Cold compressor and buffer/subcooler Dewar for superconducting solenoid Helium supply and return lines.

D-ZERO ENGINEERING NOTE # 3823.115-EN-574

January 25, 2005

Author: Michael Sarychev

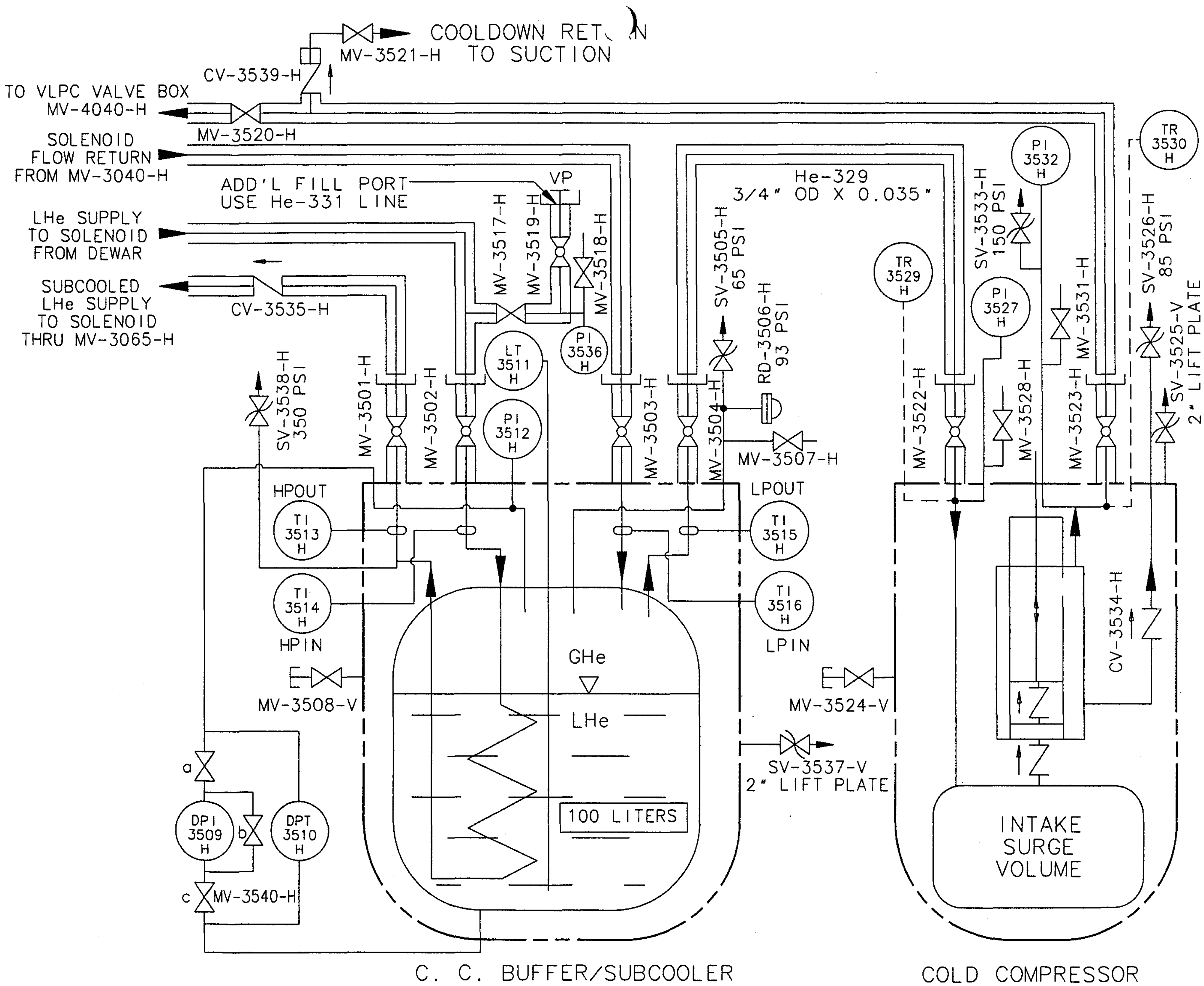
Engineer

PPD/MSD/D0 Operations

Dzero experiment needs to drop the operating temperature of the superconducting solenoid. In order to do this, a cold compressor (vessel # RSB416), along with a two-phase return Dewar (vessel # RSB409) will be installed in Dzero Assembly building in the Helium refrigerator area (flow diagram attached). The cold compressor will be installed on a 2-phase Helium return line from the solenoid and its purpose will be to drop the return line and existing Lhe subcooler (located in the solenoid Control Dewar) pressure, and therefore decrease the solenoid operating temperature. The low pressure side of the buffer/subcooler Dewar will serve as a buffer volume for the cold compressor and will be connected to the same return line. The high pressure side of this Dewar (the coil) will be used to subcool Lhe supply to the solenoid. Those vessels were previously used in Tevatron satellite refrigerator buildings. Relieving devices settings and sizing were reviewed, and it has been determined that they are not system dependent and apply to the corresponding vessels only; they are deemed appropriate and will be kept unchanged in new system configuration. The original instrumentation will not be changed as well. Therefore, since there is no subsequent changes in contents, pressures, temperatures, valving, etc., affecting the safety of those vessels, no additional review of original pressure vessel engineering notes (vessels RSB409 and RSB416) is required (per Fermilab ES&H Manual Chapter 5031).

Attachments:

1. Original Pressure Vessel Engineering notes for RSB409 and RSB416
2. Cold compressor and subcooler/buffer connections flow diagram



COOLDOWN RET
TO SUCTION
MV-3521-H
CV-3539-H
TO VLPC VALVE BOX
MV-4040-H
MV-3520-H
SOLENOID
FLOW RETURN
FROM MV-3040-H
ADD'L FILL PORT
USE He-331 LINE
VP
He-329
3/4" OD X 0.035"
LHe SUPPLY
TO SOLENOID
FROM DEWAR
SUBCOOLED
LHe SUPPLY
TO SOLENOID
THRU MV-3065-H
CV-3535-H
MV-3517-H
MV-3519-H
MV-3518-H
PI 3536 H
LT 3511 H
PI 3512 H
SV-3505-H
65 PSI
RD-3506-H
93 PSI
SV-3538-H
350 PSI
MV-3501-H
MV-3502-H
MV-3503-H
MV-3504-H
MV-3507-H
TR 3529 H
PI 3527 H
PI 3532 H
TR 3530 H
SV-3533-H
150 PSI
MV-3531-H
SV-3526-H
85 PSI
SV-3525-V
2" LIFT PLATE
MV-3522-H
MV-3528-H
MV-3523-H
HPOUT
TI 3513 H
TI 3514 H
HPIN
LPOUT
TI 3515 H
TI 3516 H
LPIN
GHe
LHe
MV-3508-V
MV-3524-V
CV-3534-H
SV-3537-V
2" LIFT PLATE
100 LITERS
a
b
c
DPI 3509 H
DPT 3510 H
MV-3540-H
INTAKE
SURGE
VOLUME
C. C. BUFFER/SUBCOOLER
COLD COMPRESSOR

OK
H Casebolt

Prepared by: J.D. Fuerst

Preparation date: 7/29/88

1. Description and Identification

Fill in the label information below:

This vessel conforms to engineering standard SD37
Vessel Title 2- Phase Return Dewar
Vessel Number RSB409
Vessel Drawing Number 1650-ME-168945
Maximum Allowable
Working Pressure (MAWP) 100 PSI
Working Temperature Range -450 °F 100 °F
Contents Helium
Designer/Manufacturer T.J. Peterson - J.D. Fuerst/
Fermilab
Test Pressure (if tested at Fermi) Acceptance
Date: 8/11/88
125 PSI, Hydraulic ______ Pneumatic X
Accepted as conforming to standard by
H Edwards
of Division/Section Acc Div 10/13/88
NOTE: Any subsequent changes in contents, pressures, temperatures, valving, etc., which affect the safety of this vessel shall require another review and test.

Obtain from Division/Section Safety Officer

Actual signature required in this space

Reviewed by: K G Weber Date: 8/9/88

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

______ Date: ______

Lab Property Number(s): ______

Lab Location Code: ______

Purpose of Vessel(s): Provide buffer volume and aftercooling for proposed cold compressor installation in satellite refrigerator buildings.

Vessel Capacity/Size: 100 liter Diameter: 24" Length: 50"

Normal Operating Pressure (OP) 3 PSIG

MAWP-OP = 97 PSI

Is the above enough to provide relief cracking pressure tolerance plus system uncertainty tolerance per M-9.

As an option, provide a photo of the entire vessel in the Appendix.

List the number of all pertinent drawings and the location of the originals. (Appended copies).

Drawing #	Location of Original
1650-ME-168945	East Booster Tower

2 Design Verification

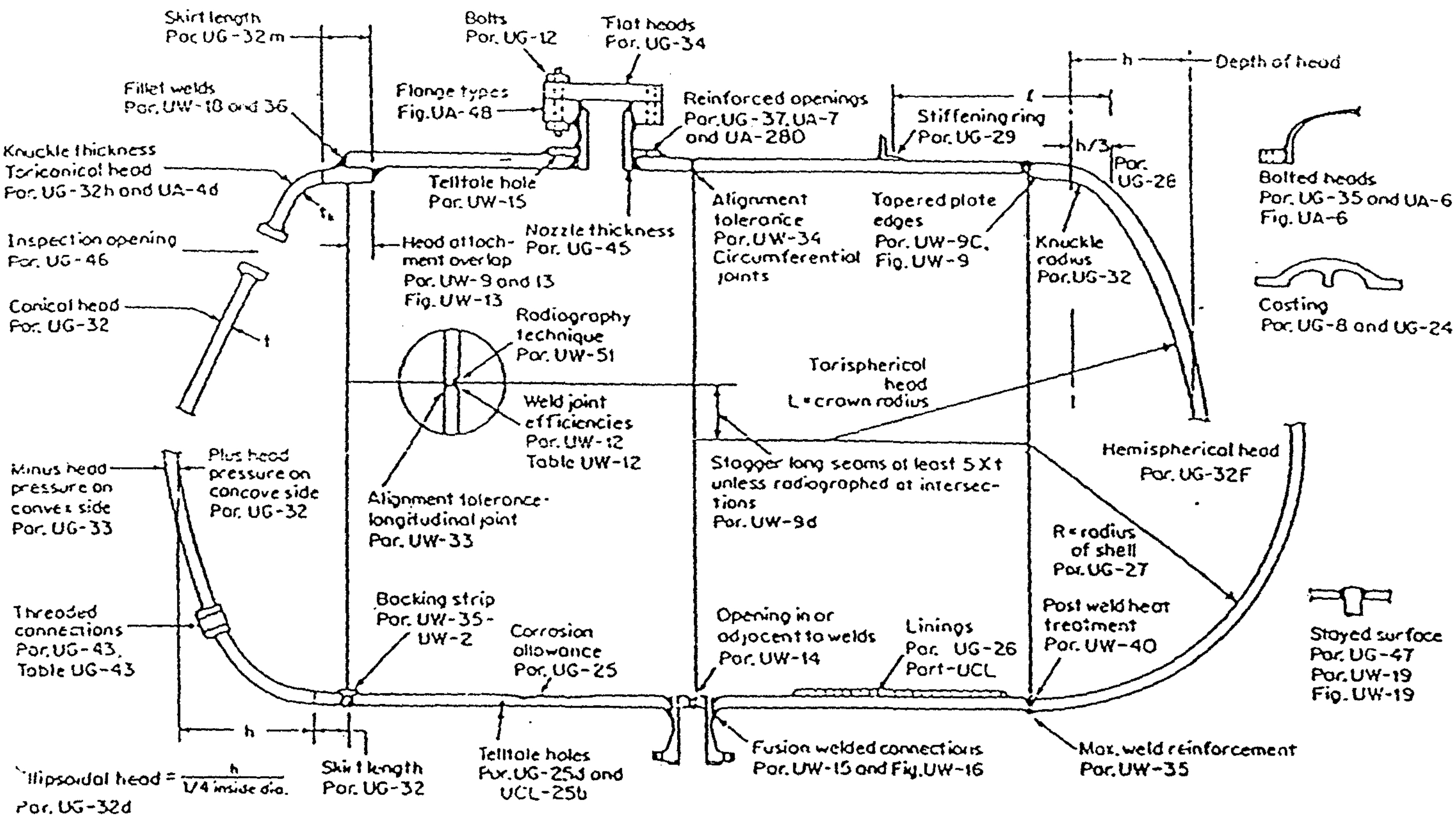
Does the vessel(s) have a U stamp? Yes________ No___X___. If ''Yes'', fill out data below and skip page 3; if ''No'', fill out page 3 and skip this page.

