National **S**pherical **T**orus e**X**periment - **U**pgrade

NSTX-U

Structural Analysis of Centerstack Casing Support in the Horizontal Position

NSTXU-CALC-12-15-00

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Jiarong Fang Digitally signed by Jiarong Fang Date: 2018.05.21 11:54:41 -04'00'

Prepared By
Jiarong Fang, Engineering Analyst

Peter H. Titus Digitally signed by Peter H. Titus Date: 2018.05.21 11:34:56 -04'00'

Reviewed By
Peter Titus, Branch Head, Engineering Analysis Division

G Douglas Loesser Digitally signed by G Douglas Loesser Date: 2018.05.22 11:35:31 -04'00'

Approved By – Responsible Engineer
Doug Loesser, Head, Mechanical Engineering

NSTX-U CALCULATION

Record of Changes

Rev.	Date	Description of Changes	Revised by
0	5/8/18	Initial Release	

NSTX-U Calculation Form

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

The centerstack casing needs to be laid down and rested by two stands on its sides during the construction or temporary storage. A horizontal force of 0.5g and full weight load will be applied on only one support leg to consider as the response of an earthquake event. The purpose of this calculation is to provide design guidance and qualification of centerstack casing support for the NSTX-U recovery project.

References:

1. SYSTEM DESIGN DESCRIPTION, Vacuum Vessel and Internal Hardware, NSTX-U-SDD-VVHW-R0, Feb. 27, 2017.
2. Seismic Analysis, NSTXU-CALC-10-02-1 Rev 1, Feb. 9, 2011, PPPL. by P. TITUS.
3. NSTX Structural Design Criteria Document, NSTX_CRIT-0001-02B.pdf, by I. Zatz.
4. Drawing B-DC11036, Centerstack Upgrade, Center Stack Case Support Fixture with Horizontal Support Structure Weldment.
5. Drawing E-DC11144, Centerstack Upgrade, Center Stack Case Support Weldment.

Assumptions:

These are discussed throughout the attached report.

Calculation:

See attached Report.

Conclusion:

The original centerstack casing support have been analyzed and manufactured for centerstack casing storage on the test cell. The extra supporting blocks and reinforcement ribs are introduced to meet the DOE standards and can survive with the earthquake.

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Appendix A. Drawings of Support Stand for Center Stack Case in the Horizontal Position.

4.0 Executive Summary

This report is intended to provide designers the structural analysis of center stack casing support in the horizontal position in order to meet the seismic requirement for the NSTX-U recovery project. A horizontal force of 0.5g and full weight load are applied on only one support leg to consider as the response of an earthquake event. The original support has some local over-stressed intersection areas between the horizontal cross support tube and vertical support tubes and also between the vertical support tubes and the floor plates. The extra side supporting blocks and reinforcement ribs will be added to the structure in order to reduce the peak stress around these joint areas and meet the stress limit for the A36 carbon steel.

