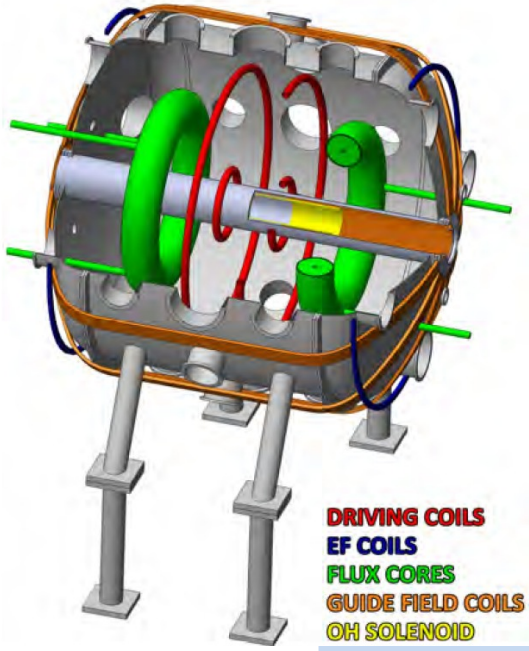
PPPL FLARE CENTER STACK DESIGN

11/11/15

FLARE Coil System Specifications & Power Supplies (11/5/14)

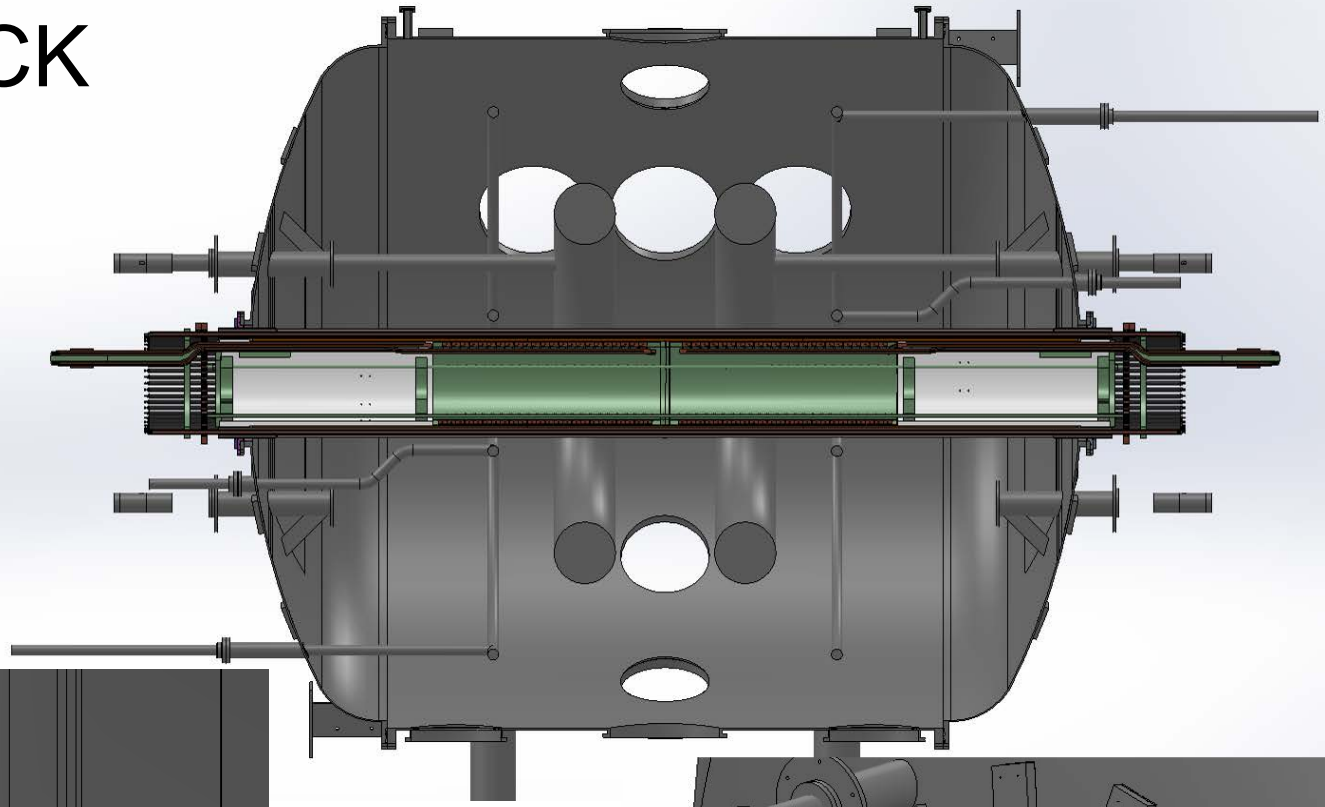


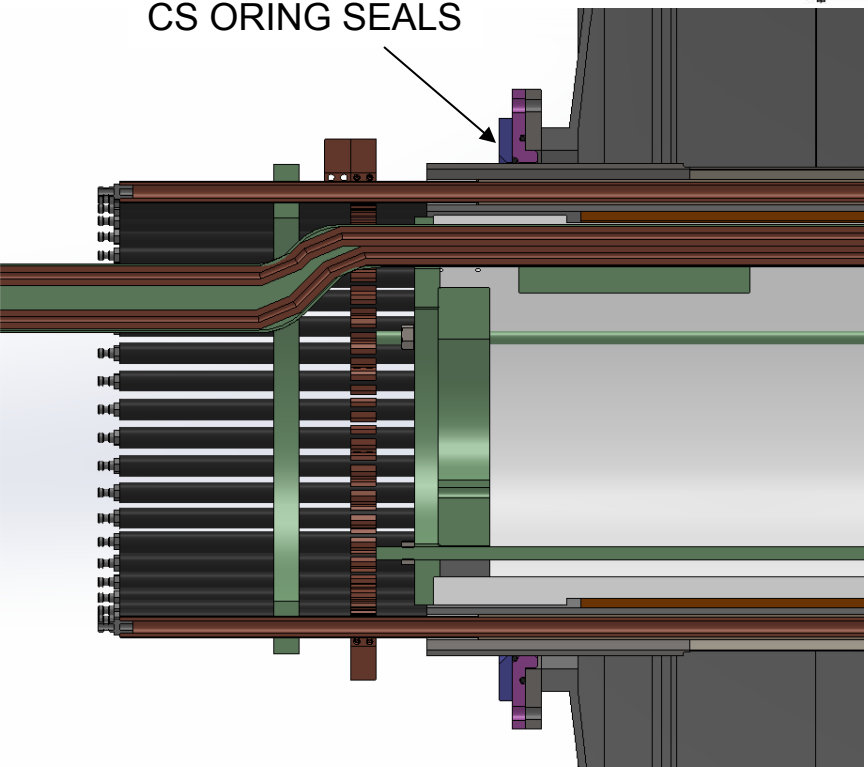
	Ohmic Heating (OH)	Equilibrium Field (EF)	Guide Field (GF)	Flux Core		Inner Driving Coil	Outer Driving Coil
				PF Coil	TF Coil		
No. Coils	2	2	1 system	2	2	2	2
Turns/coil	25	16	48	4x1	4 x 15	2	2
Circuit	Series/ Parallel	Parallel	Series	8 x 1 Parallel	8 x 15 parallel	Parallel	Parallel
Current (kA)	100	13	40	135	62.5	25	25
Capacitor Bank (mF) /kV	5.04/20	420/1.4	44/14	3.9/20	1.25/20	0.0625/10.2	0.0875/20
Bank energy (MJ)	1.01	0.41	4.3	0.78	0.25	0.0033	0.018
Pulse duration (ms)	2.6 / 1.2	60	38	0.22	0.16	0.04	0.12

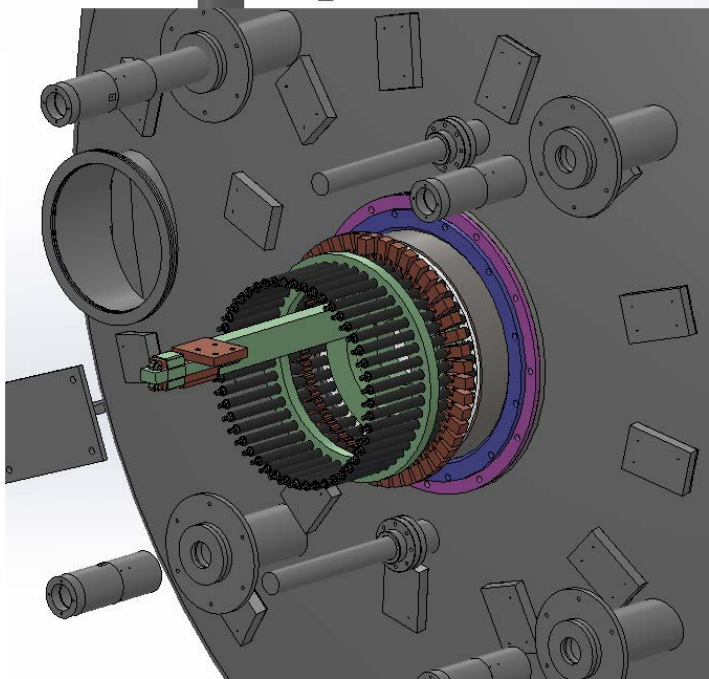
Center Stack Design

- Center stack housing must be non-metalic.
- Center stack must deal with OH-GF EM applied torque (36 K Ft-lbs) and compression. These values were provided by Peter Titus. The CS must also deal with weight of the assembly (sag, 3K lbs).
- Tried to use standard tubes to reduce cost and lead time.
  - I could not find phenolic tube manufacturers that could make long (13ft) large diameter tubes (14” -18”).
  - Pultrusion was cost prohibitive.
  - Standard Fiberglass and PVC tube were found close to our dimensions, and incorporated in our design.
- Must provide a mean to install CS into chamber, and allow end-bell removal.
- UW to provide everything except: OH coils, OH interlocking pieces, Outer Inconel sleeve, GF electrical clamps (?), GF H2O fittings (?)

