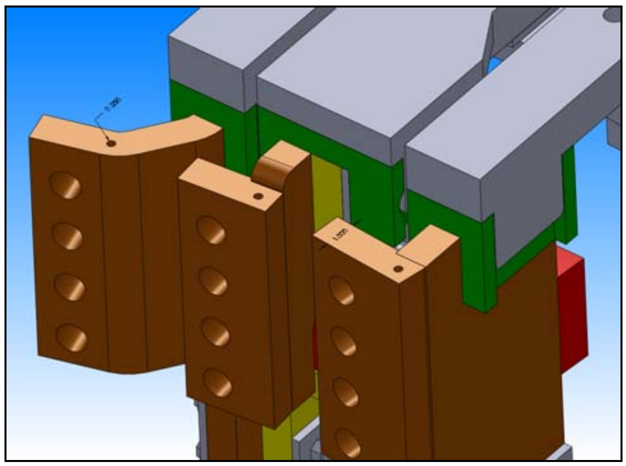
NSTX Upgrade

TF Lead Flag Extensions & Connectors

NSTXU-CALC-132-15-00

Rev. 0

December 2014



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I. Zatz,

PPPL Calculation Form

Calculation # **NSTX-CALC-132-15-00** Revision # **0** ____ WP #, if any (ENG-032) **1672**

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

The purpose of this calculation is to qualify the NSTX-U TF lead flag extensions and outer TF connectors as they have been manufactured and installed. These were originally analyzed as part of a larger model documented in calculation NSTX-CALC-132-06-00. Since that time, the design of the parts has been iterated such that the area of interest has changed. The original analysis was resurrected and results were extracted for the area of interest, specifically, the shapes of the plates that form the connectors which have been altered and the joints joining the plates are to be EB welded rather than formed from a solid.

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

(See the Body of the Calculation)

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

Per Reference [2]

Calculation (Calculation is either documented here or attached)

Analysis results included as part of this document.

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

The stresses in the electron beam welded joints in connectors 'A', 'B' and 'C' are estimated for the current design based on the analysis by Tom Willard and sub models by A. Brooks. The "A" and "B" connectors are found to be within allowables. The 'C' connector joint had a partial weld specified which left a large effective crack at the back side of the weld. This was machined away to leave a smooth surface, but left a minimum section that does not satisfy the full life requirement for the part. The life is estimated as 2000 full power shots. This will be acceptable for first year operations, but the "C" connector will need to be replaced with a part with a full section and full section welds. This recommendation is based on a conservative estimate of the R value. A Brooks has pointed out that a better estimate of the R value could lead to an extended life for the type "C" connector. Analysis is based on use of T. Willard's global model of the flex and connector assembly, plus sub models of the connectors. If another analysis of the flag connectors is undertaken, a new global model, with the proper geometry updates is required. While replacement of connector type "C" is recommended. The existing connector might be qualified by a fracture mechanics assessment. Miners Rule calculations based on the first year TF shot spectrum show a usage factor well below 1.0.

Cognizant Engineer's printed name, signature, and date

Lawrence E. Dudek

Digitally signed by Lawrence E. Dudek
Date: 2014.12.05 16:43:27 -05'00'

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

Checker's printed name, signature, and date

Irving J. Zatz

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Date: 2014.12.02 13:53:38 -05'00'

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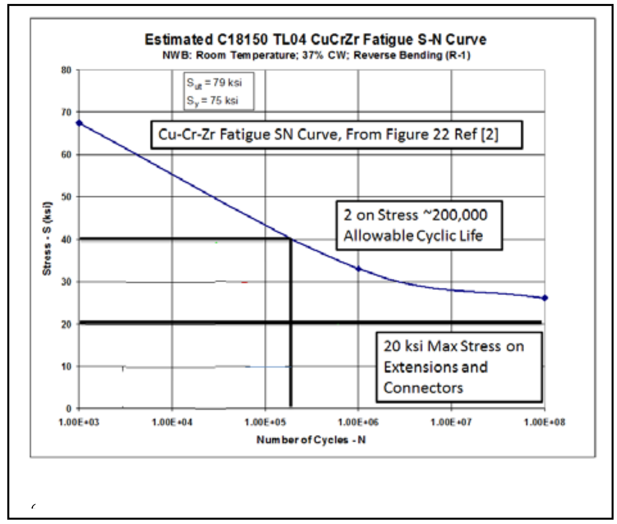
3.0 Revision Status Table

Rev 0	Initial Issue

4.0 Executive Summary



The outer TF connector design was updated in October 2013. A radial position error or discrepancy between as-builts and the CAD model caused a redesign of the connectors to gain back a 1 inch interference. The original design employed a solid plate and it was difficult to find a solid piece of CuCrZr from which to cut the dog-legged geometry. An e-beam weld jointed plate design was chosen. This was determined to be the optimal way to preserve the strength and integrity of the CuCrZr material in the joint and would be superior to brazing or conventionally welding the joint. The design changes are documented in drawings E-DC1456 thru E-DC1460 Rev. 2 (Appendix B), which apply to connector type 'A' thru 'E', respectively. The consistent ECN is #7134.

The stresses in the electron beam welded joints in connectors 'A', 'B' and 'C' are estimated for the current design based on Tom Willard's analysis and sub models by A Brooks. Two of the three joints are found to be within allowables.The 'C' connector joint, with a nominal full thickness was the most highly stressed at approximately 20 ksi. However the "C" joint was fabricated with a partial penetration e-beam weld that left a large effective crack on the backside of the weld.

Tom Willard originally modeled the entire TF joint assembly in NSTX-CALC-132-06-01 [2], which was completed in 2011. At that time, the focus of the analysis was on the TF strap that connected to the inner leg. Later calculations included the hardware connection to the outer leg. The TF strap assembly fingers were reviewed in NSTX-CALC-132-14-00 [3]. That report was based on the Tom Willard peer review from February 2013, and included the analysis results of the TF outer leg flag-to-lead bolted joint design. Also in February 2013, there was a peer review of the design of TF lead extensions and support brackets (Appendix A). Willard updated his model to include the proposed design of these components as they existed at that time. However, analytical results for the lead extensions and support brackets were never documented. This report reviews the results recently extracted from the Willard models pertaining to the lead flag extensions and connectors. In addition, it was observed that the design has been iterated since the model was last updated.

The outer TF connector design was updated in October 2013 to reflect the decision to electron beam weld the joints. This was determined to be the optimal way to preserve the strength and integrity of the CuCrZr material in the joint and would be superior to brazing or conventionally welding the joint.

Other components of the connection to the outer legs of the TF are in addressed in other calculations. The fingers that support the extensions are included in "NSTX Upgrade TF Strap Assembly Fingers" NSTXU-CALC-132-14-00 ref [3].

5.0 Input to Digital Coil Protection System

The lead flag extensions and connectors share the same loads as the flex connector. A DCPS algorithm for the flex, based on poloidal and toroidal field magnitudes is planned, and this will also limit the loads on the leads and connectors to the levels computed in this calculation. The Type "C" connector is fatigue limited and a cycle counting/Minors Rule procedure that is described in section 8.3.3 will be needed, separate from the DCPS.

6.0 Design Input

6.1 Criteria

The Criteria for this calculation are contained in the NSTX-U Structural Design Criteria, Ref [6]

6.2 References

[1] Drawings E-DC1456 thru E-DC1460 (all Rev. 2) [Appendix B]
[2] NSTX-CALC-132-06-01 TF Flex Joint & TF Bundle Stub, T. Willard.
[3] NSTX-CALC-132-14-00 TF Strap Assembly Fingers, L. Dudek. December 11, 2013
[4] email from Larry Dudek to Erik Perry Oct 10 2014

Erik,

All of the lead extensions will require some cleanup. The worst ones are the E-DC1458's. I have a separate sketch attached showing what is needed there. they will need to be cut in two places as shown on the sketch. The rest (Parts E-DC1456,57,59 & 1460) just need to have the 1/8" tab ground (or milled) off and make the machined surface smooth. I have attached the sketches and the original drawings for reference. Lew has the sketches to incorporate them into a new revision to formally document the work.

Let me know when you are ready to begin, I would like to see the first of each type to inspect. Thanks,

Larry

[5] email from Stefan Gerhardt, Oct 2 2014:

Stefan Gerhardt <sgerhard@pppl.gov> Oct 2
to James, Steve, Larry, Arthur, me, Masayuki, Jonathan

Guys,

These below in blue are some assumptions about the TF usage in the first year. My bosses are happy (enough) with this.
I would think that if 2000 pulses at 1.0 T are qualified, then 2000 pulses at less than 1.0 T are OK?
But I do wonder what assumptions were made on the background magnetic field that gives the JxB force. For instance, a VDE and associated current response could lead to higher background fields? So I wonder if we need another DCPS algorithm?
Let me know if you need more/different.

•16 run weeks, 5 days/week, 8 hours/day, 3 shots/hour = ~2000 shots (1920 in reality)

•We stated in the FWPs that we would go at high as 0.8 T, at least on occasion
•We will commission operations at 0.55 tesla.
•Operation beneath 0.45 T will be very limited.
•CHI and RF will want the highest TF that they are allowed to use.
•Shot spectrum to assume:
◦ 5% of shots at 0.45 T = 100 shots
◦30% of shots at 0.55 T = 600 shots
◦25% of shots at 0.60 T = 500 shots
◦25% of shots at 0.70 T = 500 shots
◦15% of shots at 0.80 T = 300 shots

[6] NSTX Structural Design Criteria Document, NSTX_DesCrit_IZ_080103.doc, Feb 2010 I. Zatz

[7] NSTX-U Design Point Spreadsheet http://w3.pppl.gov/~neumeyer/NSTX_CSU/Design_Point.html, C. Neumeyer

6.3 Photos and Drawing Excerpts

Design drawings are included in Appendix B. The sketches below provide the details for the weld clean-up.

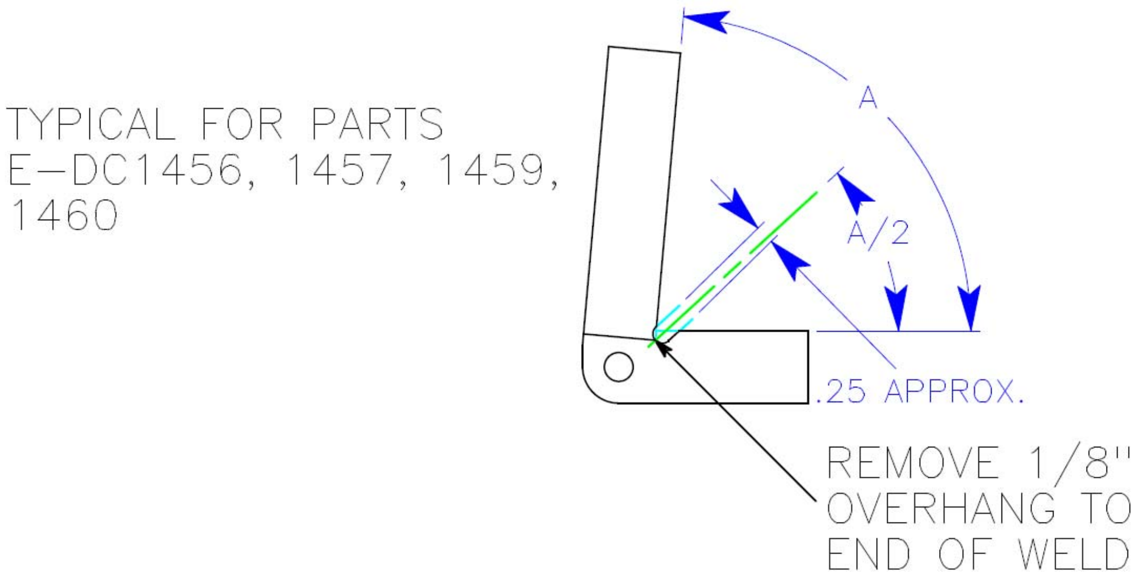


Figure 6.3.-1 Weld Clean-Up for types "A" and "B", Ref [4]

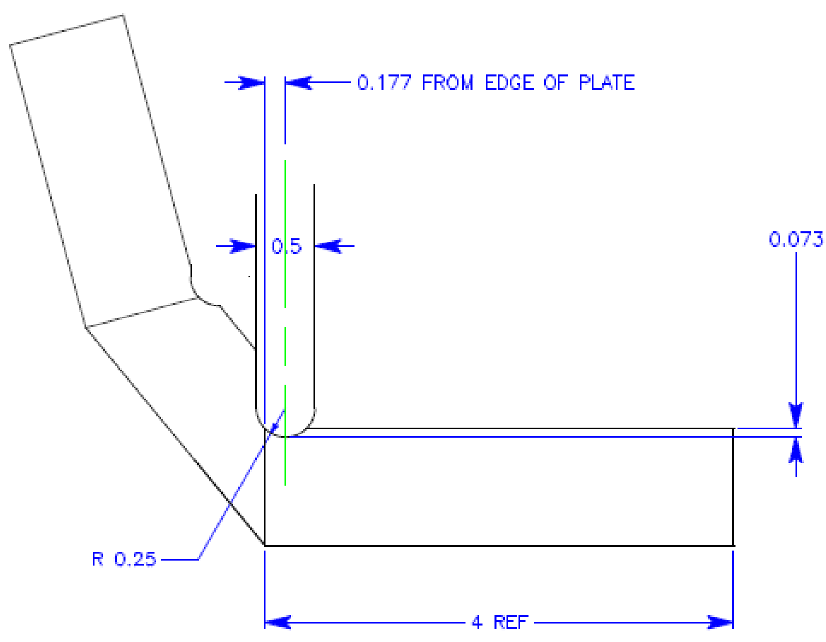


Figure 6.3.-2 Weld Clean-Up for types "C", Ref [4]

