Absorber Issues and Design

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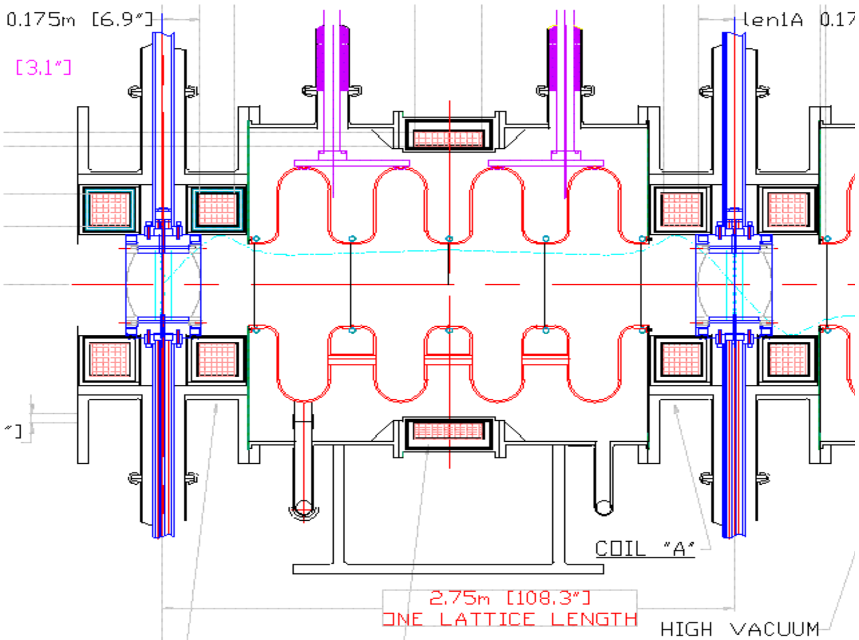
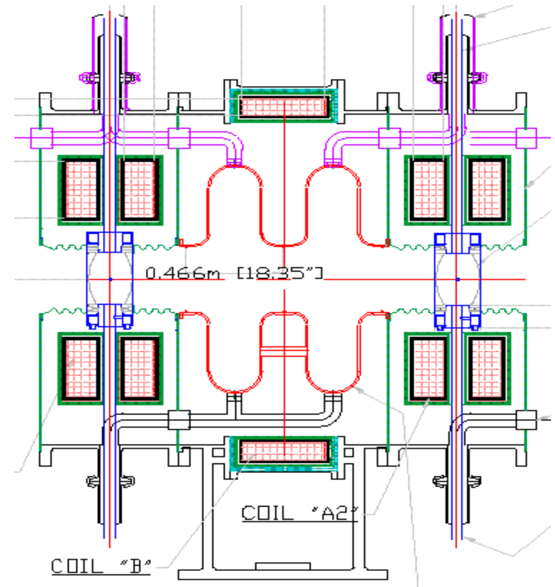
for absorber group: IIT/NIU/Miss/FNAL

