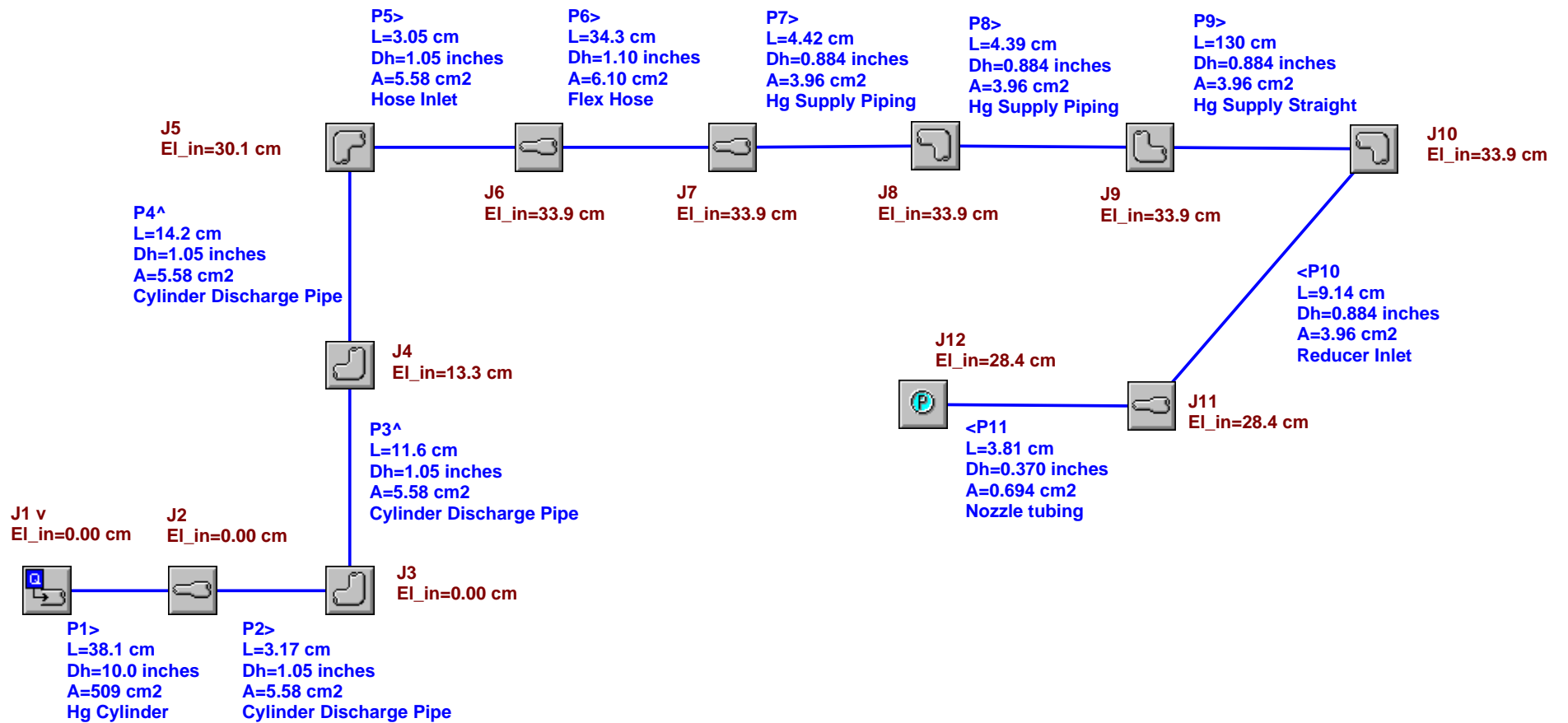


## **Appendix A. Flow Analysis Documents**

# MERIT SYRINGE FLOW ANALYSIS

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



MERIT SYRINGE FLOW ANALYSIS

Hg Syringe Model  
Reference 25 Apr 2006

MERIT SYRINGE FLOW ANALYSIS

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 (cm <sup>2</sup> )	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

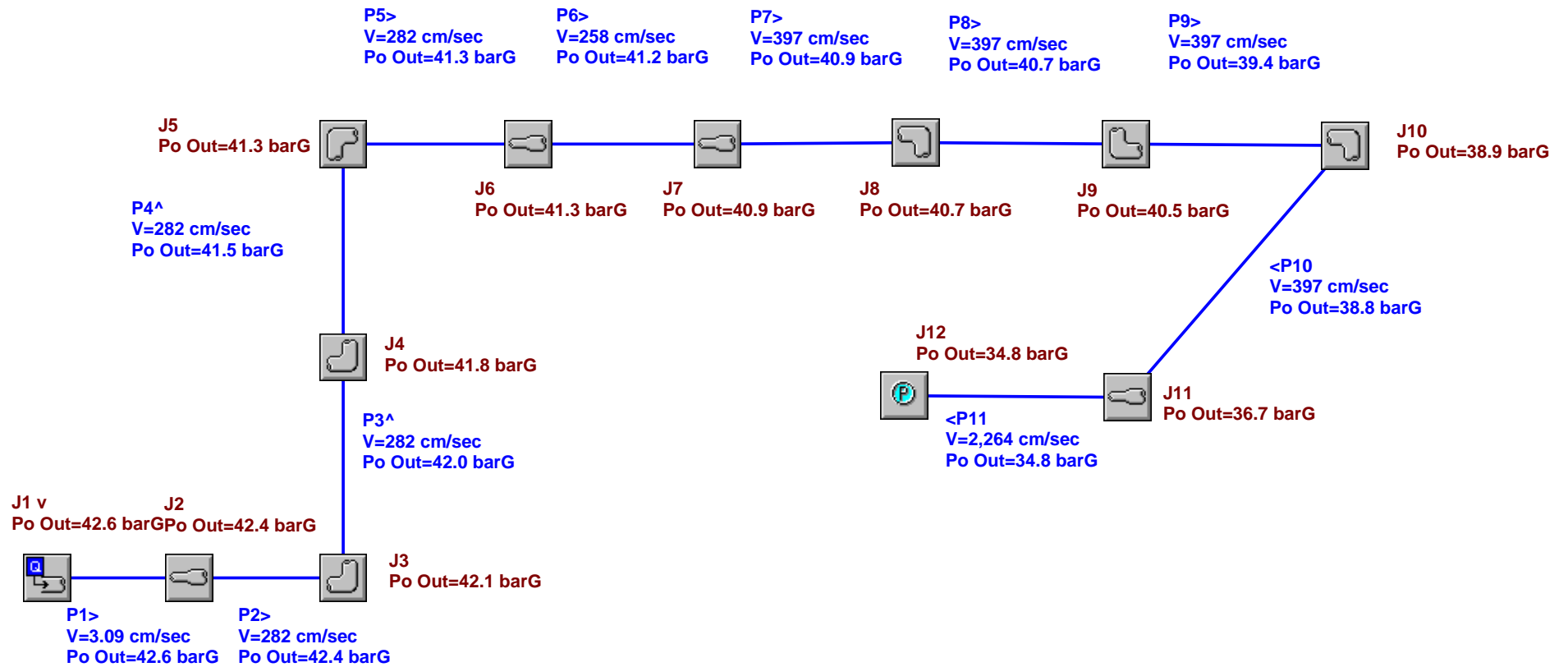
MERIT SYRINGE FLOW ANALYSIS

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.ORNLM\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 in<sup>2</sup>

**Velocity to produce 25 gpm nominal**

$25(231)/78.54 = 73.53 \text{ in/min} = 1.2255 \text{ in/sec}$

**Velocity to produce 30 gpm max**

$30(1.2255)/25 = 1.4706 \text{ in/sec}$

Drive cylinder net area = 23.37 in<sup>2</sup>

Area ration = 1.21:1

**Flow req'd for 1.2255 in/sec, Q =**

$Q = 1.2255(23.37)(60/231) = 7.44 \text{ gpm}$

Total Q = 14.88 gpm (for 25 gpm Hg)

**Return flow rate from drive cylinders**

$Q_{out} = 1.21 (14.88) = 18 \text{ gpm}$

For 30 gpm Hg,  $Q = 14.88 (30/25) = 17.86 \text{ gpm}$

NOTE: Potential for 45cc pump at 1480 rpm and  
95% vol eff = 16.7 gpm. This give ability to induce only  
 $Vel = 16.7\text{gpm} * 231\text{in}^3/\text{gal} / 60 \text{ s/min} / 23.37 \text{ in}^2 / 2\text{cyl}$   
 $Vel = 1.3756 \text{ in/sec}$

$QHg @ 1.3756 \text{ in/sec} = 1.3756 (78.54 \text{ in}^2) (60/231)$

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 in<sup>2</sup> \* 1500 psi = 117,810 lbs

Drive cyl net area = 23.37 in<sup>2</sup> x 2 cyl = 46.74 in<sup>2</sup>

Pressure @ drive cyl = 117,810 lbs / 46.74 in<sup>2</sup> =

P = 2520 psi required at cylinders.

**Estimate pressure drops at about 21 gpm:**

Prop valve @ 100% open:

PSI  
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

$P_{sys} = 2520 \text{ psi @ cyl} + 520 \text{ psi flow losses}$

$P_{sys} = 3039 \text{ psi}$
------------------------------

**Calculate drive power required**

$HP = 3039 \text{ psi} * 14.88 \text{ gpm} / (1714 * .85\text{eff})$

$HP = 31.03 \text{ HP @ } 25 \text{ gpm Hg flow (peak)}$
--

$HP = 3039 \text{ psi} * 16.7 \text{ gpm} / (1714 * .85 \text{ eff})$

$HP = 34.8 \text{ HP @ } 28 \text{ gpm Hg flow (peak)}$
---

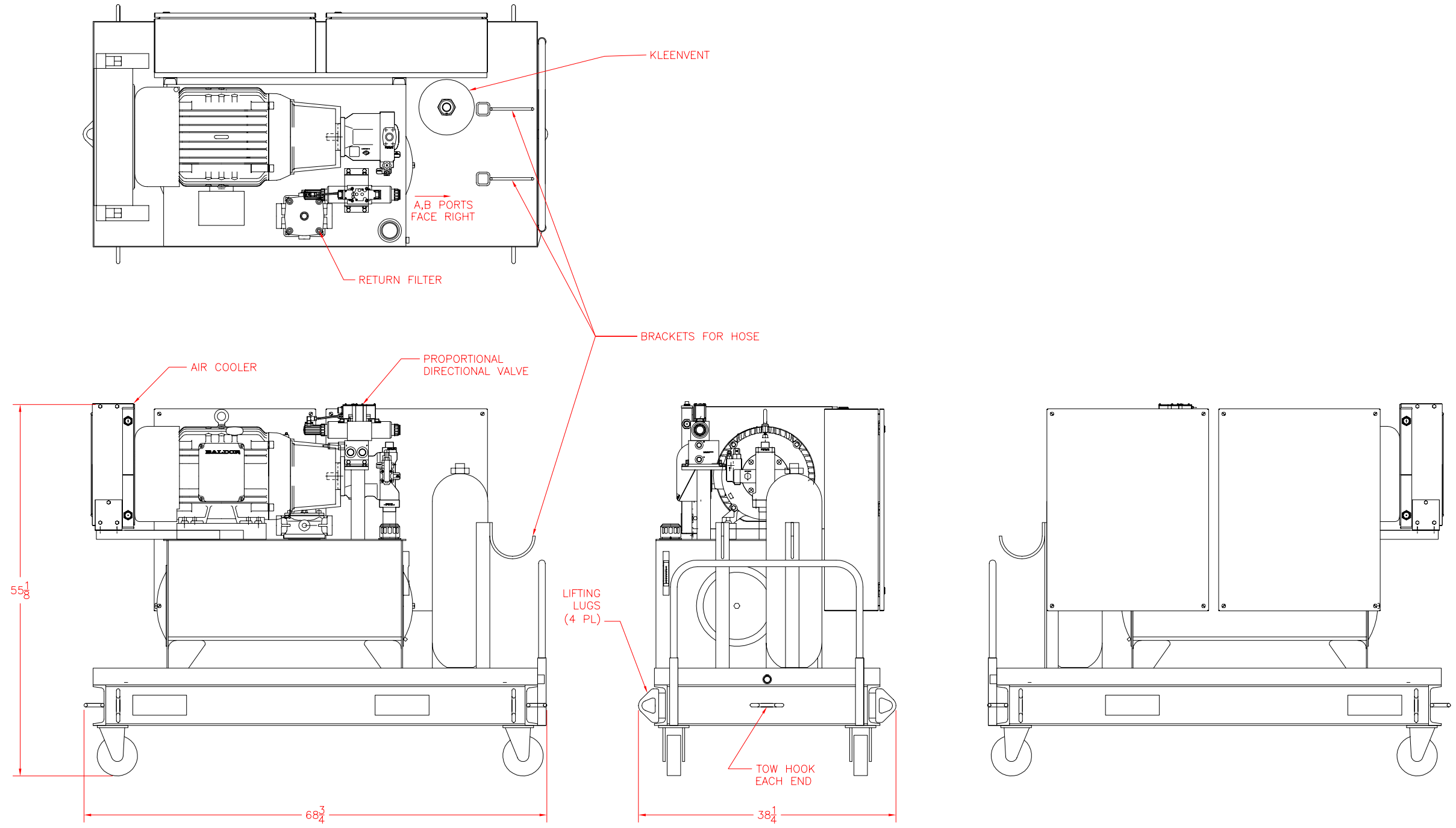
**Determine Peak power draw in USA @ 1750 rpm**


Pump flow potential 20.8 gpm at 100% vol eff, 1750 rpm

$HP = 20.8 (3039) / (1714 * .95 \text{ eff mech}) = 38.8 \text{ HP peak}$
---

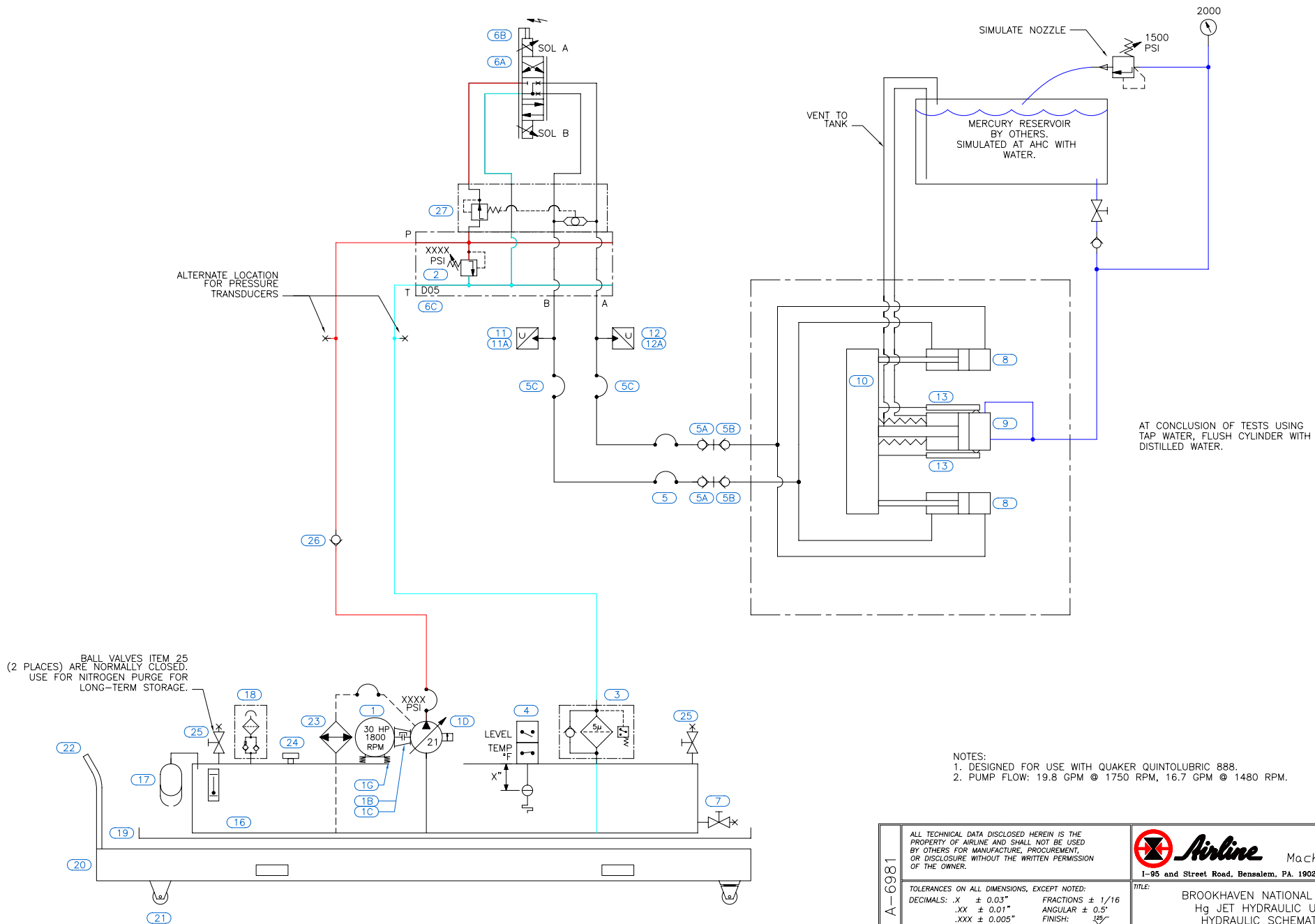
Note, this would be 129% of rated 30 HP motor

REV.	DESCRIPTIONS	DATE	BY
A	REVISED PER 11-18-05 MEETING	12/1/05	JB



JOB #: A-6981	ALL TECHNICAL DATA DISCLOSED HEREIN IS THE PROPERTY OF AIRLINE AND SHALL NOT BE USED BY OTHERS FOR MANUFACTURE, PROCUREMENT, OR DISCLOSURE WITHOUT THE WRITTEN PERMISSION OF THE OWNER.		 <b>Airline Machinery Group.</b> 1-95 and Street Road, Bensalem, PA. 19020 (215) 638-4700	
	TOLERANCES ON ALL DIMENSIONS, EXCEPT NOTED: DECIMALS: .X ± 0.03"      FRACTIONS ± 1/16 .XX ± 0.01"      ANGULAR ± 0.5° .XXX ± 0.005"     FINISH: 125		TITLE: BROOKHAVEN NATIONAL LABS Hg JET HYDRAULIC UNIT ELECTRICAL SCHEMATIC	
	DWG. #: 6981003M DATE: 11/17/05	BY: JB REV.: A	SIZE: <b>C</b> SCALE: NA	SHEET: 1 OF 1
	PERPENDICULARITY STRAIGHTNESS RUNOUT FLATNESS		CONCENTRICITY TRUE POSITION PARALLELISM PROJECTION	

REV.	DESCRIPTIONS	DATE	BY
A	PROP VALVE CHANGED WAS AN "E" SPOOL	1/4/06	JB
B	ADDED P-PORT CHECK VALVE 26	3/27/06	JB
C	ADDED HYDROSTAT 27. TRANSDUCERS WIERE IN P,T	3/31/06	JB
D	AS-BUILT, SHOWN IN AIRLINE TEST MODE	6/29/06	JB



ALTERNATE LOCATION FOR PRESSURE TRANSDUCERS

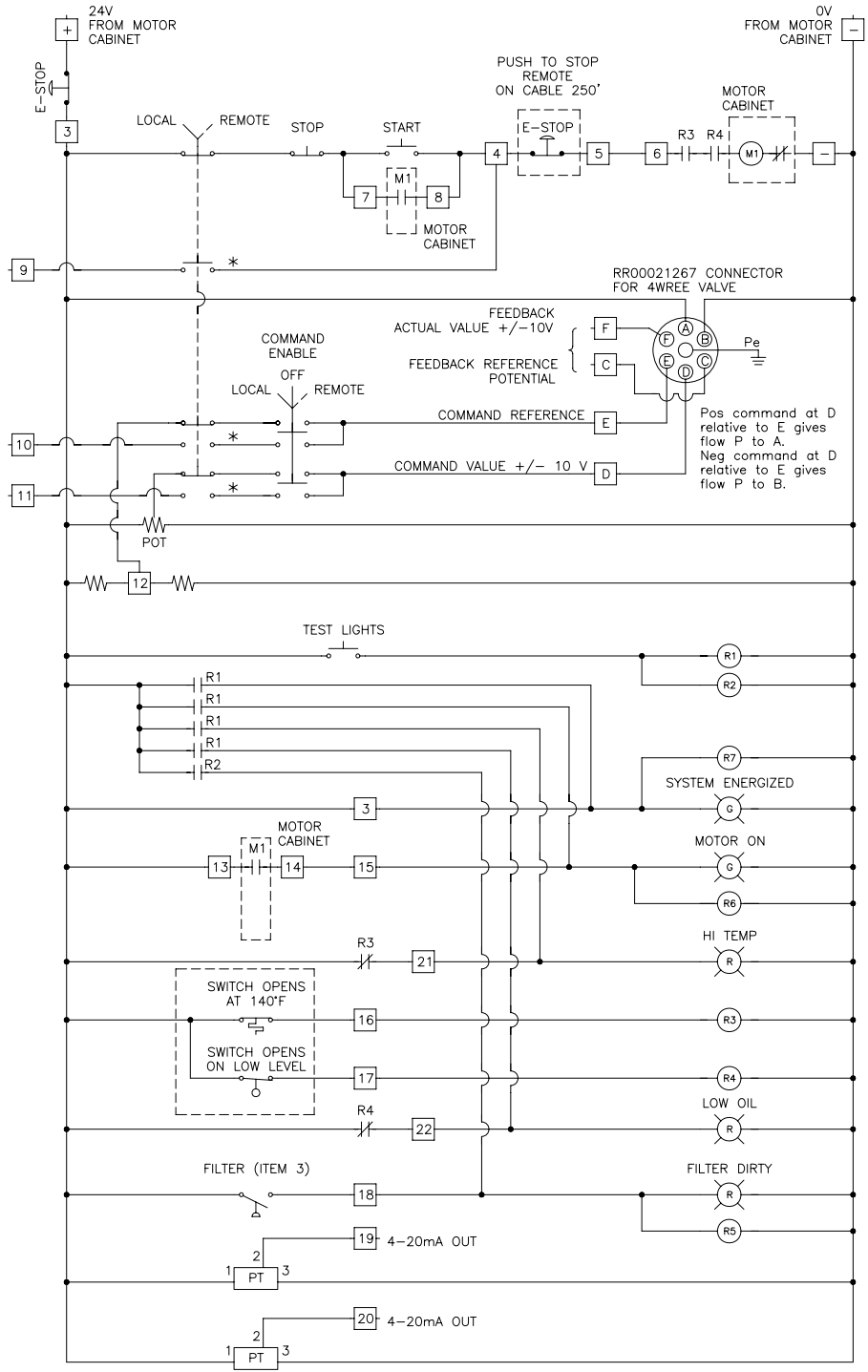
BALL VALVES ITEM 25 (2 PLACES) ARE NORMALLY CLOSED. USE FOR NITROGEN PURGE FOR LONG-TERM STORAGE.

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	ALL TECHNICAL DATA DISCLOSED HEREIN IS THE PROPERTY OF AIRLINE AND SHALL NOT BE USED BY OTHERS FOR MANUFACTURE, PROCUREMENT, OR DISCLOSURE WITHOUT THE WRITTEN PERMISSION OF THE OWNER.		TITLE: BROOKHAVEN NATIONAL LABS Hg JET HYDRAULIC UNIT HYDRAULIC SCHEMATIC	
	TOLERANCES ON ALL DIMENSIONS, EXCEPT NOTED: DECIMALS: .X ± 0.03" FRACTIONS ± 1/16 .XX ± 0.01" ANGULAR ± 0.5° .XXX ± 0.005" FINISH: 125		DWG. #: 6981001H	SIZE: C SCALE: NA
	⊥ PERPENDICULARITY — STRAIGHTNESS / RUNOUT ▭ FLATNESS	⊙ CONCENTRICITY ⊕ TRUE POSITION    PARALLELISM ⊖ PROJECTION	DATE: 11/16/05	BY: JB

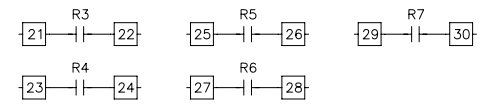
CONTROL BOX



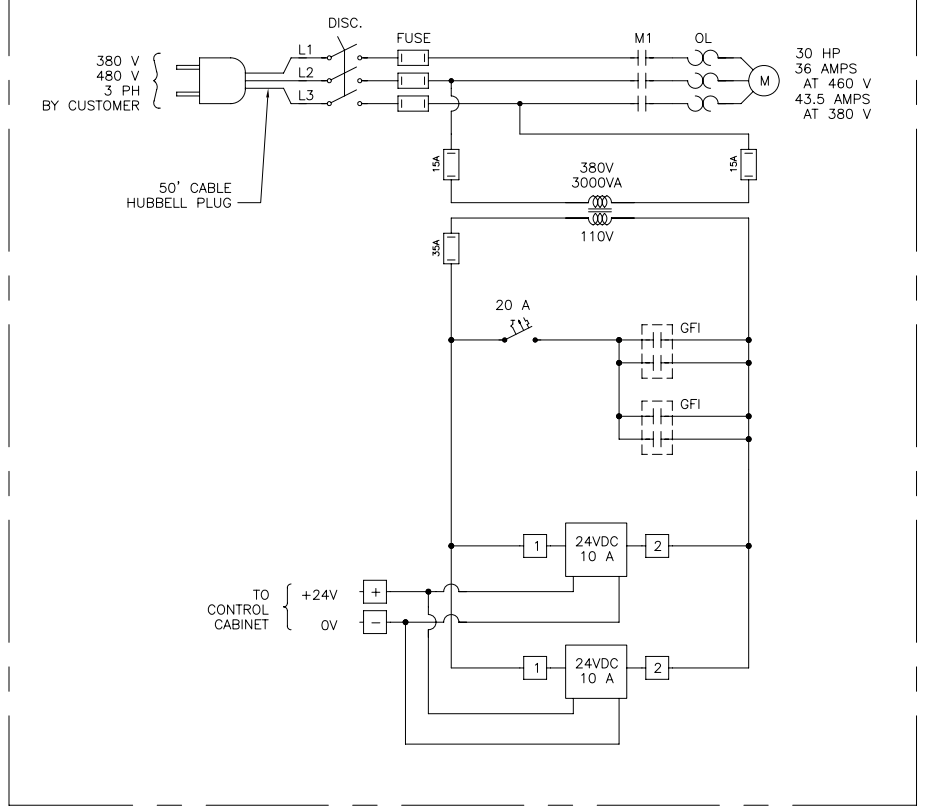
PROVIDE 50 SPARE TERMINALS.

REV.	DESCRIPTIONS	DATE	BY
A	ADDED ENABLE SWITCH TO COMMAND	12/27/05	JB
B	ADDED TERMINALS 21, 22	1/13/06	JB
C	ADDED R5,R6,R7 AND TERMINALS 21-30	3/31/06	JB

LOWER STRIP TERMINALS.



MOTOR CABINET



JOB #: A-6981	ALL TECHNICAL DATA DISCLOSED HEREIN IS THE PROPERTY OF AIRLINE AND SHALL NOT BE USED BY OTHERS FOR MANUFACTURE, PROCUREMENT, OR DISCLOSURE WITHOUT THE WRITTEN PERMISSION OF THE OWNER.			
	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 ELECTRICAL SCHEMATIC		DWG #: 6981002E	SIZE: C SCALE: NA
DATE: 11/16/05		BY: JB	REV: C	SHEET: 1 OF 1



Bill of Materials for

**BROOKHAVEN NAT'L. LABS**

per Airline Job Number A-6981 and Schematic 6981001H  
 Reference customer purchase order BNL-0000102210 for 1 unit(s).  
 This BOM is Revision A, last revised 11/3/2005

ITEM	QTY	VENDOR	DESCRIPTION	PART NUMBER	LITERATURE
1A	1	WORLDWIDE	30HP, 380/50HZ, 1425, FOR USE AT 460/60HZ, 286TC, C-FACE, TEFC WITH FEET	WWVE30-18-286TC W/ DUAL NAMEPLATE	MANUAL INSTALL.00
1B	1	VESCOR	C-FACE ADAPTER	1857	***
1C	1	REULAND	COUPLING HALF, 1 7/8 (1/2)	RC41875500	***
	1	REULAND	COUPLING HALF, 1" (1/4)	RC41000250	***
	1	REULAND	COUPLING INSERT	RG4P9	***
1D	1	REXROTH	2.75 CID, 21 GPM @1800, 4000 PSI MAX (S=1.5 CODE61, P=1" CODE61, L=SAE10), SET AT 3000 PSI AND 12.9 GPM AT 1425 RPM	AA10VSO45DR/31RPKC62N00	RA 92 711/05.95
1E	1	ANCHOR	SUCTION FLANGE, 1 1/2 NPT	W432424U	***
1F	1	ANCHOR	PRESSURE FLANGE, SAE 16	W461616U	***
1G	2	VESCOR	MOTOR DAMPENING BARS	VSM286W	CATALOG PG. 157, 158, 160
2	1	SUN	RELIEF CARTRIDGE, T3A, 4500 PSI, SET AT 3300 PSI	RPGC-LWN	RPGC SPECIFICATIONS
3	1	HYDAC	RFM 330 FILTER HOUSING, SAE 24 - 5 MICRON ABSOLUTE ELEMENT, WITH ELECTRICAL/VISUAL INDICATOR & BYPASS	RFMBN3HC330G5D1.0/12/L24	CATALOG PG. 35 THRU 40
3A	2	HYDAC	ELEMENT, 5 MICRON ABSOLUTE, 32 GPM @ 10 PSI	0330R005BN3HC	CATALOG PG. 35 THRU 40
4	1	APCO	LEVEL / TEMP. SWITCH, 140 F.	TL008-140F	DRAWING 10136
5	2	PARKER	3/4" HOSE ASSEMBLY	F575X0106121212CS-300	CATALOG PG. 24, 78
5A	2	SNAPTITE	QUICK DISCONNECT, 3/4 NPT NIPPLE	SS72N12-12F	72 SERIES BROCHURE
5B	2	SNAPTITE	QUICK DISCONNECT, 3/4 NPT COUPLER	SS72C12-12F	72 SERIES BROCHURE
5C	2	PARKER	3/4" HOSE ASSEMBLY	F451TC120503121212-900	
5D	2	PARKER	QUICK DISCONNECT, SAE 12 NIPPLE	6610-12-12	CATALOG PG. B2, B5, B6, B10, B11
5E	2	PARKER	QUICK DISCONNECT, SAE 12 COUPLER	6608-12-12	CATALOG PG. B2, B5, B6, B10, B11
6A	1	REXROTH	D05 PROPORTIONAL WITH FEEDBACK, +/- 10V COMMAND	4WREE10E502X/G24K31/A1V	RE 29 061/02.03
6B	1	REXROTH	Z31 CONNECTOR	R900021267	RE 29 061/02.03
6C	1	DAMAN	MANIFOLD, D05, -12 ORB PORTS, WITH T-3A R/V CAVITY	DD05HP013S/S	CATALOG PG. 14, 15
7	1	APOLLO	BALL VALVE, 3/4" NPT, MAX. PRESSURE 600 PSI	7710401	CATALOG PG. A-1 & BULL. 1845300
8	2	HANNA	CYLINDER, 304 SST, 6" BORE	MS7-2H-NC-6-15.00-J-SM-3B W/ STOP TUBE	DWG. 706-40527-022
9	1	HANNA	CYLINDER, 304 SST, 10" BORE	MS2-3H-NC-10.00-15.00-P-SM-3H	DWG. 706-81637-000 & DWG. 706-81637-001
10	1	HANNA	TIE BAR, SST304L	27.50 X 10.00 X 4.50	***
11	1	HYDAC	PRESURE TRANSDUCER, WITH READOUT, 0 TO 6000 PSI, SET FOR 4 TO 20 MA = 0 TO 4000 PSI	EDS3476-3-6000-400	CATALOG PG. 25, 24 & USER MANUAL
11A	1	MURR	ELECTRICAL CONNECTOR	7000-12341-014-0500	CATALOG PG. 25, 24 & USER MANUAL
12	1	HYDAC	PRESURE TRANSDUCER, WITH READOUT, 0 TO 1000 PSI, SET FOR 4 TO 20 MA = 0 TO 500 PSI	EDS3476-3-1000-400	CATALOG PG. 25, 24 & USER MANUAL
12A	1	MURR	ELECTRICAL CONNECTOR	7000-12341-014-0500	CATALOG PG. 25, 24 & USER MANUAL
13	2	CELESCO	LINEAR TRANSDUCER	CLWG-450-NC4	CATALOG PG. 58, 59
14	1	HYDAC	SST BALL VALVE, SAE 8	KHM16SAE331416X	CATALOG PG. 7, 2 & MAINTENANCE INSTRUCTIONS
15					
16	1	VESCOR	40 GALLON RESERVOIR, A-STYLE	T-40A (10040)	CATALOG PG. 4
17	1	GREER	KLEENVENT, 5 GALLON	KV05F0T01A1	CATALOG PG. 115 THRU 118
18	1	GREER	PRESS. / VACUUM RELIEF	PN1486670000	CATALOG PG. 115 THRU 118
19	1	AHC	DRIP TRAY	DPA60	***
20	1	AHC	CART	DWG. A-6981-FRAME	***
21	2	GRAINGER	SWIVEL CASTER W/ LOCK	1G427	***
	2	GRAINGER	RIGID CASTER W/ LOCK	1G427 (MODIFY TO NON SWIVEL)	***
22	1	AHC	TRANSPORT HANDLE	CUSTOM TO SUIT	***
23	1	T. TRANSF.	COOLER, CASE DRAIN	RM2422	CATALOG PG. 26, 27, 28
24	1	VESCOR	NON-VENTED FILL CAP	5232	CATALOG PG. 48
25	2	APOLLO	BALL VALVE, 1/4" NPT, MAX. PRESSURE 600 PSI	7010101	CATALOG PG. A-1 & BULL. 1845300



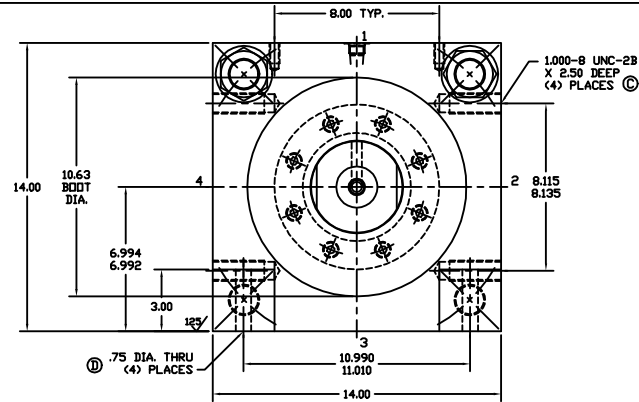
Bill of Materials for

**BROOKHAVEN NAT'L. LABS**

per Airline Job Number A-6981 and Schematic 6981001H  
 Reference customer purchase order BNL-0000102210 for 1 unit(s).  
 This BOM is Revision A, last revised 11/3/2005

ITEM	QTY	VENDOR	DESCRIPTION	PART NUMBER	LITERATURE
	55	QUAKER	FIRE RESISTANT FLUID	QUINTOLUBRIC 888	***
		AHC	MOTOR STARTER CABINET	CUSTOM TO SUIT	***
	1	ABB	DISCONNECT SWITCH	OSJ100B8150	CATALOG PG. 17.77 THRU 17.81 & 17.107 THRU 17.109
	3	GRAINGER	FUSE, 60 AMP, CLASS J	4XF39	CATALOG PG. 15
	1	SQ. D	TRANSFORMER, 3000 VA, 460 OR 380 V	3S67F	***
	1	ABB	CONTACTOR	AE50301181	CATALOG PG. 1.4, 1.5
	1	ABB	CONTACT BLOCK	CAL511	***
	1	ABB	OVERLOAD MODULE	TA75DU52	CATALOG PG. 2.2, 2.3, 2.4, 2.6
	1	HAMMOND	WIRING BOX, NEMA 4, 48 X 24 X 12	EN4SD482412GY	***
	1	HAMMOND	WIRING BOX PANEL	EP4824	***
	2	GRAINGER	FUSE BLOCK	5KK56	***
	2	GRAINGER	FUSE, 15 AMP, CLASS J	4XF32	***
	1	GRAINGER	FUSE BLOCK	5KK56	***
	1	GRAINGER	FUSE, 35 AMP, CLASS J	4XF36	***
	2	OMRON	POWER SUPPLY, 10 AMP, 24VDC	S8VS-12024	CATALOG S8VS
	1	ABB	CIRCUIT BREAKER, 20 AMP	S262B20	CATALOG PG. 14.2, 14.5
	2	GRAINGER	GFI OUTLET	1FD29	***
	2	GRAINGER	GFI OUTLET COVER	6C582	***
	50	COMM'L.	CABLE, S.O	SOW 6/4 BLACK	***
		AHC	CONTROL CABINET	CUSTOM TO SUIT	***
	1	ABB	START STOP OPERATOR	CBK2P1Y	CATALOG PG. 8.18
	8	ABB	CONTACT, NORM. OPEN	MCB10	***
	2	ABB	CONTACT, NORM. CLOSED	MCB01	***
	1	VISHAY	POTENTIOMETR, 5K OHMS	MODEL 536	CATALOG PG. 104, 105, 106
	1	VISHAY	POTENTIOMETR KNOB	MODEL 21-1-11	***
	1	ABB	2 POSITION SWITCH OPERATOR	CBK2AMK	CATALOG PG. 8.21
	7	ABB	CUSTOM NAMEPLATE	CBKNPE28	***
	1	ABB	E-STOP OPERATOR	CBKEST6R	CATALOG PG. 8.17
	2	ABB	PILOT LIGHT, 24 VDC, GREEN	CBKKLF8G	CATALOG PG. 8.39
	3	ABB	PILOT LIGHT, 24 VDC, RED	CBKKLF8R	CATALOG PG. 8.39
	1	ABB	PUSHBUTTON OPERATOR	MP110B	CATALOG PG. 8.14
	4	OMRON	RELAY, 4 POLE 24VDC	LY4NDC24	CATALOG GC RLY7
	4	OMRON	RELAY BASE 4 POLE	PTF14AE	CATALOG GC RLY7
	1	HAMMOND	WIRING BOX, NEMA 4, 48 X 24 X 12	EN4SD482412GY	***
	1	HAMMOND	WIRING BOX PANEL	EP4824	***
		AHC	REMOTE PENDANT	CUSTOM TO SUIT	***
	1	ABB	E-STOP OPERATOR	CBKPMP40R	CATALOG PG. 8.16
	1	ABB	CONTACT, NORM. CLOSED	MCB01	***
	1	ABB	CUSTOM NAMEPLATE	CBKNPE28	***
	250	COMM'L.	CABLE, S.O	STO 14/2	***
	1	ABB	NEMA 4 PENDANT BOX	CBKEP1	***





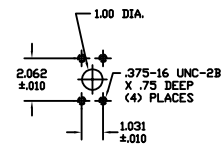
**FOR 15.00 STROKE**  
 TIE ROD TORQUE 500 FT.-LBS.  
 GLAND SCREW TORQUE = 18 FT.-LBS.

- 1) ALL 316 STAINLESS STEEL CONSTRUCTION
- 2) ROD BOOT COMPATIBLE WITH WATER & MERCURY
- 3) SAE #8 PORTS AT POS. 1 & 3
- 4) NO BRONZE WEAR RINGS ALLOWED
- 5) 1.00 SAE (4) BOLT FLANGE PORT AT POS. 5 B/H
- 6) #3B SEAL PACKINGS
- 7) TEST AT 2250 PSI, OPER. PRESS. = 1500 PSI

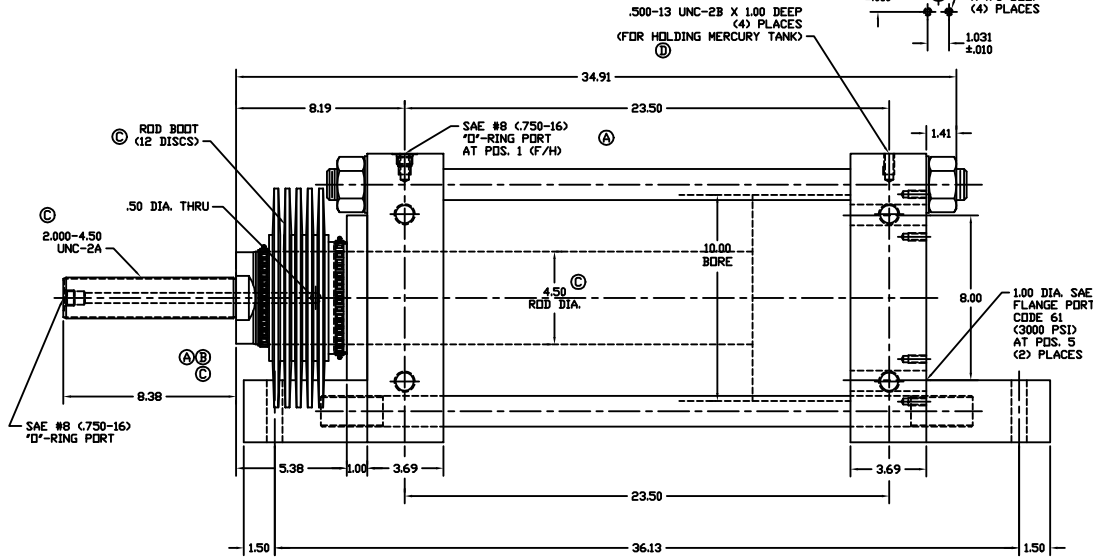
① NOTE: THIS CYLINDER CAN ONLY BE TESTED WITH WATER.  
 USE ONLY ENOUGH GREASE TO LUBRICATE THE SEALS  
 FOR ASSEMBLY OF THE CYLINDER.

