Safety Documentation

for the M.I.C.E.

2 slot VLPC Cryocooler Cryostat

D-ZERO ENGINEERING NOTE # 3823.000-EN-575

March 22, 2005

Author: Russell A. Rucinski

PPD/MD/D0 Operations

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Commissioning of 2 Slot VLPC cryostat for M.I.C.E.

Partial Operational Readiness Clearance

18 Feb 2005

**AUTHORIZATION TO OPERATE COOL DOWN AND OPERATE
CRYOCOOLER AND 2 SLOT CRYOSTAT**

REVIEWED AND APPROVED BY:

DATE

Particle Physics Division Head JIM STRAIT

3/17/05

Comments/Exceptions:

Particle Physics Division Senior Safety Officer

3/16/05

Comments/Exceptions

DØ Upgrade ESH Review Committee Chair

3/15/05

Comments/Exceptions:

Submitted By:

Russell A. Rucinski, ID #8351

[enter name]

Feb. 18. 2005

Fermilab

Fermi National Accelerator Laboratory
Technical Division
E&F Department
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Tuesday, March 15, 2005

To: Win Baker
Chairman, D0 ES&H Review Committee

From: Harry Carter
Chairman, D0 Mechanical Safety Subcommittee

Subject: Review of the M.I.C.E. VLPC Cryostat at D0

Dear Win,

I have reviewed and signed off on the pressure vessel engineering note for the M.I.C.E. VLPC cryostat. While this vessel is considered to be an exceptional vessel requiring a director's exemption by the letter of the law (FESHM5031), the vessel has been designed and constructed using sound engineering practices, and its pressure relief devices are appropriately sized such that operation of this vessel poses no hazard to equipment or personnel, thus I can recommend that a director's exemption be granted with no reservations.

I also visited D0 and inspected the cryostat and the test setup. Russ Rucinski, the responsible engineer, met with me and answered all questions that I had regarding the cryostat and the test plans. Based on that visit and my review, I have no reservations in recommending that a partial operational readiness clearance be granted for the commissioning and operation of the MICE VLPC Cryostat at D0.

Included with this memo are the original pressure vessel engineering note and the original pressure testing permit. Please see that they are routed to the proper personnel for the required signatures, then it is my understanding from Russ that they should be returned to him.

If you have any questions regarding my review or recommendations, please contact me at extension 2458 or via email: hfcarter@fnal.gov.

Best Regards,

Harry Carter

March 3, 2005

TO: Win Baker, D0 ES&H review committee

FROM: Russ Rucinski, PPD/MD/DZero Ops

SUBJECTS: pORC to operate M.I.C.E. VLPC cryostat at DZERO
Description of system

I am requesting a partial operational readiness clearance (pORC) to operate a small VLPC (visible light photon counter) cryostat system here at DZero.

We hope to be ready to operate the week of March 14th. It would be "commissioned" for both cryogenic operation and VLPC readout system in the weeks that follow. The working system will then be shipped to KEK for use in a test beam (May 24th –July 2nd). This work is for the muon ionization cooling experiment (MICE).

The system consists of a commercially obtained cryocooler (Sumitomo Heavy Industries RD-415) and a Fermilab designed 2 slot VLPC cryostat. The hazards associated with these items fall below the threshold that requires a rigorous formal review.

The cryocooler system utilizes a small cabinet size helium compressor with room temperature supply and return lines connected to the cryocooler head. There is also a power cable that links the two items. The cryocooler head is mounted in the center of the cryostat lid. There is no buffer tank or pressure vessel or liquid cryogens. (More information can be found on the SHI website: <http://www.shicryogenics.com/products/?id=6496>)

The 2 slot cryostat was uniquely designed by me to provide cooling of the VLPC chips that are packaged in the bottom of a cassette. A separate file is attached which contains pictures and a description. The envelopes (or pockets) that the cassette slip into are filled with gas helium at a slightly positive pressure to provide a heat transfer medium and to prevent potential contamination. There is an insulating vacuum on the outside of the envelopes. Technically, since the envelope has a dimension that exceeds 6", the envelopes are considered a pressure vessel if the differential pressure across the wall is greater than 15 psid. The average barometric pressure for Fermilab is 740 mmHg = 14.3 psia so at a helium operating pressure greater than 0.7 psig, the envelope technically becomes a pressure vessel per FESHM5031.

I plan to operate in the range of 1.5 +/-0.5 psig with redundant relief valves set at 2.0 psig. This is based on operational experience with previous VLPC cryostats. Therefore a pressure vessel engineering is required (separate file attached). It must be noted that the envelope's

March 3, 2005

stored potential energy is negligible (less than 180 joules). The usual threshold used is the product of the pressure times volume. For instance for the other FESHM vessel standards, if $P \cdot V > 515 \text{ psi-ft}^3$ a low pressure vessel engineering note (FESHM 5031.5) or vacuum vessel engineering note (FESHM 5033) is required. If $P \cdot V < 515 \text{ psi-ft}^3$ then the vessel is excluded from requiring formal documentation. In the case of the 2 slot VLPC cryocooler cryostat, the total empty volume is only 0.3 ft^3 and $P \cdot V = (16.3 \text{ psid}) \cdot (0.3 \text{ ft}^3) = 5 \text{ psi-ft}^3$. A similar exclusion for FESHM 5031.1 should be entertained.

Because of the unique design, a pressure vessel engineering note needs a director's exemption. This is because ASME code relief valves cannot be obtained for pressures less than 15 psig, and the vessel uses a non-code material, Invar 36. While the potential risk of operating this vessel does not justify time and effort in documentation, the safety review process requires it.

Sincerely,

Russ Rucinski

Date: Thu, 03 Mar 2005 15:52:13 -0600
From: Harry Carter <hfcarter@fnal.gov>
To: Win baker <winbaker@fnal.gov>
Cc: Russ Rucinski <rucinski@fnal.gov>
Subject: RE: pORC request for DZero/M.I.C.E. VLPC test stand (fwd)

Hi Win,

I met with Russ at D0 a little while ago to review the system before he got away on vacation. I do not see any show stoppers here, but will review the documentation in a little more detail before issuing a formal letter to you and signing off on the Pressure Vessel note. Russ gave me the original of the note, which I will send to you along with my letter, unless you would prefer that it be sent directly to the PPD Division Office.

Just thought I would give you a heads up on the status of things.

Regards,
Harry

-----Original Message-----

From: Win baker [mailto:winbaker@fnal.gov]
Sent: Thursday, March 03, 2005 10:02 AM
To: hfcarter@fnal.gov
Cc: tomski@fnal.gov; wands@fnal.gov; rucinski@fnal.gov; martha@fnal.gov; rpsmith@fnal.gov; strait@fnal.gov; winbaker@imapserver2.fnal.gov
Subject: Fw: pORC request for DZero/M.I.C.E. VLPC test stand (fwd)

Hi Harry,

It's been a while, but DZero is still there and hopefully our committee also.

Following is Russ Rucinski's request for a review of a new system. He suggests times for an inspection.

When you contact him please cc me as usual. Thanks.

Best regards,
Win

> ----- Forwarded message -----

> Date: Wed, 02 Mar 2005 12:38:05 -0600
> From: Russell Rucinski <rucinski@fnal.gov>
> To: Win Baker <winbaker@fnal.gov>
> Cc: Martha Heflin <martha@fnal.gov>, Jim Strait <strait@fnal.gov>, Richard P. Smith <rpsmith@fnal.gov>
> Subject: pORC request for DZero/M.I.C.E. VLPC test stand
>
> Hi Win,
>
> Please see the attached files.
>
> 'Request for pORC for 2 slot' is the formal memo requesting approval to operate a new system at DZERO for a few weeks of commissioning.
>
> '2SlotPVen.doc' is a pressure vessel engineering note. It requires a independent review and then a director's exemption. Due to it's negligible stored energy, a note is required by technicality only. Hopefully the review process will be trivial as all involved will recognize this.
>
> 'pORC form 2slot' is the completed pORC form usually used for signatures.
>
> The power point file 'CryoCooler Cryostat Design overview.pps' is an overview presentation of the cryostat that I pieced together from previous presentations.
>
> We would like to operate sometime around March 16th or shortly thereafter.
>
> It would be most efficient for the reviewer (D0 Mechanical subcommittee? Harry Carter?) to come out to DZero to see the setup. I am here today and tomorrow March 3rd. Due to scheduled vacation I will be unavailable Friday March 4th or the week of March 7th. If a walk thru is desired during my absence, Jim Fagan is the contact person. We could also do it on March 14th.
>
>
> Thank you.

>
> Russ Rucinski
>
>
> P.S. Jim Strait and Martha Heflin are cc'd on this since they requested
that it go through formal channels for sign off.
>

Fermilab

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Tuesday, March 15, 2005

To: Win Baker
Chairman, D0 ES&H Review Committee

From: Harry Carter
Chairman, D0 Mechanical Safety Subcommittee

Subject: Review of the M.I.C.E. VLPC Cryostat at D0

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If you have any questions regarding my review or recommendations, please contact me at extension 2458 or via email: hfcarter@fnal.gov.