Study 2 Editors' Meeting
LBL
2 Oct. 2000

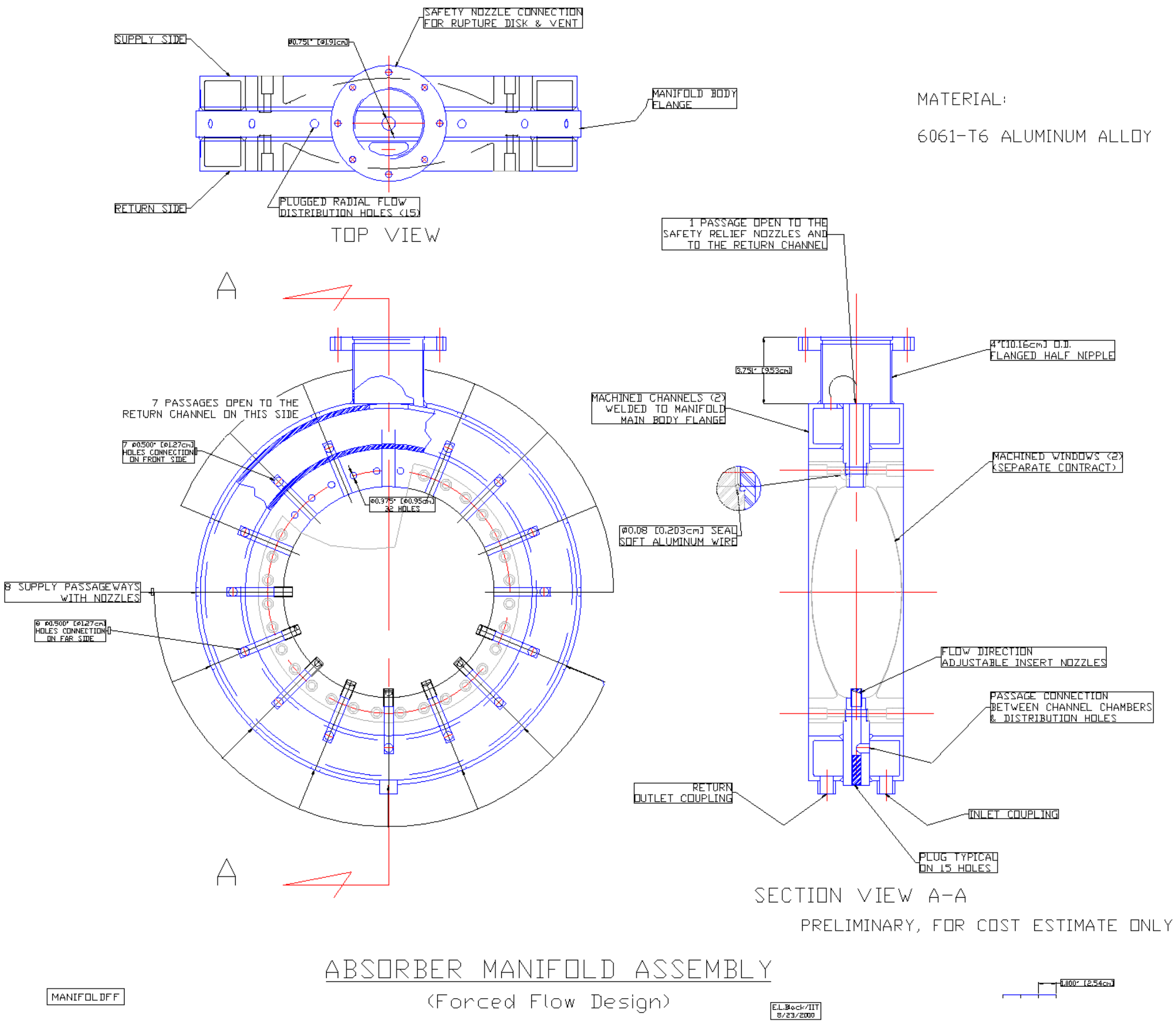
SFOFO Lattices 1 & 2 Layouts (preliminary):



