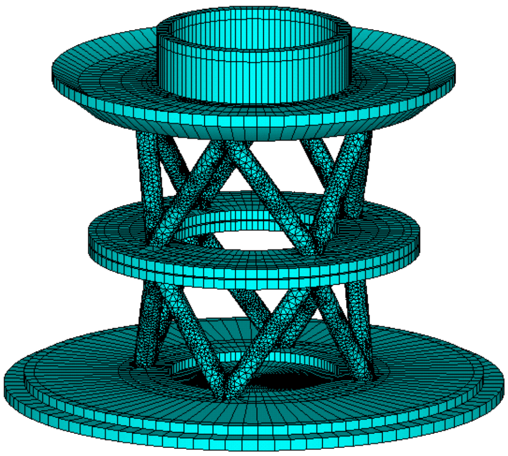
NSTX

Analysis of the NSTX Upgrade Centerstack Support Pedestal

NSTXU-CALC-12-09-00

Rev 0

May 2011



Prepared By:

Peter Titus

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Mark Smith, Cognizant Engineer

PPPL Calculation Form

Calculation # **NSTXU-CALC-12-09-00** Revision # **00** ____ WP #, **1672**
(ENG-032)

Purpose of Calculation: **(Define why the calculation is being performed.)**

The purpose of this calculation is to qualify the stresses in Pedestal support for the centerstack assembly. Additionally, the effect of the torsional stiffness of the pedestal will be assessed.

References **(List any source of design information including computer program titles and revision levels.)**

Included in the body of the calculation

Assumptions **(Identify all assumptions made as part of this calculation.)**

At the time this calculation was prepared, the torsionally stiff Vee-Pipe pedestal w as coupled with a "bent spoke" lid that carried torques either through the cell floor or through the bellows. While analysis of this configuration did not show excessive bellows torsional shear, there was a concern that alignment of the center stack, slippage at the concrete anchors and the lower halo currents on the centerstack could stress the bellows. As a result a stiffer lower spoked lid was added . This final design is closer to the CDR and PDR global models that included a more compliant pedestal and a stiff diaphragm or plate lower lid. Consequently results of both pedestal concepts are included. Stresses in the Vee-Pipe pedestal are inferred from available models and it is assumed that net loads and torques are adequately enveloped by the global model analyses [2] with a compliant lower spoked lid, and a "stand-alone" model to which loads from the design point spreadsheet can be applied directly.
In July of 2011, analysis was added of the pedestal based on a flat lower spoked lid. This confirmed the assumptions discussed above.

Other Assumptions are included in the body of the report

Calculation **(Calculation is either documented here or attached)**

See the following report

Conclusion **(Specify whether or not the purpose of the calculation was accomplished.)**

Stress levels in the support satisfy the NSTX CSU criteria. Torsional stiffness of the pedestal has minimal effect on the torsional shear stress in the TF inner leg. Torsional moments are computed and bolt shear stresses are reported in the body of the calculation. Pedestal "Vee" stresses have been found to be compressive where peak stresses develop and fatigue is not expected to be a concern.

Cognizant Engineer's printed name, signature, and date

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I have reviewed this calculation and, to my professional satisfaction, it is properly performed and correct.

Checker's printed name, signature, and date

Ali Zolfaghari Ali Zolfaghari
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2.1 Table of Contents
NSTX Centerstack Pedestal

3.0 Executive Summary:

The pedestal is a structure that provides gravity support for the centerstack and resists Coil Lorentz loads during operation.. Because it is connected to ground, the lower lid assembly, and the TF flags, and the skirt which supports the centerstack casing, it also is a contributor to the torsional stiffnesses that determine the distribution of the global torques in the machine. The pedestal must allow access to the service connections at the lower end of the centerstack. Provision must be made to allow passage of coolant lines, power leads and diagnostics. In order to service these lines, the pedestal may have to be able to be disassembled in pieces that do not

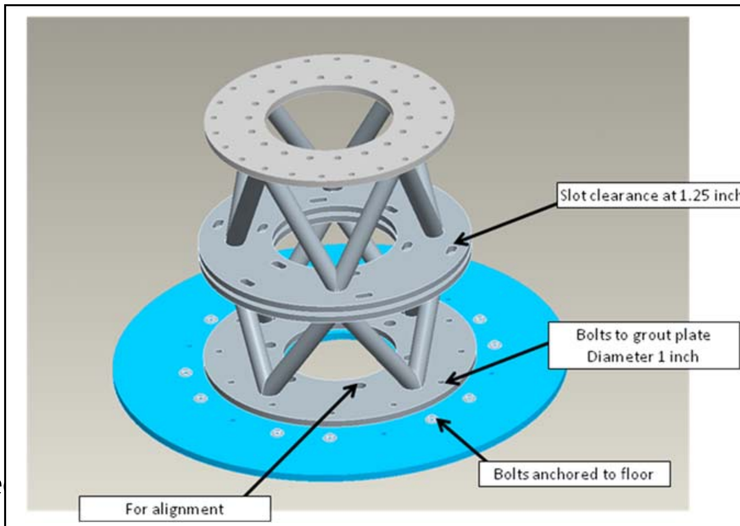


Figure 3.0-1 "Vee" Pipe Pedestal Evaluated for the FDR

capture the service connections. The current design for the FDR is shown in figure 3.0-1. The number of bolts at the mid flange is 6 pairs - but this was described as needing resolution in an email from Mark Smith[10]. The analysis model uses four bolts in a pattern around the vertices of the trusses for a total of 8 pairs. Shimming of the mid flanges is assumed to also align with the vertices of the trusses. Use of high strength bolts at the flange connections (Mid height and at the base) allows these connections to be capable of resisting the worst case power supply loads. The limit to the upward loading is the concrete anchors. Ninety four 3/4 inch anchors are required to resist the worst case power supply loads. It is not likely that this number will be used. Only five 3/4 inch anchors are needed to react the normal operating net load on the centerstack. Many more than 5 are suggested. This number will set the limit that must be maintained by the DCPS.

There have been a couple of design concepts proposed for the pedestal. During the CDR, the pedestal was a bolted plate assembly. A number of analyses were performed based on this configuration, and the gusseted plate design was acceptable. Designers were concerned that a torsionally stiffer structure was needed, although the analyses (which also had a stiff lower lid structure) did not show this.

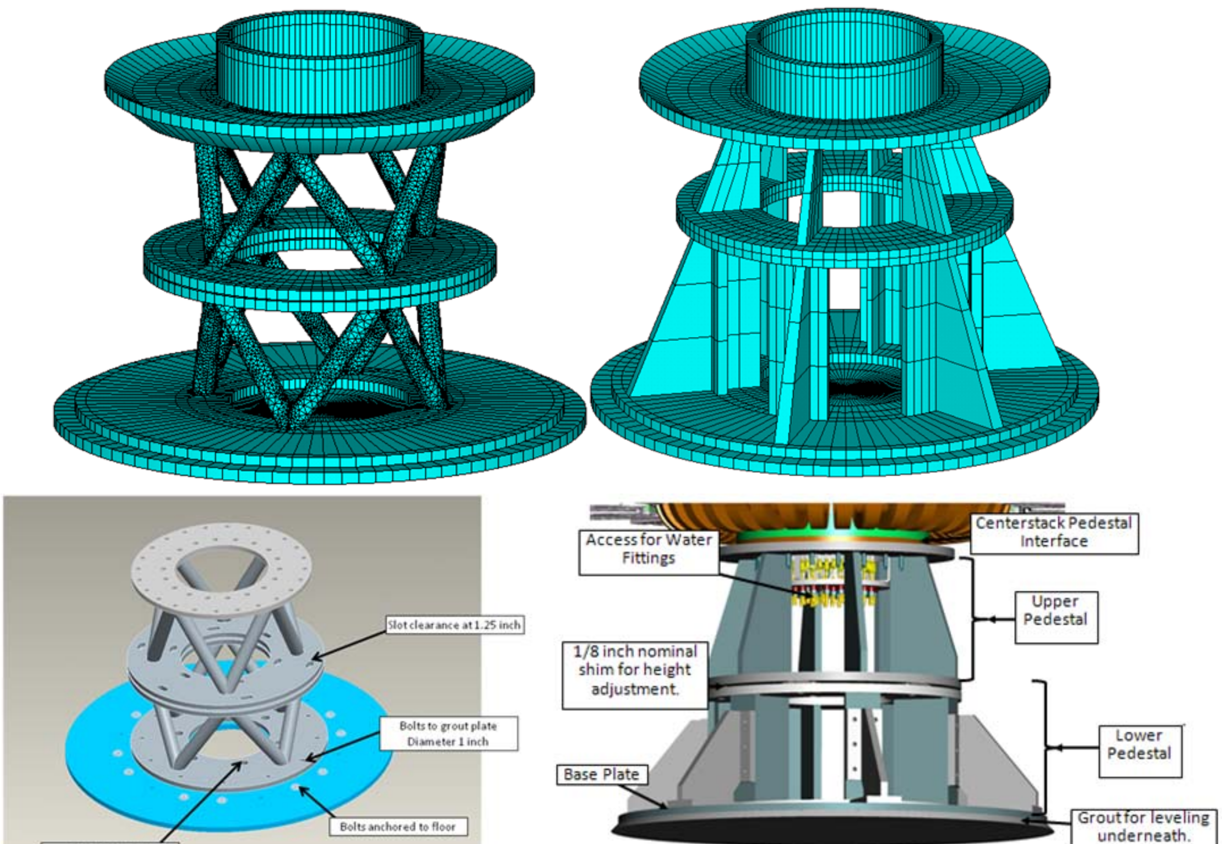


Figure 3.0-2 Two Concepts Proposed for the Pedestal; "Vee" Pipe (Left) and Gusseted Plate (Right)

Aside from qualifying the present Vee-tube structure , the global model used for the inner leg torsional shear calculation has been run with both the plate and vee-tube structure.

Section 9 is from the global model that includes the TF OOP loading, and the TF torque. It is the same model and analysis used for the TF torsional shear. Global machine torque is included. Global torque effects are discussed in a couple of places in the calc - Torque reactions at the base and bolt circle and in the discussion of the different stresses in the Vee legs indicating that a torque was being reacted by the pedestal.

If you look at the figure 9.2-4 you don't see a red contour. - the highest you see is a light green - around 135 level - stresses beyond this are very localized at the intersections and are an indication of the FEA capturing the stress concentration factor. The stress components in the pipes are shown in section 9.2.3, figures 9.2.3-1, and 2. The important observation is that the primary load in the pipes is compressive which, regardless of the stress concentration, will not allow cracks to propagate.

Also included in 9.2.3, plots from the latest global model run are included for a number of the equilibria - some go above the 135 MPa level, but not significantly. The 135 MPa quote is a reasonable reading of the contours, with the higher values more indicative of the very local peaks at the intersections. Section 9.2.3 shows results for the flat lower spoked lid. The pedistal stresses are varying a bit based on the lower lid design, but basic conclusions are not altered.

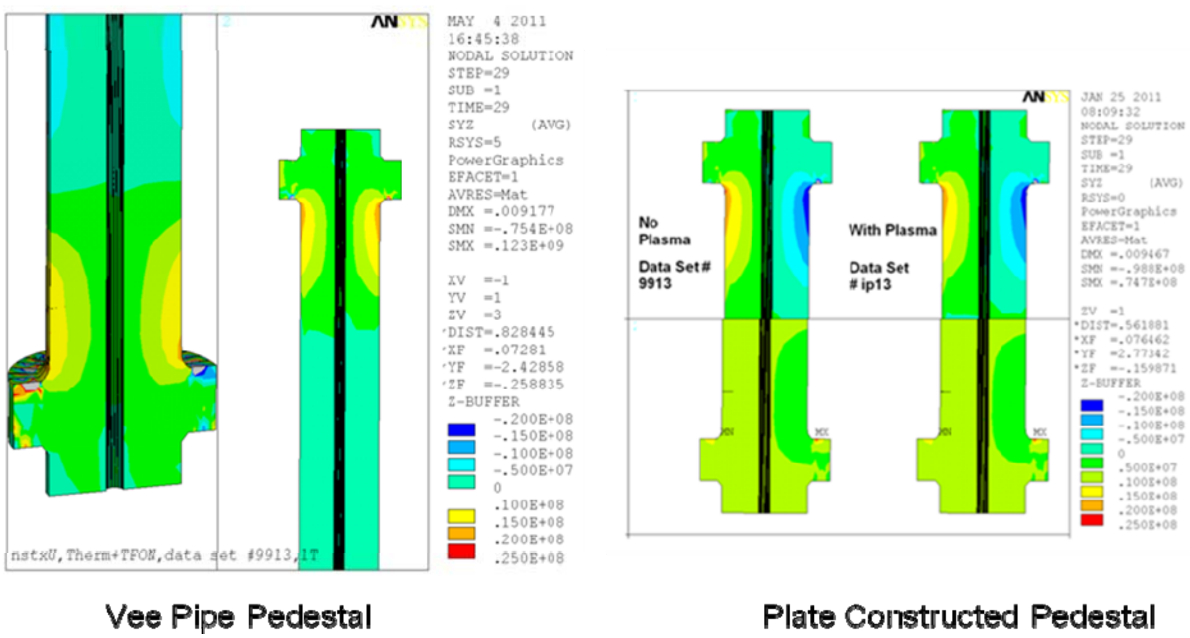


Figure 3.0-3 Inner Leg Torsional Shear For Two Pedestal Concepts

After reviewing results for the different pedestal designs, and a few scenarios, there is no difference in the max TF inner leg torsional shear of 25 MPa, but there is a difference in the shear in the lower end of the TF inner leg. This implies that there is a difference in torques transmitted via the TF flags and crown to the pedestal and lower spoked lid. For both these components, the torques have been based on an upper bound for the upper connections which have been found to be larger. So it is likely that the re-distribution of torque that is caused by the "Vee" Pipe pedestal will not be a problem, but rigorously, these should be re-investigated for the chosen pedestal design. In Bob Wooley's calculation of the inner leg torsional shear stress, he uses elements from Mark Smith's global model to construct a global torsional stiffness model that is consistent with the Vee-Pipe design - but possibly not the "flat" or not bent spoke compliance. The torsional shear values would be bracketed by the modeling available.

