Vacuum Window Engineering Note
(per Fermilab ES&H Manual Chapter 5033.1)

Vacuum Window Number: _____

Identification and Verification of Compliance:

Prepared by	Jim Kilmer, Terry Tope	Date	11/14/07	Div/Sec	PPD
Reviewed by	Dave Erickson DAVE PUSHKA	Date	11/29/07	Div/Sec	PPD
Div/Sec Head	[illegible] for J.S.	Date	12/12/07	Div/Sec	PPD

Director's signature (or designee) if vacuum window requires an exception to the provisions of this chapter.

_____

Amendment No.	Reviewed by	Date

Vacuum Vessel Title for the vacuum vessel to which the Vacuum Window is attached.

MTest downstream Differential Cerenkov counter

Vacuum Vessel Number for the vacuum vessel to which the Vacuum Window is attached.

PPD 10107

Vacuum Window Drawing Number (List all pertinent drawings):

Drawing No.	Location of Originals
9213.150-MD-444862	All drawings at BEG connect building
2926.MB-30434	
2926.MB-30228	
2926.ME-30401	

Laboratory location code	MT6
Purpose of vacuum vessel and vacuum window	Identify particles by Cerenkov radiation
Internal MAWP	8 psig
External MAWP	Full vacuum
Working Temperature Range	-20 °F to 100 °F

1. Design Verification: Provide design calculations in the Note Appendix.

2. Fabrication: Is this vacuum window fabricated in house? [X] Yes [ ] No
If "Yes", Attach the written fabrication procedure in the Note Appendix.

3. Inspection: Attach inspection reports and Travelers in the Note Appendix. Include date(s) of manufacture.

4. Testing: Attach failure and acceptance testing procedure and results in the Note Appendix. Include dates of testing

5. System Venting Verification:

Is the relieving system of the vacuum vessel to which this vacuum window is attached sufficiently sized such that if the vessel is pressurized, the maximum differential pressure across the window cannot exceed the design differential pressure of the vacuum window?
[X] Yes [ ] No

Attach Calculations in the Note Appendix

6. Operating Procedure Section:

Is an operating procedure necessary for the safe operation of this vessel? [ ] Yes [X] No
If "Yes", the operating procedure must be attached to the Note Appendix

7. Hazard Analysis: Is the safety factor on this vacuum window less than 2.0? [ ] Yes [X] No

If "Yes", a hazard analysis must be prepared and attached to the Note Appendix

8. Degradation from Exposure: Will the integrity of the window be compromised over time by exposure to radiation or cyclic stress? [X] Yes [ ] No
If "Yes", include in the technical appendix any requirements for recording exposure, as well as a change-out schedule.

Stress Calculation for Downstream Cerenkov Thin Window
11/15/2007
Jim Kilmer

This paper calculates stresses in the downstream thin window for the cerenkov counters to be installed in the M-Test beamline. This window is at the end of the beamline and is not enclosed so personnel could be exposed to parts of a broken window. It does have two beam profile counters between the window and the walkway in a direct line for a shield. It is also to be noted that because these cerenkov counters will have their gasses changed in pressure as the beam changes it is possible that for this window it could see a maximum force of less than 15 psi (15 psi vacuum) in the worst direction at any point in the run. The dimensions come from drawing 2926.MB-30228 and MB-30434..

$Fu := 130000 \cdot psi$ Ultimate strength of Ti-6Al-4V alloy titanium sheet

$Fy := 120000 \cdot psi$ Yield Strength at 0.2% offset

For this downstream window calculate the stress using Fermilab-TM-1380. Assume a window thickness of 0.003" made from Ti-6Al-4V.

$t := 0.003 \cdot in$ thickness of the window

$d := 4.481 \cdot in$ Diameter of window o-ring

$a := \frac{d}{2}$ Radius of window to the o-ring seal

$q := 15.0 \cdot psi$ Uniform pressure on the window

$E := 16 \cdot 10^6 \cdot psi$ Young modulus for window material

$$S := 0.423 \cdot \left(E \cdot q^2 \cdot \frac{a^2}{t^2} \right)^{\frac{1}{3}}$$

$$y := 0.662 \cdot a \cdot \left(q \cdot \frac{a}{E \cdot t} \right)^{\frac{1}{3}}$$

