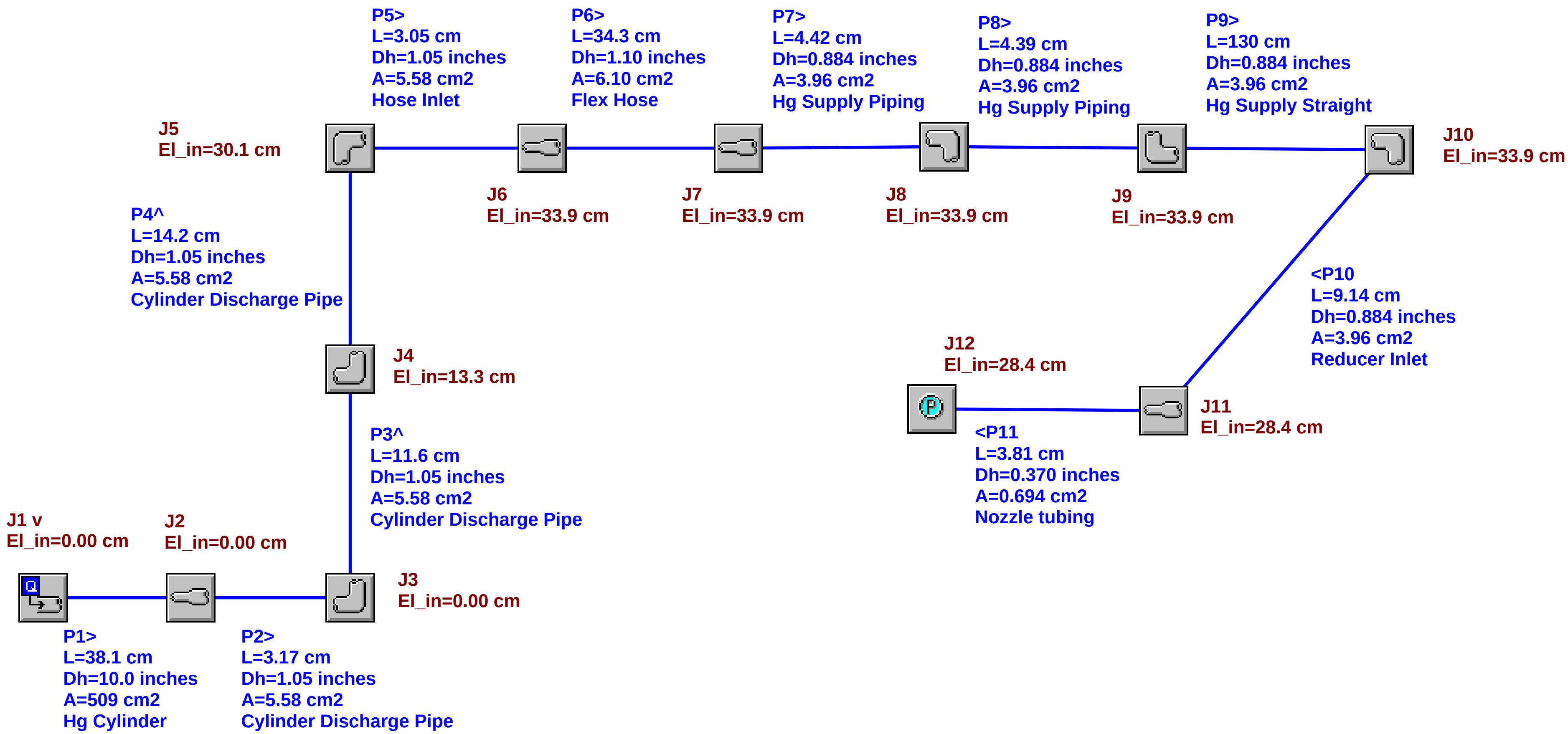
Appendix A. Flow Analysis Documents

MERIT SYRINGE FLOW ANALYSIS
C:\Documents and Settings\vbg.ORNL\My Documents\My Files\MERIT\Hg System\Fathom\MERIT Design R1.fth
Base Scenario



Hg Syringe Model
Reference 25 Apr 2006

Execution Time= 0.08 seconds
Total Number Of Head/Pressure Iterations= 0
Total Number Of Flow Iterations= 2
Total Number Of Temperature Iterations= 2
Number Of Pipes= 11
Number Of Junctions= 12
Matrix Method= Gaussian Elimination

Pressure/Head Tolerance= 0.0001 relative change
Flow Rate Tolerance= 0.0001 relative change
Temperature Tolerance= 0.0001 relative change
Flow Relaxation= (Automatic)
Pressure Relaxation= (Automatic)

Heat Transfer with Energy Balance
Fluid Database: AFT Standard
Fluid: Mercury
Max Fluid Temperature Data= 500 deg. F
Min Fluid Temperature Data= 0 deg. F
Default Temperature= 80 deg. F
Default Density= 846.7027 lbm/ft3
Default Viscosity= 3.69638 lbm/hr-ft
Default Vapor Pressure= 1.0636E-04 atm
Viscosity Model= Newtonian

Atmospheric Pressure= 1 atm
Gravitational Acceleration= 1 g
Turbulent Flow Above Reynolds Number= 4000
Laminar Flow Below Reynolds Number= 2300

MERIT SYRINGE FLOW ANALYSIS

WARNING HGL, EGL and head loss results may not be meaningful for variable density systems.

MERIT SYRINGE FLOW ANALYSIS

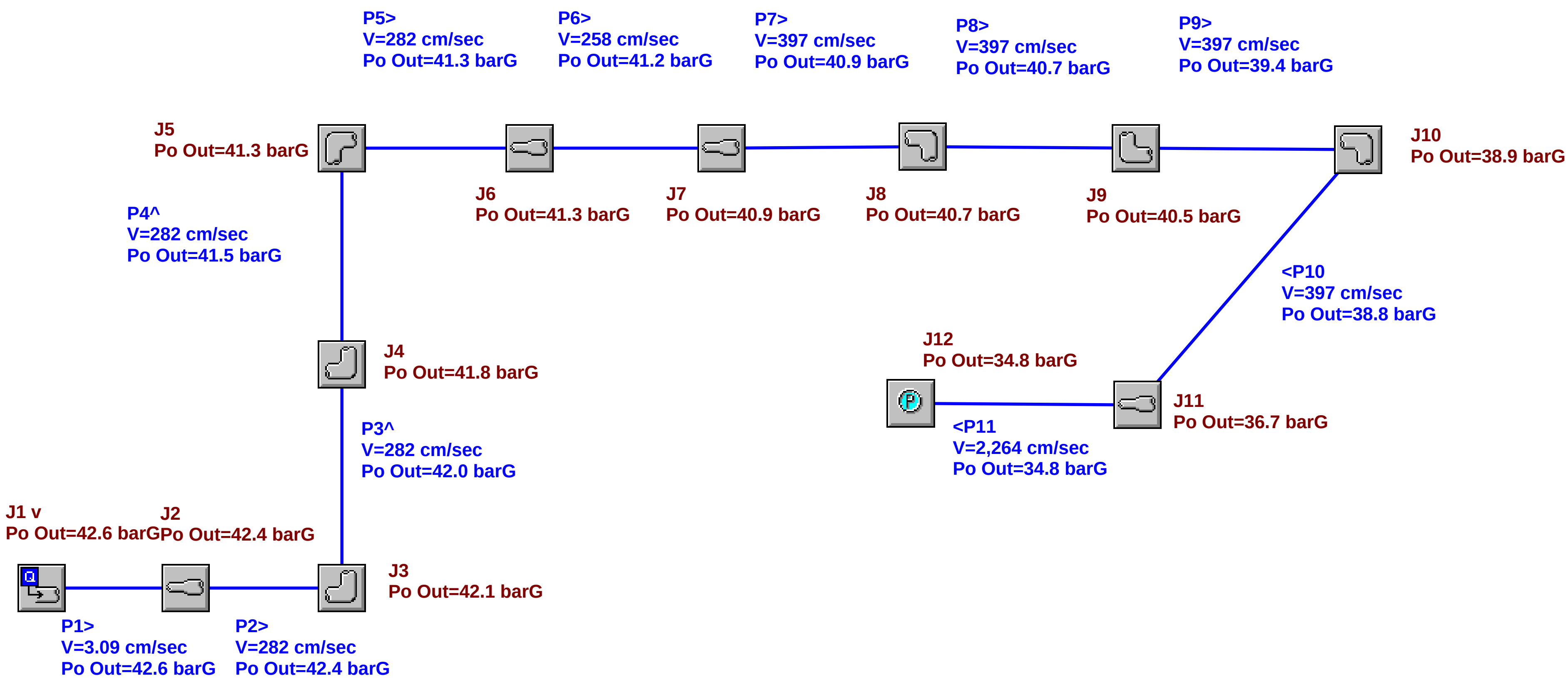
Pipe Output Table

Pipe	Name	Pipe Nominal Size	Vol. Flow (liter/sec)	Length (cm)	Flow Area (cm2)	Velocity (cm/sec)	Reynolds No.	fL/ D + K	P Stag. In (barG)	P Stag. Out (barG)	dP Stag. Total (bar)	P Static In (barG)	P Static Out (barG)	dP Static Total (bar)
1	Hg Cylinder	10 inch	1.57	38.10	508.736	3.09	6.86E+04	0.0296	42.6	42.6	0.00000191	42.63	4.26E+01	0.00000191
2	Cylinder Discharge Pipe	1 inch	1.57	3.17	5.576	281.63	6.56E+05	0.0213	42.4	42.4	0.01147854	41.83	4.18E+01	0.01147854
3	Cylinder Discharge Pipe	1 inch	1.57	11.58	5.576	281.63	6.56E+05	0.0778	42.1	42.0	0.19407322	41.61	4.14E+01	0.19407322
4	Cylinder Discharge Pipe	1 inch	1.57	14.22	5.576	281.63	6.56E+05	0.0955	41.8	41.5	0.23406301	41.23	4.10E+01	0.23406301
5	Hose Inlet	1 inch	1.57	3.05	5.576	281.63	6.56E+05	0.0205	41.3	41.3	0.01101942	40.76	4.07E+01	0.01101942
6	Flex Hose	1 inch	1.57	34.29	6.098	257.53	6.27E+05	0.2186	41.3	41.2	0.09844139	40.83	4.07E+01	0.09844139
7	Hg Supply Piping	3/4 inch	1.57	4.42	3.960	396.58	7.78E+05	0.0362	40.9	40.9	0.03869272	39.87	3.98E+01	0.03869272
8	Hg Supply Piping	3/4 inch	1.57	4.39	3.960	396.58	7.78E+05	0.0360	40.7	40.7	0.03847035	39.66	3.96E+01	0.03847035
9	Hg Supply Straight	3/4 inch	1.57	130.30	3.960	396.58	7.78E+05	1.0684	40.5	39.4	1.14076805	39.44	3.83E+01	1.14076805
10	Reducer Inlet	3/4 inch	1.57	9.14	3.960	396.58	7.78E+05	0.0750	38.9	38.8	0.08005390	37.83	3.77E+01	0.08005390
11	Nozzle tubing	1/2 inch	1.57	3.81	0.694	2,263.76	1.86E+06	0.0559	36.7	34.8	1.94466186	1.94	5.26E-07	1.94466186

All Junction Table

Jct	Name	Junction Type	Elevation Inlet (cm)	Loss Factor (K)	dH (cm)	P Stag. In (barG)	P Stag. Out (barG)	dP Stag. Total (bar)	P Static In (barG)	P Static Out (barG)	dP Static Total (bar)	T Inlet (deg. C)
1	Syringe Piston	Assigned Flow	0.0	0.00000	0.000	42.6	42.6	0.00000	42.63325119	42.63325119	0.0000	20.0
2	Area Change	Area Change	0.0	4,128.12207	20.054	42.6	42.4	0.26703	42.63324356	41.82778549	0.8055	20.1
3	Horizontal to Vertical	Bend	0.0	0.33841	13.685	42.4	42.1	0.20760	41.81630707	41.60871124	0.2076	20.1
4	Angle Bend	Bend	13.3	0.27347	11.059	42.0	41.8	0.18785	41.41463470	41.22678375	0.1879	20.1
5	Vertical to Horizontal	Bend	30.1	0.33841	13.686	41.5	41.3	0.23297	40.99272156	40.75975037	0.2330	20.1
6	Pipe to Flex	Area Change	33.9	0.00733	0.296	41.3	41.3	0.00395	40.74873352	40.83303070	-0.0843	20.1
7	Flex to Tubing	Area Change	33.9	0.54029	18.269	41.2	40.9	0.24327	40.73458862	39.87381363	0.8608	20.1
8	Piping Elbow 1	Bend	33.9	0.16817	13.485	40.9	40.7	0.17957	39.83512497	39.65555573	0.1796	20.1
9	Piping Elbow 2	Bend	33.9	0.16817	13.485	40.7	40.5	0.17957	39.61708832	39.43751907	0.1796	20.1
10	180 bend	Bend	33.9	0.50572	40.553	39.4	38.9	0.46727	38.29675293	37.82947540	0.4673	20.1
11	Tubing Reduction	Area Change	28.4	1.94864	156.258	38.8	36.7	2.08069	37.74942017	1.94466197	35.8048	20.1
12	Assigned Pressure	Assigned Pressure	28.4	0.00000	0.000	34.8	34.8	0.00000	-0.00000184	-0.00000184	0.0000	23.9

MERIT SYRINGE FLOW ANALYSIS
C:\Documents and Settings\vbg.ORNL\My Documents\My Files\MERIT\Hg System\Fathom\MERIT Design R1.fth
Base Scenario



Appendix B. Syringe Pump Documents

Job A-6981 Brookhaven National Labs
Design Calculations

Given:
Hg cylinder is 10" bore
Flow rate required: 25 gpm
Induced pressure required: 1500 psi
Drive cylinders are (2) 6" bore x 2.5" rods
Proportional valve = 4WREE10E50
Pump = 45cc piston pump, pressure comp.

Calculations
Area of 10" bore = 78.54 in2

Velocity to produce 25 gpm nominal
25(231)/78.54 = 73.53 in/min = 1.2255 in/sec

Velocity to produce 30 gpm max
30(1.2255)/25 = 1.4706 in/sec

Drive cylinder net area = 23.37 in2
Area ration = 1.21:1

Flow req'd for 1.2255 in/sec, Q =
Q= 1.2255(23.37)(60/231) = 7.44 gpm

Total Q = 14.88 gpm (for 25 gpm Hg)

Return flow rate from drive cylinders
Qout = 1.21 (14.88) = 18 gpm

For 30 gpm Hg, Q = 14.88 (30/25) = 17.86 gpm

NOTE: Potential for 45cc pump at 1480 rpm and
95% vol eff = 16.7 gpm. This give ability to induce only
Vel = 16.7gpm * 231in3/gal / 60 s/min / 23.37 in2 / 2cyl
Vel = 1.3756 in/sec
QHg @ 1.3756 in/sec = 1.3756 (78.54 in2) (60/231)

Q Hgmax = 28.06 gpm Hg when pump @ 1480 rpm

Calculate system pressure req'd to induce 1500 psi Hg
Force @ Hg cyl = 78.54 in2 * 1500 psi = 117,810 lbs

Drive cyl net area = 23.37 in2 x 2 cyl = 46.74 in2

Pressure @ drive cyl = 117,810 lbs / 46.74 in2 =

P = 2520 psi required at cylinders.

Estimate pressure drops at about 21 gpm:	**PSI**
Prop valve @ 100% open:	400

Hoses - rod side	25
Hoses - blind side	50
Filter	15
Misc fittings	30
Total estimated pressure drop at velocity = 520 psi	520

System pressure as set at pump compensator
Psys = 2520 psi @ cyl + 520 psi flow losses

Psys = 3039 psi

Calculate drive power required
HP = 3039 psi * 14.88 gpm / (1714 * .85eff)

HP = 31.03 HP @ 25 gpm Hg flow (peak)

HP = 3039 psi * 16.7 gpm / (1714 * .85 eff)

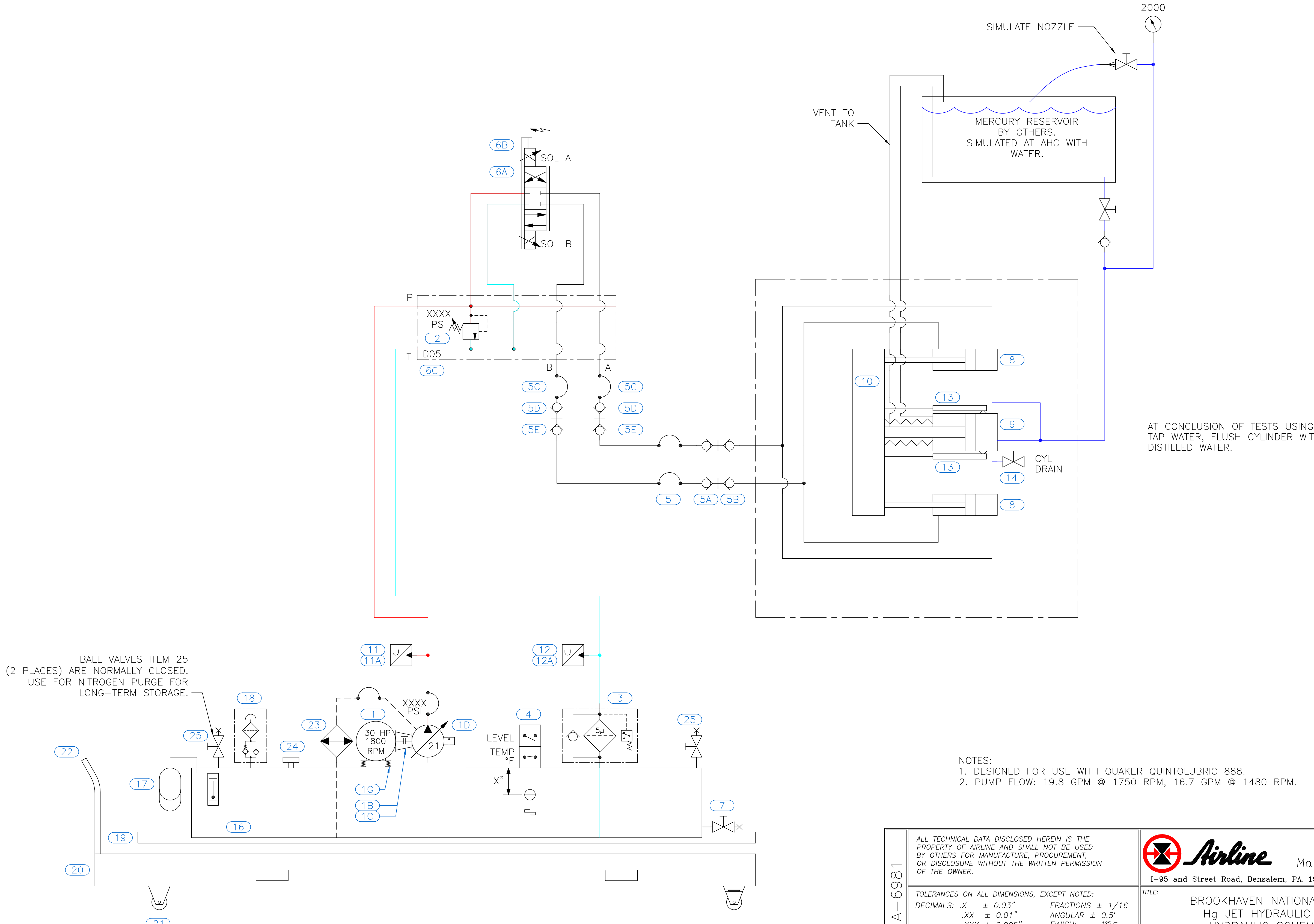
HP = 34.8 HP @ 28 gpm Hg flow (peak)

Determine Peak power draw in USA @ 1750 rpm
Pump flow potential 20.8 gpm at 100% vol eff, 1750 rpm

HP = 20.8 (3039) / (1714*.95 eff mech) = 38.8 HP peak

Note, this would be 129% of rated 30 HP motor

REV.	DESCRIPTIONS	DATE	BY



NOTES:
1. DESIGNED FOR USE WITH QUAKER QUINTOLUBRIC 888.
2. PUMP FLOW: 19.8 GPM @ 1750 RPM, 16.7 GPM @ 1480 RPM.

JOB #: A-6981

Airline Machinery Group.
I-95 and Street Road, Bensalem, PA. 19020 (215) 638-4700

TOLERANCES ON ALL DIMENSIONS, EXCEPT NOTED:
DECIMALS: .X ± 0.03" .XX ± 0.01" .XXX ± 0.005"
FRACTIONS ± 1/16
ANGULAR ± 0.5°
FINISH: 125

PERPENDICULARITY, STRAIGHTNESS, RUNOUT, FLATNESS, CONCENTRICITY, TRUE POSITION, PARALLELISM, PROJECTION

TITLE: BROOKHAVEN NATIONAL LABS
Hg JET HYDRAULIC UNIT
HYDRAULIC SCHEMATIC

DWG. #: 6981001H	SIZE: C	SCALE: NA
DATE: 11/16/05 BY: JB	REV.:	SHEET: 1 OF 1

HANNA CYLINDERS

HIGH PRESSURE HYDRAULIC TEST REPORT

USE ENGINEERING TEST STANDARD #ES3207 (UNLESS OTHERWISE INDICATED).

SERIAL #	MODEL	BORE	STROKE	JOB #
K11422704	ME5	6.00	15.00	114227004

DIMENSIONS

VERIFIED PER X DRAWING # 706-40342-030 REV D

X OTHER (Describe) DETAIL

FASTENERS

TIE ROD	TORQUED TO	300	FT-LB
S.H.C.S GLAND	TORQUED TO	18	FT-LB
	TORQUED TO		FT-LB

TESTING PRESSURE

HYD.	PSI
	500
	1000
	1200
	1500
	1800
	2200
X	3000
X	4500
	5000

BREAK-AWAY PRESSURE:

PASS X FAIL ____

LEAKAGE TESTS

EXTERNAL

X TUBE END SEAL
X ROD SEAL
___ SPECIAL PIPING

INTERNAL BYPASS

PASS X FAIL ____

REMARKS

TESTED BY: Raul Lopez DATE 3/9/06

APPROVED BY: [signature] DATE 3/9/06

HANNA CYLINDERS

HIGH PRESSURE HYDRAULIC TEST REPORT

USE ENGINEERING TEST STANDARD #ES3207 (UNLESS OTHERWISE INDICATED).

SERIAL #	MODEL	BORE	STROKE	JOB #
K11422703	ME5	6.00	15.00	114227003

DIMENSIONS

VERIFIED PER X DRAWING # 706-40342-031 REV C

X OTHER (Describe) DETAIL

FASTENERS

Fastener		Torque	
TIE ROD	TORQUED TO	300	FT-LB
GLAND Screws	TORQUED TO	18	FT-LB
	TORQUED TO		FT-LB

TESTING PRESSURE

HYD.	PSI
	500
	1000
	1200
	1500
	1800
	2200
X	3000
X	4500
	5000

BREAK-AWAY PRESSURE:

PASS X FAIL ____

LEAKAGE TESTS

EXTERNAL

X TUBE END SEAL
X ROD SEAL
____ SPECIAL PIPING

INTERNAL BYPASS

PASS ✓ FAIL ____

REMARKS

TESTED BY: Raul Lopez DATE 3/9/06

APPROVED BY: [signature] DATE 3/9/06

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HANNA CYLINDERS

HIGH PRESSURE HYDRAULIC TEST REPORT

USE ENGINEERING TEST STANDARD #ES3207
(UNLESS OTHERWISE INDICATED).

SERIAL #	MODEL	BORE	STROKE	JOB #
K114227005	MS7	10"	15"	114227005

DIMENSIONS

VERIFIED PER X DRAWING # 706-81637-000 REV E
X OTHER (Describe) DETAIL

FASTENERS

TIE RODS TORQUED TO 500 FT-LB
GLAND SCREW TORQUED TO 18 FT-LB
______ TORQUED TO ______ FT-LB

TESTING PRESSURE

HYD.	PSI
	500
	1000
	1200
	1500
	1800
X	2200
	3000
	4500
	5000

BREAK-AWAY PRESSURE:

PASS X FAIL ____

LEAKAGE TESTS

EXTERNAL

X TUBE END SEAL
X ROD SEAL
__ SPECIAL PIPING

INTERNAL BYPASS

PASS X FAIL ____

REMARKS

TESTED BY: RAUL LOPEZ DATE 3/8/06

APPROVED BY: [signature] DATE 3/8/06

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Appendix C. Primary Containment Documents

MERIT Calculation Sheet
Oak Ridge National Laboratory

CALCULATION	Optical Viewport Stresses in Pressure Testing	SHEET 1 OF 1
DRAWING NO	203-HJT-0630	
CALCULATION BY	V. Graves	DATE 12 Apr 2006

The primary containment system may be run under vacuum conditions or may be pressurized during leak testing operations. This calculation checks the integrity of the sapphire viewports under 1atm pressure. Calculations based on Roark's Formulas for Stress and Strain, 6th edition, Flat Plates case 10b.

$\nu := 0.29$ Poissons ratio

$E := 50 \cdot 10^{6} psi$ modulus of elasticity

$S_y := 40000psi$ tensile yield strength sapphire

$a := 1.5in$ outer radius of unsupported viewport

$t := 0.236in$ viewport thickness

$q := 15psi$ pressure loading

$D := \frac{E \cdot t^3}{12 \cdot \left(1 - \nu^2\right)}$ plate constant

$y_c := \frac{-q \cdot a^4}{64D}$ deflection at center

$y_c = -1.984 \times 10^{-5}\,in$

$M_c := \frac{q \cdot a^2 \cdot (1 + \nu)}{16}$ moment at center

$\sigma := \frac{6M_c}{t^2}$ stress at center

$\sigma = 293.137\,psi$

$FS := \frac{S_y}{\sigma}$ $FS = 136.455$ safety factor for pressure loading

MERIT Calculation Sheet
Oak Ridge National Laboratory

CALCULATION	Nozzle Offsets	SHEET 1 OF 1	
DRAWING NO	203-HJT-0001		
CALCULATION BY	Van Graves	DATE	26 Jan 2006

Problem is to calculate the vertical offset of the nozzle given a Z starting position relative to the center of the magnet so that the jet path intersects the beam and magnet axes simultaneously.

From the equations for projectile motion we have

$$x = v_0 \cos\theta \cdot t$$

$$y = v_0 \sin\theta \cdot t - \tfrac{1}{2} g t^2$$

$$y = f(x) = x \tan\theta - \frac{g}{2 v_0^{\,2} \cos^2\theta} x^2$$

$$\frac{dy}{dx} = \tan\theta - \frac{g}{v_0^{\,2}\cos^2\theta} x$$

With regards to these equations, coordinate system is at the center of the jet starting position. All angular references are with respect to the ground (relative to the beam for our experiment).

An approximation is made that for small angles, $\cos^2\theta \sim 1$, so we can determine a starting angle which will provide a desired slope at a specified distance.

$x := 45\text{cm}$ $\quad$ $dydx := -0.033$ $\quad$ $v_0 := 2000\,\frac{\text{cm}}{\text{s}}$

$\theta := \text{atan}\left(dydx + \frac{g}{v_0^{\,2}}\cdot x\right)$ $\quad$ $\theta = -0.022$

Now calculate the vertical drop of the jet after traveling 45cm horizontally.

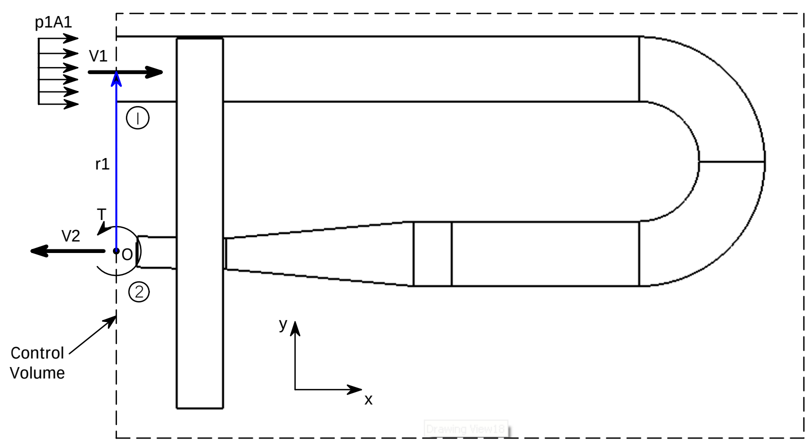
$y := \tan(\theta)\cdot x - \frac{g}{2\cdot v_0^{\,2}\cdot\cos(\theta)^2}\cdot x^2$ $\quad$ $y = -1.237\ \text{cm}$

The jet falls 1.24 cm over the distance, so the starting position of the nozzle should compensate for this fall. So for a horizontal starting position of Z=-45cm, the center of the nozzle should be 1.24cm above the beam and have a starting angle of -22mrad relative to the beam. Note this calculation does not include deflections caused by MHD effects.

MERIT Calculation Sheet
Oak Ridge National Laboratory

CALCULATION	Nozzle Flange Moment	SHEET 1 OF 2
DRAWING NO	203-HJT-0620	
CALCULATION BY	V.B. Graves	DATE 26 April 2006

Calculate the moment imparted by the flowing Hg on the flange mounting bolts. The moment is calculated at the nozzle flange face. The inlet pressure was obtained using AFT Fathom (incorporates frictional losses and pressure drops in the actual piping). Exit pressure of the nozzle is atmospheric (zero gage pressure).



$\rho := 13540 \frac{kg}{m^3}$ Fluid density $\quad Q := 1.57 \frac{liter}{s}$ Flow rate

$mflow := \rho \cdot Q \quad mflow = 21.258 \frac{kg}{s}$ mass flow rate

$d_1 := 0.884in \quad d_2 := 0.4in$ Inlet & exit diameters

$A_1 := \frac{\pi}{4} d_1^{\,2} \quad A_2 := \frac{\pi}{4} d_2^{\,2}$ Inlet & exit flow areas

$A_1 = 3.96\,cm^2 \quad A_2 = 0.811\,cm^2$

$V_1 := \frac{Q}{A_1} \quad V_2 := \frac{Q}{A_2}$ Inlet & exit velocities

$V_1 = 3.965 \frac{m}{s} \quad V_2 = 19.365 \frac{m}{s}$

p1 is obtained from AFT Fathom: $p_1 := 555psi \quad p_1 = 3.827 \times 10^6\,Pa$

CALCULATION Nozzle Flange Moment SHEET 2 OF 2

DRAWING NO 203-HJT-0620

CALCULATION BY V.B. Graves DATE 26 April 2006

For an inertial, non-deformable control volume with 1-dimensional inlets & outlets, conservation of angular momentum states that

$$\frac{d}{dt}\mathbf{H}_O = \sum \mathbf{M}_O = \sum (\mathbf{r}\times\mathbf{F})_O = \sum (\mathbf{r}\times\mathbf{V})_{out}\dot{m}_{out} - \sum (\mathbf{r}\times\mathbf{V})_{in}\dot{m}_{in}$$

$$\mathbf{T}_O + \mathbf{r}_1 \times (-p_1 A_1 \mathbf{n}_1) = (\mathbf{r}_1 \times \mathbf{V}_1)(-\dot{m}_{in})$$

$$T_O - p_1 A_1 r_1 = +\dot{m} r_1 V_1$$

$$T_O = r_1 (p_1 A_1 + \dot{m} V_1)$$

$r_1 := 3\text{in}$ $T_o := r_1 \cdot (p_1 A_1 + \text{mflow} \cdot V_1)$

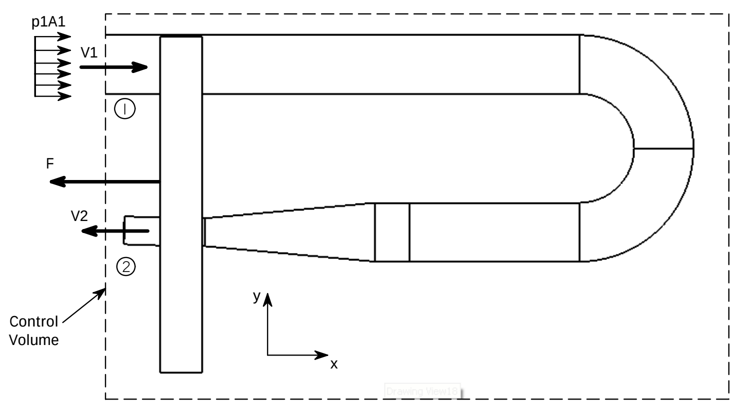
$T_o = 89.9\ \text{ft}\cdot\text{lbf}$ $T_o = 121.9\ \text{N}\cdot\text{m}$

CALCULATION Nozzle Flange Axial Force SHEET 1 OF 2

DRAWING NO 203-HJT-0620

CALCULATION BY V.B. Graves DATE 26 April 2006

Calculate the forces imparted by the flowing Hg on the flange mounting bolts. The force is calculated at the nozzle. A reference calculation of the inlet pressure is made using Bernoulli's equation, but the inlet pressure calculated using AFT Fathom (incorporates frictional losses and pressure drops in the actual piping) is used for subsequent force calculations. Exit pressure of the nozzle is atmospheric (zero gage pressure).



$\rho := 13540 \frac{kg}{m^3}$ Fluid density $Q := 1.57 \frac{liter}{s}$ Flow rate

$mass := \rho \cdot Q$ $mass = 21.258 \frac{kg}{s}$ mass flow rate

$d_1 := 0.884 in$ $d_2 := 0.4 in$ Inlet & exit diameters

$A_1 := \frac{\pi}{4} d_1^{\,2}$ $A_2 := \frac{\pi}{4} d_2^{\,2}$ Inlet & exit flow areas

$A_1 = 3.96\, cm^2$ $A_2 = 0.811\, cm^2$

$V_1 := \frac{Q}{A_1}$ $V_2 := \frac{Q}{A_2}$ Inlet & exit velocities

$V_1 = 3.965 \frac{m}{s}$ $V_2 = 19.365 \frac{m}{s}$

CALCULATION Nozzle Flange Axial Force SHEET 2 OF 2

DRAWING NO 203-HJT-0620

CALCULATION BY V.B. Graves DATE 26 April 2006

Reference pressure at 1 is given by Bernoulli's equation:

$p_{1ref} := \frac{1}{2}\rho \cdot \left(V_2^{\,2} - V_1^{\,2}\right)$ $p_{1ref} = 353\,\text{psi}$ $p_{1ref} = 2.43 \times 10^6\,\text{Pa}$

A more accurate value of p1 is obtained from AFT Fathom: $p_1 := 555\text{psi}$ $p_1 = 3.827 \times 10^6\,\text{Pa}$

A control volume analysis provides the resultant force

$$\sum \mathbf{F}_x = p_1 A_1 - F = \dot{m}(\mathbf{V}_2 - \mathbf{V}_1) = \dot{m}(-V_2 - V_1)$$
$$F = p_1 A_1 + \dot{m}(V_2 + V_1)$$

$p_1 \cdot A_1 = 341\,\text{lbf}$ $\text{mass} \cdot \left(V_2 + V_1\right) = 111\,\text{lbf}$

$F := p_1 \cdot A_1 + \text{mass} \cdot \left(V_2 + V_1\right)$ $F = 452\,\text{lbf}$ $F = 2011\,\text{N}$

The nozzle flange is attached with ten SS 18-8 #10-24 socket head cap screws. If the system were completely rigid, the stress seen in the screws due to the axial force would be

$A_t := 0.0175\text{in}^2$ shcs thread stress area

$\sigma_y := 70000\text{psi}$ yield strength

$\sigma_{act} := \frac{F}{10A_t}$ $\sigma_{act} = 2.584 \times 10^3\,\text{psi}$

$FS := \frac{\sigma_y}{\sigma_{act}}$ $FS = 27.094$ Safety Factor

MERIT Calculation Sheet
Oak Ridge National Laboratory

CALCULATION	Hg Supply Line Pressure Rating	SHEET 1 OF 1
DRAWING NO	203-HJT-0620 Item 2	
CALCULATION BY V.B. Graves		DATE 28 March 2006

This calculation supports the design of the Hg supply feedline that is between the flexible hose and the reducer. The feedline is being designed and fabricated to ASME VIII standards. Material is Grade 2 Titanium welded pipe. Nominal design is 3/4" SCH10 pipe.

$D := 1.05\text{in}$	nominal OD for 3/4" pipe
$t := 0.083\text{in}$	wall thickness for Sch 10
$P := 1500\text{psi}$	design pressure
$S := 12100\text{psi}$	max allowable stress per ASME VIII Table 1B
$E := 1$	joint efficiency per ASME VIII UW-12
$R := \frac{D - 2t}{2}$	inner radius

Circumferential Stress (Longitudinal Joints)

$t_{min1} := \frac{P \cdot R}{S \cdot E - 0.6P}$ $\quad t_{min1} = 0.059\,\text{in}$ $\quad t_{min1} = 1.504\,\text{mm}$

$P_{max1} := \frac{S \cdot E \cdot t}{R + 0.6t}$ $\quad P_{max1} = 2042\,\text{psi}$ $\quad P_{max1} = 14.08 \times 10^{6}\,\text{Pa}$

Longitudinal Stress (Circumferential Joints)

$t_{min2} := \frac{P \cdot R}{2S \cdot E + 0.4P}$ $\quad t_{min2} = 0.027\,\text{in}$ $\quad t_{min2} = 0.679\,\text{mm}$

$P_{max2} := \frac{2S \cdot E \cdot t}{R - 0.4t}$ $\quad P_{max2} = 4913\,\text{psi}$ $\quad P_{max2} = 33.877 \times 10^{6}\,\text{Pa}$

In both stress calculations, the design exceeds minimum thickness and the design pressure is below the maximum allowable.

MERIT Calculation Sheet
Oak Ridge National Laboratory

CALCULATION Hg Nozzle Pressure Rating SHEET 1 OF 1

DRAWING NO 203-HJT-0620 Item 4

CALCULATION BY V.B. Graves DATE 28 March 2006

This calculation supports the design of the Hg nozzle tube. The tube is being designed and fabricated to ASME VIII standards. Material is Grade 2 Titanium 0.5" seamless welded tubing.

$D := 0.5\text{in}$ nominal OD

$t := 0.035\text{in}$ wall thickness

$P := 1500\text{psi}$ design pressure

$S := 14300\text{psi}$ max allowable stress per ASME VIII Table 1B

$E := 1$ joint efficiency per ASME VIII UW-12

$R := \frac{D - 2t}{2}$ inner radius

Circumferential Stress (Longitudinal Joints)

$t_{min1} := \frac{P \cdot R}{S \cdot E - 0.6P}$ $t_{min1} = 0.024\ \text{in}$ $t_{min1} = 0.611\ \text{mm}$

$P_{max1} := \frac{S \cdot E \cdot t}{R + 0.6t}$ $P_{max1} = 2121\ \text{psi}$ $P_{max1} = 14.622 \times 10^{6}\ \text{Pa}$

Longitudinal Stress (Circumferential Joints)

$t_{min2} := \frac{P \cdot R}{2S \cdot E + 0.4 \cdot P}$ $t_{min2} = 0.011\ \text{in}$ $t_{min2} = 0.281\ \text{mm}$

$P_{max2} := \frac{2S \cdot E \cdot t}{R - 0.4 \cdot t}$ $P_{max2} = 4980\ \text{psi}$ $P_{max2} = 34.337 \times 10^{6}\ \text{Pa}$

In both stress calculations, the design exceeds minimum thickness and the design pressure is below the maximum allowable.

MERIT Calculation Sheet
Oak Ridge National Laboratory

CALCULATION Hg Supply Line Pressure Rating SHEET 1 OF 2

DRAWING NO 203-HJT-0670, -0680

CALCULATION BY V.B. Graves DATE 20 April 2006

This calculation supports the design of the piping that acts as the inlet and outlet from the Hg cylinder. These lines are being designed and fabricated to ASME VIII standards. Material is 3/4" and 1" SCH40 SS304L welded pipe.

$D_1 := 1.05\text{in}$ $D_2 := 1.315\text{in}$ nominal OD for 3/4" & 1" pipe

$t_1 := 0.113\text{in}$ $t_2 := 0.133\text{in}$ wall thickness for 3/4" & 1" Sch 40

$P := 1500\text{psi}$ design pressure

$S := 14200\text{psi}$ max allowable stress per ASME VIII Table 1A

$E := 1$ joint efficiency per ASME VIII UW-12

$R_1 := \frac{D_1 - 2t_1}{2}$ $R_2 := \frac{D_2 - 2t_2}{2}$ inner radii

Circumferential Stress (Longitudinal Joints) 3/4" pipe

$t_{min1} := \frac{P \cdot R_1}{S \cdot E - 0.6P}$ $t_{min1} = 0.046\text{ in}$ $t_{min1} = 1.18\text{ mm}$

$P_{max1} := \frac{S \cdot E \cdot t_1}{R_1 + 0.6t_1}$ $P_{max1} = 3344\text{ psi}$ $P_{max1} = 23.058 \times 10^6\text{ Pa}$

Longitudinal Stress (Circumferential Joints) 3/4" pipe

$t_{min2} := \frac{P \cdot R_1}{2S \cdot E + 0.4P}$ $t_{min2} = 0.021\text{ in}$ $t_{min2} = 0.541\text{ mm}$

$P_{max2} := \frac{2S \cdot E \cdot t_1}{R_1 - 0.4t_1}$ $P_{max2} = 8749\text{ psi}$ $P_{max2} = 60.323 \times 10^6\text{ Pa}$

CALCULATION Hg Supply Line Pressure Rating SHEET 2 OF 2

DRAWING NO 203-HJT-0670, -0680

CALCULATION BY V.B. Graves DATE 20 April 2006

Circumferential Stress (Longitudinal Joints) 1" pipe

$t_{min3} := \frac{P \cdot R_2}{S \cdot E - 0.6P}$ $t_{min3} = 0.059$ in $t_{min3} = 1.503$ mm

$P_{max3} := \frac{S \cdot E \cdot t_2}{R_2 + 0.6t_2}$ $P_{max3} = 3125$ psi $P_{max3} = 21.548 \times 10^6$ Pa

Longitudinal Stress (Circumferential Joints) 1" pipe

$t_{min4} := \frac{P \cdot R_2}{2S \cdot E + 0.4P}$ $t_{min4} = 0.027$ in $t_{min4} = 0.689$ mm

$P_{max4} := \frac{2S \cdot E \cdot t_2}{R_2 - 0.4t_2}$ $P_{max4} = 8014$ psi $P_{max4} = 55.258 \times 10^6$ Pa

MERIT Calculation Sheet
Oak Ridge National Laboratory

CALCULATION Deflector Forces SHEET 1 OF 1

DRAWING NO 203-HJT-0616

CALCULATION BY V.B. Graves DATE 5 Jan 2005

Calculate the force of the Hg jet on the deflector plate, which also serves as the downstream primary beam window. Material is Ti6Al4V.

$\rho := 13540 \frac{kg}{m^3}$ $\rho = 845.275 \frac{lb}{ft^3}$

$d_{nozzle} := 1cm$ $A_{jet} := \frac{\pi}{4} \cdot d_{nozzle}^{\ 2}$ $A_{jet} = 0.785\,cm^2$

$V_{jet} := 20 \frac{m}{s}$ $Q := A_{jet} \cdot V_{jet}$ $Q = 1.571 \frac{L}{s}$ $Q = 24.898 \frac{gal}{min}$

$m_{jet} := \rho \cdot Q$ $m_{jet} = 21.269 \frac{mass}{time}$ $m_{jet} = 46.889 \frac{lb}{s}$

Assume deflector is vertical and jet is horizontal to simplify calculation - very conservative assumption. Hg spray will be evenly distributed in all directions, so vertical component of resultant force will be cancelled.

$R_x := m_{jet} \cdot V_{jet}$ $R_x = 425.372\,N$ $R_x = 95.627\,lbf$

To calculate the minimum deflector thickness, assume force acts in center of deflector and that the ends are rigidly supported.

