DESIGN OF A REMOVABLE DECAY PIPE WINDOW FOR LBNF

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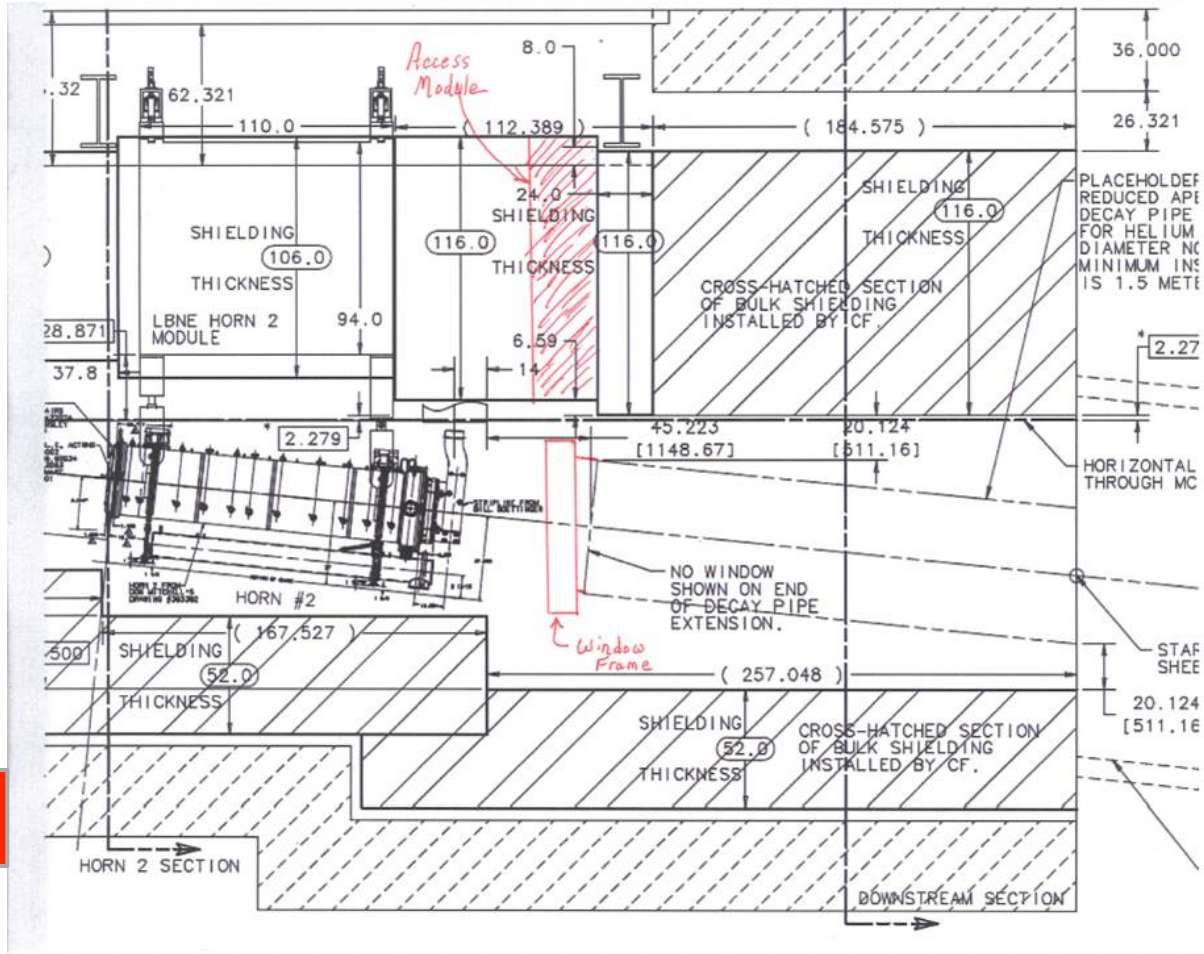
Dave Pushka, Eric James

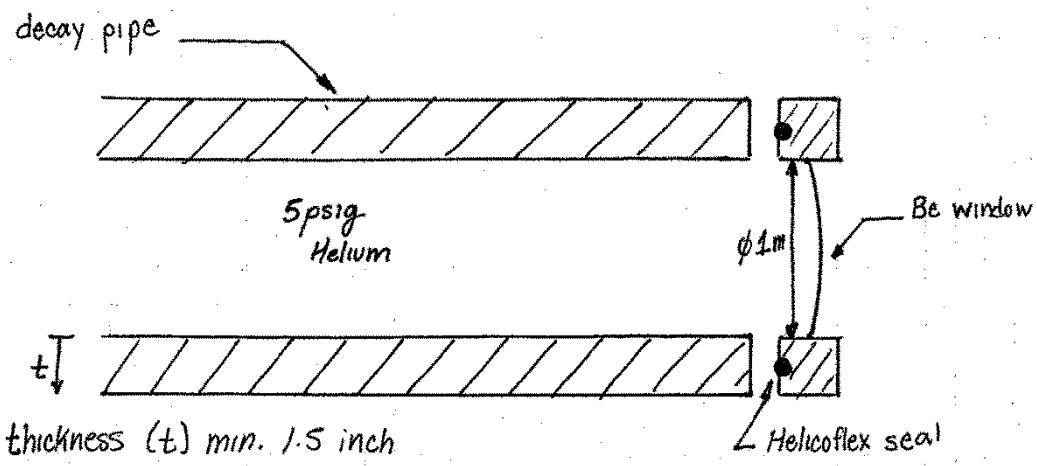
GEM Summer 2014

Project Specifications

- Positive Helium pressure 5psig
- Operation at 700 kW and 2.3MW
- Window diameter of 1 meter
- Previous analysis suggests that window should be curved and made of beryllium
- Remotely Removable

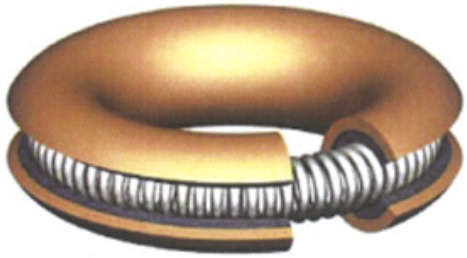


Design Challenge



- 5psig,
- 1 meter diameter opening (window)
- Leak rate less than 10^-6 Std.cc/sec
- O-ring can't be elastomer!
- Remotely apply/remove seating force
- Remotely extract/position window

Proposed Solution: Helicoflex Seal



Helicoflex Design Guide

DEFINITION OF TERMS

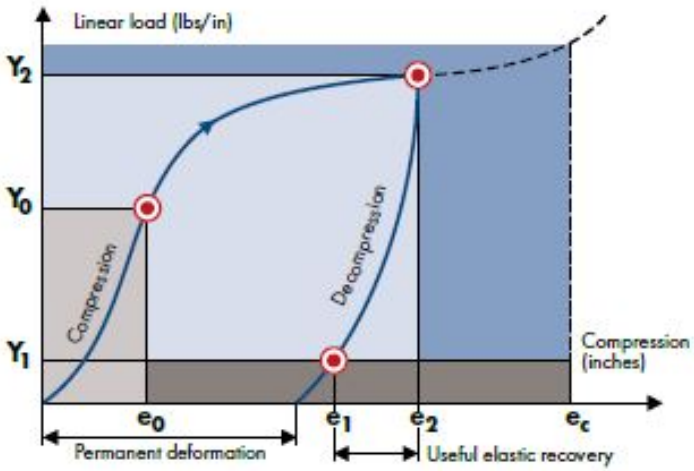
Y_0 = load on the compression curve above which leak rate is at required level