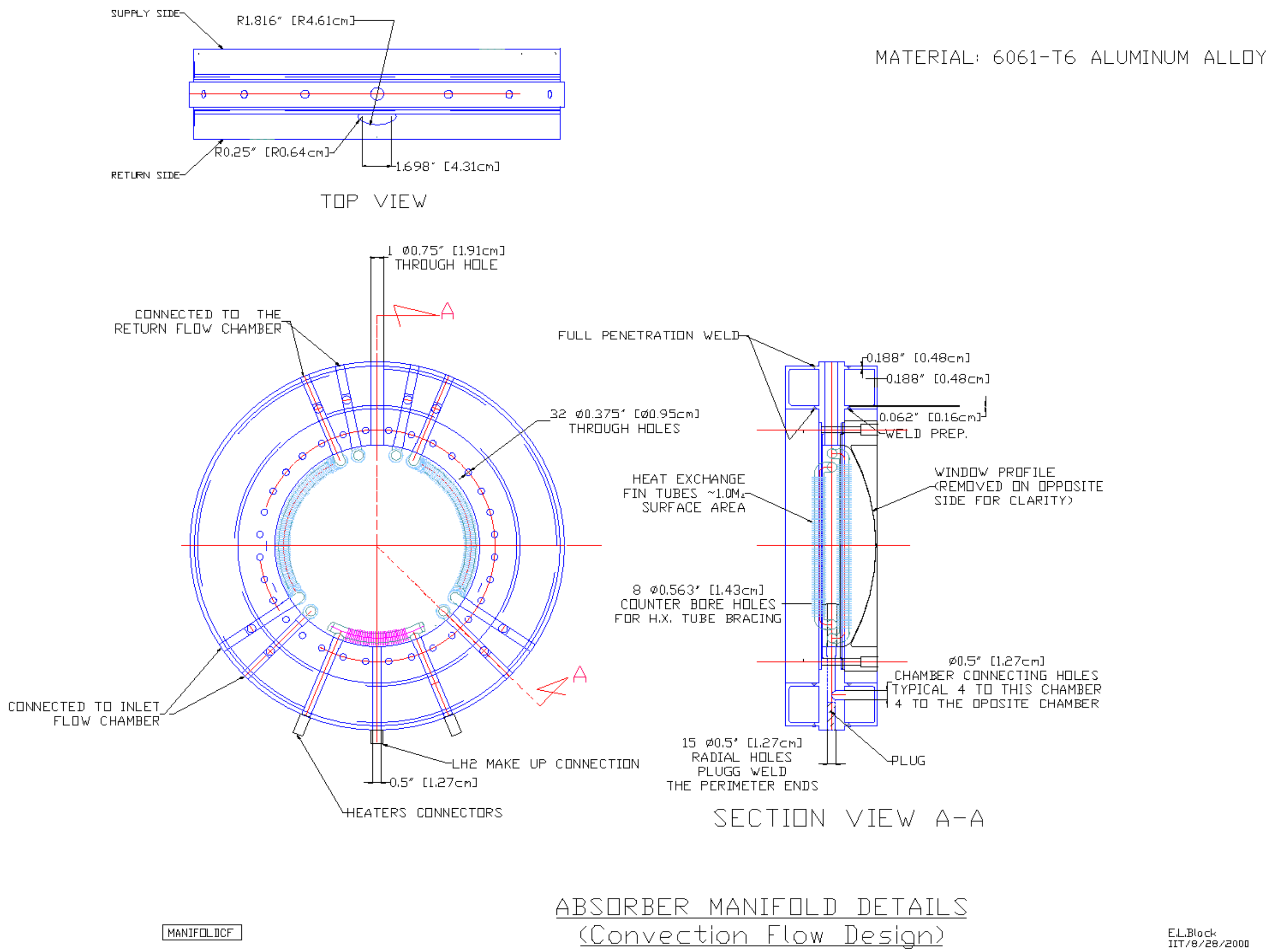


(cost estimates)

Manifold design (forced-flow):



Manifold design (convection):



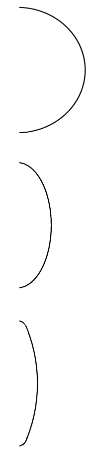
Window Thickness

- ASME UG-32, head thickness for pressure vessels:

hemispherical: $$t = \frac{0.5PL}{SE - 0.1P}, \quad s = L = 0.5D$$

ellipsoidal: $$t = \frac{0.5PD}{SE - 0.1P}, \quad s = 0.25D$$

torispherical: $$t = \frac{0.885PD}{SE - 0.1P}, \quad s = 0.169D$$



where
P = pressure differential
L = radius of curvature
D = length of major axis
S = max allowable stress
E = weld efficiency
s = sagitta

Notes: 1. ellipsoid has (major axis) = 2 × (minor axis)
2. "torisphere" has r_2 = 6% r_1

- Fermilab/ASME safety factors:
  S = smaller of $S_u/4$, $S_y/1.5$

SFOFO Absorbers & Windows (6061-T6):

P (Mpa)	Case	Abs. (m)	Rad. (m)	Hemis. (µm)	Cyl.Ln. (m)	Ellips. (µm)	Cyl.Ln. (m)	Toris. (µm)	Des. A (µm)

1 atm:

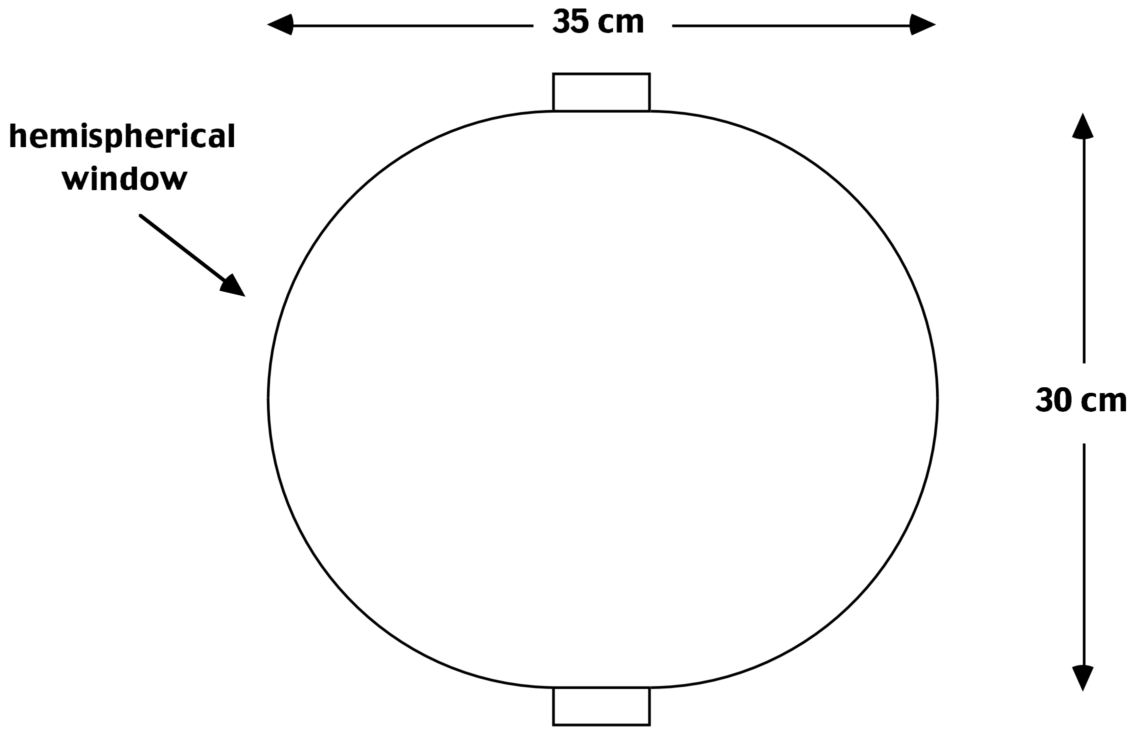
P (Mpa)	Case	Abs. (m)	Rad. (m)	Hemis. (µm)	Cyl.Ln. (m)	Ellips. (µm)	Cyl.Ln. (m)	Toris. (µm)	Des. A (µm)
0.101	1.1	0.35	0.18	126	-0.01	**252**	0.17	445	**200**
0.101	1.2	0.35	0.15	105	0.05	**210**	0.20	371	**250**
0.101	1.3	0.35	0.13	91	0.09	**182**	0.22	322	**130**
0.101	2.1	0.21	0.11	77	-0.01	**154**	0.10	272	**110**
0.101	2.2	0.21	0.1	70	0.01	**140**	0.11	247	**100**
0.101	2.3a	0.21	0.09	63	0.03	**126**	0.12	223	**90**
0.101	2.3b	0.21	0.08	56	0.05	**112**	0.13	198	**80**

?

2 atm:

P (Mpa)	Case	Abs. (m)	Rad. (m)	Hemis. (µm)	Cyl.Ln. (m)	Ellips. (µm)	Cyl.Ln. (m)	Toris. (µm)	Des. A (µm)
0.202	1.1	0.35	0.18	252	-0.01	503	0.17	891	**200**
0.202	1.2	0.35	0.15	210	0.05	419	0.20	742	**250**
0.202	1.3	0.35	0.13	182	0.09	363	0.22	643	**130**
0.202	2.1	0.21	0.11	154	-0.01	308	0.10	544	**110**
0.202	2.2	0.21	0.1	140	0.01	280	0.11	495	**100**
0.202	2.3a	0.21	0.09	126	0.03	252	0.12	445	**90**
0.202	2.3b	0.21	0.08	112	0.05	224	0.13	396	**80**

Fluid-flow design issues favor flatter windows



Problems:

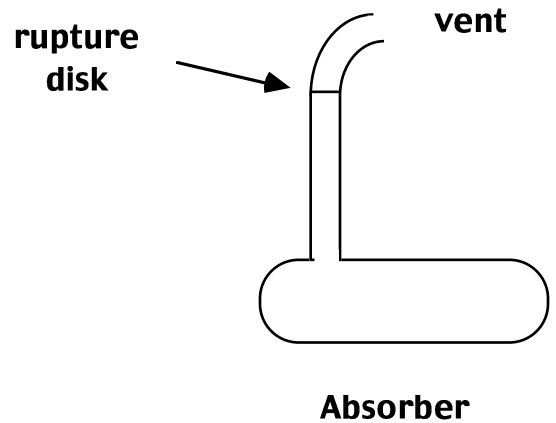
- Fluid-flow calculation necessarily 3D
- Cooling of windows and LH_2 near them by convection or jets difficult

⇒ Torispherical and ellipsoidal shapes favored over hemispherical

1-atm operation?