$S_y := 120000psi$ tensile yield strength of Ti6AlV4

Plate dimensions: $w := 2in$ $len := 6in$ $t := 2mm$ $c := \frac{t}{2}$

Moment of inertia: $I := \frac{1}{12} \cdot w \cdot t^3$

Shear $V := \frac{R_x}{2}$ $\tau := \frac{3}{2} \cdot \frac{V}{w \cdot t}$ $\tau = 455.425\,psi$

$M := \frac{R_x \cdot len}{8}$ $\sigma_{act} := \frac{M \cdot c}{I}$ $\sigma_{act} = 3.47 \times 10^4\,psi$ $FS := \frac{S_y}{\sigma_{act}}$ $FS = 3.458$

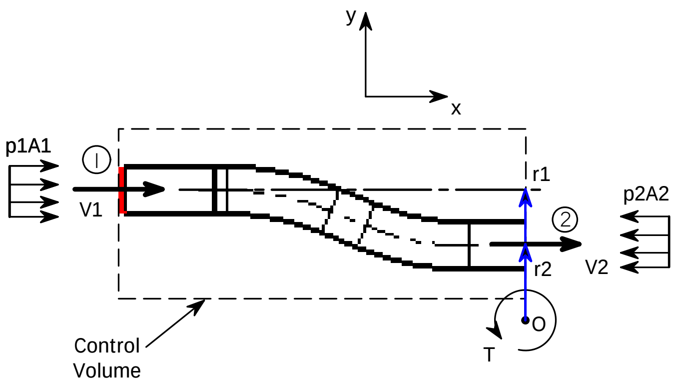
MERIT Calculation Sheet
Oak Ridge National Laboratory

CALCULATION   Hg Supply Piping Moment   SHEET 1 OF 2

DRAWING NO   203-HJT-0623

CALCULATION BY   V.B. Graves   DATE 10 May 2006

Calculate the moment imparted by the flowing Hg on the first piping restraint, assuming rigid connection. The fluid pressures were obtained using AFT Fathom so as to incorporate frictional losses and pressure drops in the actual piping.



$\rho := 13540 \frac{kg}{m^3}$ Fluid density $Q := 1.57 \frac{liter}{s}$ Flow rate

$mflow := \rho \cdot Q$ $mflow = 21.258 \frac{kg}{s}$ mass flow rate

$d := 0.884in$ Inlet & exit diameters are equal

$A := \frac{\pi}{4} d^2$ $V := \frac{Q}{A}$ $V = 3.965 \frac{m}{s}$ Flow area & velocity

$p_1 := 578psi$ $p_1 = 3.985 \times 10^6 Pa$ pressures obtained from AFT Fathom

$p_2 := 572psi$ $p_2 = 3.944 \times 10^6 Pa$

$r_1 := 1in$ $r_2 := 2.25in$ offsets

CALCULATION Hg Supply Piping Moment SHEET 2 OF 2

DRAWING NO 203-HJT-0623

CALCULATION BY V.B. Graves DATE 10 May 2006

For an inertial, non-deformable control volume with 1-dimensional inlets & outlets, conservation of angular momentum states that

$$\frac{d}{dt}\mathbf{H}_O = \sum \mathbf{M}_O = \sum (\mathbf{r} \times \mathbf{F})_O = \sum (\mathbf{r} \times \mathbf{V})_{out}\dot{m}_{out} - \sum (\mathbf{r} \times \mathbf{V})_{in}\dot{m}_{in}$$

$$\mathbf{T}_O + \mathbf{r}_1 \times (-p_1 A_1 \mathbf{n}_1) + \mathbf{r}_2 \times (-p_2 A_2 \mathbf{n}_2) = (\mathbf{r}_2 \times \mathbf{V}_2)(\dot{m}_{out}) - (\mathbf{r}_1 \times \mathbf{V}_1)(\dot{m}_{in})$$

$$T_O - r_1 p_1 A + r_2 p_2 A = \dot{m}V(r_2 - r_1)$$

$$T_O = \dot{m}V(r_2 - r_1) + A(r_1 p_1 - r_2 p_2)$$

$T_o := mflow \cdot V \cdot (r_2 - r_1) + A \cdot (r_1 \cdot p_1 - r_2 \cdot p_2)$

$mflow \cdot V \cdot (r_2 - r_1) = 1.974\ ft \cdot lbf$

$A \cdot (r_1 \cdot p_1 - r_2 \cdot p_2) = -36.263\ ft \cdot lbf$

$T_o = -34.3\ ft \cdot lbf$ $T_o = -46.5\ N \cdot m$

Stress Analysis of Hg Sump Tank - Hg Weight

Author: V.B. Graves

Company: Oak Ridge National Laboratory

Date: Nov 15, 2005

---

1. Introduction

A static analysis of the Hg sump tank is performed. Loading condition is 800 lb applied to bottom of tank to simulate weight of 23 liters Hg. No loads on the side walls were simulated.

Areas representing the square supports on the tank bottom were restrained.

Note:

Do not base your design decisions solely on the data presented in this report. Use this information in conjunction with experimental data and practical experience. Field testing is mandatory to validate your final design. COSMOSWorks helps you reduce your time-to-market by reducing but not eliminating field tests.

2. Materials

No.	Part Name	Material	Mass	Volume
1	sump tank hjt	AISI 304	59.5098 lb	205.903 in^3
2	sump tank hjt	AISI 304	59.5098 lb	205.903 in^3
3	sump tank hjt	AISI 304	59.5098 lb	205.903 in^3

3. Load & Restraint Information

Restraint	
Restraint-1 <sump tank hjt>	on **2 Face(s)** fixed.
Description:	Tank bottom restrained where it contacts supports.

Load		
Force-1 <sump tank hjt>	on **1 Face(s)** apply normal force **800 lb** using uniform distribution	Sequential Loading
Description:	Weight of 23 liters Hg applied to	

	bottom face.

---

4. Study Property

Mesh Information	
Mesh Type:	Solid mesh
Mesher Used:	Standard
Automatic Transition:	Off
Smooth Surface:	On
Jacobian Check:	4 Points
Element Size:	0.59061 in
Tolerance:	0.029531 in
Quality:	High
Number of elements:	17641
Number of nodes:	35493

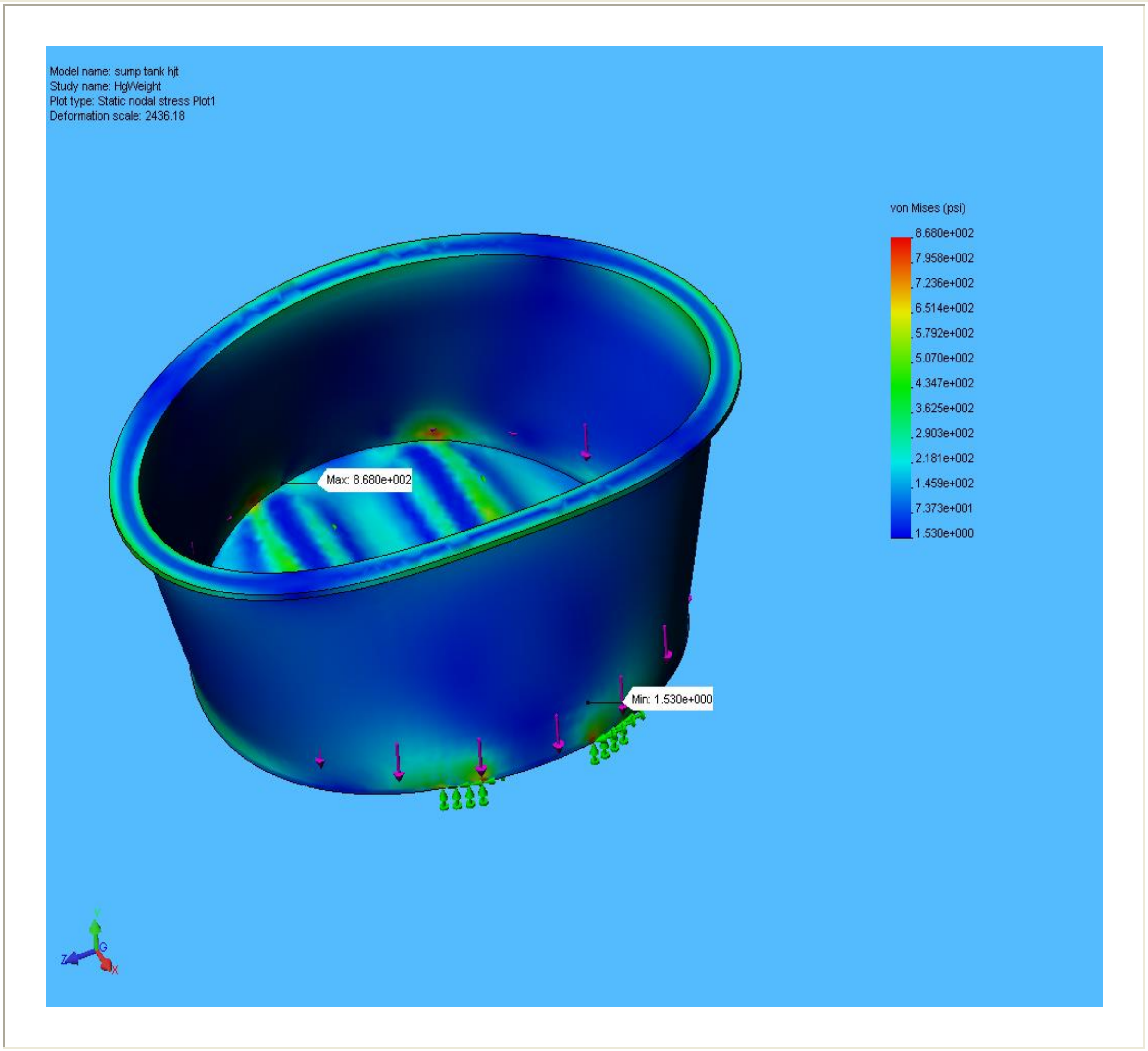
Solver Information	
Quality:	High
Solver Type:	FFEPlus
Option:	Include Thermal Effects
Thermal Option:	Input Temperature
Thermal Option:	Reference Temperature at zero strain: 25 Celsius

---

5. Stress Results

Name	Type	Min	Location	Max	Location
Plot1	VON: von Mises stress	1.52968 psi Node: 25974	(7.50297 in, 0 in, -3.2 in)	867.968 psi Node: 27866	(-9.71311 in, 0.125 in, 2.37814 in)

sump tank hjt-HgWeight-Stress-Plot1
JPEG



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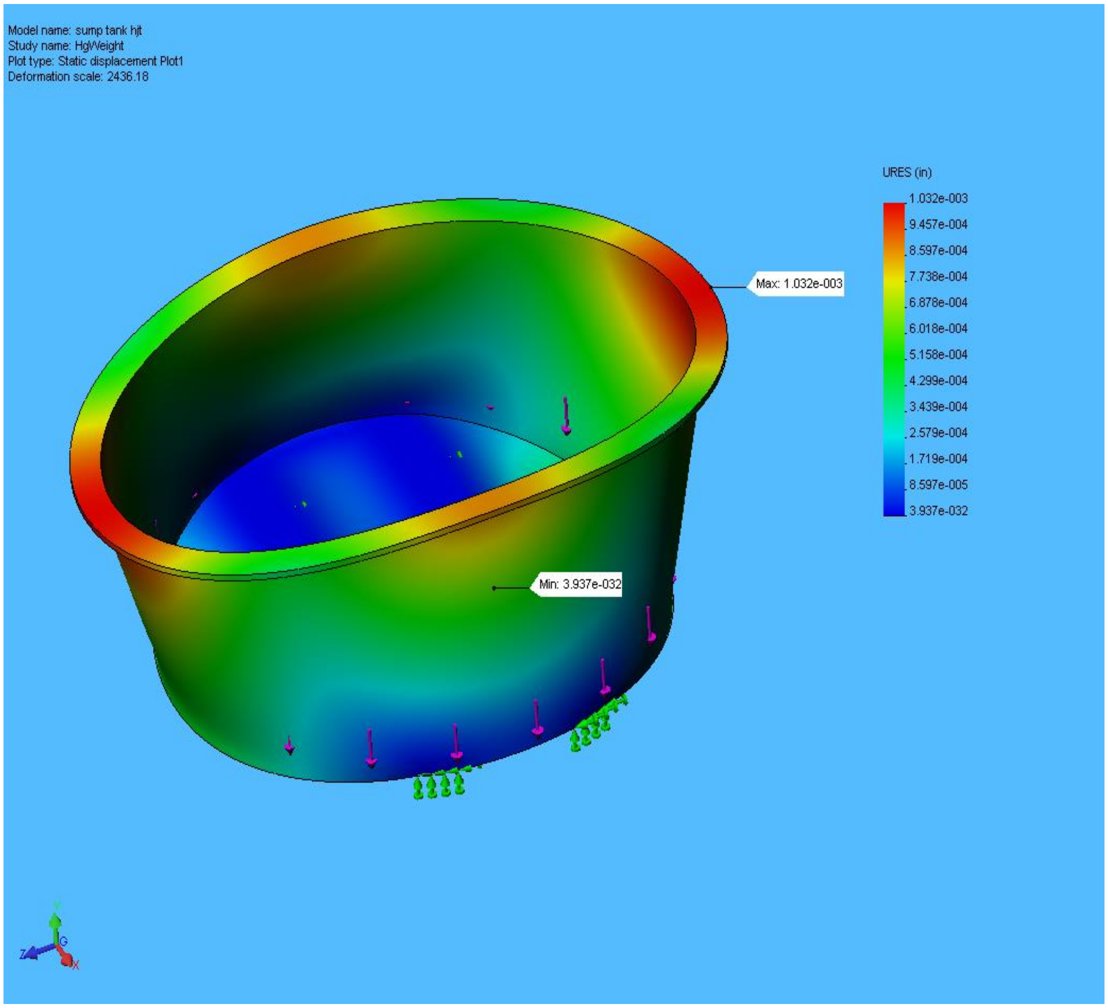
6. Displacement Results

Name	Type	Min	Location	Max	Location
Plot1	URES: Resultant displacement	0 in Node:	(9.18681 in,	0.00103167 in	(1.34711e-015 in,

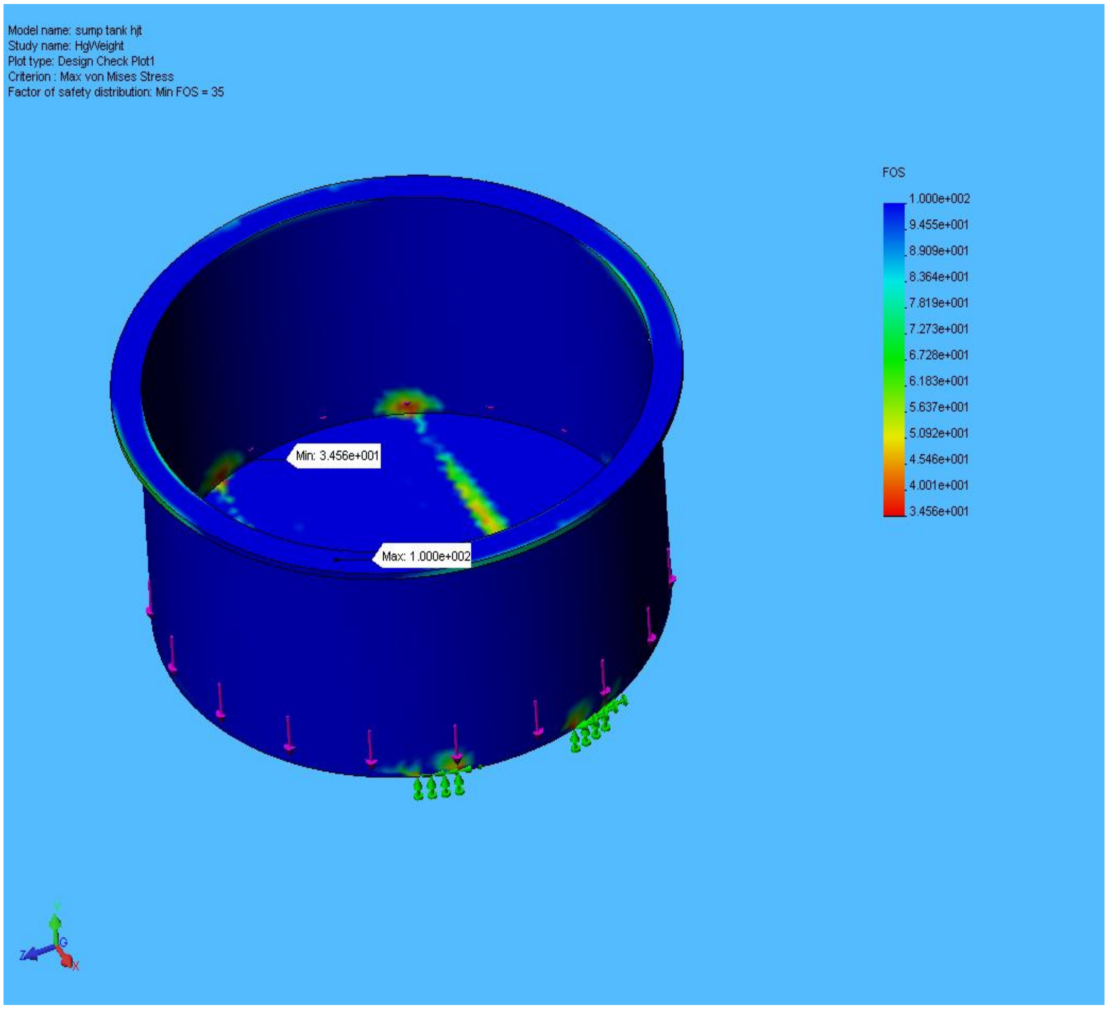
		24918	0 in, 3.95 in)	Node: 23190	9.75 in, -11 in)

sump tank hjt-HgWeight-Displacement-Plot1

JPEG



7. Design Check Results

sump tank hjt-HgWeight-Design Check-Plot1
JPEG


8. Conclusion

Analysis shows minimum safety factor > 30, so tank is considered structurally sound for this loading condition.

9. Appendix

Material name: AISI 304

Description:

Material Source: Library files

Material Library Name: cosmos materials

Material Model Type: Linear Elastic Isotropic

Property Name	Value	Units	Value Type
Elastic modulus	2.7557e+007	psi	Constant
Poisson's ratio	0.29	NA	Constant
Shear modulus	1.0878e+007	psi	Constant
Mass density	0.28902	lb/in^3	Constant
Tensile strength	74987	psi	Constant
Yield strength	29995	psi	Constant
Thermal expansion coefficient	1e-005	/Fahrenheit	Constant
Thermal conductivity	0.000214	BTU/(in.s.F)	Constant
Specific heat	0.11945	Btu/(lb.F)	Constant

Stress Analysis of Hg Jet Chamber

Author: V.B. Graves

Company: Oak Ridge National Laboratory

Date: May 19, 2006

---

1. Introduction

A static analysis of the Hg jet chamber is performed. The chamber may be tested prior to Hg loading either by a static pressure test or a vacuum rate-of-rise test. A static internal pressure of 1atm was simulated in this analysis. During operation there will be no interior pressure within the weldment.

Note:

Do not base your design decisions solely on the data presented in this report. Use this information in conjunction with experimental data and practical experience. Field testing is mandatory to validate your final design. COSMOSWorks helps you reduce your time-to-market by reducing but not eliminating field tests.

---

2. Materials

No.	Part Name	Material	Mass	Volume
1	pri tube weldment hjt	AISI 304	44.7162 lb	154.718 in^3
2	pri tube weldment hjt	AISI 304	44.7162 lb	154.718 in^3
3	pri tube weldment hjt	AISI 304	44.7162 lb	154.718 in^3
4	pri tube weldment hjt	AISI 304	44.7162 lb	154.718 in^3
5	pri tube weldment hjt	AISI 304	44.7162 lb	154.718 in^3
6	pri tube weldment hjt	AISI 304	44.7162 lb	154.718 in^3

---

3. Load & Restraint Information

Restraint	
Restraint-1 <pri tube weldment hjt>	on **1 Face(s)** fixed.
Description:	Exit end face held fixed.

Load		
Pressure-1 <pri tube weldment hjt>	on **10 Face(s)** with Pressure **15 psi** along direction normal to selected face	Sequential Loading
Description:	15 psi on all internal surfaces.	

4. Study Property

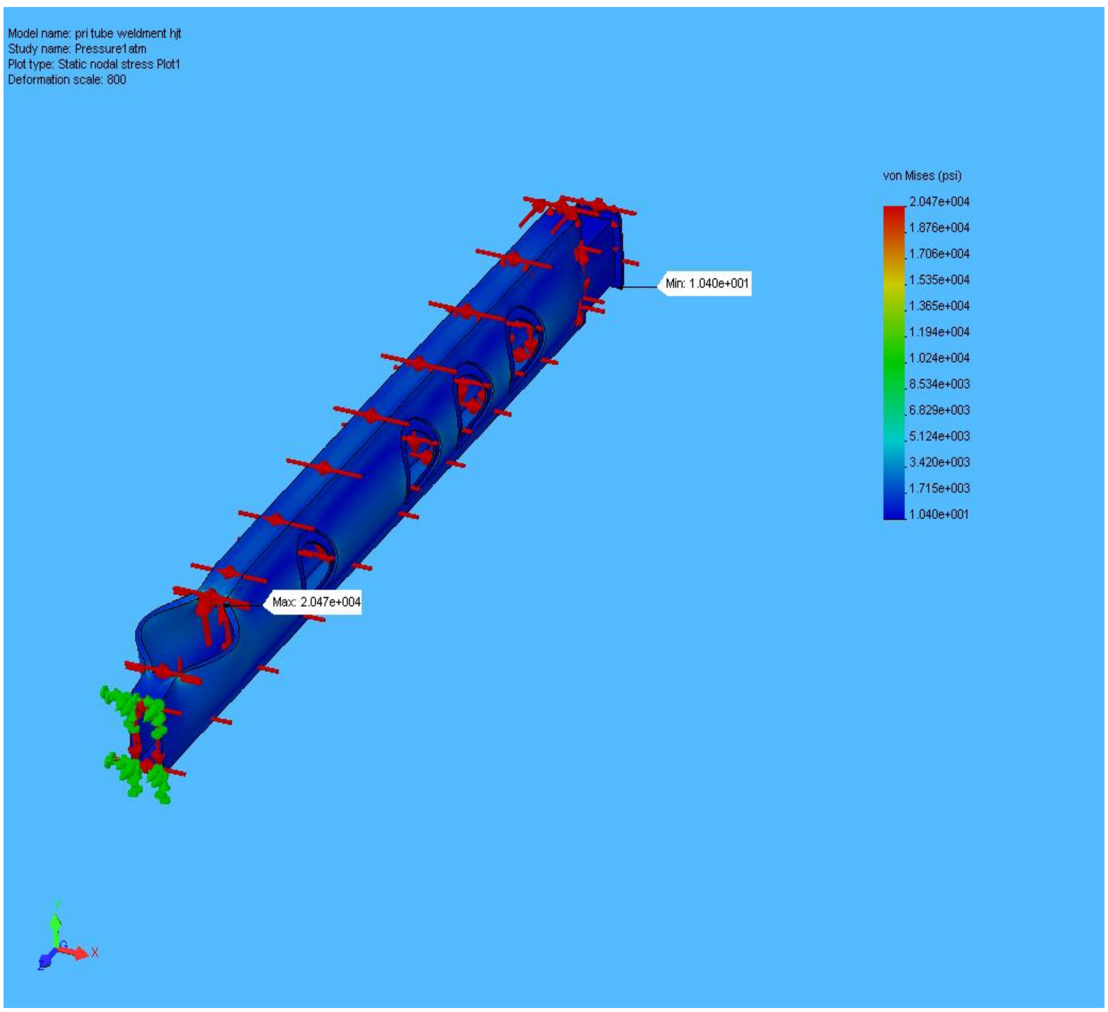
Mesh Information	
Mesh Type:	Solid mesh
Mesher Used:	Standard
Automatic Transition:	Off
Smooth Surface:	On
Jacobian Check:	4 Points
Element Size:	0.53695 in
Tolerance:	0.026848 in
Quality:	High
Number of elements:	14806
Number of nodes:	30039

Solver Information	
Quality:	High
Solver Type:	FFEPlus
Option:	Include Thermal Effects
Thermal Option:	Input Temperature
Thermal Option:	Reference Temperature at zero strain: 25 Celsius

5. Stress Results

Name	Type	Min	Location	Max	Location
Plot1	VON: von Mises stress	10.3982 psi Node: 693	(1.25 in, -2.6625 in, -18.0992 in)	20466.5 psi Node: 5620	(0.658211 in, 2.21623 in, 25.9439 in)

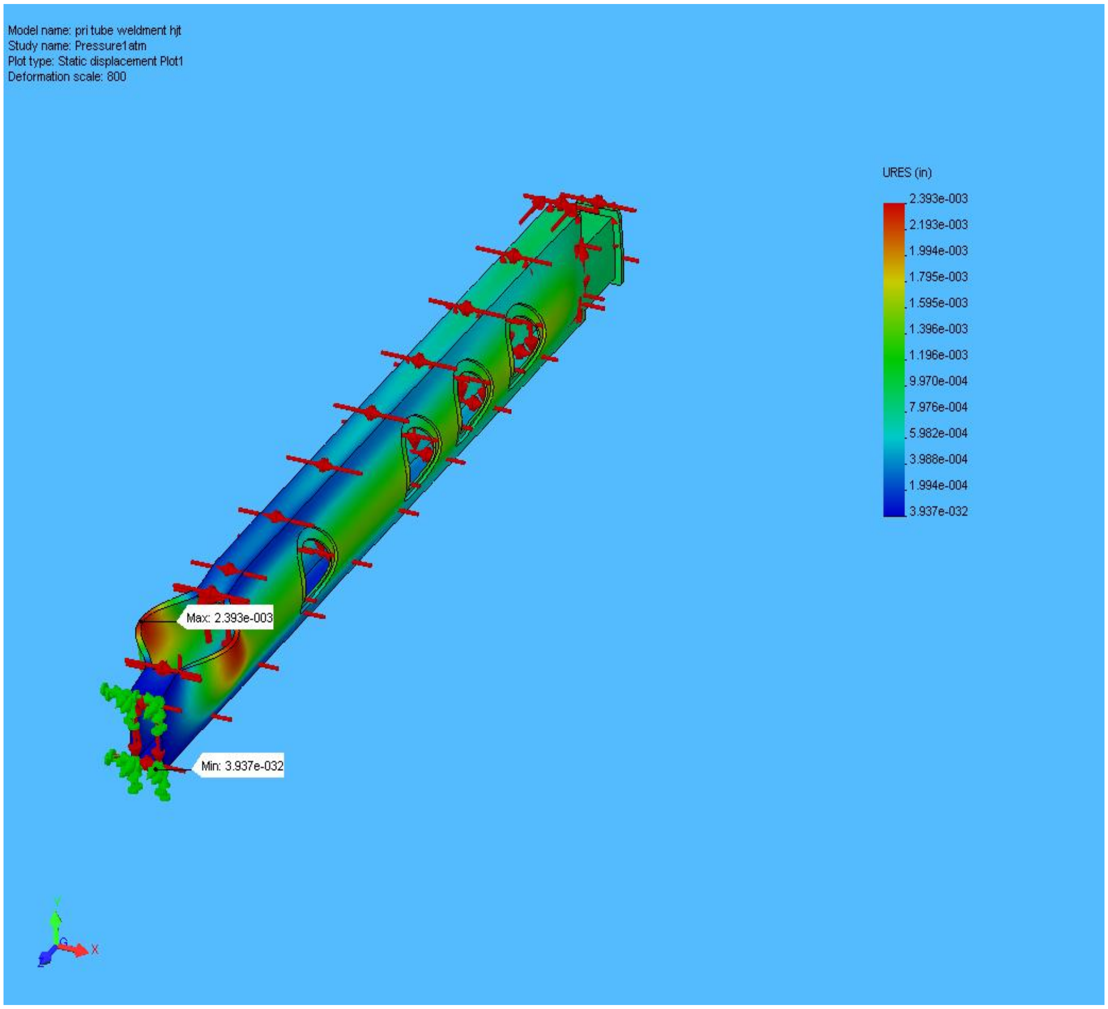
pri tube weldment hjt-Pressure1atm-Stress-Plot1
JPEG



6. Displacement Results

Name	Type	Min	Location	Max	Location
Plot1	URES: Resultant displacement	0 in Node: 1440	(-0.6875 in, 0.645291 in, 34 in)	0.0023928 in Node: 16816	(-0.8125 in, 1.88444 in, 28.9516 in)

pri tube weldment hjt-Pressure1atm-Displacement-Plot1
JPEG



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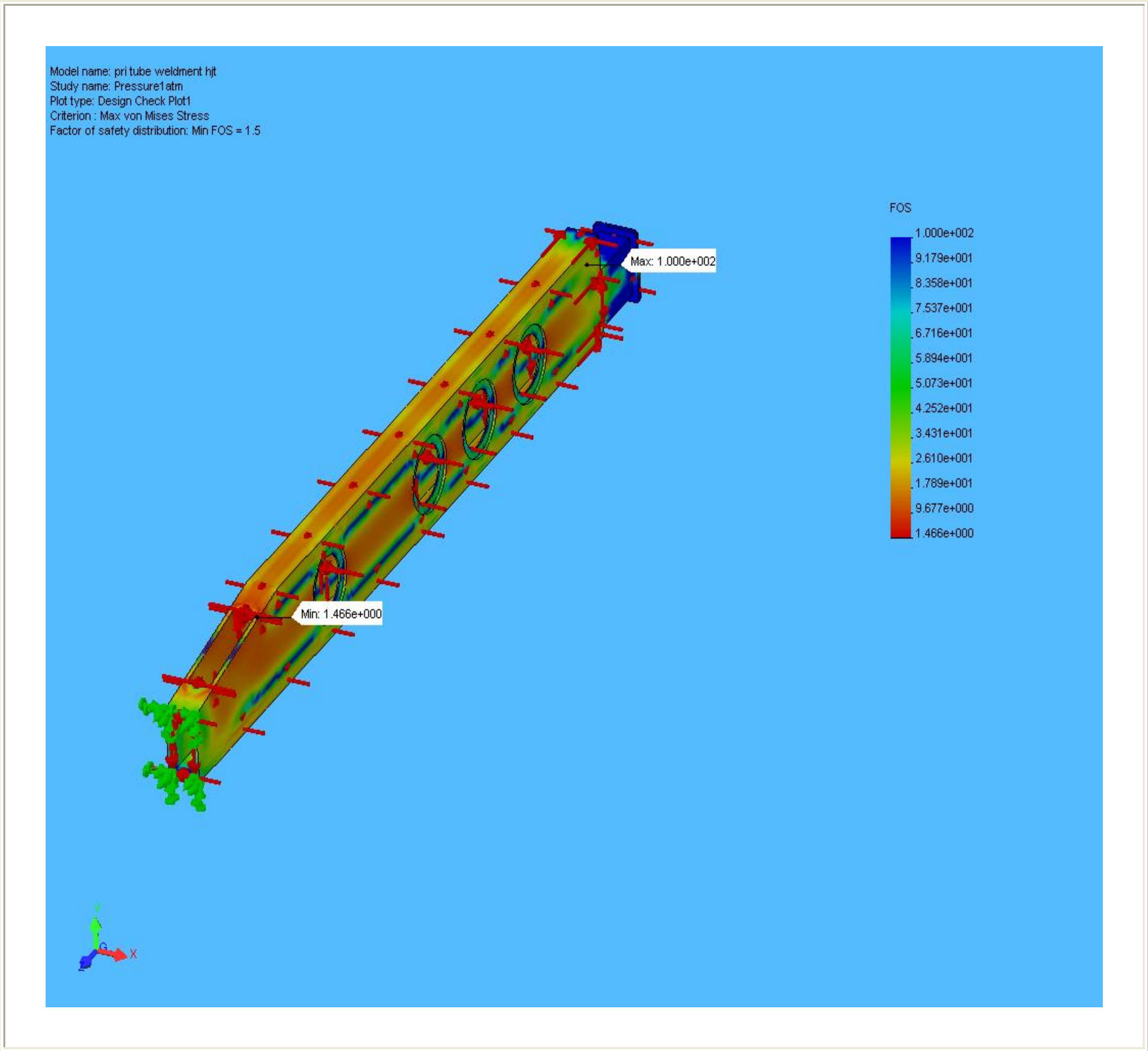
7. Design Check Results

pri tube weldment hjt-Pressure1atm-Design Check-Plot1
JPEG



---

8. Conclusion

Analysis indicates minimum safety factor > 10, so structure is considered structurally sound for the simulated loading condition.

9. Appendix

Material name: AISI 304

Description:

Material Source: Library files

Material Library Name: cosmos materials

Material Model Type: Linear Elastic Isotropic

Property Name	Value	Units	Value Type
Elastic modulus	2.7557e+007	psi	Constant
Poisson's ratio	0.29	NA	Constant
Shear modulus	1.0878e+007	psi	Constant
Mass density	0.28902	lb/in^3	Constant
Tensile strength	74987	psi	Constant
Yield strength	29995	psi	Constant
Thermal expansion coefficient	1e-005	/Fahrenheit	Constant
Thermal conductivity	0.000214	BTU/(in.s.F)	Constant
Specific heat	0.11945	Btu/(lb.F)	Constant

Stress Analysis of Hg Supply Reducer

Author: Author: Van Graves

Company: Oak Ridge National Laboratory

Date: April 12, 2006

---

1. Introduction

A static analysis of the Hg flow reducer is performed. The design pressure of 1500 psi was applied to the interior surfaces of the reducer.

Note:

Do not base your design decisions solely on the data presented in this report. Use this information in conjunction with experimental data and practical experience. Field testing is mandatory to validate your final design. COSMOSWorks helps you reduce your time-to-market by reducing but not eliminating field tests.

---

2. Materials

No.	Part Name	Material	Mass	Volume
1	hg supply reducer hjt	Titanium Ti-6Al-4V (Grade 5), Annealed	0.0998634 lb	0.623975 in^3

---

3. Load & Restraint Information

Restraint	
Restraint-1 <hg supply reducer hjt>	on **2 Face(s)** fixed.
Description:	Outer diameter and face of exit end fixed as they would be welded to the nozzle flange.

Load		
Pressure-1 <hg supply reducer hjt>	on **3 Face(s)** with Pressure **1500 psi** along direction normal to selected face	Sequential Loading
Description:	Design pressure load.	

---

4. Study Property

Mesh Information	
Mesh Type:	Solid mesh
Mesher Used:	Standard
Automatic Transition:	Off
Smooth Surface:	On
Jacobian Check:	4 Points
Element Size:	0.085485 in
Tolerance:	0.0042742 in
Quality:	High
Number of elements:	7612
Number of nodes:	15263

Solver Information	
Quality:	High
Solver Type:	FFE
Option:	Include Thermal Effects
Thermal Option:	Input Temperature
Thermal Option:	Reference Temperature at zero strain: 77 Fahrenheit

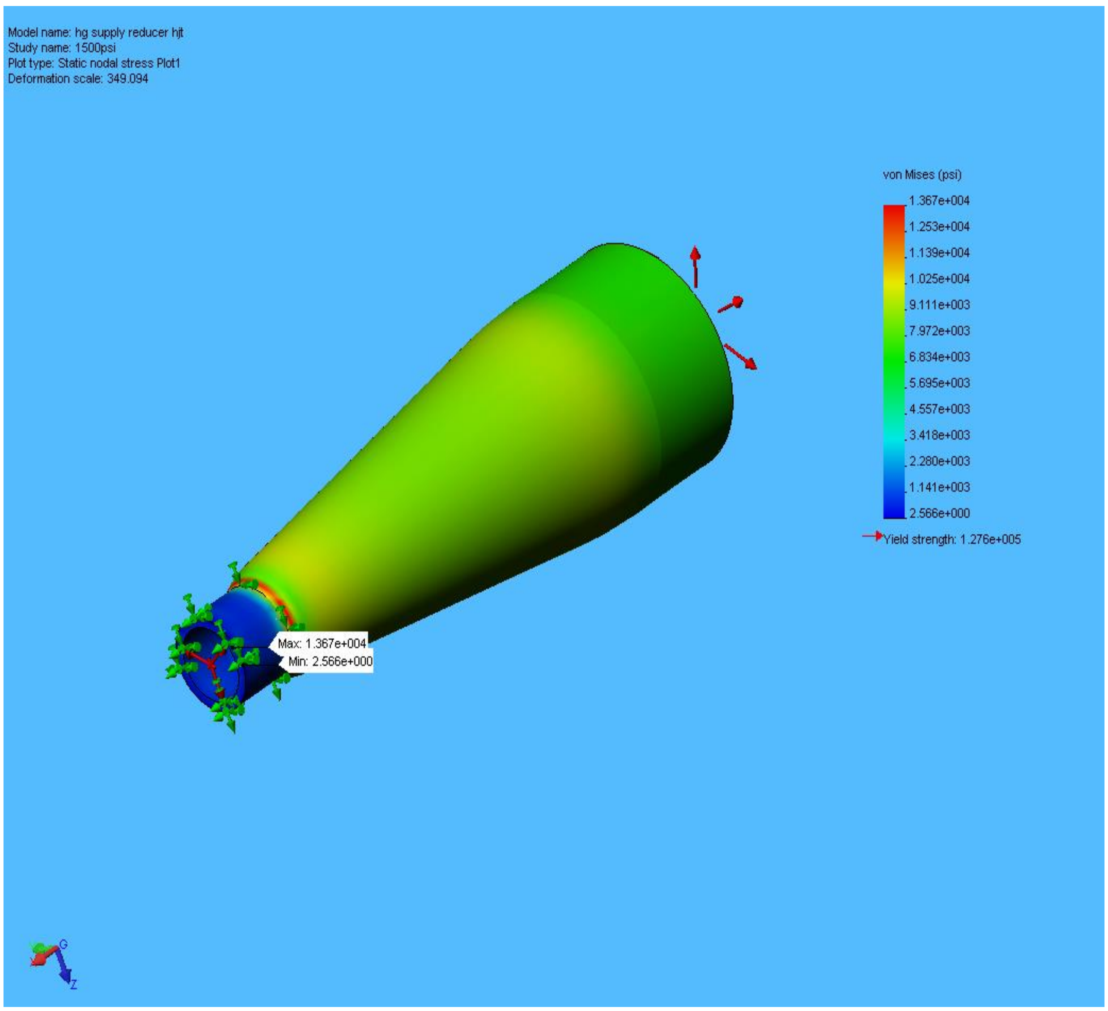
---

5. Stress Results

Name	Type	Min	Location	Max	Location
Plot1	VON: von Mises stress	2.56573 psi Node: 2509	(0.375 in, -0.249301 in, 0.0186825	13665.3 psi Node: 14939	(-0.041552 in, 0.244426

			in)		in, 0.0683738 in)

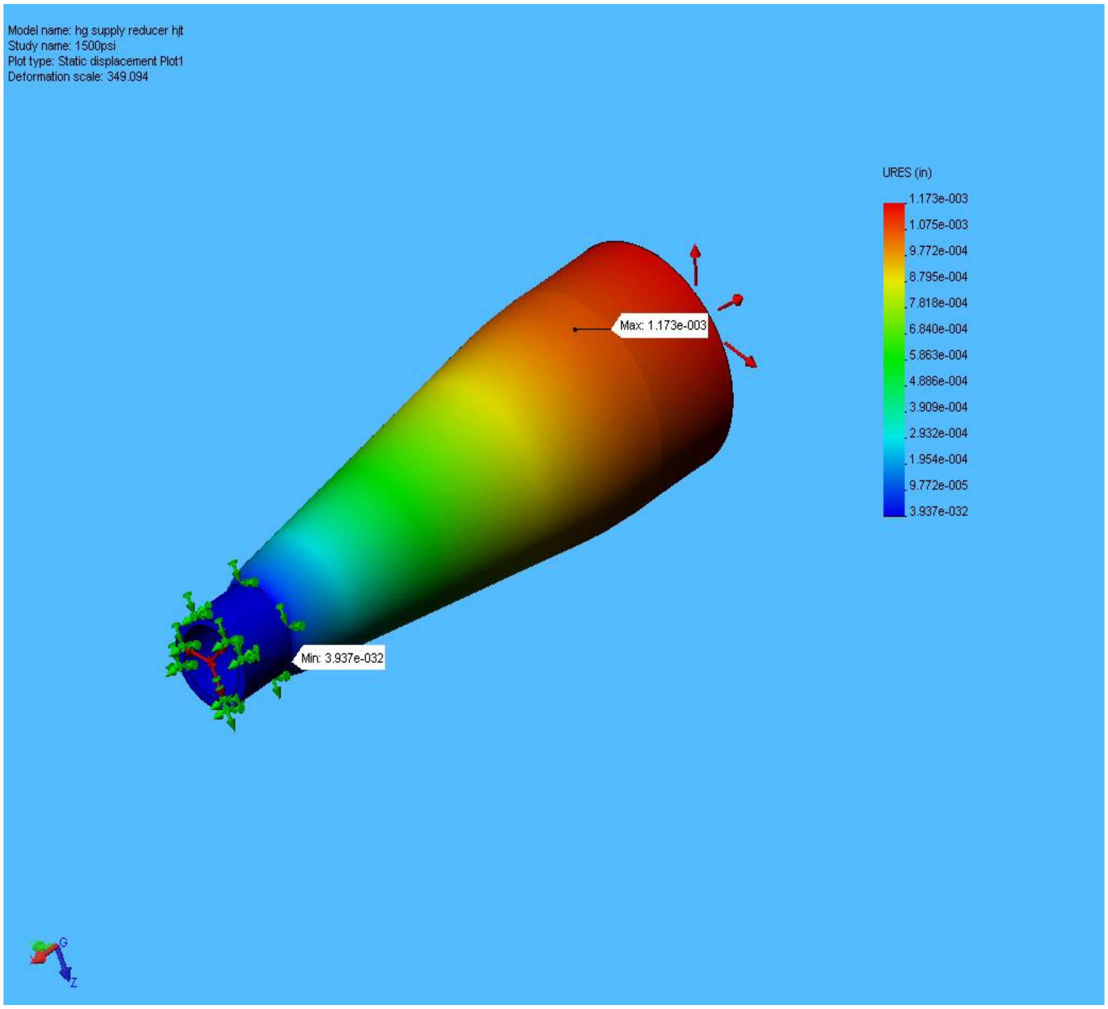
hg supply reducer hjt-1500psi-Stress-Plot1
JPEG



6. Displacement Results

Name	Type	Min	Location	Max	Location
Plot1	URES: Resultant displacement	0 in Node: 1	(0.375 in, 0.216506 in, -0.125 in)	0.00117264 in Node: 2032	(-3.625 in, 0.41769 in, -0.144564 in)

hg supply reducer hjt-1500psi-Displacement-Plot1
JPEG



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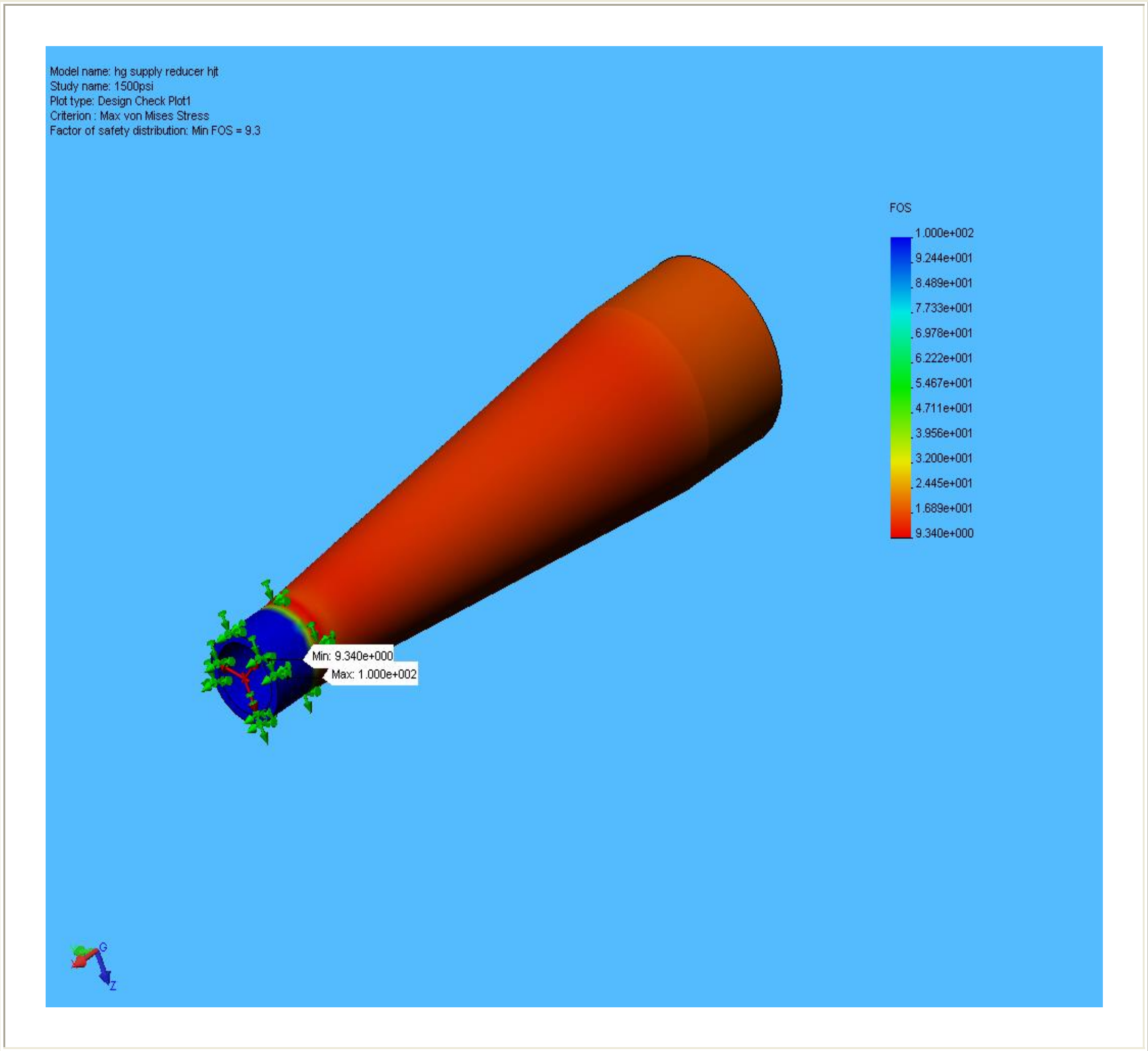
7. Design Check Results

hg supply reducer hjt-1500psi-Design Check-Plot1
JPEG



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8. Conclusion

The flow reducer should never actually encounter the full design pressure since the downstream pressure drop is due to the nozzle, which requires about 400 psi. With a minimum safety factor > 9 for the design case, the reducer is considered structurally safe for the simulated loading condition.