Y_2 = load required to reach optimum compression e2

Y_1 = load on the decompression curve below which leak rate exceeds required level

e_2 = optimum compression

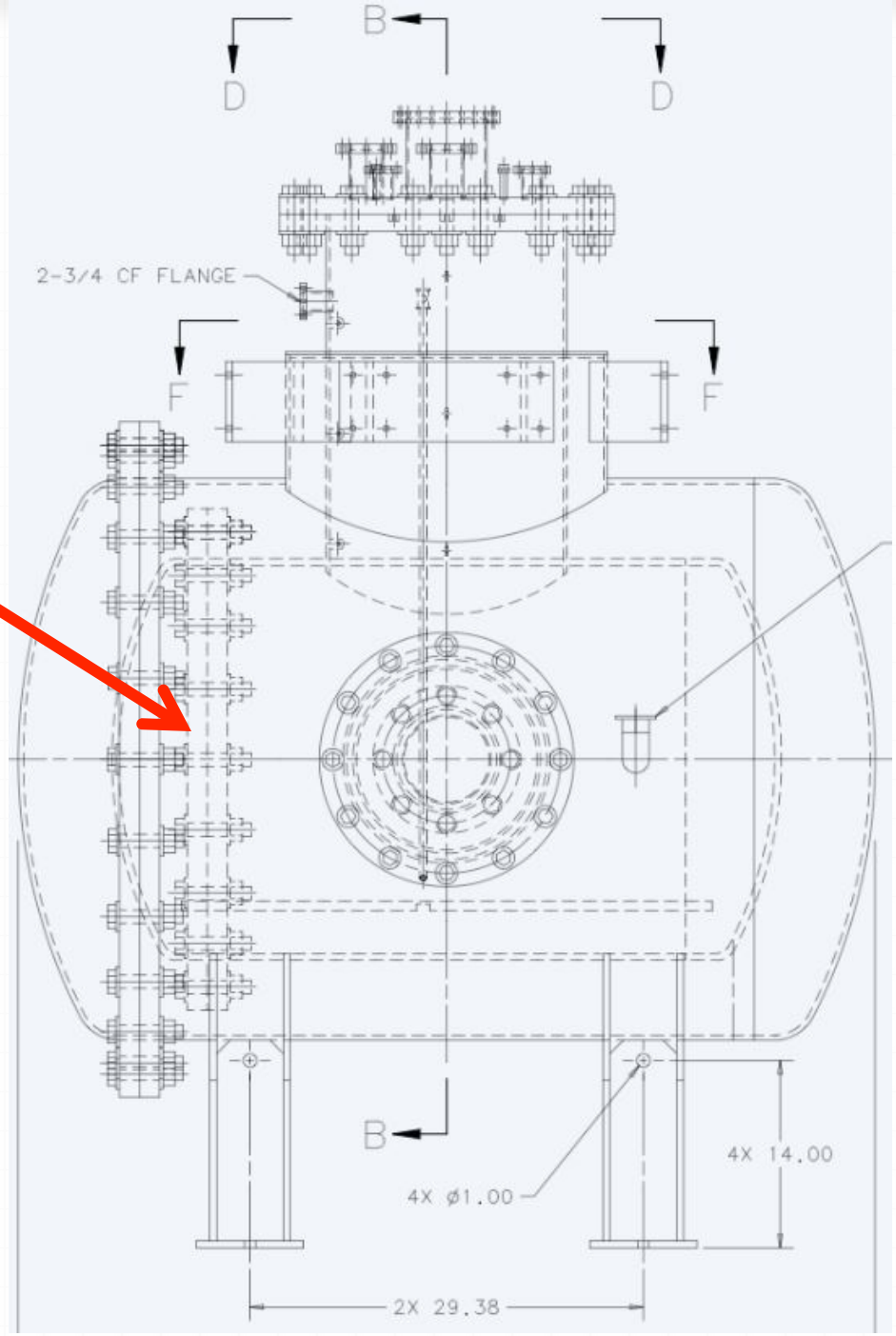
e_c = compression limit beyond which there is risk of damaging the spring



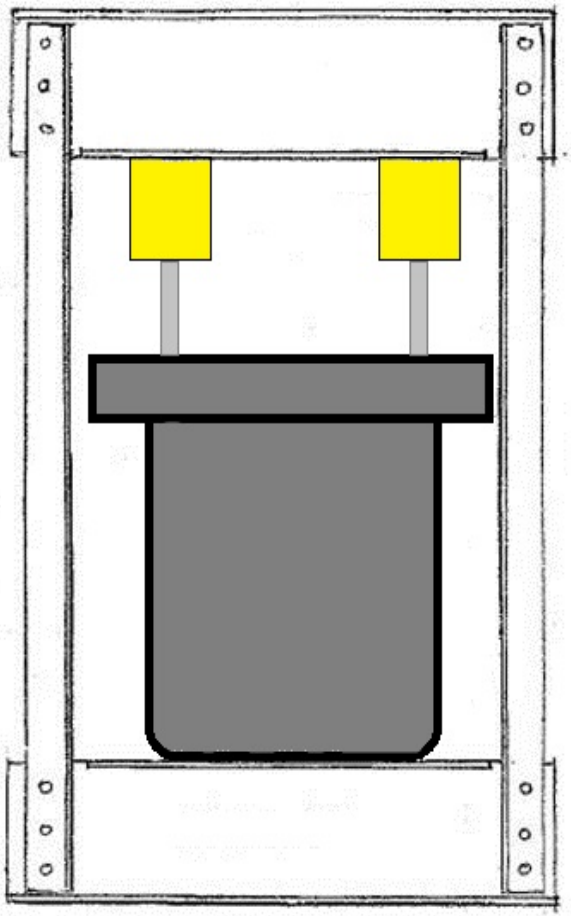
Jacket Material	HELIUM SEALING							BUBBLE SEALING					Dimensions in inches
	Cross Section	e_2	e_c	Y_2 lbs/inch	Y_1 lbs/inch	Pu68°F PSI	Pu392°F PSI	Y_2 lbs/inch	Y_1 lbs/inch	Pu68°F PSI	Pu392°F PSI	Max Temp °F	
Aluminum	0.063	0.024	0.028	857	114	7250	N/A	514	114	5075	N/A	302	
	0.075	0.028	0.033	914	114	7540	N/A	571	114	5800	N/A	302	
	0.087	0.028	0.035	942	114	7685	N/A	600	114	5800	N/A	356	
	0.098	0.028	0.035	999	114	7975	725	657	114	6090	725	428	
	0.118	0.031	0.039	1056	143	7975	1450	742	114	6525	1450	482	
	0.138	0.031	0.039	1085	143	7975	2030	799	114	6815	2030	482	
	0.157	0.035	0.043	1142	143	8700	2465	857	114	7250	2465	536	
	0.177	0.035	0.047	1199	143	8700	2900	914	114	7540	2900	536	
	0.197	0.035	0.055	1256	171	9135	3190	971	143	7975	3190	572	
	0.217	0.035	0.063	1313	171	9425	3480	1028	143	8265	3480	608	
	0.236	0.039	0.071	1399	200	9715	3625	1113	171	8700	3625	644	
	0.276	0.039	0.087	1542	228	10150	4060	1171	200	9425	4060	644	
	0.315	0.039	0.102	1656	286	10440	4640	1285	228	9860	4495	680	

Possible testing Flanges

The vessel with the flange is INSIDE another vessel!



Houston, we have lift off!