5.0 Introduction

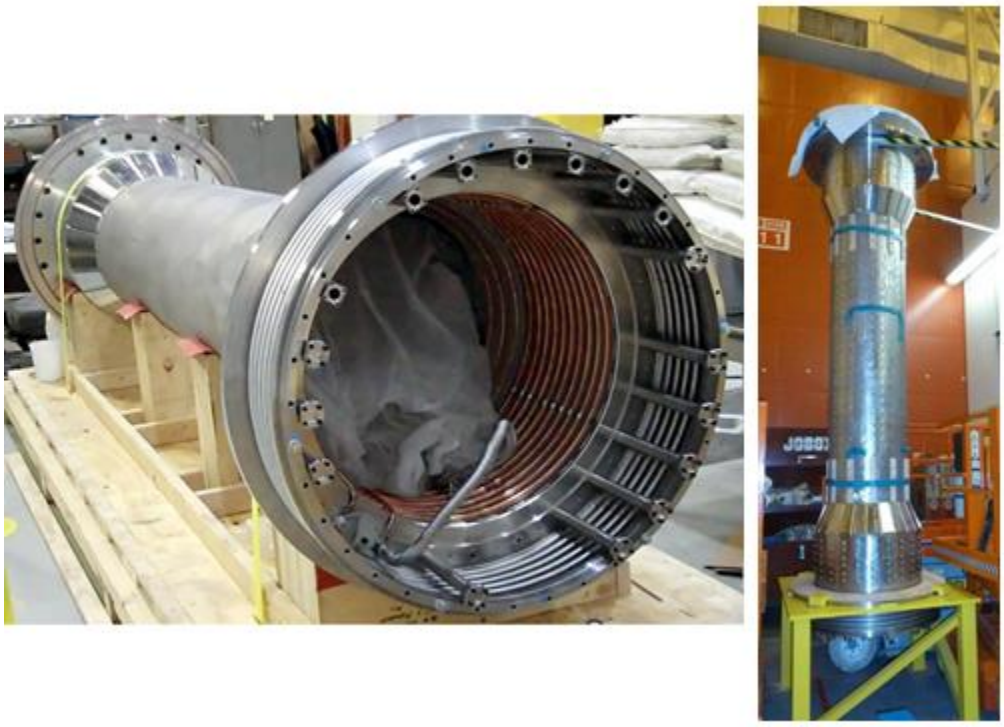


Fig. 5-1 The casing laid down on its side during construction (left) and resting on its stand (right).

The centerstack casing plays a very important role in the NSTX-U machine. It encases the inner leg conductors of both TF and OH coils, and supports the cases of inner PF coils [1]. As shown in Fig. 5-1, the centerstack casing can be resting vertically on its wooden support, but it also needs to be laid down and rested horizontally by the stands during the construction or temporary storage.

5.1 Original Design

Figure 5-2 shows a design with the two metal stands to support the centerstack casing in order to replace the wooden support as shown in Figure 5-1. The original design is to use two H-type stands to support the centerstack casing flanges at two sides as shown in Figure 5-3. There is no

connection between two H-type stands, and the base plate was grouted level and bolted to the test cell concrete floor.