**PORT DETAIL**

- ① 1.00 DIA. SAE (4) BOLT  
 FLANGE PORT DETAIL  
 CODE 61 (3000 PSI)  
 LOCATED AT POS. 5 (B/H)



① .500-13 UNC-2B X 1.00 DEEP  
 (FOR HOLDING MERCURY TANK)



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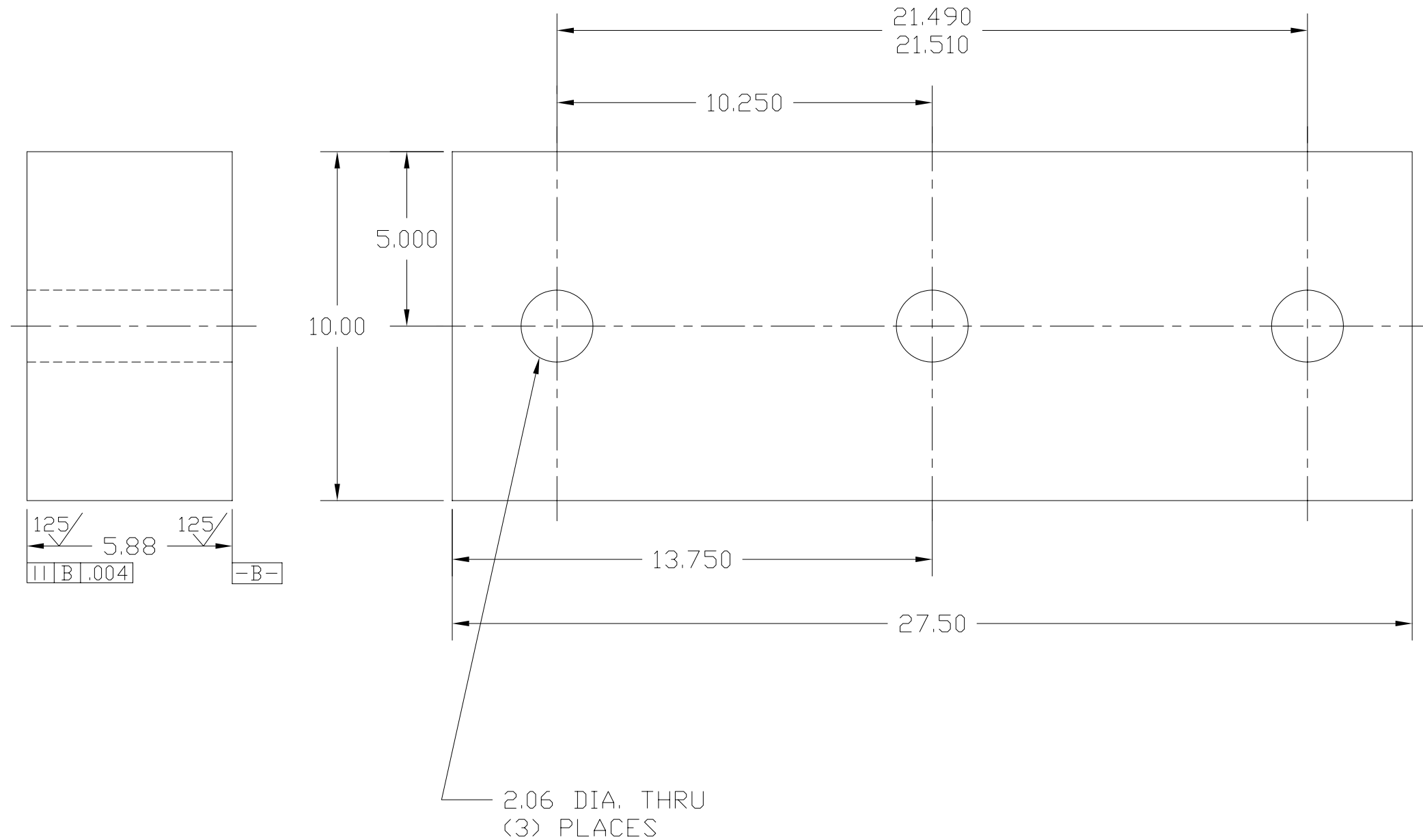






# MOUNTING BAR

MAKE FROM: 6.00 X 10.00 X 28.00 LOND  
304 STAINLESS STEEL BAR



NOTE:  
BREAK ALL SHARP CORNERS  
.010 x 45° MAX.  
ALL UNSPECIFIED RADII .02 MAX.

DATE	REVISIONS	CN	DESIGN BY	SCALE
			BJM	.25=1
			CHECKED BY	DATE 11/21/2005
				JOB NO. K1
<p>DIMENSIONS ARE IN INCHES . WHERE ADDITIVE FINISH IS SPECIFIED . LIMITS APPLY OVER FINISH . UNLESS OTHERWISE SPECIFIED . LIMITS ON FINISHED DIMENSIONS ARE AS FOLLOWS:</p> <p>TWO PLACE * THREE PLACE BEVELS &amp; CHAMFERS ±2</p> <p>DECIMALS DECIMALS ±.015</p> <p>*TOLERANCES ON "PLUS STROKE" DIMENSIONS WILL VARY SLIGHTLY FROM DIMENSIONS SHOWN DUE TO MANUFACTURING TOLERANCES AND TUBE COMPRESSION</p> <p>ANGULARITY, SQUARENESS AND PARALLELISM: ±.015 INCHES PER FOOT</p> <p>CONCENTRICITY: T.I.R. EQUALS TOLERANCE ON DIAMETER.</p>			<p>CONFIDENTIAL ALL RIGHTS RESERVED PROPERTY OF:</p> <p><b>HANNA CYLINDERS</b></p> <p>804 E. Park Avenue Libertyville, Illinois 60048 847-990-7700</p>	
			<p>MOUNTING BAR</p>	
206-40181-000				

**HANNA CYLINDERS**

**HIGH PRESSURE HYDRAULIC TEST REPORT**

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

SERIAL # <i>K11422704</i>	MODEL <i>ME5</i>	BORE <i>6.00</i>	STROKE <i>15.00</i>	JOB # <i>114227004</i>
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**DIMENSIONS**

VERIFIED PER *X* DRAWING # *706-40342-030 REV D*  
*a* OTHER (Describe) *DETAIL*

**FASTENERS**

<i>TIE ROD</i>	TORQUED TO <u><i>300</i></u>	FT-LB
<i>S.H.C.S GLAND</i>	TORQUED TO <u><i>18</i></u>	FT-LB
	TORQUED TO _____	FT-LB

**TESTING PRESSURE**

HYD. PSI _____ 500 _____ 1000 _____ 1200 _____ 1500 _____ 1800 _____ 2200 <u><i>X</i></u> 3000 <u><i>X</i></u> 4500 _____ 5000	<b>BREAK-AWAY PRESSURE:</b>  PASS <u><i>X</i></u> FAIL _____
---	--

**LEAKAGE TESTS**

<b>EXTERNAL</b>	<b>INTERNAL BYPASS</b>
<u><i>X</i></u> TUBE END SEAL <u><i>X</i></u> ROD SEAL _____ SPECIAL PIPING _____ _____	PASS <u><i>X</i></u> FAIL _____

**REMARKS**

REMARKS AREA (Empty)

TESTED BY: \_\_\_\_\_ APPROVED BY: \_\_\_\_\_

*Raul Lopez*      DATE *3/9/06*      *[Signature]*      DATE *3/9/06*

E:\ISO Manuals & Forms\Forms\QC\QC-6 High Pressure Hydraulic Test Report Rev.1.xls]Sheet1

# HANNA CYLINDERS

## HIGH PRESSURE HYDRAULIC TEST REPORT

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

SERIAL # <i>K11422703</i>	MODEL <i>ME5</i>	BORE <i>6.00</i>	STROKE <i>15.00</i>	JOB # <i>114227003</i>
------------------------------	---------------------	---------------------	------------------------	---------------------------

### DIMENSIONS

VERIFIED PER <u><i>X</i></u> DRAWING # <i>706-40342-031 REV C</i>
<u><i>K</i></u> OTHER (Describe) <u><i>DETAIL</i></u>

### FASTENERS

<i>TIE ROD</i>	TORQUED TO <u><i>300</i></u> FT-LB
<i>GLAND SCREWS</i>	TORQUED TO <u><i>18</i></u> FT-LB
	TORQUED TO _____ FT-LB

### TESTING PRESSURE

<table> <tr><td>HYD.</td><td>PSI</td></tr> <tr><td>_____</td><td>500</td></tr> <tr><td>_____</td><td>1000</td></tr> <tr><td>_____</td><td>1200</td></tr> <tr><td>_____</td><td>1500</td></tr> <tr><td>_____</td><td>1800</td></tr> <tr><td>_____</td><td>2200</td></tr> <tr><td><u><i>X</i></u></td><td>3000</td></tr> <tr><td><u><i>K</i></u></td><td>4500</td></tr> <tr><td>_____</td><td>5000</td></tr> </table>	HYD.	PSI	_____	500	_____	1000	_____	1200	_____	1500	_____	1800	_____	2200	<u><i>X</i></u>	3000	<u><i>K</i></u>	4500	_____	5000	<p style="text-align: center;"><b>BREAK-AWAY PRESSURE:</b></p> <p>PASS <u><i>X</i></u>                      FAIL _____</p>
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<u><i>X</i></u>	3000																				
<u><i>K</i></u>	4500																				
_____	5000																				

### LEAKAGE TESTS

EXTERNAL	INTERNAL BYPASS
<u><i>K</i></u> TUBE END SEAL	PASS <u><i>K</i></u> FAIL _____
<u><i>K</i></u> ROD SEAL	
_____ SPECIAL PIPING	
_____	
_____	

### REMARKS

TESTED BY:

APPROVED BY:

*Raul Lopez*                      DATE *3/9/06*                      *[Signature]*                      DATE *3/9/06*

# HANNA CYLINDERS

## HIGH PRESSURE HYDRAULIC TEST REPORT

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

SERIAL # <u>K 11422705</u>	MODEL <u>MS7</u>	BORE <u>10"</u>	STROKE <u>15"</u>	JOB # <u>114227005</u>
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### DIMENSIONS

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

### FASTENERS

<u>TIE RODS</u>	TORQUED TO	<u>500</u>	FT-LB
<u>GLAND SCREW</u>	TORQUED TO	<u>18</u>	FT-LB
	TORQUED TO		FT-LB

### TESTING PRESSURE

HYD. PSI	BREAK-AWAY PRESSURE:  PASS <u>X</u> FAIL _____
_____ 500	
_____ 1000	
_____ 1200	
_____ 1500	
_____ 1800	
<u>X</u> _____ 2200	
_____ 3000	
_____ 4500	
_____ 5000	

### LEAKAGE TESTS

EXTERNAL	INTERNAL BYPASS
<u>X</u> TUBE END SEAL	PASS <u>X</u> FAIL _____
<u>X</u> ROD SEAL	
_____ SPECIAL PIPING	
_____	
_____	
_____	

### REMARKS

TESTED BY:

APPROVED BY:

PAUL LOPEZ      DATE 3/8/06      [Signature]      DATE 3/8/06





**Specification No. 203-HJT-9000R1b**

# **Specification for a Pump System for the High Power Mercury-Jet Target Experiment**

**Nov 22, 2005**

**SPECIFICATION FOR A PUMP SYSTEM FOR THE  
HIGH POWER MERCURY-JET TARGET EXPERIMENT**

Prepared by:

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**Prepared by Oak Ridge National Laboratory for  
Brookhaven National Laboratory  
Physics Division**

**under contract DE-AC05-00OR22725  
for the  
U.S. DEPARTMENT OF ENERGY**

November 2005

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## 1.0 Scope

This procurement specification is issued on behalf of Brookhaven National Laboratory (BNL), hereafter referred to as the Company, and contains the requirements for the design, fabrication, and assembly of a pump system consisting of a syringe pump and a hydraulic power unit (HPU). The HPU provides the power to drive the syringe pump; the combination of these will be used to produce a jet of mercury within a containment barrier. Acceptance tests at the Seller's site shall use water in lieu of mercury in the syringe pump. *The Seller will not deal with nor handle mercury in any way, and the containment barrier and sump tank shown in Fig. 2 are not part of this procurement.* Upon completion of successful testing, the equipment shall be delivered to Oak Ridge National Laboratory (ORNL) in Oak Ridge, TN.

Under the provisions of this subcontract the Seller shall provide the following:

- Syringe pump
  - hydraulic cylinders,
  - cylinder tie beam
  - base support structure, and
  - position sensors.
- HPU
  - pump, motor, reservoir,
  - motor controller,
  - sensors and gauges,
  - hoses and fittings,
  - hydraulic fluid, and
  - mobile cart to support the HPU.
- Electrical power and system controls
- Detailed design documentation
- System integration and testing

Figure 1 shows the syringe pump; the two outer hydraulic cylinders drive a center cylinder that will produce a jet of mercury at the Company's testing site.

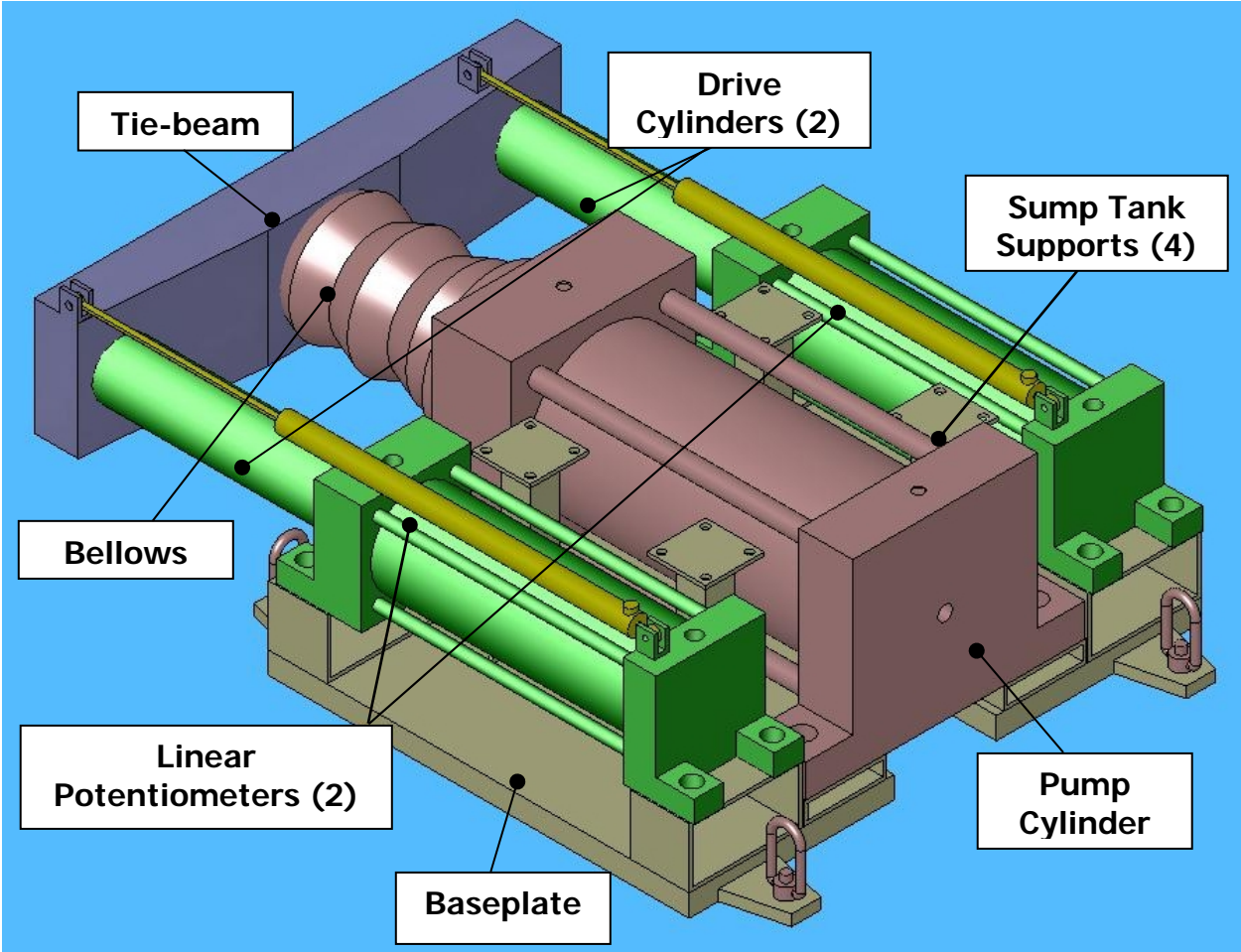


Figure 1. Syringe pump subsystem.

Figure 2 shows the syringe pump installed in a secondary containment box along with a mercury sump tank and a mercury delivery nozzle. The secondary containment, sump tank, and nozzle are shown for reference and are not part of this specification. Figure 3 shows the HPU.

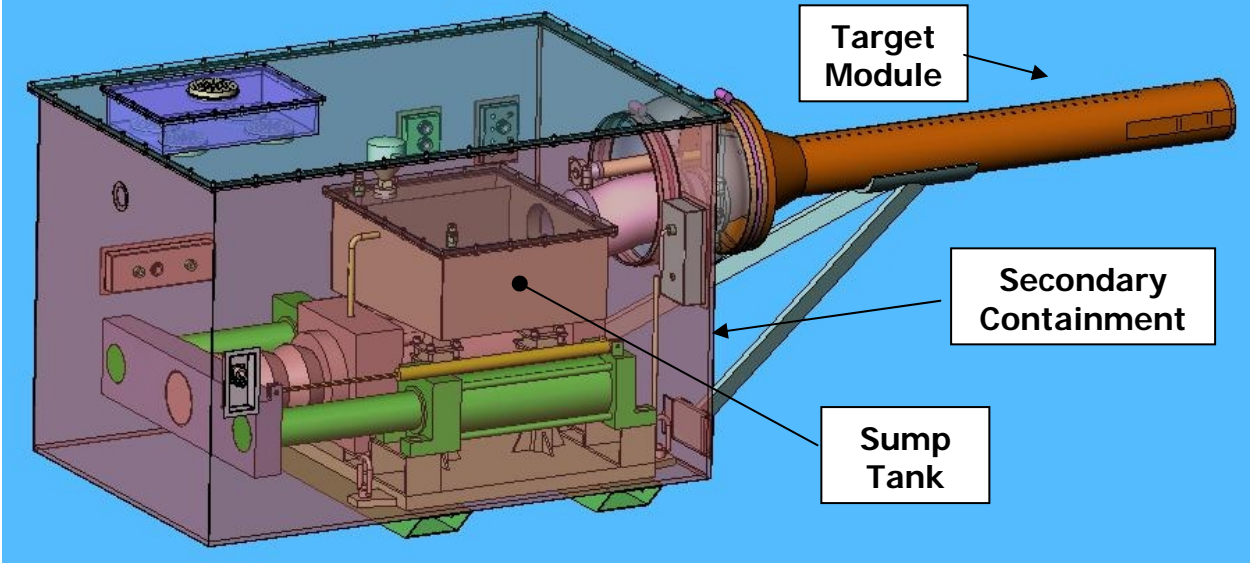


Figure 2. Syringe pump subsystem shown inside secondary containment.

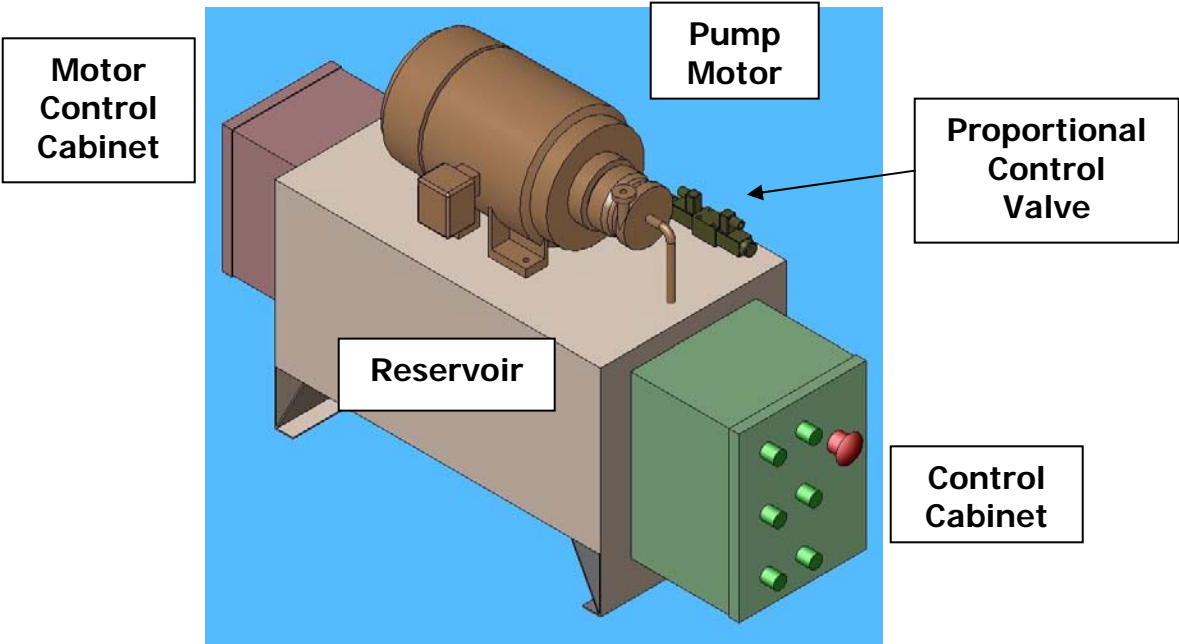


Figure 3. HPU (mobile cart not shown)

## **2.0 Applicable Codes and Standards**

- ANSI/NFPA/JIC T.2.24.1 – 3000 psi rated cylinders
- National Electric Code latest edition – standard practices
- American Welding Society D.1 – standard practices

## **3.0 Design**

### **3.1 Performance**

The system shall be capable of expelling mercury from a cylinder at room temperature over a range of flow rates from 1 gpm to 28 gpm (4 – 106 liters/min) against a flow-pressure of up to 1500 psig. For the nominal flow condition of 25 gpm, jet duration shall be 12 seconds. System shall operate with angle of tilt between 0° and 5° upward.

### **3.2 Operating Environment**

The syringe pump system shall be capable of operating in the following environment:

- temperature range of 20°C to 80°C,

The HPU shall be capable of operating in the following environment:

- temperature range of 20°C to 40°C.

### **3.3 Lifetime**

The syringe pump and HPU shall be capable of operating for 10,000 start/stop cycles.

## **4.0 Design Requirements**

The schematic diagram for the pump system is included at the end of the specification and is listed as Figure 5.

### **4.1 Hydraulic Power Unit**

#### **4.1.1 Pump & Motor**

The HPU pump shall have an nominal operating pressure of 3000 psi. The motor shall be adequately sized to drive the chosen pump. The motor shall operate with 380VAC/50Hz and 480VAC/60Hz.

#### 4.1.2 *Reservoir*

4.1.2.1 Cart - The reservoir with integrated pump/motor and electrical system shall be mounted on a mobile cart with four lockable wheels; one pair shall be swivel wheels, one pair fixed wheels. The cart shall be steered by a handle mounted in front of the swivel wheels; if detachable, provisions shall be made to store the handle on the cart. The cart shall have a drip pan under the reservoir. The cart shall have a bracket(s) for storage of the system power cord. The cart shall be designed to allow lifting with a forklift or an overhead crane.

4.1.2.2 Standard Maintenance Features – The reservoir shall have

- internal baffling,
- sight-gauge level indicator,
- low level fluid / high temperature switch (140°F),
- cleanout port,
- N<sub>2</sub> purge valve,
- clean vent,
- vacuum breaker / tank relief,
- rear-mount case-drain cooler (air-to-oil)
- drain port with ball valve and cap,
- sealed fill port, and
- minimum capacity of 40 gallons.

4.1.2.3 Hydraulic Fluid – the HPU fluid shall be fire-resistant Quintolubric® 888 or equivalent. The fluid shall be pre-filtered through a filter with a Beta<sub>5µm</sub>>25 before pumping into the system.

4.1.2.4 Flow control – flow shall be controlled with a proportional directional control valve with position feedback and integrated control electronics, Bosch 4WREE or equivalent.

4.1.2.5 Fittings – the only allowed fittings will be SAE without specific Company approval.

4.1.2.6 Hoses – One pair of hoses shall connect to the reservoir to form the supply and return lines; these shall be split into two pairs inside the secondary containment of the mercury delivery system (see Figure 5), with each pair connecting to one of the drive cylinders. The supply and return lines shall terminate at the reservoir and the secondary containment boundary with male/female fittings, with opposite sex fittings chosen to eliminate the possibility of incorrect hookup. The supply and return hoses shall have check valve quick-disconnect ends, and each hose shall be comprised of two joined sections. One section shall contain no magnetic materials and have a length of 25ft; the other section shall be standard hose with a length of 75ft. No magnetic materials are



allowed in the quick-disconnects at the secondary containment. Hoses shall incorporate OSHA-approved whip checks at the disconnects..

4.1.2.7 Contamination Control – A filter meeting the contamination control requirements of the hydraulic pump shall be installed in the return line close to the reservoir. The filter housing shall include a bypass valve, and a local visual indicator and a panel light to indicate a clogged filter condition. The HPU shall be delivered to ORNL with two spare filters.

#### 4.1.3 *Controls*

4.1.3.1 The HPU control system shall be housed in two cabinets, the motor control cabinet and the control cabinet. All components with voltages greater than 50V shall be housed in the motor control cabinet; the control cabinet shall contain only components that can be energized with less than 50V. All electrical components shall be UL listed or approved. The HPU shall be capable of operating with 3-phase, 480VAC/60Hz power for U.S. operation and 380VAC/50Hz power for European operation.

4.1.3.2 The control system shall be provided with 50 ft of NEC-approved power cable with a Hubble HBL26419 plug. The cable shall be stored on the mobile cart.

4.1.3.3 All wiring shall meet applicable National Electrical Code requirements. All conductors shall be installed with labels corresponding to those listed on the Seller-supplied wiring diagram.

4.1.3.4 The control system shall include a motor starter and the following controls and indicators:

- Main power disconnect
- Cabinet mounted motor start button
- Cabinet mounted motor stop button
- Cabinet mounted "enable" switch used during local control
- Cabinet mounted dial for controlling the directional control valve
- Cabinet mounted switch for local or remote control that enables/disables the control valve dial control and the motor start/stop buttons
- Cabinet mounted "system energized" indicator light
- Cabinet mounted "motor on" indicator light
- Cabinet mounted "filter dirty" indicator light
- Cabinet mounted "low reservoir fluid level" indicator light
- Cabinet mounted "high-temperature" indicator light
- Cabinet mounted push-to-test button to test indicator lights
- Cabinet mounted emergency stop button
- Pendant mounted emergency stop button

4.1.3.5 The control system shall be housed in NEMA 4 enclosures. The main power disconnect, fuses, relays, and motor starter shall be in the motor control cabinet. One 110V/20A circuit with breaker for external loads shall be provided, with one quad GFI-protected receptacle mounted in/on the motor control cabinet. An on-board step-down transformer from 380V to 110V shall provide power for the 110V circuit during operations in Europe; for U.S. operations the circuit can be powered through a flanged inlet receptacle. A 24VDC power supply shall be provided and sized to drive all relays and indicators and provide an additional 250W to external, Company-supplied loads.

4.1.3.6 The controls and indicator lights shall be housed in/on a separate enclosure, the control cabinet, and operated at 24VDC. The starter contactor shall operate with 24VDC. The control cabinet shall be a minimum of 24 inches tall, 20 inches wide, and 8 inches deep and shall contain full-width horizontal DIN rails attached to panel mounting brackets for mounting Seller- and Company-supplied equipment. All Seller-supplied control and sensor wiring shall connect to a terminal block mounted on one of the DIN rails. The terminal block shall provide a minimum of 48 connection points for Company-supplied wiring at a later time. The cabinet shall provide a minimum of 240 in<sup>2</sup> of space for Company-supplied equipment.

4.1.3.7 The control system shall have the ability for manual operation from the control cabinet with the motor start/stop buttons and the directional control valve dial when the local/remote switch is set to local control. When the local/remote switch is set to remote control, operation of the motor start/stop buttons and directional control valve shall come from a remote computer. Wiring from the remote computer interface will be installed by the Company. Signals to all indicator lights on the control cabinet shall be accessible to a remote computer through the Seller-provided terminal block. A bulkhead Ethernet connection with standard RJ45 ports on both sides shall be installed in the control cabinet by the Seller.

4.1.3.8 A push-to-test circuit shall be included. When the button is pushed, all indicator lamps should illuminate to verify their operation.

4.1.3.9 If a low-fluid-level or a high-fluid-temperature signal is received, the pump motor shall automatically be disabled.

4.1.3.10 The control system shall incorporate emergency stop features to stop the pump. The cabinet-mounted emergency stop button shall be a non-illuminated mushroom-style switch, two inches in diameter or larger. It shall be push-to-stop and remain in that position, and shall require twist-to-release to allow operation of the start button.

4.1.3.11 A hand-held, pendant-mounted emergency stop button shall be provided that performs the same functionality as the on-board emergency stop button. The button on the pendant shall be a non-illuminated mushroom-style switch, 1-1/2 inches in diameter. It shall be push-to-stop and remain in that position, and shall require pull to release to

allow operation of the start button. The pendant is to be on a 250-ft, SO-type cord that can be disconnected from the control cabinet when remote operation is not needed.

## 4.2 Syringe Pump

### 4.2.1 Size Constraint

The syringe pump shall be designed to fit within the secondary containment box of the mercury delivery system as shown in Figure 4. Maximum syringe pump width is 35 inches, and the maximum syringe pump extended length is 63 inches. Maximum overall height of the syringe pump is 18 inches.

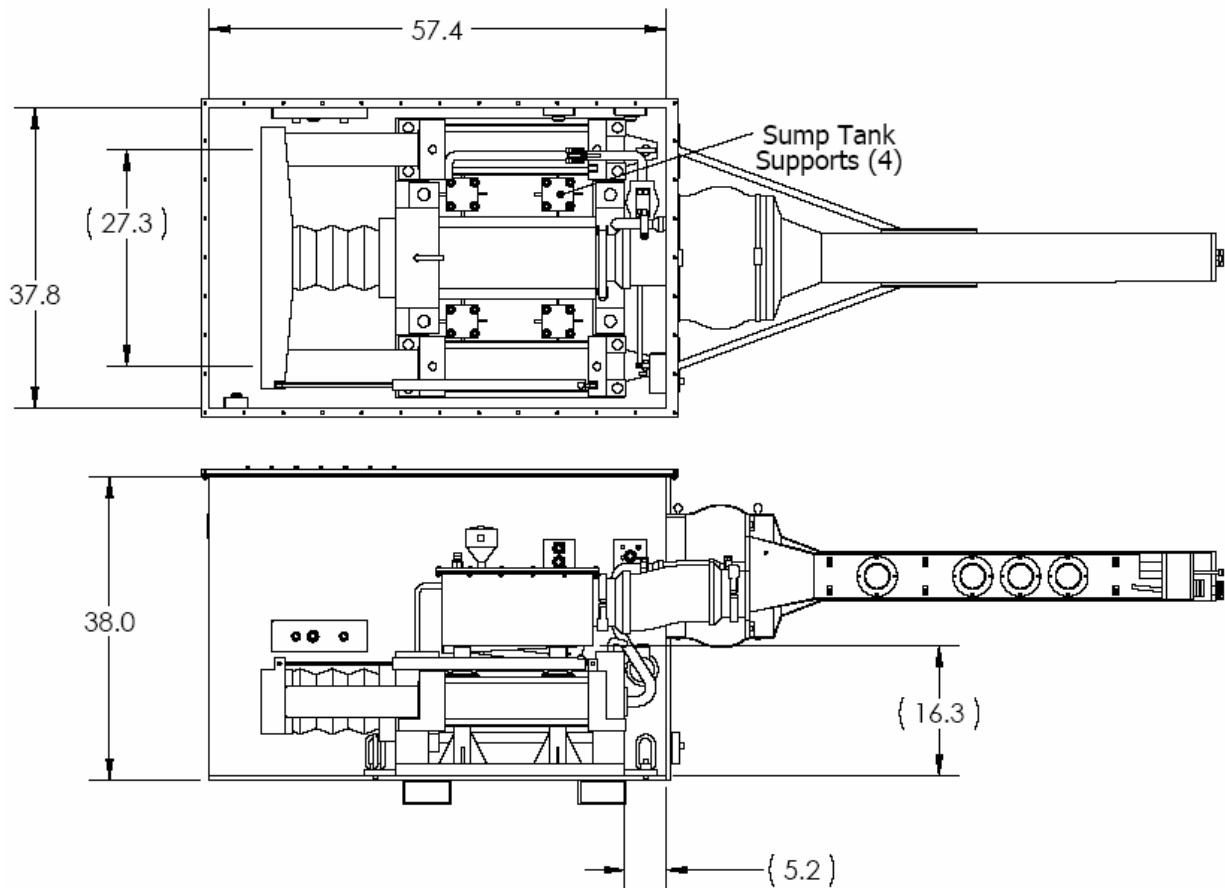


Figure 4. Syringe pump size constraints (dimensions in inches)

### 4.2.2 Pump Cylinder

4.2.2.1 The pump cylinder shall be a NFPA Industrial Type cylinder rated for 1500 psi service with a 15-inch stroke and a 10-inch bore.

4.2.2.2 Materials for the pump cylinder assembly shall be compatible with mercury; therefore, use of bronze, brass, copper, aluminum, and similar metals, for bearings, bushings, and other miscellaneous hardware is prohibited.

4.2.2.3 The cylinder, piston and rod shall be fabricated from SS304L or SS316L. The pump cylinder shall be designed for water service.

4.2.2.4 The seals in the pump cylinder shall be double-wipe Viton seals.

4.2.2.5 Ports/Fittings – Cylinder end shall have two 1-inch four-bolt flange ports for Hg inlet & outlet (SAE J518 Code 61) located at the top and bottom tangents of the cylinder bore. Rod end shall have 3/4-inch straight thread O-ring top port for vent (SAE J1926-1). Hg drain line stub shall be provided and shall include 90-deg fitting, 12 inches of 1/2" tubing, and a 1500-psig-rated stainless steel ball valve with end cap.

4.2.2.6 Containment - A boot (soft bellows) shall be provided to cover the extracted piston rod of the pump cylinder. The boot material and its connecting hardware must be compatible with mercury and shall serve as a vapor barrier. A vent port shall be provided to allow routed-venting of the boot cover. See Fig. 5.

#### 4.2.3 *Drive Cylinders*

4.2.3.1 The two drive cylinders shall be NFPA Industrial Type heavy-duty cylinders rated for a minimum 3000 psi service with suitable strokes.

4.2.3.2 The cylinder, piston and rod shall be fabricated from SS304L or SS316L.

4.2.3.3 The seals in the drive cylinders shall be double-wipe Viton seals.

4.2.3.4 Ports/Fittings – Supply and return ports shall be on the top of the drive cylinders. Ports shall be SAE J1926-1 straight-thread O-ring ports.

#### 4.2.4 *Base Support Structure*

4.2.4.1 The base support shall be fabricated from SS304L or SS316L.

4.2.4.2 The base support structure shall include four leg supports for a sump tank (that is not part of this procurement); the leg supports shall be designed to support 1000 lbs. at a height of two inches above the pump cylinder. See Figure 4 for interface dimensions.

4.2.4.3 Four swivel hoist rings shall be provided on the base support structure for vertical lifting. If the hoist rings are not easily removable, the rings shall be stainless steel. Locations shall be included on the design drawings approved by the Company prior to fabrication.

4.2.4.4 The base support structure shall include provisions for mechanical attachment to the floor of the secondary containment box through 4 studs welded to the secondary containment. The weld studs will be provided by the Company.

#### 4.2.5 *Tie Beam*

4.2.5.1 The tie beam shall be a demountable, rigid attachment joining the drive cylinder and the pump cylinder rods so that all three move simultaneously.

4.2.5.2 The tie beam shall be fabricated from SS304L or SS316L.

### 4.3 Instruments

#### 4.3.1 *Pressure Sensors*

Pressure sensors with local display and remote output capability (4-20mA output signal) shall be located at the pump discharge and inlet ports. See Fig. 5.

#### 4.3.2 *Position Sensor*

Both of the drive cylinders shall be fitted with a Celesco Model CLWG Linear Potentiometers or equivalent with a minimum of 10 ft. of instrument wire. See Fig. 1.

### 4.4 Design Documents

The Seller shall provide the complete design for the pump system, including calculations, in accordance with this specification. A complete set of design drawings and supporting documents describing key physical aspects of the pump system shall be submitted according to the Document Submission Schedule outlined in Section 9.0. The drawings and documents provided by the Seller shall include:

- Fully dimensioned and labeled assembly drawings, fabrication drawings, and relevant Seller catalog information;
- Electronic SolidWorks®-compatible 3D CAD models (with accurate external dimensions) of the pump system design for integration into the Company's overall experiment assembly model;
- Parts List of all components;
- Calculations supporting the design;
- Maintenance Manual for routine and non-routine maintenance; and
- Operations Manual for the hydraulic system.

All materials must be identified on the Seller's drawings by specification number, by generic name, and by grade or type. Company approval of the drawings and documents wherein materials are so identified, constitutes approval of the materials. Drawings shall be dimensioned in inches.

#### **4.5 Design Review**

A Design Review covering all aspects of the system design shall be held at the Seller's location within 30 days of subcontract award. The Company shall be notified at least 10 days prior to the design review date. No system components can be ordered prior to this Design Review.

#### **5.0 Inspection and Testing**

The Seller shall submit a Test and Inspection Plan for Company approval. This plan will be reviewed by the Company and returned to the Seller with hold/witness points designated. After the plan is approved, it shall constitute a part of this specification and shall be distributed to all responsible personnel involved in the manufacturing or testing of items covered by this specification. Such personnel shall be instructed to implement and carry out all provisions of the plan.

As part of the Company's quality assurance program, source surveillance activities may be conducted at the Seller's facility or any sub-tier Seller facility that the Company determines necessary to ensure that quality objectives are met. Such surveillance may include auditing and monitoring of production processes, in-process inspection and controls, chemical or physical certifications, final inspection and tests, preparation for shipment, and review of certification data. The Seller shall provide the Company representative(s) access to all data and operating areas pertinent to the contract. Source surveillance by the Company representative shall in no way relieve the Seller of the responsibility to furnish acceptable items.

#### **5.1 Acceptance Testing**

The Company shall have the right to witness final functional testing and inspection of the equipment at the Seller's site. Such testing shall be specified by the Seller to ensure full compliance of the equipment with the requirements of this specification. The Seller shall supply the Company with a Final Inspection and Testing Report. The requirement for witnessed-tests and inspections are at the Company's discretion upon receipt of the Seller's test and inspection plan.

Final acceptance tests of the syringe pump system shall be based on the tests outlined in the Test and Inspection Plan. The test setup shall include those items shown in Figure 5 as "*Needed for Test*." Tap water shall be used as the test fluid in the pump cylinder, and the cylinder shall be flush with distilled water at the conclusion of the test. At a minimum the acceptance tests shall demonstrate

- Velocity control of the pump cylinder using both local and remote control.
- Signal feedback from all sensors.
- Test fluid expulsion from the pump cylinder through a discharge pipe and nozzle. The discharge pipe shall be 1-inch dia with a minimum length of 6 ft, and the nozzle shall be

approximated by a 3-inch-long section of 5" pipe followed by a 4-inch-long section of 1/2" tube or some other method of providing a prototypic back pressure.

- Gravity intake of the test fluid through the discharge pipe.
- Operation of vent and drain ports.
- One hundred cycles of the syringe pump at a water discharge rate of 25 gpm, with a cycle rate of one complete discharge every 2 minutes.

Acceptance tests shall take place at the Seller's site using the actual components, equipment, and materials that will be delivered to the Company.

## **5.2 Seller's Responsibilities**

The Seller shall notify the Company ten (10) working days prior to the start of tests and inspections that are designated in the Test and Inspection Plan. The Company at its discretion shall have representatives witness the performance tests. Testing shall not be initiated until the Seller receives Company approval of all testing procedures to be used.

## **6.0 Quality Assurance**

The Seller shall provide a Quality Assurance Program for Company approval. The Program shall contain the following elements; training and qualification, improvement, documents and records, process control, design, procurement, inspection and test, and assessment.

### **6.1 Non-Conforming Items**

The Company expects to receive equipment items, components, materials, software, and documentation that conform to all codes, standards, specifications, and procedures in the Agreement. The Seller may use its own nonconformance program to identify, report, and recommend disposition of all non-conformances, but disposition that would leave any remaining nonconformity must be submitted to the Company for approval. A nonconformity request should identify the affected items(s) by name and serial number (if applicable), citing the drawing/specification number and revision number containing the specific requirement that has not been met. The Seller or the Seller's supplier may attach a description of the cause, and a corrective action plan and schedule if pertinent.

*Note:* The issuance and acceptance of such a request does not limit or affect the warranty provision of the Agreement. Such a request shall not establish a precedent or obligation to accept existing or future items not conforming to all provisions of the Agreement.

## **6.2 Seller's Requested Deviations**

The Seller may propose deviations from the specifications, drawings, or other technical requirements of this procurement. Where time is a consideration, the Seller may communicate the proposed deviations or changes directly to the Company's principal engineer or technical lead with a copy to the Company's buyer. The engineer or technical lead will evaluate the technical aspects and recommend to the buyer, who will communicate acceptance or disapproval to the Seller. The request should identify the affected items, drawing/specification number and revision number, a description of the proposed deviation, and the justification for it.

## **7.0 Schedule**

The pump system design, fabrication, and acceptance testing shall be completed 20 weeks after subcontract award. Delivery to ORNL shall take place immediately thereafter.

## **8.0 Packing, Shipping and Handling**

The pump system assembly(ies) shall be packed for truck shipping, and shipped via dedicated-truck transport.

### **8.1 Equipment Identification**

Each major assembly or component shall be tagged indicating the Seller's name and address, the Seller's equipment identification information, date of manufacture, and Company information as shown below:

Seller name and address  
Seller equipment identification number  
Date of manufacture

UT-Battelle, LLC  
ORNL, High Power Hg Target Experiment  
Oak Ridge, TN 37830  
Specification No.203-HJT-9000

## **9.0 Documentation**

Seller-supplied documentation shall be provided according to the schedule shown in Table 1. Wherever feasible, all documentation shall be submitted in an electronic format acceptable to the Company, in addition to any other formats. Adobe Portable Document Format (PDF) and Microsoft Word are examples of acceptable formats.