Helicoflex Engineering Drawing

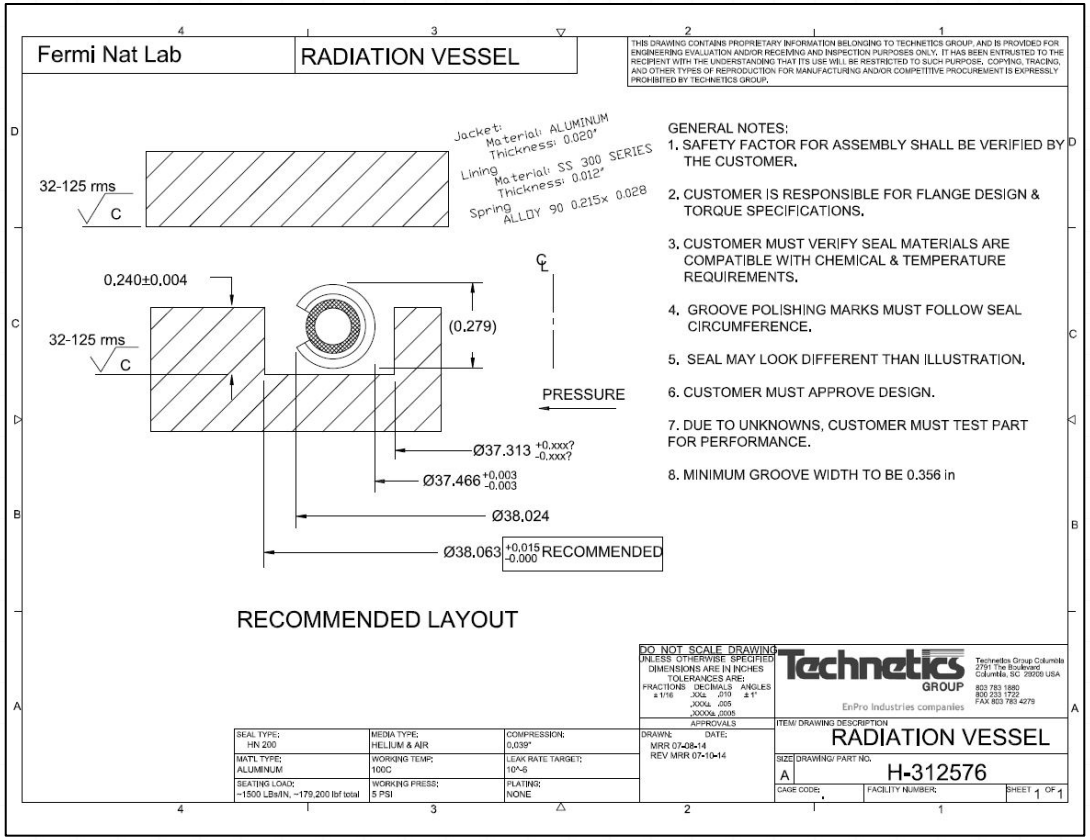
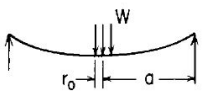
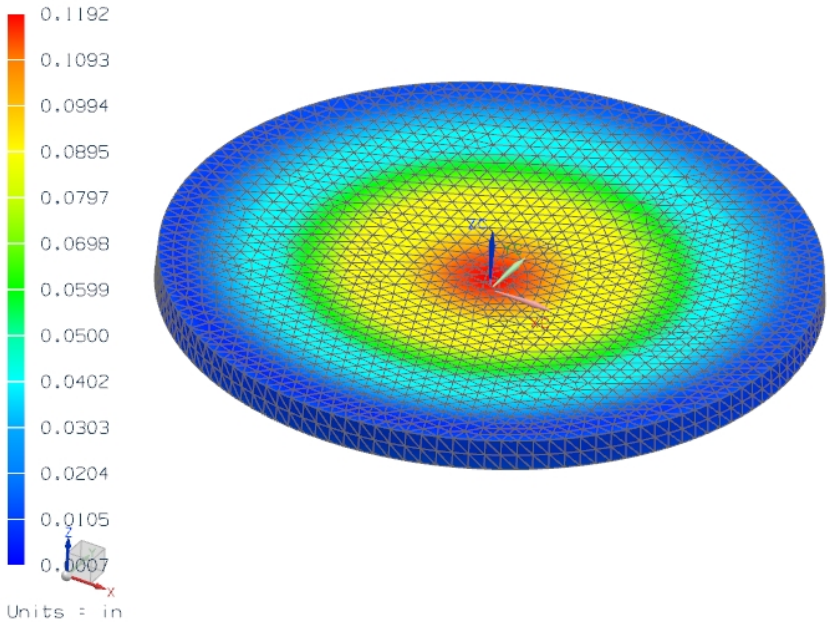
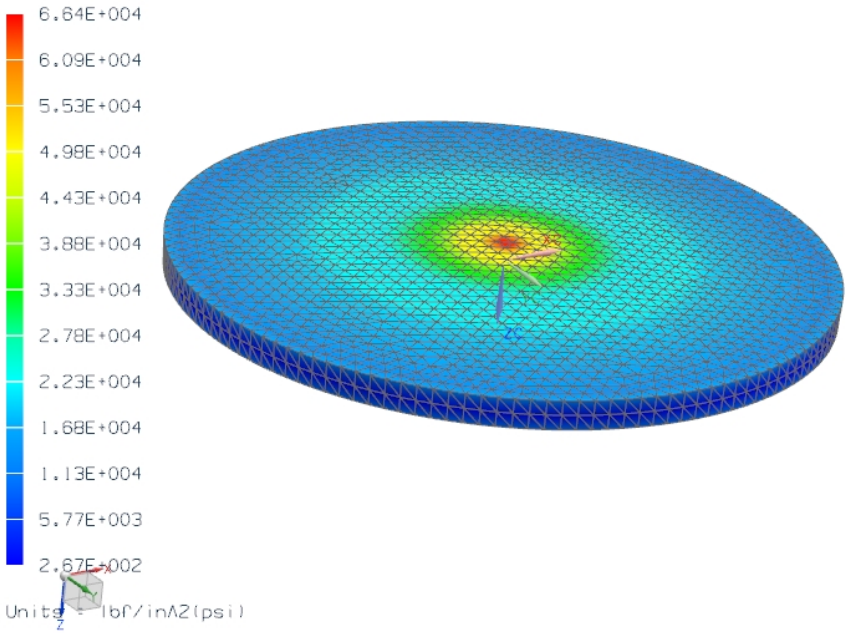
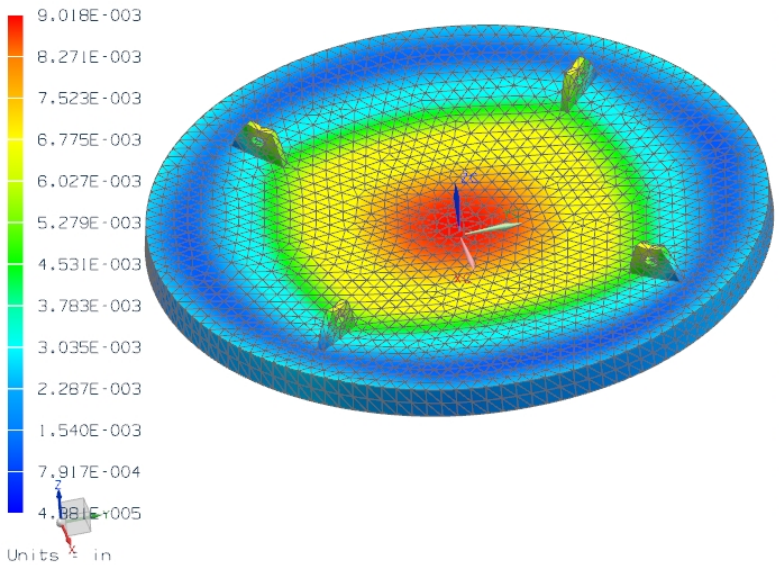