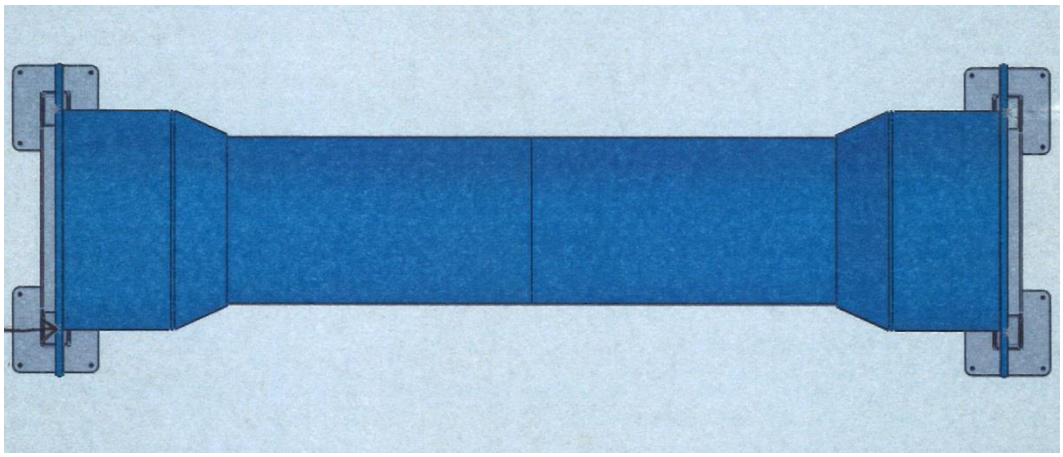


Fig. 5-2 The casing rested by two stands at its sides during construction

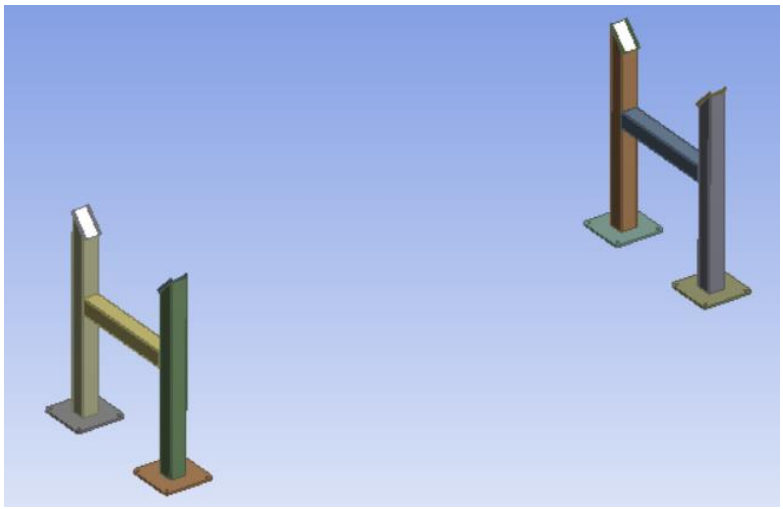


Fig. 5-3 The original design with two metal stands to support centerstack casing at its two flange sides

5.2 Reinforcement Supports

Due to the high requirement of seismic inputs with the horizontal force of 0.5g and full weight load on one support leg [2], the original support has some local over-stressed intersection areas. Figure 5-4 shows one stand with the reinforcement supports, including added new side supporting tubes along the central axis direction of resting centerstack casing to reduce the high stress caused by the horizontal seismic force 0.5g from central axis direction. The X-cross support underneath the H-type support and two ribs adding to the intersection between the vertical support tubes and horizontal cross tube to account for the horizontal seismic force from the lateral side. Since the two stands are symmetric, we just need to analyze one stand with all the required seismic loads at one leg. In Appendix A, drawings of original design and new design with reinforcement blocks for Centerstack Casing in the Horizontal Position (drawings B-DC11036 and E-DC11144) shows the structure differences and locations in details.

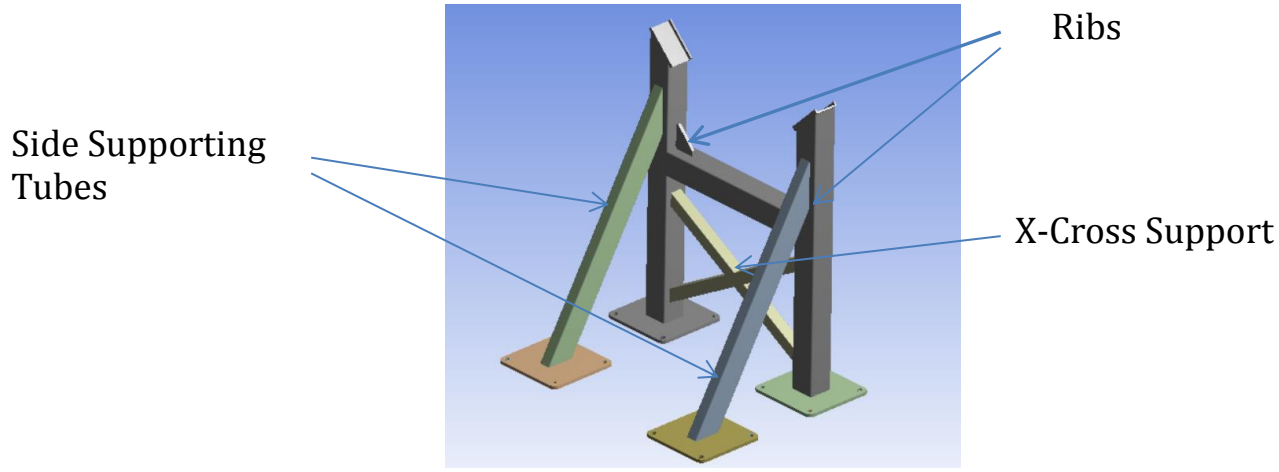


Fig. 5-4 The new design of one metal stand with the reinforcement supports

6.0 Design Input

6.1 Criteria

The NSTX Structural Design Criteria Document [3] defines the stress criteria for different structural materials. The centerstack casing support is designed for only temporary storage in the horizontal position during the construction, so the seismic loads could be simplified into a 0.5g acceleration force in the horizontal direction and 0.086g acceleration force in the vertical direction for the static analysis based on the global reaction summations of NSTX seismic analysis [2].

According to the design criteria [3], for any metallic support structure, the design Tresca stress limit shall be based on the lesser of 2/3 of minimum yield stress or 1/2 of minimum tensile strength; for preload, the stress limits for bolting materials shall not exceed 3/4 of bolt minimum yield stress.