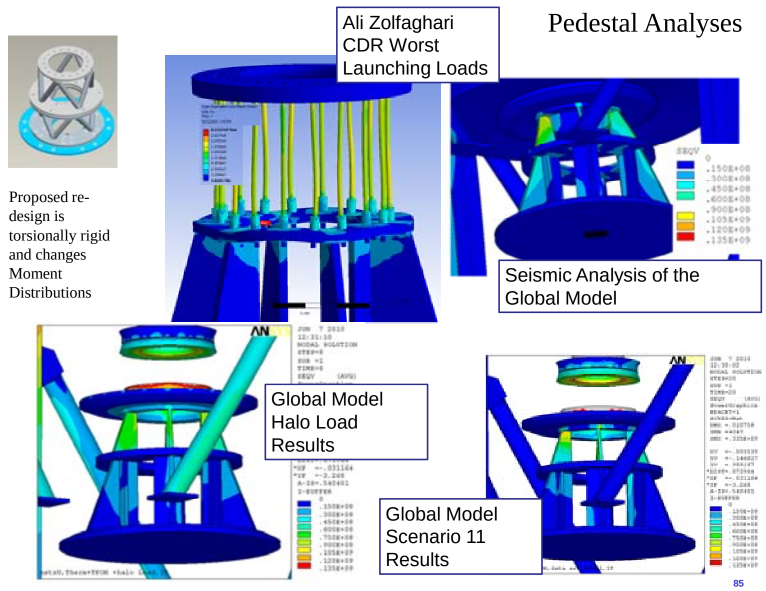


Figure 3.0-4 Present Vee Pipe (upper Left) and Earlier Pedestal Designs

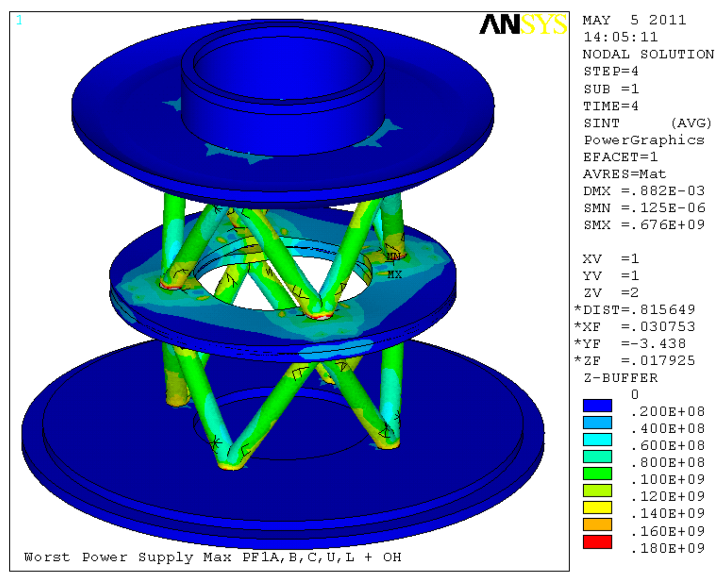


Figure 3.0-5 Representative Pedestal Stress for the Worst Case Power Supply Loads

Figure 3.0-4 shows the work performed on the pedestal up to the PDR . The gusseted plate design has upper "vanes" that are torsionally weak and appear weak with respect to side loads from seismic and halo loads, but their stresses are well within allowables. Halo Loads were considered only for the gusseted plate This was done in the global model [2] based on an early estimate of halo loads that was later confirmed by [11]. The "Vee" Pedestal design improves on the vane cross section in the gusseted plate design. . Stresses in the "Vee" pipe truss pedestal design are slightly lower than for the gusseted plate design. Both are less than 20 MPa for normal vertical loads and less than 200 MPa for the faulted vertical loads. This provides a large margin.. The global model results for the Vee Pipe design show 135 MPa typically for scenarios with significant torques. The bending allowable is 241 MPa for 316 weld material, and fatigue limit is 300 MPa (See figure 7.0-3) Assuming full penetration welds producing no stress multiplier on the stress that is reported by the FEA analyses, the welds and structural elements have a large margin against normal loads and a normal design margin for faulted loads. . Connection to the TF flags is discussed, in Ali Zolfaghari's calculation [9]

The seismic analysis [6] was checked for the "Vee" pipe design - most of the modeling was with the plate design- and the seismic stress levels in the pedestal are acceptable. In section 9.3 of this calculation and in the global model analysis [2], a static 0.5g lateral loading was done with the Vee Pipe pedestal design and the seismic stresses are about 40 MPa - below the 135 MPa in the pipe trusses for the scenario loads.

4.0 Digital Coil Protection System Input

Conceptual design of the upgrade to NSTX explored designs sized to accept the worst loads that power supplies could produce. Excessive structures resulted that would have been difficult to install and were much more costly than needed to meet the scenarios required for the upgrade mission, specified in the General Requirements Document (GRD). Instead the project decided to rely on a digital coil protection system (DCPS). For the pedestal the critical loads are the vertical loads from the OH and PF1 a and b Upper and Lower coils interacting with the rest of the PF system. For the "Vee" Pipe design torsional loads are added to the vertical loads. For the downward loads from the PF coils, both pedestal designs are adequate even for the "worst case power supply" loads.

The limit to the upward loading is the concrete anchors or Hilties. Ninety four 3/4 inch Hilties are required to resist the worst case power supply loads. It is not likely that this number will be used. Only 5 3/4 inch anchors are needed to react the normal operating net load on the centerstack. Many more than 5 are suggested. The actual number will set the limit for the DCPS.

5.0 Design Input,

5.2 Design Point Spreadsheet Loads

(PF1AU+PF1BU+PF1BL+PF1AL+OH)	Fz(lbf)	Fz(N)
Min w/o Plasma	-39635	-176312
Min w/Plasma	-53445	-237745
Min Post-Disrupt	-41843	-186134
Min	-53445	-237745
Worst Case Min	-375500	-1670374
Max w/o Plasma	20397	90733.99
Max w/Plasma	10748	47811.39
Max Post-Disrupt	19630	87322.06
Max	20397	90733.99
Worst Case Max	375501	1670378

Note that the deadweight of the centertstack is larger than 20,000 lbs

5.3 References

[1] NSTX Structural Design Criteria Document, NSTX_DesCrit_IZ_080103.doc I. Zatz

[2] NSTX-CALC-13-001-00 Rev 1 Global Model – Model Description, Mesh Generation, Results, Peter H. Titus March 2011

[4] NSTX Design Point Sep 8 2009 http://www.pppl.gov/~neumeyer/NSTX_CSU/Design_Point.html

[5] OOP PF/TF Torques on TF , R. Woolley, NSTXU CALC 132-03-00

[6] NSTX Upgrade Seismic Analysis NSTXU-CALC-10-02-00 Rev 0 February 9 2011 Prepared By: Peter Titus,

[7] "General Electric Design and Manufacture of a Test Coil for the LCP", 8th Symposium on Engineering Problems of Fusion Research, Vol III, Nov 1979

[8] "Handbook on Materials for Superconducting Machinery" MCIC- HB-04 Metals and Ceramics Information Center, Battelle Columbus Laboratories 505 King Avenue Columbus Ohio 43201

[9] NSTX Upgrade TF Flag Key Structural Analysis, Calculation number NSTXU 132-08-00 prepared by Ali Zolfaghari

[10] Email from Mark Smith:

Pete,

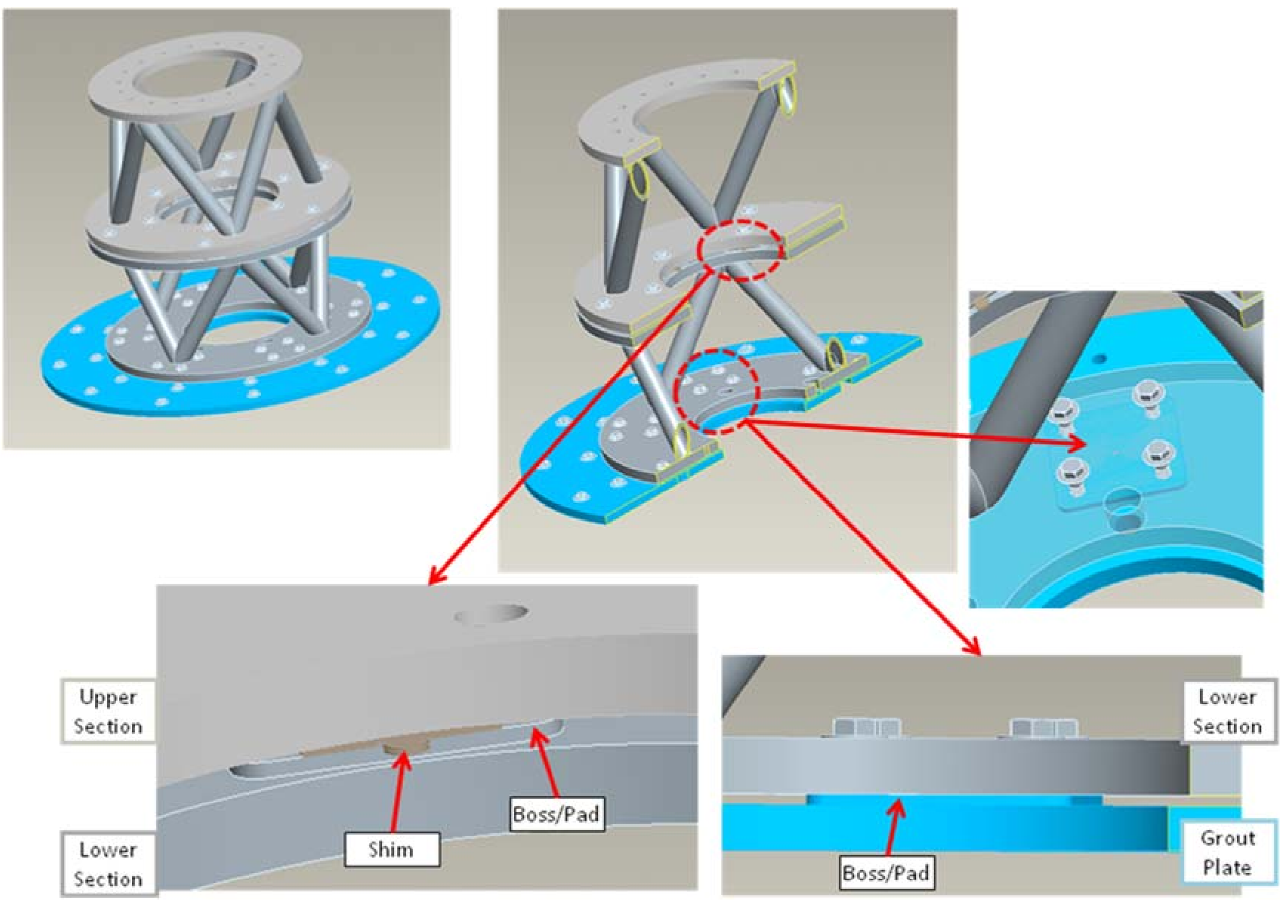
Below is a more detailed image of the pedestal design.

There are two sections: upper and lower.

There are 6 (bosses or pads) between the upper and lower sections as well as the lower section and grout plate.Also, shims will be placed between the upper and lower sections.Thus, there are gaps between these components.Also note, the structural tubing was aligned as you mentioned. However, the tubes are not aligned with all of the bosses. This needs to be resolved.

So, it will take some time to develop the CAD model for the FEA with some of these details. Hopefully, this will be completed by next week.

Note:
The bolt sizing, spacing, total number required and preload have not been determined.
These details were scheduled for the final design analysis.



[11] Email from Art Brooks Thu 3/11/2010 8:21 AM, providing Upper and Lower design loads for the centerstack casing halo loads, copy of the email is included in the appendices
[12] WBS 1.1.2 Lid/Spoke Assembly, Upper & Lower NSTX-CALC-12-08-00 Rev 0 May 2011 Prepared
[13] NSTX Upgrade Centerstack Casing and Lower Skirt Stress Summary NSTXU-CALC-133-03-00 Rev 0 August 2011 Prepared By: Peter Titus
[14] Halo Current Analysis of Center Stack NSTXU-CALC-133-05-00 Prepared By: Art Brooks, Reviewed by: Peter Titus, Cognizant Engineer: Jim Chrzanowski, WBS 1.1.3 Magnet Systems,
[15] Bellows Qualification Calc # NSTXU CALC 133-10-00, Peter Rogoff, Checked by I. Zatz

6.0 Analysis Model

The Pedestal is analyzed with two modeling approaches. It is included in the global model [2] and separate models of the pedestals are employed. Two designs have been evaluated. One which was chosen for the CDR and PDR analysis, uses gusseted plates. The second, introduced at the PDR and chosen for the FDR employs a trussed pipe design which is intended to be torsionally stiff. The pipe design basically has four stress areas at the pipes' intersection with the flanges. The gusseted plate design has six sets of gusseted plates which act as columns and flex plates (for torsion). The "Vee" Pipe design has two versions - one which is linear and is included in the global model and another version that models with a gapped interface, the shims planedd to be placed between the mid height flanges to align the pedestal with the floor and centerstack elevations.

