**LIQUID NITROGEN SUBCOOLER
FOR CALORIMETERS LN2 SUPPLY.
PRESSURE VESSEL CALCULATIONS**

ENGINEERING NOTE

3823.115-EN-570

February 16, 2004

Author: Mike Sarychev

Approved by Bill Cooper 2/12/2004

PRESSURE VESSEL ENGINEERING NOTE

PER CHAPTER 5031

Prepared by: Mike Sarychev
Preparation date: 12.11.02

1. Description and Identification

Fill in the label information below:

This vessel conforms to Fermilab ES&H Manual
Chapter 5031

Vessel Title LN₂ Subcooler

Vessel Number PPD #10075

←Obtain from Division/Section Safety Officer

Vessel Drawing Number 3823.124-ME-399599

Maximum Allowable Working Pressures (MAWP):

Internal Pressure 20 PSIG

External Pressure _____

Working Temperature Range -320 °F 300 °F

Contents LIQUID NITROGEN

Designer/Manufacturer DPWAR-MINNESOTA

VALLEY ENGINEERING, TOP-FERMI LAB

Test Pressure (if tested at Fermi) Acceptance
Date: 1/28/04

←Document per Chapter 5034
of the Fermilab ES&H Manual

22 PSIG, Hydraulic _____ Pneumatic _____
Accepted as conforming to standard by _____

see PPD #13747N

of Division/Section PPD/ES&H Date: 1/29/04

←Actual signature required

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

Reviewed by: Edward CHI Date: Jan. 28, 2004
PPD/MD/ME

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

Date: _____

Amendment No.:

Reviewed by:

Date:

Lab Property Number(s): N/A
Lab Location Code: RPIS-325 (DAB) (obtain from safety officer)
Purpose of Vessel(s): LIQUID NITROGEN CONTAINER FOR
LIQUID NITROGEN SUBCOOLING
Vessel Capacity/Size: 25.5 LITERS Diameter: 10.625" Length: 18"
Normal Operating Pressure (OP): 0 psig (ATMOSPHERIC)
MAWP-OP = 20 PSI

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

Drawing #

Location of Original

3823.124-ME-399599

DAB ASSEMBLY Building, High Bay

2. Design Verification

Is this vessel designed and built to meet the Code or "In-House Built" requirements?

Yes X No

If "No" state the standard that was used

N/A

Demonstrate that design calculations of that standard have been made and that other requirements of that standard have been satisfied.

Skip to part 3 "system venting verification."

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

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

Copy data here:

NAT'L BOARD No 20939
Minnesota Valve ENGINEERING
H-1 DEWAR W/B-FLANGE
MAWP at Full VACUUM
20 PSI at 100°F
Min. Allow Temp: -320°F
Service: LN₂ at -320°F
Serial No 217
Year Built 1988

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

Figure 1. ASME Code: Applicable Sections

2B.

Summary of ASME Code

Item	Reference ASME Code Section	CALCULATION RESULT	
		(Required thickness or stress level vs. actual thickness calculated stress level)	
FLAT HEAD	UG-34	$t_{req.} = 0.278"$	vs $0.500"$
REINFORCEMENTS	UG-39	$t_{req.} = 0.422"$	vs $0.500"$
			actual t

3. System Venting Verification Provide the vent system schematic.

Does the venting system follow the Code UG-125 through UG-137?
Yes X No

Does the venting system also follow the Compressed Gas Association Standards S-1.1 and S-1.3?
Yes X No

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

List of reliefs and settings:

<u>Manufacturer</u>	<u>Model #</u>	<u>Set Pressure</u>	<u>Flow Rate</u>	<u>Size</u>
Anderson - Greenwood	21888-8	20 psig	111 scfm Air	1" inlet/outlet
Anderson - Greenwood	21888-8	20 psig	111 scfm Air	1" - 1"

4. Operating Procedure

Is an operating procedure necessary for the safe operation of this vessel?
Yes No X (If "Yes", it must be appended)

5. Welding Information

TOP DEWAR

Has the vessel been fabricated in a non-code shop? Yes X No X
If "Yes", append a copy of the welding shop statement of welder qualification (Procedure Qualification Record, PQR) which references the Welding Procedure Specification (WPS) used to weld this vessel.