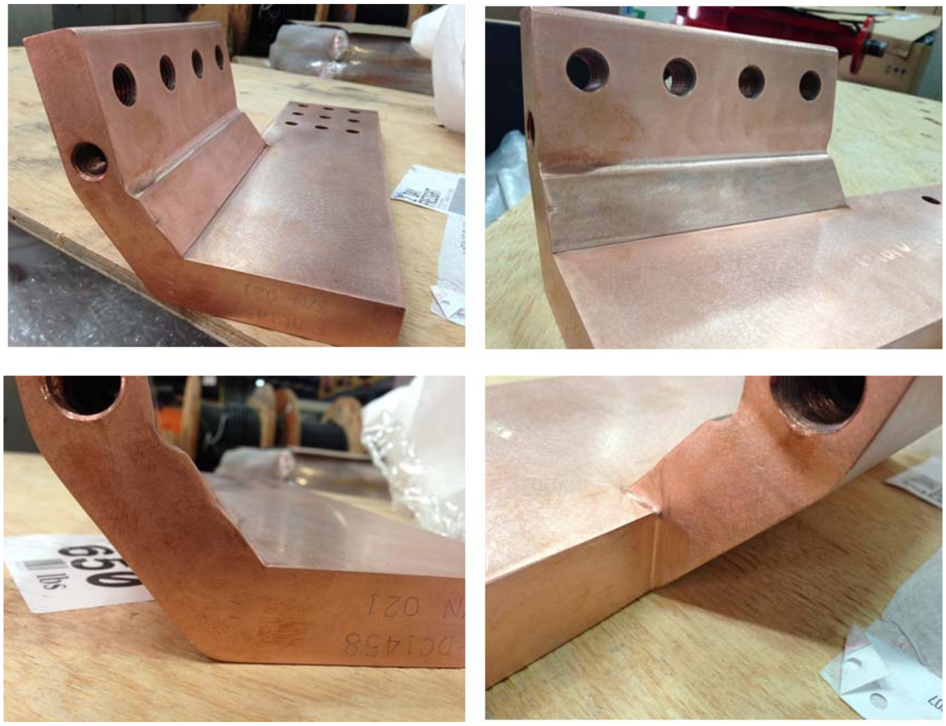


Figure 6.3.-3 Type “C” Before Weld Clean-Up

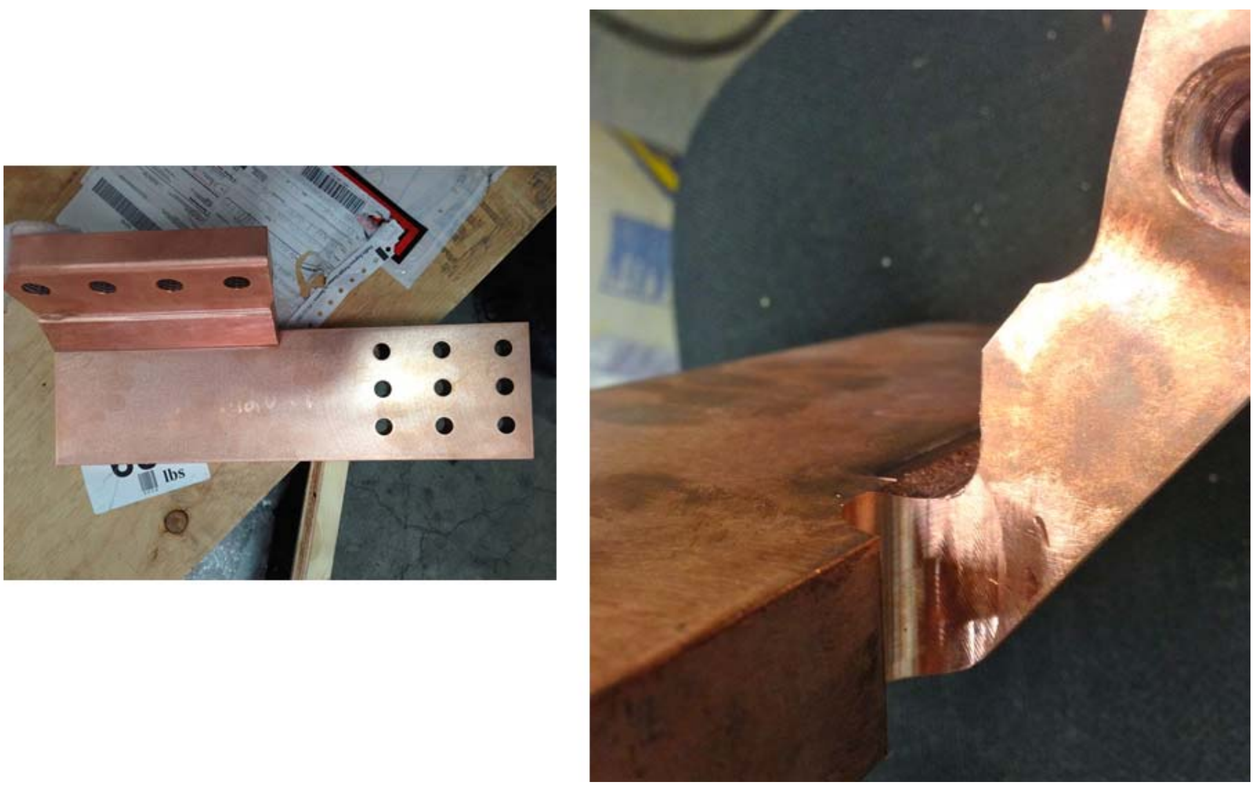


Figure 6.3.-4 Type “C” After Weld Clean-Up

6.4 Materials and Allowables

The outer TF connector was specified to be CuCrZr by T. Willard in ref 1. The design was updated in October 2013 to reflect the decision to electron beam weld the joints. This was determined to be the optimal way to preserve the strength and integrity of the CuCrZr material in the joint and would be superior to brazing or conventionally welding the joint.

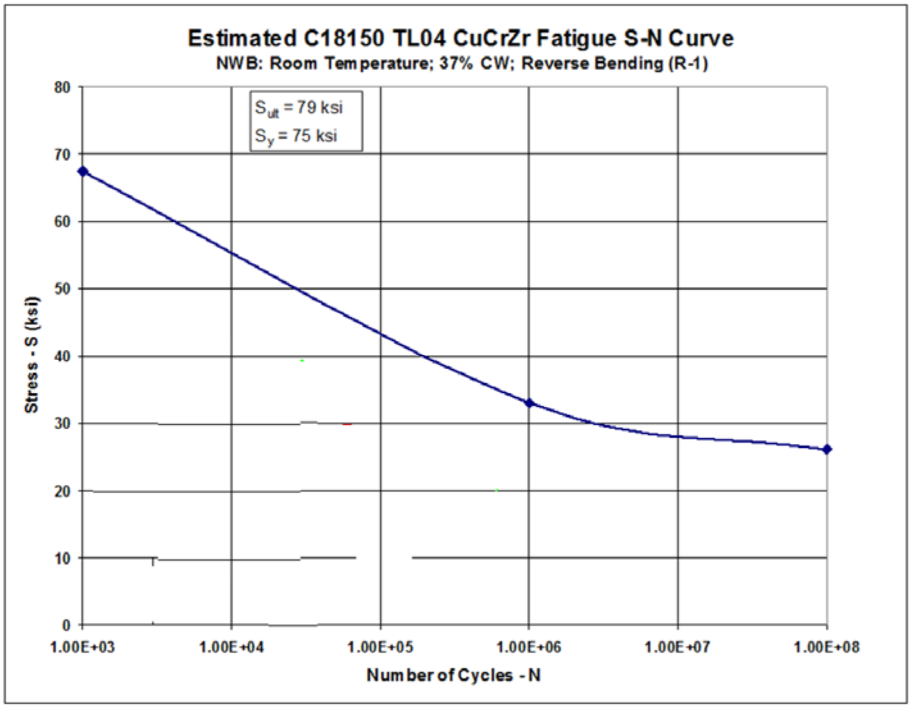


Figure 6.4-1 CuCrZr SN Data

The mill Certs for the CuCrZr used for the extensions are included in Appendix "D". A 52 ksi yield and 65.5 ksi ultimate are reported.

CuCrZr specimens

	RHb	UTS (ksi)	YS (ksi)	% Elongation	% Reduction of Area	Room Temp Charpy Set (ft-lb)	% Improvement	Grain Size	Stud Pullout (lbf)	Comment
"A" Stress Relieved	64-68	57.0	44.9	19	41	46	21%	.100mm	42,087	Stud Broke in Threads
"B" TL04 as Received from Martinez		-	-	-	-	38	--	.100mm	43,430	Stud Broke in Threads
"C" Solution Annealed / Aged		59.5	43.7	26	53	60	58%	.120mm	37,266	Threads Stripped in Coil

Investigation on the microstructure and mechanical properties of CuCrZr after manufacturing thermal cycle for plasma facing component

Jeong-Yong Park[a,*], Yang-Il Jung[a], Byung-Kwon Choi[a], Jung-Suk Lee[a], Yong Hwan Jeong[a], Bong Guen Hong[b]

49 ft-lbs*1/1.3558=36 Joules
.25in^2 = .403226 cm^2

49 ft-lbs on a .25 in square specimen is 89.28 J/cm^2

38 ft lbs is 69 J/cm^2

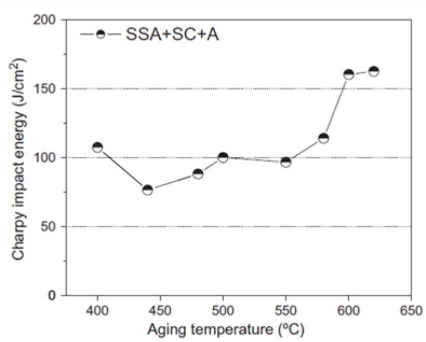


Fig. 4. Variation of Charpy impact energy of CuCrZr with aging temperature.

Figure 6.4-2 CuCrZr Charpy Impact Data

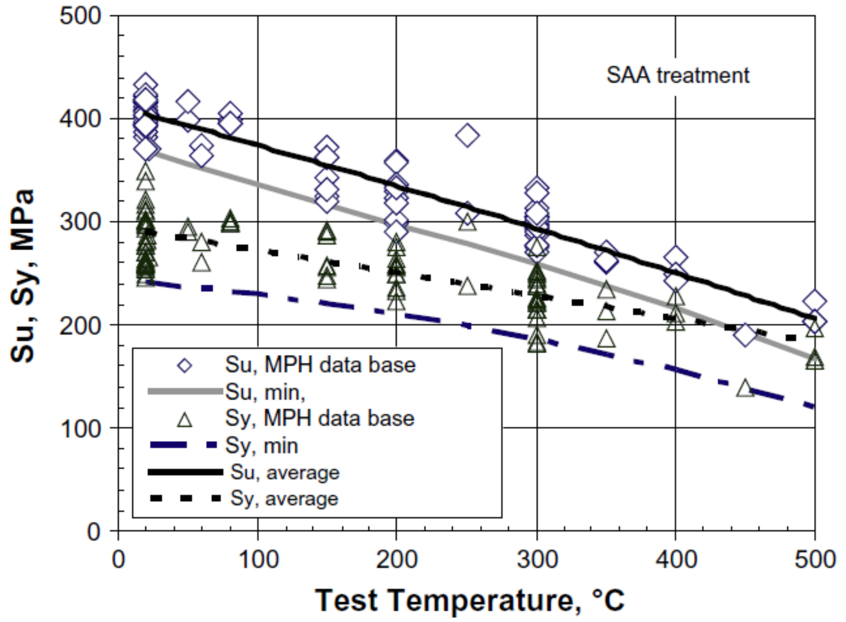


Fig. 2. Ultimate tensile strength (S_u) and yield strength (S_y) of CuCrZr alloy in SAA condition and minimum tensile strengths. Data points are from the ITER MPH database.

Figure 6.4-3 CuCrZr Physicals S_{ult} and S_{yield}

7.0 Models

Tom Willard's model includes connector types 'A', 'B' and 'C' as they were designed in 2011. In examining the most up-to-date Willard model (Figures 7-1 & 7-2), it is evident that the focus of the analysis, as documented in Reference 2, was on the flex straps and bolted electrical joints, and not the lead extensions and connectors. While the entire TF bundle/flex joint/extension assembly is included in the finite element model, certain portions of the model are more finely detailed than others. Since the lead extensions were not the focus of the analysis at that time, they were rendered rather coarsely. Plus the design of the joints, connector 'A', in particular, has changed. Nevertheless, stresses can be extracted from the results of these analyses and provide valuable insight into the adequacy of the most up-to-date design of the lead extension connectors.

All of the analysis models, results and databases were saved and stored prior Willard's departure. In response to the recently updated design, coupled with the fact that the stresses in the lead extensions and connectors were never extracted, these models were re-loaded by A. Brooks and the results were examined for the first time.

Detailed examination of the model and analysis confirms that it represents scenario #82 with only electromechanical and thermal loading. There are no plasma effects. Refer to Appendix C which contains email exchanges detailing the loading checks performed.

This analysis is based on use of T. Willard's global model of the flex and connector assembly. In order to study the local stress concentrations in the partial weld and corner stress concentrations, sub models of the connectors were used. The differences between the final design and the original Tom Willard qualified design are sufficient that if another analysis of the flag connectors is undertaken, a new global model, with the proper geometry updates, is required. This would allow the proper superposition of thermal and Lorentz loads and would allow a better assessment of the loading R value which is an important contributor to the fatigue evaluation.

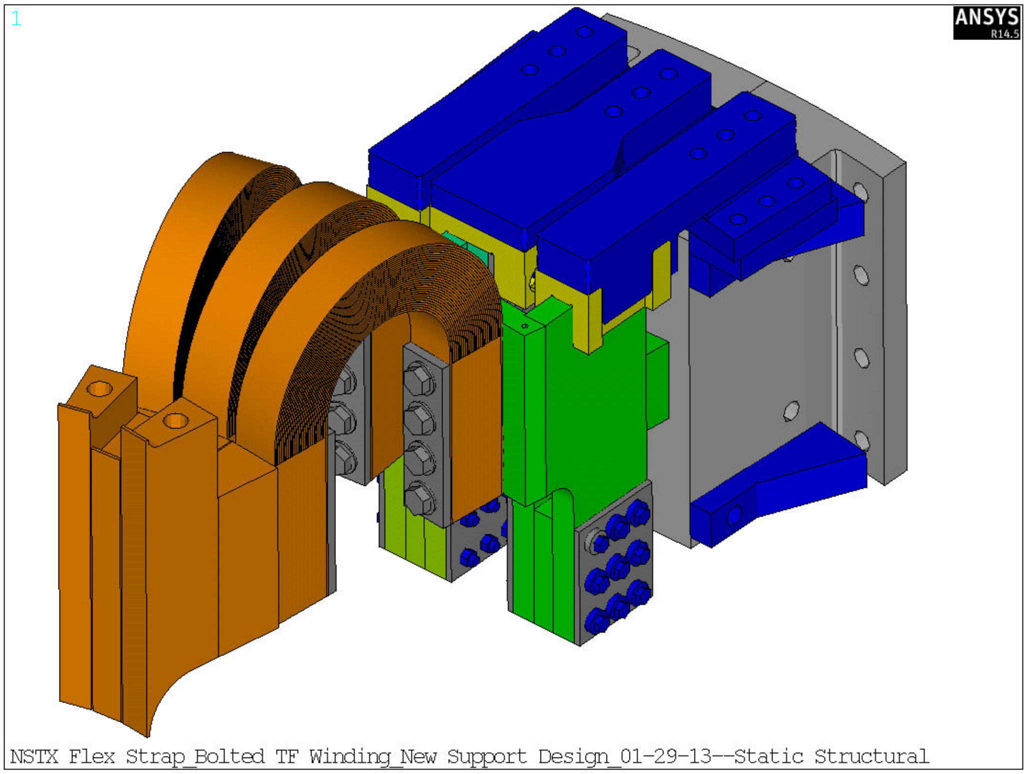


Figure 7-1 – NSTX-U TF Bundle/Flex Joint/Extension Assembly Model (Extensions & Connectors in ‘green’)

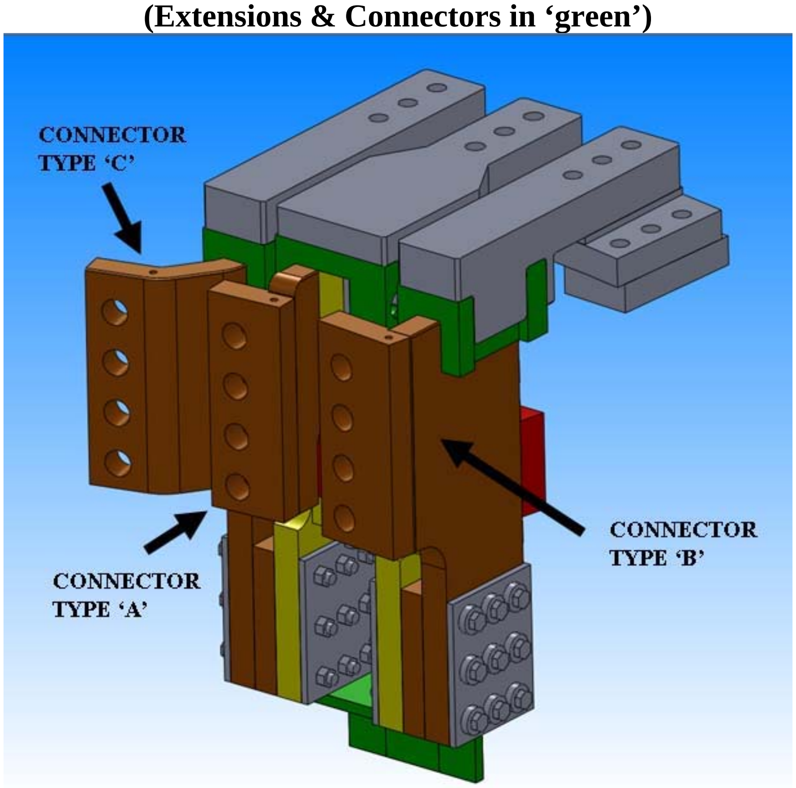


Figure 7-2 – NSTX-U TF Bundle/Flex Joint/Extension Connectors

8.0 Analysis Results

Figure 8.0-1 shows an overview of the stress intensity in connectors ‘A’, ‘B’ and ‘C’ for load scenario # 82. For the purposes of this review, the stresses in the holes (where the peak values are located), will be ignored. Rather, the focus will be to examine the stresses along the electron beam weld (EBW) lines.