**Table 1. Document Submission Schedule**

Item Description	Specification Paragraph	Seller's Submittal Date	No. of Copies*	Company Approval Required
Assembly & Fabrication Dwgs, Seller Catalog Info	4.4	30 days after award	2	Yes
Parts List & Calculations	4.4	30 days after award	2	Yes
Quality Assurance Program	6.0	30 days after award	1	Yes
Test and Inspection Plan	5.0	30 days after award	1	Yes
Operating, and Maintenance Manual	4.4	Prior to shipment	3	No
Final Inspection and Test Reports	5.1	Prior to shipment	1	No

\*Multiple copies not required if documents submitted electronically

10.0 Hydraulic Schematic

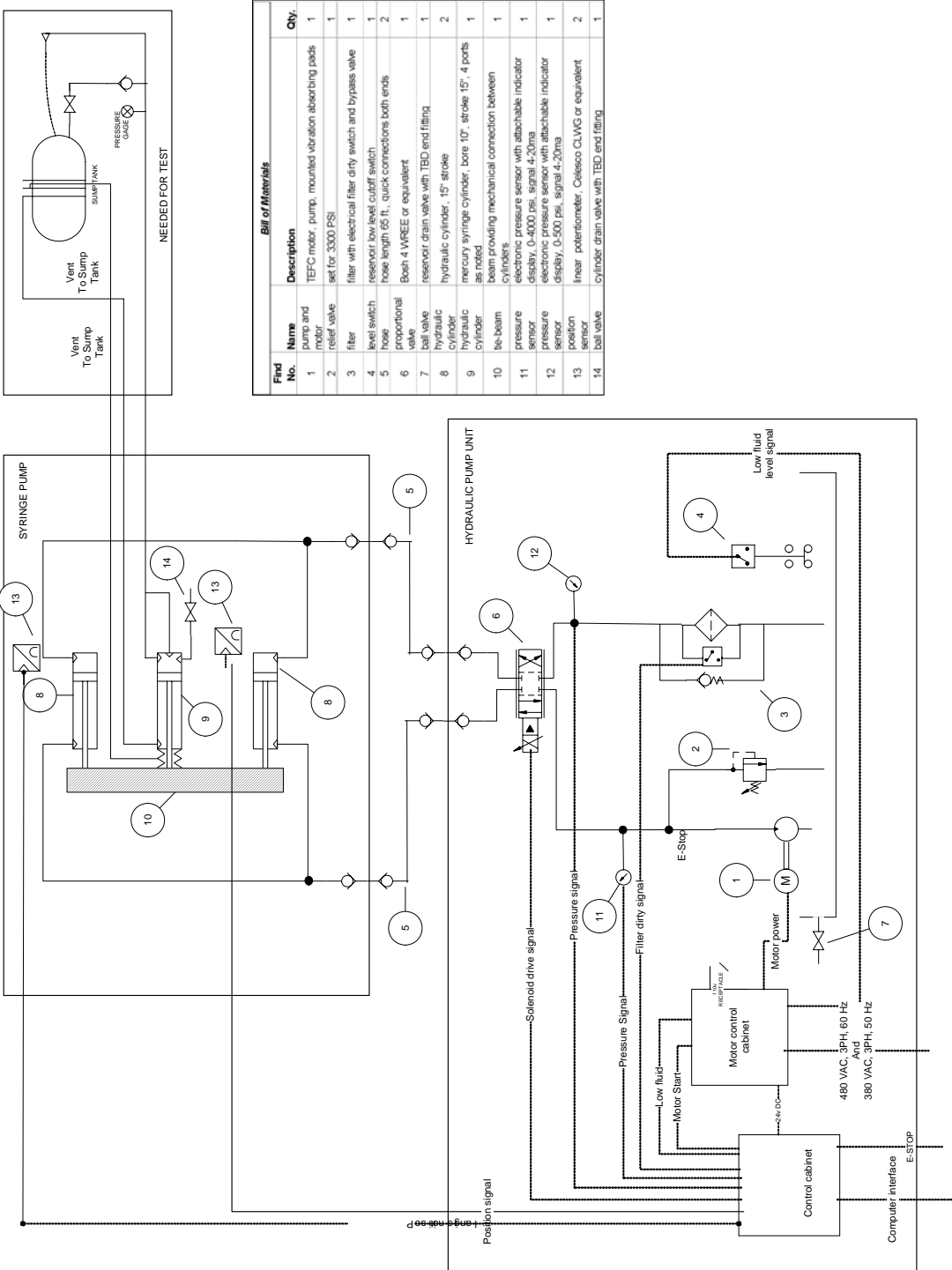


Fig. 5. Syringe Pump Schematic

August 24, 2005

## **Appendix C. Primary Containment Documents**



# 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

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

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

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

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

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

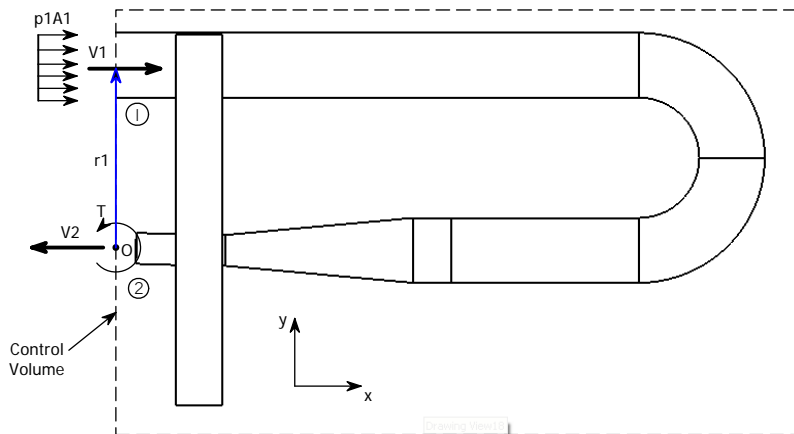
SHEET 1 OF 2

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).



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

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

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

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

$$A_1 = 3.96 \text{cm}^2 \quad A_2 = 0.811 \text{cm}^2$$

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

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

$$p_1 \text{ is obtained from AFT Fathom: } p_1 := 555 \text{psi} \quad p_1 = 3.827 \times 10^6 \text{Pa}$$



# MERIT Calculation Sheet

## Oak Ridge National Laboratory

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

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

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

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

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

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

$$T_o = 89.9 \text{ ft}\cdot\text{lbf}$$

$$T_o = 121.9 \text{ N}\cdot\text{m}$$



# MERIT Calculation Sheet

## Oak Ridge National Laboratory

CALCULATION Nozzle Flange Axial Force

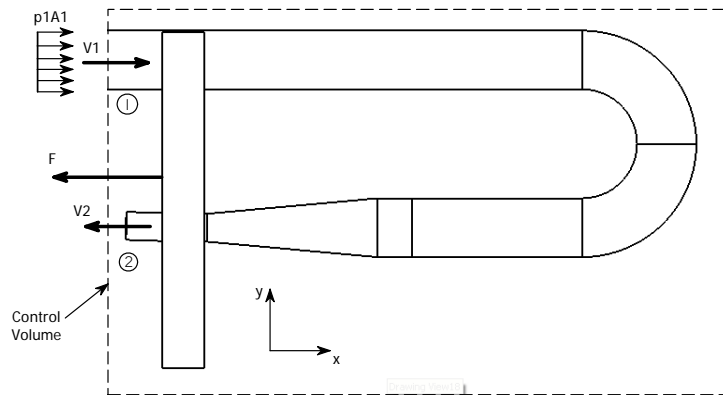
SHEET 1 OF 2

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).



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

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

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

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

$$A_1 = 3.96 \text{cm}^2 \quad A_2 = 0.811 \text{cm}^2$$

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

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



# MERIT Calculation Sheet

## Oak Ridge National Laboratory

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:

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

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

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

$$F = p_1 A_1 + \dot{m}(V_2 + V_1)$$

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

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

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

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

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

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

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





# MERIT Calculation Sheet

## Oak Ridge National Laboratory

CALCULATION Hg Supply Piping Moment

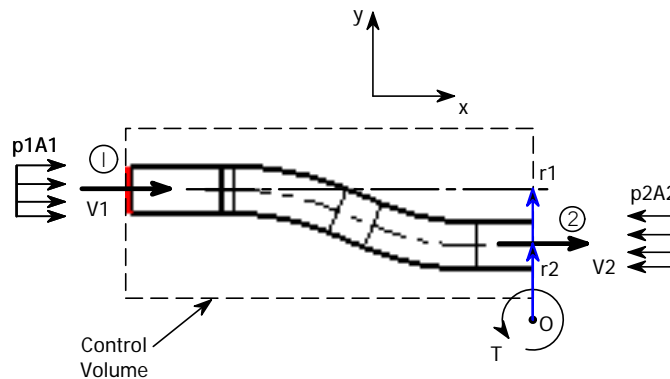
SHEET 1 OF 2

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.



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

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

$$d := 0.884 \text{in} \quad \text{Inlet \& exit diameters are equal}$$

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

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

$$p_2 := 572 \text{psi} \quad p_2 = 3.944 \times 10^6 \text{Pa}$$

$$r_1 := 1 \text{in} \quad r_2 := 2.25 \text{in} \quad \text{offsets}$$



# MERIT Calculation Sheet

## Oak Ridge National Laboratory

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

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

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

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

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

$$T_o := \text{mflow} \cdot V \cdot (r_2 - r_1) + A \cdot (r_1 \cdot p_1 - r_2 \cdot p_2) \quad \text{mflow} \cdot V \cdot (r_2 - r_1) = 1.974 \text{ ft} \cdot \text{lbf}$$

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

$$T_o = -34.3 \text{ ft} \cdot \text{lbf} \quad T_o = -46.5 \text{ N} \cdot \text{m}$$



# 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  
 $S_{\text{max}} := 12100\text{psi}$  max allowable stress per ASME VIII Table 1B  
 $E := 1$  joint efficiency per ASME VIII UW-12  
 $R_{\text{in}} := \frac{D - 2t}{2}$  inner radius

### Circumferential Stress (Longitudinal Joints)

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

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

### Longitudinal Stress (Circumferential Joints)

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

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

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 := 0.5in nominal OD  
 t := 0.035in wall thickness  
 P := 1500psi design pressure  
 $S_{\text{max}}$  := 14300psi max allowable stress per ASME VIII Table 1B  
 E := 1 joint efficiency per ASME VIII UW-12  
 $R_{\text{in}}$  :=  $\frac{D - 2t}{2}$  inner radius

### Circumferential Stress (Longitudinal Joints)

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

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

### Longitudinal Stress (Circumferential Joints)

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

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

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

$t_{\min 1} := \frac{P \cdot R_1}{S \cdot E - 0.6P}$	$t_{\min 1} = 0.046\text{ in}$	$t_{\min 1} = 1.18\text{ mm}$
$P_{\max 1} := \frac{S \cdot E \cdot t_1}{R_1 + 0.6t_1}$	$P_{\max 1} = 3344\text{ psi}$	$P_{\max 1} = 23.058 \times 10^6\text{ Pa}$

### Longitudinal Stress (Circumferential Joints) 3/4" pipe

$t_{\min 2} := \frac{P \cdot R_1}{2S \cdot E + 0.4P}$	$t_{\min 2} = 0.021\text{ in}$	$t_{\min 2} = 0.541\text{ mm}$
$P_{\max 2} := \frac{2S \cdot E \cdot t_1}{R_1 - 0.4t_1}$	$P_{\max 2} = 8749\text{ psi}$	$P_{\max 2} = 60.323 \times 10^6\text{ Pa}$



# MERIT Calculation Sheet

## Oak Ridge National Laboratory

CALCULATION Hg Supply Line Pressure Rating  
DRAWING NO 203-HJT-0670, -0680  
CALCULATION BY V.B. Graves

SHEET 2 OF 2

DATE 20 April 2006

### Circumferential Stress (Longitudinal Joints) 1" pipe

$$t_{\min 3} := \frac{P \cdot R_2}{S \cdot E - 0.6P} \quad t_{\min 3} = 0.059 \text{ in} \quad t_{\min 3} = 1.503 \text{ mm}$$

$$P_{\max 3} := \frac{S \cdot E \cdot t_2}{R_2 + 0.6t_2} \quad P_{\max 3} = 3125 \text{ psi} \quad P_{\max 3} = 21.548 \times 10^6 \text{ Pa}$$

### Longitudinal Stress (Circumferential Joints) 1" pipe

$$t_{\min 4} := \frac{P \cdot R_2}{2S \cdot E + 0.4P} \quad t_{\min 4} = 0.027 \text{ in} \quad t_{\min 4} = 0.689 \text{ mm}$$

$$P_{\max 4} := \frac{2S \cdot E \cdot t_2}{R_2 - 0.4t_2} \quad P_{\max 4} = 8014 \text{ psi} \quad P_{\max 4} = 55.258 \times 10^6 \text{ Pa}$$



# 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.

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

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

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

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

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.

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

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

$$S_y := 120000 \text{ psi} \quad \text{tensile yield strength of Ti6AlV4}$$

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

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

$$\text{Shear} \quad \tau := \frac{V}{A} = \frac{R_x}{w \cdot t} \quad \tau = 455.425 \text{ psi}$$

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



# MERIT Calculation Sheet

## Oak Ridge National Laboratory

CALCULATION Hg Supply Piping Moment

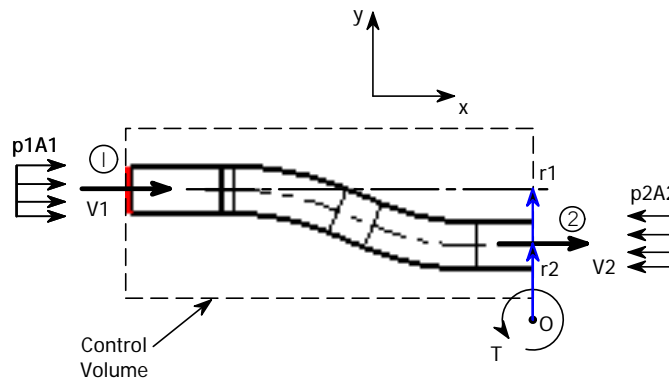
SHEET 1 OF 2

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.



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

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

$$d := 0.884 \text{in} \quad \text{Inlet \& exit diameters are equal}$$

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

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

$$p_2 := 572 \text{psi} \quad p_2 = 3.944 \times 10^6 \text{Pa}$$

$$r_1 := 1 \text{in} \quad r_2 := 2.25 \text{in} \quad \text{offsets}$$





# MERIT Calculation Sheet

## Oak Ridge National Laboratory

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

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

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

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

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

$$T_o := \text{mflow} \cdot V \cdot (r_2 - r_1) + A \cdot (r_1 \cdot p_1 - r_2 \cdot p_2) \quad \text{mflow} \cdot V \cdot (r_2 - r_1) = 1.974 \text{ ft} \cdot \text{lbf}$$

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

$$T_o = -34.3 \text{ ft} \cdot \text{lbf} \quad T_o = -46.5 \text{ N} \cdot \text{m}$$



# 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
$E := 50 \cdot 10^6 \text{ psi}$	modulus of elasticity
$S_y := 40000 \text{ psi}$	tensile yield strength sapphire
$a := 1.5 \text{ in}$	outer radius of unsupported viewport
$t := 0.236 \text{ in}$	viewport thickness
$q := 15 \text{ psi}$	pressure loading
$D := \frac{E \cdot t^3}{12 \cdot (1 - \nu^2)}$	plate constant
$y_c := \frac{-q \cdot a^4}{64D}$	deflection at center
$y_c = -1.984 \times 10^{-5} \text{ in}$	
$M_c := \frac{q \cdot a^2 \cdot (1 + \nu)}{16}$	moment at center
$\sigma := \frac{6M_c}{t^2}$	stress at center
$\sigma = 293.137 \text{ psi}$	
$FS := \frac{S_y}{\sigma}$	safety factor for pressure loading
$FS = 136.455$	

# Stress Analysis of Hg Sump Tank - Hg Weight

**Author: V.B. Graves**

**Company: Oak Ridge National Laboratory**

**Date: Nov 15, 2005**

1. [Introduction](#)
2. [Materials](#)
3. [Load & Restraint Information](#)
4. [Study Property](#)
5. [Stress Results](#)
6. [Displacement Results](#)
7. [Design Check Results](#)
8. [Conclusion](#)
9. [Appendix](#)

---

## 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	<a href="#">AISI 304</a>	59.5098 lb	205.903 in <sup>3</sup>
2	sump tank hjt	<a href="#">AISI 304</a>	59.5098 lb	205.903 in <sup>3</sup>
3	sump tank hjt	<a href="#">AISI 304</a>	59.5098 lb	205.903 in <sup>3</sup>

## 3. Load & Restraint Information

Restraint	
<b>Restraint-1 &lt;sump tank hjt&gt;</b>	on <b>2 Face(s)</b> fixed.
<b>Description:</b>	Tank bottom restrained where it contacts supports.

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

	bottom face.	
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## 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

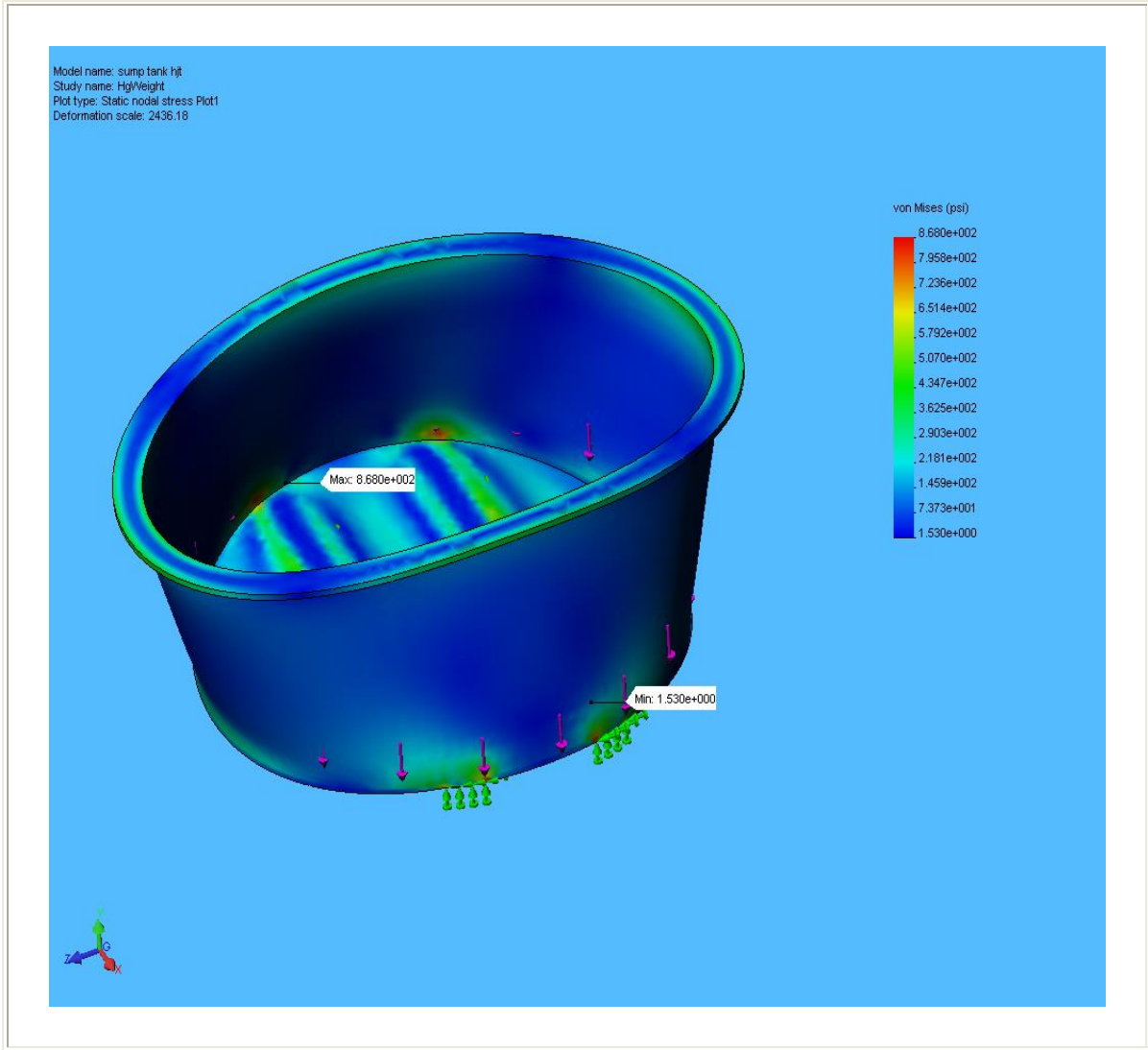
---

## 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 hgt-HgWeight-Stress-Plot1**

**JPEG**



## 6. Displacement Results

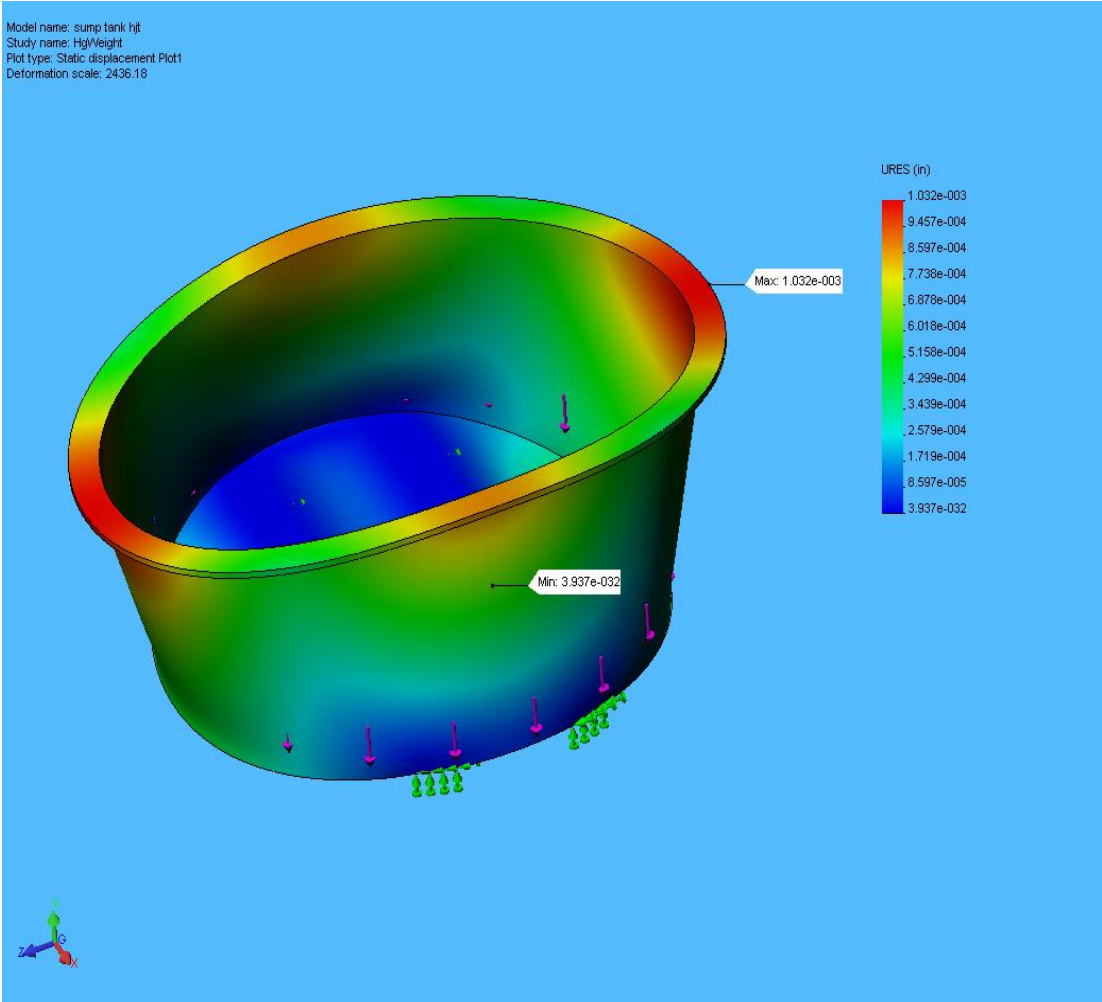
Name	Type	Min	Location	Max	Location
Plot1	URES: Resultant displacement	0 in	(9.18681	0.00103167	(1.34711e-
		Node:	in,	in	015 in,

		24918	0 in, 3.95 in)	Node: 23190	9.75 in, -11 in)
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sump tank hjt-HgWeight-Displacement-Plot1

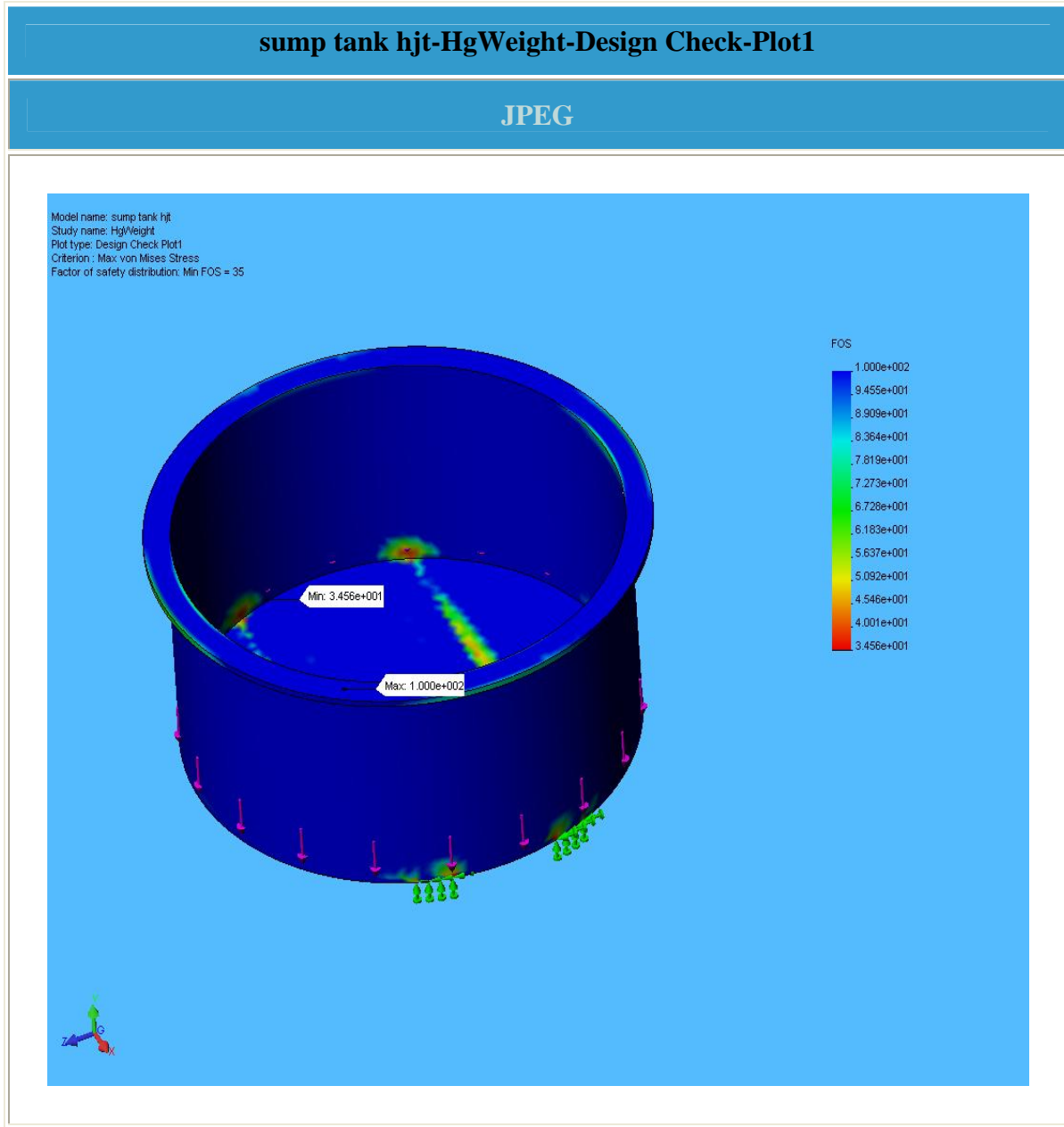
JPEG

Model name: sump tank hjt  
 Study name: HgWeight  
 Plot type: Static displacement Plot1  
 Deformation scale: 2436.18





## 7. Design Check Results



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## 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 <sup>3</sup>	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 Sump Tank - Internal Pressure

**Author: V.B. Graves**

**Company: Oak Ridge National Laboratory**

**Date: Nov 15, 2005**

1. [Introduction](#)
2. [Materials](#)
3. [Load & Restraint Information](#)
4. [Study Property](#)
5. [Stress Results](#)
6. [Displacement Results](#)
7. [Design Check Results](#)
8. [Conclusion](#)
9. [Appendix](#)

---

## 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	<a href="#">AISI 304</a>	59.5098 lb	205.903 in <sup>3</sup>
2	sump tank hjt	<a href="#">AISI 304</a>	59.5098 lb	205.903 in <sup>3</sup>
3	sump tank hjt	<a href="#">AISI 304</a>	59.5098 lb	205.903 in <sup>3</sup>

---

## 3. Load & Restraint Information

Restraint	
<b>Restraint-1 &lt;sump tank hjt&gt;</b>	on 2 Face(s) fixed.
<b>Description:</b>	Tank bottom restrained where it contacts supports.

Load		
<b>Pressure-1 &lt;sump tank hjt&gt;</b>	on 2 Face(s) with Pressure <b>15 psi</b> along direction normal to selected face	Sequential Loading
<b>Description:</b>	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

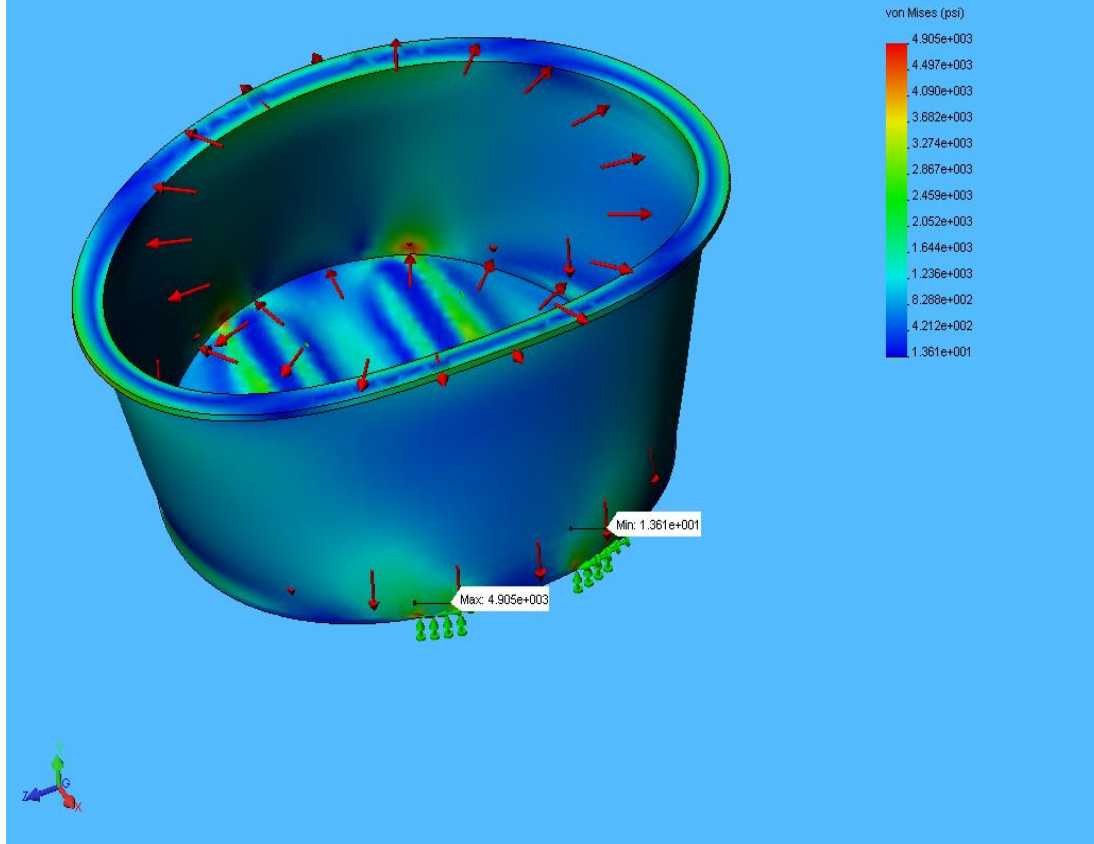
Name	Type	Min	Location	Max	Location
------	------	-----	----------	-----	----------

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

### sump tank hjt-Pressure1atm-Stress-Plot1

JPEG

Model name: sump tank hjt  
 Study name: Pressure1atm  
 Plot type: Static nodal stress Plot1  
 Deformation scale: 379.796

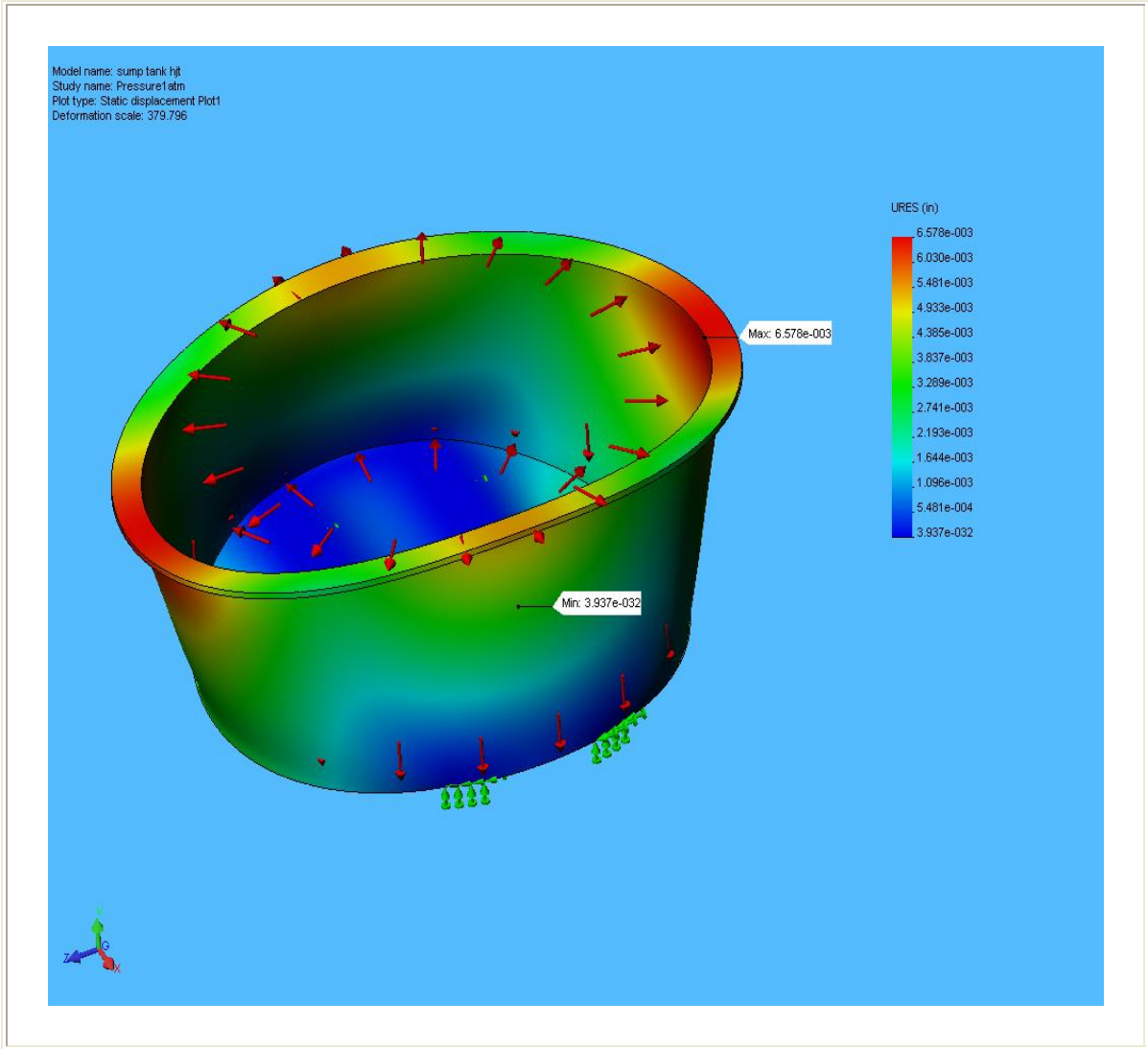


## 6. Displacement Results

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

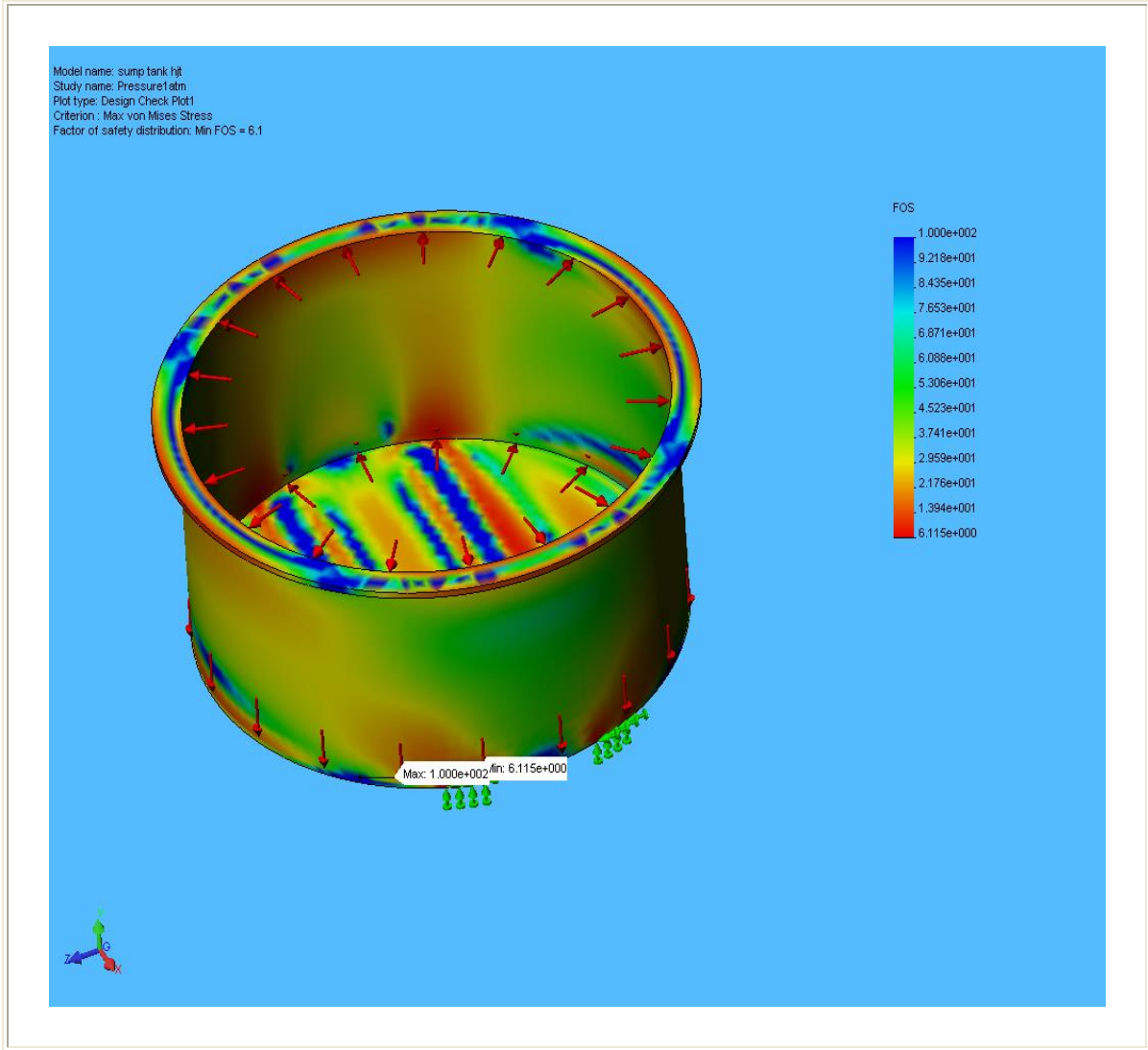


## 7. Design Check Results

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 <sup>3</sup>	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](#)
2. [Materials](#)
3. [Load & Restraint Information](#)
4. [Study Property](#)
5. [Stress Results](#)
6. [Displacement Results](#)
7. [Design Check Results](#)
8. [Conclusion](#)
9. [Appendix](#)

---

## 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	<a href="#">AISI 304</a>	44.7162 lb	154.718 in <sup>3</sup>
2	pri tube weldment hjt	<a href="#">AISI 304</a>	44.7162 lb	154.718 in <sup>3</sup>
3	pri tube weldment hjt	<a href="#">AISI 304</a>	44.7162 lb	154.718 in <sup>3</sup>
4	pri tube weldment hjt	<a href="#">AISI 304</a>	44.7162 lb	154.718 in <sup>3</sup>
5	pri tube weldment hjt	<a href="#">AISI 304</a>	44.7162 lb	154.718 in <sup>3</sup>
6	pri tube weldment hjt	<a href="#">AISI 304</a>	44.7162 lb	154.718 in <sup>3</sup>

## 3. Load & Restraint Information

Restraint	
<b>Restraint-1 &lt;pri tube weldment hjt&gt;</b>	on <b>1 Face(s)</b> fixed.
<b>Description:</b>	Exit end face held fixed.