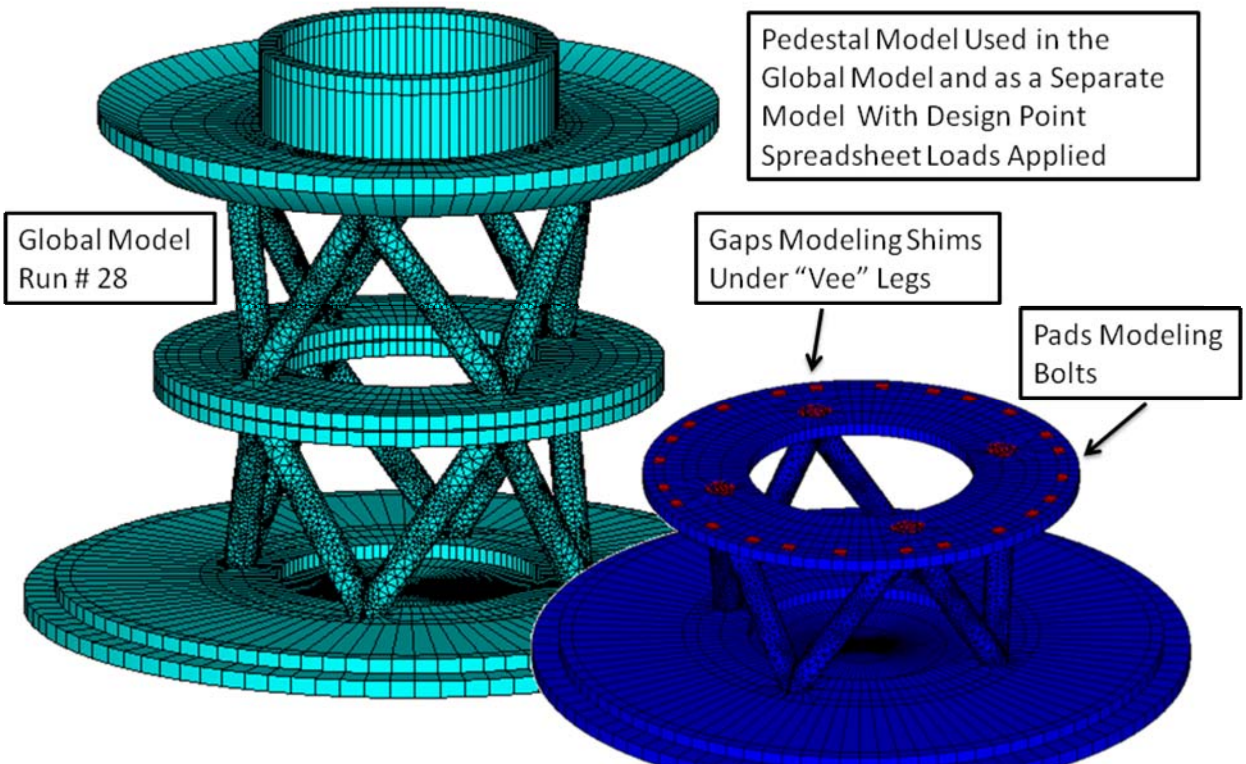


Figure 6.0-1 "Vee" Pipe model The pads modeling the bolts were repositioned, and an inner and outer bolt circle is used.

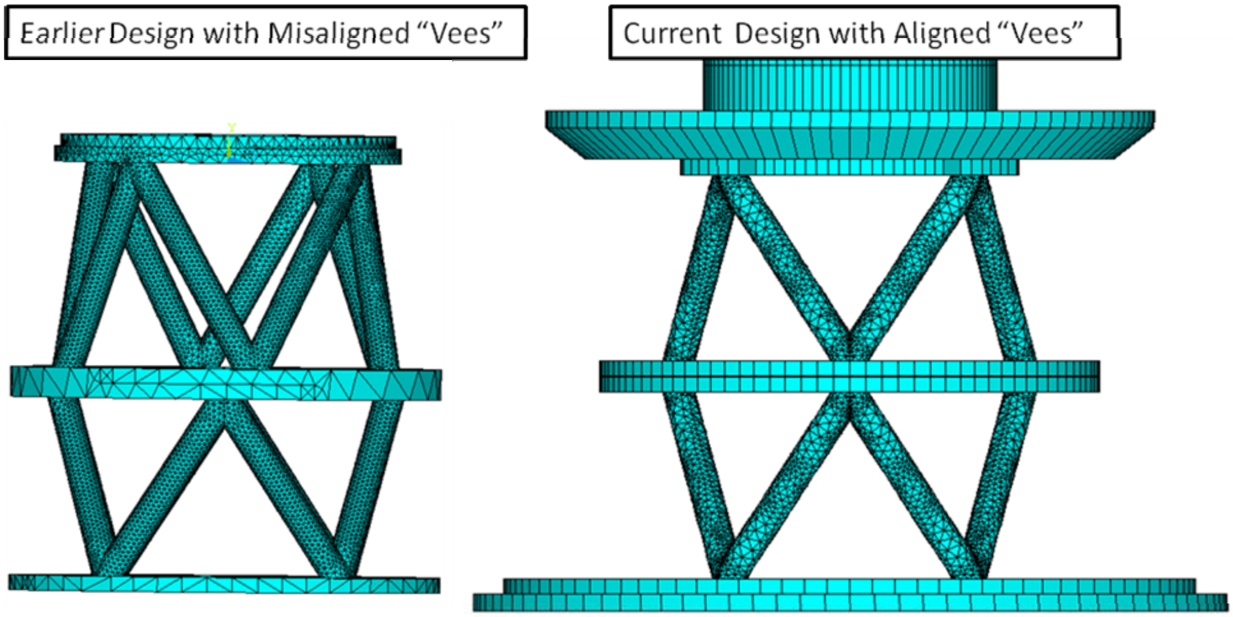


Figure 6.0-2 "Vee" Pipe models -Misaligned and Aligned

The first evolution of the Vee Pipe concept had "Vee" vertices misaligned at the mid plane where ideally, the compressive load should have been transferred directly without any offset and should not have required any plate bending to transfer the load. This was corrected in later versions of the design.

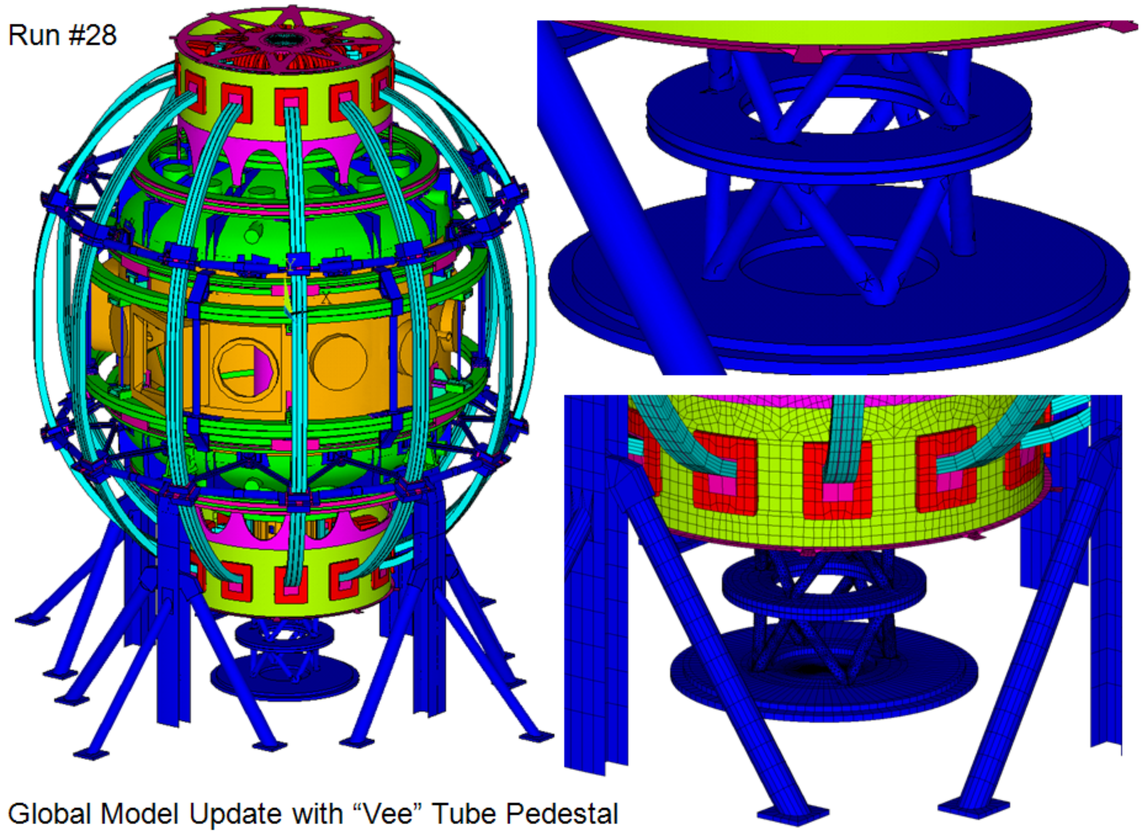


Figure 6.0-3 Ref 2 Global Model Udate with "Vee" Tube Pedestal

7.0 Materials and Allowables

Table 7.0-1Tensile Properties for Stainless Steels

Material	Yield, 292 deg K (MPa)	Ultimate, 292 deg K (MPa)
316 LN SST	275.8[7]	613[7]
316 LN SST Weld	324[7]	482[7] 553[7]
316 SST Sheet Annealed	275[8]	596[8]
316 SST Plate Annealed		579
304 Stainless Steel (Bar,annealed)	234 33.6ksi	640 93ksi
304 SST 50% CW	1089	1241 180ksi

Table 7.0-2 Coil Structure Room Temperature (292 K) Maximum Allowable Stresses, Sm = lesser of 1/3 ultimate or 2/3 yield, and bending allowable=1.5*Sm

Material	Sm	1.5Sm
316 Stainless Steel	184	276
316 Weld	161	241
304 Stainless Steel (Bar,annealed)	156MPa(22.6ksi)	234 MPa (33.9ksi)

ASTM A193 Bolt Specs from PortlandBolt.com

B8M	Class 1 Stainless steel, AISI 316, carbide solution treated.
B8	Class 2 Stainless steel, AISI 304, carbide solution treated, strain hardened
B8M	Class 2 Stainless steel, AISI 316, carbide solution treated, strain hardened

Mechanical Properties

Grade	Size	Tensile ksi, min	Yield, ksi, min	Elong, %, min	RA % min
B8 Class 1	All	75	30	30	50
B8M Class 1	All	75	30	30	50
B8 Class 2	Up to 3/4	125	100	12	35
	7/8 - 1	115	80	15	35
	1-1/8 - 1-1/4	105	65	20	35
	1-3/8 - 1-1/2	100	50	28	45
B8M Class 2	Up to 3/4	110	95	15	45
	7/8 - 1	100	80	20	45
	1-1/8 - 1-1/4	95	65	25	45
	1-3/8 - 1-1/2	90	50	30	45

The allowable for a one inch ASTM A193 B8M Class 2 would be the lesser of 115/3 or 2/3*80 =38.3 ksi

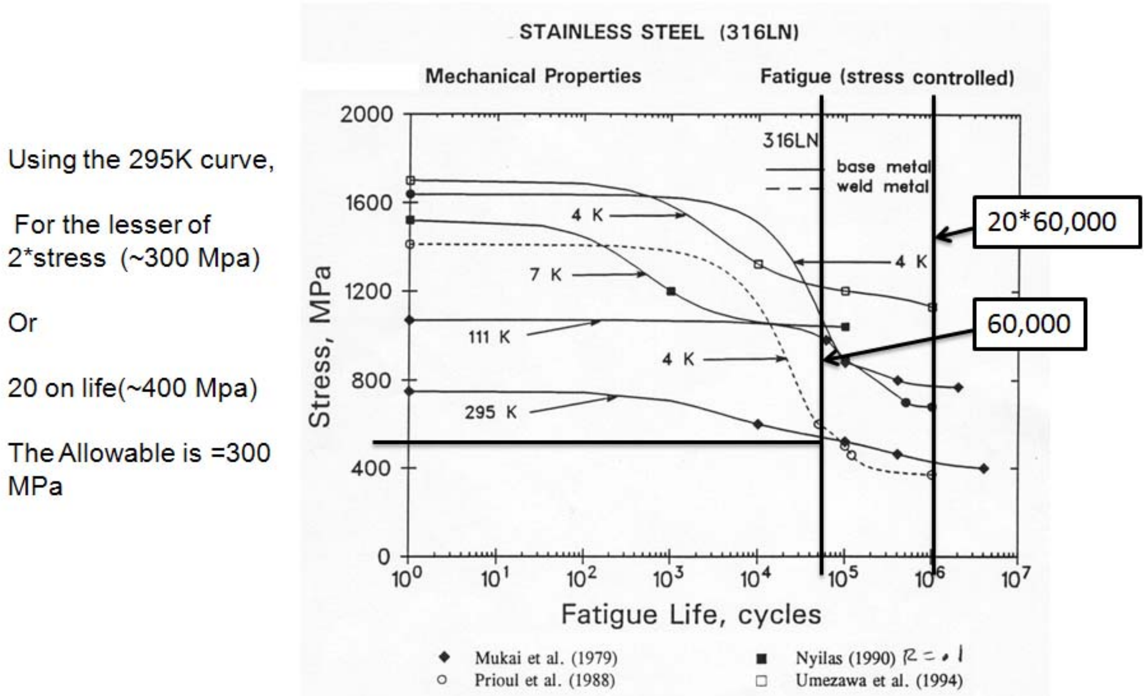
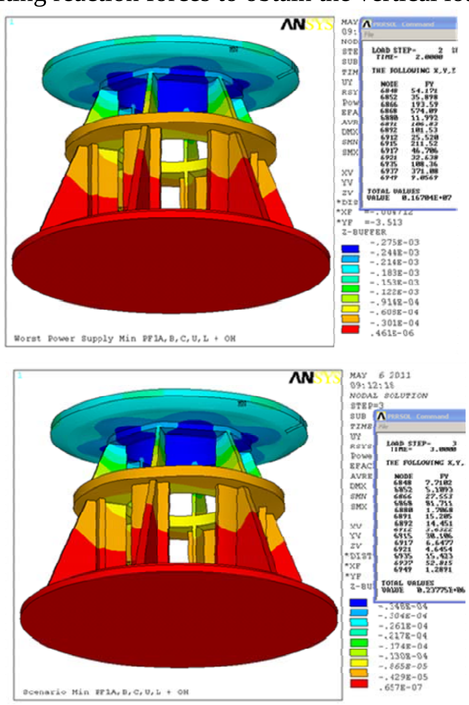


Figure 7.0-3 Fatigue S-N Curve for 316 Stainless Steel

8.0 Stand-Alone-Model Results

The Pedestal is analyzed with two modeling approaches, the global model [2] and a separate sub model or stand-alone model. In the "stand-alone" model, the pedestal model is separated from other structures and loaded via displacement constraints. An initial guess is imposed and then the displacement is scaled based on the resulting reaction forces to obtain the vertical loading specified by the design point spreadsheet.



