NCSX

Design Basis Analysis

Base Support Structure Analysis

NCSX-CALC-17-001-00

27 July 2008

Prepared by:

fdahlgre Digitally signed by fdahlgre
DN: cn=fdahlgre, o=PPPL, c=US
Date: 2008.08.15 10:42:25 -04'00'
Signature Not Verified

F. Dahlgren, PPPL

I have reviewed this calculation and, to my professional satisfaction, it is properly performed and correct. I concur with analysis methodology and inputs and with the reasonableness of the results and their interpretation.

Reviewed by:

H.M. Fan Digitally signed by H.M. Fan
DN: cn=H.M. Fan, o=PPPL, ou=Engineering Analysis, email=hmfan@pppl.gov, c=US
Date: 2008.08.15 10:49:41 -04'00'

H.M. Fan, PPPL, Engineer

Introduction

The Base Support Structure is connected to the Coil Support Structure (WBS 15) at six locations, and provides the load path for the dead weight of the entire NCSX core, which includes the MCWF shell and modular coils, vacuum vessel, as well as the conventional PF, TF, and Trim coils (See Figure 1). In addition, it must also support the weight of the cryostat and many of the coil services, which include the cryogen feeder lines and coil bus work. The outboard support columns are located 120 degrees apart at the C-C MCWF joints and with the top pedestal at an elevation of 77.25" and at a nominal radius of 79.5". The inner support columns are located at 120 degree intervals at the A-A MCWF joints at a top pedestal elevation of 77.5" and a nominal radius of 29.5". These interfaces must provide structural continuity between the floor, base structure, and coil structure for gravity and seismic loading. All EM loads will be reacted within the MC structure and TF-PF interconnections. The six interfaces at the base/coil support structure will be bolted with G11 insulating plates, washers, and bushings, to provide both electrical isolation for ground loops, and thermal insulation to minimize heat transfer from the warmer base structure to the cold coil support structure (See Figure 2) . Spherical bearings (which is not included in this analysis) will be used to allow for any angular misalignments between the MCWF/core structure and base supports and will also suppress moment constraints being transmitted to the MCWF due to rotational flexing of the modular coil structural shell. To provide radial compliance between the core and supporting structure, a low friction PTFE surface will be used between the column pedestal and spherical bearing lower clevis base plate. Z-shaped channels bolted to the base support pedestals will capture the sliding lower clevises to restrict lateral (circumferential) sliding and any vertical lifting of the core (resulting from seismic over-turning motions). All gravity loads and loads from any seismic events are reacted through these interfaces, through the base support columns and base frames to the test cell floor, and ultimately, to the C-Site basement floor.

The current analysis evaluates the adequacy of the base support frames, anchors, and columns when subjected to normal gravity and seismic loading. The analysis of the MCWF/core-base structure interface assembly (including the spherical bearing housing) is covered in the Coil Support Structure Design Basis Analysis (NCSX-CALC-15-001-00).

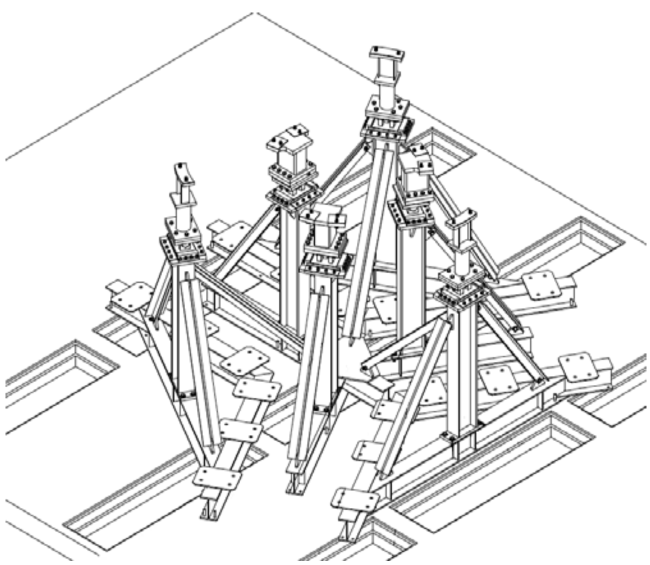


Figure 1 - Base Support Structure For NCSX

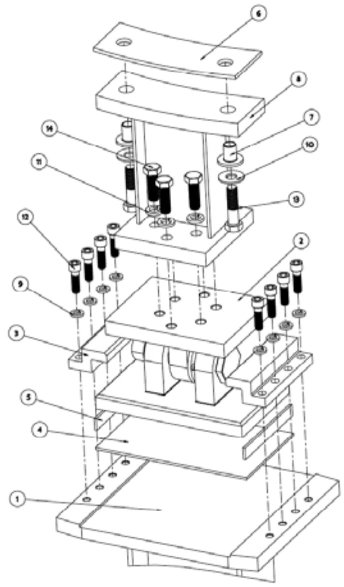


Figure 2 - MCWF/core-Base Structure Interface

Methodology

The analysis of the base support structure was accomplished using the ANSYS Finite Element Analysis program version 11.1. The FEA model of the base supports applies loads from gravity, and a static seismic loading based on the NCSX Seismic Design Criteria Document (NCSX-CRIT-SEIS-00).

Assumptions

The full weight of the stellarator core is assumed to be 300 kips (loads have been calculated from CAD models of various components and estimated for some components which are not yet finalized with a 5% additional factor added – see Appendix II).
The boundary conditions at the bottom of the building columns supporting the test cell floor are assumed to be fixed in all degrees of freedom implying an infinitely stiff basement floor. Symmetry boundary conditions are applied around the perimeter of the test cell floor to account for the remaining floor and building structure. The gravity loading is assumed to be uniformly applied at the top of the column pedestals for the outer columns. The offset from the centroid of the support columns at the inner A-A supports result in a additional applied moment necessary to react the moment arising from the minor eccentric (ie. eccentric in the radial dimension) loading there. Rigid beams attached to a concentrated mass, representing the full mass located at the C.G. of the stellarator core, apply the horizontal seismic accelerations and moments to the tops of the column pedestals. These beams are attached to the column pedestals via coupled nodes with only two translational DOFs which assumes that the spherical bearings can only transmit translational forces vertically and circumferentially and no moments. Room temperature (295 K) isotropic material properties are assumed for all components.

$E_{stainless}$ = 29 e 6 psi (200GPa) (all base support structural components)
$E_{concrete}$ = 3.12 e 6 psi (21.5GPa)
$E_{A36\text{-}stl}$ = 30 e 6 psi (207 GPa)

μ= 0.2 friction coefficient floor to base

Description

A finite element model of the NCSX base support structure including a portion of the test cell floor and basement structure is shown in Figure 1 below. The model uses 20-node hexahedral solid (brick) elements for the column and beam webs, flanges, gussets, and end plates. The test cell floor, which is 12 inch thick 3,000 lb reinforced concrete, also is modeled using 20-node brick elements (Solid45-yellow elements in Fig.1), and the appropriate elastic modulus (using solid elements rather than R.C. elements should provide a more conservative stiffness representation of the floor). The floor girders, stringers, and columns supporting the floor (light blue, purple, and red lines in Fig. 1) are modeled as beams with the appropriate section modulus and properties.

Building Steel is modeled with beam188 beam elements - Sections:

P3-columns 14WF-127
G1-girders 27WF-145
S1-stringers 12WF-106

The outer machine column lateral bracing (light blue diagonals in Figure 3), use angle beam elements with the appropriate section properties. The base to floor interface surfaces are attached with standard contact elements which allow for sliding and separation in the non-linear solution. A conservative value of 0.2 was chosen for the coefficient of friction between the concrete floor and the bottom flange of the base support beams. Coincident nodes at the anchor bolt locations are coupled together to simulate the bolted connections to the anchors, which will be embedded in the concrete floor. Semi-rigid beams (very deep BEAM188 elements with a large section modulus)) connect the top column plates to the stellarator core c.g., which is used to apply the static horizontal loads for the seismic runs. The nodes in the concrete floor elements are coupled to coincident nodes in the floor girders and stringers, whose centroids are vertically offset to the geometric centroid of the beam sections. Note, this was changed from load case 1 to the load case 2 runs. The load case 1 model had the girder and stringer nodes located at the beam centroids.

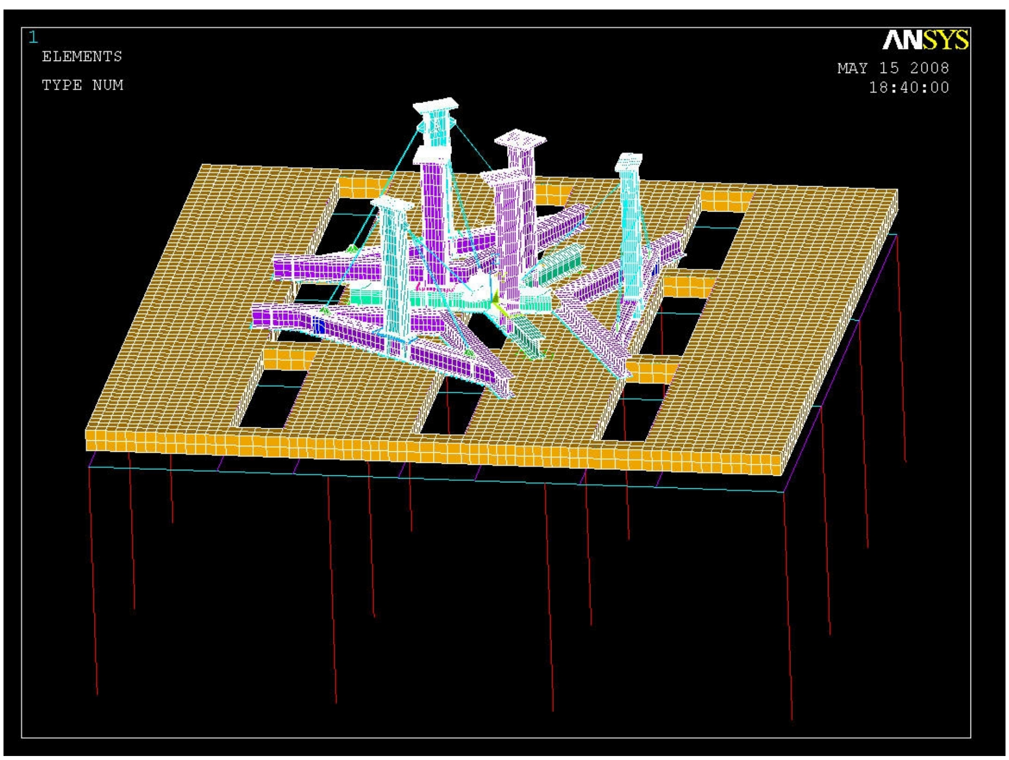


Figure 3 - ANSYS FEA Model of the Base Supports & Test Cell Floor (full-base-suppt-model-F4h)

Based on CAD and ANSYS models, the dead load of the entire Stellarator core was initially determined to be approximately 240 kips without the vessel liner, trim coils, coil services, cryostat, neutral beam duct, and diagnostics. The dead load distribution between the outer and inner supports was determined from results of the integrated global model of the Stellarator core which is shown in tabular form in Appendix I with a factor of 1.25 to account for the items mentioned above which are not yet designed. Appendix II is a summary of all dead loads in the machine core including estimate of the TBD components. To be conservative a factor of 5% over these estimates was used for this analysis. The complete (estimated dead load, including the 5%, is 300 kips). In general, based on Appendix I results, the load will shift about 3.2 kips to the outboard supports due to EM loading and cool-down, producing a 53.2-46.8 kip load split outboard to inboard during machine operations and about 51.6-48.4 kip split when sitting cold w/o EM loads applied.

Results

Load Case 1: 50 kip Inboard & Outboard Support Loading

Figure 4 below is a contour plot of the SRSS displacements due to the room temperature gravity loading condition. The load distribution is essentially uniform at 50kips per support.

