proof Stem Diverter - V1, V2 Porting
Body:	ASTM A743 CF3M, 316L Stainless Steel ASTM B283 C37700, Brass
Pipe Ends:	ASTM A743 CF3M, (316L) Stainless Steel ASTM A743 CF8M, (316) Stainless Steel ASTM B283 C37700, Brass
Seats:	Polyfill
Body Seals:	"S" Gaskets (Teflon Coated 316 Stainless Steel)
Externals:	300 Series Stainless Steel
End Connections:	SE - Screwed Pipe Ends (NPT) (Dimensions to ANSI B1.20.1) SW - Socket Weld Ends (Diameter and Depth of Bore to ANSI B16.11) SW0 - Socket Weld Ends for O.D. Tubing to ASTM A269 (Stainless Steel Only) BW1 - Butt Weld Ends for Schedule 10 Pipe (Dimensions to ANSI B16.25) (Stainless Steel Only) TE - Tube Ends (Sweat Ends for Type K, L and M Copper Tubing to ASTM B88) (Brass Only)
Ball:	ASTM A276 316 Stainless Steel, Condition A ASTM B16 HO2 Upstream relief hole (V3) in ball to relieve cavity pressure.
Stem:	ASTM A276 316 Stainless Steel, Condition A ASTM B16 HO2
Packing Follower:	AISI 316L Stainless Steel
Stem Seal:	TFE - 15% Glass Filled
Thrustbearing:	Polyfill

General Specifications

Shutoff:	The valve exceeds the tightness requirements of ISA SP79 for Level II .10 SCFH per inch of valve @ 100 psi Helium and -320°F.
Packaging:	End connections are capped or plugged, and valves are placed in 4 mil thick (minimum) polyethylene bags and heat sealed.
Operation:	Lever handle, pneumatic or electric actuators.
Cleaning:	Cleaning for all valves is based on the oxygen cleaning procedures of Linde Division Spec. GS38. Body, ball, stem and pipe ends degreased.
Lubrication:	Molycoat 321R.
Assembly:	Assembled in a Class 100 environment per Federal Standard 209B.
Testing:	Valves are dry tested, internally pressurized with 80 psi Helium, checked with hand-held helium leak detector (Helium Mass Spectrometer) sensitive to 1×10^{-5} cc/sec.

Body Temperature vs Bonnet Temperature 1/4" - 2" 3 Piece and Diverter Valves with Extension Ambient Temperature 75°F

Pressure/Temperature Ratings

Pressure Torque Curves - Polyfill Seats 1/4" - 2" C4 and C4 Diverter Valves

Pressure Torque Curves - Polyfill Seat 3"-6" Wafer and Flanged Valves

Flow Coefficient

Cv values and equivalent lengths of pipe

1/4" - 1/2"	8	3			3.1	19.6		
3/4"	12	5			6.3	30.4		
1"	32	10			3.1	27.8		
1 1/2"	82	24			4.3	43.5		
2"	120	38			7.5	22.7		
3"			350	350			7.1	7.1
4"			720	720			6.9	6.9
6"			1020	1020			20.4	20.4

AUTOMATION PNEUMATIC AND ELECTRIC CONTROLS

Easy automation is assured by our Series 39 pneumatic or Series 75 electric actuators. Both are backed by our exclusive two-year warranty. The Series 39 actuator is the toughest and most versatile rotary actuator available. Positioners (including electro-pneumatic), fail-safe feature, and mechanical and proximity limit switches provide ON/OFF or proportional control to your system with the feedback you require. Refer to Bulletin No. PB302.

Mount a Series 75 electric actuator and you have a high performance control valve package specifically designed for computer or PLC control. For ON/OFF or proportional control, the Series 75 can take a digital or analog signal. A variety of options allow you to select the performance criteria and feedback information you desire. The Series 75 is available with NEMA I, IV, VII or IX enclosures. Refer to Bulletin No. PB730.

APPLICATIONS

- Over the Road LNG-LPG Trailers
- Terminal Unloading Stations
- High Purity Cryogenic/Gas Systems
- LNG Storage and Distribution
- CO₂ and Nitrogen Injection for Enhanced Oil Recovery
- Over the Road CO₂, LN₂ Food Carriers
- Petroleum Refining Unleaded Gasoline (Gas Treatment Skids)
- Lyophilization Systems
- Air Separation Plants
- Liquid and Gaseous Oxygen for Steel Production
- Inerting and Heat Treatment

Series 39 Pneumatic Actuator

Twin piston, double rack and pinion pneumatic actuator offers long cycle life for rotary applications

PB-302-24

**Backed by Worcester's
exclusive 2-year warranty**

Series 39 Pneumatic Actuators

SO RELIABLE THAT WE BACK IT WITH AN EXCLUSIVE 2-YEAR WARRANTY.

Every Series 39 Actuator comes with our exclusive 2-year warranty to assure you of the type of performance you expect from the best quarter-turn actuator money can buy.

This warranty is our way of saying we're confident the Series 39 will perform efficiently, giving you the dependability and surety of operation that you require.

And the quality that's built in to every 39 Actuator means you will save money, not only when you install it, but also during the time it's operating.

downtime a thing of the past.

The Series 39 has been proven a true performer. In one ON/OFF application, it **cycled more than 14 million times** for 3 months without requiring service.

But we think our warranty says more about the reliability of Worcesters Controls products than any specs we could publish. We encourage you to **prove it to yourself** by putting one of our actuators to work for you. We're sure that the results will be rewarding.