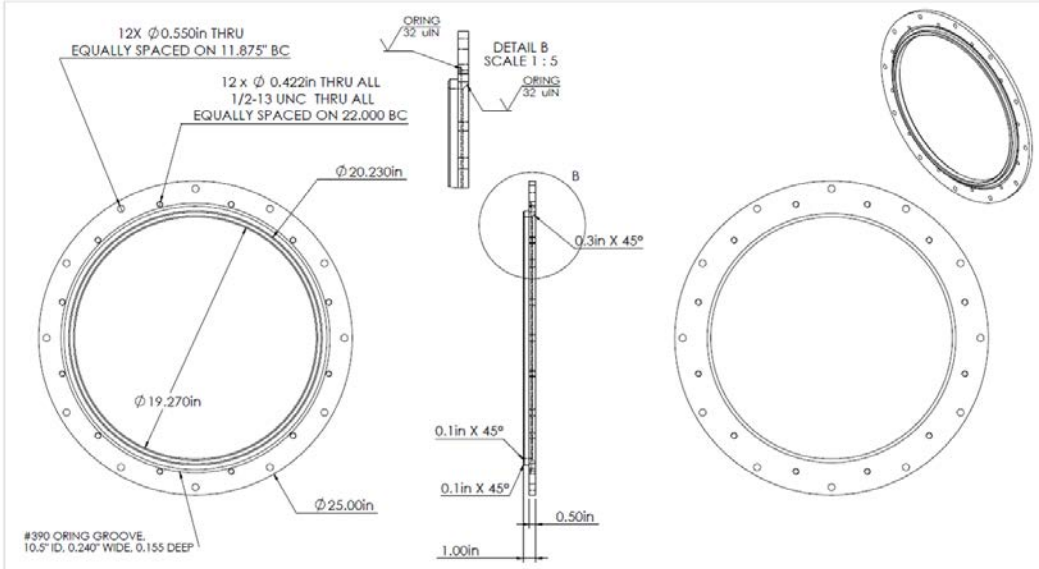
CENTER STACK INSTALLED







CENTER STACK CHAMBER SEAL FLANGES



John Wallace
University of Wisconsin - Madison
Plasma Physics
3244C Chamberlin Hall

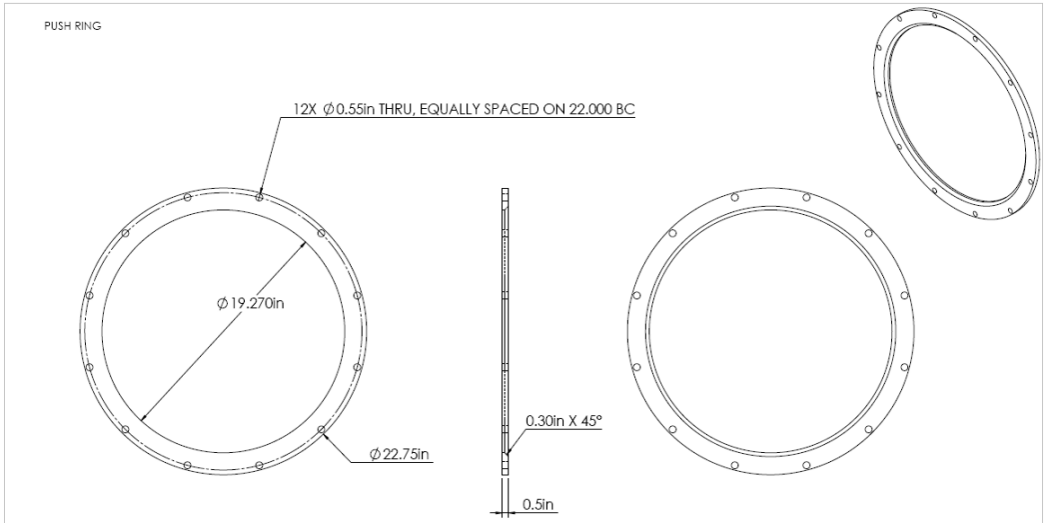
		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 0.1 ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ±0.01 THREE PLACE DECIMAL ±0.005	DRAWN		
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL AL 6061-T6	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

QUANTITY = 2

TITLE:
FLARE CS CHAMBER FLANGE
PLATE INNER E-FL600-002 JPW
REV B

SIZE	DWG. NO.	REV
A	E-FL600-002	

SCALE: 1:8 | WEIGHT: | SHEET 1 OF 1



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Phone 608-262-7768
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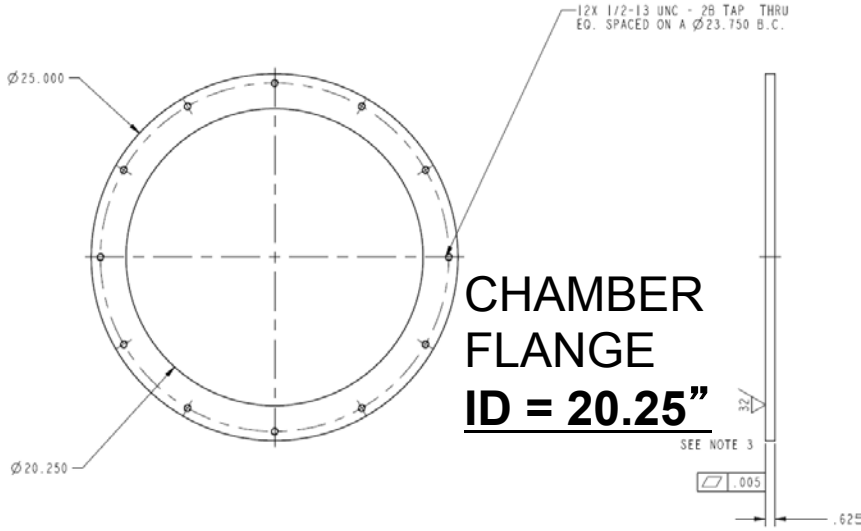
		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± 0.1 ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ±0.01 THREE PLACE DECIMAL ±0.005	DRAWN		
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL DELRIN	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