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

---

## 4. Study Property

<b>Mesh Information</b>	
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

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

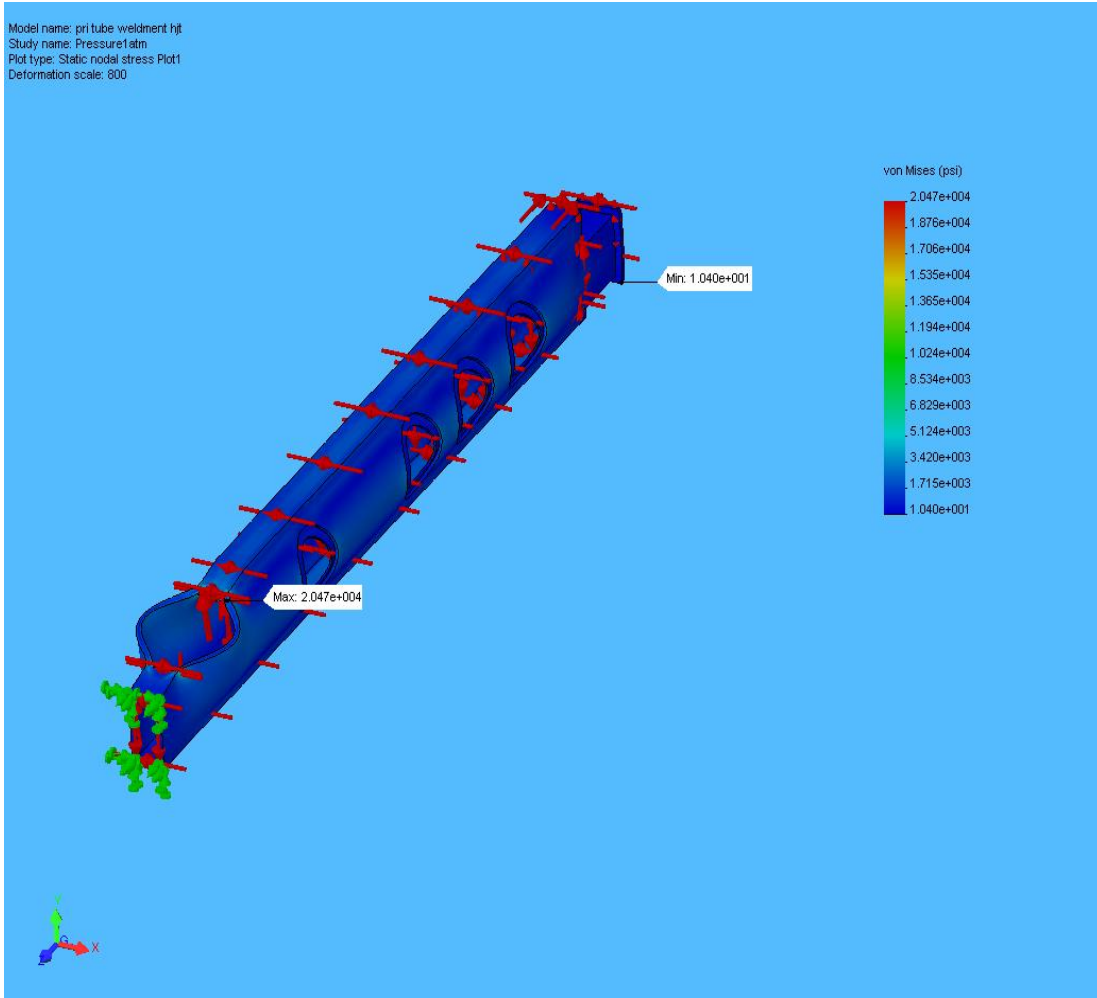
---

## 5. Stress Results

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

pri tube weldment hjt-Pressure1atm-Stress-Plot1

JPEG

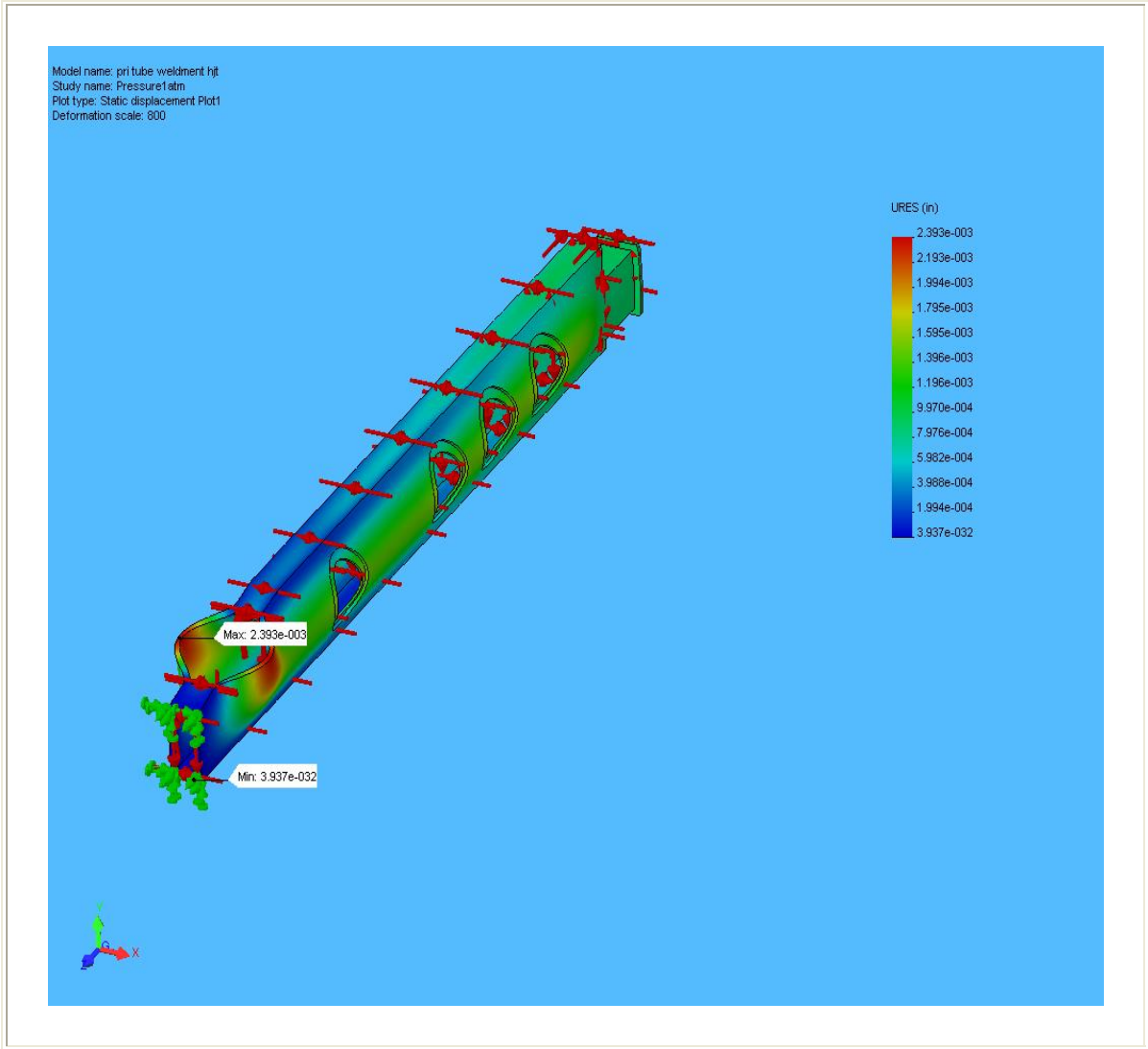


## 6. Displacement Results

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**

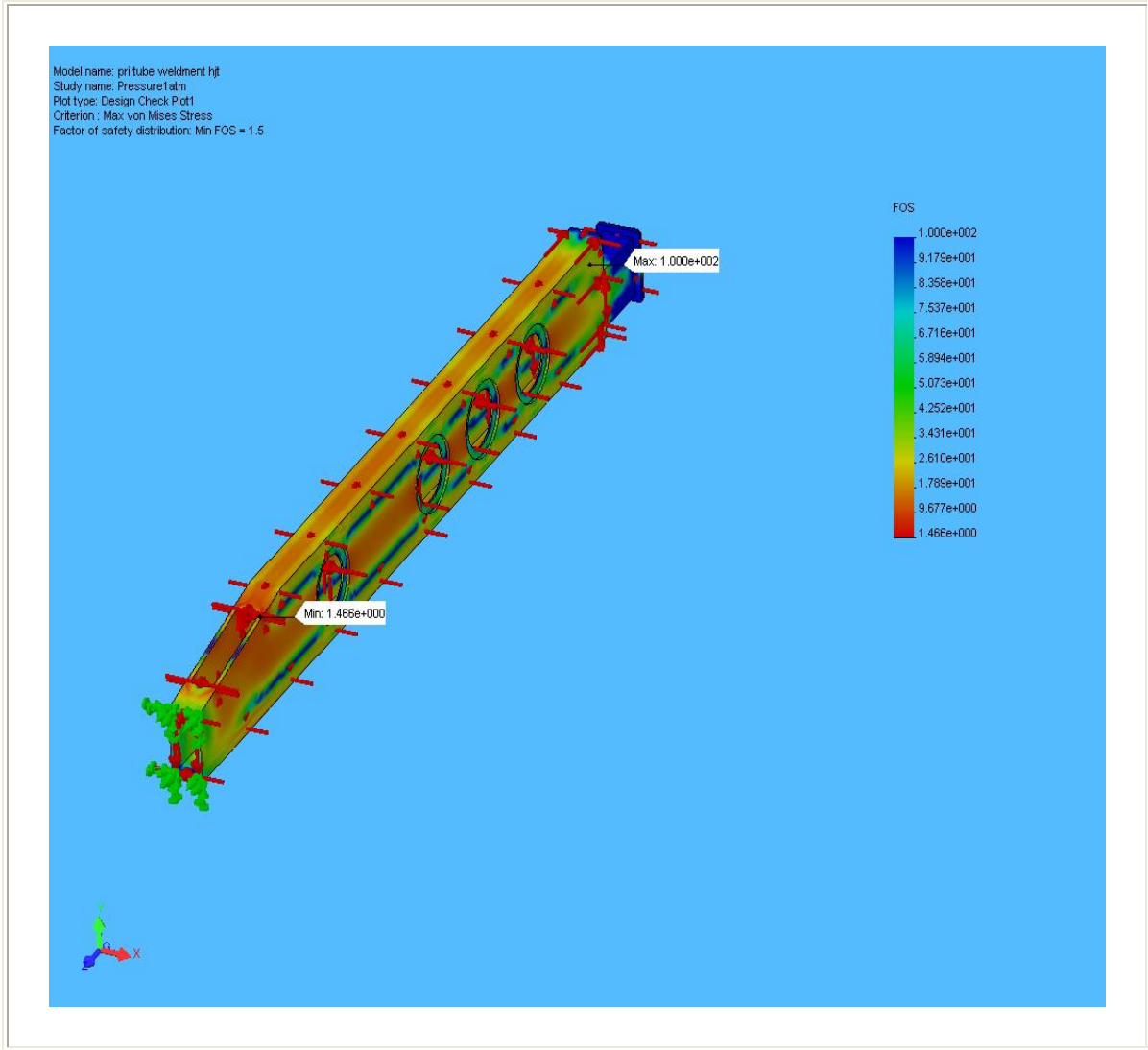


## 7. Design Check Results

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 <sup>3</sup>	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](#)
2. [Materials](#)
3. [Load & Restraint Information](#)
4. [Study Property](#)
5. [Stress Results](#)
6. [Displacement Results](#)
7. [Design Check Results](#)
8. [Conclusion](#)
9. [Appendix](#)

---

## 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	<a href="#">Titanium Ti-6Al-4V (Grade 5), Annealed</a>	0.0998634 lb	0.623975 in <sup>3</sup>

## 3. Load & Restraint Information

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

Load		
<b>Pressure-1 &lt;hg supply reducer hjt&gt;</b>	on 3 Face(s) with Pressure <b>1500 psi</b> along direction normal to selected face	Sequential Loading
<b>Description:</b>	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

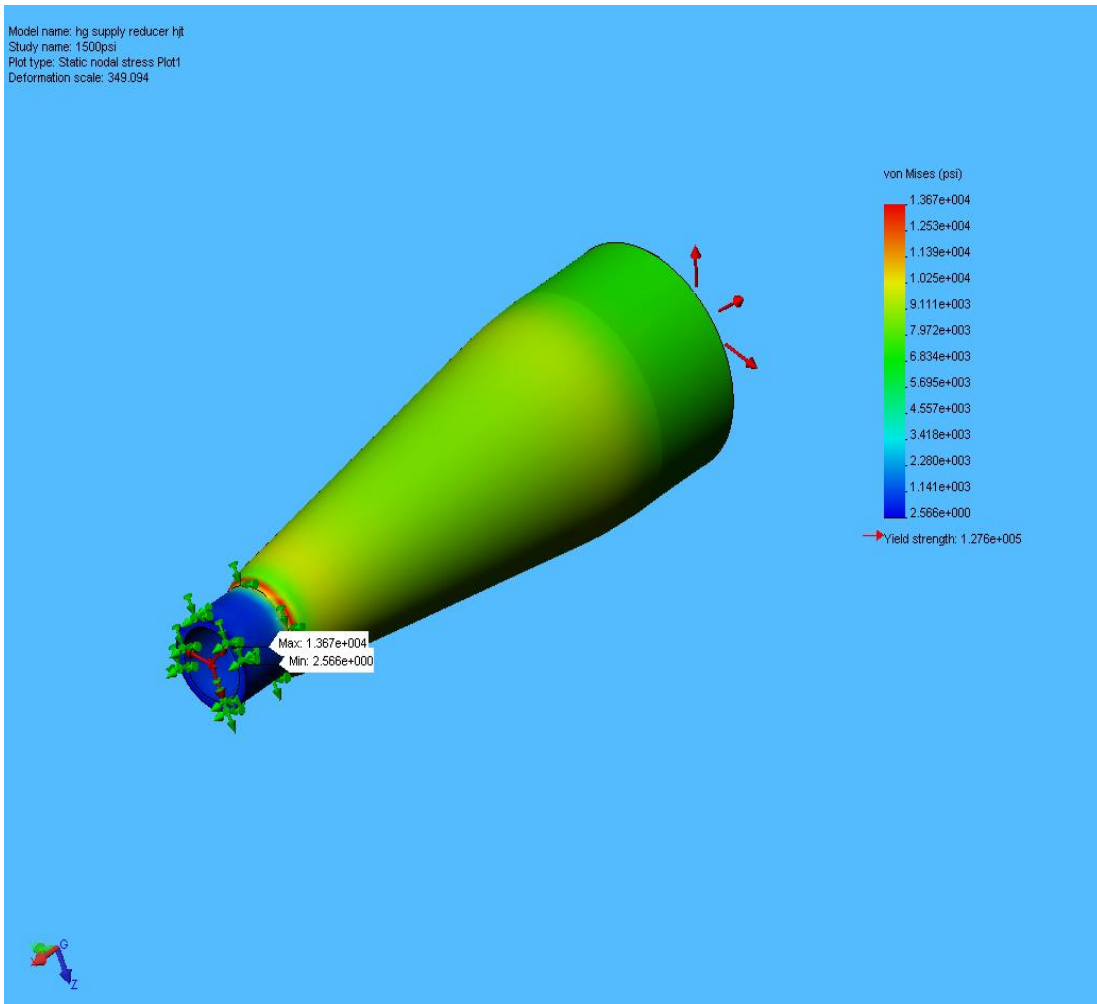
Name	Type	Min	Location	Max	Location
Plot1	VON: von Mises stress	2.56573 psi Node: 2509	(0.375 in, -0.249301 in, 0.0186825	13665.3 psi Node: 14939	(- 0.041552 in, 0.244426

			in)		in,
					0.0683738
					in)

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

JPEG

Model name: hg supply reducer hjt  
 Study name: 1500psi  
 Plot type: Static nodal stress Plot1  
 Deformation scale: 349.094

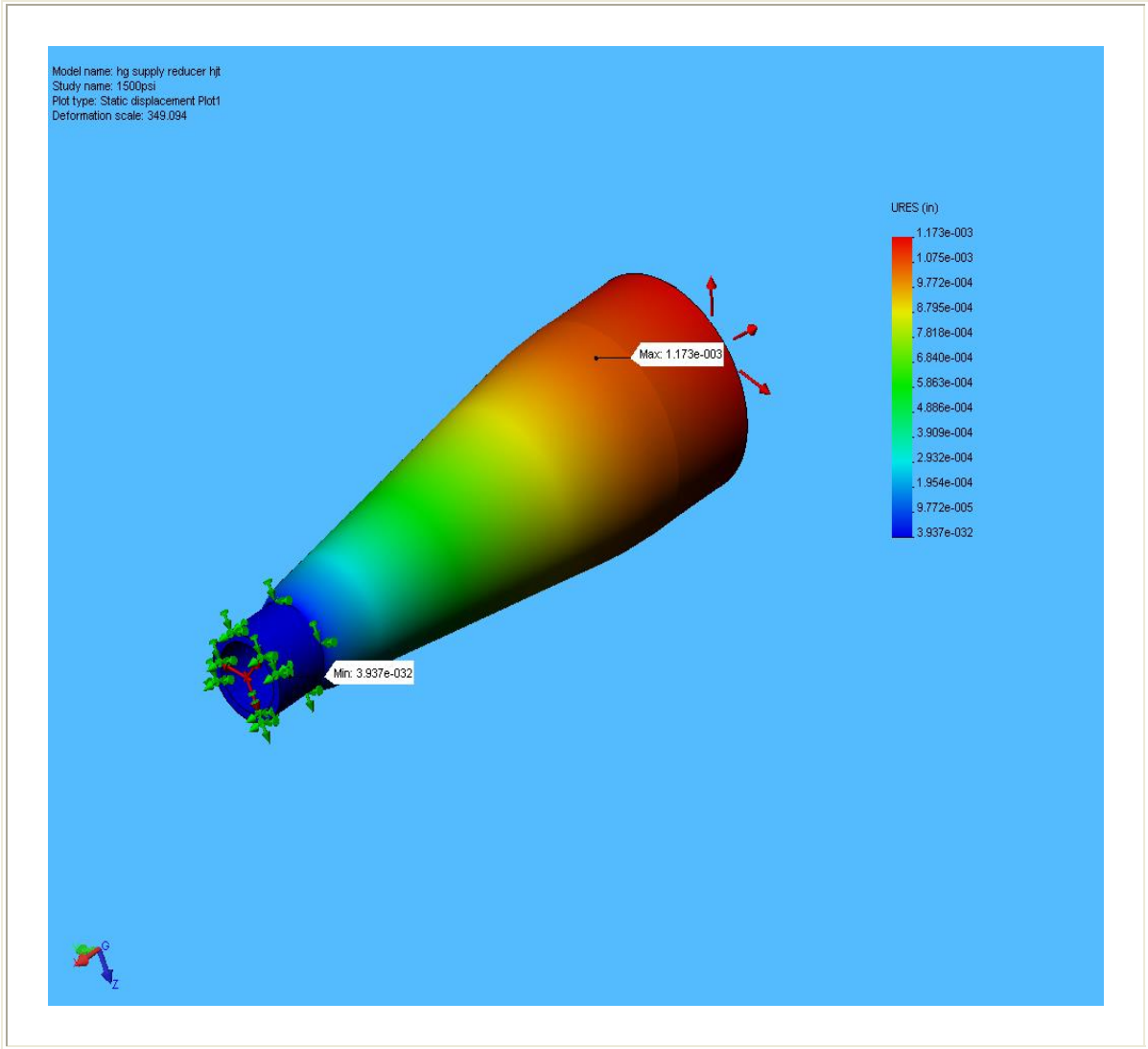


## 6. Displacement Results

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

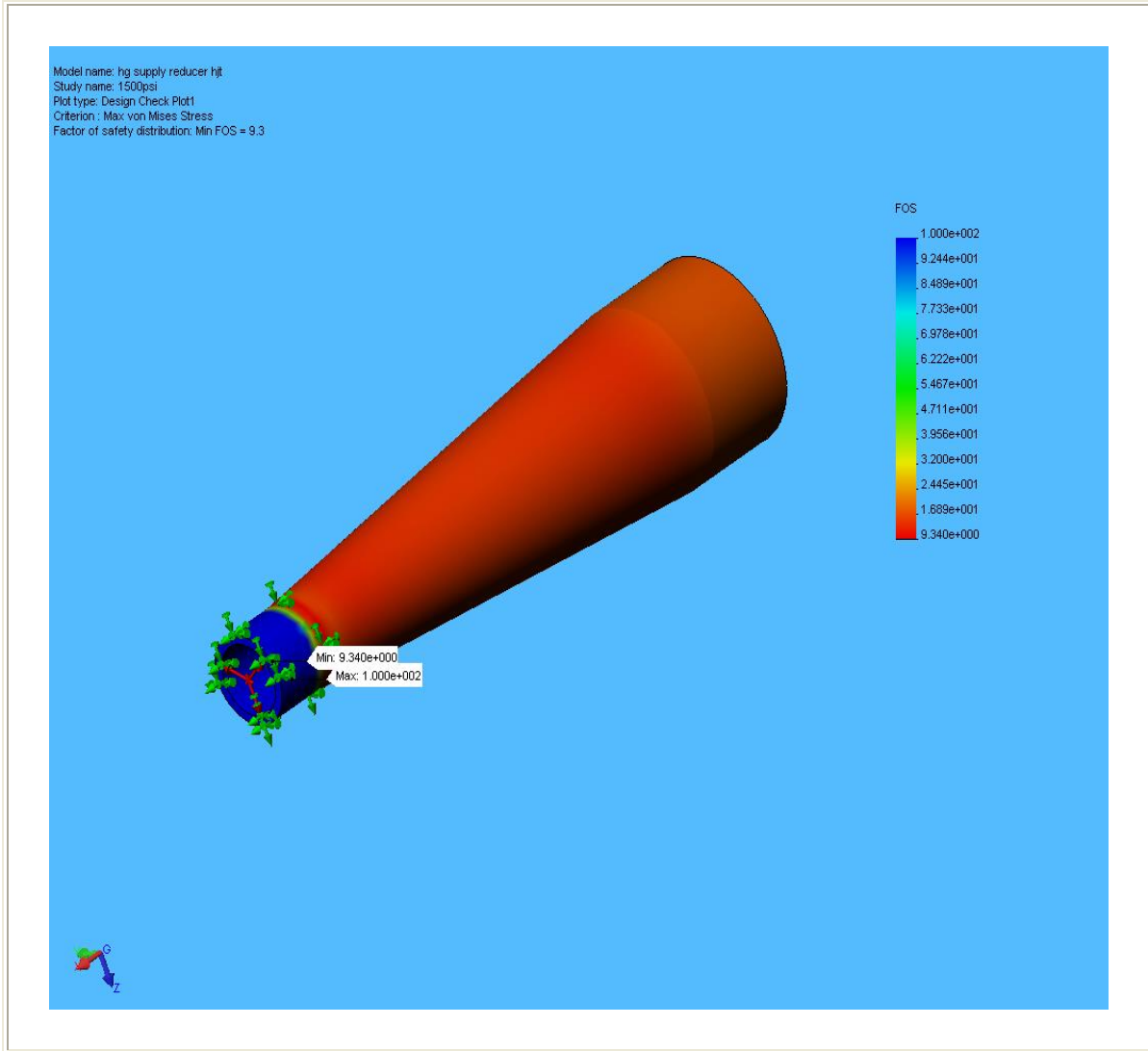


## 7. Design Check Results

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

JPEG





---

## 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 <sup>3</sup>	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

## **Appendix D. Secondary Containment Documents**

# Stress Analysis of Secondary Containment Box Supports

**Author: V.B. Graves**

**Company: Oak Ridge National Laboratory**

**Date: May 19, 2006**

1. [Introduction](#)
2. [Materials](#)
3. [Load & Restraint Information](#)
4. [Study Property](#)
5. [Stress Results](#)
6. [Displacement Results](#)
7. [Design Check Results](#)
8. [Conclusion](#)
9. [Appendix](#)

---

## 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:  $2000 * \cos(4.2) = 1995 \text{ lb}$

Horizontal load on surface:  $2000 * \sin(4.2) = 150 \text{ lb}$

**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	<a href="#">AISI 316 Annealed Stainless Steel Bar (SS)</a>	47.6618 lb	164.909 in <sup>3</sup>
2	rect tubing support hjt	<a href="#">AISI 316 Annealed Stainless Steel Bar (SS)</a>	47.6618 lb	164.909 in <sup>3</sup>
3	rect tubing support hjt	<a href="#">AISI 316 Annealed Stainless Steel Bar (SS)</a>	47.6618 lb	164.909 in <sup>3</sup>
4	rect tubing support hjt	<a href="#">AISI 316 Annealed Stainless Steel Bar (SS)</a>	47.6618 lb	164.909 in <sup>3</sup>

## 3. Load & Restraint Information

Restraint	
<b>Restraint-1 &lt;rect tubing support hjt&gt;</b>	on 1 Face(s) fixed.
<b>Description:</b>	Bottom surface restrained.

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

---

## 4. Study Property

<b>Mesh Information</b>	
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

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

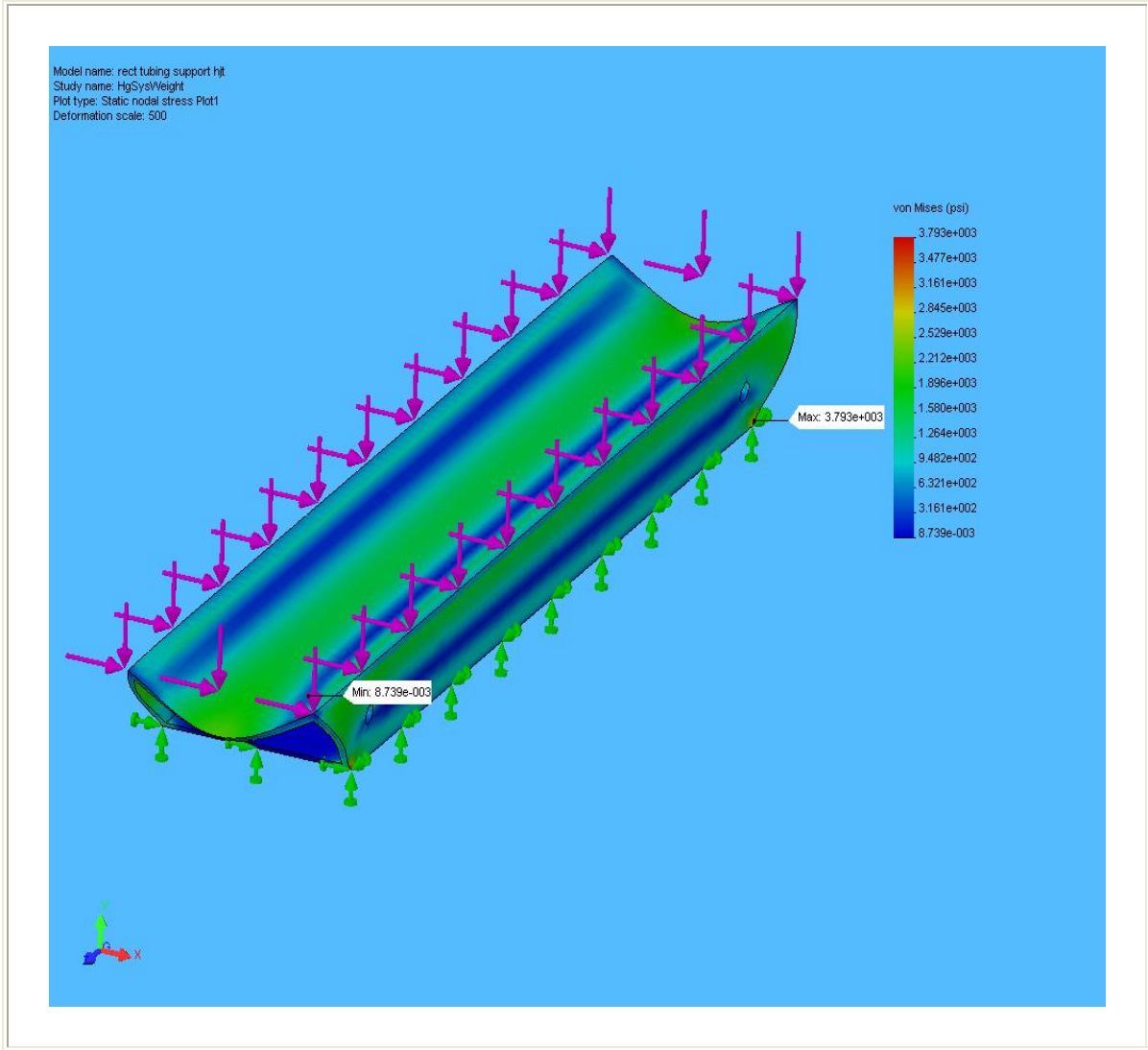
---

## 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	(3.5 in,	0.00291197	(-
		Node:	-1.5 in,	in	5.63193e-

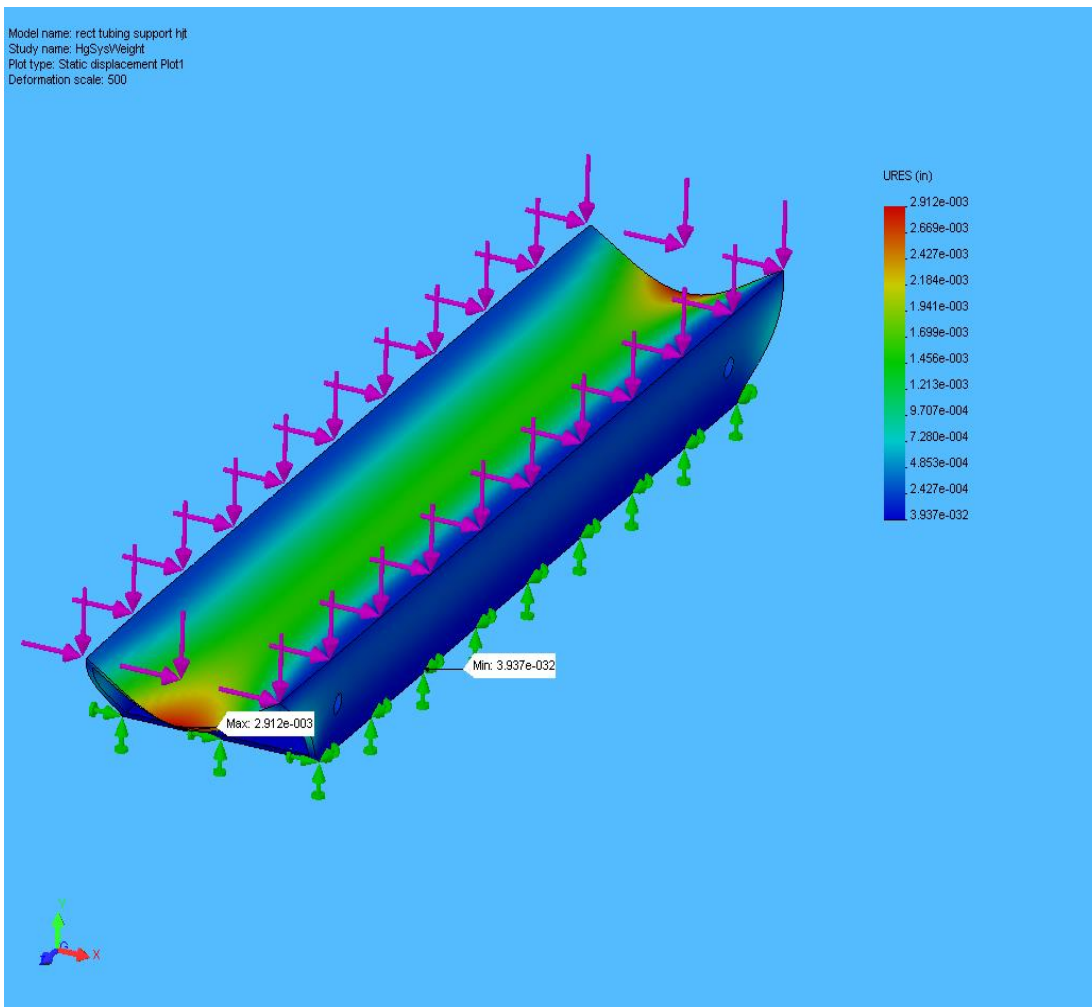


		16457	15.75 in)	Node: 4390	009 in, 1.5 in, 19 in)
--	--	-------	--------------	------------	------------------------------

**rect tubing support hjt-HgSysWeight-Displacement-Plot1**

JPEG

Model name: rect tubing support hjt  
 Study name: HgSys/Weight  
 Plot type: Static displacement Plot1  
 Deformation scale: 500

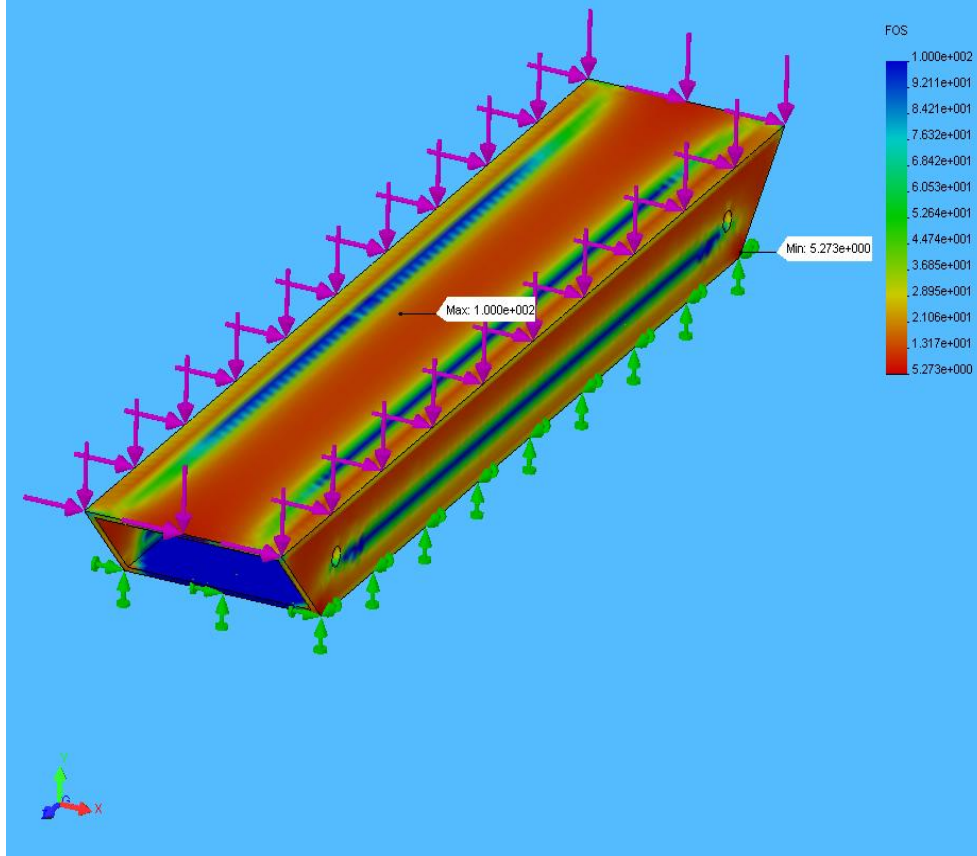


## 7. Design Check Results

rect tubing support hjt-HgSysWeight-Design Check-Plot1

JPEG

Model name: rect tubing support hjt  
Study name: HgSysWeight  
Plot type: Design Check Plot1  
Criterion: Max von Mises Stress  
Factor of safety distribution: Min FOS = 5.3



---

## 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 <sup>3</sup>	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](#)
2. [Materials](#)
3. [Load & Restraint Information](#)
4. [Study Property](#)
5. [Stress Results](#)
6. [Displacement Results](#)
7. [Design Check Results](#)
8. [Conclusion](#)
9. [Appendix](#)

---

## 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	<a href="#">User Defined</a>	0.491469 lb	3.07168 in <sup>3</sup>
2	double window hjt	<a href="#">User Defined</a>	0.491469 lb	3.07168 in <sup>3</sup>
3	double window hjt	<a href="#">User Defined</a>	0.491469 lb	3.07168 in <sup>3</sup>
4	double window hjt	<a href="#">User Defined</a>	0.491469 lb	3.07168 in <sup>3</sup>

---

## 3. Load & Restraint Information

Restraint	
<b>Restraint-1 &lt;double window hjt&gt;</b>	on <b>1 Face(s)</b> fixed.
<b>Description:</b>	Flange fixed.
<b>Restraint-2 &lt;double window hjt&gt;</b>	on <b>4 Face(s)</b> symmetry
<b>Description:</b>	

Load		
<b>Pressure-1 &lt;double window</b>	on <b>3 Face(s)</b> with Pressure <b>15 psi</b> along direction normal to selected face	Sequential Loading

<b>hjt&gt;</b>		
<b>Description:</b>	15 psi on all internal surfaces.	

---

## 4. Study Property

<b>Mesh Information</b>	
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

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

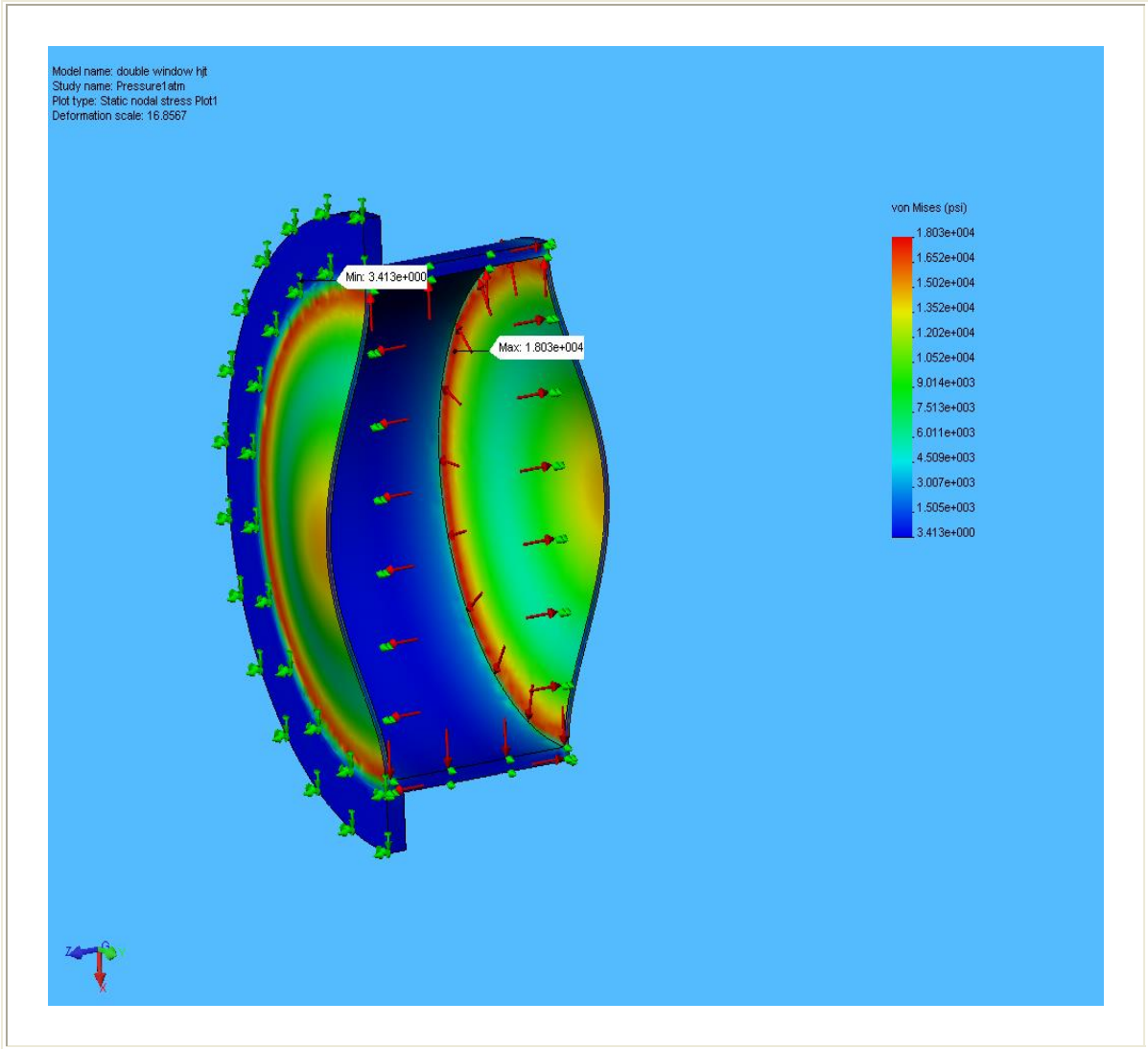
---

## 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,

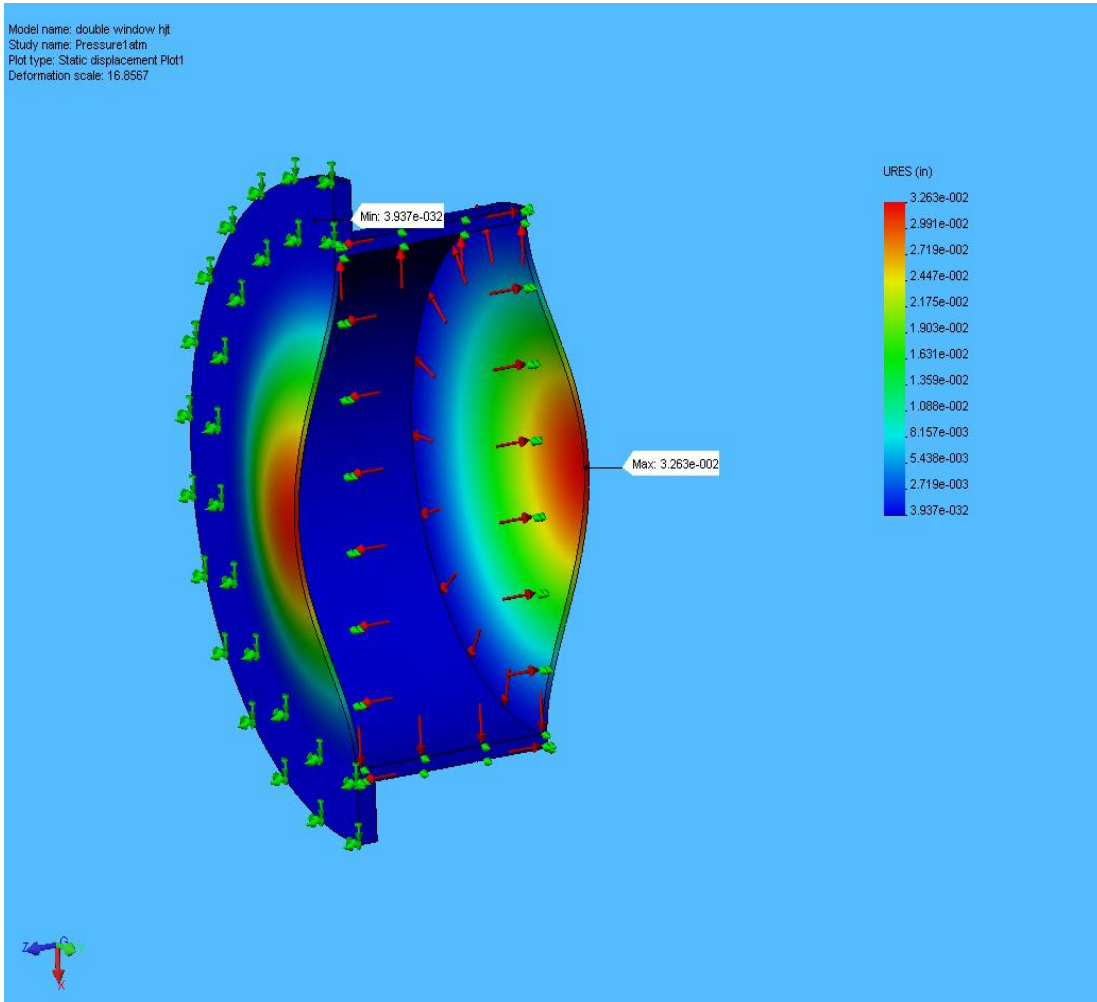


displacement	35	-2.25 in, 1 in)	Node: 36345	0 in, -0.976 in)
--------------	----	--------------------	----------------	---------------------

### double window hjt-Pressure1atm-Displacement-Plot1

JPEG

Model name: double window hjt  
 Study name: Pressure1atm  
 Plot type: Static displacement Plot1  
 Deformation scale: 16.8567

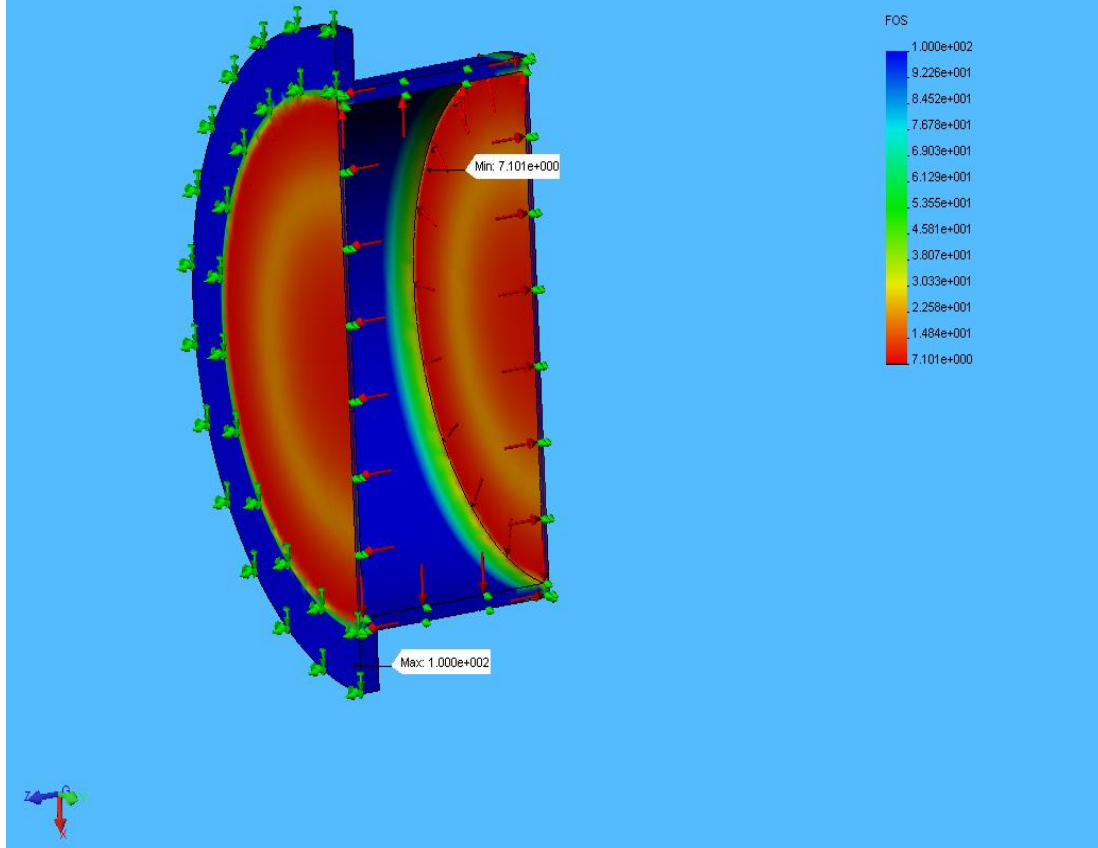


## 7. Design Check Results

double window hjt-Pressure1atm-Design Check-Plot1

JPEG

Model name: double window hjt  
Study name: Pressure1atm  
Plot type: Design Check Plot1  
Criterion: Max von Mises Stress  
Factor of safety distribution: Min FOS = 7.1