$S = 5.337 \times 10^4 \, psi$

$y = 0.132 \, in$

$$SF := \frac{S}{Fy}$$

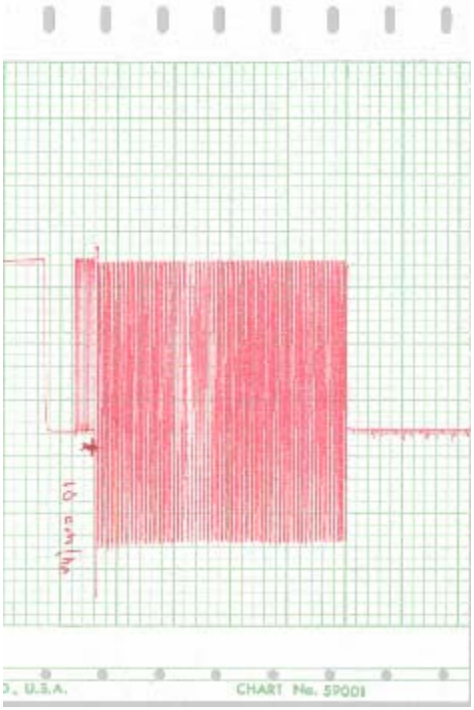
$SF = 0.445$

Procedure for making .003 titanium windows for Cerenkov Counter
Dave Erickson

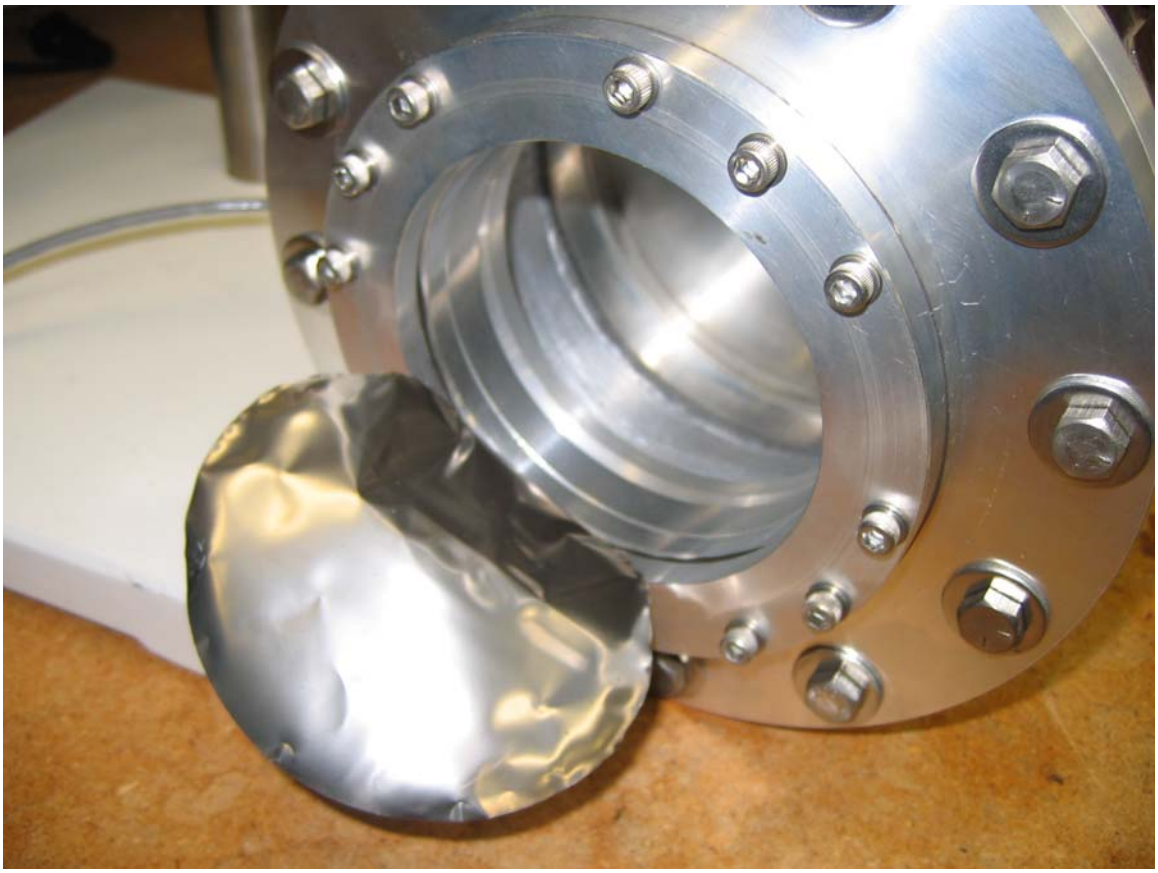
Fabrication for making .003 Titanium window is done by making a round template used to lay on sheet of .003 titanium material. Using a soft felt pen, (Sharpie) trace around template to material. Then using a sharp pair of scissors, carefully cut on the traced line as close and neatly as possible, as this will be the finish cut for the outside dimension. Make two aluminum flanges the same size as the titanium windows. The titanium (7 total) windows will be laid carefully between the two aluminum flanges and tied together with 3 small "C" clamps making one tight package. This package is then placed in a dividing head on a vertical mill and is located on center of the dividing head. From that, the mill table is then moved to the appropriate radius and holes are drilled through to size and number required around perimeter of package. Drilling through aluminum flanges allows a clean hole through titanium material which otherwise would be impossible to do without hole being distorted. One must be very careful when handling titanium windows as they are very, very sharp. Also, much care is needed handling windows; any slight bending leaves a noticeable crease.