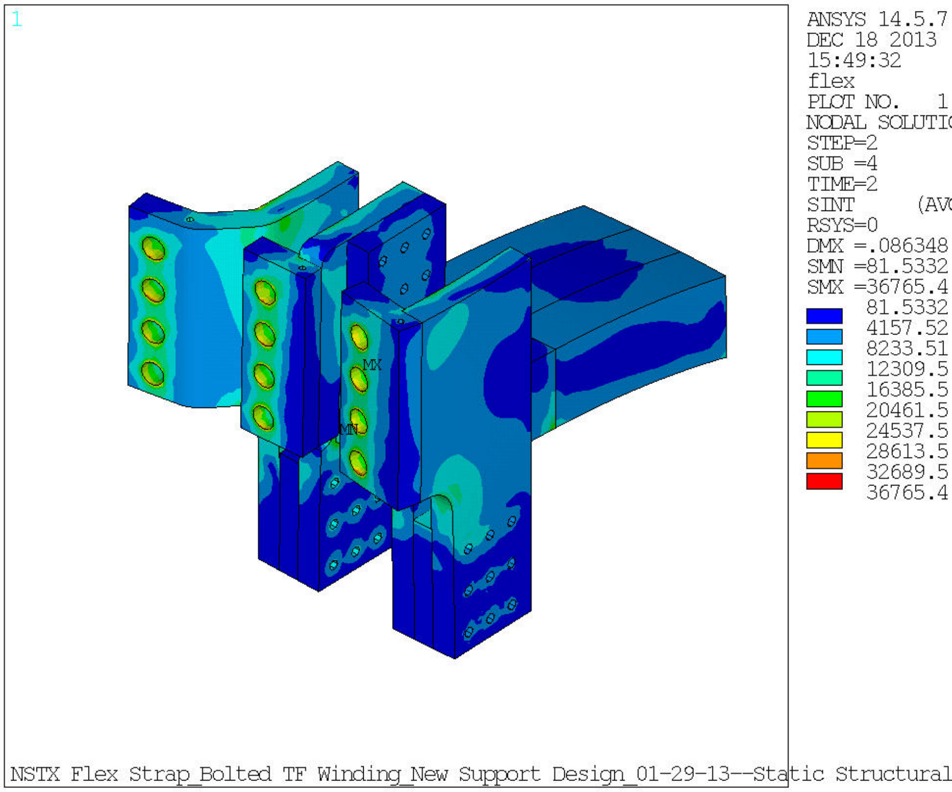


Figure 8.0-1 – Overview of Stress Intensity Values (psi) in Connectors ‘A’, ‘B’ and ‘C’ Prior to Weld Updates

8.1 Type ‘A’ Conductor

Figure 8.1-1 is the drawing of the type “A” conductor before the e-beam weld root clean-up was applied. Figure 8.1-2 is a more detailed view of the stresses in connector ‘A’. Note that in the current, updated design, the plate portion with the nine hole pattern is now EBW’d to the plate with four holes in a flush, continuous manner (see drawing E-DC1456). The fillet with the sharp corner edge is no longer present. It is just squared off. In addition, the plates are EBW’d edge to edge with no plate notch in the four-holed plate to accommodate the nine-holed plate. Figure 8.1-3 is an extreme close up of the region (cut-away view) where the plates are to be joined. The finite element mesh has been overlayed for reference. Note the coarseness of the mesh. Also note the discontinuity of the meshes of the two plates where they meet. Although the two plates are joined and the model continuous, the tying of two coarse meshes in this region will have a tendency to be overly conservative when extrapolating stresses in corners. Notice how the average stress through the middle of the joined region varies from about 6-10 ksi (light blue into green). However, the last element in the fillet corner rapidly changes five contour colors from green to red. This large stress gradient in one element is generally considered unacceptable as a finite element result and an indication that a finer mesh is needed. Accordingly, it is felt that the peak stress is probably closer to 12 ksi in this region. That includes the fillet plate effect which is also a conservative feature in the model of connector ‘A’. The 12 ksi result is well within the allowable stress for EBW’d CuCrZr, so the analysis shows that the joint design is acceptable.

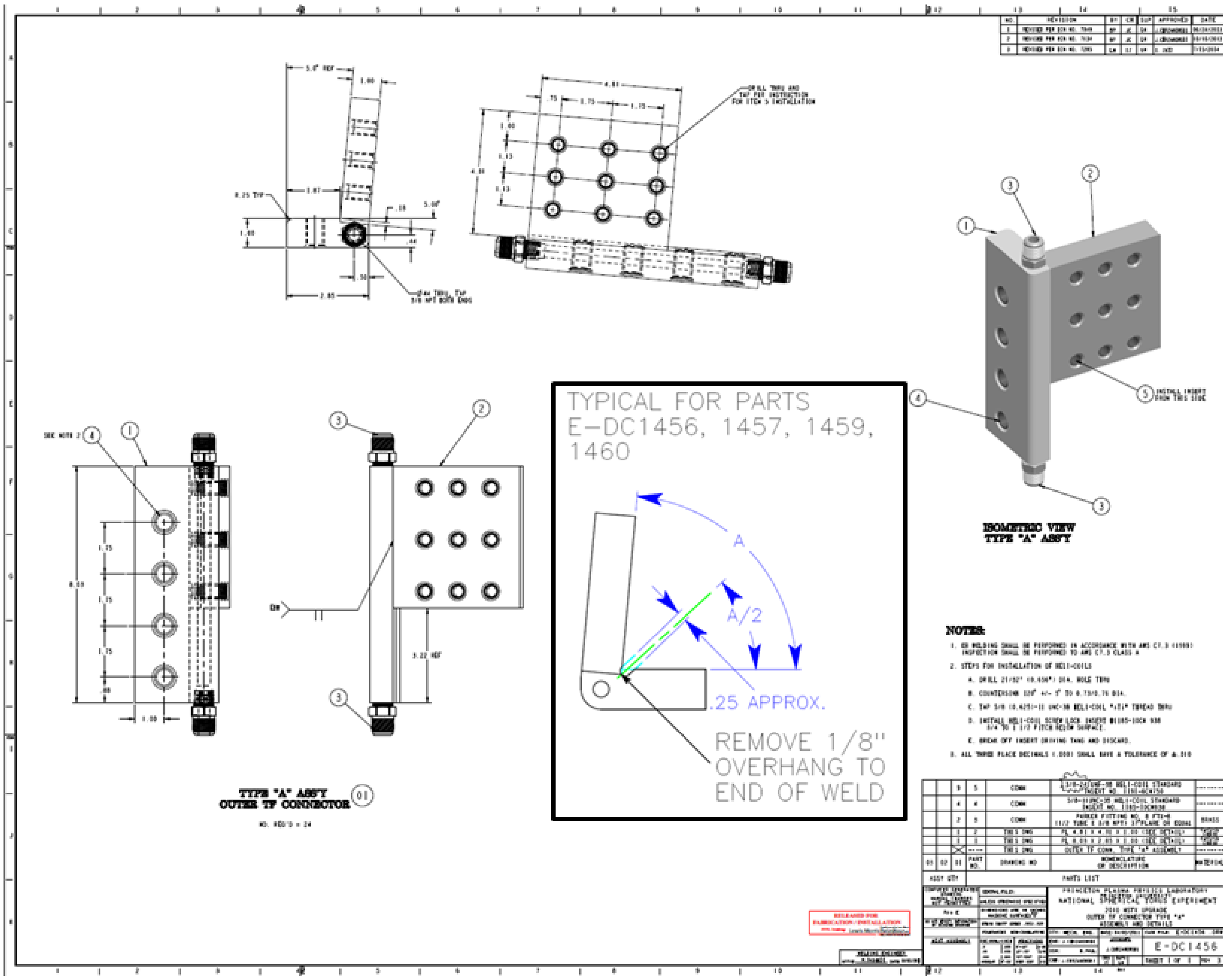


Figure 8.1-1 Type "A" Conductor

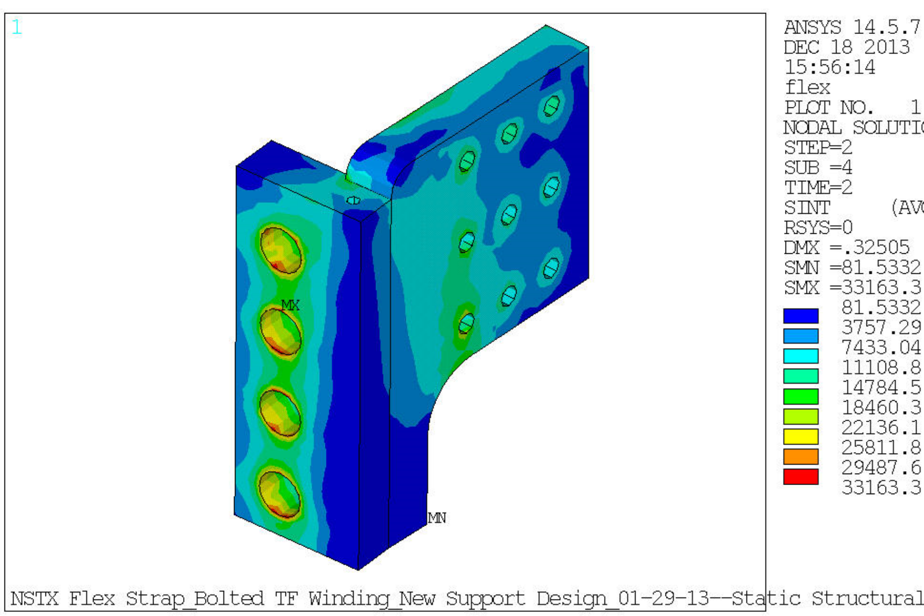


Figure 8.1-2 – Stress Intensity Values (psi) in Connector 'A'

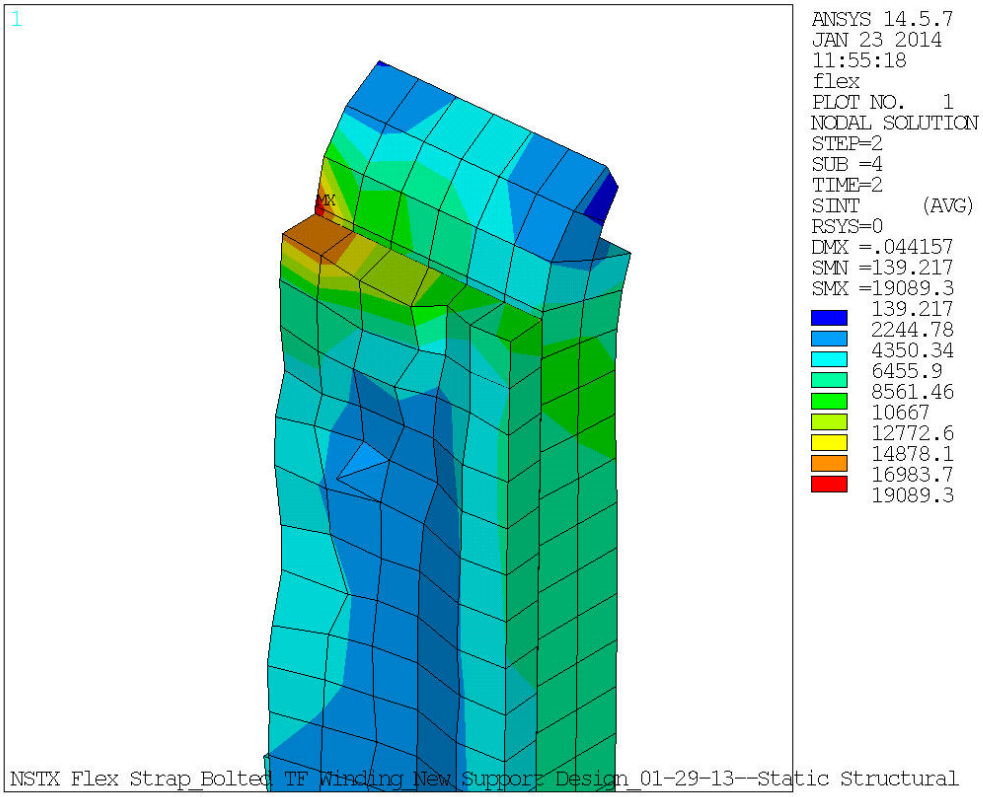


Figure 8.1-3– Cutaway View of Stresses (psi) in Connector 'A' Joint

8.2 Type 'B' Conductor

A drawing of the type B connector in included in Appendix B. Figures 8.2-1 and 8.2-2 are a wide view and cutaway close-up view, respectively, of the joint region of connector 'B'. As was noted for connector 'A', the meshing is quite coarse and discontinuous across the joint.

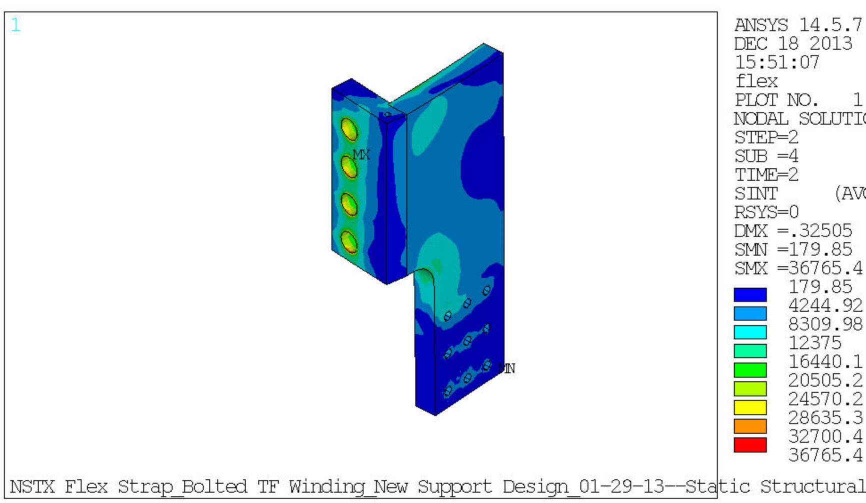


Figure 8.2-1 Stress Intensity Values (psi) in Connector 'B'

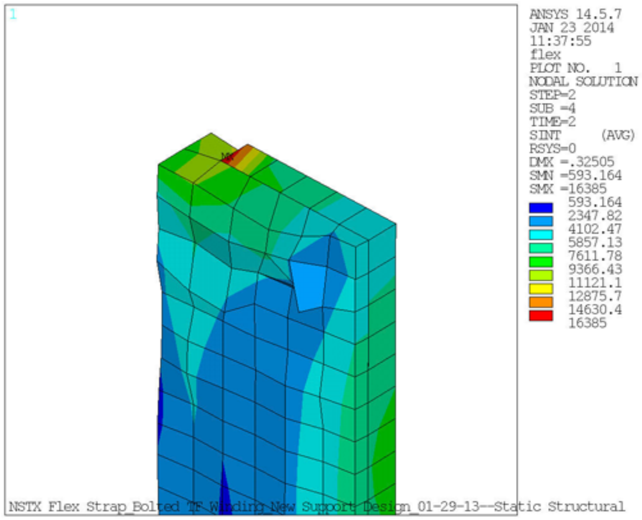


Figure 8.2-2 Cutaway View of Stresses (psi) in Connector 'B' Joint

One element has a large stress gradient of five contour colors which likely indicate an over conservative stress result. The peak stress is not likely to exceed 12 ksi, which is well within the allowable stress for the EBW'd CuCrZr joint.