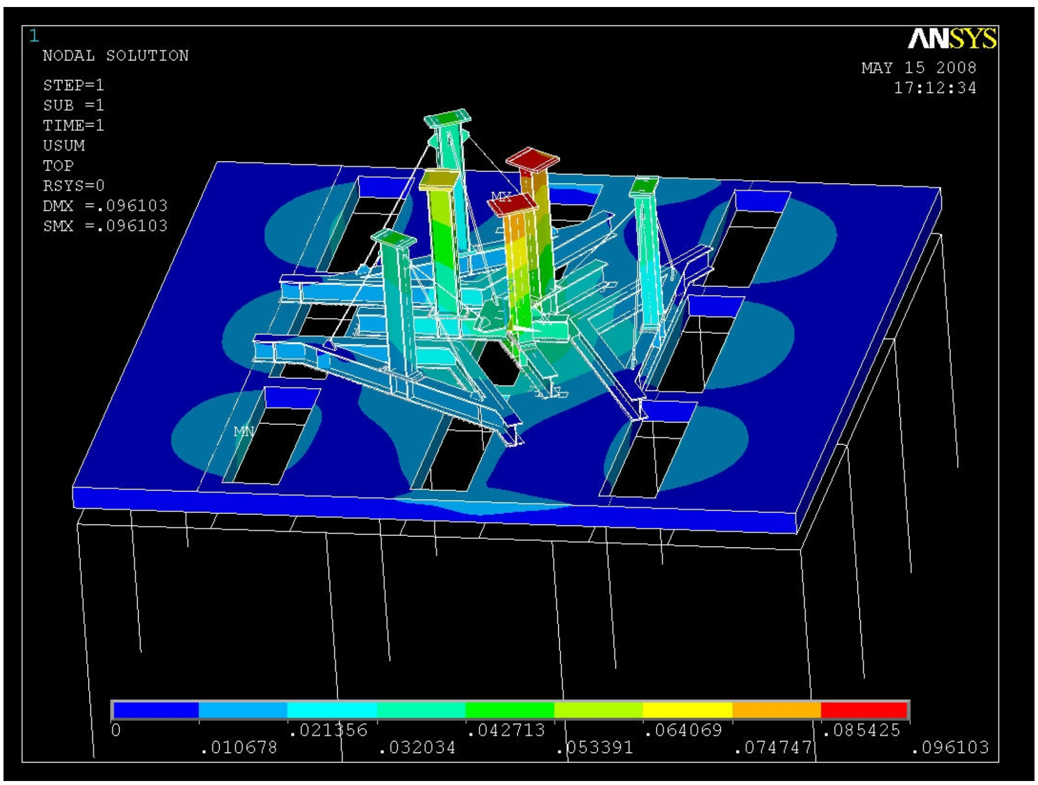


Figure 4 - SRSS Displacements due to gravity loading –Stellarator core at room temperature

Figure 5 is a contour plot of the vertical (dz) displacements due to room temperature gravity loading. The maximum vertical displacement is -0.083” occurring at the top pedestals of the west inner support columns. The one east column deflects about 0.010” less. The test cell floor peak vertical displacement is 0.042” and occurs at the edges of the middle floor cutout as shown by the darker blue contour in Figure 6.

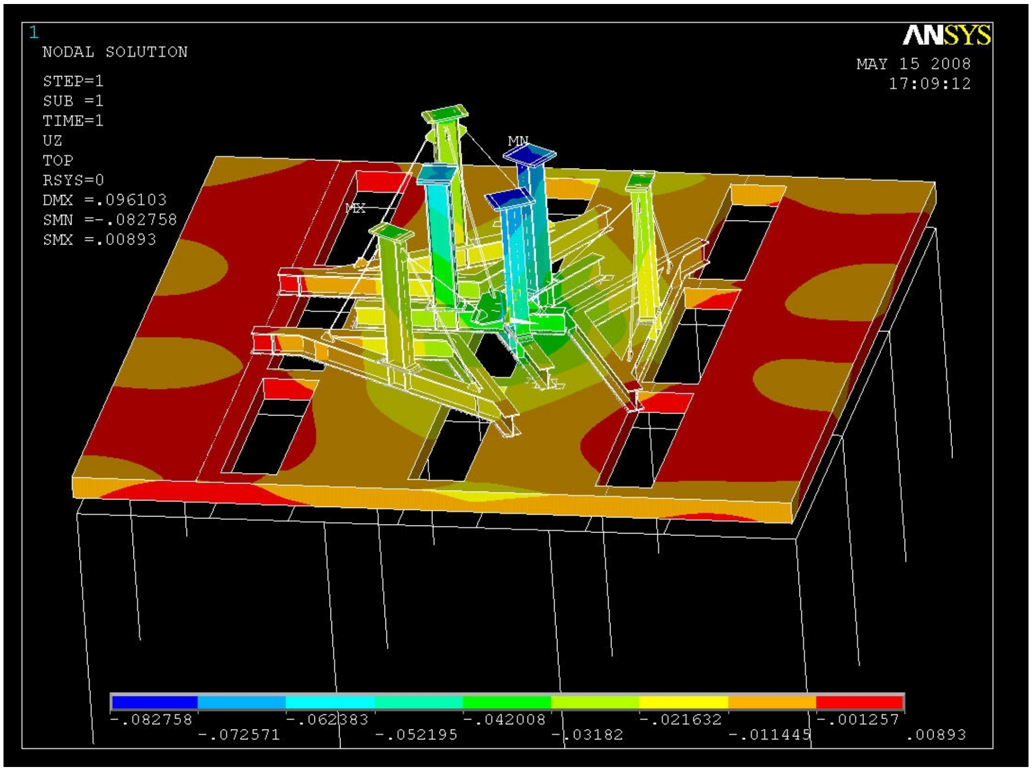


Figure 5 - Vertical (dz) displacement contours -stellarator core at room temperature

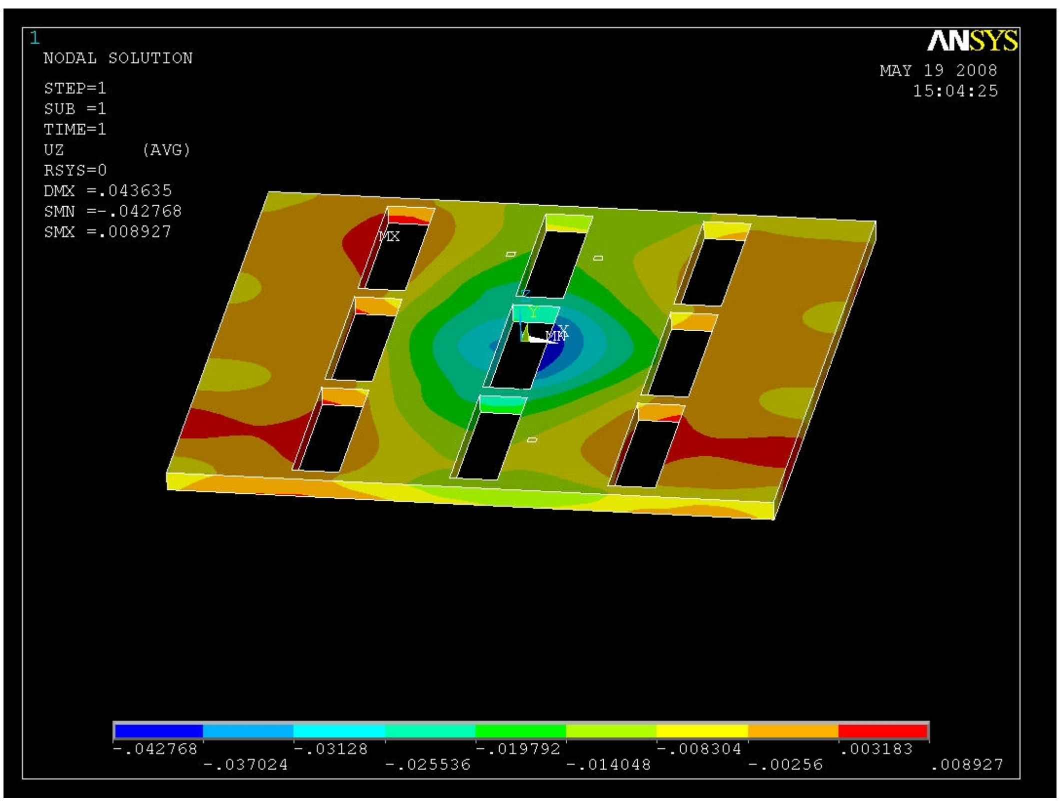


Figure 6 - Test Cell Floor Vertical (dz) displacement contours -stellarator core at room temperature

The Tresca stress contours are plotted for the room temperature gravity loading in Figure 7 and indicate a peak stress of 12.4 ksi at the anchor points of the inner base beam. The stresses in the columns are seen to be in the range of 2 to 4 ksi. The maximum stress intensity of 9 ksi in the column support assemblies is at the center of the inner support top plates.

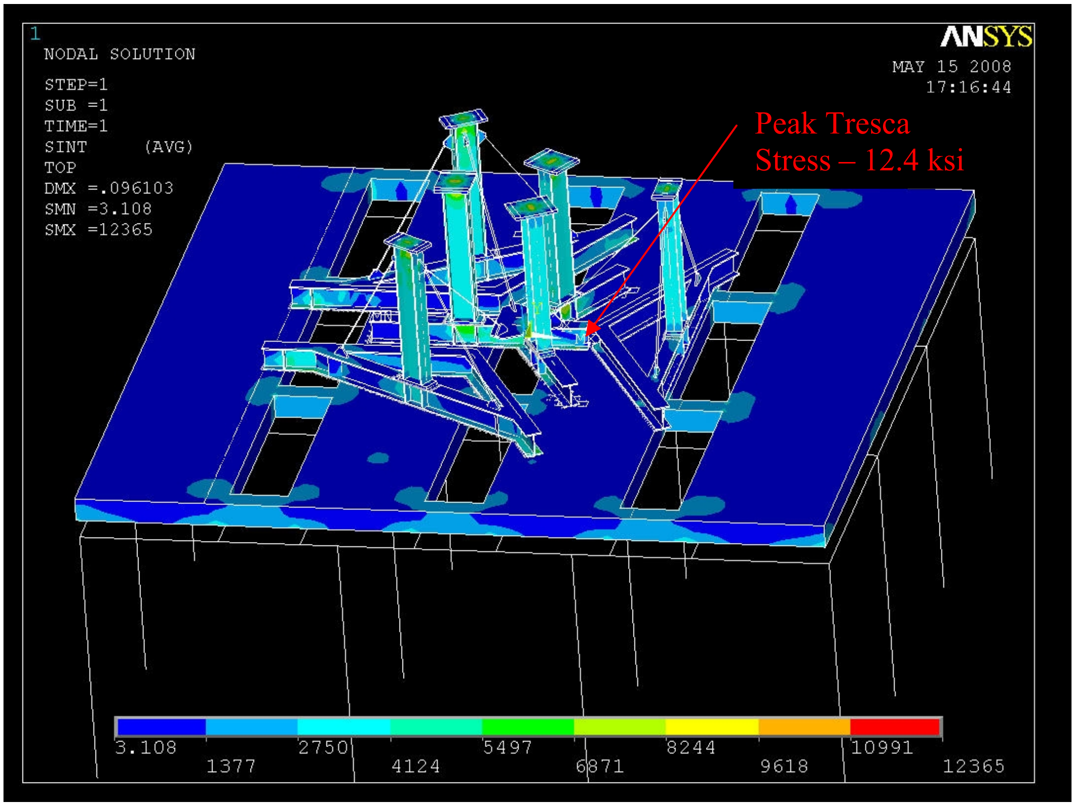


Figure 7 - Tresca stress contours -stellarator core at room temperature -peak stress is 12.4 ksi

When the stellarator core is cooled down to 77 K there is a redistribution of loads which increases the gravity loading on the outboard column supports by about 3 kips and reduces the inboard column load by the same amount. When the core is cold the outboard supports now have a total loading of 53 kip per support and the inboard columns have a 47 kip load. The arrow in figure 5 points to the peak Tresca stress which is located on the bottom flange near the end of the inboard Y middle beam (near the anchor points).