---

9. Appendix

Material name: Titanium Ti-6Al-4V (Grade 5), Annealed

Description:

Material Source: Library files

Material Library Name: titanium

Material Model Type: Linear Elastic Isotropic

Property Name	Value	Units	Value Type
Elastic modulus	1.6505e+007	psi	Constant
Elastic modulus	1.6505e+007	psi	Constant
Elastic modulus	1.6505e+007	psi	Constant
Poisson's ratio	0.342	NA	Constant
Poisson's ratio	0.342	NA	Constant
Poisson's ratio	0.342	NA	Constant
Shear modulus	6.3817e+006	psi	Constant
Shear modulus	6.3817e+006	psi	Constant
Shear modulus	6.3817e+006	psi	Constant
Mass density	0.16004	lb/in^3	Constant
Tensile strength	1.3779e+005	psi	Constant
Compressive strength	1.4069e+005	psi	Constant
Yield strength	1.2763e+005	psi	Constant
Thermal expansion coefficient	4.7778e-006	/Fahrenheit	Constant
Thermal expansion coefficient	4.7778e-006	/Fahrenheit	Constant
Thermal expansion coefficient	4.7778e-006	/Fahrenheit	Constant
Thermal conductivity	8.9611e-005	BTU/(in.s.F)	Constant
Thermal conductivity	8.9611e-005	BTU/(in.s.F)	Constant
Specific heat	0.12573	Btu/(lb.F)	Constant

Stress Analysis of Hg Sump Tank - Internal Pressure

Author: V.B. Graves

Company: Oak Ridge National Laboratory

Date: Nov 15, 2005

---

1. Introduction

A static analysis of the Hg sump tank is performed. Loading condition is 1atm internal pressure applied to bottom and wall of tank to simulate leak check operation.

Areas representing the square supports on the tank bottom were restrained.

Note:

Do not base your design decisions solely on the data presented in this report. Use this information in conjunction with experimental data and practical experience. Field testing is mandatory to validate your final design. COSMOSWorks helps you reduce your time-to-market by reducing but not eliminating field tests.

---

2. Materials

No.	Part Name	Material	Mass	Volume
1	sump tank hjt	AISI 304	59.5098 lb	205.903 in^3
2	sump tank hjt	AISI 304	59.5098 lb	205.903 in^3
3	sump tank hjt	AISI 304	59.5098 lb	205.903 in^3

---

3. Load & Restraint Information

Restraint	
Restraint-1 <sump tank hjt>	on **2 Face(s)** fixed.
Description:	Tank bottom restrained where it contacts supports.

Load		
Pressure-1 <sump tank hjt>	on **2 Face(s)** with Pressure **15 psi** along direction normal to selected face	Sequential Loading
Description:	15 psi internal pressure on bottom and wall.	

4. Study Property

Mesh Information	
Mesh Type:	Solid mesh
Mesher Used:	Standard
Automatic Transition:	Off
Smooth Surface:	On
Jacobian Check:	4 Points
Element Size:	0.59061 in
Tolerance:	0.029531 in
Quality:	High
Number of elements:	17641
Number of nodes:	35493

Solver Information	
Quality:	High
Solver Type:	FFEPlus
Option:	Include Thermal Effects
Thermal Option:	Input Temperature
Thermal Option:	Reference Temperature at zero strain: 25 Celsius

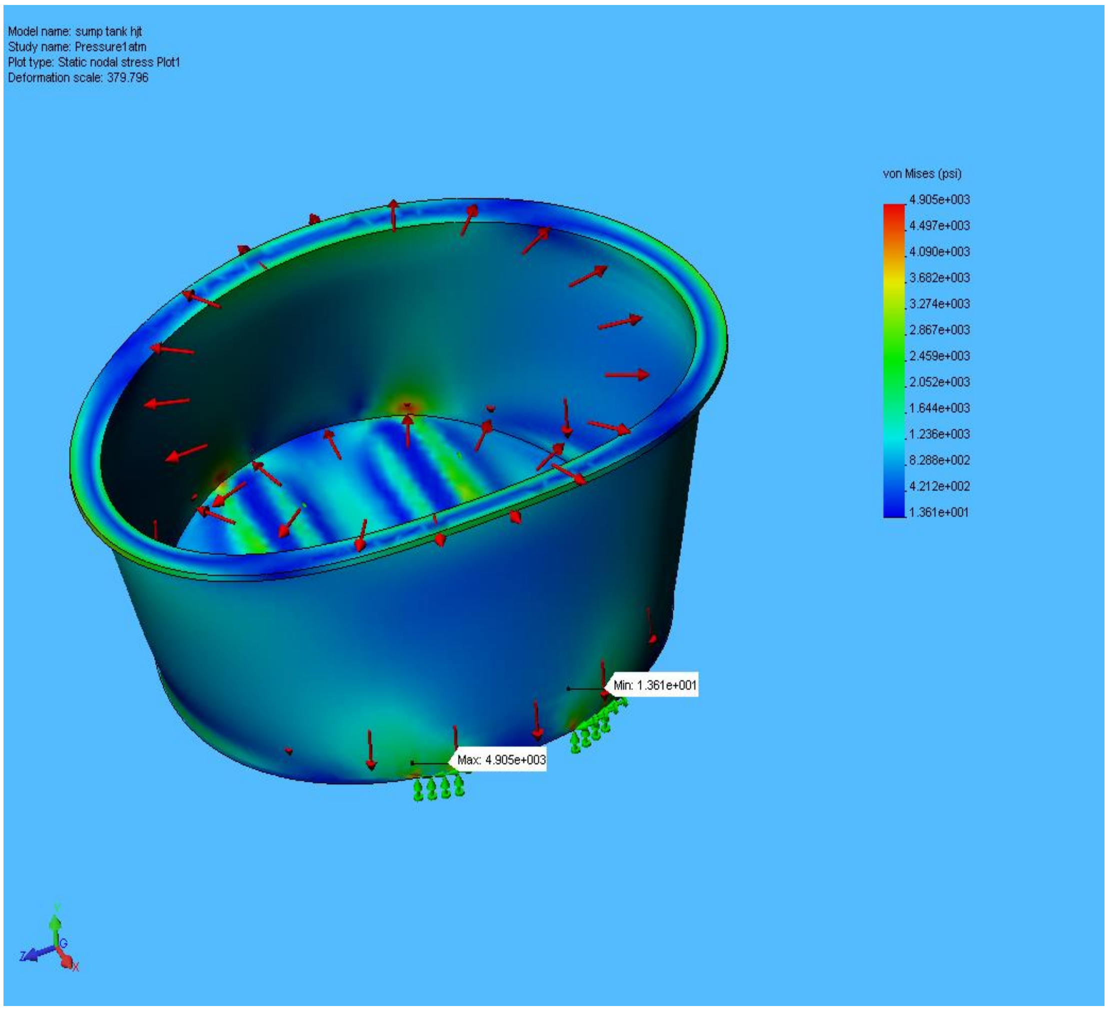
5. Stress Results

Name	Type	Min	Location	Max	Location

Plot1	VON: von Mises stress	13.6131 psi Node: 25974	(7.50297 in, 0 in, -3.2 in)	4904.86 psi Node: 5196	(8.96416 in, 0.546875 in, 3.9911 in)

sump tank hjt-Pressure1atm-Stress-Plot1

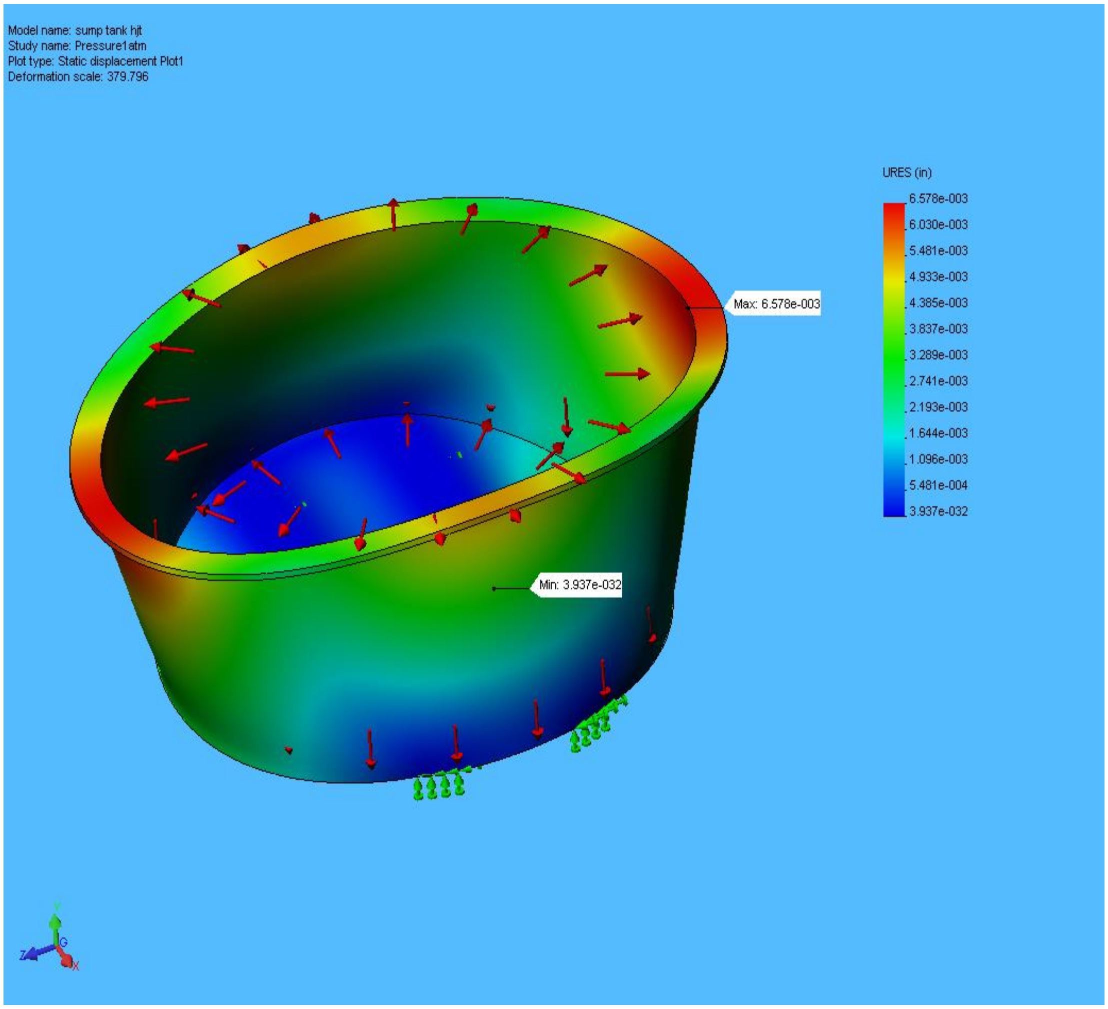
JPEG



6. Displacement Results

Name	Type	Min	Location	Max	Location
Plot1	URES: Resultant displacement	0 in Node: 24918	(9.18681 in, 0 in, 3.95 in)	0.00657775 in Node: 21565	(0 in, 9.21094 in, -10 in)

sump tank hjt-Pressure1atm-Displacement-Plot1
JPEG



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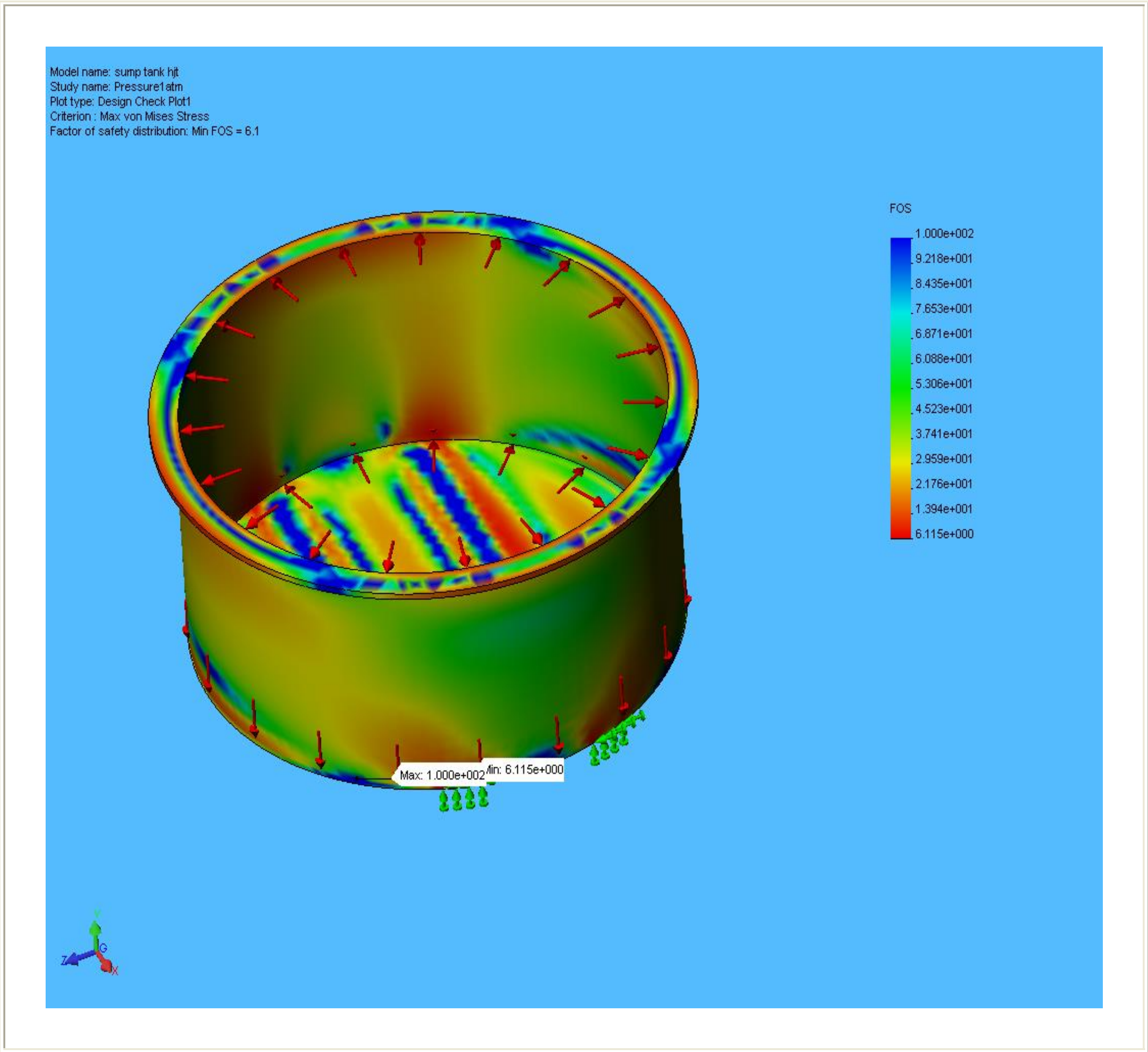
7. Design Check Results

sump tank hjt-Pressure1atm-Design Check-Plot1
JPEG



8. Conclusion

Area of highest stress near tank bottom close to support. Minimum safety factor > 6, so tank is considered structurally sound for this loading condition.

9. Appendix

Material name: AISI 304

Description:

Material Source: Library files

Material Library Name: cosmos materials

Material Model Type: Linear Elastic Isotropic

Property Name	Value	Units	Value Type
Elastic modulus	2.7557e+007	psi	Constant
Poisson's ratio	0.29	NA	Constant
Shear modulus	1.0878e+007	psi	Constant
Mass density	0.28902	lb/in^3	Constant
Tensile strength	74987	psi	Constant
Yield strength	29995	psi	Constant
Thermal expansion coefficient	1e-005	/Fahrenheit	Constant
Thermal conductivity	0.000214	BTU/(in.s.F)	Constant
Specific heat	0.11945	Btu/(lb.F)	Constant

Appendix D.   Secondary Containment Documents

Mercury Removal From Gas Streams

Mercury Issues

Because of the extreme toxicity of mercury vapor, removal of mercury from air and process gas stream is critical for both safety and environmental compliance. The threshold limit value (TLV) for mercury exposure is 0.05 mg/m^3. In addition, the presence of trace mercury in process gas streams (e.g. natural gas, hydrogen) can lead to significant process problems, such as corrosion and catalyst poisoning. Barnebey Sutcliffe provides three different products for vapor phase mercury control for different applications: activated carbon types CB, CBII, and CY. These products can reduce mercury to part per trillion levels and can achieve capacities as high as 20% by weight.

Development of CB Carbon

Virgin activated carbon has a relatively low capacity for mercury vapors. In 1960, Barnebey Sutcliffe developed the first generation of impregnated carbon to remove Hg. This product used potassium iodide (KI) and iodine (I_3) to react with mercury according to the following reaction:

$$3\,Hg + I_3 \longrightarrow 3\,HgI$$

Barnebey Sutcliffe today offers an improved version of this product under the trade name Type CB. It is used for specialty applications, such as H_2 purification because it is resistant to side reactions (H_2S formation).

Type CBII Carbon

Sulfur has long been known to be effective in removing mercury vapor via the following reaction:

$$Hg + S \longrightarrow HgS$$

Barnebey Sutcliffe has developed a proprietary process for impregnation of carbon with sulfur and carbon base materials that provided optimum pore structure for mercury capture. Using this technology Barnebey Sutcliffe markets a sulfur-impregnated product under the trade name CBII. CBII can achieve an adsorption capacity of 20% w/w under ideal conditions. It is widely used for mercury removal from air streams and from natural gas streams.

Type CY Carbon

CY is a specialty impregnated product specifically designed for use in mercury vapor respirators. It meets the stringent requirements of NIOSH for mercury protective equipment.

Design Considerations

Because mercury is so toxic, it is critical to properly design mercury adsorption systems. Efficiency of mercury removal is affected by temperature, pressure, relative humidity, concentration of mercury, species of mercury (e.g. ionic, elemental), etc. Because mercury is chemisorbed on carbon, the residence time requirements are different than those for standard adsorption application. Please contact the Barnebey Sutcliffe technical department for assistance in designing a system for your particular application.

Test Data

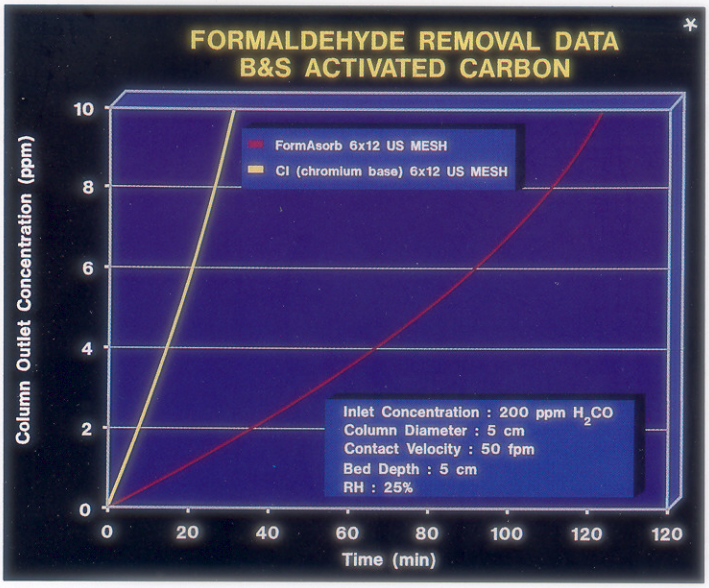
Performance tests were conducted to compare CBII to other commercially available products. Miller-Nelson Research, Monterrey, California performed the testing by passing 40 l/min. of zero air through a mercury diffusion vial to generated a 2 ppm mercury stream. The mercury stream then passed through a 2.5" x 7.5" adsorption column, and the inlet and outlet concentration were measured using a Jerome Meter. Three types of carbon were tested: CBII 4 x 10 and 2 commercially available carbons impregnated with >15% sulfur (Sample A and Sample B). The removal efficiency vs. bed volume feed date was collected at different time intervals and the results are shown below. The test was terminated after 10,000 bed volumes of air has passed through the column.

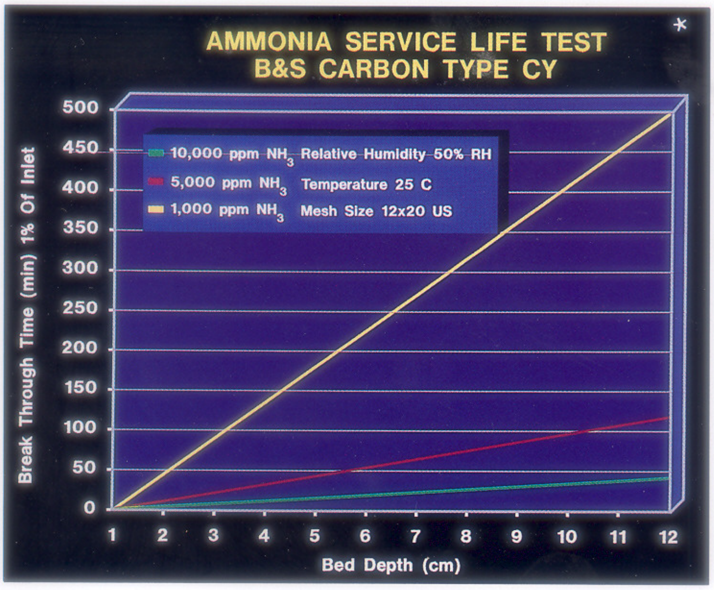
Carbon	Initial Mercury Effluent	Time Until Test Completion
CBII	Non-detect	24 hours
Sample A	Non-detect	24 hours
Sample B	Non-detect	2 hours

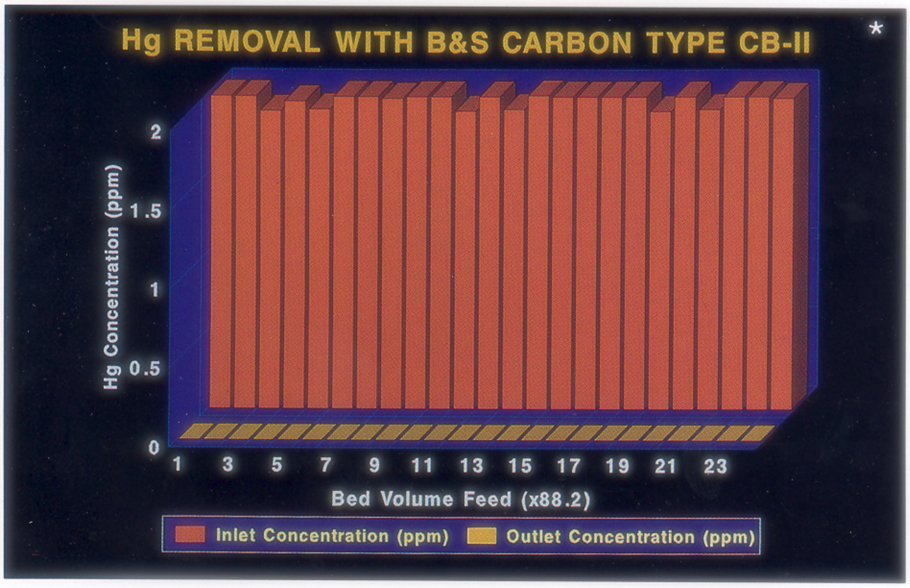
Operating Temperature

The maximum recommended operating temperature for CBII is 70 ^{o}C. Above this temperature, the performance for mercury removal declines appreciably. CBII has been used at temperatures up to 100 ^{o}C. Operation above this temperature may result in loss of sulfur impregnant. CBII has a high ignition temperature. Measurements of ignition temperature using ASTM Method D–346D range from 450 ^{o}C to over 500 ^{o}C.

Performance Data







CARBON SELECTION TABLE

	209CKINA	CY	CA	FormAsorb	ST	ETO	487	727	717	787	CBI	CBII
CL2	●				●							
SO2	●				●							
NH3		●	●			●						
Monomethyl Amine		●	●									
Formaldehyde				●								
H2S	●				●							
CLO2	●				●							
Methyl Iodine							●	●	●	●		
HCL	●				●							
HF	●				●							
HBr	●				●							
Ethylene Oxide						●						
H2SO4	●				●							
Hg	●										●	●

Note: CA replaced by AmmonAsorb II

Your Single Source Supplier

Barnebey & Sutcliffe provides quality activated carbon products and equipment along with highly skilled technical support and customer service. You can count on the most cost-effective materials available, custom designed to meet your specific applications. Make Barnebey & Sutcliffe your single source for all your specialty carbon requirements.

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With more than 100 established impregnated carbons currently available, Barnebey & Sutcliffe has the expertise and applications experience to design a special carbon adsorbent for your needs.

* All tests conducted by
Miller-Nelson Research, Inc.

For more information on a specific specialty carbon to meet your application requirements, call or write:

Barnebey & Sutcliffe Corporation
P.O. Box 2526
Columbus, Ohio 43216
Telephone: 614-258-9501
Fax number: 614-258-3464

Stress Analysis of Secondary Containment Box Supports

Author: V.B. Graves

Company: Oak Ridge National Laboratory

Date: May 19, 2006

---

1. Introduction

A static analysis is performed of the rectangular tubes that support the secondary containment box. Loading condition simulated put one-half Hg system weight (2000 lbs) to tube top surface. Loading direction simulated slope of TT2 tunnel.

Vertical (normal) load on surface: 2000 * cos(4.2) = 1995 lb

Horizontal load on surface: 2000 * sin(4.2) = 150 lb

Note:

Do not base your design decisions solely on the data presented in this report. Use this information in conjunction with experimental data and practical experience. Field testing is mandatory to validate your final design. COSMOSWorks helps you reduce your time-to-market by reducing but not eliminating field tests.

---

2. Materials

No.	Part Name	Material	Mass	Volume
1	rect tubing support hjt	AISI 316 Annealed Stainless Steel Bar (SS)	47.6618 lb	164.909 in^3
2	rect tubing support hjt	AISI 316 Annealed Stainless Steel Bar (SS)	47.6618 lb	164.909 in^3
3	rect tubing support hjt	AISI 316 Annealed Stainless Steel Bar (SS)	47.6618 lb	164.909 in^3
4	rect tubing support hjt	AISI 316 Annealed Stainless Steel Bar (SS)	47.6618 lb	164.909 in^3

---

3. Load & Restraint Information

Restraint	
Restraint-1 <rect tubing support hjt>	on **1 Face(s)** fixed.
Description:	Bottom surface restrained.

Load		
Force-1 <rect tubing support hjt>	on **1 Face(s)** apply normal force **1995 lb** using uniform distribution	Sequential Loading
Description:	2000 lbs on top surface with 4.2deg inclination.	
Force-2 <rect tubing support hjt>	on **1 Face(s)** apply force **-150 lb** normal to reference plane with respect to selected reference **Edge< 1 >** using uniform distribution	Sequential Loading
Description:		

4. Study Property

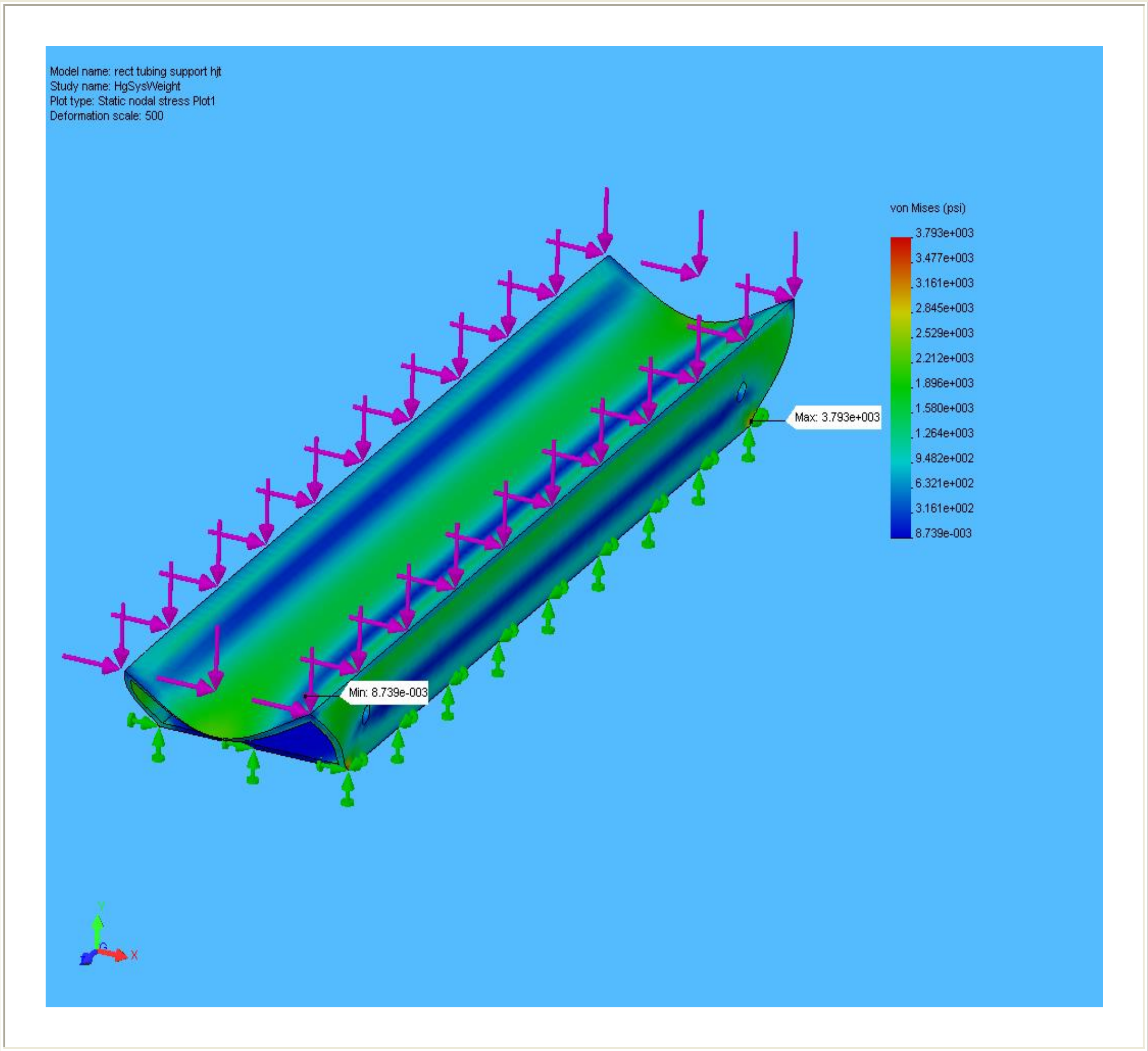
Mesh Information	
Mesh Type:	Solid mesh
Mesher Used:	Standard
Automatic Transition:	Off
Smooth Surface:	On
Jacobian Check:	4 Points
Element Size:	0.54849 in
Tolerance:	0.027424 in
Quality:	High
Number of elements:	14228
Number of nodes:	28696

Solver Information	
Quality:	High
Solver Type:	FFEPlus
Option:	Include Thermal Effects
Thermal Option:	Input Temperature
Thermal Option:	Reference Temperature at zero strain: 25 Celsius

5. Stress Results

Name	Type	Min	Location	Max	Location
Plot1	VON: von Mises stress	0.00873863 psi Node: 18480	(-0.269231 in, -1.5 in, 11.1336 in)	3792.81 psi Node: 19738	(3.5 in, -1.375 in, -15.8854 in)

rect tubing support hjt-HgSysWeight-Stress-Plot1
JPEG

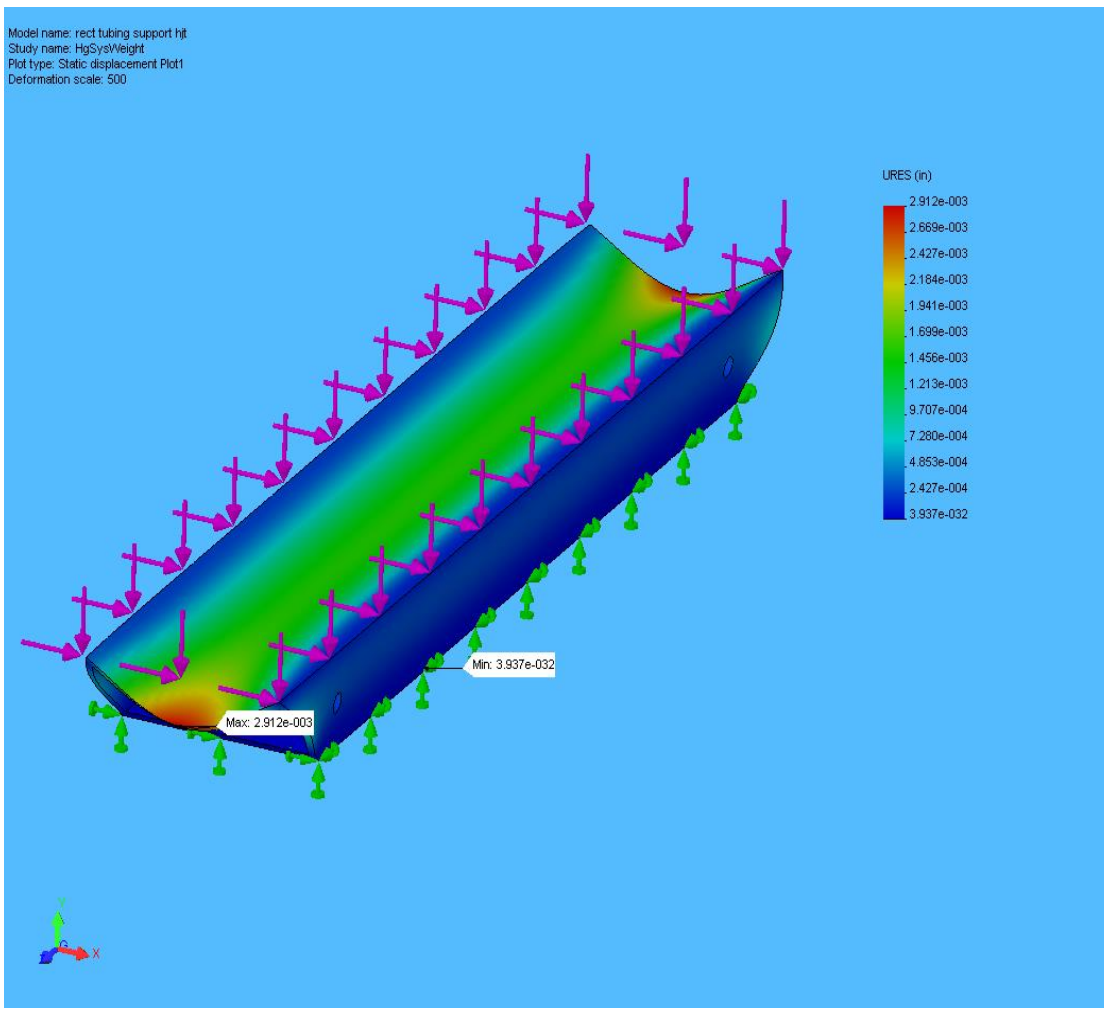


6. Displacement Results

Name	Type	Min	Location	Max	Location
Plot1	URES: Resultant displacement	0 in Node:	(3.5 in, -1.5 in,	0.00291197 in	(- 5.63193e-

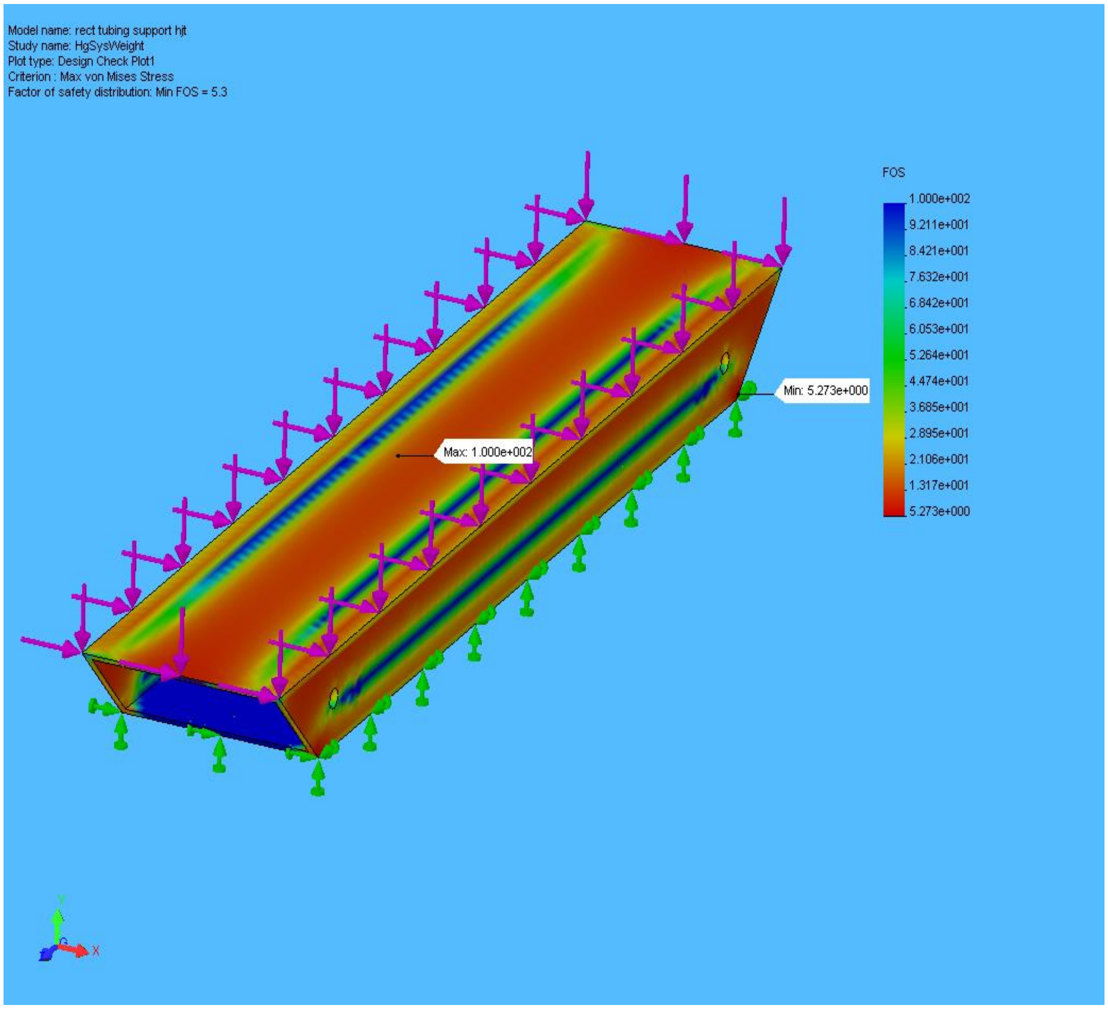
		16457	15.75 in)	Node: 4390	009 in, 1.5 in, 19 in)

rect tubing support hjt-HgSysWeight-Displacement-Plot1
JPEG



7. Design Check Results

rect tubing support hjt-HgSysWeight-Design Check-Plot1
JPEG



8. Conclusion

Analysis indicates minimum safety factor > 5. Tube considered structurally sound for simulated loading condition.

9. Appendix

Material name: AISI 316 Annealed Stainless Steel Bar (SS)

Description:

Material Source: Library files

Material Library Name: cosmos materials

Material Model Type: Linear Elastic Isotropic

Property Name	Value	Units	Value Type
Elastic modulus	2.7992e+007	psi	Constant
Poisson's ratio	0.3	NA	Constant
Mass density	0.28902	lb/in^3	Constant
Tensile strength	79771	psi	Constant
Yield strength	20000	psi	Constant
Thermal expansion coefficient	8.8889e-006	/Fahrenheit	Constant
Thermal conductivity	0.00021801	BTU/(in.s.F)	Constant
Specific heat	0.11945	Btu/(lb.F)	Constant
Hardening factor (0.0-1.0; 0.0=isotropic; 1.0=kinematic)	0.85	NA	Constant

Stress Analysis of Downstream Double Beam Window

Author: V.B. Graves

Company: Oak Ridge National Laboratory

Date: Feb 16, 2006

---

1. Introduction

A static analysis of the downstream secondary beam window is performed. Loading condition is 1atm internal pressure, which simulates window monitoring conditions.

Analysis does not consider any beam-induced stresses.

Note:

Do not base your design decisions solely on the data presented in this report. Use this information in conjunction with experimental data and practical experience. Field testing is mandatory to validate your final design. COSMOSWorks helps you reduce your time-to-market by reducing but not eliminating field tests.

---

2. Materials

No.	Part Name	Material	Mass	Volume
1	double window hjt	User Defined	0.491469 lb	3.07168 in^3
2	double window hjt	User Defined	0.491469 lb	3.07168 in^3
3	double window hjt	User Defined	0.491469 lb	3.07168 in^3
4	double window hjt	User Defined	0.491469 lb	3.07168 in^3

---

3. Load & Restraint Information

Restraint	
Restraint-1 <double window hjt>	on **1 Face(s)** fixed.
Description:	Flange fixed.
Restraint-2 <double window hjt>	on **4 Face(s)** symmetry
Description:	

Load		
Pressure-1 <double window	on **3 Face(s)** with Pressure **15 psi** along direction normal to selected face	Sequential Loading

hjt>		
Description:	15 psi on all internal surfaces.	