---

## 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 <sup>3</sup>	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](#)
2. [Materials](#)
3. [Load & Restraint Information](#)
4. [Study Property](#)
5. [Stress Results](#)
6. [Displacement Results](#)
7. [Design Check Results](#)
8. [Conclusion](#)
9. [Appendix](#)

---

## 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	<a href="#">6061-T6 (SS)</a>	13.4186 lb	137.565 in <sup>3</sup>
2	support cradle hjt	<a href="#">6061-T6 (SS)</a>	13.4186 lb	137.565 in <sup>3</sup>
3	support cradle hjt	<a href="#">6061-T6 (SS)</a>	13.4186 lb	137.565 in <sup>3</sup>
4	support cradle hjt	<a href="#">6061-T6 (SS)</a>	13.4186 lb	137.565 in <sup>3</sup>
5	support cradle hjt	<a href="#">6061-T6 (SS)</a>	13.4186 lb	137.565 in <sup>3</sup>
6	support cradle hjt	<a href="#">6061-T6 (SS)</a>	13.4186 lb	137.565 in <sup>3</sup>

---

## 3. Load & Restraint Information

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

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

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

---

## 4. Study Property

<b>Mesh Information</b>	
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

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

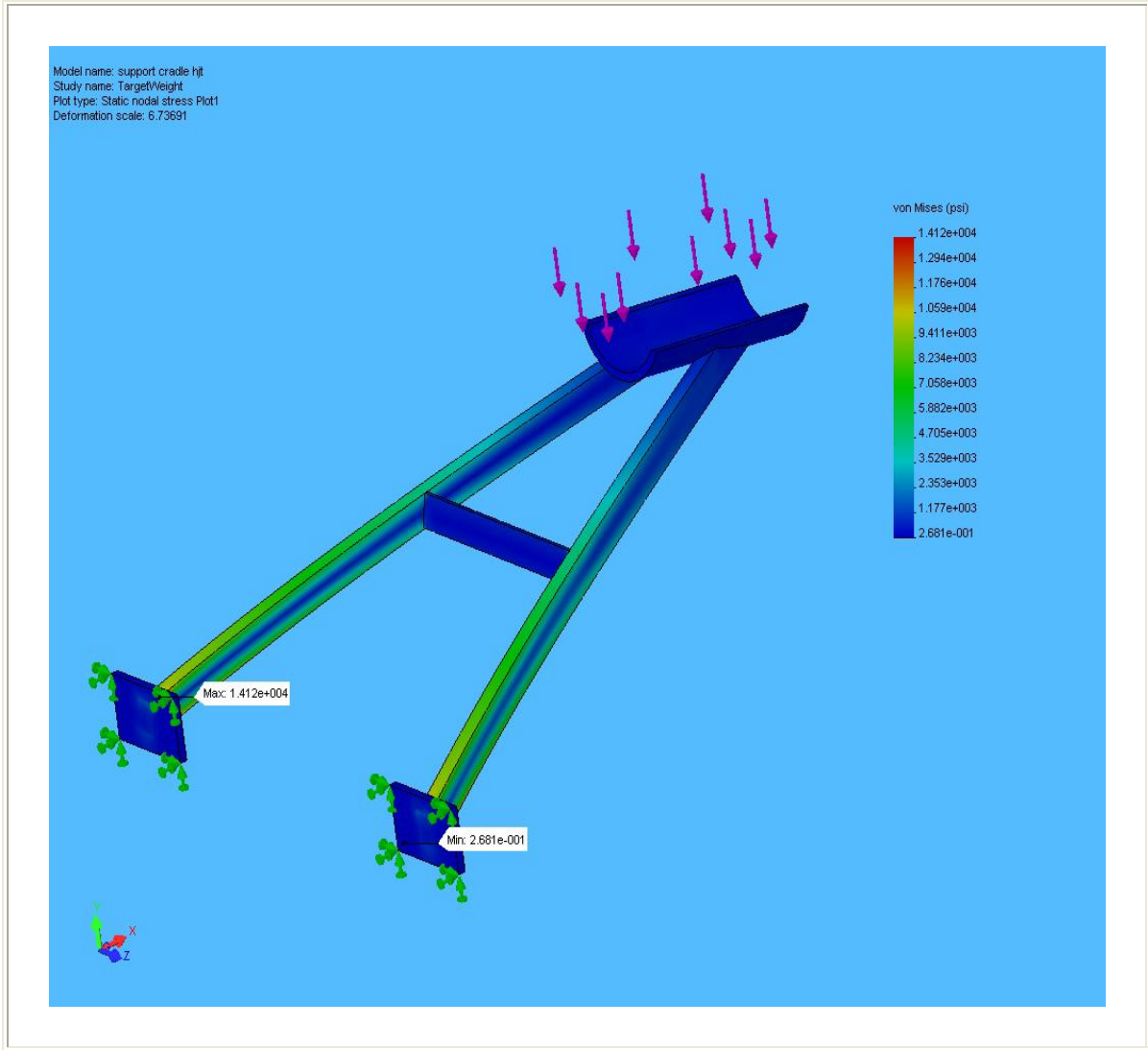
---

## 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	(0 in,	0.649145	(40 in,
		Node:	2 in,	in	17.9149

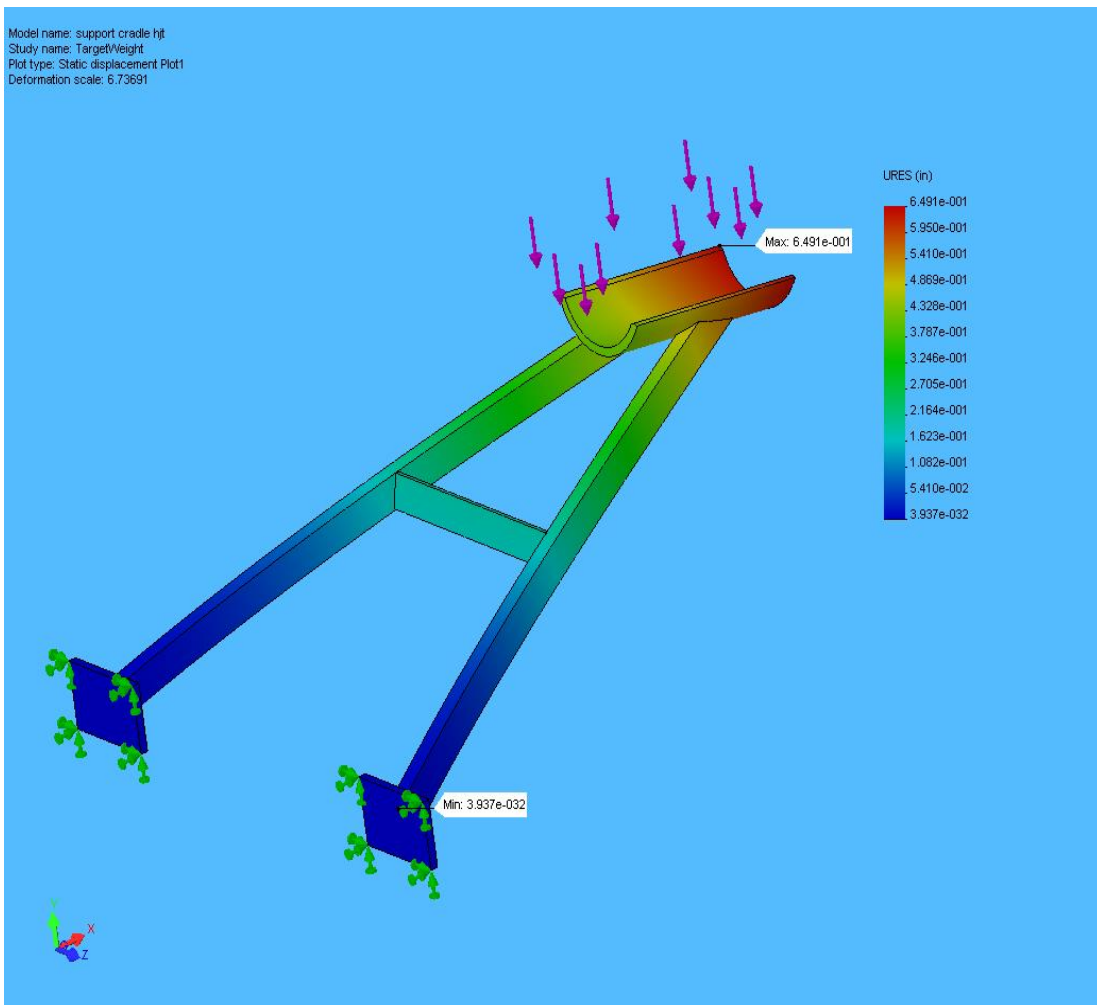


		28395	16.725 in)	Node: 742	in, - 3.46455 in)
--	--	-------	---------------	--------------	----------------------------

**support cradle hjt-TargetWeight-Displacement-Plot1**

JPEG

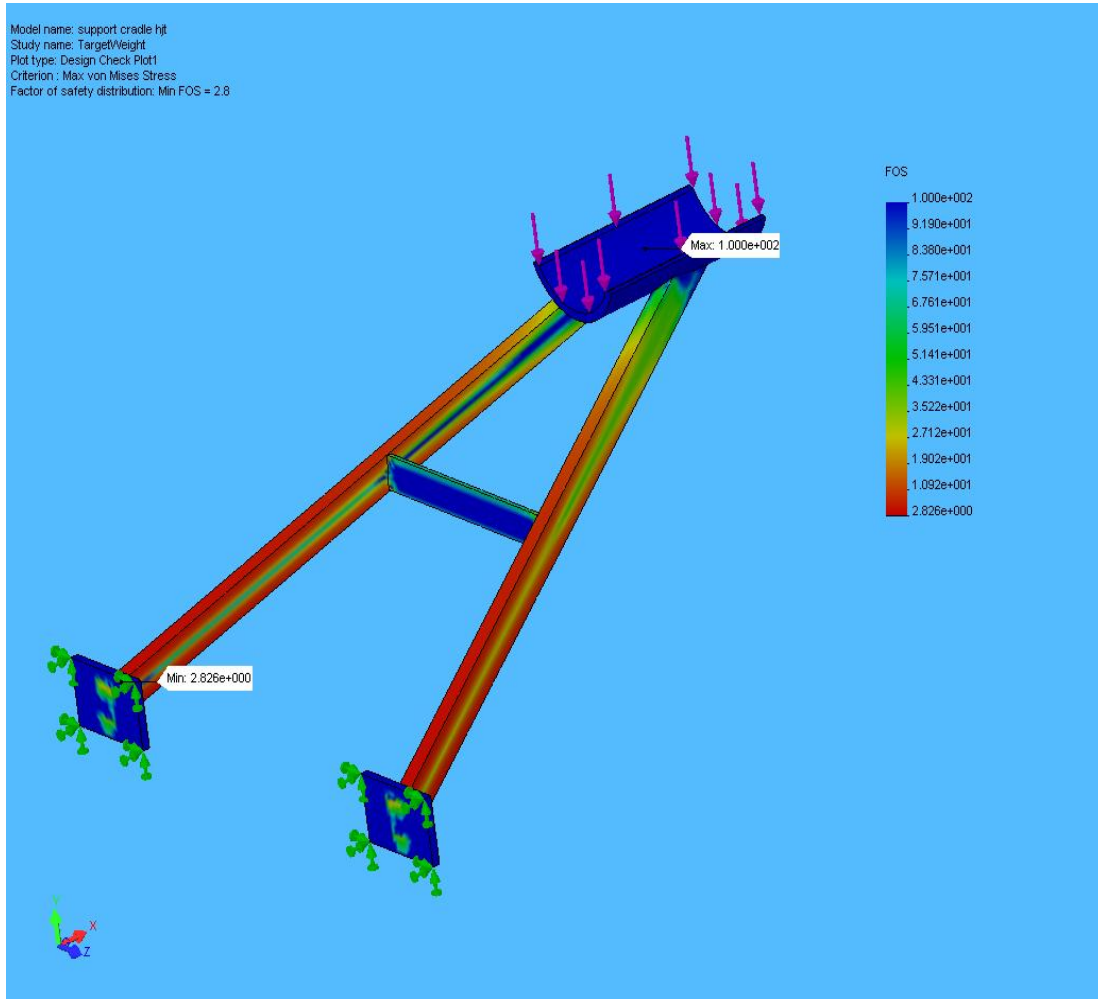
Model name: support cradle hjt  
 Study name: TargetWeight  
 Plot type: Static displacement Plot1  
 Deformation scale: 6.73691



## 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 <sup>3</sup>	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

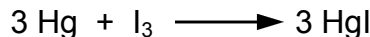
# Mercury Removal From Gas Streams

## 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<sup>3</sup>. 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

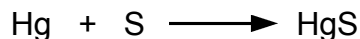
Virgin activated carbon has a relatively low capacity for mercury vapors. In 1960, Barnebey Sutcliffe developed the first generation of impregnated carbon to remove Hg. This product used potassium iodide (KI) and iodine (I<sub>3</sub>) to react with mercury according to the following reaction:



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<sub>2</sub> purification because it is resistant to side reactions (H<sub>2</sub>S formation).

## Type CBII Carbon

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



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, Monterey, California performed the testing by passing 40 l/min. of zero air through a mercury diffusion vial to generate 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.

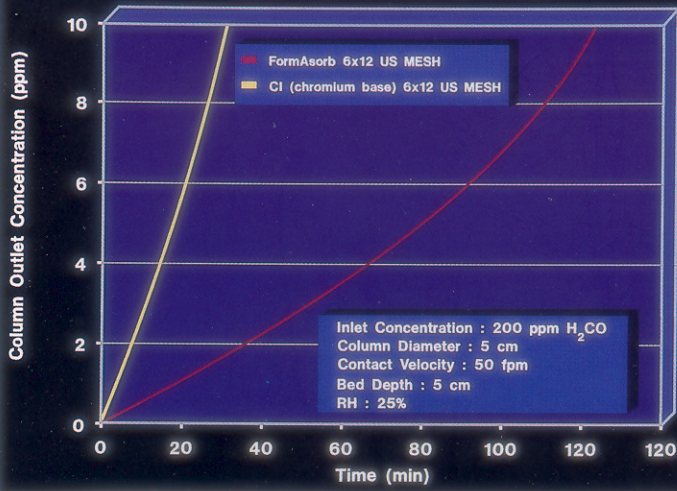
Carbon	Initial Mercury Effluent	Time Until Test Completion
CBII	Non-detect	24 hours
Sample A	Non-detect	24 hours
Sample B	Non-detect	2 hours

### Operating Temperature

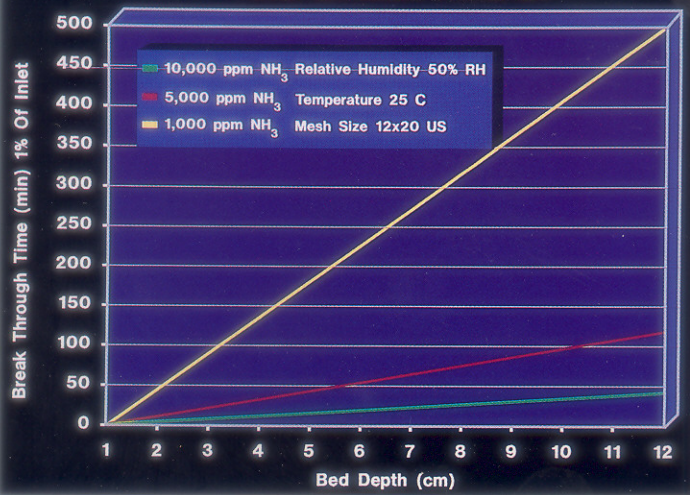
The maximum recommended operating temperature for CBII is 70 °C. Above this temperature, the performance for mercury removal declines appreciably. CBII has been used at temperatures up to 100 °C. Operation above this temperature may result in loss of sulfur impregnant. CBII has a high ignition temperature.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

# Performance Data

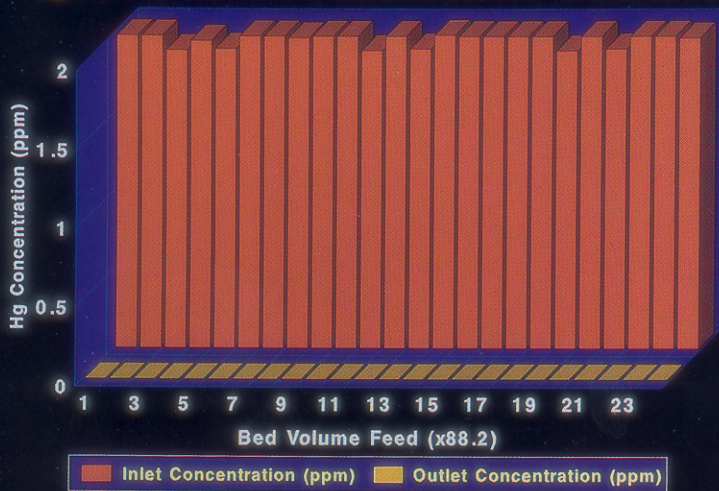
## FORMALDEHYDE REMOVAL DATA B&S ACTIVATED CARBON



## AMMONIA SERVICE LIFE TEST B&S CARBON TYPE CY



## Hg REMOVAL WITH B&S CARBON TYPE CB-II



## 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.

## Tailor-Made Specialty Carbons

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.

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\* 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



## **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!

$$W := 1000\text{ lbf}$$

Baseplate weight

$$F := \frac{W}{4}$$

Load on each lift point

$$S_y := 40000\text{ psi}$$

Tensile yield strength Al 6061-T6

$$S_{sy} := 0.58S_y$$

Distortion energy criteria for shear strength

$$h := 0.375\text{ in}$$

Weld leg length

$$t := 0.707 \cdot h$$

Weld throat

$$L := 1.5\text{ in}$$

Weld length

$$A := 2t \cdot L$$

Weld stress area. Neglect horizontal weld segments.

$$\text{shear} := \frac{F}{A}$$

$$\text{shear} = 314.317\text{ psi}$$

Shear stress

$$FS := \frac{S_{sy}}{\text{shear}}$$

$$FS = 73.811$$

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.

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

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

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

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

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

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

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

$$t := 0.707 \cdot h \quad \text{Weld throat}$$

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

$$A := 2t \cdot L \quad \text{Weld stress area}$$

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

$$M := F \cdot d \quad \text{Bending moment}$$

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

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

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

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

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



# 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.

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

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

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

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

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

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

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

$$t := 0.707 \cdot h \quad \text{Weld throat}$$

$$L := 5 \text{ in} \quad \text{Weld length}$$

$$A := 2t \cdot L \quad \text{Weld stress area}$$

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

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



# 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.

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

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

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

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

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

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

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

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

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

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

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

$$M := F \cdot d \quad \text{Bending moment}$$

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

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

$$\text{shear} := \frac{F}{A} \quad \text{shear} = 523.862 \text{ psi} \quad \text{Shear stress}$$

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

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



# 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 := 4000lbf      Conservative assumption of system with Hg

$\theta$  := 4.23deg      tt2 floor slope

h := 5in      height of horizontal jack bolt hole above base

d := 2in      distance from vertical shcs hole to edge of bracket. used to determine load on tie-down bolt.

F := W · sin( $\theta$ )      F = 295.042 lbf      force on jack bolt

M := F · h      M = 1.475 × 10<sup>3</sup> lbf · 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

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

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

# Stress Analysis of Cart Restraint Bracket

**Author: V.B. Graves**

**Company: Oak Ridge National Laboratory**

**Date: May 19, 2006**

1. [Introduction](#)
2. [Materials](#)
3. [Load & Restraint Information](#)
4. [Study Property](#)
5. [Stress Results](#)
6. [Displacement Results](#)
7. [Design Check Results](#)
8. [Conclusion](#)
9. [Appendix](#)

---

## 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.

---

## 2. Materials

No.	Part Name	Material	Mass	Volume
1	cart jacking plate hjt	<a href="#">6061-T6 (SS)</a>	2.45111 lb	25.1284 in <sup>3</sup>
2	cart jacking plate hjt	<a href="#">6061-T6 (SS)</a>	2.45111 lb	25.1284 in <sup>3</sup>
3	cart jacking plate hjt	<a href="#">6061-T6 (SS)</a>	2.45111 lb	25.1284 in <sup>3</sup>

---

## 3. Load & Restraint Information

Restraint	
<b>Restraint-1 &lt;cart jacking plate hjt&gt;</b>	on <b>1 Face(s)</b> fixed.
<b>Description:</b>	Vertical hole threads restrained.

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

---

## 4. Study Property

<b>Mesh Information</b>	
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

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

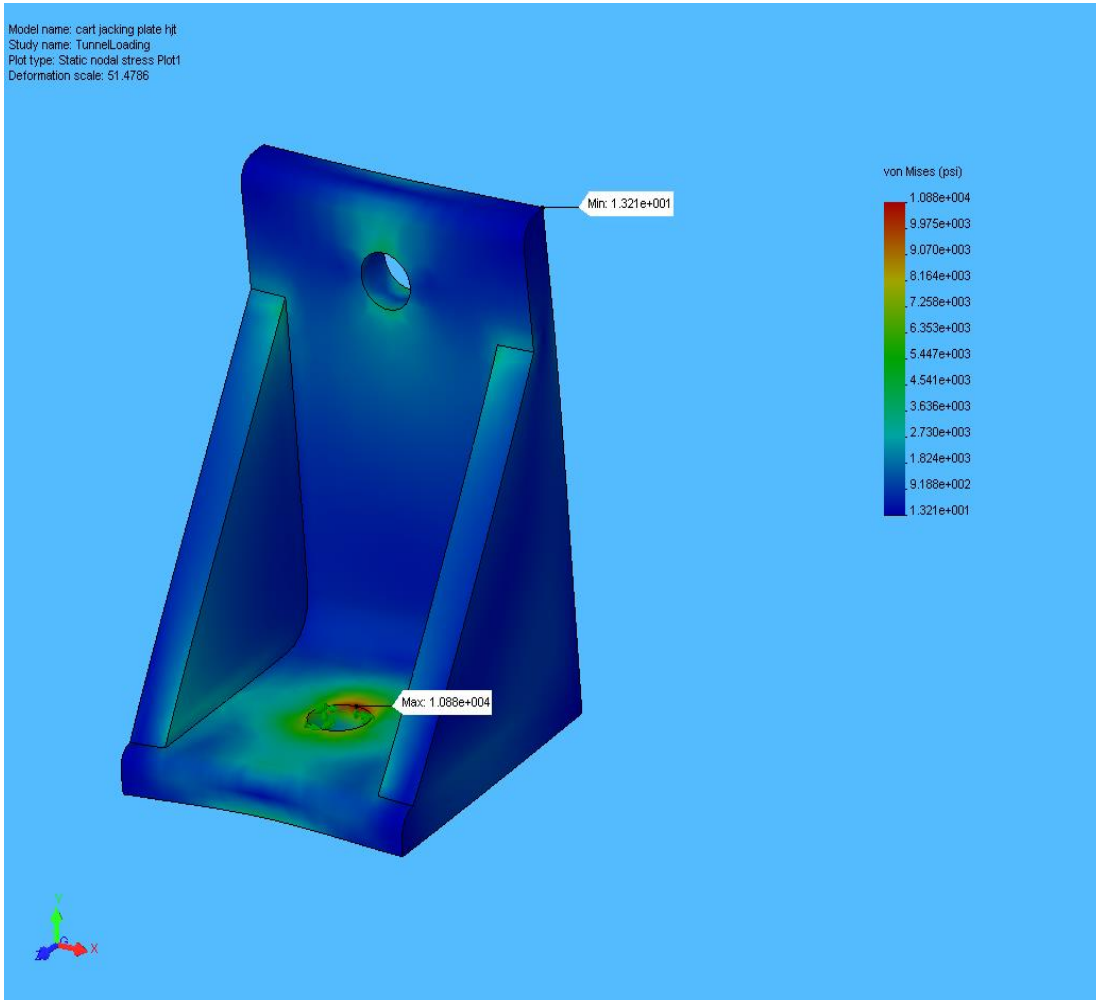
---

## 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





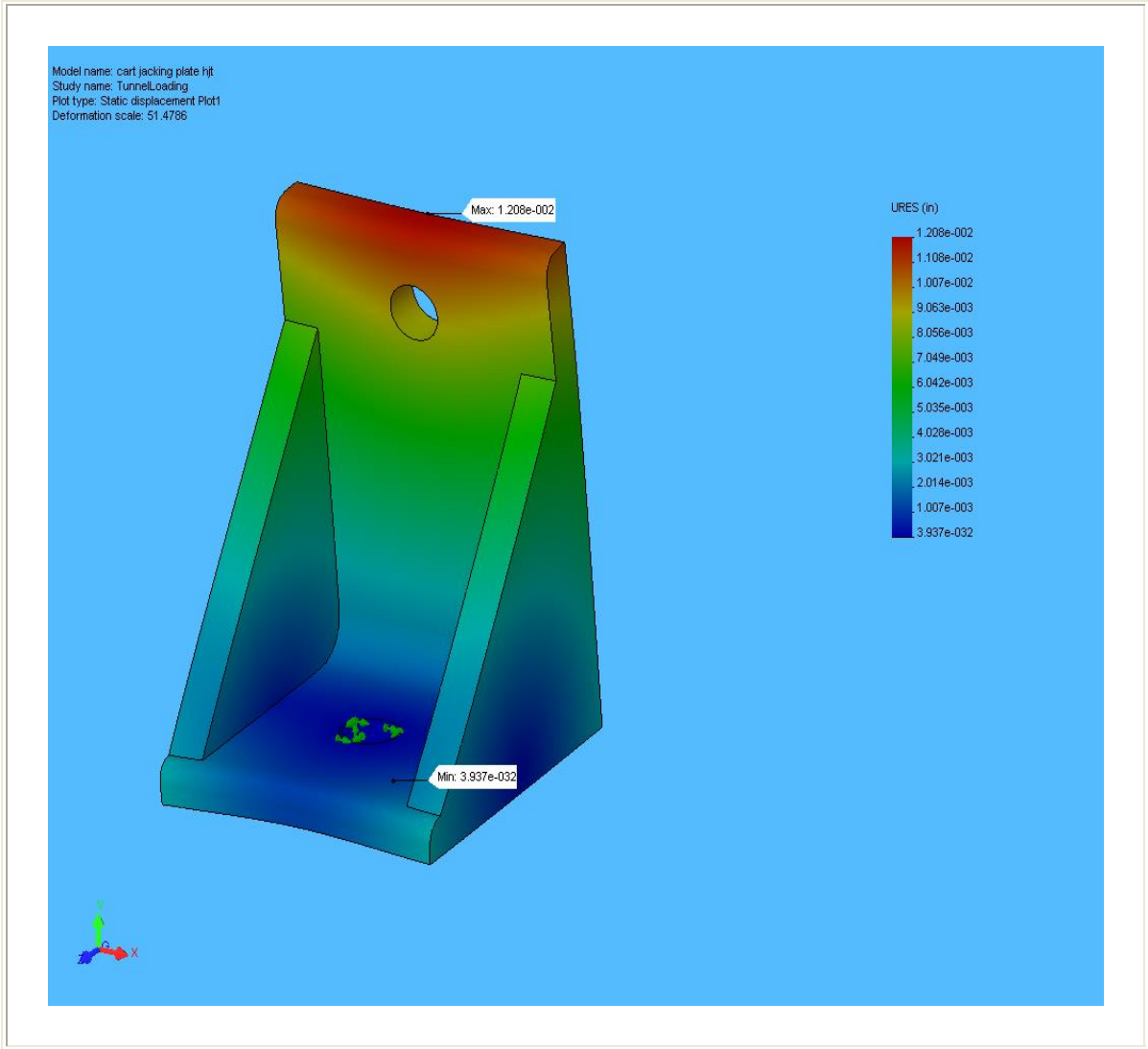
---

## 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**

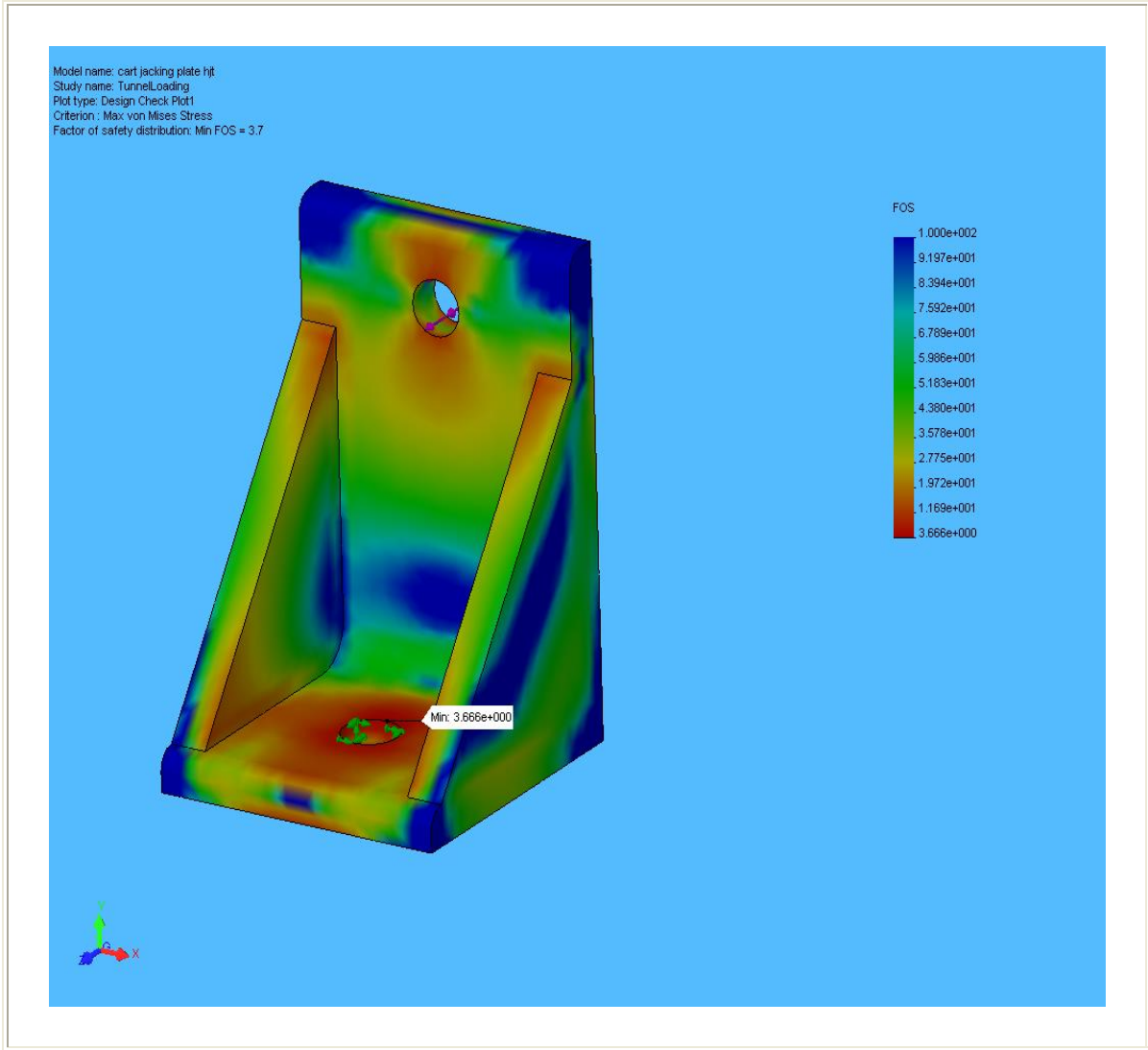
**JPEG**



## 7. Design Check Results

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

JPEG



---

## 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 <sup>3</sup>	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**

1. [Introduction](#)
2. [Materials](#)
3. [Load & Restraint Information](#)
4. [Study Property](#)
5. [Stress Results](#)
6. [Displacement Results](#)
7. [Design Check Results](#)
8. [Conclusion](#)
9. [Appendix](#)

---

## 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	<a href="#">6061-T6 (SS)</a>	28.4115 lb	291.269 in <sup>3</sup>
2	magnet end support hjt	<a href="#">6061-T6 (SS)</a>	28.4115 lb	291.269 in <sup>3</sup>
3	magnet end support hjt	<a href="#">6061-T6 (SS)</a>	28.4115 lb	291.269 in <sup>3</sup>
4	magnet end support hjt	<a href="#">6061-T6 (SS)</a>	28.4115 lb	291.269 in <sup>3</sup>
5	magnet end support hjt	<a href="#">6061-T6 (SS)</a>	28.4115 lb	291.269 in <sup>3</sup>
6	magnet end support hjt	<a href="#">6061-T6 (SS)</a>	28.4115 lb	291.269 in <sup>3</sup>
7	magnet end support hjt	<a href="#">6061-T6 (SS)</a>	28.4115 lb	291.269 in <sup>3</sup>
8	magnet end support hjt	<a href="#">6061-T6 (SS)</a>	28.4115 lb	291.269 in <sup>3</sup>
9	magnet end support hjt	<a href="#">6061-T6 (SS)</a>	28.4115 lb	291.269 in <sup>3</sup>
10	magnet end support hjt	<a href="#">6061-T6 (SS)</a>	28.4115 lb	291.269 in <sup>3</sup>
11	magnet end support hjt	<a href="#">6061-T6 (SS)</a>	28.4115 lb	291.269 in <sup>3</sup>
12	magnet end support hjt	<a href="#">6061-T6 (SS)</a>	28.4115 lb	291.269 in <sup>3</sup>
13	magnet end support hjt	<a href="#">6061-T6 (SS)</a>	28.4115 lb	291.269 in <sup>3</sup>

## 3. Load & Restraint Information

Restraint	
<b>Restraint-1 &lt;magnet end support hjt&gt;</b>	on 2 Face(s) fixed.

<b>Description:</b>	Bottom faces fixed.
---------------------	---------------------

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

---

## 4. Study Property

<b>Mesh Information</b>	
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

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

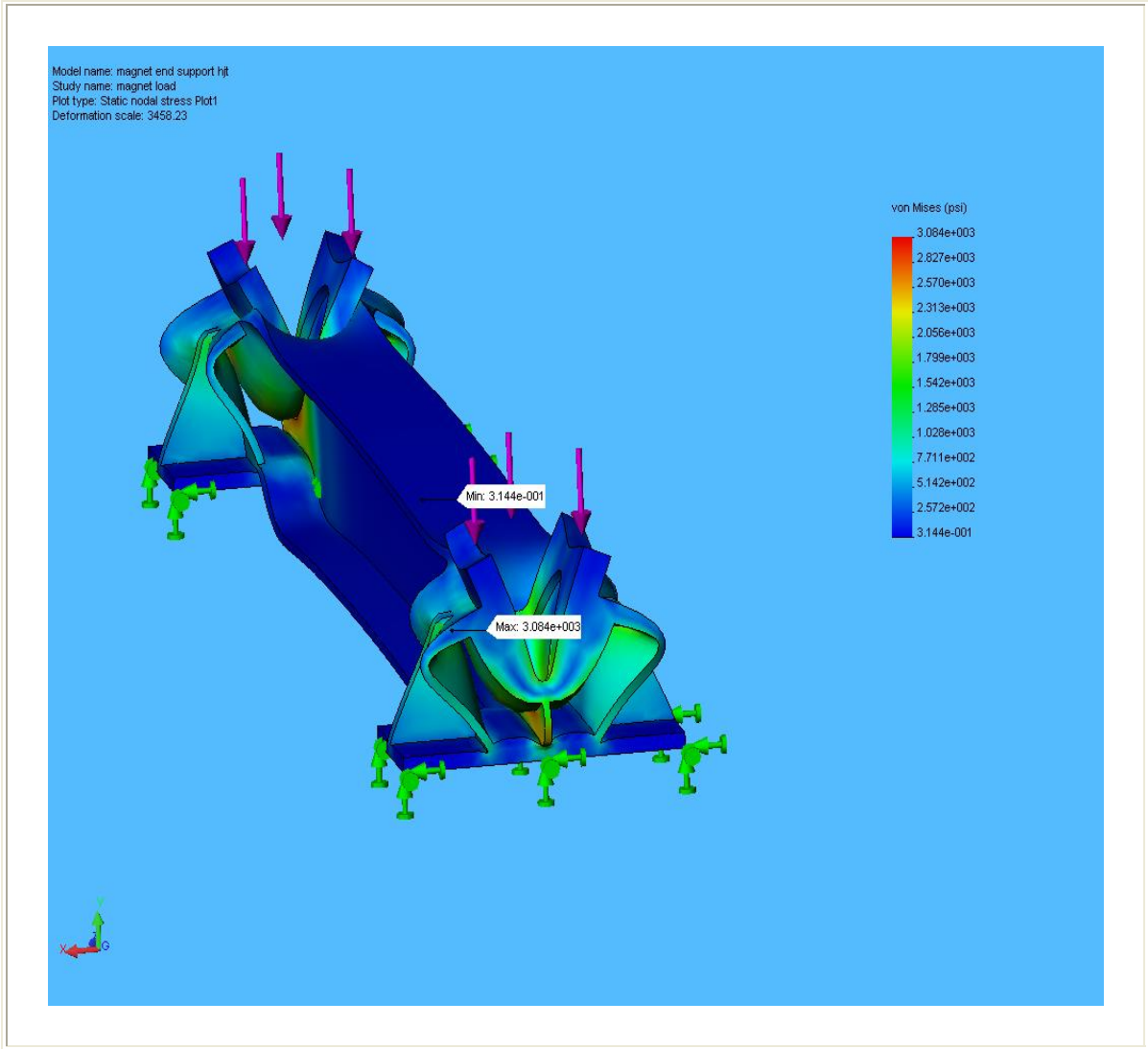
## 5. Stress Results

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**





## 6. Displacement Results

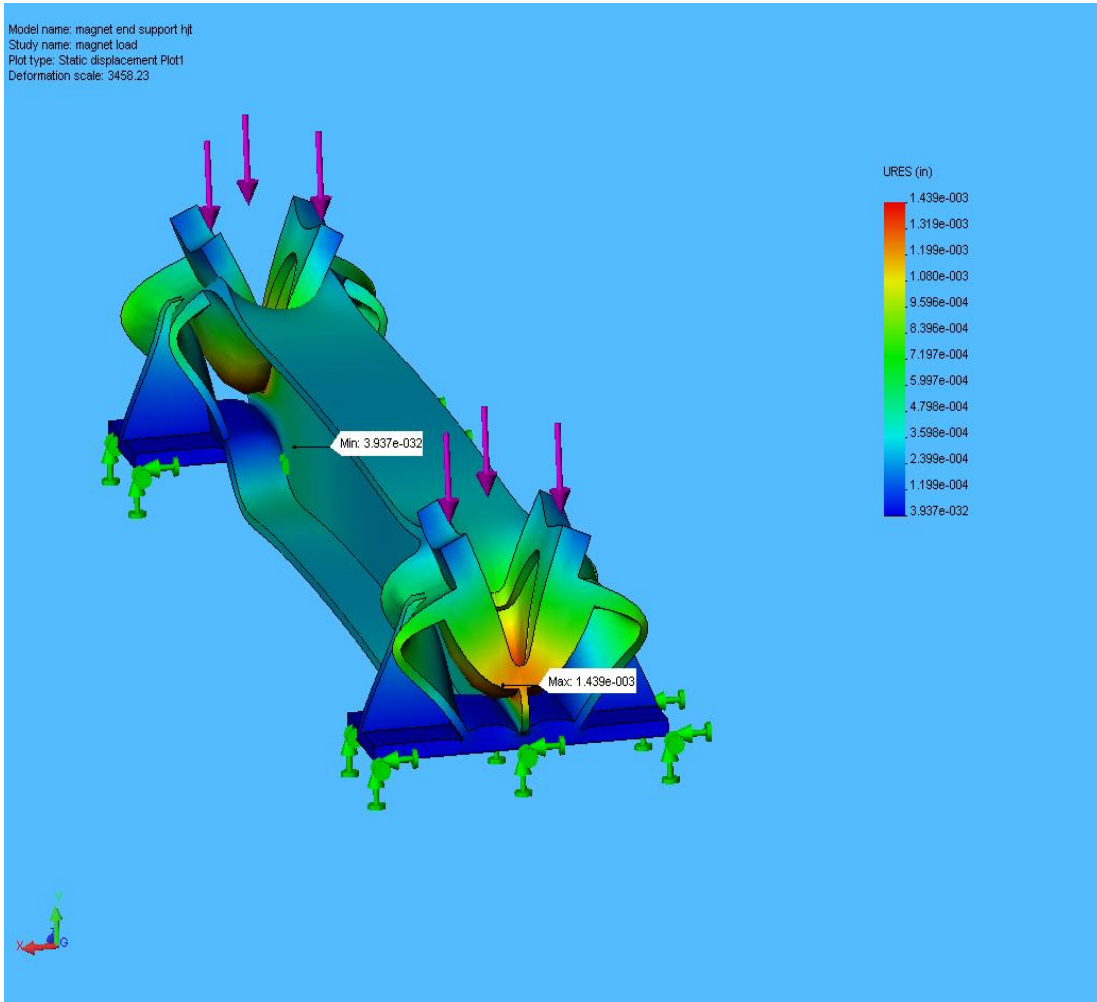
Name	Type	Min	Location	Max	Location
Plot1	URES: Resultant displacement	0 in	(5 in,	0.00143937	(0.333333
		Node:	-3.5 in,	in	in,

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

### magnet end support hjt-magnet load-Displacement-Plot1

JPEG

Model name: magnet end support hjt  
 Study name: magnet load  
 Plot type: Static displacement Plot1  
 Deformation scale: 3458.23

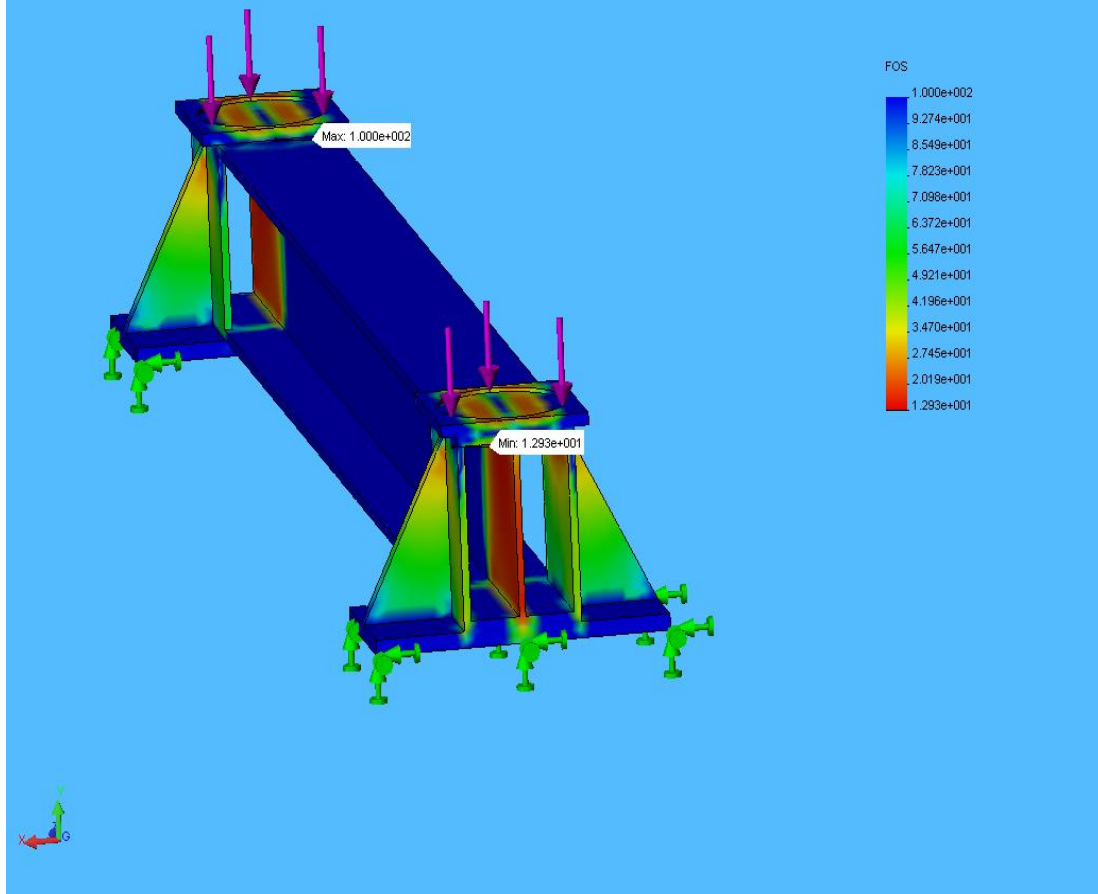


## 7. Design Check Results

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

JPEG

Model name: magnet end support hjt  
Study name: magnet load  
Plot type: Design Check Plot1  
Criterion: Max von Mises Stress  
Factor of safety distribution: Min FOS = 13



---

## 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

<b>Material name:</b>	6061-T6 (SS)
<b>Description:</b>	
<b>Material Source:</b>	Library files
<b>Material Library Name:</b>	cosmos materials
<b>Material Model Type:</b>	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 <sup>3</sup>	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](#)
2. [Materials](#)
3. [Load & Restraint Information](#)
4. [Study Property](#)
5. [Stress Results](#)
6. [Displacement Results](#)
7. [Design Check Results](#)
8. [Conclusion](#)
9. [Appendix](#)

---

## 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	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
2	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
3	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
4	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
5	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
6	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
7	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
8	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
9	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
10	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
11	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
12	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>

13	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
14	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
15	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
16	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
17	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
18	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
19	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
20	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
21	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
22	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
23	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
24	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
25	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
26	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
27	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
28	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
29	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
30	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
31	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
32	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>

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

---

### 3. Load & Restraint Information

<b>Restraint</b>
------------------



<b>Restraint-5 &lt;base weldment hjt-1&gt;</b>	on <b>8 Face(s)</b> fixed.
<b>Description:</b>	Bracket attachment holes restrained.