6. Existing, Used and Unmanned Area Vessels

Is this vessel or any part thereof in the above categories? *
Yes X No

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

7. Exceptional Vessels

Is this vessel or any part thereof in the above category?
Yes No X

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

* The Minnesota Valley C-Stamped Dewar was used on Argon purity test - vessel # RD-1102

Pressure relief calculations

Summary

Case	Req'd Flow Rate scfm air	Actual Flow Rate scfm air
Emergency Conditions (loss of vacuum)	1.47	111
Fire	5.24	111
Maximum Fill Rate	21.3	111

Fermilab

Date: 01/05/04

EXHIBIT B
Pressure Testing Permit*

Type of Test ☐ Hydrostatic ☒ Pneumatic

Test Pressure 22 psig Maximum Allowable Working Pressure 20 psig

Items to be Tested LN₂ Subcooler assembly PPD# 10075

Location of Test DAB Date and Time 01/20/04

Hazards Involved None

Safety Precautions Taken Fences will be installed to prevent unauthorized access.

Special Conditions or Requirements None

Qualified Person and Test Coordinator Michael Sarychev
Dept/Date PPD/MP/DX 01/05/04

Division/Section Safety Officer Martha Kaplan
Dept/Date 1-5-04

Results Used high sensitivity Alcatel leak detector for vacuum jackets on "Shrap" liquid for the other joints. Pressure gradually increased to 22 psig. No leaks detected. Test passed

Witness Eric McHugh 13747N Dept/Date PPD/ESPH 1/20/04
(Safety Officer or Designee)

* Must be signed by division/section safety officer prior to conducting test. It is the responsibility of the test coordinator to obtain signatures.

SUBJECT

LN₂ subcooler top lead calculations

NAME

Mike Sarychev

DATE

9/27/02

REVISION DATE

CHECKED RUCINSKI
10/10/02

ASME code is used
to determine the thickness
of LN₂ subcooler flat head

Subject to: UG-34(a-c)(2)

$$d = 11.5"$$

$$h_g = 0.75"$$

$$c = 0.3$$

EQN (2) applies:

$$t = d \sqrt{\frac{cP}{SE} + \frac{1.9Wh_g}{SEd^3}}$$

Our configuration
is similar to two
sketch (k) in Fig UG-34

$P = 20$ psig - design pressure

$S = 16,700$ psi (ASME) - for 316L SS. plate
per Fermilab, $S = S_{ASME} \times 0.8$

$$S = 16,700 \cdot 0.8 = 13,360 \text{ psi}$$

$E = 1.0$ - joint efficiency

W - total bolt load (Appendix 2-5)

1. Operating conditions:

$$W = W_m = H + H_p, \text{ where } H \text{ is hydrostatic}$$

Since $b_{20} = 0.7856^2 \cdot P + (2b \times 3.146nd)$ end force
for 20 rings,
 $H_p = 0$, so $W = 0.7856^2 P$
 H_p - total joint
contact
compression load

SUBJECT

LN₂ SUBCOOLER
TOP LID CALCULATIONS

NAME

Mike Sarcher

DATE

9/27/02

REVISION DATE

12/20/02

$$W = W_m = 20(\text{psig}) \cdot 0.785 \cdot 11.5^2 (\text{in}^2) = 2077.4$$

$$\approx 2078 \text{ lbs}$$

2. Gasket Seating

$$W = \frac{(A_m + A_g) S_a}{2} \quad (\text{eqn. (4) app. 2-5})$$

A_m is a greater of A_{m1} and A_{m2} , where
 $A_{m1} = \frac{W_{m1}}{S_b}$; and $A_{m2} = \frac{W_{m2}}{S_a}$

Per (2-5)(3)(b), $W_{m2} = 0$, since "O-rings"
 are considered
 self-energized gaskets.

$$A_{m2} = 0$$

$$S_a = S_b = 20,000 \text{ psi} \times 0.8 = 16,000 \text{ psi}$$

$$A_{m1} = A_m = \frac{2078}{16,000} = 0.1299 \text{ in}^2$$

$$A_g = 0.0524 \text{ in}^2 \times 12 =$$

$$= 0.6288 \text{ in}^2$$

(tensile stress area
 for 5/16 bolts)

$$W = \frac{(0.1299 + 0.6288) \times 16,000}{2} =$$

per Machinery
 Handbook, table 4A
 page 1740)

$$= 6070 \text{ lbs}$$

PPD/40/DA

operations

3823.115

3

SUBJECT

LN₂ subcooler
top lid calculations

NAME

Mike Sanyalov

DATE

9/27/02

REVISION DATE

12/20/02

The required plate thickness for operating conditions:

$$t = 11.5(in) \sqrt{\frac{(0.3 \cdot 20 \text{ psi})}{13,600 \text{ (psi)} \cdot 1} + \frac{2078 \text{ (lb)} \cdot 1.9 \cdot 0.75 \text{ (in)}}{13,600 \text{ (psi)} \cdot 11.5^3 \text{ (in}^3\text{)}}}$$

$$= 0.278 \text{ in}$$

for gasket seating ($P=0$), per UG-39

$$t = 11.5(in) \sqrt{\frac{6070 \cdot 1.9 \cdot 0.75}{13,600 \cdot 11.5^3}} = 0.235 \text{ in}$$