---

4. Study Property

Mesh Information	
Mesh Type:	Solid mesh
Mesher Used:	Standard
Automatic Transition:	Off
Smooth Surface:	On
Jacobian Check:	4 Points
Element Size:	0.11088 in
Tolerance:	0.0055439 in
Quality:	High
Number of elements:	19276
Number of nodes:	36992

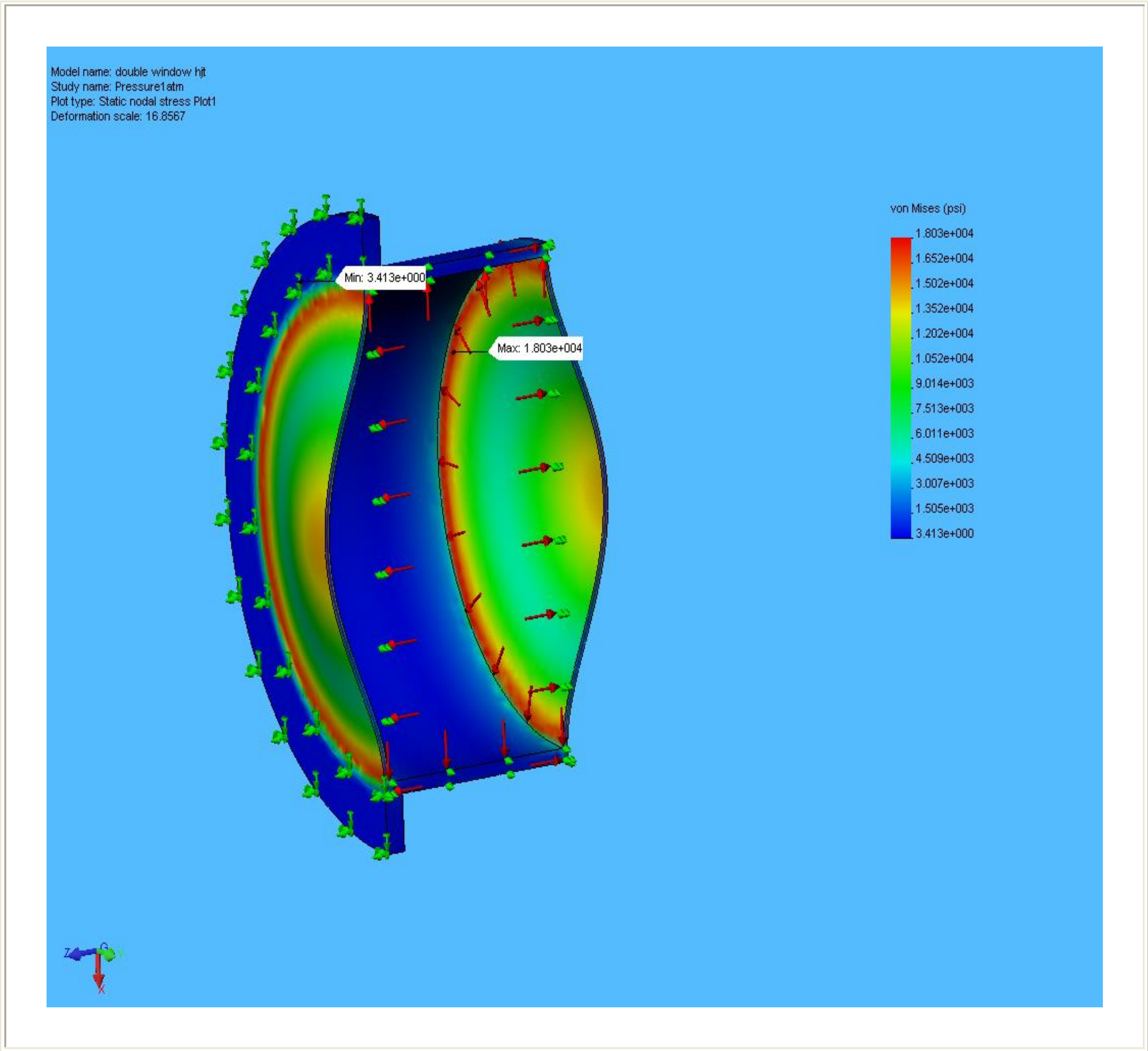
Solver Information	
Quality:	High
Solver Type:	FFEPlus
Option:	Include Thermal Effects
Thermal Option:	Input Temperature
Thermal Option:	Reference Temperature at zero strain: 25 Celsius

---

5. Stress Results

Name	Type	Min	Location	Max	Location
Plot1	VON: von Mises stress	3.41338 psi Node: 3224	(-2.00785 in, -1.19598 in, 1 in)	18025.4 psi Node: 29934	(-0.994874 in, -1.77189 in, -0.952 in)

double window hjt-Pressure1atm-Stress-Plot1
JPEG

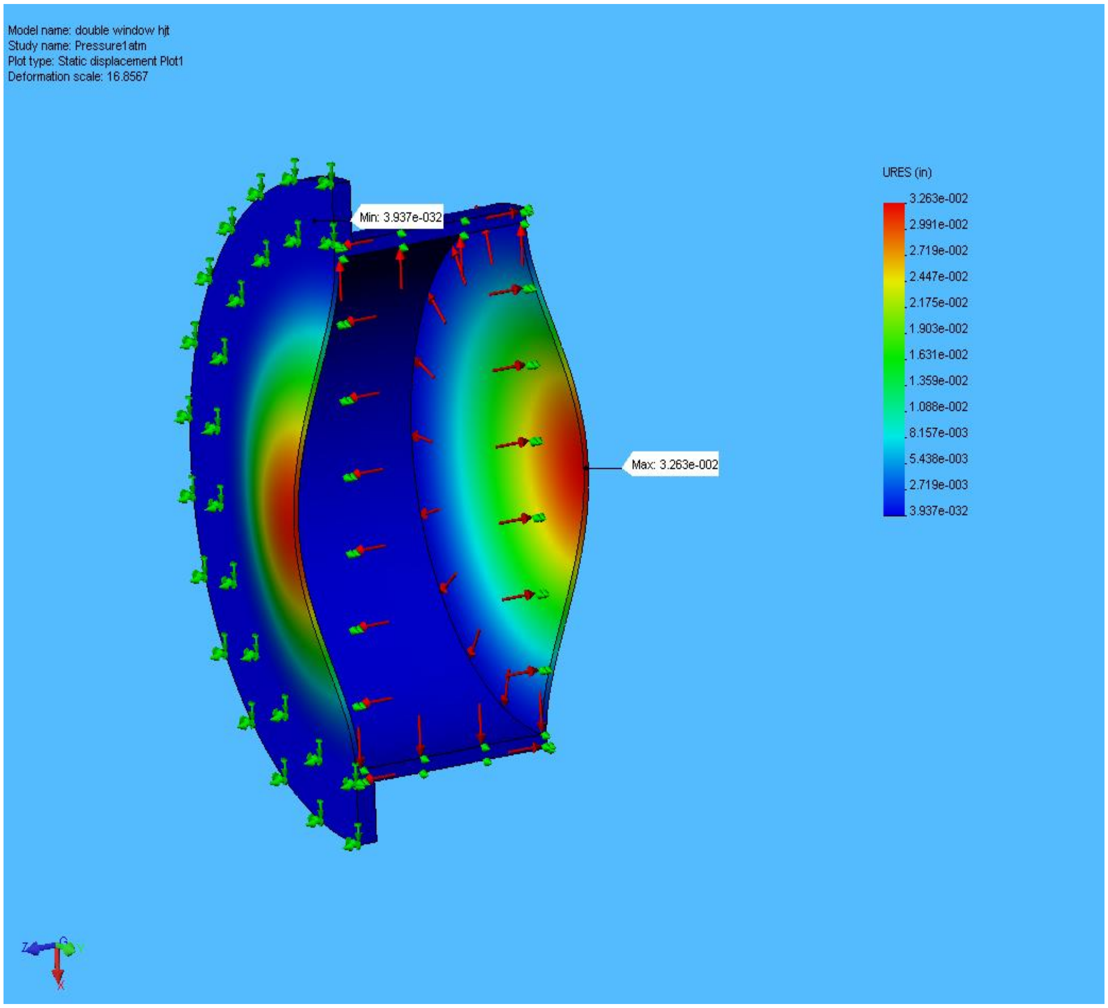


6. Displacement Results

Name	Type	Min	Location	Max	Location
Plot1	URES: Resultant	0 in Node:	(4.13318e-016 in,	0.032628 in	(0.000173533 in,

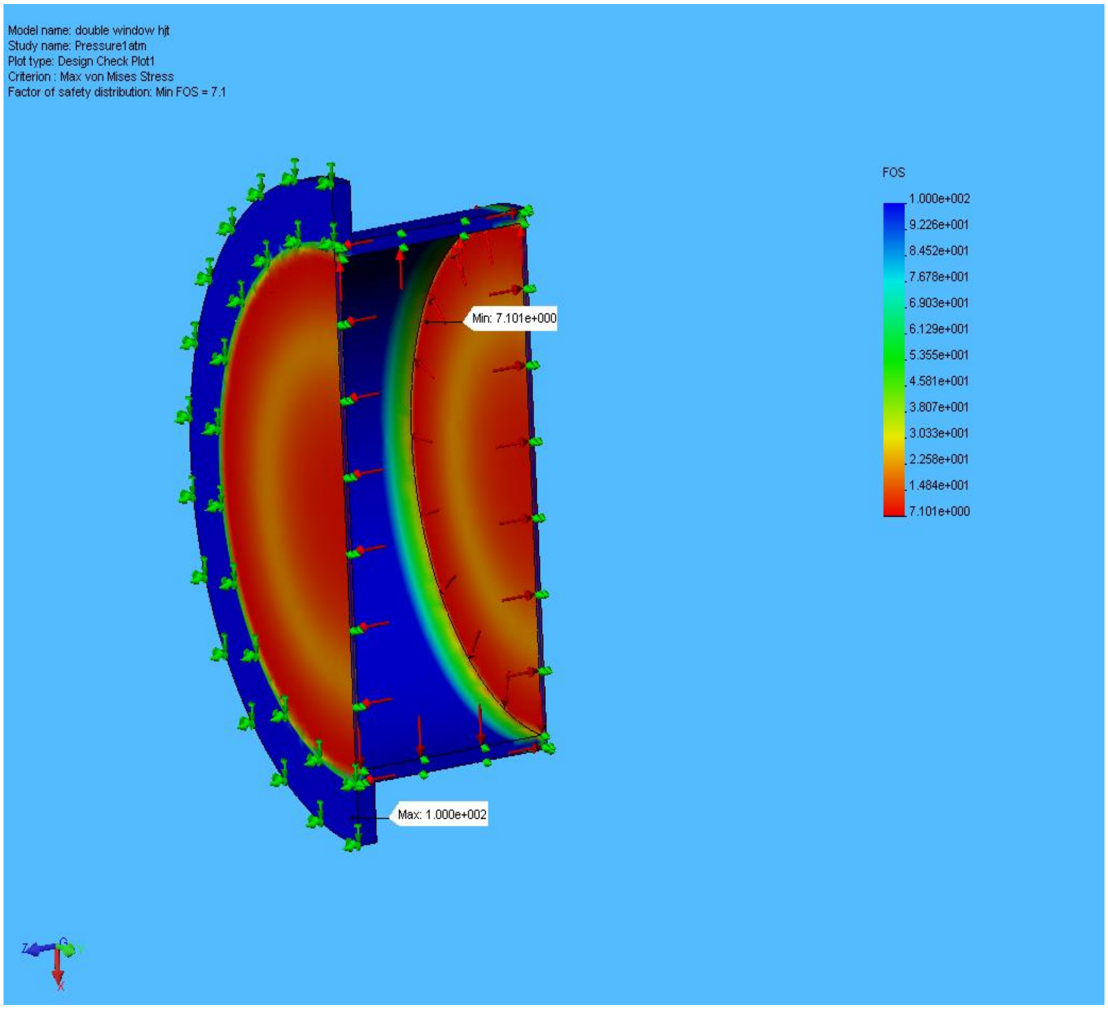
	displacement	35	-2.25 in, 1 in)	Node: 36345	0 in, -0.976 in)

double window hjt-Pressure1atm-Displacement-Plot1
JPEG



7. Design Check Results

double window hjt-Pressure1atm-Design Check-Plot1
JPEG



8. Conclusion

Analysis indicates minimum safety factor > 7 for the window membranes, not considering any beam interactions. For the condition simulated, the structure is considered adequate.

9. Appendix

Material name: User Defined

Description:

Material Source: Input

Material Model Type: Linear Elastic Isotropic

Property Name	Value	Units	Value Type
Elastic modulus	1.52e+007	psi	Constant
Poisson's ratio	0.31	NA	Constant
Shear modulus	5.95e+006	psi	Constant
Mass density	0.16	lb/in^3	Constant
Tensile strength	1.2e+005	psi	Constant
Yield strength	1.28e+005	psi	Constant
Thermal expansion coefficient	5e-006	/Fahrenheit	Constant
Thermal conductivity	8.9611e-005	BTU/(in.s.F)	Constant
Specific heat	0.14	Btu/(lb.F)	Constant
Hardening factor (0.0-1.0; 0.0=isotropic; 1.0=kinematic)	0.85	NA	Constant

Stress Analysis of Target Module Support Cradle

Author: V.B. Graves

Company: Oak Ridge National Laboratory

Date: Feb 8, 2006

---

1. Introduction

A static analysis of the target module support cradle is performed. Target module weight was estimated at 200 lbs for this analysis. An important simplification made was that the turnbuckles which provide vertical support were not included; thus the cradle was analyzed as self-supporting.

Note:

Do not base your design decisions solely on the data presented in this report. Use this information in conjunction with experimental data and practical experience. Field testing is mandatory to validate your final design. COSMOSWorks helps you reduce your time-to-market by reducing but not eliminating field tests.

---

2. Materials

No.	Part Name	Material	Mass	Volume
1	support cradle hjt	6061-T6 (SS)	13.4186 lb	137.565 in^3
2	support cradle hjt	6061-T6 (SS)	13.4186 lb	137.565 in^3
3	support cradle hjt	6061-T6 (SS)	13.4186 lb	137.565 in^3
4	support cradle hjt	6061-T6 (SS)	13.4186 lb	137.565 in^3
5	support cradle hjt	6061-T6 (SS)	13.4186 lb	137.565 in^3
6	support cradle hjt	6061-T6 (SS)	13.4186 lb	137.565 in^3

---

3. Load & Restraint Information

Restraint	
Restraint-1 <support cradle hjt>	on **2 Face(s)** fixed.
Description:	Pads were restrained horizontally and vertically.

Load		
Force-1 <support	on **1 Face(s)** apply force **200 lb** normal	Sequential

cradle hjt>	to reference plane with respect to selected reference **Edge< 1 >** using uniform distribution	Loading
Description:	Target module weight simulated as 200 lb vertical load.	

---

4. Study Property

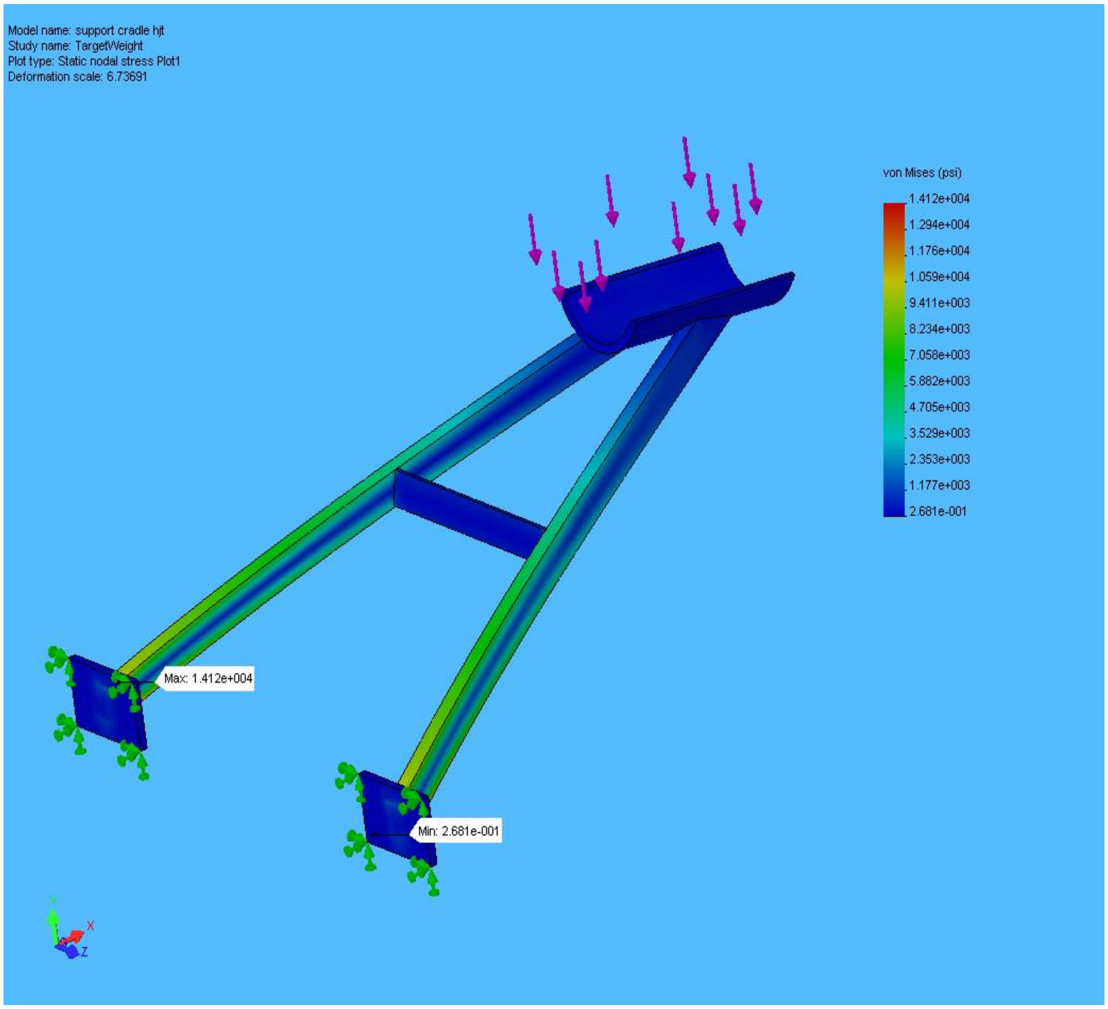
Mesh Information	
Mesh Type:	Solid mesh
Mesher Used:	Standard
Automatic Transition:	Off
Smooth Surface:	On
Jacobian Check:	4 Points
Element Size:	0.51633 in
Tolerance:	0.025816 in
Quality:	High
Number of elements:	15445
Number of nodes:	31017

Solver Information	
Quality:	High
Solver Type:	FFEPlus
Option:	Include Thermal Effects
Thermal Option:	Input Temperature
Thermal Option:	Reference Temperature at zero strain: 25 Celsius

5. Stress Results

Name	Type	Min	Location	Max	Location
Plot1	VON: von Mises stress	0.268075 psi Node: 29395	(0.5 in, -1.75 in, 10.725 in)	14115.6 psi Node: 17171	(0.719063 in, 1.21296 in, -12.9818 in)

support cradle hjt-TargetWeight-Stress-Plot1
JPEG

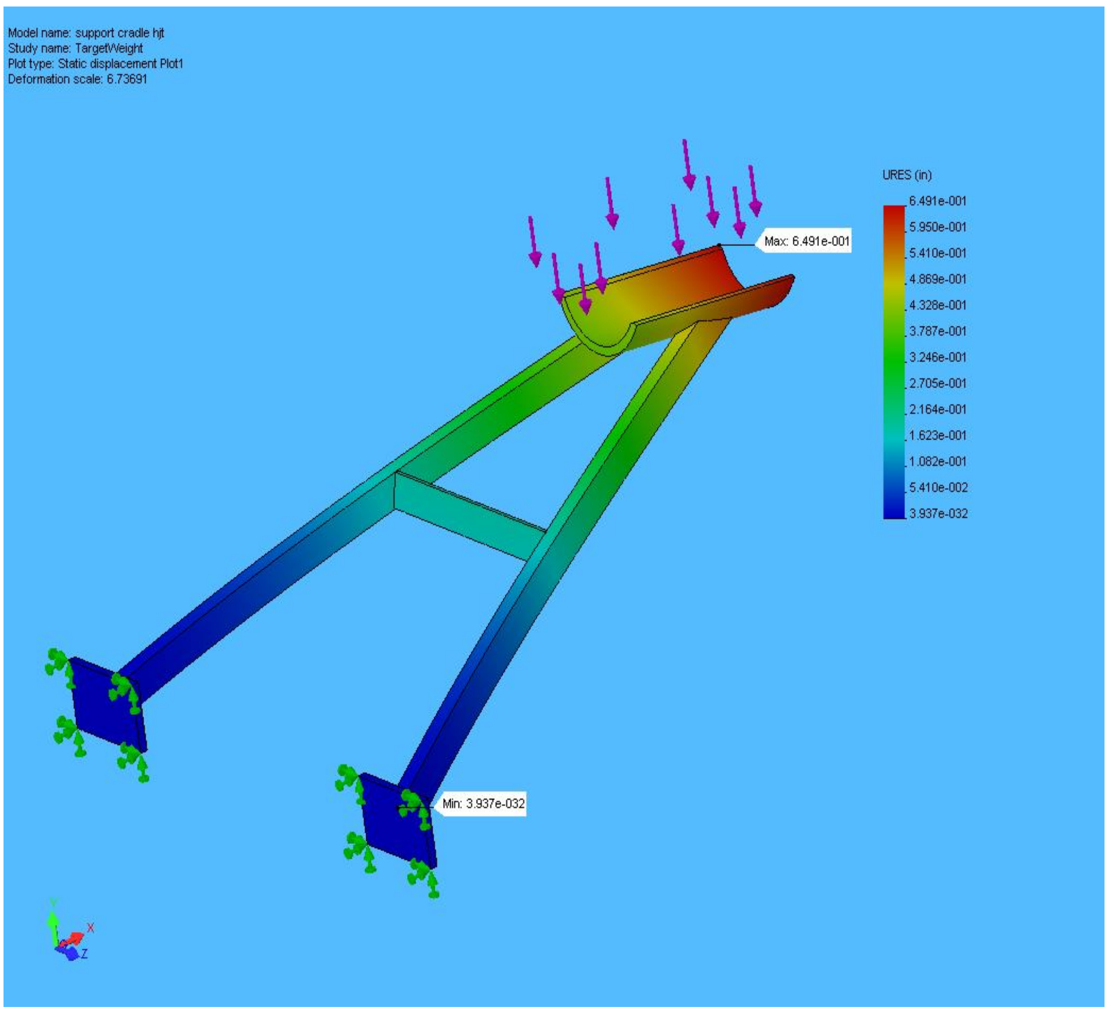


6. Displacement Results

Name	Type	Min	Location	Max	Location
Plot1	URES: Resultant displacement	0 in Node:	(0 in, 2 in,	0.649145 in	(40 in, 17.9149

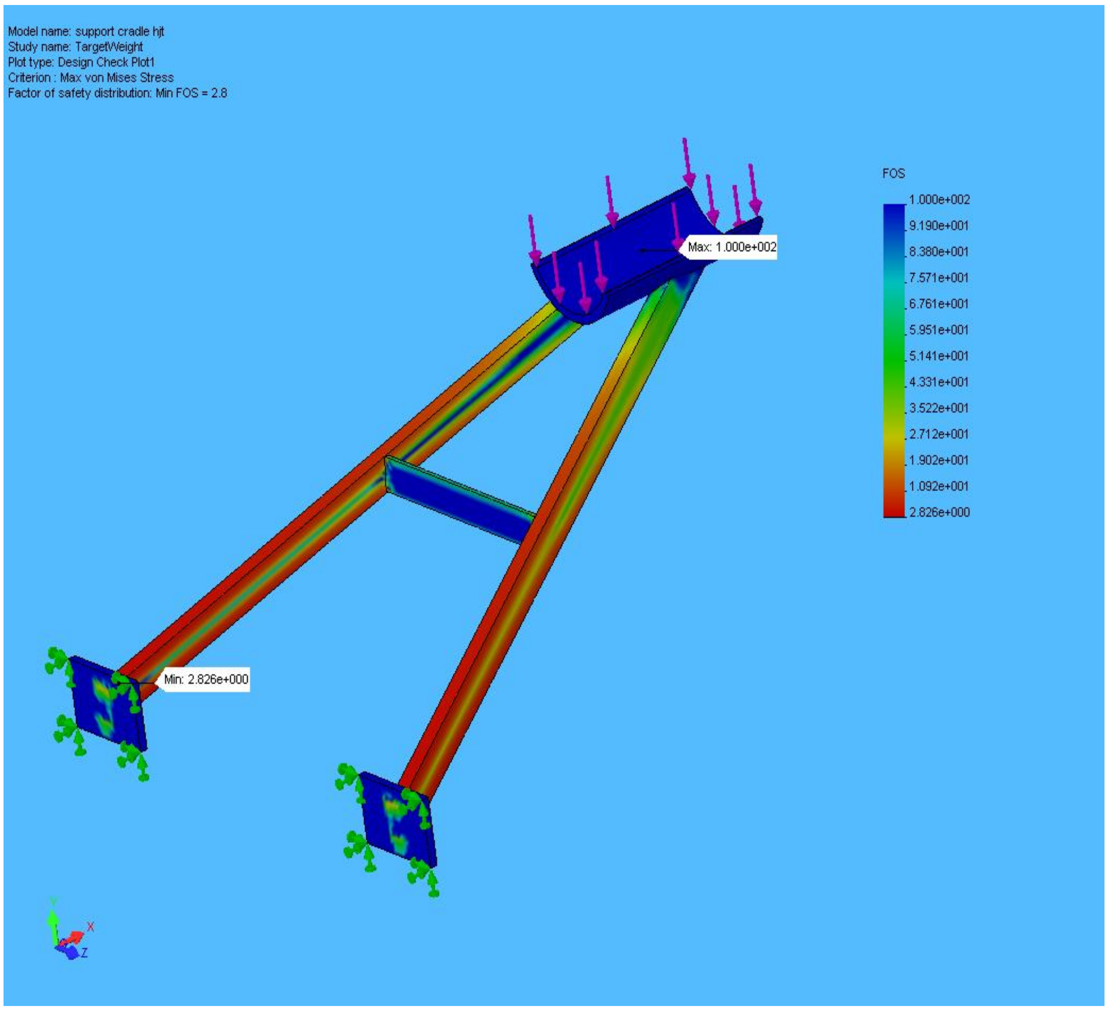
		28395	16.725 in)	Node: 742	in, - 3.46455 in)

support cradle hjt-TargetWeight-Displacement-Plot1
JPEG



7. Design Check Results

support cradle hjt-TargetWeight-Design Check-Plot1
JPEG



8. Conclusion

Analysis indicates minimum safety factor of 2.8 for this loading condition. Considering that the turnbuckles provide most of the vertical support, this analysis indicates the cradle structure is adequate for this loading condition.

9. Appendix

Material name: 6061-T6 (SS)

Description:

Material Source: Library files

Material Library Name: cosmos materials

Material Model Type: Linear Elastic Isotropic

Property Name	Value	Units	Value Type
Elastic modulus	1.0008e+007	psi	Constant
Poisson's ratio	0.33	NA	Constant
Shear modulus	3.771e+006	psi	Constant
Mass density	0.097544	lb/in^3	Constant
Tensile strength	44962	psi	Constant
Yield strength	39885	psi	Constant
Thermal expansion coefficient	1.3333e-005	/Fahrenheit	Constant
Thermal conductivity	0.0022322	BTU/(in.s.F)	Constant
Specific heat	0.21405	Btu/(lb.F)	Constant
Hardening factor (0.0-1.0; 0.0=isotropic; 1.0=kinematic)	0.85	NA	Constant

Appendix E. Base Support Structure Documents

MERIT Calculation Sheet
Oak Ridge National Laboratory

CALCULATION	Baseplate Lift Point Welds	SHEET 1 OF 1	
DRAWING NO	203-HJT-0110 Weld W-1		
CALCULATION BY	V. Graves	DATE	12 Apr 2006

Lift point welds on the baseplate are checked. Symmetric loading assumed. Baseplate lifted with no other loads!

$W := 1000 lbf$ Baseplate weight

$F := \frac{W}{4}$ Load on each lift point

$S_y := 40000 psi$ Tensile yield strength Al 6061-T6

$S_{sy} := 0.58 S_y$ Distortion energy criteria for shear strength

$h := 0.375 in$ Weld leg length

$t := 0.707 \cdot h$ Weld throat

$L := 1.5 in$ Weld length

$A := 2t \cdot L$ Weld stress area. Neglect horizontal weld segments.

$shear := \frac{F}{A}$ $shear = 314.317\ psi$ Shear stress

$FS := \frac{S_{sy}}{shear}$ $FS = 73.811$ Safety Factor

MERIT Calculation Sheet
Oak Ridge National Laboratory

CALCULATION	Hydraulic Jack Bracket Welds	SHEET 1 OF 1	
DRAWING NO	203-HJT-0131 Weld W-1		
CALCULATION BY	V. Graves	DATE	12 Apr 2006

Four jacking brackets are attached to the baseplate. Worst case loading is for the two under the magnet, with assumed loads of magnet and half the baseplate weight.

$W_{mag} := 12000\text{lbf}$ Magnet weight

$W_{base} := 1000\text{lbf}$ Baseplate weight

$F := \frac{W_{mag} + 0.5W_{base}}{2}$ Load on one bracket

$F = 6.25 \times 10^3 \text{ lbf}$

$S_y := 40000\text{psi}$ Tensile yield strength Al 6061-T6

$S_{sy} := 0.58S_y$ Distortion energy criteria for shear strength

$h := 0.25\text{in}$ Weld leg length

$t := 0.707 \cdot h$ Weld throat

$L := 11.25\text{in}$ Weld length

$A := 2t \cdot L$ Weld stress area

Out-of-plane eccentric loading $d := 2.25\text{in}$ Offset

$M := F \cdot d$ Bending moment

$I_v := \frac{L^3 t}{12}$ $I_x := 2 \cdot I_v$ Weld segment moment of inertia

$normal := \frac{M \cdot L}{2 \cdot I_x}$ $normal = 1.886 \times 10^3 \text{ psi}$ Normal stress

$shear := \frac{F}{A}$ $shear = 1.572 \times 10^3 \text{ psi}$ Shear stress

$total := \sqrt{normal^2 + shear^2}$ $total = 2.455 \times 10^3 \text{ psi}$ total stress assumed to act in shear plane

$FS := \frac{S_{sy}}{total}$ $FS = 9.451$ Safety Factor

MERIT Calculation Sheet
Oak Ridge National Laboratory

CALCULATION	Hydraulic Jack Bracket Welds	SHEET 1 OF 1	
DRAWING NO	203-HJT-0131 Weld W-2		
CALCULATION BY	V. Graves	DATE	12 Apr 2006

Four jacking brackets are attached to the baseplate. Worst case loading is for the two under the magnet, with assumed loads of magnet and half the baseplate weight.

$W_{mag} := 12000\text{lbf}$ — Magnet weight

$W_{base} := 1000\text{lbf}$ — Baseplate weight

$F := \frac{W_{mag} + 0.5W_{base}}{2}$ — Load on one bracket

$F = 6.25 \times 10^{3}\ \text{lbf}$

$S_y := 40000\text{psi}$ — Tensile yield strength Al 6061-T6

$S_{sy} := 0.58S_y$ — Distortion energy criteria for shear strength

$h := 0.25\text{in}$ — Weld leg length — Only consider fillet welds

$t := 0.707 \cdot h$ — Weld throat

$L := 5\text{in}$ — Weld length

$A := 2t \cdot L$ — Weld stress area

$\text{shear} := \frac{F}{A}$ $\quad \text{shear} = 3.536 \times 10^{3}\ \text{psi}$ — Shear stress

$FS := \frac{S_{sy}}{\text{shear}}$ $\quad FS = 6.561$ — Safety Factor

MERIT Calculation Sheet
Oak Ridge National Laboratory

CALCULATION	Hydraulic Jack Bracket Welds	SHEET 1 OF 1
DRAWING NO	203-HJT-0131 Weld W-1	
CALCULATION BY V. Graves		DATE 12 Apr 2006

Four jacking brackets are attached to the baseplate. Worst case loading is for the two under the magnet, with assumed loads of magnet and half the baseplate weight.

$W_{mag} := 12000\,lbf$ — Magnet weight

$W_{base} := 1000\,lbf$ — Baseplate weight

$F := \frac{W_{mag} + 0.5 W_{base}}{2}$ — Load on one bracket

$F = 6.25 \times 10^3\,lbf$

$S_y := 40000\,psi$ — Tensile yield strength Al 6061-T6

$S_{sy} := 0.58 S_y$ — Distortion energy criteria for shear strength

$h := 0.25\,in$ — Fillet weld leg length — $h_{vweld} := .5\,in$ — V weld leg length

$t := 0.707 \cdot h$ — Fillet weld throat — $t_{vweld} := 0.707 h_{vweld}$ — V weld throat

$L := 11.25\,in$ — Weld length

$A := 2t \cdot L + 2 \cdot t_{vweld} \cdot L$ — Weld stress area

Out-of-plane eccentric loading — $d := 2.25\,in$ Offset

$M := F \cdot d$ — Bending moment

$I_v := \frac{L^3 t}{12}$ — $I_x := 2 \cdot I_v$ — Weld segment moment of inertia

$normal := \frac{M \cdot L}{2 \cdot I_x}$ — $normal = 1.886 \times 10^3\,psi$ — Normal stress

$shear := \frac{F}{A}$ — $shear = 523.862\,psi$ — Shear stress

$total := \sqrt{normal^2 + shear^2}$ — $total = 1.957 \times 10^3\,psi$ — total stress assumed to act in shear plane

$FS := \frac{S_{sy}}{total}$ — $FS = 11.853$ — Safety Factor

MERIT Calculation Sheet
Oak Ridge National Laboratory

CALCULATION	Hg Cart Bracket Loading	SHEET 1 OF 1	
DRAWING NO	203-HJT-0120		
CALCULATION BY V.B. Graves		DATE	3 Feb 2006

The loading condition on the Hg delivery system jacking bracket is calculated. This bracket is located on the common baseplate and the target transporter. Worst case loading occurs on the target transporter when the Hg system is being lowered down the sloped TT2 tunnel.

$W := 4000\,lbf$	Conservative assumption of system with Hg
$\theta := 4.23\,deg$	tt2 floor slope
$h := 5\,in$	height of horizontal jack bolt hole above base
$d := 2\,in$	distance from vertical shcs hole to edge of bracket. used to determine load on tie-down bolt.

$F := W \cdot \sin(\theta)$	$F = 295.042\,lbf$	force on jack bolt
$M := F \cdot h$	$M = 1.475 \times 10^{3}\,lbf \cdot in$	moment on bracket
$T := \frac{M}{d}$	$T = 737.604\,lbf$	tension force on vertical shcs

SHCS material is SS 18-8 with minimum yield of 100,000 psi. Diameter is 0.75inch, so stress on bolt is

$$stress := \frac{T \cdot 4}{\pi \cdot (0.75in)^2} \qquad stress = 1.67 \times 10^{3}\,psi$$

$$safety := \frac{100000psi}{stress} \qquad safety = 59.895$$

Stress Analysis of Cart Restraint Bracket

Author: V.B. Graves

Company: Oak Ridge National Laboratory

Date: May 19, 2006

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1. Introduction

A static analysis of the cart jacking bracket is performed. Loading condition simulates Hg delivery system resting against horizontal jack bolt while entire assembly is on the sloped floor of the TT2 tunnel (4.23 deg slope).

Horizontal load on hole threads is 4000 * sin(4.23) = 300 lb.

Note:

Do not base your design decisions solely on the data presented in this report. Use this information in conjunction with experimental data and practical experience. Field testing is mandatory to validate your final design. COSMOSWorks helps you reduce your time-to-market by reducing but not eliminating field tests.

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2. Materials

No.	Part Name	Material	Mass	Volume
1	cart jacking plate hjt	6061-T6 (SS)	2.45111 lb	25.1284 in^3
2	cart jacking plate hjt	6061-T6 (SS)	2.45111 lb	25.1284 in^3
3	cart jacking plate hjt	6061-T6 (SS)	2.45111 lb	25.1284 in^3

---

3. Load & Restraint Information

Restraint	
Restraint-1 <cart jacking plate hjt>	on **1 Face(s)** fixed.
Description:	Vertical hole threads restrained.

Load		
Force-1 <cart jacking plate hjt>	on **1 Face(s)** apply force **300 lb** normal to reference plane with respect to selected reference **Face< 1 >** using uniform distribution	Sequential Loading
Description:	Horizontal hole thread loaded by jack bolt.	

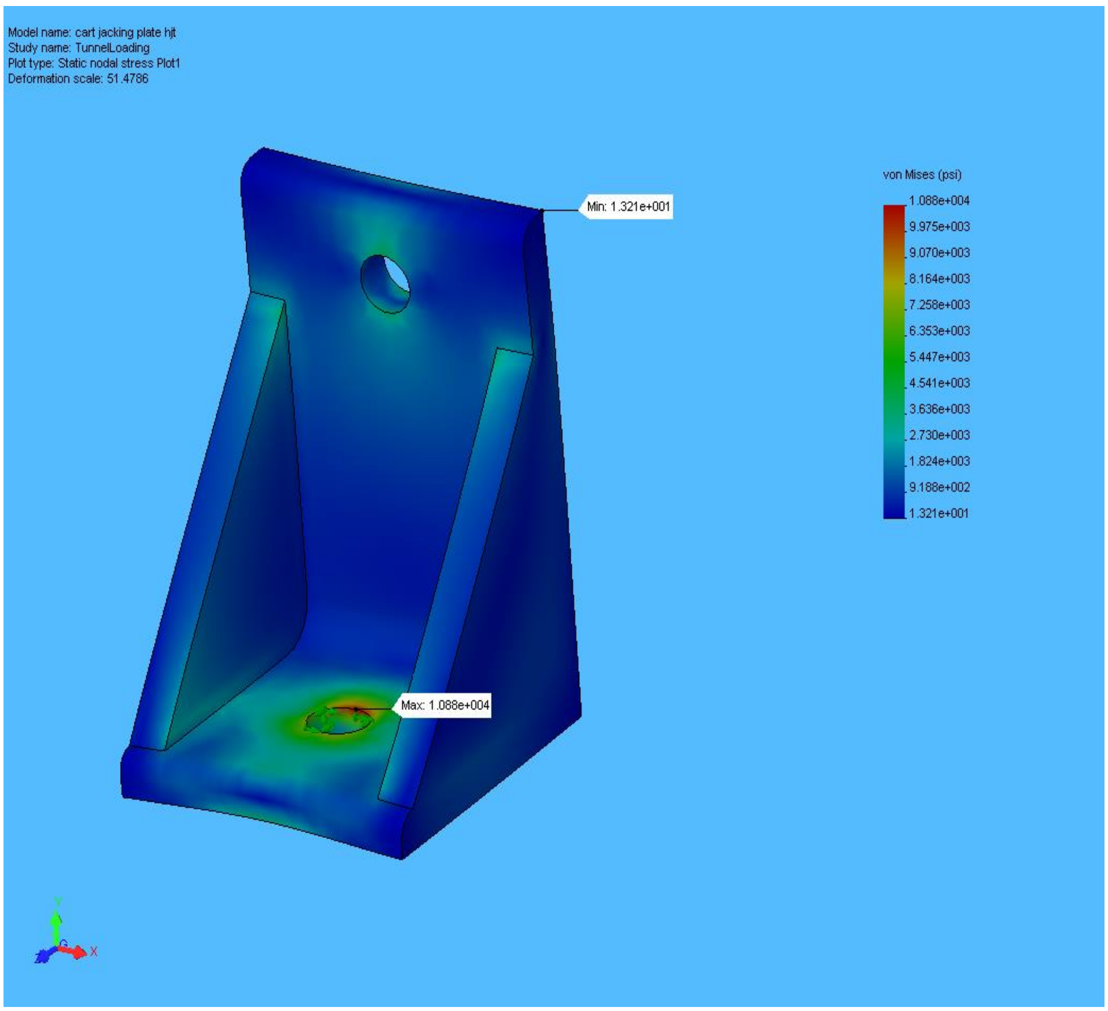
4. Study Property

Mesh Information	
Mesh Type:	Solid mesh
Mesher Used:	Standard
Automatic Transition:	Off
Smooth Surface:	On
Jacobian Check:	4 Points
Element Size:	0.29298 in
Tolerance:	0.014649 in
Quality:	High
Number of elements:	4993
Number of nodes:	9458

Solver Information	
Quality:	High
Solver Type:	FFEPlus
Option:	Include Thermal Effects
Thermal Option:	Input Temperature
Thermal Option:	Reference Temperature at zero strain: 25 Celsius

5. Stress Results

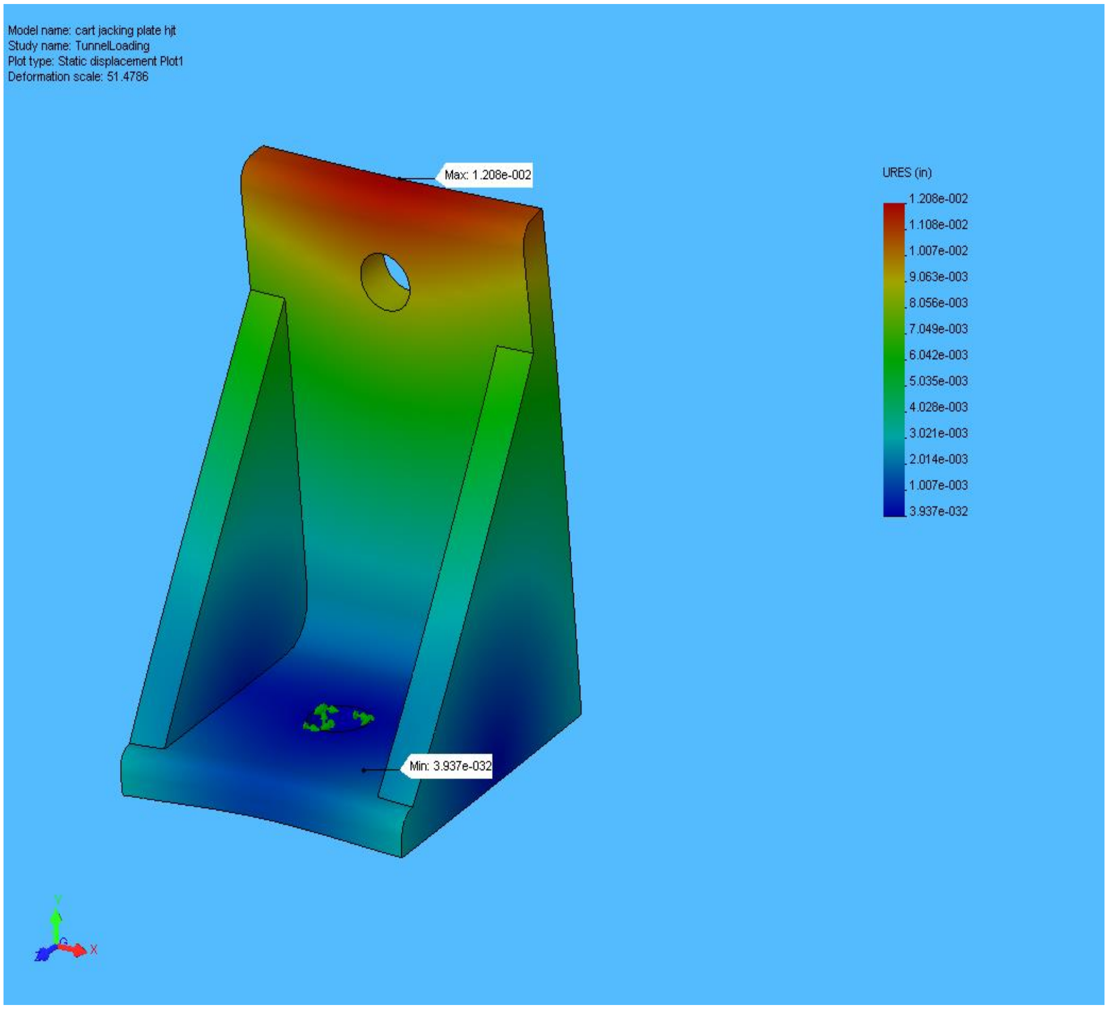
Name	Type	Min	Location	Max	Location
Plot1	VON: von Mises stress	13.214 psi Node: 2155	(2 in, 6 in, 0 in)	10880.8 psi Node: 8007	(2.41704e-008 in, 0.5 in, 1.85937 in)

cart jacking plate hjt-TunnelLoading-Stress-Plot1
JPEG


6. Displacement Results

Name	Type	Min	Location	Max	Location
Plot1	URES: Resultant displacement	0 in Node: 1657	(0.338291 in, 0.5 in, 2.05469 in)	0.0120834 in Node: 2148	(0 in, 6 in, 0 in)

cart jacking plate hjt-TunnelLoading-Displacement-Plot1
JPEG



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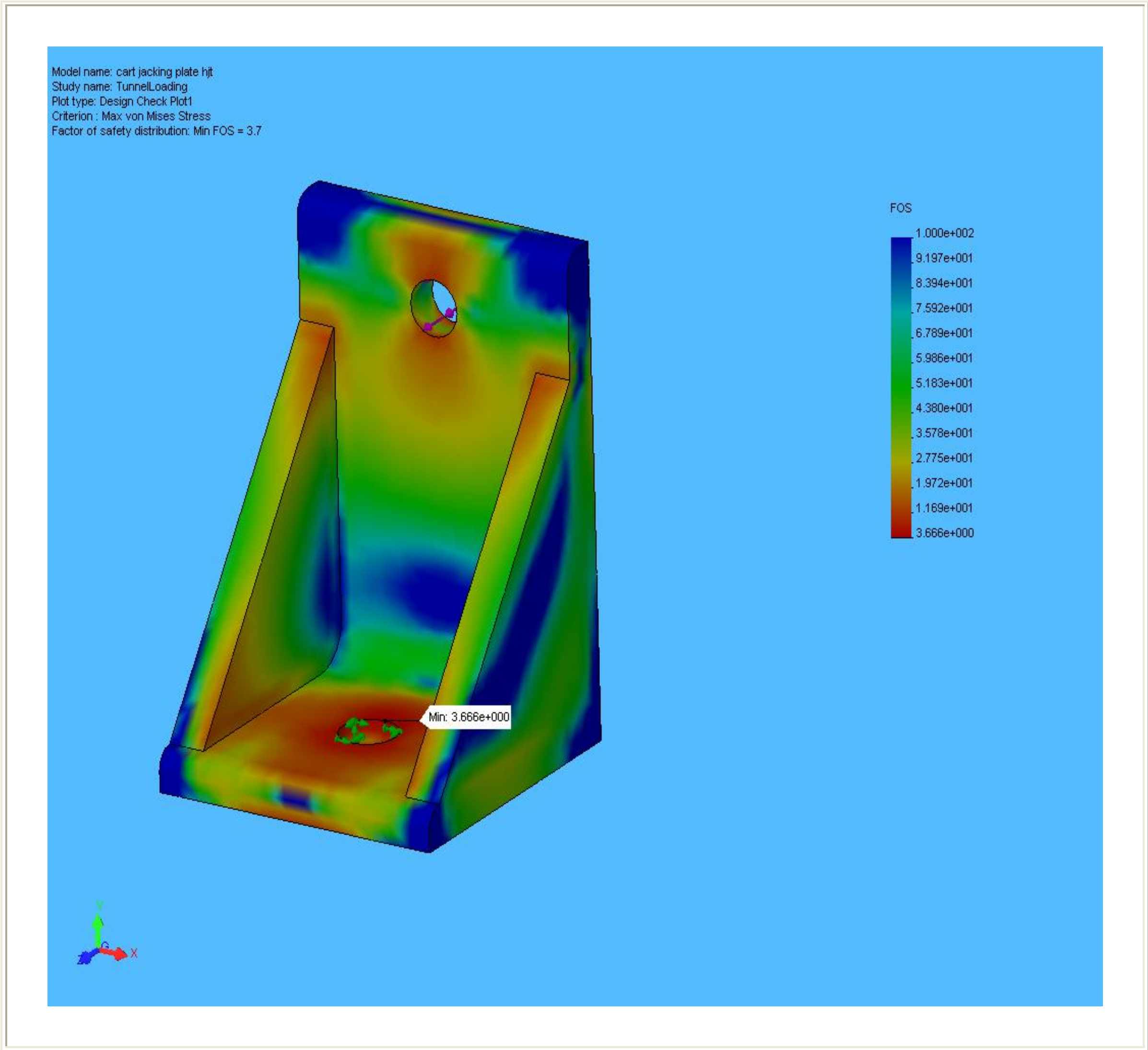
7. Design Check Results

cart jacking plate hjt-TunnelLoading-Design Check-Plot1
JPEG



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8. Conclusion

Maximum stress located near vertical hole, with a corresponding safety factor > 3. Stresses in this region are localized and would relieve as necessary. Bracket considered structurally sound for the simulated loading condition.