Design Features

COMPACT DOUBLE-PISTON DESIGN

develops extremely high torque output from a short stroke. Plant air from a single connection is valved through ports in sliding piston guide rods to inner and outer air chambers alternately. Both pistons thus provide power for both opening and closing actions. Each piston is affixed to, centered, and guided by a moving stainless steel guide rod, operating in new, lower friction acetal resin bearings, eliminating side loading of shaft.

RACK AND PINION power transfer with constant balanced-force engagement minimizes backlash and provides balanced piston loading for equal wear. Gear teeth cut across the full face of pistons and pinion provides massive engagement with minimum tooth loading. Internal piston bearings eliminate side loads on "O" rings, extending life.

RUGGED CONSTRUCTION - CORROSION RESISTANT

body of the Series 39 actuator is aluminum, Coro-lube coated, both inside and outside, for strength and corrosion resistance. Increased metal thickness of body improves life of shaft bearing. Pistons are aluminum for strength and corrosion resistance. End caps are aluminum, Coro-lube coated. Integral pinion and shaft is steel, plated for corrosive resistance. Stainless steel end cap screws are used.

Coro-lube is a nickel-acetate filled coating. It provides greater resistance to wear and corrosion and also provides increased lubricity on internal surfaces.

EXTENDED TOP SHAFT provides visual indication of valve position and permits the use of optional accessories, such as top-mounted limit switches, a pneumatic positioner or means for manually overriding the

actuator. It also allows the operation of two valves with a single actuator. The extended shaft simplifies mounting to virtually any rotary valve.

LOWER INTERNAL FRICTION results from Coro-lube coatings, low coefficient-of-friction acetal resin bearings, and polished piston guide rods. Operating speed and torque output are improved as a result of requiring a very small pressure differential to produce motion.

SPRING RETURN models are available for applications requiring the valve to move to either a closed or opened position on failure of electrical or air supplies. Depending on air supply pressure, the multi-spring design provides sufficient torque to cycle the valve in the event of such failures. The failure mode can be changed simply by inverting the actuator, changing the valve position and remounting the actuator.

In corrosive or contaminating environments, the spring chamber port can be piped to a cleaner environment to reduce corrosion inside the actuator.

CONTROL BLOCK provides extremely fine independently adjustable speed control for both opening and closing strokes of double acting units. Only the spring stroke is adjustable on spring return units. Available with General Purpose NEMA I, Watertight NEMA IV, Hazardous Environment NEMA VII (UL & CSA listed for Class I, Group D) and NEMA IX (Class II, Groups E, F & G) solenoids for 24, 115 and 230V AC and 6, 12 and 24V DC operation, NEMA IV and VII solenoid in one enclosure is also available. In the event of electrical failure or when local operation is desired, the double-acting solenoid may be overridden by manual operation of the control block.

Operating Sequence

Double Acting

Air in center chamber pushes pistons apart.

In a double acting actuator, air enters the center chamber to push the pistons apart, opening the valve. When closing the valve, the double acting actuator relies on air supplied on the outside of each piston to push the pistons together again.

Spring Return

Springs in end caps of spring return actuator push pistons back together for fail safe operation.

In a spring return actuator, air is supplied through the center chamber to push the pistons apart. Springs located in the end caps of the actuator relax to automatically push the pistons back together, thus closing the valve. These springs also provide a dependable fail safe closure in the event of

Engineering Data (Revision 3)

TORQUE OUTPUT — Double Acting Actuator

MODEL NO.	OPERATING PRESSURE											PSI (Bar)
	30	40	50	60	70	80	90	100	110	120		
1039	80	125	160	200	245	270	310	350	385	425	in.-lb.	
1539	155	240	300	370	460	510	580	650	725	790	Nm	
2039	285	435	545	680	840	935	1070	1200	1330	1460	in.-lb.	
2539	590	785	980	1180	1375	1570	1770	1965	2160	2355	in.-lb.	
3039	790	1200	1500	1860	2305	2580	2935	3290	3645	4000	in.-lb.	
3539	2220	2975	3900	4800	5600	6400	7200	8000	8800	9600	in.-lb.	
4039 Rev. 1	3110	4900	6200	7600	8900	10230	11500	12800	14200	15500	in.-lb.	
4539 Rev. 1	9000	12700	16100	19500	22700	26000	29400	32600	36000	39500	in.-lb.	
5039 Rev. 1	13145	19000	24000	29000	34000	40000	45000	50000	55000	60000	in.-lb.	

*Standard solenoids will not run with operating pressure less than 30 PSIG.

STROKE TIME (seconds) (double acting)*

MODEL NO.	MINIMUM (UNLOADED)	WITH MAXIMUM SPEED CONTROL
1039	Less than 1	10
1539	Less than 1	15
2039	1	15
2539	2 - 3	18
3039	3 - 4	20
3539	4 - 5	25
4039 Rev. 1	5 - 6	30
4539 Rev. 1	10 - 12	40
5039 Rev. 1	12 - 14	60

*Average times under 50% load conditions, 80 psi (with standard solenoid).

NOTE: These figures are meant as an indication of obtainable speeds only. For more precise figures for any particular application, contact Worcester Controls. Faster speeds are obtainable, if required, by using additional control equipment.