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

---

## 4. Study Property

<b>Mesh Information</b>	
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

<b>Solver Information</b>	
Quality:	High

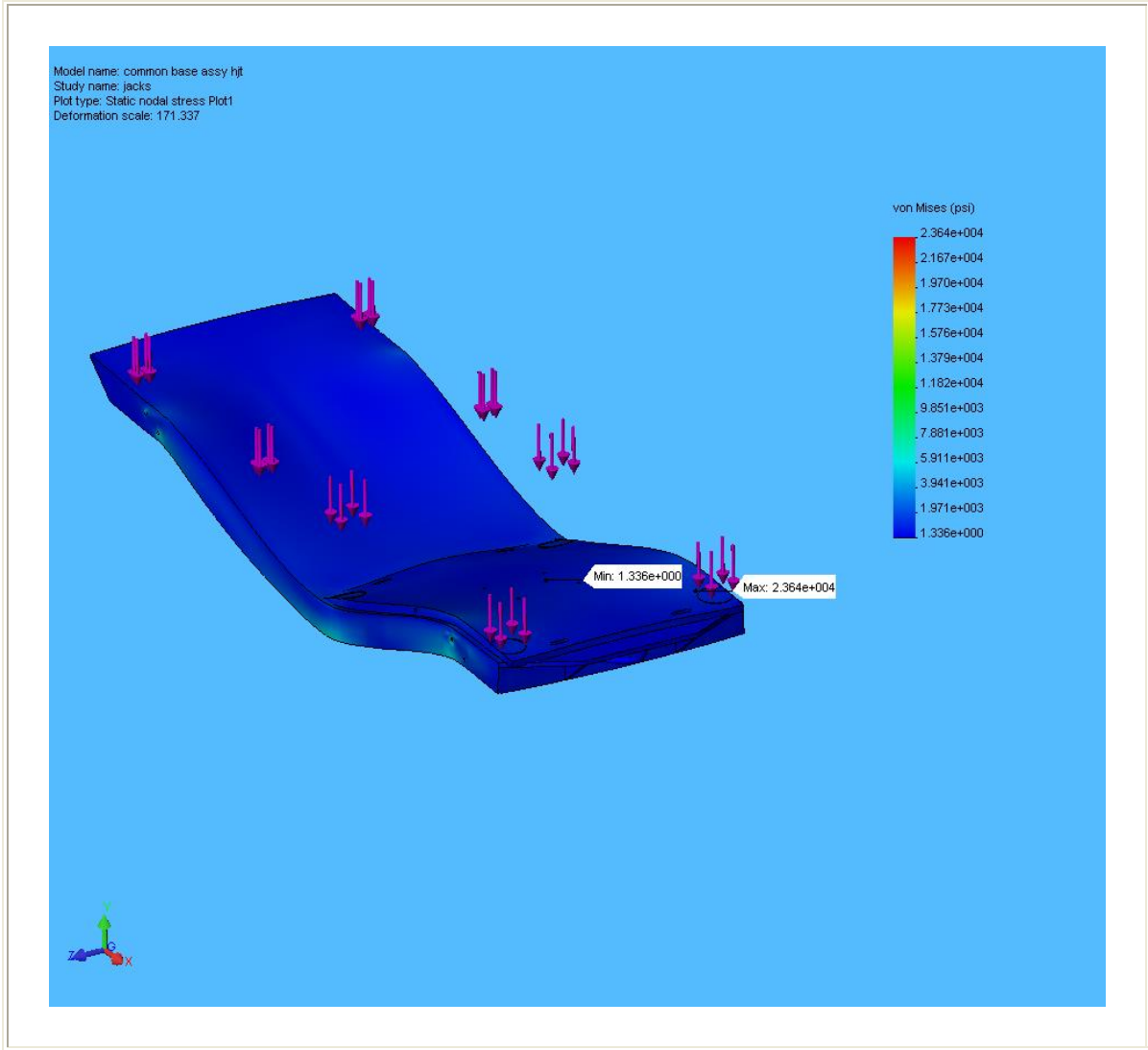
Solver Type:	FFEPlus
Option:	Include Thermal Effects
Thermal Option:	Input Temperature
Thermal Option:	Reference Temperature at zero strain: 77 Fahrenheit

## 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



## 6. Displacement Results

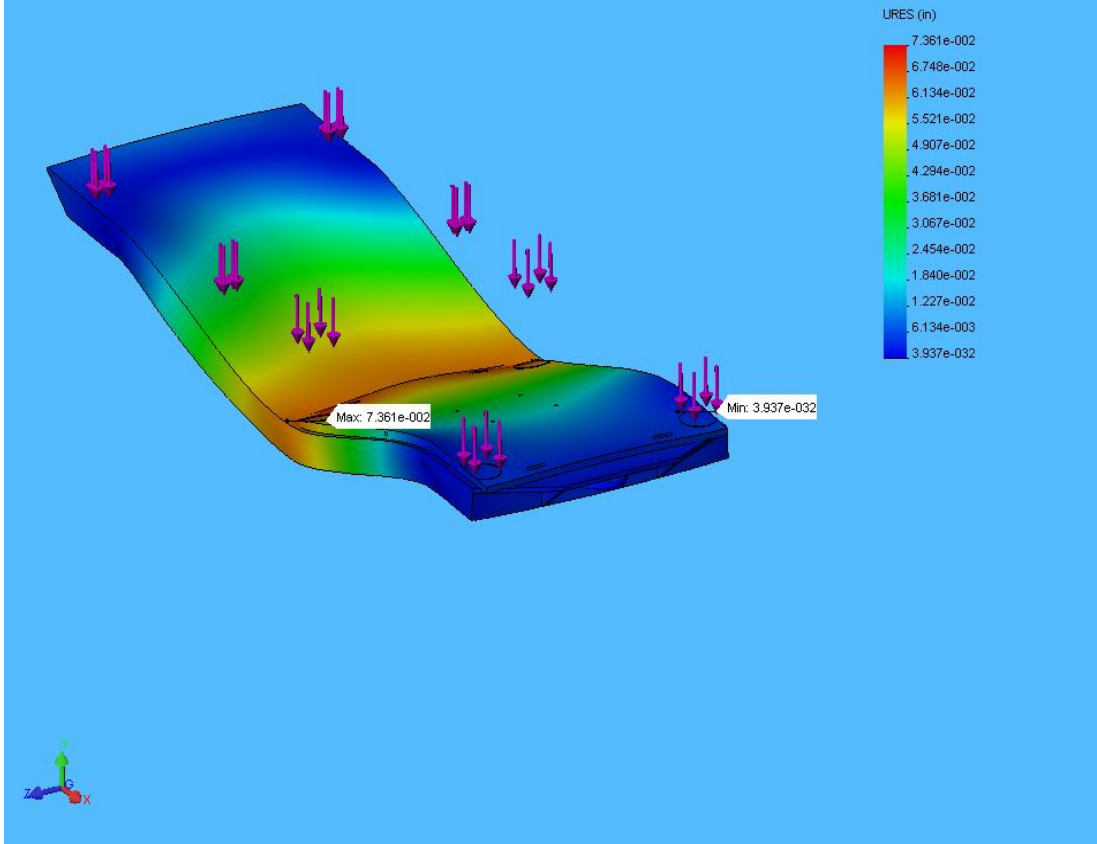
Name	Type	Min	Location	Max	Location
Plot1	URES: Resultant displacement	0 in	(46.8828	0.0736117	(3 in,
		Node:	in,	in	3.875

		107	0.644984 in, -19.68 in)	Node: 48521	in, 19 in)
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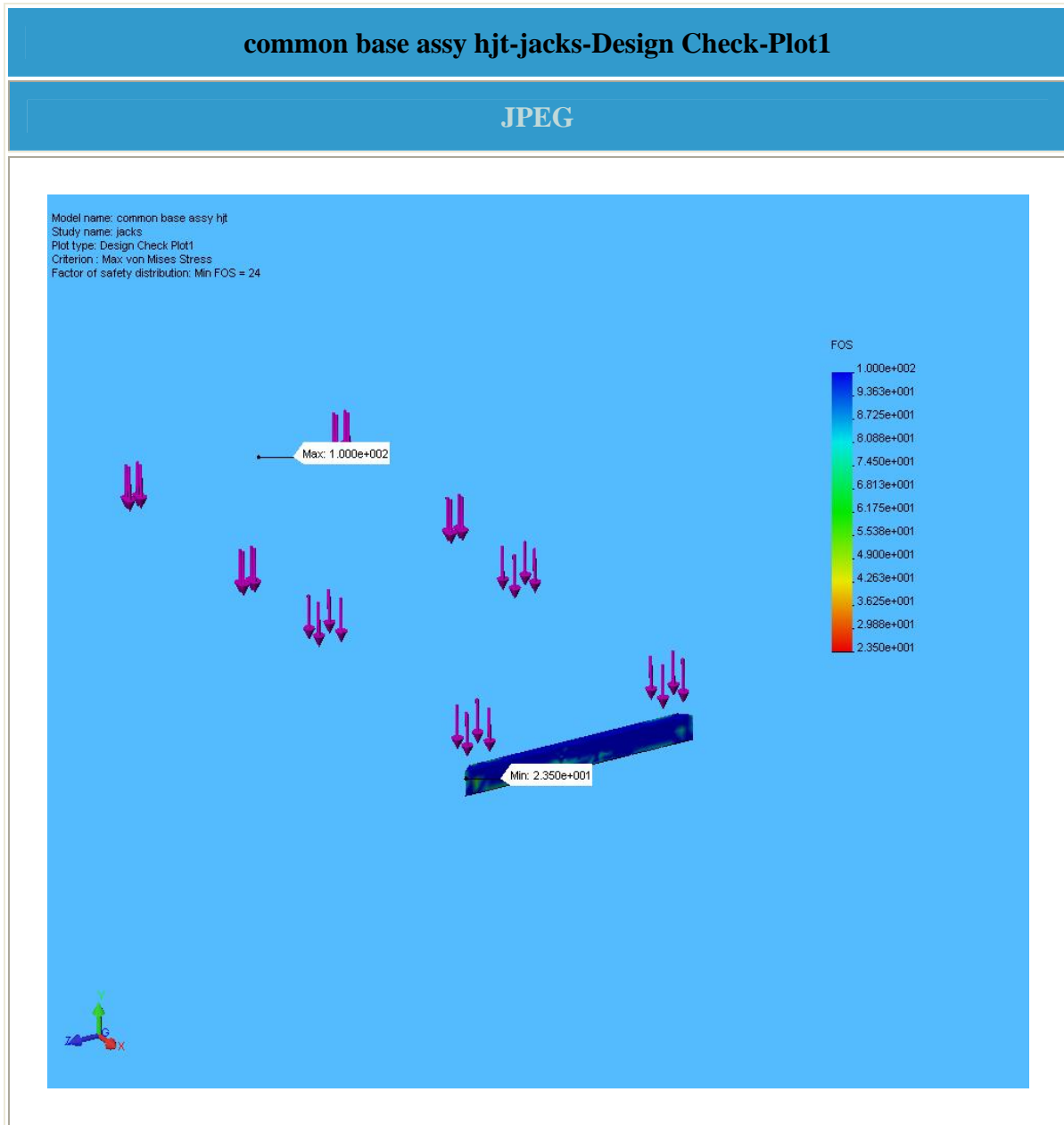
**common base assy hjt-jacks-Displacement-Plot1**

JPEG

Model name: common base assy hjt  
 Study name: jacks  
 Plot type: Static displacement Plot1  
 Deformation scale: 171.337



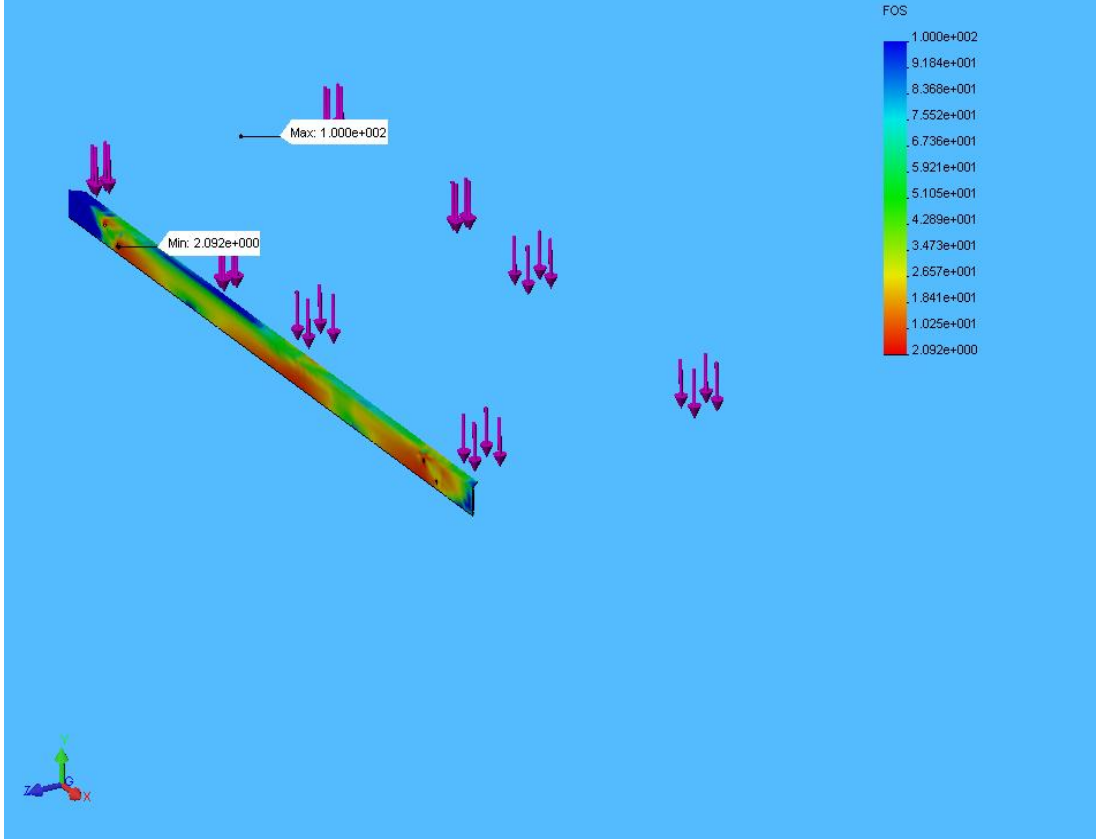
## 7. Design Check Results



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

JPEG

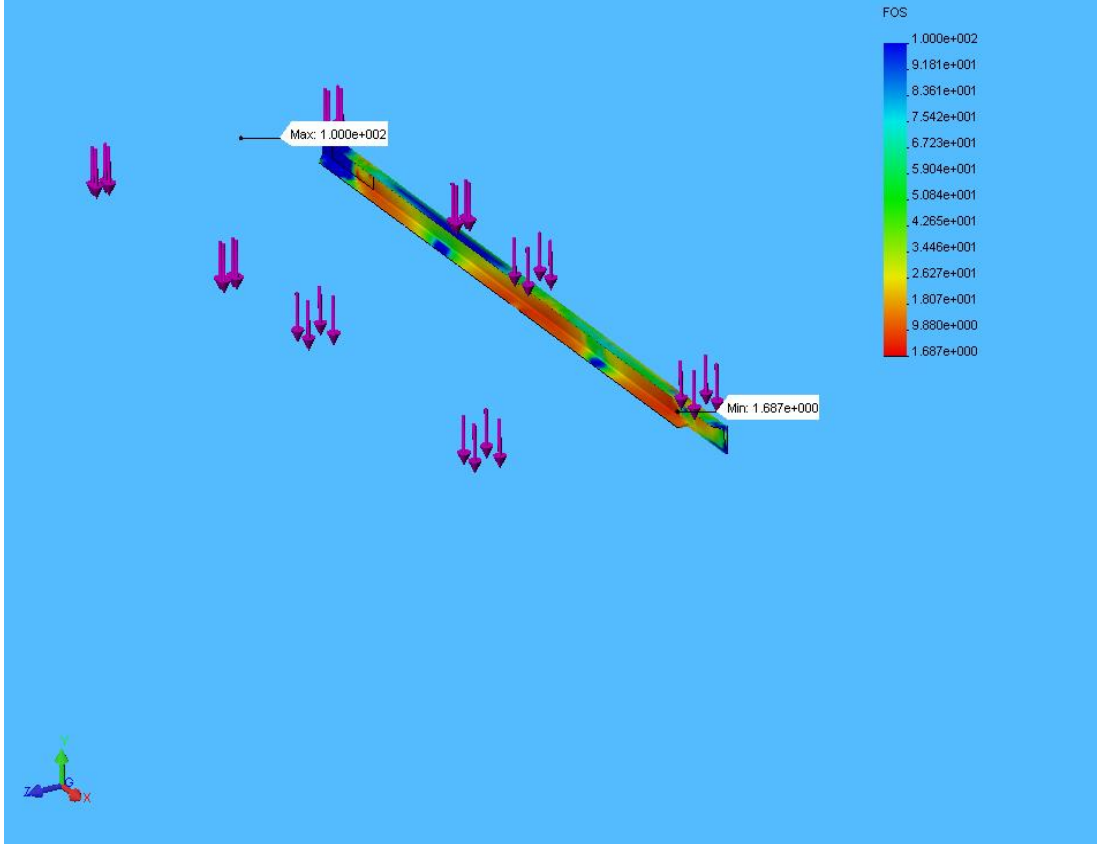
Model name: common.base assy hjt  
Study name: jacks  
Plot type: Design Check Plot2  
Criterion: Max von Mises Stress  
Factor of safety distribution: Min FOS = 2.1



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

JPEG

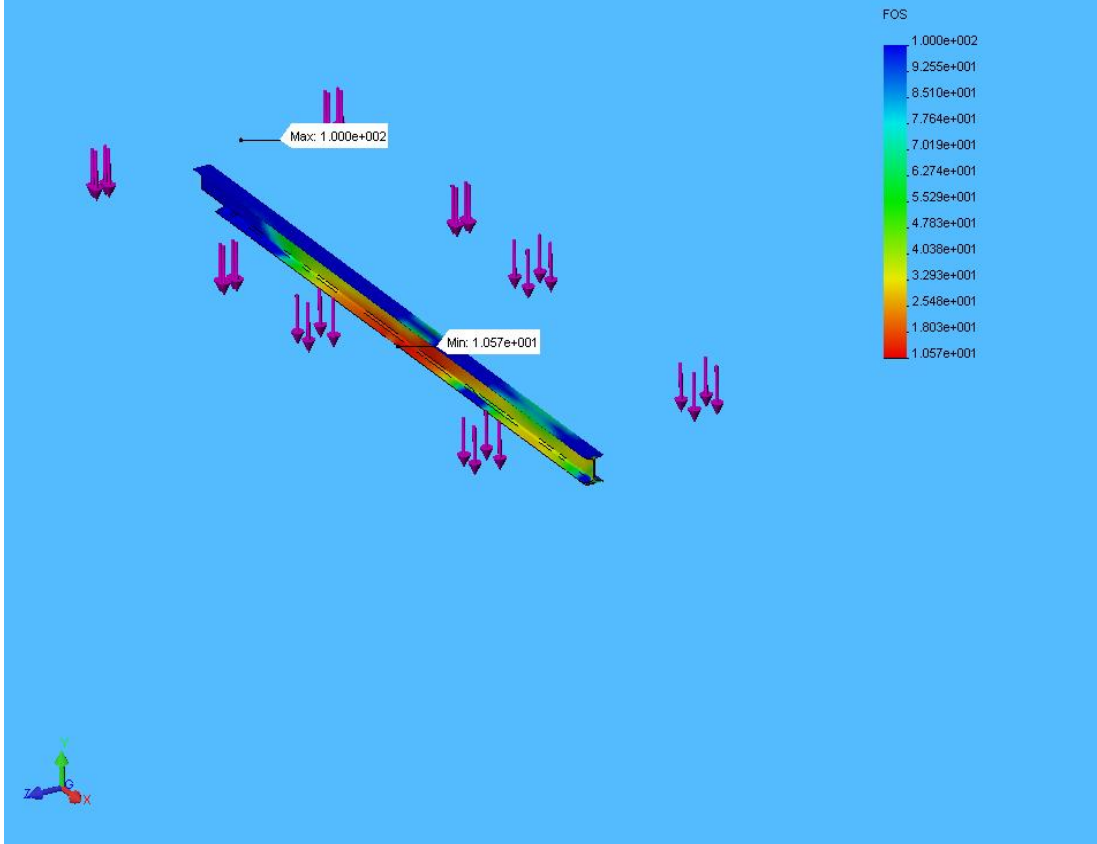
Model name: common base assy hjt  
Study name: jacks  
Plot type: Design Check Plot3  
Criterion : Max von Mises Stress  
Factor of safety distribution: Min FOS = 1.7



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

JPEG

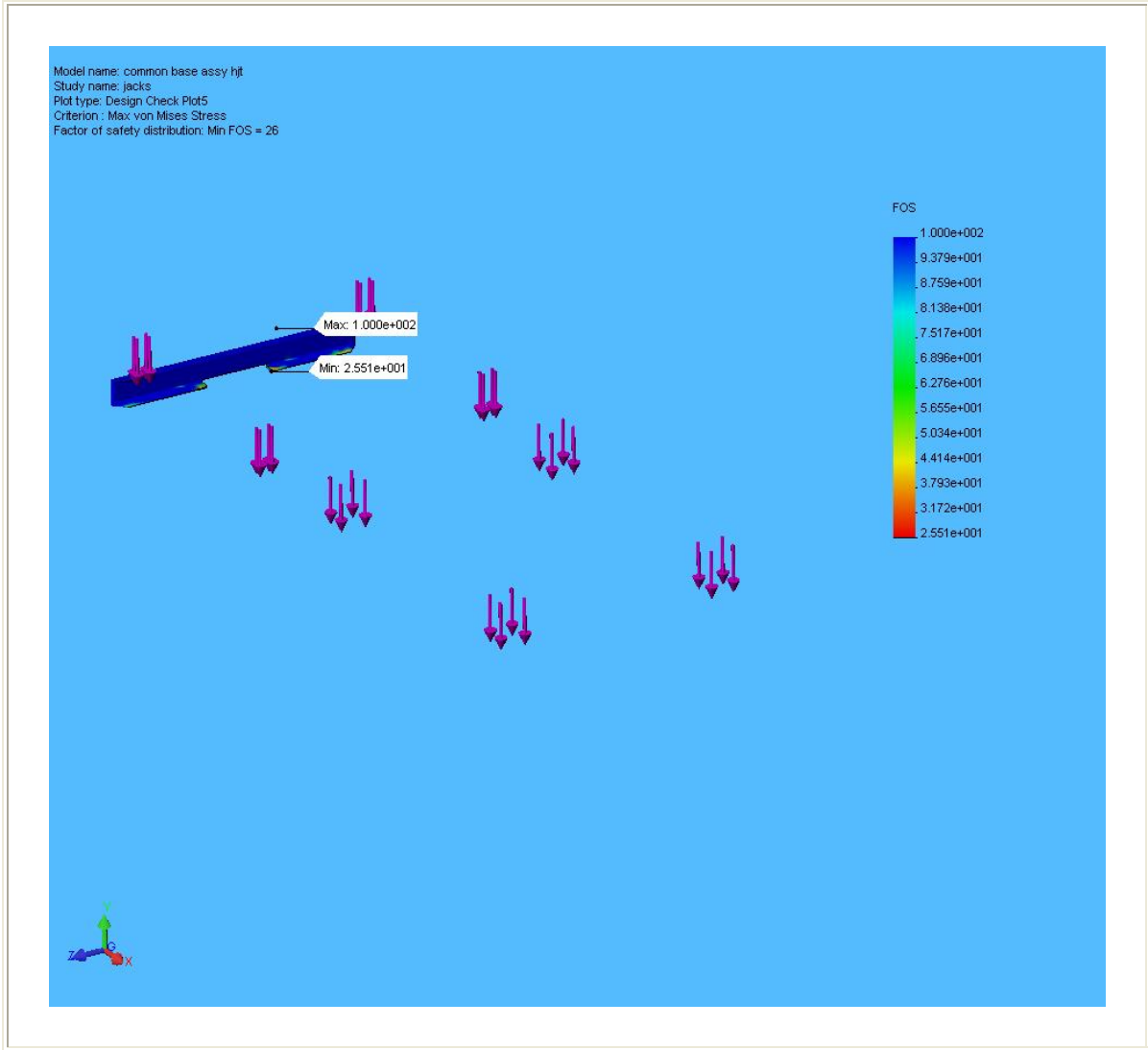
Model name: common base assy hjt  
Study name: jacks  
Plot type: Design Check Plot4  
Criterion : Max von Mises Stress  
Factor of safety distribution: Min FOS = 11



**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 <sup>3</sup>	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](#)
2. [Materials](#)
3. [Load & Restraint Information](#)
4. [Study Property](#)
5. [Stress Results](#)
6. [Displacement Results](#)
7. [Design Check Results](#)
8. [Conclusion](#)
9. [Appendix](#)

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## 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.

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## 2. Materials

No.	Part Name	Material	Mass	Volume
1	hyd jack weldment hjt	<a href="#">[SW]6061 Alloy</a>	7.34375 lb	75.2868 in <sup>3</sup>
2	hyd jack weldment hjt	<a href="#">[SW]6061 Alloy</a>	7.34375 lb	75.2868 in <sup>3</sup>
3	hyd jack weldment hjt	<a href="#">[SW]6061 Alloy</a>	7.34375 lb	75.2868 in <sup>3</sup>
4	hyd jack weldment hjt	<a href="#">[SW]6061 Alloy</a>	7.34375 lb	75.2868 in <sup>3</sup>

---

## 3. Load & Restraint Information

Restraint	
<b>Restraint-1 &lt;hyd jack weldment hjt&gt;</b>	on <b>1 Face(s)</b> fixed.
<b>Description:</b>	Top of weldment held fixed.

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

	on the two bolt holes.	
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## 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

---

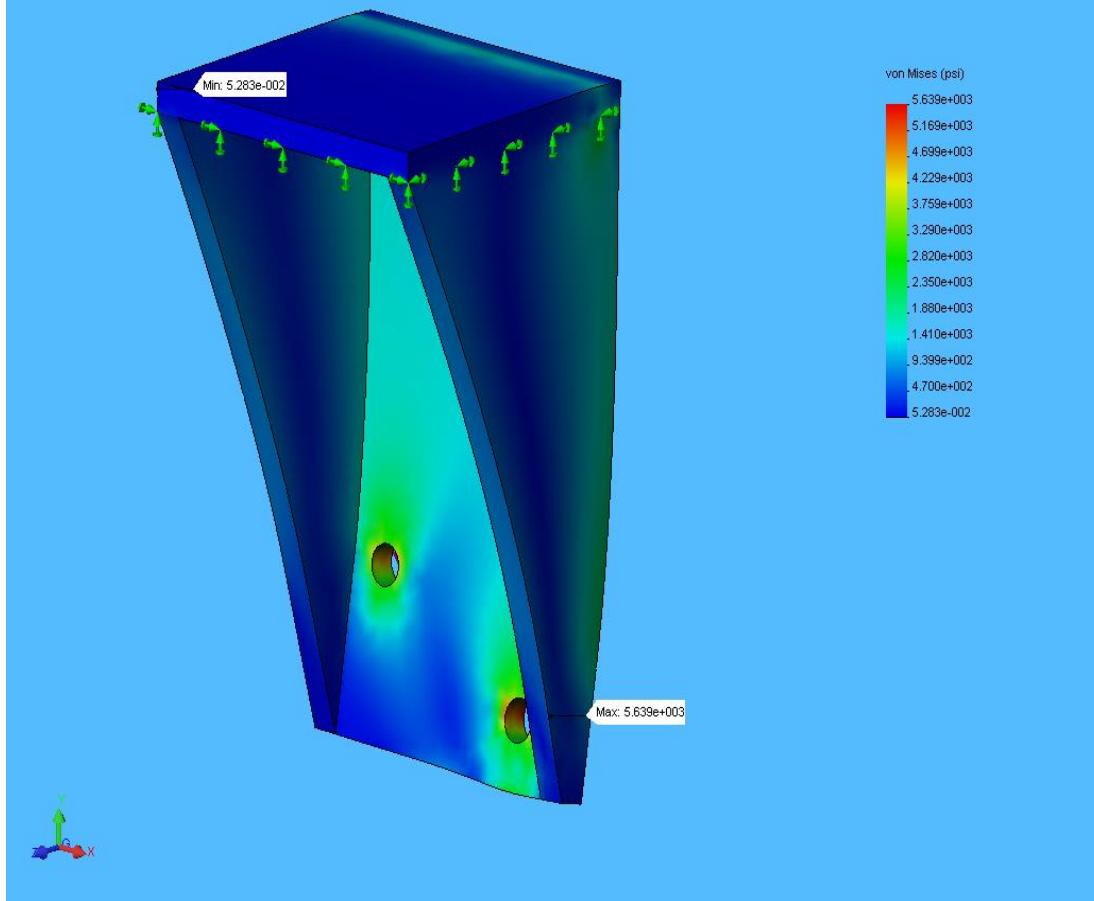
## 5. Stress Results

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

Model name: hyd jack weldment hjt  
 Study name: loaded  
 Plot type: Static nodal stress Plot1  
 Deformation scale: 226.331



---

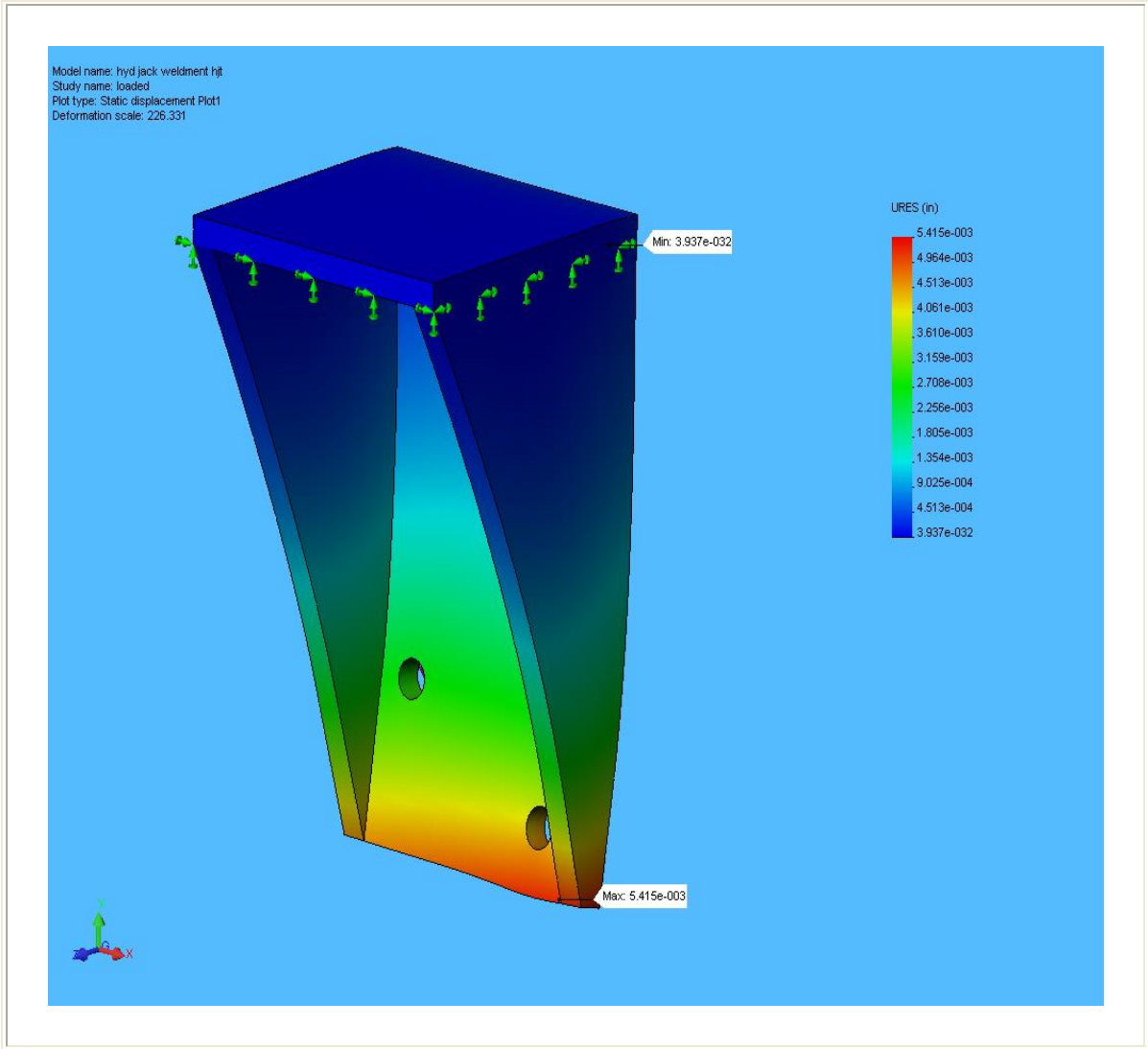
## 6. Displacement Results

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**

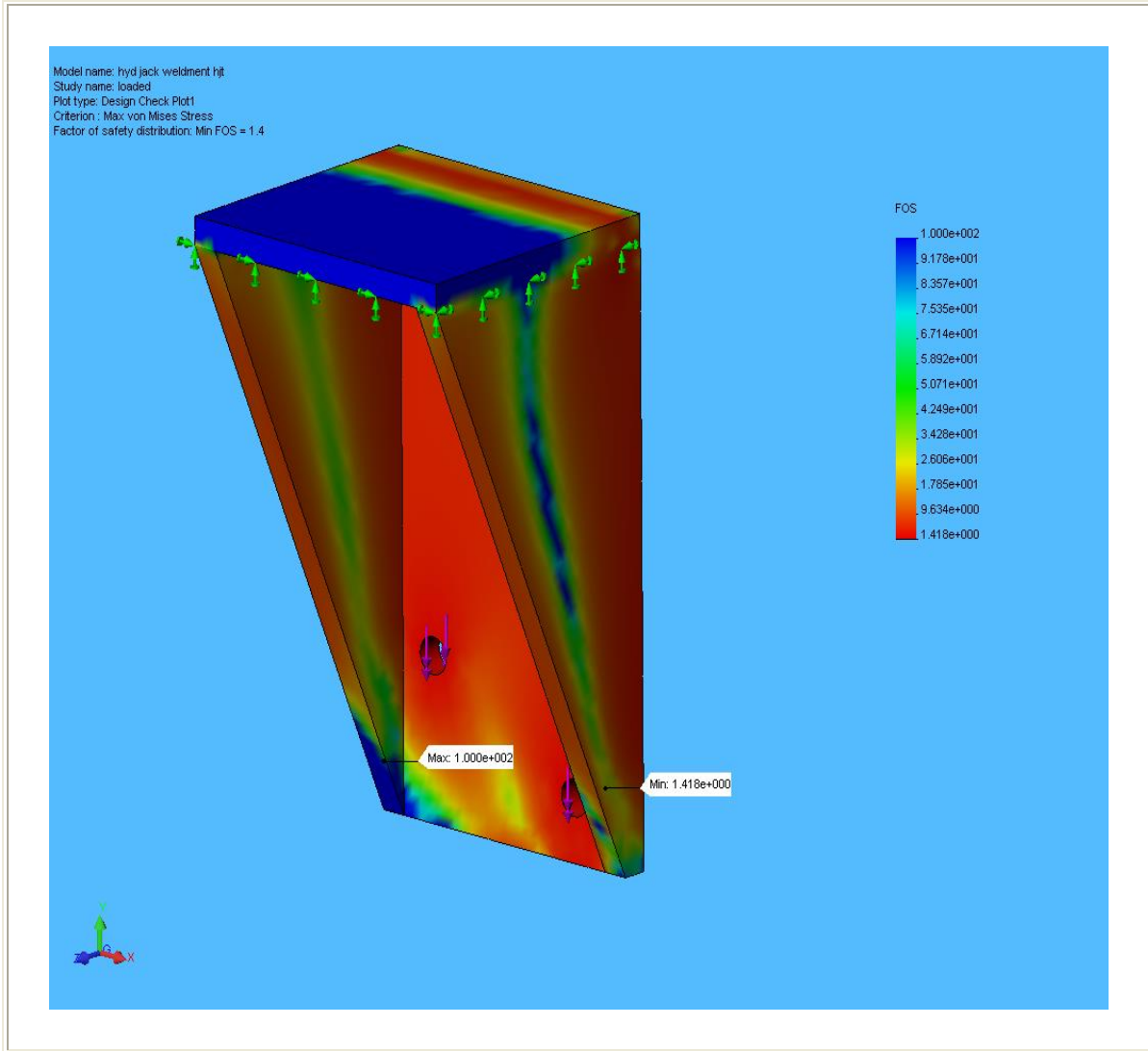




## 7. Design Check Results

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 <sup>3</sup>	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](#)
2. [Materials](#)
3. [Load & Restraint Information](#)
4. [Study Property](#)
5. [Stress Results](#)
6. [Displacement Results](#)
7. [Design Check Results](#)
8. [Conclusion](#)
9. [Appendix](#)

---

## 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	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
2	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
3	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
4	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
5	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
6	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
7	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
8	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
9	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
10	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
11	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
12	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
13	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>

14	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
15	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
16	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
17	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
18	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
19	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
20	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
21	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
22	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
23	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
24	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
25	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
26	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
27	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
28	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
29	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
30	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
31	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
32	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>
33	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	447.976 lb	4592.57 in <sup>3</sup>

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

---

### 3. Load & Restraint Information

Restraint	
<b>Restraint-3 &lt;base weldment hjt-1&gt;</b>	on 4 Face(s) fixed.