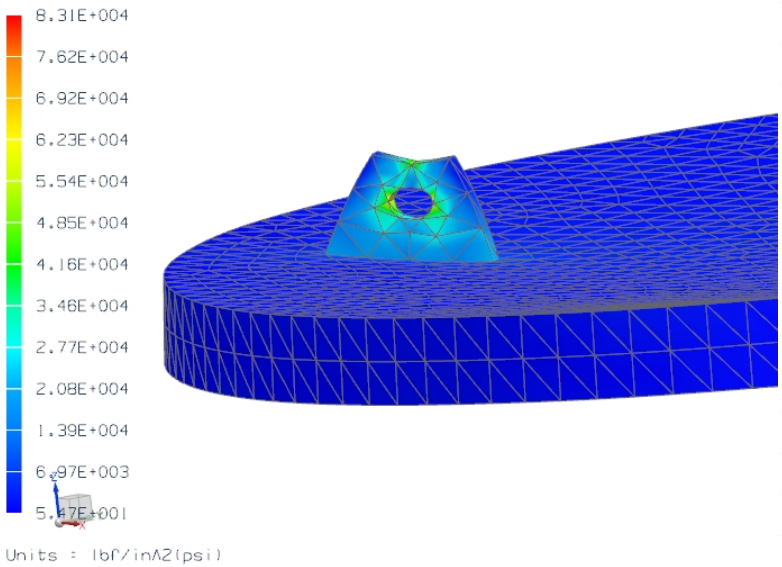
Plate Analysis

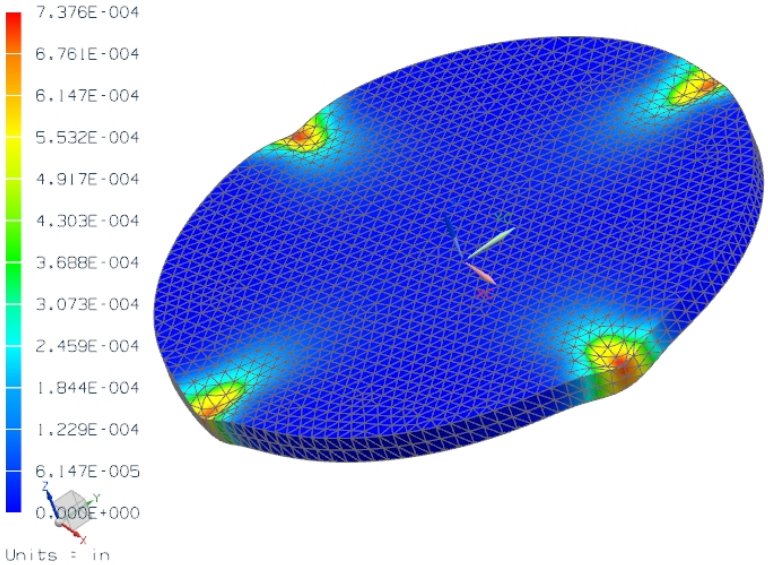
Case no., loading, restraints	Formulas	Special cases
16. Uniform load over a very small central circular area of radius r_o; edge simply supported  $W = q\pi r_o^2$	For $r > r_o$ $y = \frac{-W}{16\pi D}\left[\frac{3+\nu}{1+\nu}(a^2 - r^2) - 2r^2 \ln\frac{a}{r}\right]$ $\theta = \frac{Wr}{4\pi D}\left(\frac{1}{1+\nu} + \ln\frac{a}{r}\right)$ $M_r = \frac{W}{16\pi}\left[4(1+\nu)\ln\frac{a}{r} + (1-\nu)\left(\frac{a^2 - r^2}{a^2}\right)\frac{r_o'^2}{r^2}\right]$ where $r_o' = \sqrt{1.6r_o^2 + t^2} - 0.675t$ if $r_o < 0.5t$ or $r_o' = r_o$ if $r_o > 0.5t$ $M_t = \frac{W}{16\pi}\left[4(1+\nu)\ln\frac{a}{r} + (1-\nu)\left(4 - \frac{r_o'^2}{r^2}\right)\right]$	$y_{\max} = \frac{-Wa^2}{16\pi D}\frac{3+\nu}{1+\nu}$ at $r = 0$ $\theta_{\max} = \frac{Wa}{4\pi D(1+\nu)}$ at $r = a$ $(M_r)_{\max} = \frac{W}{4\pi}\left[(1+\nu)\ln\frac{a}{r_o'} + 1\right]$ at $r = 0$ $(M_t)_{\max} = (M_r)_{\max}$ at $r = 0$






9.018E-003
8.271E-003
7.523E-003
6.775E-003
6.027E-003
5.279E-003
4.531E-003
3.783E-003
3.035E-003
2.287E-003
1.540E-003
7.917E-004
4.881E-005
Units : in


8.31E+004
7.62E+004
6.92E+004
6.23E+004
5.54E+004
4.85E+004
4.16E+004
3.46E+004
2.77E+004
2.08E+004
1.39E+004
6.97E+003
5.47E+001
Units : lbf/in^2(psi)


7.376E-004
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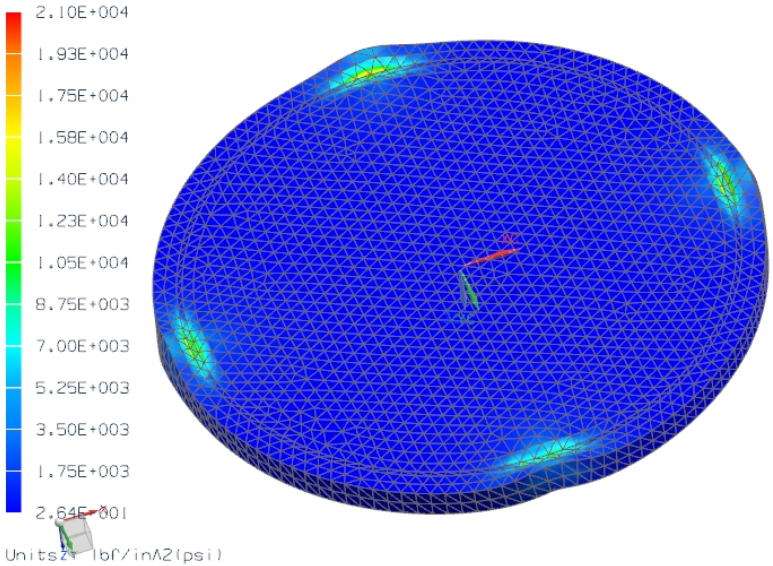
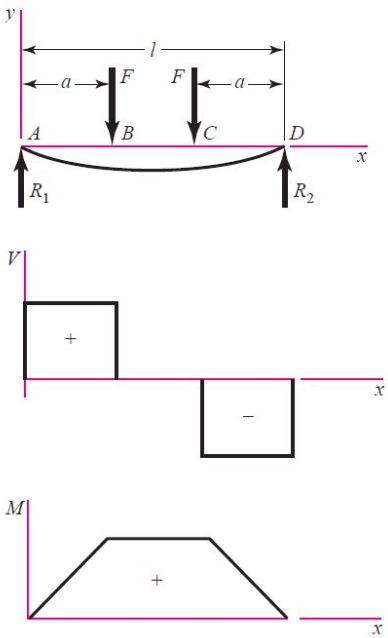
6.147E-004
5.532E-004
4.917E-004
4.303E-004
3.688E-004
3.073E-004
2.459E-004
1.844E-004
1.229E-004
6.147E-005
0.000E+000
Units : in


2.10E+004
1.93E+004
1.75E+004
1.58E+004
1.40E+004
1.23E+004
1.05E+004
8.75E+003
7.00E+003
5.25E+003
3.50E+003
1.75E+003
2.64E-001
Units : lbf/in^2(psi)

Beam Analysis

9 Simple supports—twin loads



$$R_1 = R_2 = F \qquad V_{AB} = F \qquad V_{BC} = 0$$

$$V_{CD} = -F$$

$$M_{AB} = Fx \qquad M_{BC} = Fa \qquad M_{CD} = F(l - x)$$

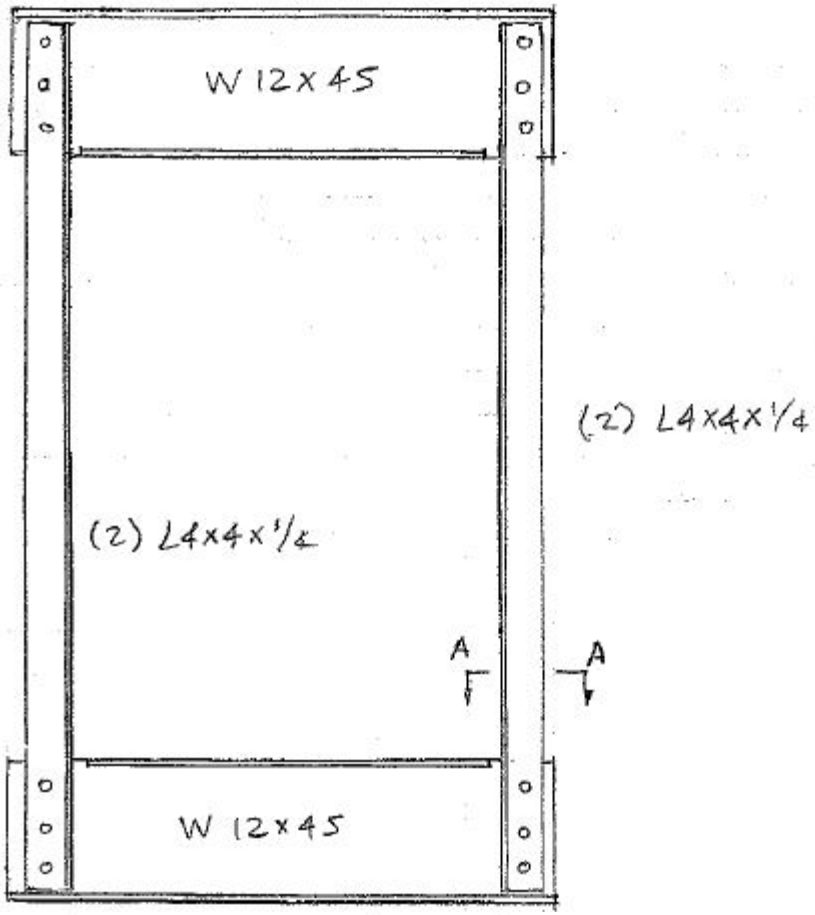
$$y_{AB} = \frac{Fx}{6EI}(x^2 + 3a^2 - 3la)$$

$$y_{BC} = \frac{Fa}{6EI}(3x^2 + a^2 - 3lx)$$

$$y_{\max} = \frac{Fa}{24EI}(4a^2 - 3l^2)$$

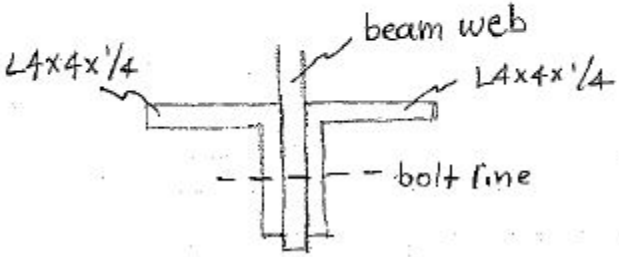
Failure Modes:

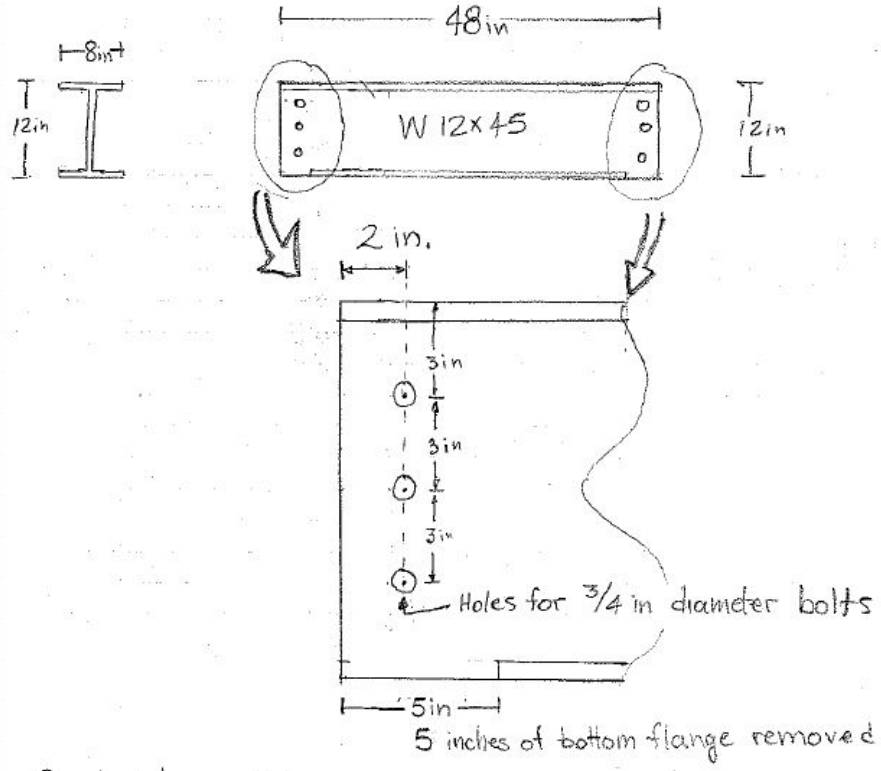
Tension rupture of angles
Bolt shear
Bolt bearing on angles
Shear yielding of angles
Shear rupture of angles
Block shear rupture of angles
Yielding due to bending of beam
Lateral torsional Buckling
Bolt bearing of beam web
Block shear rupture of beam web
Flexural rupture of coped section
Local web buckling at coped section
Shear yielding of web
Shear rupture of web



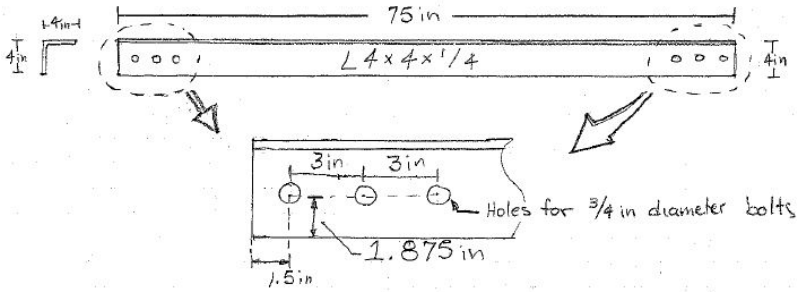
Double-Angle connections

Section A-A



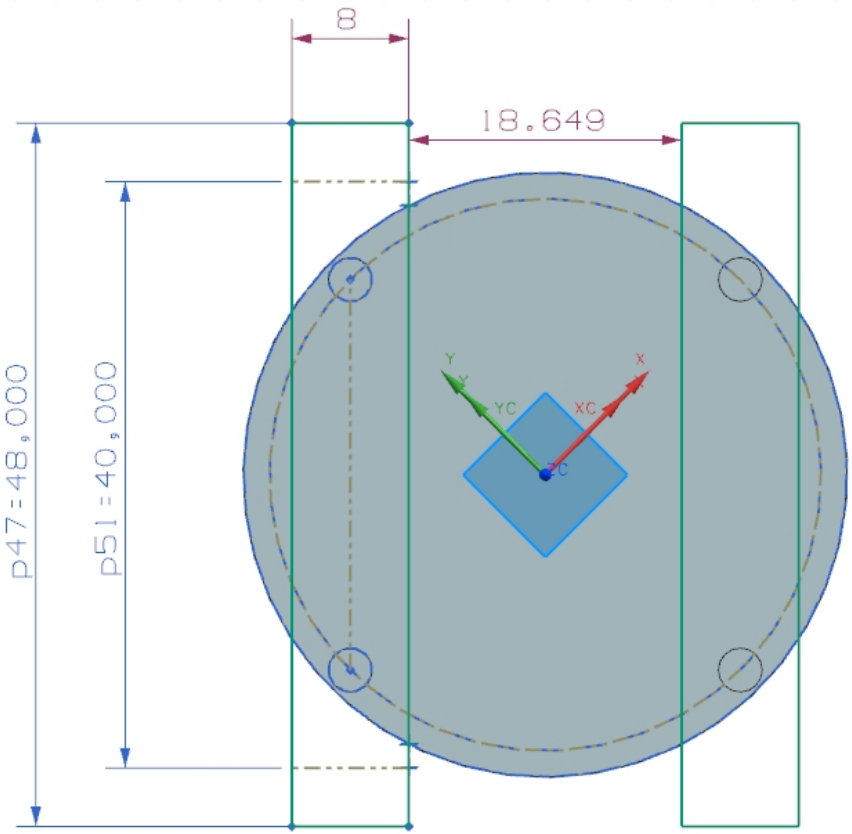


Quantity : 4 beams



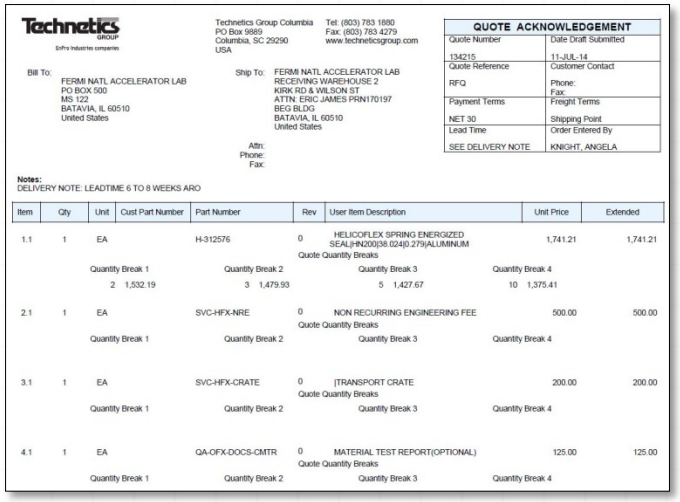
Quantity : 8 angles

TA-DA!



Next Steps for Seal Testing

- Spec hydraulic system
- Order Helicoflex Seals
- Break some seals!!