Air Consumption per Stroke (free air)

	1039	1539	2039	2539	3039	3539	4039	4539	5039
To OPEN	0.04	0.08	0.16	0.28	0.43	0.9	1.26	3.1	5.5
To CLOSE (D.A. only)	0.05	0.09	0.17	0.3	0.47	1.27	1.43	4.6	7.0

ACTUATOR WEIGHTS*

ACTUATOR MODEL	DOUBLE ACTING	SPRING RETURN
	Lbs. (kg)	Lbs. (kg)
1039	3 (1.3)	3.5 (1.6)
1539	6 (2.7)	7 (3.1)
2039	10 (4.5)	12 (5.5)
2539	16.25 (7.4)	18.5 (8.4)
3039	24.6 (11)	27 (12)
3539	58 (26)	65 (30)
4039 Rev. 1	70 (32)	80 (36)
4539 Rev. 1	213 (97)	253 (115)
5039 Rev. 1	304 (138)	355 (161)

*without solenoid

SIZING

Determine appropriate valve torque requirements from valve literature. For double-acting actuators, select the actuator whose torque output at available air supply exceeds breakaway torque requirements of the valve. For detailed instructions, consult Worcester Controls Actuator Sizing Manual, bulletin ASM.

For fail-closed, spring-return actuators, select the appropriate size actuator whose torque output at end of spring stroke (at available air supply) is sufficient to close the valve.

For fail-open spring-return actuators, select appropriate actuator whose torque output at the end of the air stroke is sufficient to close the valve. For fail-open actuators, it is also necessary to determine that the torque output

TORQUE OUTPUT — Spring Return Actuator

		OPERATING PRESSURE										
		40 (2.7)		50 (3.4)		60 (4.1)		70 (4.1)		80 (5.4)		PSI (Bar)
No. of Springs		4		6		8		8		10		
MODEL NO.	STROKE	START	END	START	END	START	END	START	END	START	END	
1039	AIR	85 3.4	60 2.4	105 3.9	60 2.4	125 5.0	70 2.7	170 6.3	120 4.8	175 6.3	95 3.4	in.-lb.
	SPRING	60 2.4	35 1.2	95 3.4	55 2.0	125 5.0	75 2.7	125 5.0	75 2.7	160 5.7	95 3.4	in.-lb.
1539	AIR	130 4.7	85 3.0	200 7.2	125 4.6	240 8.3	150 5.4	260 8.3	155 5.4	325 11.6	190 6.9	in.-lb.
	SPRING	105 3.9	65 2.3	165 5.9	105 3.9	220 7.9	145 5.2	220 7.9	145 5.2	280 9.8	185 6.6	in.-lb.
2039	AIR	300 10.3	240 8.3	340 12.1	235 8.5	415 14.8	280 10.1	575 20.3	440 15.5	600 21.2	360 12.8	in.-lb.
	SPRING	300 10.3	125 4.4	300 10.3	195 6.9	400 13.8	265 9.5	400 13.8	265 9.5	505 17.9	335 11.9	in.-lb.
2539	AIR	560 19.6	400 14.5	600 21.2	350 12.5	730 25.8	420 15.1	925 32.8	655 23.3	980 34.5	550 19.6	in.-lb.
	SPRING	345 12.1	210 7.6	540 19.0	330 11.7	720 25.4	450 15.9	720 25.4	450 15.9	915 32.2	575 20.7	in.-lb.
3039	AIR	840 29.8	610 21.9	965 33.8	600 21.2	1130 39.9	690 24.8	1575 55.8	1145 40.6	1650 57.8	920 33.1	in.-lb.
	SPRING	560 19.6	340 12.1	870 30.9	535 19.0	1160 32.2	730 25.8	1160 32.2	730 25.8	1470 51.8	920 33.1	in.-lb.
3539	AIR	2100 73.8	1470 52.1	2360 83.1	1450 51.3	2850 98.3	1730 61.3	3570 125.8	2615 92.3	3850 135.8	2210 78.3	in.-lb.
	SPRING	1330 46.3	850 29.8	2070 73.1	1330 46.3	2770 97.3	1815 64.3	2770 97.3	1815 64.3	3500 123.8	2300 82.3	in.-lb.
No. of Springs		12		16		18		22		24		
4039 Rev. 1	AIR	3400 115.8	1150 39.9	4250 148.3	1150 39.9	5400 187.3	1900 63.8	6150 212.3	2050 67.3	7230 253.3	2830 94.3	in.-lb.
	SPRING	3850 134.3	1500 50.3	5050 176.3	1950 64.3	5700 199.3	2200 75.3	6850 241.3	2750 96.3	7400 261.3	3000 105.3	in.-lb.
4539 Rev. 1	AIR	8700 307.3	4000 137.3	10600 372.3	4300 150.3	13200 462.3	5900 207.3	14900 523.3	6100 214.3	17600 623.3	8000 283.3	in.-lb.
	SPRING	8300 293.3	4000 137.3	11800 413.3	5500 196.3	15600 549.3	6300 227.3	16600 588.3	7800 276.3	18000 634.3	8400 298.3	in.-lb.
5039 Rev. 1	AIR	12500 423.3	6000 214.3	15500 518.3	6000 214.3	19500 678.3	8500 303.3	21800 768.3	8000 283.3	26500 928.3	11500 408.3	in.-lb.
	SPRING	13000 458.3	6500 230.3	18000 634.3	8500 303.3	20500 723.3	9500 336.3	26000 918.3	12200 433.3	28500 1008.3	13500 483.3	in.-lb.

Nm = Newton-Meter, the standard metric measure of torque.