8.3 Type 'C' Conductor

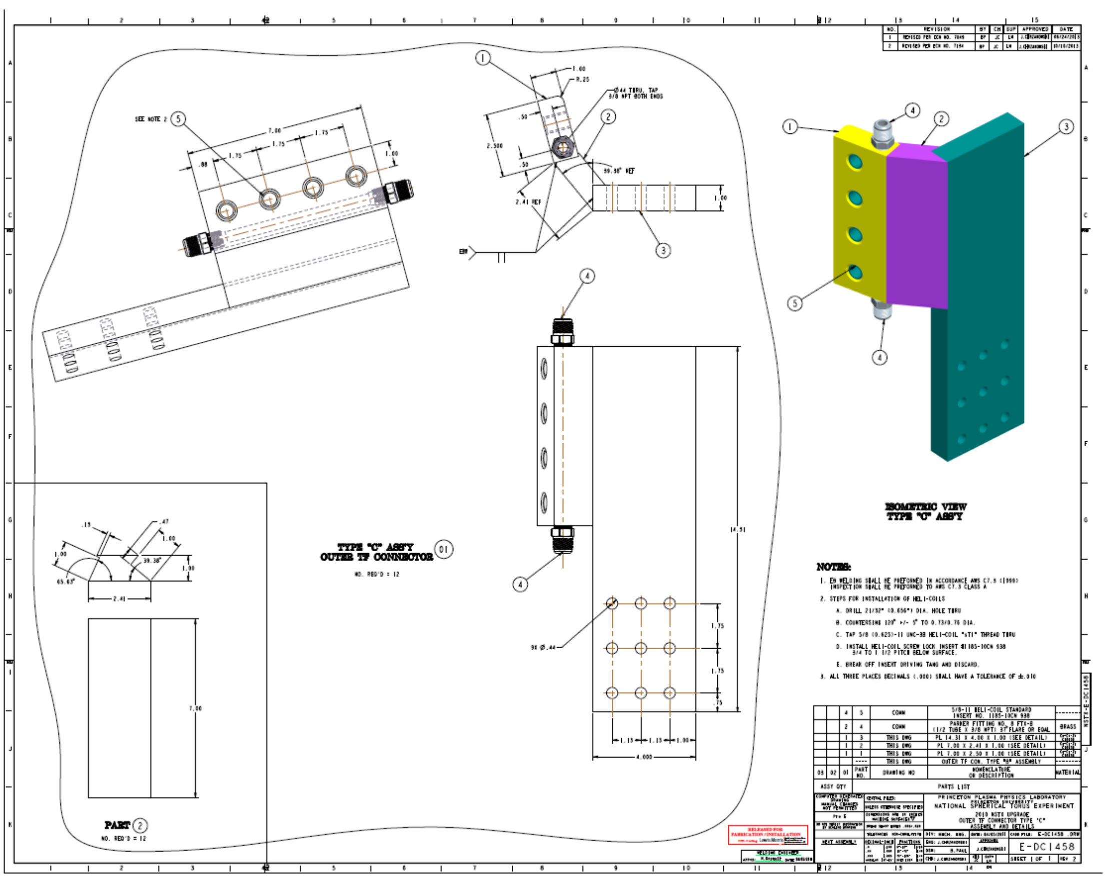


Figure 8.3-1 Drawing of the Type C connector, Before Relief of Stress Concentrations

8.3.1 Stresses in the Type "C" Conductor

Figures 8.3.1-1 and 8.3.1-2 are a wide view and cutaway close-up view, respectively, of the joint region of connector 'C'. As was noted for the other connectors, the meshing is quite coarse. The edge elements have a large stress gradient of five contour colors which, once again is a likely indicator of an over conservative stress result. The peak stress is not likely to exceed 20 ksi, which is within the allowable stress for the EBW'd CuCrZr joint. Based on the results of Tom Willard's model, connector 'C' is to be considered as the most highly stressed connector of the three examined.

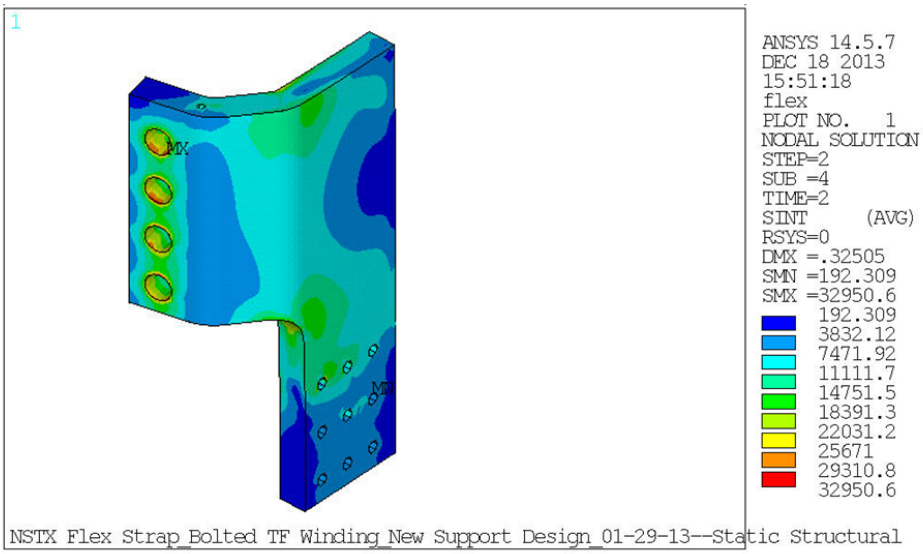


Figure 8.3.1-1 Stress Intensity Values (psi) in Connector 'C'

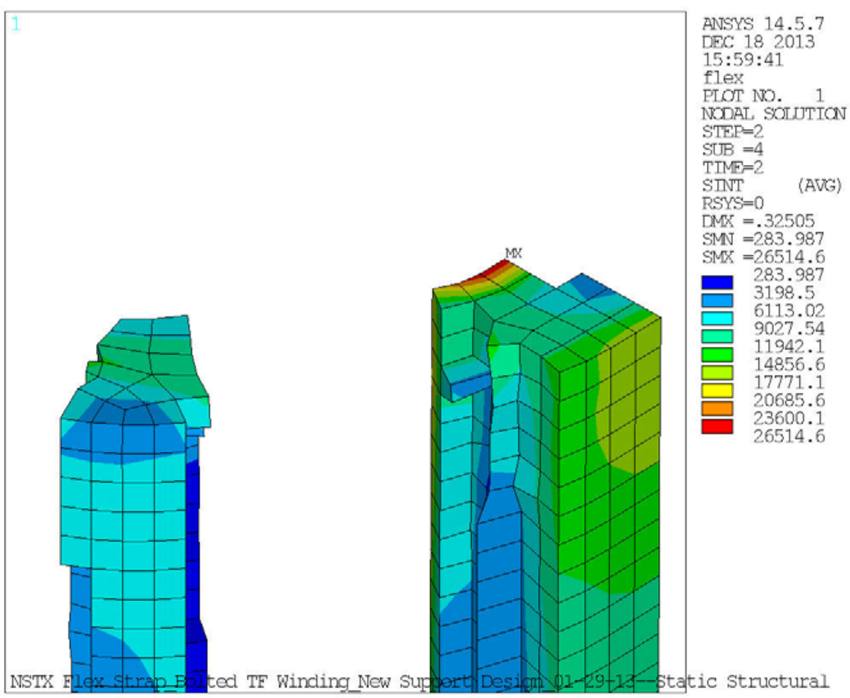


Figure 8.3.1-2 – Cutaway View of Stresses (psi) in Part of the Connector 'C' Joint

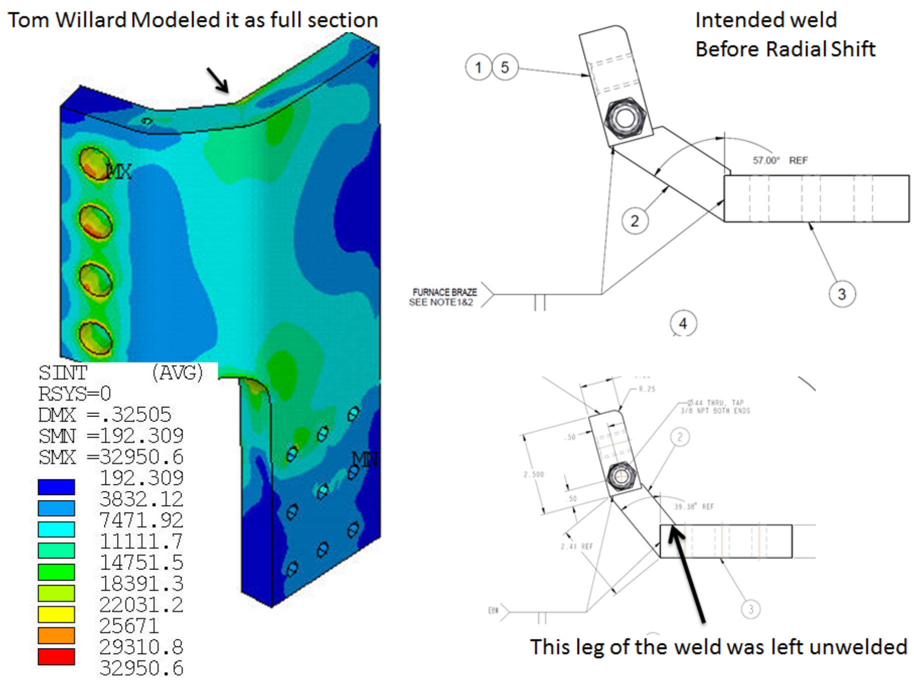


Figure 8.3.1-3 – T. Willard's Model of the Type "C" Conductor and the e beam weld detail

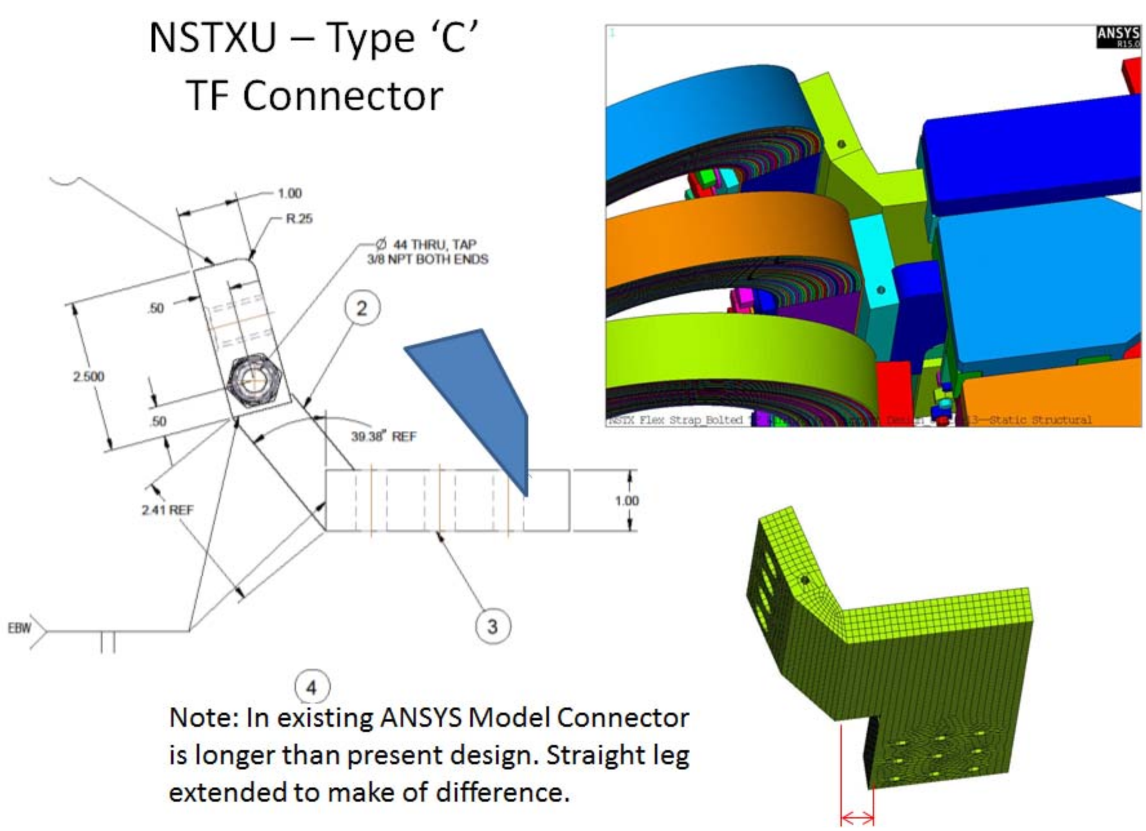


Figure 8.3.1-4 – Sub Model of the Type "C" Conductor Modeling the .62 in Thin Section

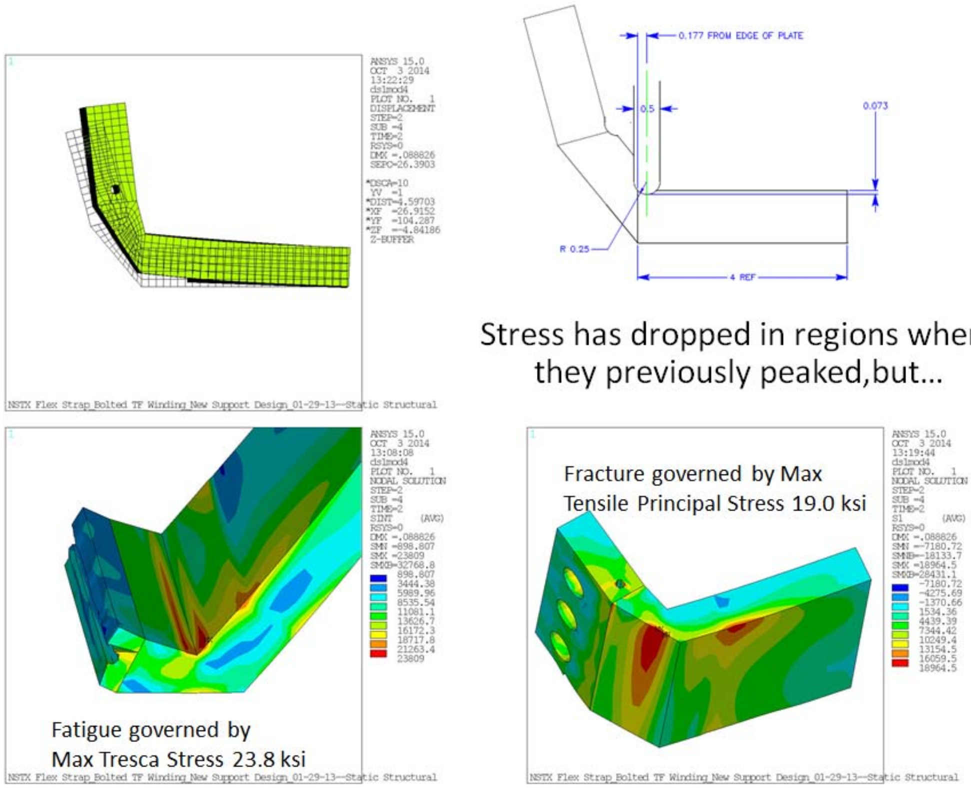


Figure 8.3.1-5 – Sub Model of the Type "C" Conductor Modeling the .62 in Thin Section