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nsel,y,-4,-3.93
d,all,all,0.0
esel,mat,5
nelem
d,all,uy,-.01
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solve
/title, Scenario Max PF1A,B,C,U,L + OH
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nelem
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nall
eall
solve
save
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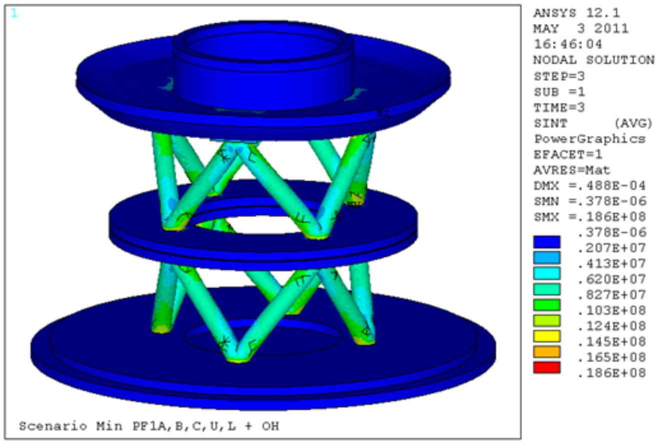
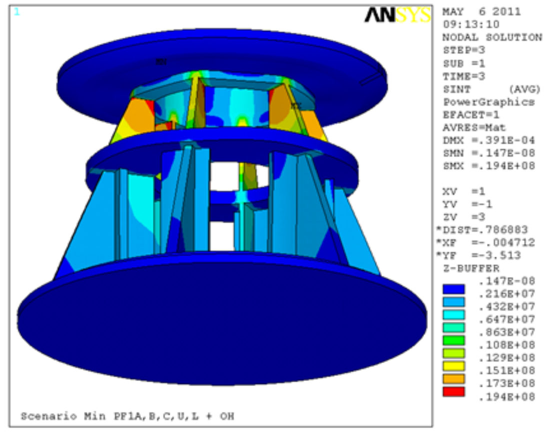
Figure 8.0-1 Displacement Constraints on the Gusseted plate model along with the script that applies displacement constraints scaled to produce the required applied load

8.1 Normal Operating Downward Loads **8.1**

Scenario Min (Largest Normal Downward Load)

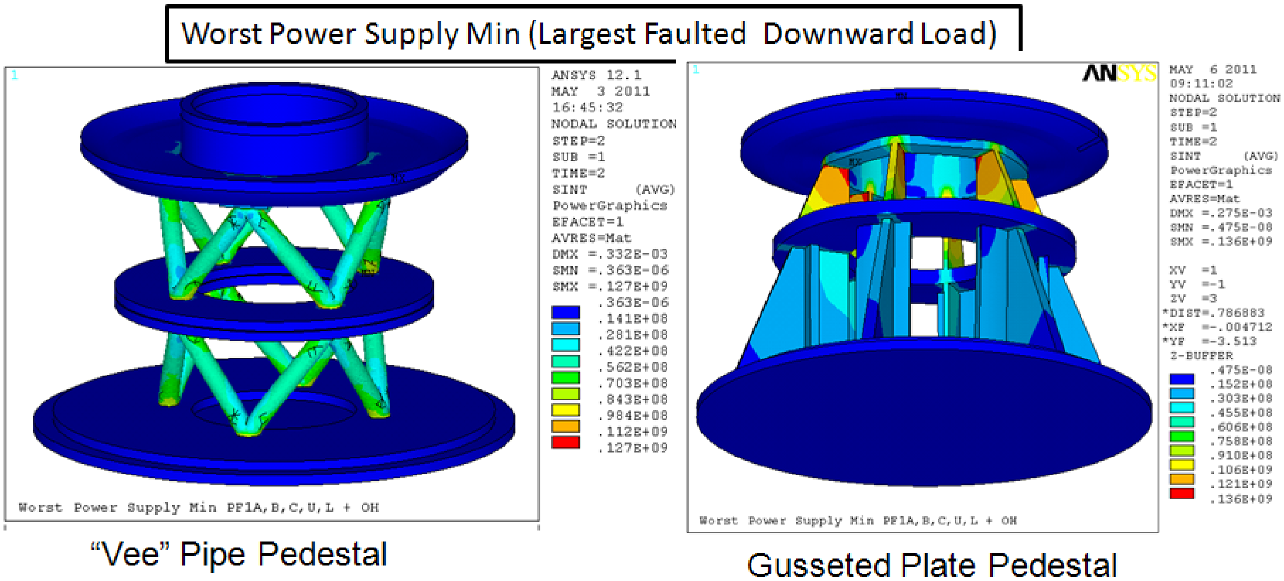


“Vee” Pipe Pedestal



Gusseted Plate Pedestal

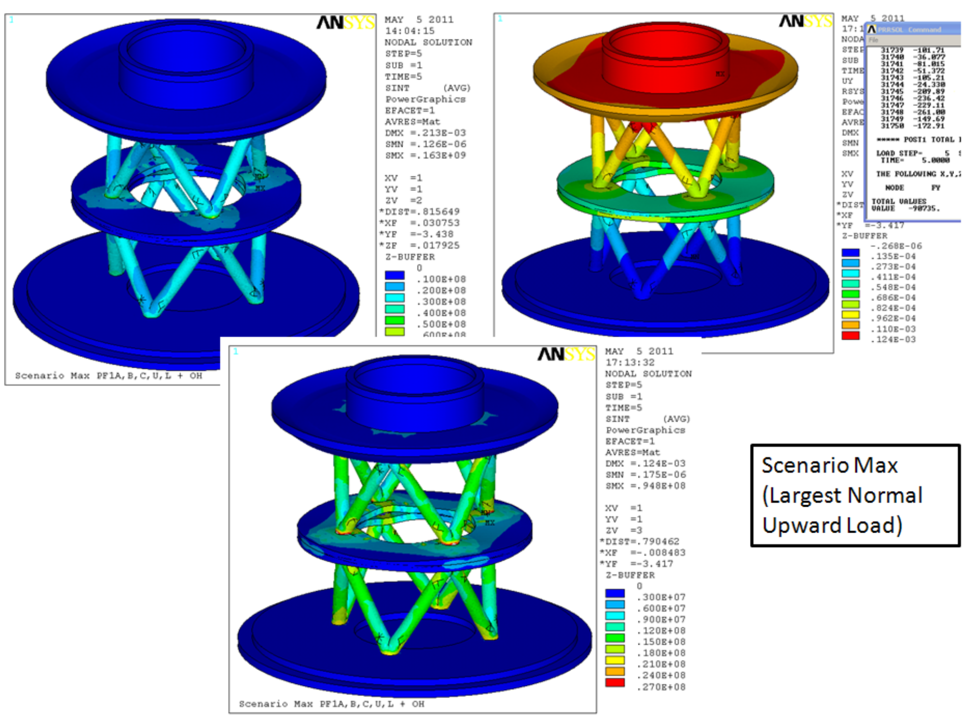
8.2 Faulted Downward Loads



Downward and Normal and Faulted Stresses are acceptable for both pedestal concepts. Stresses are almost the same for both concepts.

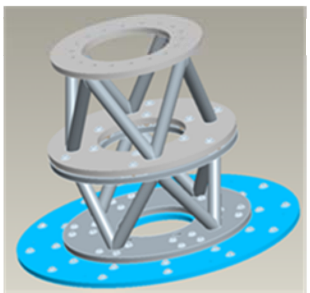
8.3 Normal Operating Upward Loads

8.3.1 Pipe and Plate Stresses for Normal Operating Upward Loads



8.3.2 Bolting and Embedment Anchors for the Normal Operating Upward Loads

(PF1AU+PF1BU+PF1BL+PF1AL+OH)		
	Fz(lbf)	Fz(N)
Min w/o Plasma	-39635	-176312
Min w/Plasma	-53445	-237745
Min Post-Disrupt	-41843	-186134
Min	-53445	-237745
Worst Case Min	-375500	-1670374
Max w/o Plasma	20397	90733.99
Max w/Plasma	10748	47811.39
Max Post-Disrupt	19630	87322.06
Max	20397	90733.99
Worst Case Max	375501	1670378



Hilti Drop-In

Hilti HDI Concrete Flush Anchor Tests

	2000 psi	Concrete	4000 psi	Concrete	6000 psi	Concrete
Anchor Size	Tension	Shear	Tension	Shear	Tension	Shear
HDI 1/4	[illegible]	1738	2251	1781	[illegible]	[illegible]
HDI 3/8	3174	[illegible]	4942	4225	[illegible]	[illegible]
HDI 1/2	3997	5873	6751	6224	10200	9350
HDI 5/8	5549	8883	9696	12205	10400	13600
HDI 3/4	8857	15105	[illegible]	[illegible]	[illegible]	21200

Allowable Design Loads are ¼ these Values, i.e. a F.S. of 4 is recommended

375550/(16000/4) = 94 ¾ Hilties to take the Worst Power Supply Loads
20397/(1600/4) = 5 ¾" Hilties to take the Max Scenario Load

There are really only 13 Effective in the Outer Two Rows.

Figure 8.3.2-1 Pedestal Hilti Capacity

The analysis model uses four bolts in a pattern around the vertices of the trusses. Also shimming of the mid flanges is assumed to also align with the vertices of the trusses. Bolt sizes are assumed to be 1 inch diameter ASTM A 193 B8 bolts with an 80 ksi yield. There are 16 bolts in the final design. One inch bolts have a .6051 in^2 stress area and thus the total upward capacity of the mid flange connection is 16*80000*.6051 = 774528 lbs. which is above the worst power supply load of 375500 lbs. So the flange bolts capable of resisting the faulted upward tensile load.

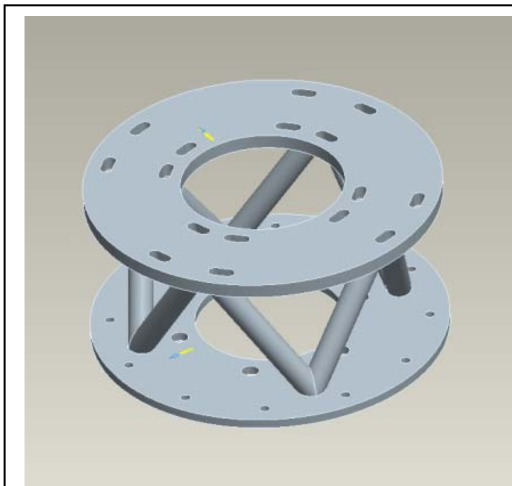
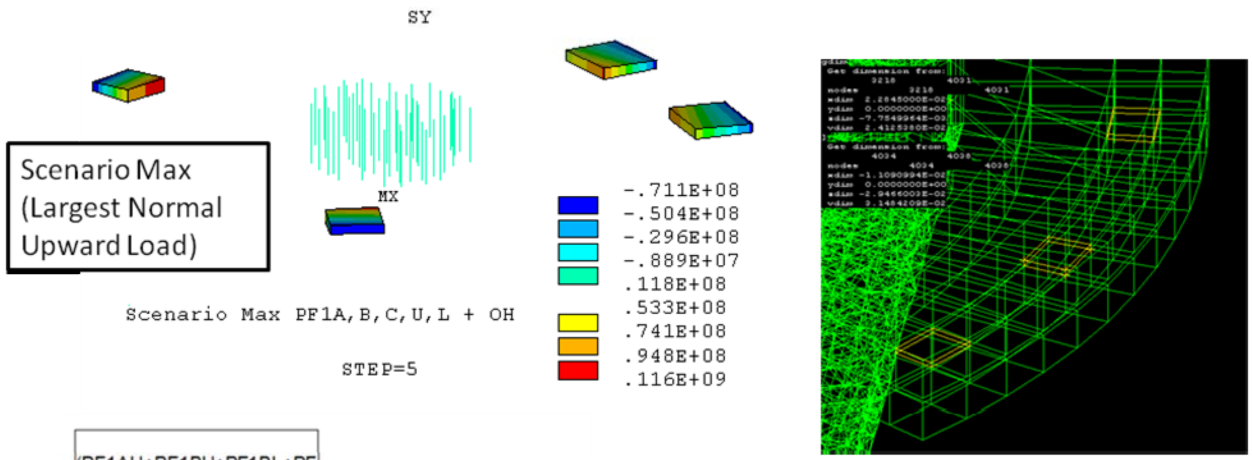


Figure 8.3.2-2 Pedestal final Design, showing 16 bolt holes t mid-height flange.