Staple photo of U stamp plate below.

Copy ''U'' label details to the side if photo is not clear or if copies are unreadable.

Copy data here:

On the sketch below, circle all applicable sections of the ASME code per Section VIII, Division I. list the results of all calculations. (Insert copies of calculations in he appendix).



Summary of ASME Code

Item	Reference ASME Code Section	CALCULATION RESULT (Required thickness or stress level vs. actual thickness or calculated stress level)
See Appendix	for calculations	vs.
Heads (Inner &	outer vessel)	vs.
Shells (Inner	& outer vessel)	vs.
		vs.
		vs.

If this vessel is exceptional or had exceptional parts, list their details under 5.6. Yes ______ No __X__

3 System Venting. Provide the system schematic in the Appendix, if the vessel safety is system sensitive.

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

Yes______ No__X___

If ''Yes;;, the system must conform to M-5. Provide an explanation of the appended schematic. (An isolatable vessel, not conforming to M-5 violates the Standard.)

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

Yes___X__No______ Actual setting ___65_________PSIG
(A no response violates the Standard.)

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

Yes__X__ 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 violate the Standard.)

List of reliefs and settings:

Manufacturer	Relief	Setting	Flow Rate	Size
Circle Seal	Valve	65 psig	425 scfm air	1"
#M5120-N-8M-65ASME				
Continental	Disc	93 psig	2400 scfm air	1"

Is the relief device an ASME stamped device? Yes __X__ No ______

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

Yes __X__ No _____. If ''Yes'', please append.

5. Welding Information

Has the vessel been fabricated in a Fermilab shop? Yes ___X___ No _______

If ''Yes'', append a copy of the welding shop statement of welder qualification and a copy of the Welding Procedure Specification (WPS) used to weld this vessel.

6 Exceptional, Existing, Used, and Non-Manned Area Vessels

Is this vessel or any part thereof in the above categories? Yes _____ No __X__

If ''Yes'', follow the Engineering Note requirements for documentation in free form below.

Procedure for Putting the 2-Phase Return Dewar On-line at A1

Tom Peterson TJP
May 11, 1987

1. PUMP AND BACKFILL tube side (HP) and dewar (LP) with helium at least 5 times. Leave about 10 psig helium in both. ~~(Dewar relief cracks at about 10 psig.)~~ TJP

2. CRASH BUILDING (close EV-101)

3. EVBY Local Open.

4. EVLH Local Close.

5. EVJT Local Open.

6. Engines off, pressures all ≤10 psig.

7. PULL long HP U-tube.

8. PURGE and INSERT valvebox to dewar HP U-tube.

9. PURGE and INSERT heat exchanger end box to dewar HP U-tube.

10. PULL long LP U-tube.

11. PURGE and INSERT valvebox to dewar LP U-TUBE.

12. PURGE and INSERT heat exchanger end box to dewar LP U-tube.

13. EVJT CLOSE (still local).

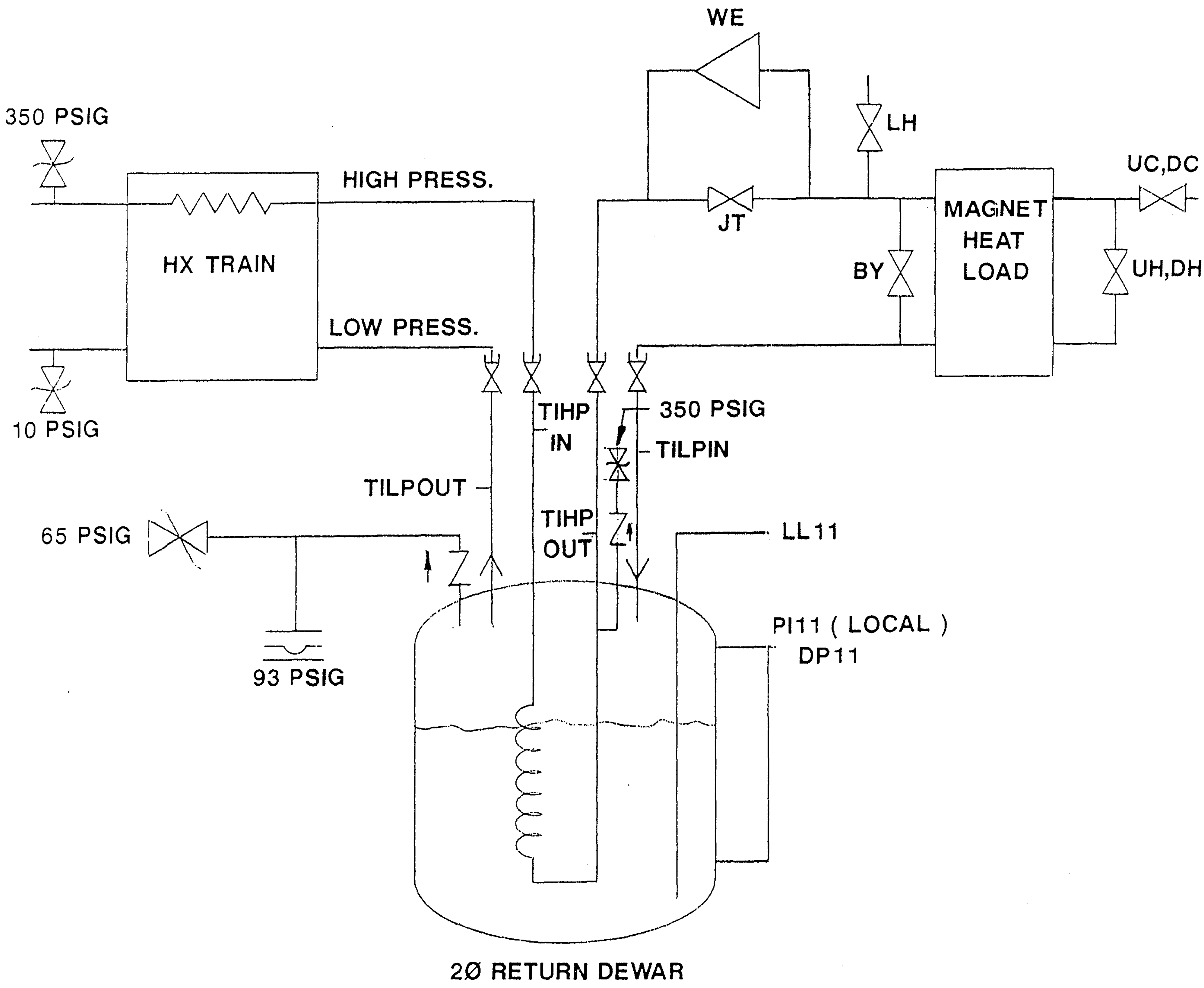
14. OPEN EV-101.

15. EVLH OPEN (still local).

16. RUN WET ENGINE SLOWLY
bypass still open so cooling 2-phase return dewar.
Watch wet engine and dewar VPT's for cooling.

17. When dewar and wet engine cold enough (a judgement call) put EVJT, EVBY, EVLH, WET ENGINE in REMOTE.

es


WE
350 PSIG
LH
HIGH PRESS.
UC,DC
MAGNET
HEAT
LOAD
JT
HX TRAIN
BY
UH,DH
LOW PRESS.
350 PSIG
TIHP
IN
TILPIN
10 PSIG
TILPOUT
TIHP
OUT
65 PSIG
LL11
PI11 (LOCAL)
DP11
93 PSIG
2Ø RETURN DEWAR

Appendix
Revised 9-SEP-88

Outline of Code Calculations

I. STAINLESS STEEL INNER VESSEL

- A. Internal Pressure
  1. Heads
  2. Shell
  3. Head/Neck weld reinforcement
- B. External Pressure
  1. Heads
  2. Shell

II. STAINLESS STEEL VACUUM VESSEL

- A. Internal Pressure
  1. Heads
  2. Shell
  3. Head/Neck Weld reinforcement
- B. External Pressure
  1. Heads
  2. Shell

III. RELIEF VALVE SIZING

- A. Vacuum Vessel
- B. Inner Vessel
  1. Failure Modes
  2. Relief Capacities

IV. SUMMARY OF CALCULATIONS

I. STAINLESS STEEL INNER VESSEL

This vessel was constructed by the Accelerator Division Cryogenic Systems Group at Fermilab. Since it is not clear whether 304 or 304L stainless steel was used in fabrication,calculations are performed assuming 304L.

A. Internal Pressure

1. Heads UG-32 (ellipsoidal)

P = 2SEt/(D+0.2t)
S = max. all stress value, psi = (13300)(.85)(.80) = 9044
E = joint efficiency (weld) = 1.0 (no welds in head)
t = thickness in = 0.25
D = inside length of maj. axis of head = 18"

P = 250 psi

2. Shell UG - 27 (welded pipe)

S = (13300)(.80) = 10640 psi
E = 0.6 (UW-12)
R = inside radius of shell, in. = 8.75
P = SEt/(R+0.6t)(circumferential = 179 psi
P = 2SEt/(R-0.4t)(longitudinal) = 369 psi

P = 179 psi

3. Head/Neck Weld Reinforcement UG-37

d = opening dia. = 1.90-2(0.109) = 1.682"

F = corr. factor for plane angle = 1

P = MAWP = 115 psia

E = 1

D = 18"

t_r = req'd thickness = PD/(2SE - 0.2P) = 0.1146"

A = $A_{req'd} = dt_rF = (1.682)(0.1146)(1) = 0.1928$ ins^2

$A_{act} = d(t-t_r)F = (1.682)(0.1354)(1) = 0.2277$ in^2

A_{act} > A (req'd) therefore **no additional reinforcement req'd.**

B. External Pressure

1. Heads UG - 33

$P_1 = P_{concave}/(1.67)$ or $P_2 = B/(R_o/t)$, whichever is less.

$P_{concave} = 250$ psi $\therefore$ $P_1 = 150$ psi

"A" $= 0.125/(R_o/t)$ where R_o = equiv. outside spherical radius, in. Using table UG-33.1, $R_o = 16.2$.

t = head thickness, in. = 0.25
A = 0.0019 therefore "B" = 10000
(fig. 5-UHA-28.3 up to 100F)
P_2 = 154 psi so $P_1 < P_2$

P = <u>150 psi</u>

2. Shell UG - 28C

L = shell length, in. = 20" (incl. head skirts)
D_o = outside dia. of shell, in. = 18"
t = 0.25"
then $D_o/t = 80$ (> 10) and $L/D_o = 1.111$
$\therefore$ factor "A" = 0.0018 and "B" = 10000 (fig. 5-UHA-28.3 up to 100F)
$P = 4B/3(D_o/t)$

P = <u>167 psi</u>

II. STAINLESS STEEL VACUUM VESSEL

This vessel was constructed by the Accelerator Division Cryogenic Systems Group at Fermilab. Since it is not clear whether 304 or 304L stainless steel was used in fabrication, calculations are performed assuming 304L.

A. Internal Pressure

1. Heads UG - 32 (as per inner vessel) $t = 0.25$ in. $D = 24$ in.

   $P = \underline{\underline{188 \text{ psi}}}$

2. Shell UG - 27 (as per inner vessel) $R = 12$ in.

   Circumferential: $P = 131$ psi
   Longitudinal : $P = 268$ psi

   $P = \underline{\underline{131 \text{ psi}}}$

3. Head/Neck Weld reinforcement UG - 37 (as per inner vessel)

   d = 3.5" -2 (0.083") = 3.334" (worst case)

   D = 24"

   P = 1.67 (required ext. press. per SD-41) = 1.67 (7.5 psia) = 12.5 psi

   E = 1

   F = 1

   t_r = 0.0166"

   $A_{req} = dt_rF = 0.0553 \text{ in}^2$

   $A_{act} = d(t-t_r) = 0.7782 \text{ in}^2$

   A_{act} > A (req'd.) therefore **no additional reinforcement req'd.**

B. External Pressure

1. Heads UG - 33 (as per inner vessel)

   $P_1 = P_{concave}/(1.67) = 93$ psi

   "A" = 0.0014 where $R_o = 21.6$ and $t = 0.25$"

   therefore "B" = 9500 (fig. 5 UHA-28.3 up to 100 F)

   so $P_2 = 131$ psi

   $P = \underline{\underline{93 \text{ psi}}}$

2. Shell UG - 28C

L = 32" (incl. head skirts)
D_o = 24"
t = 0.25"
D_o/t = 96 (>10), L/D_o = 1.333
factor "A" = .0012, factor "B" = 9000 (as above)
then $P = 4B/3(D_o/t)$

P = 125 psi

III. RELIEF VALVE SIZING

A. Vacuum Vessel

CGA 341 specifies a minimum 0.00024 in^2 discharge area per pound water capacity of the liquid container.