<b>Description:</b>	Threaded holes for leveling jacks are fixed.
---------------------	--

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

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## 4. Study Property

<b>Mesh Information</b>	
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

<b>Solver Information</b>	
Quality:	High
Solver Type:	FFEPlus
Option:	Include Thermal Effects



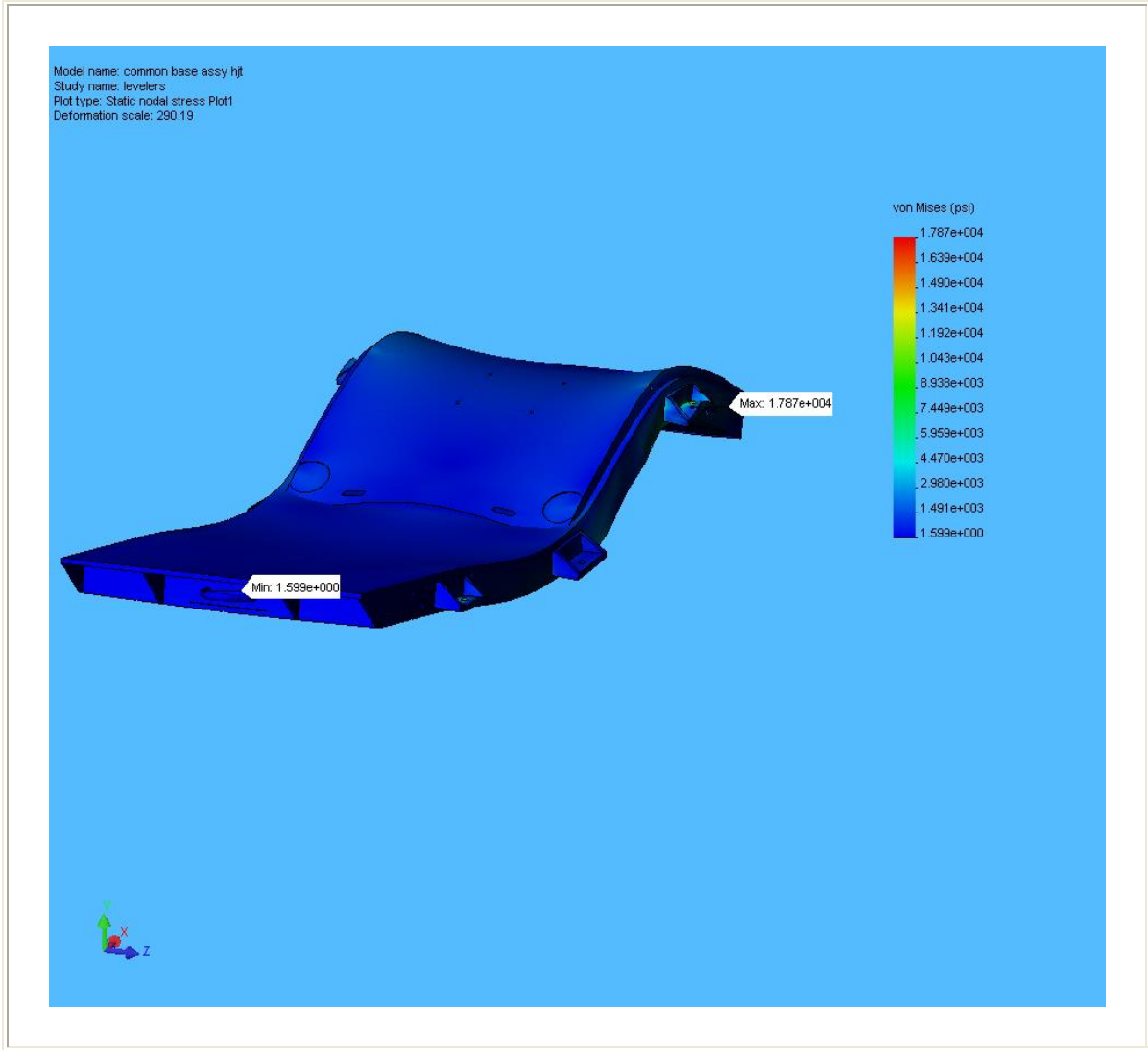
Thermal Option:	Input Temperature
Thermal Option:	Reference Temperature at zero strain: 77 Fahrenheit

## 5. Stress Results

Name	Type	Min	Location	Max	Location
Plot1	VON: von Mises stress	1.59852 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

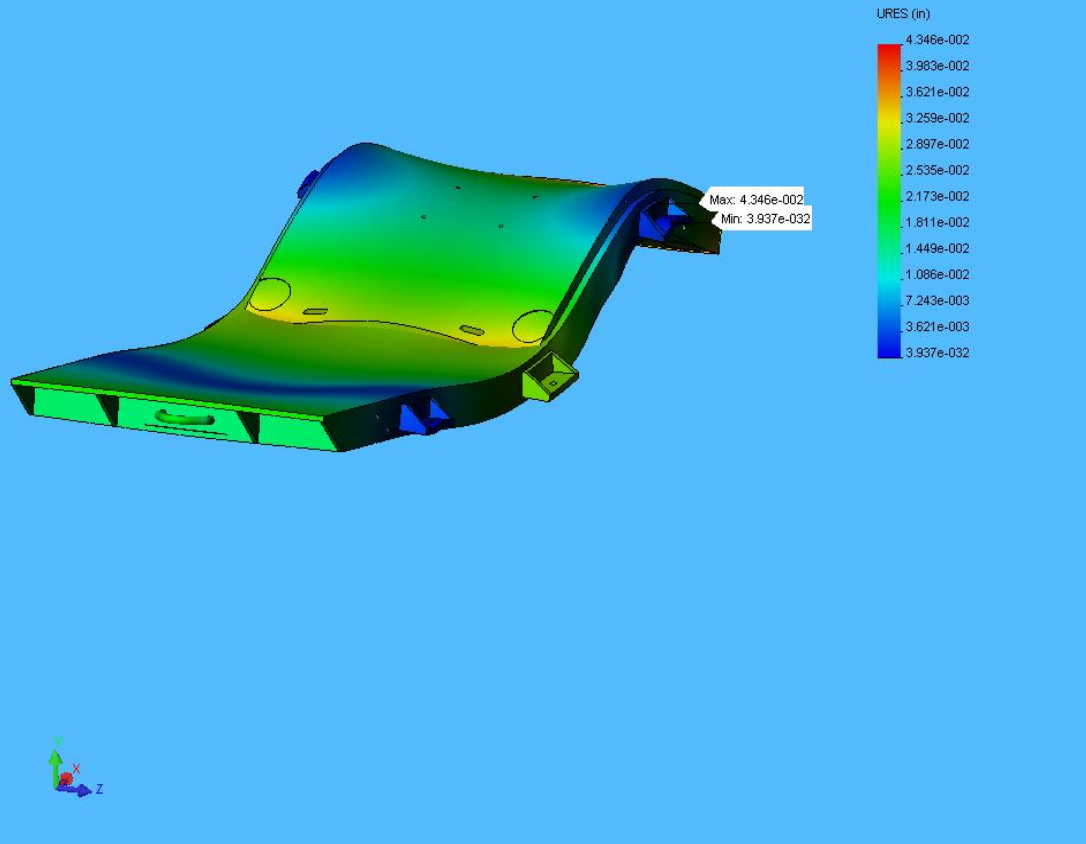
Name	Type	Min	Location	Max	Location
Plot1	URES: Resultant displacement	0 in	(36.3789	0.0434563	(63 in,
		Node:	in,	in	2.625

		35637	-0.5 in, 22.0312 in)	Node: 2545	in, 9.25 in)
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**common base assy hjt-levelers-Displacement-Plot1**

JPEG

Model name: common base assy hjt  
 Study name: levelers  
 Plot type: Static displacement Plot1  
 Deformation scale: 290.19



## 7. Design Check Results

common base assy hjt-levelers-Design Check-Plot12

JPEG

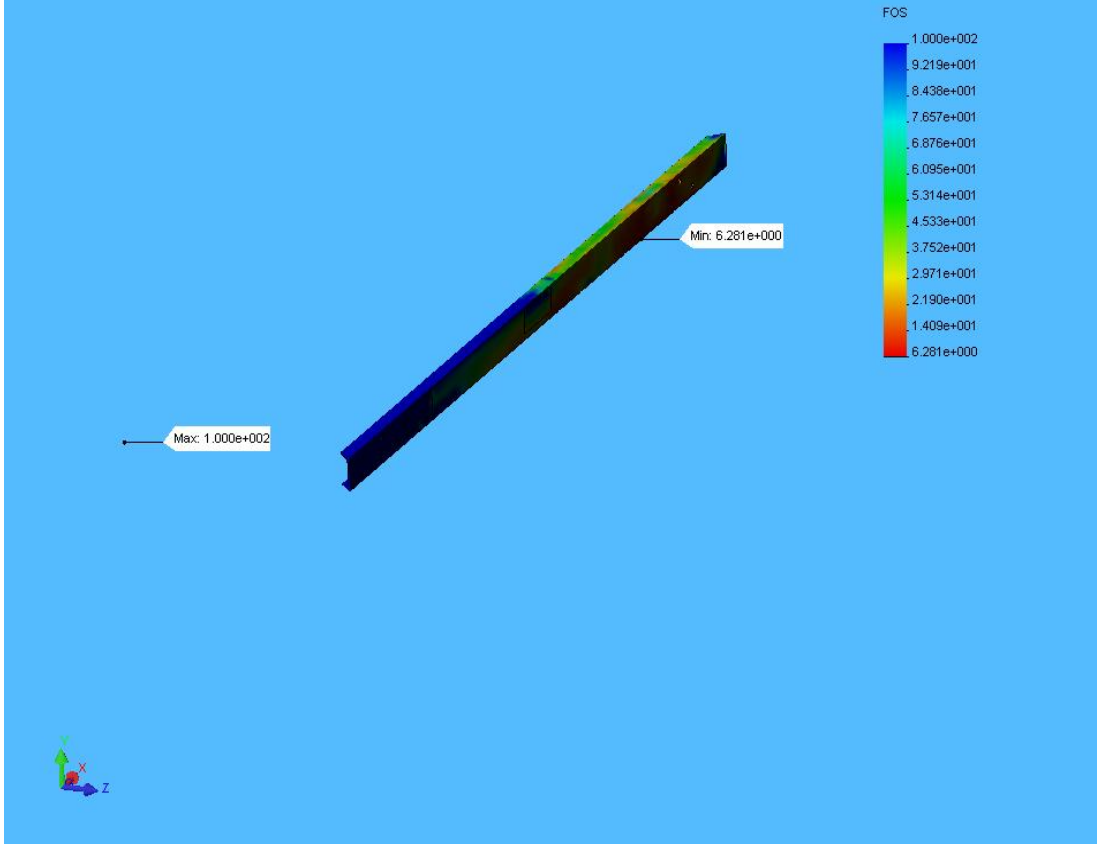
Model name: common base assy hjt  
Study name: levelers  
Plot type: Design Check Plot12  
Criterion: Max von Mises Stress  
Factor of safety distribution: Min FOS = 2.2



common base assy hjt-levelers-Design Check-Plot17

# JPEG

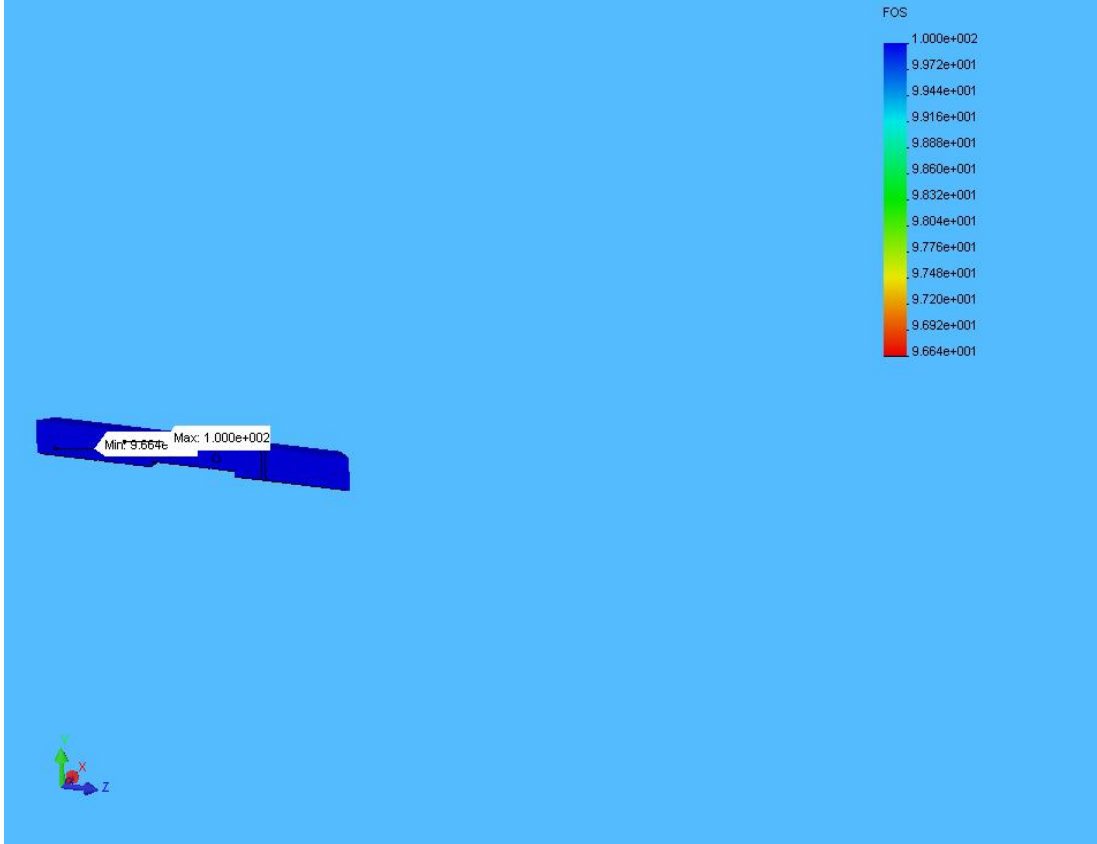
Model name: common base assy hjt  
Study name: levelers  
Plot type: Design Check Plot17  
Criterion: Max von Mises Stress  
Factor of safety distribution: Min FOS = 6.3



**common base assy hjt-levelers-Design Check-Plot18**

# JPEG

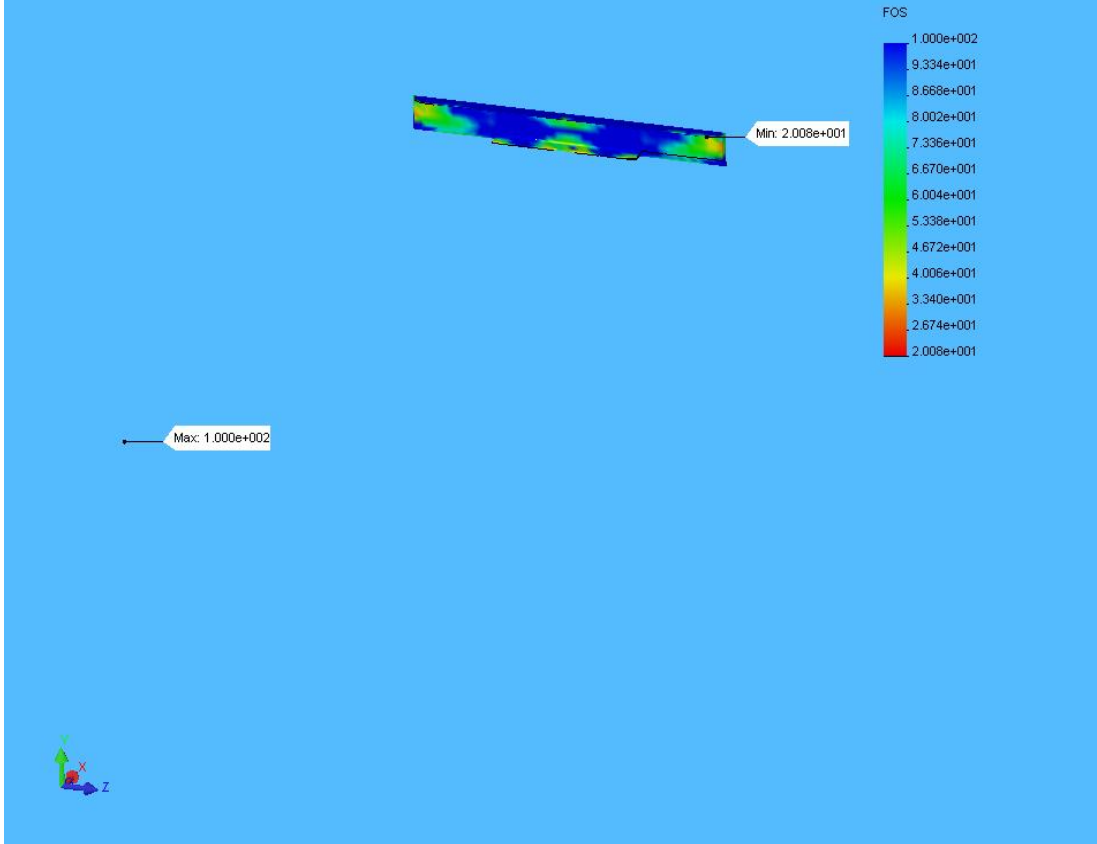
Model name: common base assy hjt  
Study name: levelers  
Plot type: Design Check Plot18  
Criterion : Max von Mises Stress  
Factor of safety distribution: Min FOS = 97



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

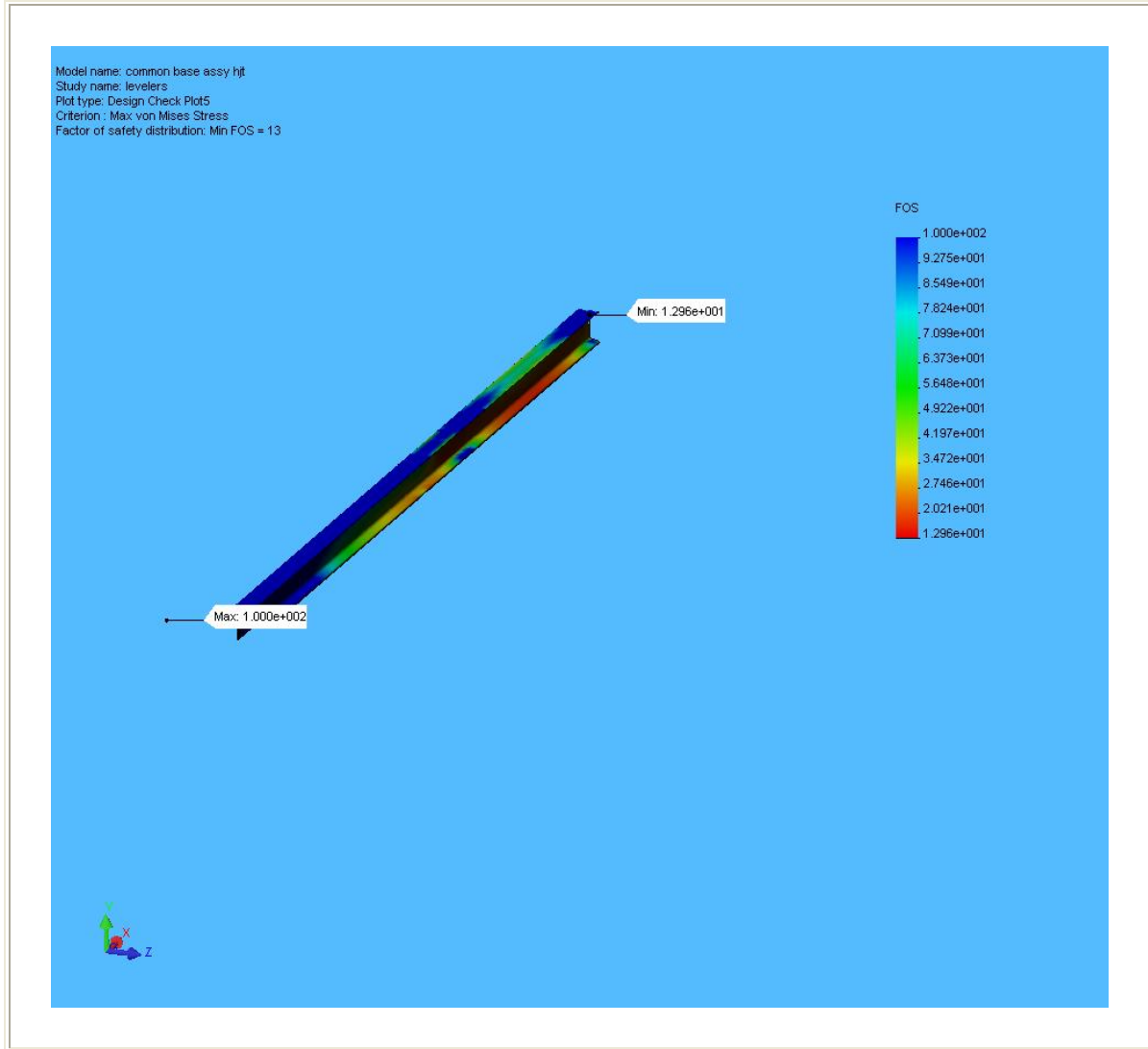
**JPEG**

Model name: common base assy hjt  
Study name: levelers  
Plot type: Design Check Plot4  
Criterion : Max von Mises Stress  
Factor of safety distribution: Min FOS = 20



**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 <sup>3</sup>	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 <sup>3</sup>	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 <sup>3</sup>	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](#)
2. [Materials](#)
3. [Load & Restraint Information](#)
4. [Study Property](#)
5. [Stress Results](#)
6. [Displacement Results](#)
7. [Design Check Results](#)
8. [Conclusion](#)
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---

## 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	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
2	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
3	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
4	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
5	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
6	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
7	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
8	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
9	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
10	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
11	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
12	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>

13	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
14	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
15	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
16	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
17	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
18	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
19	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
20	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
21	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
22	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
23	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
24	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
25	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
26	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
27	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
28	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
29	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
30	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
31	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>
32	base weldment hjt-1	<a href="#">6061-T6 (SS)</a>	428.213 lb	4389.96 in <sup>3</sup>

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

---

### 3. Load & Restraint Information

<b>Restraint</b>
------------------

<b>Restraint-1 &lt;base weldment hjt-1&gt;</b>	on <b>3 Face(s)</b> fixed.
<b>Description:</b>	Roller pads fixed

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

---

## 4. Study Property

<b>Mesh Information</b>	
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

<b>Solver Information</b>	
Quality:	High

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

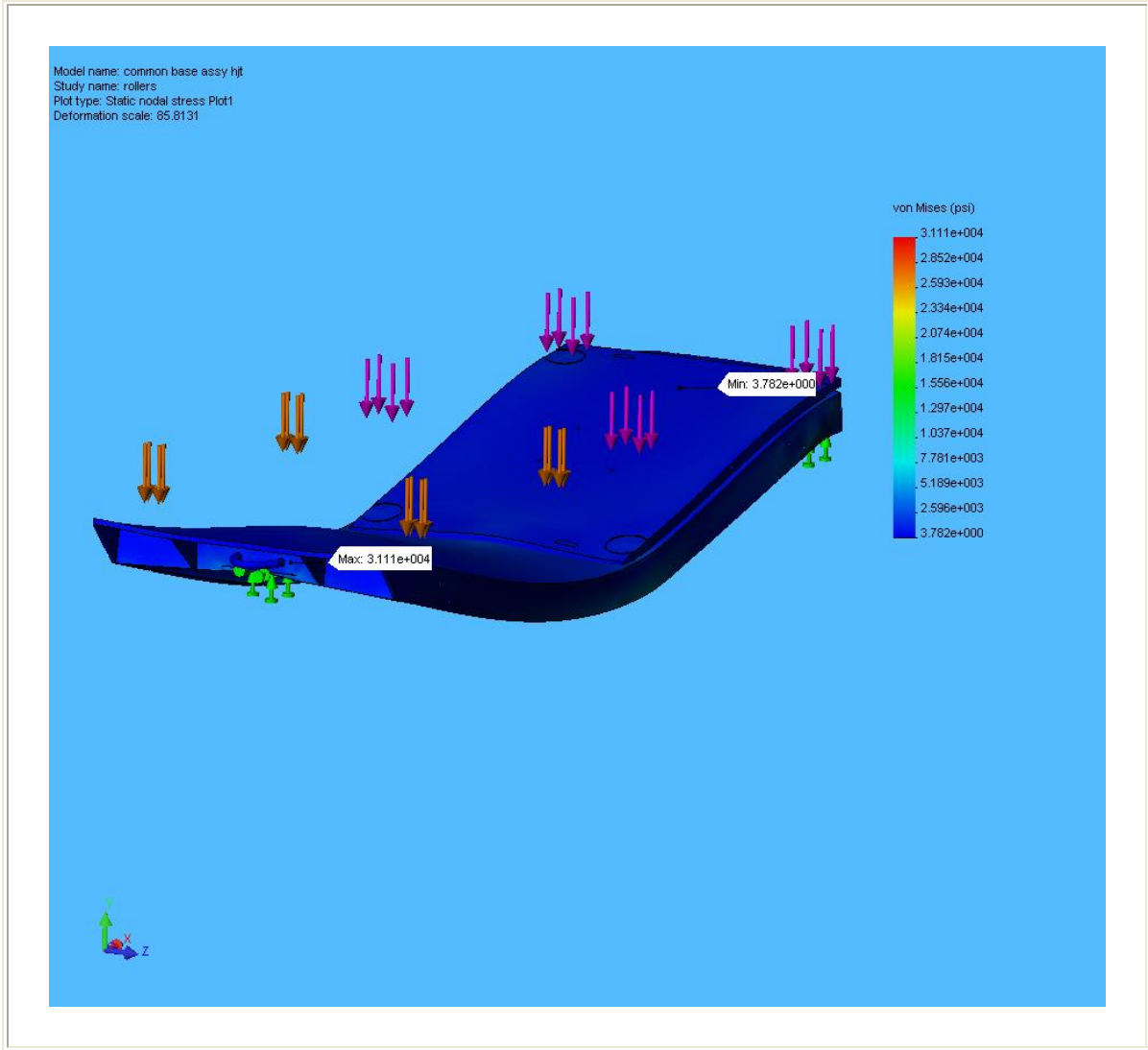
## 5. Stress Results

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**





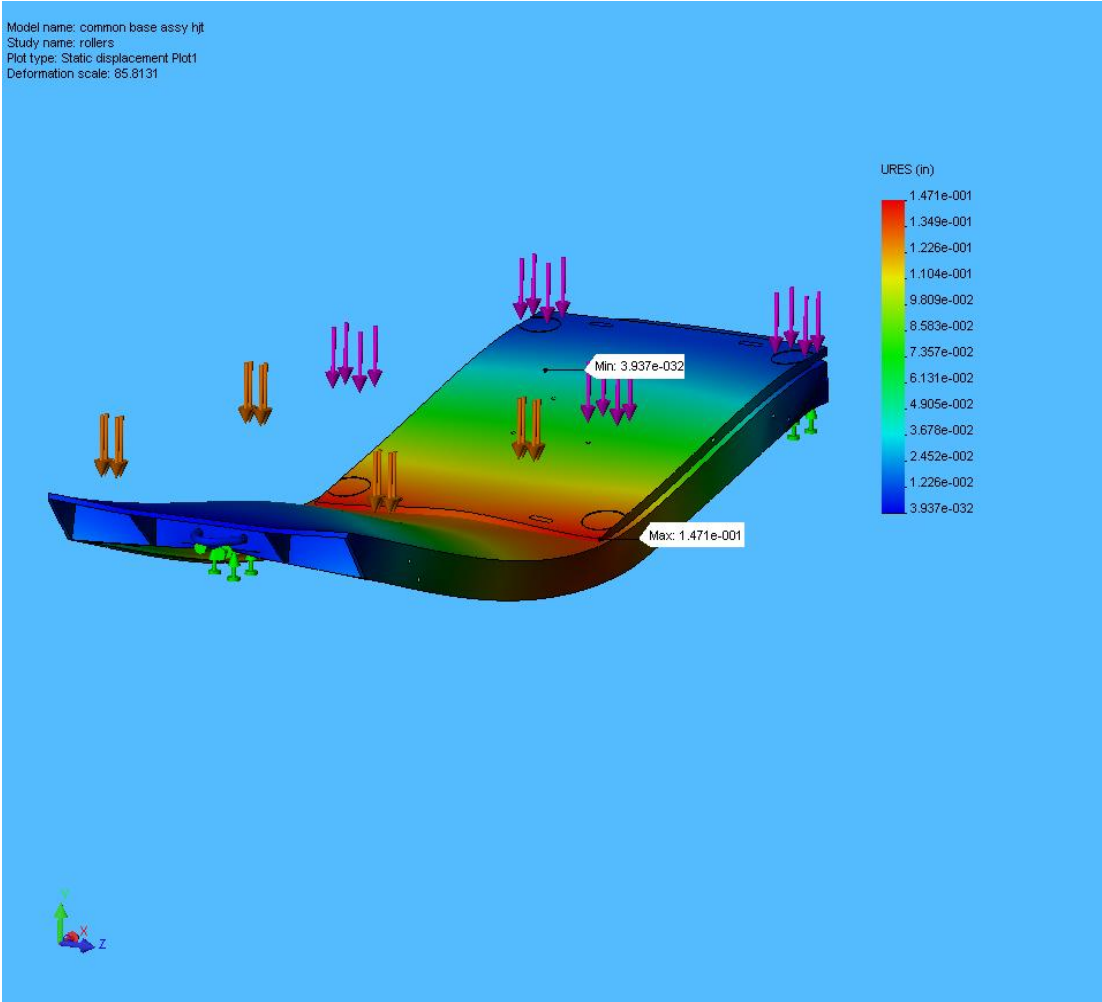
## 6. Displacement Results

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

		27840	-19.5 in)	Node: 64726	in, 19 in)
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common base assy hjt-rollers-Displacement-Plot1

JPEG

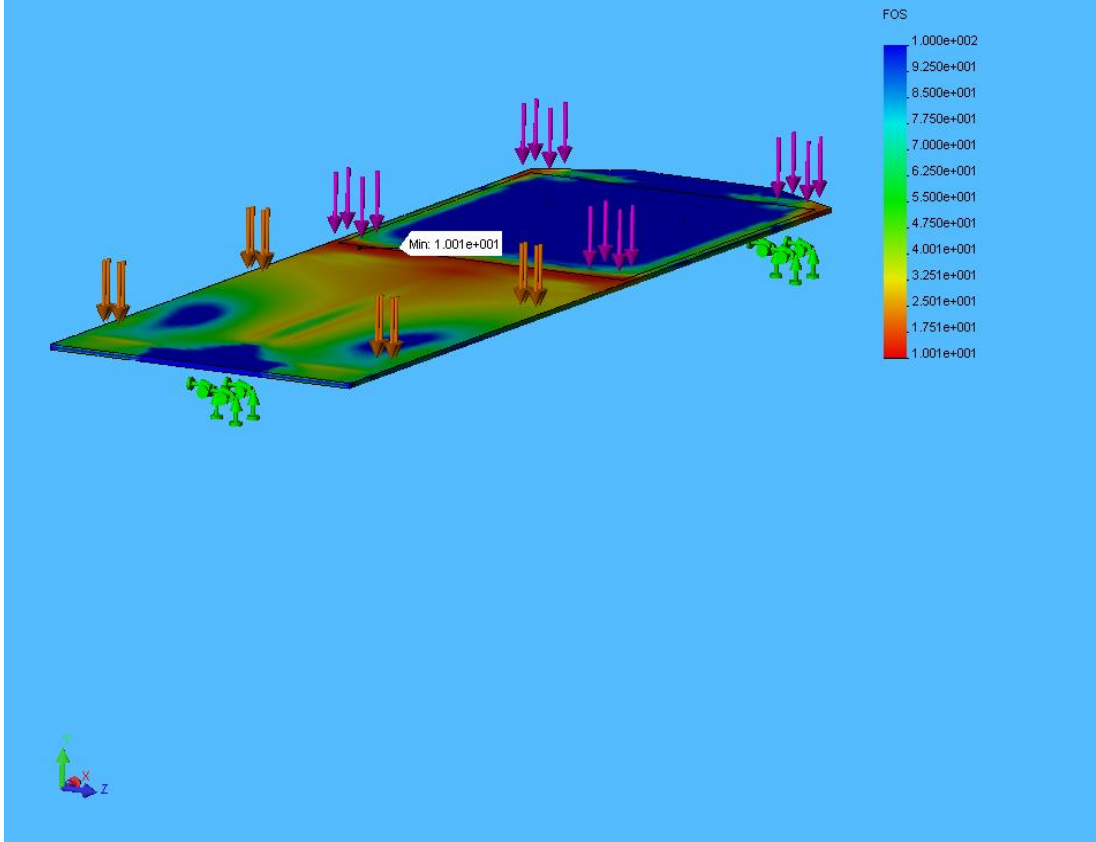


## 7. Design Check Results

common base assy hjt-rollers-Design Check-Plot4

JPEG

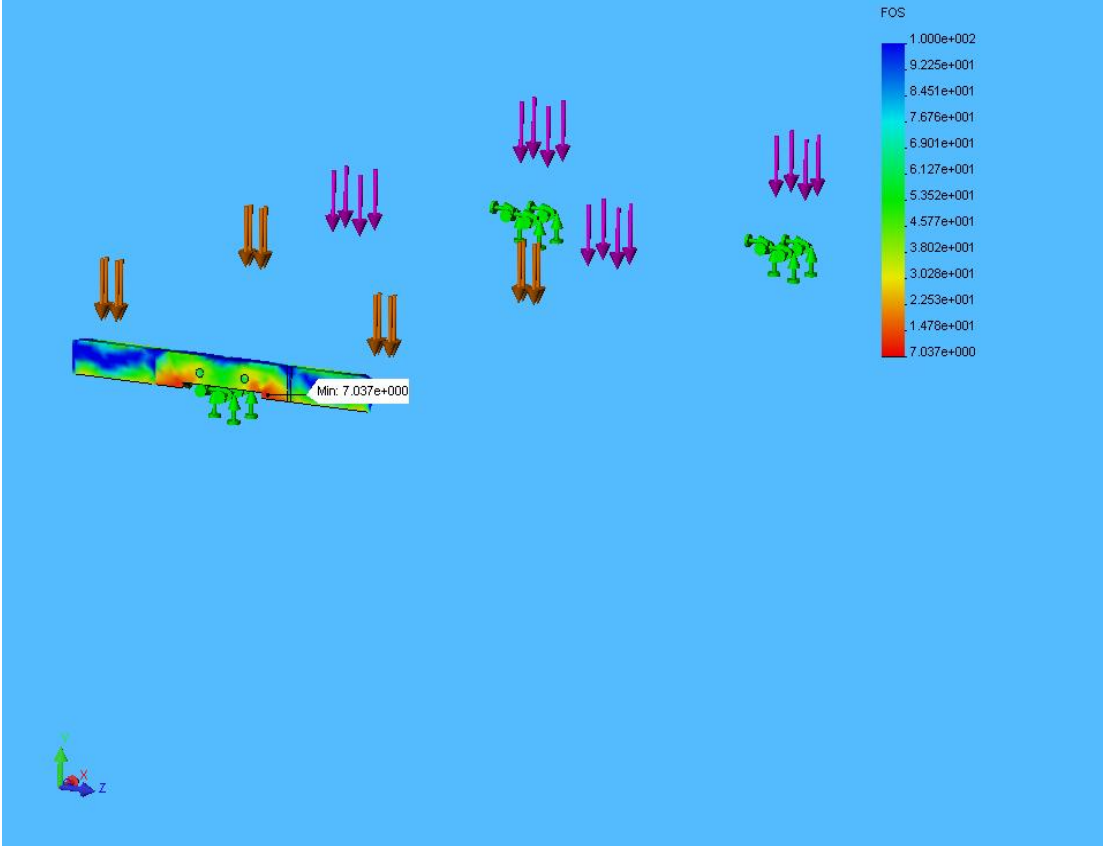
Model name: common base assy hjt  
Study name: rollers  
Plot type: Design Check Plot4  
Criterion: Max von Mises Stress  
Factor of safety distribution: Min FOS = 10



common base assy hjt-rollers-Design Check-Plot7

JPEG

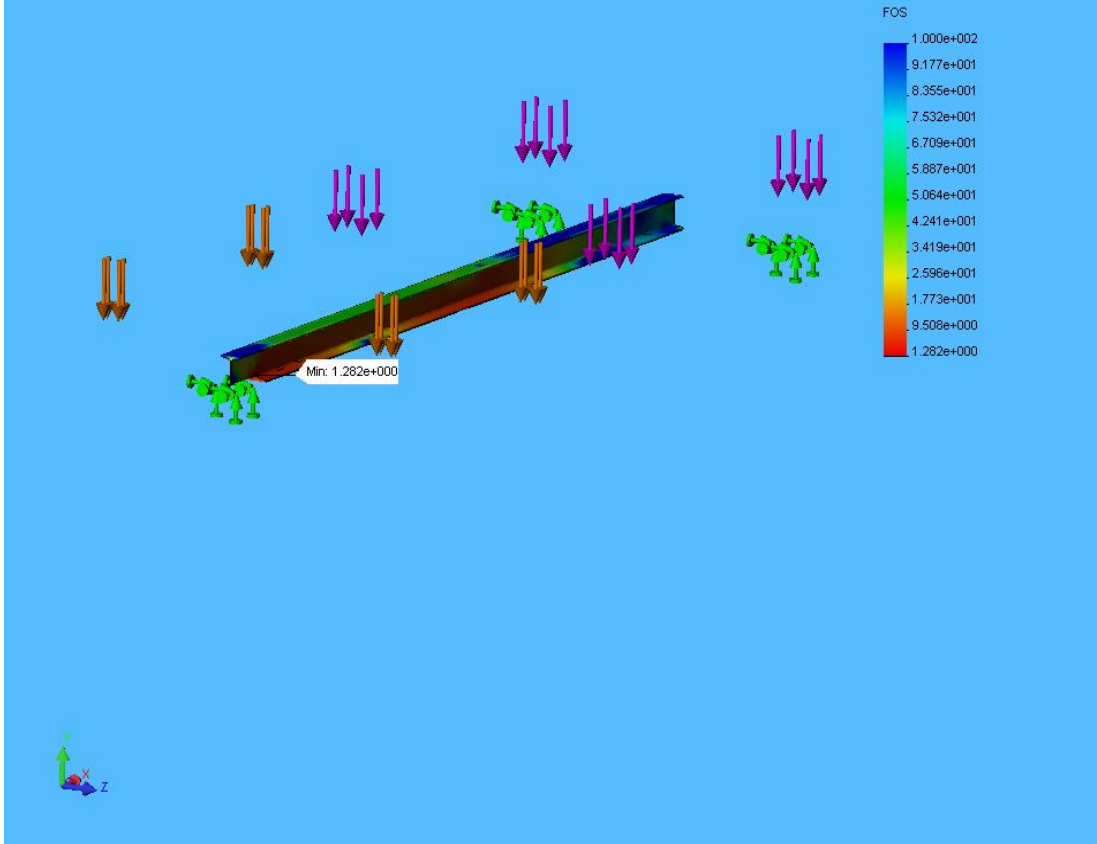
Model name: common base assy hjt  
Study name: rollers  
Plot type: Design Check Plot7  
Criterion: Max von Mises Stress  
Factor of safety distribution: Min FOS = 7



common base assy hjt-rollers-Design Check-Plot9

JPEG

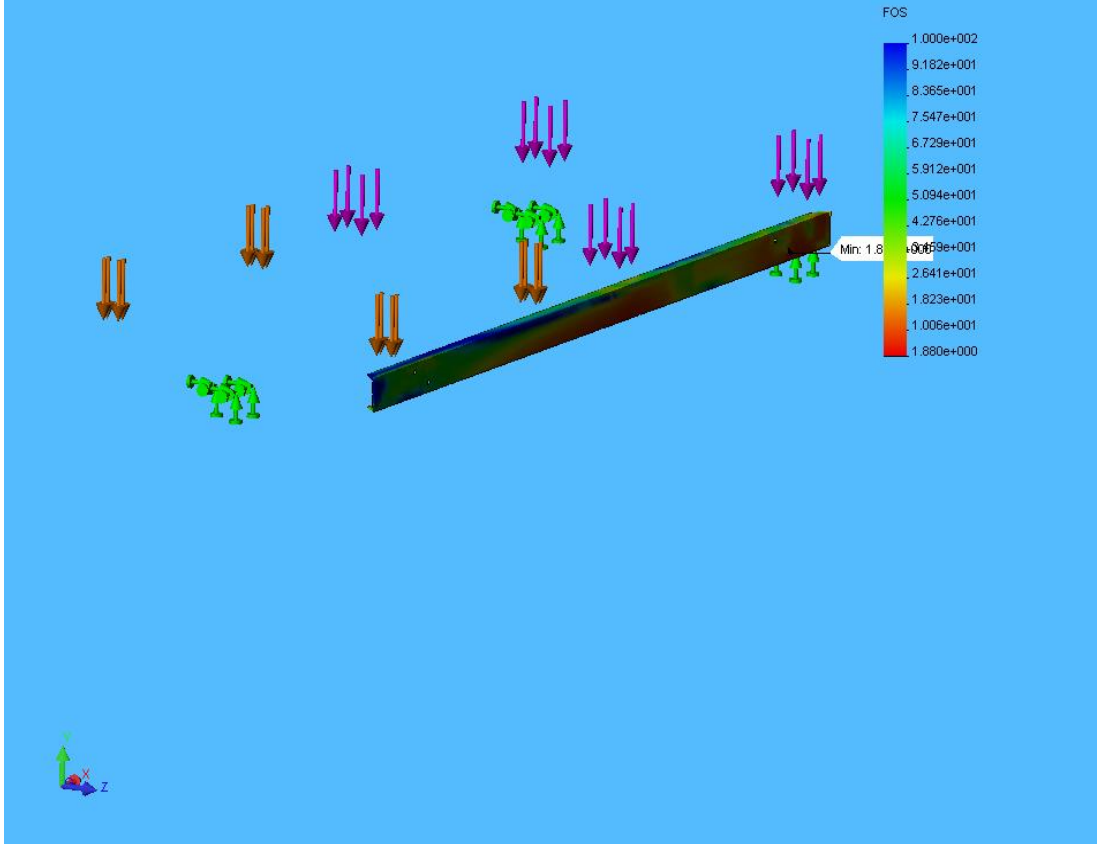
Model name: common base assy hjt  
Study name: rollers  
Plot type: Design Check Plot9  
Criterion: Max von Mises Stress  
Factor of safety distribution: Min FOS = 1.3



**common base assy hjt-rollers-Design Check-Plot6**

**JPEG**

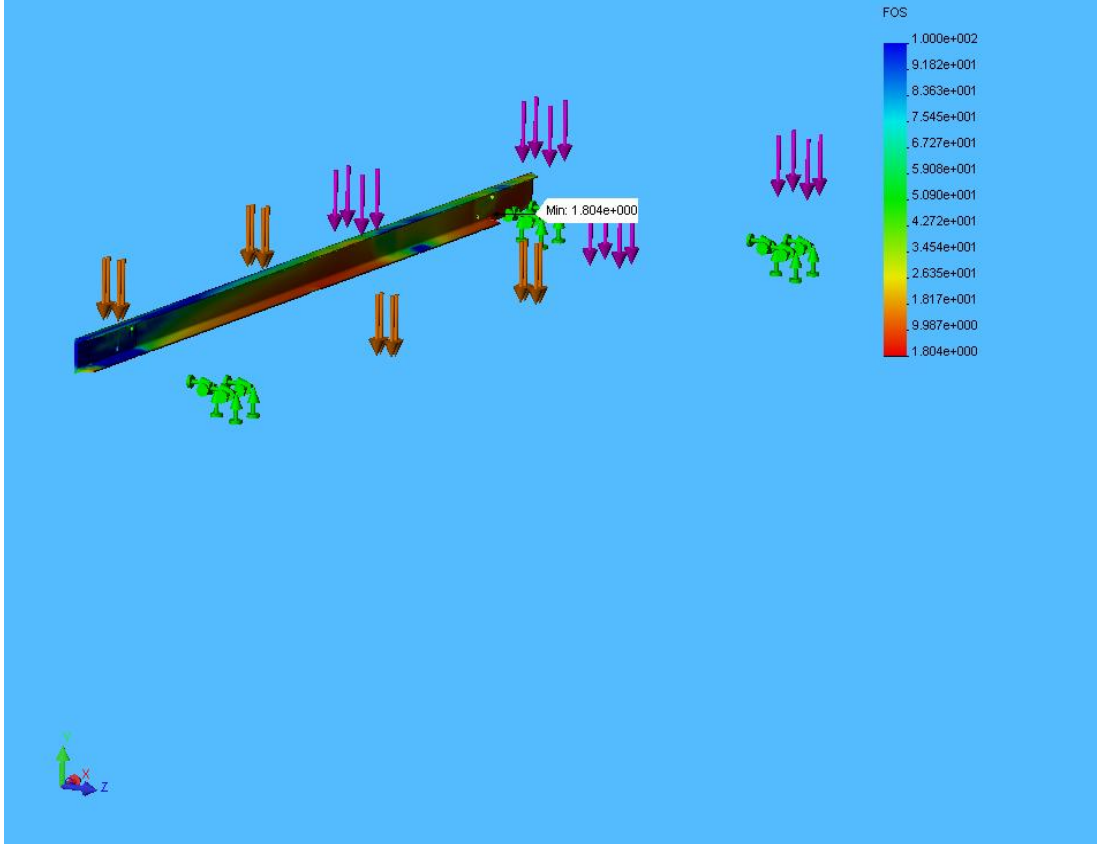
Model name: common base assy hjt  
Study name: rollers  
Plot type: Design Check Plot6  
Criterion: Max von Mises Stress  
Factor of safety distribution: Min FOS = 1.9



**common base assy hjt-rollers-Design Check-Plot8**

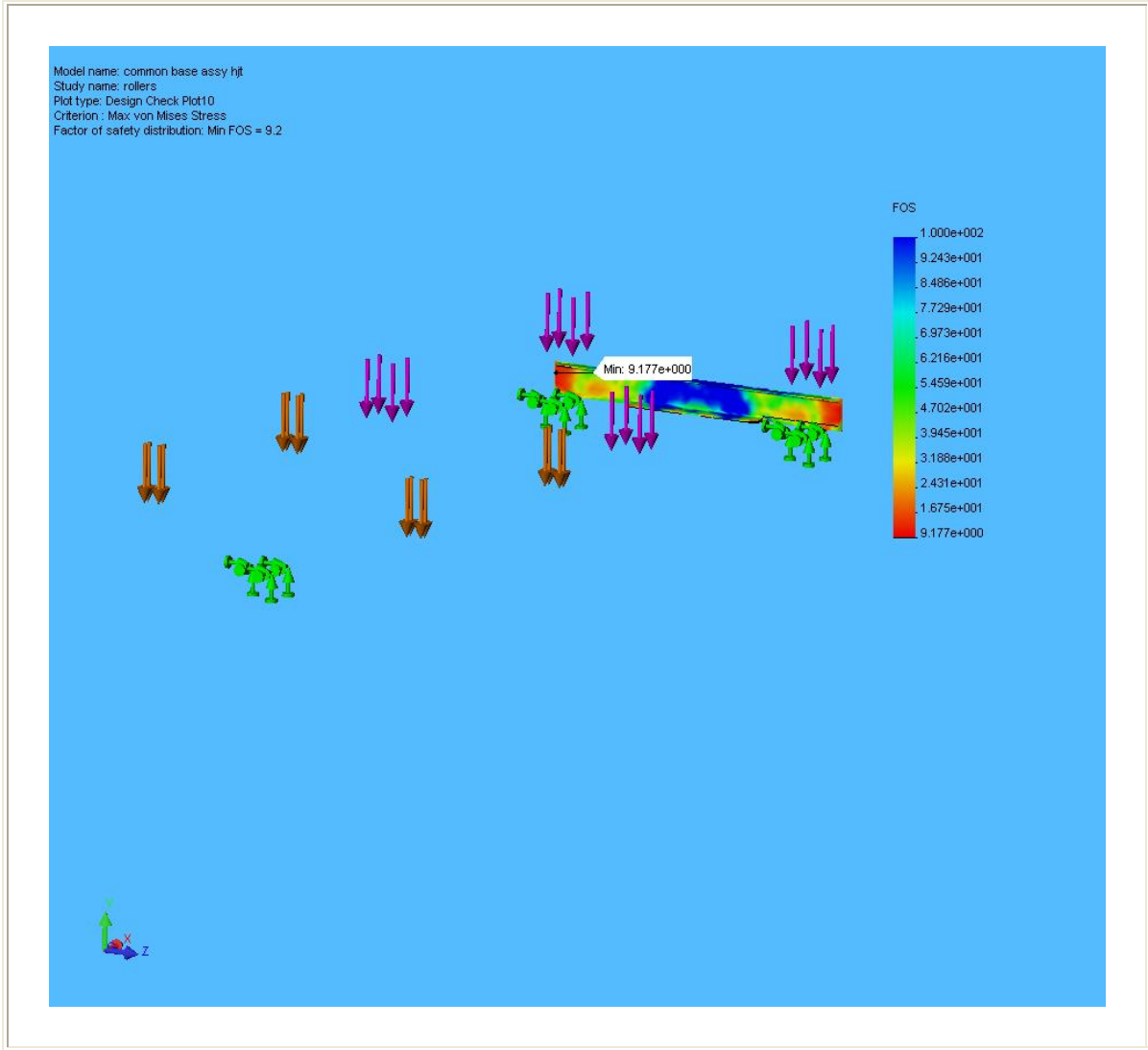
JPEG

Model name: common base assy hjt  
Study name: rollers  
Plot type: Design Check Plot8  
Criterion: Max von Mises Stress  
Factor of safety distribution: Min FOS = 1.8



**common base assy hjt-rollers-Design Check-Plot10**

JPEG



## 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 <sup>3</sup>	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](#)
2. [Materials](#)
3. [Load & Restraint Information](#)
4. [Study Property](#)
5. [Stress Results](#)
6. [Displacement Results](#)
7. [Design Check Results](#)
8. [Conclusion](#)
9. [Appendix](#)

---

## 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	<a href="#">6061-T6 (SS)</a>	104.029 lb	1066.49 in <sup>3</sup>
2	cart lower plate hjt	<a href="#">6061-T6 (SS)</a>	104.029 lb	1066.49 in <sup>3</sup>
3	cart lower plate hjt	<a href="#">6061-T6 (SS)</a>	104.029 lb	1066.49 in <sup>3</sup>
4	cart lower plate hjt	<a href="#">6061-T6 (SS)</a>	104.029 lb	1066.49 in <sup>3</sup>
5	cart lower plate hjt	<a href="#">6061-T6 (SS)</a>	104.029 lb	1066.49 in <sup>3</sup>
6	cart lower plate hjt	<a href="#">6061-T6 (SS)</a>	104.029 lb	1066.49 in <sup>3</sup>
7	cart lower plate hjt	<a href="#">6061-T6 (SS)</a>	104.029 lb	1066.49 in <sup>3</sup>
8	cart lower plate hjt	<a href="#">6061-T6 (SS)</a>	104.029 lb	1066.49 in <sup>3</sup>
9	cart lower plate hjt	<a href="#">6061-T6 (SS)</a>	104.029 lb	1066.49 in <sup>3</sup>

---

## 3. Load & Restraint Information

Restraint	
<b>Restraint-1 &lt;cart lower plate hjt&gt;</b>	on 4 Face(s) fixed.
<b>Description:</b>	Axles holes fixed.