(PF1AU+PF1BU+PF1BL+PF1AL+OH)	Fz(lbf)	Fz(N)
Min w/o Plasma	-39635	-176312
Min w/Plasma	-53445	-237745
Min Post-Disrupt	-41843	-186134
Min	-53445	-237745
Worst Case Min	-375500	-1670374
Max w/o Plasma	20397	90733.99
Max w/Plasma	10748	47811.39
Max Post-Disrupt	19630	87322.06
Max	20397	90733.99
Worst Case Max	375501	1670378

Estimating the Bolt Load from the Contours:
.022845*.03148*(116e6-71e6)/2 *.2248 =
3637 lbs per bolt

For 16 bolts the net load is 58200 lbs – It should be 20397 lbs

Figure 8.3.2-3 Bolt Loads including the non-linear prying/bending action on the Bolts - -

8.4 Faulted Upward Loads

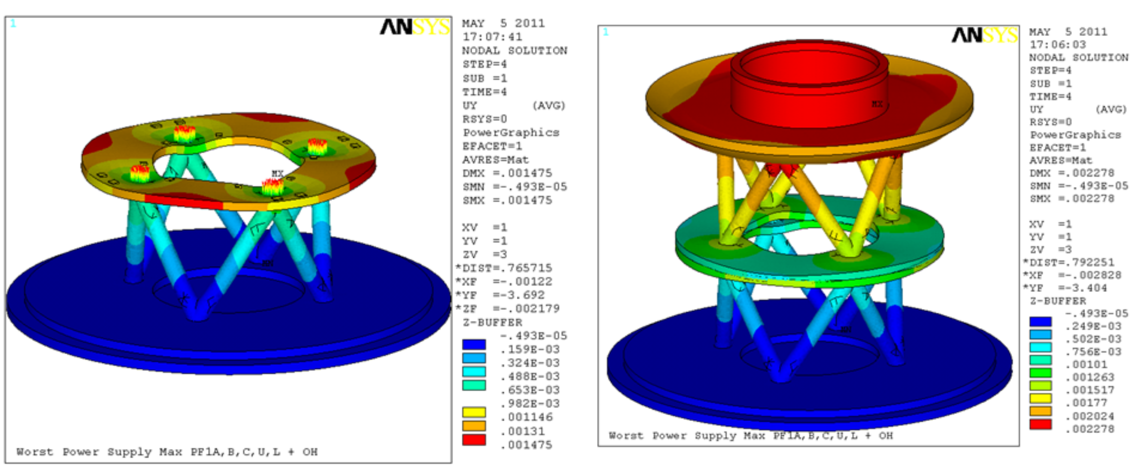
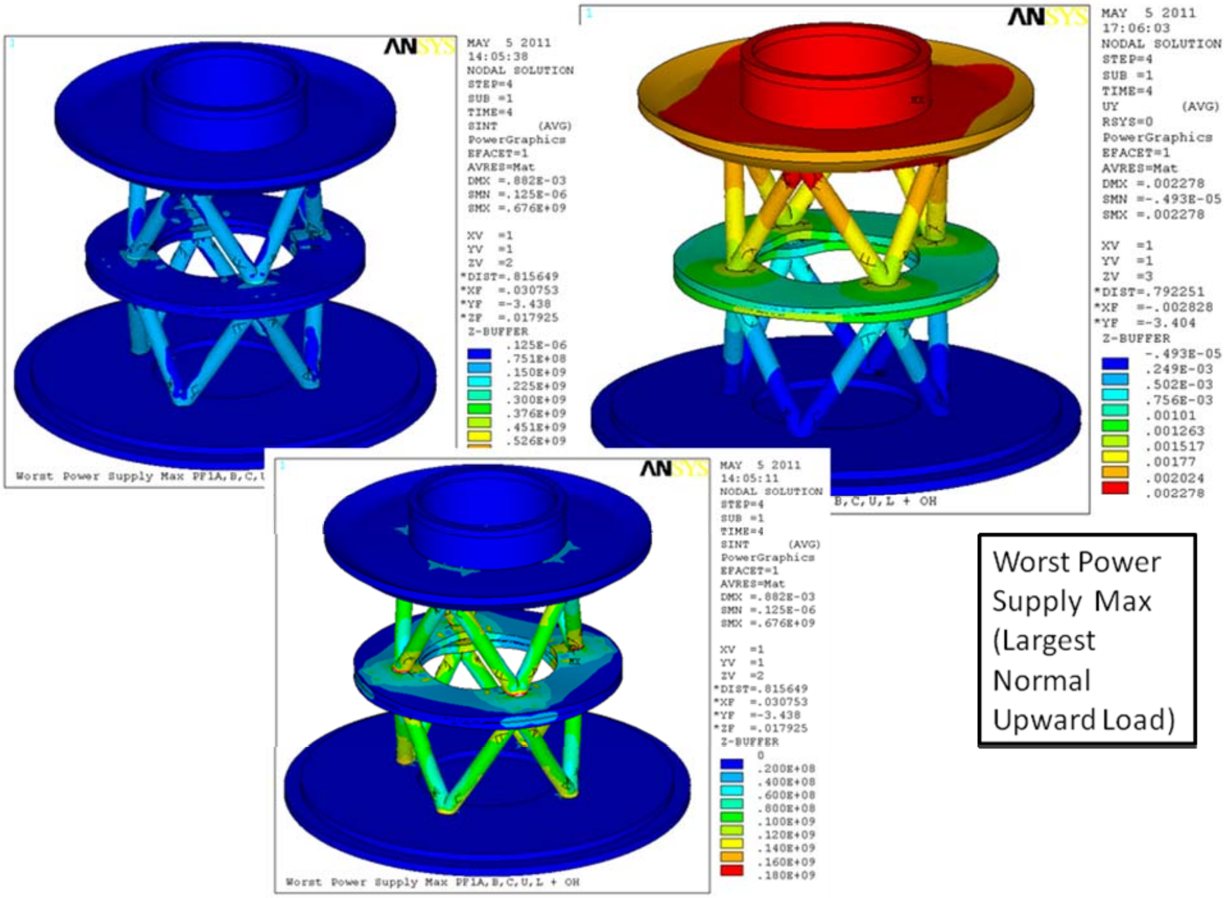


Figure 8.4-1 Vertical Displacements With Max Power Supply Loads Applied.

In figure 8.4-1, the displacement profile shows the lift-off at the gap elements that model the shims under the Vee vertices.

Again, the flanges are capable of resisting the faulted upward tensile load.



Upward Normal and Faulted Stresses are acceptable for both pedestal concepts. Stresses are similar for both concepts.

9.0 Global Model Results

Ref [2] describes the global model of the tokamak that was updated with the Vee tube pedestal in run#28. This analysis provides results for a number of load cases not readily available from the design point spreadsheet[4] . The design point spreadsheet provides only axisymmetric loads from the PF coil currents.

9.1 Deadweight

Figure 9.1-1 shows the deadweight stresses , which are in the few MPa range, and are not limiting

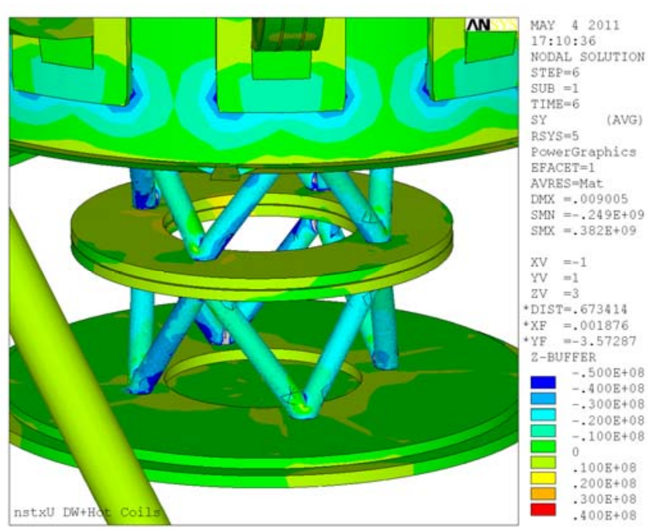


Figure 9.1-1 Deadweight Stresses in the Pedestal

9.2 Normal Operating Loads

9.2.1 Gusseted Plate Pedestal

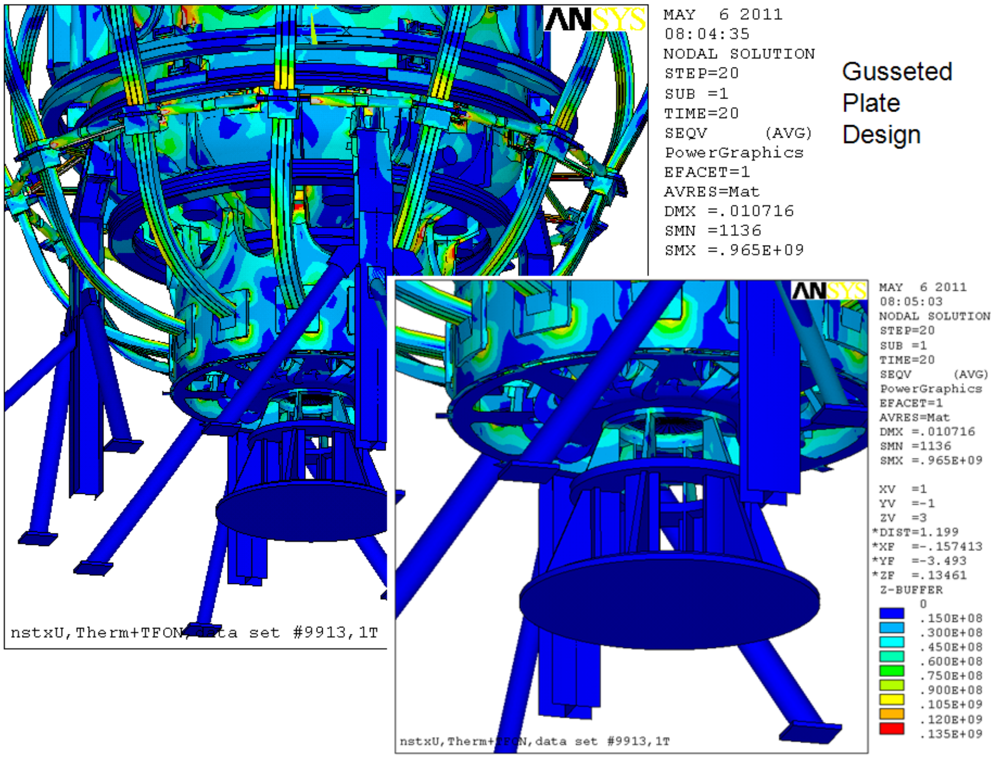


Figure 9.2.1-1 Scenario 13 Gusseted Plate Pedestal Stresses

9.2.2 Vee Pipe Pedestal Design with Bent Spoke Lower Lid

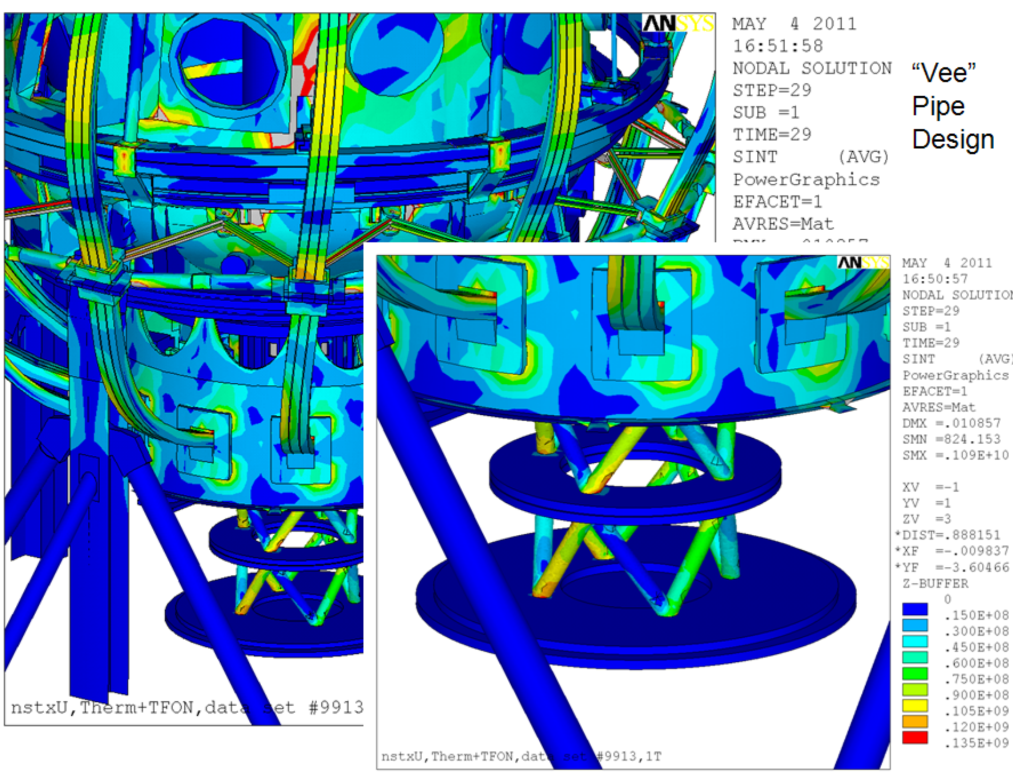


Figure 9.2.2-1 Scenario 13 "Vee" pipe Pedestal Stresses

Note that the Stresses in the "Vee" truss are not equal - this is an indication that some portion of the machine global torque is being transmitted into the truss.