9. Appendix

Material name: 6061-T6 (SS)

Description:

Material Source: Library files

Material Library Name: cosmos materials

Material Model Type: Linear Elastic Isotropic

Property Name	Value	Units	Value Type
Elastic modulus	1.0008e+007	psi	Constant
Poisson's ratio	0.33	NA	Constant
Shear modulus	3.771e+006	psi	Constant
Mass density	0.097544	lb/in^3	Constant
Tensile strength	44962	psi	Constant
Yield strength	39885	psi	Constant
Thermal expansion coefficient	1.3333e-005	/Fahrenheit	Constant
Thermal conductivity	0.0022322	BTU/(in.s.F)	Constant
Specific heat	0.21405	Btu/(lb.F)	Constant
Hardening factor (0.0-1.0; 0.0=isotropic; 1.0=kinematic)	0.85	NA	Constant

Stress Analysis of Magnet Support Beam

Author: Author: Van Graves

Company: Oak Ridge National Laboratory

Date: May 11, 2006

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1. Introduction

A static analysis of the baseplate support beam is performed. Loading condition simulates in-beam conditions with the beam supporting a percentage of the weights of the magnet (6T), Hg system (2T), and baseplate (800 lbs). Manual calculations show the resultant load on the beam to be 11600 lbs. Loading was evenly distributed on the two circular recesses and applied vertically.

Note:

Do not base your design decisions solely on the data presented in this report. Use this information in conjunction with experimental data and practical experience. Field testing is mandatory to validate your final design. COSMOSWorks helps you reduce your time-to-market by reducing but not eliminating field tests.

2. Materials

No.	Part Name	Material	Mass	Volume
1	magnet end support hjt	6061-T6 (SS)	28.4115 lb	291.269 in^3
2	magnet end support hjt	6061-T6 (SS)	28.4115 lb	291.269 in^3
3	magnet end support hjt	6061-T6 (SS)	28.4115 lb	291.269 in^3
4	magnet end support hjt	6061-T6 (SS)	28.4115 lb	291.269 in^3
5	magnet end support hjt	6061-T6 (SS)	28.4115 lb	291.269 in^3
6	magnet end support hjt	6061-T6 (SS)	28.4115 lb	291.269 in^3
7	magnet end support hjt	6061-T6 (SS)	28.4115 lb	291.269 in^3
8	magnet end support hjt	6061-T6 (SS)	28.4115 lb	291.269 in^3
9	magnet end support hjt	6061-T6 (SS)	28.4115 lb	291.269 in^3
10	magnet end support hjt	6061-T6 (SS)	28.4115 lb	291.269 in^3
11	magnet end support hjt	6061-T6 (SS)	28.4115 lb	291.269 in^3
12	magnet end support hjt	6061-T6 (SS)	28.4115 lb	291.269 in^3
13	magnet end support hjt	6061-T6 (SS)	28.4115 lb	291.269 in^3

3. Load & Restraint Information

Restraint	
Restraint-1 <magnet end support hjt>	on **2 Face(s)** fixed.

Description:	Bottom faces fixed.

Load		
Force-1 <magnet end support hjt>	on **2 Face(s)** apply normal force **5800 lb** using uniform distribution	Sequential Loading
Description:	Vertical loading on both recesses.	

---

4. Study Property

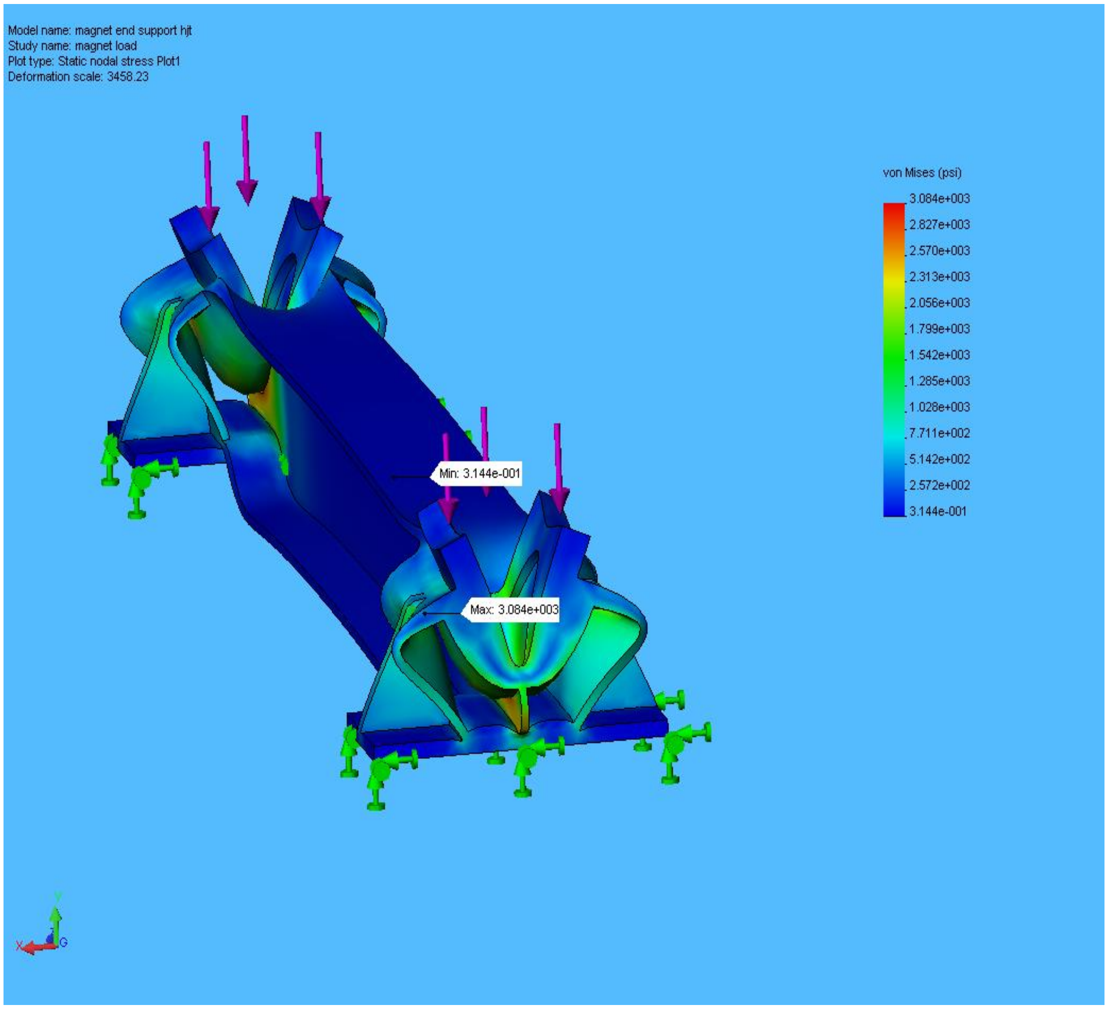
Mesh Information	
Mesh Type:	Solid mesh
Mesher Used:	Standard
Automatic Transition:	Off
Smooth Surface:	On
Jacobian Check:	4 Points
Element Size:	0.66299 in
Tolerance:	0.03315 in
Quality:	High
Number of elements:	14905
Number of nodes:	29272

Solver Information	
Quality:	High
Solver Type:	FFEPlus
Option:	Include Thermal Effects
Thermal Option:	Input Temperature
Thermal Option:	Reference Temperature at zero strain: 77 Fahrenheit

5. Stress Results

Name	Type	Min	Location	Max	Location
Plot1	VON: von Mises stress	0.314444 psi Node: 9949	(-0.0644952 in, 1.16065 in, -1.52176 in)	3083.53 psi Node: 28859	(1.75 in, 2.23333 in, -22.5625 in)

magnet end support hjt-magnet load-Stress-Plot1
JPEG



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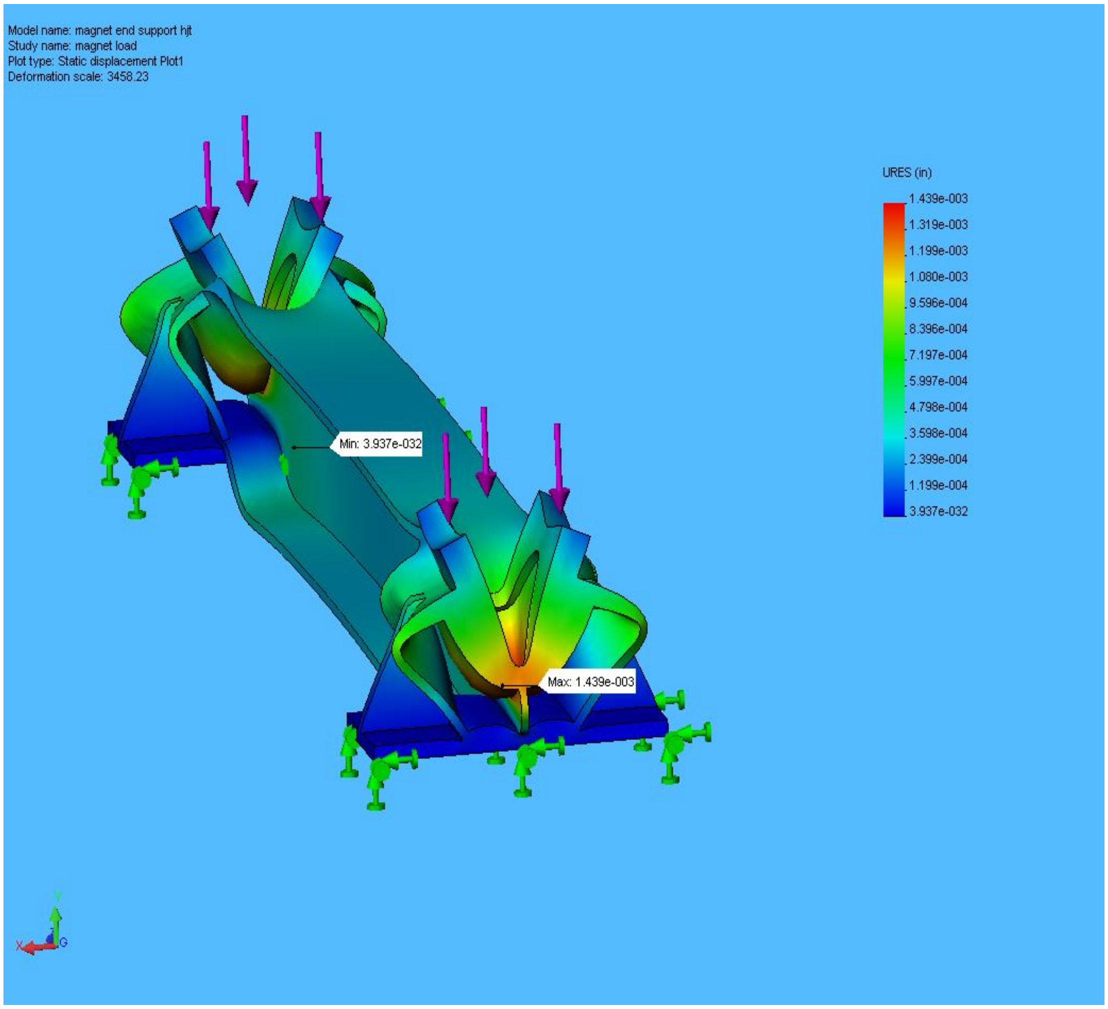
6. Displacement Results

Name	Type	Min	Location	Max	Location
Plot1	URES: Resultant displacement	0 in Node:	(5 in, -3.5 in,	0.00143937 in	(0.333333 in,

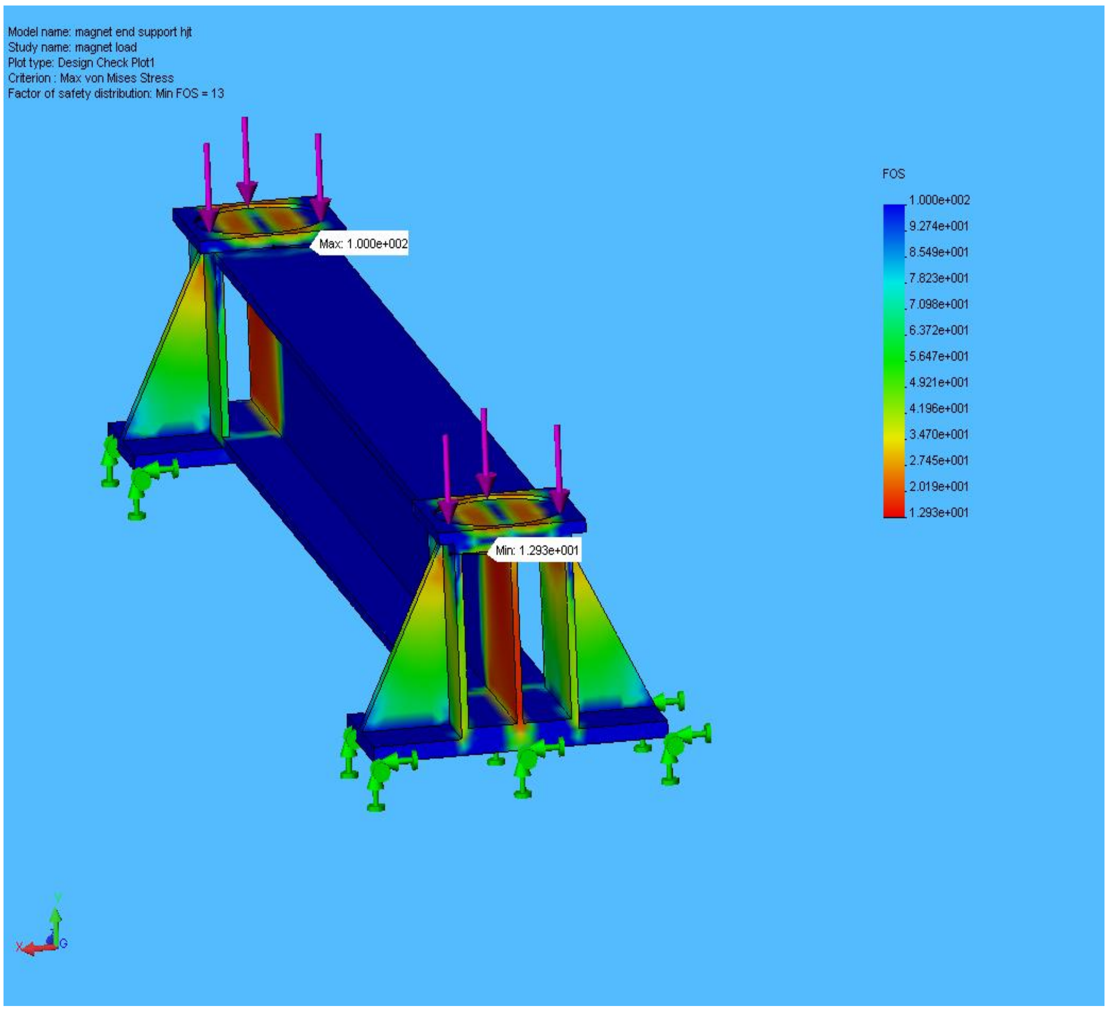
		22000	24.75 in)	Node: 26759	3.125 in, -22.727 in)

magnet end support hjt-magnet load-Displacement-Plot1

JPEG



7. Design Check Results

magnet end support hjt-magnet load-Design Check-Plot1
JPEG


8. Conclusion

Based on maximum calculated stresses, the safety factor is much greater than 3 when compared to material yield strength. The design is considered adequate for the loading condition simulated.

9. Appendix

Material name: 6061-T6 (SS)

Description:

Material Source: Library files

Material Library Name: cosmos materials

Material Model Type: Linear Elastic Isotropic

Property Name	Value	Units	Value Type
Elastic modulus	1.0008e+007	psi	Constant
Poisson's ratio	0.33	NA	Constant
Shear modulus	3.771e+006	psi	Constant
Mass density	0.097544	lb/in^3	Constant
Tensile strength	44962	psi	Constant
Yield strength	39885	psi	Constant
Thermal expansion coefficient	1.3333e-005	/Fahrenheit	Constant
Thermal conductivity	0.0022322	BTU/(in.s.F)	Constant
Specific heat	0.21405	Btu/(lb.F)	Constant
Hardening factor (0.0-1.0; 0.0=isotropic; 1.0=kinematic)	0.85	NA	Constant

Stress Analysis of Common Baseplate - 4 Levelers

Author: Author: Van Graves

Company: Oak Ridge National Laboratory

Date: March 14, 2006

---

1. Introduction

A static analysis of the common base assembly is performed. The loading condition simulates that encountered when the loaded baseplate (magnet & Hg system) is supported by four leveling jacks. Since the jacking brackets are mechanically attached to the baseplate, the attachment holes were restrained in this analysis. The brackets will be analyzed separately.

Note:

Do not base your design decisions solely on the data presented in this report. Use this information in conjunction with experimental data and practical experience. Field testing is mandatory to validate your final design. COSMOSWorks helps you reduce your time-to-market by reducing but not eliminating field tests.

---

2. Materials

No.	Part Name	Material	Mass	Volume
1	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
2	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
3	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
4	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
5	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
6	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
7	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
8	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
9	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
10	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
11	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
12	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3

13	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
14	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
15	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
16	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
17	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
18	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
19	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
20	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
21	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
22	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
23	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
24	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
25	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
26	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
27	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
28	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
29	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
30	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
31	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
32	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3

33	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
34	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
35	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
36	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
37	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
38	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
39	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
40	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
41	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
42	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
43	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
44	flat rail hjt-1	Wrought Stainless Steel	18.7862 lb	65 in^3
45	flat rail hjt-2	Wrought Stainless Steel	18.7862 lb	65 in^3
46	magnet support plate hjt-1	6061-T6 (SS)	205.676 lb	2108.55 in^3
47	slick sheet hjt-1	Delrin 2700 NC010, Low Viscosity Acetal Copolymer (SS)	2.32213 lb	455.861 in^3

---

3. Load & Restraint Information

Restraint

Restraint-5 <base weldment hjt-1>	on **8 Face(s)** fixed.
Description:	Bracket attachment holes restrained.

Load		
Force-1 <magnet support plate hjt-1>	on **4 Face(s)** apply normal force **3000 lb** using uniform distribution	Sequential Loading
Description:	Magnet weight (6T) distributed on support plate pads.	
Force-2 <flat rail hjt-2, flat rail hjt-1>	on **4 Face(s)** apply normal force **1000 lb** using uniform distribution	Sequential Loading
Description:	Hg system weight (2T) distributed on rails at wheel contact locations.	

---

4. Study Property

Mesh Information	
Mesh Type:	Solid mesh
Mesher Used:	Standard
Automatic Transition:	Off
Smooth Surface:	On
Jacobian Check:	4 Points
Element Size:	1.9207 in
Tolerance:	0.096036 in
Quality:	High
Number of elements:	35123
Number of nodes:	63665

Solver Information	
Quality:	High

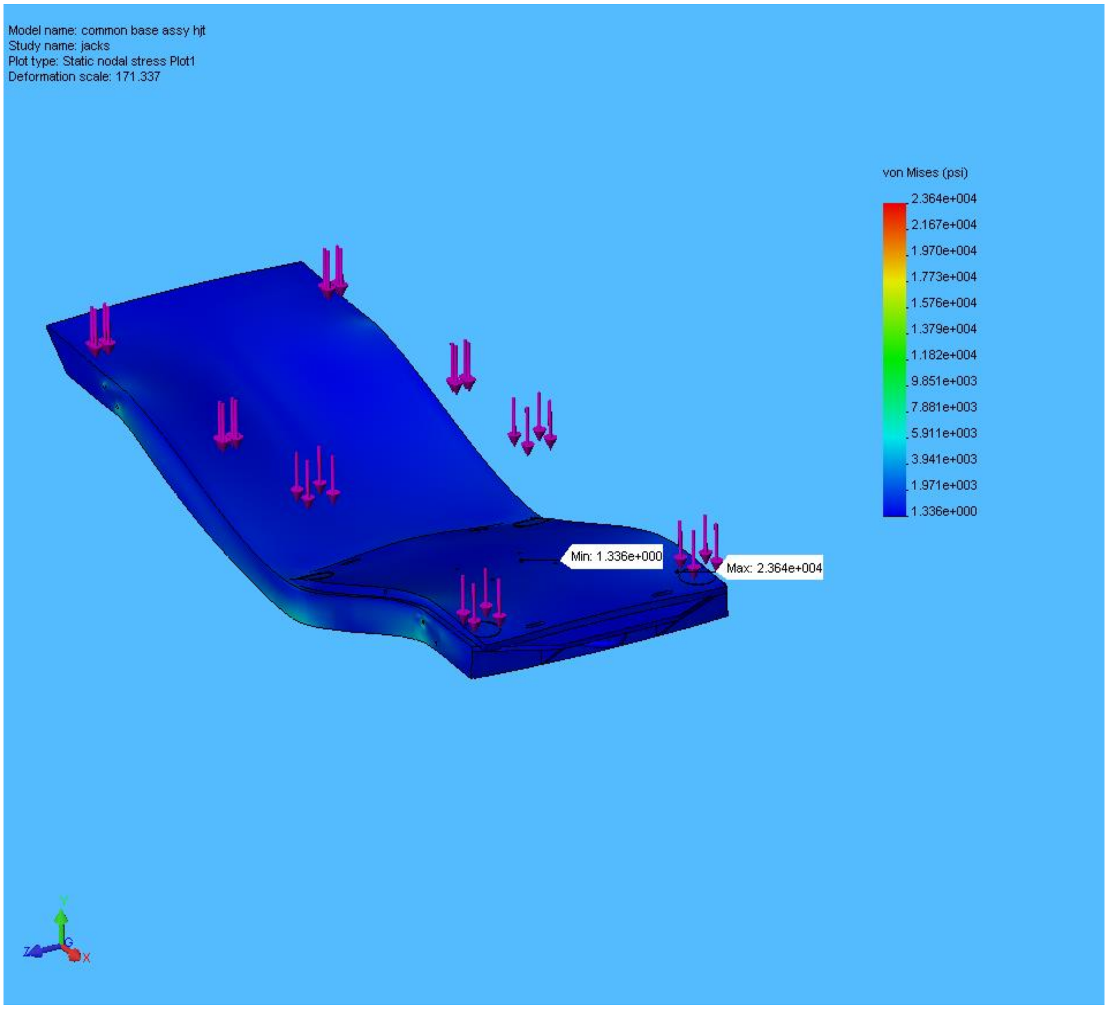
Solver Type:	FFEPlus
Option:	Include Thermal Effects
Thermal Option:	Input Temperature
Thermal Option:	Reference Temperature at zero strain: 77 Fahrenheit

---

5. Stress Results

Name	Type	Min	Location	Max	Location
Plot1	VON: von Mises stress	1.33608 psi Node: 63616	(25.9546 in, 2.875 in, -4.99199 in)	23640.5 psi Node: 39565	(43.1172 in, -1.10502 in, -19.84 in)

common base assy hjt-jacks-Stress-Plot1
JPEG



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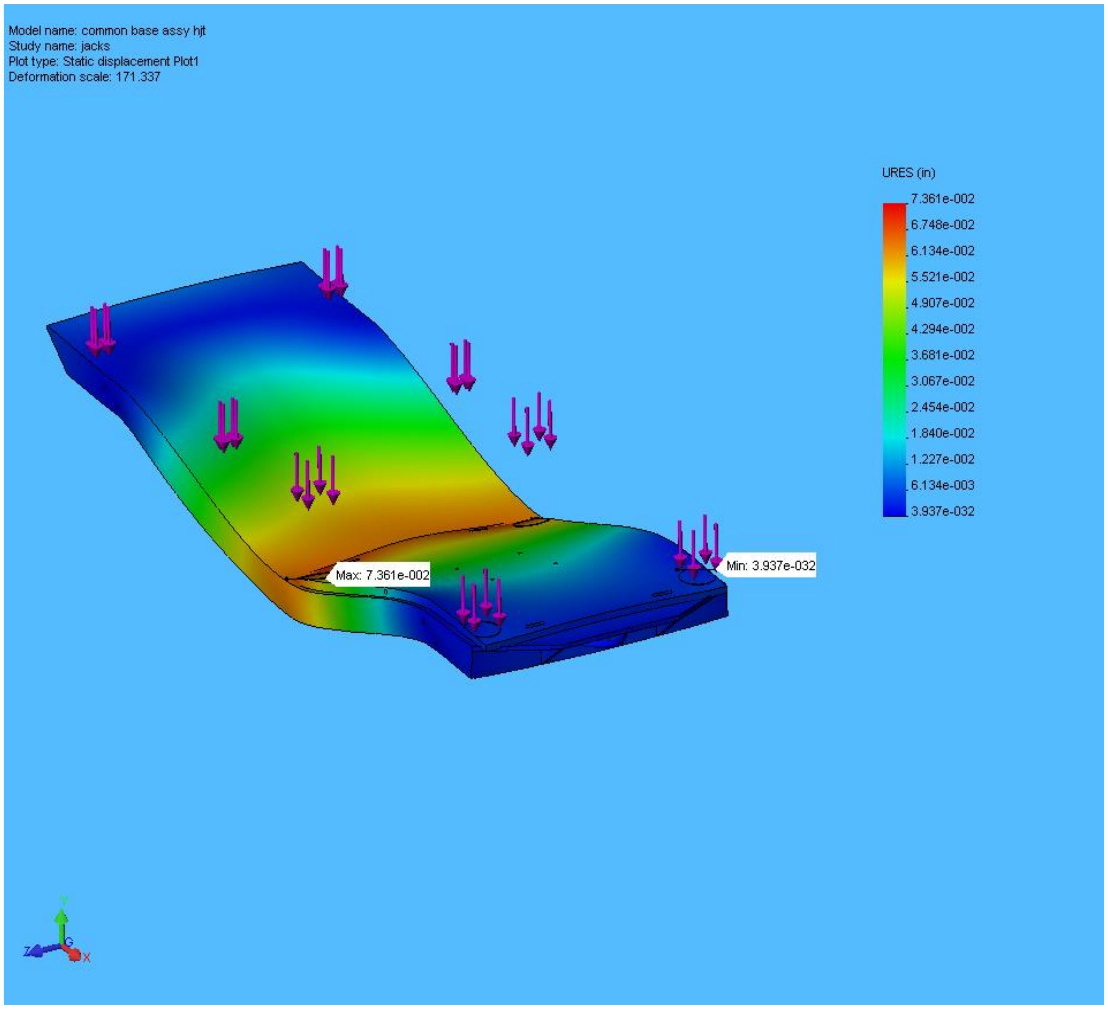
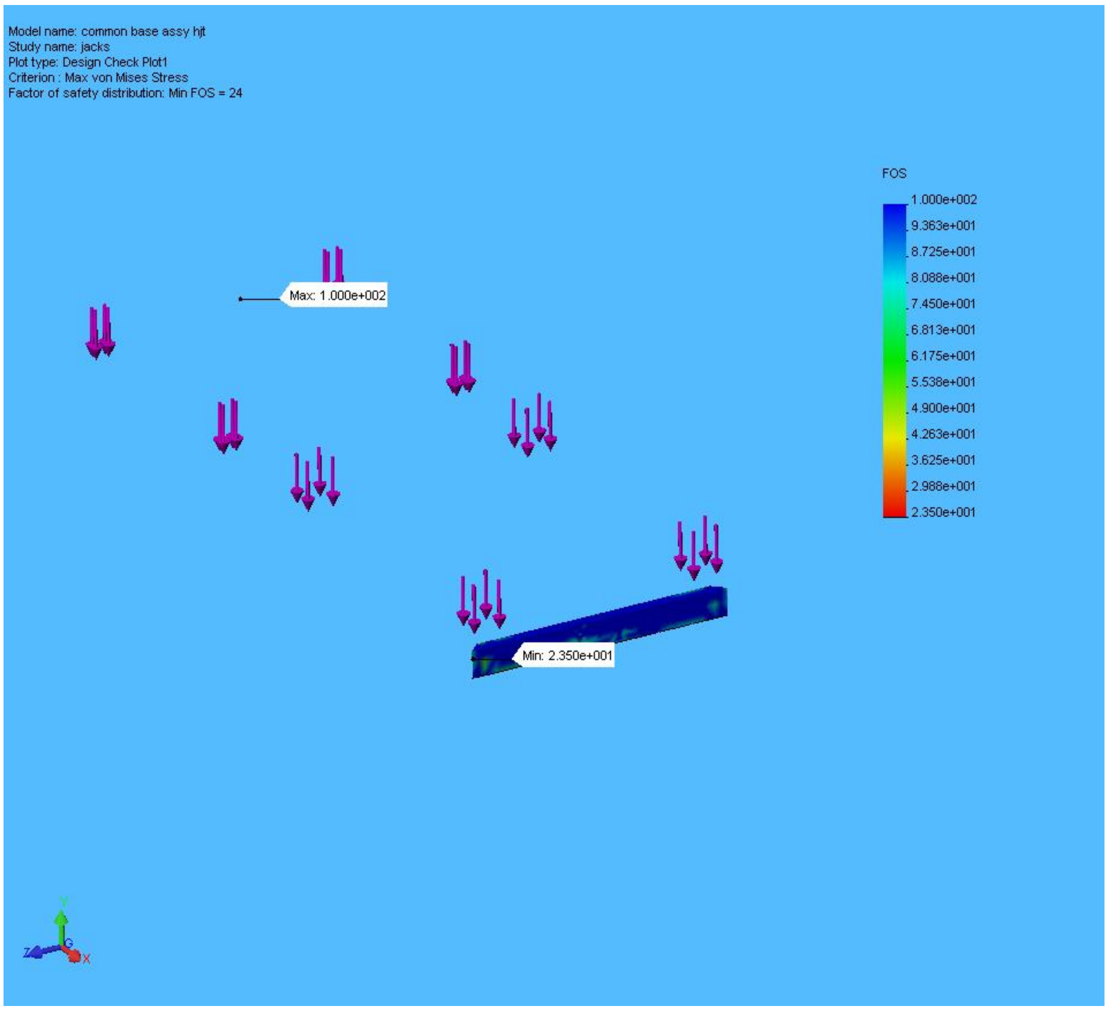
6. Displacement Results

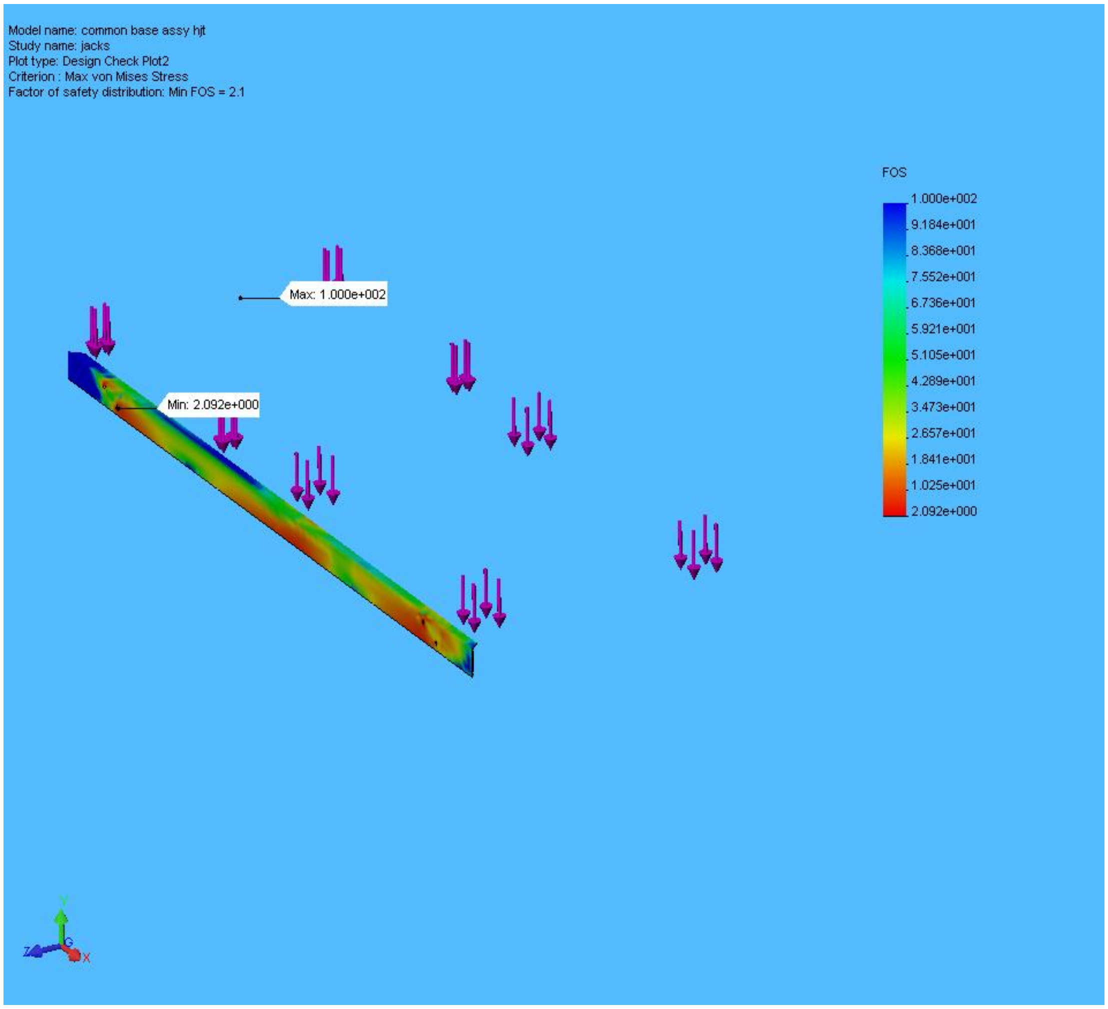
Name	Type	Min	Location	Max	Location
Plot1	URES: Resultant displacement	0 in Node:	(46.8828 in,	0.0736117 in	(3 in, 3.875

		107	0.644984 in, -19.68 in)	Node: 48521	in, 19 in)

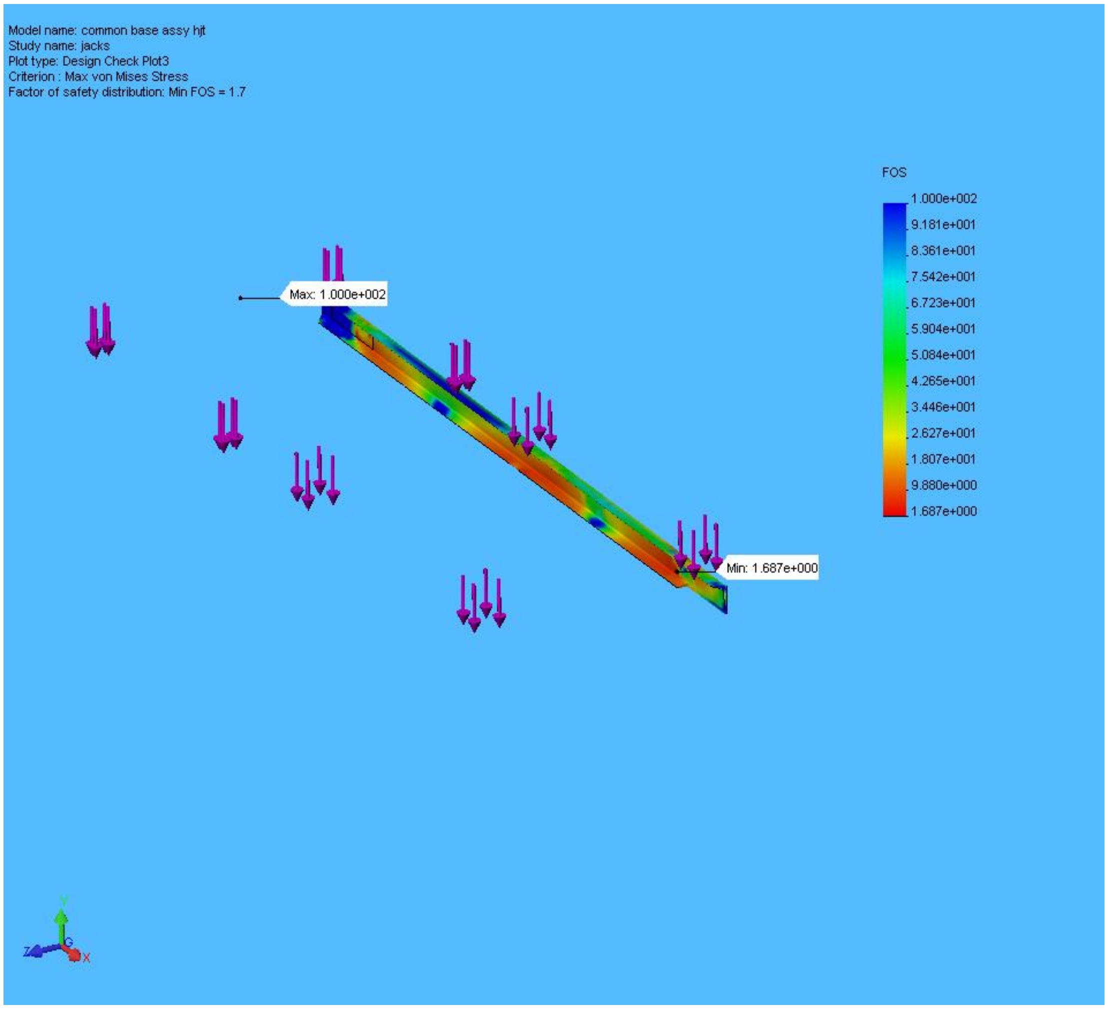
common base assy hjt-jacks-Displacement-Plot1
JPEG


7. Design Check Results

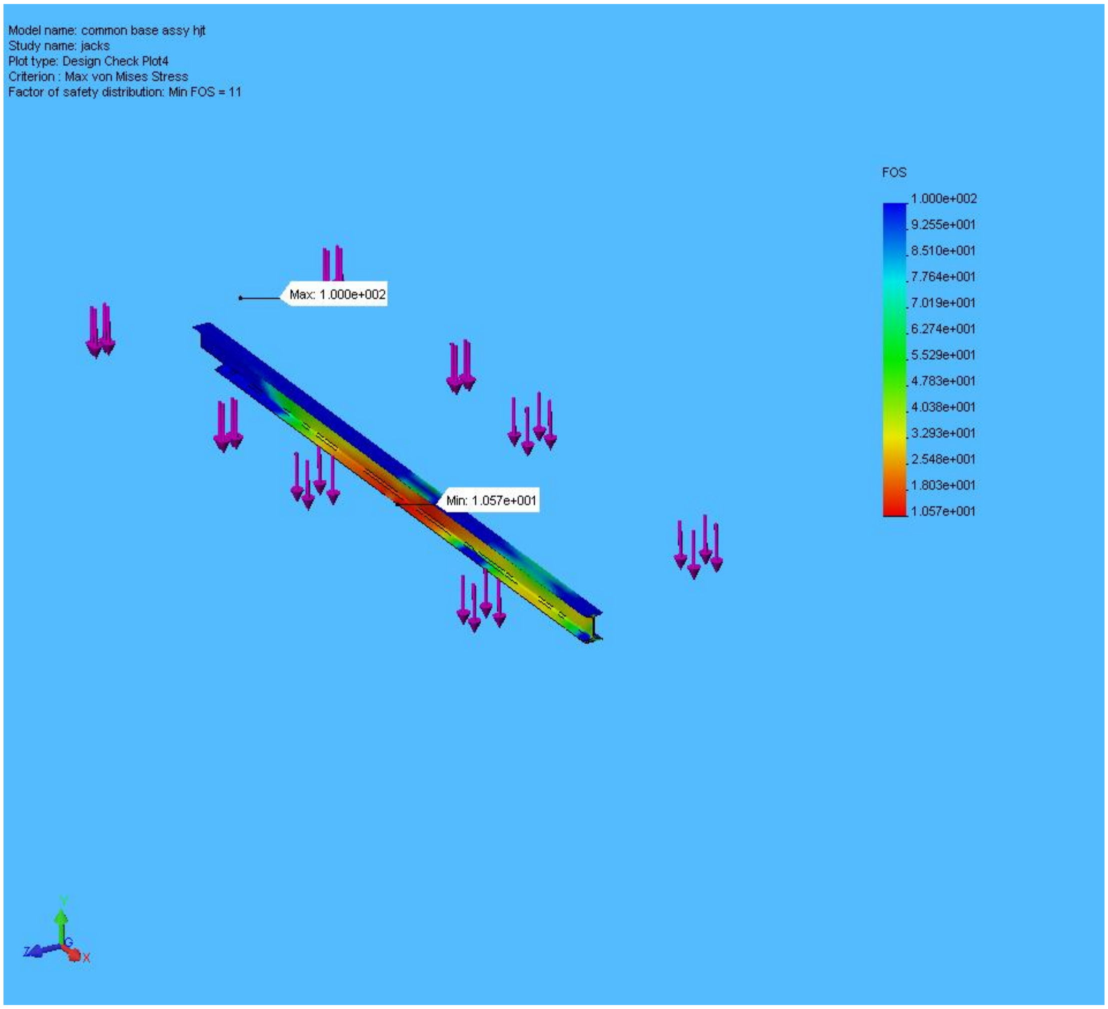
common base assy hjt-jacks-Design Check-Plot1
JPEG


common base assy hjt-jacks-Design Check-Plot2
JPEG


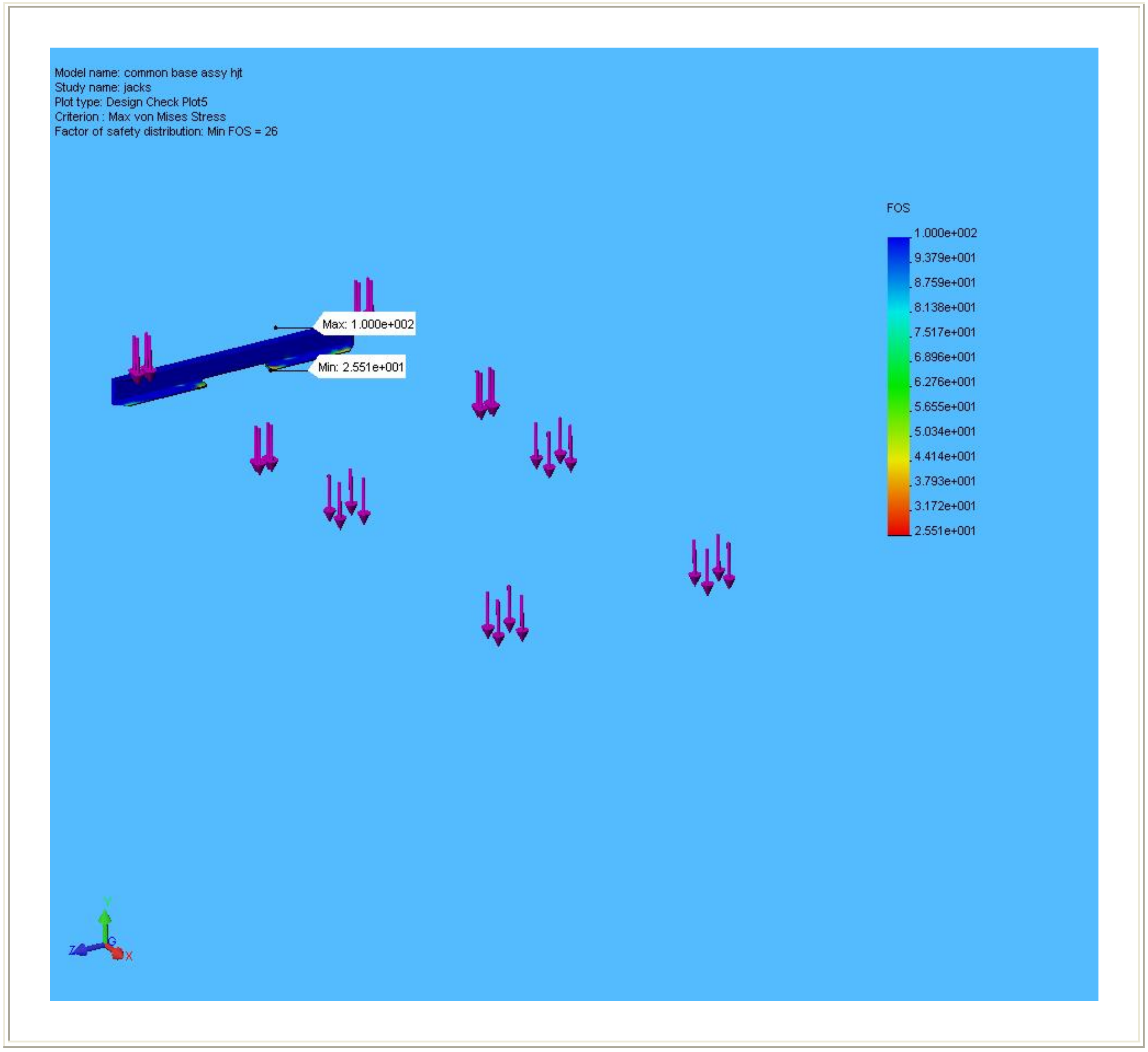
common base assy hjt-jacks-Design Check-Plot3
JPEG



common base assy hjt-jacks-Design Check-Plot4
JPEG



common base assy hjt-jacks-Design Check-Plot5
JPEG



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8. Conclusion

There are some local areas of high stress near the bolt holes in which the calculated safety factor is less than 3. However, these areas are very localized and are not indicative of a high general stress level.