Technetics GROUP
Entro Industries companies

Technetics Group Columbia
PO Box 9889
Columbia, SC 29290
USA

Tel: (803) 783 1880
Fax: (803) 783 4279
www.techneticsgroup.com

QUOTE ACKNOWLEDGEMENT	
Quote Number	Date Draft Submitted
134215	11-JUL-14
Quote Reference	Customer Contact
RFQ	Phone: Fax:
Payment Terms	Freight Terms
NET 30	Shipping Point
Lead Time	Order Entered By
SEE DELIVERY NOTE	KNIGHT, ANGELA

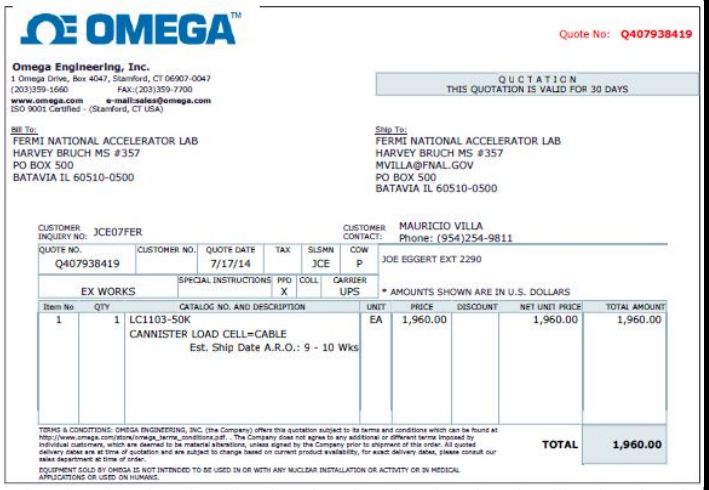
Bill To:
FERMI NATL ACCELERATOR LAB
PO BOX 500
MS 122
BATAVIA, IL 60510
United States

Ship To: FERMI NATL ACCELERATOR LAB
RECEIVING WAREHOUSE 2
KIRK RD & WILSON ST
ATTN: ERIC JAMES PRN170197
BEG BLDG
BATAVIA, IL 60510
United States

Attn:
Phone:
Fax:

Notes:
DELIVERY NOTE: LEADTIME 6 TO 8 WEEKS ARO

Item	Qty	Unit	Cust Part Number	Part Number	Rev	User Item Description	Unit Price	Extended
1.1	1	EA		H-312576	0	HELICOFLEX SPRING ENERGIZED SEAL[HN200][38.024][0.279][ALUMINUM	1,741.21	1,741.21
						Quote Quantity Breaks		
		Quantity Break 1		Quantity Break 2		Quantity Break 3	Quantity Break 4	
		2 1,532.19		3 1,479.93		5 1,427.67	10 1,375.41	
2.1	1	EA		SVC-HFX-NRE	0	NON RECURRING ENGINEERING FEE	500.00	500.00
						Quote Quantity Breaks		
		Quantity Break 1		Quantity Break 2		Quantity Break 3	Quantity Break 4	
3.1	1	EA		SVC-HFX-CRATE	0	[TRANSPORT CRATE	200.00	200.00
						Quote Quantity Breaks		
		Quantity Break 1		Quantity Break 2		Quantity Break 3	Quantity Break 4	
4.1	1	EA		QA-OFX-DOCS-CMTR	0	MATERIAL TEST REPORT(OPTIONAL)	125.00	125.00
						Quote Quantity Breaks		
		Quantity Break 1		Quantity Break 2		Quantity Break 3	Quantity Break 4	



OMEGA™

Quote No: Q407938419

Omega Engineering, Inc.
1 Omega Drive, Box 4047, Stamford, CT 06907-0047
(203)359-1660 FAX:(203)359-7700
www.omega.com e-mail:sales@omega.com
ISO 9001 Certified - (Stamford, CT USA)

QUOTATION
THIS QUOTATION IS VALID FOR 30 DAYS

Bill To:
FERMI NATIONAL ACCELERATOR LAB
HARVEY BRUCH MS #357
PO BOX 500
BATAVIA IL 60510-0500

Ship To:
FERMI NATIONAL ACCELERATOR LAB
HARVEY BRUCH MS #357
MVILLA@FNAL.GOV
PO BOX 500
BATAVIA IL 60510-0500

CUSTOMER INQUIRY NO. JCE07FER
CUSTOMER CONTACT: MAURICIO VILLA
Phone: (954)254-9811

QUOTE NO.	CUSTOMER NO.	QUOTE DATE	TAX	SLSMN	COW	
Q407938419		7/17/14		JCE	P	JOE EGGERT EXT 2290

SPECIAL INSTRUCTIONS	PPD	COLL	CARRIER
EX WORKS	X		UPS

* AMOUNTS SHOWN ARE IN U.S. DOLLARS

Item No	QTY	CATALOG NO. AND DESCRIPTION	UNIT	PRICE	DISCOUNT	NET UNIT PRICE	TOTAL AMOUNT
1	1	LC1103-50K CANNISTER LOAD CELL=CABLE Est. Ship Date A.R.O.: 9 - 10 Wks	EA	1,960.00		1,960.00	1,960.00

TERMS & CONDITIONS: OMEGA ENGINEERING, INC. (the Company) offers this quotation subject to its terms and conditions which can be found at http://www.omega.com/store/omega_terms_conditions.pdf. . The Company does not agree to any additional or different terms imposed by individual customers, which are deemed to be material alterations, unless signed by the Company prior to shipment of this order. All quoted delivery dates are at time of quotation and are subject to change based on current product availability, for exact delivery dates, please consult our sales department at time of order.