Testing of the MTBF Downstream Differential CKOV Downstream Window.

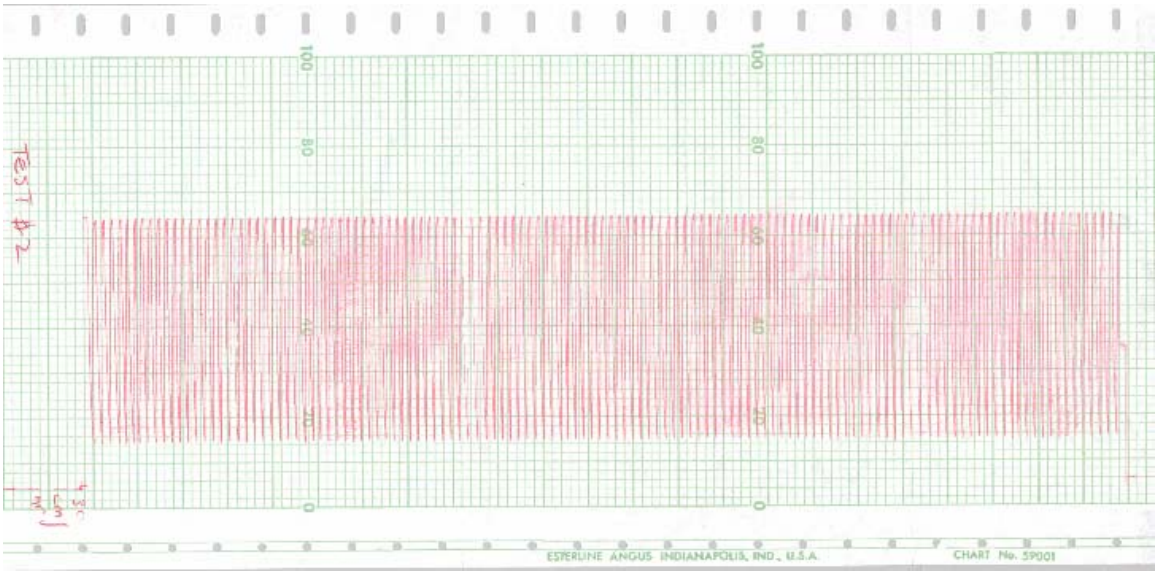
Above is the hardware fabricated by Jim Tweed used for the window testing. A relay with a timer switches a solenoid valve between a gas and vacuum source. The relay and solenoid apply the 15 psig gas source for 10 seconds and the vacuum source for 10 seconds. With the restrictions in the system, the vacuum source achieves about 4 psia in 10 seconds. Thus the 15 psig gas source simulates full vacuum and the vacuum source reaching 4 psia simulates the 10 psig set point of the ckov relief valves.