9. Appendix

Material name: 6061-T6 (SS)

Description:

Material Source: Library files

Material Library Name: cosmos materials

Material Model Type: Linear Elastic Isotropic

Property Name	Value	Units	Value Type
Elastic modulus	1.0008e+007	psi	Constant
Poisson's ratio	0.33	NA	Constant
Shear modulus	3.771e+006	psi	Constant
Mass density	0.097544	lb/in^3	Constant
Tensile strength	44962	psi	Constant
Yield strength	39885	psi	Constant
Thermal expansion coefficient	1.3333e-005	/Fahrenheit	Constant
Thermal conductivity	0.0022322	BTU/(in.s.F)	Constant
Specific heat	0.21405	Btu/(lb.F)	Constant
Hardening factor (0.0-1.0; 0.0=isotropic; 1.0=kinematic)	0.85	NA	Constant

Material name: Wrought Stainless Steel

Description:

Material Source: Library files

Material Library Name: cosmos materials

Material Model Type: Linear Elastic Isotropic

Property Name	Value	Units	Value Type
Elastic modulus	2.9008e+007	psi	Constant

Poisson's ratio	0.26	NA	Constant
Shear modulus	1.1458e+007	psi	Constant
Mass density	0.28902	lb/in^3	Constant
Tensile strength	74987	psi	Constant
Yield strength	29995	psi	Constant
Thermal expansion coefficient	6.1111e-006	/Fahrenheit	Constant
Thermal conductivity	0.00025412	BTU/(in.s.F)	Constant
Specific heat	0.11945	Btu/(lb.F)	Constant

Material name:	Delrin 2700 NC010, Low Viscosity Acetal Copolymer (SS)
Description:	
Material Source:	Library files
Material Library Name:	cosmos materials
Material Model Type:	Linear Elastic Isotropic

Property Name	Value	Units	Value Type
Elastic modulus	4.2061e+005	psi	Constant
Poisson's ratio	0.3	NA	Constant
Mass density	0.0050939	lb/in^3	Constant
Tensile strength	5903	psi	Constant
Yield strength	9137.4	psi	Constant
Hardening factor (0.0-1.0; 0.0=isotropic; 1.0=kinematic)	0.85	NA	Constant

Stress Analysis of Hydraulic Jack Weldment

Author: Author: Van Graves

Company: Oak Ridge National Laboratory

Date: May 5, 2006

---

1. Introduction

A static analysis of the hydraulic jack weldment is performed. The loading condition simulated mimics the worst case scenario of a loaded baseplate (weight of magnet, Hg system, and baseplate). The load applied was manually calculated based on the distances between the load points and the bracket locations.

Note:

Do not base your design decisions solely on the data presented in this report. Use this information in conjunction with experimental data and practical experience. Field testing is mandatory to validate your final design. COSMOSWorks helps you reduce your time-to-market by reducing but not eliminating field tests.

---

2. Materials

No.	Part Name	Material	Mass	Volume
1	hyd jack weldment hjt	[SW]6061 Alloy	7.34375 lb	75.2868 in^3
2	hyd jack weldment hjt	[SW]6061 Alloy	7.34375 lb	75.2868 in^3
3	hyd jack weldment hjt	[SW]6061 Alloy	7.34375 lb	75.2868 in^3
4	hyd jack weldment hjt	[SW]6061 Alloy	7.34375 lb	75.2868 in^3

---

3. Load & Restraint Information

Restraint	
Restraint-1 <hyd jack weldment hjt>	on **1 Face(s)** fixed.
Description:	Top of weldment held fixed.

Load		
Force-1 <hyd jack weldment hjt>	on **2 Face(s)** apply force **-3000 lb** normal to reference plane with respect to selected reference **Edge< 1 >** using uniform distribution	Sequential Loading
Description:	Total load (6000lbs) evenly distributed	

	on the two bolt holes.	

---

4. Study Property

Mesh Information	
Mesh Type:	Solid mesh
Mesher Used:	Standard
Automatic Transition:	Off
Smooth Surface:	On
Jacobian Check:	4 Points
Element Size:	0.42235 in
Tolerance:	0.021117 in
Quality:	High
Number of elements:	5513
Number of nodes:	11121

Solver Information	
Quality:	High
Solver Type:	FFEPlus
Option:	Include Thermal Effects
Thermal Option:	Input Temperature
Thermal Option:	Reference Temperature at zero strain: 77 Fahrenheit

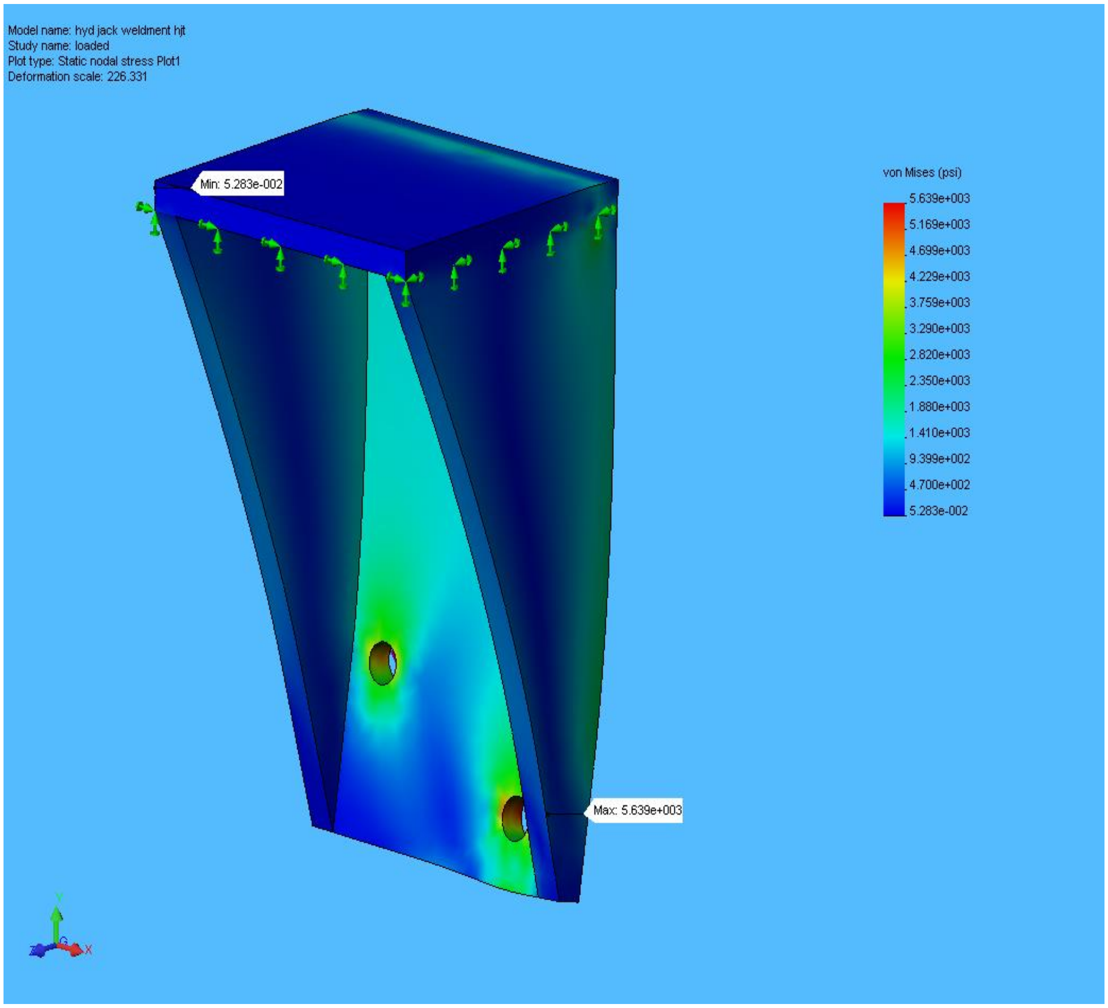
---

5. Stress Results

Name	Type	Min	Location	Max	Location
Plot1	VON: von Mises stress	0.0528316 psi Node: 6003	(-3 in, -0.125 in, 5.5 in)	5639.15 psi Node: 2377	(2.05831 in, -10.0128 in, 0 in)

hyd jack weldment hjt-loaded-Stress-Plot1

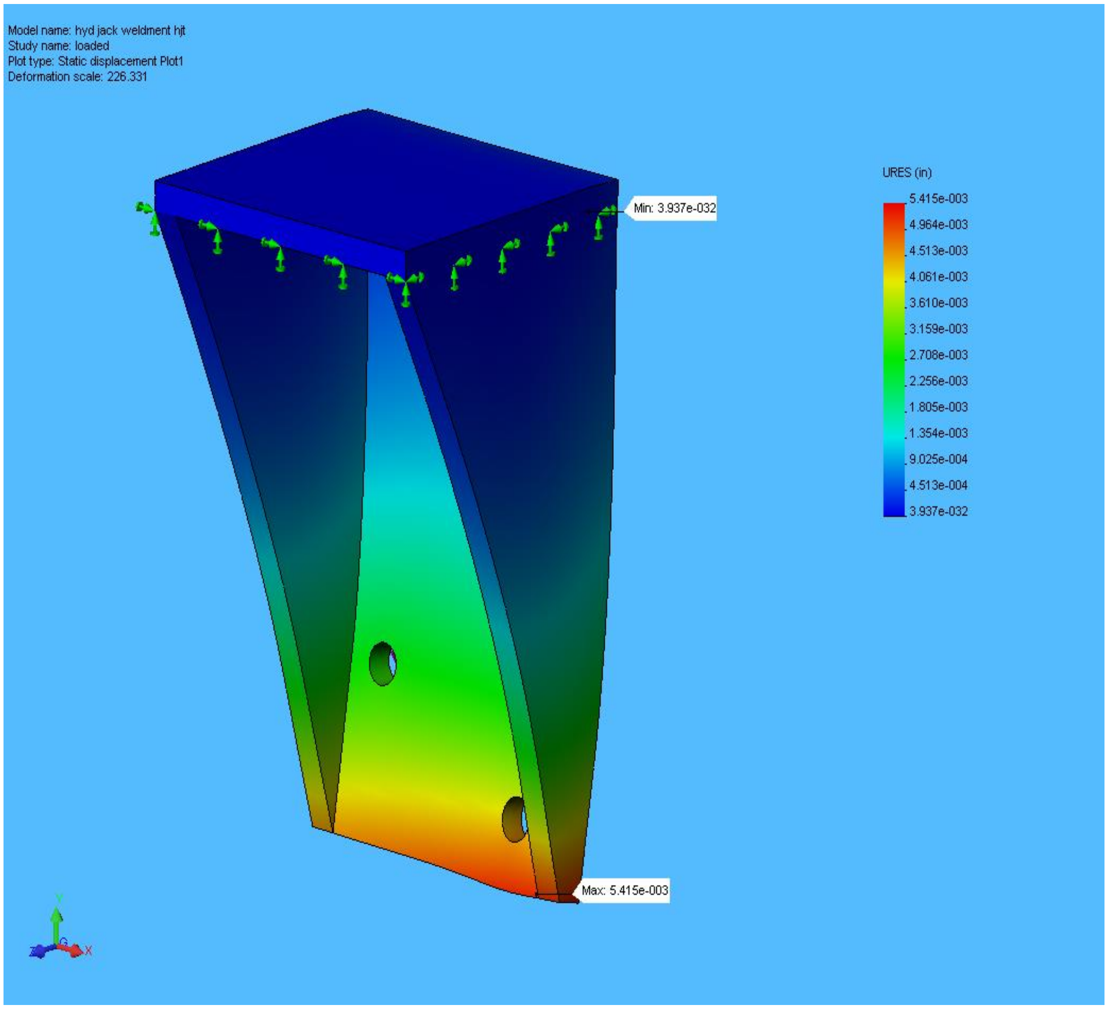
JPEG



6. Displacement Results

Name	Type	Min	Location	Max	Location
Plot1	URES: Resultant displacement	0 in Node: 19	(-2.5 in, -0.5 in, 0.5 in)	0.00541518 in Node: 2145	(2 in, -11.25 in, 0 in)

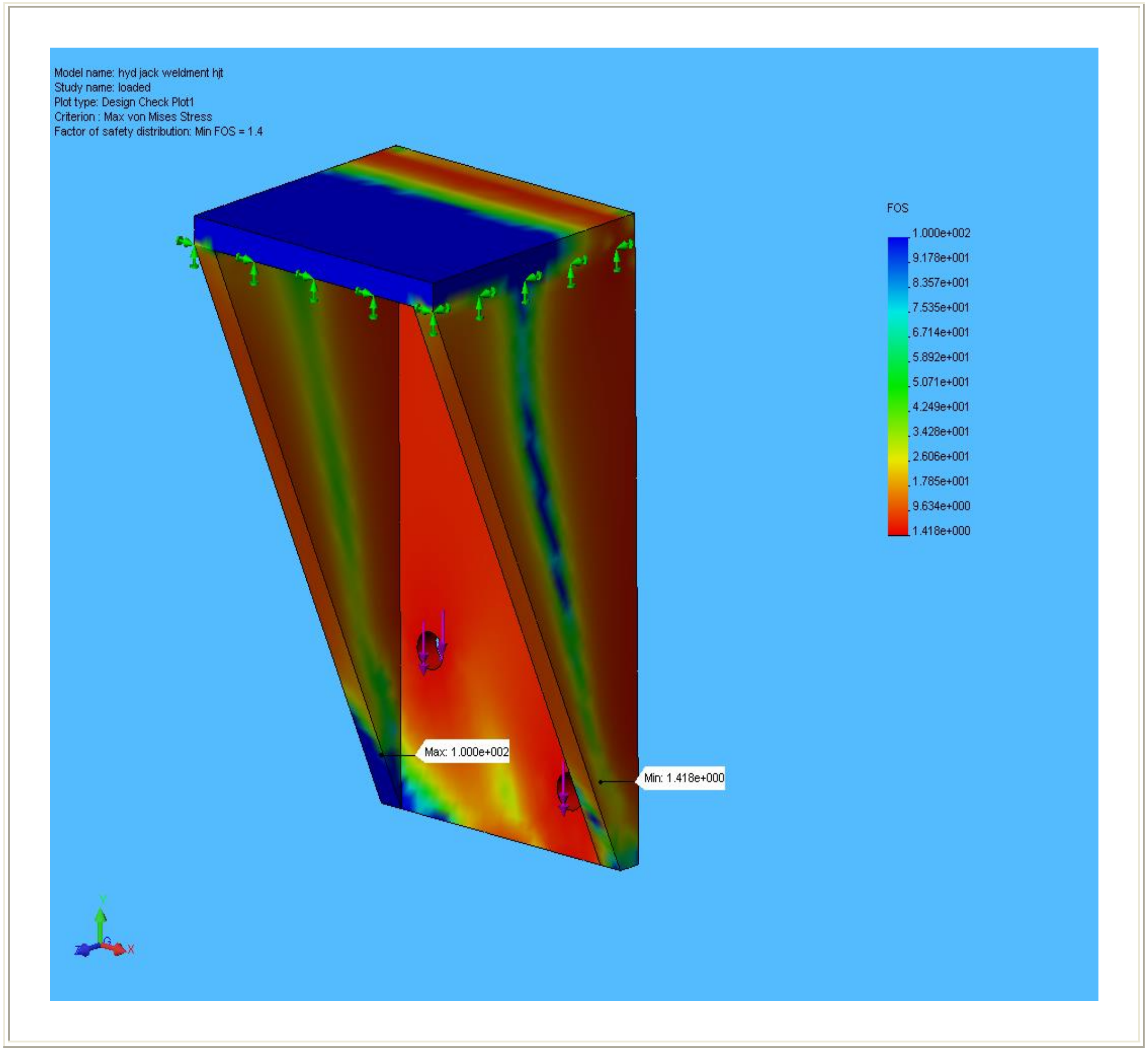
hyd jack weldment hjt-loaded-Displacement-Plot1
JPEG



---

7. Design Check Results

hyd jack weldment hjt-loaded-Design Check-Plot1
JPEG



---

8. Conclusion

The analysis indicates localized high stresses near the bolt holes, but no stresses are above yield strength of the material. Any local deformation will relieve the stresses, so the structure is considered adequate for the simulated loading condition.

9. Appendix

Material name: [SW]6061 Alloy

Description:

Material Source: Used SolidWorks material

Material Library Name:

Material Model Type: Linear Elastic Isotropic

Property Name	Value	Units	Value Type
Elastic modulus	1.0008e+007	psi	Constant
Poisson's ratio	0.33	NA	Constant
Shear modulus	3.771e+006	psi	Constant
Mass density	0.097544	lb/in^3	Constant
Tensile strength	17997	psi	Constant
Yield strength	7998.6	psi	Constant
Thermal expansion coefficient	1.3333e-005	/Fahrenheit	Constant
Thermal conductivity	0.0022737	BTU/(in.s.F)	Constant
Specific heat	0.31056	Btu/(lb.F)	Constant

Stress Analysis of Common Baseplate - 4 Levelers

Author: Author: Van Graves

Company: Oak Ridge National Laboratory

Date: March 14, 2006

---

1. Introduction

A static analysis of the common base assembly is performed. The loading condition simulates that encountered when the loaded baseplate (magnet & Hg system) is supported by four leveling jacks.

Note:

Do not base your design decisions solely on the data presented in this report. Use this information in conjunction with experimental data and practical experience. Field testing is mandatory to validate your final design. COSMOSWorks helps you reduce your time-to-market by reducing but not eliminating field tests.

---

2. Materials

No.	Part Name	Material	Mass	Volume
1	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
2	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
3	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
4	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
5	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
6	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
7	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
8	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
9	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
10	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
11	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
12	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
13	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3

14	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
15	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
16	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
17	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
18	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
19	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
20	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
21	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
22	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
23	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
24	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
25	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
26	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
27	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
28	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
29	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
30	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
31	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
32	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
33	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3

34	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
35	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
36	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
37	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
38	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
39	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
40	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
41	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
42	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
43	base weldment hjt-1	6061-T6 (SS)	447.976 lb	4592.57 in^3
44	flat rail hjt-1	Wrought Stainless Steel	18.7862 lb	65 in^3
45	flat rail hjt-2	Wrought Stainless Steel	18.7862 lb	65 in^3
46	magnet support plate hjt-1	6061-T6 (SS)	205.676 lb	2108.55 in^3
47	slick sheet hjt-1	Delrin 2700 NC010, Low Viscosity Acetal Copolymer (SS)	2.32213 lb	455.861 in^3

---

3. Load & Restraint Information

Restraint	
Restraint-3 <base weldment hjt-1>	on **4 Face(s)** fixed.

Description:	Threaded holes for leveling jacks are fixed.

Load		
Force-1 <magnet support plate hjt-1>	on **4 Face(s)** apply normal force **3000 lb** using uniform distribution	Sequential Loading
Description:	Magnet weight (6T) distributed on support plate pads.	
Force-2 <flat rail hjt-2, flat rail hjt-1>	on **4 Face(s)** apply normal force **1000 lb** using uniform distribution	Sequential Loading
Description:	Hg system weight (2T) distributed on rails at wheel contact locations.	

---

4. Study Property

Mesh Information	
Mesh Type:	Solid mesh
Mesher Used:	Standard
Automatic Transition:	Off
Smooth Surface:	On
Jacobian Check:	4 Points
Element Size:	1.6804 in
Tolerance:	0.08402 in
Quality:	High
Number of elements:	45106
Number of nodes:	81757

Solver Information	
Quality:	High
Solver Type:	FFEPlus
Option:	Include Thermal Effects

Thermal Option:	Input Temperature
Thermal Option:	Reference Temperature at zero strain: 77 Fahrenheit

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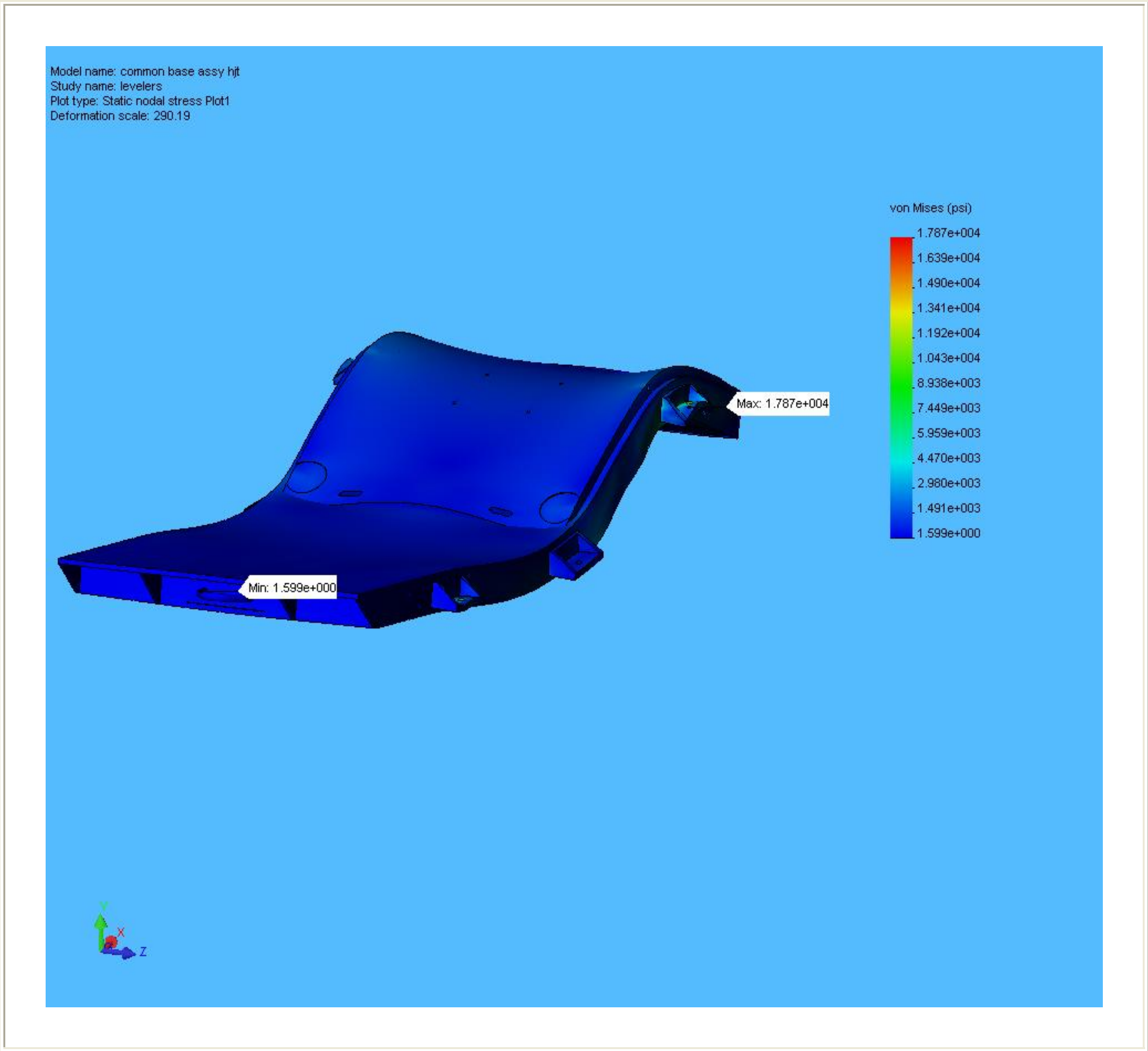
5. Stress Results

Name	Type	Min	Location	Max	Location
Plot1	VON: von Mises stress	1.59852 psi Node: 58699	(-59.2137 in, 0.302294 in, -2.5138 in)	17874.7 psi Node: 35675	(36.3789 in, -1.25 in, 22.0312 in)

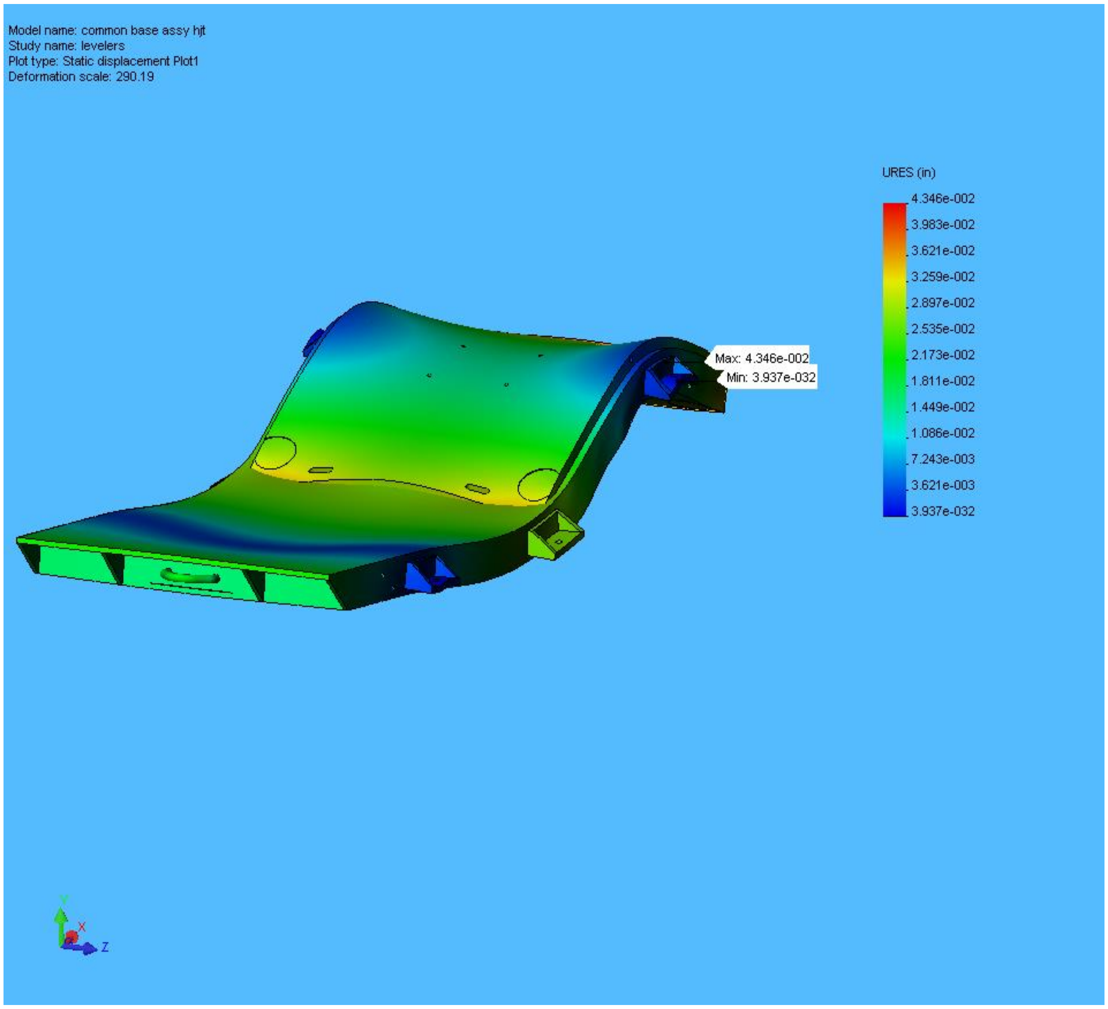
common base assy hjt-levelers-Stress-Plot1
JPEG



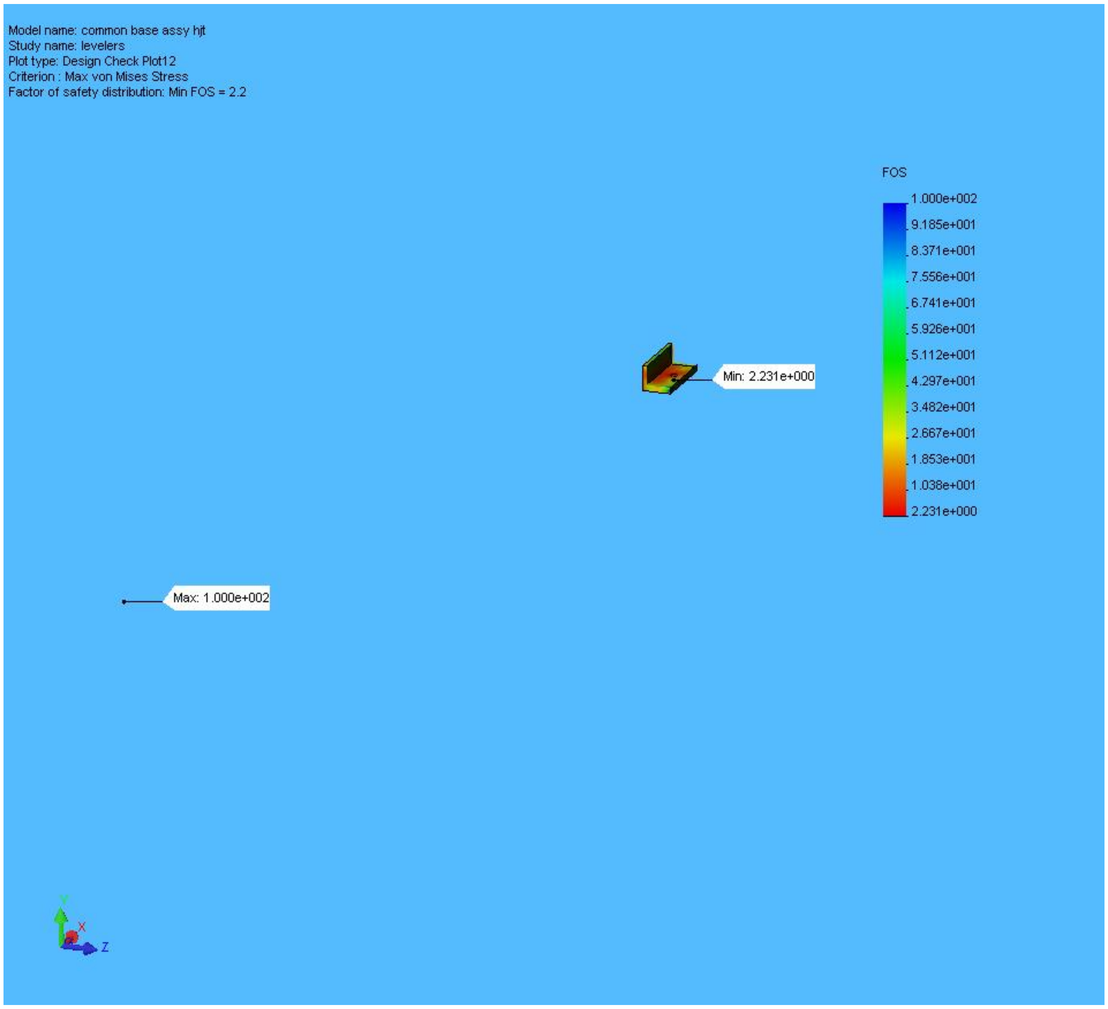
6. Displacement Results

Name	Type	Min	Location	Max	Location
Plot1	URES: Resultant displacement	0 in Node:	(36.3789 in,	0.0434563 in	(63 in, 2.625

		35637	-0.5 in, 22.0312 in)	Node: 2545	in, 9.25 in)

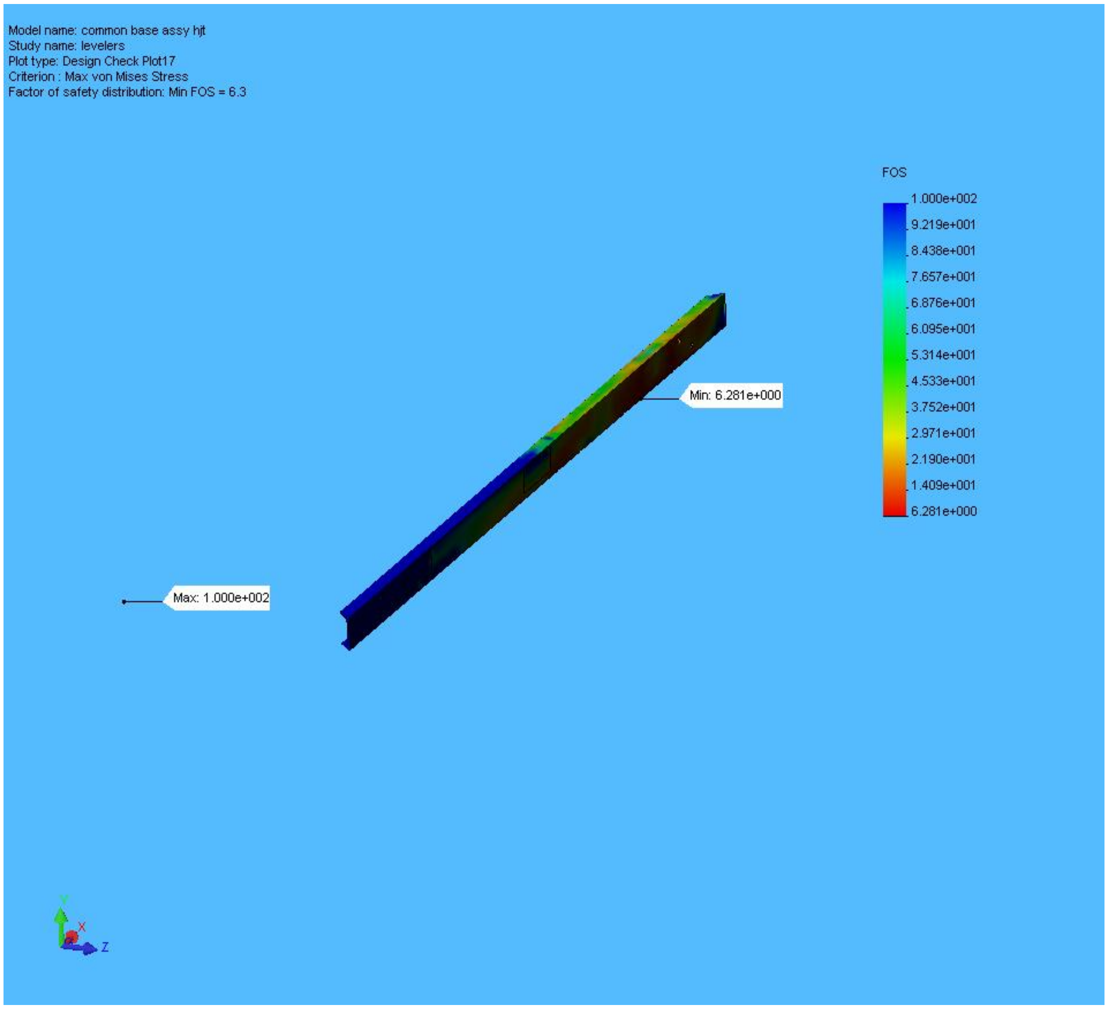
common base assy hjt-levelers-Displacement-Plot1
JPEG


7. Design Check Results

common base assy hjt-levelers-Design Check-Plot12
JPEG


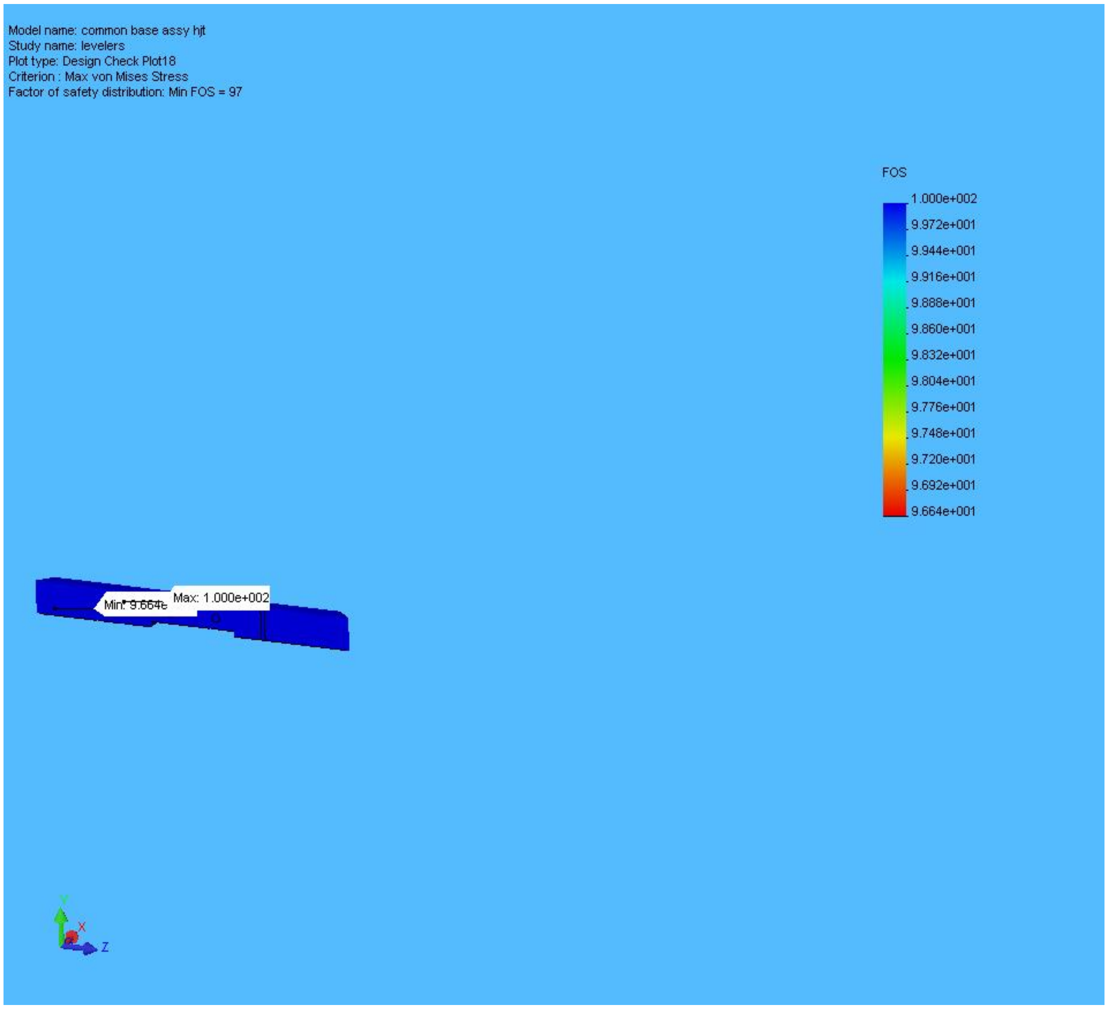
common base assy hjt-levelers-Design Check-Plot17

JPEG

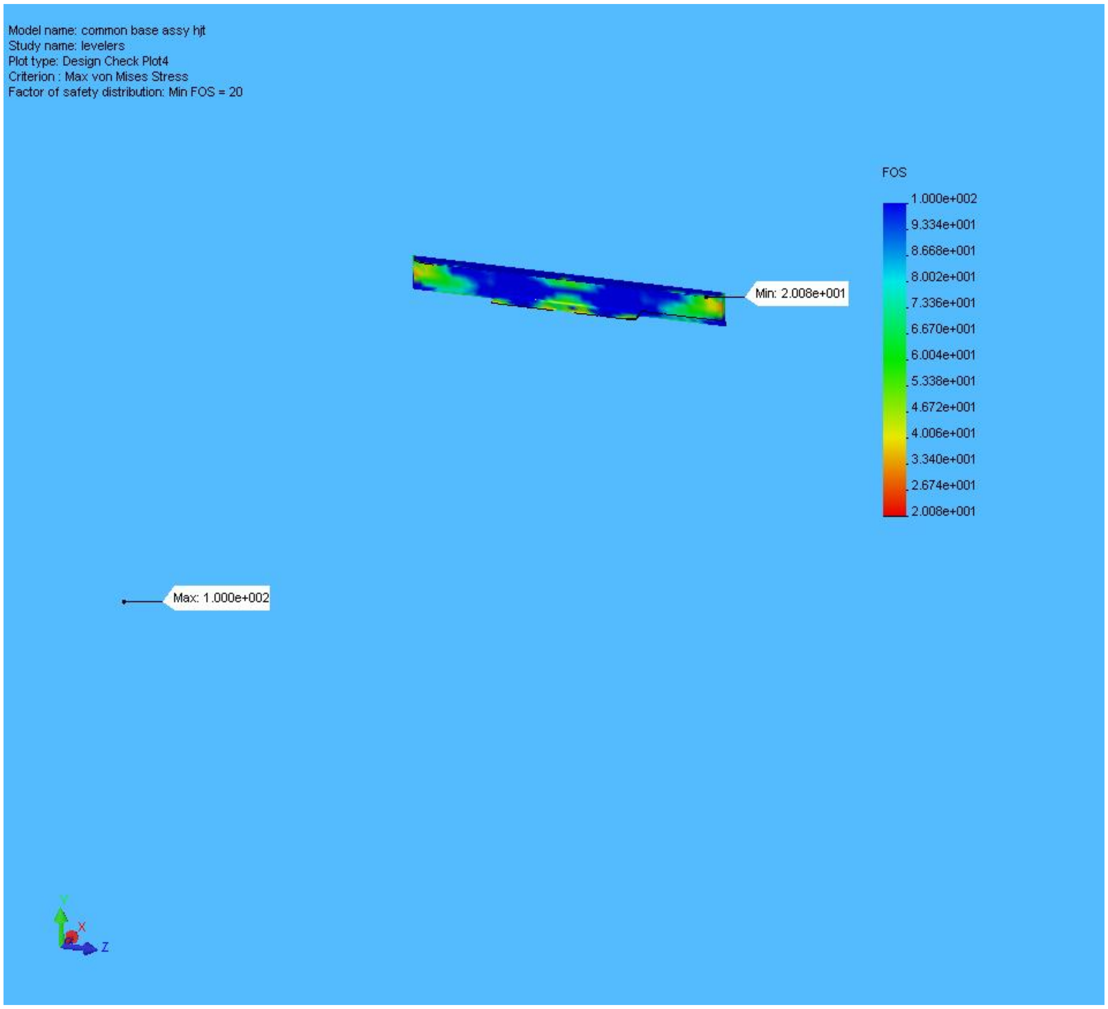


common base assy hjt-levelers-Design Check-Plot18

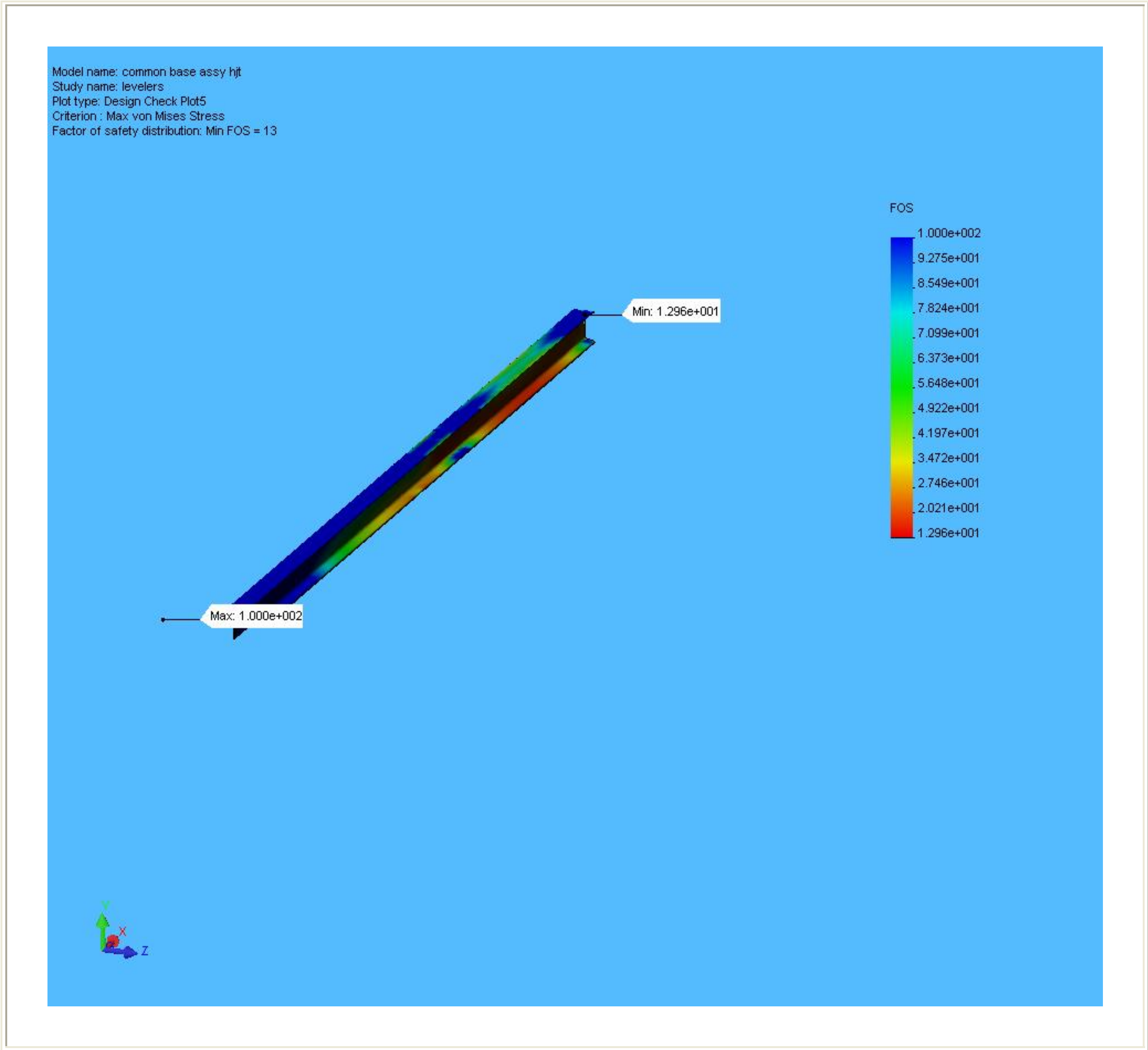
JPEG



common base assy hjt-levelers-Design Check-Plot4
JPEG



common base assy hjt-levelers-Design Check-Plot5
JPEG



---

8. Conclusion

Analysis indicates minimum safety factor (2.2) near edge of leveling jack holes under magnet. These are localized stresses and are not indicative of a general stress level. Local deformation will relieve these stresses, so the baseplate design is considered structurally adequate for the simulated loading condition.