Load Case 2: 46.87 kip Inboard, & 53.13 kip Outboard Support Loading

For load case 2 there was a minor model change, re-locating the girder, stringer, and top column nodes to be co-planar with the bottom nodes of the test cell floor slabs, and off-setting the beam origins to their proper heights. The model, shown in Figure 8 below, should more accurately represent the composite floor-beam stiffness.

The vertical displacement contours of the floor for load case 2 are shown in Figure 9. The maximum displacement of the floor, shown as the darker blue contour, is -0.025”. Note the positive displacement of 0.014” in adjacent floor bays due to the negative displacements at the central bays.

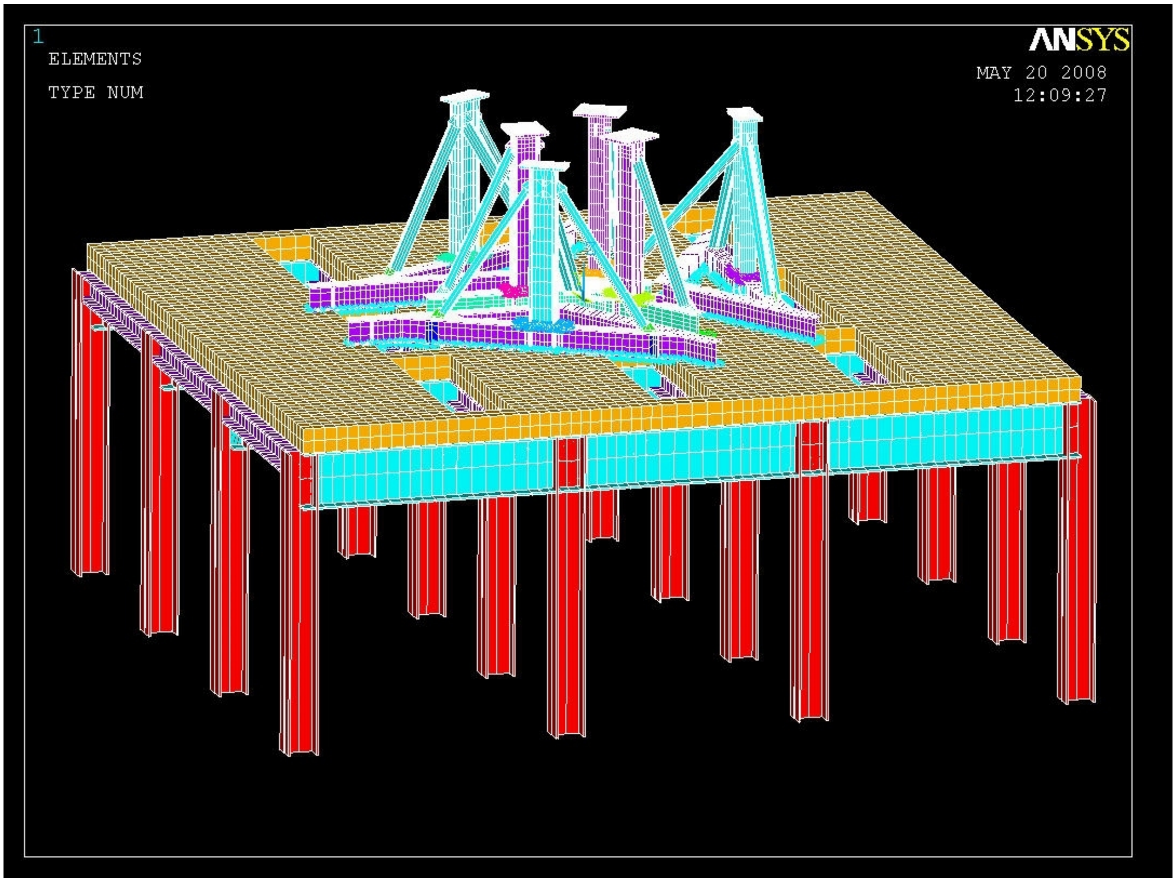


Figure 8 - Re-modeled floor girders & stringers (full-base-suppt-model-F4j)

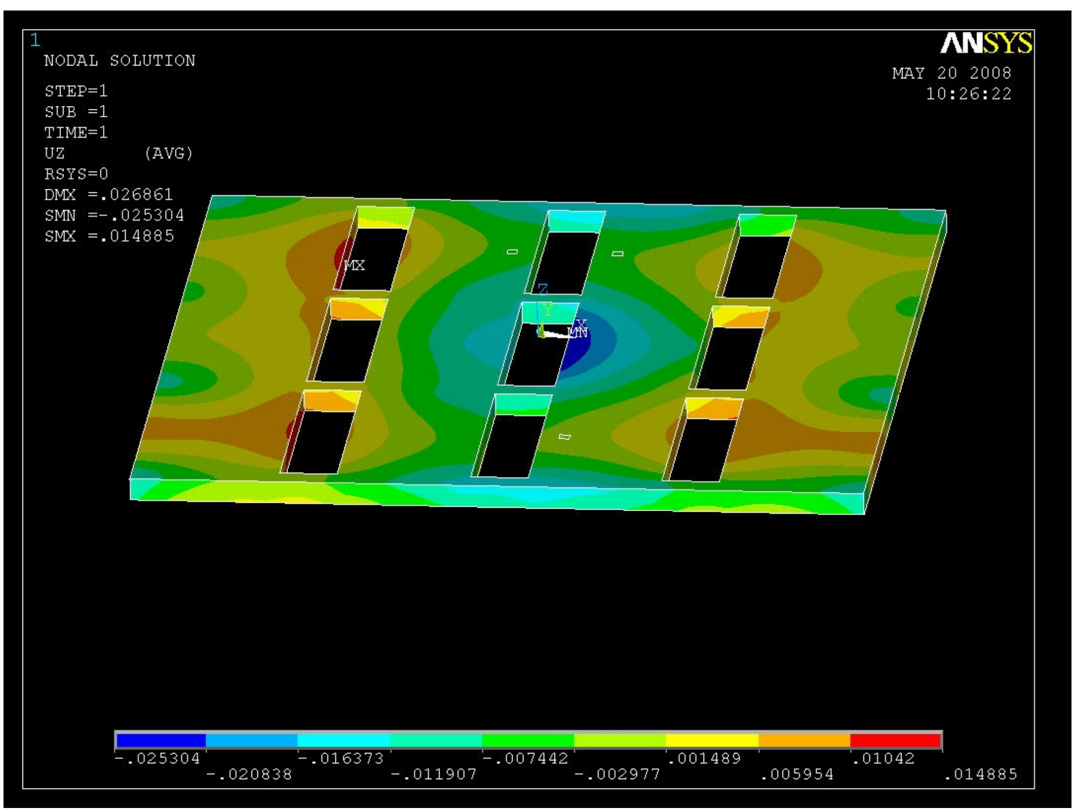


Figure 9 - Vertical displacements of the test cell floor – Load Case 2

The vertical displacement contours of the full model load case 2 are shown in Figure 10. The peak displacement is 0.066" and occurs at the top of the two inner columns located over one of the central floor openings and is represented by the dark blue contours.

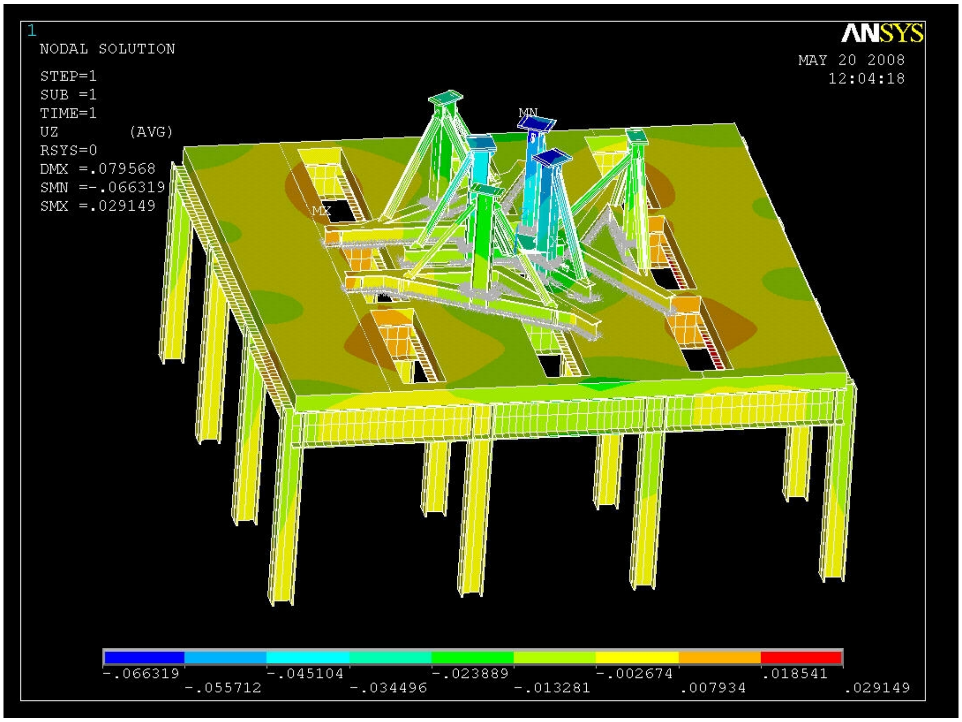


Figure 10 - Vertical displacements of the base support structure – Load Case 2

The SRSS (vector sum) displacement contours for load case 2 are shown in Figure 11. The maximum displacement of ~0.08" is at the top of the two inboard support pedestals over the floor cutout shown in red.

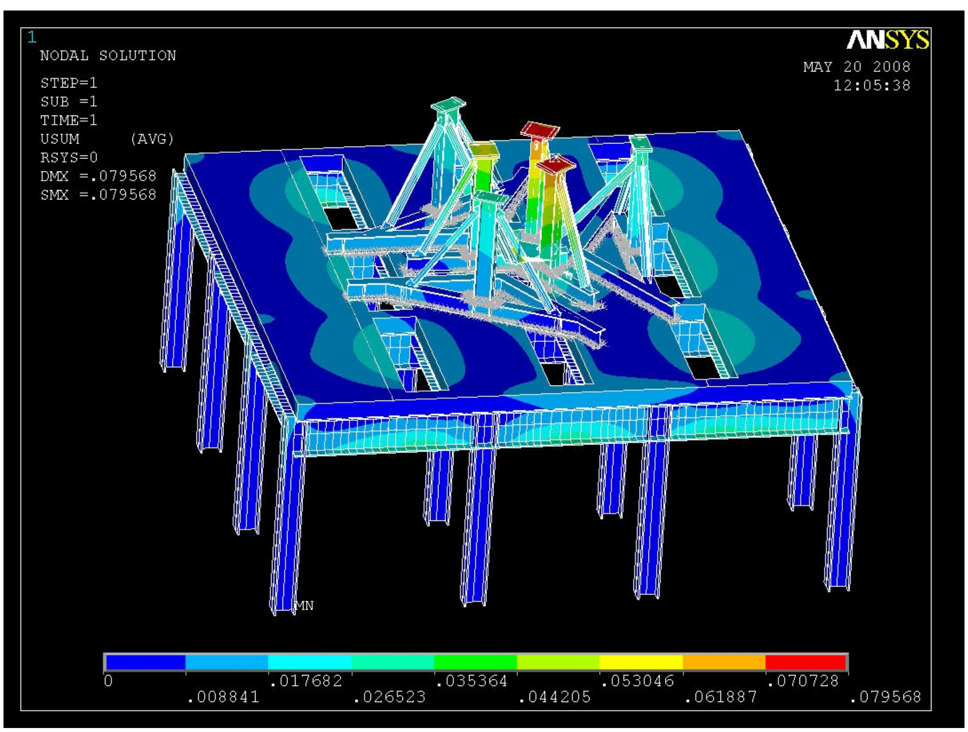


Figure 11 - SRSS Displacement contours of base supports – Load Case 2

The Tresca stress contours for the floor and base supports for load case 2 are shown in Figure 12below. The peak stress is about 16 ksi (110MPa) and occurs at the upper inboard column pedestal at the corner intersection of the web, flange, and top pedestal. This single point peak coincides with the vertex of a pentahedral transition element, which tends to be overly stiff thereby over estimating the stress at this point. In general the stresses in the base supports are in the range of 3ksi to 12ksi (21 to 83 MPa), with the major portion of the columns less than 7 ksi (<50 MPa).