6.2 Assumptions

The horizontal seismic force could be loaded from the lateral side or axial direction along the central line of centerstack casing. Considering the worst case that the full weight of centerstack casing is applied solely on one leg due to the earthquake, the structure analysis of centerstack casing should include the following two cases:

1. Static structural model with full casing weight plus horizontal seismic force from the lateral side on one leg;
2. Static structural model with full casing weight plus horizontal seismic force along central axis direction on one leg.

6.3 Materials and Allowable

Mechanical Properties

The common carbon steel A36 or equivalent is used for the basic support construction material and the strong Inconel alloy 625 bolts with preloads are applied to tighten the base plates and concrete floor together. Their mechanical properties are provided in Table 6-1.

Table 6-1 Mechanical properties of A36 steel and Inconel alloy 625 at 20^0 C

Item	**A36**	**Inconel 625**
Elastic modulus (GPa)	200	207
Poisson ratio	0.26	0.31
Yield stress (MPa)	250	460
Ultimate tensile stress (MPa)	400	880

Stress Allowable

Based on the material property data from Table 6-1, the design Tresca stress of centerstack casing support should not exceed the following stress limits as listed in Table 6-2.

Table 6-2 Static stress allowable for A36 steel and Inconel alloy 625 at 20^0 C.

Item	**A36**	**Inconel 625**
2/3 yield stress (MPa)	170	
1/2 ultimate tensile stress (MPa)	200	
3/4 of bolt yield stress (MPa)		345
Stress limit (MPa)	170	345

7.0 Modelling

7.1 One Stand Mode with Lateral Seismic Force

Figure 7-1 shows the original design of one metal stand with lateral 0.5g (9,345N) and vertical 0.086g (1,607N) Seismic Forces and full casing weight (18,690N) on the support plate of one leg. The model includes a plate of concrete floor in order to simulate the bolt stress with preloads. As shown in Fig. 7-1, there are totally 2 base plates with 8 bolts preloaded with 2,500 lbf (11,200N) each.

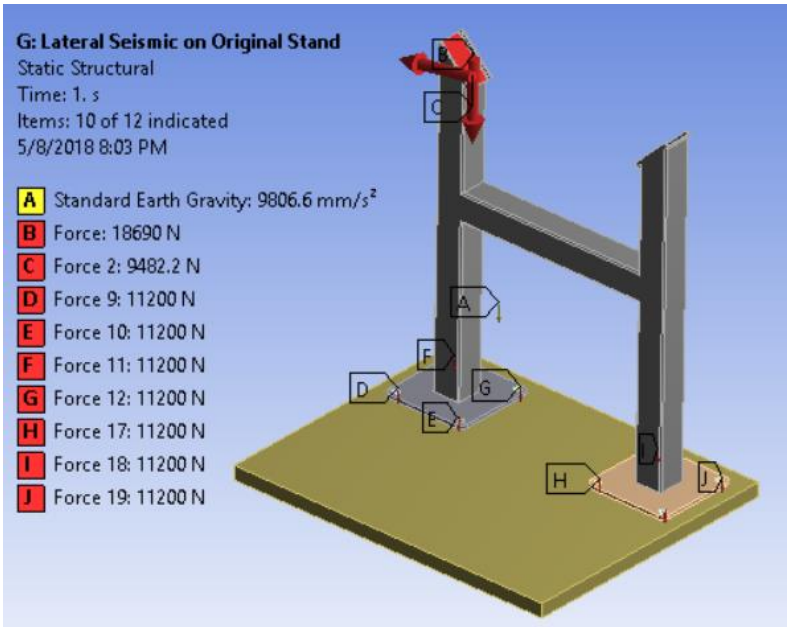


Fig. 7-1 The original design of one metal stand with lateral 0.5g Seismic Force on one leg