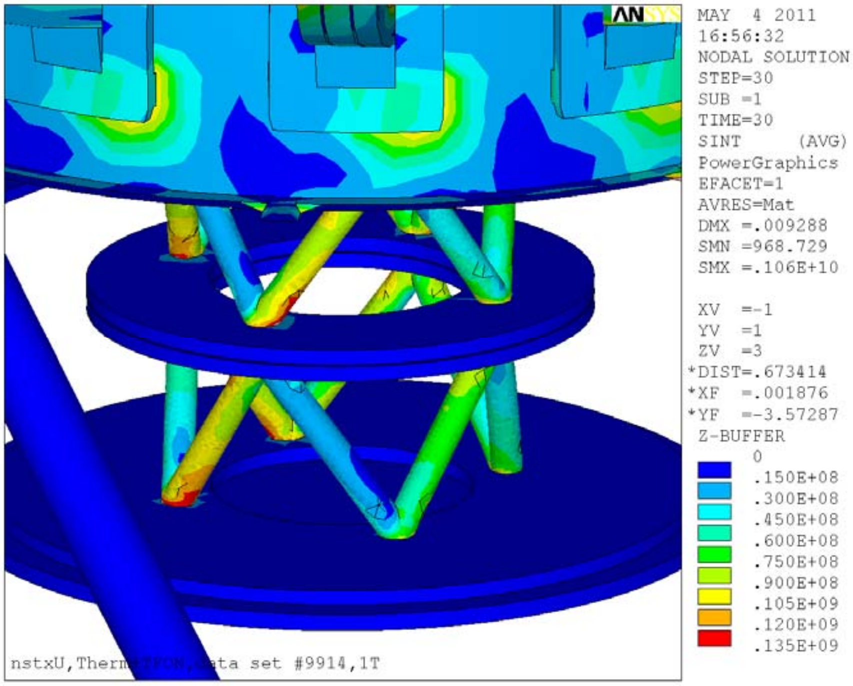


Figure 9.2.2-2 Scenario 14 "Vee" Pipe Pedestal Stresses

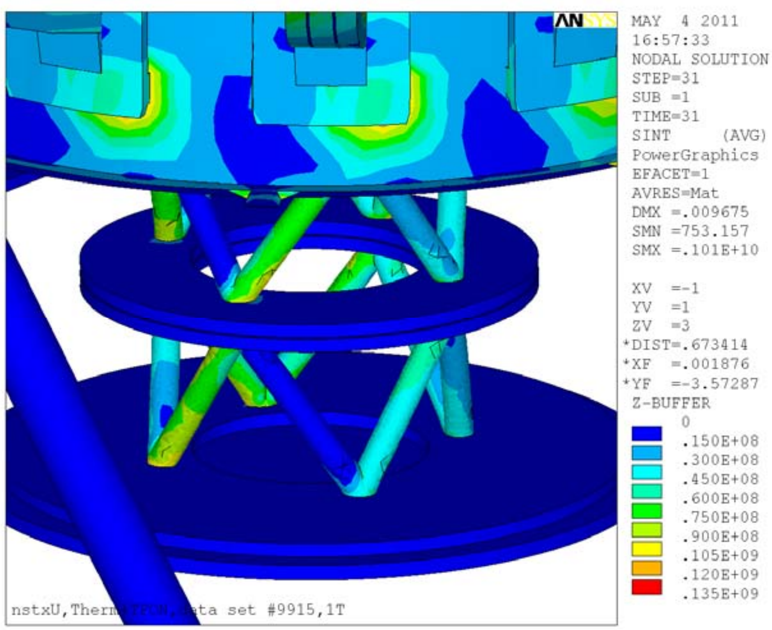


Figure 9.2.2-3 Scenario 15 "Vee" Pipe Pedestal Stresses

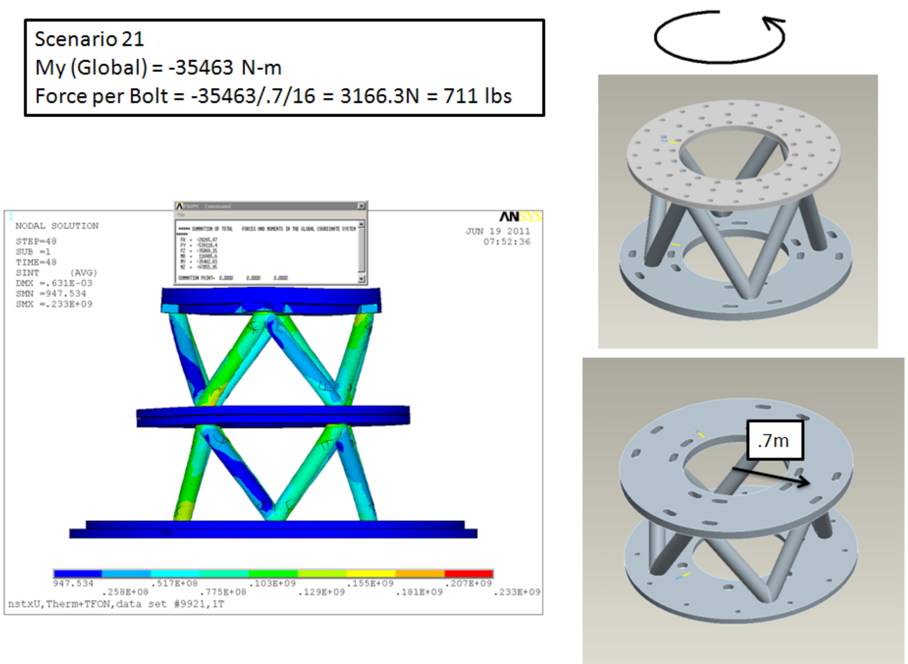


Figure 9.2.2-4 Pedestal Moment Diagram

The torques that are carried through the pedestal have been determined only for a few scenarios. Scenario 21 is larger than one of the usual larger torque scenarios, #32. The maximum moment found so far is 35463 N-m or 313860 in-lbs. More moment summations are included in [2] To envelope other scenarios, double the torque, and use 1 inch high strength bolts. The one inch bolts were recommended in section 8.3.2 to resist the worst case power supply vertical tensile or launching loads. These bolts also provide frictional resistance to the torque. with a stress area of ..6051 in^2 The allowable for ASTM A193 B8M Class 2 would be the lesser of 115/3 or 2/3*80 =38.3 ksi. Each would be preloaded to 23175 lbs and each would have a frictional capacity of (.3-.15)* 23175 = 3476 Lbs - Significantly larger than even twice the scenario 21 load. The other scenarios need to be addressed but it is expected that this margin is more than enough to envelope them all.

9.2.3 Vee Pipe Pedestal Design with Flat Spoke Lower Lid

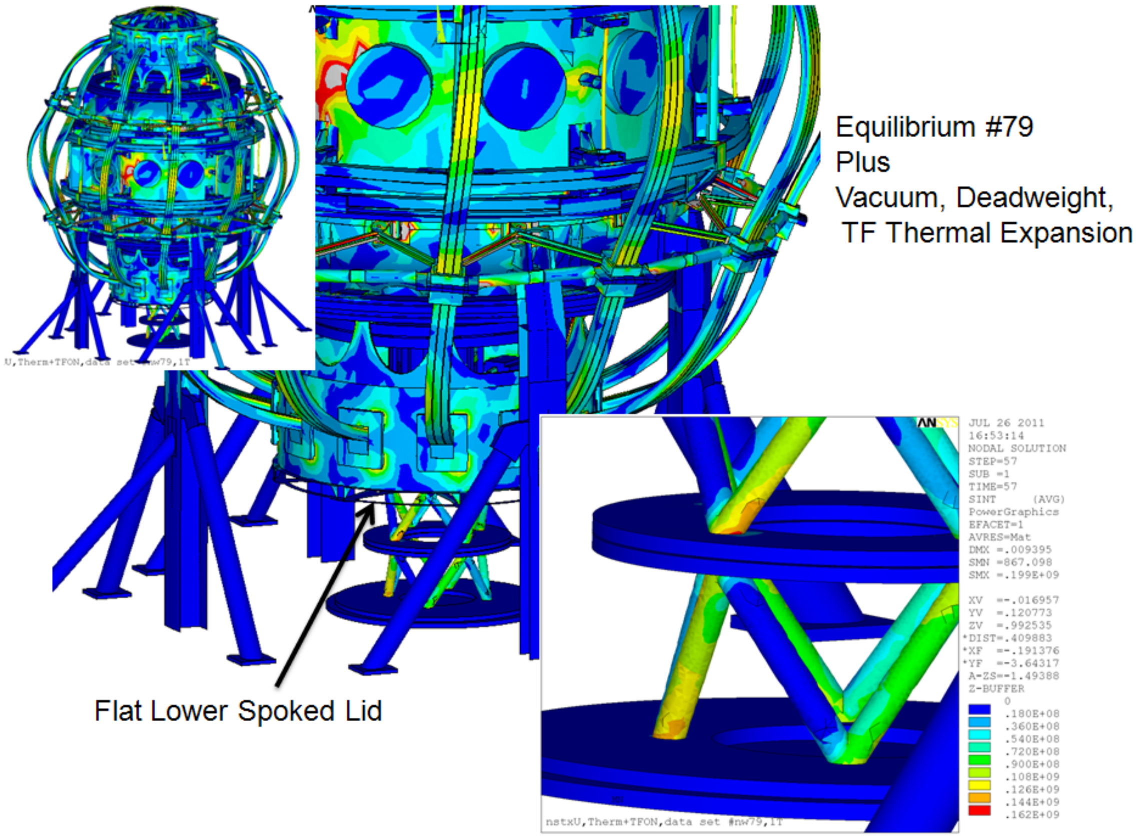


Figure 9.2.3-1 Model with Flat Lower Spoked Lid

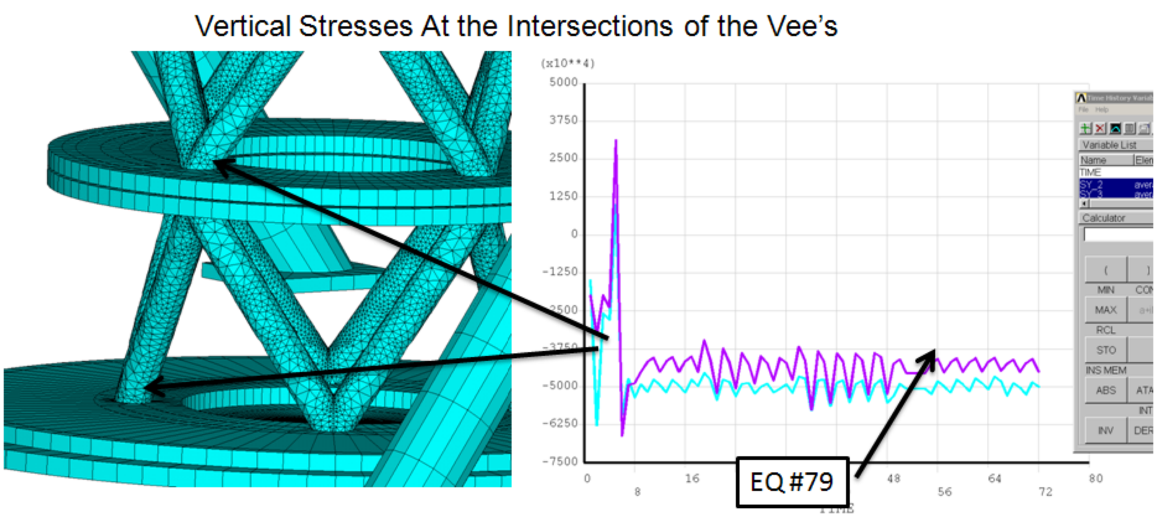


Figure 9.2.3-2 TimHis 6 ANSYS Vertical Stress Postprocess for Most of the Scenarios

Note that the vertical stress component at the Vee intersection is compressive. except for the initial seismic and bake-out and other thermal load cases.

The global run load cases are:

1 deadweight (not turned off)
2 seismic (turned off in subsequent load steps)
3 deadweight plus vacuum (not turned off)
4 hot centerstack casing, 500C (operating Condition)
5 bake-out vessel at 150, PP at 350 (turned off in subsequent load steps

6 dead weight + 100C TF inner leg, 50C outer legs 50 C PF coils (This remains on for all the EQ with and without plasma loads)
7 TF on only. -No PF loads
8 TF on + Centerstack Halo (This is turned off for the remaining EQ load steps) and was not used in the pedestal plot - I reinstated the load case in run 35
9 through 104 96 EQ -no plasma
104 through 200 EQ with plasma

The tensile spike is the bake-out load case which has a hot vessel, and cold TF. As the vessel expands it flexes the spoked lid opposite to its normal 8mm positive displacement and puts the TF inner leg assembly in tension and pulls upward on the pedestal. The tensile stress on the Vee due to bake-out is 25 MPa. The seismic stress is -62 MPa and would be tensile in the opposite side of the pedestal. The bolting was qualified for the seismic and other upward loads.

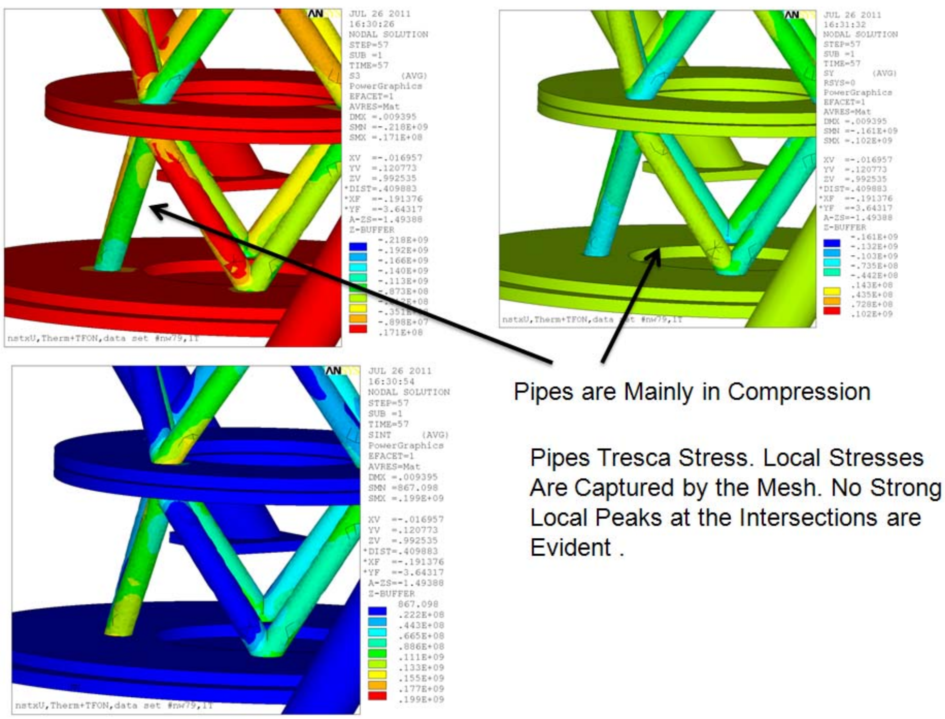


Figure 9.2.3-3 ANSYS Contour plots of Sig3, Vertical Stress, and Tresca Stress for EQ79