Air Flow Requirements

Actuator Size	Under 4 Ft. Run	Over 4 Ft. Run
1039, 1539 2039, 2539	1/8" Tubing	1/4" Tubing
3039, 3539, 4039 4539, 5039	1/4" Tubing	1/2" Tubing

Operating Conditions

Pressure Range	30 - 120 PSI Double Acting 40 - 120 PSI All Spring Return Versions*
Media	Air or non-corrosive gas.
Temperature Range	0° To 212°F (-18° to 100°C) Actuator Only To 130°F (54°C) Actuator with G.P. or X.P. Solenoid To 160°F (71°C) Actuator With W.P. or NEMA IV/VII Solenoid High temperature option to 250°F continuous, to 300°F intermittent (without solenoid) Low temperature option to -70°F (without solenoid)
Rotation	Actuators rotate in counter-clockwise direction when the outer air connection is pressurized.
Movement	
Sizes 10-35:	90° with up to 1° overtravel counterclockwise (valve open) and up to 3° overtravel clockwise (valve closed)
Sizes 40-50:	90° with up to 1½° overrun each end
SUPPLY AIR	The Series 39 Actuator is factory lubricated. For optimum performance, standard filtered and lubricated air is recommended.

FERMILAB	SECTION	PROJECT	SERIAL-CATEGORY	PAGE
	ENGINEERING NOTE	RD/DØ	LN ₂ DEWAR	3823.115	A5
SUBJECT				NAME	
LN ₂ DEWAR RELIEF SIZING REQUIREMENTS				RUSS RUCINSKI	
				DATE	REVISION DATE
				11-5-96	

CASE 5 : FILLING A WARM DEWAR

THE INITIAL FILL OR ANY WARM FILL OF THIS DEWAR WILL BE SUPERVISED BY FERMILAB PERSONNEL (MYSELF OR A DESIGNEE).

REGARDLESS OF OUR PRESENCE HOWEVER, THE VESSEL IS PROTECTED BY THE AUTOMATIC FILL SHUT-OFF VALVE THAT WAS DESCRIBED IN CASE 4.

FERMILAB
ENGINEERING NOTE

SECTION

RD/D6

PROJECT

LN₂
DEWAR

SERIAL-CATEGORY

3823-115

PAGE

C1

SUBJECT

RELIEF PIPING PRESSURE DROP

NAME

RUSS RUCINSKI

DATE

11-6-96

REVISION DATE

MATH CHECK
M. ZACZEK

11.8

- THE PRESSURE DROP OF INLET PIPING FOR THE MAXIMUM RELIEVING CASE WILL BE CALCULATED.

THE MAX. FLOW RATE REQ'D = 683 lbm/hr SAT. N₂ VAPOR FOR CASE 3, PRESSURE BUILDING COIL FAILURE.

THE PHYSICAL PIPING ARRANGEMENT IS SKETCHED BELOW. THE PIPE SIZE IN THE VACUUM SPACE WAS CONFIRMED BY THE VESSEL MANUFACTURER, MVE. (SEE FAX SHEETS THIS APPENDIX)

SKETCH C.1 RELIEF VENT PIPING.

METHOD OF CALCULATION: I WILL CONVERT THE FITTINGS AND VALVES TO EQUIVALENT PIPE LENGTHS OF 1 1/2" SCH. 5S PIPE. THEN I WILL USE THE DARCY EQUATION TO CALCULATE PRESSURE DROP.

SUBJECT

RELIEF PIPING PRESSURE DROP

NAME

RUSS RUCINSKI

DATE

11-6-96

REVISION DATE

- EQUIVALENT PIPING LENGTHS { REF. CRANE TECHNICAL PAPER #410. } MATH CH 2. PG. A-28, 29 11-

ELBOWS:

$$K_{\text{ELBOWS}} = (4 \text{ ELBOWS}) 12 F_T$$

$$L = \frac{K D}{F} = \frac{48 F_T D}{F_T} = 48 D$$

$$L_{\text{ELBOWS}} = 48 \left(\frac{1.77}{12} \text{ ft} \right) = 7.1 \text{ FEET } 1\frac{1}{2}'' \text{ SCH. 5S PIPE}$$

TEE:

$$K_{\text{TEE}} = 60 F_T \quad K_{1\frac{1}{2}} = K_{1\frac{1}{4}} \left(\frac{d_{1\frac{1}{2}}}{d_{1\frac{1}{4}}} \right)^4$$

$$\text{LET: } F_T|_{1\frac{1}{4}} \approx F_T|_{1\frac{1}{2}}$$

$$L_{\text{TEE}} = \frac{60 F_T}{F_T} D_{1\frac{1}{2}} \left(\frac{d_{1\frac{1}{2}}}{d_{1\frac{1}{4}}} \right)^4 = 60 \left(\frac{1.77}{12} \right) \left(\frac{1.77}{1.53} \right)^4 = 15.9 \text{ FEET, } 1\frac{1}{2}'' \text{ SCH. 5S PIPE}$$

REDUCERS:

$$1\frac{1}{4}'' \times 1\frac{1}{2}'' \text{ CONTRACTION} \quad K_{\text{max}} = 0.5 \left(1 - \frac{d_{\text{small}}^2}{d_{\text{big}}^2} \right) = .5 \left(1 - \frac{1.53^2}{1.77^2} \right)$$

$$K_{\text{max}} = .1264 \text{ IN TERMS OF } 1\frac{1}{4}'' \text{ PIPE}$$

$$L_{\text{RED}} = .1264 \left(\frac{1.77}{12} \right) \left(\frac{1.77}{1.53} \right)^4 = 0.03 \text{ FT. NEGLIGIBLE.}$$

NEGLECT $1\frac{1}{4}'' \times 1\frac{1}{2}''$ ENLARGEMENT

$1\frac{1}{2}'' \times 1''$ REDUCER, CONTRACTION

$$K_{\text{max}} = .5 \left(1 - \frac{1.09^2}{1.77^2} \right) = .31038 \text{ IN TERMS OF } 1'' \text{ PIPE}$$

$$L_{\text{RED}} = .31038 \left(\frac{1.77}{12} \right) \left(\frac{1.77}{1.09} \right)^4 = .318 \text{ FT.}$$