QUANTITY = 2

TITLE:
JM_OUTER_SEAL_RING JPW E-FL600-003 REV B

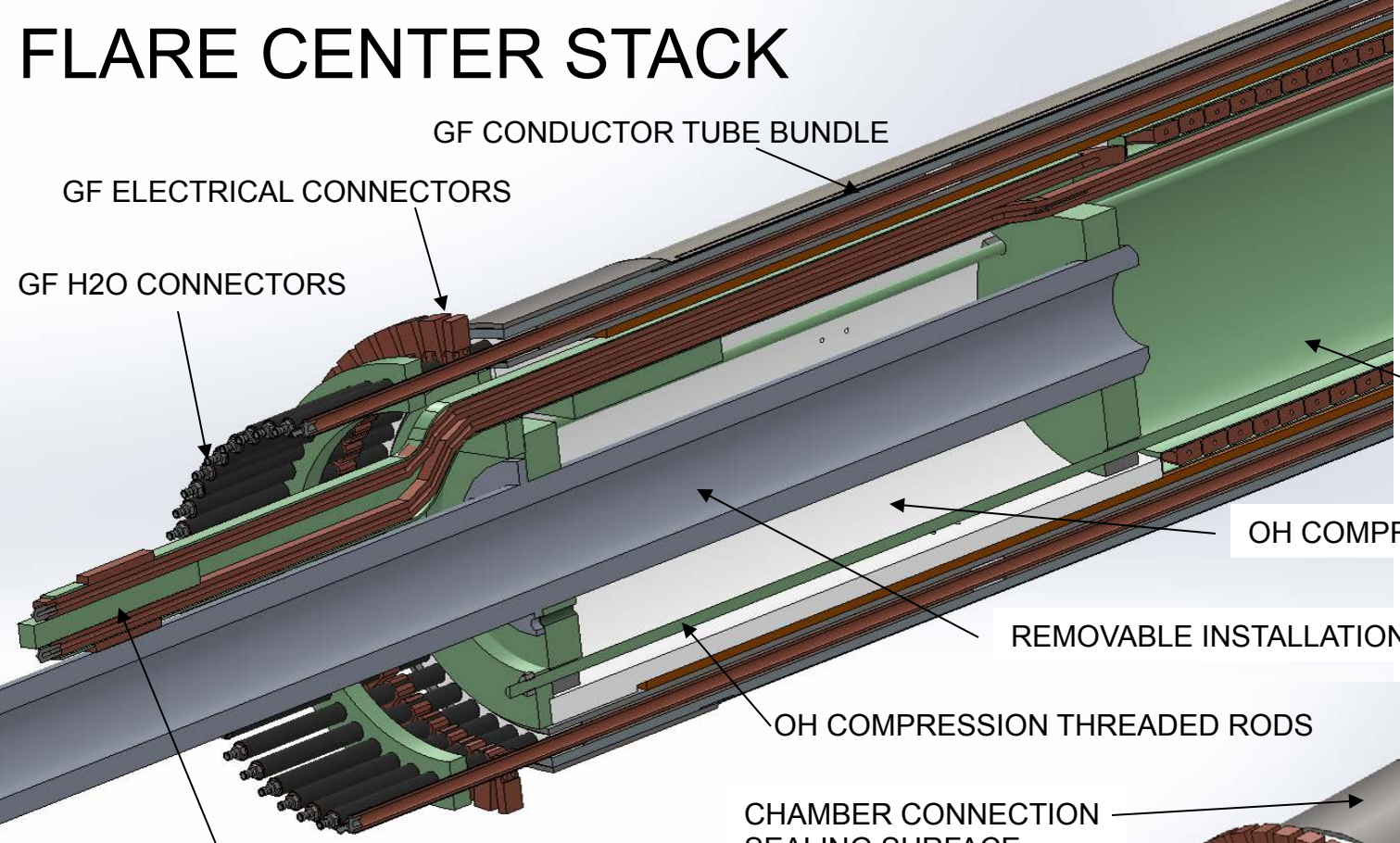
SIZE	DWG. NO.	REV
A	E-FL600-003	

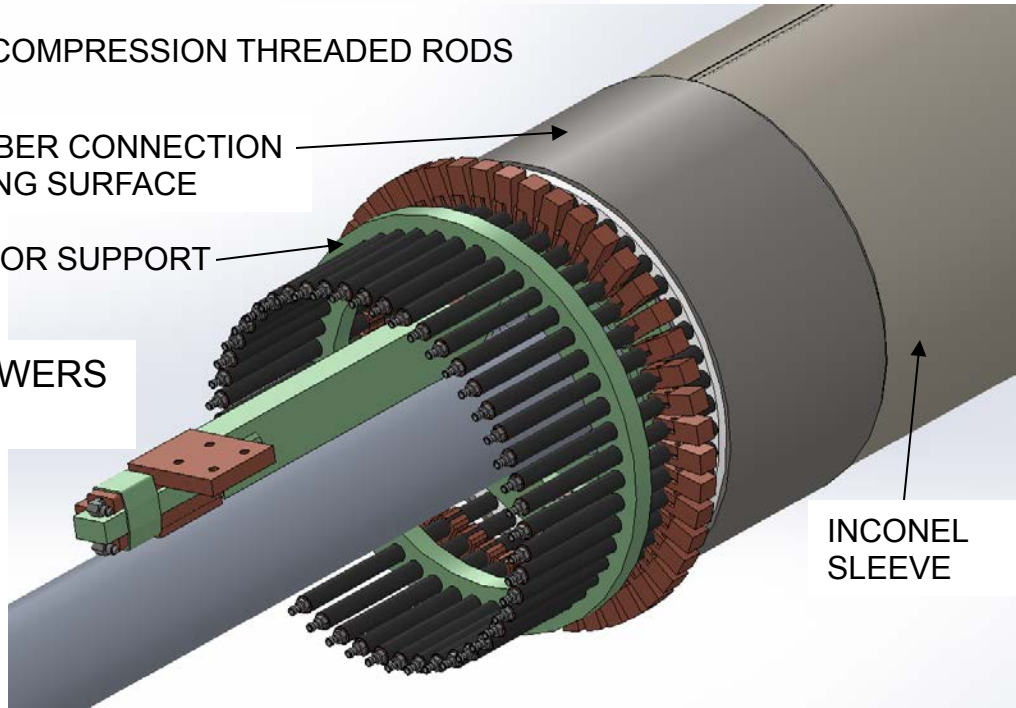
SCALE: 1:8 | WEIGHT: | SHEET 1 OF 1



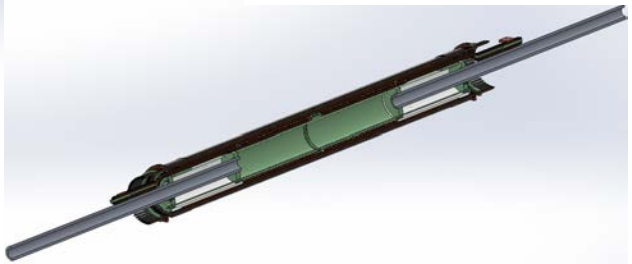
CHAMBER FLANGE
ID = 20.25”