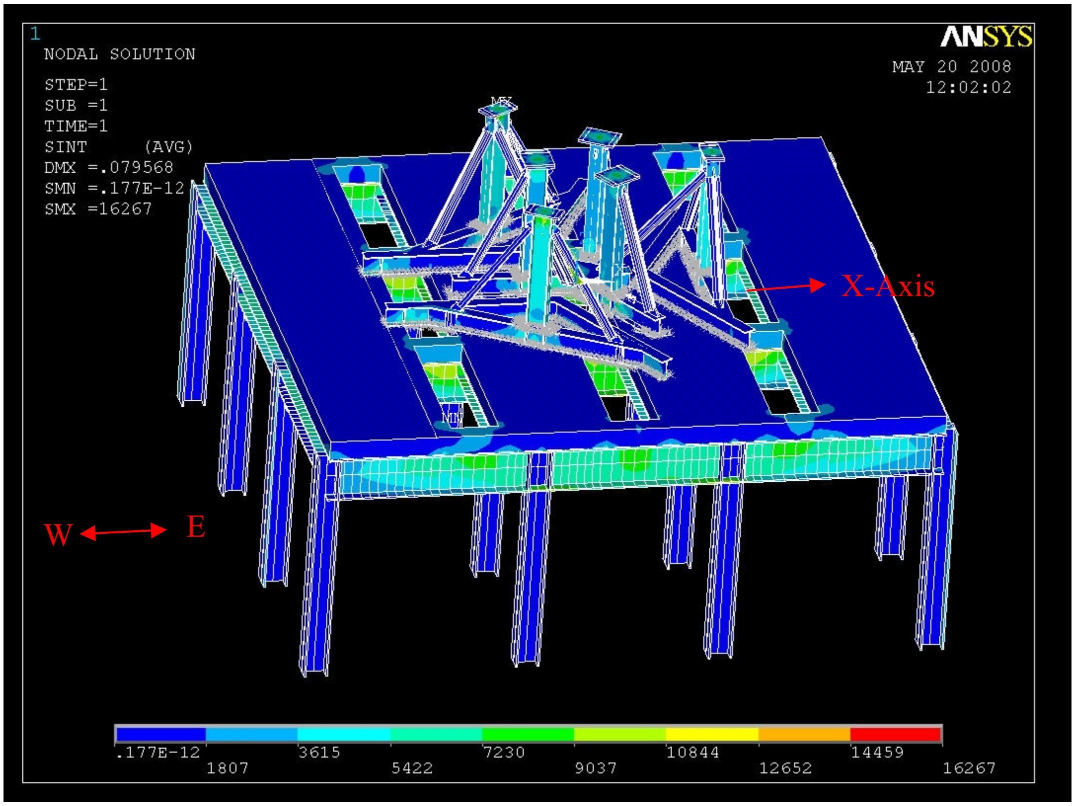


Figure 12 - Tresca Stress contours for Load Case 2

Load Case 3: Seismic Loading with 46.87 kip Inboard, & 53.13 kip Outboard Support:

The seismic loading considered is based on the NCSX Seismic Design Criteria (NCSX-CRIT-SEIS-00), which requires a .171 g static load applied at the machine core c.g. per Table 1. A modal analysis predicts the primary flexible mode will be @ 1.7 Hz as a lateral flex at 30 degrees off the X-axis.

Simplified for the Test Cell:

Fp = Sc*Ip*Wp

Where Seismic Coefficient Sc Equals:

	Low Deformability Rp=1.25	Limited Deformability Rp=2.5
Rigid Structures a.p = 1 (Fn=16.7 hz)	**.114**	**.072** (Calculated=.057 but reverts to min. value)
Non Rigid Structures a.p = 1.5 (Fn<16.7 hz)	**.171**	**.085**

Table 1 - (REF. NCSX-CRIT-SEIS-00)

This translates into a static horizontal load of 51,300 lbs applied at a height of 15.2 feet above the test cell floor. To model the machine core, six semi-rigid beams were added to the base support structure model to represent the approximate stiffness of the core. The beam elements extend from 4” above the support column pedestals to the machine c.g. located 15.2 feet above the floor at the machine center. The revised seismic model is shown below in Figure 13. To represent the radially oriented sliding base of the machine supports the lower nodes of the six beams are coupled vertically and circumferentially to nodes on the pedestals which represent the radial guides which physically capture the sliding bases (all nodes have their displacement coordinates defined in the global cylindrical coordinate system and therefore these guides permit radial motions while restraining circumferential and vertical motion). The static horizontal load is applied in the North-South and East-West directions as two separate loading conditions. A vertical load of 1.1g is also applied at machine c.g.

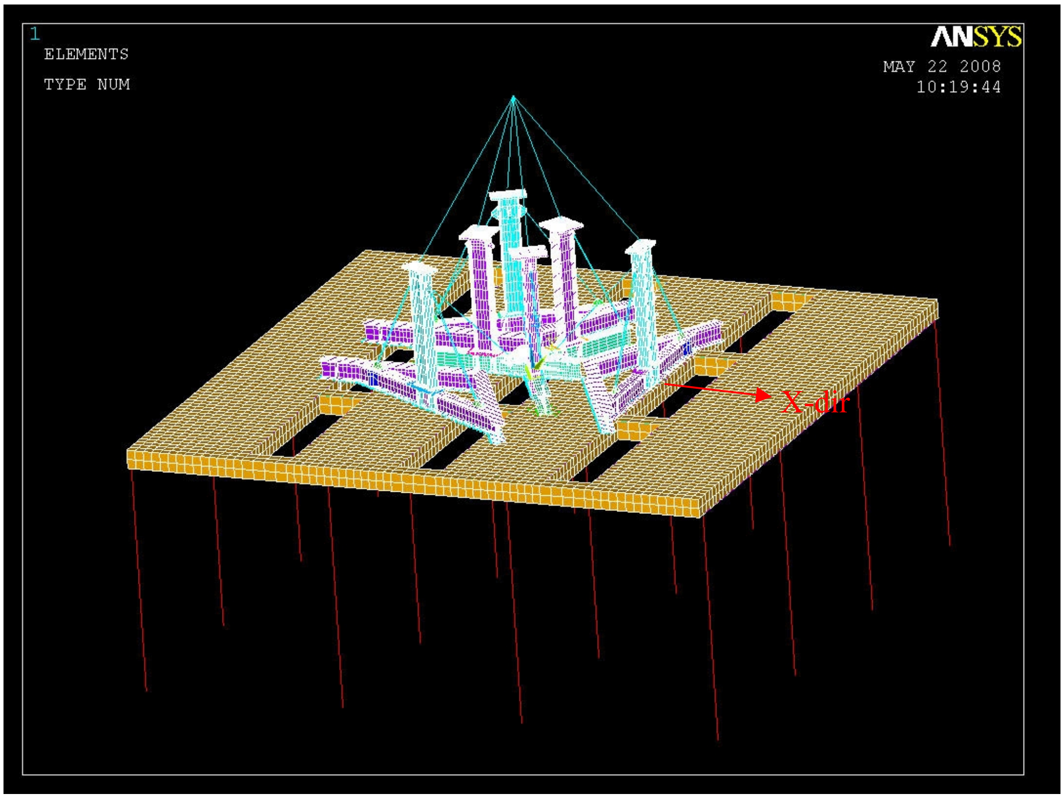


Figure 13 - Seismic model of NCSX machine base supports

Displacement results of the east-west acceleration loading (X-dir.) are shown in Figure 14. The SRSS (vector sum) displacement at the c.g. is 0.11”, primarily, as you would expect, in the x direction. The Tresca stress contours for this loading are shown in **Error! Reference source not found.**and indicate a peak stress of 17.2 ksi (118.6 Mpa). As can be seen in the insert, the location is at the corner/edge interface of one of the lateral brace brackets and is largely the result of local modeling issue (due to how the nodal points of these brackets are coupled to the top of the base support beam flange). Figure 14 shows the SRSS displacements for a north-south static seismic loading and indicates the peak displacement of the c.g. is, again as expected, 0.11” primarily in the north-south direction. The Tresca stress contours, plotted in figure 15, indicate a peak stress of 18.4 ksi (126 MPa) at the inboard base beam/floor interface just below the reinforcing rib (see the enlarged insert in figure 15). This peak is highly localized with the remaining structure stresses falling in the range of 8 to 12 ksi (55 to 83 MPa).

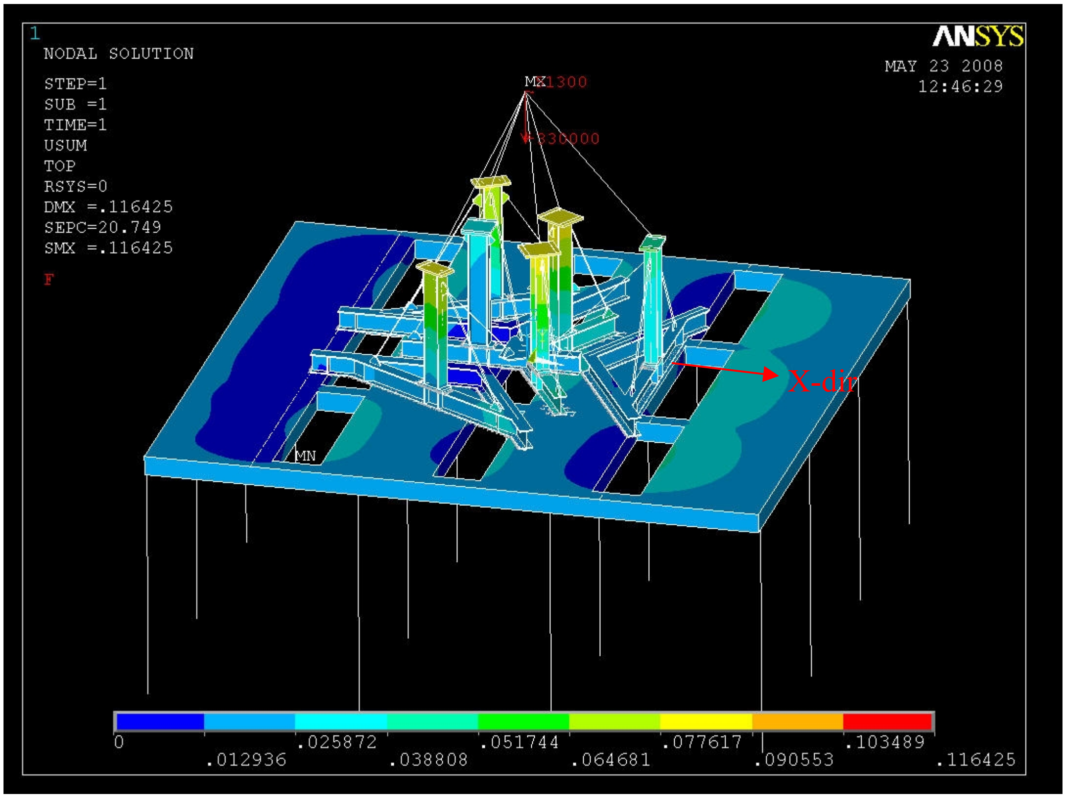


Figure 14 - SRSS Displacements due to an east-west static seismic loading condition