DIVERTER VALVE: $C_v = 24$ FROM WORCESTER CATALOG.

$$C_v = \frac{29.9 d^2}{\sqrt{K}} \quad \text{EQ'N 2-6 CRANE,}$$

$$K_{\text{VALVE}} = \left[\frac{29.9 d^2}{C_v} \right]^2 = \left[\frac{29.9 (1.77)^2}{24} \right]^2 = 15.23$$

$$L_{\text{VALVE}} = \frac{K D}{F} = \frac{(15.23) \left(\frac{1.77}{12} \right)}{.021} = 107 \text{ FEET}$$

TEE @ OUTLET OF DIVERTER:

$$K_{\text{THRU BRANCH}} = 20 F_T$$

$$L = 20 \left(\frac{1.77}{12} \text{ ft} \right) = 3.0 \text{ FEET}$$

FERMILAB

ENGINEERING NOTE

SECTION

RD/DØ

PROJECT

LN2
DEWAR

SERIAL-CATEGORY

3823.115

PAGE

C3

SUBJECT

RELIEF PIPING PRESSURE DROP

NAME

RUSS RUCINSEI

DATE

11-6-96

REVISION DATE

MATH CHE

Mr. ZACZ.

11-8-96

TOTAL LENGTH

$$L_{\text{TOTAL}} = \sum L = 35 \text{ FEET} + 7.1 + 15.9 + 107 + 3.0 + .3 = 168.3 \text{ ft.}$$

• REYNOLDS * IN PIPE

$$Re = 6.31 \frac{W}{d\mu} = 6.31 \frac{(683 \frac{\text{lbm}}{\text{hr}})}{(1.77 \text{ in.})(67 \times 10^{-6} \frac{\text{g}}{\text{cm-s}})(100 \frac{\text{cp}}{\frac{\text{g}}{\text{cm-s}}})}$$

$\uparrow$ UGAS @ 5 atm, T_{SAT}.

$$Re = 3.63 \times 10^5$$

$$\epsilon/D = \frac{.00015}{\frac{1.77}{12}} = .0011 \quad f = .022$$

• PRESSURE DROP $\Delta P = 3.36 \times 10^{-6} \frac{FLW^2}{d^5}$

$$\Delta P = 3.36 \times 10^{-6} \frac{(.022)(168.3 \text{ ft})(683 \frac{\text{lbm}}{\text{hr}})^2}{(.0209 \frac{\text{g}}{\text{cc}})(2.2 \frac{\text{lbm}}{1000 \text{ g}})(\frac{28317 \text{ cc}}{\text{ft}^3})(1.77 \text{ in.})^5}$$

$$\Delta P = 0.257 = \underline{0.3 \text{ PSI}}$$

$$\% \text{ SET PRESSURE} = \frac{.3 \text{ PSI}}{60 \text{ PSI}} (100) = \underline{0.5 \%}$$

MAX. VESSEL PRESSURE @ MAX. RELIEF REQ'D MT = 60.3 PSI $P_{\text{MAX}} < 110 \% \text{ MAWP}$, UG-125(c) MET.

INLET LOSSES < 3% SET PRESSURE, API RP520 MET.

10/29/96 16:30

630 840 8481

DO ASSEMBLY BLD.

GARY PAULYC4
2001

Fermilab

10-29-96

D-Zero Department
FAX Cover Page
Fax Number (630) 840-8481

To: PEGGY ERPELONG, MVE
From: RUSS RUCINSKI [PHONE 630-840-2888]
Subject: VLS-9000, SN6109 RELIEF PIPE.

PEGGY,

WHAT SIZE IS THE RELIEF VALVE INLET
PIPING FOR THIS TANK? PLEASE FAX
BACK ANSWER.

PIPE SIZE?

THANKS,
RUSSP.S. U-1 DATA SHEET ATTACHED
FOR THIS TANK, F.Y.I.BLOW
DOWN

Number of Pages: 2 (including this cover page)

If you have any difficulty receiving this transmission, please call
Barbara Edmonson at (630) 840-3695.

C5

MVE, Inc.
407 Seventh Street NW
P.O. Box 234
New Prague, MN 56071-0234
ph/612.758.4484 • fx/612.758.8293

FAX COVER SHEET

DATE: 10-30-96TO: RUSS RUCINSKI FAX: 630-840-8481FERMI LABFROM: GARY PAULY
MVE INC.PHONE: 612-758-8277
FAX: 612-758-8215

RE: _____

CC: _____

Number of pages including cover sheet: 2

Message:

Russ

THE INTERNAL VENT PIPE FOR THE
VLS-9000 S/N 109 IS 1 1/2" P.S. (1.90" OD)
SCH. 5

G. PAULY

EXHIBIT A-1
AMMENDED
Vacuum Vessel Engineering Note
(per Fermilab ES&H Manual Chapter 5033)

Prepared By RUSS RUCINSKI Date 11-7-96 Div/Sec RD/D-ZERO MECH.
Reviewed By [Signature] Date 1/17/97 Div/Sec BD/Cryogenics
Div/Sec Head [Signature] Date 1/24/97 Div/Sec PPD

1. **Identification and Verification of Compliance**

Fill in the Fermilab Engineering Conformance Label information below:

This vessel conforms to Fermilab ES&H Manual Chapter 5033

Vessel Title LN₂ STORAGE DEWAR
Vessel Number RDV2045
Vessel Drawing Number NA
Internal MAWP > RELIEF SETTING
External MAWP N/A
Working Temperature Range -320 of 100 of
Designer/Manufacturer MVE CRYOGENICS
Date of Manufacture 1985
Acceptance Date _____

Director's signature (or designee) if vessel is for manned area and requires an exception to the provisions of this chapter.