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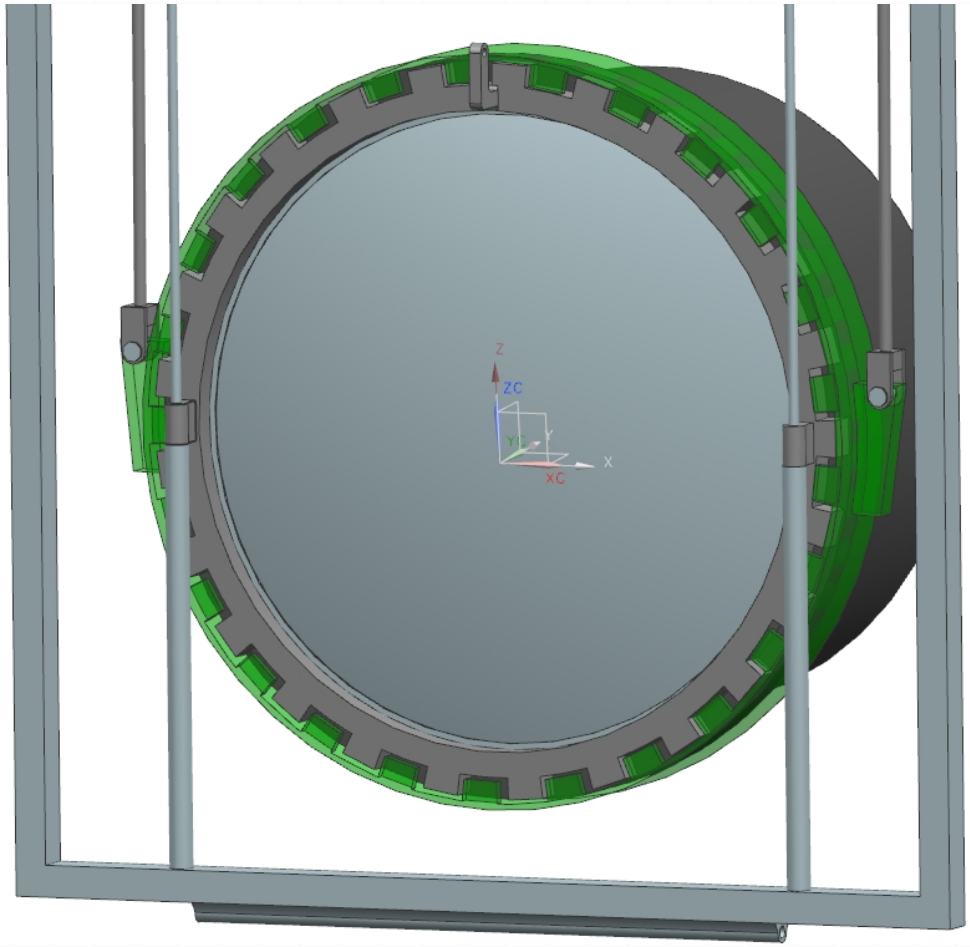
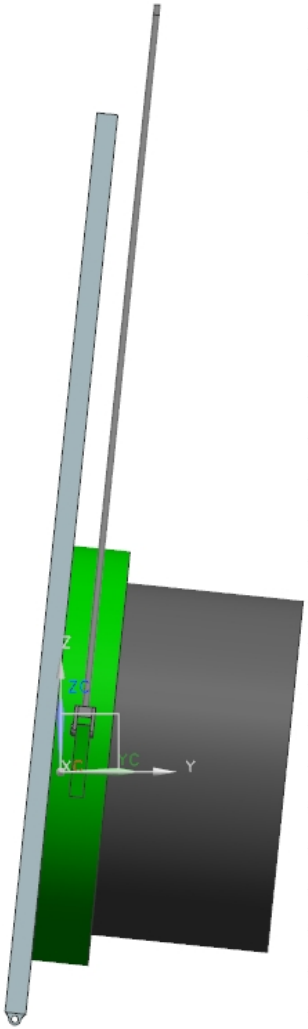
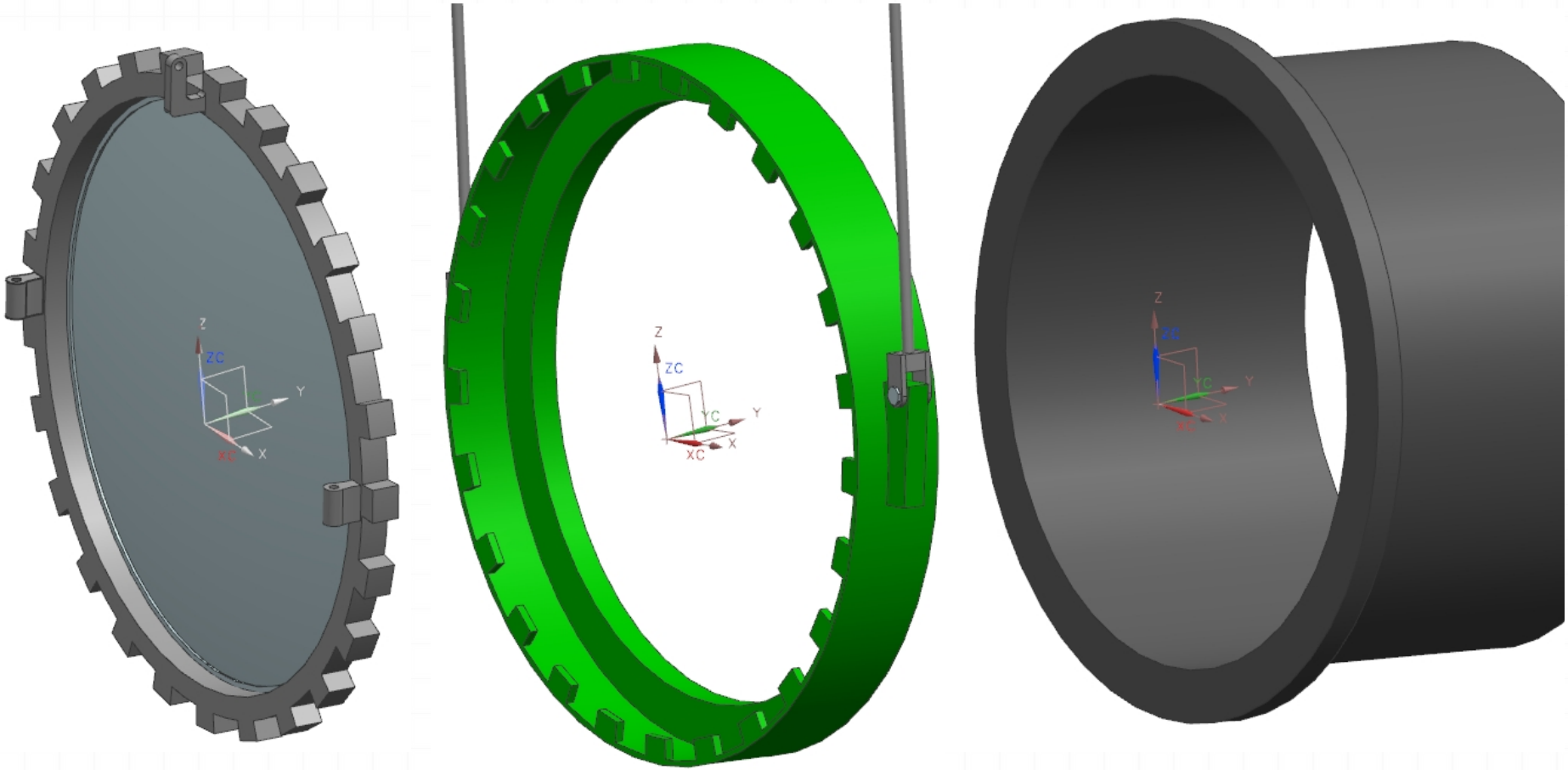
TOTAL 1,960.00

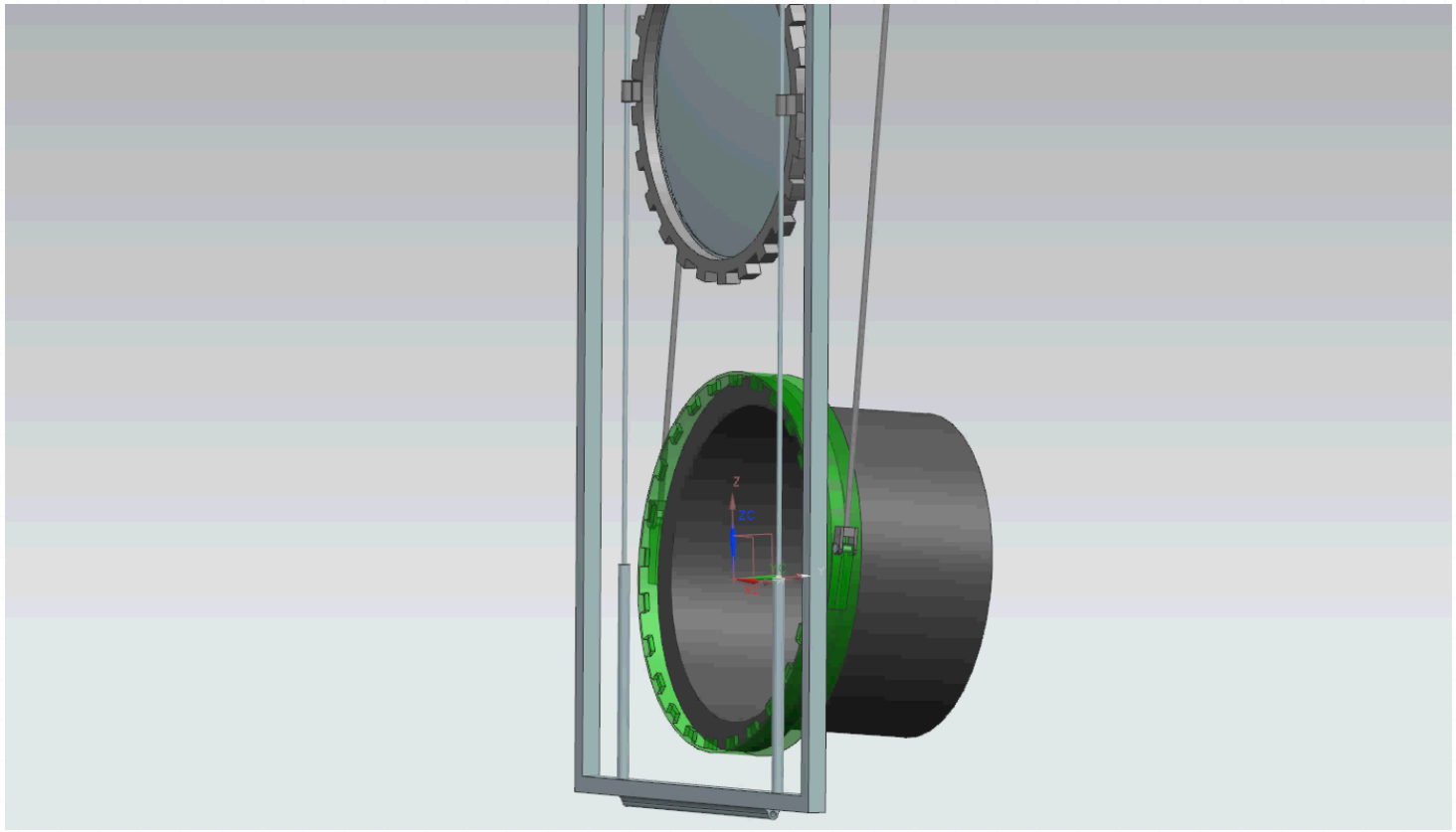
“Autoclave” Conceptual Design





“Autcoclave” Conceptual Design

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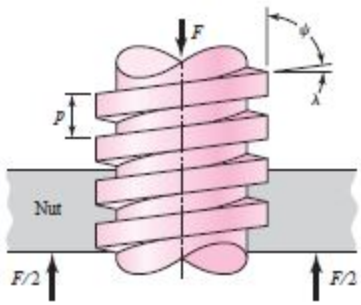
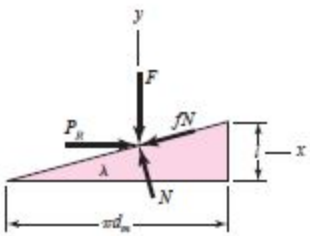
ZC