100 liter inner vessel = 100 kg H_2O = 220 lb H_2O

Relief area req'd. = (0.00024)(220) = 0.0528 in^2
Actual vacuum relief is a 2" parallel plate device (Fermi dwg. 9130-MC-129784) supplying 3.14 in^2 area.

3.14 in^2 vs. 0.0528 in^2

B. Inner Vessel

MAWP = 100 psi

1. Failure modes

a. Loss of vacuum - vacuum filled with 1 atm GHe (vacuum relief point).

$Q_a = (130\text{-}t)/4(1200\text{-}t) = G_iUA$

b. Loss of vacuum, condensative heat transfer by air - NBS Monograph 111 chart 6.3

c. Fire condition $Q_a = G_iUA^{0.82}$ from CGA S-1.3

d. Rupture of finned tubing exposing inner vessel to high pressure.

Q_a = flow capacity req'd. (SCFM air)
G_i = 52.5 for He relieving at or below 200 psi (CGA - S-1.3)
A = outside surface area of vessel (16 ft^2)
U = total thermal conductance of insulating material (Btu/hr ft^2F) when saturated with gaseous lading or air at 1 atm, whichever is greater.
t = Temp. (^oF) of gas at pressure and flowing conditions.

<u>Case A</u>:

Q_a = 130-t/4(1200-t) = G_iUA
U = K/L where K = avg. therm. cond. of He (0-300K)
= 1.55 MW/cmk
L = thickness of superinsulation
= 1" (~60 layers)
U = (1.55MW/cmk)/2.54 cm = 0.6102 MW/cm^2k
= 1.075 Btu/hr ft^2F
t = -450^oF
so Q_a = {(130+450)/[4(1200+450)]} = G_iUA

<u>77.4 SCFM air</u>

<u>Case B</u>:

Relieving pressure = (1.16)(100+14.5) = 132.8 psia from NBS Mono 111 fig. 6A-2 and taking worst case:

L' = 14 Btu/lb efflux
T = 10^oR
From NBS Mono 111 fig. 6.3:

Heat flux = 16000 Btu/hr.

16000 Btu/hr/(14 Btu/lbefflex) = 1143 lb/hr

Q_a = [13.1WCa/60C][ZTMa/MZaTa]$^{1/2}$ from ~~NB~~ NBS Mono 111 eq. 6A-1

Q_a = req'd capacity, SCFM air

where W = lb/hr req'd gas flow

C_a = gas const. = 356 for air

C = gas const. of the gas

Z_a = compressibility factor = 1.0 for air @ STP

Z = compressibility factor for the gas @ flow cond.

M_a = molecular weight of air = 28.97

M = molecular weight of the gas

T_a = temp. of air @ STP = 520R

T = temp. of gas @ flow cond.

$$Q_a = \frac{(13.1)(1143)(356)}{60(378)}\left[\frac{0.98(10)(28.97)}{4(1.0)(520)}\right]^{\frac{1}{2}} = 82.3 \text{ SCFM air}$$

Note: It is possible to arrive at higher values of Q_a if different values for L' and T are taken from Fig. 6A-2 of NBS mono 111. For instance, at L' = 12 and T = 12^{O}R along the 100 psia line, Q_a = 105 SCFM air. if L' = 14 and T = 14, then Q_a = 97.3 SCFM air. The required relief capacity is the largest of these values.

105 SCFM air

Case C:

$Q_a = G_i UA^{0.82}$

$Q_a = 52.5\,(1.075)(16)^{.82}$ = 548 SCFM air

548 SCFM air

Case D:

Assume a worst case scenario in which a finned tube becomes disconnected, providing a 1/2" hole from high pressure (up to 300 psi) to vessel pressure (rupture disc burst pressure = 100 psi).

Since under sonic conditions (present here) mass flow scales linearly with both pressure and flow area, one can argue that the required burst disc area must be greater than they envisioned flow area produced by the failure by the ratio of the driving pressures.

- 1/2" hole provides 0.1963 in^2 of flow area with a back pressure of 300 psi.
- burst disc pressure is 100 psi.
- burst disc area should be:

  $(300/100)(0.1963\ in^2) = 0.5890\ in^2$

This translates to a disc diameter of 0.8660 in.; therefore a 1" disc is considered adequate.

Such a disc will provide 2400 scfm air flow under burst conditions.

2. Relief Capacities

The inner vessel is relieved by one 1" Circle Seal relief valve #5120B-8MP-65 (65 psi relief point). This device is stamped at 425 SCFM. A 1" rupture disc (100 psi burst press.) is also present, supplying 2400 scfm air relieving cpacity to satisfy fire conditions and possible rupture of high pressure finned tubing inside vessel.

IV. SUMMARY OF CALCULATIONS

INNER VESSEL

PART	EXTERNAL PRESS			INTERNAL PRESS		
	Actual		Required	Actual		Required
S.S. Heads	150 psi	vs.	7.5 psi	250 psi	vs.	100 psi
S.S. Shell	167 psi	vs.	7.5 psi	179 psi	vs.	100 psi

Relieving capacity: 425 + 2400 = 2825 SCFM supplied us. 548SCFM req'd. (air)
Head/Neck weld reinforcement: 0.2277 in^2 supplied vs. 0.1928 in^2 req'd.

VACUUM VESSEL

PART	EXTERNAL PRESS		INTERNAL PRESS	
	Actual	Required	Actual	Required
Heads	93 psi	7.5 psi	188 psi	<100 psi
Shell	125 psi	7.5 psi	131 psi	<100 psi

Relieving capacity: 3.14 in^2 supplied vs. 0.0528 in^2 req'd.
Head/neck weld reinforcement: 0.7782 in^2 supplied vs. 0.0553 in^2 in^2 req'd.

jp

PITTSBURGH TESTING LABORATORY
4412 WEST ROOSEVELT ROAD
HILLSIDE, ILLINOIS 60162

11-4-76
Lab 1423-61

DESCRIPTION: Welder Qualification Tests

REPORTED TO: Fermi National Accelerator Lab
Batavia, Illinois 60510

PROCEDURE QUALIFICATION NO.: FNI-WP 900 SPECIFICATION NO.: FNI-WP 900

WELDER'S NAME: Clint Vickers S.S. NO.: 321-44-1502

SAMPLE NO.: TS-1076-28 POSITION: 6G JOINT TYPE: Vee Groove

DIAMETER: 6" SCHEDULE: 40 QUAL. RANGE: 0.062 to 0.560

RADIOGRAPHIC RESULTS:

GUIDED BEND TEST RESULTS:

Face #1	Passed	Root #2	Passed
Face #3	Passed	Root #4	Passed

REDUCED SECTION TENSILE TESTS:

SPECIMEN NO.	DIMENSIONS-INCHES		AREA SQ. IN.	ULTIMATE TOTAL LOAD. LBS.	ULTIMATE UNIT STRESS, PSI	CHARACTER OF FAILURE AND LOCATION
	WIDTH	THICKNESS				

RESULTS (DO/~~DO NOT~~) MEET REQUIREMENTS OF ASME SECTION IX AND III

TESTING CONDUCTED BY: PITTSBURGH TESTING LABORATORY

DAVID A. DUNN, DISTRICT MANAGER

TESTING WITNESSED BY: NUCLEAR WELDING, INC.

John H. Robertson

JOHN H. ROBERTSON

ADDENDUM

J.D. Fuerst 8/10/88

Temporary Primary Relief Valve Installed on the Second 2-Phase Dewar

The design for the 2-phase return dewar calls for one 1" 65 psi ASME coded Circle Seal relief (#M5120-N-8M-65ASME) as primary relief and one 1" 100 psi rupture disc as secondary (required only by the fire condition).

As of this writing, the Cryogenic Systems group has not received the 65 psi Circle Seal relief from the vendor; it is expected at the begining of September. Consequently, we are forced to use an appropriate alternative if we wish to begin testing before the Circle Seal arrives.

We located an Anderson Greenwood type 81S relief valve with a 1/2" orifice set for 145 psi. After ordering the proper spring for resetting, the valve was reconfigured by qualified, AGCO certified Fermilab personnel to relieve at 65 psig. The valve was tested to verify this relief setting. According to the Anderson Greenwood catalog, this valve will pass 252 SCFM with a 65 psig relief point.

252 SCFM is sufficient for all relief conditions except for the fire condition (the Circle Seal by itself is also insufficient for fire conditions). In that case, the rupture disc will blow and provide more than enough relieving capacity.

After the Circle Seal relief arrives, we will wait for an opportunity to warm up the vessel. We will then replace the temporary A&G relief with the Circle Seal. Since the A&G is a temporary relief, it was not considered necessary to rewrite this 2-phase return dewar's engineering note to reflect the change. This addendum has been written to clarify this issue.

Preparer's signature J.D. Fuerst 8/10/88

Reviewer's signature Katharine J Weber 8/11/88

10/14/88

Accelerator Division
Cryogenic Systems Group

Welder Qualification Voucher

The vessel Two-Phase Return Dewar RSB409,
has been welded in accordance with Fermilab drawing #1650-MD-257650, "Accelerator Cryogenic Systems - Cryogenic Pressure Vessels - Typical Welded Joint Designs" and in agreement with generally accepted welding practice.

The welders involved with the fabrication of this vessel (listed below) are qualified to perform the aforementioned welds, as attested to by the completion of Welder Qualification Tests and in the judgement of the Lead Welder.

Welders J. O'Neill

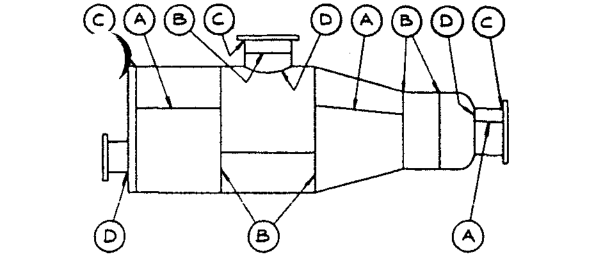
M. Santana

R. Krause

R. Williams

Lead Welder James M. O'Neill

Date 10/14/88



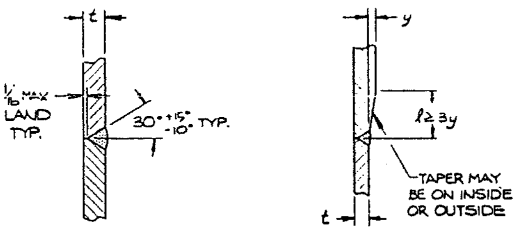
SAMPLE WELDED JOINT LOCATIONS TYPICAL OF CATEGORIES A,B,C & D

CATEGORY A - LONGITUDINAL WELDED JOINTS WITHIN THE MAIN SHELL, COMMUNICATING CHAMBERS, TRANSITIONS IN DIAMETER, OR NOZZLES; ANY WELDED JOINT WITHIN A FORMED OR FLAT HEAD, OF [illegible] THE SIDE PLATES OF A FLAT SIDED VESSEL.

CATEGORY B - CIRCUMFERENTIAL WELDED JOINTS WITHIN THE MAIN SHELL, COMMUNICATING CHAMBERS, NOZZLES, OR TRANSITIONS IN DIAMETER INCLUDING JOINTS BETWEEN THE TRANSITION AND A CYLINDER AT EITHER THE LARGE OR SMALL END; CIRCUMFERENTIAL WELDED JOINTS CONNECTING FORMED HEADS OTHER THAN HEMISPHERICAL TO MAIN SHELLS, TO TRANSITIONS IN DIAMETER, TO NOZZLES, OR TO COMMUNICATING CHAMBERS.