---

9. Appendix

Material name: 6061-T6 (SS)

Description:

Material Source: Library files

Material Library Name: cosmos materials

Material Model Type: Linear Elastic Isotropic

Property Name	Value	Units	Value Type
Elastic modulus	1.0008e+007	psi	Constant
Poisson's ratio	0.33	NA	Constant
Shear modulus	3.771e+006	psi	Constant
Mass density	0.097544	lb/in^3	Constant
Tensile strength	44962	psi	Constant
Yield strength	39885	psi	Constant
Thermal expansion coefficient	1.3333e-005	/Fahrenheit	Constant
Thermal conductivity	0.0022322	BTU/(in.s.F)	Constant
Specific heat	0.21405	Btu/(lb.F)	Constant
Hardening factor (0.0-1.0; 0.0=isotropic; 1.0=kinematic)	0.85	NA	Constant

Material name: Wrought Stainless Steel

Description:

Material Source: Library files

Material Library Name: cosmos materials

Material Model Type: Linear Elastic Isotropic

Property Name	Value	Units	Value Type
Elastic modulus	2.9008e+007	psi	Constant
Poisson's ratio	0.26	NA	Constant
Shear modulus	1.1458e+007	psi	Constant
Mass density	0.28902	lb/in^3	Constant
Tensile strength	74987	psi	Constant
Yield strength	29995	psi	Constant
Thermal expansion coefficient	6.1111e-006	/Fahrenheit	Constant
Thermal conductivity	0.00025412	BTU/(in.s.F)	Constant
Specific heat	0.11945	Btu/(lb.F)	Constant

Material name:	Delrin 2700 NC010, Low Viscosity Acetal Copolymer (SS)
Description:	
Material Source:	Library files
Material Library Name:	cosmos materials
Material Model Type:	Linear Elastic Isotropic

Property Name	Value	Units	Value Type
Elastic modulus	4.2061e+005	psi	Constant
Poisson's ratio	0.3	NA	Constant
Mass density	0.0050939	lb/in^3	Constant
Tensile strength	5903	psi	Constant
Yield strength	9137.4	psi	Constant
Hardening factor (0.0-1.0; 0.0=isotropic; 1.0=kinematic)	0.85	NA	Constant

Stress Analysis of Common Baseplate - 3 Rollers

Author: Author: Van Graves

Company: Oak Ridge National Laboratory

Date: April 23, 2006

---

1. Introduction

A static analysis of the common base assembly is performed. The loading condition simulates one encountered when the loaded baseplate (with magnet & Hg system) is supported by three Hilman rollers. This situation will occur during system alignment with the beamline.

Note:

Do not base your design decisions solely on the data presented in this report. Use this information in conjunction with experimental data and practical experience. Field testing is mandatory to validate your final design. COSMOSWorks helps you reduce your time-to-market by reducing but not eliminating field tests.

---

2. Materials

No.	Part Name	Material	Mass	Volume
1	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
2	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
3	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
4	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
5	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
6	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
7	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
8	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
9	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
10	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
11	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
12	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3

13	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
14	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
15	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
16	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
17	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
18	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
19	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
20	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
21	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
22	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
23	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
24	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
25	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
26	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
27	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
28	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
29	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
30	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
31	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
32	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3

33	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
34	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
35	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
36	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
37	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
38	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
39	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
40	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
41	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
42	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
43	base weldment hjt-1	6061-T6 (SS)	428.213 lb	4389.96 in^3
44	flat rail hjt-1	Wrought Stainless Steel	18.7862 lb	65 in^3
45	flat rail hjt-2	Wrought Stainless Steel	18.7862 lb	65 in^3
46	magnet support plate hjt-1	6061-T6 (SS)	205.676 lb	2108.55 in^3
47	slick sheet hjt-1	Delrin 2700 NC010, Low Viscosity Acetal Copolymer (SS)	2.32213 lb	455.861 in^3

---

3. Load & Restraint Information

Restraint

Restraint-1 <base weldment hjt-1>	on **3 Face(s)** fixed.
Description:	Roller pads fixed

Load		
Force-1 <magnet support plate hjt-1>	on **4 Face(s)** apply normal force **3000 lb** using uniform distribution	Sequential Loading
Description:	Magnet weight evenly distributed on pads	
Force-2 <flat rail hjt-1, flat rail hjt-2>	on **4 Face(s)** apply normal force **1000 lb** using uniform distribution	Sequential Loading
Description:	Hg system weight evenly distributed on sections of rail	

---

4. Study Property

Mesh Information	
Mesh Type:	Solid mesh
Mesher Used:	Standard
Automatic Transition:	Off
Smooth Surface:	On
Jacobian Check:	4 Points
Element Size:	1.5846 in
Tolerance:	0.07923 in
Quality:	High
Number of elements:	46335
Number of nodes:	83724

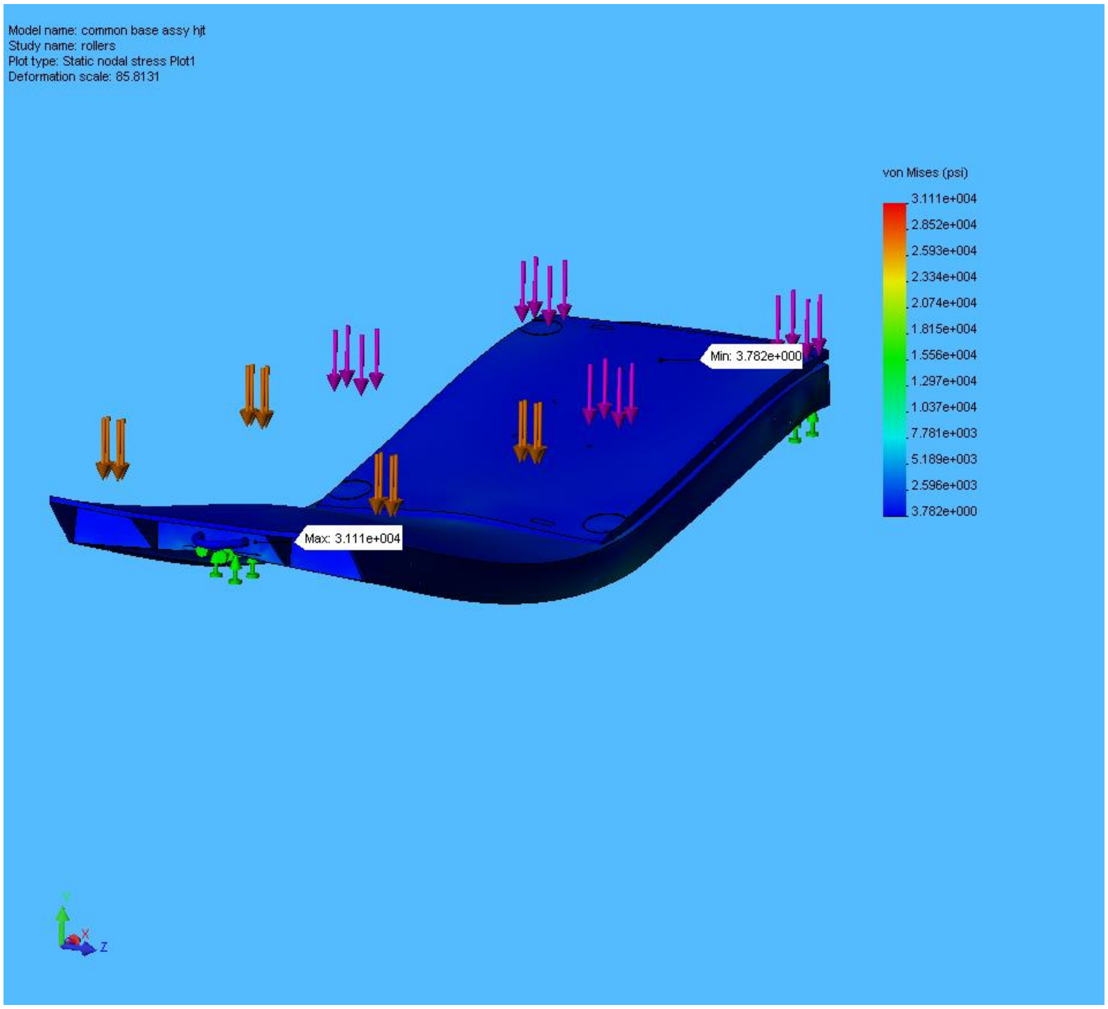
Solver Information	
Quality:	High

Solver Type:	FFEPlus
Option:	Include Thermal Effects
Thermal Option:	Input Temperature
Thermal Option:	Reference Temperature at zero strain: 77 Fahrenheit

5. Stress Results

Name	Type	Min	Location	Max	Location
Plot1	VON: von Mises stress	3.78184 psi Node: 80530	(52.6774 in, 2.75 in, -9.22699e-007 in)	31114.5 psi Node: 36807	(-49 in, -1.33534 in, 0.098234 in)

common base assy hjt-rollers-Stress-Plot1
JPEG



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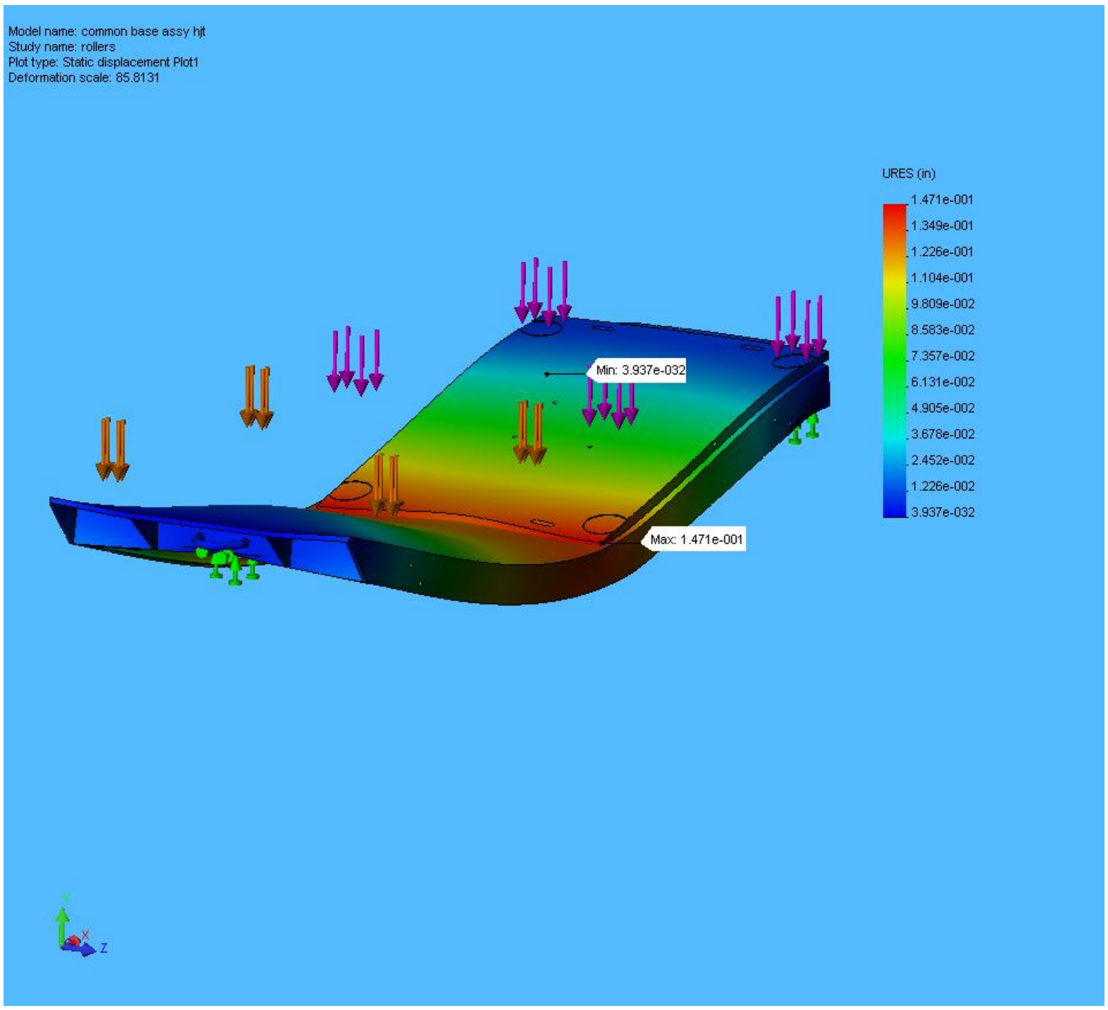
6. Displacement Results

Name	Type	Min	Location	Max	Location
Plot1	URES: Resultant displacement	0 in Node:	(54 in, -1.9 in,	0.14714 in	(3 in, 3.875

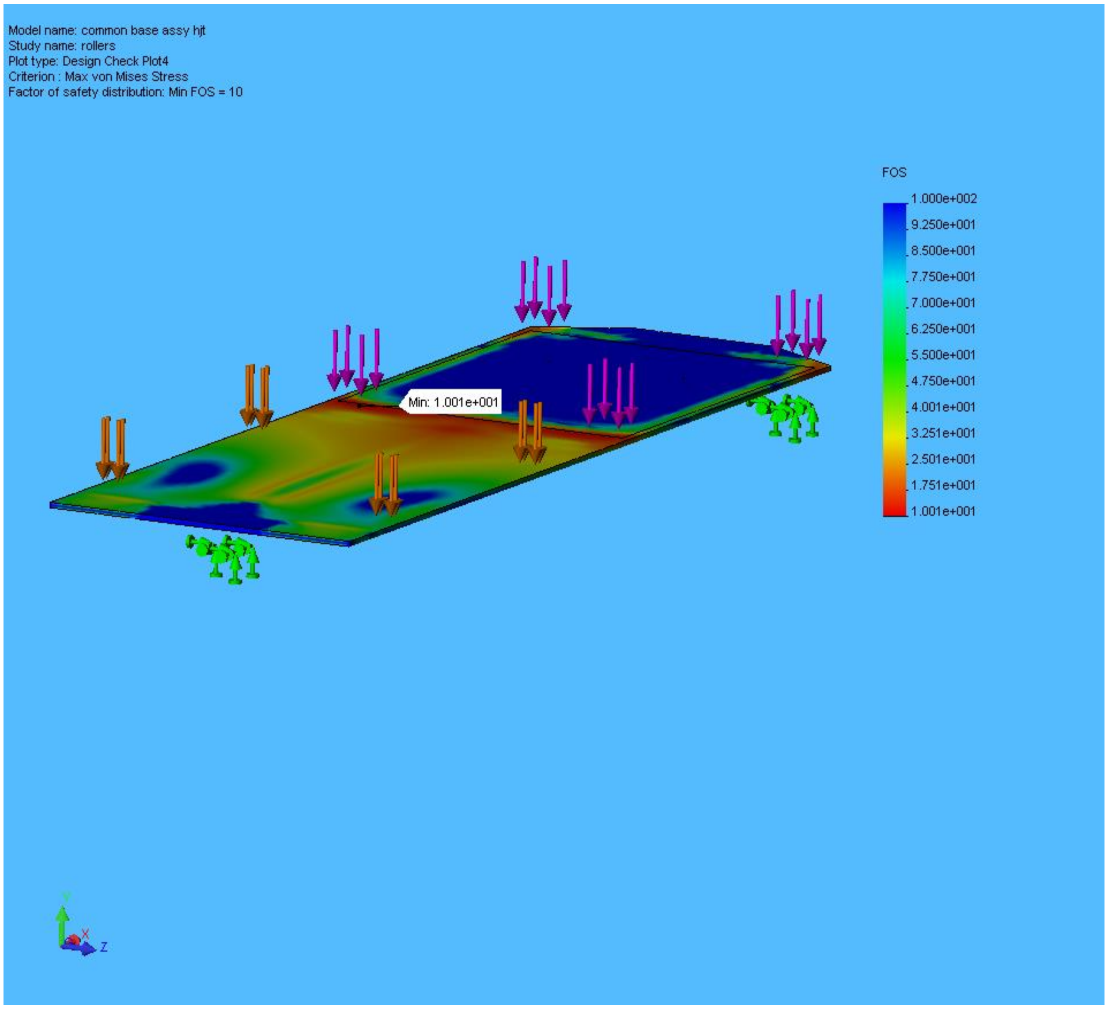
		27840	-19.5 in)	Node: 64726	in, 19 in)

common base assy hjt-rollers-Displacement-Plot1
JPEG



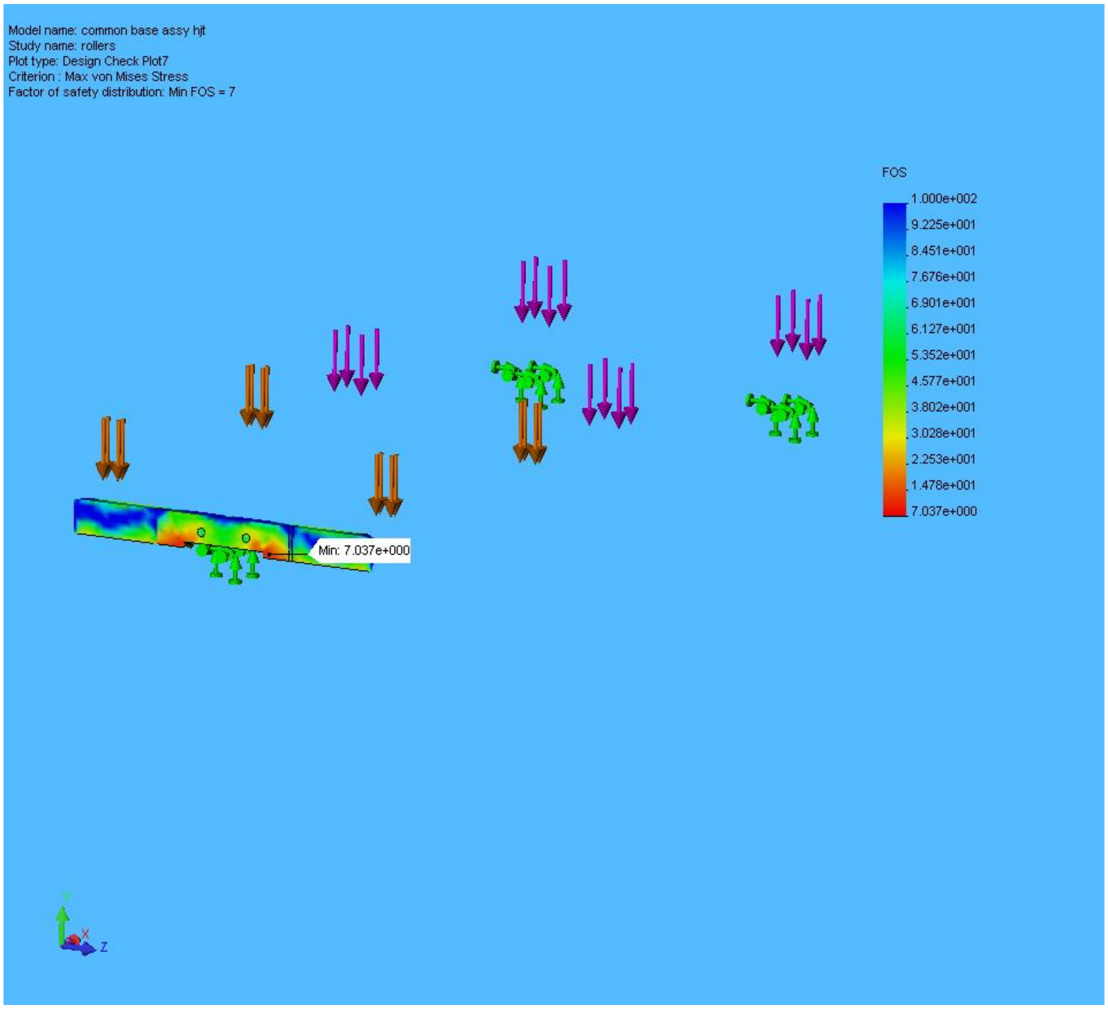
7. Design Check Results

common base assy hjt-rollers-Design Check-Plot4
JPEG



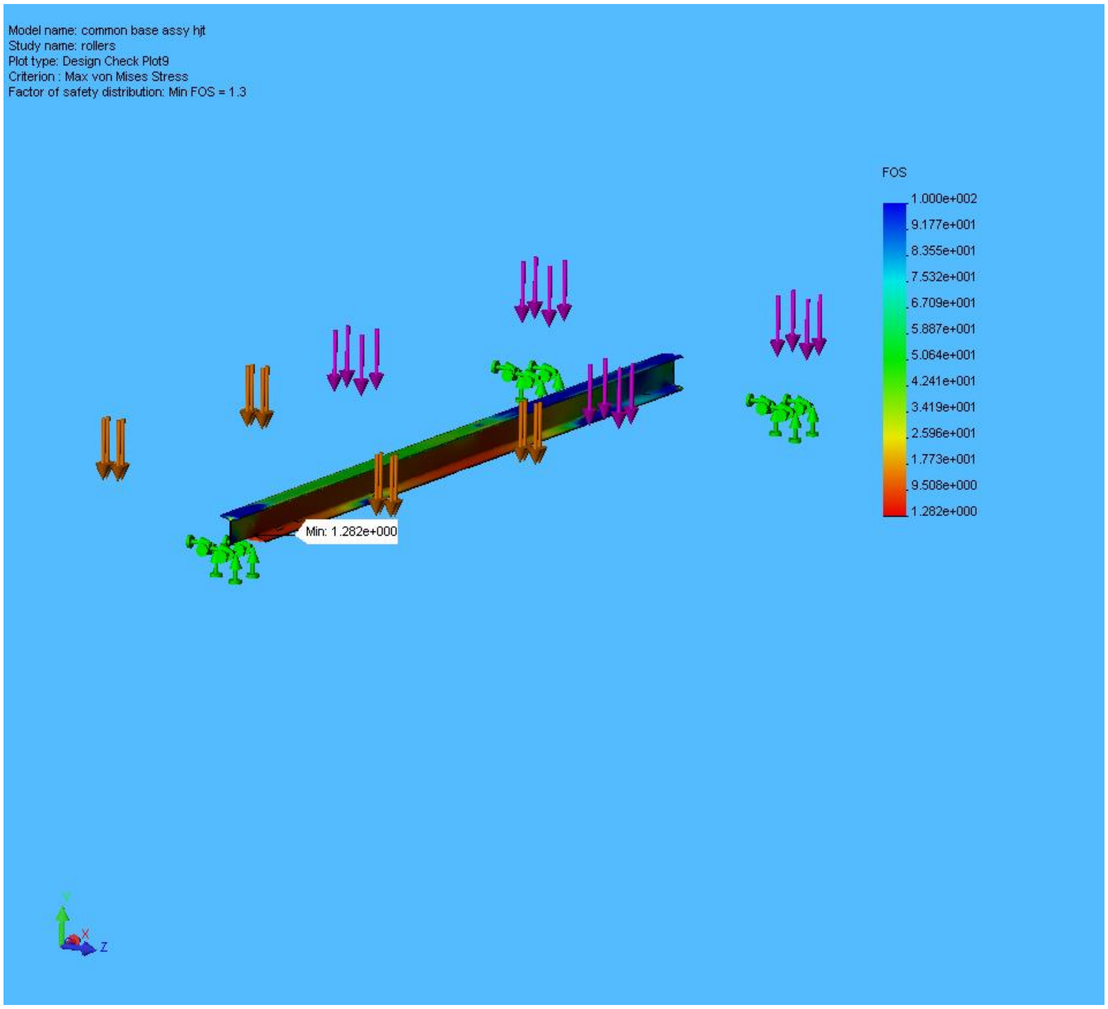
common base assy hjt-rollers-Design Check-Plot7

JPEG



common base assy hjt-rollers-Design Check-Plot9

JPEG



common base assy hjt-rollers-Design Check-Plot6
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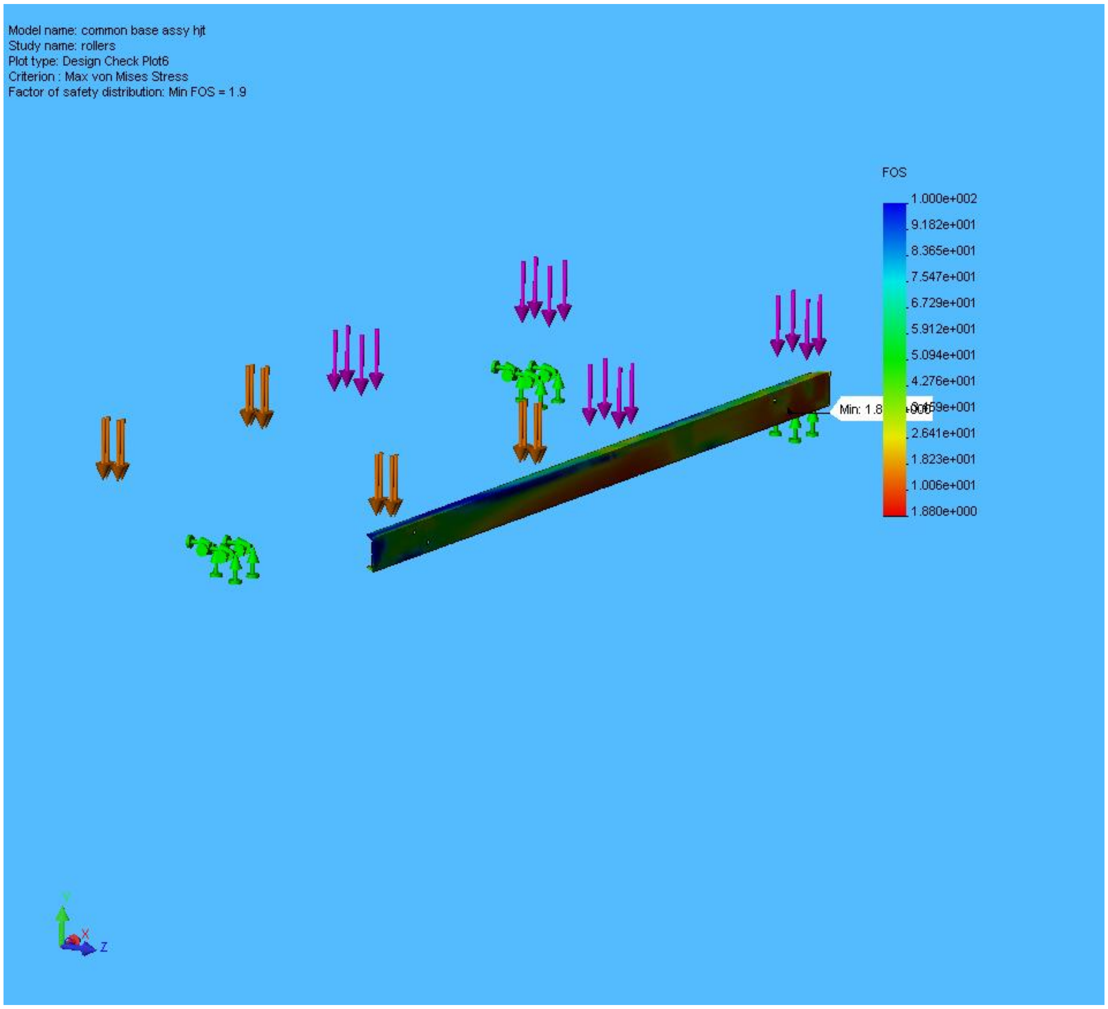
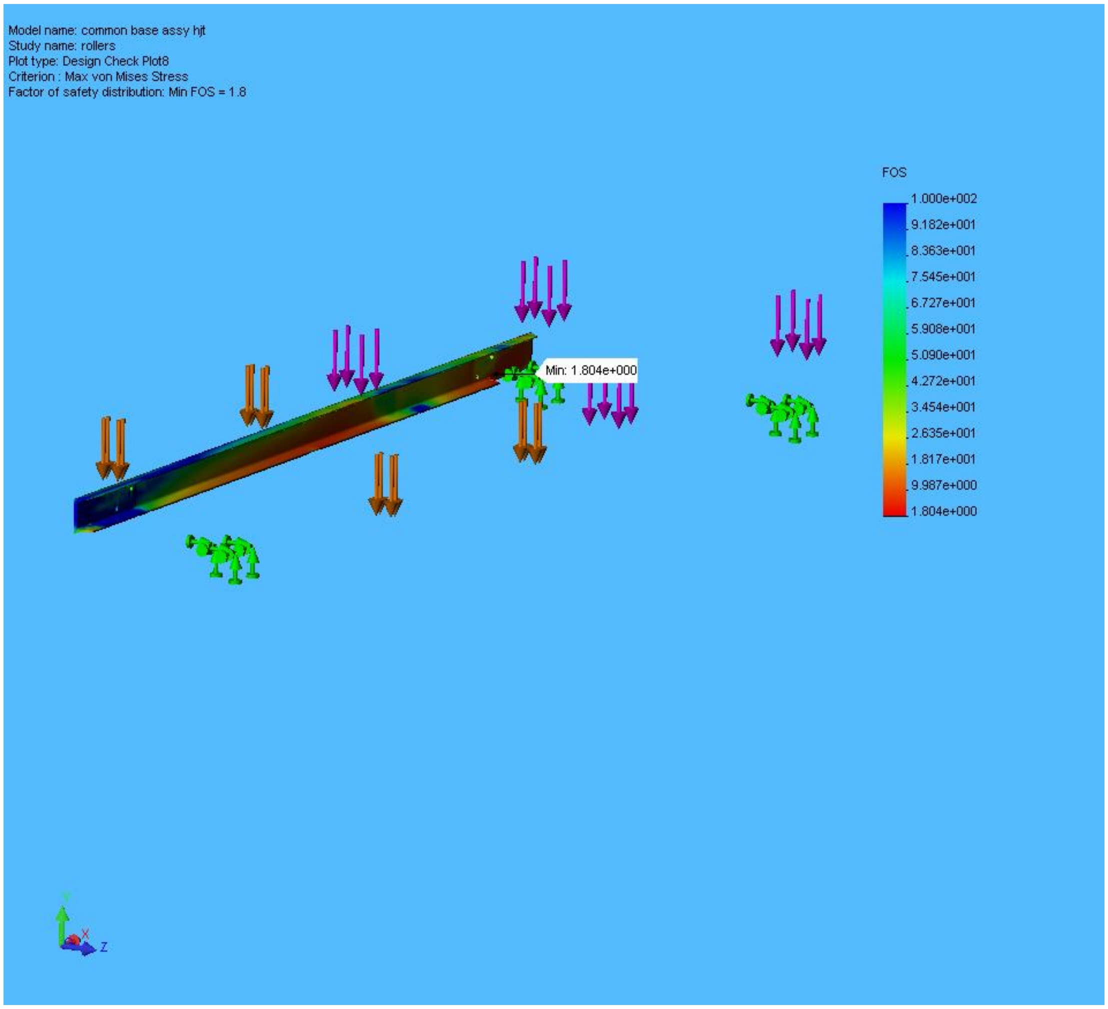


common base assy hjt-rollers-Design Check-Plot8

JPEG



common base assy hjt-rollers-Design Check-Plot10
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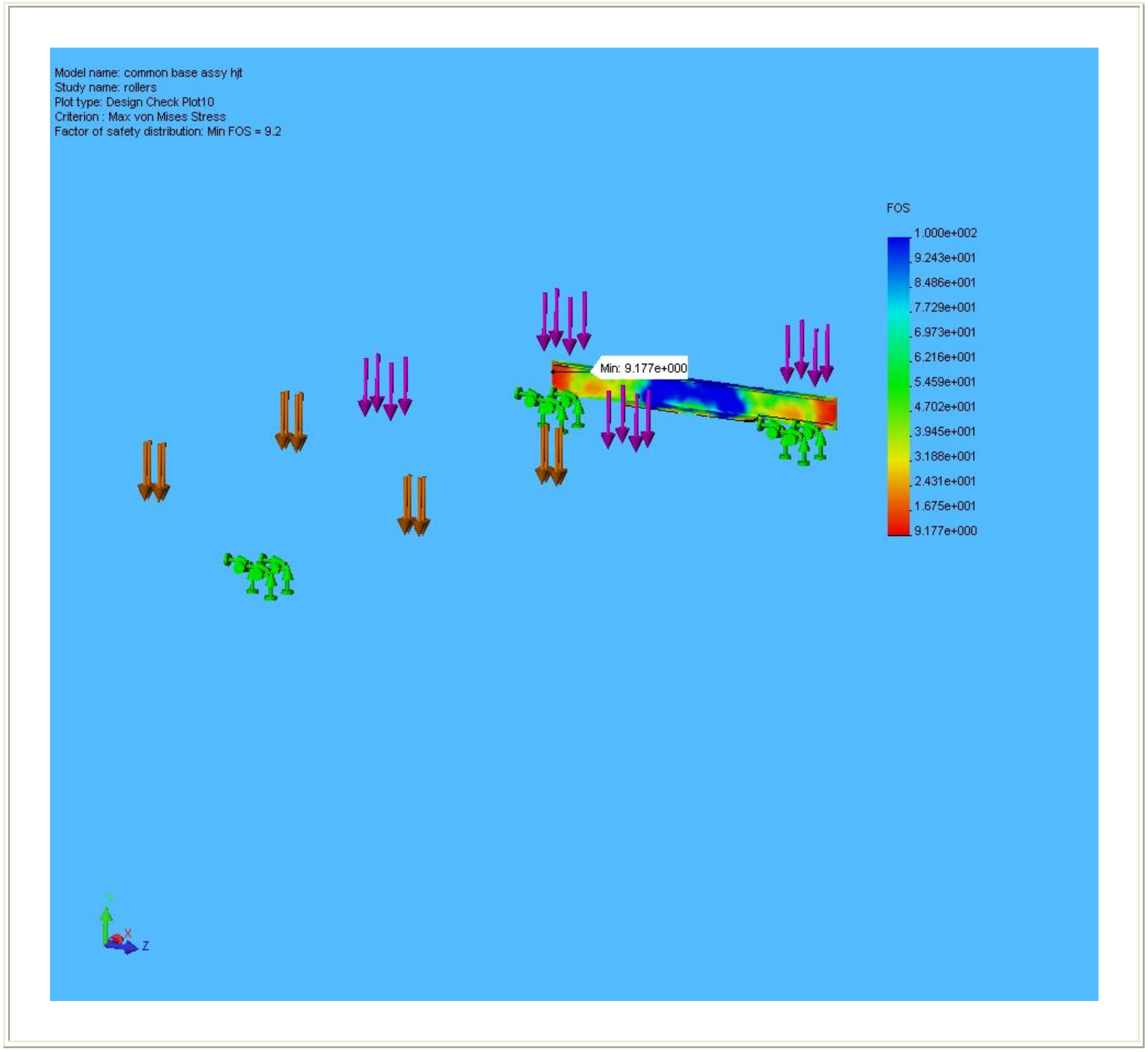


8. Conclusion

Localized high stress areas occur near several weld areas, but generalized stresses in the structure are well above material yield, so the baseplate assembly is considered structurally sound for the loading condition simulated.

9. Appendix

Material name: 6061-T6 (SS)

Description:

Material Source: Library files

Material Library Name: cosmos materials

Material Model Type: Linear Elastic Isotropic

Property Name	Value	Units	Value Type
Elastic modulus	1.0008e+007	psi	Constant
Poisson's ratio	0.33	NA	Constant
Shear modulus	3.771e+006	psi	Constant
Mass density	0.097544	lb/in^3	Constant
Tensile strength	44962	psi	Constant
Yield strength	39885	psi	Constant
Thermal expansion coefficient	1.3333e-005	/Fahrenheit	Constant
Thermal conductivity	0.0022322	BTU/(in.s.F)	Constant
Specific heat	0.21405	Btu/(lb.F)	Constant
Hardening factor (0.0-1.0; 0.0=isotropic; 1.0=kinematic)	0.85	NA	Constant

Material name: Wrought Stainless Steel

Description:

Material Source: Library files

Material Library Name: cosmos materials

Material Model Type: Linear Elastic Isotropic

Property Name	Value	Units	Value Type
Elastic modulus	2.9008e+007	psi	Constant

Poisson's ratio	0.26	NA	Constant
Shear modulus	1.1458e+007	psi	Constant
Mass density	0.28902	lb/in^3	Constant
Tensile strength	74987	psi	Constant
Yield strength	29995	psi	Constant
Thermal expansion coefficient	6.1111e-006	/Fahrenheit	Constant
Thermal conductivity	0.00025412	BTU/(in.s.F)	Constant
Specific heat	0.11945	Btu/(lb.F)	Constant

Material name:	Delrin 2700 NC010, Low Viscosity Acetal Copolymer (SS)
Description:	
Material Source:	Library files
Material Library Name:	cosmos materials
Material Model Type:	Linear Elastic Isotropic

Property Name	Value	Units	Value Type
Elastic modulus	4.2061e+005	psi	Constant
Poisson's ratio	0.3	NA	Constant
Mass density	0.0050939	lb/in^3	Constant
Tensile strength	5903	psi	Constant
Yield strength	9137.4	psi	Constant
Hardening factor (0.0-1.0; 0.0=isotropic; 1.0=kinematic)	0.85	NA	Constant

Stress Analysis of Hg System Cart

Author: V.B. Graves

Company: Oak Ridge National Laboratory

Date: May 19, 2006

---

1. Introduction

A static analysis of the Hg system transport cart is performed. Simulated load of 4000 lbs was evenly distributed on two strips across the top surface of the cart. Actual assembly includes UMHW sheet and another Aluminum plate, with the loading occurring on the top plate. Simulated condition should provide conservative results since upper plate will further distribute load on lower plate. Other simplifying assumption was the removal of the cart wheel, so the axle holes were restrained.

Note:

Do not base your design decisions solely on the data presented in this report. Use this information in conjunction with experimental data and practical experience. Field testing is mandatory to validate your final design. COSMOSWorks helps you reduce your time-to-market by reducing but not eliminating field tests.

---

2. Materials

No.	Part Name	Material	Mass	Volume
1	cart lower plate hjt	6061-T6 (SS)	104.029 lb	1066.49 in^3
2	cart lower plate hjt	6061-T6 (SS)	104.029 lb	1066.49 in^3
3	cart lower plate hjt	6061-T6 (SS)	104.029 lb	1066.49 in^3
4	cart lower plate hjt	6061-T6 (SS)	104.029 lb	1066.49 in^3
5	cart lower plate hjt	6061-T6 (SS)	104.029 lb	1066.49 in^3
6	cart lower plate hjt	6061-T6 (SS)	104.029 lb	1066.49 in^3
7	cart lower plate hjt	6061-T6 (SS)	104.029 lb	1066.49 in^3
8	cart lower plate hjt	6061-T6 (SS)	104.029 lb	1066.49 in^3
9	cart lower plate hjt	6061-T6 (SS)	104.029 lb	1066.49 in^3

---

3. Load & Restraint Information

Restraint	
Restraint-1 <cart lower plate hjt>	on **4 Face(s)** fixed.
Description:	Axles holes fixed.

Load		
Force-1 <cart lower plate hjt>	on **2 Face(s)** apply normal force **2000 lb** using uniform distribution	Sequential Loading
Description:	2000 lbs on each load strip.	