Amendment No.:

Reviewed By:

Date:

Laboratory location code RPIS-325 (DAB)
Laboratory property number NAL 51464
Purpose of vessel INSULATING VACUUM

Drawing No.:

Location of Original:

DRG. 3823.115-ME-317223 SHT. 1, FLOW SCHEMATIC. ~~DO~~ ASS'Y BLDG. FILES.
ALSO KEPT ELECTRONICALLY IN XDCS, ~~DO~~ MECH. VAULT

2. Design Verification

Provide design calculations in the Note Appendix.

COMMERCIALLY MANUFACTURED DEWAS
BUILT TO INDUSTRY STANDARDS.
SEE ATTACHED VENDOR INFO.

3. System Venting Verification

Can this vessel be pressurized either internally or externally? ☐ Yes ☒ No
If yes, to what pressure? _____

List all reliefs and settings. Provide a schematic of the relief system components and appropriate calculations or test results to prove that the vessel will not be subjected to pressures greater than 110% beyond the maximum allowable internal or external pressure.

Manufacturer	Relief	Pressure Setting	Flow Rate	Size
MVE INC.	6" LIFT PLATE	1 PSI	N/A	FLOW AREA = 7.625 IN ²

4. Operating Procedure Section

Is an operating procedure necessary for the safe operation of this vessel?

Yes _____ No ☒ (If "Yes", it must be appended)

Is a testing procedure necessary for the safe acceptance testing (proof testing) of this vessel?
☐ Yes ☒ No

If yes, the written procedure must be approved by the Division Head prior to testing and supplied with this Engineering Note.

5. Welding Information

Has the vessel been fabricated in a Fermilab shop? [] Yes ☒ No

If "Yes," append a copy of the welding shop statement of welder qualification.

6. Exceptional (Existing) Used and Non-Manned Area Vessels

Is this vessel or any part thereof in the above categories?

Yes ☒ No ☐

If "yes" follow the Engineering Note requirements for documentation and append to note.

THIS VESSEL IS AN EXISTING LN₂ DEWAR
THAT WAS MOVED FROM THE E-706
EXPERIMENT (NOW DE-COMMISSIONED) TO
THE D-ZERO EXPERIMENT.

THIS PHOTO VERIFIES
THE LIFT PLATE
ON THE VACUUM
VESSEL IS NOT
BOLTED DOWN.
IT MEASURES 8 1/2"
OUTSIDE DIA. BY
ABOUT 3/8" THICK
PHOTO TAKEN 11-8-96
(AT TOP OF DEWAR)
R. RUCINSKI

OUTER VESSEL RELIEF

Required area:

$$A = 2.4 \text{ E-4 in}^2/\text{lb-H}_2\text{Ocap} \times \text{Density H}_2\text{O} \times \text{Volume}$$

$$\text{Density H}_2\text{O} = 8.36 \text{ lb/gal of H}_2\text{O}$$

$$\text{Volume} = 9000 \text{ gal}$$

$$A = 2.4\text{E-4}(8.36)(9000) = 18.1 \text{ in}^2$$

$$\underline{A = 18.1 \text{ in}^2 \text{ required}}$$

Actual area: A_t

$$\text{Dia} = 7.625 \text{ in, flow area of the relief device}$$

$$A_t = 45.66 \text{ in}^2, \text{ area of the relief device}$$

$$\underline{A_t > A \quad 45.66 > 18.1}$$

The outer vessel relief device is a lift plate tested by the manufacturer to lift at 1 psig.

MVE, Inc.

TECHNICAL MANUAL

VERTICAL STORAGE SYSTEMS

VCS/VLS
SERIES

MANUAL # AAA0429

SAFETY SUMMARY

MVE customer stations are safely designed with the following features:

1. A vacuum maintenance system specifically designed to provide long life and all possible safety provisions.
2. Safety relief devices to protect the pressure vessel and vacuum casing, sized and selected in accordance with ASME standards to include a pressure control valve and rupture disc to protect the pressure vessel and a reverse buckling rupture disc or lift plate to protect the vacuum casing from overpressure. While MVE equipment is designed and built to the most rigid standards, no piece of mechanical equipment can ever be made 100% foolproof. Strict compliance with proper safety and handling practices is necessary when using a Vertical Customer Station (VCS) or Vertical Liquid Station (VLS). We recommend that all our customers emphasize safety and safe handling practices to all their employees and customers. While every possible safety feature has been designed into the unit and safe operations are anticipated, it is essential that the user carefully read and fully understand all WARNING and CAUTION notes listed in this safety summary and enumerated below. Also read to fully understand the information provided in the Safety Bulletins for Oxygen and Inert Gases located in Appendix C of this Manual. Periodic review of the Safety Summary is recommended.

WARNING

Excess accumulation of oxygen creates an oxygen enriched atmosphere (defined by the Compressed Gas Association as an oxygen concentration above 23%). In an oxygen enriched atmosphere, flammable items burn vigorously and could explode. Certain items considered non-combustible in air may burn rapidly in such an environment. Keep all organic materials and other flammable substances away from possible contact with oxygen; particularly oil, grease, kerosene, cloth, wood, paint, tar, coal dust, and dirt which may contain oil or grease. DO NOT permit smoking or open flame in any area where oxygen is stored, handled, or used. Failure to comply with this warning may result in serious personal injury.

WARNING

Nitrogen and argon vapors in air may dilute the concentration of oxygen necessary to support or sustain life. Exposure to such an oxygen deficient atmosphere can lead to unconsciousness and serious injury, including death.