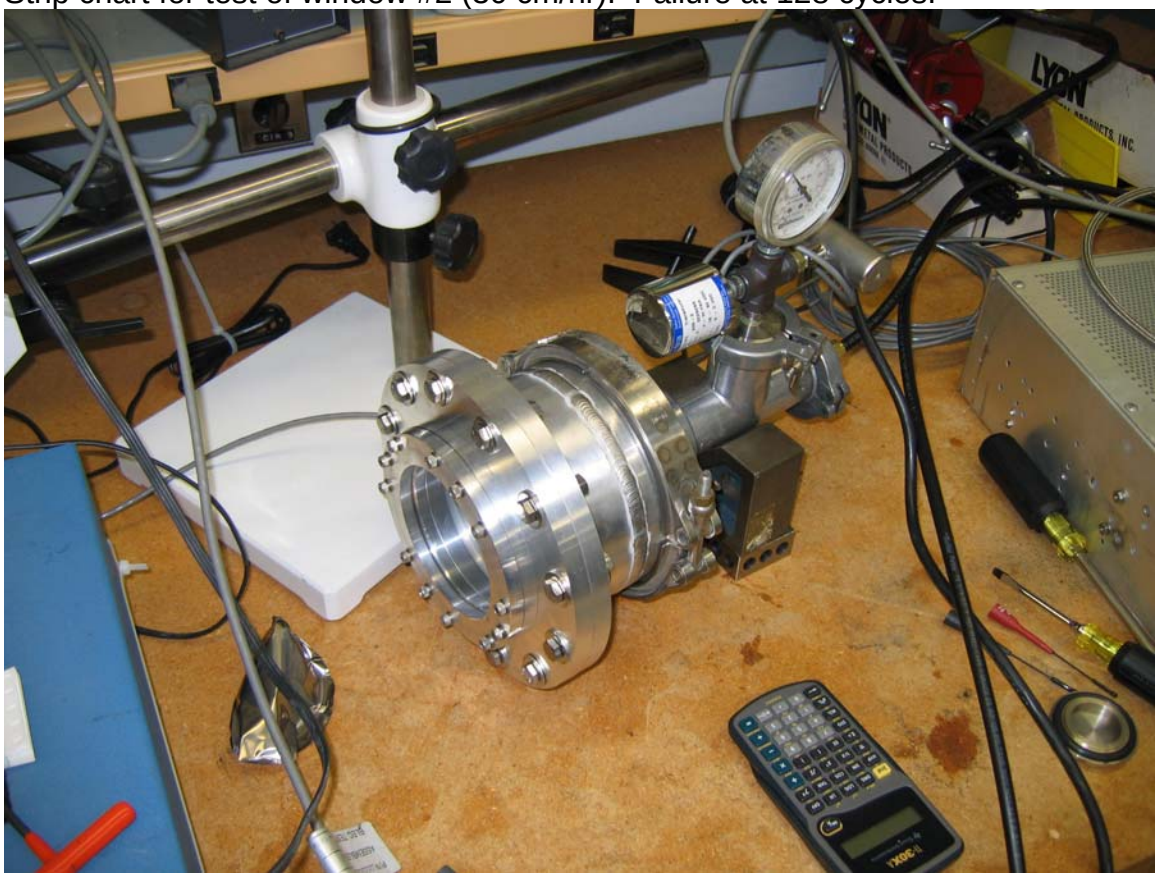
Strip chart for test of window #1 (10 cm/hr). Failure at 71 cycles.



Window #1 after failure at 71 cycles.