- **Key safety issue:** need rupture disk in case of excessive overpressure

  If rupture disk breaks, H_2 must vent:



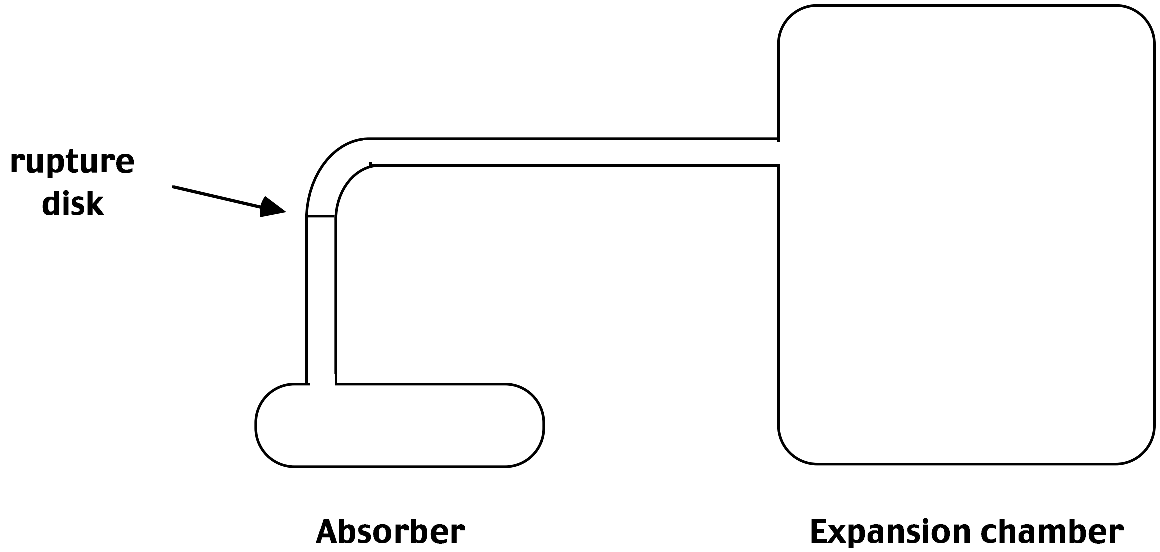
- If absorber at 1 atm, rupture disk below 1 atm

  ⇒ air could leak in and freeze, clogging vent

→ **Proposed solution** (J. Kilmer): run absorber at substantial overpressure w.r.t. surrounding atmosphere ⇒ ≈2 atm

Alternative solution?

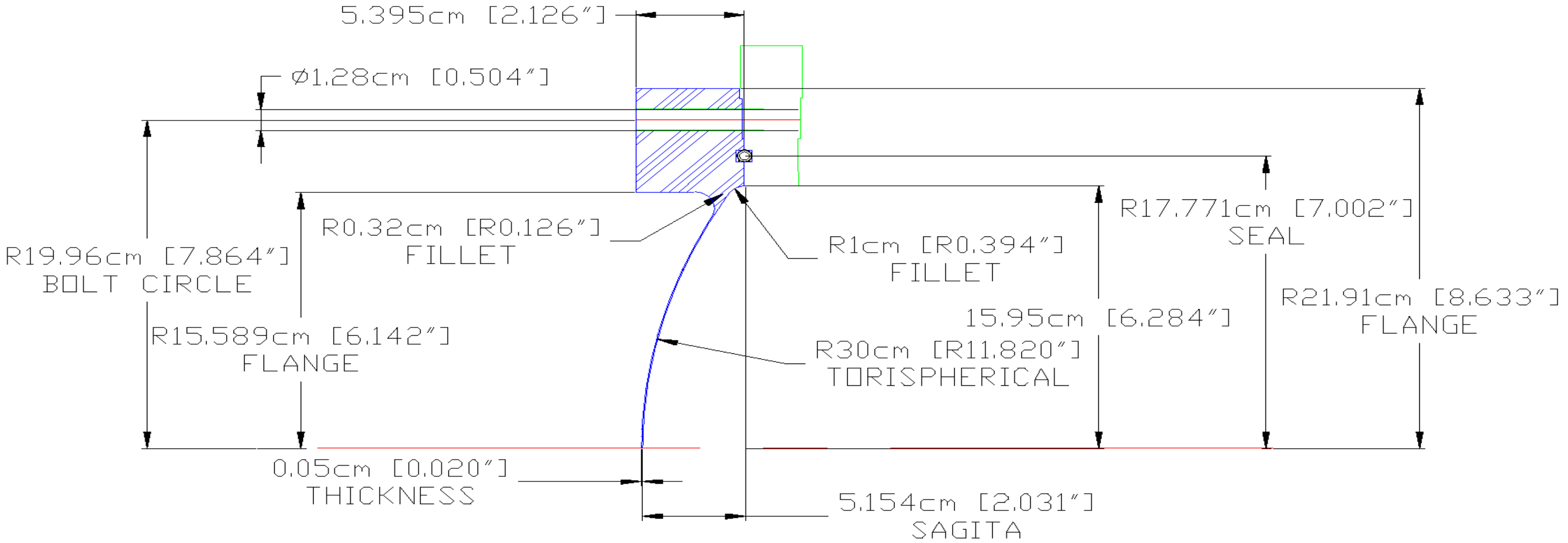
- Vent into evacuated expansion chamber
  (req'd anyway to avoid explosion hazard?)