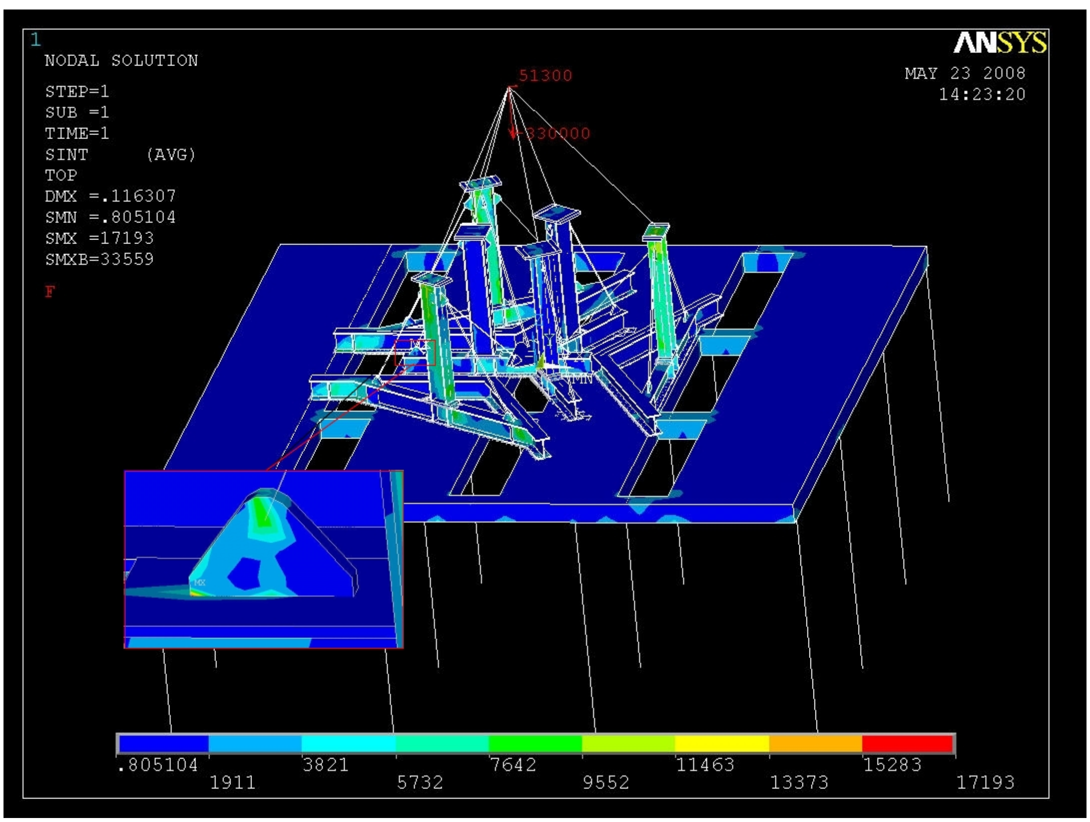


Figure 15 - Tresca Stress contours due to east-west seismic loading condition

Figure 16 and Figure 17below are contour plots of the vector sum displacements resulting from an applied static seismic loading in the north-south direction. The peak displacement, at the machine c.g., is 0.11" in the north south direction.

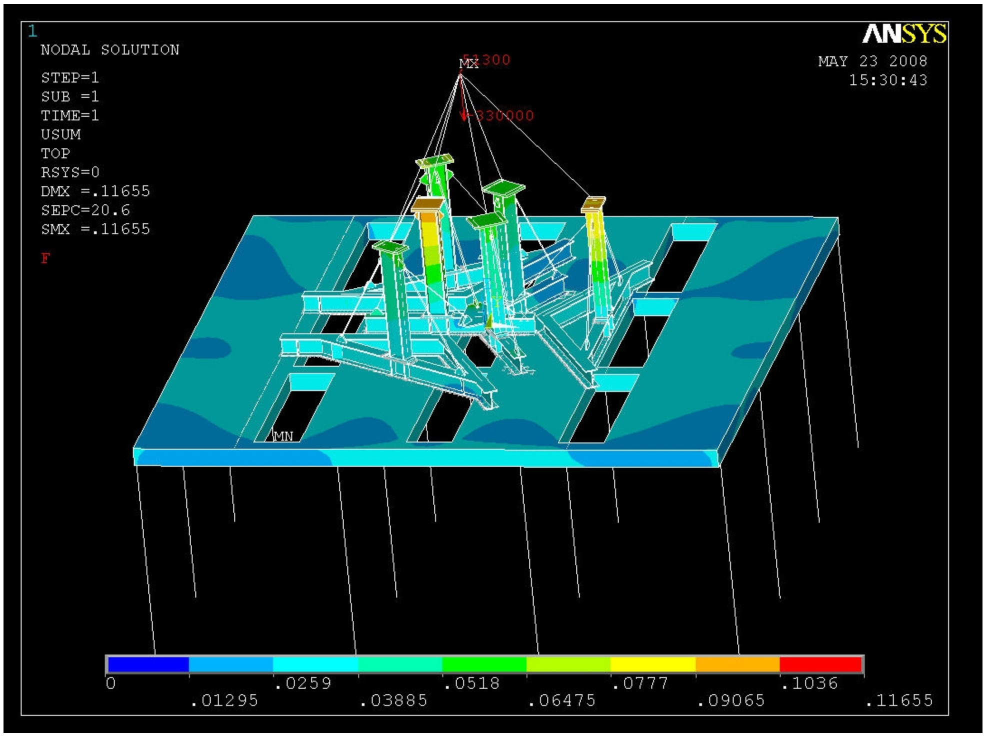


Figure 16 - SRSS Displacements for north-south seismic loading condition

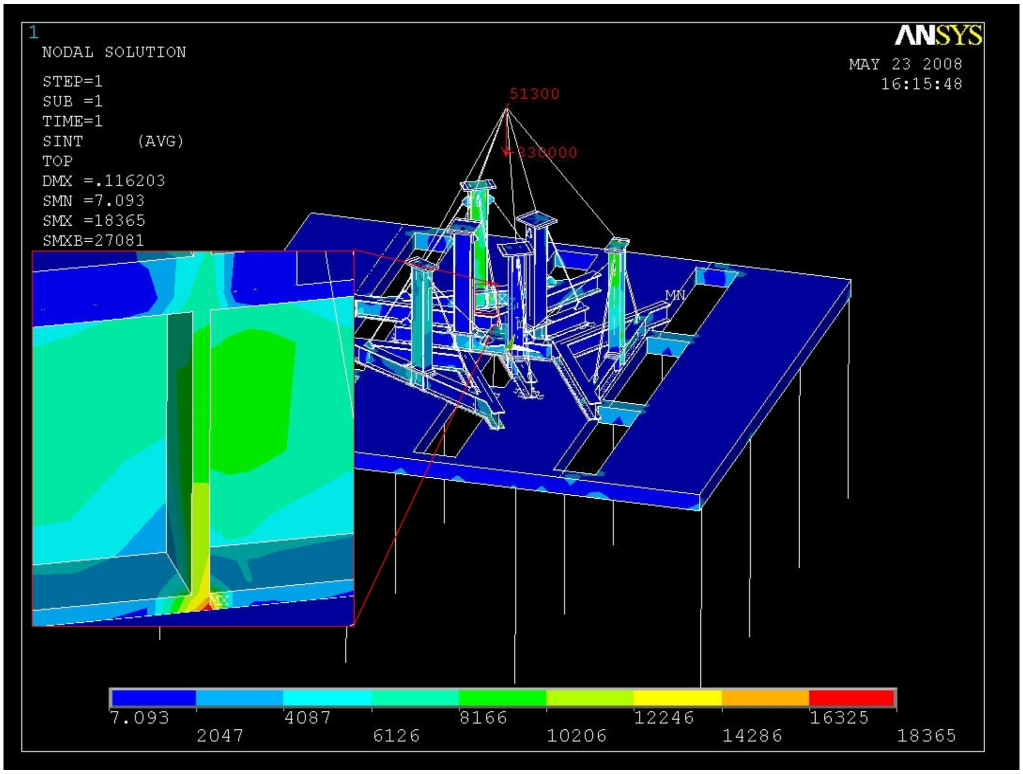


Figure 17 - Tresca Stress contours for north-south seismic loading condition

Anchoring:

Seismic Loading on Anchors:
(w/o. 12 addition anchors)

Forces on concrete wedge studs:

NODE	FX	FY	FZ
16560	398.70	-2210.4	4315.8
16612	4552.2	-3412.6	-3288.6
17234	826.51	5147.6	-1534.6
17286	-492.71	667.62	52.423
19454	-3423.9	3347.4	340.46
19467	-2536.8	-3199.8	-955.54
21988	444.46	-2947.8	674.77
22070	-136.47	-3393.3	2775.4
22698	-799.82	6116.4	1872.8
27352	-3.9376	446.26	2409.3
27434	1713.6	-1165.6	2378.7
27982	5766.0	-5069.0	-450.61
28064	-687.22	618.00	-962.14
32724	-424.18	186.34	-697.50
32806	8688.9	7165.1	-462.25
33354	7462.7	4044.8	6025.2
33436	-1419.8	-1271.9	5776.6

For minimum embedment 4.5" in 4,000 lb R.C.

Shear area of stud .78 sq.in.
Max. Shear force 11,262 lbs (node 32806)
Max. Shear in stud 14.4 ksi
Max. pullout load 6.03 kip (node 33354)

Rated stud capacity 13,000 lbs pullout
Rated Shear cap. 22,920 lbs

Reduction for 3,000psi concrete 75%:
Stud capacity 9,750 lbs pullout
Shear capacity 17,190 lbs

For recommended stud spacing:

Margin on shear load 1.5x
Margin on pullout 1.6x

Reduction for stud less spacing 75% of rated values:

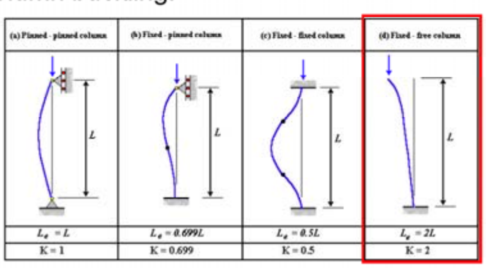
Stud capacity 7,312 lbs pullout
Shear capacity 12,890 lbs

Margin on shear ~1.1x
Margin on pullout ~1.2x

Loading & stress on the anchors for all operating conditions are su
this DBE seismic loading

Buckling:

Column buckling:



Eulers formula:
for end condition (d): $F_{cr} = \pi^2 EI / 4L^2$

WF12 x 50
L = 77.25 in
I_{yy} = 56.3 in^4
E = 29e6 psi
A = 14.4 in^2

F_{cr} = 675,070lbs

(Note these values are for columns with no lateral bracing)

Buckling Margins:

For 100 kip loading:

WF12x50 margin = 6.7

For 25 ksi min. yield, the buckling stress for a WF12x50 column:
29.1 ksi
Probable failure mode is yielding

For lateral braces:
(a): $F_{cr} = \pi^2 EI / L^2$ (Simple Support)

4 x 4 - 3/8 thk. Angle
L = 75 in x 1.38 = 103.5
I_{yy} =4.36 in^4
E = 29e6 psi
A = 2.86 in^2

F_{cr} = 116 kips - max axial =14.7kip

Margin = 7.9x

Fatigue:

Fatigue Considerations:

The facility shall be designed for the following m
reference scenarios defined in Section 3.2.1.5.3.3 in
the
NCSX Structural and Cryogenic Design Criteria

- 100 per day;
- 13,000 per year; and
- 130,000 lifetime.