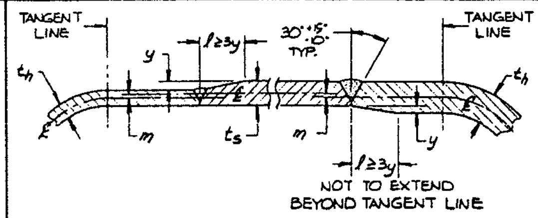
CATEGORY C - WELDED JOINTS CONNECTING FLANGES OR FLAT HEADS TO MAIN SHELL, TO FORMED HEADS, TO TRANSTIONS IN DIAMETER, TO NOZZLES, OR TO COMMUNICATING CHAMBERS; ANY WELDED JOINT CONNECTING ONE SIDE PLATE TO ANOTHER SIDE PLATE OF A FLAT-SIDED VESSEL.

CATEGORY D - WELDED JOINTS CONNECTING COMMUNICATING CHAMBERS OR NOZZLES TO MAIN SHELLS, TO TRANSITIONS IN DIAMETER, TO HEADS, OR TO FLAT-SIDED VESSELS, AND THOSE JOINTS CONNECTING NOZZLES TO COMMUNICATING CHAMBERS (FOR NOZZLES AT THE SMALL END OF A TRANSITION IN DIAMETER. SEE CATEGORY B).



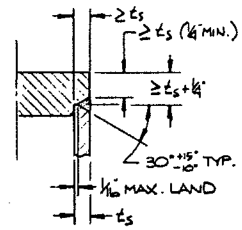
WHEN $y >$ THE SMALLER OF $t/4$ OR 1/8", THEN A TAPER OF A LENGTH $\geq 3y$ IS REQUIRED.

CATEGORY A OR B

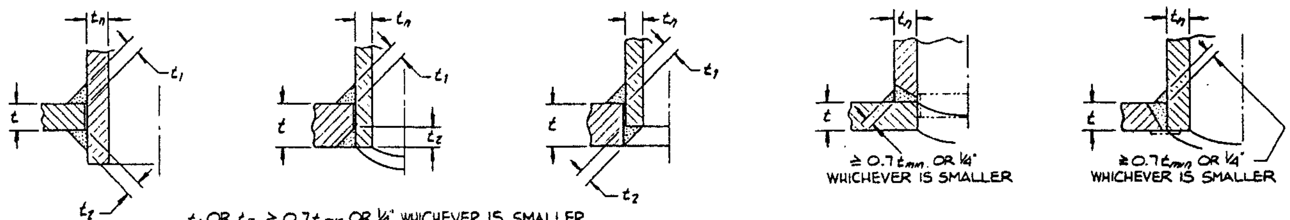


$m \leq$ ONE-HALF THE DIFFERENCE BETWEEN THE ACTUAL SHELL AND HEAD THICKNESS.
WHEN $y >$ THE SMALLER OF $t/4$ OR 1/8", THEN A TAPER OF A LENGTH $\geq 3y$ IS REQUIRED.
THE SHELL PLATE ℄ MAY BE ON EITHER SIDE OF HEAD PLATE ℄.

CATEGORY B

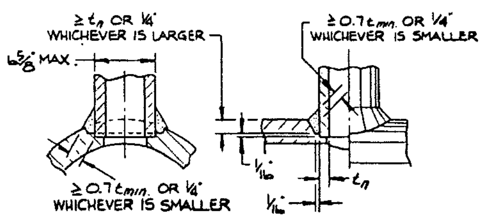


CATEGORY C

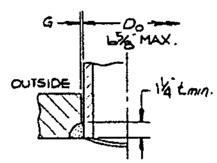


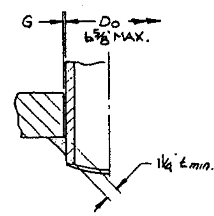
t_1 OR $t_2 \geq 0.7 t_{min}$ OR 1/4" WHICHEVER IS SMALLER
$t_1 + t_2 \geq 1\frac{1}{4} t_{min}$

CATEGORY D



CATEGORY D





FOR APPLICATIONS WHERE THERE ARE NO EXTERNAL LOADS:
G = 1/8" MAX.
WITH EXTERNAL LOADS:
G = 0.005" FOR $D_o \leq 1$"
G = 0.010" FOR 1" < $D_o \leq 4$"
G = 0.015" FOR 4" < $D_o \leq 6\frac{5}{8}$"

CATEGORY D

LEGEND

- ◺ - DENOTES DEPOSITED WELD METAL ONLY. ALL WELDS MUST BE 100% COMPLETE PENETRATION.
- t, t_s, t_h - NOMINAL THICKNESS OF FLAT PLATE, VESSEL SHELL OR HEAD LESS CORROSION ALLOWANCE (INCHES).
- t_{min} - THE SMALLER OF 3/4" OR THE THICKNESS LESS CORROSION ALLOWANCE OF THE THINNER OF THE PARTS JOINED BY A FILLET, SINGLE-BEVEL, OR SINGLE-J WELD.
- t_n - NOMINAL THICKNESS OF NOZZLE WALL LESS CORROSION ALLOWANCE (INCHES).
- G - RADIAL GAP (INCHES).

REV.	DESCRIPTION	DRAWN / APPD.	DA

ITEM NO.	PART NO.	DESCRIPTION OR SIZE
PARTS LIST		

UNLESS OTHERWISE SPECIFIED				
FRACTIONS ±	DECIMALS ±	ANGLES ±		
1. BREAK ALL SHARP EDGES 1/64 MAX. 2. DO NOT SCALE DWG. 3. DIMENSIONING IN ACCORD WITH ANSI Y14.5 STD's. √ MAX. ALL MACHINED SURFACES				
			ORIGINATOR	J. THEILACKER
			DRAWN	D. RICHARDSON	10-6-…
			CHECKED	
			APPROVED	J C Theilacker	10-13-…
			USED ON	
			MATERIAL-	

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

ACCELERATOR CRYOGENIC SYSTEMS
CRYOGENIC PRESSURE VESSELS
TYPICAL WELDED JOINT DESIGNS

SCALE	FILMED	DRAWING NUMBER
NONE		1650-MD-257650

8-11-88

Subject: Pressure testing
20 Dewar #2.

Pressurized Low Press side of vessel to 125 psig for 10 min

Technician: Ken Allen
Supervised: F. Walter
Safty: R. H. Lenz

OK - R.H. Lewis 11/3/89

PRESSURE VESSEL ENGINEERING NOTE
PER MANDATORY STANDARD SD37

Prepared by: J.D. Fuerst

Preparation date: 9/28/89

1 Description and Identification

Fill in the label information below:

This vessel conforms to engineering standard SD37
Vessel Title CCI Cold Compressor Cryostat #010
Vessel Number RSB416
Vessel Drawing Number CCI Dwg. 24036-E
Maximum Allowable
Working Pressure (MAWP) 85 psig + full ext. vac.
Working Temperature Range -452 °F 100 °F
Contents Helium
Designer/Manufacturer Cryogenic Consultants, Lamm's Machine, Inc.
Test Pressure (if tested at Fermi) +Full ext. vac. 110 PSIG Hydraulic ____ Pneumatic X
Acceptance Date: 10-4-89
Accepted as conforming to standard by G. Dugan
of Division/Section Accelerator 11/8/89
NOTE: Any subsequent changes in contents, pressures, temperatures, valving, etc., which affect the safety of this vessel shall require another review and test.

Obtain from Division/Section Safety Officer

Actual signature required in this space

Reviewed by: K. Weber Date: 10/31/89

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

______ Date: ______

Lab Property Number(s): ______

Lab Location Code: ______

Purpose of Vessel(s): Reduce pressure of Tevatron satellite refrigerator 2-phase circuit

Vessel Capacity/Size: 25 liters Diameter: 12" Length: 12"

Normal Operating Pressure (OP) 5 PSIG

MAWP-OP = 80 PSIG

Is the above enough to provide relief cracking pressure tolerance plus system uncertainty tolerance per M-9.

As an option, provide a photo of the entire vessel in the Appendix.

List the number of all pertinent drawings and the location of the originals. (Appended copies).

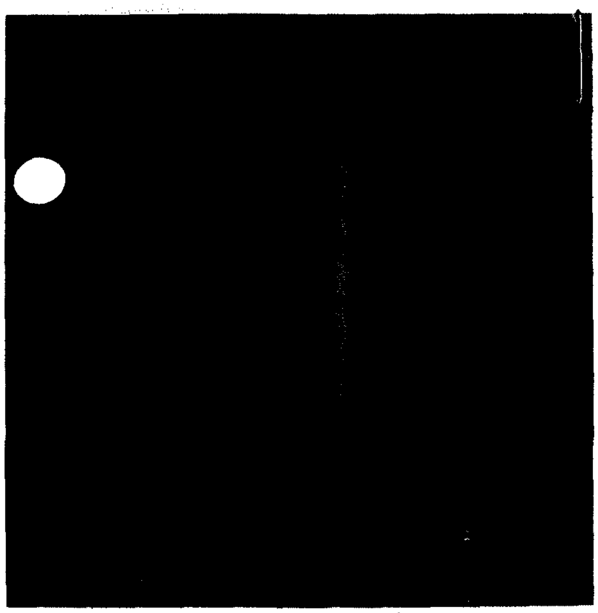
Drawing #	Location of Original
CCI 24036-E	Cryogenic Consultants, Inc.
CCI 24091-E	Allentown, PA
CCI 24002-E	
CCI 24118-D	

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 if photo is not clear or if copies are unreadable.

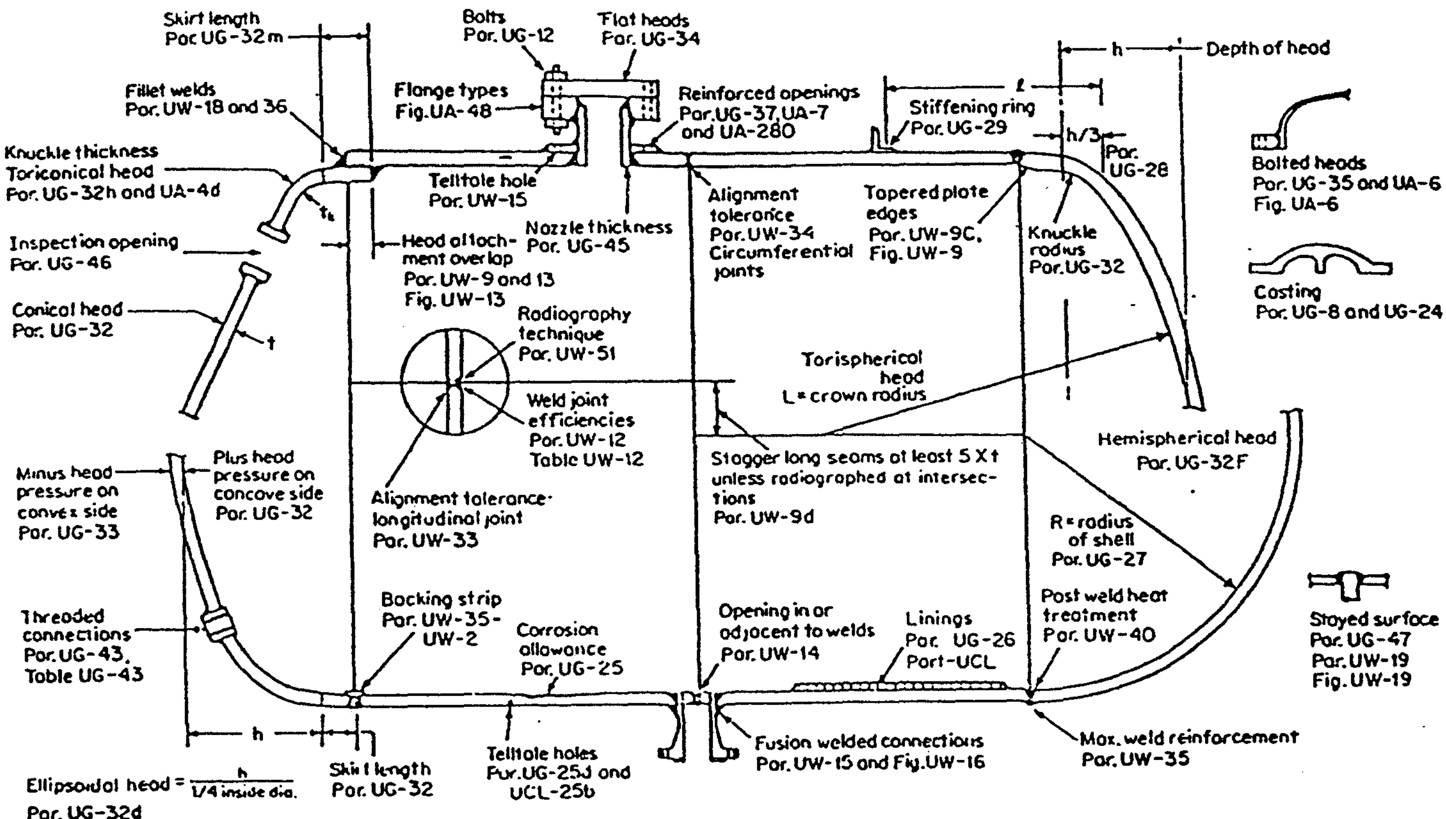


Copy data here:

Natn'l. Bd. #010
certified by Lamm's
Machine, Inc.
Allentown, PA 18103
85 psi at 100°F (Max.
allowable working press.)
with full external VAC.
-452°F at 85 psi
(Min. Design Metal
Temperature)
with full external VAC.
Mfgr's serial no. 010
year built 1989

DUPLICATE

On the sketch below, circle all applicable sections of the ASME code per Section VIII, Division I. List the results of all calculations. (Insert copies of calculations in the appendix).