⇒ **Need to work this through in detail!**

But ≈1-atm operation looks feasible in principle

Window shape (preliminary):



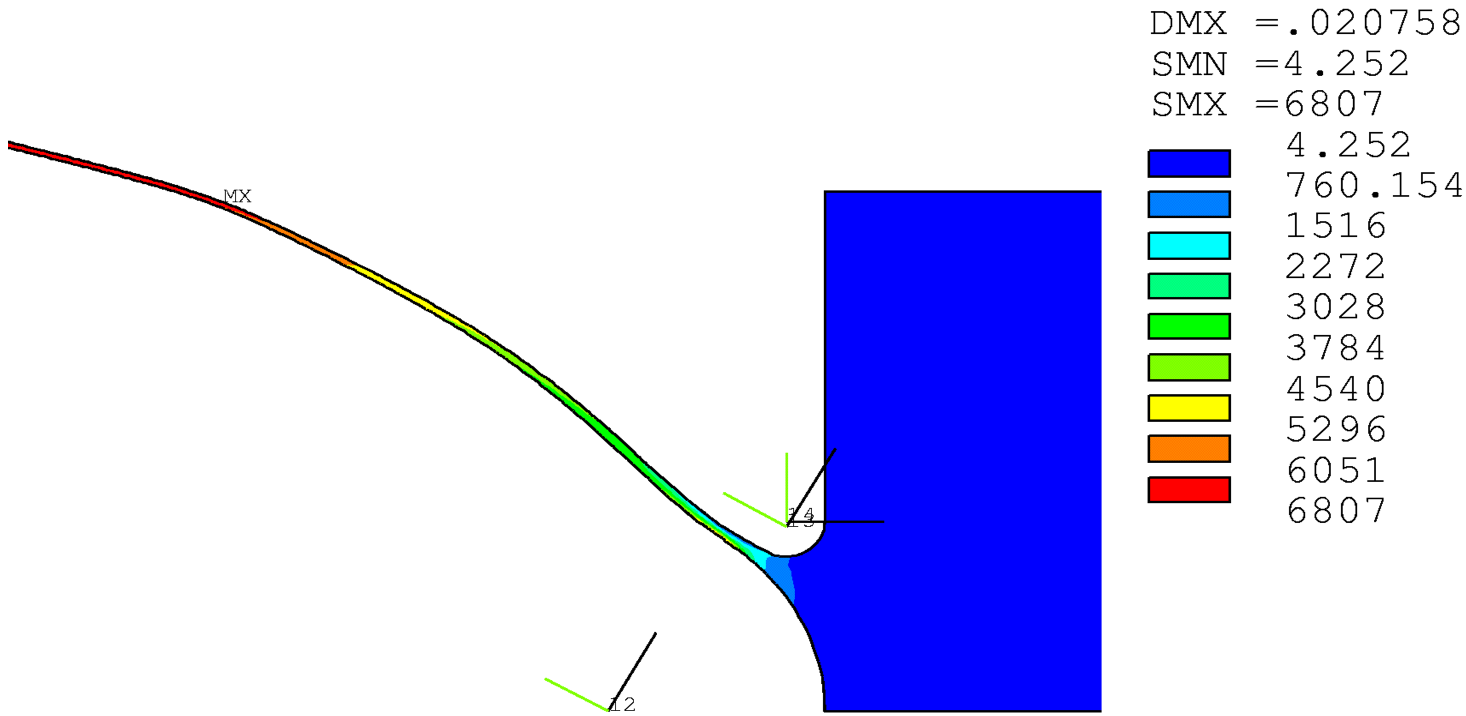
MACHINED WINDOW DETAIL

MATERIAL: 6061T6 ALUMINUM ALLOY

PRESSURE (ON COCAVE SIDE): 2 ATMOSPHERES

Window stress (preliminary):

(E. Black, M. Cummings, Z. Tang)