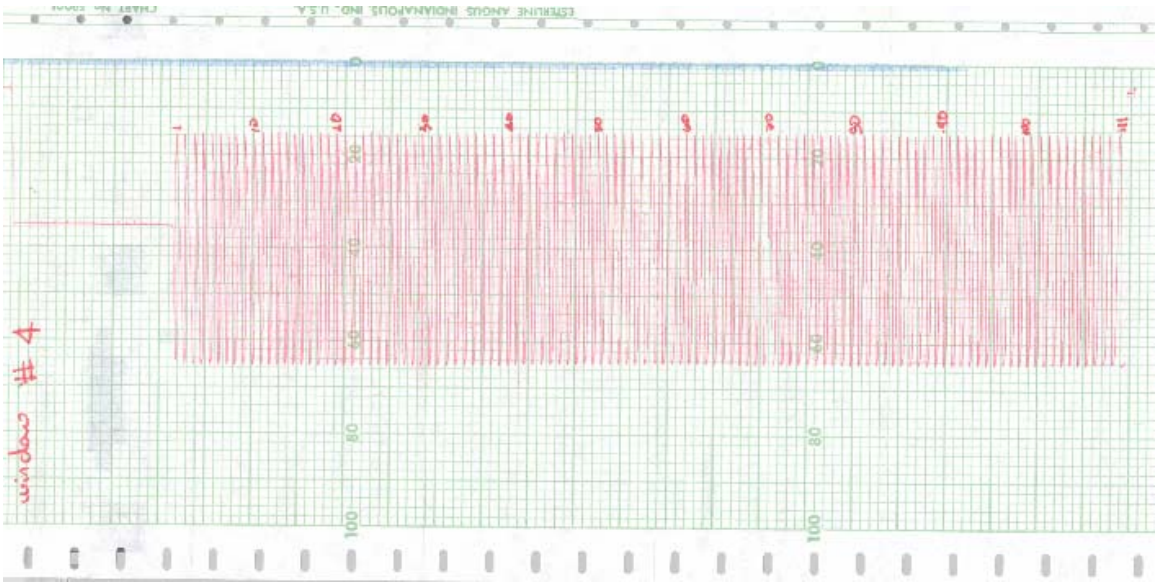


Strip chart for test of window #2 (30 cm/hr). Failure at 128 cycles.

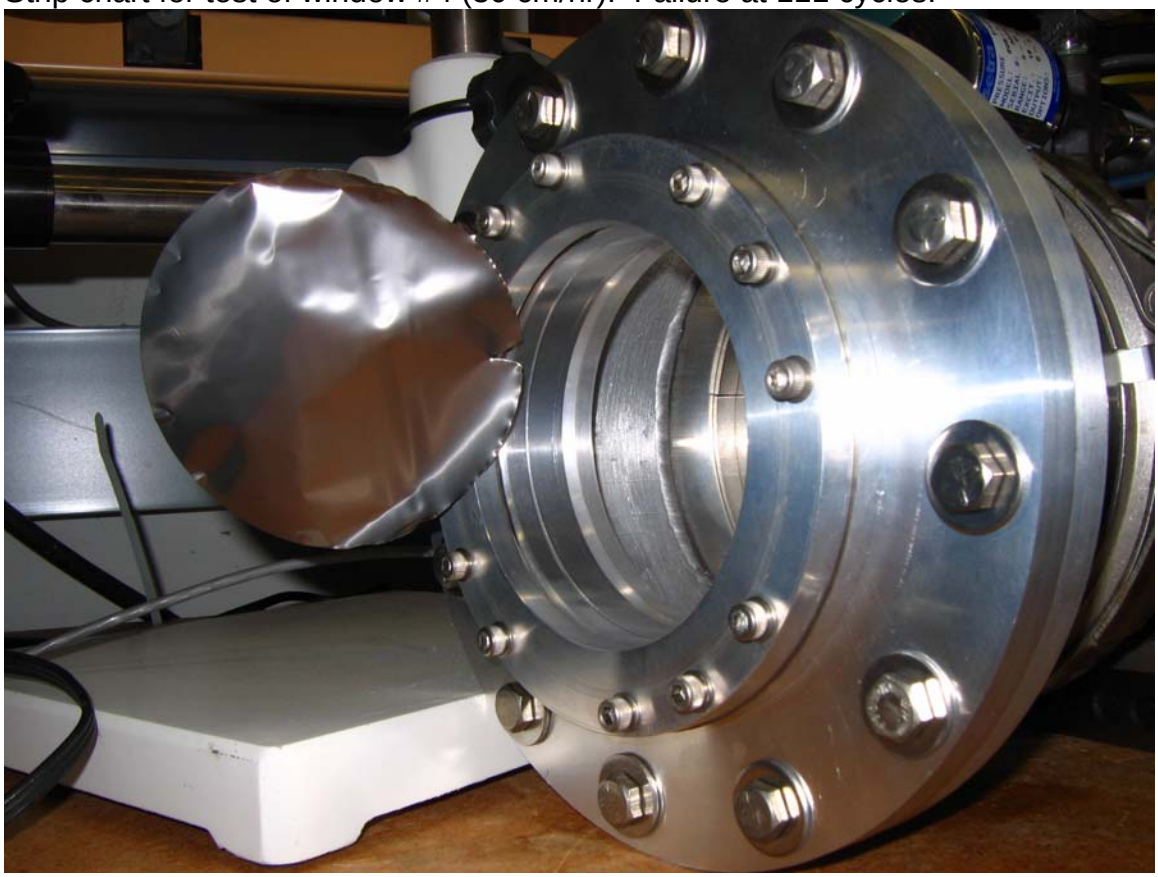


Window #2 after failure at 128 cycles. Window completely blew out of flange.