Best Regards,

Harry Carter

PRESSURE VESSEL ENGINEERING NOTE
PER CHAPTER 5031

Prepared by:

Russ Rucinski, PPD/MD/DZERO Ops

Preparation date: Feb. 14, 2005

1. Description and Identification

Fill in the label information below:

This vessel **DOES NOT CONFORM** to Fermilab ES&H Manual Chapter 5031

Vessel Title 2 slot VLPC cryo cooler cryostat

Vessel Number Not applicable: for use at KEK

Vessel Drawing Number 3823.111-ME-434117

Maximum Allowable Working Pressures (MAWP):

Internal Pressure 2 psig + full vacuum (16.7 psid)

External Pressure none

Working Temperature Range -452 F to 100 F

Contents Gaseous Helium

Designer/Manufacturer Fermilab, Russ Rucinski

Test Pressure (if tested at Fermi) Date: 3/3/05

4 PSIG, Hydraulic _____ Pneumatic X - GHe

Accepted as conforming to standard by _____

of Division/Section _____ Date: _____

Reviewed by:

HARRY F. CARTER

3236

Date:

3/15/05

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

Date: _____

Amendment No.:

Reviewed by:

Date:

Lab Property Number(s): Not Applicable

Lab Location Code: N/A for use at KEK (obtain from safety officer)

Purpose of Vessel(s): _____

Contains gas helium and VLPC cassettes operating at 9 K.

Vessel Capacity/Size: 2 volumes, each 1.45 inches x 10.5 inches x 16.8 inches

Normal Operating Pressure (OP) 1.5 PSIG + full vacuum = 16.2 psid

MAWP-OP = 0.5 PSI

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

Drawing #

Location of Original

3823.111-ME-434.117

DZERO Assembly Building Highbay drg.files

(Electronically stored in lab's drawing control system)

2. Design Verification

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

Yes___ No X.

If "No" state the standard that was used:

Engineering stress and deflection calculations with stresses were kept below an ASME code, Section ~~II~~^{VIII}, Div. 2 derived allowable stress for Invar 36 (34 ksi for local bending stress). A design pressure of 21 psid was used for calculation of stresses. MAWP is 16.7 psid. Along with good engineering practice, I used Roark's Formulas for stress & strain, 6th edition, edited by Warren C. Young. Material certifications for the materials were obtained.

Demonstrate that design calculations of that standard have been made and that other requirements of that standard have been satisfied.
Skip to part 3 "system venting verification."

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

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

Figure 1. ASME Code: Applicable Sections

2B.

Summary of ASME Code

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

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

Figure 1. ASME Code: Applicable Sections

2B.

Summary of ASME Code

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

3. System Venting Verification Provide the vent system schematic.

Does the venting system follow the Code UG-125 through UG-137?
Yes___ No_ X {Non ASME coded relief}

Does the venting system also follow the Compressed Gas Association Standards S-1.1 and S-1.3?
Yes _____ No_ X {Non ASME coded relief}

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.

ASME code valves are not available < 15 psig set point. Required flow rate for loss of vacuum = 0.3 scfm. No other source of overpressurization is applicable. The gas supply line is connected upstream of the relief device and tubing size is less than relief size.

Note that stored energy of the vessel is negligible. Vessel is contained within a vacuum jacket as well. Volume x Pressure = 5 psig-ft³. Threshold used for review is 535 psig-ft³. At 4 psig test pressure there is only 182 Joules of stored potential energy. This is probably less stored energy than that in a 2 liter bottle of soda pop.

List of reliefs and settings:

<u>Manufacturer</u>	<u>Model #</u>	<u>Set Pressure</u>	<u>Flow Rate</u>	<u>Size</u>
<u>Circle Seal Controls</u>	<u>559B-4MP-2</u>	<u>2 psig</u>	<u>4 scfm</u>	<u>1/4 inch</u>
<u>Circle Seal Controls</u>	<u>559B-4MP-2</u>	<u>2 psig</u>	<u>4 scfm</u>	<u>1/4 inch</u>
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

4. Operating Procedure

Is an operating procedure necessary for the safe operation of this vessel?
Yes___ No_ X (If "Yes", it must be appended)

No procedure is required for Personnel safety. A procedure/precaution is only necessary to prevent possible mechanical or monetary damages.

Envelope must never be evacuated without vacuum container also evacuated to an equal or lesser pressure. Warning label applied directly to vessel.

5. Welding Information

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

6. Existing, Used and Unmanned Area Vessels

Is this vessel or any part thereof in the above categories?
Yes_____ No_ X ___

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 X No _____

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

1. DO NOT EVACUATE CASHETS SPACE VOLUME WITHOUT VACUUM CONTAINER (ITEM #18) AND/OR EVALUATED TO AN EQUAL OR LOWER PRESSURE. FAILURE TO HEED THIS WARNING MAY RESULT IN DAMAGE TO VLP/C CASHETS (ITEM #18) AND CASSETTE ENVELOPE (ITEM #6) ON LOG. (6-344118).
2. DO NOT EVACUATE VACUUM CONTAINER (ITEM #1) IF ALL COMPONENTS OF TOP PLATE SUB-ASSEMBLY ARE NOT COMPLETE.
3. GAS INLET PORT: A PRESSURE RELIEFING DEVICE SET TO 9.13 MPa (9.14 MPa MAXIMUM) MUST BE ATTACHED TO EACH CASSETTE SPACE VOLUME TO PREVENT MECHANICAL DAMAGE TO VLP/C CASHETS (ITEM #18) AND/OR CASSETTE ENVELOPE (ITEM #6) ON LOG. (6-344118).
4. INSTRUMENTATION PORT: THIS IS THE SUGGESTED PORT FOR INSTRUMENTATION. SET TOP PLATE ASSEMBLY (ITEM #6) FOR SUGGESTED INSTRUMENTATION.

18	MC-434106	BARTON, PAUL - BOSTON TEL AREA 10-2230 1964	2
14		BRADY, JAMES - NEW YORK BRUNWILL PLAT. B-4-C. 2700AM	1
13		WASHER, FLAT, 100 TYPE 10-C STAINLESS	1
12		WASHER, FLAT, 100 TYPE 10-C STAINLESS	1
11		BRADY, JAMES - NEW YORK BRUNWILL PLAT. B-4-C. 2700AM	1
10	ME-317466	1004 DANIEL WOLF GARRETT APT. 7 TYPE 10-C STAINLESS	1
9		WASHER, FLAT, 100 TYPE 10-C STAINLESS	1
8	ME-434110	TOP PLATE SUB-ASSEMBLY TYPE 10-C STAINLESS	1
7		WASHER, FLAT, 100 TYPE 10-C STAINLESS	1
6		WASHER, FLAT, 100 TYPE 10-C STAINLESS	1
5		WASHER, FLAT, 100 TYPE 10-C STAINLESS	1
4		WASHER, FLAT, 100 TYPE 10-C STAINLESS	1
3		WASHER, FLAT, 100 TYPE 10-C STAINLESS	1
2	ME-434118	VACUUM CONTAINER TYPE 10-C STAINLESS	1
1	1704	WASHER, FLAT, 100 TYPE 10-C STAINLESS	1

PARTS LIST									
VALVE PRESSURE SWITCH		ORIGINATOR	6 AUGUST 81	50-33-30					
		DESIGN	6 JANUARY 81	50-33-30					
A. DESIGN NO. 1000		CHANGED	6 AUGUST 81	10-00-00					
B. REVISED NO. 1000		APPROVED	6 AUGUST 81	10-00-00					
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SUBJECT

RELIEF VALVE SIZING
2 - SLOT CRYO COOLER CRYOSTAT.

NAME

RUSS RUCINSKI

DATE

2-14-05

REVISION DATE

MAWP = 6 PSIG.

NORMAL OPERATING PRESSURE = 1 ~ 1.5 PSIG.

PUT RELIEF S.P. AT 2.0 PSIG BASED ON CASSETTE

TEST PRESSURE = 3.0 PSIG. (REF. 8/24/04 E-MAIL DISCUSSION)
ABOUT DØ VLPC RELIEFS

PROPOSED SCHEMATIC

RELIEF CASES

- A.) LOSS OF VACUUM — 0.3 scfm AIR (SEE PG. 5)
- B.) MAXIMUM DELIVERY, ASSUME GHE
— PREVENTED BY 2 PSIG RELIEF ON BOTH CONNECTION LINES. NOT APPLICABLE.
- C.) FIRE — NOT APPLICABLE, POLYURETHANE GASKETS WOULD MELT DURING A FIRE CASE.

SUBJECT

RELIEF VALVE SIZING

LOSS OF VACUUM CASE

NAME

RUSS RUCINSKI

DATE

2-14-05

REVISION DATE

A.) LOSS OF VACUUM RELIEF CONDITION.

RELIEVING RATE IS A FUNCTION OF THE HEAT LOAD ON THE INVAR ENVELOPE.

$$\dot{m}_e = \frac{\dot{Q}_{CV}}{[C_v T_{CV} + h_e]}$$

WHERE $\dot{Q}_{CV}$ - HEAT INPUT TO THE CONTROL VOLUME

T_{CV} - AVG. TEMPERATURE OF CONTROL VOL. $\approx 50K$

h_e - ENTHALPY OF EXITING GAS

$\dot{m}_e$ = RELIEF MASS FLOW RATE.