“Autoclave” Analysis



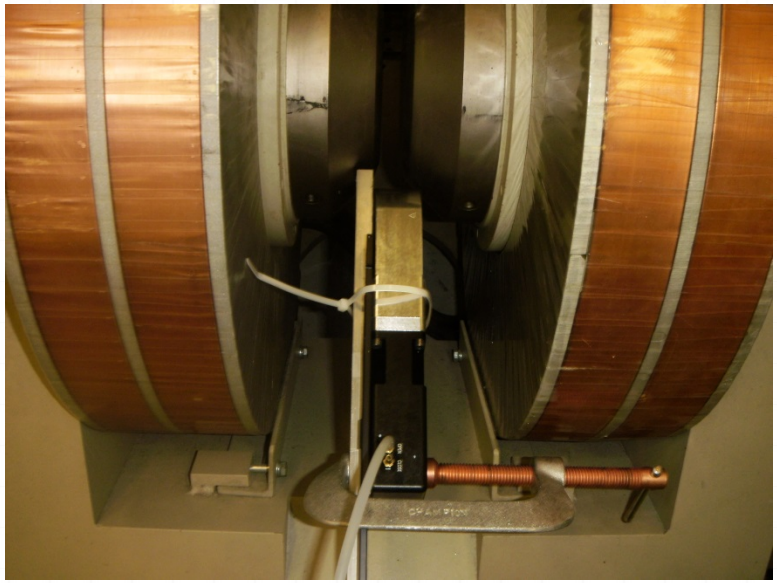


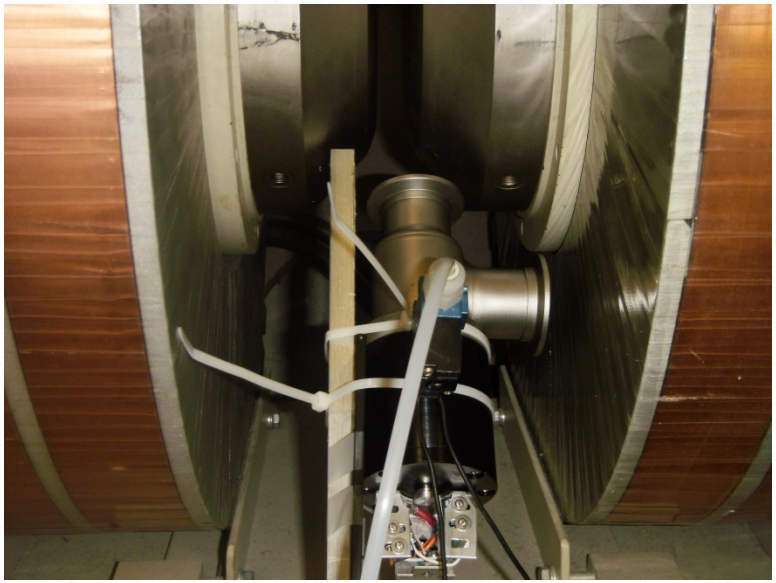
$$\sum F_x = P_R - N\sin\lambda - fN\cos\lambda = 0$$

$$\sum F_y = -F - fN\sin\lambda + N\cos\lambda = 0$$

First-Order Analysis of "Autoclave" Closure		
Helicoflex Seal Diameter	42	in.
Fraction of Circumference used by teeth	0.4	-
Bearing Pressure	2000	psi
Number of teeth	20	-
Inclination Angle	0.8	degrees
Static Friction Coefficient	0.2	-
Tooth Cicrcle Diameter	42	in.
Req. Compression Force	173,246.27	lbs
Contact Area	86.62	in^2
Tooth Width	1.64	in.
Tooth Length	2.64	in.
Tooth Height	0.04	in.
Total Force Requried to Tighten	37,172.20	lbs
Torque Required to Tighten	780,616.12	lbs in
	65,051.34	lbs ft

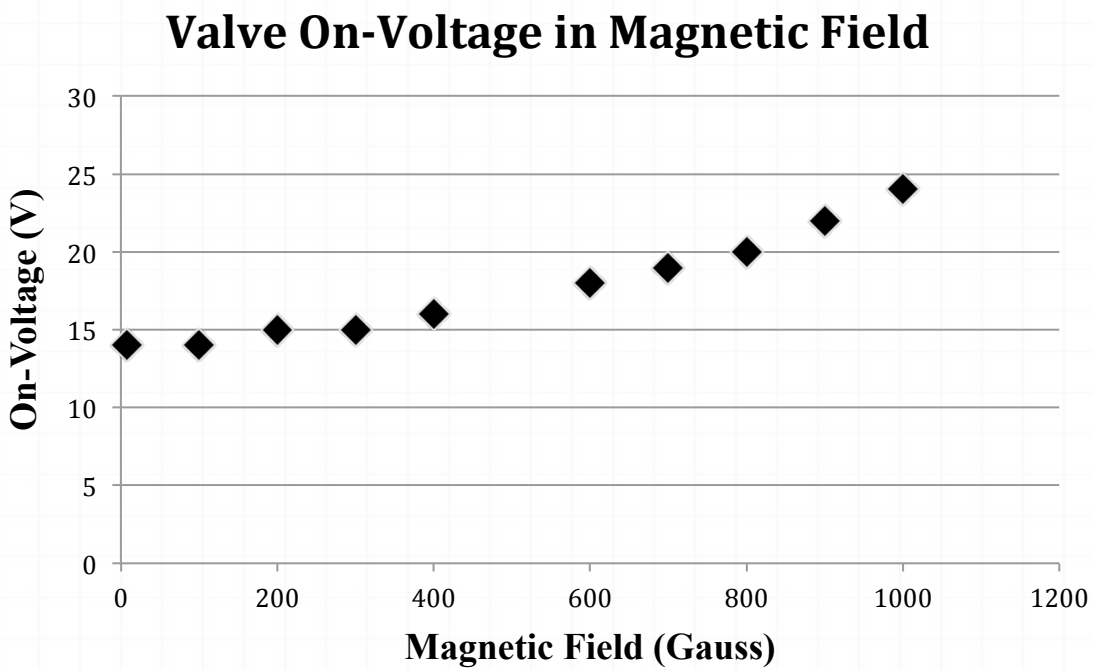
Valve Testing in Magnetic Field





- Evaluate operation in fields ~1000 Gauss
- Extensive engineering analysis for mounting mechanism
- Both functioned normally…almost

Valve Testing in Magnetic Field



- Evaluate operation in fields ~1000 Gauss
- Both functioned normally…almost

See, I learned something

- Exposure to Siemens NX
- Exposure to FEA (NX NASTRAN)
- Conceptual Design Work
- Documentation of Work (Engineering Notes)
- Working with manufacturers, and engineers
- Available Strength Design (ASD) Analysis

References

- Deutschman, Aaron D., Walter J. Michels, and Charles E. Wilson. *Machine Design; Theory and Practice*. New York: Macmillan, 1975. Print.
- Roark, Raymond J., and Warren C. Young. *Roark's Formulas for Stress and Strain*. 7th ed. New York: McGraw-Hill, 1989. Print.
- Shigley, Joseph Edward., and Larry D. Mitchell. *Mechanical Engineering Design*. New York: McGraw-Hill, 1983. Print.
- *Steel Construction Manual*. 14th ed. Chicago, IL: American Institute of Steel Construction, 2011. Print.

Questions?

A Special Thanks to…

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