FLARE CENTER STACK

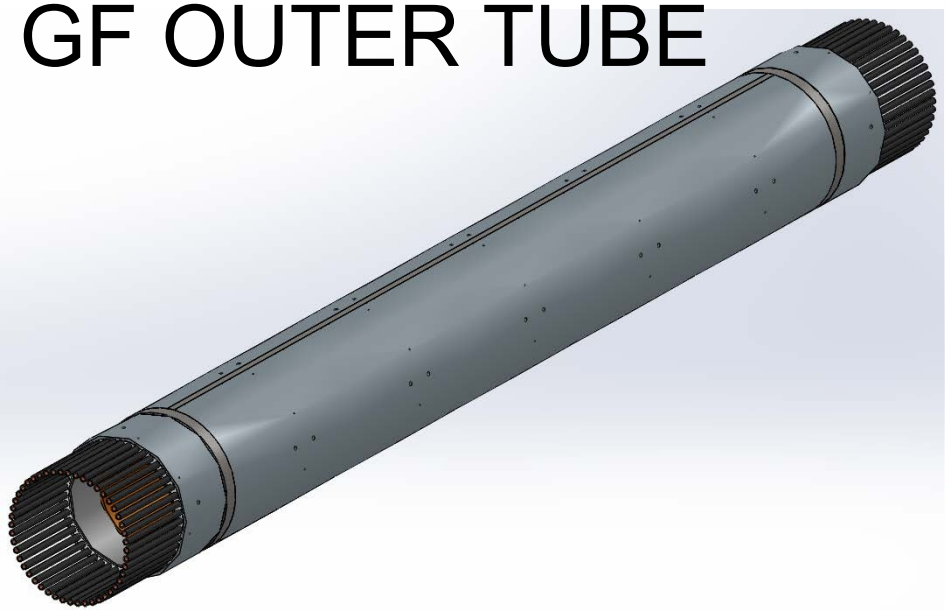




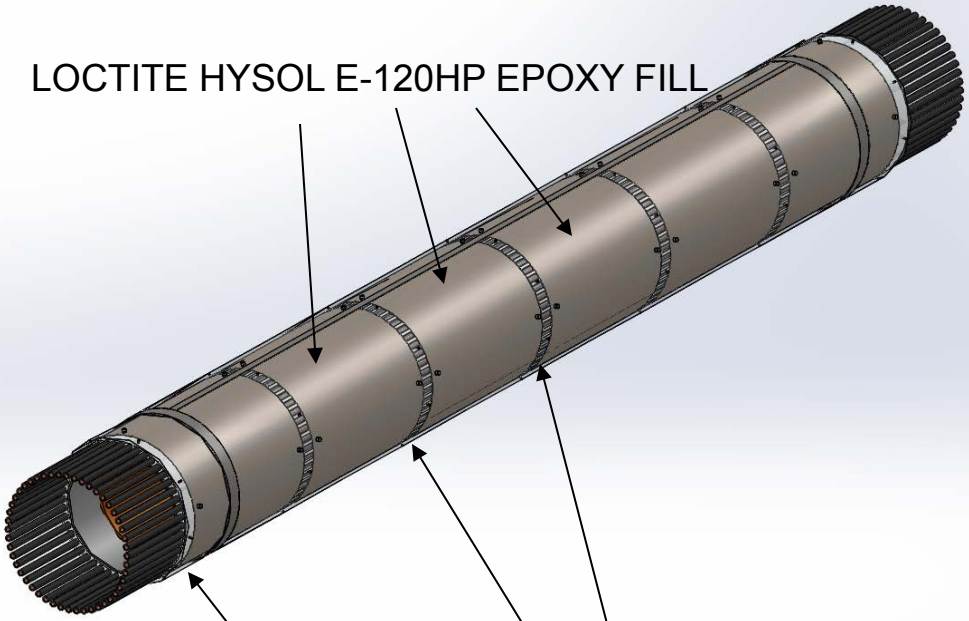
TOTAL CS WITH SKEWERS
= 3150 pounds



GF OUTER TUBE



LOCTITE HYSOL E-120HP EPOXY FILL

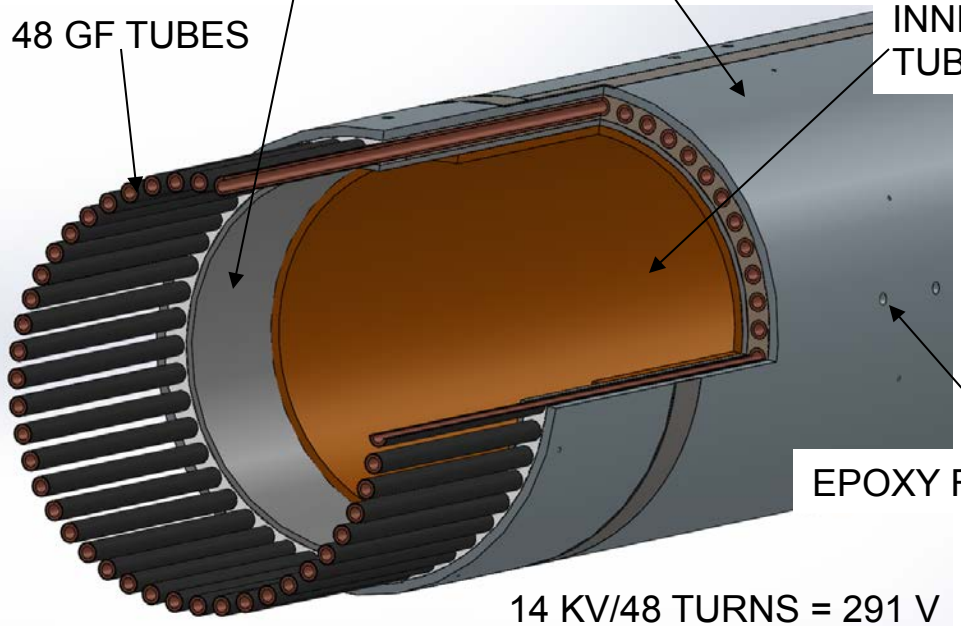


INNER FIBERGLASS TUBE

OUTER FIBERGLASS TUBE

48 GF TUBES

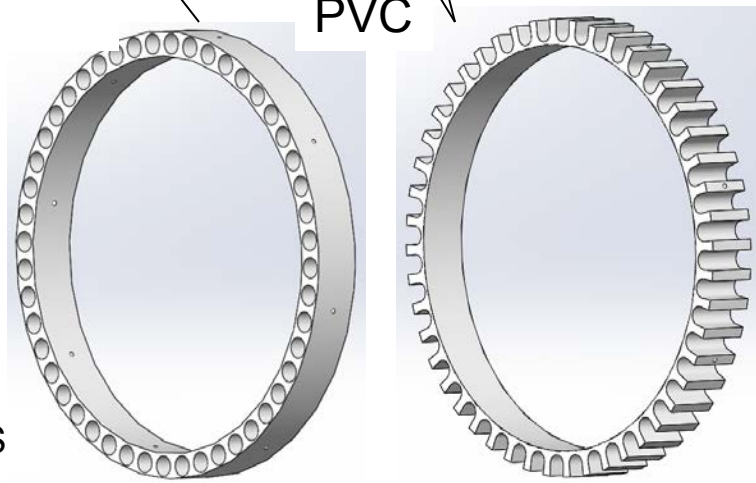
INNER PHENOLIC TUBE SPACER



EPOXY FILL HOLES

14 KV/48 TURNS = 291 V

PVC



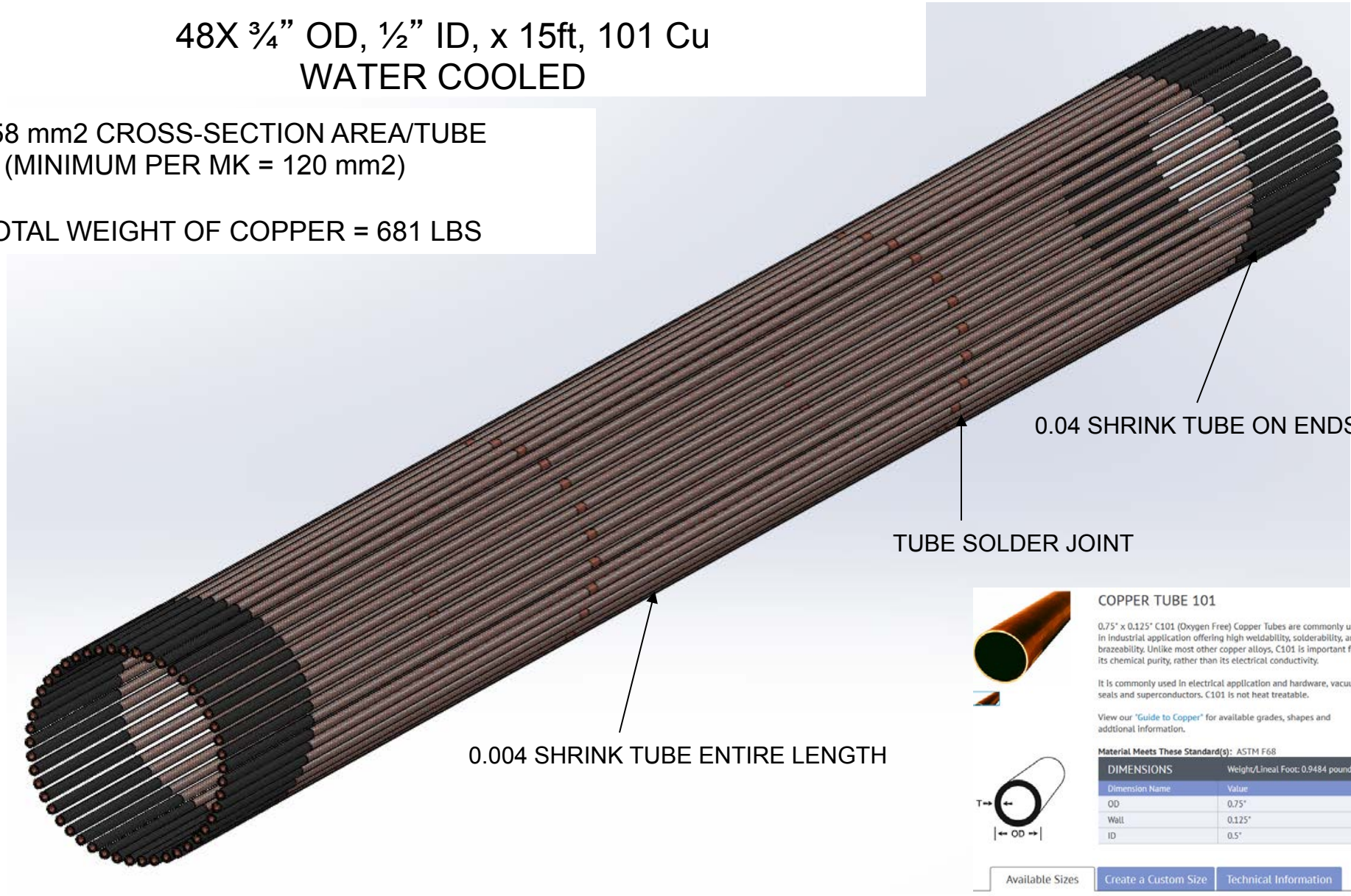
PINS HOLD PVC SPACERS IN PLACE

GF Conductor Cu Tubes

48X ¾” OD, ½” ID, x 15ft, 101 Cu
WATER COOLED

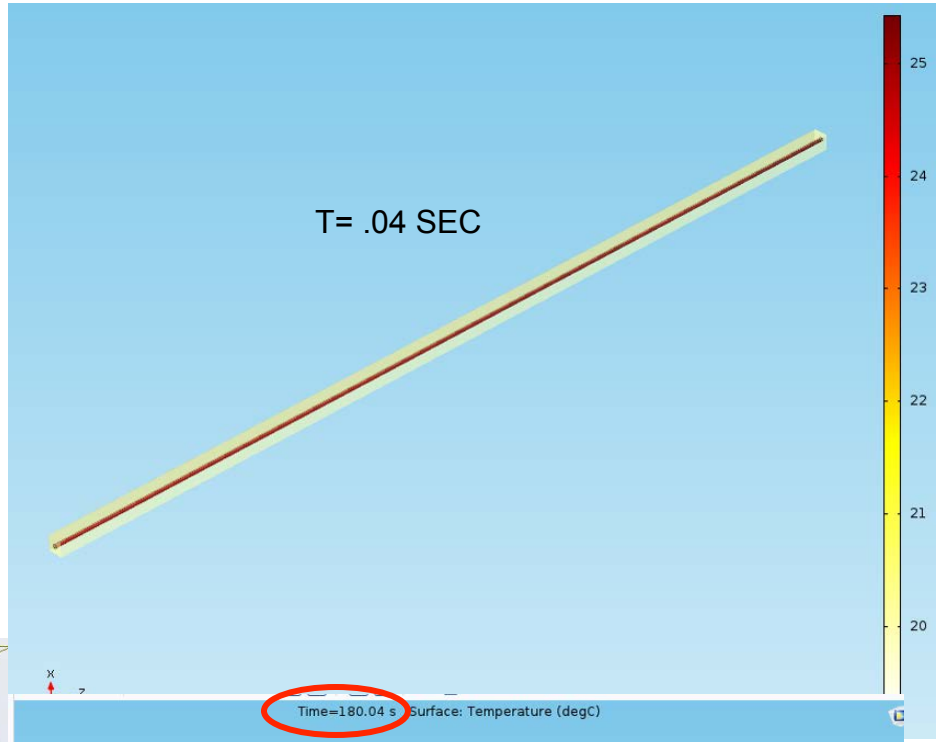
158 mm2 CROSS-SECTION AREA/TUBE
(MINIMUM PER MK = 120 mm2)