Figure 8.3.1-6 –Type "C" Weld Relief – As Machined

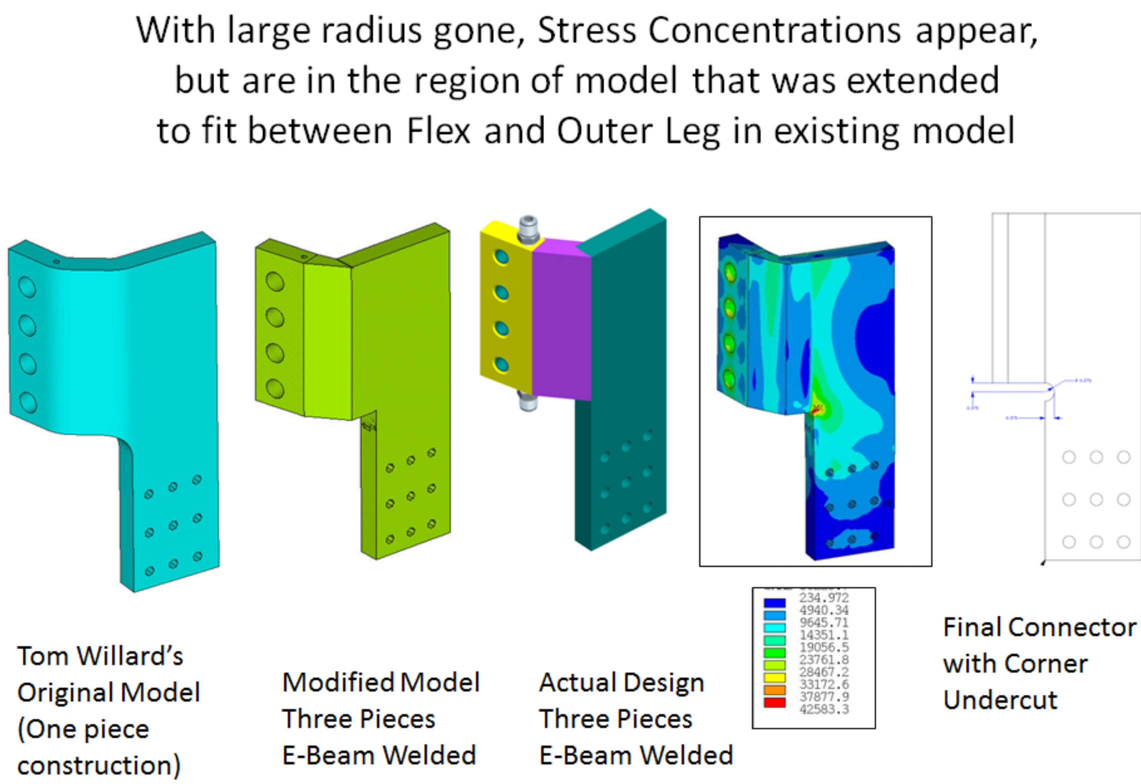
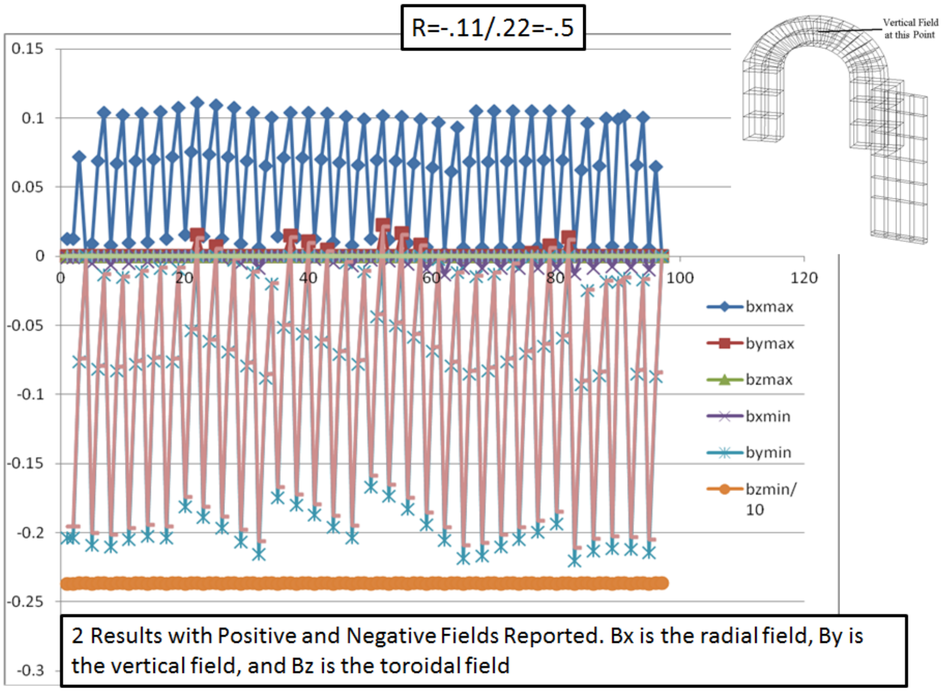


Figure 8.3.1-7 –Type "C" Design and Analysis Progression

With a sharp corner modeled at the lower end of the flag weld, the stress is 42 ksi (above, Figure 8.3.1-7). If an undercut with a radius of .25 is used, the connector at the e-beam weld, the Tresca stress drops from 42 ksi to just under 30 ksi. This is the result that will be used in subsequent fatigue calculations.

8.3.2 Cyclic Loading and R Value

The R value was estimated from the vertical field values for the 96 equilibria listed in the design point spreadsheet. Art Brooks has pointed out that when you add the thermal and radial toroidal field effects, the R value may be higher, but the estimate outlined below should be conservative.



8.3.3 S-N Fatigue and Usage Factor Calculation

The first estimate of the thinning needed to clean off the back side of the partial penetration e-beam weld was that a.72 inch thick section would remain. With a 79 ksi ultimate stress for the CuCrZr, then all the flags would satisfy normal fatigue allowables - even with the flag thinned to .72 inches at the partial EB weld.

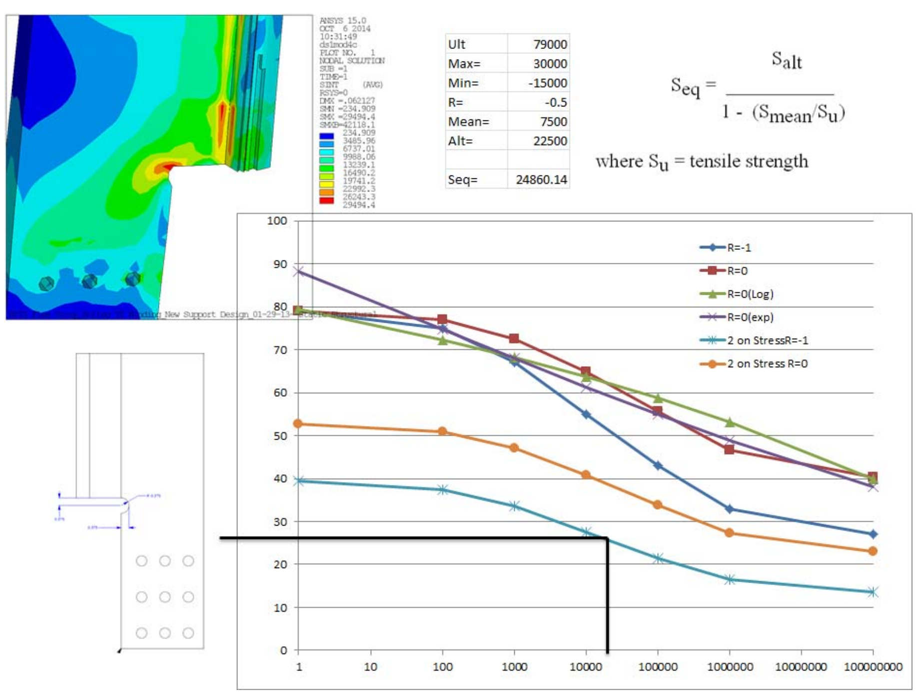


Figure 8.3.3-1 SN Evaluation Based on 30 ksi Peak Tresca Stress and a 79 ksi Tensile Strength

The results in figure 8.3.3-1 are acceptable for the 20,000 cycle life requirement, but the measured tensile strength of the CuCrZr as delivered was not 79 ksi, but 65 ksi. (See Appendix D). Re-doing the analysis with the S-N curve scaled down by the ratio of the ultimate strengths, and taking credit for the spectrum of TF loading in the first year of operation only produced a 2000 cycle allowed life.

•

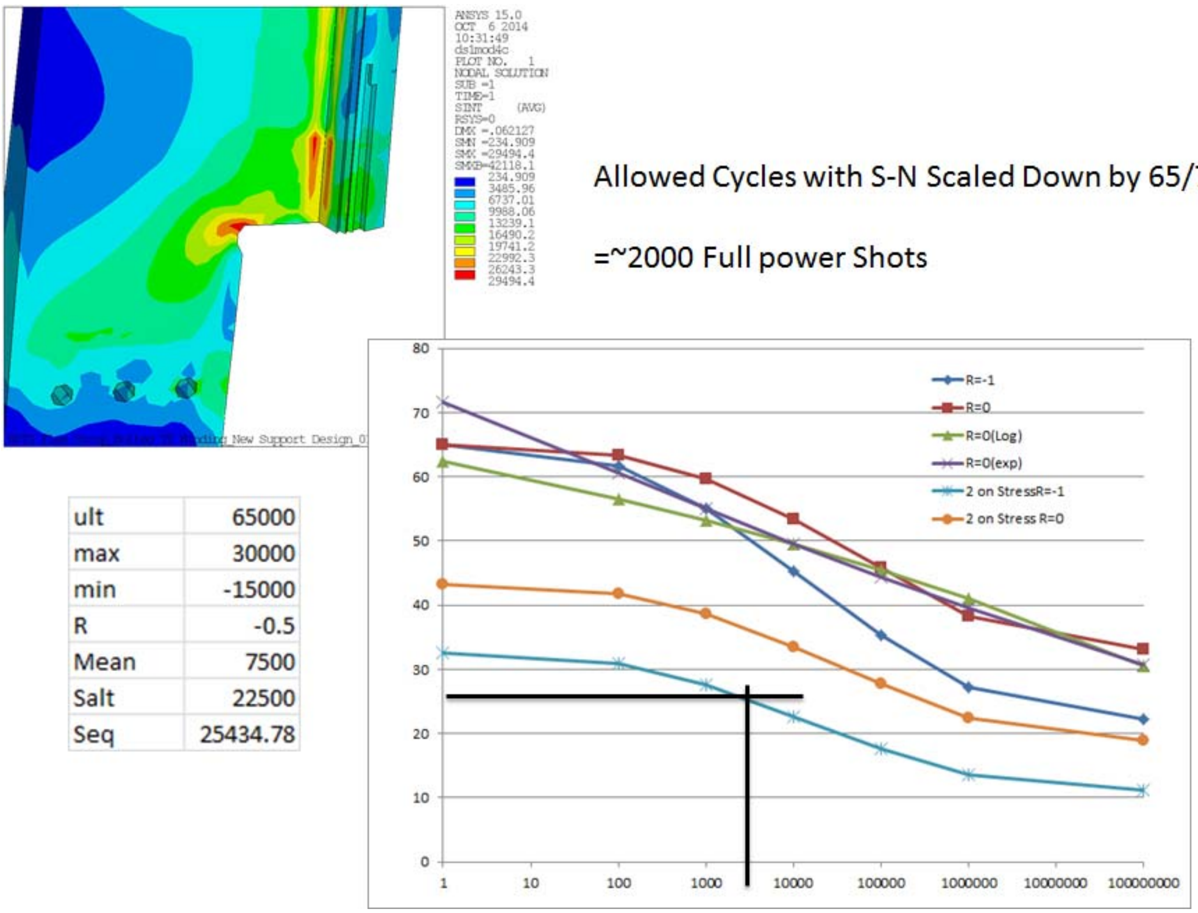


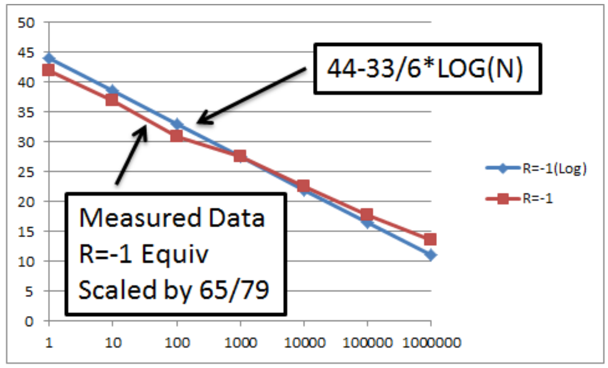
Figure 8.3.3-1 SN Evaluation Based on 30 ksi Peak Tresca Stress and a 65 ksi Tensile Strength

The SN data in Figure 8.3.3-1 is scaled down by the ratio of the ultimate stress from the mill certs in Appendix D and that shown in the SN plot in section 6.0. –a factor of 65/79. The result was only a 2000 full power shot cycle life. Stefan Gerhard was asked what the actual TF shot spectrum would look like in the first year. He provided the following data[5] :

- 16 run weeks, 5 days/week, 8 hours/day, 3 shots/hour = ~2000 shots (1920 in reality)
- We stated in the FWPs that we would go at high as 0.8 T, at least on occasion
- We will commission operations at 0.55 tesla.
- Operation beneath 0.45 T will be very limited.
- CHI and RF will want the highest TF that they are allowed to use.
- Shot spectrum to assume:
    - 5% of shots at 0.45 T = 100 shots
    - 30% of shots at 0.55 T = 600 shots
    - 25% of shots at 0.60 T = 500 shots
    - 25% of shots at 0.70 T = 500 shots
    - 15% of shots at 0.80 T = 300 shots

The usage factor calculation was implemented in a spreadsheet and the usage factor for the first year was well below 1.0

	N		R=-1(Log)	R=-1
	1		44	42
	10		38.5	37
	100		33	30.85443038
	1000		27.5	27.56329114
	10000		22	22.62658228
	100000		16.5	17.68987342
	1000000		11	13.57594937
	10000000		5.5	11.10759494



$$S_{eq} = \frac{S_{alt}}{1 - (S_{mean}/S_u)}$$

where S_u = tensile strength

ult	65000
max	30000
min	-15000
R	-0.5
Mean	7500
Salt	22500
Seq	25434.78

Load				I1	I2	I3	I4	I5	I6
TF Field (Tesla)				0.45	0.55	0.6	0.7	0.8	1
Stress (ksi), Scaled from Field				5.150543478	7.694021739	9.156521739	12.46304	16.27826	25.43478
Number of Cycles at Load				100	600	500	500	300	0
Allowed Number of Cycles at Load				11575441.1	3991048.05	2163604.448	541991	109727.7	2374.073
Usage Factor			0.004046637	8.63898E-06	0.000150336	0.000231096	0.000923	0.002734	0
			Total						
			Usage Factor						

Figure 8.3.3-1 SN Usage Factor Based on 30 ksi Peak Tresca Stress and a 65 ksi Tensile Strength, and The First Year Shot Spectrum

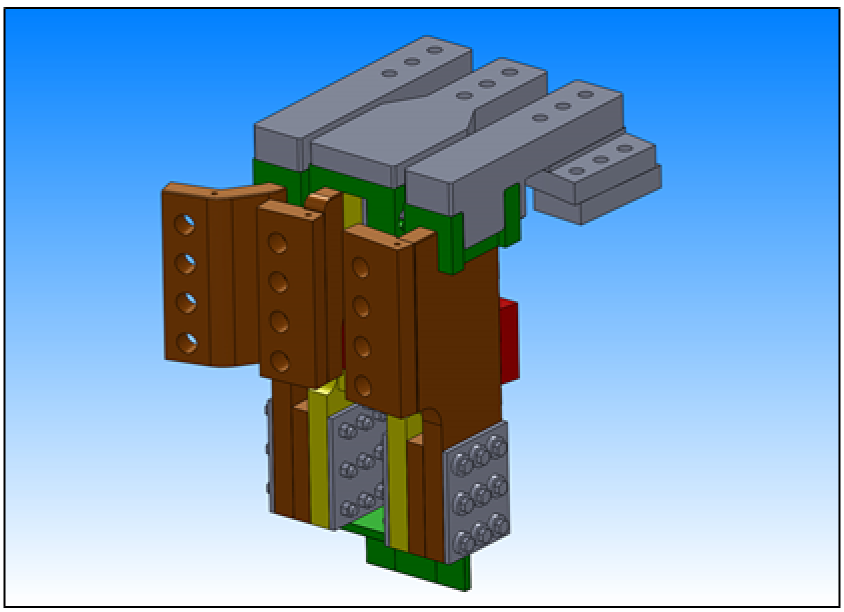
The problem connector and the predicted peak stress area are inspectable, so, it would be appropriate to add it to the inspection list and accept a 65 ksi ultimate temper of the CuCrZr.