7.2 One Stand Mode with Axial Seismic Force

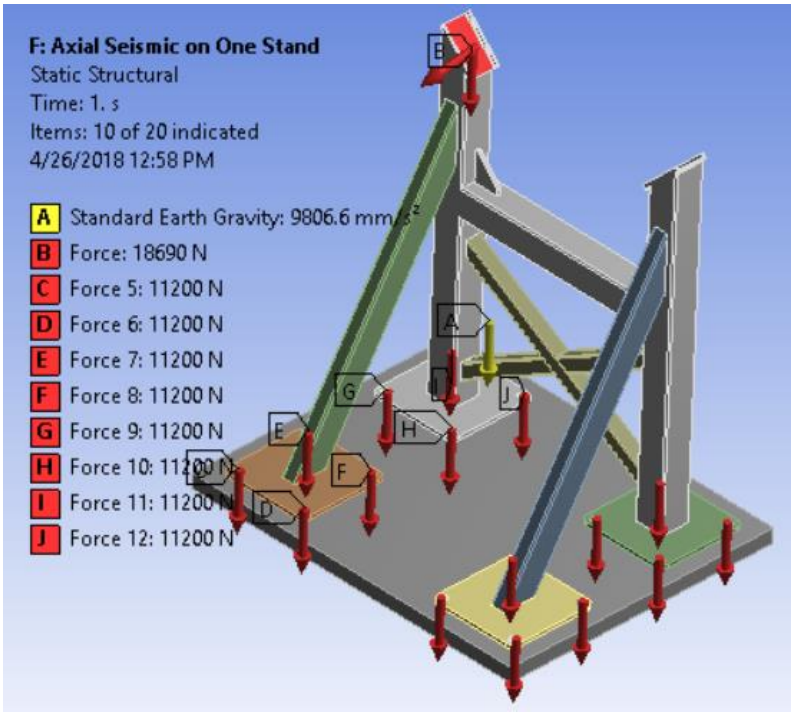


Fig. 7-2 The new design of one metal stand with axial 0.5g seismic force on one leg

Another type of model with the axial 0.5g (9,345N) seismic force on one leg is shown in Figure 7-2. In comparison with the original design, this new design with extra side supporting blocks needs 2 more base plates, so 4 base plates will have 16 bolts with the same preload as before.

8.0 Evaluation of Added Supports for CS Casing

8.1 Original Stand

We need to do the structural stress of original centerstack casing support first to check local over-stress issue around the intersection areas due to the high requirement of seismic inputs with the horizontal force of 0.5g and full weight load on one support leg. Seen from Figure 8-1, the peak deformation happened with the support plate along the lateral horizontal direction, and the peak Tresca tress is located at the joint corner between the cross support and column support leg with the full weight load and seismic force.

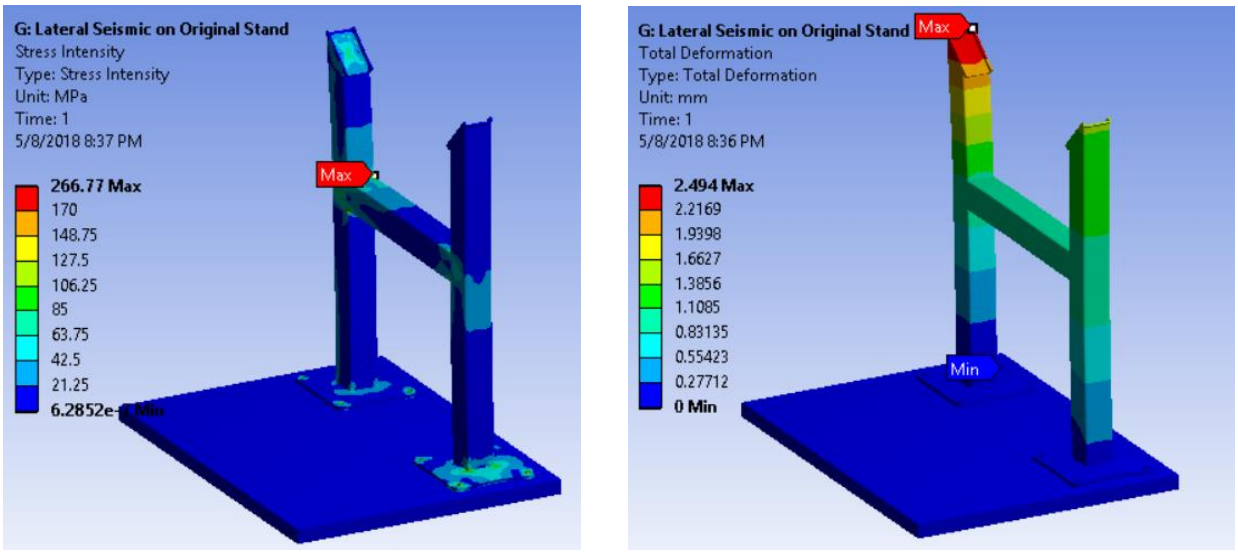


Figure 8-1 Tresca tress and deformation of original centerstack casing support with lateral 0.5g Seismic Force