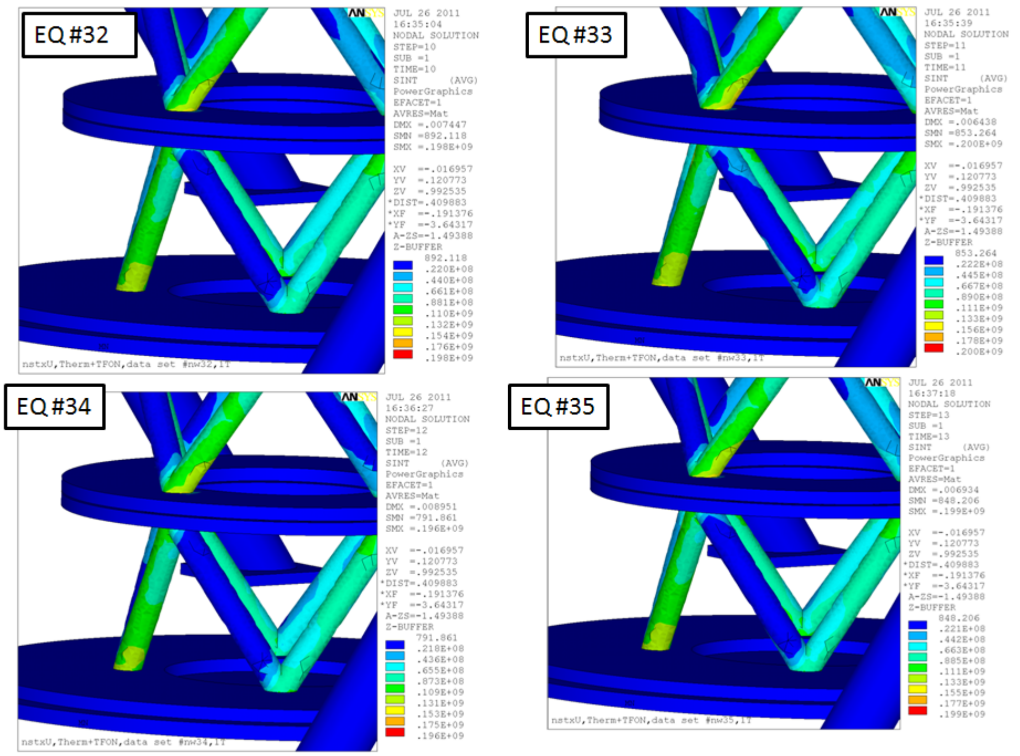


Figure 9.2.3-4 ANSYS Contour plots of Tresca Stress for Various Equilibria

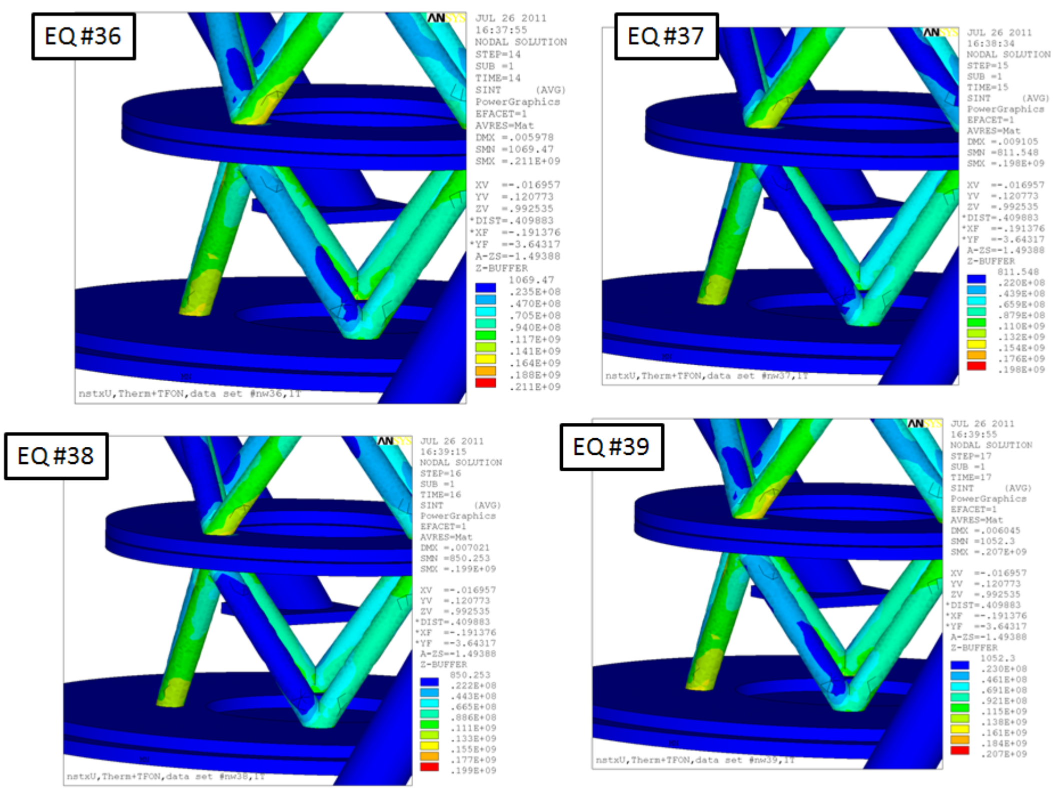


Figure 9.2.3-5 ANSYS Contour plots of Tresca Stress for Various Equilibria

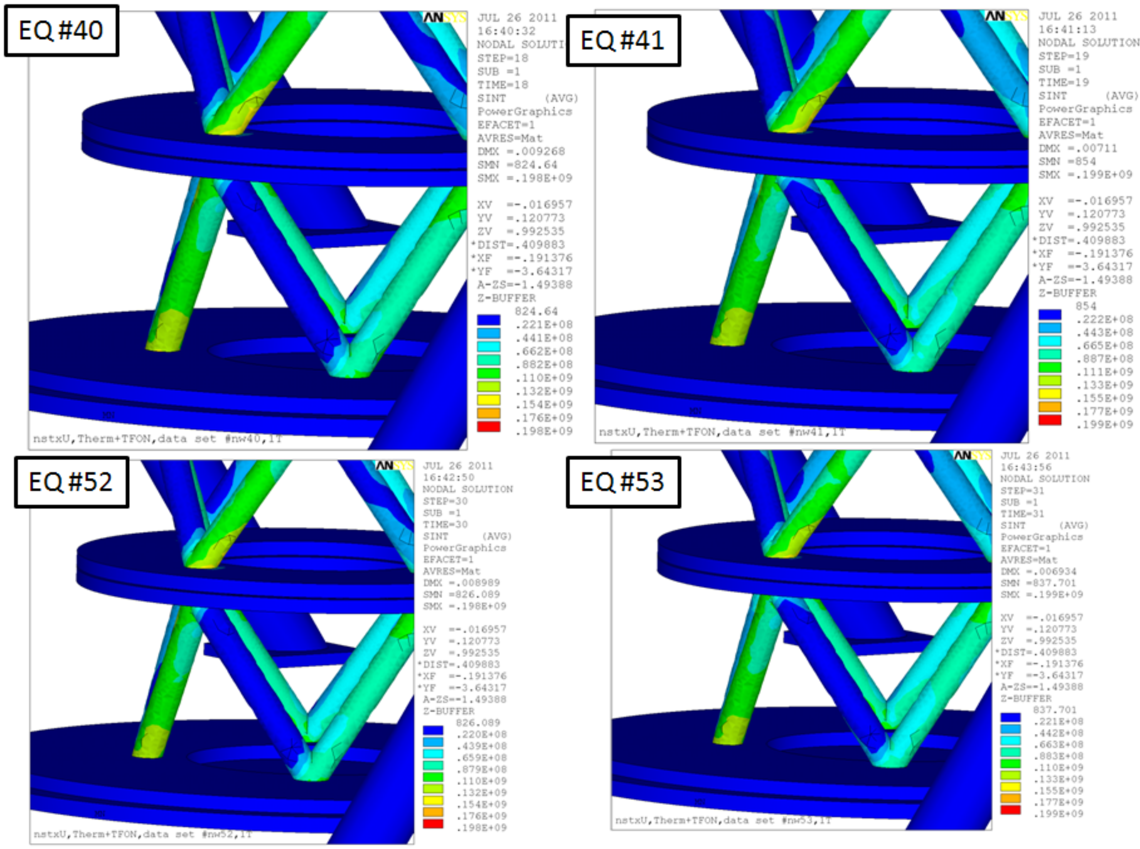


Figure 9.2.3-6 ANSYS Contour plots of Tresca Stress for Various Equilibria

9.3 Seismic Loads

Seismic analysis of NSTX may be found in Reference [6], based on the global model analysis described in reference [2]. Both of these calculations - as of May 2011- were based on the earlier gusseted plate pedestal concept. The global model was re-run with the .5 g lateral load applied, which is representative of the seismic response based on the more elaborate response spectra modal analysis also included in reference [6] The seismic stress in the V truss is only 40 MPa vs. 135 for a typical operating scenario.

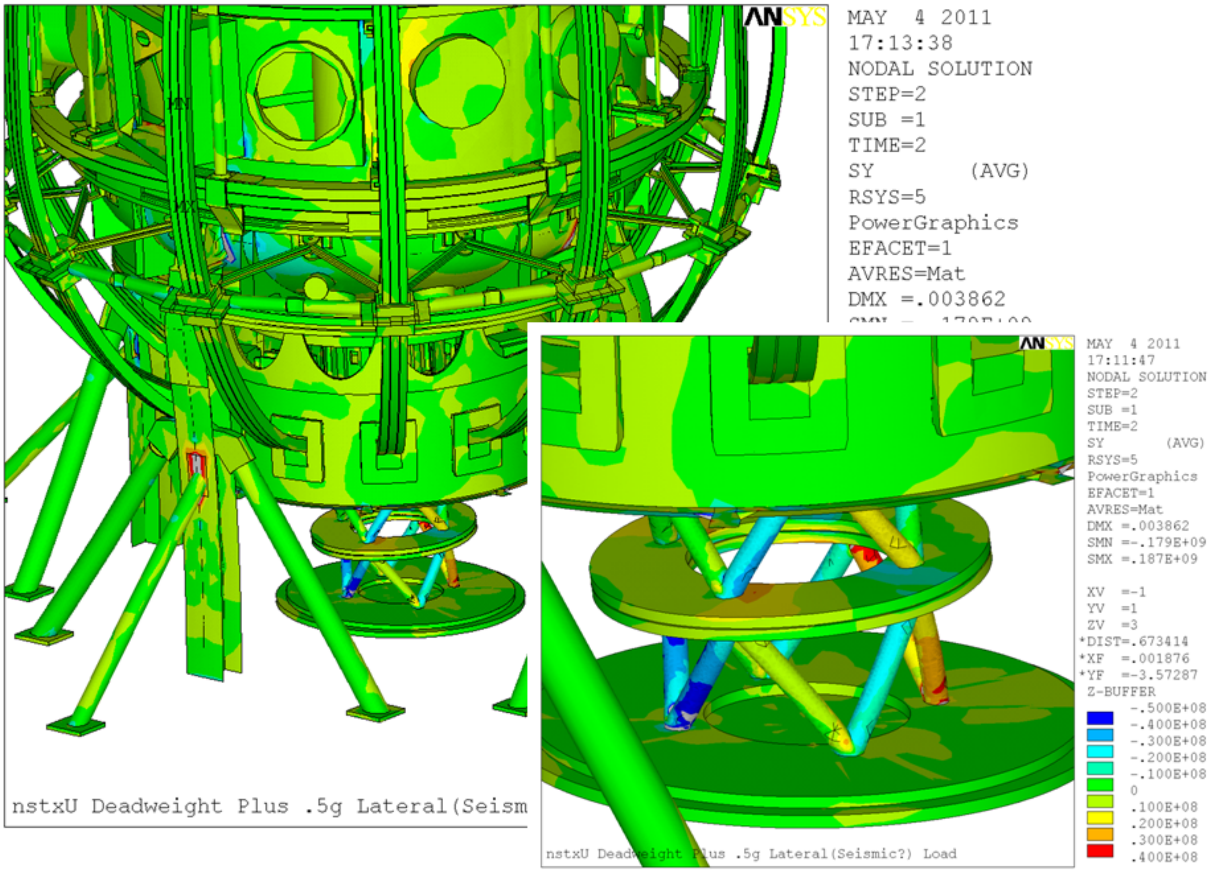


Figure 9.3-1 Seismic Stresses in the "Vee" Pipe Pedestal Design.

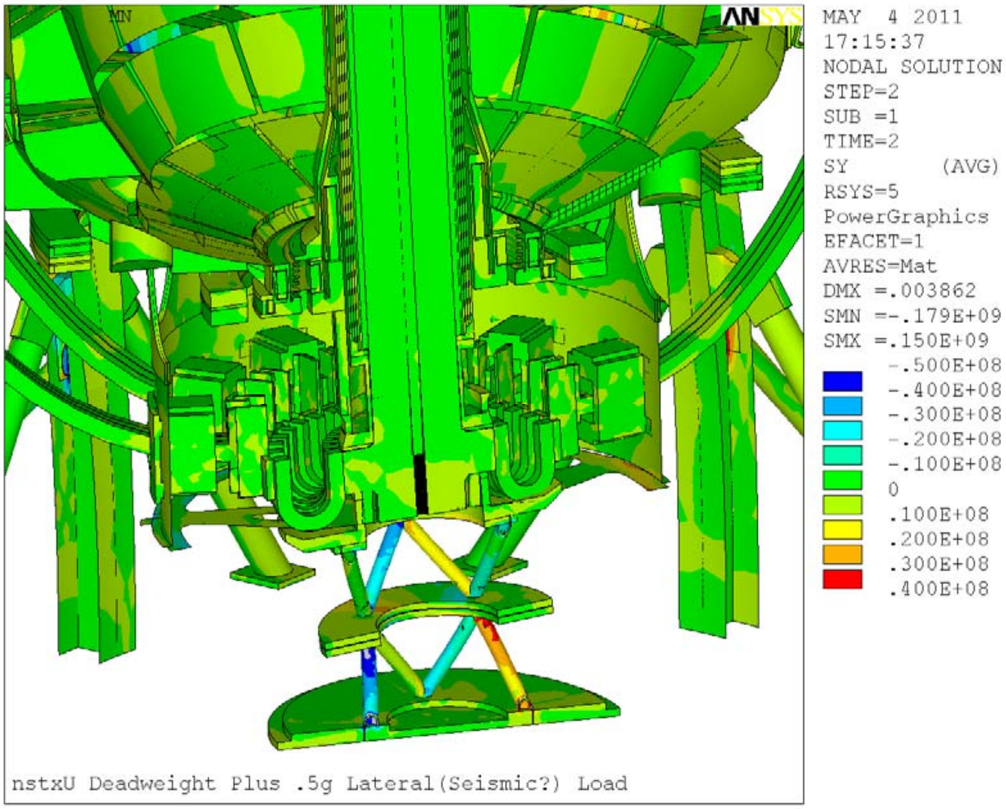


Figure 9.3-2 Section Through the machine with .5g Lateral Accelerations Applied.