Appendix A

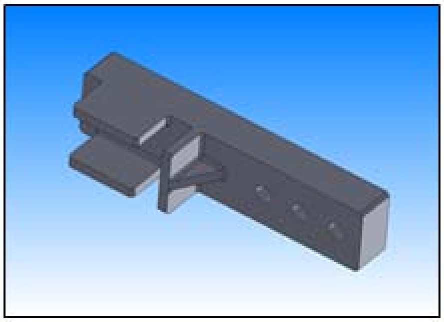
Excerpts from T. Willard peer review presentation of TF lead extensions and support bracket proposed designs (presented 2/14/13)

NSTX Upgrade TF Lead Extensions Support Bracket Proposed Designs

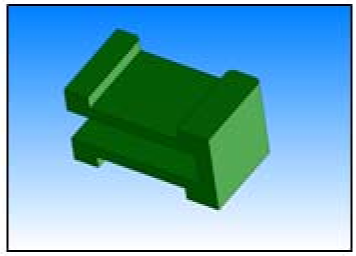
02-04-13



NSTX Upgrade TF Lead Extensions Support Brackets Proposed Designs

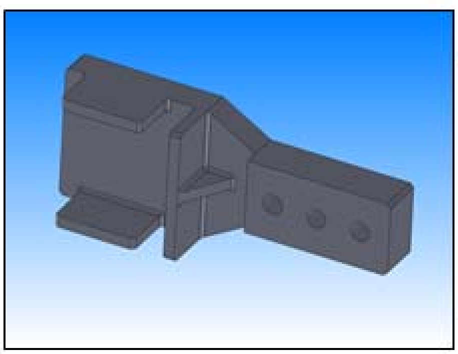


Material: A286, HT/Aged per AMS 5525



Material: FR4

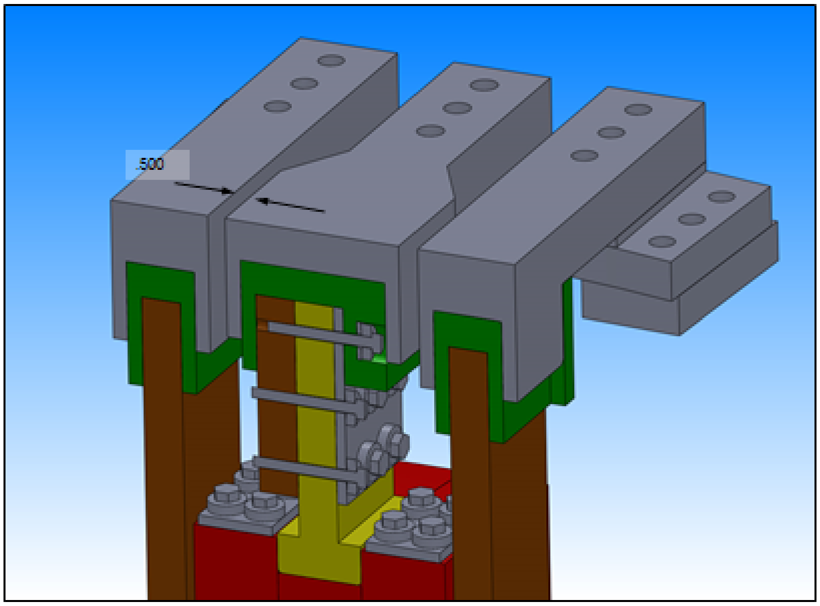
Left/ Right TF Lead Extension Support Bracket and Insulator



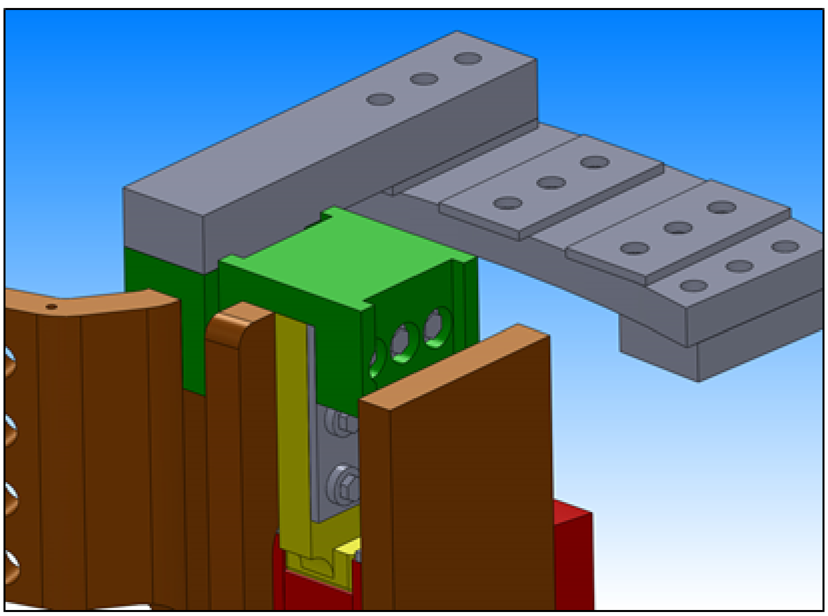
Material: A286, HT/Aged per AMS 5525

Material: FR4

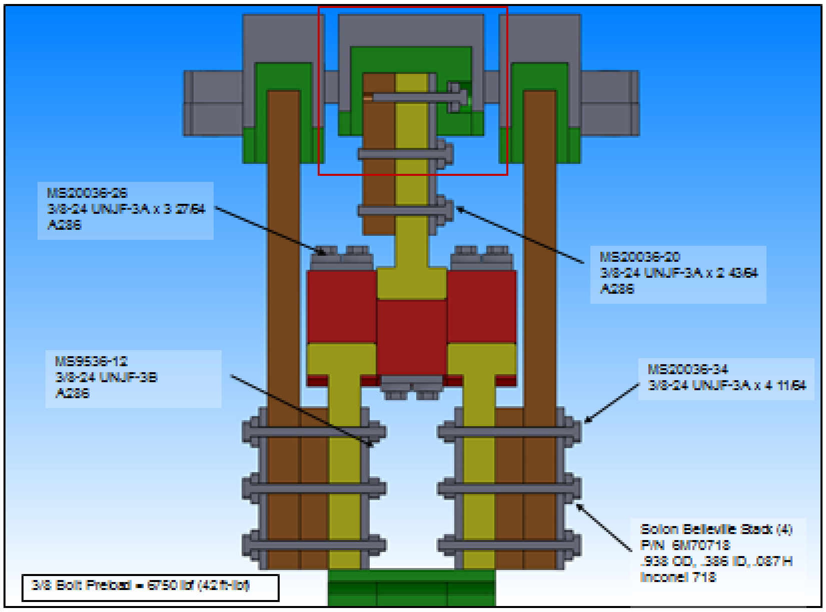
Center TF Lead Extensions Support Bracket and Insulator



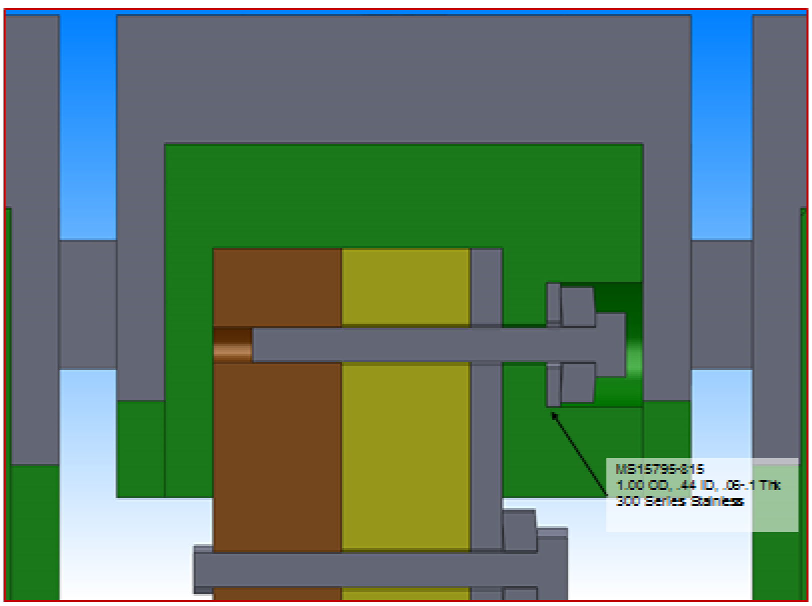
NSTX Upgrade TF Lead Extensions Support Brackets Proposed Designs
Cross Section View



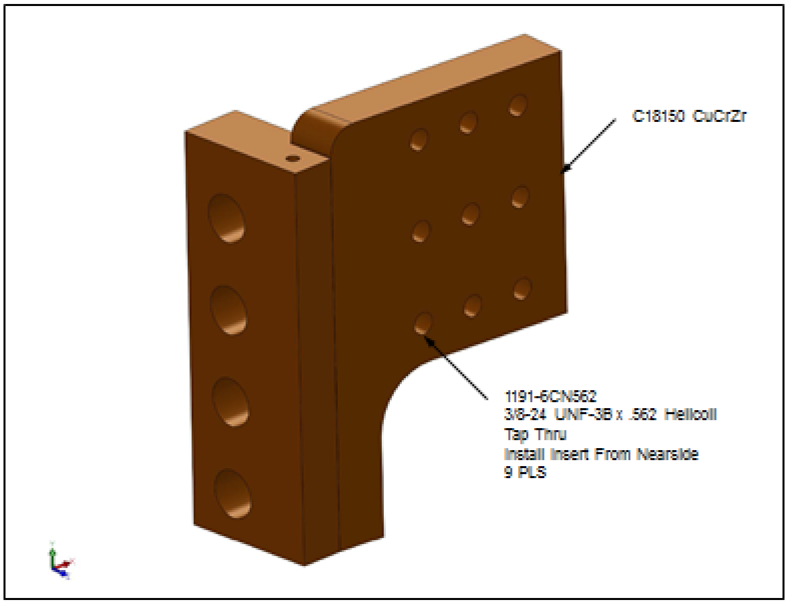
Center TF Lead Extension Support Bracket w/ FR4 Insulator Design
Shown with Support Brackets 2 & 3 Removed



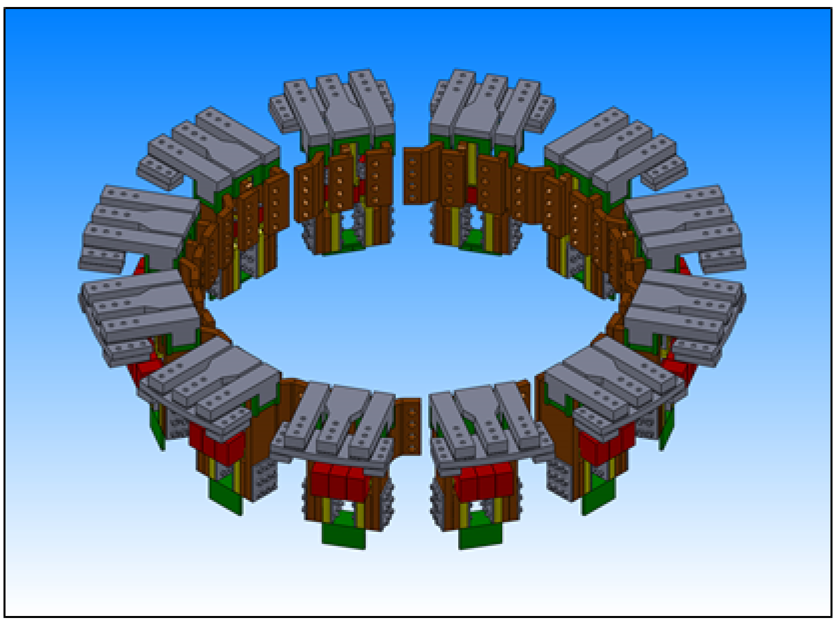
Proposed TF Lead Extension Support Brackets: Bolted Joint Detail
Cross Section View 1



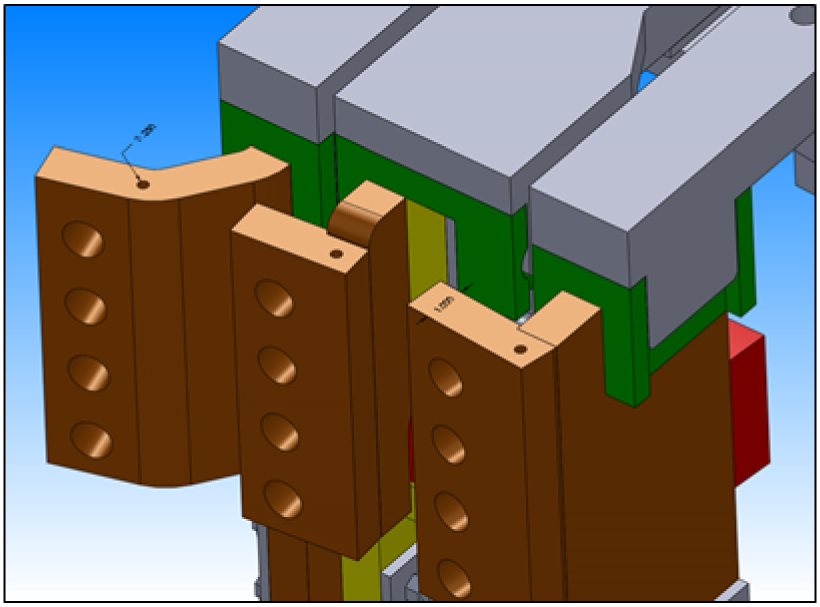
Center TF Lead Extension Support Bracket: Bolted Joint Detail
Cross Section View 2