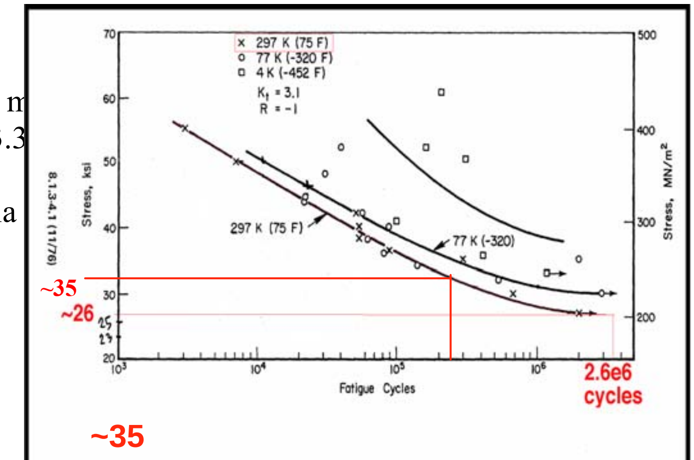


FIGURE 8.1.3-ME2.1. AXIAL FATIGUE LIFE CURVES FOR NOTCHED ANNEALED 304L STAINLESS STEEL BAR [95168] [Up to 2.540 cm (1.000 in.) diameter]

Max. operational load O.B. columns: 53.9

S max = 14.2 ksi, S min = 12.0 ksi
S mean = 13.1 ksi
Seq. = 2.67 ksi

20x life = 2.6e6 cycles

---> 26 ksi limit >> max stress intensity
---> S max < 2 x $S_{130,000\ cycles}$

Column Buckling with applied moment

Buckling of columns with eccentrically applied loading normally require the addition of a moment end condition to account for the eccentricity. Since all gravity loads from the core are applied to the columns through the center of the spherical bearing housing (nominally aligned to the centroidal axis of the columns) the only eccentric axial load is due to tolerances and the radial sliding displacements of the housing base which is minor (maximum ~ 0.25" due to cooldown + 0.095" for seismic + 0.03 for tolerances). The eccentricity in the lateral (circumferential) direction is controlled by the manufacture, fit-up and assembly tolerances of the brackets and housing and does not exceed .125" which produces negligible bending, and is applied in the much stiffer direction of the column section. Since the bearing housing sliding is normal to the weaker section of the column, both the weaker and stronger section modulii have been used in the calculations presented in Appendix IV part A. See Appendix IV part B for the combined axial and bending criteria calculations.

Conclusions:

The base support structure meets the design allowables (Sm) for the NCSX project which for primary stresses is 2/3rd the minimum yield stress of the materials at temperature. For the 304L and 316L structurals this Sm is 16.6 ksi (110 MPa). Under seismic loading conditions the peak stress intensity is 18.4 ksi (126.9 MPa) occurring at a bracket-base beam flange interface. The stress in this area is artificially higher due to constraints imposed by coupling the bracket end nodes to nodes on the top flange surface. In general the stress due to seismic loading is well below the design allowable (1.5 Sm = 25 ksi, for bending). Buckling margins for columns exceed the project requirements (> 5 -Euler) and the AISC code. The room temperature lower sigma fatigue curve indicates we have substantial margin on the 2xS @130,000 cycles and 20x life requirements. A more detailed analysis of anchor stresses and bolts is recommended prior to machine assembly to confirm the preliminary results of Appendix III.

Appendix I

New model - Hexahedral-shaped TF bracket, higher weight and reviced Ex and Alpx

Loads	Items	Unit	Model 1R	Remarks	Comments
Dead load	D max	mm	3.02E-01	w/o support block	Dmax at PF6
● w/o Wt. increase	DZ	mm	(-0.292 to 0.0314)	w/o support block	
● stellalloy E=199GPa	Seqv	Pa	1.10E+08	PowerGraphics OFF	Max.Seqv at sup. Block
	Seqv	ksi	1.60E+01	PowerGraphics OFF	Max.Seqv at sup. Block
	OB reaction	N	1.53E+05		
	OB reaction	kip	3.43E+01	**Total weight**	
	IB reaction	N	1.60E+05	3.122E+05	**G10 shim on PF6 sup.**
	IB reaction	kip	3.59E+01	7.018E+01	Calculated weight
Dead load	D max	mm	3.34E-01	w/o support block	Dmax at PF6
● DL Factor = 1.14	DZ	mm	(-0.324 - 0.0310)	w/o support block	
● stellalloy E=199GPa	Seqv	Pa	9.68E+07	PowerGraphics OFF	Max.Seqv at sup. Block
	Seqv	ksi	1.40E+01	PowerGraphics OFF	Max.Seqv at sup. Block
	OB reaction	N	1.82E+05		
	OB reaction	kip	4.09E+01	**Total weight**	
	IB reaction	N	1.74E+05	3.559E+05	**G10 shim on PF6 sup.**
	IB reaction	kip	3.91E+01	8.001E+01	
Dead load	D max	mm	3.33E-01	w/o support block	Dmax at PF6
● DL Factor = 1.14	DZ	mm	(-0.323 to 0.0314)	w/o support block	
● stellalloy E=145GPa	Seqv	Pa	9.68E+07	PowerGraphics OFF	Max.Seqv at sup. Block
● Regular PF shim	Seqv	ksi	1.40E+01	PowerGraphics OFF	Max.Seqv at sup. Block
	OB reaction	N	1.74E+05		
	OB reaction	kip	3.92E+01	**Total weight**	
	IB reaction	N	1.82E+05	3.561E+05	**SS shim on PF6 sup.**
	IB reaction	kip	4.09E+01	8.005E+01	

EM load	D max	mm	2.793	w/o support block	Type C modular coil
● **stellalloy E=145GPa**	DZ	mm	(-0.993 - 1.359)	w/o support block	
● **Regular PF shim**	Seqv	Pa	4.05E+08	PowerGraphics OFF	MCWF flange shim
	Seqv	ksi	5.87E+01	PowerGraphics OFF	
	OB reaction	N	6.61E+04		
	OB reaction	kip	1.49E+01	**Total weight**	
	IB reaction	N	-6.62E+04	-9.900E+01	**SS shim on PF6 sup.**
	IB reaction	kip	-1.49E+01	-2.226E-02	
DL & EM	D max	mm	2.766	w/o support block	Dmax at MC type C
● **DL Factor = 1.14**	DZ	mm	(-1.152 - 1.199)	w/o support block	
● **stellalloy E=145GPa**	Seqv	Pa	4.05E+08	PowerGraphics OFF	at TF shim?, others 2.51E8
	Seqv	ksi	5.87E+01	PowerGraphics OFF	
	OB reaction	N	2.40E+05		
	OB reaction	kip	5.40E+01	**Total weight**	
	IB reaction	N	1.16E+05	3.558E+05	**SS shim on PF6 sup.**
	IB reaction	kip	2.60E+01	7.999E+01	
DL & Cooldown	D max	mm	4.51	w/o support block	Dmax at TF coil mid-plane
● **DL Factor = 1.14**	DZ	mm	(-1.019 - 1.144)	w/o support block	
● **stellalloy E=145GPa**	Seqv	Pa	4.75E+08	PowerGraphics OFF	TF bracket
● **PF shim Gxy/50**	Seqv	ksi	6.89E+01	PowerGraphics OFF	
	OB reaction	N	2.46E+05		
	OB reaction	kip	5.52E+01	**Total weight**	
	IB reaction	N	1.10E+05	3.559E+05	**G10 shim on PF6 sup.**
	IB reaction	kip	2.48E+01	8.001E+01	
DL & Cooldown	D max	mm	4.509	w/o support block	Dmax at TF coil mid-plane
● **DL Factor = 1.14**	DZ	mm	(-0.990 - 1.112)	w/o support block	
● **stellalloy E=145GPa**	Seqv	Pa	4.78E+08	PowerGraphics OFF	TF bracket
● **Regular PF shim**	Seqv	ksi	6.93E+01	PowerGraphics OFF	
	OB reaction	N	2.46E+05		

	OB reaction	kip	5.52E+01	**Total weight**	
	IB reaction	N	1.10E+05	3.559E+05	**G10 shim on PF6 sup.**
	IB reaction	kip	2.48E+01	8.001E+01	
DL & Cooldown	D max	mm	4.505	w/o support block	Dmax at TF coil mid-plane
● DL Factor = 1.14	DZ	mm	(-1.253 - 1.389)	w/o support block	
● stellalloy E=145GPa	Seqv	Pa	6.00E+08	PowerGraphics OFF	TF bracket
● Regular PF shim	Seqv	ksi	8.70E+01	PowerGraphics OFF	
● PF shim COF effect	OB reaction	N	2.46E+05		
	OB reaction	kip	5.53E+01	**Total weight**	
	IB reaction	N	1.10E+05	3.561E+05	**SS shim on PF6 sup.**
	IB reaction	kip	2.48E+01	8.005E+01	
DL & Cooldown	D max	mm	4.026	w/o support block	Dmax at TF coil mid-plane
● DL Factor = 1.14	DZ	mm	(-1.321 - 1.465)	w/o support block	
● stellalloy E=145GPa	Seqv	Pa	8.32E+08	PowerGraphics OFF	TF bracket
● Regular PF shim	Seqv	ksi	1.21E+02	PowerGraphics OFF	
● PF shim COF effect	OB reaction	N	3.26E+05		
● TF shim COF effect	OB reaction	kip	7.32E+01	**Total weight**	
	IB reaction	N	3.04E+04	3.561E+05	**SS shim on PF6 sup.**
	IB reaction	kip	6.83E+00	8.005E+01	
Cooldown	D max	mm	4.074	w/o support block	Dmax at TF coil mid-plane
● stellalloy E=145GPa	DZ	mm	(-1.314 - 1.643)	w/o support block	
● Regular PF shim	Seqv	Pa	8.31E+08	PowerGraphics OFF	TF bracket
● PF shim COF effect	Seqv	ksi	1.21E+02	PowerGraphics OFF	
● TF shim COF effect	OB reaction	N	1.52E+05		
Run: co-h2	OB reaction	kip	3.42E+01	**Total weight**	
	IB reaction	N	-1.52E+05	0.000E+00	**SS shim on PF6 sup.**
	IB reaction	kip	-3.42E+01	0.000E+00	
Cooldown	D max	mm	4.078	w/o support block	Dmax at TF coil mid-plane
● stellalloy E=145GPa	DZ	mm	(-1.445 - 1.615)	w/o support block	

• Regular PF shim	Seqv	Pa	8.31E+08	PowerGraphics OFF	TF bracket
• PF shim COF effect	Seqv	ksi	1.21E+02	PowerGraphics OFF	ALPX=2.90E-5
• TF shim COF effect	OB reaction	N	6.91E+04		ALPX=2.90E-5
Vertical spring support	OB reaction	kip	1.55E+01	**Total weight**	
Run: co-h3	IB reaction	N	-6.91E+04	0.000E+00	**SS shim on PF6 sup.**
	IB reaction	kip	-1.55E+01	0.000E+00	
Change alpx for shim					
Cooldown	D max	mm	4.692	w/o support block	Dmax at TF coil mid-plane
• stellalloy E=145GPa	DZ	mm	(-0.932 - 1.180)	w/o support block	
• Regular PF shim	Seqv	Pa	4.71E+08	PowerGraphics OFF	TF bracket
• PF shim COF effect	Seqv	ksi	6.83E+01	PowerGraphics OFF	ALPX=9.829E-6
• TF shim COF effect	OB reaction	N	2.08E+04		ALPX=9.829E-6
Vertical spring support	OB reaction	kip	4.67E+00	**Total weight**	
Run: co-h3a	IB reaction	N	-2.08E+04	0.000E+00	**SS shim on PF6 sup.**
	IB reaction	kip	-4.67E+00	0.000E+00	
Cooldown	D max	mm	4.667	w/o support block	Dmax at TF coil mid-plane
• stellalloy E=145GPa	DZ	mm	(-0.823 - 0.877)	w/o support block	
• Regular PF shim	Seqv	Pa	4.69E+08	PowerGraphics OFF	TF bracket
• PF shim COF effect	Seqv	ksi	6.80E+01	PowerGraphics OFF	ALPX=9.829E-6
• TF shim COF effect	OB reaction	N	8.29E+03		ALPX=9.829E-6
Vertical spring support	OB reaction	kip	1.86E+00	**Total weight**	
Run: co-h4	IB reaction	N	-8.29E+03	0.000E+00	**SS shim on PF6 sup.**
w/PF6 link	IB reaction	kip	-1.86E+00	0.000E+00	
Dead load	D max	mm	5.39	w/o support block	Dmax at PF6
• stellalloy E=145GPa	DZ	mm	(-5.37 - 0)	w/o support block	
• Regular PF shim	Seqv	Pa	9.51E+07	PowerGraphics OFF	TF bracket
• PF shim COF effect	Seqv	ksi	1.38E+01	PowerGraphics OFF	ALPX=9.829E-6
• TF shim COF effect	OB reaction	N	1.79E+05		ALPX=9.829E-6
Vertical spring support	OB reaction	kip	4.02E+01	**Total weight**	