4. Study Property

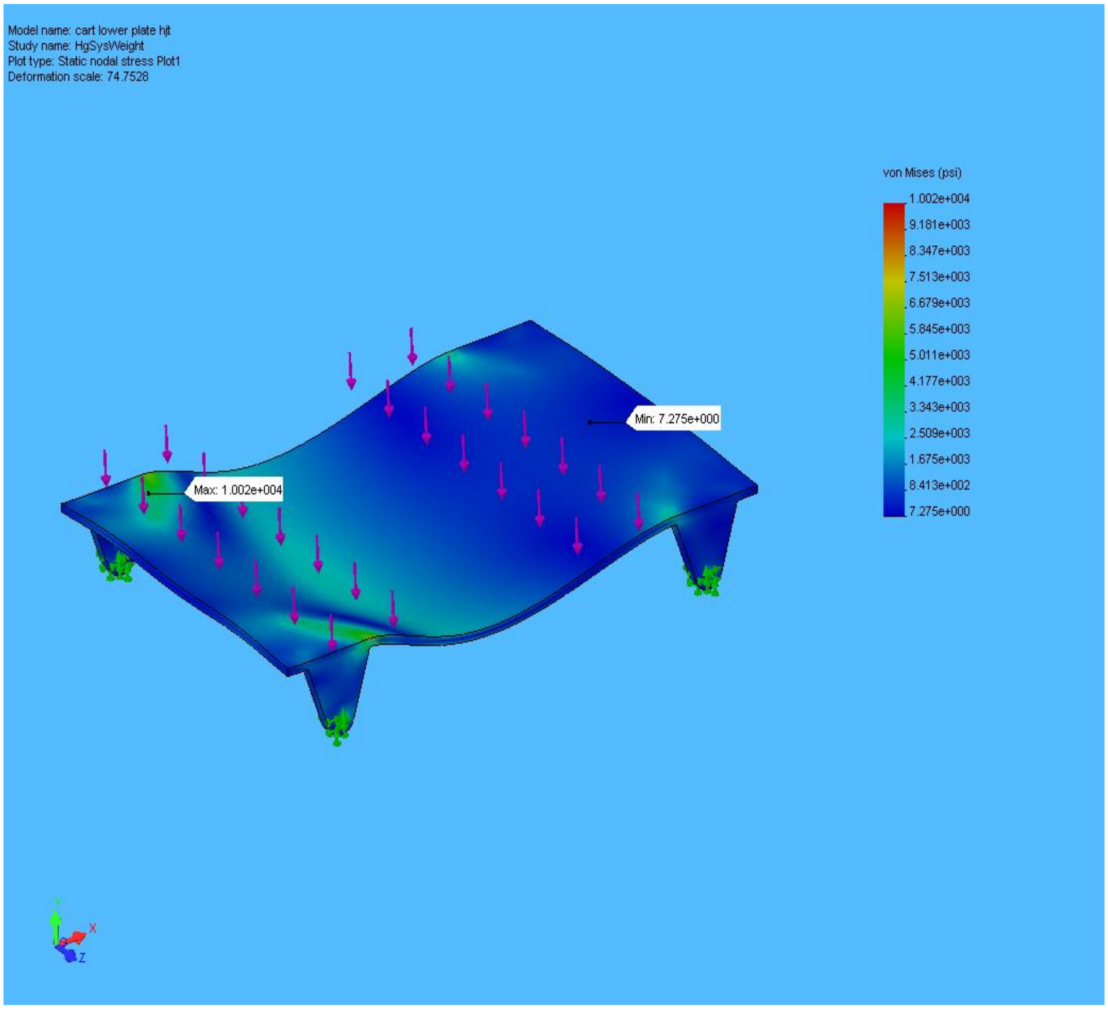
Mesh Information	
Mesh Type:	Solid mesh
Mesher Used:	Standard
Automatic Transition:	Off
Smooth Surface:	On
Jacobian Check:	4 Points
Element Size:	1.0218 in
Tolerance:	0.051091 in
Quality:	High
Number of elements:	9988
Number of nodes:	20458

Solver Information	
Quality:	High
Solver Type:	FFEPlus
Option:	Include Thermal Effects
Thermal Option:	Input Temperature
Thermal Option:	Reference Temperature at zero strain: 25 Celsius

5. Stress Results

Name	Type	Min	Location	Max	Location
Plot1	VON: von Mises stress	7.27537 psi Node: 13063	(18.3384 in, 0 in, -1.0218 in)	10015 psi Node: 19332	(-15.1511 in, -0.767816 in, -15.5 in)

cart lower plate hjt-HgSysWeight-Stress-Plot1
JPEG

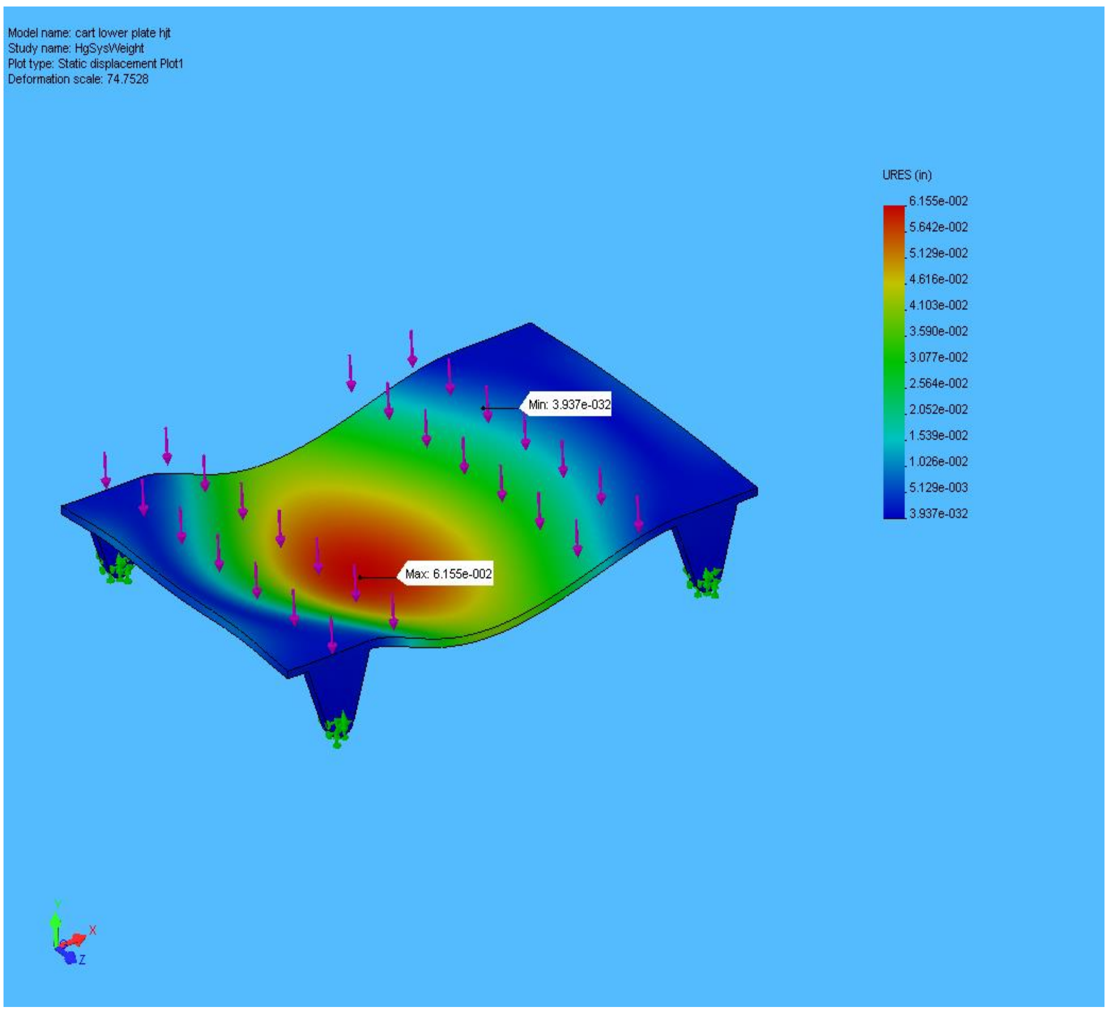


6. Displacement Results

Name	Type	Min	Location	Max	Location
Plot1	URES: Resultant displacement	0 in Node:	(18.5 in, -5.6325	0.0615473 in	(-5.07733 in,

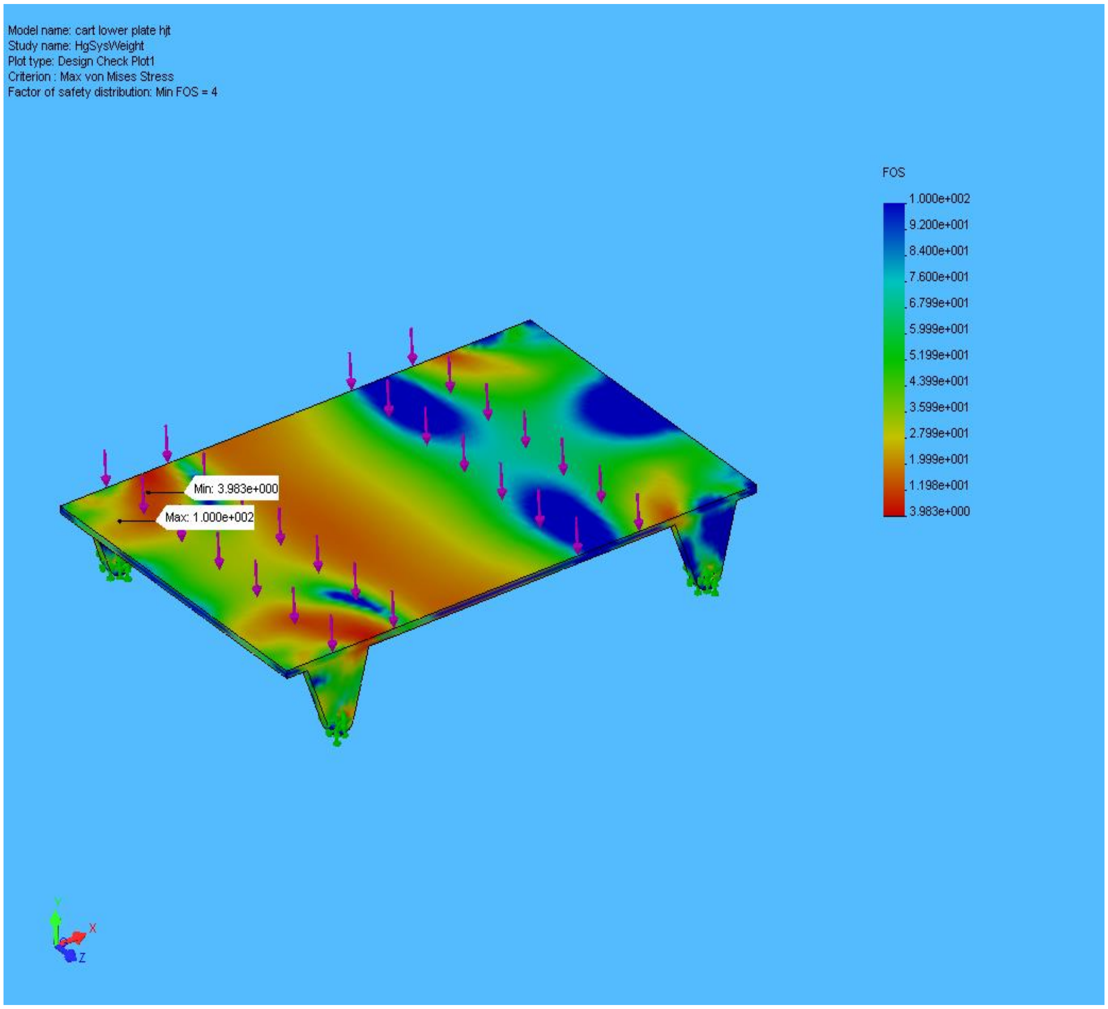
		18426	in, -15.5 in)	Node: 11466	0 in, - 0.00920064 in)

cart lower plate hjt-HgSysWeight-Displacement-Plot1
JPEG



7. Design Check Results

cart lower plate hjt-HgSysWeight-Design Check-Plot1
JPEG



8. Conclusion

Analysis shows minimum safety factor = 4, with maximum stress occuring in localized area near welded joint. Structure is considered structurally sound for loading condition simulated.

9. Appendix

Material name: 6061-T6 (SS)

Description:

Material Source: Library files

Material Library Name: cosmos materials

Material Model Type: Linear Elastic Isotropic

Property Name	Value	Units	Value Type
Elastic modulus	1.0008e+007	psi	Constant
Poisson's ratio	0.33	NA	Constant
Shear modulus	3.771e+006	psi	Constant
Mass density	0.097544	lb/in^3	Constant
Tensile strength	44962	psi	Constant
Yield strength	39885	psi	Constant
Thermal expansion coefficient	1.3333e-005	/Fahrenheit	Constant
Thermal conductivity	0.0022322	BTU/(in.s.F)	Constant
Specific heat	0.21405	Btu/(lb.F)	Constant
Hardening factor (0.0-1.0; 0.0=isotropic; 1.0=kinematic)	0.85	NA	Constant

Appendix F. Jerome® Vapor Monitor

Arizona Instrument LLC
800-528-7411
602-470-1414
www.azic.com

Jerome® 431-X

Mercury Vapor Analyzer

The Jerome 431-X mercury vapor analyzer uses a patented gold film sensor for accurate detection and measurement of toxic mercury concerns for applications such as industrial hygiene monitoring, mercury spill clean up and mercury exclusion testing. Simple, push-button operation allows users to measure mercury levels from 0.003 to 0.999 mg/m^3 in just seconds.

The gold film sensor is inherently stable and selective to mercury, eliminating interferences common to ultraviolet analyzers, such as water vapor and hydrocarbons. When the sample cycle is activated, the internal pump in the 431-X draws a precise volume of air over the sensor. Mercury in the sample is absorbed and integrated by the sensor, registering it as proportional change in electrical resistance. The instrument computes the concentration of mercury in milligrams per cubic meter or nanograms, and displays the final result in the LCD readout. An improved film regeneration circuit in the 431-X makes the sensor last even longer than earlier models.

Additional accessories are available to customize the Jerome 431-X to meet individual application needs. An optional communications configuration allows data logging, computer interface, and dosimeter analysis capabilities. For data acquisition during portable surveys, a Jerome data logger plugs into the 431-X. Using Jerome Communications Software (JCS), the analyzer and data logger download recorded data to a computer for analysis, printout, and permanent record storage. The software can also program the instrument for stand-alone monitoring. If the sensor becomes saturated while the 431-X is attached to the data logger or computer, the analyzer automatically regenerates the sensor and then resumes sampling. Jerome gold coil dosimeters, used in conjunction with a low-flow pump and a communications-configured 431-X, provide time-weighted averages for personal mercury exposure. Analysis is quickly performed in-house with these reusable dosimeters. They can also be used as collection devices for applications such as gas stream analysis. An available internal option board allows auto-zeroing, DC power operation, timed regeneration, and timed sampling during prolonged, unattended sampling periods. The option board also allows external fresh air solenoid support and 4-20 mA or 0-2 V analog output. A molded hard carrying case or soft field case give added versatility and organized storage for the instrument and its accessories.

Jerome® 431-X
Mercury Vapor Analyzer

Arizona Instrument LLC
800-528-7411
602-470-1414
www.azic.com

Features:
Rugged and easy operate
Inherently stable gold film sensor
Pressure sensitive membrane switch operation
Accurate analysis of mercury vapor in seconds
Rechargeable internal battery pack for portability
Wide detection range allows for multiple applications
Automatic LCD backlight during low light conditions
Survey mode for rapid source detection of mercury vapor concentrations
Microprocessor ensures a linear response throughout the entire range of the sensor

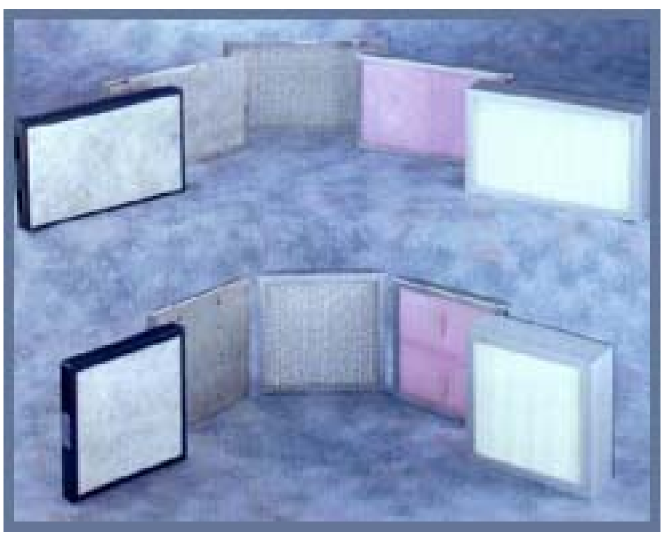
Specifications:

Resolution	0.001 mg/m^3
Detection Range	0.003-0.999 mg/m^3
Precision	5% Relative Standard Deviation at 0.100 mg/m^3
Accuracy	±5% at 0.100 mg/m^3
Response Time	13 seconds in Sample Mode; 4 seconds in Survey Mode
Flow Rate	750 cc/min
Environmental Range	0-40°C, noncondensing, nonexplosive
Interface	RS-232 port using Jerome Communications Software
Dimensions	431-X: 6” W x 13” L x 4” H/ 16 cm W x 33 cm L x 10 cm H
	431-XE: 7” W x 14” L x 7” H / 18 cm W x 35 cm L x 18 cm H
Weight	431-X: 7 lbs / 3 kg
	431-XE: 8 lbs / 3.5 kg
Internal Battery Pack	Rechargeable nickel-cadmium
Power Requirements	100-120 V~, 50/60 Hz, 1 A or 220-240 V~, 50/60 Hz, 1 A
Warranty	1 year, factory parts and labor
Marks	European Communities (CE) for 220-240 V~ 431-XE model only

Options:
Data Logger to record field monitoring information
Maintenance Kit for routine maintenance and upkeep
Functional Test Kit for sensor operation verification in the field
Hard or Soft Field Carrying Case for versatile handling and additional storage
Jerome Communications Software Kit for downloading information from the data logger to a PC or for unattended, fixed-point sampling
Dosimeters to provide time-weighted averages for personal mercury exposure or gas steam analysis (reusable)
Option Board for external fresh air solenoid support, auto-zeroing, DC power operation, timed regeneration, 4-20 mA or 0-2 V analog output, and timed sampling
Calibration Check to verify low-level detection limits at 0.010 mg/m^3 and 0.025 mg/m^3

Applications:
Mercury Surveys and Soil Screening
Spill Response
Worker Safety
Hazardous Waste Sites
Research Projects for Stack, Flue and Natural Gas
Mercury Exclusion Tests
Monitor Disposal and Recycling of Fluorescent Lamps
Exhaust Duct Analysis

Appendix G. Scavenger



SCAVENGER SERIES

***HS-3000A1* Single Hose Scavenger**

Capture fumes and particles at the source

Ideal for use in:

- **Soldering**
- **Small scale welding**
- **Jewelry manufacture**
- **Potting**
- **Buffing and grinding**

Get Prices

***HS-3000A2* Two Hose Scavenger**

Custom Hood

The Scavenger Series portable fume/particle extractors are an inexpensive solution to all small scale, yet potentially hazardous, fume and particle problems. These powerful yet quiet, fully portable systems are ideal for use in work spaces that are too small for conventional fume hoods. They can be used on the table top or wall mounted. The unit combines a 530 cfm blower with either one or two intake scoops, each with a 5 foot heavy duty flex hose, which can be easily moved to capture the contaminant at the source. Each blower is operated with a variable speed control knob and is virtually vibration free.

Primarily designed to improve safety and hygiene in light industrial settings, the Scavenger can also be used in laboratories where a fume source can be isolated. Examples include wall mounted units to capture harmful exhaust from microwave ovens in histology labs, and spectrophotometers in analytical chemistry applications.

Get Prices

Like all Airfiltronix systems, the Scavengers can accommodate a variety of filters: charcoal, four stage dacron, aluminum, and HEPA filters, to capture broad range of chemical fumes, odors and particles - at their source.

Get Prices

SCAVENGER SERIES SPECIFICATIONS
Model No: **HS-3000A1** - Single Hose Scavenger: includes one 5" diameter hose and one tapered collector scoop.

HS-3000A2 - Double Hose Scavenger: includes two 5" diameter hoses and 2 tapered collector scoops.

Blower Dimensions: - 16" H x 12.5"D x 23.5" W

Hose: - 5" diameter heavy duty chemical resistant PVC flexible hose. Single 5 foot length for HS300OAl and double 5 foot lengths for HS-3000A2

Standard Nozzles: - Wedge shaped Nozzles measure 9.5" D x 6.5"H, sloping to 3.5" H x 6.5" W (custom scoops and other adapters available)

Power Requirements: - 115V AC, 100 Watts, 50/60 Hz, 230V AC optional for export.

Weight: - HS-300OAl - 37 lbs. HS-300OA2 - 43 lbs.

Noise Level: - A weighted noise level 68 dB at 1 meter

Custom Variations: - We can manufacture the scavenger series in many different configurations (i.e. wall mounted blower, mini-hood with hose attachment, unique adapter fabricated to attach to existing equipment - please call to discuss your special application).

Scavenger Options:

- Wall Mount Kit
- Additional Flex Hose 5" Diameter
- Blocked Filter Alarm Unit
- Outside Vent Adapter Kit
- Stainless Steel Cart
- Carry Handle

Airflow Performance Statistics		
Unit	**HS-3000A1**	**HS-3000A2**

Get Prices

Filters Installed	Max Airflow **CFM**	Face Velocity **FPM**	Max Airflow **CFM**	Face Velocity **FPM**
None	173	1275	273	1010
HEPA	118	870	154	565
HEPA/Dacron/.5" Carbon	116	850	143	525
HEPA/Dacron/2"	94	690	110	405

Carbon				
0.5" Carbon	156	1150	228	840
2" Carbon	110	812	160	590
2 each - 2" Carbon	94	690	120	440

All numbers refer to average readings taken at full blower speed

NOTE: For filter info see our Filter Page
Get Prices

AIRFILTRONIX CORP.
154 Huron Avenue
Clifton, NJ 07013
Phone: 973.779.5577
Toll Free: 800.452.8510
Fax: 973.779.5954
airfiltron@aol.com

Appendix H. Tiger-Vac® Vacuum Cleaner

MERCURY RECOVERY VACUUM CLEANER SYSTEMS
FOR WET AND DRY RECOVERY
MRV-16

ALL STAINLESS STEEL CONSTRUCTION

STATIC FREE AND ESD SAFE

HEPA FILTER EFFICIENCY 99.99% ON 0.3 MICRONS

MRV-16

SPECIFICATIONS:

Models Part No	HP	1 Phase/Volts @ 60 HZ	Amps	Vacuum Pressure at Sealed Orifice H2O	Airflow CFM/l/s
MRV-16					
110800A	1.6	120	10.5	110"	110/48

Recovery Capacity of Mercury Recovery Jar: 20 ounces (591ml)
Recovery Capacity: Dry: 5 gallons (19 litres)
Liquids: 12.5 gallons (50 litres)

Suction Orifice on all models: 1.5" (38mm)

Models Part No	KW	1 Phase/Volts @ 50 HZ	Amps	Vacuum Pressure at Sealed Orifice mm H20	Airflow l/s
MRV-16					
110800B	1.05	240	5	2100	48

Recovery Capacity of Mercury Recovery Jar: 591 millilitres
Recovery Capacity: Dry: 19 litres
Liquids: 50 litres

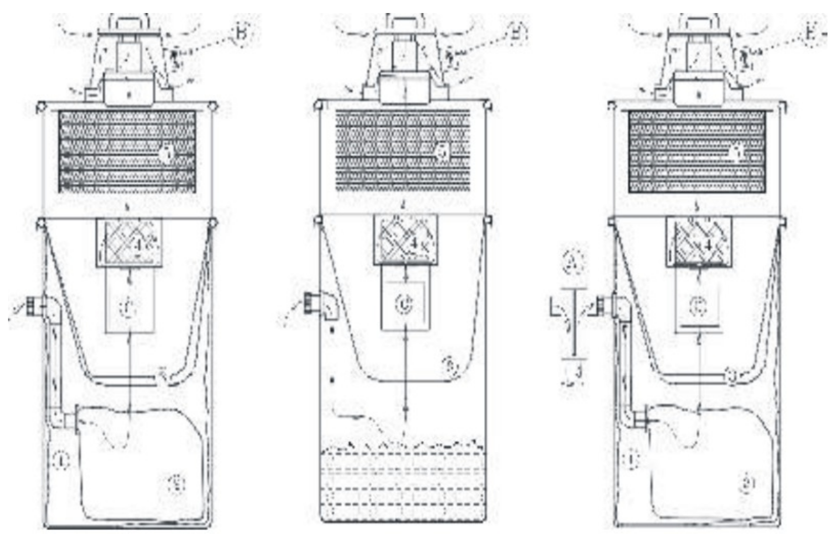
Suction Orifice : 38mm

list activated carbon and picture

Design Application

- Mercury Recovery Vacuum Cleaner System for wet and dry recovery
- All Stainless Steel Construction with an autoclavable recovery tank.
- Hour Counter
- Internal HEPA Filter 99.99% efficiency on 0.3 micron.
- Suction hose with Mercury Separator

Special Features and Specifications



Dry Recovery Liquid Recovery Mercury Separator

A. **Mercury Separator & detachable mercury recovery jar:** Separates the liquid mercury and directs it into the recovery jar. The mercury separator is made of stainless steel for excellent corrosion resistance and easy decontamination. Separator assembly includes 2 jars.
B. **Houst Counter / Timer:** Facilitates the measuring of the carbon filter life.
C. **Floater:** Cuts-off suction when recovered liquids reach capacity level.
1. **Poly liner:** Clear poly line (6 mil) disposable, to facilitate recovery and disposal.
2. **Paper Filter Bag:** Disposable paper filter bag with latex micro-liner, on micron efficiency. Facilitates recovery and disposal.
3. **Double Cloth Filter:** Washable, one micron efficiency.
4. **HEPA Filter:** 99.99% efficiency on 0.3 microns
5. **Carbon Cartridge Assembly:** For the adsorption of mercury vapors and odors. Designed to completely adsorb mercury vapors for one hour of continuous exposure. After one hour of exposure the concentrations of mercury vapors will begin to rise above 0.000 mg/M3. Once the carbon has been exposed to mercury vapors for one hour, it is the operator's responsibility to ensure that the exhaust air falls within permissible exposure limits. The recommended device is the Jerome brand mercury analyzer or othe similar devices. (Not included with the vacuum cleaner.
6. **Liquid Filter:** Made of polypropylene mesh. Prevents large particles from being sucked-up during liquid recovery.

More Special Features and Specifications

- All models include Suction hose with Mercury Separator
- All units include a Carbon Cartridge Assembly filled with 18 lbs (8kg) of 3mm Mersorb brand carbon for the adsorption of mercury fumes and odors.
- Noise level of vacuum cleaner at high speed is 70 dB (A) @ 6.5 ft (2m).
- EMI/RFI Shielded with electronic filter suppressor for Class B computing devices.
- Static free / ESD safe

WARNING!

Not to be used to vacuum up flammable or ignitable materials or dusts.
Do not use this vacuum cleaner in hazardous locations.
Please consult out technical representatives if an Explosion Proof / Dust Ignition Proof vacuum cleaner is needed for hazardous locations.

Appendix I. Peristaltic Pump

Peristaltic Pump Test Results

Date: Mon, 3 May 1999 16:27:45 -0400
To: gabrielta@ornl.gov, hainesjr@ornl.gov, rennichmj@ornl.gov, mcmanamytj@ornl.gov, martinsrjr@ornl.gov, taleyarkharp@ornl.gov, kims@ornl.gov, tsaic@ornl.gov, manneschmiet@ornl.gov, palmerwe1@ornl.gov, burgesstw@email.rpsd.ornl.gov, ray@email.rpsd.ornl.gov, schrock@email.rpsd.ornl.gov, scottch@ornl.gov, spampina@email.rpsd.ornl.gov
From: Van Graves <gravesvb@ornl.gov>
Subject: Mercury Pumping Results

On April 30, Phil Spampinato and myself were able to test the ability of our tubing pump to remove mercury from one of the Y-12 flasks. With the help of Eric Manneschmidt we were able to transfer mercury between containers and obtain some rough estimates of pumping rates. Some pictures of the pumping equipment are shown below, and I've included some notes we jotted down. But the bottom line is that this technique seems to be a safe, efficient, and ergonomic method of loading mercury into the TTF storage tanks.

The pumping equipment was purchased from Cole-Palmer and consists of a removable pump head mounted to a variable-speed, bi-directional drive motor. Flexible Tygon tubing is inserted in between rollers in the pump head. These rollers pinch the tubing, creating a vacuum and pulling mercury through the tube. Thus, only the tubing comes in contact with the liquid, so the pump equipment is not contaminated. In our experiment we used plastic hose clamps to connect the flexible tubing to a section of rigid stainless tubing that was used as a dip tube for the mercury flasks. The other end of the flexible tubing was left open to empty into another container; for actual loading operations it would be connected to some rigid pipe which drained into the storage tank.

In our initial tests with water we were able to achieve a maximum flow rate of approximately 0.15 liters/sec. With mercury, the best flow rate we could get was 0.03 l/s, based on rough volume and time measurements. At this flow rate we could expect to empty a flask in 75 seconds. Hence, it appears that the Hg loading operation can be accomplished in less than half of the two-week estimate envisioned for pouring the flasks.

Other items of interest:

* Due to the way the pump works, once air enters the dip tube, vacuum is lost, and any mercury remaining in the dip tube will fall back into the flask. In our experiment the leftover quantity was approximately 15 ml. Over the entire 540 flasks, this equates to less than one liter not being transferred. To keep this quantity to a

minimum, the top of the dip tube needs to be the highest point in the system. We also plan on slightly tipping the pallets to maximize the amount of mercury pulled from the flasks before suction is lost.

* When removing the dip tube from the flask, no dripping was observed. This should minimize the possibility of contaminating the exterior of any flasks or of the pallet. We plan on wiping the dip tube with cheesecloth as it's removed from each flask to further reduce the risk of drips.

* The pump has an "occlusion adjustment" that controls how tightly the pump rollers pinch the tubing and the amount vacuum created. The standard setting worked well with water but was not enough to start the mercury flow. Increasing the setting solved this problem, but it has the side effect of reducing the tubing life. Once flow is initiated the adjustment can be decreased without losing flow. Since tubing failure seems to be the worst accident envisioned we will periodically replace the tubing or move it to a different position so the rollers aren't wearing on the same tube location.

* This test was originally scheduled to be done in Rusi Taleyarkhan's lab at the Engineering Technology Division. Once the equipment was set up, we found that we were unable to remove the plug from the flask using available tools. From discussions with Y-12 personnel, many of the plugs have been put on using an impact wrench, and in addition the plugs are somewhat rusty. Removing the plugs without taking the flasks from the pallet may be the most difficult part of this process. We hope they can be removed the same way they were inserted and will try this when the mercury flasks are on site.

Figure H-1. Tube pump test setup; M & C Division fume hood.

Figure H-2. Pump under operation with mercury in the tube.

Appendix K. Material Safety Data Sheets

Material Safety Data Sheet

Print date: 04/07/2005 *Version: 5* *Revision date: 04/07/2005*

1. COMPANY AND PRODUCT IDENTIFICATION

Product code: 014113-03 02
Product name: **QUINTOLUBRIC® 888 46**

Supplier:
Quaker Chemical Corporation
Quaker Park One
901 Hector Street
Conshohocken, PA 19428
610-832-4000
E-mail: she@quakerchem.com

Emergency telephone number:
* 24 HOUR TRANSPORTATION:
**CHEMTREC: 1-800-424-9300
703-527-3887 (Call collect outside of US)
* 24 HOUR EMERGENCY HEALTH & SAFETY:
**QUAKER CHEMICAL CORPORATION: (800) 523-7010(Within US only)
Outside of US call (703) 527-3887

2. COMPOSITION/INFORMATION ON INGREDIENTS

HAZARDOUS COMPONENTS

This product does not contain any hazardous ingredients as defined under 29 CFR 1910.1200.

3. HAZARDS IDENTIFICATION

Emergency Overview
Mild eye irritation.
May cause skin irritation and/or dermatitis.
May cause irritation of respiratory tract.
May be harmful if swallowed.

Principle routes of exposure: Eyes, skin and inhalation.

Signal word: CAUTION

Eye contact: May cause slight irritation.

Skin contact: Substance may cause slight skin irritation.

Inhalation: Vapors and/or aerosols which may be formed at elevated temperatures may be irritating to eyes and respiratory tract.

Ingestion: Ingestion may cause gastrointestinal irritation, nausea, vomiting and diarrhoea.

Physico-chemical properties: No hazards resulting from material as supplied.

4. FIRST AID MEASURES

General advice: If symptoms persist, call a physician. INJECTION INJURY WARNING: If product is injected into or under the skin, or into any part of the body, regardless of the appearance of the wound or its size, the individual should be evaluated immediately by a physician as a surgical emergency. Even though initial symptoms from high pressure injection may be minimal or absent, early surgical treatment within the first few hours may significantly reduce the ultimate extent of the injury.

Eye contact: Rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes. If symptoms persist, call a physician.

Skin contact: Wash off immediately with soap and plenty of water. If skin irritation persists, call a physician.

Ingestion: If swallowed, seek medical advice immediately and show this container or label. Never give anything by mouth to an unconscious person.

Inhalation: Move to fresh air in case of accidental inhalation of vapors. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Consult a physician.

Notes to physician: Treat symptomatically.

Medical condition aggravated by exposure: Dermatitis.

5. FIRE-FIGHTING MEASURES

Flash point (°C): 260 **Flash point (°F):** 500 **Flash Point Method:** COC

Flammable limits in air - upper (%): Not determined **Flammable limits in air - lower (%):** Not determined

Suitable extinguishing media: Use dry chemical, CO_2, water spray or `alcohol` foam.

Unusual hazards: None known

Special protective equipment for fire-fighters: As in any fire, wear self-contained breathing apparatus pressure-demand, MSHA/NIOSH (approved or equivalent) and full protective gear.

Specific methods: Water mist may be used to cool closed containers.

6. ACCIDENTAL RELEASE MEASURES

Personal precautions: Ensure adequate ventilation.

Environmental precautions: Do not flush into surface water or sanitary sewer system.

Methods for cleaning up: Soak up with inert absorbent material (e.g. sand, silica gel, acid binder, universal binder, sawdust).

7. HANDLING AND STORAGE

Handling

Technical measures/precautions: Provide sufficient air exchange and/or exhaust in work rooms.

Safe handling advice: In case of insufficient ventilation, wear suitable respiratory equipment.

Storage

Technical measures/storage conditions: Store at room temperature in the original container

Incompatible products: No special restrictions on storage with other products

Safe storage temperature: 40-100 ° F

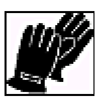
Shelf life: 12 months and re-evaluate

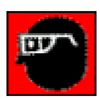
8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Engineering measures: Ensure adequate ventilation.

Personal Protective Equipment

- **General:** Eye Wash and Safety Shower
- **Respiratory protection:** Not required; except in case of aerosol formation.
- **Hand protection:** Neoprene gloves
- **Skin and body protection:** Usual safety precautions while handling the product will provide adequate protection against this potential effect.
- **Eye protection:** Safety glasses with side-shields.
- **Hygiene measures:** Avoid contact with skin, eyes and clothing.





9. PHYSICAL AND CHEMICAL PROPERTIES:

Physical state: Liquid
Color: Clear, Amber
Odour: Mild
Boiling point/boiling range (°C): >260
Boiling point/range (°F): >500
Vapour pressure: Not determined
Vapour density: Not determined
VOC Content Product: 0.030 lb/gal (EPA Method 24)
Solubility: Insoluble
Evaporation rate: Not determined
pH: Not applicable
Flash point (°C): 260
Flash point (°F): 500
Decomposition temperature: Not determined
Auto-ignition temperature: Not determined

Density @ 15.5 ° C (g/cc) :	0.911
Bulk density @ 60 ° F (lb/gal):	7.60
Partition coefficient (n-octanol/water, log Pow):	Not determined

Explosive properties:

- upper limit:	No data available
- lower limit:	No data available

10. STABILITY AND REACTIVITY

Conditions to avoid:

None known

Materials to avoid:

Strong oxidising agents

Hazardous decomposition products:

Nitrogen oxides (nox), Oxides of phosphorus, Carbon oxides, Sulphur oxides

Stability:

Stable under recommended storage conditions.

Polymerization:

Not applicable

11. TOXICOLOGICAL INFORMATION

Oral toxicity (rats): Practically non-toxic (LD50>10ml/kg). Based on testing of the product or a similar product.
Inhalation toxicity (rats): practically non-toxic (LC50>200ml/kg). Based on testing the product or a similar product.
Eye irritation (rabbits): Essentially a non-irritant (Draize score = 0). Based on testing of the product or a similar product.
Skin irritation (rabbits): Slighlty irritating (Primary Irritation Index = 1.46). Based on testing of the product or a similar product.

Human Patch Skin Study: Not an irritant or a sensitizer (Modified Shelanski). Based on testing of the product or a similar product.

12. ECOLOGICAL INFORMATION

Persistence and degradability:	Environmental Fate and Effects: Under the modified Sturm Test (40 CFR 796.3620), this product is readily biodegradable.
Mobility:	No data available
Bioaccumulation:	No data available
Ecotoxicity effects:	No data available
Aquatic toxicity:	Aquatic Toxicity: Acute LC/EC50 (fish) - this product is non-toxic (LC50 > 2000ppm) based on testing of this product or a similar product.

13. DISPOSAL CONSIDERATIONS

Waste from residues/unused products: Waste disposal must be in accordance with appropriate Federal, State, and local regulations. This product, if unaltered by use, may be disposed of by treatment at a permitted facility or as advised by your local hazardous waste regulatory authority.

Contaminated packaging: Do not re-use empty containers

Methods for cleaning up: Take up mechanically and collect in suitable container for disposal.

14. TRANSPORT INFORMATION

U. S. DEPARTMENT OF TRANSPORTATION:

Proper shipping name: Not Regulated

Shipping Desciption:

TDG (CANADA):

Proper shipping name: Not Regulated

IMDG/IMO:

Proper shipping name: Not Regulated

IATA/ICAO:

Proper shipping name: Not Regulated

15. REGULATORY INFORMATION

CLASSIFICATION AND LABELING

OSHA Hazard Communication Standard: This product is considered non-hazardous under the OSHA Hazard Communication Standard.

Canada - WHMIS Classification Information: This product has been classified according to the hazard criteria of the CPR and the MSDS contains all the information required by the CPR.

Product Classification: None Required

Product Classification Graphic(s):

Component Classification Data:

Canadian National Pollution Inventory Data:

U.S. REGULATIONS:

SARA (311, 312) hazard class: This product possesses the following SARA Hazard Categories:

Immediate Health (Acute): No
Delayed Health (Chronic): No

Flammability:	No
Pressure:	No
Reactivity:	No

RCRA Status Not Regulated

STATE REGULATIONS (RTK):

California Proposition 65 Status: No components are listed

INVENTORY STATUS:

United States TSCA - Sect. 8(b) Inventory: This product complies with TSCA

Canada DSL Inventory List - DSL Compliance has not been determined

EC No. Compliance has not been determined

16. OTHER INFORMATION

Sources of key data used to compile the data sheet: Material safety data sheets of the ingredients.

Reason for revision: This data sheet contains changes from the previous version in section(s) 4

Prepared by: Quaker Chemical Corporation -Safety, Health and Environmental Affairs Group - US

HMIS classification:

Health:
1

Flammability:
1

Reactivity:
0

Personal Protection:
B

NFPA rating:

Health:
1

Flammability:
1

Reactivity:
0

Special:
NA

* Indicates possible chronic heath effect

Personal protection recommendations should be reviewed by purchasers. Workplace conditions are important factors in specifying adequate protection.

Disclaimer
This product's safety information is provided to assist our customers in assessing compliance with safety/health/environmental regulations. The information contained herein is based on data available to us and is believed to be accurate. However, no warranty of merchantability, fitness for any use, or any other warranty is expressed or implied regarding the accuracy of this data, the results to be obtained from the use thereof, or the hazards connected with the use of the product. Since the use of this product is within the exclusive control of the user, it is the user's obligation to determine the conditions for safe use of the product. Such conditions should comply with all regulations concerning the product. Quaker Chemical Corporation ("Quaker") assumes no liability for any injury or damage, direct or consequential, resulting from the use of this product unless such injury or damage is attributable to the gross negligence of Quaker.

End of Safety Data Sheet

Calgon Carbon Corporation

Material Safety Data Sheet

U.S. Department of Labor
Occupational Safety and Health Administration
Form Approved OMB No. 1218-0072
This form is used to comply with
OSHA's Hazard Communication Standard,
29 CFR 1910.1200.

Product Type: Impregnated Activated Carbon - CB II

SECTION I

Barnebey Sutcliffe Corporation	**Emergency Telephone Number** 614-258-9501
835 North Cassady Avenue	**Telephone Number for Information** 614-258-9501
Columbus, Ohio 43216	**Date Prepared** 3/6/03
	Signature of Preparer *(optional)*

SECTION II - HAZARD INGREDIENTS/IDENTITY INFORMATION

Hazardous Components (Specific Chemical Identity; Common Name(s))	**OSHA PEL**	**ACGIH TLV**	**CAS**	**%**
Activated Carbon	Not Defined	Not Defined	7440-44-0	> 75%
Potassium Iodide			7681-11-0	<10%
Triethylene Diamine			280-57-9	< 5%
Silver			7440-22-4	< 1.1%
Copper Chloride			13933-17-0	< 25%
Sodium Hydroxide			1310-73-2	< 8%
Potassium Hydroxide			1310-58-3	< 10%
Diammonium Molybdate			27546-07-02	< 5%
Nickel Chloride			7718-54-9	< 25%
Copper Oxide			01317-38-0	<12%
Phosphoric Acid			7664-38-2	< 20%
Sulfur			7704-34-9	< 25%
Iodine			7553-56-2	< 15%
Iron Oxide			1307-37-1	<20%
Sulfuric Acid			7664-93-9	<20%
Citric Acid			77-92-9	<20%

SECTION III - PHYSICAL/CHEMICAL CHARACTERISTICS

Boiling Point	NA	**Specific Gravity**	0.4 – 0.9
Vapor Pressure (mm Hg.)	0	**Melting Point**	NA

Vapor Density (AIR = 1)	Solid	**Evaporation Rate**	NA
Solubility in Water	Soluble Impregnant		
Appearance and Odor	Black granules, powder or pellets		

SECTION IV - FIRE AND EXPLOSION HAZARD DATA

Flash Point	**Flammable Limits**	**LEL**	**UEL**
NA	Ignition Temperature > 220 ^{o}C	NA	NA

Extinguishing Media
Large volumes of water or inert gas

Special Fire Fighting Procedures
None

SECTION V - REACTIVITY DATA

Stability	Unstable		**Conditions to Avoid**
	Stable	XX	High concentrations of organics in air will cause temperature rise due to heat of adsorption. At very high concentration levels this could cause a bed fire. High concentrations of ketones and aldehydes can cause a bed temperature rise due to adsorption and oxidation.

Incompatibility ***(Materials to Avoid)***
Strong oxidizers such as ozone, oxygen, permanganate, chlorine.

Hazardous Decomposition or Byproducts
Carbon monoxide may be generated in a fire.

Hazardous Polymerization	May Occur		Conditions to Avoid None
	Will Not Occur	XX	

SECTION VI - HEALTH HAZARD DATA

Route(s) of Entry:	**Inhalation?**	**Skin?**	**Ingestion?**
	Irritation of respiratory system by dust and carbon fines	May cause skin irritation	May irritate digestive tract

Health Hazards *(Acute and Chronic)*
Possible eye injury from dust exposure. Effect of long term exposure to dust on respiratory system has not been defined.

Carcinogenicity:	**NTP?**	**IARC Monographs?**	**OSHA Regulated?**
NA	NA	NA	NA

Signs and Symptoms of Exposure
Irritation of eyes and respiratory system may result from exposure to carbon fines

Medical Conditions Generally Aggravated by Exposure
NA

Emergency and First Aid Procedures
For eye contact, immediately flush with copious amounts of water for at least 15 minutes and seek medical attention. For inhalation, fresh air and rest. For skin contact, wash with soap and

water. For ingestion, treat as for ingestion of impregnant.

SECTION VII - PRECAUTIONS FOR SAFE HANDLING AND USE

Steps to Be Taken in Case Material is Released or Spilled Sweep or shovel up carbon into closed container. Discard, repackage or recycle. Report in accordance with local, state and federal regulations.
Waste Disposal Method Dispose of carbon in accordance with local, state and federal regulations.
Precautions to Be taken in Handling and Storing Wet activated carbon removes oxygen from air posing a hazard to workers inside carbon vessels or enclosed/confined spaces. Before entering such an area, sample air to assure sufficient oxygen supply. Use work procedures for low oxygen levels, observing all local, state and federal regulations.

SECTION VIII - CONTROL MEASURES

Respiratory Proctection *(Specify Type)* NIOSH approved particulate filter if dust in generated in handling.		
Ventilation	Local Exhaust Recommended	Special
	Mechanical *(General)* Recommended	Other
Protective Gloves Rubber or latex gloves		**Eye Protection** Safety glasses or goggles
Other Protective Clothing or Equipment As needed.		
Work/Hygienic Practices Avoid generation of dust in handling. Avoid skin and eye contact.		