8.2 Added Supports

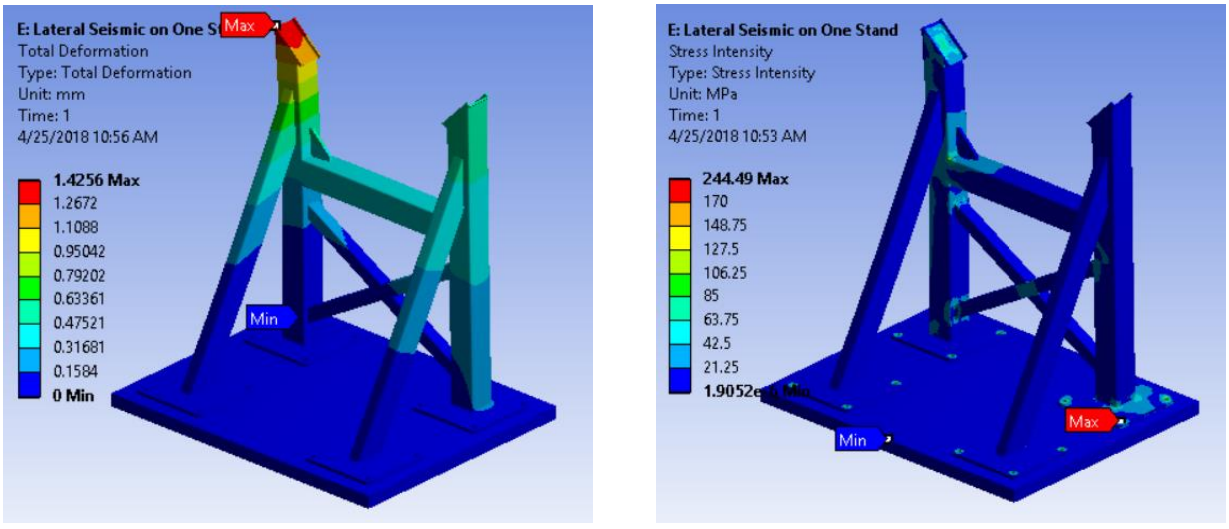


Figure 8-2 Deformation and Tresca tress of new centerstack casing support with lateral 0.5g Seismic Force

The extra support blocks and reinforcement ribs are added to the structure in order to reduce the peak stress and meet the stress limit for the A36 carbon steel. Figure 8-2 shows the deformation and Tresca tress of new centerstack casing support with the same lateral 0.5g Seismic Force as the original design case. Compared with the original design, the deformation of new design is almost reduced by half, and the peak stress will be transferred to the bolting area, but the stress of whole support structure is much less than the stress limit of A36 carbon steel.