Choose the greater of 2 $\Rightarrow t = 0.278 \text{ in}$

Reinforcements (per UG-39)

Since none of the openings exceeds one half of the head diameter (7") and no pair have an average diameter greater than one quarter of head diameter (3.5"), apply UG-39(e); the spacing between pairs is more than $1\frac{1}{4}$ the average diameter for all pairs (UG-39(e)(2), the reinforcements may be determined by rule (d), multiplied by "h".

SUBJECT

1/2 N₂ Subcooler
TOP lid calculations

NAME

Mike Sarychev

DATE

9/27/02

REVISION DATE

12/20/02

Ref. Max opening diameter is 1.900 in
max. average pair diameter is 1.900 in
(same diameter holes) with the
spacing of 2.956 in

Per UG-39(d)(2), the value under
the square root must be doubled, and from
previous rule, (UG-39(e)(e)), multiplied
by the factor of "h", where

$$h = \sqrt{\frac{0.5}{e}}$$

$$e = \left[\frac{p - d_{ave}}{p} \right]$$

e - smallest ligament
efficiency of
adjacent openings

$$e = \frac{2.956 - 1.9}{2.956} = 0.357$$

p - spacing, p = 2.956 in
d_{ave} = d = 1.9 in

$$h = \sqrt{\frac{0.5}{0.357}} = 1.183$$

the top lid thickness will be:

$$t = 11.5 \text{ in} \sqrt{2 \cdot 1.183 \left(\frac{0.3 \cdot 20 \text{ (psi)}}{13,600 \text{ (psi)}} + 1 \right) + \frac{2078 \text{ (lb)} \cdot 1.9 \cdot 0.75 \text{ (in)}}{13,600 \text{ (psi)} \cdot 1 \cdot 11.5^3 \text{ (in}^3\text{)}}}$$

$$= 0.428 \text{ in}$$

Will choose 1/2" thick plate.

SUBJECT

N₂ Subcooler

NAME

Mike Sanyal

DATE

12/20/02

REVISION DATE

01/06/03

TOP LID REINFORCEMENT VERIFICATION

$$t = 0.5'' \text{ (Actual)} ; t_n = 0.278 \text{ (per 46-39)}$$

Circular grooves with .125 x .250 cross section are used to relieve stress occurring during the welding operation. We can verify if the material removed from the flat head to make this grooves will not affect the head's reinforcement.

Per 46-39(b)(2) for multiple openings in flat heads, the cross-sectional area of required reinforcement for every single opening:

$$A = 0.5 d \cdot t + t t_n (1 - f_r)$$

We use the same material for reinforcement (300 Hives S.S.), so $S_n = S_v$, and

$$f_r = \frac{S_n}{S_v} = 1 \Rightarrow A = 0.5 d t = 0.5 \cdot 1.750 \cdot .278 = 0.243 \text{ in}^2$$

SUBJECT

LN₂ Subcooler
TOP LID REINFORCEMENT VERIFICATION

NAME

Mike Inychev

DATE

12/20/02

REVISION DATE

01/06/03

In our case, where the spacing between two adjacent openings (in the worst case) is less than twice the average diameter, but more than $1\frac{1}{4}$ of the average diameter, the reinforcement should be calculated for each hole, and 50% of the sum put between these two holes. In our case the openings are the same, and the area for reinforcement is

$$A = A_1 + A_2 + A_3 \quad ((A+A) \times 0.5 = A)$$

A_1 - area of increased thickness

A_2 - $1/8"$ fillet weldment

A_3 - area available in nozzle, projecting outwards.

$$A_1 = 1.056 \times (0.5 - 0.278) - 2(0.125 \cdot 0.25) = 0.172 \text{ in}^2$$

$$A_2 = 0.125^2 = 0.0156 \text{ in}^2$$

$$A_3 = 2(1.09 \times 2.5 - 0.109) = 0.594$$

$$A = 0.246 \text{ in}^2 > A_{\text{required}} = 0.243 \text{ in}^2$$

Therefore, $1/2"$ thick flat head with $1/4" \times 1/2"$ circular grooves will be reinforced enough ~~for~~ for 2 adjacent 1.98 openings with $1-1/2"$ sch. 10 pipe nozzles welded with $1/8"$ fillet.