WARNING

Before removing parts or loosening fittings, empty the container contents of liquid and release the vapor pressure in a safe manner. External valves and fittings can become extremely cold and may cause painful burns to personnel unless properly protected. Personnel must wear protective gloves and eye protection whenever removing parts or loosening fittings. Failure to do so may result in personal injury because of the extreme cold and pressure in the vessel.

WARNING

Accidental contact of liquid gases with skin or eyes may cause a freezing injury similar to a burn. Handle liquid so that it will not splash or spill. Protect your eyes and cover skin where the possibility of contact with liquid, cold pipes and cold equipment, or cold gas exists. Safety goggles or a face shield should be worn if liquid ejection or splashing may occur or cold gas may issue forcefully from equipment. Clean, insulated gloves that can easily be removed and long sleeves are recommended for arm protection. Cuffless trousers should be worn outside boots or over the shoes to shed spilled liquid.

1-1. GENERAL

The Minnesota Valley Engineering (**MVE**) cryogenic container is a compact, self-contained, and stationary liquid gas storage and delivery system. They are multi-layer or perlite insulated, medium pressure containers designed for storage of liquid argon, nitrogen, or oxygen, and for product withdrawal in either gaseous or liquid form.

The model designation **VLS** indicates that the cryogenic container is a "Vertical Liquid Station" intended for liquid withdrawal only. There are 6 standard models currently available, in multi-layer insulation only.

The model designation **VCS** indicates that the cryogenic container is a "Vertical Customer Station" intended for either gaseous or liquid withdrawal. The model numbers, i.e., 300, 500, 900, etc., indicate the approximate net capacity (in gallons) of the particular **VCS**.

1-2. PHYSICAL DESCRIPTION

An **MVE** Station is designed for long-term storage of cryogenic liquefied gases under pressure in the range of 5 to 250 PSIG. Operation of the station is fully automatic with the unit's regulator systems set to maintain preset pressure and flow conditions into a customer's pipeline. While hardware may vary slightly from model to model, each unit essentially performs the same functions.

The **VCS** or **VLS** is comprised of an alloy steel inner tank encased in an outer carbon steel vacuum shell. The insulation system between the inner and outer containers consists of multiple layer or powder insulation and high vacuum to ensure long holding time. The insulation system, designed for long-term vacuum retention, is permanently sealed at the factory to ensure vacuum integrity. The units have a tank pressure relief device which is set at the factory. As a secondary pressure relief device, the container is further protected from overpressurization by a rupture disc. The bursting disc will rupture completely to relieve inner tank pressure in the event the tank relief valve fails and pressure exceeds the rupture disc setting. The vacuum space is protected from overpressurization by use of a tank annulus rupture disc assembly. Pressure relief devices used on **VCS**' or **VLS**' meet the requirements of CGA Pamphlet S1.3, "Pressure Relief Device Standards, Part 1, for Stationary Vessels."

The **VCS** or **VLS** is leg mounted. On the smaller units (300-1500 gallon), lifting lugs are secured to one leg and to the top head of the container. On units larger than 1500 gallon, the lifting lugs are located on the top and bottom heads. The lifting lugs are provided to facilitate handling. Moving requires the use of a crane and adherence to specific rigging instructions (see Chapter 4 in this manual for details on handling).

Controls used to operate the system are mounted under the customer station. The pressure gauge and liquid level gauge are located at eye level on the container for ease of viewing.

The **VCS** has a dual regulator system which uses both an economizer regulator and a pressure building regulator. The economizer regulator automatically allows vapor space gas to be introduced preferentially into the final line or gas use circuit when the customer station pressure exceeds the regulator setting. The pressure building regulator is used to maintain a minimum set pressure in the vessel. An optional third regulator, the final line regulator, can be used to control pressure and gas flow into the customer's line.

The **VLS** units only have a pressure building system, since they are designed for liquid use exclusively.

The vessels also contain a pressure building coil and a strainer assembly. The pressure building coil vaporizes the liquid to build up pressure in the tank. The strainer assembly protects the pressure building system from damage by contaminants.

Some **VCS** containers are shipped with an ambient air vaporizer. Containers are ready for service as soon as they are erected, bolted to the foundation, and have the process pipeline connected to the vaporizer outlet. **VCS** Models 315 through 1500 are shipped with the vaporizer mounted on the side of the tank (unless a tank is ordered without the vaporizer). Due to dimensional limitations for shipping, vaporizers are not factory installed on **VCS**'s larger than Model 1500. On **VCS**'s larger than Model 1500, the vaporizer is located adjacent to the container on the foundation.

The normal operating pressure range of a **VCS** is from approximately 50 to approximately 150 PSI, with a maximum working pressure of approximately 250 PSI. Operating pressure can be increased or decreased as desired by adjusting the regulators. Vessels with a higher pressure rating are available.