THIS WAS DERIVED PREVIOUSLY FOR FULL VLPC CRYOSTATS PGS. 7-9 INCLUDED AS REFERENCE.

SKETCH OF SITUATION

• CALCULATE MAXIMUM HEAT FLUX POSSIBLE.

SUBJECT

RELIEF VALVE SIZING
LOSS OF VACUUM CASE

NAME

RUSS RUCINSKI

DATE

2-16-05

REVISION DATE

CALCULATE OUTSIDE SURFACE
CONVECTION COEFFICIENT:

$$h = f(Ra)$$

Ra - RAYLEIGH

$$Ra = \frac{g \beta (T_s - T_\infty) L^3}{\nu^2 Pr}$$

$$\text{LET } T_s = 50 \text{ K } T_\infty = 290$$

$$= \frac{9.81 \frac{\text{m}}{\text{s}^2} \left(\frac{1}{170 \text{ K}} \right) (290 - 50) (.25 \text{ m})^3}{(130 \times 10^{-6} \text{ m}^2/\text{s})^2} (0.66)$$

$$Ra = 1100$$

$$Ra < 10^9 \therefore \text{LAMINAR FLOW}$$

$$\overline{Nu}_L = \frac{\overline{h} L}{k} = \frac{4}{3} \left(\frac{Gr_L}{4} \right)^{1/4} g(Pr)$$

VERTICAL PLATE
LAMINAR FLOW
EQ. 9.21 FUNDAMENTALS
OF HEAT & MASS
T-FCR

WHERE:

$$g(Pr) = \frac{.75 Pr^{1/2}}{(.609 + 1.221 Pr^{1/2} + 1.238 Pr)^{1/4}}$$

EQ. 9.20

$$g(Pr) = .49$$

$$Gr_L = \frac{Ra}{Pr} = \frac{1100}{.66} = 1667$$

$$\overline{Nu}_L = \frac{4}{3} \left(\frac{1667}{4} \right)^{1/4} (.49) = 3.0$$

$$\overline{h} = \overline{Nu} \frac{k}{L} = (3.0) \frac{(.10 \text{ W/m} \cdot \text{K})}{.25 \text{ m}} = 1.2 \frac{\text{W}}{\text{m}^2 \cdot \text{K}}$$

A LITTLE LOW.
BUT IT IS COLD He.

ASSUME INNER CONVECTION COEFFICIENT IS THE SAME.
(CONSERVATIVE SINCE $T_s - T_\infty$ WILL BE LOWER)

$$h_{\text{INNER}} \approx 1.2 \text{ W/m}^2 \cdot \text{K} \quad (\text{ACTUALLY WILL BE LESS})$$

SUBJECT

RELIEF VALVE SIZING
LOSS OF VACUUM CASE

NAME

RUSS RUCINSKI

DATE

2-16-05

REVISION DATE

• INVAR WALL

$$R = \frac{L}{KA} = \frac{.38 \times 10^{-3} \text{ m}}{(11 \frac{\text{W}}{\text{m} \cdot \text{K}})(.46 \text{ m}^2)} = .000075 \frac{\text{K}}{\text{W}}$$

$$\text{AREA} = (.25 \text{ m}) \uparrow \text{HEIGHT.} (.92 \text{ m}) \uparrow \text{PERIMETER OF ONE CASS.} (2 \text{ CASS. SLOTS}) = 0.46 \text{ m}^2$$

TOTAL THERMAL RESISTANCE

$$R_{\text{TOTAL}} = \frac{1}{h_o A} + \frac{L}{KA} + \frac{1}{h_i A}$$

$$= \frac{1}{(1.2 \frac{\text{W}}{\text{m}^2 \cdot \text{K}})(.46 \text{ m}^2)} + .000075 \frac{\text{K}}{\text{W}} \uparrow_{\text{small}} + \frac{1}{(1.2)(.46)}$$

$$= 3.62 \frac{\text{K}}{\text{W}}$$

$$Q_{\text{CV}} = \frac{\Delta T}{R} = \frac{290 \text{ K} - 50 \text{ K}}{3.62 \frac{\text{K}}{\text{W}}} = 66 \text{ WATTS.}$$

CALCULATE RELIEVING FLOW

$$\dot{m}_e = \frac{Q_{\text{CV}}}{(C_v T_{\text{CV}} + h_e)} = \frac{66 \text{ WATTS}}{[(3.116 \frac{\text{J}}{\text{g} \cdot \text{K}})(50 \text{ K}) + 275 \frac{\text{J}}{\text{g}}]}$$

$$\dot{m}_e = 0.15 \frac{\text{g}}{\text{s}} \quad \text{AT } 50 \text{ K} \neq 2 \text{ PSIG.}$$

50K
GAS
EXITS
CONSERVATIVE

SUBJECT

RELIEF VALVE SIZING.
LOSS OF VACUUM CASE

NAME

RUSS RUCINSKI

DATE

2-16-05

REVISION DATE

CONVERTING MASS FLOW TO SCFM AIR.

SCALE FROM SAME CALL., REF. PAGE 10

$$Q_a = 7.1 \text{ scfm AIR} \times \left[\frac{.15^{3/5}}{30.6^{3/5}} \right] \times \frac{\sqrt{50 \text{ K}}}{\sqrt{80 \text{ K}}}$$

$$Q_a = 0.28 \text{ scfm AIR.}$$

SMALL, AS EXPECTED.

JUST ABOUT ANY

RELIEF $\geq 1/8$ " WOULD

WORK.

• RELIEF VALVE USED

CIRCLE SEAL 559B-4MP-2

SET @ 2.0 , RESET 1.8 PSI

FLOW CURVES SHOW IT IS VERY OVERSIZED
(NEEDED TO SEAL PROPERLY)

$$\Delta P = 2 \text{ PSI-} , \text{ FLOW} = 4 \text{ SCFM}$$

SO AT 4PSIG INLET (26 PSI MAWP)

THERE WOULD BE 4 SCFM CAPACITY

ONLY 0.3 SCFM IS REQ'D.

SUBJECT

FIRE CASE - RELIEF SIZING

NAME

RUSS RUCINSKI

DATE

5-9-00

REVISION DATE

6-22-00 Δ RAR

MATH CHECKED BY

Thang Nguyen 5-11-00

TO DETERMINE THE MASS FLOW RATE THAT WILL NEED TO BE
RELIEVED, I WILL USE THERMODYNAMIC LAWS.

1ST LAW: $E_{IN} - E_{OUT} = E_{STORED}$ BASIC CONCEPT

$$\dot{Q}_{cv} + \sum \dot{m}_i \left(h_i + \frac{V_i^2}{2} + gZ_i \right) = \frac{dE_{cv}}{dt} + \sum \dot{m}_e \left(h_e + \frac{V_e^2}{2} + gZ_e \right) + \dot{W}_{cv}$$

WE CAN ASSUME THE $\frac{V^2}{2}$ (KINETIC) AND gZ TERMS ARE NEGLIGIBLE.

(EQN. 5.45 FUNDAMENTALS OF
THERMODYNAMICS
WYLEN & SONTAG
3rd EDITION

ALSO $\dot{m}_i = 0$ AS NO MASS IS ENTERING THE CONTROL VOLUME

$\dot{W}_{cv} = 0$ BECAUSE NO WORK IS BEING DONE ACROSS CONTROL VOLUME BOUNDARY

$\dot{Q}_{cv}$ IS SIMPLY THE HEAT INPUT (BY FIRE IN THIS CASE)

THE 1ST LAW OF THERMODYNAMICS SIMPLIFIES TO

$$\dot{Q}_{cv} = \frac{dE_{cv}}{dt} + \dot{m}_e h_e$$

Δ REVISED

THE CHANGE OF ENERGY IN THE CONTROL VOLUME; $\frac{dE_{cv}}{dt} = M_{cv} c_v \frac{dT_{cv}}{dt}$

SUBJECT

FIRE CASE - RELIEF SIZING

NAME

RUSS RUCINSKI

DATE

5-10-00

REVISION DATE

6-22-00 Δ RAR

SUBSTITUTING THAT IN

$$\dot{Q}_{cv} = M_{cv} C_v \frac{dT_{cv}}{dt} + \dot{m}_e h_e$$

EQN. (1)

FIRST LAW AS APPLIED TO THE CV, APPLIES AT ANY TIME INSTANT.