SUBJECT

L_{N2} Subcooler
PRESSURE RELIEF Calculations

NAME

MIKE JARYCHEV

DATE

12/11/02

REVISION DATE

Operation emergency conditions, excluding fire (i.e. vacuum loss).

PER C&A S-1.3, paragraph 5.2.2

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

F - connections factor; F = 1 (conn. pipe less than 2' PER S.1.4)

U - OVERALL heat transfer coefficient
in BTU/HR. ft². °F

G_i - gas factor - table 1 of C&A S-1.3

$$G_i = 10.2$$

A - arithmetic mean area of inside and outside surface areas of inner vessel

$$D_{\text{mean}} = \frac{10.625 + 10.875}{2} = 10.75 \text{ in}$$

$$A = A_{\text{cyl}} + A_{\text{hemisphere}}$$

$$A_{\text{cyl}} = \pi D H = \pi \cdot 10.75 \cdot 16 = 540.08 \text{ in}^2$$

$$A_{\text{hem.}} = \frac{\pi}{4} (S^2 + 4h^2) =$$

$$= \frac{\pi}{4} (10.75^2 + 4 \cdot 2^2) = 103.27$$

$$A = 540.08 + 103.27 = 643.35 \text{ in}^2$$

$$= 4.46 \text{ ft}^2$$

SUBJECT

$\angle N_2$ subcooler
Pressure relief calculations

NAME

Mike Sarychen

DATE

12/11/02

REVISION DATE

Flow rating pressure for primary system
- 110% of MWAP (per CGA 4.3.3.1)
Per 4.1.13 for vacuum insulated vessels,

$$P = \frac{110}{100} \cdot 20 + \frac{110}{100} \cdot 14.7 - 14.7 = 23.47 \text{ psig} \\ = 38.17 \text{ psia} = 2.6 \text{ atm. abs.}$$

$$T_{\text{sat}} @ 2.6 \text{ atm} = 86^\circ \text{K} = 154.8^\circ \text{R}$$

$$U = \frac{K}{x}$$

I would assume 25 layers of MYLAR + Fiber-glass mesh, $\approx 3/8$ thick

K for fiberglass (Borron, Table 1-9, p.25)

$$K = 0.014 \frac{\text{BTU}}{\text{hr} \cdot \text{ft} \cdot ^\circ \text{F}}$$

$$Q_a = \frac{(590 - 154.8(F))}{4(1660 - 154.8(F))} \times 1 \times 10.2 \times \frac{0.014 \frac{\text{BTU}}{\text{hr} \cdot \text{ft} \cdot ^\circ \text{F}}}{\frac{.375 \text{ in}}{12 \frac{\text{in}}{\text{ft}}}} \times 4.46 \text{ ft}^2 \\ = 1.475 \text{ cfm}$$

Flow capacity under fire condition.

Per CGA 5-1.3, paragraph 5.3.3

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

$$F = 1 ; G_i = 10.2 \quad A = 4.46 \text{ ft}^2$$

SUBJECT

LN₂ Subcooler
Pressure Relief calculations

NAME

Mike Seay

DATE

12/11/02

REVISION DATE

U - overall heat transfer coefficient
I will use K for air @ atmospheric pressure, since multilayer insulation may be deteriorated during the fire.

$$K = 0.0157 \text{ BTU/hr.ft.}^2\text{.}^{\circ}\text{F}$$

Assuming the gap between the inner and the outer vessels $x = \frac{1}{2}''$

$$U = \frac{0.0157}{\frac{0.5}{12}} = 0.3768 \frac{\text{BTU}}{\text{hr.ft.}^2\text{.}^{\circ}\text{F}}$$

$$Q_a = 1 \times 10.2 \times 0.3768 \cdot 4.46^{0.82} = \underline{5.24 \text{ scfm}}$$

Now I will determine a maximal flow rate through the vessel in worst case scenario.

(This situation is almost impossible). Under normal working conditions, the pressure inside is atmospheric.

- 1) ~~the~~ The evaporated nitrogen is vented to the atmosphere without any restriction or closing device. I will assume this line is totally plugged.
- 2) the working pressure in the liquid Nitrogen line is 35 psig. I will assume it will raise to the MWAP of Dewar 42 - 65 psig.
- 3) In the event of instrument air loss, the fill valve ~~will~~ will be closed by the regulator. I will assume the valve is stuck in 100% open position.

SUBJECT

LN₂ subcooler
Pressure relief calculations

NAME

Mike Szycher

DATE

12/11/02

REVISION DATE

4) The amount of LN₂ to the vessel is very small - 1.825 g/s during the normal operation, and 25 g/s flow is going to the calorimeters (ECN 3823.115-EN-562). I will assume that for some reason the flow to calorimeters stopped.