- Modified "torisphere" w/ sagitta = 5 cm, radius = 15 cm, pressure = 2 atm
- Max stress = 68 MPa vs. ANSI tensile strength of 6061-T6 Al = 289 MPa

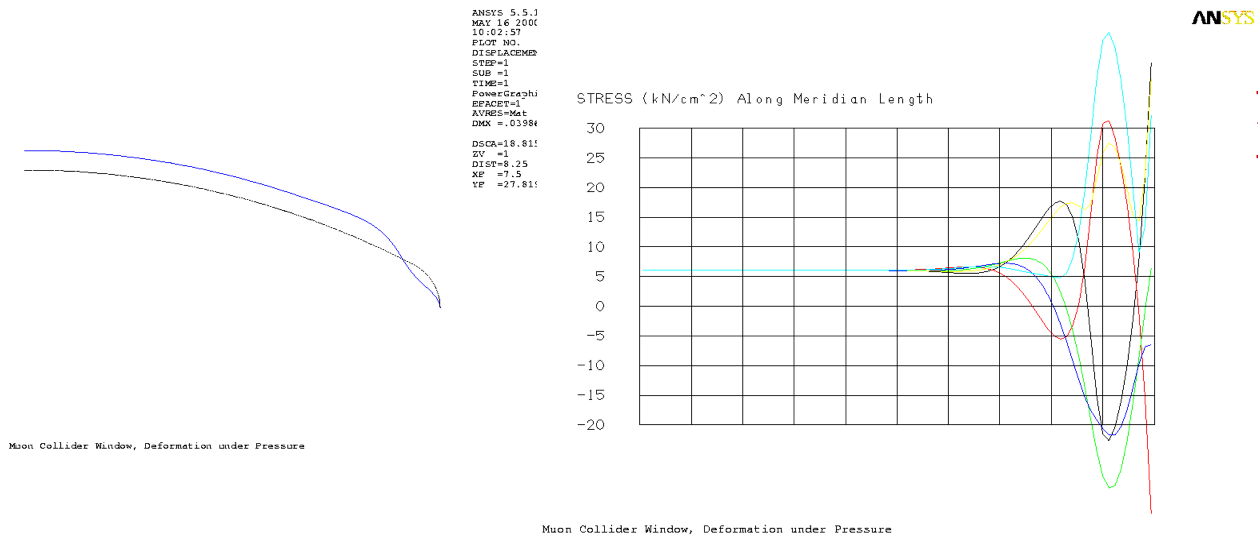
  ⇒ Safety factor satisfied since 289/69 = 4.25
- Center thickness = 500 μm, 20% worse than ellipsoidal w/ r = 15 cm