Run: dl-h4	IB reaction	N	1.78E+05	3.571E+05	**SS shim on PF6 sup.**
w/PF6 link	IB reaction	kip	4.01E+01	8.028E+01	**add wt. from PF6 links**
EM load	D max	mm	2.794	w/o support block	Type C modular coil
• stellalloy E=145GPa	DZ	mm	(-0.998 - 1.323)	w/o support block	
• Regular PF shim	Seqv	Pa	4.05E+08	PowerGraphics OFF	MCWF flange shim
• PF shim COF effect	Seqv	ksi	5.87E+01	PowerGraphics OFF	ALPX=9.829E-6
• TF shim COF effect	OB reaction	N	2.36E+04		ALPX=9.829E-6
Vertical spring support	OB reaction	kip	5.30E+00	**Total weight**	
Run: em-h4	IB reaction	N	-2.37E+04	-9.900E+01	**SS shim on PF6 sup.**
w/PF6 link	IB reaction	kip	-5.32E+00	-2.226E-02	
Cooldown	D max	mm	4.062	w/o support block	Dmax at TF coil mid-plane
• stellalloy E=145GPa	DZ	mm	(-0.942 - 0.896)	w/o support block	
• Regular PF shim	Seqv	Pa	4.64E+08	PowerGraphics OFF	TF bracket
• PF shim COF effect	Seqv	ksi	6.73E+01	PowerGraphics OFF	ALPX=9.829E-6
• TF shim COF effect	OB reaction	N	4.42E+04		ALPX=9.829E-6
Vertical spring support	OB reaction	kip	9.93E+00	**Total weight**	
Run: co-h4a	IB reaction	N	-4.42E+04	0.000E+00	**SS shim on PF6 sup.**
w/PF6 link & bonded TF shim	IB reaction	kip	-9.93E+00	0.000E+00	
EM load	D max	mm	2.756	w/o support block	Type C modular coil
• stellalloy E=145GPa	DZ	mm	(-1.02 - 1.322)	w/o support block	
• Regular PF shim	Seqv	Pa	4.03E+08	PowerGraphics OFF	MCWF flange shim
• PF shim COF effect	Seqv	ksi	5.85E+01	PowerGraphics OFF	ALPX=9.829E-6
• TF shim COF effect	OB reaction	N	2.95E+04		ALPX=9.829E-6
Vertical spring support	OB reaction	kip	6.63E+00	**Total weight**	
Run: em-h4a	IB reaction	N	-2.96E+04	-1.000E+02	**SS shim on PF6 sup.**
w/PF6 link & bonded TF shim	IB reaction	kip	-6.65E+00	-2.248E-02	
DL, EM & Cooldown	D max	mm	5.154	w/o support block	Dmax at TF coil mid-plane
• stellalloy E=145GPa	DZ	mm	(-1.889 - 1.252)	w/o support block	Dzmax at PF coil (near center)
• Regular PF shim	Seqv	Pa	5.01E+08	PowerGraphics OFF	TF bracket?

• **PF shim COF effect**	Seqv	ksi	7.27E+01	PowerGraphics OFF	ALPX=9.829E-6
• **TF shim COF effect**	OB reaction	N	2.06E+05		ALPX=9.829E-6
Vertical spring support	OB reaction	kip	4.64E+01	**Total weight**	
Run: h5-emdlco-2T000s	IB reaction	N	1.51E+05	3.570E+05	**SS shim on PF6 sup.**
w/PF6 link	IB reaction	kip	3.39E+01	8.026E+01	
***Note: model h5 running from single step file is identical to model h4 (from multi-step files)**					
DL, EM & Cooldown	D max	mm	5.829	unsel Type255-spring	Dmax at TF coil mid-hight
• **stellalloy E=145GPa**	DZ	mm	(-4.307 to -1.167)	unsel Type255-spring	Dzmax at PF coil (near center)
• **Regular PF shim**	Seqv	Pa	5.00E+08	PowerGraphics OFF	TF bracket?
• **PF shim COF effect**	Seqv	ksi	7.25E+01	PowerGraphics OFF	ALPX=9.829E-6
• **TF shim COF effect**	OB reaction	N	1.90E+05		ALPX=9.829E-6
New support springs	OB reaction	kip	4.28E+01	**Total weight**	
Run: h6-emdlco-2T-HB000s	IB reaction	N	1.67E+05	3.570E+05	**SS shim on PF6 sup.**
w/PF6 link	IB reaction	kip	3.75E+01	8.026E+01	
DL, EM & Cooldown	D max	mm	6.838	unsel Type255-spring	Dmax at TF coil mid-hight
• **stellalloy E=145GPa**	DZ	mm	(-4.330 to -1.190)	unsel Type255-spring	Dzmax at PF coil (near center)
• **Regular PF shim**	Seqv	Pa	4.97E+08	PowerGraphics OFF	TF bracket?
• **PF shim COF effect**	Seqv	ksi	7.21E+01	PowerGraphics OFF	ALPX=9.829E-6
• **TF shim COF effect**	OB reaction	N	1.89E+05		ALPX=9.829E-6
New support springs	OB reaction	kip	4.26E+01	**Total weight**	
Run: h6-emdlco-2T-HB440s	IB reaction	N	1.67E+05	3.562E+05	**SS shim on PF6 sup.**
w/PF6 link	IB reaction	kip	3.75E+01	8.007E+01	
DL, EM & Cooldown	D max	mm	6.26	unsel Type255-spring	Dmax at TF coil mid-hight
• **stellalloy E=145GPa**	DZ	mm	(-4.066 to -1.446)	unsel Type255-spring	Dzmax at PF6 coil
• **Regular PF shim**	Seqv	Pa	5.03E+08	PowerGraphics OFF	TF bracket?
• **PF shim COF effect**	Seqv	ksi	7.30E+01	PowerGraphics OFF	ALPX=9.829E-6
• **TF shim COF effect**	OB reaction	N	1.89E+05		ALPX=9.829E-6
New support springs	OB reaction	kip	4.25E+01	**Total weight**	

Run: h6-emdlco-17T-Om000s	IB reaction	N	1.67E+05	3.564E+05	**SS shim on PF6 sup.**
w/PF6 link	IB reaction	kip	3.76E+01	8.013E+01	
DL, EM & Cooldown	D max	mm	5.699	unsel Type255-spring	Dmax at TF coil mid-hight
• stellalloy E=145GPa	DZ	mm	(-4.154 to -1.471)	unsel Type255-spring	Dzmax at PF6 coil
• Regular PF shim	Seqv	Pa	4.90E+08	PowerGraphics OFF	TF bracket?
• PF shim COF effect	Seqv	ksi	7.11E+01	PowerGraphics OFF	ALPX=9.829E-6
• TF shim COF effect	OB reaction	N	1.89E+05		ALPX=9.829E-6
New support springs	OB reaction	kip	4.25E+01	**Total weight**	
Run: h6-emdlco-17T-Om440s	IB reaction	N	1.68E+05	3.570E+05	**SS shim on PF6 sup.**
w/PF6 link	IB reaction	kip	3.77E+01	8.027E+01	
DL, EM & Cooldown	D max	mm	9.664	unsel Type255-spring	Dmax at TF coil mid-hight
• stellalloy E=145GPa	DZ	mm	(-4.131 to -1.395)	unsel Type255-spring	Dzmax at PF6 coil
• Regular PF shim	Seqv	Pa	4.96E+08	PowerGraphics OFF	TF bracket
• PF shim COF effect	Seqv	ksi	7.19E+01	PowerGraphics OFF	ALPX=9.829E-6
• TF shim COF effect	OB reaction	N	1.87E+05		ALPX=9.829E-6
New support springs	OB reaction	kip	4.21E+01	**Total weight**	
Run: h6-emdlco-17T-iota065	IB reaction	N	1.66E+05	3.530E+05	**SS shim on PF6 sup.**
w/PF6 link	IB reaction	kip	3.73E+01	7.937E+01	
DL, EM & Cooldown	D max	mm	9.296	unsel Type255-spring	Dmax at TF coil mid-hight
• stellalloy E=145GPa	DZ	mm	(-3.939 to -1.453)	unsel Type255-spring	Dzmax at PF6 coil
• Regular PF shim	Seqv	Pa	4.85E+08	PowerGraphics OFF	TF bracket
• PF shim COF effect	Seqv	ksi	7.04E+01	PowerGraphics OFF	ALPX=9.829E-6
• TF shim COF effect	OB reaction	N	1.84E+05		ALPX=9.829E-6
New support springs	OB reaction	kip	4.13E+01	**Total weight**	
Run: h6-emdlco-17T-iota019	IB reaction	N	1.64E+05	3.478E+05	**SS shim on PF6 sup.**
w/PF6 link	IB reaction	kip	3.69E+01	7.819E+01	
DL, EM & Cooldown	D max	mm	5.671	unsel Type255-spring	Dmax at TF coil mid-hight
• stellalloy E=145GPa	DZ	mm	(-4..039 to -1.386)	unsel Type255-spring	Dzmax at PF6 coil
• Regular PF shim	Seqv	Pa	4.95E+08	PowerGraphics OFF	TF bracket?

• PF shim COF effect	Seqv	ksi	7.18E+01	PowerGraphics OFF	ALPX=9.829E-6
• TF shim COF effect	OB reaction	N	1.90E+05		ALPX=9.829E-6
New support springs	OB reaction	kip	4.26E+01	**Total weight**	
Run: h6-emdlco-17T-shear01	IB reaction	N	1.67E+05	3.570E+05	**SS shim on PF6 sup.**
w/PF6 link	IB reaction	kip	3.76E+01	8.026E+01	
DL, EM & Cooldown	D max	mm	4.86	unsel Type255-spring	Dmax at TF coil mid-hight
• stellalloy E=145GPa	DZ	mm	(-3.629 to -1.978)	unsel Type255-spring	Dzmax at PF6 bracket
• Regular PF shim	Seqv	Pa	4.72E+08	PowerGraphics OFF	TF bracket
• PF shim COF effect	Seqv	ksi	6.85E+01	PowerGraphics OFF	ALPX=9.829E-6
• TF shim COF effect	OB reaction	N	1.80E+05		ALPX=9.829E-6
New support springs	OB reaction	kip	4.05E+01	**Total weight**	
Run: h6-emdlco-05T-TF	IB reaction	N	1.64E+05	3.442E+05	**SS shim on PF6 sup.**
w/PF6 link	IB reaction	kip	3.69E+01	7.739E+01	
EM & Cooldown	D max	mm	3.976	unsel Type255-spring	Dmax at TF coil mid-hight
• stellalloy E=145GPa	DZ	mm	(-0.693 to 0.980)	unsel Type255-spring	Dzmax at PF6 bracket
• Regular PF shim	Seqv	Pa	4.64E+08	PowerGraphics OFF	TF bracket
• PF shim COF effect	Seqv	ksi	6.73E+01	PowerGraphics OFF	ALPX=9.829E-6
• TF shim COF effect	OB reaction	N	-5.91E+03		ALPX=9.829E-6
New support springs	OB reaction	kip	-1.33E+00	**Total weight**	
Run: h6-emco-05T-TFa	IB reaction	N	-6.96E+03	-1.287E+04	**SS shim on PF6 sup.**
w/PF6 link	IB reaction	kip	-1.56E+00	-2.893E+00	
Cooldown	D max	mm	4.667	unsel Type255-spring	Dmax at TF coil mid-hight?
• stellalloy E=145GPa	DZ	mm	(-0.820 to 0.879)	unsel Type255-spring	Dzmax at PF6 bracket?
• Regular PF shim	Seqv	Pa	4.68E+08	PowerGraphics OFF	TF bracket?
• PF shim COF effect	Seqv	ksi	6.79E+01	PowerGraphics OFF	ALPX=9.829E-6
• TF shim COF effect	OB reaction	N	-1.27E+03		ALPX=9.829E-6
New support springs	OB reaction	kip	-2.86E-01	**Total weight**	
Run: h6-co-05T-TFb	IB reaction	N	1.27E+03	0.000E+00	**SS shim on PF6 sup.**
w/PF6 link	IB reaction	kip	2.86E-01	0.000E+00	