5) If events 1, 2, 3 and 4 occur at the same time (probability ≈ 0), then the liquid nitrogen will flow through the relief valve with the pressure equal to flow rating pressure $P = 38.17 \text{ psia}$ or 2.6 atm. abs. (see previous calculations). It will be a 2 phase flow @ saturation temperature of 86°K (154.8°R). To be conservative, I will assume 100% gas @ saturation temperature to maximize the possible flow through the valve.

PPD/MD/PP

OPERATIONS

3823,115

9

SUBJECT

4 N₂ Subcooler
Pressure relief calculations

NAME

Mike Larychev

DATE

12/11/02

REVISION DATE

I will neglect 1-1/2" pipe, CV=34 valve and all the elbows and turns in the system since they have much less pressure drop than CV=0.32 fill valve and reducers.

① 1-1/2" pipe to 1/2" reducer (θ=30°)

Note: All pipe sizes are for Sch. 40 pipe as required by CRANE. The values of K are then converted to Sch. 10 pipe (1/2" size)

Per CRANE equ. 3-18

$$K = 0.8 \sin \frac{\theta}{2} (1 - \beta^2)$$

1-1/2" pipe I.D. = 1.61

1/2" ————— = .622

$$\beta = \frac{0.622}{1.61} = 0.386$$

$$K = 0.8 \cdot \sin 15^\circ (1 - 0.386^2) = 0.176$$

Converted to Sch. 10 pipe

$$K_{Sch.10} = K_{Sch.40} \left(\frac{d_{Sch.40}}{d_{Sch.10}} \right)^4 \quad (2-5 \text{ CRANE})$$

$$K_{Sch.10} = 0.176 \left(\frac{0.674}{0.622} \right)^4 = 0.242$$

② 1/2" pipe to 1/2" tube reducer

$$K = 0.8 \cdot \sin 15^\circ \cdot \left[1 - \left(\frac{0.5}{0.622} \right)^2 \right] = 0.133$$

$$\text{for Sch. 10} \quad K = 0.133 \left(\frac{0.674}{0.622} \right)^4 = 0.184$$

PPD/MD/D4

DΦ
OPERATIONS

3823.115

10

SUBJECT

N₂ subcooler
Pressure relief calculations

NAME

Mike Jorychen

DATE

12/11/02

REVISION DATE

12/20/02

③ 1/2" tube to 1/2" pipe enlargement:

$$K = 2.6 \sin \frac{\theta}{2} (1 - \beta^2)^2 \quad (\text{Crane 3-17})$$

$$K = 2.6 \sin 15^\circ \left[1 - \left(\frac{0.5}{0.622} \right)^2 \right]^2 = 0.084$$

$$\text{for sch. 10} \quad K = 0.084 \left(\frac{0.674}{0.622} \right)^4 = \underline{0.116}$$

④ Valve, C_v = 0.32, 1/2" pipe

$$K = \frac{891 \cdot d^4}{C_v^2} \quad (\text{Crane 3-16})$$

$$K = \frac{891 \cdot 0.622^4}{0.32^2} = 1302.38 \quad (! - \text{determines the flow})$$

for sch. 10

$$K = 1302.38 \left(\frac{0.674}{0.622} \right)^4 = \underline{1795.6}$$

⑤ 3/4" pipe elbow to 1/4" pipe reducer (before the phase separator)
(θ = 180°)
(Crane 3-18.1)

$$K = 0.5 \sqrt{\sin \frac{\theta}{2}} \cdot (1 - \beta^2)$$

$$K = 0.5 \sqrt{\sin 90^\circ} \left[1 - \left(\frac{0.5}{0.622} \right)^2 \right] = 0.392$$

for sch. 10

$$K = 0.392 \left(\frac{0.674}{0.622} \right)^4 = \underline{0.541}$$

$$\Sigma K = .242 + .184 + .116 + 1795.6 + .541 = 1796.7$$

Equivalent length

$$L_{\text{sch. 10}} = \frac{\Sigma K \cdot D_{\text{sch. 10}}}{f_{\text{sch. 10}}} = \frac{1796.7 \cdot \left(\frac{0.674}{12} \right)}{0.027} = 375.75 \text{ ft} \quad f = 0.027 \quad (\text{Crane A-26})$$