- THE IDEAL GAS LAW AS APPLIED TO THE CONTROL VOLUME,

$$PV = M_{cv} RT$$

DIFFERENTIATING WITH TIME

$$\frac{d}{dt}(PV) = \frac{d}{dt}(M_{cv} R T_{cv})$$

$$\frac{dP}{dt} \cdot V + \frac{dV}{dt} \cdot P = \frac{dM_{cv}}{dt} \cdot RT + \frac{dR}{dt} \cdot M_{cv} T + \frac{dT}{dt} M_{cv} R$$

BY CHAIN RULE

FOR THE RELIEF CASE ASSUME THE PRESSURE IS CONSTANT AS THE RELIEF VALVE HAS A SET POINT AND IS MAINTAINING CONTROL VOLUME PRESSURE CONSTANT BETWEEN MAWP & 121% MAWP.

$$\therefore \frac{dP}{dt} = 0 \quad \frac{dV}{dt} = 0 \quad \text{SINCE VOLUME DOESN'T CHANGE SIZE}$$

$$\frac{dR}{dt} = 0 \quad \text{SINCE } R \text{ IS A GAS CONSTANT}$$

SUBST. $0 = \frac{dM_{cv}}{dt} \cdot RT + \frac{dT}{dt} M_{cv} \cdot R$

SOLVING FOR $\frac{dT}{dt}$

$$\frac{dT_{cv}}{dt} = - \frac{dM_{cv}}{dt} \left(\frac{T_{cv}}{M_{cv}} \right)$$

EQN. (2)

IDEAL GAS LAW APPLIED TO THE CV. ASSUMING CONSTANT RELIEFING PRESSURE & VOLUME. APPLIES AT ANY INSTANT IN TIME.

- CONSERVATION OF MASS

$$M_{cv}(t) = M_{cv}(t=0) - \int_{t=0}^t \dot{m}_e dt$$

$$\frac{dM_{cv}}{dt} = -\dot{m}_e$$

EQN. (3)

SUBSTITUTING (3) INTO (2);

$$\frac{dT_{cv}}{dt} = \dot{m}_e \frac{T_{cv}}{M_{cv}}$$

EQN. (4)

MATH CHECKED BY
THANG NGUYEN
5-11-00

SUBJECT

FIRE CASE - RELIEF SIZING

NAME

RUSS RUCINSKI

DATE

5-11-00

REVISION DATE

1 6-22-00 RAP

MATH checked By

Thang NGUYEN 5-11-00

SUBSTITUTING (4) INTO (1)

$$\dot{Q}_{cv} = M_{cv} C_v \left(\dot{m}_e \frac{T_{cv}}{M_{cv}} \right) + \dot{m}_e h_e$$

SOLVE FOR $\dot{m}_e$, THE RELIEVING MASS FLOW

$$\dot{Q}_{cv} = \dot{m}_e \left[\frac{M_{cv} C_v \cdot T_{cv}}{M_{cv}} + h_e \right]$$

$$\dot{m}_e = \frac{\dot{Q}_{cv}}{[C_v T_{cv} + h_e]}$$

EQN. (5)

RELIEVING MASS FLOW
RATE FOR GIVEN
HEAT INPUT AND
AVERAGE GAS TEMP.

BY INSPECTION OF EQUATION (5) ONE CAN SEE THAT $\dot{m}_e$ WILL BE A MAXIMUM WHEN T_{cv} IS A MINIMUM. OR PUT ANOTHER WAY WITH TIME T_{cv} INCREASES BECAUSE OF THE HEAT INPUT WHICH CAUSES $\dot{Q}_{cv}$ TO DECREASE (THE NUMERATOR OF EQN. (5)) AND ALSO THE DENOMINATOR INCREASES, THUS THE $\dot{m}_e$ WILL DECREASE WITH TIME.

MAXIMUM RELIEF CAPACITY:

WILL OCCUR @ $t=0$.

$$\dot{Q}_{cv}(t=0) = 20,800 \text{ WATTS}$$

$$T_{cv}(t=0) = 80 \text{ KELVIN}$$

$$h_e(t=0, T_{cv}) = 431 \text{ J/g}$$

$$C_v(t=0, T_{cv}) = 3.117 \text{ J/g} \cdot \text{K}$$

SUBSTITUTING THESE VALUES INTO EQN (5);

$$\dot{m}_{e \text{ MAX}} = \frac{\dot{Q}_{cv}}{[C_v T_{cv} + h_e]} = \frac{20,800 \text{ J/s}}{[3.117 \text{ J/g} \cdot \text{K} \cdot 80 \text{ K} + 431 \text{ J/g}]} = 30.6 \text{ g/s}$$

AT 80K
& 3 PSIG

FERMILAB
ENGINEERING NOTE

SECTION
PPD / ETT
DB

PROJECT
VLPC FULL
CRYOSTAT

SERIAL-CATEGORY
3823.113

PAGE
10

SUBJECT

FIRE CASE - RELIEF SIZING

NAME

Russ Rucinski

DATE

5-11-00

REVISION DATE

6-22-00 RAR

MATH CHECKED 5-11-00

THANG NGUYEN

CONVERTING MASS FLOW TO SCFM AIR:

I WILL USE EQUATION 6A-1 FROM TECHNOLOGY OF LHE. NBS MONOGRAPH 111

$$Q_a = \frac{13.1 W C_a}{60 C} \sqrt{\frac{Z T M_a}{M Z_a T_a}} \quad \text{EQN. 6A-1}$$

THE VARIABLES ARE DEFINED ON THE REFERENCE PAGE (NEXT PAGE)

$$W = 30.6 \frac{g}{s} \times \frac{2.2 \text{ lbm}}{1000 g} \times \frac{3600 s}{hr} = 242 \frac{\text{lbm}}{hr} \quad \Delta$$

$$C_a = 356 \text{ FOR AIR}$$

$$C = 377 \text{ FOR HELIUM}$$

$$Z_a = 1.0$$

$$\text{FOR LHe; } T/T_c = \frac{80 K}{5.19 K} = 15.4 \quad \frac{P}{P_c} = \frac{122000 Pa}{227460 Pa} = 0.54 \Rightarrow Z = 1.0$$

FROM FIG. A.5

GENERAL COMPRESSIBILITY
CHART.

FUNDAMENTALS OF THERMODYNAMICS

$$Z = 1.0$$

$$T = 80 K \times \frac{1.8 R}{K} = 144 R$$

$$T_a = 520 R$$

$$M_a = 28.97$$

$$M = 4.0 \text{ FOR HELIUM}$$

SUBSTITUTING IN;

$$Q_a = \frac{13.1 (242 \frac{\text{lbm}}{hr}) (356)}{60 (377)} \sqrt{\frac{(1.0)(144)(28.97)}{(4.0)(1.0)(520)}}$$

$$Q_a = 71 \text{ scfm AIR}$$

REQUIRED RELIEF CAPACITY FOR FIRE Δ

APPENDIX A. SIZING OF RELIEF DEVICES

The Compressed Gas Association [19] provides information for sizing of relief devices for compressed gases, including pressurized liquid oxygen, nitrogen, and argon and liquefied hydrogen, in cargo, portable, and storage tanks. A value of G_i (the parameter used to size relief devices) is listed for each commodity and is dependent on the latent heat of vaporization and other physical properties of the specific fluid.

Sizing of relief devices for liquid helium containers is somewhat more complex, since the relieving pressure is usually above the critical pressure where no latent heat value exists. A method for handling helium is presented herein, a G_i value being computed in typical fashion, but based on L' , an equivalent value used in place of the latent heat of vaporization. The units of L' are Btu/lb, where Btu's represent the total heat added to the vapor between temperatures T_1 and T_x per pound of efflux gas leaving the container at constant pressure, P . The L' varies significantly with T_x , and has its lowest value shortly after start of relief.

Sizing for Fire Condition

The basic equation for sizing relief devices is

$$Q_a = \frac{13.1 W C_a}{60 C} \left(\frac{Z T M_a}{M Z_a T_a} \right)^{1/2} \quad (6A-1)$$

where Q_a = scfm of air at 520 R (289 K) and 14.7 psia, required capacity of the relief device

W = lb/hr, required flow of the gas

C_a = Gas constant = 356 for air

C = Gas constant of the gas

Z_a = Compressibility factor = 1.0 for air at STP

Z = Compressibility factor for the gas at the flow condition

M_a = Molecular weight of air = 28.97

M = Molecular weight of the gas

T_a = Temperature of air at STP = 520 R

T = Temperature of the gas at the flow condition.