Center TF Lead Extension: Outer Flag Helicoil Mtg Holes



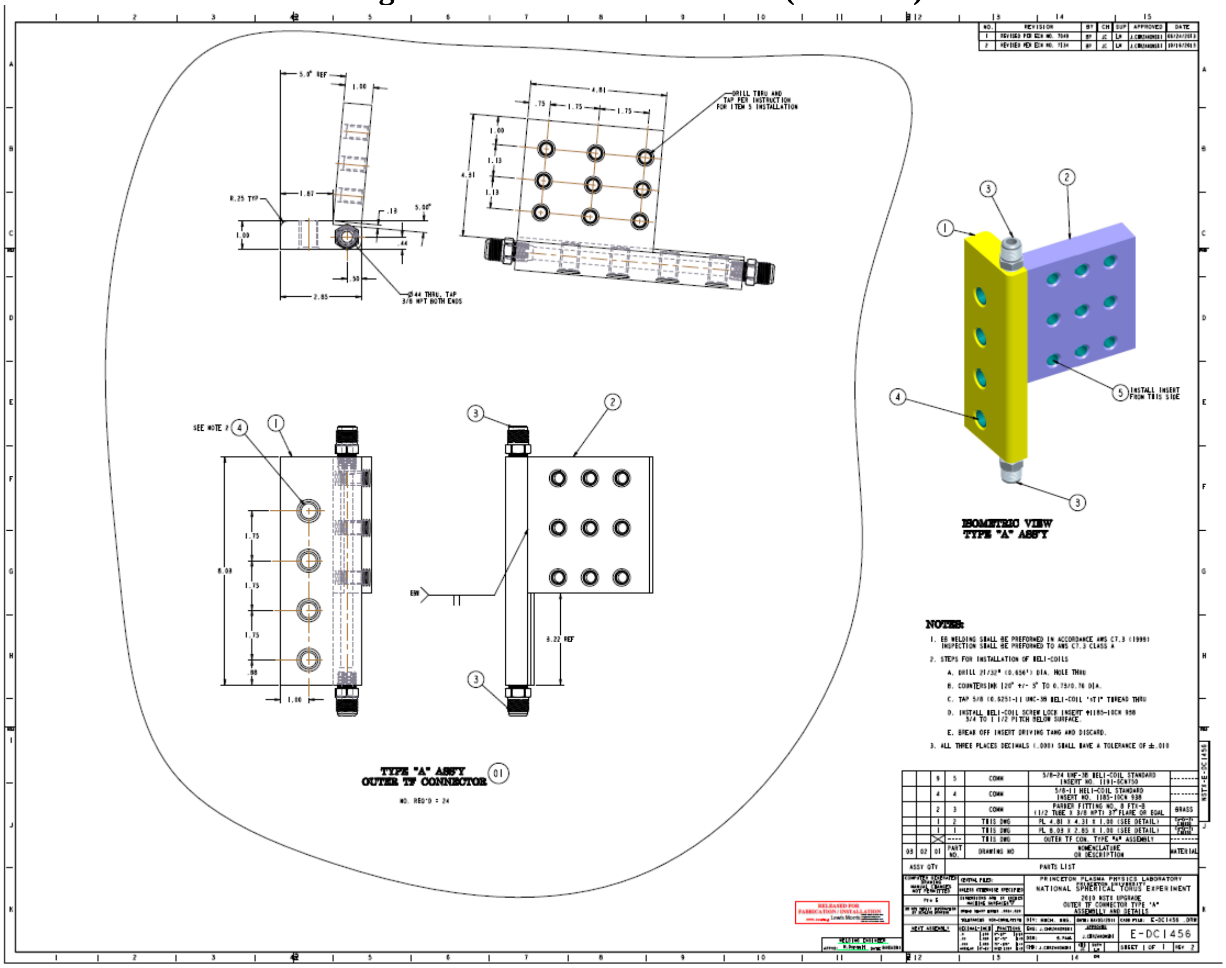
TF Lead Extension Support Brackets: 360° Circular Pattern View
Showing Adequate Toroidal Clearance for Bolt Installation on Bottom Joints

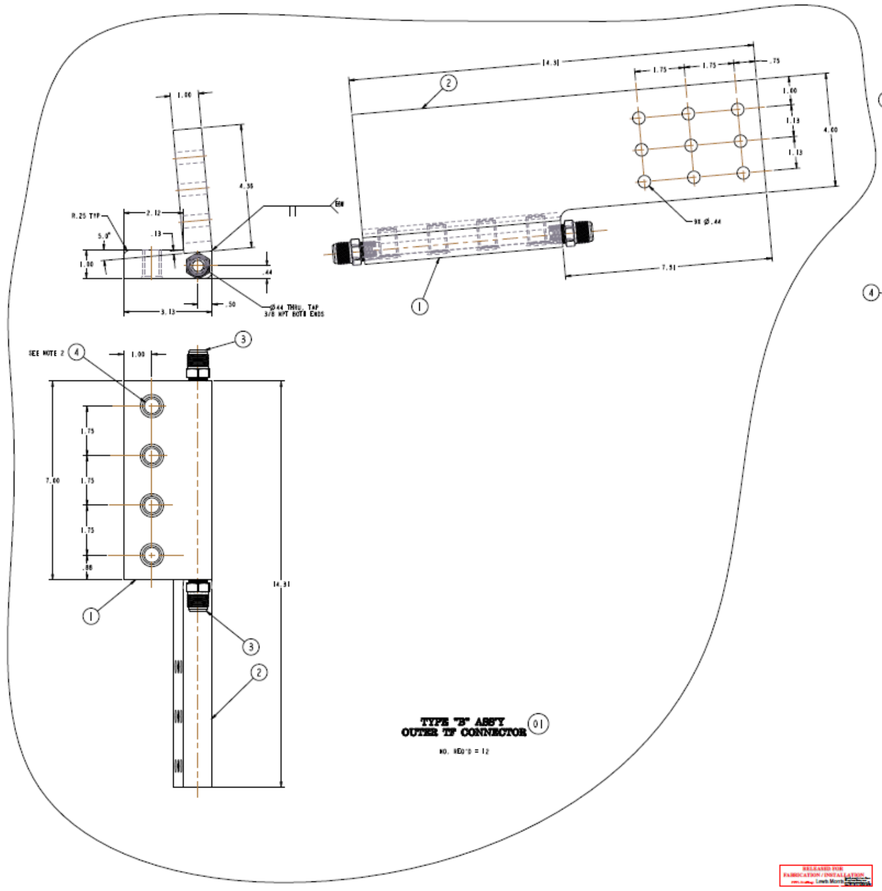


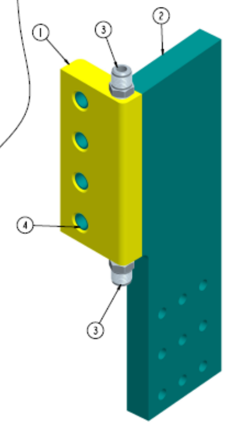
Baseline-Design TF Outer Leg Lead Extensions: 1.00" CuCrZr Plates
Water Cooling Maximum Thru Hole Diameter = .25"

Appendix B

Drawings E-DC1456 thru E-DC1460 (all rev. 2)







NO.	REVISION	BY	CH	SUP	APPROVED	DATE
1	REVISED PER ECN NO. 7049	BP	JC	LH	J.CHRZANOWSKI	06/24/2015
2	REVISED PER ECN NO. 7154	BP	JC	LH	J.CHRZANOWSKI	10/16/2018

NOTES:

1. EB WELDING SHALL BE PREFORMED IN ACCORDANCE AWS C7.3 (1999) INSPECTION SHALL BE PREFORMED TO AWS C7.3 CLASS A
2. STEPS FOR INSTALLATION OF HELI-COILS
   - A. DRILL 21/32" (0.656") DIA. HOLE THRU
   - B. COUNTERSINK 120° +/- 5° TO 0.73/0.76 DIA.
   - C. TAP 5/8 (0.625)-11 UNC-3B HELI-COIL "STI" THREAD THRU
   - D. INSTALL HELI-COIL SCREW LOCK INSERT #1185-10CN 938 3/4 TO 1 1/2 PITCH BELOW SURFACE.
   - E. BREAK OFF INSERT DRIVING TANG AND DISCARD.
3. ALL THREE PLACES DECIMALS (.000) SHALL HAVE A TOLERANCE OF ±.010

03	02	01	PART NO.	DRAWING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL
		4	4	COMM	5/8-11 HELI-COIL STANDARD INSERT NO. 1185-10CN 938	--------
		2	3	COMM	PARKER FITTING NO. 8 FTX-8 (1/2 TUBE X 3/8 NPT) 37° FLARE OR EQAL	BRASS
		1	2	THIS DWG	PL 14.31 X 4.36 X 1.00 (SEE DETAIL)	[illegible]
		1	1	THIS DWG	PL 7.00 X 3.13 X 1.00 (SEE DETAIL)	[illegible]
		X	----	THIS DWG	OUTER TF CON. TYPE "B" ASSEMBLY	--------

ASSY QTY — PARTS LIST

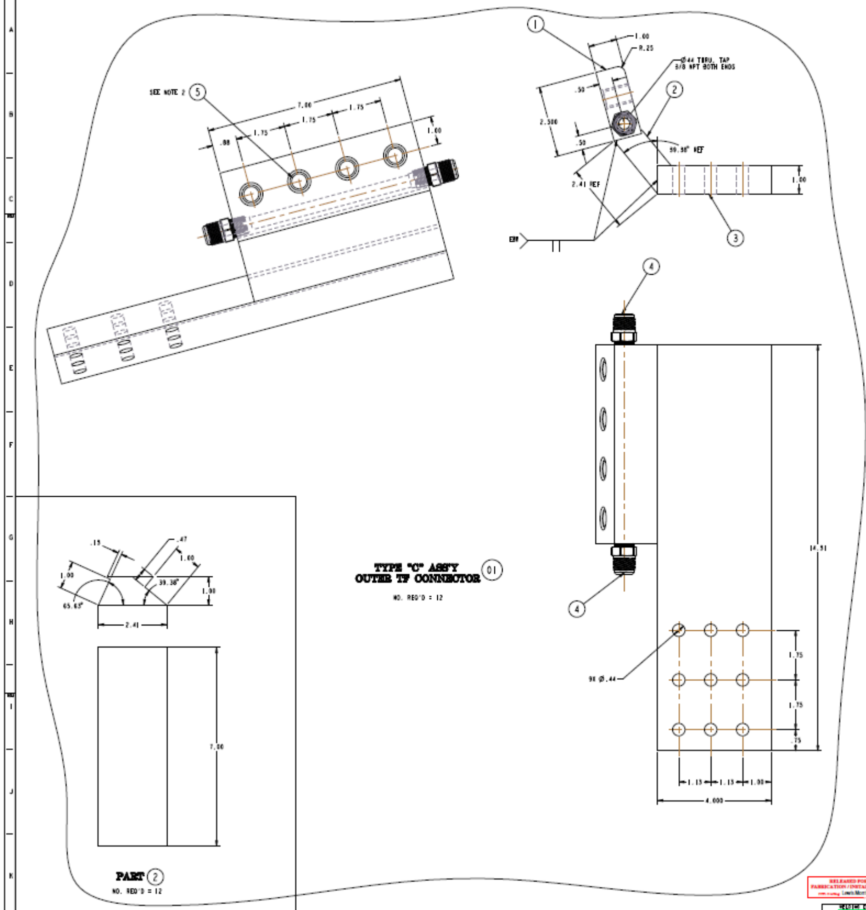
PRINCETON PLASMA PHYSICS LABORATORY
PRINCETON UNIVERSITY
NATIONAL SPHERICAL TORUS EXPERIMENT
2010 NSTX UPGRADE
OUTER TF CONNECTOR TYPE "B"
ASSEMBLY AND DETAILS

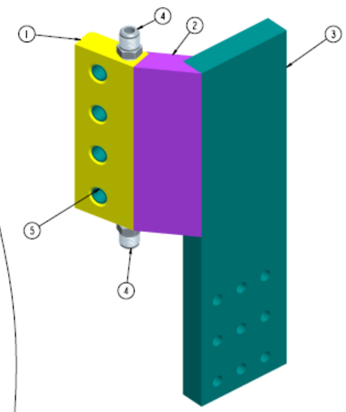
E-DC1457

SHEET 1 OF 1 — REV 2

CAD FILE: E-DC1457 .DRW

NSTX-E-DC1457





NO.	REVISION	BY	CH	SUP	APPROVED	DATE
1	REVISED PER ECN NO. 7049	BP	JC	LW	J.CHRZANOWSKI	05/24/2013
2	REVISED PER ECN NO. 7194	BP	JC	LW	J.CHRZANOWSKI	10/18/2013

NOTES:

1. EN WELDING SHALL BE PREFORMED IN ACCORDANCE AWS C7.5 (1999) INSPECTION SHALL BE PREFORMED TO AWS C7.5 CLASS A
2. STEPS FOR INSTALLATION OF HELI-COILS
   A. DRILL 21/32" (0.656") DIA. HOLE THRU
   B. COUNTERSINK 120° +/- 5° TO 0.73/0.76 DIA.
   C. TAP 5/8 (0.625)-11 UNC-3B HELI-COIL "STI" THREAD THRU
   D. INSTALL HELI-COIL SCREW LOCK INSERT #1185-10CN 938 3/4 TO 1 1/2 PITCH BELOW SURFACE.
   E. BREAK OFF INSERT DRIVING TANG AND DISCARD.
3. ALL THREE PLACES DECIMALS (.000) SHALL HAVE A TOLERANCE OF ±.010

03	02	01	PART NO.	DRAWING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL
		4	5	COMM	5/8-11 HELI-COIL STANDARD INSERT NO. 1185-10CN 938	--------
		2	4	COMM	PARKER FITTING NO. 8 FTX-B (1/2 TUBE X 3/8 NPT) 37° FLARE OR EQAL	BRASS
		1	3	THIS DWG	PL 14.31 X 4.00 X 1.00 (SEE DETAIL)	[illegible]
		1	2	THIS DWG	PL 7.00 X 2.41 X 1.00 (SEE DETAIL)	[illegible]
		1	1	THIS DWG	PL 7.00 X 2.50 X 1.00 (SEE DETAIL)	[illegible]
			----	THIS DWG	OUTER TF CON. TYPE "B" ASSEMBLY	--------