PPP/HD/PP

OPERATIONS

3823.115

11

SUBJECT

LN₂ subcooler

NAME

Mike Szycher

Pressure relief calculations

DATE

12/11/02

REVISION, DATE

12/02/02

add 2.36 ft of 1/2" sc 40 pipe

$$L = 3757.58 + 2.36 = 3760.0 \text{ ft.}$$

Rearranged Darcy's formula:

$$W^2 = \frac{\Delta P_{TOTAL}}{3.36 \cdot 10^{-6}} \left[\frac{f_{pipe} \cdot L_{pipe}}{\rho \cdot d_{pipe}^5} + \frac{f_{tube} \cdot L_{tube}}{\rho \cdot d_{tube}^5} \right]^{-1}$$

 $f = 0.027$ for 1/2" pipeI will use $f = 0.026$ for 1/2" copper tube
(see eng. note 3823.115-EN-568)

$$W = \sqrt{\frac{(65 - 23.5)}{3.36 \cdot 10^{-6}} \left[\frac{0.027 \cdot 3760.0}{47.7 \cdot 0.674^5} + \frac{0.026 \cdot 14.13}{47.7 \cdot 0.5^5} \right]} = 891 \text{ lb/hr}$$

$$\rho = 76.42 \cdot 10^{-2} \text{ g/cm}^3 = 47.7 \text{ lb/ft}^3 \quad \text{for } P = 23.5 \text{ psig}$$

$T = 86 \text{ K}$ for saturated liquid

Check friction factors:

$$Re = 6.31 \frac{W}{d \cdot \mu}$$

$$Re_{pipe} = 6.31 \frac{891}{.674 \cdot 0.1104} = 7.6 \cdot 10^4$$

$$\mu = 0.1104 \text{ cp}$$

$$Re_{tube} = 6.31 \frac{891}{.5 \cdot 0.1104} = 10.2 \cdot 10^4$$

$$\Downarrow$$

$$f_{pipe} = 0.028; f_{tube} = 0.0285$$

(Craue A-25)

SUBJECT

LN_2 Subcooler
Pressure relief calculations

NAME

Mike Langley

DATE

12/11/02

REVISION DATE

12/02/02

Recalculate the max. flow

$$W = \sqrt{\frac{(65 - 23.5) \left[\frac{0.028 \cdot 3760.0}{47.7 \cdot 0.694^5} + \frac{0.0285 \cdot 14.13}{47.7 \cdot 0.5^5} \right]^{-1}}{3.36 \cdot 10^{-6}}} = 874.74 \approx 875 \text{ lb/hr}$$

As I mentioned before, I will assume 100% gas @ saturation temp. and 23.5 psig pressure

$$\rho = 1.12 \cdot 10^{-2} \text{ g/cm}^3 = 0.7 \text{ lb/ft}^3$$

$$V = \frac{W}{\rho} = \frac{875}{0.7} = 1250 \text{ ft}^3/\text{hr} = \underline{20.8 \text{ ft}^3/\text{min}}$$

Conclusion:

I will choose 2 Anderson - Greenwood pressure relief valves (available and calibrated) as a primary and secondary relief systems.

Set pressure is 20 psig,

Capacity is 111 scfm each.

ports (inlet and outlet) - 1"

model #81888-8

Note: reminder - the vessel is working at the atmospheric pressure and there is no isolation between the vessel's inside volume and the atmosphere.

NOTES: 1. VACUUM TEST: NO LEAK SHALL BE DETECTABLE ON THE MOST SENSITIVE SCALE OF A HELIUM LEAK DETECTOR.

2. ITEMS 36, 31, 32 & 38 TO BE WRAPPED WITH 15 LAYERS OF ALUMINUMIZED MYLAR SUPERINSULATION. ONLY WRAP THOSE AREAS ENCLOSED BY AN OUTER VACUUM JACKET.

3. TACK AFTER ALIGNMENT OF ITEMS #59 & 51.

VALVE REPAIR WORK ORDER

Page _____ of _____ VSCR- 3391

Customer Fermilab PO# PROCARD

Location _____ Date Rec'd 9-16-02

RECORD OF ORIGINAL NAMEPLATE DATA

Prv. Mfr. Anderson Greenwood Capacity 172 SCFM **CHANGE IN SET PRESSURE:**
Type No. 81B88 8 ASME Code Stamp UV Reset To 20 PSIG
Inlet/Outlet 1 in. / 1 in. Mfr. S/N 758254 New Capacity 111 SCFM
Set Press 40 PSIG Tag No. _____

RECORD OF PRETEST (AS FOUND)

Trim No. _____
Test Pressure _____ Pretest Sign-Off _____
Blowdown _____ Tested by _____
Tightness _____ Date _____
Action _____ M&TE S/N _____