Window #3 after failure at an unknown # of cycles.



Strip chart for test of window #4 (30 cm/hr). Failure at 111 cycles.



Window #4 after failure at 111 cycles. Window almost blew out of flange.

Fermilab

Date: 9/27/07

EXHIBIT B
Pressure Testing Permit*

Type of Test: [ ]Hydrostatic [X] Pneumatic

Test Pressure 30 psig **Maximum Allowable Working Pressure** 15 psig

Items to be Tested
4 inch diameter, 0.003" thick titanium window. Window has to be "proof" tested to 30 psig before it can be used in the beam line.

Location of Test PAB Calibration Shop **Date and Time** 9/28/07

Hazards Involved
Bursting of thin titanium window which will create a loud noise and possible very light flying debris.

Safety Precautions Taken
Safety glasses and ear protection will be worn by those present. Window will be directed away from personnel.

Special Conditions or Requirements

Qualified Person and Test Coordinator Terry Tope
Dept/Date PPD/MD/PE

Division/Section Safety Officer
Dept/Date

Results
Window passed 30 psig proof test T. Tope

Witness (Safety Officer or Designee) **Dept/Date** 9-28-07

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

Fermilab ES&H Manual 5034TA-1
Revised 3/2001

Window to be installed into the beamline was pressure tested to 30 psig.

Relief Valve Sizing for the Meson Test Beam Facility Differential Cerenkov

The Meson Test Beam Facility differential cerenkov counter will be operated with nitrogen gas. The vessel will operate from full vacuum up to its relief valve set point of 8 psig.

Nitrogen is supplied by a 160 liter high pressure stockroom dewar located outside the gas shed on the west side of the MS4 service building. This supply is backed up by two nitrogen cylinders located inside the gas shed. Print ME-397793 provides a schematic of this gas system. Both sources of nitrogen are relieved at 100 psig and typically operate at a much lower regulated pressure. The nitrogen flows thru 1,000 inches of ¼" copper tubing and then 800 inches of 3/8" black poly tubing. The gas delivery tube lengths were taken from the vacuum vessel engineering note for vessel PPD10093, the previous vessel to occupy this space in the beam line. For ease of calculation, the only restriction considered is the ¼ inch tubing. The restriction provided by the numerous valves between the gas source and the vessel is ignored as is the section of 3/8 inch tubing. The maximum flow that can be delivered thru the ¼ inch tubing is calculated using equation 3-20 from Crane's Technical Paper 410 which is applicable to the discharge of compressible fluid thru pipe.

$$q_m^{'} = 412\frac{Yd^2}{S_g}\sqrt{\frac{\Delta P \rho_1}{K}}$$

where

q_m' = net rate of flow, in cubic feet per minute at standard conditions (SCFM).
Y = net expansion factor for compressible flow through pipe (found from chart on page A-22 in Crane's Technical Paper 410, 0.71).
d = internal diameter of pipe, inches (0.19 in. for ¼ in. copper tube).
S_g = specific gravity of a gas (1.0 for nitrogen).
ΔP = differential pressure between inlet and outlet (a function of K and P_1', found from chart on page A-22, the full available pressure drop of 98 psi is used as a conservative value).
P_1' = inlet pressure, psia (100*1.1 + 14.7 = 124.7 psia, which is the maximum supply pressure that occurs when the supply relief is at 10% over pressure).
ρ_1 = density of gas at inlet (0.6278 lbm ft^{-3} for nitrogen at 124.7 psia and 70 ^oF).
K = resistance coefficient calculated from the following

$$K = f\frac{L}{D}$$

where

f = friction factor found from chart on page A-25 where f is a function of the Reynolds number (Re), 0.038.

L = length of pipe in feet (1000 inches = 83.3 feet of the ¼ inch tubing)
D = pipe internal diameter in feet (Internal diameter of ¼ inch refrigeration tubing is 0.19 inches which is 0.01583 feet).

The Reynolds number is found from

$$\mathrm{Re} = 0.482\frac{q_h^{'}S_g}{d\mu}$$

where

μ = viscosity of nitrogen in centipoise (0.01743 cp for nitrogen at 124.7 psia and 60 ^{o}F).