Summary of ASME Code

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

If this vessel is exceptional or had exceptional parts, list their details under 5.6. Yes ______ No __X__

3 System Venting. Provide the system schematic in the Appendix, if the vessel safety is system sensitive.

Is it possible to isolate the relief valves by a valve from the vessel? NO JDF 11/8/89

Yes______ No__X____

If ''Yes;;, the system must conform to M-5. Provide an explanation of the appended schematic. (An isolatable vessel, not conforming to M-5 violates the Standard.)

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

Yes__X____No_______ Actual setting ________85______PSI
(A no response violates the Standard.)

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

Yes__X___ 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 violate the Standard.)

List of reliefs and settings:

Manufacturer	Relief	Setting	Flow Rate	Size
Mercer Valve	81125411O7RI	85 psig	335 SCFM air	1" NPT

Is the relief device an ASME stamped device? Yes __X___ No ______

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

Yes ____ No __X__. If ''Yes'', please append.

5. Welding Information

Has the vessel been fabricated in a Fermilab shop? Yes _______ No ___X___

If ''Yes'', append a copy of the welding shop statement of welder qualification and a copy of the Welding Procedure Specification (WPS) used to weld this vessel.

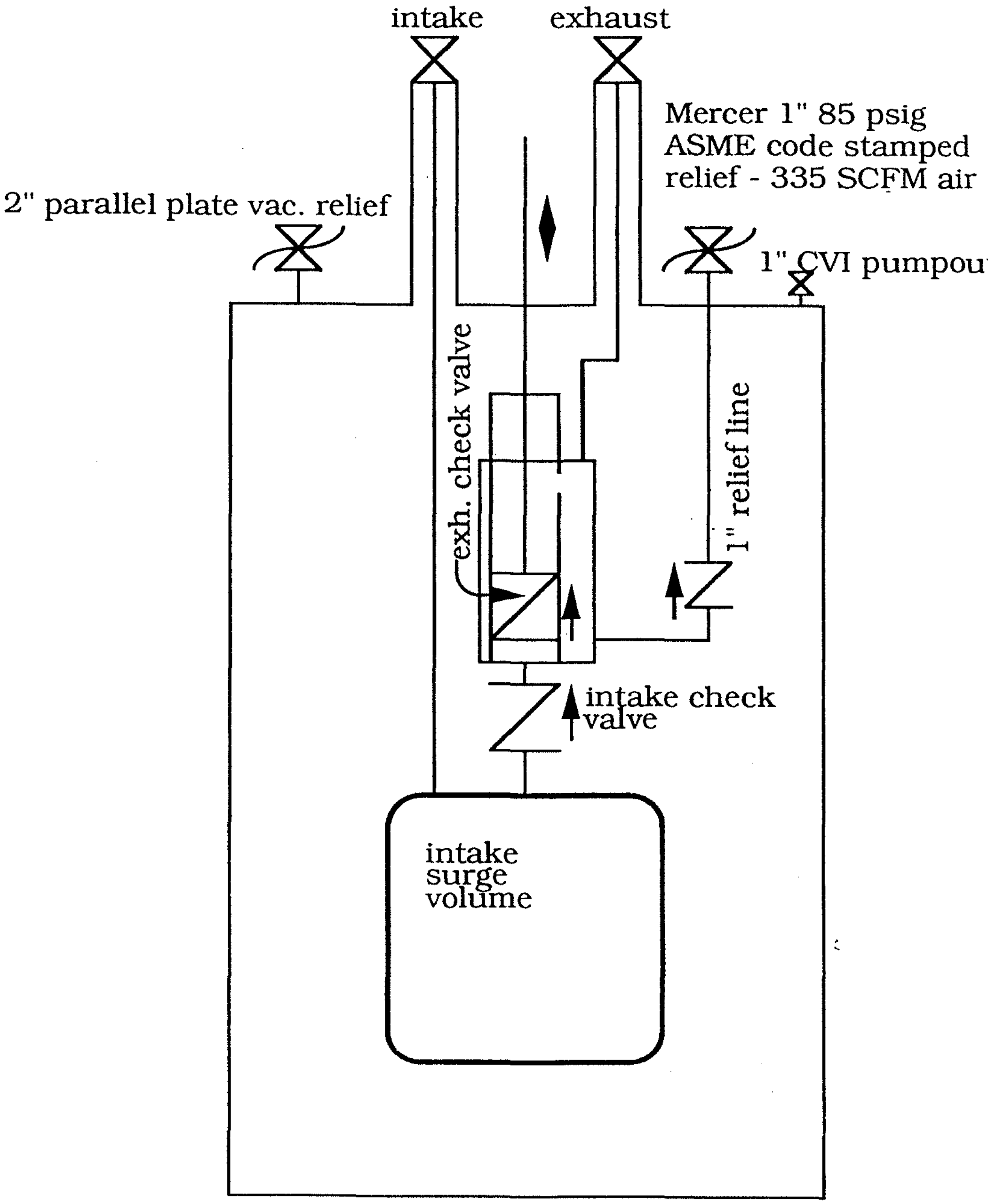
6 Exceptional, Existing, Used, and Non-Manned Area Vessels

Is this vessel or any part thereof in the above categories? Yes _____ No __X__

If ''Yes'', follow the Engineering Note requirements for documentation in free form below.

03 NOV 1988
REV. 16 OCT 1989

CCI Cold Compressor Schematic

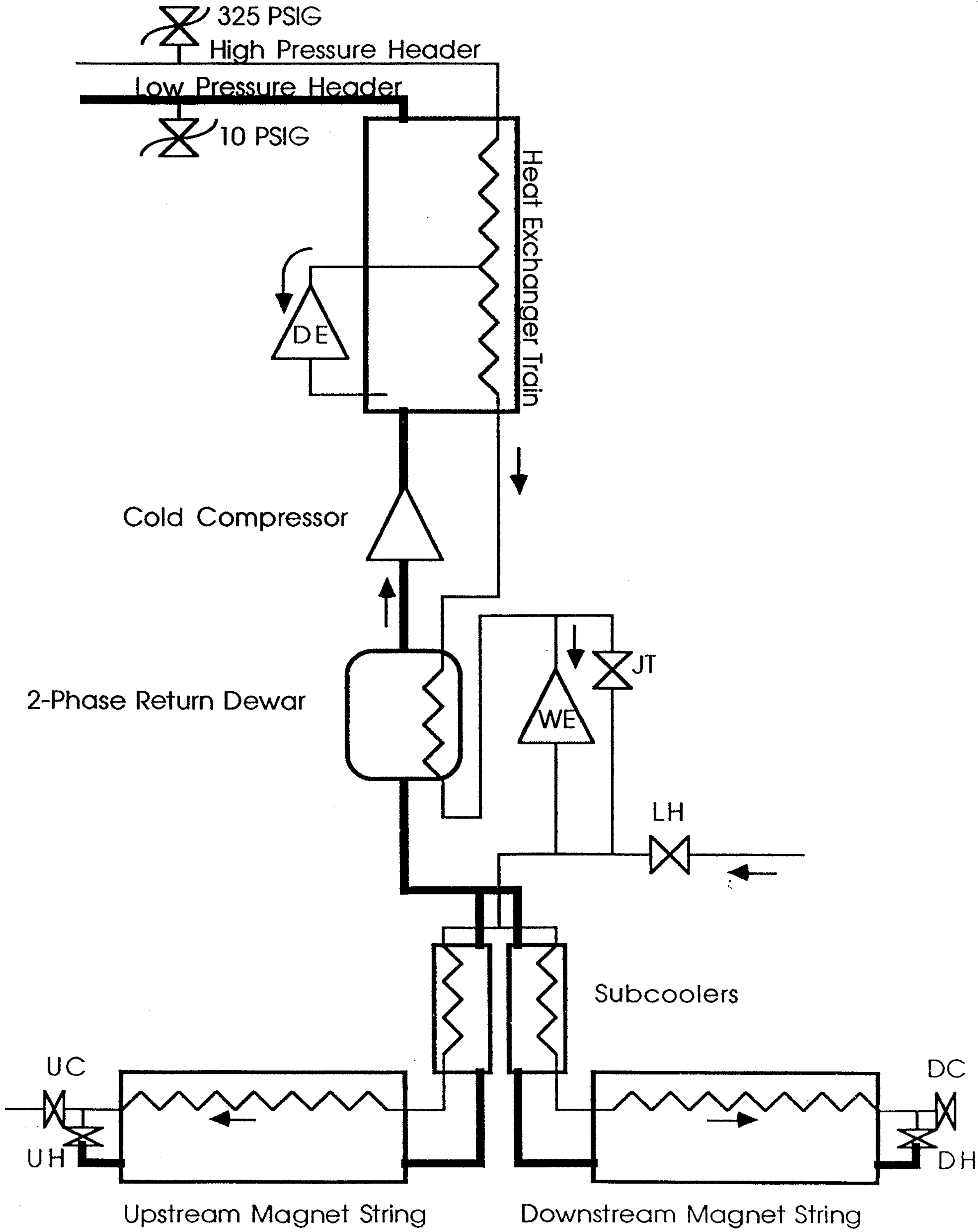


Fermilab

01 NOV 1988

SATELLITE REFRIGERATOR WITH COLD COMPRESSOR AND 2-PHASE RETURN DEWAR

J.D. FUERST



Total Heat Load 560W static + 240W AC

Fermilab

EXHIBIT B

Pressure Testing Permit*

Date: 9/27/89

Type of Test: [ ] Hydrostatic [X] Pneumatic

Test Pressure: 110 psig +full ext. vac. Maximum Allowable Working Pressure: 85 psig +full ext vac

Items to be Tested: CCI Cold Compressor #010

Location of Test: AZ frig bldg. Date and Time: Week of Oct 2

Hazards Involved: High press.

Safety Precautions Taken: Personnel removed from bldg. during test, appropriate reliefs on test equip.

Special Conditions or Requirements: Contact Accelerator Safety for final inspection & witness

Test Coordinator: J.D. Fuerst Dept/Date: AD/Cryo 9/27/89

Division/Section Safety Officer: [signature] Dept/Date: 9/27/89

Division/Section Head: [signature] Dept/Date: ~~[illegible]~~ 9/27/89 9/27/89

Results: Completed OK

Witness: [signature] (Safety Officer or Designee) Dept/Date: AD/Safety 10-4-89

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

5034TA-6
6/86

Appendix

16-OCT-89

Outline of Code Calculations

1.) INNER VESSEL - vessel is ASME code stamped

2.) VACUUM VESSEL

3.) RELIEF VALVE SIZING

- A.) Vacuum Vessel
- B.) Inner Vessel
  - i) failure modes
  - ii) relief capacities

4.) SUMMARY OF CALCULATIONS

1.) INNER VESSEL

This vessel was constructed by Cryogenic Consultants, Inc. and certified by Lamm's Machine, Inc. for MAWP of 85 psig plus full external vacuum (see photo of "U" label).

2.) VACUUM VESSEL

The vacuum vessel was constructed from carbon steel of unknown grade by Cryogenic Consultants, Inc. (CCI). It consists of a 20" SCH 10 pipe with a 1/2" thick bottom plate and a 1/2" thick top plate with penetrations. The ASME code stress value for grade A carbon steel (the weakest grade) is 10200 psi for welded pipe and 10400 psi for plate. The allowable stress value used in these calculations will be 80% of 10200 psi =8160 psi.