RECORD OF PREVIOUS REPAIR

By _____
Model _____ Set _____
Capacity _____ Date _____
Unique # _____ VR Stamp _____

RECORD OF DISASSEMBLY & CLEANING

Item (s): "As Found Conditions"
Cap and Lever
Bonnet/Compr Scr: .780
Spring/Steps
Spindle/Disc
Base/Nozzle
Guide/Adj. Rings
Other (Specify)

RECORD OF CRITICAL INSPECTION & MACHINING

Comments	OK	Machine	Replace
	X		
	X		
Spring# <u>758254 BIK DWN</u>			X
T.I.R.			X
Bore Dia. <u>.500</u>		<u>LAP</u>	
	X		

RECORD OF REPLACEMENT PARTS

Part No	Description	PO#
<u>04-4805-005</u>	<u>SPRING</u>	<u>CUSTOMER SUPPLIED</u>
<u>04-4805-005</u>	<u>SOFT GOODS KIT</u>	<u>CUSTOMER SUPPLIED</u>

Notes _____

RECORD OF TECHNICIAN SIGN-OFF

Repair Step Initials Date
Nameplate TS 9-16-02
Disassembly TS 9-16-02
Cleaning TS 9-16-02
Inspection TS 9-16-02
Machining _____
Parts TS 9-16-02
Assembly TS 9-16-02
Testing TS 9-23-02
Final-Assembly TS 9-24-02
VR Stamp TS 9-24-02

RECORD OF FINAL TEST RESULTS

Test Stand/Media 12000A AIV
Test Pressure 20
Blowdown FACTORY SPEC. 1.5 DOWN
Tightness 18
M&TE S/N TG600

Repaired by
GM&C VALVE SERVICE COMPANY
Elk Grove Village, IL VR No. 396 & 500
VSCR 3389 DATE 9-02
STYLE 81B88-8
SET PRESS 20
CAP 111 SCFM VR

**TEST DOCUMENTATION
CODE STAMPED RELIEF VALVES**

This form should be used for relief valves returned from a vendor to check the accuracy and quality of the vendor's work. It should also be used to check code stamped valves for the 6 year test. Valves that pass this test can be put in service if the original seal from a vendor is still in place and not broken.

All valves should be bubble tight at 90% of set pressure while increasing pressure, lift within the code requirement, and reset bubble tight. Reset pressure as a percent of set pressure would vary, depending on the blowdown setting.

The valve should be connected to the appropriate test chamber with adapters as required being careful not to choke the valve with fittings smaller than the valve inlet.

Date - October 1, 2002

Vessel number (from silver sticker) - _____

Physical location and valve number - _____

Manufacturer - Auderson Greenwood

Model number - 81388-8

Serial number - 158254

Valve size - 1"

Seal intact - yes

Set pressure - 20 psig

Bubble tight at 90% set pressure - @ 18 psig - Slight leakage - OK @ 16.0 psig = 80%

Valve lift within +/- 2 psig for settings 70 psig and below or within 3% for higher settings? Tolerances defined by UG-134(d) (1) OK

Test 1 - 20.3 psi Test 2 - 20.3 psi Test 3 20.3 psi

Bubble tight at reset - @ 13.0 psi

If valve passed test, attach a brass tag to valve with "TEST ONLY", date, and tester's initials.

Notes; Performance test of Vendor's Certification

Signed [Signature]
Date 10-1-02

VALVE REPAIR WORK ORDER

Page 1 of 1 VSCR- 3389

Customer Fermilab PO# PROCARD

Location _____ Date Rec'd 9-20-02

RECORD OF ORIGINAL NAMEPLATE DATA

Prv. Mfr. ANALOG GREENWOOD Capacity 172 SCFM CHANGE IN SET PRESSURE:
Type No. 81B88-8 ASME Code Stamp CU Reset To 20 PSIG
Inlet/Outlet 1 in. / 1 in. Mfr. S/N 758258 New Capacity 111 SCFM
Set Press _____ PSIG Tag No. _____

RECORD OF PRETEST (AS FOUND)

Test Pressure _____ Pretest Sign-Off _____
Blowdown _____ Tested by _____
Tightness _____ Date _____
Action _____ M&TE S/N _____

Trim No. _____

RECORD OF PREVIOUS REPAIR

By _____
Model _____ Set _____
Capacity _____ Date _____
Unique # _____ VR Stamp _____

RECORD OF DISASSEMBLY & CLEANING

Item (s): "As Found Conditions"
Cap and Lever
Bonnet/Compr Scr: .978
Spring/Steps
Spindle/Disc
Base/Nozzle
Guide/Adj. Rings 1.5
Other (Specify) _____