TOTAL WEIGHT OF COPPER = 681 LBS

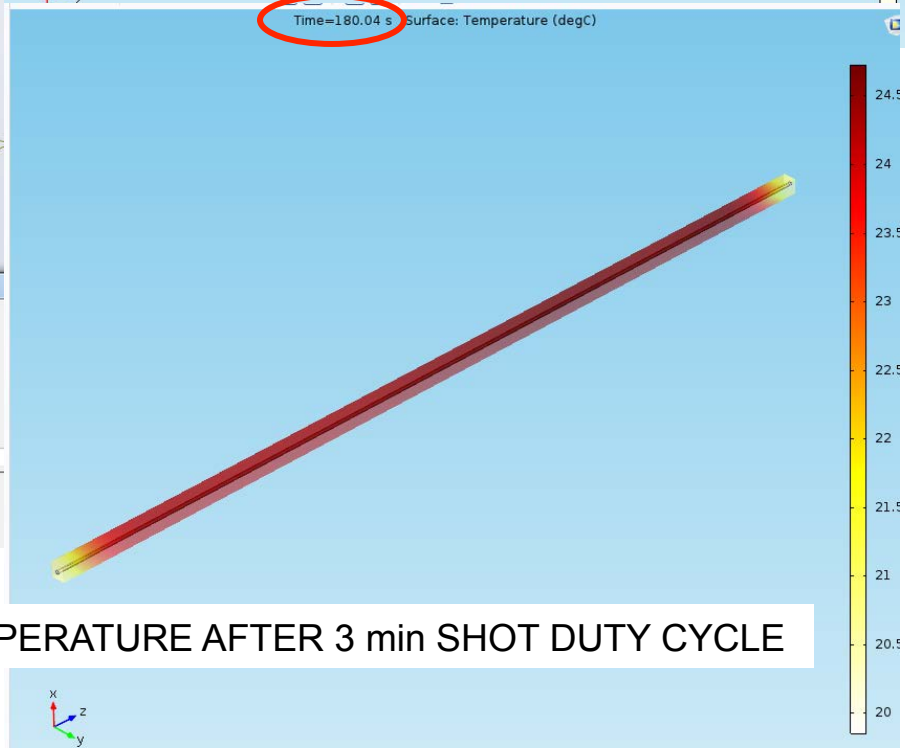


COMSOLSimulation If GF Conductors are Solid

The case for H2O cooling
40KA for 38 msec

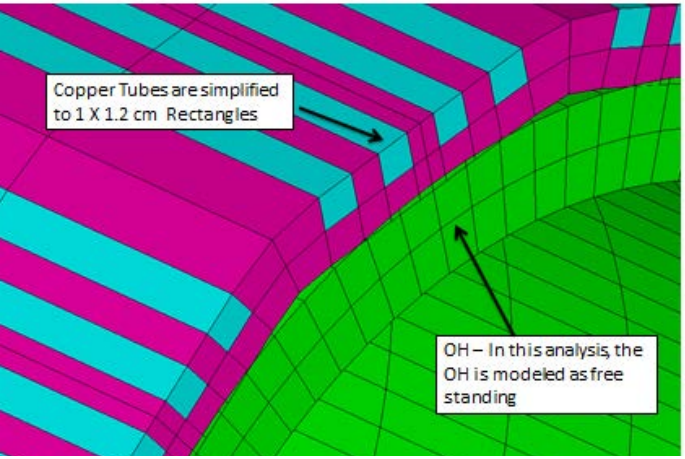


.75in dia.
0.442in^2 area

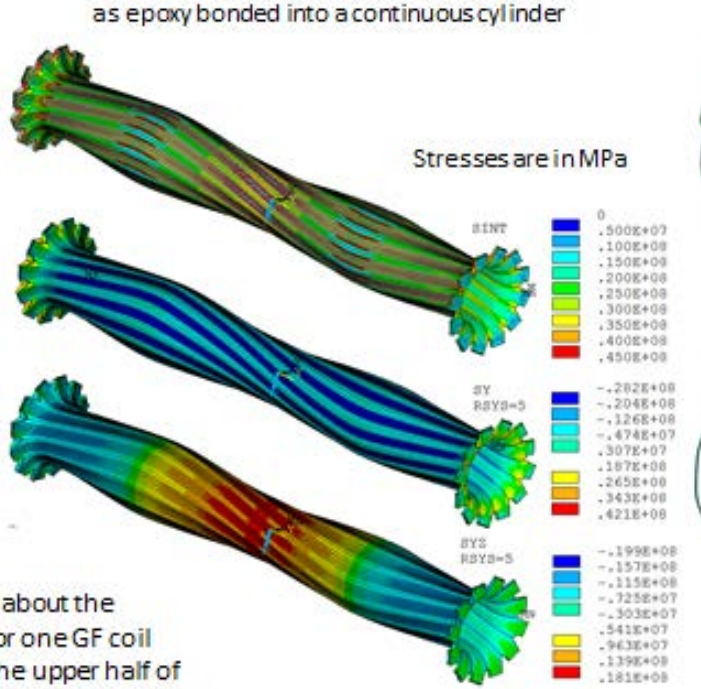


RESIDUAL TEMPERATURE AFTER 3 min SHOT DUTY CYCLE

Peter Titus 10/27/15



GF Inner Leg Stresses. The GF Inner legs are modeled as epoxy bonded into a continuous cylinder

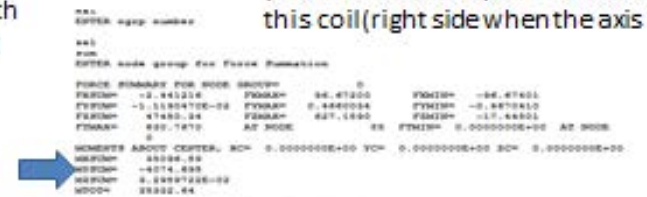


GF Only

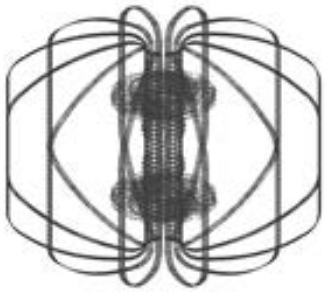
GF+PF

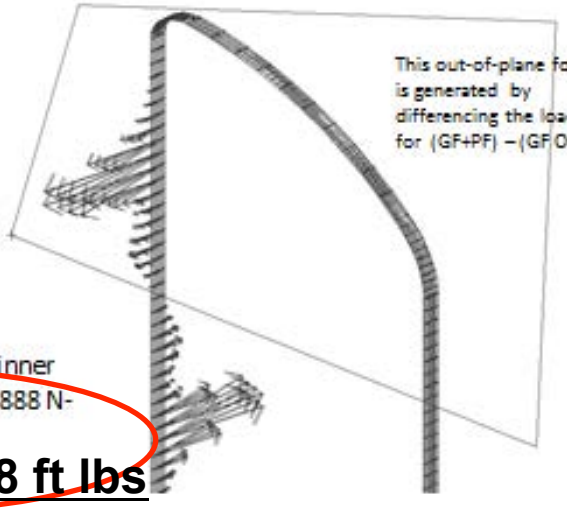
FLARE GF coils are modeled with twelve 4 conductor bundles, with each conductor having 40kA.

This is a moment summation about the machine axis (y in this plot) for one GF coil (with 4 conductors). It is for the upper half of this coil (right side when the axis is horizontal)



45 MPa = 6,526 PSI





This out-of-plane force plot is generated by differencing the load files for (GF+PF) – (GF Only)

Total Twisting moment for the GF inner leg assembly is 12*4074 N-m = 48,888 N-m = 3349.8 ft-lbs

Actually = 36,058 ft lbs

Re: Calculations for FLARE Center Stack

Peter Titus <ptitus@pppl.gov>

This message is part of a tracked conversation. Click here to find all related messages or to open the original flagged message.