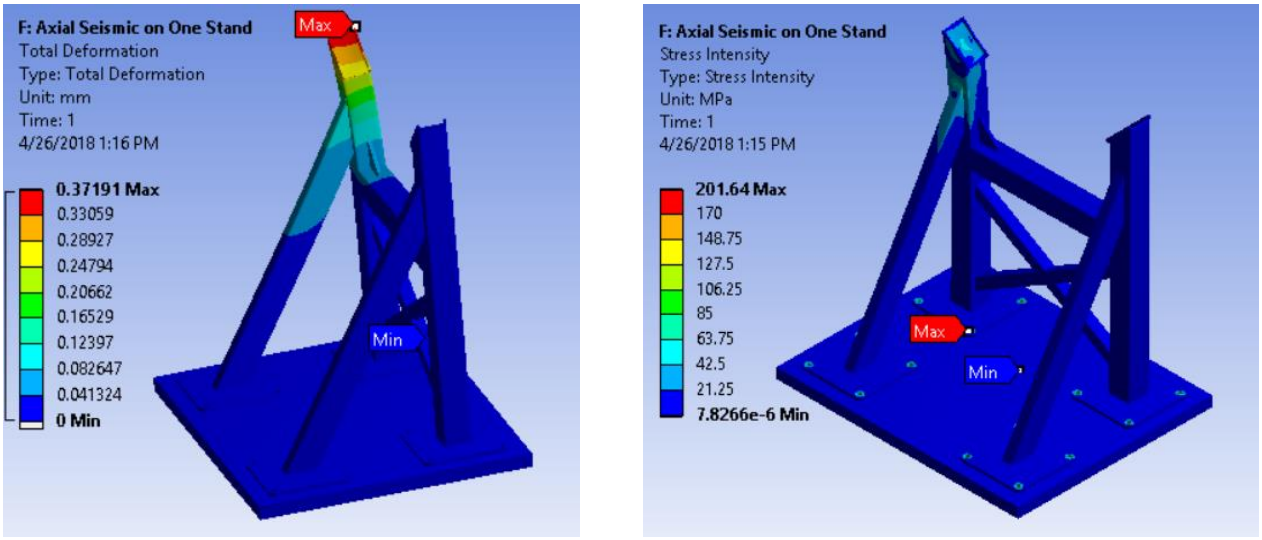
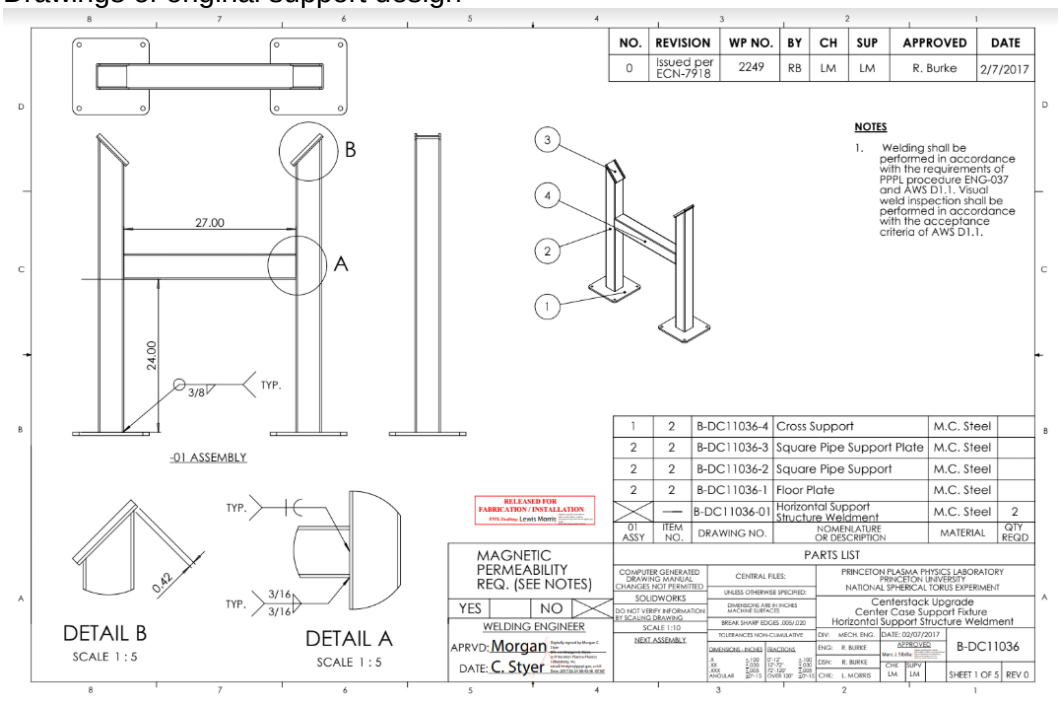


Figure 8-3 Deformation and Tresca tress of new centerstack casing support with axial 0.5g Seismic Force on one leg

Figure 8-3 shows the deformation and Tresca tress of new centerstack casing support with the axial 0.5g Seismic Force. Compared with the lateral seismic force case, the deformation of axial seismic case is only about 1/4 of lateral one due to the strong side support blocks along the central axis direction, and also the peak stress is dropped down by 20%. Seen from the Figure 8-3, the problematic stress is with the bolt only, so the Inconel alloy 625 bolting material is selected to meet the stress limit for the bolt areas.

Appendix A. Drawings of Support Stand for Center Stack Case in the Horizontal Position

Drawings of original support design



Drawings of new support design