A.) External Pressure

i) Shell (UG-28C): a 41 1/2" long piece of 20" SCH 10S (20"o.d., 0.188" wall). $D_o/t = 20/0.188 =$ **106** (> 10); $L/D_o = 41.5/20 =$ **2.1**. Factor "A" from fig. 5-UGO-28.0 = **0.00065**, giving a factor "B" from fig. 5-UCS-28.1 up to 300F of **9500 psi.**

Then $P_{max} = 4B/(3D_o/t) =$ **<u>119 psi</u>**

ii) Bottom Plate (UG-34): a 20" dia, 1/2" thick flat plate.

d =head diameter=20"
C =head attachment factor=0.33
P =pressure, psi
S =(10200)(.80)=8160 psi
E =weld efficiency =0.6

$t_{req} = d(CP/SE)^{1/2}$, or $P = (SE/C)(t/d)^2$

with t=1/2", P=9.3 psi This is greater than the minimum 7 psi differential required by Fermilab Engineering Standard SD-41 (vacuum pressure vessel safety standard).

iii) Top Plate (UG-34): a 20" dia, 1/2" thick flat plate with penetrations. Penetrations will be handled in (iv) per UG-39. As above, **P=9.3 psi**.

iv) Top Plate Reinforcement (UG-39):

with P_{diff}=7.5 psi per SD-41, required plate thickness (flat, solid plate) = **0.327"** (UG-34 analysis). The cross-sectional area available for reinforcement (using the worst case [largest] hole of 8.5" dia, see CCI dwg. #24036-E) may be found like this:

$$A_{avail.reinf.} = d_{hole}(t_{act} - t_{req}) = 8.5(0.5-0.327) = \underline{1.47\ in^2}.$$

The required cross-sectional area = 0.5dt, where d = largest hole diameter = 8.5" and t = 0.327". This quantity = $\underline{1.39\ in^2}$.

$A_{actual} > A_{req'd}$ therefore No Extra Reinforcement Req'd.

3.) RELIEF VALVE SIZING

A.) Vacuum Vessel

CGA 341 specifies a minimum 0.00024 in^2 discharge area per pound water capacity of the liquid container. The total "inner vessel" volume of this device is something less than 2000 in^3 = **72.2** lb water.

relief area req'd. = (0.000241)(72.2) = **0.0174** in^2 = 0.15" dia relief port. The can is relieved by a 2" parallel plate vacuum relief so there is no problem.

B.) Inner Vessel: MAWP = 85 psi plus full external vacuum

Failure Modes-

i) loss of vacuum-vacuum filled with 1 atm GHe (vacuum relief point): $Q_a = [(130\text{-}t)/4(1200\text{-}t)]G_iUA$

ii) loss of vacuum, condensative heat transfer by air - NBS Monograph 111 chart 6.3.

iii) fire condition: $Q_a = G_iUA^{0.82}$ from CGA S-1.3

Definitions of quantities:

Q_a = flow capacity required, SCFM air
G_i = 52.5 for He relieving at or below 200 psi (CGA-S-1.3)
A = outside surface area of vessel = 7 sq ft
U = total thermal conductance of insulating material (Btu/hr ft^2F) when saturated with gaseous lading or air at 1 atm, whichever is greater
t = temperature (^{O}F) of gas at pressure and flowing conditions

Case i):

U = K/L where K = avg. thermal conductivity of He (0-300K) = **1.55 mW/cmK** and L = thickness of superinsulation = **1"** (~100 layers quoted by CCI). Therefore, U = (1.55mW/cmK)/(2.54cm) = **0.6102 mW/cm^{2}K**, which = **1.075 Btu/hr ft^{2}F**. With t = **-450^{O}F**, Q_a is then equal to:

[(130 + 450)/4(1200 + 450)](52.5)(1.075)(10) =

<u>49.6 SCFM air required</u>.

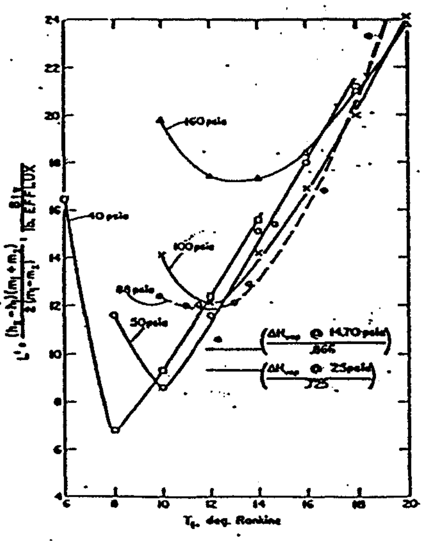
Case ii):

For this case, a value of 110% of the absolute relieving pressure = 1.1(85 + 15) = 110 psia is used as the relieving pressure (single relief). Using figure 6A-2 from NBS monograph 111 (reproduced below), the following values of L' and T are determined for worst case Q_a:

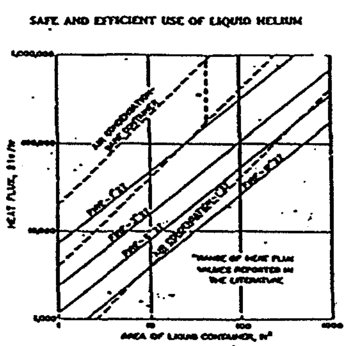
$L' = 12$ Btu/lb efflux, $T = 12^{O}R$

From fig. 6.3 of NBS mono 111 (also reproduced below), a heat flux of **5000 Btu/hr** is determined for air condensation with 1" of superinsulation on 7 sq. ft. of surface area.

The required gas flow in lb/hr is found by dividing the heat flux by L', giving **417 lb/hr** flow. Required relief valve flow capacity is found using NBS mono 111 equation 6A-1:



6A-2



6.3

Q_a $= [(13.1WC_a)/(60C)][(ZTM_a)/(MZ_aT_a)]^{1/2}$ where:

Q_a = req'd valve capacity, SCFM air

W = lb/hr req'd gas flow

C_a = gas constant = 356 for air

C = gas constant of the gas = 378

Z_a = compressibility factor = 1.0 for air at STP

Z = compressibility factor for the gas at flow conditions = 0.88

M_a = molecular weight of air = 28.97

M = molecular weight of the gas = 4.0

T_a = temperature of air at STP = 520°R

T = temperature of the gas at flow conditions = 12°R

$$Q_a = \frac{(13.1)(417)(356)}{60(378)}\left[\frac{0.88(12)(28.97)}{4(1)(520)}\right]^{\frac{1}{2}}$$

= <u>32.9 SCFM air</u>

Case iii):

Fire condition:

$$Q_a = G_i UA^{0.82} = 52.5(1.075)(7)^{0.82} = \underline{278 \text{ SCFM air}}$$

Relief Capacities:

The inner vessel is relieved by one ASME "U" stamped 1" Mercer relief valve set for 85 psig with a stamped flow capacity of **335 SCFM air** fed by a 1" stack, satisfying all relief flow requirements. The vacuum jacket is relieved by a 2" parallel plate vacuum relief. As discussed in 3(A), this size is more than adequate.

4.) SUMMARY OF CALCULATIONS

Inner Vessel:

Vessel is ASME code stamped - MAWP = 85 psig plus full vacuum.

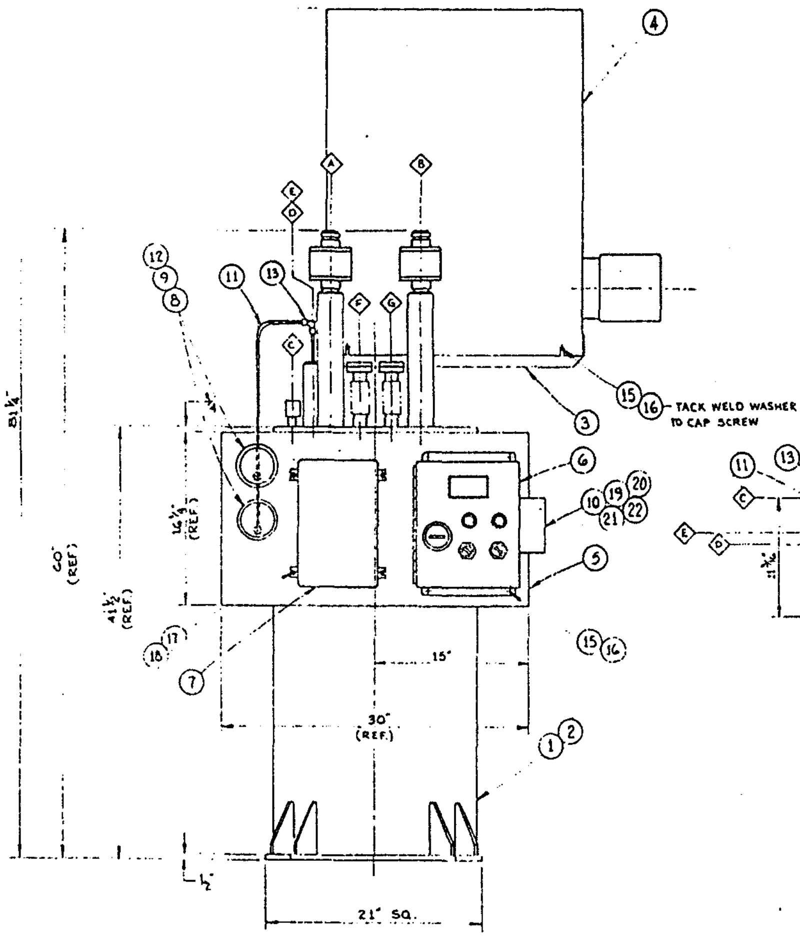
Relief capacity through the code stamped Mercer 1" 85 psig relief = 335 SCFM air at 85 psig vs. a maximum required relief capacity of 278 SCFM air under fire conditions.

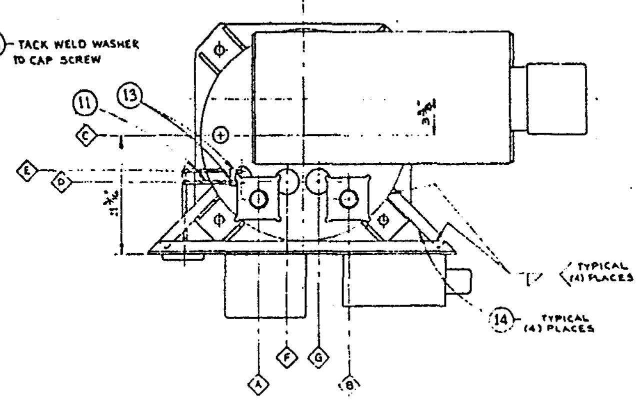
Vacuum Vessel:

Max. external pressure (per SD-37) = 9.3 psi vs. 14.5 psi actual maximum. According to Fermi Std. SD-41, vacuum vessels must withstand collapsing pressure of 30 psid (15 psid with a safety factor of two). Since the ASME pressure vessel code has a built-in safety factor of four, any vacuum vessel designed according to ASME code may use 7 psid as minimum criterion to satisfy the safety factor of two in SD-41. This was the procedure for this vacuum shell: 9.3 psi > 7 psi.

The max. internal pressure is also 9.3 psi and is satisfactory since the vacuum vessel is properly relieved (relief sized large enough and set low enough).

Relief capacity = a 2" parallel plate vacuum relief vs. a required 0.15" dia. hole as specified by CGA 341.