Table A.4 Continued

T (K)	ρ (kg/m ³)	c_p (kJ/kg · K)	$\mu \cdot 10^7$ (N · s/m ²)	$\nu \cdot 10^6$ (m ² /s)	$k \cdot 10^3$ (W/m · K)	$\alpha \cdot 10^6$ (m ² /s)	Pr
Helium (He)							
100	0.4871	5.193	96.3	19.8	73.0	28.9	0.686
120	0.4060	5.193	107	26.4	81.9	38.8	0.679
140	0.3481	5.193	118	33.9	90.7	50.2	0.676
160	—	5.193	129	—	99.2	—	—
180	0.2708	5.193	139	51.3	107.2	76.2	0.673
200	—	5.193	150	—	115.1	—	—
220	0.2216	5.193	160	72.2	123.1	107	0.675
240	—	5.193	170	—	130	—	—
260	0.1875	5.193	180	96.0	137	141	0.682
280	—	5.193	190	—	145	—	—
300	0.1625	5.193	199	122	152	180	0.680
350	—	5.193	221	—	170	—	—
400	0.1219	5.193	243	199	187	295	0.675
450	—	5.193	263	—	204	—	—
500	0.09754	5.193	283	290	220	434	0.668
550	—	5.193	—	—	—	—	—
600	—	5.193	320	—	252	—	—
650	—	5.193	332	—	264	—	—
700	0.06969	5.193	350	502	278	768	0.654
750	—	5.193	364	—	291	—	—
800	—	5.193	382	—	304	—	—
900	—	5.193	414	—	330	—	—
1000	0.04879	5.193	446	914	354	1400	0.654
Hydrogen (H ₂)							
100	0.24255	11.23	42.1	17.4	67.0	24.6	0.707
150	0.16156	12.60	56.0	34.7	101	49.6	0.699
200	0.12115	13.54	68.1	56.2	131	79.9	0.704
250	0.09693	14.06	78.9	81.4	157	115	0.707
300	0.08078	14.31	89.6	111	183	158	0.701
350	0.06924	14.43	98.8	143	204	204	0.700
400	0.06059	14.48	108.2	179	226	258	0.695
450	0.05386	14.50	117.2	218	247	316	0.689
500	0.04848	14.52	126.4	261	266	378	0.691
550	0.04407	14.53	134.3	305	285	445	0.685
600	0.04040	14.55	142.4	352	305	519	0.678
700	0.03463	14.61	157.8	456	342	676	0.675
800	0.03030	14.70	172.4	569	378	849	0.670
900	0.02694	14.83	186.5	692	412	1030	0.671
1000	0.02424	14.99	201.3	830	448	1230	0.673
1100	0.02204	15.17	213.0	966	488	1460	0.662
1200	0.02020	15.37	226.2	1120	528	1700	0.659
1300	0.01865	15.59	238.5	1279	568	1955	0.655
1400	0.01732	15.81	250.7	1447	610	2230	0.650
1500	0.01616	16.02	262.7	1626	655	2530	0.643

Russell Rucinski

From: "George Ginther 630-840-6337" <ginther@fnal.gov>
"Russell Rucinski" <rucinski@fnal.gov>
Sent: Tuesday, August 24, 2004 7:54 AM
Subject: Re: Cassette space pressure reliefs

Hi Russ:

Thanks for checking into this matter. 2.0 sounds more comfortable.

I did not locate additional information regarding the initial prototype tests of the seal designs, but FYI, the written cassette leak check procedure specifies pump and backfill to about 17.5 psia twice, followed by pump and backfill to 3 psig. And I am actually quite sure that 3 was used, since there are leak test sheets for each cassette showing pressure and elapsed time, and I have looked at several of them. (I also performed quite a few of these leak tests myself since I was heavily involved in the studies and repairs of the cassettes that initially leaked.)

GG

On Mon, 23 Aug 2004, Russell Rucinski wrote:

> George,

>

> What I found in my notes about the cassette space gaskets was that they were tested to 2 psig at the factory, known to leak at 6 psig and blow out at 9 psig.

>

> .ginally planned on the normal operating pressure to be 0.5 psig with the low pressure reliefs set at 1.5 psig, and the main reliefs set at a MAWP of 3.0 psig on the vessel.

>

> Either your memory of 3 psig being the test pressure or my notes are in error. But in any case, we all will sleep better if the low pressure relief goes at 2.0 psig rather than 2.75 psig.

>

> I will have them set at 2.0 psig. Thanks for pointing this out and paying attention.

>

> Russ

>

**CIRCLE SEAL
CONTROLS**

RELIEF VALVES 500 Series

**Popoff, inline
.5-150 PSI**

OPERATING CHARACTERISTICS

ZERO LEAKAGE — to 95-98% of cracking pressure.

INCREASED SEALING EFFICIENCY — as pressure increases. Resilient "Q" ring seal is forced against metal seat as pressure increases up to set cracking pressure.

CRACKING PRESSURE ACCURACY — Valves can be preset to required cracking pressure.

WIDE RANGE — of cracking pressures, without sacrificing flow characteristics, provided through interchangeable springs and simple adjustment. (See replacement springs and adjusting information.)

TAMPER-PROOF ADJUSTMENT — Adjustable only from inlet side for safety against tampering. Permits precise setting for the most exacting system requirements.

STICKING ELIMINATED — Poppet head provides metal seat on low pressure side of seal, limits squeeze on resilient seal ring. Prevents water and dirt from entering valve.

LONG, MAINTENANCE-FREE SERVICE — Parts will not wear out in normal service. Overhaul, if necessary, is quickly made by replacing resilient seal.

VARIATIONS — Vent to atmosphere or inline connections, various materials.

HOW IT WORKS

CLOSED

Resilient seal design prevents leakage. Sealing efficiency increases with increased pressure up to cracking pressure. Metal to metal seat on low pressure side supports spring load, prevents sticking.

OPEN

When system pressure overcomes spring force poppet opens momentarily exposing variable orifice between poppet and body to pass increasing flow with minimum pressure rise without blowdown.

RESEALING

Resilient seal automatically establishes line of contact with spherical seat. Seal provides dead tight reseal very close to cracking pressure.

CIRCLE SEAL CONTROLS, INC.

2301 WARDLOW CIRCLE
P.O. BOX 3300
CORONA, CALIFORNIA 91713
PHONE (909) 270-6200 • FAX (909) 270-6201

RELIEF VALVES 500 Series

Popoff, inline
.5-150 PSI

TECHNICAL DATA

MATERIAL..... Body and
internal parts—bar stock

SPRING Stainless steel 302
or 17-7Ph

RESILIENT SEAL..... See service
recommendations

OPERATING PRESSURE... 0-200 PSI
Satisfactory for vacuum applications

CRACKING PRESSURE... .5-150 PSI
Higher cracking pressures available—
please check with factory. (Cracking
pressure is defined as 5 cc/mi. with
gas, except for 520 Series for which
flow is 0.02 SCFM.) **NOTE:** See
exceptions for Teflon and Silicone
under Service Recommendations.

FOR INLINE VALVES:
PROOF PRESSURE 400 PSI
BURST PRESSURE .. Above 500 PSI

ADJUSTMENT Adjustment is
on inlet side, and cannot be tampered
with after valve is installed.

†Alpha Code is for Circle Seal internal use only.

MODEL NUMBER	O-RING MATERIAL	OPERATING TEMPERATURE	SUITABLE FOR
559	Buna N	-40° to +250°F	General Purpose, Air, Acetylene, Ammonia, Freon 12, Hydrogen, Inert Gases
532	Viton	-20° to +400°F	Aromatic Fuels, Synthetic Oils, Solvents, Carbon Tetrachloride, Toluene, Trichloroethylene, Steam
533	Neoprene	-40° to +250°F	Oxygen, Helium, Air, Hydrogen, Carbon Dioxide, Nitrogen, Acetylene
562	Ethylene Propylene	-65° to +300°F	Skydrol, Air, Steam
524	Silicone	-65° to +400°F	Air, Chlorinated Transformer Oil, Oxygen. Not available for cracking pressures above 74.9 PSI
520	Teflon	-100° to +400°F	Chemically inert. Suitable for nearly all fluids. Not available for cracking pressures below 2.5 PSI
K520T1	Teflon	-320° to +165°F	Especially assembled and LOX cleaned
580T1	Teflon	-320° to +165°F	No cryogenic processing

HOW TO ORDER

PART NUMBER DESIGNATION

VARIATION IDENTIFICATION

D—Prefixed Part Number is supplied with a cap which diverts high pressure blasts from personnel and instruments. Serves as a rain and dust shield. Increases flow capacity and facilitates manual override.

NOT RECOMMENDED FOR CRACKING PRESSURES BELOW 2 PSI

K—Cryogenic service (stainless steel valves only) (Specially manufactured, cleaned and tested for cryogenic temperatures)

BASIC MODEL NUMBER

MATERIAL

A—Aluminum T1—Stainless, 316
B—Brass

END CONNECTIONS—INLET/OUTLET

(size in 1/8")
M—Male pipe P—Female pipe

CRACKING PRESSURE—Specify setting in psi.

D 559 A-6MP-10

1M thru 2M & 2MP thru 3MP			3M thru 12M & 4MP thru 10MP		
CODE†	C.P. SETTING	C.P. RANGE	CODE†	C.P. SETTING	C.P. RANGE
A	0.5	.2-.9	A	1	.5-2.4
B	1	1.0-2.3	B	4	2.5-5.9
C	4	2.4-5.5	C	10	6.0-13.9
D	10	5.6-13.9	D	20	14.0-31.0
E	20	14.0-27.9	E	50	31.0-72.9
F	30	28.0-33.9	F	100	73.0-150.0
G	55	34.0-74.9			
H	90	75.0-104.9			
J	125	105.0-147.9

PIPE SIZE MALE	L	HEX	D DIA. MAX
1/8	1.14	1/2	.63
1/4	1.38	3/4	.90
3/8	1.43	3/4	1.21
1/2	1.98	1	1.45
3/4	2.31	1 1/4	1.45
1	3.16	1 1/2	1.89

HEX
ACROSS
FLATS

PIPE SIZE MALE & FEMALE	L	HEX
1/4	1.62	3/4
3/8	2.08	3/4
1/2	2.34	1 1/4
3/4	2.72	1 1/4
1	3.62	1 1/2
1 1/4	4.67	1 1/2

*Complete part number must include cracking pressure. See chart on previous page.