Using a simultaneous equation solver, the calculations yield

$$q_m^{'} = 412\frac{0.71(0.19)^2}{1.0}\sqrt{\frac{(98.0)0.6278}{200.0}} = 5.86\ SCFM$$ of nitrogen.

$$K = 0.038\frac{83.3}{0.01583} = 200.0$$

$$\mathrm{Re} = 0.482\frac{(5.86)60(1.0)}{(0.19)0.01743} = 51143.$$

The vessel is equipped with a Circle Seal D532B-4M relief valve set at 8 psig. Interpolating from the flow table provided by Circle Seal yields a flow of 15 SCFM for a 4M valve with an 8 psig cracking pressure at 50% overpressure which is 12 psig.

The 15 SCFM relief valve capacity is greater than the 5.92 SCFM the nitrogen system can deliver. Thus the vessel will not exceed 12 psig of internal pressure.

Circle Seal 500 Series Relief Valve Capacities.

500 Series

.5–150 PSI

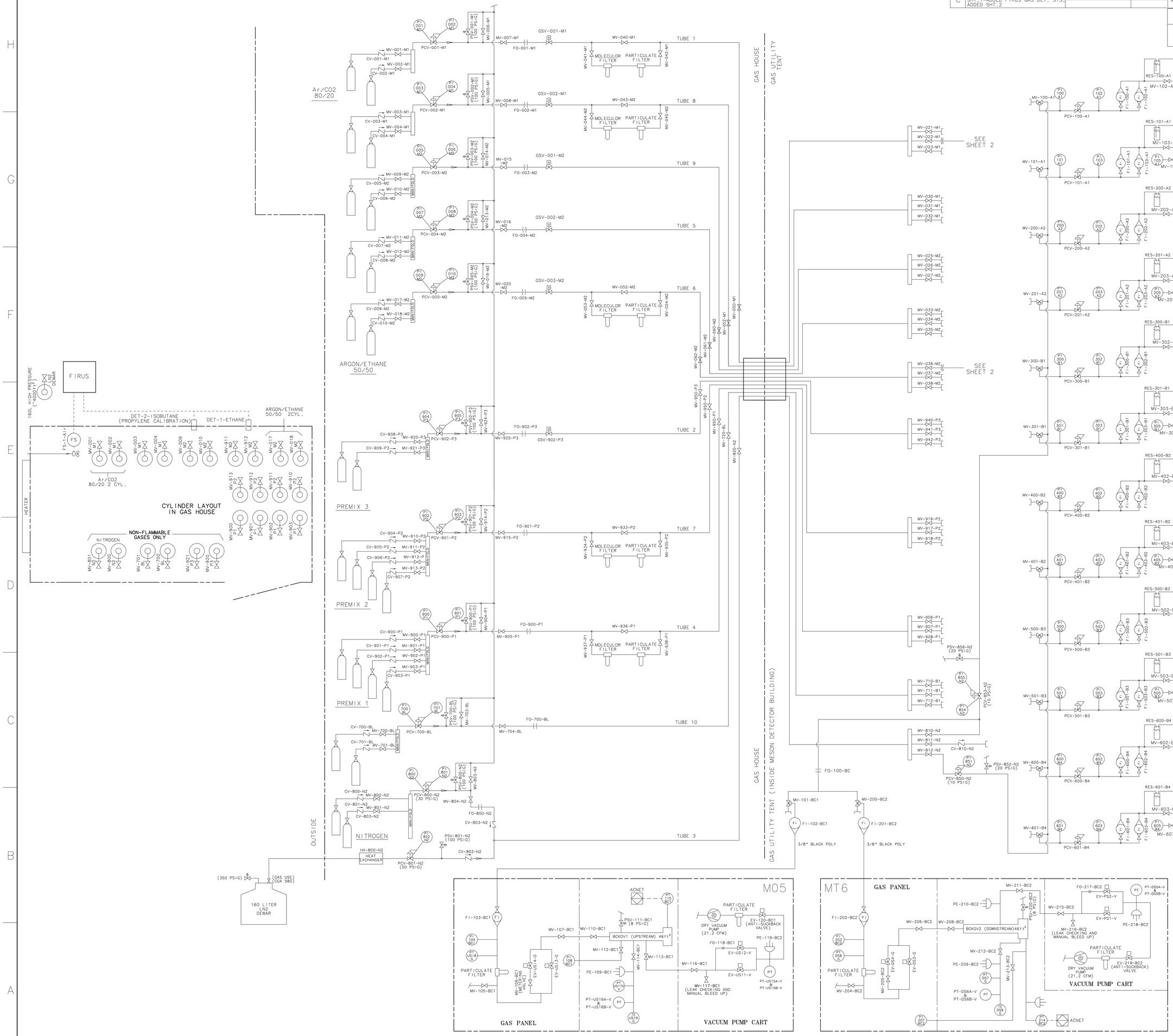
Air Flow Rates (500-M & -MP)