  ⇒ ≈×2 too thick for design A

→ **May be some additional optimization possible**

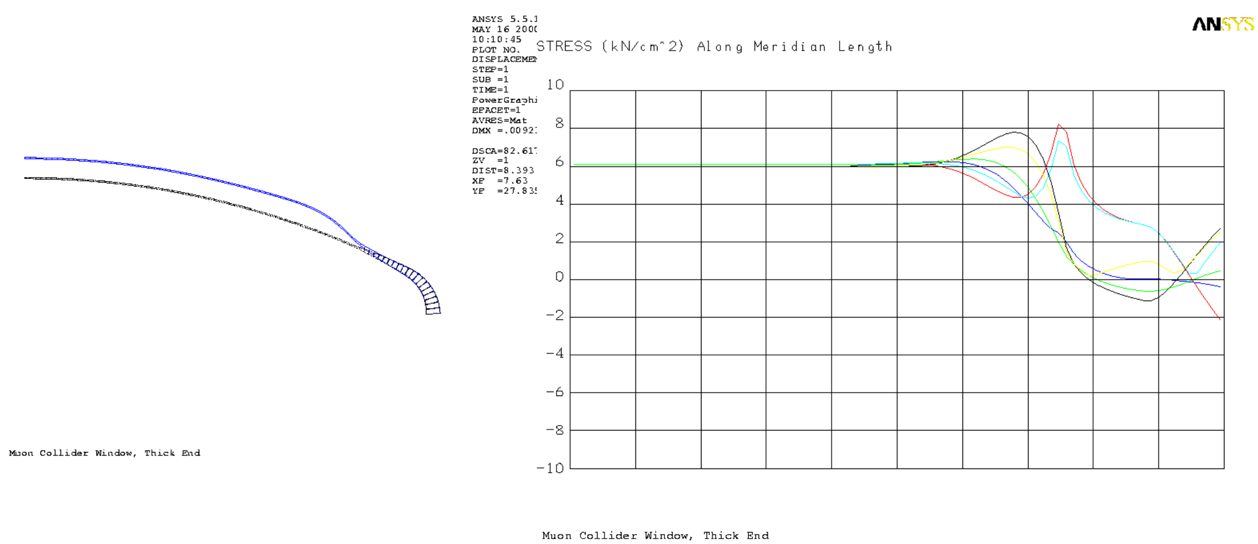
1st window taper study

(spring '00)



(a) Uniform thickness.

gain ≈ x 5



(b) Tapered profile.

(found: max stress near knee – but neglected add'l stress on window due to flange)

Aluminum alloy info:

(D. Summers)

Alloy	Compos.	(by	weight)	...	Dens.	Yld. Str.	Tensile Str.		Rad. Ln.
	(%)	(%)	(%)	(%)	(g/cc)	(MPa)@300K	(MPa)@300K	@20K	(cm)
6061-T6	1.0Mg	6Si	0.3Cu	2Cr	2.70	280	310	470	8.86
5083-T0	4.4Mg	0.7Mn	0.15Cr		2.66	145	290	480	8.99
7075-T6	2.5Mg	5.6Zn	1.6Cu	2Cr	2.80	440	520	793	8.04
2090-T8	2.7Cu	2.2Li	0.12Zr		2.59	510	570	830	9.18

⇒ Could go ≈45% thinner if 2090-T8 OK for cryo applications

- Also investigating AlBeMet and beryllium options

- **NOTE:** Al alloys contain high-*Z* elements

→ Will (e.g.) single-scattering tail or straggling cause problems?

⇒ Should simulate with accurate alloy composition!

Milestones:

I. Design/construct/test absorber window (IIT/NIU/MISS)

1. 10/00 design certification to meet applicable safety codes (including test fixture and procedures)
2. 1/01 construction of 1st prototypes and test fixture
3. 2/01 pressure-test 1st prototypes
4. ongoing evaluate alternative window materials (under discussion for collaboration with KEK)

II. Design/test fluid flow (IIT)

1. 10/00 “flow-through-design” certification
2. 2/01 assemble “flow-through-design” room-temp. model
3. 3/01 test “flow-through-design” room-temp. model
4. 5/01 “convective-design” certification
5. 6/01 assemble “convective-design” room-temp. model
6. 7/01 test “convective-design” room-temp. model

(Items 5 and 6 are under discussion for collaboration with KEK.)

III. Design/construct/test refrigeration system (FNAL)

1. 1/01 occupancy of absorber cryo test area at FNAL
2. 3/01 cryo system bench test

IV. Design/construct/test absorber assembly (IIT/UIUC/NIU/FNAL)

1. 5/01 design certification
2. 7/01 complete construction of 1st prototypes and test fixtures
3. 8/01 begin absorber bench testing
4. 1/02 begin absorber high-power beam test

Conclusions:

1. Long (SFOFO) absorbers technically easier than short (FOFO)
2. Design A has aggressive window parameters
   $\rightarrow$ need R&D to establish feasibility
3. Operation at $\approx$1 atm appears feasible in principle
4. Development of window fabrication techniques now in progress
5. Plan pressure test of window prototypes in early 2001
6. Exploration of alternative materials beginning
7. More detailed window-material simulations desirable
8. Detailed structural engineering is tricky
   – FEA underway