			559	533	532	524
ALUMINUM	POPOFF	1/8	559A-1M-*	533A-1M-*	532A-1M-*	524A-1M-*
		1/4	559A-2M-*	533A-2M-*	532A-2M-*	524A-2M-*
		3/8	559A-3M-*	533A-3M-*	532A-3M-*	524A-3M-*
		1/2	559A-4M-*	533A-4M-*	532A-4M-*	524A-4M-*
		3/4	559A-6M-*	533A-6M-*	532A-6M-*	524A-6M-*
		1	559A-8M-*	533A-8M-*	532A-8M-*	524A-8M-*
	INLINE	1/4	559A-2MP-*	533A-2MP-*	532A-2MP-*	524A-2MP-*
		3/8				
		1/2				
		3/4				
BRASS	POPOFF	1/8	559B-1M-*	533B-1M-*	532B-1M-*	524B-1M-*
		1/4	559B-2M-*	533B-2M-*	532B-2M-*	524B-2M-*
		3/8	559B-3M-*	533B-3M-*	532B-3M-*	524B-3M-*
		1/2	559B-4M-*	533B-4M-*	532B-4M-*	524B-4M-*
		3/4	559B-6M-*	533B-6M-*	532B-6M-*	524B-6M-*
		1	559B-8M-*	533B-8M-*	532B-8M-*	524B-8M-*
	INLINE	1/4	559B-2MP-*	533B-2MP-*	532B-2MP-*	524B-2MP-*
		3/8	559B-3MP-*	533B-3MP-*	532B-3MP-*	524B-3MP-*
		1/2	559B-4MP-*	533B-4MP-*	532B-4MP-*	524B-4MP-*
		3/4	559B-6MP-*	533B-6MP-*	532B-6MP-*	524B-6MP-*
316 S.S.	POPOFF	1/8	559T1-1M-*	533T1-1M-*	532T1-1M-*	524T1-1M-*
		1/4	559T1-2M-*	533T1-2M-*	532T1-2M-*	524T1-2M-*
		3/8	559T1-3M-*	533T1-3M-*	532T1-3M-*	524T1-3M-*
		1/2	559T1-4M-*	533T1-4M-*	532T1-4M-*	524T1-4M-*
		3/4	559T1-6M-*	533T1-6M-*	532T1-6M-*	524T1-6M-*
		1	559T1-8M-*	533T1-8M-*	532T1-8M-*	524T1-8M-*
	INLINE	1/4	559T1-2MP-*	533T1-2MP-*	532T1-2MP-*	524T1-2MP-*
		3/8	559T1-4MP-*	533T1-4MP-*	532T1-4MP-*	524T1-4MP-*
		1/2	559T1-6MP-*	533T1-6MP-*	532T1-6MP-*	524T1-6MP-*
		3/4

For ASME code valve, available in 1/4 inch size only. Add ASME after valve number. For operation details see ASME Valve catalog sheet, Form Number CSP-366L.

C.P. RANGE	1M/2MP	2M/3MP	C.P. RANGE	3M/4MP	4M/6MP	6M/8MP	8M/10MP
0.2-0.9	22335-0.5	22336-0.5	.5-2.4	10362-1	10462-1	10662-1	10845-1
1.0-2.3	22335-1	22336-1	2.5-5.9	10362-4	10462-4	10662-4	10845-4
2.4-5.5	22335-4	22336-4	6.0-13.9	10362-10	10462-10	10662-10	10845-10
5.6-13.9	22335-10	22336-10	14.0-31.0	10362-20	10462-20	10662-20	10845-20
14.0-27.9	22335-20	22336-20	31.1-72.9	10362-50	10462-50	10662-50	10845-50
28.0-33.9	22335-30	22336-30	73.0-150.0	10362-100PH	10462-100PH	10662-100PH	10845-100PH
34.0-74.9	22335-55	22336-55					
75.0-104.9	22335-90PH	22336-90PH					
105.0-147.9	22335-125PH	22336-125PH					

**Springs for each valve size are interchangeable. The Cracking Pressure range can be changed by replacing the spring with one covering the desired range.

CIRCLE SEAL CONTROLS, INC.

2301 WARDLOW CIRCLE
P.O. BOX 3300
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TYPICAL FLOW CURVES

Use the curves below to determine the pressure increase over cracking pressure for a given cracking pressure, flow rate and valve size. Interpolate between the curves for cracking pressures not shown.

500 SERIES

D500 SERIES

CIRCLE SEAL CONTROLS, INC.

2301 WARDLOW CIRCLE
P.O. BOX 3300
CORONA, CALIFORNIA 91718
PHONE (909) 270-6200 • FAX (909) 270-6201

708-597-9880

4839 W 128th PLACE
ALSIP, IL. 60803

www.instrumentassociates.com

TO:

FERMILAB-PROCARD
E. KIRK ROAD & WILSON ST
BATAVIA
60510

CUSTOMER PO#
PRN#53312
CUST PN
559B-4MP-2
QTY: 1
DESCRIPTION
RELIEF VALVE
ITEM NUMBER
559B-4MP-2

708-597-9880

4839 W 128th PLACE
ALSIP, IL. 60803

www.instrumentassociates.com

TO:

FERMILAB-PROCARD
E. KIRK ROAD & WILSON ST
BATAVIA
60510

CUSTOMER PO#
PRN#53312
CUST PN
559B-4MP-2
QTY: 1
DESCRIPTION
RELIEF VALVE
ITEM NUMBER
559B-4MP-2

FERMILAB RECEIVING DEPARTMENT
MMS PACKING LIST

Print Date: 22-DEC-04

=====

Receipt Date: 22-DEC-04 Receipt Number: 94467
Req: 174736 Ext: 2888 Deliver: RUCINSKI

VENDOR: R Z TOOL INC
PURCHASE ORDER: 560047-0

=====

PO Rec.

Line	Line	Part Num/Item Description	Ord.	Unit	Recd	Due
1	1	Envelope assembly FLANGE, Machined per Fermilab drawing 3823.111-MD-434125, rev. A. Made from 36% Nickel, balance iron alloy, (INVAR 36). Provide material certification sheet for the raw material used.	4	EACH	4	
2	2	Envelope assembly PLUG, Machined per Fermilab drawing 3823.111-MD-434126, rev. none. Made from 36% Nickel, balance iron alloy, (INVAR 36). Provide material certification sheet for the raw material used.	4	EACH	4	

EAGLE ALLOYS CORP.

117 West Park Ct ~ Talbott, TN. 37877

MATERIAL TEST REPORTS

Date: 11/16/04

CUSTOMER

CUSTOMER ORDER NO.

OUR No.#

RZ Tool Inc.

Verbal - Samantha

11-0833

We Certify that

<u>Description</u>	<u>Qty. / Weight</u>	<u>Conforms to</u>
Invar 36 1/2" Thk x 1.402"±.125 x 16.764"±.125	4 Pcs.	Heat # 876040615 ASTM F-1684 UNS K83813

CHEMICAL ANALYSIS

NI: 36.77	AL: 0.01
MIN: 0.43	C: 0.01
SI: 0.12	P: 0.003
CR: 0.02	S: 0.001
CO: 0.02	TI: <0.01
MG: 0.02	FE: Balance
ZR: 0.01	

MECHANICAL PROPERTIES

HARDNESS: HRB 68

COEFFICIENT OF THERMAL EXPANSION:

1.1 cm/cm °C X 10⁽⁻⁴⁾ @ 100 °C

2.0 cm/cm °C X 10⁽⁻⁴⁾ @ 50 °C

2.5 cm/cm °C X 10⁽⁻⁴⁾ @ 100 °C

6.9 cm/cm °C X 10⁽⁻⁴⁾ @ 150 °C

9.2 cm/cm °C X 10⁽⁻⁴⁾ @ 250 °C

SIGNED:

(QUALITY CONTROL)

EAGLE ALLOYS CORP.

117 West Park Ct. - Talbott, TN. 37877

MATERIAL TEST REPORTS

Date: 11/16/04

CUSTOMER

RZ Tool Inc.

CUSTOMER ORDER NO.

Verbal - Samantha

OUR No.#

11-0833

We Certify that

Description	Qty. / Weight	Conformance
Invar 36 1/2" Thk x 4.347" x .125 x 10.658" x .125	4 Pcs.	Heat # 976040815 ASTM F-1684 UNS K83 03

CHEMICAL ANALYSIS

NI: 36.77	AL: 0.01
MN: 0.43	C: 0.01
SI: 0.12	P: 0.003
CR: 0.02	S: 0.001
CO: 0.02	TT: <0.01
MG: 0.02	FE: Balance
ZR: 0.01	

MECHANICAL PROPERTIES

HARDNESS: HRB 68

COEFFICIENT OF THERMAL EXPANSION:

1.1 cm/cm °C X 10⁻⁴ @ 100 °C
2.0 cm/cm °C X 10⁻⁴ @ 50 °C
2.5 cm/cm °C X 10⁻⁴ @ 100 °C
6.9 cm/cm °C X 10⁻⁴ @ 50 °C
9.2 cm/cm °C X 10⁻⁴ @ 50 °C

SIGNED:

(QUALITY CONTR. IL)

Fermilab

3/2/2005

M.I.C.E. 2 slot Cryocooler cryostat

Pressure Testing Permit*

Type of Test: ☒ Pneumatic – helium

Test Pressure: 4 psig + vacuum = 18.7 psia. (112% MAWP)

Maximum Allowable Working Pressure: 2 psig + vacuum = 16.7 psia.