RECORD OF CRITICAL INSPECTION & MACHINING

Comments	OK	Machine	Replace
	X		
	X		
Spring# <u>21 B1V B1K B1N</u>			X
T.I.R.			X
Bore Dia. <u>.500</u>		<u>LAP</u>	
	X		

RECORD OF REPLACEMENT PARTS

Part No	Description	PO#
<u>04-4805-005</u>	<u>81 SOFT GOODS KIT</u>	<u>CUSTOMER SUPPLIED</u>
	<u>SPRING PINK B1K B1K B1N</u>	<u>CUSTOMER SUPPLIED</u>

Notes RUBBER WAS STUCK IN INLET

RECORD OF TECHNICIAN SIGN-OFF

Repair Step Initials Date Test Stand/Media TB1000B AIV
Nameplate TB 9-20-02 Test Pressure 20
Disassembly TB 9-20-02 Blowdown FACTORY SPEC. 1.5 INCH
Cleaning TB 9-20-02 Tightness 18
Inspection TB 9-20-02 M&TE S/N T6600
Machining _____
Parts TB 9-20-02
Assembly TB 9-23-02
Testing TB 9-23-02
Final-Assembly TB 9-24-02
VR Stamp N TB 9-24-02

RECORD OF FINAL TEST RESULTS

Repaired by
GM&C VALVE SERVICE COMPANY
Elk Grove Village, IL VR No. 396 & 500
VSCR 3389 DATE 9-02
STYLE 81B88-8
SET PRESS 20
CAP 111 SCFM VR

TEST DOCUMENTATION
CODE STAMPED RELIEF VALVES

This form should be used for relief valves returned from a vendor to check the accuracy and quality of the vendor's work. It should also be used to check code stamped valves for the 6 year test. Valves that pass this test can be put in service if the original seal from a vendor is still in place and not broken.

All valves should be bubble tight at 90% of set pressure while increasing pressure, lift within the code requirement, and reset bubble tight. Reset pressure as a percent of set pressure would vary, depending on the blowdown setting.

The valve should be connected to the appropriate test chamber with adapters as required being careful not to choke the valve with fittings smaller than the valve inlet.

Date - October 1, 2002

Vessel number (from silver sticker) - _____

Physical location and valve number - _____

Manufacturer - Anderson Greenwood

Model number - 81 B 88-8

Serial number - 758258

Valve size - 1"

Seal intact - yes

Set pressure - 20 psig

Bubble tight at 90% set pressure - OK @ 16.5 psig @ 82.5%

Valve lift within +/- 2 psig for settings 70 psig and below or within 3% for higher settings? Tolerances defined by UG- 134(d) (1) OK

Test 1 - 19.5 psi Test 2 - 19.6 psi Test 3 19.5 psi

Bubble tight at reset - @ 16.5 psig

If valve passed test, attach a brass tag to valve with "TEST ONLY", date, and tester's initials.

Notes; Performance test of Vendor's Certification

Signed
Date 10-1-02

FERMILAB**COPY****Welder Qualification Test Record**Welder's Name Leonard Harbacek Ident No. 122261 Date 03/19/99Welding Process GTAW Type ManualTest in Accordance With WPS # ES-155003 Root OpenMaterial Specification SA 53-B To Material Specification SA 53-BP-No 1 To P-No 1 Thickness .280" Diam 6"Filler Metal Specification SFA A5.18 Classification ER-70S-2 F-No 6Thickness Deposited .280Backing Argon Gas Shielding ArgonPosition 6-G Progression UpwardElectrical Characteristics: Current DC Polarity StraightThickness Qualified .560" Max Diameter Qualified 2-7/8" O.D. and over**GUIDED BEND TEST RESULTS**

Specimen No	Type	Figure	Results
1	Face	QW-462.3a	Acceptable
2	Face	QW-462.3a	Acceptable
3	Root	QW-462.3a	Acceptable
4	Root	QW-462.3a	Acceptable

Test Conducted By IFR Engineering Test No. 008-09-01 Date 3/19/99

We certify that the statements in this record are correct and that the test welds were prepared, welded and tested in accordance with the requirements of Section IX of the ASME Code.

By: Date: 4/22/99

January 30, 2004

To: John Cooper
From: Kurt Krempetz
Subject: Recommendation to Approve Pressure Vessel # 10075-LN2 Subcooler

John,

I have looked into unusual features with Engineering Pressure Vessel Note for vessel #10075-LN2 Subcooler and have no concerns. This note does follow the Fermilab Pressure Vessel Standard Chapter 5031 and I recommend that you sign off on the Engineering Note.