M—Popoff valves 1/2″–1″
MP—Inline valves 3/8″–1-1/4″

Crack Pressure PSIG	Percent Over Pressure Beyond Cracking (SCFM air at room temperature)								
	10%			25%			50%		
	4M/6MP	6M/8MP	8M/10MP	4M/6MP	6M/8MP	8M/10MP	4M/6MP	6M/8MP	8M/10MP
.5	.07	.07	—	.50	.50	—	.80	2.2	—
1	.10	.10	—	.70	.70	—	1.7	3.2	—
1.5	.30	.30	—	1.0	1.4	—	2.2	5.5	—
2	.50	.50	—	1.2	1.7	—	3.0	7.0	—
2.5	.60	.60	—	1.8	3.0	—	4.2	10.5	—
3	.80	.80	—	2.2	4.0	—	5.0	13	—
4	1.0	1.0	1.5	3.0	5.0	30	7.5	17	56
5	1.0	1.2	2.5	3.5	6.0	34	9.0	20	64
10	1.0	2.4	7.0	6.0	12	60	19	40	115
15	1.6	3.0	7.0	8.5	22	60	27	80	160
20	2.0	5.0					34	110	190
25	3.0	5.5					43	116	—
30	3.5	6.0					50	121	—
40	5.5	8.5					72	136	—
50	7.0	10					90	150	—
60	11	13					100	165	—
70	15	17					111	182	—
80	20	21	77	56	81	215	123	204	—
90	26	26	88	68	94	235	138	225	—
100	30	30	100	75	105	250	150	240	—
110	33	38	115	80	112	258	166	—	—
120	37	47	132	86	125	270	183	—	—
130	41	57	150	93	150	282	201	—	—
140	46	71	175	102	163	290	222	—	—
150	50	80	190	110	175	300	240	—	—

Interpolate to 15 SCFM for 8 psig cracking pressure

REV	DESCRIPTION	DRAWN	DATE
		APPROVED	DATE
A	UPDATED AND REVISED	N.CADENA	11/19/02
		T.TOPE	11/20/02
B	UPDATED AND REVISED,ADDED SET POINT TO SAFTY VALVES,ADDED BCKOV 1 & 2 AND ASSOC. INSTRUMENTATION,AND GAS HOUSE BOTTLE LAYOUT,AND MV-102-BC,MV-202-BC ADDED FI,PSV-100,200-BC,MV-105,205-BC PT-102,202-BC,FO-100-BC	N.CADENA	8/24/04
		T.TOPE	8/26/04
C	SHT.1-ADDED FIRUS GAS DET. SYS. ADDED SHT.2	N.CADENA	9/13/05



UNLESS OTHERWISE SPECIFIED			ORIGINATOR	T.TOPE	00-MAR-2002
.XX	.XXX	ANGLES	DRAWN	N.CADENA	26-APR-2002
±	±	± 1°	CHECKED	T.TOPE	05-JUN-2002
1. BREAK ALL SHARP EDGES MAX. 2. DO NOT SCALE DRAWING. 3. DIMENSIONS BASED UPON ASME Y14.5M-1994 4. MAX. ALL MACH. SURFACES 125 5. DRAWING UNITS: U.S.INCH			APPROVED	T.TOPE	05-JUN-2002
			USED ON		
			MATERIAL		

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

PPD/MECHANICAL DEPARTMENT
MESON TEST BEAM GAS SYSTEM
PIPING & INSTRUMENTATION DIAGRAM

SCALE	DRAWING NUMBER	SHEET	REV
NONE	9214.000-ME-397793	1 OF 2	C

CREATED WITH : Ideas12NXSeries GROUP: PPD/MECHANICAL DEPARTMENT

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