Items to be Tested: Stagnant cassette gas helium space.

Location of Test: D-Zero Ass'y Building Date: March 3rd, 2005

Hazards Involved: None, very little store energy. (134 ft-lbs, 182 joules stored energy).

Safety Precautions Taken: Test area is sufficiently isolated from incidental traffic.

Special Conditions or Requirements: Vacuum Jacket will be evacuated to < 1 torr. A helium mass spectrometer leak detector will be monitoring the vacuum space for leaks..

Test Coordinator: Russ Rucinski Dept/Date PPD/MD/D0 Ops 3/1/2005

Division/Section Safety Officer Martha Hefner Dept/Date ESH 3/2/05

Division/Section Head [Signature] Dept/Date PPD 3/2/05

Results CASSETTE SPACE HELD 4.0 PSIG + FULL VACUUM.

FOR MORE THAN 10 MINUTES WHEN ISOLATED. THERE IS A
SMALL O-RING LEAK TO VACUUM SPACE. $\approx (4 \mu\text{m/min RISE})$
THAT NEEDS TO BE FIXED. VACUUM PRESSURE 10×10^{-3} TORR TO

Witness [Signature] PPD/MD/D0 Dept/Date 3-3-05

(Safety Officer or Designee)

James Fagan PPD/MD/D0

100 $\times 10^{-3}$ TORR
DURING
TEST.

CRYOSTAT PASSED PRESSURE TEST.

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

SUBJECT

PRESSURE TEST OF M.I.C.E.
CRYOCOOLER CRYOSTAT.

NAME

RUSS RUCINSKI

DATE

2-28-05

REVISION DATE

OPERATING PRESSURE 1.5 PSIG $\pm$.5 PSI

RELIEF PRESSURE = 2 PSIG.

CASSETTE GASKETS GOOD TO 3 PSIG?

PROPOSE TEST PRESSURE = 4 PSIG. (18.7 PSIA)

$$\% \text{ OVERPRESSURE} = \frac{4 + 14.7}{2 + 14.7} (100) = \underline{\underline{112\%}}$$

$$\text{VOLUME} = 0.3 \text{ ft}^3$$

STORED ENERGY CALCULATION

(REF. BNL HS-5060-17)
PRESSURE SAFETY COURSE.

$$E = \frac{P_1 V_1}{K-1} \left[1 - \left(\frac{P_2}{P_1} \right)^{\frac{K-1}{K}} \right] \times C$$

$$= \frac{(18.7 \text{ PSIA}) (0.3 \text{ ft}^3) \left(\frac{1728 \text{ in}^3}{\text{ft}^3} \right)}{1.4 - 1} \left[1 - \left[\frac{14.7 \text{ PSIA}}{18.7 \text{ PSIA}} \right]^{\frac{0.4}{1.4}} \right] \times C$$

$$8.33 \times 10^{-2}$$

$$= 134 \text{ ft-lbs STORED ENERGY.}$$

$$= 182 \text{ JOULES}$$

Energy of Gas System

Gas confined under high pressure is like a hungry tiger in a cage. If it should suddenly escape in a populated area, someone would probably be injured. When a gas-pressure vessel fails, it propels jagged vessel fragments out in all directions.

To better understand the energy released when a container of gas ruptures, imagine that a 10-ft³ vessel of nitrogen fails at 6000 psig. Compare this to the 4.62 MJ (3.42×10^6 ft-lb) of energy released when 1 kg (2.2 lb) of TNT is detonated. The energy of the gas, assuming isentropic expansion, is¹

$$U_{\text{gas}} = \frac{P_1 V_1}{\gamma - 1} \left[1 - \left(\frac{P_2}{P_1} \right)^{\frac{\gamma}{\gamma - 1}} \right],$$

where

P_1 = container pressure

P_2 = atmospheric pressure

$$\gamma = \frac{C_p}{C_v} = 1.41 \text{ for } N_2$$

This expression as written, will yield an energy value in joules if pressure and volume units are in megapascals (Mpa), and cubic centimeters (cc), respectively. For units of ft-lb psi, and ft³, a conversion factor to these units is required as

$$U_{\text{gas}} =$$

$$(8.33 \times 10^{-2}) \frac{6015 \times 10 \times 1728}{1.4 - 1} \left[1 - \left(\frac{14.7}{6015} \right)^{\frac{1.41 - 1}{1.41}} \right]$$

$$= 1.74 \times 10^7 \text{ ft-lb or } 23.6 \text{ MJ}$$

The weight of equivalent explosive is

$$\frac{1.74 \times 10^7}{3.42 \times 10^6} = 5.1 \text{ kg}$$

which is over 11 lb. of TNT.

A liquid confined under high pressure is also a potential safety hazard. However, for systems of comparable volume and pressure the amount of stored energy in the liquid case will be considerably less than that contained in the gas. The energy involved in the sudden failure of a liquid filled vessel may be conservatively determined from

$$U_{\text{liq}} = \frac{1}{2} \left(\frac{P_1^2 V}{B} \right)$$

where

B = Liquid bulk modulus

Some typical bulk modulus values are

$B = 300,000$ psi for water

$B = 225,000$ psi for oil

$B = 630,000$ psi for glycerin

Were the container above filled with water,

$$U_{\text{liq}} = 1/2 \left(\frac{6015^2 \times 10 \times 1728}{30000 \times 12} \right)$$

$$= 8.683 \times 10^4 \text{ ft. lb.}$$

In this case the weight of equivalent explosive is

$$\frac{8.683 \times 10^4}{3.42 \times 10^3} = 25.4 \text{ gms TNT}$$

FERMILAB
ENGINEERING NOTE

SECTION
PPD/MD
DZERO OPS

PROJECT
40 - M.I.C.E.

SERIAL-CATEGORY
40.24.03

PAGE
1

SUBJECT

M.I.C.E. CRYO COOLER
FLOW SCHEMATIC

NAME

RUSS RUCINSKI

DATE

2-24-05

REVISION DATE

M.I.C.E. Cryocooler C, Jstat - Components list

Russ Rucinski, 2/28/2005

Tag #	Description	Manufacturer	Model	Setting or range	Pressure Rating	Size
MV-1	Cassette space helium supply valve	VAT	26332 KA01	n/a	2 atm.	KF40
MV-2	Cassette space purge or vent valve					
MV-3	Insulating vacuum isolation valve					
MV-4	Cassette space vacuum pump out valve					
MV-5	Gas helium supply regulator isolation valve	Victor Equipment company	n/a	n/a	60 psi min.	1/4" NPT
MV-6	Gas helium cylinder valve	not applicable	n/a	n/a	n/a	n/a
PI-1	Cassette space helium supply pressure indicator	US Gage	19267	30" Hg vacuum - 0 - 15 psig	15 psig	1/4" NPT
PI-2	Cassette space pressure indicator		DV-6	0 - 1 Torr	30 psi	1/4" NPT
PI-3	Insulating vacuum pressure indicator	Hastings				
PI-5	Regulated helium cylinder supply pressure	US Gage		0 - 60 psig (0-0.4 Mpa) range	90 psi min.	1/4" NPT
PI-6	Helium cylinder pressure	US Gage		0-4000 psig (0-28 Mpa) range	4000 psig min.	1/4" NPT
PRV-1	Cassette space helium supply pressure regulator	Victor Equipment company	TS-450B	set @ 1.0 psig	3000 psi	CGA 580
PRV-5	Helium supply cylinder pressure regulator			set @ 10 psig		
PSV-1	Cassette space pressure relief valve	Circle Seal Controls, inc.	559B-4MP-2	2 psig (0.115MPa)	400 psi	1/2" MNPT
PSV-2	Cassette space pressure relief valve	Circle Seal Controls, inc.	559B-4MP-2	2 psig (0.115MPa)	400 psi	1/2" MNPT
PSV-3	Vacuum space pressure relief valve	Circle Seal Controls, Inc.	532B-3M-8	8 psig (0.156MPa)	200 psi	3/8" NPT

REV	DESCRIPTION	BY	DATE
A	ADDED ITEMS #1-	WYSEBET	10-20-64
		BUTTSKI	10-20-64

NOTES:

1. DO NOT EVACUATE CASSETTE SPACE VOLUME WITHOUT VACUUM CONTAINER (ITEM #1) ALSO EVACUATED TO AN EQUAL OR LESSER PRESSURE. FAILURE TO HEED THIS WARNING MAY RESULT IN DAMAGE TO VLPc CASSETTE (ITEM #10) AND CASSETTE ENVELOPE (ITEM #6 ON DRG. ME-434119).
2. DO NOT EVACUATE VACUUM CONTAINER (ITEM #1) IF ALL COMPONENTS OF TOP PLATE SUB-ASSEMBLY ARE NOT COMPLETE.
3. GAS HELIUM PORT: A PRESSURE RELIEVING DEVICE SET TO 0.12 MPa (10.14 MPa MAXIMUM) MUST BE ATTACHED TO EACH CASSETTE SPACE VOLUME TO PREVENT MECHANICAL DAMAGE TO VLPc CASSETTE (ITEM #10) AND/OR CASSETTE ENVELOPE (ITEM #6 ON DRG. ME-434119).
4. INSTRUMENTATION PORT: THIS IS THE SUGGESTED PORT FOR INSTRUMENTATION. SEE TOP PLATE ASSEMBLY (ITEM #6) FOR SUGGESTED INSTRUMENTATION.