ASSY QTY — PARTS LIST

PRINCETON PLASMA PHYSICS LABORATORY
PRINCETON UNIVERSITY
NATIONAL SPHERICAL TORUS EXPERIMENT

2010 NSTX UPGRADE
OUTER TF CONNECTOR TYPE "C"
ASSEMBLY AND DETAILS

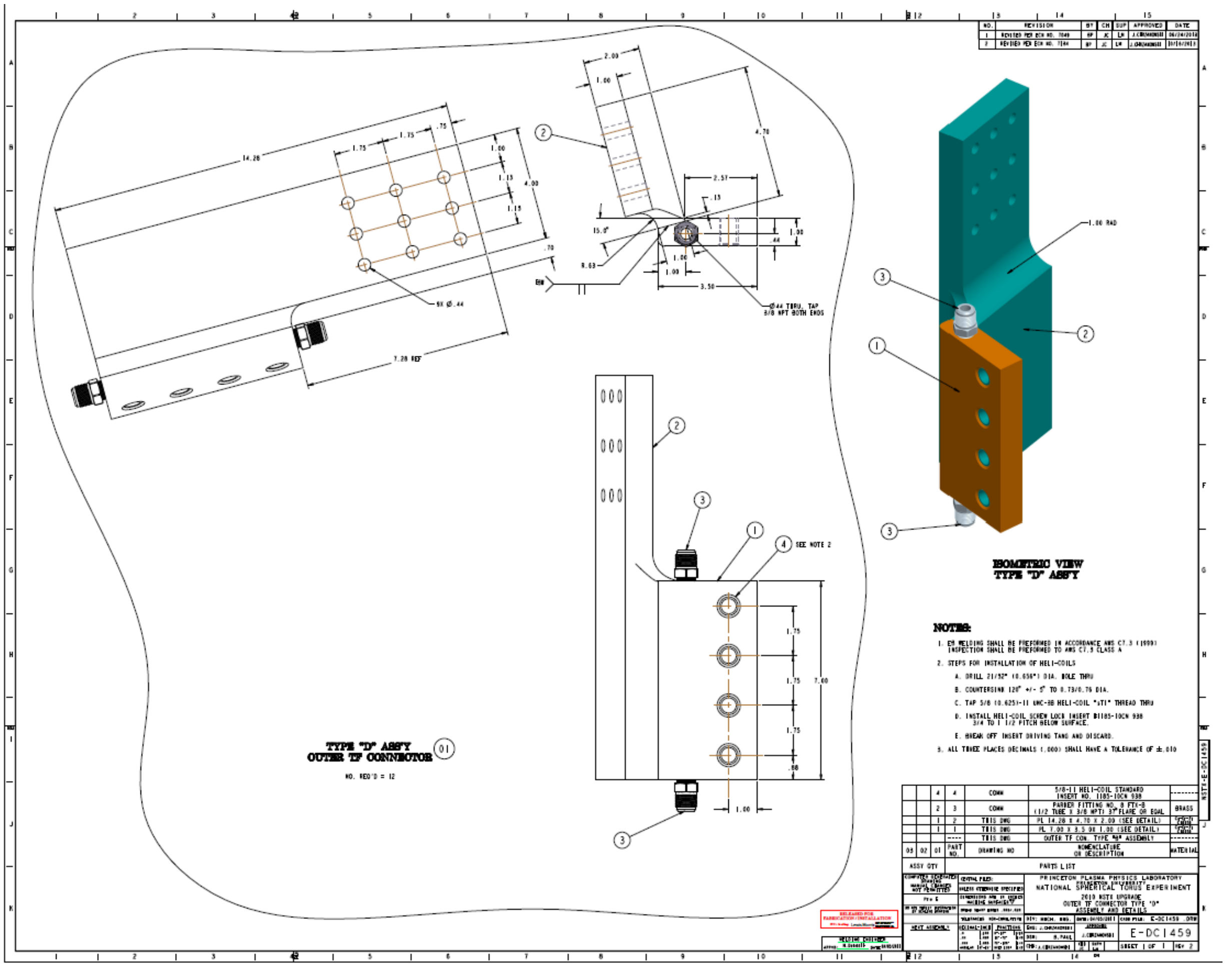
DIV: MECH. ENG. | DRN: B. PAUL | CHK: J.CHRZANOWSKI | APPROVED: J.CHRZANOWSKI

CADD FILE: E-DC1458 .DRW

E-DC1458

SHEET 1 OF 1 | REV 2

NSTX-E-DC1458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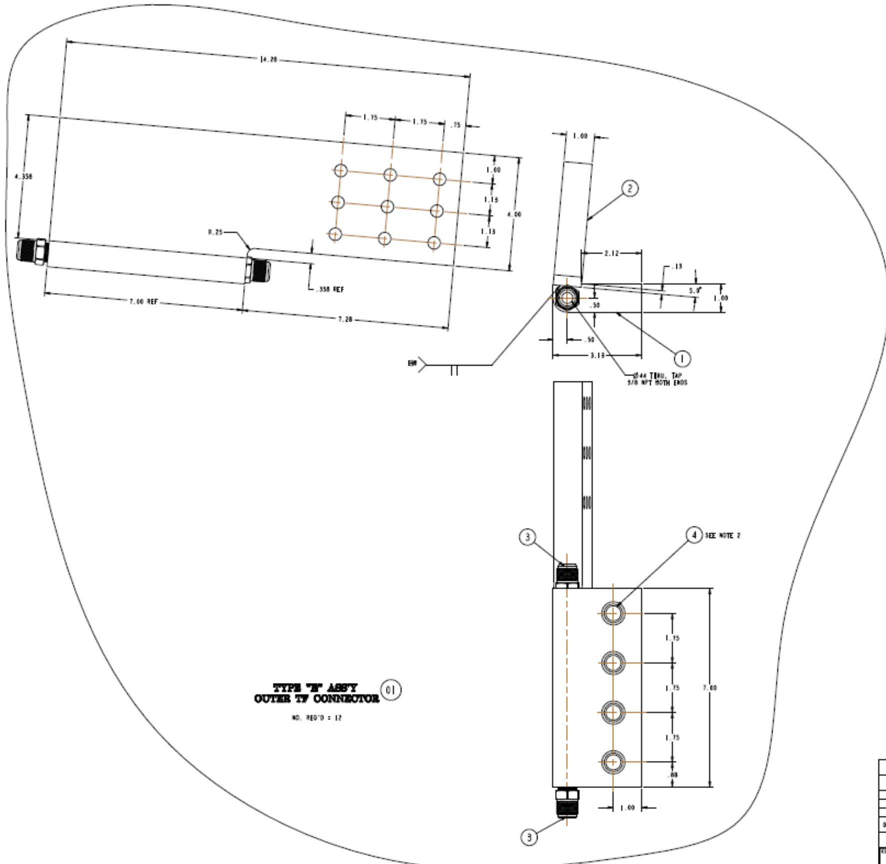
2 | REVISED PER ECN NO. 7144 | BP | JC | LM | J.CHRZANOWSKI | 10/10/2013
14.28
1.75
1.75
.75
1.00
1.13
1.15
4.00
.70
8X Ø.44
7.28 REF
2.00
1.00
4.70
2.57
.13
15.0°
8.63
1.00
1.00
3.50
1.00
.44
Ø.44 THRU, TAP 3/8 NPT BOTH ENDS
1.00 RAD
SEE NOTE 2
1.75
1.75
1.75
7.00
.88
1.00
ISOMETRIC VIEW
TYPE "D" ASS'Y
TYPE "D" ASS'Y
OUTER TF CONNECTOR
01
NO. REQ'D = 12
NOTES:
1. EB WELDING SHALL BE PREFORMED IN ACCORDANCE AWS C7.3 (1999) INSPECTION SHALL BE PREFORMED TO AWS C7.3 CLASS A
2. STEPS FOR INSTALLATION OF HELI-COILS
A. DRILL 21/32" (0.656") DIA. HOLE THRU
B. COUNTERSINK 120° +/- 5° TO 0.73/0.76 DIA.
C. TAP 5/8 (0.625)-11 UNC-3B HELI-COIL "STI" THREAD THRU
D. INSTALL HELI-COIL SCREW LOCK INSERT 81185-10CN 938 3/4 TO 1 1/2 PITCH BELOW SURFACE.
E. BREAK OFF INSERT DRIVING TANG AND DISCARD.
3. ALL THREE PLACES DECIMALS (.000) SHALL HAVE A TOLERANCE OF ±.010
| | 4 | 4 | COMM | 5/8-11 HELI-COIL STANDARD INSERT NO. 1185-10CN 938 | --------
| | 2 | 3 | COMM | PARKER FITTING NO. 8 FTX-B (1/2 TUBE X 3/8 NPT) 37° FLARE OR EQAL | BRASS
| | 1 | 2 | THIS DWG | PL 14.28 X 4.70 X 2.00 (SEE DETAIL) |
| | 1 | 1 | THIS DWG | PL 7.00 X 3.5 0X 1.00 (SEE DETAIL) |
| | | ---- | THIS DWG | OUTER TF CON. TYPE "D" ASSEMBLY | --------
03 | 02 | 01 | PART NO. | DRAWING NO | NOMENCLATURE OR DESCRIPTION | MATERIAL
ASSY QTY | PARTS LIST
PRINCETON PLASMA PHYSICS LABORATORY
PRINCETON UNIVERSITY
NATIONAL SPHERICAL TORUS EXPERIMENT
2010 NSTX UPGRADE
OUTER TF CONNECTOR TYPE "D"
ASSEMBLY AND DETAILS
CENTRAL FILES:
NEXT ASSEMBLY
CAD FILE: E-DC1459 .DRW
E-DC1459
SHEET 1 OF 1
REV 2
NSTX-E-DC1459

NO.	REVISION	BY	CH	SUP	APPROVED	DATE
1	REVISED PER ECN NO. 7649	[illegible]	JC	LM	J.CHRZANOWSKI	06/24/2013
2	REVISED PER ECN NO. 7184	[illegible]	JC	LM	J.CHRZANOWSKI	10/10/2013



TYPE "E" ASSY
OUTER TF CONNECTOR (01)

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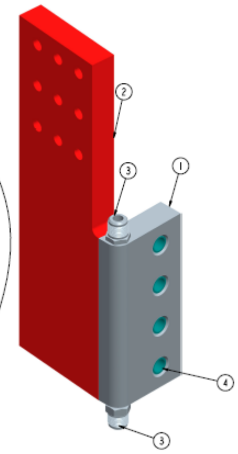

ISOMETRIC VIEW
TYPE "E" ASS'Y

NOTES:

1. EB WELDING SHALL BE PREFORMED IN ACCORDANCE AWS C7.3 (1999)
   INSPECTION SHALL BE PREFORMED TO AWS C7.3 CLASS A
2. STEPS FOR INSTALLATION OF HELI-COILS
   A. DRILL 21/32" (0.656") DIA. HOLE THRU
   B. COUNTERSINK 120° +/- 5° TO 0.75/0.76 DIA.
   C. TAP 5/8 (0.625)-11 UNC-3B HELI-COIL 'STI' THREAD THRU
   D. INSTALL HELI-COIL SCREW LOCK INSERT #1185-10CN 938
      3/4 TO 1 1/2 PITCH BELOW SURFACE.
   E. BREAK OFF INSERT DRIVING TANG AND DISCARD.
3. ALL THREE PLACES DECIMALS (.000) SHALL HAVE A TOLERANCE OF ±.010

		4	4	CONN	5/8-11 HELI-COIL STANDARD INSERT NO. 1185-10CN 938	--------
		2	3	CONN	PARKER FITTING NO. 8 FTX-B (1/2 TUBE X 3/8 NPT) 37° FLARE OR EQAL	BRASS
		1	2	THIS DWG	PL 14.28 X 4.358 X 1.000 (SEE DETAIL)	[illegible]
		1	1	THIS DWG	PL 7.000 X 3.13 X 1.00 (SEE DETAIL)	[illegible]
			----	THIS DWG	OUTER TF CON. TYPE "E" ASSEMBLY	--------
03	02	01	PART NO.	DRAWING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL
ASSY QTY			PARTS LIST			

RELEASED FOR FABRICATION/INSTALLATION

COMPUTER GENERATED DRAWING MANUAL CHANGES NOT PERMITTED

CENTRAL FILES:

UNLESS OTHERWISE SPECIFIED

NEXT ASSEMBLY

PRINCETON PLASMA PHYSICS LABORATORY
PRINCETON UNIVERSITY
NATIONAL SPHERICAL TORUS EXPERIMENT

2010 NSTX UPGRADE
OUTER TF CONNECTOR TYPE "E"
ASSEMBLY AND DETAILS

DIV: MECH. ENG.

CADD FILE: E-DC1460 .DRW

ENG: J.CHRZANOWSKI

APPROVED J.CHRZANOWSKI

E-DC1460

CHK: J.CHRZANOWSKI

SHEET 1 OF 1

REV 2

NSTX-E-DC1460

Appendix C

Email correspondence

Irving Zatz <zatz@pppl.gov>

Check on flex model loads

2 messages

Arthur Brooks <abrooks@pppl.gov> Thu, Jan 23, 2014 at 5:01 PM
To: Irving Zatz <zatz@pppl.gov>
Cc: Peter Titus <ptitus@pppl.gov>

Irv,

I looked at the reaction loads on the flex model to see what loads where applied. The net reaqctions were Fx=11827 lbs, Fy=-71635 lbs, Fz=14310 lbs with x radial, y vertical and z OOP. This agrees with what I get doing an analytic check of the TF vertical force with Btf=1 T at R=.9344 as designed. The OOP load agrees roughly with the ~.2 T vertical field from scenario #82 at the flex crossed with the 130 kA current per turn.

There doesn't seem to be any other structural load case result in the rest of the WB files, just the thermal and EM results.

So I think you've got it all.

Art

Irving Zatz <zatz@pppl.gov> Thu, Jan 23, 2014 at 5:04 PM
To: Arthur Brooks <abrooks@pppl.gov>
Cc: Peter Titus <ptitus@pppl.gov>

Art:

That sounds good to me and is consistent with Willard's report (except for writing scenario #81 in his summary).

Thanks again for checking these numbers.

Irving
[Quoted text hidden]

PPPL

Irving Zatz <zatz@pppl.gov>

Re: Code for PF Field Calculations

1 message

Peter Titus <ptitus@pppl.gov> Fri, Jan 24, 2014 at 12:28 PM
To: Arthur Brooks <abrooks@pppl.gov>
Cc: Irving Zatz <zatz@pppl.gov>

Thanks . As a minimum can Irv add the emails to the calculation to document the check of Tom's input, and the check of the post disruption currents? I think the max post disruption vertical field of .25 T vs .23 T which was the basis of the loads Tom used, is not going to violate the margins that Tom had for the strap. -Peter

On Fri, Jan 24, 2014 at 11:53 AM, Arthur Brooks <abrooks@pppl.gov> wrote:

> Peter,
>
> Tom's model does NOT contain the plasma, just the OH, PF1-5 and the TF, which is good. The current values do agree with the scenario #82 values. The vertical fields at the Flex Strap are higher for this scenario without plasma 0.23 T vs 0.19 T with plasma.
>
> The Post Disruptions currents give rise to slightly higher fields and occur at scenario #31 .Without plasma the vertical field is 0.25 T vs 0.21 T with plasma.
>
> Art
>
> On Thu, Jan 23, 2014 at 3:55 PM, Peter Titus <ptitus@pppl.gov> wrote:
>
>> I suppose we don't know whether Tom used the with or without plasma equilibria. It would be nice to document that Toms calculation enveloped all the equilibria with and without the plasma. - and post disruption. Attached is a spreadsheet that calculates the torsional shear for Charlies post disruption data. I believe it is on the web in his design point spreadsheet, or you can trust that I extracted it properly. Either way could you run it through your code and see if it is substantially higher than the nominal fields? Can you find the currents input to Maxwell to determine if Tom used the "without plasma" data? -Peter
>>
>> On Thu, Jan 23, 2014 at 3:15 PM, Arthur Brooks <abrooks@pppl.gov> wrote:
>>
>>> Peter,
>>>
>>> For now I have a code on the Unix Cluster in directory:
>>>
>>> /p/eaddata/abrooks/nstx_csu/pfcalc
>>>
>>> The code executable is called pfcalc3.x; the FORTAN source is pfcalc3.f. It reads the scenario data from the file pfcalc3.inp and point data from the file pfcalc3.pts (you shouldn't need to change the scenario data). It outputs the max values in pfcalc3.max and all values in pfcalc3.brbz.
>>>
>>> For the TF Flex, the max vertical field magnitiude at r=0.487, z=2.849 is for scenario 82 and is 0.19T with plasma. Without plasma it increases to 0.23T (also for scenario 82).
>>>
>>> The full set of fields is plotted in the attached spreadsheet for the TF Flex location.

Art

Appendix D
Mill Certs for the CuCrZr Plate

Cadi Company Inc.
60 RADO DRIVE
NAUGATUCK, CT 06770
203-729-1111
FAX: 203-729-1919

RESISTANCE WELDING ELECTRODES AND ACCESSORIES
COPPER ALLOY RAW MATERIALS

MATERIAL CERTIFICATION

Customer: **Martinez & Turek, Inc.**

Order #: **1402860**

Customer P.O. #: **69416**

Dimension:	**1" x 3" x 8.120"**	**C2 C18150**	**(26PCS)**	Qty.: **230 lbs.**
	1" x 4.620" x 5"	**C2 C18150**	**(26PCS)**	Qty.: **217 lbs**
	1" x 3.250" x 7.120"	**C2 C18150**	**(14PCS)**	Qty.: **118 lbs**
	1" x 4.500" x 14.500"	**C2 C18150**	**(14PCS)**	Qty.: **325 lbs**
	1" x 2.620" x 7.120"	**C2 C18150**	**(14PCS)**	Qty.: **96 lbs**
	1" x 2.500" x 7.120"	**C2 C18150**	**(14PCS)**	Qty.: **92 lbs**
	1" x 4.120" x 14.500"	**C2 C18150**	**(14PCS)**	Qty.: **298 lbs**
	1" x 3.620" x 7.120"	**C2 C18150**	**(14PCS)**	Qty.: **131 lbs**
	1" x 3.250" x 7.120"	**C2 C18150**	**(14PCS)**	Qty.: **118 lbs**
	1" x 4.562" x 14.500"	**C2 C18150**	**(14PCS)**	Qty.: **325 lbs**
	1" x 1" x R/L'S	**C2 C18150**	**(4PCS)**	Qty.: **230 lbs**

Heat No: **32184**

Mechanical/Physical Test Results:

Conductivity: 84/87 % I.A.C.S.
Hardness Rockwell "B": 72/77 $^{R}{}_{b}$
Tensile: 65,500 PSI
Yield Strength: 52,000 PSI
Elongation in 2 inches or 4 D %: 29 % (2 ")

Chemical Analysis:

Chromium: 0.690 %
Zirconium: 0.090 %

Copper including Silver plus named elements 99.70 % Min: Balance

WE HEREBY CERTIFY that the material shipped on the above order has been produced in accordance with the above specification/order by our standard practice. We further certify that no Mercury was in contact with the metal at any time during its manufacture and testing.

Norman L. Finke Jr. *October 6, 2014*

Norman L. Finke Jr.
Quality Assurance Manager

Date Approved

ISO DOC.FORMS\F-4.2.4-6 Rev A 12/02