Figure 6-7. Parts Identification View
VCS 9000-SS-250-MVE-0
VLS 9000-SS-75-MVE-0
VCS 9000-SP-250-MVE-0
VCS 9000-NP-250-MVE-0
VLS 9000-SP-75-MVE-0

**Table 6-13. Parts Identification List
9000 Gallon Units**

TAG	NOMENCLATURE	COMP. PART NO.	DESCRIPTION
V-1	TOP FILL	90-5932-2	ANGLE VALVE, 1-1/2" NOM
V-2	BOTTOM FILL	90-7845-2	ANGLE VALVE, 1-1/2" NOM
V-3	FULL TRYCOCK	17-1320-2	SHUTOFF VALVE, 3/8" NPT
V-4	VENT	17-1387-2	GLOBE VALVE, 1" NOM
V-5	P.B. FEED	90-5152-2	1/2" NOM* 1/2" NPT
V-6	P.B. ISOLATION	17-1324-2	GLOBE VALVE, 1" NOM
V-7	GAS USE	17-1327-2	GLOBE VALVE, 1" NPT
V-8	LIQUID PHASE HIGH	17-1188-2	ANGLE VALVE, 1/4" ODT* 1/4" MPT
V-9	GAS PHASE LOW	17-1188-2	ANGLE VALVE, 1/4" ODT* 1/4" MPT
V-10	EQUALIZATION	17-1048-2	NEEDLE VALVE, 1/4" NPT
V-11	FILL DRAIN	17-1670-2	SHUTOFF VALVE, 3/8" NPT
V-12	EVACUATION	17-1322-4	DIAPHRAGM VALVE, 1-1/2"
V-13	ECONOMIZER ISOLATION	17-1110-2	GATE VALVE, 1/2" NOM
V-16	TC ISOLATION	17-1287-2	BELLOWS SEALED, 1/8"
CV-1	FILL CHECK	17-1358-2	1-1/2" NPT
CV-3	ECONOMIZER CHECK	17-1357-2	1/2" NPT
S-1	STRAINER	49-1023-2	3/8" NPT
RV-1	LINE TRAP SAFETY	18-1048-2	350 PSIG, 1/4" NPT
RV-2	INNER VESSEL SAFETY	18-1040-2	250 PSIG, 1/2" MPT* 3/4" FPT
BD-1	INNER BURST DISC	19-1112-5	375 PSIG, 3/4" MPT
BD-2	ANNULUS BURST DISC	19-1084-1	6" LIFT PLATE
R-1	P.B. REGULATOR	21-1007-2	TYPE B, 1/2" NPT, 120 PSIG
R-2	ECONOMIZER REGULATOR	21-1008-2	TYPE FRM, 1/2" NPT, 140 PSIG
	REBUILD KIT	97-1557-2	REGULATOR RENEWAL KIT
	SPRING KIT		
C-1	FILL CONNECTION	65-1047-2	CGA-OXYGEN
		65-1057-2	CGA-NITROGEN
		65-1087-2	CGA-ARGON
		65-1038-2	FLANGE-OXYGEN
		65-1038-2	FLANGE-ARGON
		65-1038-2	FLANGE-NITROGEN
C-2	CUSTOMER GAS USE		1" NPT
C-3	FULL TRYCOCK	39-1015-6	PLUG 3/8" MPT PLASTIC
C-4	VENT	15-1058-3	ELBOW 1" FTG
C-5	AUXILIARY LIQUID	12-1108-2	CAP 1-1/4" FPT BRASS
		17-1327-2	VALVE (OPTIONAL)
		12-1052-2	STREET ELBOW (OPTIONAL)
C-6	AUXILIARY VENT	12-1100-2	CAP 1" FPT BRASS
C-7	DRAIN CONNECTION	39-1015-6	PLUG 3/8" MPT PLASTIC
C-8	PUMP FEED	12-1108-2	CAP 1-1/4" FPT BRASS
C-9	PUMP RETURN	12-1097-2	CAP .5" FPT BRASS
1	STAUFF CLAMP	34-1080-8	1-1/4" O.D. CLAMP
		34-1059-4	.25 SM NUT
2	P.B. CONNECTION	10-1158-2	M. CONNECTOR .625 O.D.T. x .500 MPT
6	FILL GASKET	65-1006-2	GASKET, FILL FITTING
7	NUT	65-1035-2	NUT
8	STUD-SS	65-1034-1	STUD
9	CAP-CGA	65-1058-5	NITROGEN SERVICE
		65-1070-5	OXYGEN SERVICE
		65-1069-5	ARGON SERVICE
10	CAP-FLANGE	65-1033-1	COMB. FLANGE CAP
12	LIQUID LEVEL GAUGE	20-1152-9	0-600" H ₂ O
		20-1209-2	0-600" H ₂ O W/ALARM
13	PRESSURE GAUGE	20-1027-2	0-400 PSI
14	ECONOMIZER FITTINGS	10-1182-2	M. ELBOW 90D .625 O.D.T. x .375 MPT

**Table 6-14. Liquid Contents Chart
VCS 9000-SS-250-MVE-0
VLS 9000-SS-75-MVE-0
VCS 9000-SP-250-MVE-0
VCS 9000-NP-250-MVE-0
VLS 9000-SP-75-MVE-0**

GAUGE (IN.)	ARGON (GAL.)	OXYGEN (GAL.)	NITROGEN (GAL.)
0	0	0	0
10	60	84	164
20	215	291	523
30	425	554	911
40	651	824	1299
50	878	1093	1688
60	1104	1363	2076
70	1330	1632	2464
80	1557	1901	2853
90	1783	2171	3241
100	2010	2440	3629
110	2236	2710	4018
120	2462	2979	4406
130	2689	3249	4794
140	2915	3518	5183
150	3141	3787	5571
160	3368	4057	5959
170	3594	4326	6348
180	3820	4596	6736
190	4047	4865	7124
200	4273	5135	7513
210	4499	5404	7901
220	4726	5673	8289
230	4952	5943	8678
240	5179	6212	9061
250	5405	6482	9333
260	5631	6751	
270	5858	7021	
280	6084	7290	
290	6310	7560	
300	6537	7829	
310	6763	8098	
320	6989	8368	
330	7216	8637	
340	7442	8907	
350	7669	9156	
360	7895		
370	8121		
380	8348		
390	8574		
400	8800		
410	9023		
420	9215		
430			
435			

NOTE: Contents based on liquid saturated at 0 PSIG.