TOP VIEW

ITEM	DESCRIPTION
22	HEX NUT, #8-32UNC ZN. PLTD.
21	LOCKWASHER, #8 SIZE ZN. PLTD.
20	RD. HD. MACH. SCREW, #8-32UNC x ½" LG. ZN. PLTD.
19	CONDUIT NIPPLE, ½" SIZE, RIGID #424-104 w/NUT
18	FLAT WASHER, #10 NOM. ST. STL.
17	HEX. HD. CAP SCREW, #10-32UNF x ¾" LG., ST. STL.
16	FLAT WASHER, ¼" NOM. ST. STL.
15	HEX HD. CAP SCREW, ¼" x 20UNC x ¾" LG. ST. STL.
14	ANGLE, 1" x 1" x ⅛" x 7" LG. A-36
13	UNION ELBOW, SWAGELOK #SS-400-9
12	FEMALE CONNECTOR, SWAGELOK #SS-400-7-4
11	TUBE, ¼ O.D. x .035" WL. A-269, TP304
10	THERMOSTAT, GRAINGER #2E399
9	SNUBBER, HELICOID # S-2
8	PRESSURE GAUGES, HELICOID TYPE 310
7	MOTOR SPEED CONTROLLER FINCOR #2402150 WITH SIGNAL FOLLOWER # 1049
6	CONTROL BOX DWG. Nº. 24087-D
5	CONTROL PANEL DWG. Nº. 24103-D
4	COVER DWG. Nº. 24020-D
3	WARM END DWG. Nº. 24002-E
2	COLD END DWG. Nº. 24091-E
1	VACUUM BOX DWG. Nº. 24100-E

BILL OF MATERIAL

DEC ±	ANG ±	MAX.	MIN.
TOLERANCE		BREAK SHARP EDGES	
0 - 20"	20" - 60"	OVER 60"	MACHINED SURFACES
FRACTIONAL TOLERANCE			FINISH

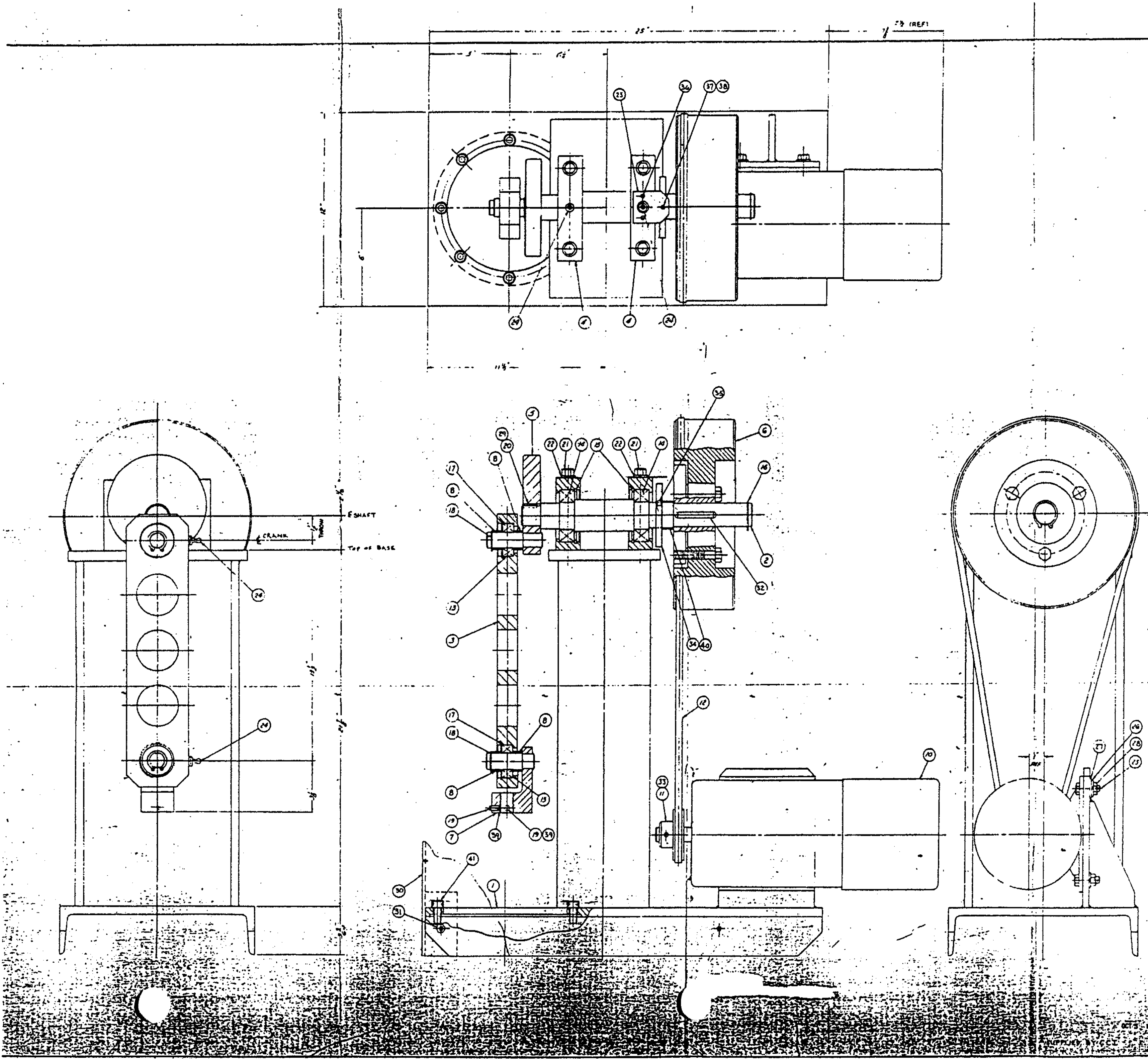
CRYOGENIC CONSULTANTS,
ALLENTOWN, PA.

FINAL ASSEMBLY
COLD GAS PUMP

DR. BY R.H. MOYER	7/14/88	SCALE 1" = 1'-0"	PROJ. NO 564
CHK. BY C.J. HARMES	7/15/88	WT.	DWG. NO 24118-D
APPD. BY C.J. HARMES	7/18/88		

OCT 3 1988

8 7 6 5 4 3 2 1



	ITEM	DESCRIPTION	QUAN
	41	HEX SOC. MACH SCR. 1/2-13UNC x 1 1/2 LG. ST. STL.	8
	40	TUBING, 1/4 [illegible] X .020 [illegible]	1
	39	DISC, [illegible] DIA. x 3/32 THK BRASS	2
*	38	NUT, HEX, [illegible] 40 [illegible] BRASS	1
*	37	MAGNET SENSOR [illegible] DIGITAL [illegible]	1
	36	HEX SOC. HD. CAP SCREW #10-32 UNF x 1 1/4 LG.	2
	35	BAR, ROUND. 1/4" DIA. x 3/8" LG CRS	1
	34	GEAR, PULSE GENERATOR, DR. 24024-0	1
*	33	BUSHING, BROWNING #H-7/8 w/STD. KEYSEAT	1
	32	KEYSTOCK 3/16" SQ. x 2 3/8" LG.	1
	31	HEX HD. MACH SCREW, 1/4-20 UNC x 1" LG. STL. ZN. PLTD	4
	30	COVER, COLD GAS PUMP, DR. 24020-0	1
	29	HEX SOC. SET SCREW, 5/16-18UNC-2A x 3/4 LG. CUP POINT	2
	28	HEX NUT, 5/16-18UNC-2B C.S. ZN. PLTD	4
	27	FLAT WASHER, 5/16 STD. C.S. ZN. PLTD	4
	26	LOCKWASHER 5/16 STD. C.S. ZN. PLTD	4
	25	HEX HD CAP SCREW, 5/16-18UNC-2A x 1 [illegible] C.S. ZN. PLTD	4
*	24	GREASE FITTING "ALEMITE" #1610-BL 1/8 NPT.	4
	23	BRACKET, SPEED SENSOR, DR. 24033-B	1
	22	LOCKWASHER 1/2" STANDARD C.S. ZN. PLTD	4
	21	HEX HD CAP SCR. 1/2-13UNC-2A x 5 1/2 LG. C.S. ZN. PLTD	4
	20	KEY—KEYSTOCK 1/4" SQ. x 3/4 LG.	1
	19	SET SCREW, 5/16-18UNC-2A x 1/2" LG. CUP POINT	2
*	18	RETAINING RING "TRUARC" PT No 5100-98	2
*	17	RETAINING RING "TRUARC" PT No N5000-206	2
*	16	RETAINING RING "TRUARC" PT No 5100-150	1
*	15	RETAINING RING "TRUARC" PT No N5000-315	2
*	14	BEARING "MC GILL" PT No SB-22208-SS	2
*	13	BEARING "MC GILL" PT No SB-22206-SS	2
*	12	V-BELT BROWNING # 3VX650	2
*	11	PULLEY "BROWNING" PT. NO. 3H3V31	1
*	10	MOTOR, 1 1/2 HP DC FINCOR #93150BTF	1
	8	SPACER (DET-ITEM-5) DR 5309-D	4
	7	CLEVIS SUB-ASSEM. DR 5304-D	1
	6	FLYWHEEL DR 5305-D	1
	5	CRANK SUB-ASSEM. DR 5304-D	1
	4	BRG BLOCK. (DET-ITEM-2) DR 5301-D	2
	3	CONNECTING ROD. DR. 24021-0	1
	2	SHAFT (DET-ITEM-1) DR 5301-D	1
	1	BASE PLATE DR 5300-D	1

BILL OF MATERIAL

DEC. ± / ANG. ± / MAX. / MIN.

TOLERANCE / BREAK SHARP EDGES

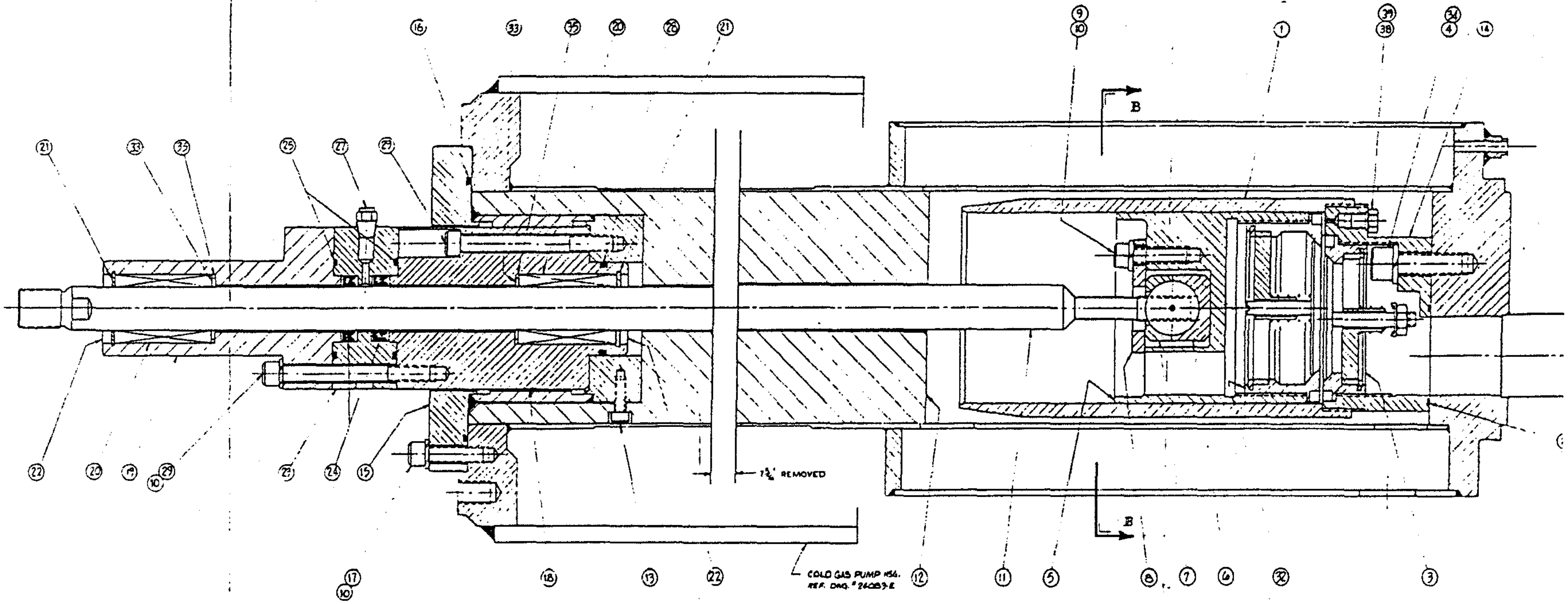
FRACTIONAL TOLERANCE / OVER 60" / MACHINED SURFACES / FINISH

CR[illegible]NIC. CONSULTANTS, INC.
ALLENTOWN, PA.