Sent: Tue 10/27/2015 3:25 PM
To: Michael Kalish
Cc: John P Wallace

A clarification: If the shear stress in the G-10 tube is cut by the reinforcing cloth and the tube is really a tape wound high pressure laminate form with a G-10 -like glass density then the torsional shear allowable would be .6* the tension allowable. Below, the tensile strength is ~400 Mpa or 58 ksi for good material at RT. so the shear allowable would be 58/3*.6= 11.6 ksi. The Tresca allowable for the combined stresses would be 58/3=19.7 ksi

Insulating Material Strengths

	@4	@77	@292 degK
Comp.Strength Normal to Fiber			
G-10CR	749	693	420 Mpa Ref[7]
G-11CR	776	799	461 MPa Ref[7]
Tensile Strength (Warp)			
G-10CR	862	825	415 MPa Ref[7]
G-11CR	872	827	469 MPa Ref[7]
Tensile Strength (Fill)			
G-10CR	496	459	257 MPa Ref[7]
G-11CR	553	580	329 MPa Ref[7]

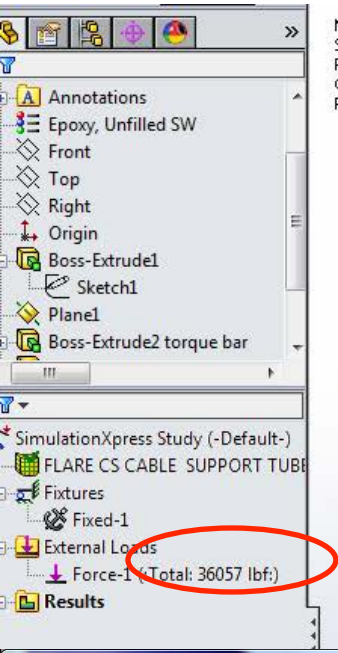
On Tue, Oct 27, 2015 at 3:37 PM, Michael Kalish <mkalish@pppl.gov> wrote:
Hi John,

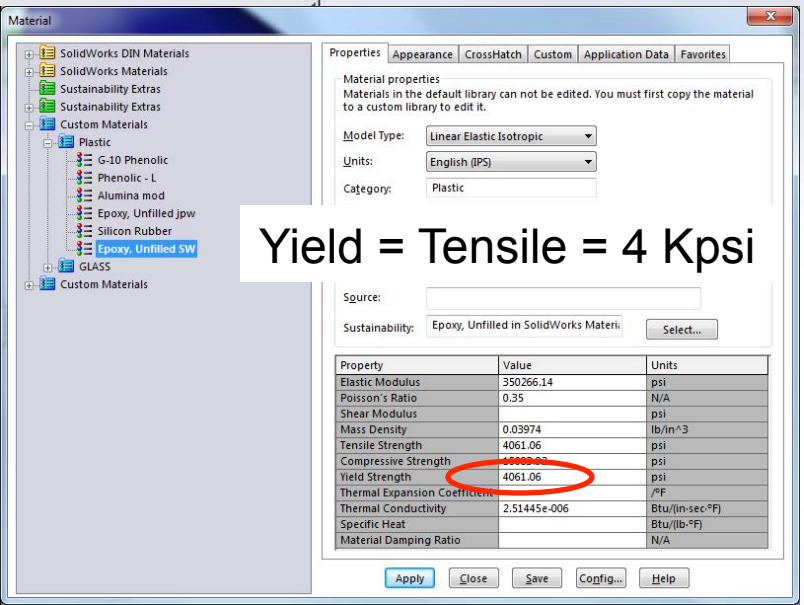
On a related topic we were concerned here about the adhesion of the epoxy to the inner PVC tube. When you get to the part where you're sourcing that tube please explore the possibility of using G10 or another material that would provide better adhesion. If it's not cost prohibitive we should consider the G10.... Also note that I'm out on Jury duty tomorrow so the weekly meeting is moved to Thursday (I've got my excuses all lined up so hopefully I won't be chosen for a case).

Thanks,
Mike

Outer Fiberglass Tube Torque Analysis

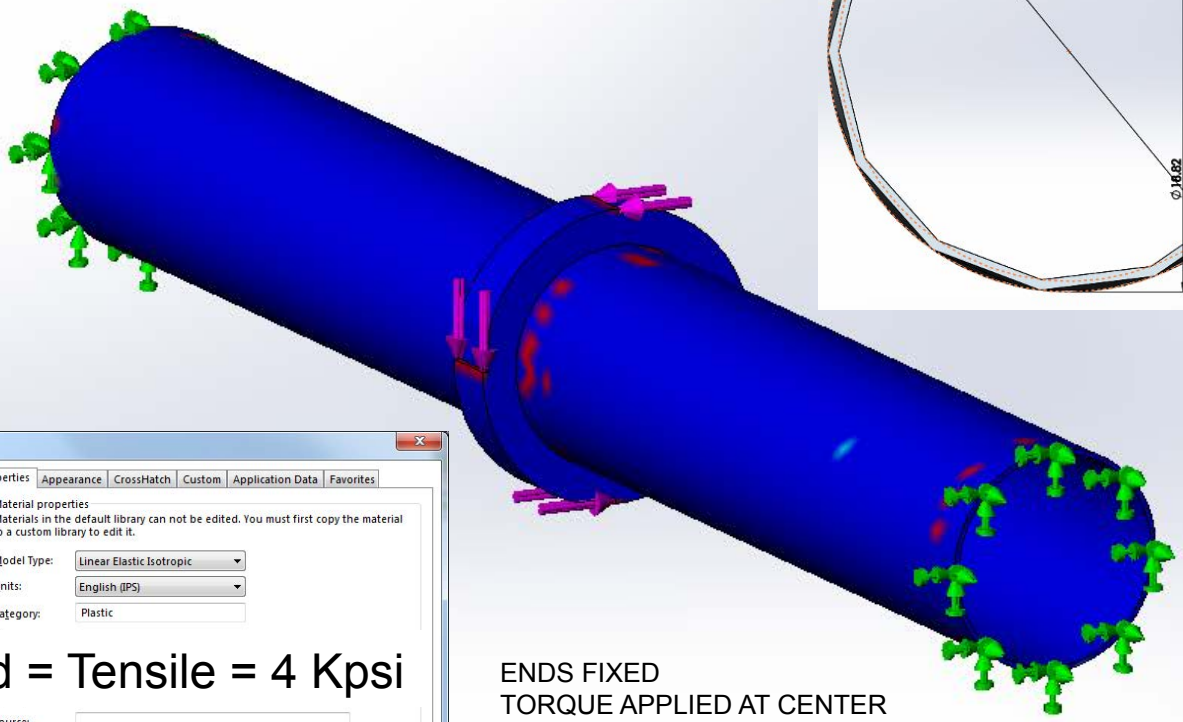
Assume GF conductors are securely glued to this tube, and thus this tube takes the torque. Because SW does not model non-isotropi materials, we model it as isotropic non-fill-epoxy (weakest link), 18" ID, 18.82" OD. Epoxy properties used are from SW library, and a weaker than typical industry, **this is only the outer tube**

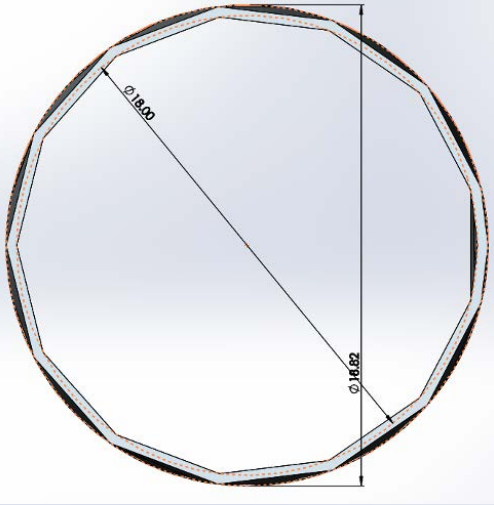




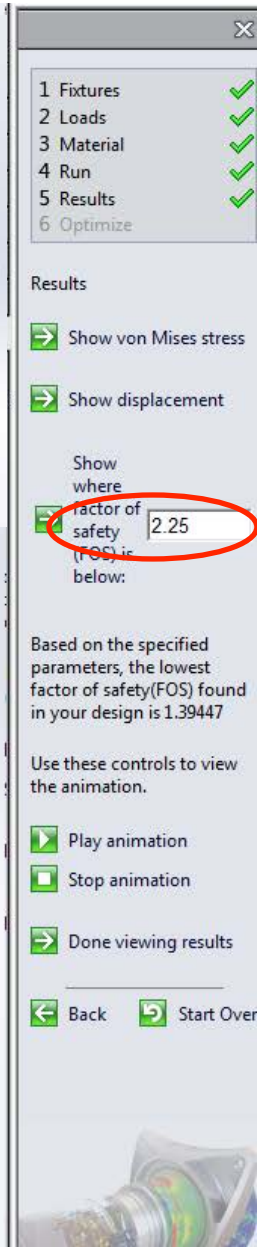
Yield = Tensile = 4 Kpsi

Model name: FLARE CS CABLE SUPPORT TUBE outer FEA torque
Study name: SimulationXpress Study(-Default-)
Plot type: Factor of Safety Factor of Safety
Criterion : Max von Mises Stress
Red < FOS = 2.25 < Blue