Sectional Elevation
(CASSETTE NOT SHOWN IN RIGHT HAND SLOT)

15	MC-434145	WASHER, FLAT, M20	1
14		VACUUM INSULATED CASSETTE ENVELOPE (ITEM #6 ON DRG. ME-434119)	1
13		WASHER, FLAT, M20	4
12		WASHER, FLAT, M20	4
11		WASHER, FLAT, M20	4
10	ME-317446	1004 CHANNEL VLPc CASSETTE ASSEMBLY	1
9		WASHER, FLAT, M20	16
8		WASHER, FLAT, M20	28
7		WASHER, FLAT, M20	16
6	ME-434118	TOP PLATE SUB-ASSEMBLY	1
5		WASHER, FLAT, M20	1
4		WASHER, FLAT, M20	5
3		WASHER, FLAT, M20	5
2		WASHER, FLAT, M20	1
1	ME-434116	VACUUM CONTAINER	1
ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.

PARTS LIST			
QUANTITY	DESCRIPTION	REVISION	DATE
1	WASHER, FLAT, M20	1	10-20-64
2	WASHER, FLAT, M20	2	10-20-64
3	WASHER, FLAT, M20	3	10-20-64
4	WASHER, FLAT, M20	4	10-20-64
5	WASHER, FLAT, M20	5	10-20-64
6	WASHER, FLAT, M20	6	10-20-64
7	WASHER, FLAT, M20	7	10-20-64
8	WASHER, FLAT, M20	8	10-20-64
9	WASHER, FLAT, M20	9	10-20-64
10	WASHER, FLAT, M20	10	10-20-64
11	WASHER, FLAT, M20	11	10-20-64
12	WASHER, FLAT, M20	12	10-20-64
13	WASHER, FLAT, M20	13	10-20-64
14	WASHER, FLAT, M20	14	10-20-64
15	WASHER, FLAT, M20	15	10-20-64
16	WASHER, FLAT, M20	16	10-20-64
17	WASHER, FLAT, M20	17	10-20-64
18	WASHER, FLAT, M20	18	10-20-64
19	WASHER, FLAT, M20	19	10-20-64
20	WASHER, FLAT, M20	20	10-20-64
21	WASHER, FLAT, M20	21	10-20-64
22	WASHER, FLAT, M20	22	10-20-64
23	WASHER, FLAT, M20	23	10-20-64
24	WASHER, FLAT, M20	24	10-20-64
25	WASHER, FLAT, M20	25	10-20-64
26	WASHER, FLAT, M20	26	10-20-64
27	WASHER, FLAT, M20	27	10-20-64
28	WASHER, FLAT, M20	28	10-20-64
29	WASHER, FLAT, M20	29	10-20-64
30	WASHER, FLAT, M20	30	10-20-64
31	WASHER, FLAT, M20	31	10-20-64
32	WASHER, FLAT, M20	32	10-20-64
33	WASHER, FLAT, M20	33	10-20-64
34	WASHER, FLAT, M20	34	10-20-64
35	WASHER, FLAT, M20	35	10-20-64
36	WASHER, FLAT, M20	36	10-20-64
37	WASHER, FLAT, M20	37	10-20-64
38	WASHER, FLAT, M20	38	10-20-64
39	WASHER, FLAT, M20	39	10-20-64
40	WASHER, FLAT, M20	40	10-20-64
41	WASHER, FLAT, M20	41	10-20-64
42	WASHER, FLAT, M20	42	10-20-64
43	WASHER, FLAT, M20	43	10-20-64
44	WASHER, FLAT, M20	44	10-20-64
45	WASHER, FLAT, M20	45	10-20-64
46	WASHER, FLAT, M20	46	10-20-64
47	WASHER, FLAT, M20	47	10-20-64
48	WASHER, FLAT, M20	48	10-20-64
49	WASHER, FLAT, M20	49	10-20-64
50	WASHER, FLAT, M20	50	10-20-64
51	WASHER, FLAT, M20	51	10-20-64
52	WASHER, FLAT, M20	52	10-20-64
53	WASHER, FLAT, M20	53	10-20-64
54	WASHER, FLAT, M20	54	10-20-64
55	WASHER, FLAT, M20	55	10-20-64
56	WASHER, FLAT, M20	56	10-20-64
57	WASHER, FLAT, M20	57	10-20-64
58	WASHER, FLAT, M20	58	10-20-64
59	WASHER, FLAT, M20	59	10-20-64
60	WASHER, FLAT, M20	60	10-20-64
61	WASHER, FLAT, M20	61	10-20-64
62	WASHER, FLAT, M20	62	10-20-64
63	WASHER, FLAT, M20	63	10-20-64
64	WASHER, FLAT, M20	64	10-20-64
65	WASHER, FLAT, M20	65	10-20-64
66	WASHER, FLAT, M20	66	10-20-64
67	WASHER, FLAT, M20	67	10-20-64
68	WASHER, FLAT, M20	68	10-20-64
69	WASHER, FLAT, M20	69	10-20-64
70	WASHER, FLAT, M20	70	10-20-64
71	WASHER, FLAT, M20	71	10-20-64
72	WASHER, FLAT, M20	72	10-20-64
73	WASHER, FLAT, M20	73	10-20-64
74	WASHER, FLAT, M20	74	10-20-64
75	WASHER, FLAT, M20	75	10-20-64
76	WASHER, FLAT, M20	76	10-20-64
77	WASHER, FLAT, M20	77	10-20-64
78	WASHER, FLAT, M20	78	10-20-64
79	WASHER, FLAT, M20	79	10-20-64
80	WASHER, FLAT, M20	80	10-20-64
81	WASHER, FLAT, M20	81	10-20-64
82	WASHER, FLAT, M20	82	10-20-64
83	WASHER, FLAT, M20	83	10-20-64
84	WASHER, FLAT, M20	84	10-20-64
85	WASHER, FLAT, M20	85	10-20-64
86	WASHER, FLAT, M20	86	10-20-64
87	WASHER, FLAT, M20	87	10-20-64
88	WASHER, FLAT, M20	88	10-20-64
89	WASHER, FLAT, M20	89	10-20-64
90	WASHER, FLAT, M20	90	10-20-64
91	WASHER, FLAT, M20	91	10-20-64
92	WASHER, FLAT, M20	92	10-20-64
93	WASHER, FLAT, M20	93	10-20-64
94	WASHER, FLAT, M20	94	10-20-64
95	WASHER, FLAT, M20	95	10-20-64
96	WASHER, FLAT, M20	96	10-20-64
97	WASHER, FLAT, M20	97	10-20-64
98	WASHER, FLAT, M20	98	10-20-64
99	WASHER, FLAT, M20	99	10-20-64
100	WASHER, FLAT, M20	100	10-20-64

FEDERAL NATIONAL ACCELERATOR LABORATORY UNITED STATES DEPARTMENT OF ENERGY			
DO/DO UPGRADE 2 SLOT VLPc CRYOCOOLER CRYOSTAT ASSEMBLY			
SCALE	DESIGN NUMBER	SHEET	REV
1/8"	3823.111-ME-434117	1 OF 1	A
DRAWN BY: 10-20-64			

[illegible]

MICE PRESSURE TEST OF CASSETTE SPACE

R. RUCINSKI

3/3/05

VACUUM/LEAK DETECTOR CASS SPACE

10:38 52x5 SCALE ATM, HE
6 μ RESIDUAL

10:41 50-78x5 1.5 PSI He
6 μ

50x50 $\uparrow$

10:44 VALVED OFF LEAK DETECTOR
WE HAVE A SMALL HE LEAK
ISOLATED VACUUM PUMPS.

10:45 13 μ

10:47 26 μ 2.2 PSI

10:49 32 μ

10:54 52 μ 1.5 PSI GASKETS
LEAK ON
BLANKS

ROR = 4 μ /MIN

> 1.5 PSI

TOO THIN

10:59 66 μ 3.2 PSI
HOLDS

CLAMPING

11:01 74 μ 4.0 PSIG, HOLDS

11:02 77 μ 4.0 PSIG ISOLATED INLET VALVE

11:06 86 μ 4.0 PSIG

11:10 95 μ 4.0 PSI

11:12 100 μ

4.0 PSI

BLOWING DOWN - END TEST