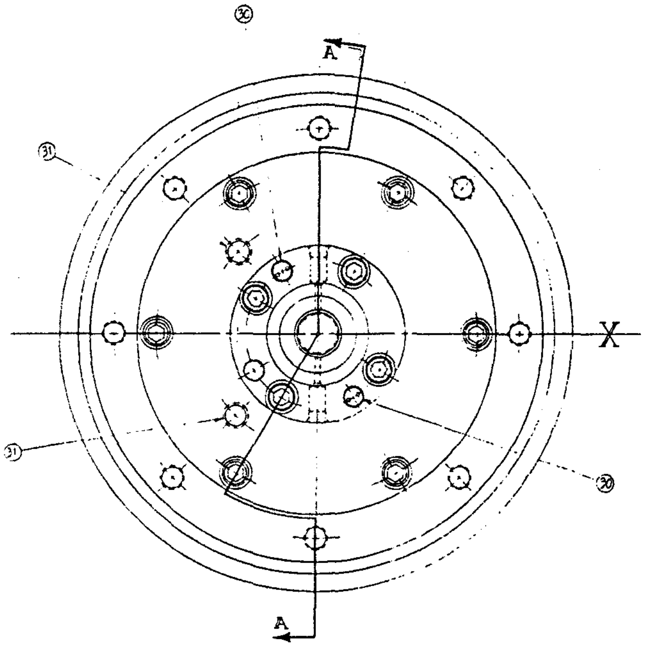
W[illegible] END ASSEMBLY
COLD GAS PUMP

SCALE HALF / PROJ. NO. 749

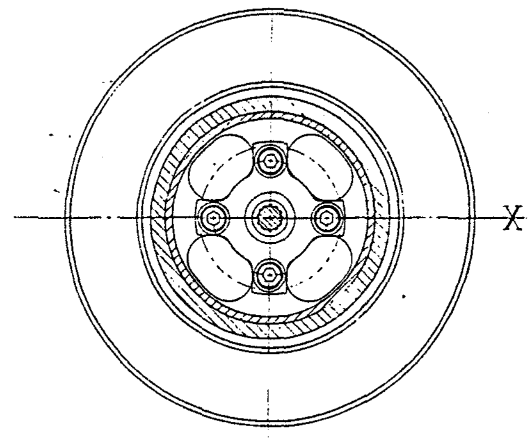
DWG. NO. 24002-E



SECTION 'A-A'



PLAN VIEW



VIEW 'B-B'

NOTES:

1. LOWER ITEM-14 INTO CAVITY USING POTIONING TOOL DWG. NR. 24110-B

PROPRIETARY AND CONFIDENTIAL

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ITEM	DESCRIPTION
	BILL OF MATERIAL

TOLERANCE: DEC. ± / ANG. ± — MAX. / MIN. — BREAK SHARP EDGES

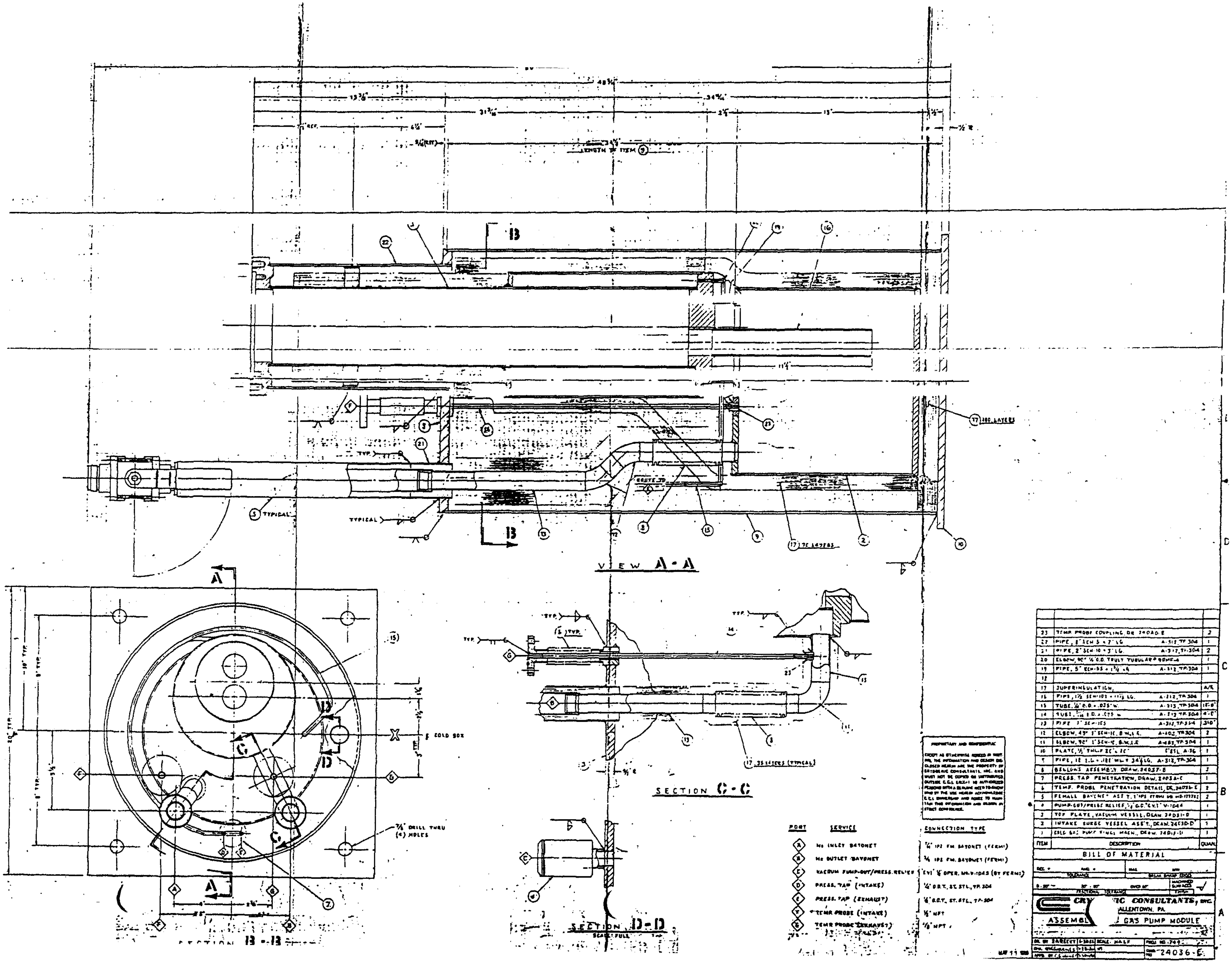
FRACTIONAL TOLERANCE: 0 - 30" / 30" - 60" / OVER 60" — MACHINED SURFACE FINISH

CRYOGENIC CONSULTANTS
ALLENTOWN, PA.

COLD END ASSEMBLY
COLD GAS PUMP

DR. BY	11-4-87	SCALE FULL	PROJ. NO. 794
CHK. BY	11-4-87	WT.	DWG. NO. 2409
APPD. BY	11-4-87		

OCT 3



PORT	SERVICE	CONNECTION TYPE
A	He INLET BAYONET	1/4" IPS FM. BAYONET (FERMI)
B	He OUTLET BAYONET	1/4 IPS FM. BAYONET (FERMI)
C	VACUUM PUMP-OUT/PRESS. RELIEF	"CVI" 1/2" OPER. No. V-1043 (BY FERMI)
D	PRESS. TAP (INTAKE)	1/4" O.D.T., ST. STL., TP. 304
E	PRESS. TAP (EXHAUST)	1/4" O.D.T., ST. STL., TP-304
F	TEMP. PROBE (INTAKE)	1/8" NPT
G	TEMP. PROBE (EXHAUST)	1/8" NPT

ITEM	DESCRIPTION		QUAN.
23	TEMP. PROBE COUPLING, DR. 24040-E		2
22	PIPE, 8" SCH 5 × 7" LG.	A-312, TP 304	1
21	PIPE, 2" SCH 10 × 3" LG.	A-312, TP-304	2
20	ELBOW, 90° 1/4" O.D. TRULY TUBULAR® 90MF-4		1
19	PIPE, 5" SCH-5S × 1 3/4" LG.	A-312, TP-304	1
18			
17	SUPERINSULATION,		A/R
16	PIPE, 1 1/2" SCH-10S × 11 1/2" LG.	A-312, TP-304	1
15	TUBE, 1/4" O.D. × .035" W.	A-213, TP-304	15'-0"
14	TUBE, 1/16 I.D. × .035 W.	A-213, TP-304	4'-0"
13	PIPE 1" SCH-10S	A-312, TP-304	3'-0"
12	ELBOW, 45° 1" SCH-10, B.W., L.R.	A-403, TP 304	2
11	ELBOW, 90° 1" SCH-10, B.W., L.R.	A-403, TP-304	1
10	PLATE, 1/2" THK. × 20" × 20"	C'STL, A-36	1
9	PIPE, 12 I.D. × .188" WALL × 34 1/4" LG.	A-312, TP-304	1
8	BELLOWS ASSEMBLY, DRAW. 24037-E		3
7	PRESS. TAP PENETRATION, DRAW. 2403A-C		1
6	TEMP. PROBE PENETRATION DETAIL, DR. 24038-E		2
5	FEMALE BAYONET ASSY, 1" IPS (FERMI DR. ND-173781)		2
4	PUMP-OUT/PRESS. RELIEF, 1/2" O.D. "CVI" V-1044		1
3	TOP PLATE, VACUUM VESSEL, DRAW. 24031-D		1
2	INTAKE SURGE VESSEL ASS'Y., DRAW. 24030-D		1
1	COLD GAS PUMP FINAL MACH., DRAW. 24033-D		1

BILL OF MATERIAL

CRY[illegible]IC CONSULTANTS, INC.
ALLENTOWN, PA.

ASSEMBL[illegible] GAS PUMP MODULE

DR. BY SARGENT · SCALE: HALF · PROJ. NO. 749
DWG. NO. 24036-E

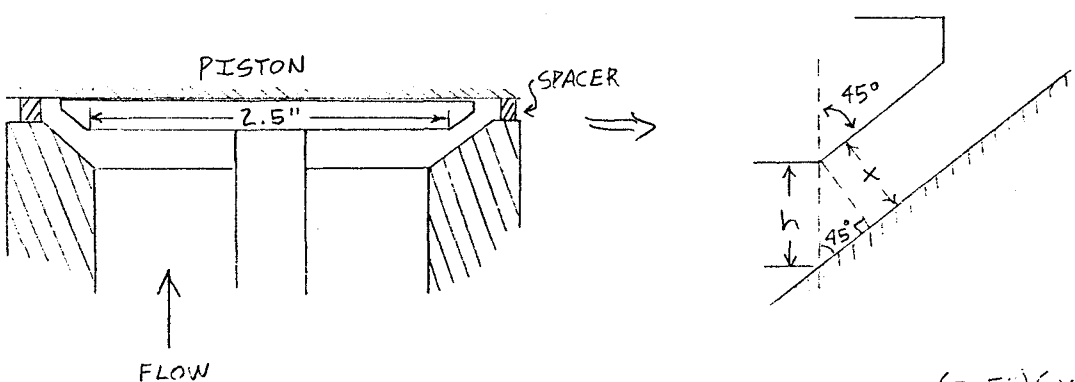
03 November 1989
JDF

ADDENDUM

It must be impossible to isolate relief valves from their associated volumes. Also, lines connecting volumes to relief valves must not diminish relieving capacity such that capacity falls below the criteria stated on page 4 of SD-37. With this in mind, the following calculations show the adequacy of the relief system on CCI cold compressors #010 and #011.

Given the geometry of the compressor, the flow path leading to the 1" 85 psig Mercer relief valve from the intake surge volume passes through both the intake and exhaust check valves. If the piston were ever to come to rest on the bottom of the cylinder (through improper dead volume adjustment or disconnection of the crank arm, for example), one might expect the piston to hold the intake valve shut. This would both obstruct the flow path through the compressor and isolate the relief valve from the intake side of the machine.

This scenario is prevented through installation of thin spacers tack welded to the top of the piston. These spacers ensure that the piston can never come to rest at the cylinder bottom and hold the intake valve closed. Spacer thickness was determined by ensuring that when the piston/cylinder head clearance is equal to spacer thickness, the intake valve can open enough to supply the same amount of flow area as that supplied by the 1" line leading to the 1" Mercer relief valve. This required spacer height is 0.141". A spacer thickness of 5/32" has been chosen. The sketches below outline the details of the calculation of required intake valve travel (spacer thickness).



Flow area of 1" hole = 0.785 in^2

Flow area $= \pi(2.5")(x") = 0.785 \text{ in}^2$

where $x = h/\sqrt{2}$

so $h = \dfrac{\sqrt{2}\,(0.785 \text{ in}^2)}{\pi\,(2.5 \text{ in})} = 0.141"$

$\therefore$ spacer height $= \underline{\underline{5/32"}} = 0.156"$