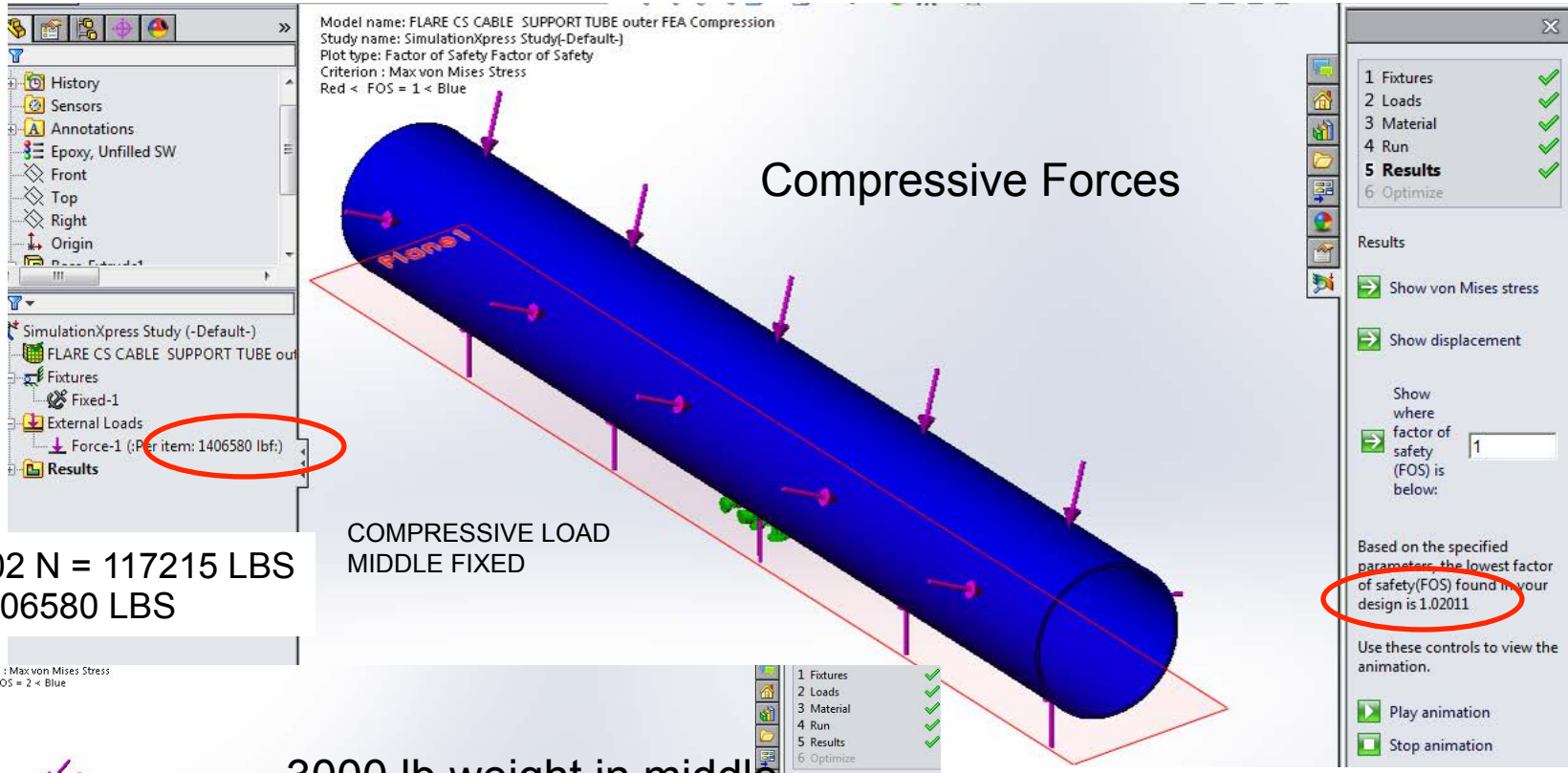
ENDS FIXED
TORQUE APPLIED AT CENTER



For reference PVC tensile =7.4Kpsi

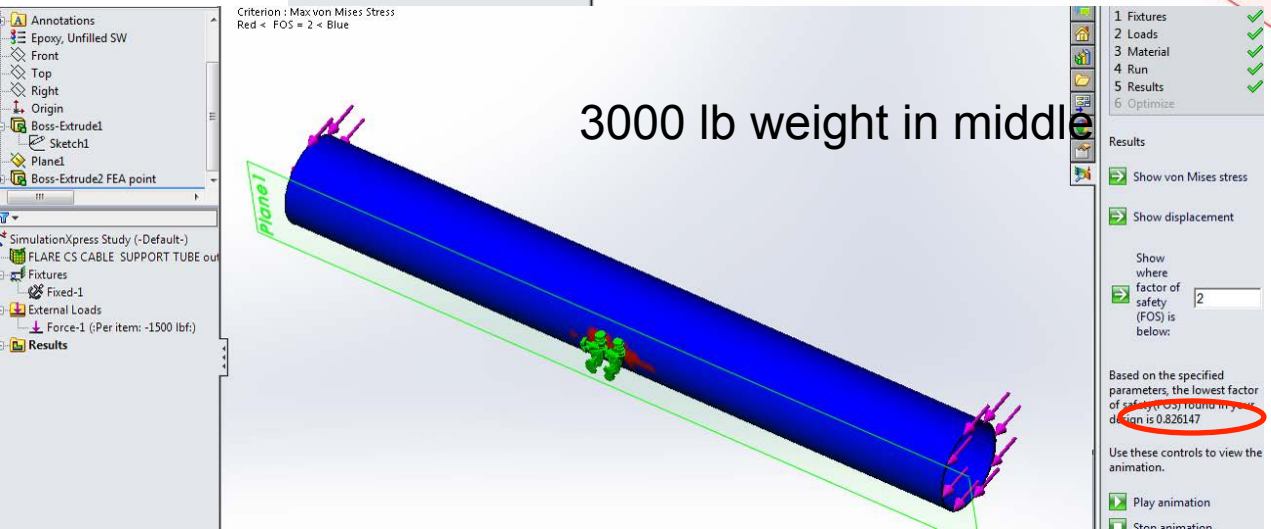
Outer Fiberglass Tube Load Analysis

Assume GF conductors are securely glued to this tube, and thus this tube takes the torque. Because SW does not model non-isotropic materials, we model it as isotropic non-fill-epoxy (weakest link), 18" ID, 18.82" OD. Epoxy properties used are from SW library, and are weaker than typical industry, **this is only the outer tube**