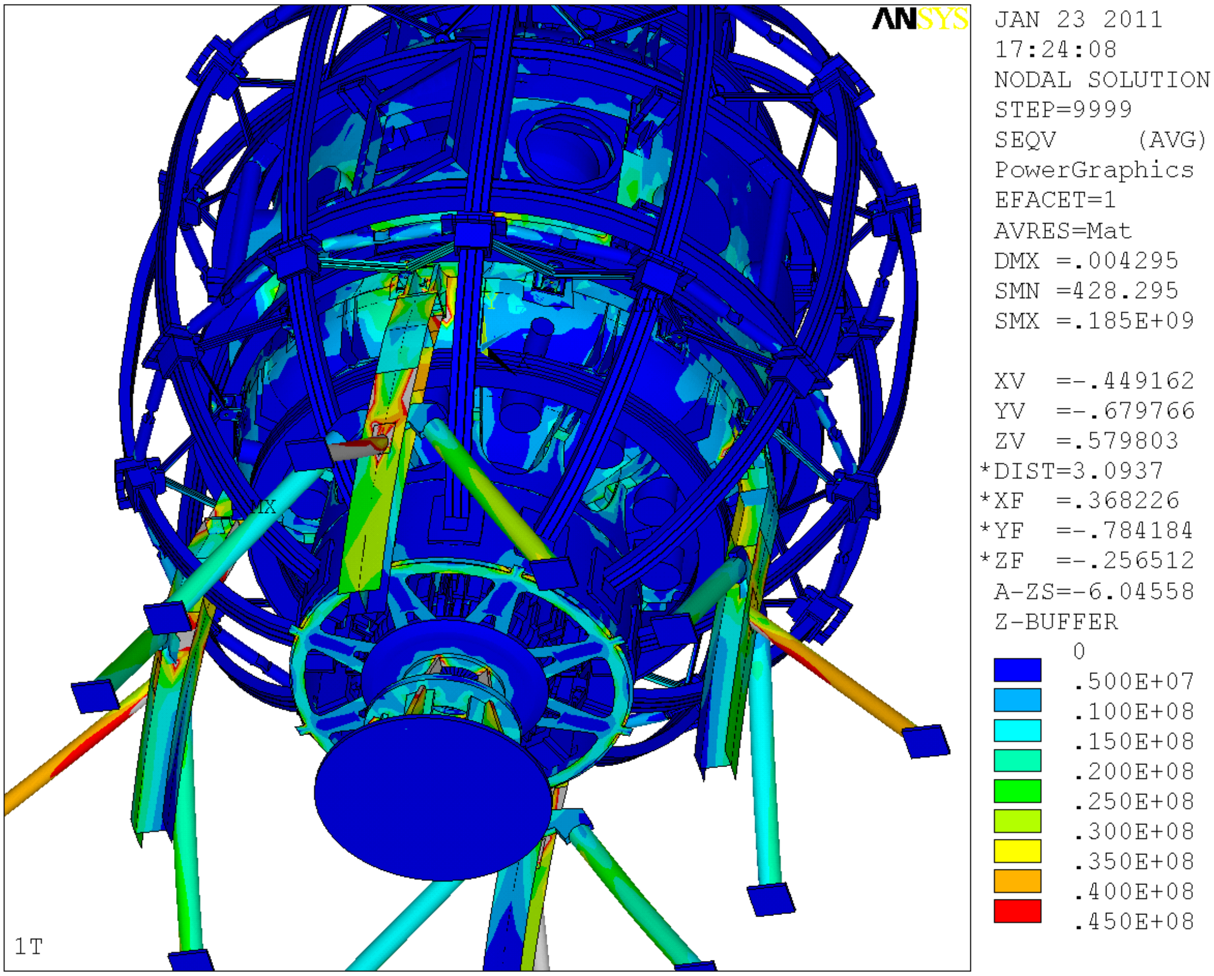


Figure 9.3-3 Plate Gusset Pedestal Seismic Stresses From Reference [6]

The seismic stresses in the pedestal are modest for both pedestal concepts.

9.4 Halo Loads

The stiffness of the pedestal and lower lid partially determine where the halo load goes. In the spoked lid calc it is claimed that the pedestal is stiff enough that it will see the halo from the centerstack casing and that the halo load from the passive plates is carried through the spoked lid[12] and reacted at the pedestal[24]. The halo loading (from Art) on the skirt and skirt to pedestal bolting is addressed in the centerstack casing calc: NSTXU-CALC-133-03-00[13], **.** The halo load is tracked more rigorously in the bellows calculation[15]. Judgmentally, if the (upper) bellows can take the centerstack load, the heavier skirt, pedestal, vessel, spoked lid structures will be able to take the load. A. Brooks'[14] and P. Rogoff [15] trade reaction forces at the bellows. The halo loads are dynamic impulsive loads and are treated in a very conservative manner in this global model calculation as static loads - P. Rogoff and A. Brooks reduced the loads by including P. Rogoff's bellows stiffness in the dynamic analysis. In this global model calculation an earlier estimate by A. Brooks of 50,000 lbs is applied on the upper and lower region of the centerstack. This is also the basis for the loads that A. Zolfaghari uses to qualify the TF crown bolting calculation.

Halo Loads are included in one of the static load cases in the global model run - Figure 9.4-1 shows the earlier pedestal model and the stresses were low, 135 MPa, and are about the same for the pipe truss design.

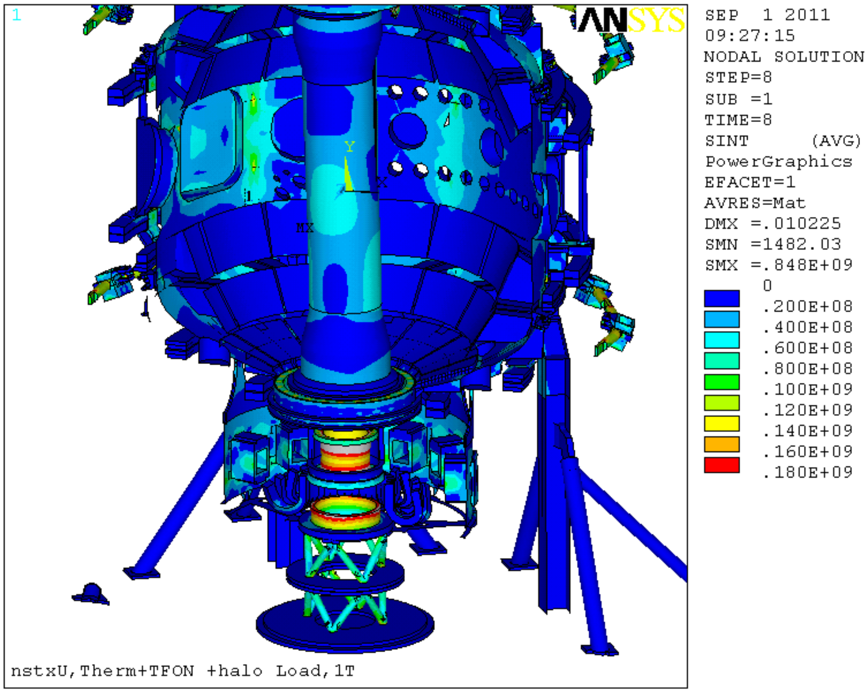


Figure 9.4-1 Global Model Results With 50,000lb assumed Halo Load

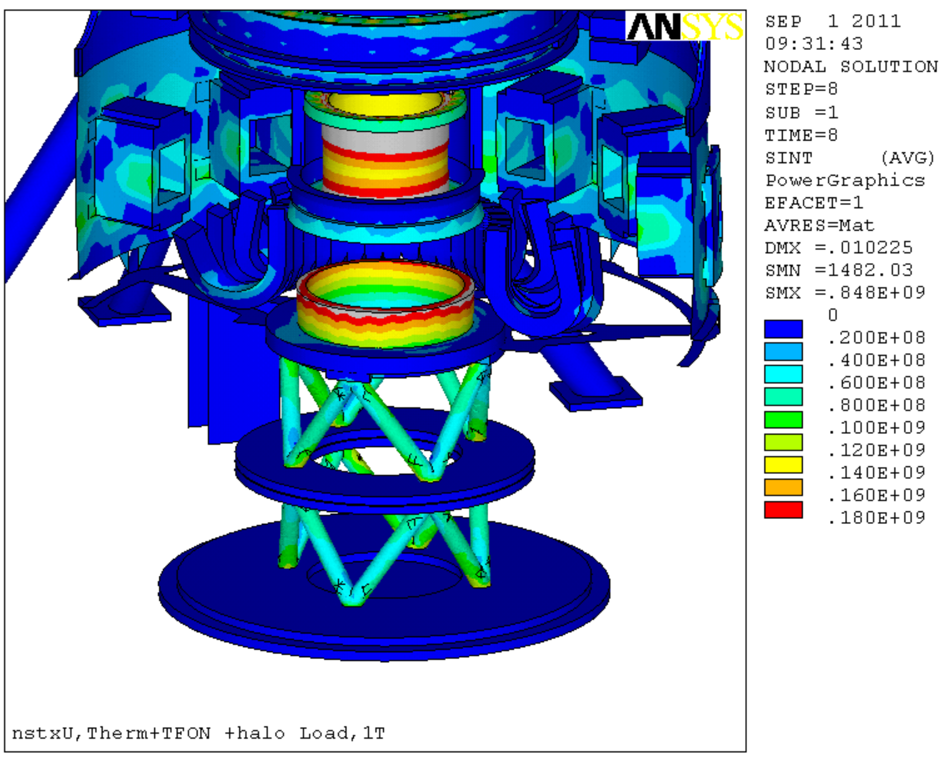


Figure 9.4-2 Pedestal Area Global Model Results With 50,000lb assumed Halo Load

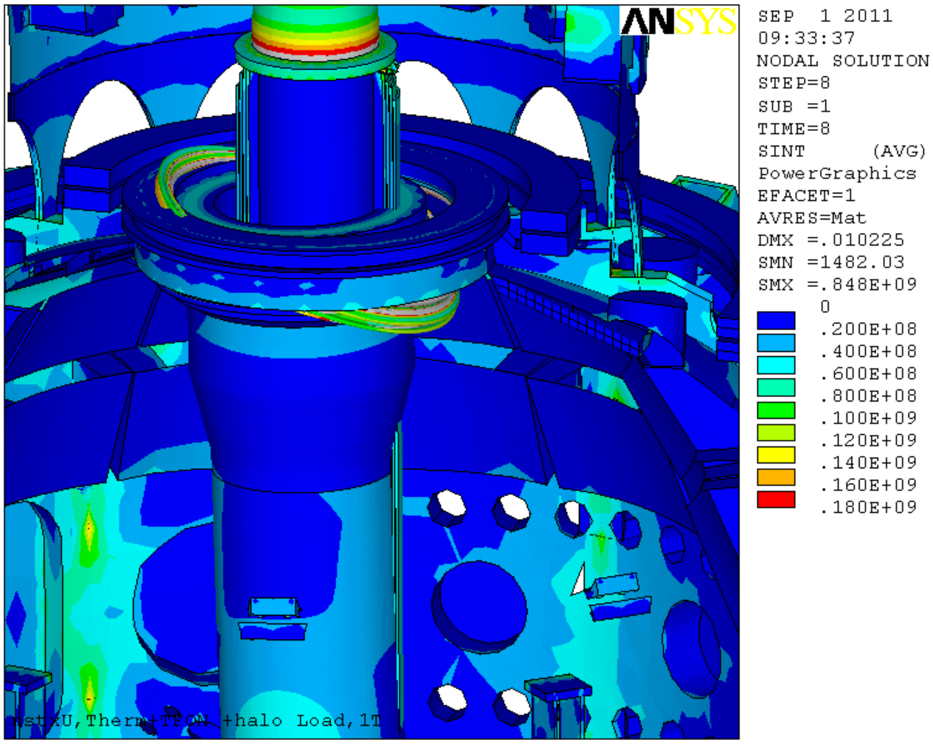


Figure 9.4-3 Global Model Upper Bellows Area Results With 50,000lb assumed Halo Load

Based on the stress levels above, Halo loads have the potential of severely loading the upper bellows. This structural interaction is addressed in the two calculations discussed above, [15] and [14]. With dynamic effects appropriately applied bellows loading is acceptable.

Attachment 1 Ref 11 text

Thu 3/11/2010 8:21 AM

Peter,

Summing up the applied halo forces for the resistive distribution scenario (for the strike at z=+/-0.6m) with PF and TF (1/R) fields I get:

Applied Load Sum on CS

Fx = -30695.6 N, Fy=Fz=0
Mx = 80400.7 N-m, My=Mz=0

I ran these thru a stress pass constraining all the points on the top and bottom flanges and looked at the reaction loads:

Reaction Loads on CS when Upper&Lower Flanges Fully Constrained

	Fx, N	Fy	Fz	Mx, N-m	My	Mz
Up	15347.	32464.	44662.	-40200.9	56846.7	-201.8

Low	15349.	-32463.	-44661.	-40199.6	-56848.9	201.8

The sum of the Up and Low values do add to negative the applied loads as expected. It just highlights the need to look at the reaction moments as well when considering support design loads.

Art