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

---

## 4. Study Property

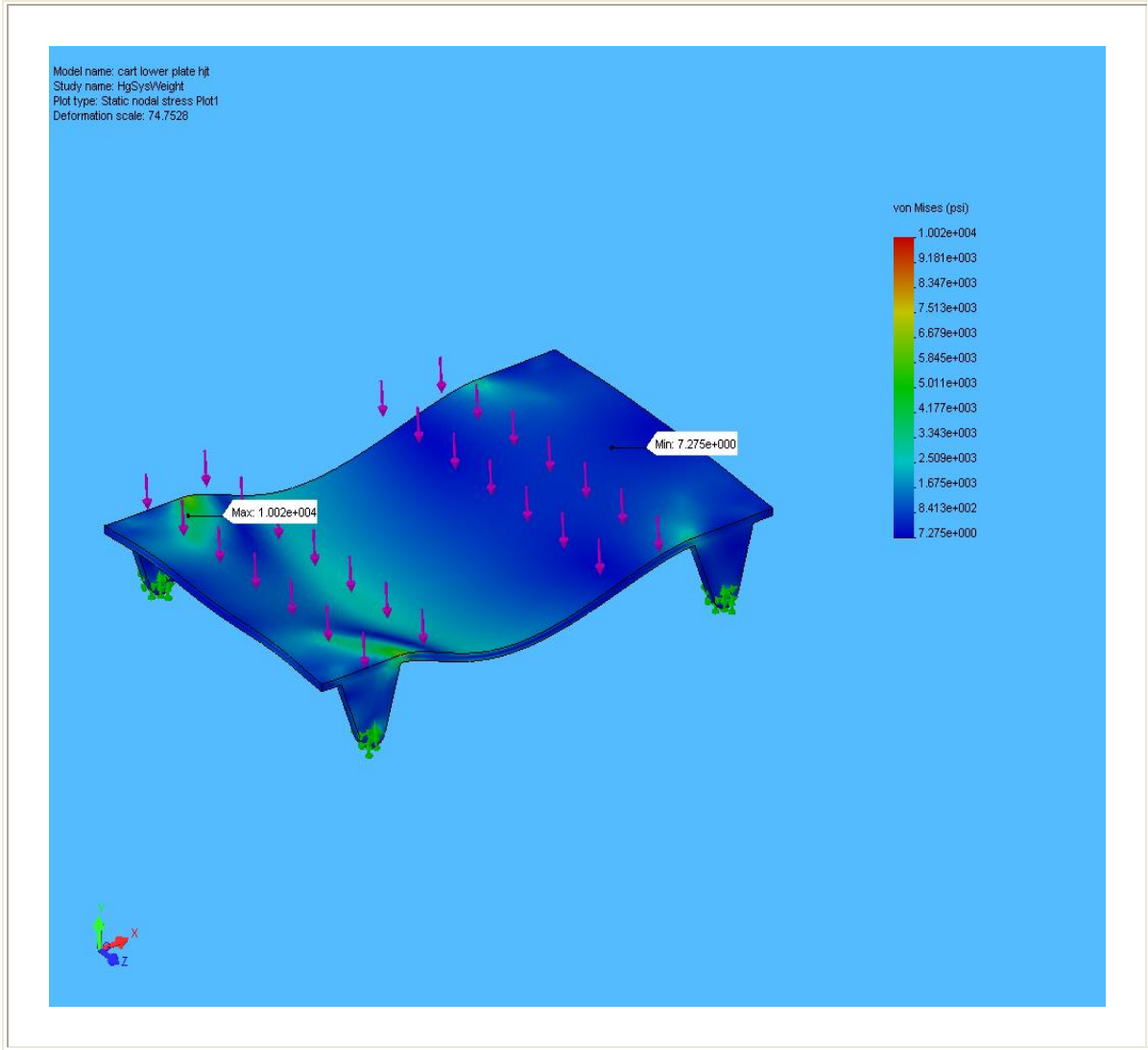
<b>Mesh Information</b>	
Mesh Type:	Solid mesh
Mesher Used:	Standard
Automatic Transition:	Off
Smooth Surface:	On
Jacobian Check:	4 Points
Element Size:	1.0218 in
Tolerance:	0.051091 in
Quality:	High
Number of elements:	9988
Number of nodes:	20458

<b>Solver Information</b>	
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)

<b>cart lower plate hjt-HgSysWeight-Stress-Plot1</b>
<b>JPEG</b>



## 6. Displacement Results

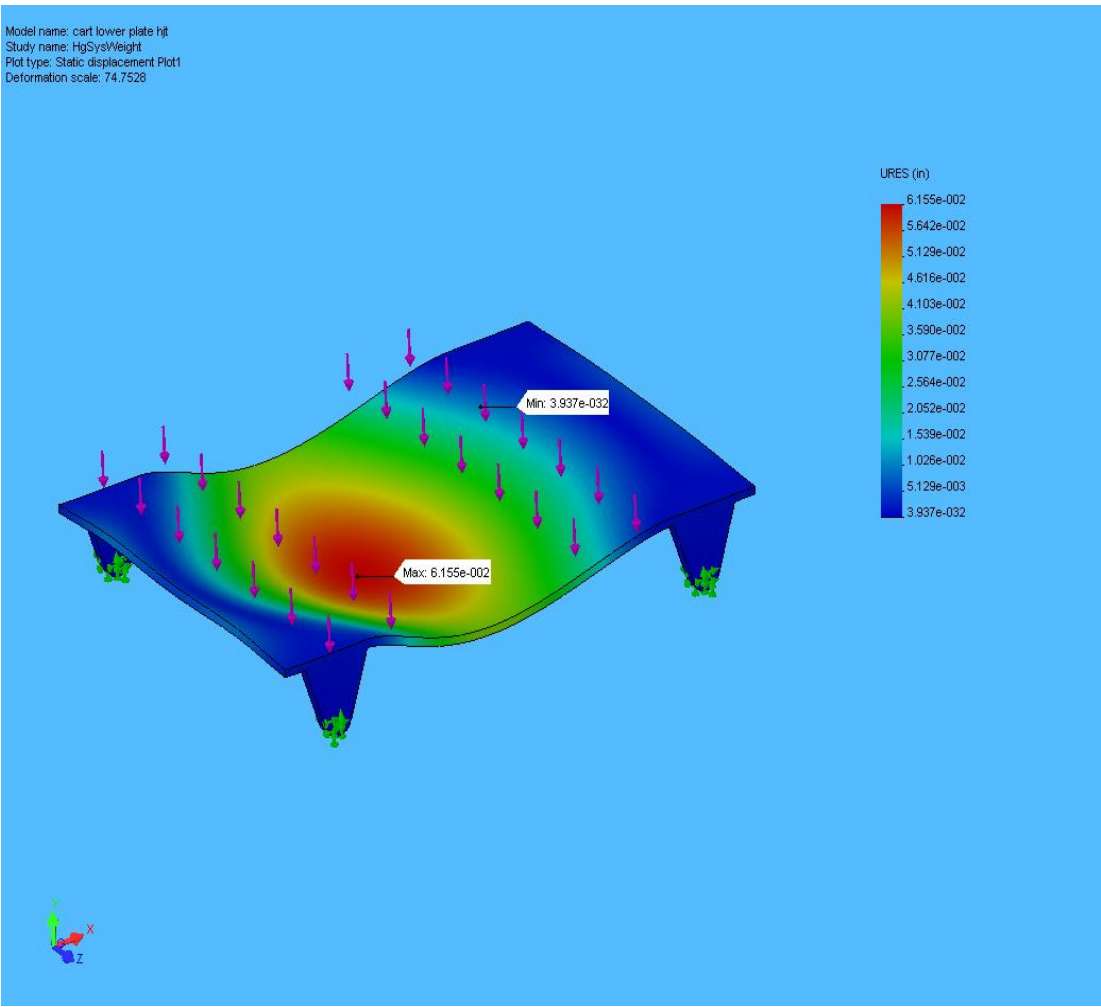
Name	Type	Min	Location	Max	Location
Plot1	URES: Resultant displacement	0 in	(18.5 in,	0.0615473 in	(-5.07733 in,
		Node:	-5.6325		

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

**cart lower plate hjt-HgSysWeight-Displacement-Plot1**

JPEG

Model name: cart lower plate hjt  
 Study name: HgSysWeight  
 Plot type: Static displacement Plot1  
 Deformation scale: 74.7528



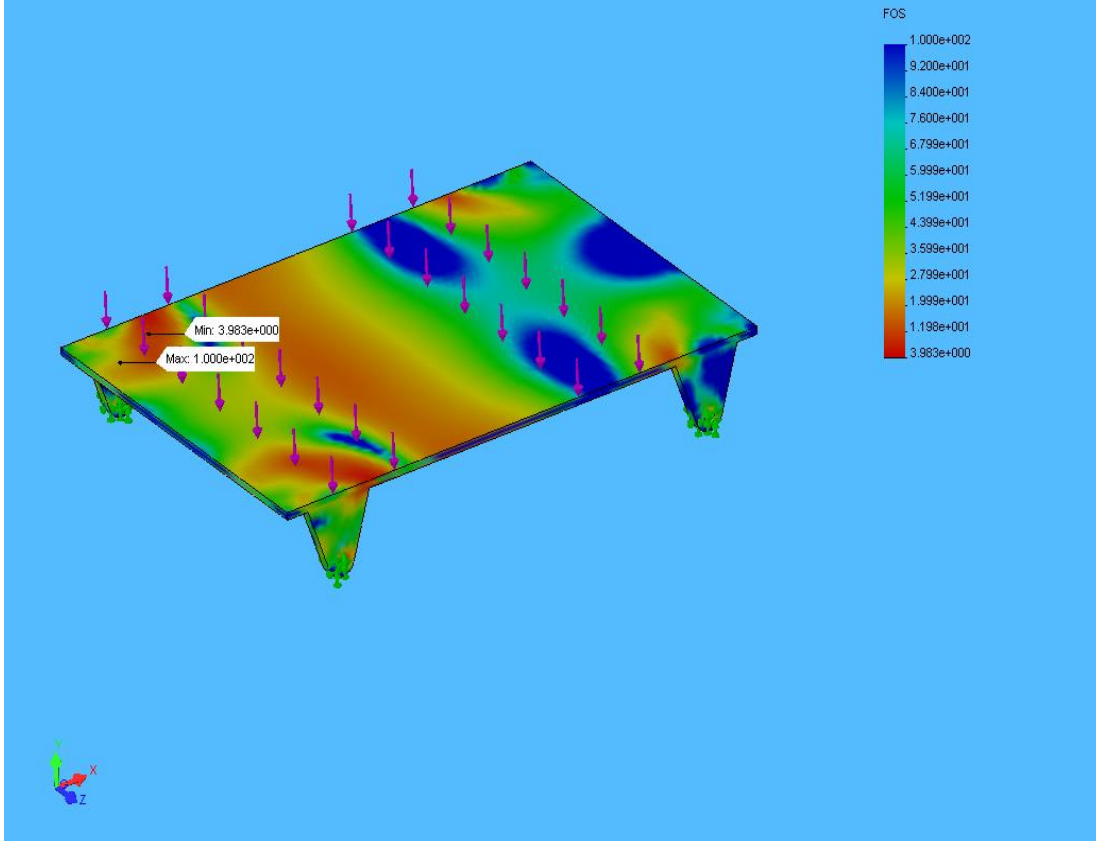


## 7. Design Check Results

cart lower plate hjt-HgSysWeight-Design Check-Plot1

JPEG

Model name: cart lower plate hjt  
Study name: HgSysWeight  
Plot type: Design Check Plot1  
Criterion : Max von Mises Stress  
Factor of safety distribution: Min FOS = 4



---

## 8. Conclusion

Analysis shows minimum safety factor = 4, with maximum stress occurring 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 <sup>3</sup>	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



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<sup>3</sup> 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



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:

<b>Resolution</b>	0.001 mg/m <sup>3</sup>
<b>Detection Range</b>	0.003-0.999 mg/m <sup>3</sup>
<b>Precision</b>	5% Relative Standard Deviation at 0.100 mg/m <sup>3</sup>
<b>Accuracy</b>	±5% at 0.100 mg/m <sup>3</sup>
<b>Response Time</b>	13 seconds in Sample Mode; 4 seconds in Survey Mode
<b>Flow Rate</b>	750 cc/min
<b>Environmental Range</b>	0-40°C, noncondensing, nonexplosive
<b>Interface</b>	RS-232 port using Jerome Communications Software
<b>Dimensions</b>	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
<b>Weight</b>	431-X: 7 lbs / 3 kg 431-XE: 8 lbs / 3.5 kg
<b>Internal Battery Pack</b>	Rechargeable nickel-cadmium
<b>Power Requirements</b>	100-120 V~, 50/60 Hz, 1 A or 220-240 V~, 50/60 Hz, 1 A
<b>Warranty</b>	1 year, factory parts and labor
<b>Marks</b>	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<sup>3</sup> and 0.025 mg/m<sup>3</sup>

### Applications:

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

## Appendix G. Scavenger

## SCAVENGER SERIES



**HS-3000A1 Single Hose Scavenger**

[Get Prices](#)



**HS-3000A2 Two Hose Scavenger**



**Custom Hood**

### **Capture fumes and particles at the source**

Ideal for use in:

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

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 HS3000A1 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-3000A1 - 37 lbs. HS-3000A2 - 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 Face Velocity		Max Airflow Face Velocity	
	CFM	FPM	CFM	FPM
None	173	1275	273	1010
HEPA	118	870	154	565
HEPA/Dacron/.5" Carbon	116	850	143	525
HEPA/Dacron/2" Carbon	94	690	110	405
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](#)



154 Huron Avenue  
Clifton, NJ 07013  
Phone: 973.779.5577  
Toll Free: 800.452.8510  
Fax: 973.779.5954  
[airfiltron@aol.com](mailto:airfiltron@aol.com)

Web Design by:

**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:**

<b>Models Part No</b>	<b>HP</b>	<b>1 Phase/Volts @ 60 HZ</b>	<b>Amps</b>	<b>Vacuum Pressure at Sealed Orifice H2O</b>	<b>Airflow CFM/l/s</b>
---------------------------	-----------	----------------------------------	-------------	--	----------------------------

**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)

<b>Models Part No</b>	<b>KW</b>	<b>1 Phase/Volts @ 50 HZ</b>	<b>Amps</b>	<b>Vacuum Pressure at Sealed Orifice mm H2O</b>	<b>Airflow l/s</b>
---------------------------	-----------	----------------------------------	-------------	---	------------------------

**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

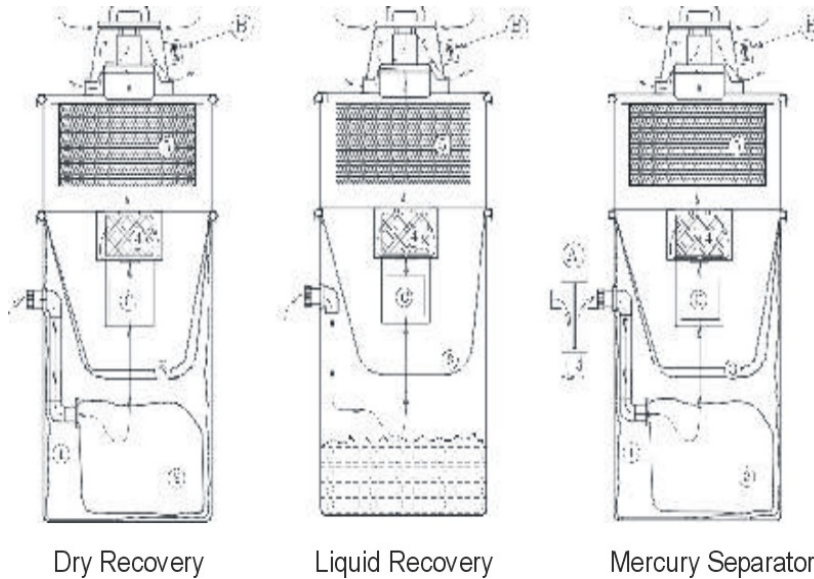
**Suction Orifice :** 38mm

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



microns

**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. Hour 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

**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/M<sup>3</sup>. 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 other 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 Mannes Schmidt 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 J. Material Safety Data Sheets**

# Material Safety Data Sheet

Mercury, 99.999%

ACC# 96252

## Section 1 - Chemical Product and Company Identification

**MSDS Name:** Mercury, 99.999%

**Catalog Numbers:** AC193480000, AC193480500

**Synonyms:** Colloidal mercury; Hydrargyrum; Metallic mercury; Quick silver; Liquid silver

**Company Identification:**

Acros Organics N.V.

One Reagent Lane

Fair Lawn, NJ 07410

**For information in North America, call:** 800-ACROS-01

**For emergencies in the US, call CHEMTREC:** 800-424-9300

## Section 2 - Composition, Information on Ingredients

CAS#	Chemical Name	Percent	EINECS/ELINCS
7439-97-6	Mercury	99.999	231-106-7

## Section 3 - Hazards Identification

### EMERGENCY OVERVIEW

Appearance: silver liquid.

**Danger!** Corrosive. Harmful if inhaled. May be absorbed through intact skin. Causes eye and skin irritation and possible burns. May cause severe respiratory tract irritation with possible burns. May cause severe digestive tract irritation with possible burns. May cause central nervous system effects. This substance has caused adverse reproductive and fetal effects in animals. Inhalation of fumes may cause metal-fume fever. May cause liver and kidney damage. Possible sensitizer.

**Target Organs:** Blood, kidneys, central nervous system, liver, brain.

### Potential Health Effects

**Eye:** Exposure to mercury or mercury compounds can cause discoloration on the front surface of the lens, which does not interfere with vision. Causes eye irritation and possible burns. Contact with mercury or mercury compounds can cause ulceration of the conjunctiva and cornea.

**Skin:** May be absorbed through the skin in harmful amounts. May cause skin sensitization, an allergic reaction, which becomes evident upon re-exposure to this material. Causes skin irritation and possible burns. May cause skin rash (in milder cases), and cold and clammy skin with cyanosis or pale color.

**Ingestion:** May cause severe and permanent damage to the digestive tract. May cause perforation of the digestive tract. May cause effects similar to those for inhalation exposure. May cause systemic effects.

**Inhalation:** Causes chemical burns to the respiratory tract. Inhalation of fumes may cause metal fume fever, which is characterized by flu-like symptoms with metallic taste, fever, chills, cough, weakness, chest pain, muscle pain and increased white blood cell count. May cause central nervous system effects including vertigo, anxiety, depression, muscle incoordination, and emotional instability. Aspiration may lead to pulmonary edema. May cause systemic effects. May cause respiratory sensitization.

**Chronic:** May cause liver and kidney damage. May cause reproductive and fetal effects. Effects may be delayed. Chronic exposure to mercury may cause permanent central nervous system damage, fatigue, weight loss, tremors, personality changes. Chronic ingestion may cause accumulation of mercury in body tissues. Prolonged or repeated exposure may cause inflammation of the mouth and gums, excessive salivation, and loosening of the teeth.

## Section 4 - First Aid Measures

**Eyes:** Get medical aid immediately. Do NOT allow victim to rub eyes or keep eyes closed. Extensive irrigation with water is required (at least 30 minutes).

**Skin:** Get medical aid immediately. Immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse. Destroy contaminated shoes.

**Ingestion:** Do not induce vomiting. If victim is conscious and alert, give 2-4 cupfuls of milk or water. Never give anything by mouth to an unconscious person. Get medical aid immediately. Wash mouth out with water.

**Inhalation:** Get medical aid immediately. Remove from exposure and move to fresh air immediately. If breathing is difficult, give oxygen. Do NOT use mouth-to-mouth resuscitation. If breathing has ceased apply artificial respiration using oxygen and a suitable mechanical device such as a bag and a mask.

**Notes to Physician:** The concentration of mercury in whole blood is a reasonable measure of the body-burden of mercury and thus is used for monitoring purposes. Treat symptomatically and supportively. Persons with kidney disease, chronic respiratory disease, liver disease, or skin disease may be at increased risk from exposure to this substance.

**Antidote:** The use of d-Penicillamine as a chelating agent should be determined by qualified medical personnel. The use of Dimercaprol or BAL (British Anti-Lewisite) as a chelating agent should be determined by qualified medical personnel.

## Section 5 - Fire Fighting Measures

**General Information:** As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear. Water runoff can cause environmental damage. Dike and collect water used to fight fire. During a fire, irritating and highly toxic gases may be generated by thermal decomposition or combustion.

**Extinguishing Media:** Substance is nonflammable; use agent most appropriate to extinguish surrounding fire. Use water spray, dry chemical, carbon dioxide, or appropriate foam.

**Flash Point:** Not applicable.

**Autoignition Temperature:** Not applicable.

**Explosion Limits, Lower:** Not available.

**Upper:** Not available.

**NFPA Rating:** (estimated) Health: 3; Flammability: 0; Instability: 0

## Section 6 - Accidental Release Measures

**General Information:** Use proper personal protective equipment as indicated in Section 8.

**Spills/Leaks:** Absorb spill with inert material (e.g. vermiculite, sand or earth), then place in suitable container. Avoid runoff into storm sewers and ditches which lead to waterways. Clean up spills immediately, observing precautions in the Protective Equipment section. Provide ventilation.

## Section 7 - Handling and Storage

**Handling:** Wash thoroughly after handling. Remove contaminated clothing and wash before reuse. Minimize dust generation and accumulation. Keep container tightly closed. Do not get on skin or in eyes. Do not ingest or inhale. Use only in a chemical fume hood. Discard contaminated shoes. Do not breathe vapor.

**Storage:** Keep container closed when not in use. Store in a tightly closed container. Store in a cool, dry, well-ventilated area away from incompatible substances. Keep away from metals. Store protected from azides.

## Section 8 - Exposure Controls, Personal Protection

**Engineering Controls:** Facilities storing or utilizing this material should be equipped with an eyewash facility and a safety shower. Use only under a chemical fume hood.

### Exposure Limits

Chemical Name	ACGIH	NIOSH	OSHA - Final PELs
Mercury	0.025 mg/m <sup>3</sup> TWA; Skin - potential significant contribution to overall exposure by the cutaneous route	0.05 mg/m <sup>3</sup> TWA (vapor) 10 mg/m <sup>3</sup> IDLH	0.1 mg/m <sup>3</sup> Ceiling (vapor)

**OSHA Vacated PELs:** Mercury: 0.05 mg/m<sup>3</sup> TWA (vapor)

### Personal Protective Equipment

**Eyes:** Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166.

**Skin:** Wear appropriate protective gloves to prevent skin exposure.

**Clothing:** Wear appropriate protective clothing to prevent skin exposure.

**Respirators:** A respiratory protection program that meets OSHA's 29 CFR 1910.134 and ANSI Z88.2 requirements or European Standard EN 149 must be followed whenever workplace conditions warrant respirator use.

## Section 9 - Physical and Chemical Properties

**Physical State:** Liquid

**Appearance:** silver

**Odor:** odorless

**pH:** Not available.

**Vapor Pressure:** 0.002 mm Hg @ 25C

**Vapor Density:** 7.0

**Evaporation Rate:** Not available.

**Viscosity:** 15.5 mP @ 25 deg C

**Boiling Point:** 356.72 deg C

**Freezing/Melting Point:** -38.87 deg C

**Decomposition Temperature:** Not available.

**Solubility:** Insoluble.

**Specific Gravity/Density:** 13.59 (water=1)

**Molecular Formula:** Hg

**Molecular Weight:** 200.59

## Section 10 - Stability and Reactivity

**Chemical Stability:** Stable under normal temperatures and pressures.

**Conditions to Avoid:** High temperatures, incompatible materials.

**Incompatibilities with Other Materials:** Metals, aluminum, ammonia, chlorates, copper, copper alloys, ethylene oxide, halogens, iron, nitrates, sulfur, sulfuric acid, oxygen, acetylene, lithium, rubidium, sodium carbide, lead, nitromethane, peroxyformic acid, calcium, chlorine dioxide, metal oxides, azides, 3-bromopropyne, alkynes + silver perchlorate, methylsilane + oxygen, tetracarbonylnickel + oxygen, boron diiodophosphide.

**Hazardous Decomposition Products:** Mercury/mercury oxides.

**Hazardous Polymerization:** Will not occur.

## Section 11 - Toxicological Information

**RTECS#:**

**CAS#** 7439-97-6: OV4550000

**LD50/LC50:**

Not available.

**Carcinogenicity:**

**CAS#** 7439-97-6: Not listed by ACGIH, IARC, NTP, or CA Prop 65.

**Epidemiology:** Intraperitoneal, rat: TDLo = 400 mg/kg/14D-I (Tumorigenic - equivocal tumorigenic agent by RTECS criteria - tumors at site of application).

**Teratogenicity:** Inhalation, rat: TCLo = 1 mg/m<sup>3</sup>/24H (female 1-20 day(s) after conception) Effects on Embryo or Fetus - fetotoxicity (except death, e.g., stunted fetus).

**Reproductive Effects:** Inhalation, rat: TCLo = 890 ng/m<sup>3</sup>/24H (male 16 week(s) pre-mating) Paternal Effects - spermatogenesis (incl. genetic material, sperm morphology, motility, and count).; Inhalation, rat: TCLo = 7440 ng/m<sup>3</sup>/24H (male 16 week(s) pre-mating) Fertility - post-implantation mortality (e.g. dead and/or resorbed implants per total number of implants).

**Mutagenicity:** Cytogenetic Analysis: Unreported, man = 150 ug/m<sup>3</sup>.

**Neurotoxicity:** The brain is the critical organ in humans for chronic vapor exposure; in severe cases, spontaneous degeneration of the brain cortex can occur as a late sequela to past exposure.

**Other Studies:**

## Section 12 - Ecological Information

**Ecotoxicity:** Fish: Rainbow trout: LC50 = 0.16-0.90 mg/L; 96 Hr; UnspecifiedFish: Bluegill/Sunfish: LC50 = 0.16-0.90 mg/L; 96 Hr; UnspecifiedFish: Channel catfish: LC50 = 0.35 mg/L; 96 Hr; UnspecifiedWater flea Daphnia: EC50 = 0.01 mg/L; 48 Hr; Unspecified In aquatic systems, mercury appears to bind to dissolved matter or fine particulates, while the transport of mercury bound to dust particles in the atmosphere or bed sediment particles in rivers and lakes is generally less substantial. The conversion, in aquatic environments, of inorganic mercury compd to methyl mercury implies that recycling of mercury from sediment to water to air and back could be a rapid process.

**Environmental:** Mercury bioaccumulates and concentrates in food chain (concentration may be as much as 10,000 times that of water). Bioconcentration factors of 63,000 for freshwater fish and 10,000 for salt water fish have been found. Much of the mercury deposited on land, appears to revaporize within a day or two, at least in areas substantially heated by sunlight.

**Physical:** All forms of mercury (Hg) (metal, vapor, inorganic, or organic) are converted to methyl mercury. Inorganic forms are converted by microbial action in the atmosphere to methyl mercury.

**Other:** No information available.

## Section 13 - Disposal Considerations

Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. US EPA guidelines for the classification determination are listed in 40 CFR Parts 261.3. Additionally, waste generators must consult state and local hazardous waste regulations to ensure complete and accurate classification.

**RCRA P-Series:** None listed.

**RCRA U-Series:**

**CAS#** 7439-97-6: waste number U151.

## Section 14 - Transport Information

<b>Shipping Name:</b>	DOT regulated - small quantity provisions apply (see 49CFR173.4)	MERCURY
<b>Hazard Class:</b>		8
<b>UN Number:</b>		UN2809
<b>Packing Group:</b>		III

## Section 15 - Regulatory Information

### US FEDERAL

#### TSCA

CAS# 7439-97-6 is listed on the TSCA inventory.

#### Health & Safety Reporting List

None of the chemicals are on the Health & Safety Reporting List.

#### Chemical Test Rules

None of the chemicals in this product are under a Chemical Test Rule.

#### Section 12b

None of the chemicals are listed under TSCA Section 12b.

#### TSCA Significant New Use Rule

None of the chemicals in this material have a SNUR under TSCA.

#### CERCLA Hazardous Substances and corresponding RQs

CAS# 7439-97-6: 1 lb final RQ; 0.454 kg final RQ

#### SARA Section 302 Extremely Hazardous Substances

None of the chemicals in this product have a TPQ.

#### SARA Codes

CAS # 7439-97-6: immediate, delayed.

#### Section 313

This material contains Mercury (CAS# 7439-97-6, 99.999%), which is subject to the reporting requirements of Section 313 of SARA Title III and 40 CFR Part 373.

#### Clean Air Act:

CAS# 7439-97-6 (listed as Mercury compounds) is listed as a hazardous air pollutant (HAP).

This material does not contain any Class 1 Ozone depleters.

This material does not contain any Class 2 Ozone depleters.

#### Clean Water Act:

None of the chemicals in this product are listed as Hazardous Substances under the CWA. CAS# 7439-97-6 is listed as a Priority Pollutant under the Clean Water Act. CAS# 7439-97-6 is listed as a Toxic Pollutant under the Clean Water Act.

#### OSHA:

None of the chemicals in this product are considered highly hazardous by OSHA.

#### STATE

CAS# 7439-97-6 can be found on the following state right to know lists: California, New Jersey, Pennsylvania, Minnesota, Massachusetts.

#### California Prop 65

WARNING: This product contains Mercury, a chemical known to the state of California to cause developmental reproductive toxicity.

California No Significant Risk Level: None of the chemicals in this product are listed.

### European/International Regulations

#### European Labeling in Accordance with EC Directives

#### Hazard Symbols:

T

#### Risk Phrases:

R 23 Toxic by inhalation.

R 33 Danger of cumulative effects.

#### Safety Phrases:

S 45 In case of accident or if you feel unwell, seek medical advice immediately (show the label where possible).

S 7 Keep container tightly closed.

**WGK (Water Danger/Protection)**

CAS# 7439-97-6: 3

**Canada - DSL/NDSL**

CAS# 7439-97-6 is listed on Canada's DSL List.

**Canada - WHMIS**

This product has a WHMIS classification of D2A, E.

This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations and the MSDS contains all of the information required by those regulations.

**Canadian Ingredient Disclosure List**

CAS# 7439-97-6 is listed on the Canadian Ingredient Disclosure List.

<b>Section 16 - Additional Information</b>
--

**MSDS Creation Date:** 6/15/1999

**Revision #4 Date:** 2/05/2004

*The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no event shall Fisher be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential or exemplary damages, howsoever arising, even if Fisher has been advised of the possibility of such damages.*

[Back](#)**HgX<sup>®</sup>****Material Safety Data Sheet****SECTION I****PRODUCT IDENTIFICATION****HAZARD RATING**

PRODUCT NAME: HgX<sup>®</sup> Mercury Decontaminant Powder  
 MANUFACTURER NAME: Acton Technologies, Inc.  
 CHEMICAL FAMILY: Salt/Chelating Agent  
 FORMULA: Proprietary Blend of Sodium Thiosulfate and Ethylenediaminetetraacetic Acid

**SECTION II****HAZARDOUS INGREDIENTS**

NONE

**SECTION III****PHYSICAL DATA**

VAPOR DENSITY:	Not Applicable	PERCENT VOLATILE:	Not Applicable
SOLUBILITY IN H <sub>2</sub> O:	Appreciable	SPECIFIC GRAVITY:	Est. above 1.0 (No Data)
EVAPORATION RATE:	Not Applicable	ODOR:	None
APPEARANCE:	Granular (white)		

**SECTION IV****FIRE AND EXPLOSION HAZARD DATA**

FLASH POINT:	Not Applicable	AUTO-IGNITION TEMPERATURE:	Not Applicable
FLAMMABLE LIMITS IN AIR:	Not Flammable	EXTINGUISHING MEDIA:	Not Applicable
FIRE FIGHTING PROCEDURES:	Extremely high temperatures may cause evolution of toxic SO <sub>2</sub> or H <sub>2</sub> S gases.		

**SECTION V****HEALTH HAZARD DATA**

PERMISSIBLE EXPOSURE DATA: Not Applicable  
 EFFECT OF OVEREXPOSURE: None Known  
 FIRST AID PROCEDURES:

Inhalation: Avoid breathing dust by wearing dust respirator. Remove to fresh air if effects occur.  
 Eyes: Irrigate eyes for 15 minutes. For serious irritation, seek medical attention.  
 Skin: Flush skin with water for 15 minutes. For serious irritation, seek medical attention.  
 Ingestion: Ingestion in gross quantities could be harmful - seek medical attention.

**SECTION VI****REACTIVITY DATA**

STABILITY:	Stability limited in solution	HAZARDOUS POLYMERIZATION: Will not occur.
INCOMPATIBILITY:	Acids, oxidizing agents	
CONDITIONS TO AVOID:	High temperatures, Acids and oxidization agents	HAZARDOUS DECOMPOSITION OF PRODUCTS: High temperatures (800-900°F) may cause evolution of toxic SO <sub>2</sub> or H <sub>2</sub> S gases.

**SECTION VII****SPILL OR LEAK PROCEDURE**

STEPS TO BE TAKEN IN CASE OF SPILL OR LEAK: Sweep up and remove excess. Flush residue with water.



**DISPOSAL PROCEDURE:**

Unused, in dry form HgX® may be stored indefinitely. It may be disposed of according to local, state and federal environmental regulations.

HgX® which has been used to decontaminate a mercury spill must be handled as follows: Separate the solids and do a toxicity test on the solids and the liquid. Depending on the toxicity readings, more HgX® may be added to further decontaminate the liquid or solids which then should be disposed of according to local, state, and federal environmental regulations.

**SECTION VIII**

**SPECIAL PROTECTION INFORMATION**

**VENTILATION:**

As necessary to remove dust.

**EYE PROTECTION:**

Wear safety glasses with side shields.

**PROTECTIVE GLOVES/APRON:**

Wear clothing sufficient to protect skin from contact.

**SECTION IX**

**SPECIAL PRECAUTIONS**

Store in cool, dry area. Avoid storage where contact with acids or oxidizing agents is likely. Avoid breathing dust. Avoid skin and eye contact.

**\*\*\*NOTICE\*\*\***

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HgX® Mercury Decontaminant Powder  
Revised: November 2002

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# 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

<b>General advice:</b>	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.
<b>Eye contact:</b>	Rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes. If symptoms persist, call a physician.
<b>Skin contact:</b>	Wash off immediately with soap and plenty of water. If skin irritation persists, call a physician.
<b>Ingestion:</b>	If swallowed, seek medical advice immediately and show this container or label. Never give anything by mouth to an unconscious person.
<b>Inhalation:</b>	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.
<b>Notes to physician:</b>	Treat symptomatically.
<b>Medical condition aggravated by exposure:</b>	Dermatitis.

## 5. FIRE-FIGHTING MEASURES

<b>Flash point (°C):</b> 260	<b>Flash point (°F):</b> 500	<b>Flash Point Method:</b> COC
<b>Flammable limits in air - upper (%):</b> Not determined	<b>Flammable limits in air - lower (%):</b> Not determined	
<b>Suitable extinguishing media:</b>	Use dry chemical, CO2, water spray or `alcohol` foam.	
<b>Unusual hazards:</b>	None known	
<b>Special protective equipment for fire-fighters:</b>	As in any fire, wear self-contained breathing apparatus pressure-demand, MSHA/NIOSH (approved or equivalent) and full protective gear.	
<b>Specific methods:</b>	Water mist may be used to cool closed containers.	

## 6. ACCIDENTAL RELEASE MEASURES

<b>Personal precautions:</b>	Ensure adequate ventilation.
<b>Environmental precautions:</b>	Do not flush into surface water or sanitary sewer system.
<b>Methods for cleaning up:</b>	Soak up with inert absorbent material (e.g. sand, silica gel, acid binder, universal binder, sawdust).

## 7. HANDLING AND STORAGE

### Handling

<b>Technical measures/precautions:</b>	Provide sufficient air exchange and/or exhaust in work rooms.
<b>Safe handling advice:</b>	In case of insufficient ventilation, wear suitable respiratory equipment.
<b>Storage</b>	
<b>Technical measures/storage conditions:</b>	Store at room temperature in the original container
<b>Incompatible products:</b>	No special restrictions on storage with other products
<b>Safe storage temperature:</b>	40-100 ° F
<b>Shelf life:</b>	12 months and re-evaluate

## 8. EXPOSURE CONTROLS / PERSONAL PROTECTION

**Engineering measures:** Ensure adequate ventilation.

### Personal Protective Equipment

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



## 9. PHYSICAL AND CHEMICAL PROPERTIES:

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

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

<b>Persistence and degradability:</b>	Environmental Fate and Effects: Under the modified Sturm Test (40 CFR 796.3620), this product is readily biodegradable.
<b>Mobility:</b>	No data available
<b>Bioaccumulation:</b>	No data available
<b>Ecotoxicity effects:</b>	No data available
<b>Aquatic toxicity:</b>	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

<b>Waste from residues/unused products:</b>	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.
<b>Contaminated packaging:</b>	Do not re-use empty containers
<b>Methods for cleaning up:</b>	Take up mechanically and collect in suitable container for disposal.

## 14. TRANSPORT INFORMATION

### U. S. DEPARTMENT OF TRANSPORTATION:

**Proper shipping name:** Not Regulated

**Shipping Description:**

### 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:**

**NFPA rating:**

**Health:**  
1

**Health:**  
1

**Flammability:**  
1

**Flammability:**  
1

**Reactivity:**  
0

**Reactivity:**  
0

**Personal Protection:**  
B

**Special:**  
NA

\* Indicates possible chronic health 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**

## 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.

<b>Product Type:</b> Impregnated Activated Carbon - CB II
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**SECTION I**

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

**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 NA	Flammable Limits Ignition Temperature > 220 °C	LEL NA	UEL NA
Extinguishing Media Large volumes of water or inert gas			
Special Fire Fighting Procedures None			

#### SECTION V - REACTIVITY DATA

Stability	Unstable		Conditions to Avoid 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.
	Stable	XX	
Incompatibility ( <i>Materials to Avoid</i> ) 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? Irritation of respiratory system by dust and carbon fines	Skin? May cause skin irritation	Ingestion? May irritate digestive tract
Health Hazards ( <i>Acute and Chronic</i> ) Possible eye injury from dust exposure. Effect of long term exposure to dust on respiratory system has not been defined.			
Carcinogenicity: NA	NTP? NA	IARC Monographs? NA	OSHA Regulated? 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 Protection (*Specify Type*)

NIOSH approved particulate filter if dust is generated in handling.

<b>Ventilation</b>	Local Exhaust Recommended	Special
	Mechanical ( <i>General</i> ) 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.