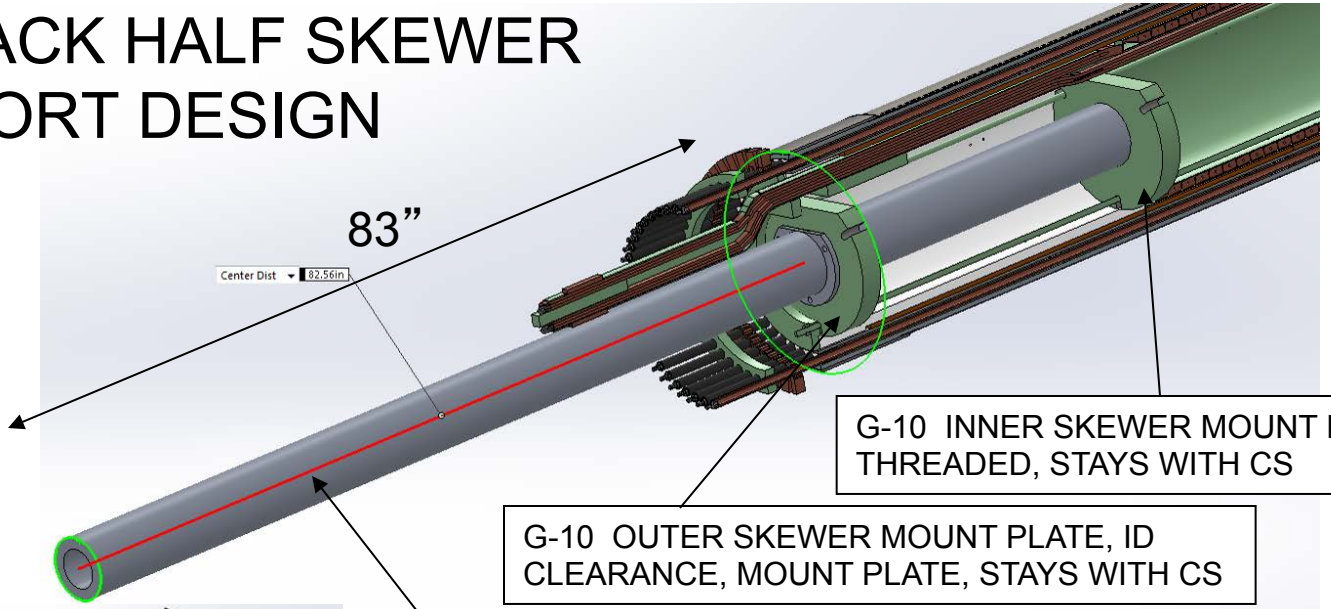
COMPRESSIVE LOAD
MIDDLE FIXED

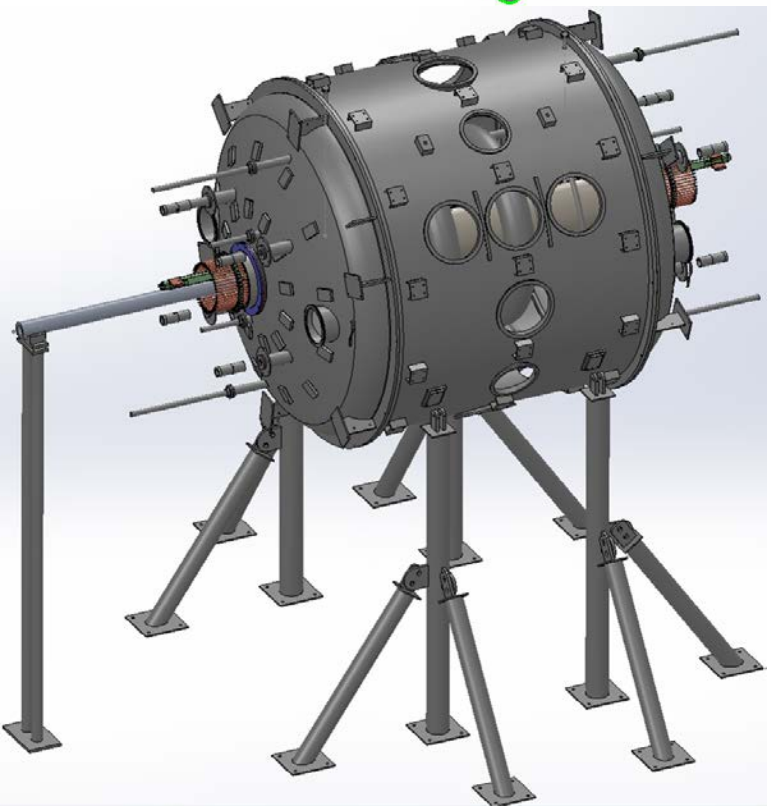
FXSUM= 521402 N = 117215 LBS
X12 LEGS = 1406580 LBS

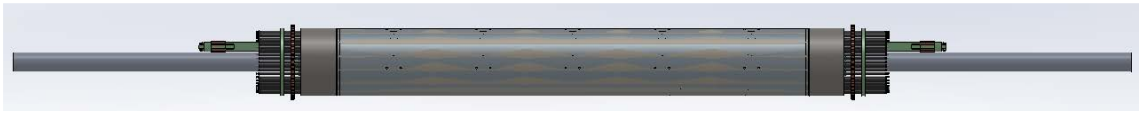


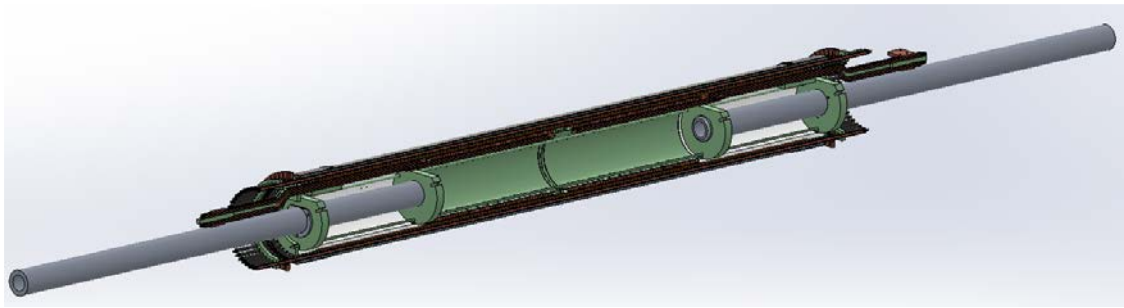
CENTER STACK HALF SKEWER SUPPORT DESIGN

Skewers are aluminum and removable



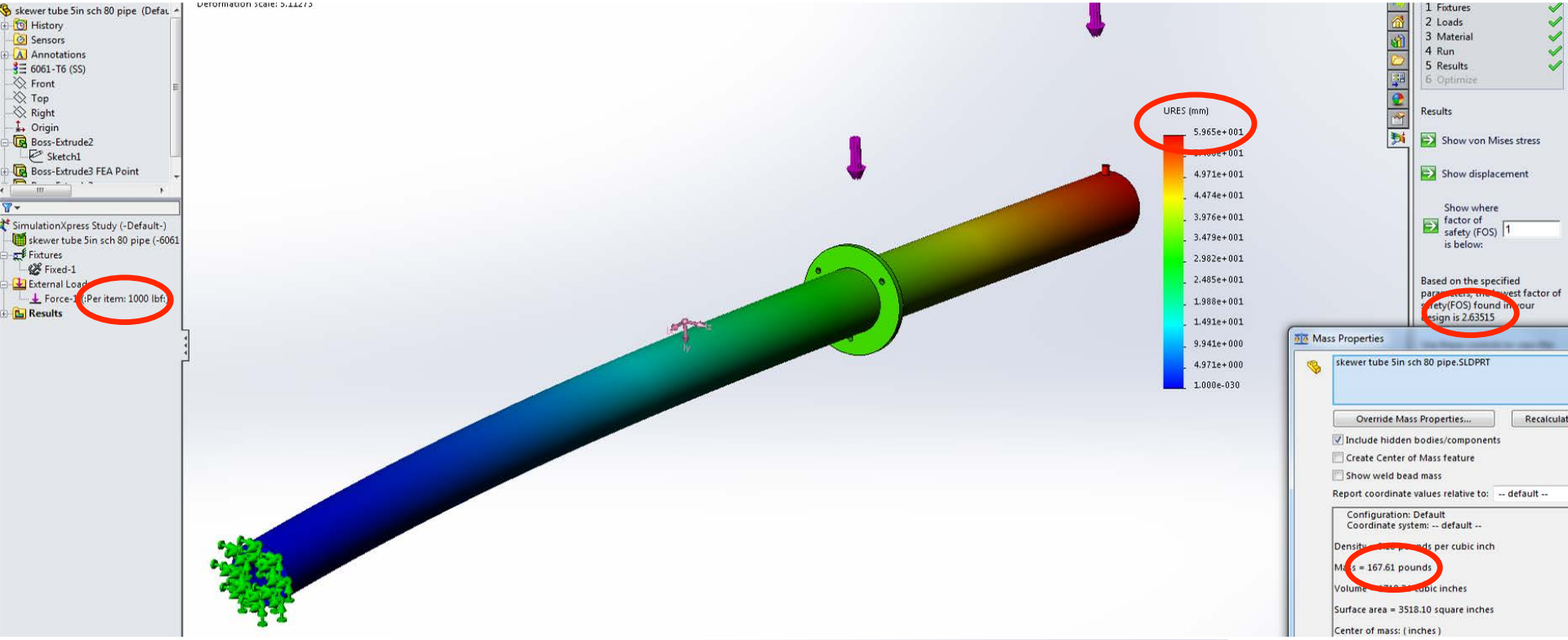


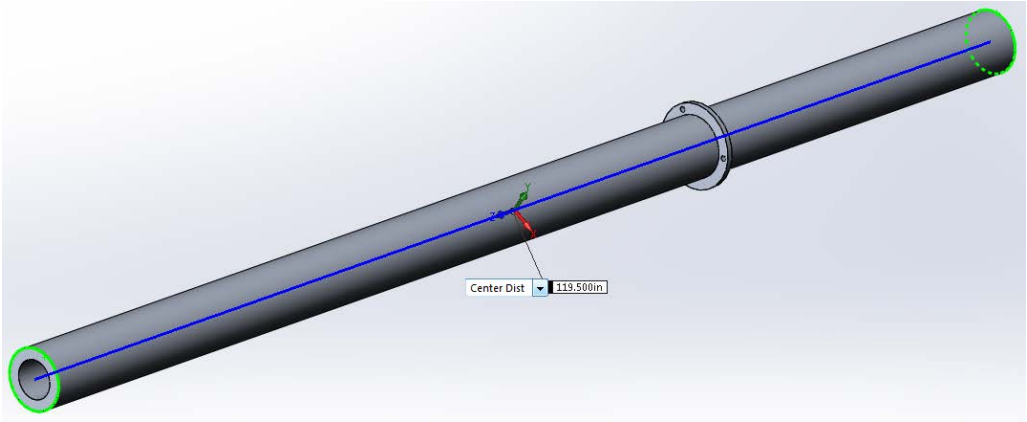




HALF SKEWER DESIGN

5.5 OD, 1” wall structural Al 6061-T6





10FT LONG