EM Load	D max	mm	0.708	unsel Type255-spring	Dmax at TF coil mid-hight?
● stellalloy E=145GPa	DZ	mm	(0.006 to 0.244)	unsel Type255-spring	Dzmax at PF6 bracket?
● Regular PF shim	Seqv	Pa	3.37E+07	PowerGraphics OFF	TF bracket?
● PF shim COF effect	Seqv	ksi	4.89E+00	PowerGraphics OFF	ALPX=9.829E-6
● TF shim COF effect	OB reaction	N	-7.18E+03		ALPX=9.829E-6
New support springs	OB reaction	kip	-1.61E+00	**Total weight**	
Run: h6-em-05T-TFc	IB reaction	N	-5.69E+03	-1.287E+04	**SS shim on PF6 sup.**
w/PF6 link	IB reaction	kip	-1.28E+00	-2.893E+00	

Appendix II

FIELD PERIOD ASSY WEIGHT **Component**	Pro E Weight lbs	tons	contingency	Total Weight tons	delta lbs
Vacuum Vessel	6,776	3.4	5%	3.6	339
Modular Coils	43,402	21.7	5%	22.8	2,170
TF Coils	8,100	4.1	5%	4.3	405
Heating/Cooling Hdwr	529	0.3	5%	0.3	26
PF Coils	5,505	2.8	5%	2.9	275
PFCs & NBL-duct	12,043	6.0	5%	6.3	602
Trim coils & supp'ts	2,007	1.0	5%	1.1	100
PF & TF Structure & C.S.	11,236	5.6	5%	5.9	562
Total Weight	**89,599**	**44.8**	5%	**47.0**	4,480
				47.0	

Does not include	Guessed Wt.
Insulation	600
Cryostat panels & structure	3,500
Magnetic Loops	100
some of the Fastners	500
Full Period Total Wt.:	**94,299**
Full Period Project weight (estimate for design purposes)	**100,000**

APPENDIX III

	N-S Seismic Loading on Anchors			E-W Seismic Loading on anchors		
NODE	FX	FY	FZ	FX	FY	FZ
7851	-5948.1	-86.826	1350.4	-7763.2	-144.32	1511
7855	-7103.4	-287.15	1494.4	-7745	165.16	1465.3
8977	-3650.1	-6612.3	107.43	-3840.4	-4899.7	5.142
9029	5085.4	-784.84	104.49	5140.9	148.42	0.31892
9651	-3808.2	2509.4	763.41	-3633.9	4655.5	70.015
9703	5020	-188.29	942.53	4939.8	44.941	-45.344
11871	9021.6	-31.045	563.91	6533	528.65	348.02
11884	7837.6	-950.26	384.59	6324.3	-529.08	337.51
13773	2604.3	-894.01	1323.7	2306.8	-994.68	1408.9
13827	3270.7	-8232.5	5229.2	-214.61	-12674	2408.1
13855	-8563.9	-58.095	128.9	-8519.1	-463.87	-44.272
14375	-1308.4	14428	1826.2	-401.54	12620	2333.9
14403	-8065.4	517.63	-25.064	-8270.5	550.43	-43.056
14485	2520.3	713.07	1296.6	2016.8	981.27	1472.2
16090	3479.5	21966	-355.91	4224.4	18620	-404.29
16630	1890.1	-6513.5	4333.2	3986	-18906	-447.79
18481	-10256	-475.29	1083.4	-9121.3	-3185.7	1013.3
18523	13784	-1019.2	3015.2	29499	-5266.5	7603.4
18563	-4132.4	-894.71	1656.7	-6886.3	-2084.5	1768.1
19071	-9169.8	16797	4255.2	3530.4	3589.5	1096.2
19111	5675.9	-3910.5	1224.5	5092.5	-1469.6	1094.2
19153	-4070.2	1600	846.84	-5138.8	4086.8	-272.15
19193	57.521	-4537.2	760.91	2133.8	-4475.5	721.37
23149	-6652.3	-4158.2	1596.6	-6357.5	-3989.6	1453.5
23189	2771.6	5472.8	737.04	2689.7	5054.7	770.06
23231	1794.3	-5682	1586.4	3182.7	-3954.4	1270.3
23271	6344.8	1862.1	611.58	5800.7	1189.1	841.76
23779	23074	3356	5064.2	27624	4983.5	7292
23819	-3999.6	1471.7	1385.4	-6052.1	2437.4	1867.9
23861	2378.9	1819.4	3257.3	2052.7	1198	5157
23901	-8141.4	2617.1	926.19	-8798.7	3241	1336.2
28464	754.58	-5553	1967.1	-716.08	-8362.3	-1913.1
28465	2286.5	-616.49	1899.9	4823.6	-552.72	-2251.6
28563	9277.4	-16857	-3579.6	-3589	-3608.8	-698.45
29904	-3282	8353.1	-4314.5	222.03	12785	-1845.5
29906	-1938.2	6553.4	-3745.2	-4085.8	19363	2930.7
31717	-2264.8	-1862.2	-2531.8	-1885.2	-1247.8	-4059.8
31719	-23074	-3356	-5064.2	-27624	-4983.5	-7292
31730	-13810	1021.5	-2884.1	-29500	5266.6	-7598.1
31732	-7034.5	480.66	-2321.2	-2781.1	1241.1	-4376.5
32134	2696.9	3772.3	-347.25	4278.9	3577.5	2064.4
32135	1972.4	-4033.9	-612.62	4438.2	-3565.8	2211.6
32274	-9176.7	48.441	216.19	-6793.6	-530.55	954.65
32275	-7915.4	959.94	7.223	-6598.1	529.54	1030.9
32347	-2795.7	-5519.3	-447.89	-2725.3	-5105.8	-427.8
32348	-6350.2	-1864	-582.49	-5808.8	-1191.3	-799.88
32362	-36.505	4573.7	-497.03	-2158.5	4515.3	-446.22
32737	3856	-2527.7	-330.65	3661.8	-4703.6	405.29
32752	3594.1	6752.9	1525.2	3859.6	4949.6	601.43
32758	-5082.9	186.89	-410.71	-4996.3	-49.269	397.3
32771	-5144.3	808.66	536.77	-5205.4	-139.91	457.46
32784	7193.9	293.32	-1040.6	7852.7	-167.37	-926.84
32785	6027.3	96.005	-951.43	7869.4	146.67	-980.06
34104	-2932.6	10201	-3680.1	-808.28	8607.4	-2043
34105	8228.2	67.479	-5979	4977.7	422.28	-2509.2
34125	1323.6	-14561	-1155.1	410.44	-12738	-1737
34127	-3595.3	-22665	4981.7	-4328.6	-19090	3022.4
37006	-1838.1	5731.4	-1199.4	-3238	3978.6	-889.02
39862	8165.9	-2623.7	-799.07	8832.5	-3255.2	-1152
39867	4010	-1473.4	-1332.7	6062.7	-2439.9	-1813.3
39868	-5705.1	3933.5	-1038.8	-5113.2	1476.3	-985.26
39873	4152.9	895.81	-1554	6905.5	2089.4	-1669.1
39874	10271	474.82	-1008.4	9141.9	3194.2	-901.56
39882	4070.2	-1600	-846.84	5138.8	-4086.8	272.15
39883	6652.3	4158.2	-1596.6	6357.5	3989.6	-1453.5
39886	8128	-517.81	679.96	8333.6	-549.06	790.03
39891	8635.3	57.549	607.03	8590	465.72	878.02
39892	-2538.2	-712.55	-1033.8	-2032	-981.01	-1170.7
39897	-2623.8	894.51	-1031.9	-2323.6	994.97	-1075.1
49253	-755.84	5429.3	795.38	715.7	8361.3	1918.2
49257	-2233.4	522.78	463.46	-4798.5	571.28	2742
49359	-8190.5	-74.089	7278.5	-4954.5	-440.17	2994.3
49363	2932.6	-10201	3680.1	807.97	-8606.6	2047.3
49473	-2672.1	-3768.2	484.12	-4047.8	-3565.6	700.76
49478	-1946.2	4026.8	762.55	-4191.4	3557.5	706.74

APPENDIX IV

Buckling analysis for axial AISC code allowables and for combined axial loads and moments (P-delta effects):

Part A: AISC axial load calculation:

$\lambda_c = (KL/r\pi)\ (F_y/E)^{1/2}$ = 0.765 & 0.293 (weak & strong sections)
$(\lambda_c)^2$ = 0.5852 & 0.08585
K = 2.1
L = 77.25”
r = 1.98” & 5.18”
F_y = 25 ksi
E = 29e6 psi
A = 14.4 sq.in.
KL/r = 82 & 31 (< 200)

$C_c = (2\pi^2 \bullet E/F_y)^{½} = 151.3$

$F_{cr} = .658^{\lambda_c \wedge 2} \bullet F_y$ = 19.5 ksi & 24.1 ksi,

but per ASD (Allowable Stress Design rules), since KL/r < C_c use:

$F_a = F_y \bullet (1-(KL/r)^2/2C_c^2) / (5/3 + 3(KL/r)/8C_c - (KL/r)^3/8C_c^3)$
= 25 • (1- 961/45602) / (1.67 + 93/1210.4 – 29791/1210.4)
= 14 ksi allowable stress or 202 kips max. allowable load per ASD
(using the smaller KL/r value of 31)

Per AISC code:

The LRFD (Load & Resistance Factor Design rules) yield allowable critical buckling load as 281 kip for un-braced columns in the weak section, and 347 kip in the strong section. (Note, lateral bracing will increase these allowables).

Since the ASD rules are more restrictive the maximum allowable load is 202 kip,
yielding a margin of > 2X for the anticipated100 kip assembly load.

Part B: ASD P-delta for combined bending and compression:

$ØP_{\mathbf{n}} = 0.85 \bullet A \bullet F_{\mathbf{cr}} = 238$ kips

$f_a = 14$ ksi
$f_a/F_a = .496$
$F^1{}_e = 12\pi^2E/23(KL/r)^2 \Rightarrow F^1{}_{ex} = 155.4$ & $F^1{}_{ey} = 22.2$
$F_{bx} = F_{by} = 2/3\ F_y = 16.6$ ksi
$Z_x = 63.2\ in^3$
$Z_y = 13.9\ in^3$
$f_{bx} = M_1/Z_x = 100(0.125)/63.2 = 0.197$ ksi (bending stress strong axis)
$f_{by} = M_2/Z_y = 100(0.375)/13.9 = 2.698$ ksi (bending stress weak axis)
$C_m = 1.0$ (worst case end conditions)

$$f_a/F_a + C_m\, f_{bx} / (1- f_a/ F^1{}_{ex})\, F_{bx} + C_m\, f_{by} / (1- f_a/ F^1{}_{ey})\, F_{by} < 1.0$$

$0.496 + 0.197/(1- 14/155.4)16.6 + 2.698/(1 – 14/22.2)16.6 = 0.949 < 1.0$ -ok

$f_a/F_a + f_{bx} / F_{bx} + f_{by} / F_{by} = 0.496 + .197/16.6 + 2.699/16.6 = 0.67 < 1.0$ -ok

Ref: "Structural Steel Designers Handbook" 2nd Ed., R.L.Brockenbrough, F.S. Merritt, Sections 6.35 – 6.42 (applied per AISC code)